Combined Sewer Overflow Program

Long-Term Control Plan

Volume 5
Phases 2–3 Flow Monitoring Report

2009–2010

RESTORE OUR WATERS
SEATTLE PUBLIC UTILITIES
COMBINED SEWER OVERFLOW REDUCTION

December 2010

Seattle Public Utilities

SEATTLE PUBLIC UTILITIES
LONG-TERM CONTROL PLAN

VOLUME 5

PHASES 2 AND 3 FLOW MONITORING REPORT
2009–2010 DRY AND WET SEASONS

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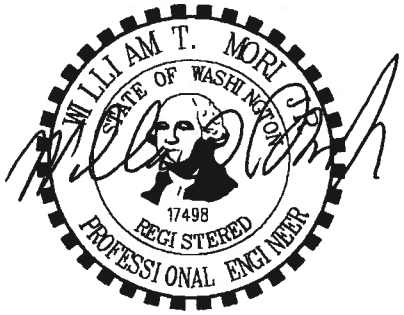
December 2010



This report has been prepared under the direction of a registered professional engineer

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LIST OF ABBREVIATIONS

ADS	ADS Environmental Services, a manufacturer of flow meters such as the FlowShark and Pulse
A/V	area/velocity
City	City of Seattle
CSO	combined sewer overflow
CSS	combined sewer system
DAS	Data Analysis (tool in ZFM2)
DDF	depth-duration-frequency
DWF	dry weather flow
Ecology	Washington State Department of Ecology
EPA	United States Environmental Protection Agency
fps	feet per second
GIS	Geographic Information System
GSI	Green Street Infrastructure
LFD	low-flow diversion
LTCP	Long-Term Control Plan
MG	million gallons
mgd	million gallons per day
MH	maintenance hole
MP	monitoring point
NPDES	National Pollutant Discharge Elimination System
PS	pump station
QAPP	Quality Assurance Project Plan
RG	rain gauge
SCADA	supervisory control and data acquisition
SOP	standard operating procedure
SPU	Seattle Public Utilities
WWF	wet weather flow
ZFM2	software provided by Stantec for maintenance and analysis of flow data

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EXECUTIVE SUMMARY

This Seattle Public Utilities (SPU) Long-Term Control Plan (LTCP) Flow Monitoring Report (Report) documents the results of the LTCP Flow Monitoring project conducted within 12 combined sewer overflow (CSO) basins in SPU's combined sewer system (CSS). The 2-year LTCP Flow Monitoring project began on 10/1/2008 and continued through 5/31/2010. The data collection effort was divided into three phases: Phase 1 covered the wet weather period from 10/1/2008 through 5/31/2009, Phase 2 covered the dry weather period from 6/1/2009 through 8/31/2009, and Phase 3 covered 9/1/2009 through 5/31/2010. The data collected during Phase 1 is documented in Volume 4 of the LTCP Flow Monitoring Report (Phase 1 Flow Monitoring Report, 2010). This report assesses the quality of the data collected at each meter for Phases 2 and 3.

The goal of the CSO LTCP is to develop and submit to the Washington State Department of Ecology (Ecology) a single plan by July 2015 that performs the project development (monitoring, modeling, and planning) and preliminary engineering for all of the City of Seattle (City)'s CSO basins. The LTCP will identify an approved list of CSO reduction projects that will be carried into design and construction in the future to meet the City's required CSO reduction targets. The goal of the LTCP Flow Monitoring project is to collect continuous rainfall depth, level, velocity, and operational data in the CSS for two wet seasons, 10/1/2008 through 5/31/2010. The collected data must accurately represent the conditions throughout the CSS. These data will be used to characterize the hydrologic and hydraulic performance of the CSS and support development of the LTCP.

Flow monitoring is the collection of simultaneous measurements of velocity and depth (which are used to compute flow), as well as rainfall and operational data, at strategic points within the system. The objectives of the LTCP Flow Monitoring project are as follows:

- Adequately and accurately characterize the hydrologic and hydraulic performance of the CSS by collecting rainfall depth, level, velocity, and operational data.
  - Hydrologic performance is defined as the hydrologic response of a subcatchment to rainfall.
  - Hydraulic performance is defined as the operating characteristics of structures and facilities in the CSS, including in-line and offline storage, HydroBrakes, gates, weirs, diversions, regulators, and pump stations.
- Capture data before, during, and after a wide range of storm events with a range of antecedent moisture conditions. In terms of recurrence intervals this objective can be defined as a minimum of three storm events of recurrence interval between 6 months and 1 year at any duration, and a minimum of two storm events of recurrence interval between 1 year and 10 years at any duration spaced throughout the wet season.
- Recommend storm events for model calibration and future flow monitoring in the event that the desired storms do not occur during the project monitoring period.

The CSO basins included in the LTCP Flow Monitoring project are approximately 5,538 acres (8.65 square miles) in size and comprise 182 miles of the CSS (see Figure ES-2). Phase 1 of the LTCP Flow Monitoring project focused on 12 basins—Ballard, Delridge/Longfellow, Duwamish, Fremont/Wallingford, Interbay, Leschi, Madison Park/Union Bay, Magnolia, Montlake, North Union Bay, Portage Bay/Lake Union, and West Seattle. Approximately 150 temporary monitors were installed throughout these 12 basins. The majority

of the monitors remained installed for Phases 2–3, with the exception of the monitors in the Magnolia and West Seattle Basins, for which sufficient data had been collected at the conclusion of Phase 1 monitoring.

Approximately 200 meters were in place at the beginning of Phases 2- 3 monitoring. Of these, 89 were new monitoring locations. The new sites are categorized as follows:

1. 53 meters installed in the City and County system for purposes of providing calibration data for a system-wide model and for supporting the City's Green Stormwater Infrastructure (GSI) efforts and capacity assessment
2. 6 meters installed in the storm drain system for purposes of characterizing stormwater flows in National Pollutant Discharge Elimination System (NPDES) basins
3. 30 meters installed in NPDES basins where additional data were required for system characterization.

Additional data were obtained from the following sources:

- 83 SPU-maintained permanent flow meters installed at NPDES outfalls
- supervisory control and data acquisition (SCADA) data from SPU pump stations associated with the CSO basins
- precipitation data from SPU's rain gauges (RGs) 02, 03, 07, 08, 09, 12, 15, and 20
- SCADA data from King County monitoring locations as necessary to provide boundary conditions for the CSO basin models.

To ensure the highest possible data quality, monitoring data were screened on a biweekly basis during the wet weather season. The screening focused on consistency and completeness of meter response. Data screeners noted anomalies, if any, which were then reviewed and resulted in action items for attention by the metering contractor if appropriate. In addition, monthly workshops were conducted to review the data for modeling suitability. These meetings focused on review of consistency of upstream and downstream meters (flow balance), flow response to rainfall, and the quality of the data for modeling purposes. These reviews resulted in removal and replacement of meters where suitable data could not be captured, and the identification of suitable and unsuitable portions of the data in locations where meter performance was challenged. Where data were still in question, detailed analysis of the monitoring site and meter response were conducted including installation of alternative flow meter technology when warranted.

Additional details on the screening activities and outcomes are contained in the monitoring plans (Volumes 2–3) and workshop presentations, which can be found in Appendix Q. Overall, these screening activities resulted in the collection of data that can confidently be used in model calibration.

Rainfall during the fall and winter of the Phases 2–3 monitoring period can be characterized generally as above average in volume and number of significant events at most gauges. Figure ES-1 shows the monthly long-term Sea-Tac average rainfall together with the observed rainfall at three rain gauges spanning the system. June through August 2009 showed minimal rainfall. Significant events occurred in September, October, and November 2009 and in the first half of January 2010. The months of February through April 2010 were average in total rainfall, and May 2010 was above average due to two large events.

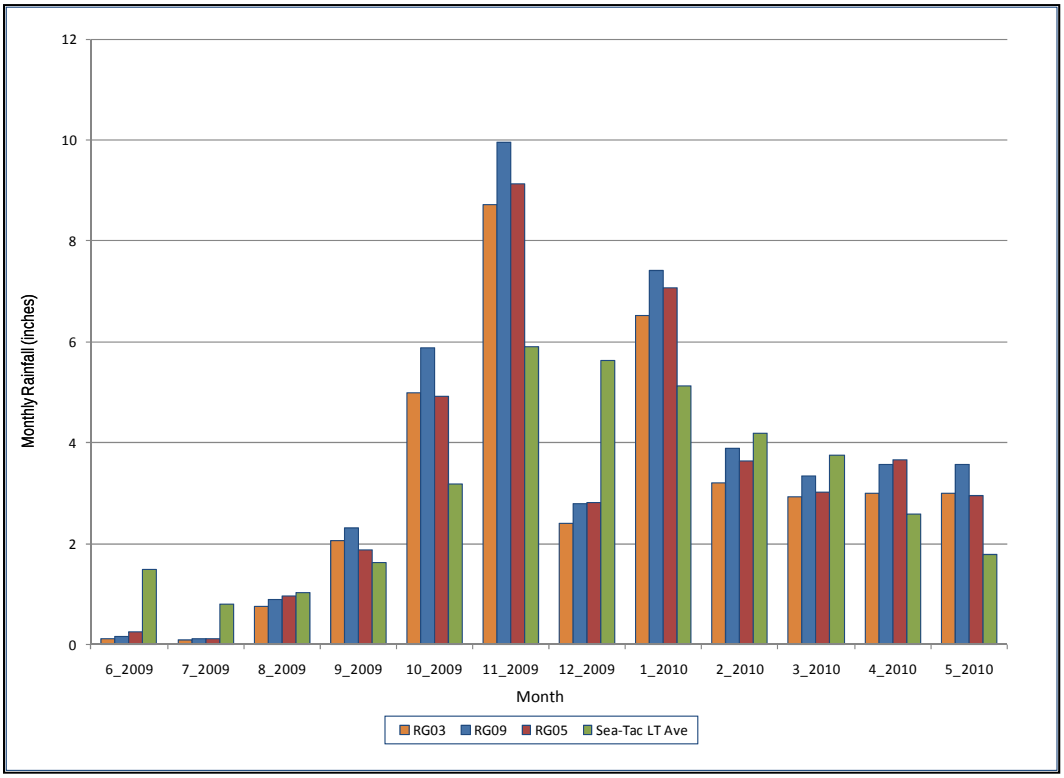

Figure ES-1. Monthly average precipitation at three SPU gauges compared to the long-term average

As stated in the Quality Assurance Project Plan 2009–2010, the objectives for the Phases 2–3 LTCP Flow Monitoring project were as follows:

- Capture data before, during, and after a wide range of storm events with a range of antecedent moisture conditions. In terms of recurrence intervals this objective is achieved by meeting both of the following criteria:
  - A minimum of three storm events of recurrence interval between 6 month and 1 year at any duration
  - A minimum of two storm events of recurrence interval between 1 year and 10 year at any duration spaced throughout the wet season.
- Recommend storm events for model calibration and future flow monitoring in the event that the desired storms do not occur during the project monitoring period.

After the conclusion of Phase 3 monitoring and in combination with the data collected during Phases 1 and 2, all of the above-stated objectives of the monitoring have been exceeded at each gauge. In addition, the characteristics of the rainfall that occurred provide excellent opportunities to calibrate both the impervious runoff and groundwater flows in the models. No further monitoring is required to meet the project objectives. The events identified in Table 3-1 through Table 3-3 are recommended for model calibration.

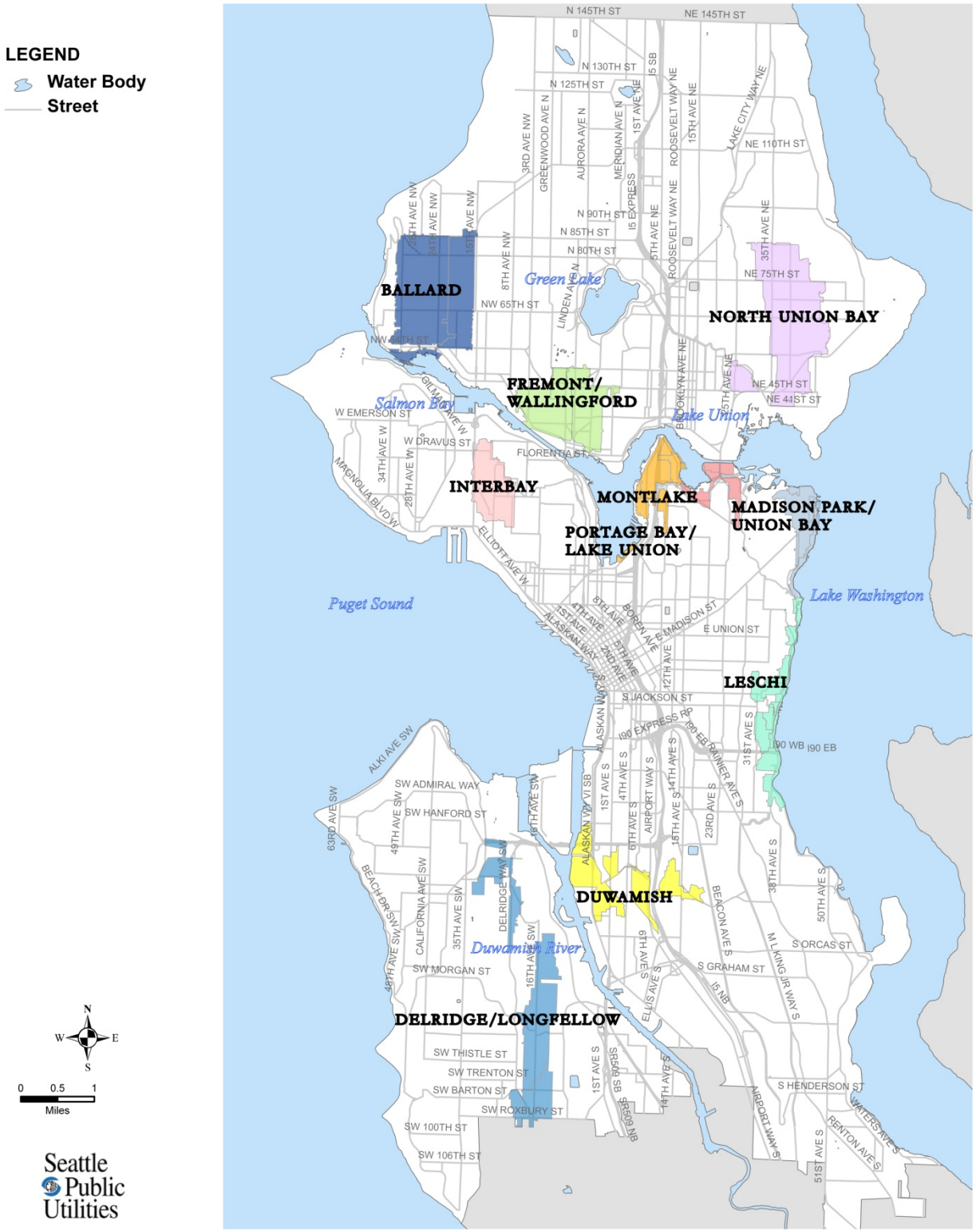

Figure ES-2. Long-Term Control Plan flow monitoring basins

1. INTRODUCTION

Seattle Public Utilities (SPU) is currently implementing a program to reduce combined sewer overflows (CSOs). The Long-Term Control Plan (LTCP) will develop options to reduce CSOs in the most cost-effective manner. One of the requirements of the LTCP is to have accurate hydraulic models of the combined sewer system (CSS). SPU is undertaking flow monitoring of the CSS over a 2-year period to capture sufficient data to calibrate the hydraulic models. Phase 1 of this three-part monitoring program was conducted from 10/1/2008 through 5/31/2009 and its results are summarized in the Phase 1 Seattle Data Monitoring Report. Phase 2 was conducted from 6/1/2009 through 9/30/2009, and Phase 3 was conducted from 10/1/2009 through 5/31/2010. The results for the last two phases are summarized in this report. The Phases 2 and 3 Seattle Data Monitoring Report 2009–2010 describes the monitoring effort that was undertaken during these periods, including the quality of the collected data and their suitability for use in the calibration of hydrologic and hydraulic models and system capacity assessments.

1.1 Goals

The goal of the CSO LTCP is to identify an approved list of CSO reduction projects that will be carried into design and construction in the future to meet the City's CSO reduction regulatory requirements.

The goal of the LTCP Flow Monitoring project is to collect continuous rainfall depth, level, velocity, and operational data in the CSS for two complete wet seasons: 10/1/2008 through 5/31/2010. This report summarizes Phases 2–3 of the monitoring, which extends from 6/1/2009 through 5/31/2010. The collected data must accurately represent the conditions throughout the CSS.

The data will be used to characterize and assess the hydrologic and hydraulic performance of the CSS and support development of the LTCP. The data collected during this period will provide flows for the calibration of CSO basin models and the King County system-wide model, and support Green Stormwater Infrastructure (GSI) pilot studies.

1.2 Monitoring Objectives

The objectives of flow monitoring are as follows:

- Adequately and accurately characterize the hydrologic and hydraulic performance of the CSS by collecting rainfall depth, level, velocity, and operational data. The adequacy and accuracy of data will be assessed using the following criteria identified in Section 14 of the Quality Assurance Project Plan (QAPP), December 2009:
  - Hydrologic performance is defined as the response of a subcatchment to rainfall.
  - Hydraulic performance is defined as the operating characteristics of structures and facilities in the CSS, including in-line and offline storage, HydroBrake gates, weirs, diversions, regulators, and pump stations.

- Capture data before, during, and after a wide range of storm events with a range of antecedent moisture conditions. In terms of recurrence intervals, this objective can be defined as a minimum of three storm events of recurrence interval between 6 months and 1 year at any duration, and a minimum of two storm events of recurrence interval between 1 and 10 years at any duration spaced throughout the wet season.
- Recommend storm events for model calibration and future flow monitoring in the event that the desired storms do not occur during the project monitoring period.

1.3 Study Boundaries

The study boundaries for Phases 2–3 monitoring were expanded outside the National Pollutant Discharge Elimination System (NPDES) basins monitored during Phase 1 to include additional areas throughout the city and King County's CSS.

1.3.1 Uncontrolled NPDES Basins

Ten NPDES Basins—Ballard, Delridge/Longfellow, Duwamish, Fremont/Wallingford, Interbay, Leschi, Madison Park/Union Bay, Montlake, North Union Bay, and Portage Bay/Lake Union—were monitored during Phases 2–3 of the monitoring program. These basins occupy a total area of approximately 5,500 acres (8.5 square miles) and comprise a number of areas draining to an overflow point, which is designated by an NPDES number. These basins are served by a CSS, which conveys wastewater and runoff from directly connected rooftops, streets, and area drains to the King County interceptor system and ultimately to the King County West Point Treatment Plant. An overview of the monitoring locations by NPDES basins is shown in Figure 1-1 through Figure 1-4. A majority of the Phase 1 monitors remained in place for Phases 2–3. The monitoring locations shown as Phases 2–3 installations in Figure 1-1 through Figure 1-4 were additions or replacements. Actual install and removal dates are given in the site datasheets found in Appendix C through M.

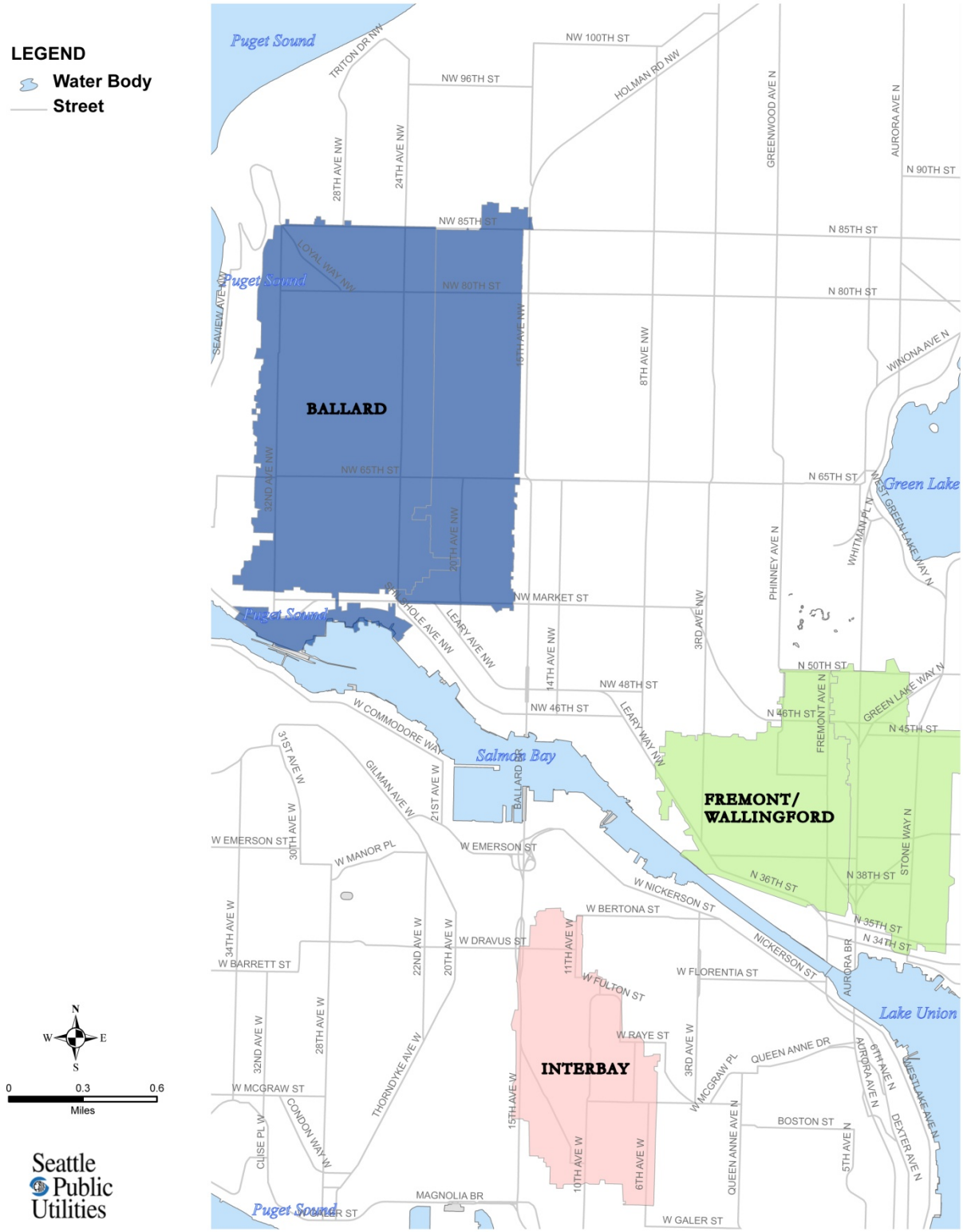

Figure 1-1. Basin overview map: Ballard, Fremont/Wallingford, and Interbay Basins

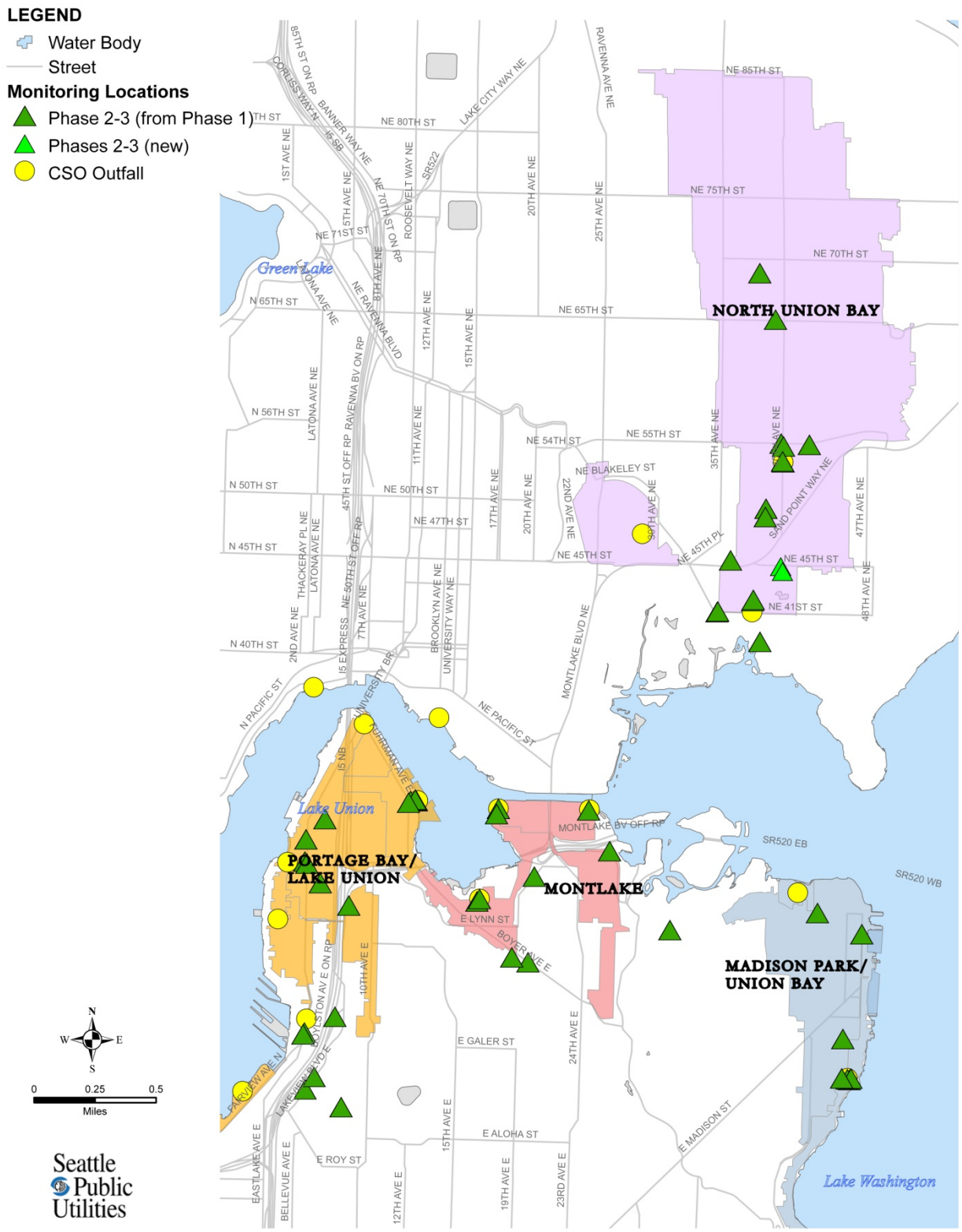

Figure 1-2. Basin overview map: Madison Park/Union Bay, Montlake, Portage Bay/Lake Union, and North Union Bay Basins

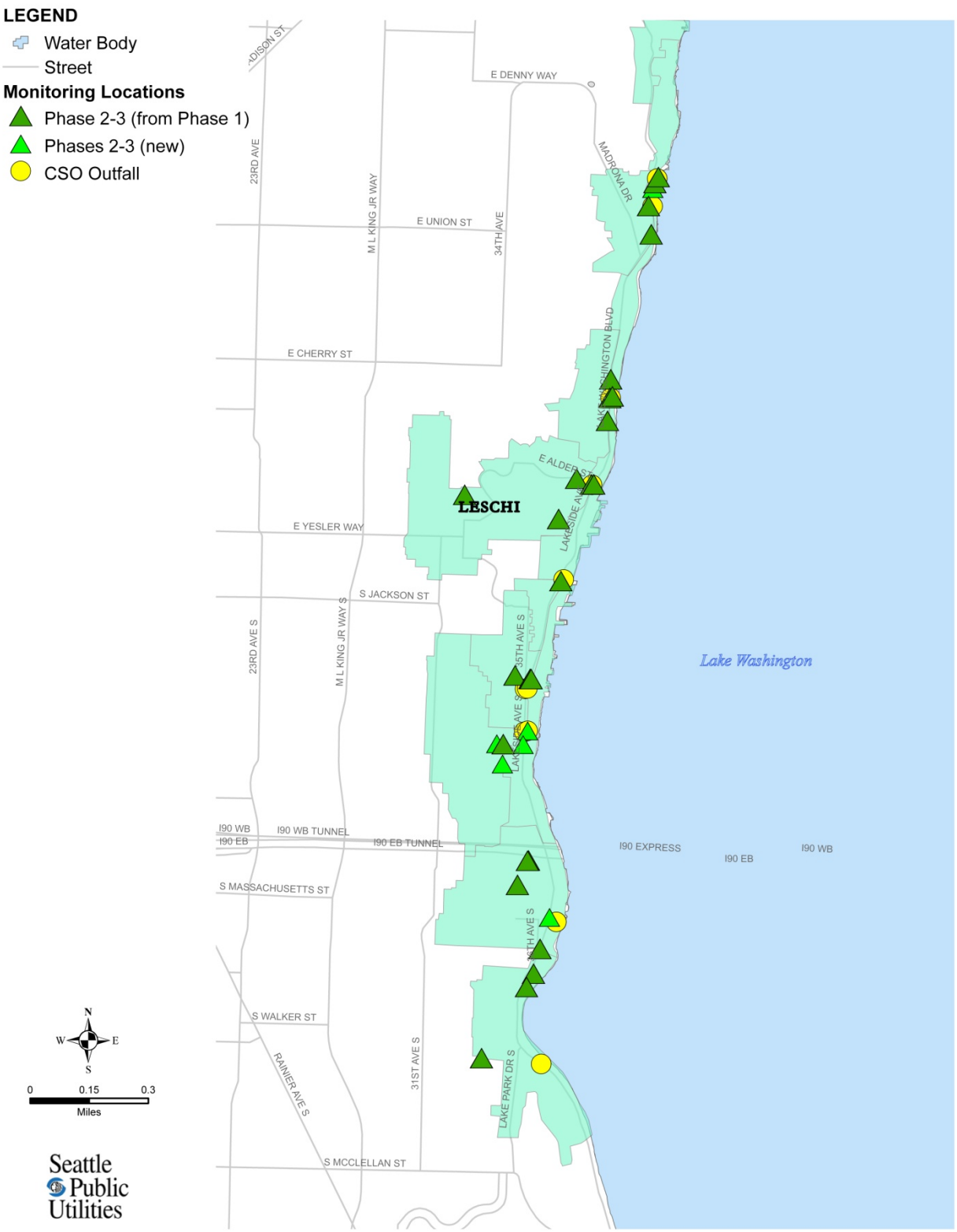

Figure 1-3. Basin overview map: Leschi Basin

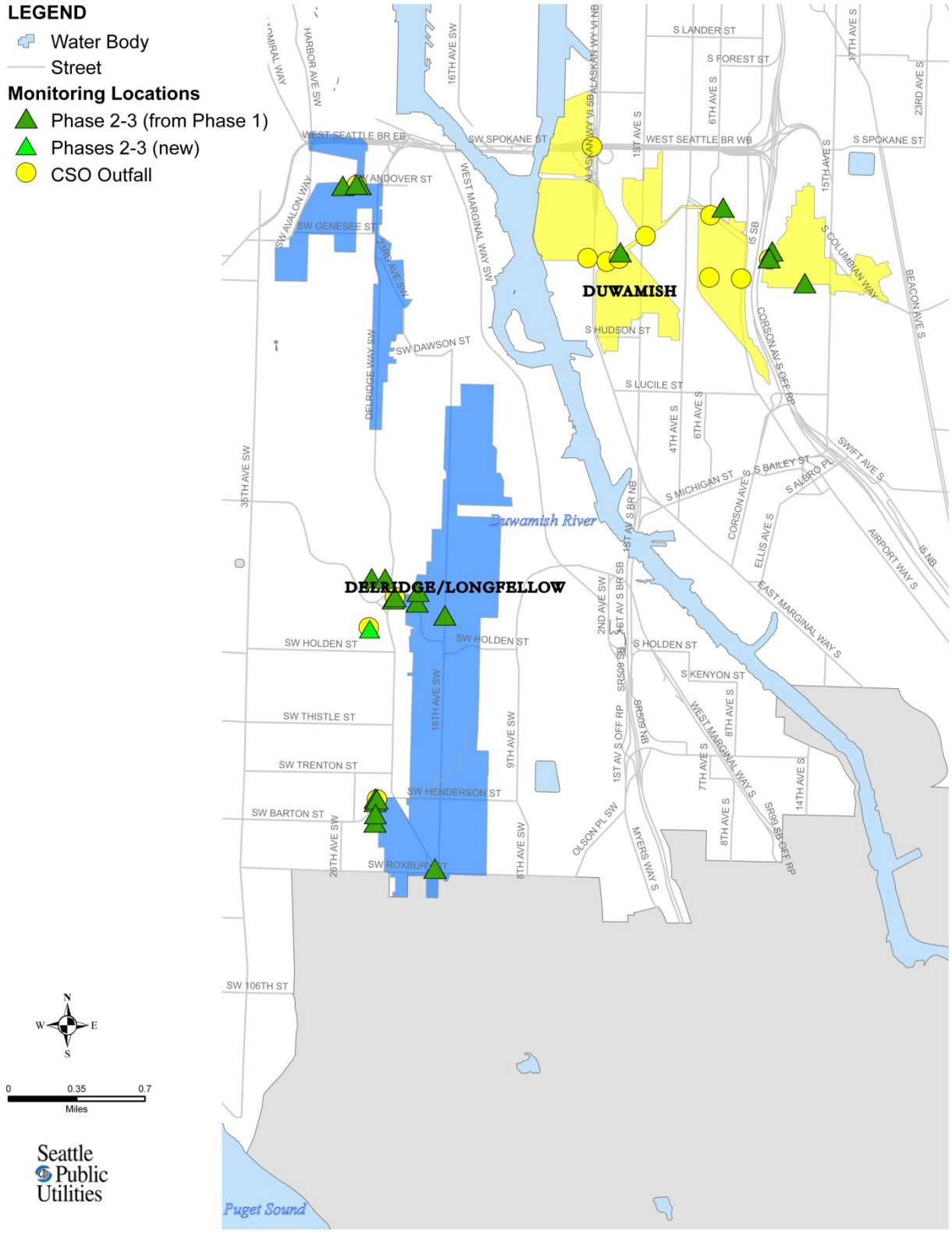

Figure 1-4. Basin overview map: Delridge/Longfellow and Duwamish Basins

1.3.2 System-Wide Basins

Given that the City's CSS drains into King County's CSS and that both systems affect each other hydraulically, a system-wide collaborative effort was undertaken. As part of this approach, Phases 2–3 of the flow monitoring plan included monitoring locations that collected data to be used in the calibration of a system-wide model.

The system-wide monitoring locations were selected to capture the flows from the City's combined sewer network before draining into King County's system in areas not covered by the CSO basin-specific model. The system-wide model basins were previously delineated by Aqualyze Inc. The delineation was performed by tracing the pipe network upstream from the maintenance hole connecting the last City-owned pipe to the King County interceptor system. In some cases, several connection points were combined into a single basin where SPU connections to the King County system are closely spaced. A total of 53 system-wide monitoring sites were installed for Phases 2 and 3 monitoring. Overview maps of these monitoring basins and locations are presented in Figure 1-5 through Figure 1-7.

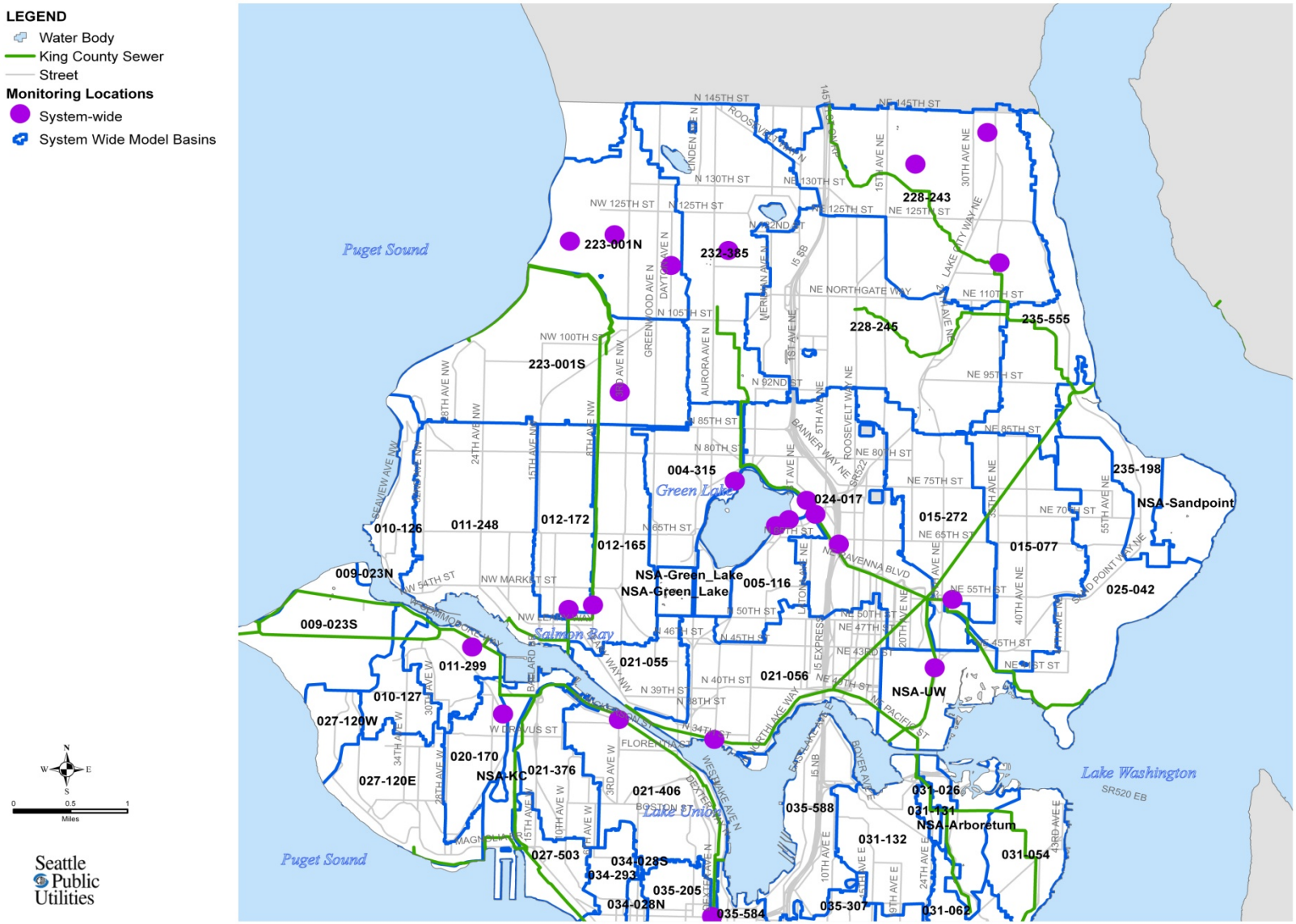

Figure 1-5. System-wide monitoring locations: North Seattle

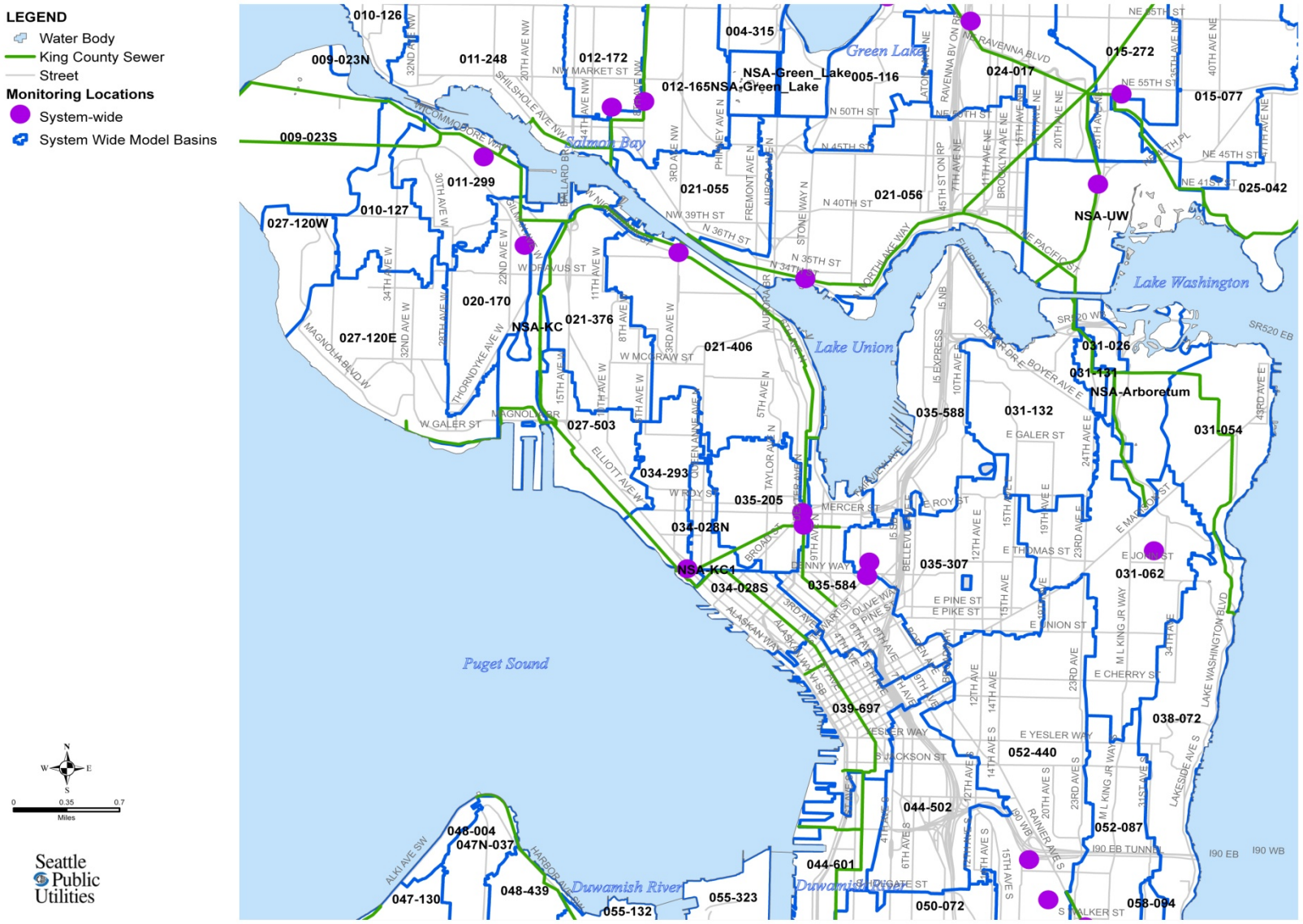

Figure 1-6. System-wide monitoring locations: Central Seattle

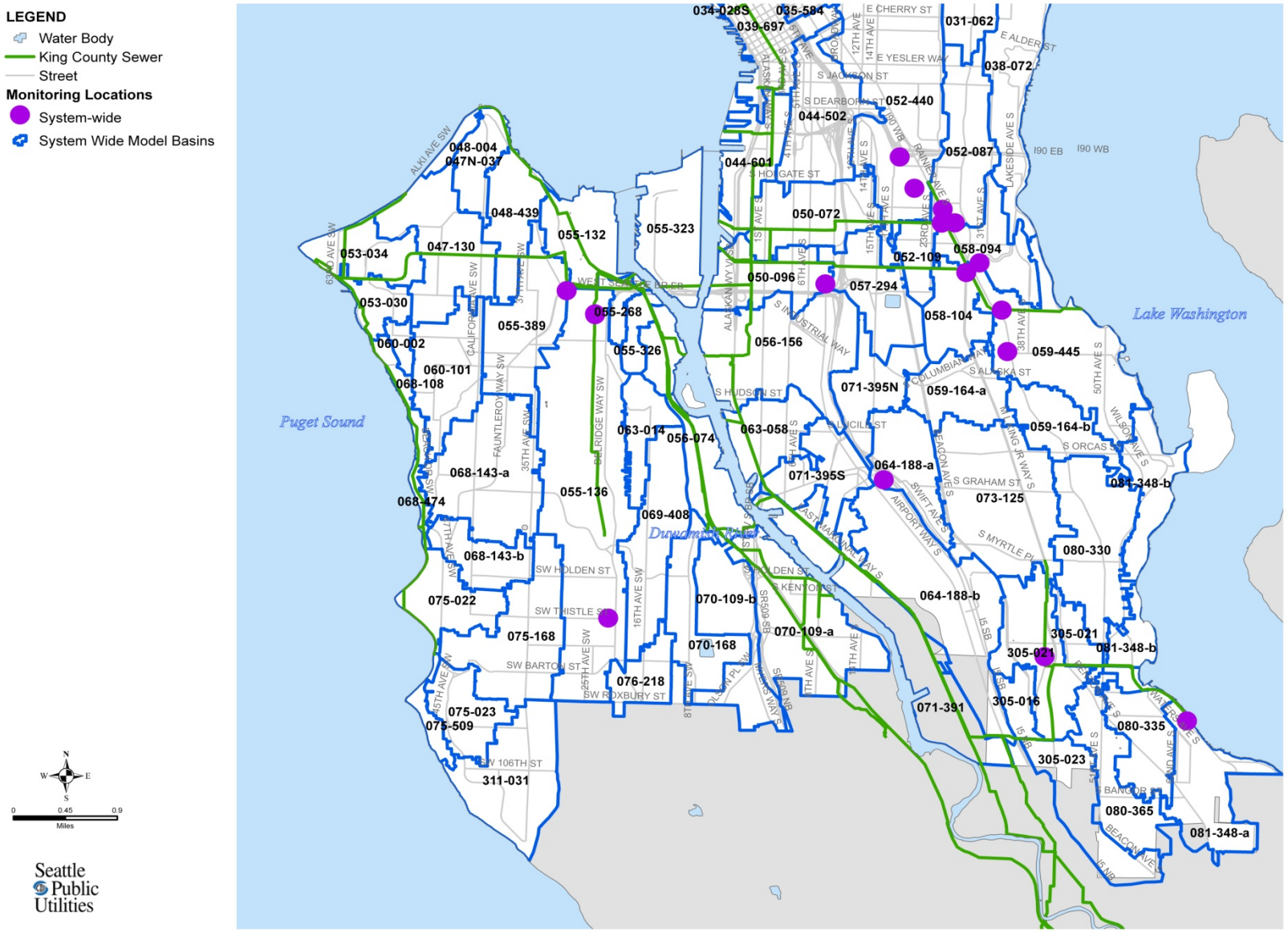

Figure 1-7. System-wide monitoring locations: South Seattle

1.4 Report Organization

This report documents Phases 2–3 of data collection, from 6/1/2009 through 5/31/2010. The organization of the reported is summarized below:

Section 1: Introduction

Section 2: Methodology

Section 3: Monitoring Data

Section 4: Suitability of Data for Hydrologic and Hydraulic Modeling Efforts

Section 5: Conclusions

The appendices of this report contain data site sheets by NPDES basin and by system-wide model site. These data site sheets are meant to supply more quantitative information for each site and include the following information:

- purpose of each location
- site installation photos
- upstream pipe traces
- period meter installed and collecting data
- field-verified pipe diameter
- extent of scatter-of-depth and velocity data
- flow regime
- range of depth, velocity, and flow during the monitoring period.

The data collected from all temporary sites are stored in a ZFM2 database developed by Stantec. The database also includes information such as silt/sediment measurements, field verification measurements, site maintenance, and data finalization notes for all temporary meters.

The data collected from NPDES-permitted CSO outfall monitors are stored on IntelliServe, a Web site database developed by ADS Environmental Services (ADS). The Web site contains information such as silt/sediment measurements, field verification measurements, site maintenance, and data finalization notes for all permanent meters.

ADS collected the data from SPU rain gauges and stored them on IntelliServe. Data were also imported in the ZFM2 database for temporary meter comparison to rainfall.

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2. METHODOLOGY

This section provides an overview of the methodology used to monitor flow, rainfall, pump stations, and overflows in the CSS. More detailed information can be found in the *Quality Assurance Project Plan. Long-Term Control Plan: Flow Monitoring Plan 2009–2010* (QAPP December 2009).

2.1 Monitoring Locations

This section presents a description of the different types of monitoring locations from which data were collected during the review period.

2.1.1 Permanent Monitoring Locations

The City has 90 currently active permitted CSO outfalls. The permitted outfalls have a total of 108 discharge points; for example, NPDES111 Basin has 8 overflow weirs discharging to the outfall pipe. ADS operates and maintains monitors at 82 of the discharge points, utilizing 92 monitoring points (including redundant meters to confirm overflows). These meters comply with the City's NDPES requirements for reporting CSO overflows to Ecology. The ADS meters cover 65 of the 90 permitted outfalls. The SPU pump station supervisory control and data acquisition (SCADA) system monitors the rest of the permitted outfalls. As part of this LTCP monitoring review, 50 of the existing ADS monitoring points were reviewed for data quality.

Twenty-nine of the permanent meters were expected to provide only depth data to identify and quantify overflow events. These meters were termed "wet weather" sites because they were used only to determine overflows. Twenty-one of the meters provided continuous depth and velocity information that was used to calculate both dry and wet weather flows. These meters were termed "dry weather" sites. ADS finalized the velocity and computed flow data from these meters, which were used in this project to characterize dry and wet weather flows within a basin and to supplement the information obtained from the temporary meters. In some of the smaller basins, the permanent meters were used to characterize the hydrology as well as structure performance. The wet weather and dry weather meters are designated in all the basin schematics in Appendix B as "DW" and "WW," respectively.

Details of the permanent meters used for this project, including their location, overflow condition, and meter type, are summarized in T-16 in the *QAPP/2009–2010 Flow Monitoring Plan, SPU CSO Reduction Program, CSO LTCP* (December 2009).

2.1.2 Temporary Monitoring Locations

In addition to the permanent monitoring locations, a total of 210 temporary sites were monitored during Phases 2–3. Stantec was responsible for installing and maintaining the temporary meters.

The meters were installed in locations that would divide the basins into monitoring subcatchments sufficient to characterize hydrology. Sites were also selected to provide data for the characterization of key structures (HydroBrakes, sluice gates, weirs, storage tanks, etc.) in the basins. During the course of the project, some temporary meters were removed if the project team determined that they had captured sufficient data or that the data captured were not suitable for model calibration. Hydraulic conditions at some initial sites were

found not conducive to accurate data collection. These meters were moved to alternate sites, either to capture better-quality data or to characterize additional areas of the system or structures in the system.

Details of the temporary meters, including their location, meter type, and purposes, are summarized in T-17 in the QAPP (SPU, December 2009).

2.1.3 SCADA Monitoring Locations

SCADA data were obtained from SPU pumping stations to supplement the calibration and verification of the model. These data consist of wet-well levels at a 1-minute data resolution and pump run time data. SCADA data were also collected from the detention tank and control structures in the Delridge Basin.

SPU also completed drawdown tests for the pumping stations to determine the capacities of the stations. The SCADA data and drawdown test results were used to calculate flow hydrographs for use in model calibration.

2.1.4 King County Monitoring Locations

King County maintains a network of flow meters throughout its trunk sewer system at pump stations and regulator stations. For purposes of model calibration, data from the existing King County meters associated with the LTCP monitoring basins were collected to supplement the data from temporary meters. The King County data are not assessed within this data report. Assessment of these data will occur as they are used in the modeling.

2.1.5 Rainfall Monitoring Locations

SPU maintains a network of rain gauges throughout the City. ADS collected the data from SPU's network and in collaboration with SPU and MGS Engineers, reviewed, corrected, and finalized the data monthly. Rain data are stored on the IntelliServe site. Thiessen polygons were created for the SPU rain gauges to determine which rain gauge would be used for each flow meter location. It was determined that the meter locations were located within the area covered by nine separate rain gauges. The data from these gauges were sufficient for model calibration and analysis. Data from additional gauges will be used as necessary. Figure 3-1 shows the locations of the rain gauges.

2.2 Equipment

The parameters of concern for flow monitoring of the sewer system included velocity, water surface levels, and flow rates.

Ultrasonic or pressure sensors were used to measure depth in pipes, hydraulic control structures, or detention tanks at 5-minute intervals. An ultrasonic sensor typically measures velocity. The sensor transmits a continuous ultrasonic wave and measures the frequency shift of returned echoes reflected by air bubbles or suspended particles in the flow. Specific configurations vary by site.

Flow rates can be determined using a combination of measured velocity and flow area. Water surface levels were measured directly using an ultrasonic instrument where free surface conditions existed, or by using a pressure sensor. At most sites both ultrasonic and pressure sensors were used to measure water surface levels. For this project, measuring the depth within a cross-section of flow and the average velocity within that cross-section determined the flow rates. The flow rate was calculated by multiplying the area of flow by the average velocity (continuity equation). CSOs are typically measured by applying weir equations to the measured depth over a weir.

During the Phases 2–3 monitoring period, site verifications were performed to ensure that the meters were accurately measuring both velocity and depth. Site gain (peak- to average-velocity ratio) and any depth adjustments were evaluated throughout the monitoring period. Measurement quality was reviewed and validated according to the SPU Hydraulics SOP HYDR Q1100: Data Review, Assessment, Validation and Verification (SPU, June 2008).

The different types of flow monitoring equipment used for this project are summarized in the following subsections.

2.2.1 ADS FlowShark

The ADS FlowShark is an area-velocity flow meter that measures depth and velocity; the continuity equation is used to calculate flow. Three types of data acquisition sensors are available for the FlowShark: an ultrasonic depth sensor, a pressure depth sensor, and a velocity sensor.

The primary depth measurement device is the ADS quad-redundant ultrasonic level sensor mounted at the top of the pipe. It operates by measuring the elapsed time for an ultrasonic signal to travel to the flow surface and back, and calculates the distance to the flow surface. This information and the programmed pipe geometry are used to compute area of flow.

A pressure depth sensor is also used. It measures the depth of flow by recording the difference in atmospheric pressure and water height pressure. The pressure sensor is used as a backup measurement to the ultrasonic depth sensor. It is also used to record depth in surcharged maintenance holes (MHs) where the ultrasonic depth measurement cannot be used.

The ADS V-3 digital Doppler velocity sensor measures peak velocity in the cross-sectional area of flow. An ultrasonic carrier is transmitted upstream into the flow and is reflected by suspended particles, air bubbles, or organic matter with a frequency shift proportional to the velocity of the reflecting objects. The reflected signal is received by the sensor and processed using digital spectrum analysis to determine the peak flow velocity.

2.2.2 ADS FlowShark Pulse

During this project, ADS FlowShark Pulse meters were utilized in applications where the hydraulic conditions of large pipes included low velocities. ADS FlowShark Pulse meters are suitable for a wide range of applications, but they are much more expensive than the FlowShark meters. The ADS FlowShark Pulse meters have gated cross-correlation technology with digital pattern detention to measure velocity at multiple depths in the flow profile. The meters also have an upward-looking ultrasonic sensor to directly measure depth. The ADS FlowShark Pulse meters are best suited for applications where hydraulic conditions are not suitable for general purpose meters, such as sites with large pipes and low velocity. However, the meters are prone to sedimentation, restricting their usage.

2.2.3 Micromonitors

The Micromonitors consist of a custom-fabricated flume coupled with an ADS FlowShark to measure depth and velocity. The depth is used to compute flow through the flume, and the velocity is used to confirm the rating curve. The Micromonitors were used in sites with low flow, where a custom-fabricated flume created a critical depth control section for flow measurement. Stantec is creating rating curves in laboratory to convert the level data into flows. The Micromonitors and the developed rating curves will be used to monitor pre- and post-development hydrographs and assess the effects of the GSI pilot studies in the Ballard Basin.

2.2.4 ISCO 2150 Area Velocity Flow Module

The ISCO 2150 flow module uses continuous-wave Doppler technology to measure mean velocity. The sensor transmits a continuous ultrasonic wave, and then measures the frequency shift of returned echoes reflected by air bubbles or particles in the flow.

The 2150 has an area velocity probe built on digital electronics so that the analog level is digitized in the sensor itself to overcome electromagnetic interference. A pressure sensor within the AV probe measures the level. The probe is factory-calibrated for 10-foot span at different temperatures, which eliminates drift in the level signal.

2.2.5 ISCO 2110 Ultrasonic Flow Module

The ISCO 2110 ultrasonic flow module provides non-contact liquid level measurement. The ultrasonic level sensor, mounted above the flow, transmits sounds waves that are reflected by the liquid surface. The elapsed time between the transmitted and returned signal determines the liquid level. The device then calculates flow rate using the water level and the pre-programmed pipe dimensions.

2.2.6 ISCO 4230 Bubbler

The ISCO 4230 bubbler uses an internal air compressor to force air from a bubble tube submerged in the flow. The depth of flow is determined by measuring the pressure needed to force bubbles out of the line. The 4230 then converts the depth into a flow rate. For this project, the ISCO bubbler was used to measure depth in structures where there is a restriction on electronic signals from in-stream sensors.

2.3 Data Collection, Processing, and Analysis

This section provides a description of the techniques that were employed to ensure the integrity of the data, and the procedures used by ADS and Stantec for the processing and analysis of the data.

2.3.1 Permanent Meters

During the Phases 2–3 monitoring period, field crews visited each monitoring location to retrieve data if remote communications were not available, verified proper meter operation, and documented field conditions. The following quality assurance steps were taken to ensure the integrity of the collected data (ADS Quality Assurance and Implementation Plan, ADS Environmental Services, June 2009):

Measure power supply: A dry-cell battery pack powered the meter. Power levels were recorded and battery packs were replaced, if necessary. A separate battery provided backup power to memory, which allowed the primary battery to be replaced without the loss of data.

Maintenance: Maintenance was performed if requested by the data analyst or determined by the field crew to be needed. Maintenance tasks included sensor "scrubbing" (removal of debris) and replacement of system parts if a malfunction of a part occurred. Maintenance was both preventive and reactive for the flow meter and sensors. Maintenance records were posted to the IntelliServe site on request.

Perform confirmations and validate depth and velocity: Once equipment and sensor installation was accomplished, a member of the field crew descended into the maintenance hole to perform a field measurement of depth and velocity to confirm their agreement with the meter. Because the ADS V-3 velocity sensor measures peak velocity in the wetted cross-sectional area of flow, velocity profiles were also taken to develop a relationship between peak and average velocity in lines that meet the hydraulic criteria.

Measure silt level: During site confirmation, a member of the field crew descended into the maintenance hole and measured and recorded the depth of silt at the bottom of the pipe. These data were used to compute the true area of flow.

Confirm meter synchronization: The field crew checked the flow meter clock for accuracy. If the meter and computer time were different by more than 5 minutes, the meter was activated with the current computer time. The data for this project were also synchronized with those of the temporary flow meters.

Upload and review data: Data collected by the meter were uploaded and reviewed for comparison with previous data. Data for this project were collected remotely via wireless communication and uploaded to the ADS IntelliServe system. In the event that the signal strength did not permit remote data collection, the data were collected as per the current ADS Contract Scope of Work. All readings were checked for consistency and screened for deviations in the flow patterns, which indicated system anomalies or equipment failure.

Flow meters were programmed to collect data at 5-minute intervals throughout the monitoring period unless circumstances dictated a more frequent sample rate (for example, rapidly changing flows due to pump station influence). For this project, the flow meters were programmed to collect data at 5-minute intervals to achieve high-resolution data that were suitable for model calibration.

The meter stored raw data consisting of (1) the air range (distance from sensor to top of flow) for each active ultrasonic depth sensor pair and (2) the peak velocity. If the meter was equipped with a pressure sensor, then a depth reading from this sensor was also stored. When the field personnel collected the data, the air range was converted to depth data based on the pipe height and physical offset (distance from the top of the pipe to the surface of the ultrasonic sensor) and/or the offset from a weir. The data were imported into the ADS Profile™ software, and a data analyst examined the data to verify their consistency. The data analyst also reviewed the daily field reports and site visit records to identify conditions that would affect the collected data.

The data analyst reviewed the velocity profiles and line confirmation data developed by the field personnel to identify inconsistencies and verify velocity data reliability. Velocity profiles were reviewed and an average-to-peak velocity ratio was calculated for the site. This ratio was used in converting the peak velocity measured by the sensor to the average velocity used in the continuity equation.

The data analyst reviewed the meter selection for which the depth sensor entity was used to calculate the final depth information. Any silt levels present at each site visit were reviewed and representative silt levels were established.

Selections for the above parameters were constant or changed during the Phases 2–3 monitoring period. While the data analysis process is described in a linear manner, it often required an iterative approach to complete it accurately.

2.3.2 Temporary Meters

Every 4 weeks, the crews performed level checks and velocity profile measurements. All field observations and maintenance records were translated into ZFM2 as a record, and the paperwork was scanned and organized in ZFM2. If any changes were made at the site, engineers reviewed them and made appropriate changes in the data (editing) using the Data Analysis (DAS) tool in ZFM2.

Photographs of the upstream pipe, band, and any other object of concern were taken and organized in ZFM2 for each specific site.

The flow meters were set to record data at 5-minute intervals, and data were collected through wireless telemetry and weekly for sites that required data to be collected manually. Numerous types of meters were

installed, and each meter used its proprietary software to log the data. Thus, the data processing was slightly different for data from each of the meters.

ADS FlowShark: The two methods of collecting data from an ADS FlowShark included a remote wireless connection and an onsite serial connection. For both methods, upon successful connection the meter supplied flow data in the format of BIN files. The BIN files for the download were then transferred to the computer in Stantec's Seattle field office. The ADS Profile™ software identified the BIN files, which were then processed using the BIN file processor. The data were stored in the ADS Profile™ database, then compressed and transferred to the Stantec network server and the City of Seattle file transfer protocol (FTP) site. The data were readily available to engineers at Stantec's Cincinnati office for further processing.

The ADS Profile™ database was quickly reviewed for the current day's downloads, and the raw data were exported as text files. The exported raw data comprised the following entities: DFinal (depth), Vfinal (velocity) and Qfinal (flow). The Final Data Generator in ADS Profile™ generated the entities.

The exported raw data were then imported into the ZFM2 database, where they were compressed and uploaded onto the City of Seattle FTP site. This process was performed on a daily basis.

ADS FlowShark Pulse: The data from these meters were supplied as text files. The text files were transferred to the office and after some minimal formatting in Excel, the formatted files were imported into the ZFM2 database.

ISCO meters: The downloaded database was transferred to the office; the office personnel then exported the data as CSV files. These files were then imported into the ZFM2 database.

All data obtained from flow meters were reviewed using ZFM2 software. To account for data gaps or periods where the data were incorrect or suspect, data were edited in ZFM2. The following situations describe data gaps that were editable and corrected or filled in with data from another time period:

- **Level adjusts:** Site visits identified instances in which pipe diameters were incorrectly recorded. This usually occurred when a probe was changed or a band was moved. Following verification of the correct diameter, the raw data in ZFM2 were adjusted to account for the difference in level.
- **Daily pattern:** During dry weather, the daily pattern from another dry period was substituted where data were missing.
- **Missing velocity:** When the level data appeared to be consistent and of suitable quality, the missing velocity was filled in using the implied Manning's curve.
- **Data "pops":** Site conditions or random meter problems can cause spurious depth and velocity measurements. These data were removed from the raw data by using adjacent data as a best approximation of the correct value.
- **Peak velocity limited**: Peak velocity limits only apply to ADS FlowShark meters. Meters were usually installed with a velocity recording range of 0 to 10 feet per second (fps). It was found that certain sites exhibited peak velocities above that range, necessitating a reset of the meter electronics to measure higher velocities. The previously measured velocities restricted to 10 fps were adjusted based on subsequent data with a higher measurement range.
- **Sediment depth:** Depths of sediment at the meters were recorded at each site visit. These data, however, were not used to correct computed flows.

3. MONITORING RESULTS

3.1 Rainfall

Rainfall data were collected for the LTCP through the City rain gauge network. Data from 9 of the 17 gauges were applicable to the NPDES basins included in the LTCP. Each of the nine gauges was assigned to an NPDES basin for review of flow monitoring results. This section describes those data, compares the gauges to each other, and compares the data to historical precipitation statistics.

The Phase 2 monitoring period was from 6/1/2009 to 9/30/2009; the Phase 3 monitoring period was from 10/1/2009 to 5/31/2010. Unless otherwise noted, stated values are for the Phase 2 and 3 periods. The long-term average rainfall at Sea-Tac International Airport for the period from June through May is 37.1 inches. During the Phases 2–3 monitoring period, the actual total measured precipitation at Sea-Tac was 40.17 inches, indicating a higher than normal rate of precipitation during this period. Total precipitation at each of the nine gauges used in this review varied from that recorded at Sea-Tac in the same period, ranging from 37.8 inches at RG 03 to 43.9 inches at RG 09. A map of the SPU rain gauge network is presented in Figure 3-1. Figure 3-2 shows cumulative precipitation for the monitoring period for each of the LTCP rain gauges compared to that of Sea-Tac.

The fall and winter rainfall of the monitoring period can be characterized generally as above average in volume and number of events at most gauges. Figure 3-3 shows the monthly long-term Sea-Tac average rainfall together with the observed rainfall at RG 05, RG 03, and RG 09. June through August 2009 showed minimal rainfall. Significant events occurred in October and November 2009 and in January 2010. The months of February through April 2010 were average in total rainfall, while May 2010 was above average due to two large events. In contrast to Phase 1, no snowfall occurred in Phases 2–3.

During the Phases 2–3 monitoring period, SPU began to install SCADA equipment at rain gauge locations for remote collection of data. This equipment was installed while ADS data loggers were still in place. It was discovered during the monitoring that this activity generated electromagnetic interference with the data loggers, resulting in the recording of false bucket tips. Mel Schaefer of MGS Engineering Consultants examined the data. By comparing data to nearby unaffected gauges and the occurrence of multiple tips in short time periods, Mr. Schaefer was able to identify periods with false tips and remove them from the record. The problem and correction methodology is further described in Appendix P. This adds some uncertainty to the rainfall data at RG 01, RG 03, RG 08, RG 14, RG 17, and RG 18—three of which are associated with the LTCP model basins.

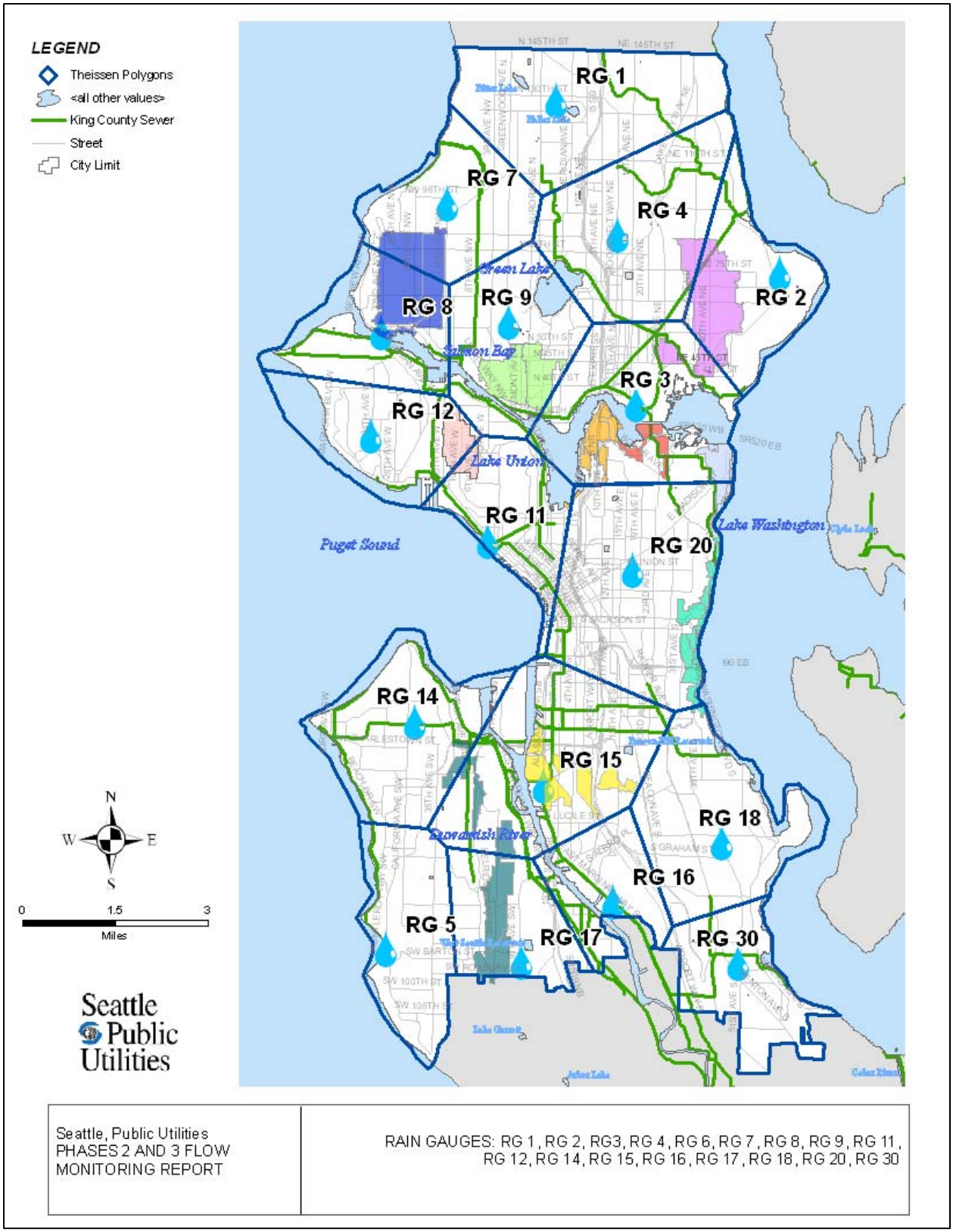

Figure 3-1. Thiessen polygons for each of the SPU rain gauges; north and south borders are the city limits

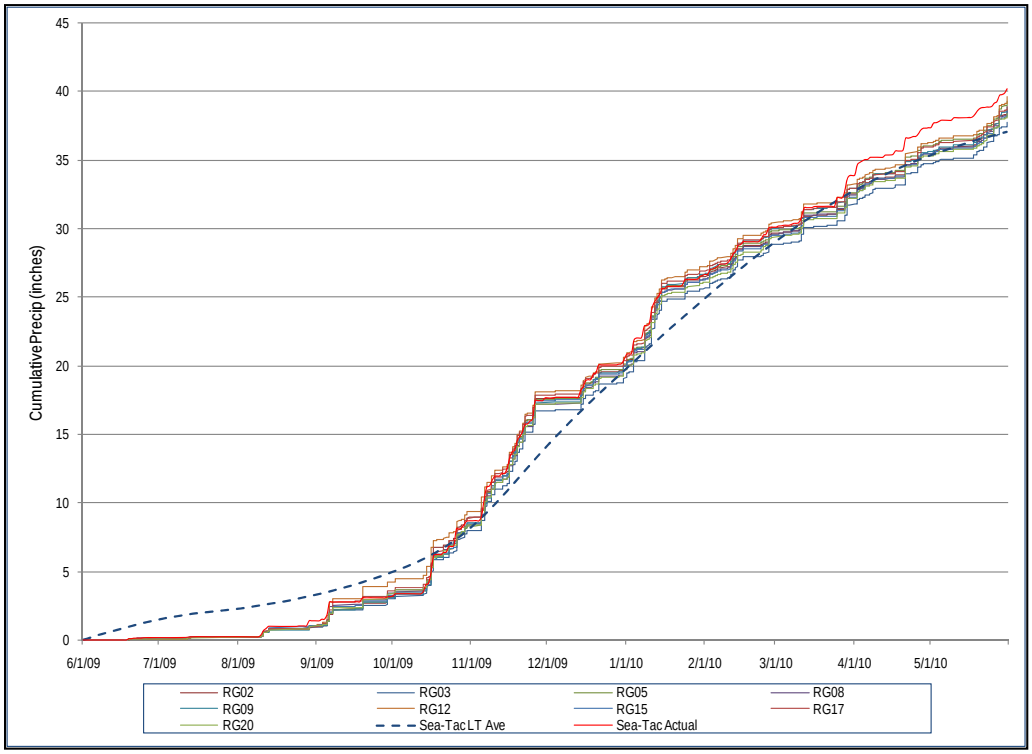

Figure 3-2. Cumulative precipitation for each of the SPU rain gauges used for the LTCP, compared to the actual precipitation and historical average at Sea-Tac

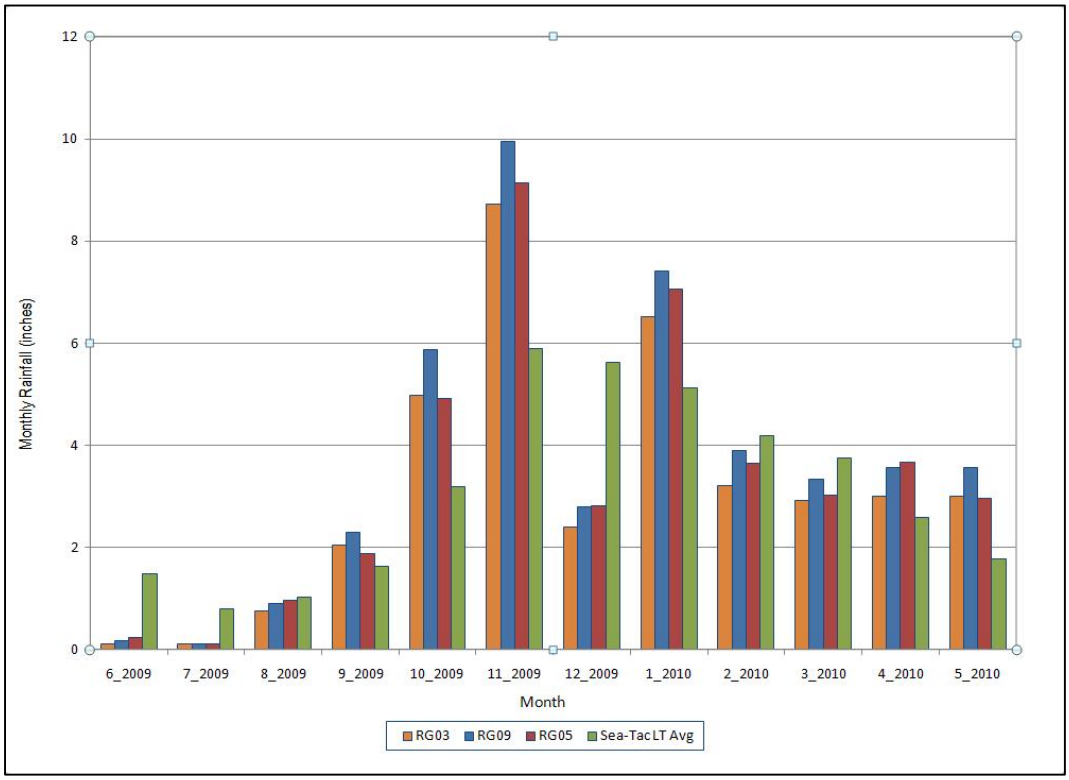

Figure 3-3. Monthly average precipitation at three SPU gauges compared to the long-term average

3.1.1 Variations between Rain Gauges

Total precipitation during the monitoring period for the nine gauges examined varied between 37.8 and 43.9 inches. In general, the longer-term rainfall was fairly uniform across the city. Table 3-1 indicates that the 7-day total rainfall in the 10 events examined varied by less than 0.5 inches up to about an inch across the network.

Peak rainfall intensities were somewhat more variable across the city, particularly in the fall and spring events as indicated in Table 3-2. Variation in peak intensities is expected; however, each gauge indicated short-term intensities of 1-year recurrence and larger during the monitoring period.

Depth-Duration-Frequency (DDF) graphs for both short and long durations can be found in Appendix A. These graphs, taken from Analysis of Precipitation-Frequency and Storm Characteristics for the City of Seattle (MGS Engineering Consultants, Inc., 2003), show the difference in frequency of selected storms between the rain gauges at different durations.

3.1.2 Snowfall

No significant amount of snow fell in Seattle during the Phases 2–3 monitoring period.

3.1.3 Summary of Rain Gauge Data

From the monitoring period, 10 storm event periods representing the largest events were chosen for return-period analysis. These events are listed in Table 3-1 through Table 3-3.

Summaries of rain gauge storm depths and return intervals are reported in Table 3-1 through Table 3-3. These tables report statistics for all nine rain gauges used as part of the flow monitoring, for the nine events chosen for analysis as part of the LTCP.

Table 3-1 presents the maximum rainfall volume that occurred over a 7-day period for each event, together with the total monitoring period volume at each gauge. This provides an indication of the potential effect of each event since much of the tributary area will respond to prolonged higher-volume storms.

Table 3-2 presents the maximum recurrence frequency for each event at each gauge constructed by comparing the maximum rainfall depths at any duration with the short-term (5-minute to 3-hour) DDF curves. Uncontrolled CSO basins with significant impervious area respond greatly to high short-term intensities. The short-term DDF curves do not vary across the city.

Table 3-3 presents the maximum recurrence frequency for each event at each gauge when comparing the maximum rainfall depths at any duration in the long-term (6 hours to 168 hours or 7 days) DDF curves. The long-term DDF vary by rain gauge. Events near a 1-year recurrence frequency are desirable.

Table 3-1. Summary of Selected Event 7-Day Storm Depths for Each Rain Gauge											
Selected events			Rain gauge 7-day depth (inches)								
Event number	Start date	End date	2	3	5	8	9	12	15	17	20
1	9/1/2009	9/8/2009	1.29	1.20	1.20	1.53	1.46	1.30	1.35	1.36	1.62
2	10/12/2009	10/19/2009	2.83	2.67	2.60	2.94	3.44	3.05	2.60	2.85	2.68
3	10/25/2009	11/1/2009	2.15	1.72	1.70	1.62	1.76	1.51	1.78	2.08	1.74
4	11/5/2009	11/12/2009	2.77	3.00	3.50	3.21	3.31	3.25	3.58	3.67	3.01
5	11/14/2009	11/20/2009	2.58	2.65	2.99	3.19	3.26	2.94	2.84	3.05	2.74
6	11/21/2009	11/27/2009	3.59	3.79	3.80	4.38	4.39	4.03	3.96	4.11	3.86
7	1/8/2010	1/15/2010	3.61	3.69	3.88	3.77	4.11	3.94	3.62	3.76	3.48
8	3/27/2010	4/3/2010	1.52	1.54	2.60	1.83	1.95	1.98	1.97	2.17	1.64
9	5/1/2010	5/8/2010	0.87	0.78	0.98	0.96	1.01	0.93	1.00	1.20	0.78
10	5/18/2010	5/25/2010	1.16	1.14	1.10	1.58	1.34	1.67	1.06	0.87	1.26
Entire period	6/1/2009	5/31/2010	19.78	19.48	21.36	21.73	22.69	21.57	20.82	21.97	19.99

Table 3-2. Maximum Recurrence Intervals for Selected Storm Events by Rain Gauge: Short Duration (5 min to 3 hr) [a]											
Selected events			Rain gauge short-duration maximum return-period								
Event number	Start date	End date	2	3	5	8	9	12	15	17	20
1	9/1/2009	9/8/2009	1 yr	6 mo	2 yr	4 yr	1 yr	6 mo	2 yr	2 yr	1 yr
2	10/12/2009	10/19/2009	4 yr	2 yr	1 yr	1 yr	2 yr	3 yr	4 yr	6yr	3 yr
3	10/25/2009	11/1/2009	6 mo	< 6 mo	1 yr	6 mo	~ 1 yr	6 mo	2 yr	2 yr	~ 1 yr
4	11/5/2009	11/12/2009	< 6 mo	6 mo	3 yr	2 yr	< 6 mo	2 yr	6 mo	6 mo	~ 1 yr
5	11/14/2009	11/20/2009	< 6 mo	6 mo	5 yr	~ 1 yr	~ 1 yr	6 mo	6 mo	6 mo	6 mo
6	11/21/2009	11/27/2009	1 yr	1 yr	< 6 mo	1 yr	2 yr	1 yr	6 mo	< 6 mo	~ 1 yr
7	1/8/2010	1/15/2010	< 6 mo	< 6 mo	< 6 mo	6 mo	6 mo	6 mo	6 mo	< 6 mo	< 6 mo
8	3/27/2010	4/3/2010	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo
9	5/1/2010	5/8/2010	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo	1 yr	< 6 mo	< 6 mo	< 6 mo
10	5/18/2010	5/25/2010	6 mo	6 mo	2 yr	6 yr	< 6 mo	1 yr	< 6 mo	< 6 mo	< 6 mo

[a] *Maximum recurrence noted at any duration in the series from 5 minutes to 3 hours.*
~ indicates approximately.

Table 3-3. Summary of Selected Event Long-Duration Maximum Return-Periods for Each Rain Gauge (6 hr to 7 days)[a]										
Selected events			Rain gauge long-duration maximum return-period							
Event number	Start date	End date	2	3	5	8	9	12	15	17	20
1	9/1/2009	9/8/2009	< 3 mo	< 3 mo	< 3 mo	3 mo	3 mo	< 3 mo	3 mo	3 mo	3 mo
2	10/12/2009	10/19/2009	1 yr	1 yr	3 mo	6 mo	2 yr	< 1 yr	< 1 yr	6 mo	< 1 yr
3	10/25/2009	11/1/2009	6 mo	3 mo	3 mo	3 mo	< 1 yr	3 mo	1 yr	1 yr	6 mo
4	11/5/2009	11/12/2009	6 mo	6 mo	1 yr	6 mo	< 1 yr	< 1 yr	6 mo	6 mo	< 6 mo
5	11/14/2009	11/20/2009	6 mo	6 mo	6 mo	< 1 yr	< 1 yr	< 1 yr	6 mo	6 mo	6 mo
6	11/21/2009	11/30/2009	1 yr	1 yr	6 mo	< 2 yr	2 yr	1 yr	1 yr	1 yr	1 yr
7	1/8/2010	1/15/2010	1 yr	6 mo	6 mo	< 1 yr	< 2 yr	1 yr	< 1 yr	< 6 mo	< 6 mo
8	3/27/2010	4/3/2010	< 3 mo	< 3 mo	3 mo	3 mo	3 mo	< 3 mo	3 mo	3 mo	< 3 mo
9	5/1/2010	5/8/2010	< 3 mo	< 3 mo	< 3 mo	< 3 mo	< 3 mo	< 3 mo	< 3 mo	< 3 mo	< 3 mo
10	5/18/2010	5/25/2010	< 3 mo	< 3 mo	< 3 mo	3 mo	< 3 mo	< 3 mo	< 3 mo	< 3 mo	< 3 mo

[a] *Maximum recurrence noted at any duration in the series from 6 hours to 7 days.*
< indicates frequency is between that indicated and the next lower value.

3.1.4 Comparison of Storm Events to Project Objectives

As stated in the Quality Assurance Project Plan 2009–2010, the objective for Phases 2–3 rainfall monitoring were as follows:

- Capture data before, during, and after a wide range of storm events with a range of antecedent moisture conditions. In terms of recurrence intervals this objective is achieved by meeting both of the following criteria:
  - A minimum of three storm events of recurrence interval between 6 months and 1 year at any duration
  - A minimum of two storm events of recurrence interval between 1 year and 10 years at any duration spaced throughout the wet season.
- Recommend storm events for model calibration and future flow monitoring in the event that the desired storms do not occur during the project monitoring period.

In addition, MGS Engineers noted that the automated calibration process that will be used for the hydraulic models will work best with storms of about a 1-year recurrence with widespread spatial distribution (Mel Schaefer, personal communication). Each of the nine rain gauges captured storm events that met the objectives of this project during the Phases 2–3 monitoring period. Within these storm events there are excellent rainfall data for calibration purposes. Some of the larger storm events captured during the Phases 2–3 monitoring period are discussed below.

The storm event of 9/1–8/2009 included a total rainfall volume of approximately 1.4 inches falling mostly on 9/6/2009. The 7 days preceding this event had a total rainfall of approximately 0.2 inch, and there was approximately 0.9 inch of rain in the preceding 30 days. Overflows resulted at 13 of the NPDES Basins considered in this project. The short-term rainfall intensities ranged from 6 months to 4-year recurrence across the system. The longer-term intensities were about 3-month recurrence. The event was evenly distributed across the system.

The storm event of 10/12–19/2009 included a total rainfall volume of approximately 3.0 inches falling mostly on 10/16/2009 and 10/17/2009. The 7 days preceding this event had almost no precipitation, with approximately 1.2 inches of rain occurring within the preceding 30 days. Overflows resulted at 33 of the NPDES Basins considered in this project. The short-term rainfall intensities ranged from a 1-year to 6-year recurrence across the system. The longer-term intensities ranged from 3 months to 2-year recurrences. The event was evenly distributed across the system.

The storm event of 11/5–12/2009 included a total rainfall volume of approximately 3.5 inches. The 7 days preceding this event had a total rainfall of 0.6 inch, with approximately 5.4 inches of rain occurring within the preceding 30 days. Overflows resulted at 16 of the NPDES Basins considered in this project. The short-term rainfall intensities ranged from less than 6 months to 2-year recurrence across the system. The longer-term intensities ranged from 6 months to 2-year recurrences. The event was evenly distributed across the system.

The storm event of 1/8–15/2010 included a total rainfall volume of approximately 4.4 inches**.** The 7 days preceding this event had a total rainfall of 1.5 inches, with approximately 4.1 inches of rain occurring within the preceding 30 days. Overflows resulted at 22 of the NPDES Basins considered in this project. The short-term rainfall intensities were all about 6 months. The longer-term intensities ranged from 6 months to slightly less than a 2-year recurrence. The event was evenly distributed across the system.

Those events with minimal preceding rainfall provide a specific advantage for calibration of the impervious hydrologic portion of the models. The lack of preceding rainfall at several of these large events will limit the initial runoff to that from impervious areas. Examples include the September 2009, October 2009, and May 2010 events.

Storms with larger volume and antecedent rainfall are expected to result in groundwater infiltration, which will assist in setting parameters for the groundwater module of the models. The late November 2009 and early January 2010 events are key in this regard.

In conclusion, at the end of Phases 2–3 of the LTCP monitoring period and in combination with Phase 1 monitoring, all the stated objectives of the monitoring have been exceeded at each gauge; no further monitoring is required to meet these objectives. The events identified in Table 3-1 through Table 3-3 are recommended for model calibration.

3.2 Ballard Basin

The Ballard Basin, located in northwest Seattle, is more than 1,100 acres in area. The sewer system generally drains from north to south by gravity to the King County Ballard regulator for conveyance to the West Point Wastewater Treatment Plant (WWTP). The Ballard Basin contains two subcatchments, NPDES152 and NPDES150/151, which are described in the next section.

Flows from the NPDES150/151 Basin flow from north to south by gravity into the King County system just upstream from the King County Ballard regulator. Just prior to entering the King County system, flows from the NPDES152 Basin are combined with the flows from the NPDES151 Basin at MH 011-184. The northern part of the NPDES152 Basin flows into the NPDES150/151 Basin by gravity, while the flows from the southern portion of the NPDES152 Basin are collected in PS 84 and then pumped into a 36-inch trunk line for conveyance into the NPDES150/151 Basin.

Two SPU rain gauges are installed near the Ballard Basin. RG 07 is located at Whitman Middle School at 15th Avenue NW to the north of NW 90th Street, which is just past the northeast boundary of the upper portion of the NPDES150/151 Basin. RG 08 is located near the Hiram M. Chittenden Locks in the lower portion of the NPDES152 Basin. An examination of the flow monitoring data during storm events shows that these rain gauges provide an excellent representation of the timing, intensity, and spatial distribution of rainfall in the area.

ADS maintains permanent flow monitoring stations at the two overflow structures within the Ballard Basin. Stantec maintained a total of 17 temporary flow monitoring locations during portions of Phases 2–3. For the purpose of model calibration and the estimation of CSO control volumes no additional data are needed after the Phase 3 period. At the end of Phase 3, several temporary meters remain in place to support pre-construction and post-construction performance monitoring of SPU's Green Stormwater Infrastructure (GSI) projects. Detailed information on Ballard monitoring data can be found in Appendix C; a Basin schematic is contained within Appendix B.

3.2.1 NPDES150/151 Basin

The NPDES150/151 Basin, located in the eastern portion of the Ballard Basin, is approximately 400 acres in area. The NPDES150 Basin extends from NW 85th Street south to NW Market Street and from 16th Avenue NW west to 22nd Avenue NW. North of NW 65th Street, the basin is fully combined, while south of NW 65th Street, the basin is partially separated. In the partially separated areas, storm drains convey street runoff and a portion of the roof runoff and other private property stormwater flow.

The NPDES150/151 CSO structure is located in MH 011-184. When wastewater in the structure reaches the level of the weir, overflows start to occur. Downstream of the overflow structure, the CSO flows are divided into two separate flow branches and separate outfalls: NPDES150 and NPDES151. Both outfalls discharge to Salmon Bay. The CSO structure is monitored both upstream and downstream of the overflow weir. The meter on the upstream side (known as the MP1 meter) records the depth in the CSO structure. The meter on the downstream side (a reverse install, known as the MP2 meter) is used to calculate the overflow rate.

In addition to the permanent monitoring station, four temporary monitoring locations were monitored in the NPDES150/151 Basin during Phases 2–3. At the conclusion of Phase 3 monitoring, all temporary meters were removed and only the permanent meter remained to continue monitoring overflows at the NPDES150/151 Overflow Structure.

BAL150_002-273A

BAL150_002-273A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/15/2008 to characterize the hydrology of the combined sewer area in the northwest portion of the NPDES150/151 Basin.

The data at this site captured a clear and repeatable dry weather flow pattern. During storm events, the meter showed a consistent response and recorded suitable level and velocity data. The data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for model calibration.

The site was removed on 3/2/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for model calibration.

BAL150_002-274A

BAL150_002-274A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/10/2008 to characterize the hydrology of the combined sewer area of the north-central section of the NPDES150/151 Basin.

The data at this site captured a clear and repeatable dry weather flow pattern. The level data presented numerous spikes, which were corrected during data finalization. The data quality of finalized data was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for model calibration.

The site was removed on 3/2/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for model calibration.

BAL150_011-176A

BAL150_011-176A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/29/2008 to calculate the flows from the NDPES150/151 Basin and characterize its hydrology. BAL150_011-176A monitored flows from combined and partially separated portions of the basin.

BAL150_011-176A was located two blocks upstream of the NPDES150/151 Overflow Structure and received about 90 percent of the flows from the total basin area. The data at this site captured a clear and repeatable dry weather flow pattern. During storm events, the site showed a consistent response. With its downstream location and high-quality flow data, the site provides a very good estimation of the range of flows for the NPDES150/151 Basin. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for model calibration.

The site was removed on 2/9/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for model calibration.

BAL150_011-242A

BAL150_011-242A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/11/2008 to calculate the flows in the 42-inch-diameter trunk line downstream of both the NPDES152 and NPDES150/151 Overflow Structures. As such, this site recorded all non-CSO sewer flows leaving the NPDES152 and NPDES150/151 Basins. BAL150_011-242A also served as the hydraulic downstream boundary for the Ballard Basin calibration model.

The data at this site captured a clear and repeatable dry weather flow pattern. During storm events, the site showed a consistent response. The data quality was classified as "Excellent" for Phases 2–3, which matches

the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for model calibration.

The site was removed on 3/15/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for model calibration.

BAL150_D012-079A

BAL150_D012-079A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/29/2009 to characterize the range of stormwater flows in a partially separated area of the NPDES150/151 Basin.

The data at this site captured a clear and repeatable dry weather flow pattern. Because the meter was installed in a storm drains, only wet weather flow data were assessed. The meter failed to record data from 2/7/2010 to 2/28/2010. This data gap period did not include any significant storm events. The meter responded well during all other storm events. The data quality was classified as "Good" for Phases 2–3. These data will not be used in calibration of the CSO models. However, all data for Phases 2–3 are suitable for future model calibration if needed.

The site was removed on 3/15/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for model calibration.

BAL150_DWF-011184

BAL150_DWF-011184 is a permanent monitoring station that records level and velocity on the upstream and downstream (i.e., overflow) side of the CSO weir. The upstream meter (referred to as the MP1 meter; install date 7/23/2007) records both level and velocity, although only the level data are used for the determination of CSO events. The downstream meter (referred to as the MP2 meter; install date 6/18/2009) monitors CSO flows exiting the structure and thus provides a recording of CSO events.

Separate metering locations are used, because the hydraulic conditions in the CSO structure present challenges for calculating overflows. The site was therefore classified as a wet-weather-only site and only level data are finalized.

The MP1 meter reliably records level data and is suitable for model calibration. The MP1 level data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. In general, the MP2 meter reliably records overflow data, although the recorded flows during the late-October 2009 CSO events included a lot of data noise. The MP2 data are suitable for the hydraulic calibration of the CSO structure and estimation of CSO frequency and volume.

BAL150_DWF-011184 is a permanent meter and will continue to be screened in the future. Subsequent to Phase 3, SPU moved the MP2 meter downstream to MH 011-185 for improved hydraulic conditions.

3.2.2 NPDES152 Basin

The NPDES152 Basin, located in the western portion of the Ballard Basin, is approximately 770 acres in area. The NPDES152 Basin extends from NW 85th Street south to the waterfront, and from 22nd Avenue NW west beyond 32nd Avenue NW. North of NW 65th Street, the basin is fully combined, while south of NW 65th Street, the basin is partially separated. In the partially separated areas, storm drains convey street runoff and a portion of the roof runoff and other private property stormwater flow. South of NW Market Street and in the vicinity of the Chittenden Locks, wastewater flow is conveyed by gravity to PS 84. The pump station conveys flows to the 36-inch-diameter sewer downstream of MH 011-189.

The basin contains two CSO structures, known as NPDES152A and NPDES152B. NPDES152A, located at PS 84, is not known to produce any overflows. The NPDES152B structure (often simply referred to as NPDES152) is located in MH 011-189 and is active. When wastewater in the structure reaches the level of the weir, overflows start to occur. The CSO outfall discharges to Salmon Bay. The CSO structure is monitored both upstream and downstream of the overflow weir. The meter on the upstream side (known as the MP1 meter) records the depth in the CSO structure. The meter on the downstream side (a reverse install, known as the MP2 meter) is used to calculate the overflow rate.

In addition to the permanent monitoring station, 13 temporary monitoring locations were monitored in the NPDES152 Basin during Phases 2–3. At the conclusion of Phase 3 monitoring, all temporary meters were removed except for the meters in the northwest portion of the basin that are being used to support pre-construction and post-construction performance monitoring of SPU's GSI projects. Additionally, the permanent meter will remain in service to monitor overflows at the NPDES152 Overflow Structure.

BAL152_001-009A

BAL152_001-009A is a temporary monitoring site that records level only. The site was installed during Phase 3 monitoring on 2/8/2010 and was used to characterize hydrology in the northwest part of the NPDES152 Basin and support the City's GSI projects.

BAL152_001-009A is a Micromonitor. The Micromonitor is useful for locations with very low flows where traditional area-velocity meters are not accurate. The meter responded well to storm events and captured a clear and consistent dry weather flow pattern. The level data quality was classified as "Good" for Phase 3.

All data for Phase 3 are suitable for model calibration and the analysis of GSI projects. BAL152_001-009A remained installed at the conclusion of Phase 3 monitoring.

BAL152_002-015A

BAL152_002-015A is a temporary monitoring site that records both level and velocity. The site was monitored using an ADS FlowShark meter installed on 9/9/2009 to characterize the hydrology in the northwest part of the NPDES152 Basin to support SPU's GSI projects in the area.

The dry weather data exhibit periods of poor resolution at low flows; however, periods of suitable dry weather flow pattern exist. The low resolution is attributed to gravel and debris found in the site (Figure 3-4), which prevented the capture of clear velocity data. The meter responded well during storm events. A second meter was installed at this site to verify the flow data. The monitoring data also showed a semi-regular pattern of increased flows associated with the SPU potable water flushing station flows (see BAL152_002-016A for more detail).

The data quality was classified as "Some Limitations" for Phase 3. All wet weather flow data for Phase 3 are suitable for model calibration. Dry weather flow data should be used with caution during model calibration according to the data screening notes.

BAL152_002-015A remained installed at the conclusion of Phase 3 monitoring.

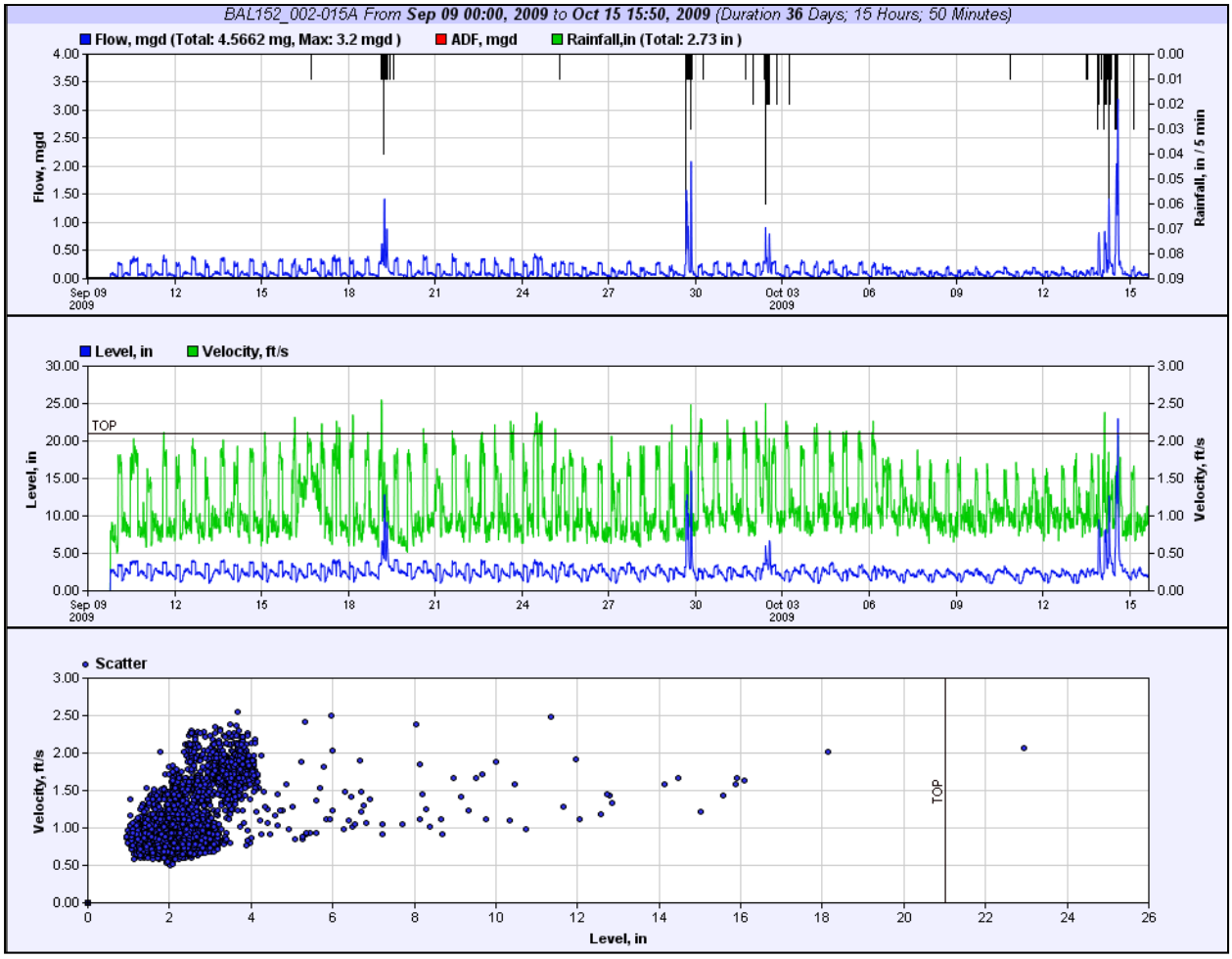

Figure 3-4. ADS FlowShark meter "low flow" scattergraph at BAL152_002-015A

BAL152_002-015B

BAL152_002-015B is a temporary monitoring site that records both level and velocity. The site was monitored using an ISCO 2151 meter installed on 12/7/2009 to verify the flow measurements at BAL152_002-015A.

BAL152_002-015B was located in the same manhole as 002-015A. The data captured confirmed the readings by the ADS FlowShark meter at BAL152_002-015A. Backwater condition was identified at this site during large storm events. Figure 3-5 shows the flattened scattergraph during a storm event, which is characteristic of backwater conditions. A subsequent analysis of upstream piping verified that the observed backwater conditions would not extend far enough upstream to affect the monitoring data recorded by the Micromonitor at MH 001-009. The quality of data was classified as "Good" for Phases 2–3. The data collected at this site could be used in conjunction with the data collected at BAL_152-015A for model calibration purposes.

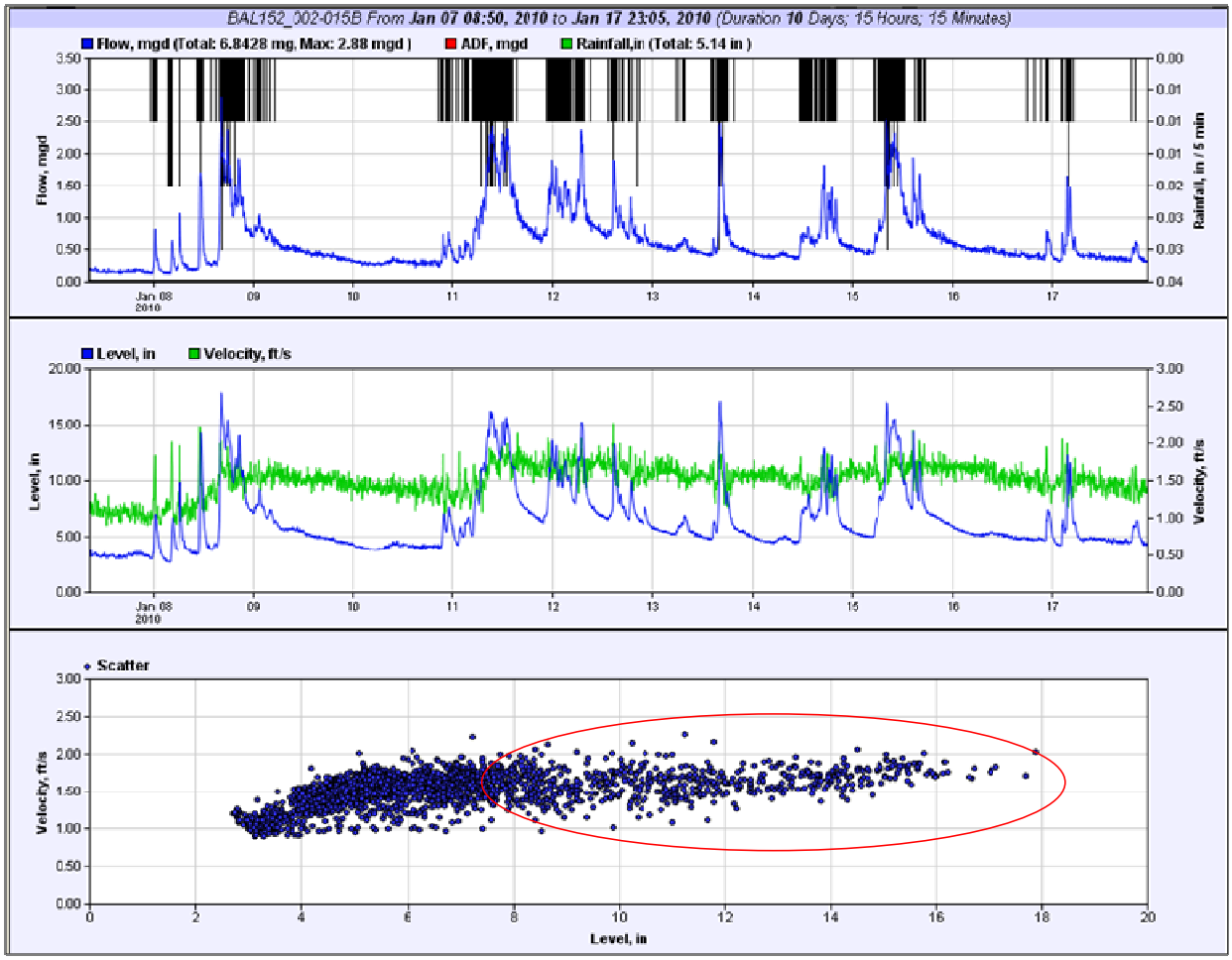

Figure 3-5. Backwater condition at BAL152_002-015

Before the conclusion of Phase 3 monitoring, the ISCO meter at BAL152_002-015B confirmed the readings by the ADS FlowShark at BAL152_002-015A; nevertheless, the meter remained installed for further data collection.

BAL152_002-016A

BAL152_002-016A is a temporary monitoring site that records both level and velocity. The site was installed on 9/9/2008 to calculate the flows from the northwest part of the NPDES152 Basin and characterize its hydrology.

The dry weather data exhibit periods of poor resolution at low flows; however, periods of suitable dry weather flow pattern exist. The meter responded well during storm events. The data recorded during Phases 1 and 2 show consistent large and nontraditional flows at this site at 5:00 a.m. and 3:00 p.m., which are attributed to a potable water flushing station upstream of this site. The potable water station discharges between the hours of 1:00 and 5:00 a.m. and then again between 2:00 and 5:00 p.m. The effects of the potable water flushing station were not captured in the data signature during Phase 3 monitoring. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All wet weather flow data for Phases 2–3 are suitable for model calibration.

BAL152_002-016A remained installed at the conclusion of Phase 3 monitoring.

BAL152_002-032A

BAL152_002-032A is a temporary monitoring site that records both level and velocity. The site was installed on 9/11/2009 to measure the flows in the west-central part of the NPDES152 Basin and characterize its hydrology.

BAL152_002-032A is located at the boundary between the combined section (to the north) and the partially separated section of the NPDES152 Basin. The data at this site captured a consistent and repeatable response during both dry and wet weather flow periods. However, the dry weather flow balance computed using this meter and upstream and downstream meters suggests that the dry weather flows were not accurately measured. The upstream pipe is a 28-inch-diameter brick sewer; the shallow flows combined with the irregular shape of the brick sewer may contribute to the difficulties in measuring low flows. Suitable dry weather flows are available upstream at BAL152_002-016A and downstream at BAL152_011-160A.

The potable water flushing station flows (described for BAL152_002-016A above) are observable within the BAL152_002-032A flow data. The effects of the potable water flushing station can be observed in the data prior to November 2008 and after June 2009 (Figure 3-6). The data quality was classified as "Good" for Phases 2–3. The quality classification of the data collected during Phase 1 was classified as "Excellent." All wet weather flow data for Phases 2–3 are suitable for model calibration. Dry weather flow should be used with caution.

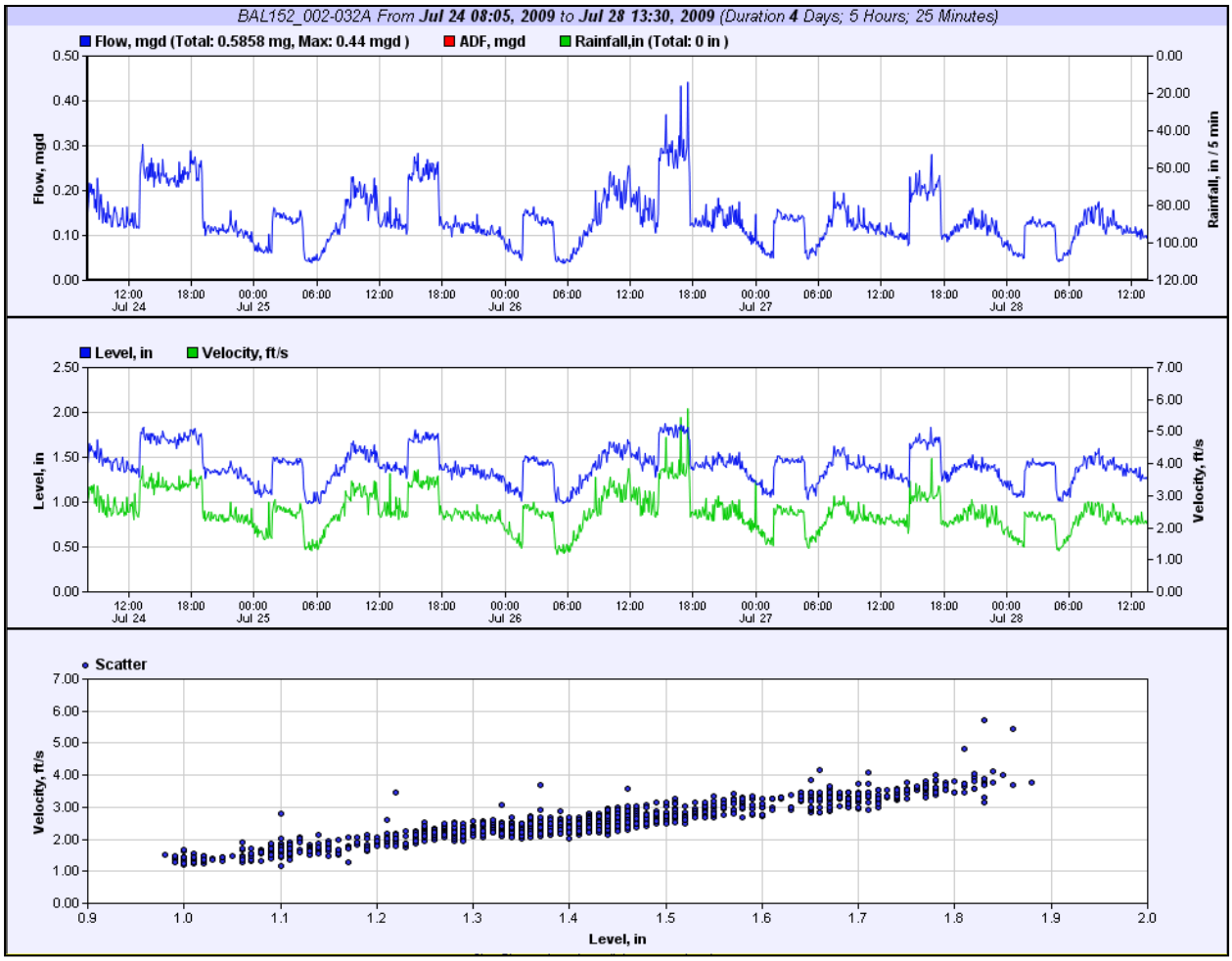

Figure 3-6. Influence of potable water flushing station on data signature at BAL152_002-032A

BAL152_002-032A remained installed at the conclusion of Phase 3 monitoring.

BAL152_002-082A

BAL152_002-082A is a temporary monitoring site that records level only. The site was installed during Phase 3 monitoring on 12/15/2009 and was used to characterize hydrology in the northwest part of the NPDES152 Basin. This site is located just downstream of a GSI project and will be used to characterize pre-construction and post-construction flows.

BAL152_001-082A is a Micromonitor. The Micromonitor is useful for locations with very low flows where traditional area-velocity meters are not accurate. The meter responded well to storm events and captured a clear and consistent dry weather flow pattern. The level data quality was classified as "Good" for Phase 3.

All data for Phase 3 are suitable for model calibration and the analysis of GSI projects. BAL152_002-082A remained installed at the conclusion of Phase 3 monitoring.

BAL152_002-096A

BAL152_002-096A is a temporary monitoring site that records both level and velocity. The site was monitored using an ADS FlowShark meter installed on 9/9/2009, and was used to characterize hydrology in the northwest part of the NPDES152 Basin and support the City's GSI pilot studies.

BAL152_002-096A was located in MH 002-096. The dry weather data exhibit periods of poor resolution at low flows; however, periods of suitable dry weather flow pattern exist. The data showed that the site's hydraulics change drastically before and after a storm event. Flow balances performed around this site suggested that the meter was overestimating the flows. To verify the flows recorded at this site a redundant ISCO 2150 meter was installed upstream of it. The installation of a redundant meter affected the hydraulics of the site; therefore, comparison while both meters were in place was not possible. Nevertheless, when comparing meter B data with the data collected by meter A prior to the installation of the redundant meter, the flows are within the same range. The data quality was classified as "Some Limitations" for Phases 2–3. Data should be used with caution during model calibration.

BAL152_002-096A remained installed at the conclusion of Phase 3 monitoring.

BAL152_002-096B

BAL152_002-096B is a temporary monitoring site that records both level and velocity. The flows were monitored using an ISCO 2150 meter. The site was installed on 2/12/2010 to verify the flows recorded at BAL152_002-096A.

BAL152_002-096B was located in MH 002-096. The data at this site captured a clear and consistent dry weather flow pattern. The meter responded well to storm events. The installation of this meter affected the hydraulics seen at the BAL152_002-096A site. Therefore, the data could not be compared or used to verify the flows recorded by the ADS FlowShark meter while both meters were in place. However, when comparing the flows of meter A prior to the installation of meter B, they seem to be congruent. The data quality was classified as "Excellent" for Phase 3.

The meter was removed on 4/6/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been for verification purposes.

BAL152_002-123A

BAL152_002-123A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/10/2008 to measure the flows from the combined sewer area in the northeast part of the NPDES152 Basin and characterize its hydrology.

The data at this site captured two flow regimes during low flows attributed to pooling behind the meter (Figure 3-7). During storm events the meter responded very consistently and collected suitable velocity and level data. The data quality—particularly the storm flow data—was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All wet weather data for Phases 2–3 are suitable for model calibration.

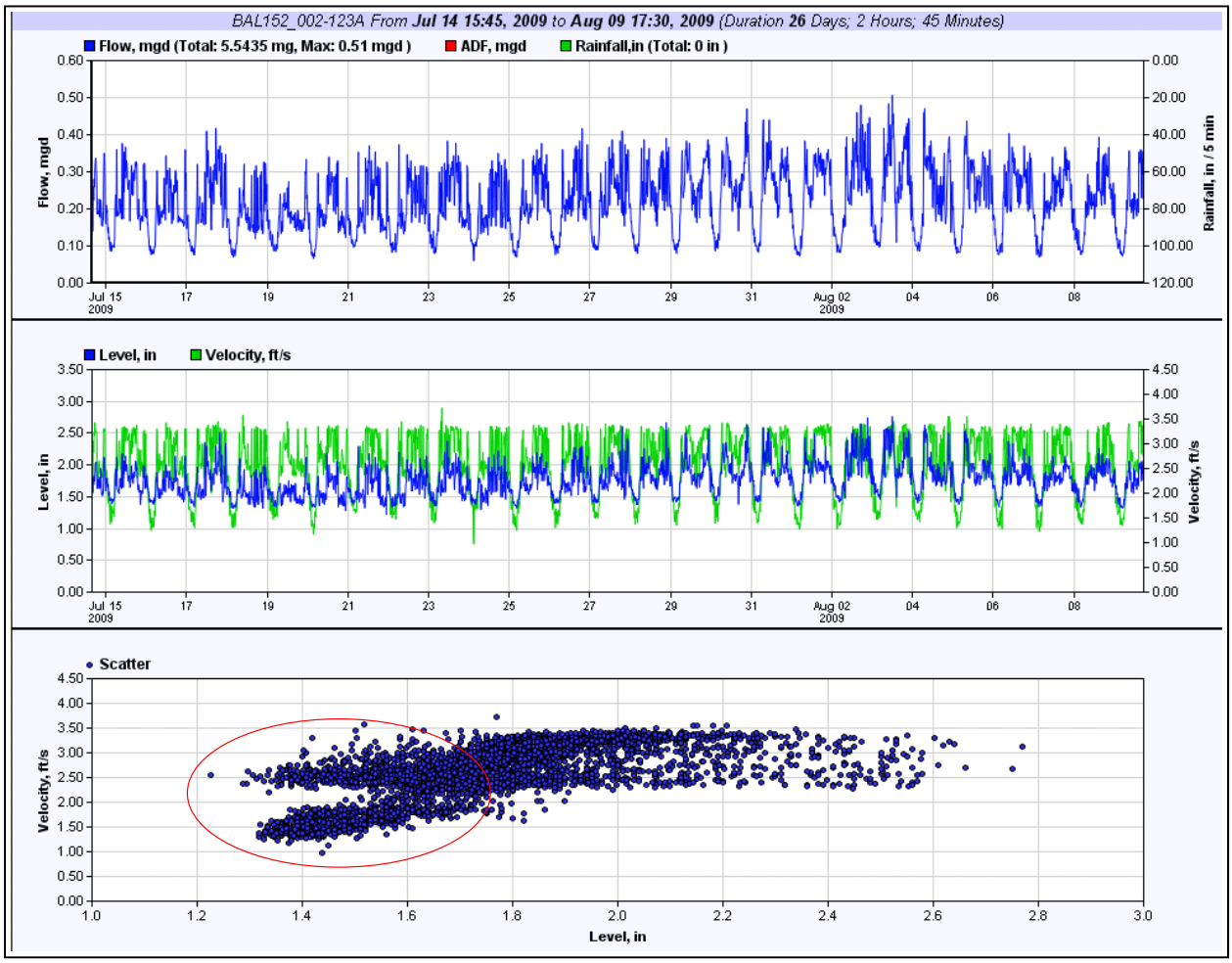

Figure 3-7. Pooling behind meter effect captured at BAL152_002-123A

The meter was removed on 3/15/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

BAL152_002-232A

BAL152_002-232A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/18/2008 to provide an estimate of hydrologic model parameters that might be applicable to other nearby subcatchments if data from BAL152_002-123A were not suitable.

BAL152_002-232A was located upstream from the meter at BAL152_002-016A. The data at this site captured a clear and consistent dry weather flow pattern. The data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for model calibration. The meter was removed on 10/19/2009, at the beginning of

Phase 3 monitoring, as it was determined that the data collected at BAL152_002-123A was suitable for model calibration.

BAL152_011-090A

BAL152_011-090A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/22/2008 to characterize hydrology for a partially separated area in the eastern part of the NPDES152 Basin.

The meter at this site captured a consistent and repeatable response of the data during both dry and wet weather periods. Additionally, because of its excellent data quality rating and location collecting flows in a partially separated area, the data collected at BAL152_011-090A will be useful for determining the impact of sewer separation that has occurred on private property within the NPDES152 Basin. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for model calibration.

The meter was removed on 10/19/2009, at the beginning of Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for model calibration.

BAL152_011-160A

BAL152_011-160A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/30/2009 to measure the flows just upstream of the NPDES152 Basin Overflow Structure to characterize the hydrology of the lower part of the NPDES152 basin and verify flows at the permanent meter downstream. This meter captures flows from more than 95 percent of the area that contributes flow to the NPDES152 CSO structure.

BAL152_011-160A was located 1 block upstream of the NPDES152 Basin Overflow Structure. The data at this site captured a clear and consistent dry weather flow pattern. The meter responded well to storm events and collected suitable level and velocity data. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data for Phases 2–3 are suitable for model calibration.

The meter was removed on 3/15/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data have been collected for model calibration.

BAL152_011-187A

BAL152_011-187A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/10/2008 to characterize flows downstream from the NPDES152 Basin Overflow Structure.

BAL152_011-187A was located downstream of the NPDES152 Basin Overflow Structure. The site is also located downstream of the PS 84 force main connection and measures the flows from the NPDES152 Basin being conveyed to King County's Ballard regulator.

Initially, the line presented silt accumulation that reached up to 8 inches. The data would need to be adjusted to account for this sedimentation in model calibration. Figure 3-8 shows the transition after the line was cleaned in October 2009. The flow data quality was classified as "Good" for Phase 3 following the line cleaning. Data for Phases 2–3 prior to the line cleaning should be used with caution for flow calibration purposes, according to the data screening notes. The level data are classified as "Excellent" and suitable for the hydraulic calibration of the lower part of the NPDES152 Basin in Phases 2–3.

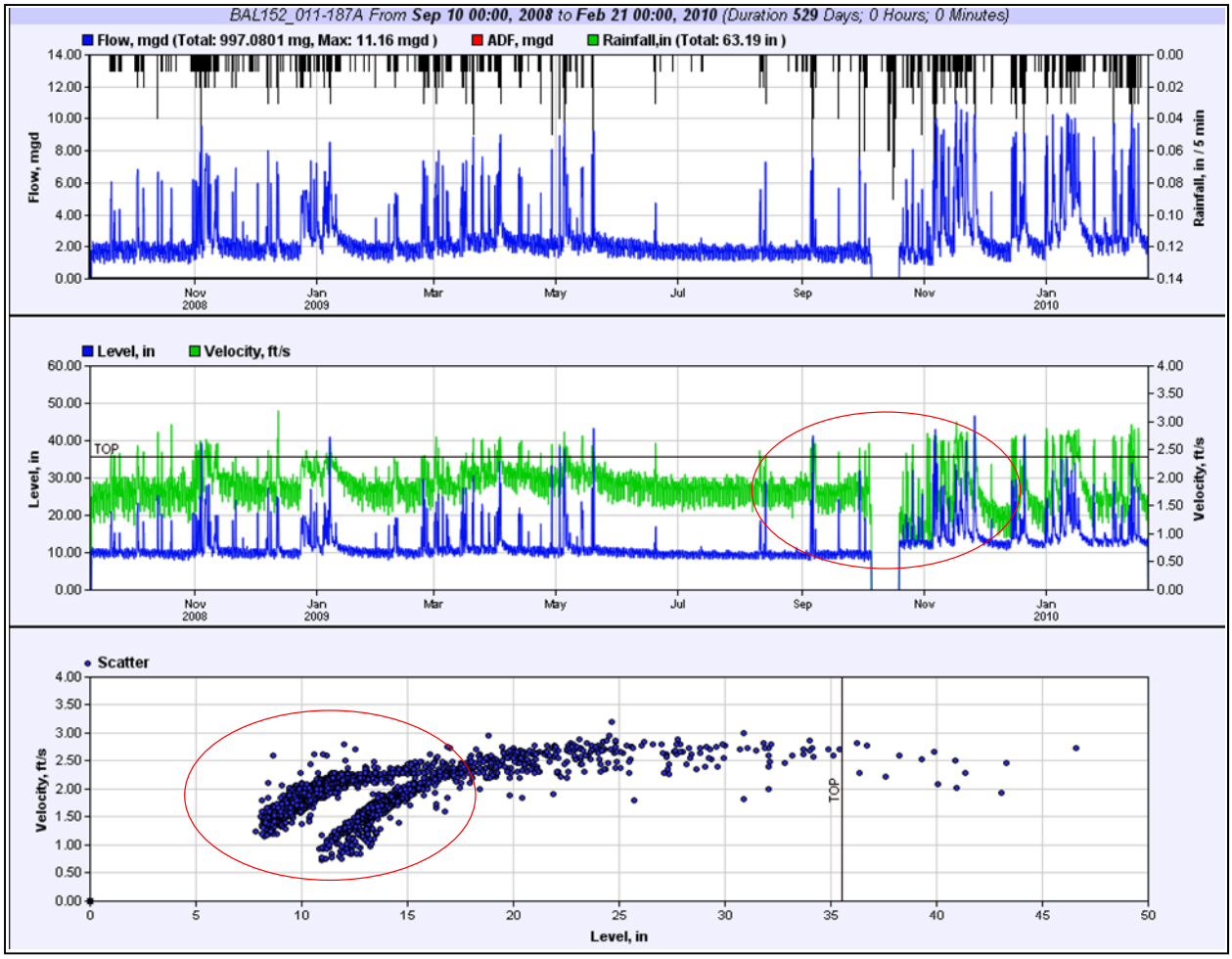

Figure 3-8. Data signature changed after line cleaning for BAL152_011-187A

BAL152_DWF-011189

BAL152_DWF-011189 is a permanent monitoring station that records level and velocity on the upstream and downstream (i.e., overflow) side of the CSO weir. The upstream meter (referred to as the MP1 meter; install date 7/31/2007) records both level and velocity, although only the level data are used for the determination of CSO events. The downstream meter (referred to as the MP2 meter; install date 5/20/2009) monitors CSO flows exiting the structure, providing volume of CSO events. Separate metering locations are used because the hydraulic conditions in the CSO structure present challenges for monitoring overflows. The site is classified as a wet-weather-only site. The MP1 meter reliably records level data and is suitable for model calibration. The MP1 level data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. In general, the MP2 meter reliably records overflow data. The MP2 data are suitable for the hydraulic calibration of the CSO structure and estimation of CSO frequency and volume.

BAL152_DWF-011189 is a permanent meter and will continue to be screened in the future.

3.2.3 Combined Sewer Overflows

ADS reported that 87 CSOs occurred in the Ballard Basin during Phases 2–3. Table 3-4 lists the CSOs reported during the monitoring period.

Table 3-4. 2009–2010 Combined Sewer Overflows in Ballard Basin 6/1/2009 through 5/31/2010			
NPDES outfall	Start date of overflow	Duration (hrs:min)	Volume (gal)
150/151	8/13/2009	0:10	389
	9/6/2009	10:10	123,215
	9/29/2009	3:55	5,510
	10/14/2009	1:40	253,087
	10/17/2009	14:00	283,010
	10/26/2009	0:05	160
	11/5/2009	48:07	599,054
	11/9/2009	0:05	7
	11/10/2009	0:15	21
	11/13/2009	16:55	122
	11/16/2009	18:37	7,305
	11/19/2009	1:50	17
	11/21/2009	12:02	962,318
	11/25/2009	11:05	573,592
	12/14/2009	19:00	56
	12/16/2009	0:35	45
	12/21/2009	1:05	196,699
	1/4/2010	2:15	1,933
	1/8/2010	7:10	4,750
	1/11/2010	7:10	7,165
	1/13/2010	43:45	6,026
	1/17/2010	0:05	1
	1/24/2010	0:20	18
	2/3/2010	3:00	46
	2/7/2010	0:05	3
	2/12/2010	9:30	7,417
	2/14/2010	1:45	172
	2/16/2010	0:15	17
	3/29/2010	9:09	705
	4/2/2010	0:05	3
	4/8/2010	0:05	188
	4/21/2010	0:26	2,333
	5/19/2010	0:20	15,781
	5/21/2010	0:55	96,269
	5/22/2010	0:05	17
152	8/13/2009	0:25	42,521
	9/5/2009	12:00	682,969
	9/19/2009	0:20	7,028

Table 3-4. 2009–2010 Combined Sewer Overflows in Ballard Basin 6/1/2009 through 5/31/2010			
NPDES outfall	Start date of overflow	Duration (hrs:min)	Volume (gal)
152	9/29/2009	4:30	214,274
	10/2/2009	3:30	5,705
	10/13/2009	16:48	682,332
	10/16/2009	30:20	2,206,353
	10/23/2009	0:50	963
	10/26/2009	5:38	984,713
	10/29/2009	0:30	479
	10/30/2009	0:47	72,659
	11/5/2009	49:10	3,098,374
	11/9/2009	36:20	841,344
	11/13/2009	2:18	158,737
	11/20/2009	97:50	4,085,433
	11/21/2009	20:50	2,224,781
	11/25/2009	25:25	3,054,351
	12/4/2009	0:05	24
	12/14/2009	50:10	580,447
	12/1/2009	60:40	583,064
	12/31/2009	6:20	38,199
	1/1/2010	12:55	89,114
	1/4/2010	20:05	499,065
	1/8/2010	28:10	1,087,494
	1/10/2010	120:35	4,987,225
	1/16/2010	21:50	138,096
	1/24/2010	13:35	217,496
	2/3/2010	35:35	124,850
	2/7/2010	0:35	17,228
	2/11/2010	37:05	333,003
	2/13/2010	8:00	428,767
	2/16/2010	6:00	112,981
	2/26/2010	29:00	98,272
	3/7/2010	0:15	10,603
	3/11/2010	33:31	790,197
	3/25/2010	0:40	25,117
	3/28/2010	42:54	703,389
	4/2/2010	4:15	223,182
	4/3/2010	0:05	142
	4/4/2010	41:18	31,269
	4/8/2010	2:45	128,481
	4/9/2010	0:20	9,047

Table 3-4. 2009–2010 Combined Sewer Overflows in Ballard Basin 6/1/2009 through 5/31/2010			
NPDES outfall	Start date of overflow	Duration (hrs:min)	Volume (gal)
152	4/17/2010	0:10	160
	4/21/2010	6:35	494,326
	4/26/2010	18:54	70,205
	4/28/2010	0:24	9,167
	5/10/2010	0:45	45,253
	5/19/2010	1:35	257,854
	5/21/2010	25:45	695,144
	5/25/2010	14:15	16,799
	5/28/2010	7:45	31,882
	5/31/2010	0:40	22,515

Figure 3-9 shows the maximum water level recorded by ADS at each of the overflow structures in the basin as a percentage of the weir height.

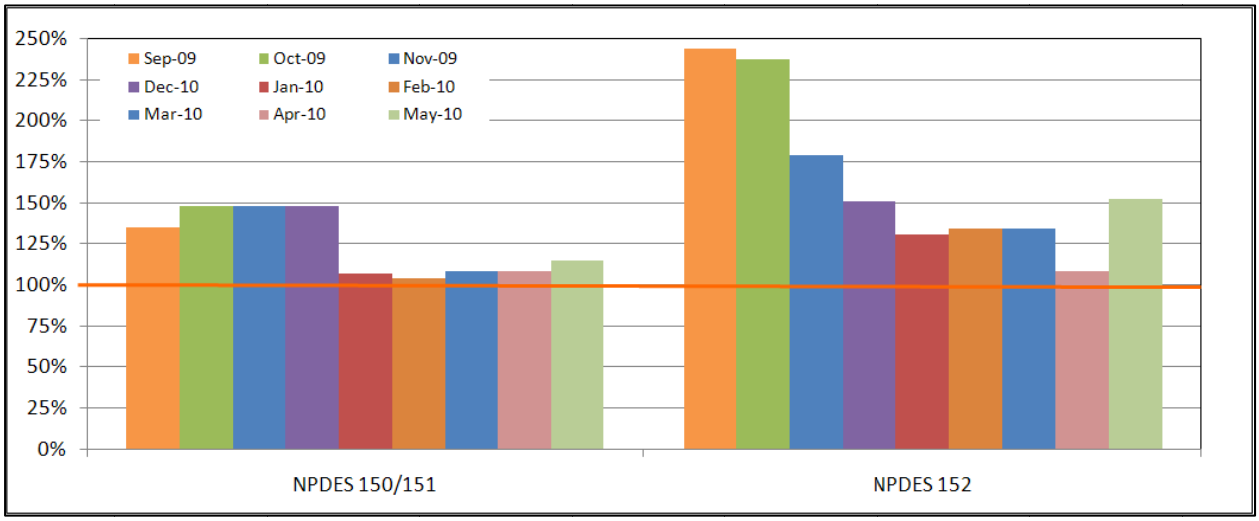

Figure 3-9. Maximum recorded levels compared to weir heights for major events

3.2.4 Facility Operations

The CSO control facilities in the Ballard Basin consist of two overflow structures. No HydroBrakes or storage structures are located within this basin. One pump station (PS 84) is located in the NPDES152 Basin.

Pump Station 84

PS 84 is located in the NPDES152 Basin at 5390 28th Avenue NW. PS 84 is located in the NPDES152 Basin at 5390 28th Avenue NW, just to the south of NW Market Street. The pump station collects flows from the

southern part of the NPDES152 Basin and pumps flow just upstream from monitoring location BAL152_011-187. The pump station has two pumps connected to one 8-inch force main.

During the monitoring period, SCADA data were reviewed to compare wet well elevation with run times of pumps 1 and 2. Even during the CSO events in the NPDES150/151 and NPDES152 Basins, the lead pump was sufficient to manage flow demands. The lag pump was not needed to manage wet weather flows. The upstream monitoring indicated a lack of direct connections of stormwater to the sewer system in the area that are tributary to PS 84.

3.2.5 Recommendations for Additional Data Collection

At the conclusion of Phase 3 monitoring, no additional data needed to be collected in the Ballard Basin for the purposes of model calibration and development. Only the temporary meters that collect data to support the City's GSI projects should remain in place.

3.3 Delridge/Longfellow Basin

The Delridge/Longfellow Basin, which consists of the NPDES099, NPDES168, NPDES169, and NPDES170 Basins, is approximately 718 acres in area.

The combined sewage in the NPDES099 Basin flows by gravity from south to north through permanent meter NPDES099_MH055477. Overflows from the NPDES099 Basin flow into the West Waterway at the mouth of the Duwamish River.

Combined sewage in the northern part of the NPDES168 Basin flows from north to south by gravity, and combined sewage in the southern part of the NPDES168 Basin flows from south to north by gravity. The northern and southern parts combine, then head west to permanent meter NPDES168_MH069428, and eventually enter the King County system.

The NPDES169 Basin flows east to northwest where wet weather flows are directed to CSO Facility 3. Overflows from this control facility were monitored at NPDES169_MH076367, and non-CSO flow is conveyed north to the King County system. Dry weather flows from the NPDES169 Basin are conveyed directly north to the King County system.

Combined sewage from the NPDES170 Basin flows west to CSO Facility 2, where the permanent meter DEL170_DWF-069144 monitors overflows from this control facility to the King County system. Overflows from the NPDES168, NPDES169, and NPDES170 Basins flow into Longfellow Creek, which eventually flows into the mouth of the Duwamish River at Elliott Bay.

Rainfall in the NPDES099 Basin is monitored by RG 15, which is located at the Puget Sound Clean Air Monitor Station. Rainfall in the NPDES168, NPDES169, and NPDES170 Basins is monitored by RG 17, which is located near the West Seattle reservoir.

During Phases 2–3, ADS maintained 4 permanent monitoring sites and Stantec maintained 29 temporary monitoring sites that measured combined sewage flow within the Delridge/Longfellow Basin. At the conclusion of Phase 3 three temporary meters remained in the Delridge/Longfellow Basin. One of those meters remained to collected data for the CSO retrofit project, and the other two were recommended for removal; the four permanent monitoring sites remained in place.

Detailed information on Delridge/Longfellow monitoring locations can be found in Appendix D; a basin schematic is contained in Appendix B.

3.3.1 NPDES099 Basin

The NPDES099 Basin, located to the south of the West Seattle Bridge near the mouth of the Duwamish River, is approximately 134acres in area. CSO Facility 34 is located in the NPDES099 Basin. The facility contains a 0.16 MG offline storage pipe, a HydroBrake, and an overflow weir.

During Phases 2–3, there were four temporary monitoring sites and one permanent monitoring location in the NPDES099 Basin. One temporary monitoring site, DEL99_055-223A, was removed at the beginning of Phase 2. At the conclusion of Phase 3 no temporary meters remained in the NPDES099 Basin. The one permanent monitoring site remained.

DEL99_055-165A

DEL99_055-165A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/18/2008 to characterize the NPDES099 Basin hydrology and characterize the HydroBrake located in CSO Facility 34.

DEL99_055-165A was the most downstream meter in the NPDES099 Basin. The site captured a consistent diurnal dry weather flow pattern. During Phases 2–3, the data quality for both dry and wet weather flows was classified as "Excellent," which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

During Phases 2–3, velocity dropouts were edited by Stantec. There was a data gap between 11/5/2009 and 11/6/2009 when the meter was replaced on 11/6/2009, but the data was recovered from the previous meter in the lab.

The meter was removed on 2/23/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DEL99_055-223A

DEL99_055-223A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/19/2008 to measure the combined flows from the eastern part of the NPDES099 Basin.

The meter was located upstream of the NPDES099 Basin overflow weir and HydroBrake. During Phases 2–3 the site captured suitable dry weather flow data. During Phase 1, wet weather flows at the site were influenced by the operation of the low-flow diversion (LFD) stormwater valve installed at MH 055-476; therefore, the data were classified as "Some Limitations." The LFD stormwater valve was closed to remove the influence of the valve on the data at the end of Phase 2 monitoring, on 9/16/2009. For all three monitoring phases, during the large storm events backwatering occurred at peak flows due to the downstream HydroBrake. Data collected during Phases 2–3 were classified as "Good." All data from Phases 2–3 are suitable for use in model calibration.

The meter was removed on 2/16/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DEL99_055-473A

DEL99_055-473A was a temporary monitoring site that recorded level only. The site was installed on 10/13/2008 to measure the storage utilization in the 83-inch-diameter offline storage pipe that receives wet weather combined flows from the NPDES099 Basin.

DEL99_055-473A was located in the offline storage pipe, and was approximately 3.7 inches above the bottom of the pipe. The storage pipe was adjacent to the NPDES099 Basin overflow weir and HydroBrake. Wet weather flow enters the storage pipe via a 95-inch weir in the CSO chamber and drains back into the mainline through a flap gate in the weir. There was no dry weather flow at this site. The site captured suitable data throughout all three monitoring periods. The data indicated that there was heavy leakage through the flap gate between the CSO chamber and the storage tank. Operational issues such as leaky flap gates will be evaluated by the CSO retrofit project. The storage tank pre-fills before the tank overflow weir is overtopped. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

During Phases 2–3 dry weather flow periods, the probe tended to get buried under sludge but the quality of the data was not affected. Maintenance issues such as sludge accumulation have been identified and SPU Field Operations and Maintenance will perform follow-up actions separately.

The meter was removed on 2/2/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NPDES099_MH055477

NPDES099_MH055477 is a permanent monitoring site that records both level and velocity. The site is classified as a wet weather site because it is not expected to provide high-quality velocity data. Thus, only level data were finalized at this site. The site was installed on 9/6/2007 to identify and quantify CSO events occurring from the NPDES099 Basin. Overflows occur when the level in NPDES099_MH055477 reaches 108.5 inches. The meter reads 94.2 inches when flow goes over the storage diversion weir.

NPDES099_MH055477 is located at the NPDES099 Overflow Structure downstream from CSO Facility 34. Level monitored at this location is used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The level data are also used to determine the characteristics of the HydroBrake immediately downstream. The level data at this site captured a consistent dry weather flow pattern. During storm events, the data were consistent. The level data collected during Phases 2–3 were classified as "Excellent." The level data quality during Phase 1 was classified as "Good" because the level sensors did not function during the January 2009 storm event. All level data from Phases 2–3 are suitable for use in model calibration.

NPDES099_MH055477 is a permanent meter and will continue to be screened in the future.

3.3.2 NPDES168 Basin

NPDES168 Basin, located to the southeast of the NPDES099 Basin in the Longfellow Creek drainage system, is approximately 350 acres in area. CSO Facility 2 is located in the NPDES168 Basin, and consists of a 1.6 MG offline storage tank, a HydroBrake, and an overflow weir.

During Phases 2–3, nine temporary monitoring sites and three permanent monitoring sites were located in the NPDES168 Basin. In addition, the SPU SCADA system monitors the site to provide real-time level in the overflow structure. At the conclusion of Phase 3 three temporary meters remained in the NPDES168 Basin. The two permanent meters that monitor the overflow point within the basin remained.

SPU_069-242A

SPU_069-242A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/19/2008 to measure the western stream of flow that joins the King County system at MH 069-184, including flow from NPDES168.

SPU_069-242A was located upstream of the King County system. Data at the site captured a consistent diurnal dry weather flow pattern, which correlated well with the theoretical Manning's curve during storm flows. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

During Phases 2–3, velocity spikes and dropouts were edited by Stantec.

The meter was removed on 3/16/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DEL168_069-280A

DEL168_069-280A was a temporary monitoring site that recorded both level and velocity. The meter was installed on 9/13/2008 to measure the combined flows from the southern and western parts of the NPDES168 Basin.

DEL168_069-280A was located upstream from the CSO Facility 2. The site captured a consistent diurnal dry weather flow pattern. During storm events, the site showed a consistent response. The data quality was

classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

The meter was removed on 3/16/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DEL168_069-346A

DEL168_069-346A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/9/2008 to characterize the hydrology of the northern and eastern parts of the NPDES168 Basin.

DEL168_069-346A was located upstream from the CSO Facility 2. The site captured a consistent dry weather flow pattern. During storm events, the data correlated well with the theoretical Manning's curve. The data quality for both dry and wet weather flows was classified as "Excellent" for Phase 2 and as "Good" for Phase 3 because of data gaps at the beginning of November 2009. Phase 2 data matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

During Phases 2–3, it was found that during large wet weather events there was ramping over the meter. Meter bidirectional velocity was activated on 12/9/2008, but was turned off on 2/3/2010. The data gaps from 11/2/2009 to 11/3/2009 and 11/4/2009 to 11/5/2009 were not recoverable.

The meter was removed on 3/16/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DEL168_069-370A

DEL168_069-370A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/30/2008 to characterize the hydrology of the eastern part of the NPDES168 Basin.

The meter was located upstream from DEL168_069-346A. The site captured data that correlates well with the theoretical Manning's curve during both dry and wet weather. The data quality was classified as "Excellent" for Phases 2 and as "Good" for Phase 3 because the velocity data during the January 2010 storm appeared to pop between two regimes. The flow data in Phase 2 matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

During Phases 2–3, level spikes and dropouts were edited by Stantec. During the January 2010 storm event, the velocity data seems to pop between a lower and higher regime.

The meter was removed on 2/23/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DEL168_069-406A

DEL168_069-406A was a temporary monitoring site that recorded both level and velocity. The site was installed on 12/15/2008 to measure the combined flows downstream of CSO Facility 2 for use in characterizing the HydroBrake.

DEL168_069-406A was located downstream of the HydroBrake located in CSO Facility 3. During Phase 1 monitoring, rocks and debris impacted the meter, originally installed in September 2008. Removing the rocks and debris took an extended period, delaying the site installation until 12/15/2008. Data were characterized as "Some Limitations" during Phase 1 monitoring because debris was typical at the site, and weekly cleaning began in January 2009. In Phases 2–3, the site captured a consistent diurnal dry weather flow pattern.

Flow balancing was undertaken using the data from this site during Phases 2–3.The total flow from two upstream temporary monitoring sites (DEL168_069-346 and DEL168_069-280) was compared to the downstream flow at DEL168_069-406. The flow balance indicated that the calculated flows from DEL168_069-406 were underestimated.

Because of the underestimation of flows, the data quality was classified as "Some Limitations" for Phases 2–3. All level data from Phases 2–3 are suitable for use in model calibration. Velocity data are underestimated, and should not be used in model calibration.

During Phases 2–3, velocity spikes and dropouts were edited by Stantec. The site was susceptible to debris and sediment buildup.

The meter remained installed at the conclusion of Phase 3 monitoring to continue collecting data to be used in the CSO retrofit project.

DEL168_069-408A

DEL168_069-408A was a temporary monitoring site that recorded level only. The site was installed on 9/26/2008 to measure the level in the storage tank in CSO Facility 2.

DEL168_069-408A was located in the storage tank in CSO Facility 2. The site did not capture a dry weather flow pattern, because it was located in an offline storage tank. During storm events, the data responded consistently, and indicated leakage from the CSO chamber through the duckbill valves into the storage tank, as seen in Figure 3-10. The data at the site corresponded well with data from MH 069-428. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

During Phases 2–3, the site was susceptible to debris and sediment buildup but the quality of the data was not affected in the storage tank because the meter was located above the debris.

The meter was removed on 2/9/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

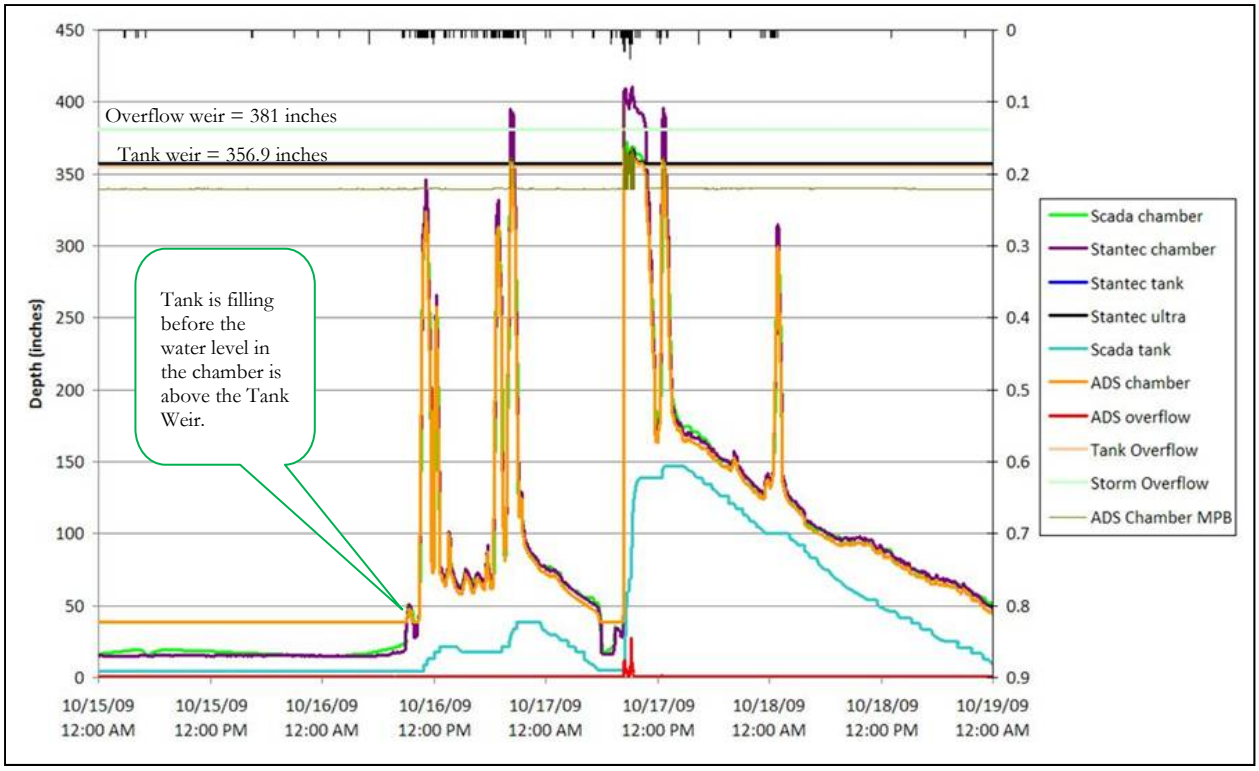

Figure 3-10. DEL168_069-408A (Stantec Ultra): Leaking duckbill valve, note level increase in storage tank prior to depth of storage tank weir

DEL168_069-428A

DEL168_069-428A was a temporary monitoring site that recorded level only. The site was installed on 9/26/2008 to confirm the data of the permanent meters (NPDES168_MH069428 and NPDES168_B_MH069428), and to characterize the upstream depth of the HydroBrake located in CSO Facility 2.

DEL168_069-428A was located upstream of the HydroBrake located in CSO Facility 2. The pressure level meter was mounted on the CSO chamber wall 13 inches above the floor. The pressure probe was determined to be reading a level of approximately 393 inches when flow overtops the storage weir. At a level of 432 inches the overflow weir is overtopped. The probe was replaced in July 2009 to improve the dynamic range on the probe during Phase 2 monitoring. The meter was installed specifically to provide more accurate data in the mid to low depth range that occurs in the HydroBrake chamber. The permanent meter provides more accurate data for the upper range of depths.

This site did not capture a consistent dry weather pattern because it was mounted 13 inches from the chamber floor. The site occasionally recorded dry weather flow, when the HydroBrake was partially plugged. During storm events, the data collected from this site closely agreed with the data from NPDES168_MH069428 in the low- to mid-level range (14 to 340 inches), but tended to overestimate in the high-level range (greater than 340 inches). This was expected based on the purpose of the meter described above. As a result, only the lower range of the data from this temporary meter should be used to characterize the HydroBrake. The data quality was classified as "Excellent" for Phases 2–3, because the meter was intended to provide accurate data in the mid to low depth range. High levels from Phases 2–3 are not suitable for use in model calibration. Level data from Phases 2–3 in the low to mid range of the chamber are suitable for use in model calibration.

During Phase 2 monitoring, the meter was replaced on 9/1/2009 because the dynamic range of the replaced submersible probe appeared to change.

The meter was removed on 12/29/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration. A total of four level meters monitored MH 069-428.

DEL168_069-428B

DEL168_069-428B was a temporary monitoring site that recorded level only. The meter was installed on 9/19/2008 inside the flow control chamber at CSO Facility 2 in the NPDES168 Basin. The purpose of this meter was to confirm the permanent meter (NPDES168_MH069428 and NPDES168_B_MH069428) data at levels above the storage weir.

DEL168_069-428B was located upstream of the HydroBrake in CSO Facility 2. The ultrasonic meter was mounted on the CSO chamber wall and aimed at a plate level with the crest of the storage weir. The site did not capture a dry weather pattern. During large storm events where the level in MH 069-428 reached the storage weir crest, the data collected from this site closely agreed with the permanent meters NPDES168_MH069428 and NPDES168_B_MH069428. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

During Phase 3 monitoring, the meter was replaced on 1/6/2010 because the sensors were not picking up readings.

The meter was removed on 2/9/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration. It was also determined that the site could be removed because five level meters were monitoring MH 069-428 at the time.

NPDES168_MH069428

NPDES168_MH069428 is a permanent monitoring site that measures level only with a single pressure meter. The site is classified as a wet weather site because it is expected to provide only high-quality level data. The site was installed on 8/22/2007 to quantify CSO events that occur from the NPDES168 Basin. Overflows occur when the level in NPDES168_MH069428 reaches 381.63 inches.

NPDES168_MH069428 is located upstream of the HydroBrake located in CSO Facility 2. The pressure meter was mounted on the wall of the chamber 36.5 inches above the floor. The site did not capture a dry weather flow pattern because it is located above the chamber floor. During storm events, the level data were consistent with the other level meters located in MH 069-428. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

NPDES168_MH069428 is a permanent meter and will continue to be screened in the future.

NPDES168_B_MH069428

NPDES168_B_MH069428 is a permanent monitoring site that measures level only with a single ultrasonic meter. The site is classified as a wet weather site because it is expected to provide only level data. The site was installed on 4/10/2008 to quantify CSO events that occur from the NPDES168 Basin. Overflows occur when the level in NPDES168_B_MH069428 reaches 41.63 inches.

NPDES168_B_MH069428 is located upstream of the HydroBrake located in CSO Facility 2. The ultrasonic meter was used to quantify when overflows occurred in the NPDES168 Basin and their volumes using a weir equation. The ultrasonic meter was mounted on the maintenance hole ceiling and aimed at a plate located

339.63 inches above the chamber floor. The meter reads 16.77 inches when flow goes over the storage diversion weir.

The site did not capture a dry weather pattern because it was mounted above the chamber floor. During storm events where the level in the chamber was above 339.63 inches, the level data corresponded with data collected at the other level meters located in MH 069-428. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

NPDES168_B_MH069428 is a permanent meter and will continue to be screened in the future.

NPDES168_O_MH069428

NPDES168_O_MH069428 was a permanent monitoring site that recorded both level and velocity. The permanent meter was installed on 8/22/2007 to verify overflows and their volumes downstream from the NPDES168 Basin overflow weir.

NPDES168_O_MH069428 was located in the overflow pipe from CSO Facility 2 into the stormwater system. During Phases 2–3, it was determined that this site indicated the occurrence of CSOs during storm events where the water level in MH 069-428 did not exceed the overflow weir height, as shown in Figure 3-11. It was determined that data collected at NPDES168_O_MH069428 was influenced by flow in the stormwater system. The meter was located in the downstream end of the overflow pipe from CSO Facility 2. When the stormwater in the adjacent stormwater system backed up, the velocity and level meters at NPDES168_O_MH069428 became submerged and a CSO was reported. In many cases the CSO was falsely reported because the site reported the stormwater flow instead of the CSO flow from the overflow weir in CSO Facility 2. This issue was resolved by relocating the meters farther upstream in the CSO pipe, which was done on 11/23/2009. Following the relocation the site no longer indicated CSOs during storm events where the level data in MH 069-428 was below the overflow weir crest. The data quality was classified as "Some Limitations" for Phases 2–3, due to the influence of the stormwater on the data. Data collected through 11/23/2009 are not suitable for use in model calibration. Data collected after that data are suitable for model calibration.

The site was removed on 1/6/2010 because it was decided to report CSOs based on level data in MH 069-428 as it recorded more accurate data.

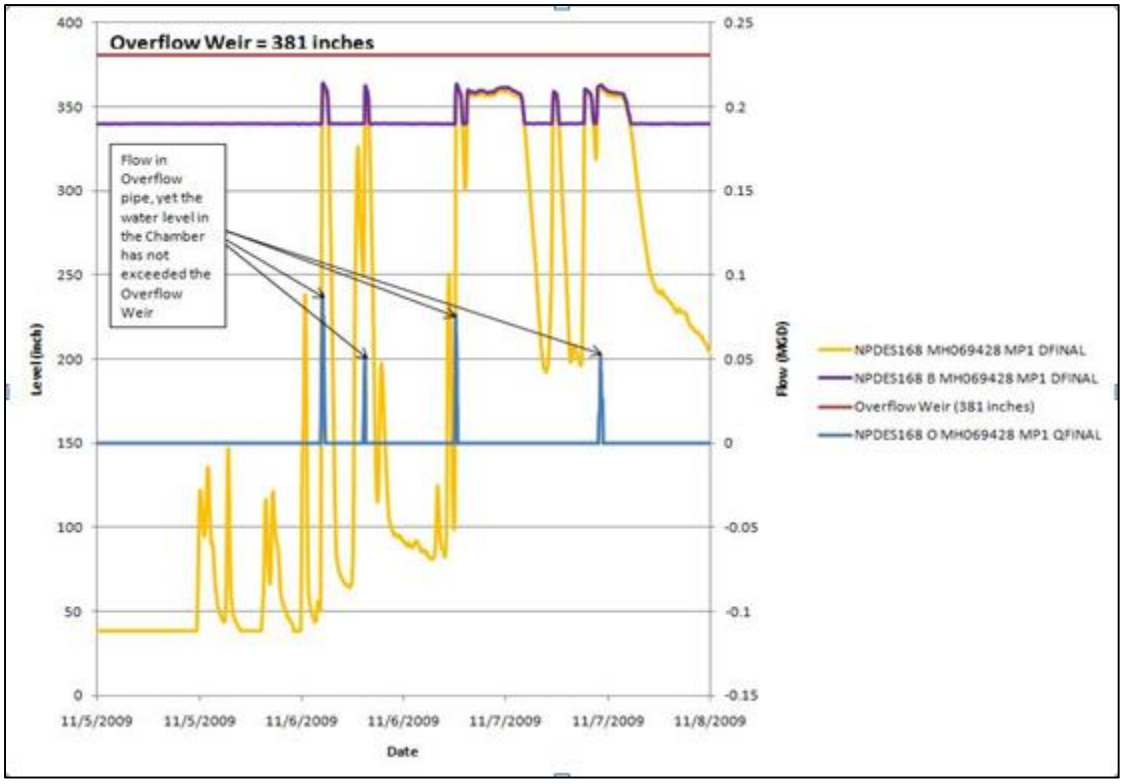

Figure 3-11. NPDES168_O_MH069428: Overflow estimated in overflow pipe, yet the water level in the chamber has not exceeded the overflow weir

3.3.3 NPDES169 Basin

The NPDES169 Basin, located south of the NPDES168 Basin, is approximately 184 acres in area. CSO Facility 3 is located in the NPDES169 Basin. The facility contains a 1.6 MG offline storage tank, a HydroBrake, and an overflow weir.

During Phases 2–3, eight temporary monitoring sites and three permanent monitoring sites were located in the NPDES169 Basin. In addition, the site is monitored through the SPU SCADA system, which provides real-time level in the overflow structure. At the conclusion of Phase 3 no temporary meters remained in the basin. Two permanent monitoring sites remained in the basin.

SPU_069-198A

SPU_069-198A was a temporary monitoring site that recorded both level and velocity. The meter was installed on 9/9/2008 to measure the eastern flow from the NPDES170 Basin that joins the King County system at MH 069-184.

SPU_069-198A was located immediately upstream from the King County system, and was downstream of both the NPDES169 and NPDES170 Basins. The data captured a consistent diurnal dry weather flow pattern. During storm events, the site received backwater from the downstream King County system, resulting in a flattened scattergraph at 6 fps as seen in Figure 3-12. The data quality was classified as "Good" for Phases 2–3 because of the backwater from the downstream King County system during peak wet weather flows. Data collected during Phase 1 was classified as "Excellent." All data from Phases 2–3 are suitable for use in model calibration.

During Phases 2–3, level spikes and velocity dropouts were edited by Stantec. The band was moved upstream on 2/3/2010 because it was found that there was a hydraulic jump on the probe which affected dry weather flows.

The meter was removed on 3/16/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

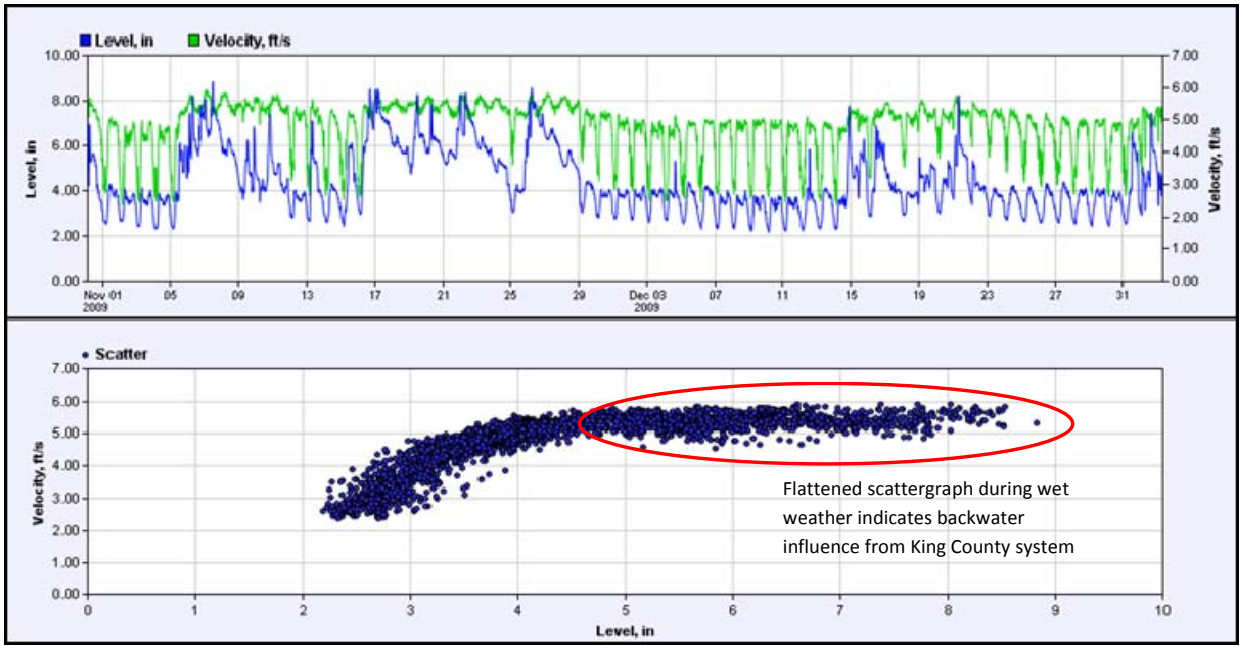

Figure 3-12. SPU_069-198: Hydrograph from 11/1/2009 through 12/31/2009

SPU_076-217A

SPU_076-217A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/20/2008 to characterize the hydrology in the NPDES169 Basin, and to measure the dry weather flows from the NPDES169 Basin downstream from the leaping weir diversion to the King County system.

The site captured a consistent diurnal dry weather flow pattern, which correlated well with the theoretical Manning's curve during storm flows. For all three monitoring periods, peak flow depths monitored at this location seldom exceeded 3 inches in the 8-inch pipe. During larger storm events, the depth would briefly reach 5 inches. During Phase 1 monitoring, investigations showed that the cause of the low depths was the leaping weir, which was not functioning as designed. A weir plate that deflects flow into the dry weather pipe was missing, which caused additional flow to divert to the CSO control facility. The site captured suitable data for all three monitoring periods. The data quality for both dry and wet weather flows was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

During Phases 2–3, some level spikes and velocity dropouts were edited by Stantec.

The meter was removed on 3/16/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DEL169_076-218A

DEL169_076-218A was a temporary monitoring site that recorded level only. The meter was installed on 9/23/2008 to measure the water depth in the sump of the leaping weir structure, which diverts low flow away from CSO Facility 3 directly to the King County system.

The level data collected from this meter indicated when wastewater flow was being diverted over the leaping weir to CSO Facility 3. The leaping weir is approximately 16.2 inches higher than the sump bottom, or maintenance hole invert. The pressure depth probe was mounted on the wall of the sump and level with the leaping weir. The meter was set to have an offset of 8 inches and to read negative depths because when installed the sump was approximately 8 inches full. If the water level in the sump is level with the leaping weir the meter reads zero. The site data indicated that the sump did not fill to capacity (or have a zero reading) before high flows leaped over the weir and downstream to the offline NPDES169 Basin CSO Facility 3. The site captured suitable data for all three monitoring periods. During the end of Phase 1 and beginning of Phase 2, the meter was removed from 5/18/2009 to 6/15/2009 for pipe cleaning. The data quality was classified as "Excellent" during Phases 2–3. All data from Phases 2–3 are suitable for use in model calibration.

The meter was reinstalled on 6/15/2009 after the line was cleaned on 5/18/2009. During Phases 2–3, it was found that splashing around the probe made the exact level measurement inaccurate. It was also found from photos that flow goes into the overflow line when the sump is only half full.

The meter was removed on 2/3/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DEL169_076-232A

DEL169_076-232A was a temporary monitoring site that recorded both level and velocity. The meter was installed on 9/22/2008 to measure the combined flows upstream of the leaping weir diversion structure in the NPDES169 Basin.

The meter was located just upstream from the basin's leaping weir diversion structure. The site captured a consistent diurnal dry weather flow pattern, which correlated well with the theoretical Manning's curve during storm flows. During all three monitoring periods, standing waves and a hydraulic jump at approximately 4 inches in water level occurred, which is typical for the type of clay-tiled pipes at the site. During Phase 1, bidirectional velocity was activated on 12/15/2008. During Phases 2–3, flow balancing with downstream meters suggested that the meter may have been overestimating the velocity at lower depths due to the hydraulic jump. Detailed examinations by Stantec indicate that the meter was likely overestimating velocity at all flow depths below about 7 inches. Figure 3-13 shows the flow balance of the January 2009 storm event between the upstream meter (DEL169-076-232A) and the two downstream meters (SPU_076-217A and DEL169_076-370A); from this figure it appears that data above 7 inches is reliable. The data quality was therefore classified as "Some Limitations" for Phases 2–3 due to the hydraulic jump, and modelers should be aware that data at depths below 7 inches should not be used in calibration. This data classification is consistent with Phase 1 monitoring. All data at depths greater than 7 inches is suitable for model calibration.

During Phases 2–3, some velocity dropouts were edited by Stantec.

The meter was removed on 3/16/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

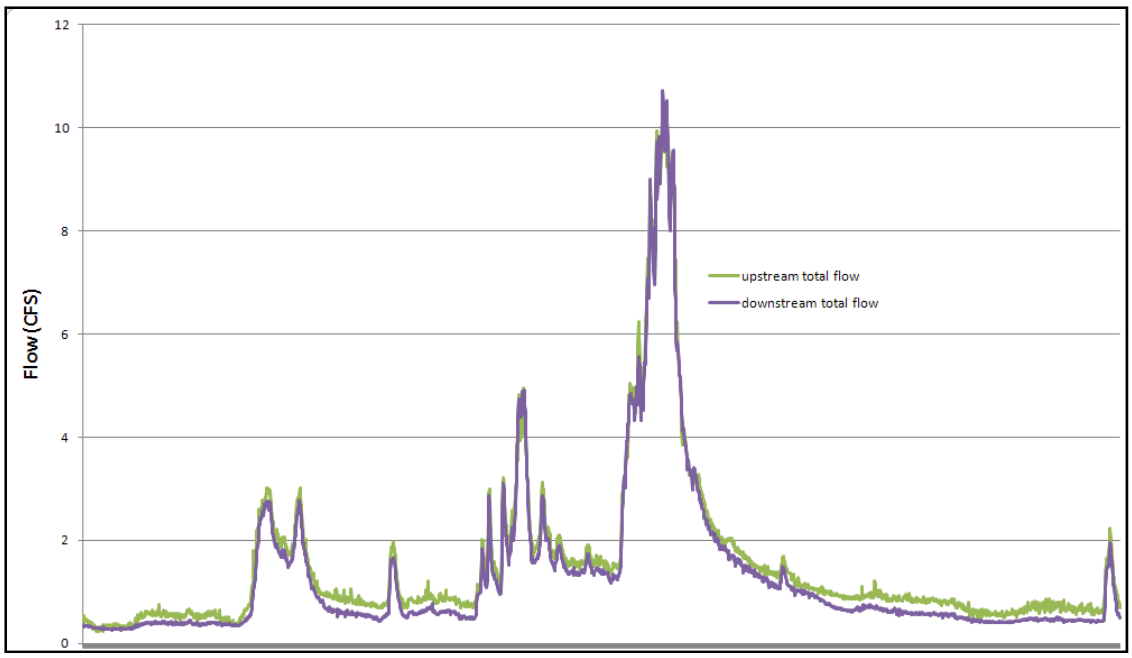

Figure 3-13. DEL169-076-232: Phase 1, January 2009 storm—overestimates flow for depths in the 2.5- to 7-inch range. Depth is reliable above 7 inches.

DEL169_076-351A

DEL169_076-351A was a temporary monitoring site that recorded both level and velocity. The meter was installed on 9/26/2008 to measure flows from the eastern part of the NPDES169 Basin upstream from that basin's leaping weir diversion structure.

The site occasionally experienced backwatering from the downstream confluence. Over the short duration that the meter was online during Phase 2, the data were classified as "Excellent." The data were classified as "Some Limitations" during Phase 1 monitoring due to wide data scatter at low flows, potential debris influence on the velocity reading, and the backwatering from the inflow just downstream. All data from Phase 2 are suitable for use in model calibration.

During Phases 2–3, some velocity spikes were edited by Stantec.

The meter was removed on 7/17/2009, during Phase 2 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DEL169_076-351B

DEL169_076-351B was a temporary monitoring site that recorded both level and velocity. The meter was installed on 9/26/2008 to determine the amount of flow from the stormwater system that was directed to the CSS during wet weather flow from the southern part of the NPDES169 Basin.

The meter was located at the same manhole with meter DEL169_076-351A but inside the stormwater pipe. The site received flow only during wet weather. The data correlated well with the theoretical Manning's curve during storm flows. During Phase 1, the maximum velocity was set to 15 fps on 11/17/2008. Over the short duration that the meter was online during Phase 2, the data were classified as "Excellent," which matches the quality classification of the data collected during Phase 1. All data from Phase 2 are suitable for use in model calibration.

During Phase 2, velocity dropouts were edited by Stantec.

The meter was removed on 7/17/2009, during Phase 2 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DEL169_076-362A

DEL169_076-362A was a temporary monitoring site that recorded both level and velocity. The meter was installed on 9/9/2008 to measure the wet weather combined flows from the NPDES169 Basin downstream from the NPDES169 Basin CSO Facility 3 and HydroBrake.

Because of the leaping weir upstream, no flow was recorded at this location during dry weather. The wet weather flow data correlated well with the theoretical Manning's curve. The site captured suitable data for Phases 2–3. The data quality was classified as "Good" for Phases 2–3 because of debris issues. The data were classified as "Good" during Phase 1 monitoring because of wide scatter. All data from Phase 2 are suitable for use in model calibration.

During Phases 2–3, debris was typical in the pipe which caused large level spikes with no velocity increase.

The meter was removed on 1/9/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DEL169_076-366A

DEL169_076-366A was a temporary monitoring site that recorded depth only. The meter was installed on 9/26/2008 to measure the use of the storage tank at CSO Facility 3 in the NPDES169 Basin.

The pressure depth probe was mounted on the floor of the storage tank. The site captured suitable data for Phases 2–3. During Phases 1–3 monitoring, data indicated leakage from the CSO chamber through the duckbill check valves, as seen in Figure 3-14. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

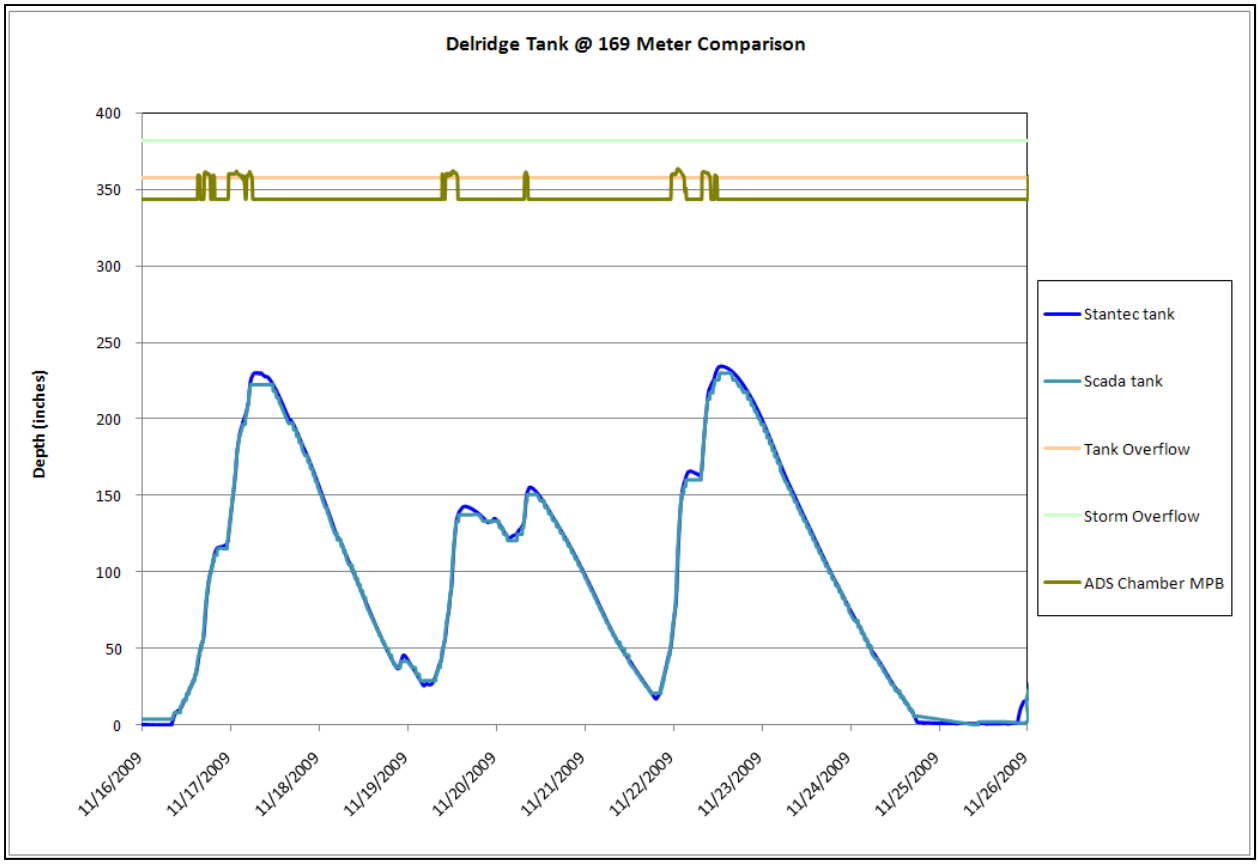

Figure 3-14. DEL169_076-366A (Stantec Tank): Leaking duckbill valve, note level increase in storage tank prior to depth of storage tank weir

During Phases 2–3, debris buildup was common at the site but the quality of the data was not affected in the storage tank because the meter was located above the debris.

The meter was removed on 2/2/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DEL169_076-367A

DEL169_076-367A was a temporary monitoring site that recorded depth only. This pressure meter was installed on 9/26/2008 to confirm the permanent meters (NPDES169_MH076367and NPDES169_B_MH076367) data at CSO Facility 3 in the NPDES169 Basin. The data were also used to characterize the HydroBrake located inside the CSO facility.

The pressure depth probe, mounted on the floor of the CSO chamber, was determined to be reading 357.9 inches of water depth when the weir to the storage tank overflowed and 382 inches when the overflow weir overflowed. The high level readings from this meter matched readings from the permanent ultrasonic meter NPDES169_B_MH076367 exactly, and the low level readings closely agreed with meter NPDES169_MH076367. The site captured suitable data for Phases 2–3. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

The meter was removed on 2/2/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DEL169_076-367B

DEL169_076-367B was a temporary monitoring site that recorded pressure depth only. This ultrasonic meter was installed on 9/20/2008 to confirm the permanent meters (NPDES169_MH076367 and NPDES169_B_MH076367) data at CSO Facility 3 in the NPDES169 Basin, specifically the overflows from the CSO chamber into the storage tank.

The ultrasonic depth probe was mounted on the CSO chamber ceiling and aimed at a plate level with the top of the weir to the storage tank. The meter does not record a depth until the water level in the chamber reaches the elevation of the storage weir. The probe was determined to be reading greater than zero inches of water depth when the weir to the storage tank overflowed. Data collected by this meter closely agree with data collected by the other three meters at the same location: DEL169_076-367A, NPDES169_MH076367, and NPDES169_B_MH076367. The site captured suitable data for Phases 2–3. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

During Phase 3, the meter was replaced on 12/28/2009 because the meter was not reading properly from 12/18/2009 and 12/28/2009.

The meter was removed on 2/2/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DEL169_076-370A

DEL169_076-370A was a temporary monitoring site that recorded both level and velocity. The meter was installed on 9/10/2008 to measure the wet weather combined flows from the NPDES169 Basin downstream from the leaping weir diversion of wet weather flows to the NPDES 169 storage tank. Little to no flow was recorded during dry weather.

The data correlated well with the theoretical Manning's curve during storm events. During Phase 1, the maximum velocity was set to 15 fps on 11/25/2008. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

During Phases 2–3, velocity dropouts were edited by Stantec. The velocity readings during low flow are not reliable.

The meter was removed on 3/16/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NPDES169_MH076367

NPDES169_MH076367 is a permanent monitoring site that records depth only. The meter was installed on 8/22/2007 to measure the depth at the NPDES169 Basin overflow weir and then calculate the overflow volumes using the weir formula. Overflows occur when the level in NPDES169_MH076367 reaches 382 inches.

The pressure depth probe, mounted on the wall of the CSO chamber 10 inches above the floor, measured 382 inches when an overflow occurred. Data collected by this meter showed agreement with meter DEL169_076-367A and meter NPDES169_B_MH076367 at the low- to mid-level range, but slightly above the readings from those two meters when the CSO occurred. The site captured suitable data for Phases 2–3. The data quality was classified as "Good" for Phases 2–3 because the meter overestimated the level readings during a CSO event. Data collected during Phase 1 was classified as "Excellent." All data from Phases 2–3 are suitable for use in model calibration.

NPDES169_MH076367 is a permanent meter and will continue to be screened in the future.

NPDES169_B_MH076367

NPDES169_B_MH076367 is a permanent monitoring site that records depth only. The meter was installed on 4/10/2008 to measure the depth at the NPDES169 Basin overflow weir and then calculate the overflow volumes using the weir formula. Overflows occur when the level in NPDES169_B_MH076367 reaches 38 inches.

The ultrasonic depth probe was mounted on the ceiling of the CSO chamber and aimed at a plate 38 inches below the top of the overflow weir. Readings from the meter matched readings from the temporary pressure meter DEL169_076-367A, and are in very good agreement with the other two meters at this location, NPDES169_MH076367 and DEL169_076-367B. The site captured suitable data for Phases 2–3. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

NPDES169_B_MH076367 is a permanent meter and will continue to be screened in the future.

NPDES169_O_MH076367

NPDES169_O_MH076367 was a permanent monitoring site that recorded depth only. The permanent meter was installed on 8/22/2007 to measure the overflow volumes downstream from the NPDES169 Basin overflow weir.

The sensors were installed in the overflow drainage line downstream from the overflow weir. The site captured suitable data for Phases 2–3. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

The meter was removed on 1/6/2010, during Phase 3 monitoring, as it was determined that accurate overflow volumes could be calculated using a weir equation and meter NPDES169_B_MH076367.

3.3.4 NPDES170 Basin

The NPDES170 Basin, located due west of the NPDES168 Basin, is approximately 50 acres in area. The NPDES170 Basin contains three control structures: a 0.2 MG in-line storage pipe, a HydroBrake, and an overflow weir.

During Phases 2–3, there were and three temporary monitoring locations and one permanent monitoring location in the NPDES170 Basin. At the conclusion of Phase 3 temporary meters DEL170_069-146B and DEL170_069-146C remained installed in the Delridge/Longfellow NPDES170 Basin but were recommended for removal. One overflow point within Delridge/Longfellow NDPES170 Basin will continue to be monitored on a permanent basis.

DEL170_069-146A

DEL170_069-146A was a temporary monitoring site recording pressure depth only. The ISCO 2150 pressure meter was installed on 9/1/2010, to monitor the depth in the HydroBrake chamber.

The pressure depth probe was mounted 5 inches above the floor of the CSO chamber. The site captured suitable data for Phases 2–3; therefore, the data quality was classified as "Excellent." The meter was not installed during Phase 1 monitoring. All data from Phases 2–3 are suitable for use in model calibration.

The meter was removed on 3/16/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DEL170_069-146B

DEL170_069-146B is a temporary monitoring site recording velocity and ultrasonic depth on the HydroBrake side of the chamber located in the NPDES170 Basin. The ADS FlowShark meter was installed on 12/8/2009, to help characterize the HydroBrake located in the NPDES170 Basin.

The velocity was spotty throughout Phase 3 monitoring because of standing water in the chamber. The velocity data will not be used for modeling purposes; the level data were characterized as "Excellent." The meter was not installed for Phases 1 and 2. All level data from Phase 3 are suitable for use in model calibration.

The temporary meter was not removed by the conclusion of Phase 3 monitoring but was recommended for removal as sufficient data were collected for the purpose of model calibration.

DEL170_069-146C

DEL170_069-146C is a temporary monitoring site recording velocity and depth on the storage side of the chamber located in the NPDES170 Basin. The ADS FlowShark meter was installed on 12/8/2009, to estimate storage utilization in the NPDES170 Basin.

The velocity was spotty throughout Phase 3 monitoring because of standing water in the storage tank; therefore, the velocity data will not be used for modeling purposes therefore. The level data were characterized as "Excellent." The meter was not installed for Phases 1 and 2. All data from Phase 3 are suitable for use in model calibration.

During Phase 3 monitoring, there is a data gap between 4/27/2010 and 5/7/2010 because the meter was not reporting data. The meter was replaced on 5/7/2010.

The temporary meter was not removed by the conclusion of Phase 3 monitoring but was recommended for removal as sufficient data were collected for the purpose of model calibration.

DEL170_DWF-069144

DEL170_DWF-069144 is a permanent monitoring site that records both velocity and level. The meter was installed on 8/16/2007 in the upstream pipe and on the dry weather side of the NPDES170 Basin overflow weir. Overflows occur when the level in DEL170_DWF-069144 reaches 13.13 inches.

Data collected by this meter were used both for calculating the overflow volume and characterizing the HydroBrake downstream. The site captured suitable data for all three monitoring periods. During Phase 1 data collected was classified as "Excellent." The data quality was classified as "Some Limitations" for Phases 2–3 because during model calibration it was found that the flow spikes throughout the monitoring period were not realistic. SPU placed the site on the dry weather list to provide finalized velocity and flow data. The source and accuracy of the flow spikes is being researched by SPU. The two overflows that were reported at this site were caused by the HydroBrake being plugged with debris. This site is considered to be controlled based on previous monitoring.

DEL170_DWF-069144 is a permanent meter and will continue to be screened in the future.

3.3.5 Combined Sewer Overflows

ADS Environmental Services reported that seven CSOs occurred in the Delridge/Longfellow Basin during Phases 2–3. Table 3-5 lists the CSOs reported by ADS during Phases 2–3.

Table 3-5. 2009–2010 Combined Sewer Overflows in Delridge/Longfellow Basin			
NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
99	--	--	--
168	11/20/2009	4:02	78,034
	11/22/2009	22:59	954,776
	11/26/2009	20:15	574,510
	1/11/2010	103:08	3,161,649
169	1/12/2010	2:52	64,110
170[a]	10/26/2009	13:13	11,719
	10/28/2009	10:15	4,903

a. Overflows were associated with a plugged HydroBrake.

Figure 3-15 shows the maximum water level recorded by ADS at each of the overflow structures in the basin as a percentage of the weir height.

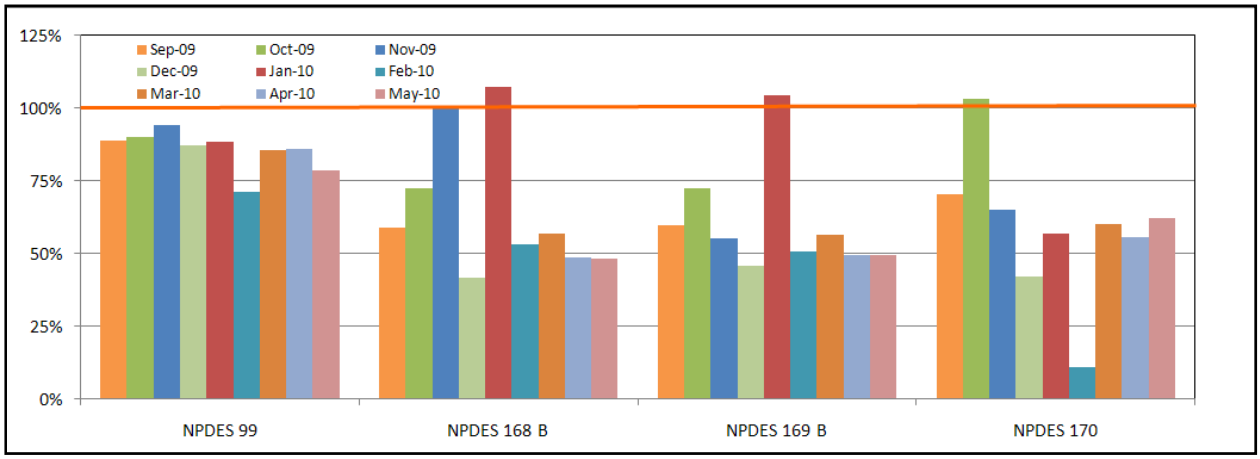

Figure 3-15. Maximum recorded levels over weir heights in Delridge/Longfellow Basin for major events

Based upon the data collected, the overflow meters (NPDES168_O and NPDES169_O) at NPDES168 and NPDES169 did not produce reliable data to predict overflow events.

3.3.6 Facility Operations

The CSO facilities in the Delridge/Longfellow Basin consist of the following:

- NPDES099 Basin includes CSO Facility 34, which has an offline storage tank, HydroBrake, and overflow weir.
- NPDES168 Basin includes CSO Facility 2, which has an offline storage tank, HydroBrake, and overflow weir.

- NPDES169 Basin includes CSO Facility 3, which has an offline storage tank, HydroBrake, and overflow weir.
- NPDES170 Basin includes CSO Facility 1, which has a storage tank downstream from the overflow weir with a horizontal HydroBrake in the tank.
- There are no pump stations.

Figure 3-16 summarizes the storage utilization for the Phases 2–3 monitoring periods.

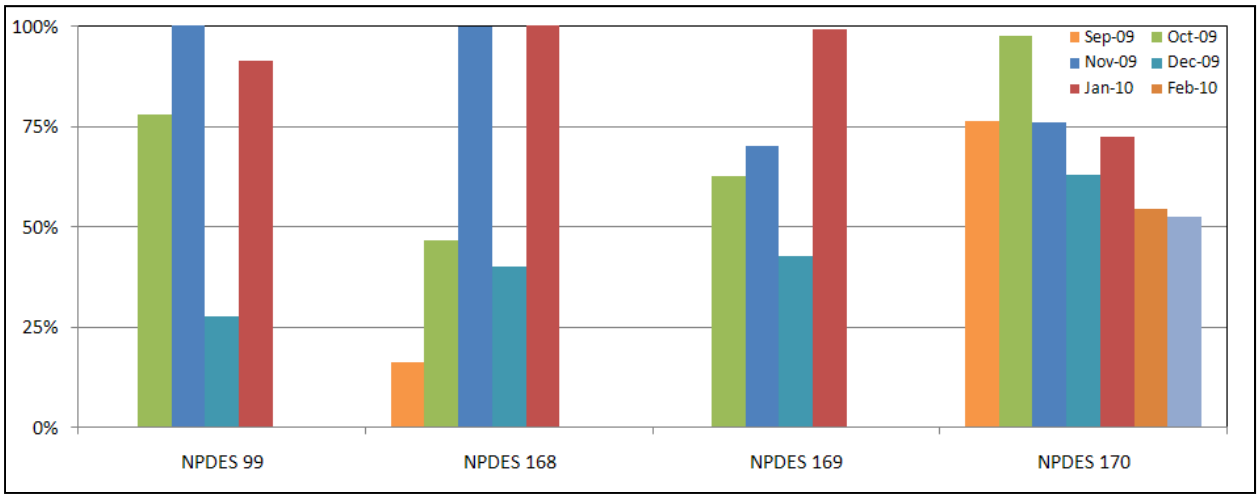

Figure 3-16. Delridge/Longfellow storage utilization

Based upon the data collected to produce Figure 3-15 the storage tank in NPDES099 was completely utilized in November 2009, and no overflows were reported during that month. The overflow weir at this location is higher than the top of the storage tank.

The storage tank in NPDES168 was completely utilized in November 2009 and January 2010, as shown in Figure 3-16; three overflow events were reported to Ecology in November 2009 and one overflow was reported in January 2010.

At the NPDES169 Basin three overflows were reported to Ecology in January 2010 by ADS, as shown in Table 3-5. Figure 3-16 shows that the storage tank was filled to approximately 98 percent.

At the NPDES170 Basin two overflows were reported in October 2009 by ADS, as shown in Table 3-5. Figure 3-16 shows that the approximately 95 percent of the storage tank was utilized during October 2009. These overflows were associated with the plugged HydroBrake. The overflow weir at this location is slightly lower than the top of the storage chamber.

NPDES099 Basin HydroBrake

Figure 3-17 shows the HydroBrake curves based upon monitoring data at the upstream meter DEL99_055-175 and the downstream meter DEL99_055-165 with respect to the HydroBrake location. The level data at the upstream meter 044-477 was used for the HydroBrake analysis. The level and flow data at the downstream meter 055-165 were also used for the analysis. The gathered data were then compared to the HydroBrake manufacturer's curve. Figure 3-17 shows October 2008 to May 2009 data (Phase 1 monitoring data), May 2009 data, and September 2009 through January 2010 data.

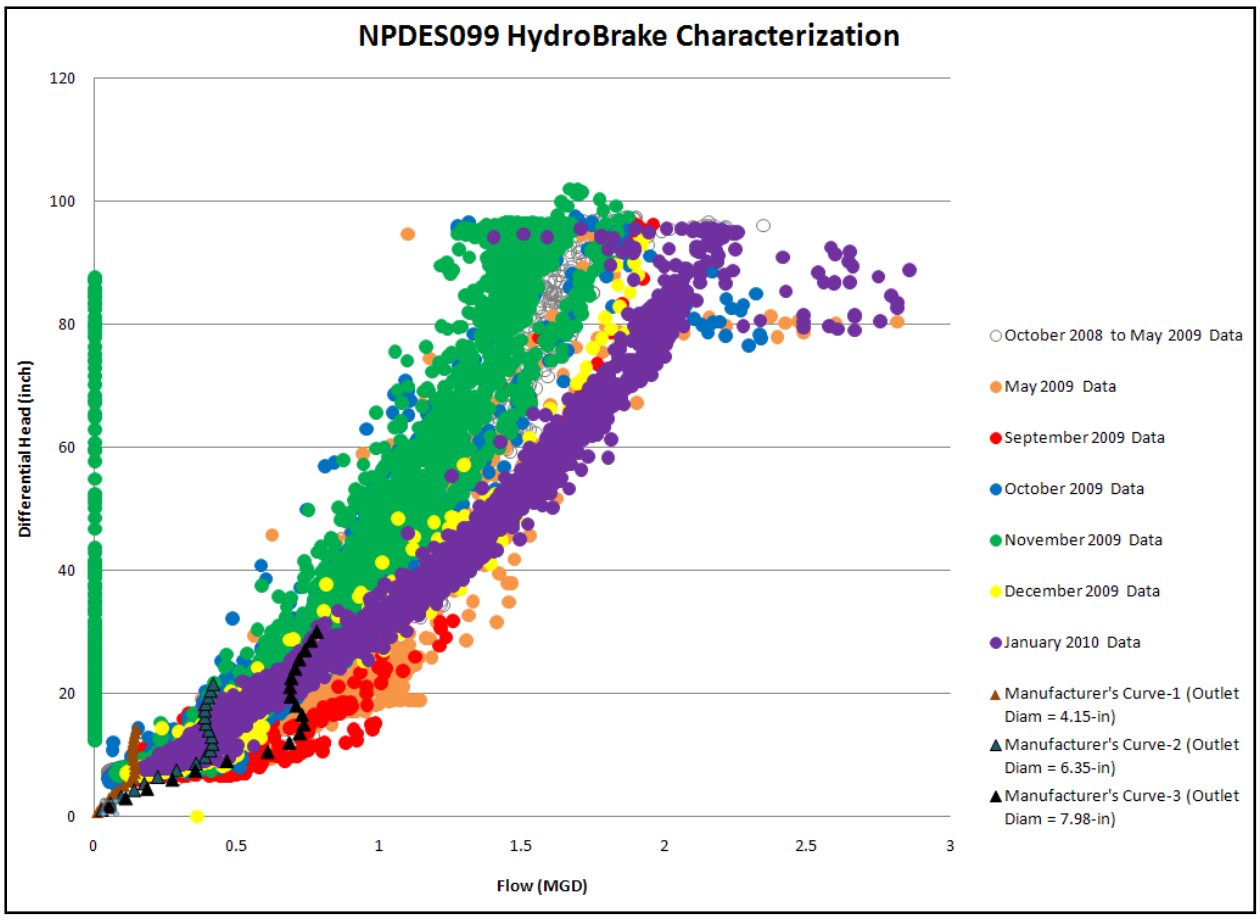

Figure 3-17. NPDES099 Basin HydroBrake characterization

The offline storage tank located at MH 055-473 works in conjunction with HydroBrake 055-478. When the HydroBrake triggers during storm events, the tank fills. Temporary meter DEL99_055-473 measures the level in the storage tank during wet weather events. During large wet weather events the flow begins to fill the 84-inch-diameter, 550-foot-long storage tank. The total volume of the storage tank is 0.16 MG. During the November 2009 storm events, the entire storage was utilized and no overflows were reported at the permanent meter.

The overflow weir for the NPDES099 Basin is located on the south end of CSO Facility 34 at MH 055-477. Once the level in the chamber pipe reaches a depth of 108.36 inches and the offline storage pipe is full, flow is diverted over the 113-inch-long overflow weir into a CSO outfall pipe that discharges to the West Waterway at the mouth of the Duwamish River.

NPDES168 Basin HydroBrake

As explained above, the meter at DEL168_069-406 has a history of underestimating flow; therefore, the HydroBrake curve was developed by using a mass balance based on measured upstream flow and storage. The flow rate through the HydroBrake was calculated by using the change in volume in the storage tank and chamber. Figure 3-18 shows the resulting HydroBrake characterization curve.

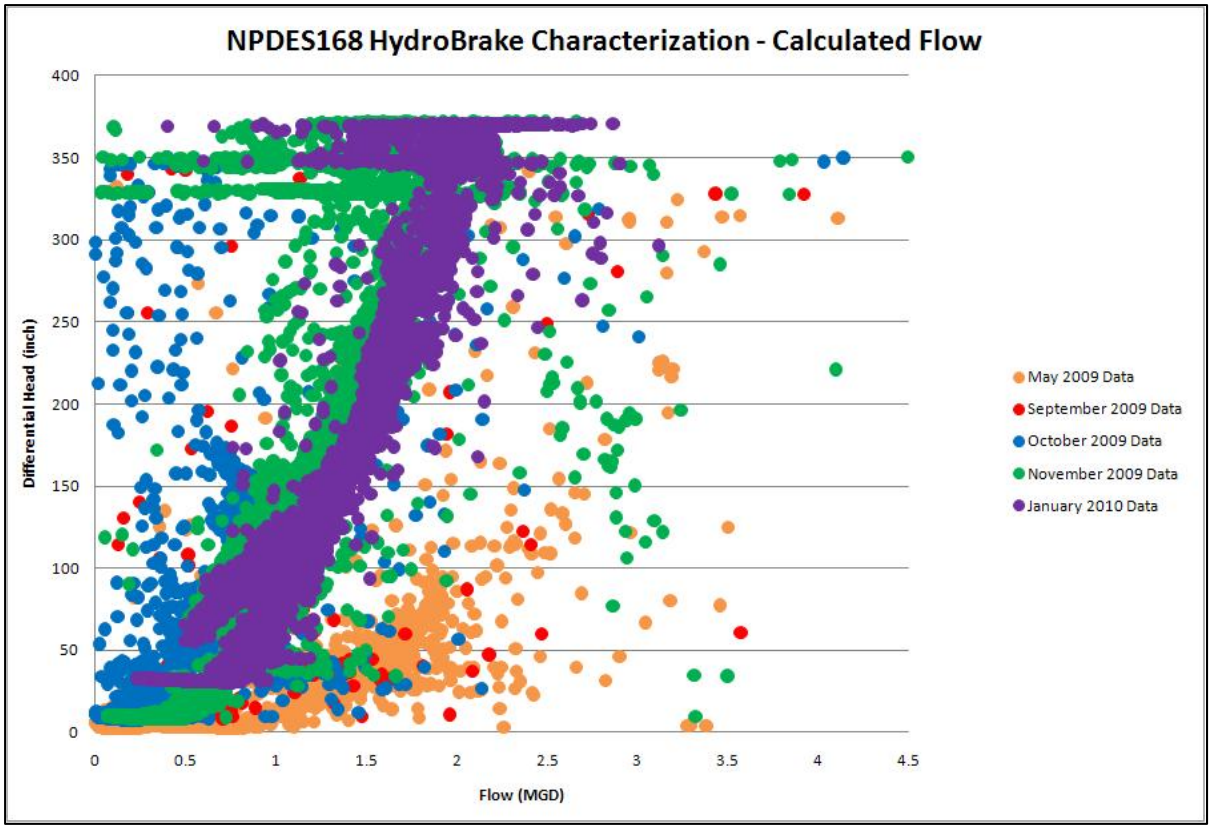

Figure 3-18. NPDES168 Basin HydroBrake characterization: calculated flow

The offline storage tank located at MH 069-428 works in conjunction with HydroBrake 069-428. When the HydroBrake triggers during storm events, the tank fills. Temporary meter DEL168_069-408 measures the level in the storage tank during wet weather events. During large wet weather events, the flow begins to fill the 100-foot-diameter, 27-foot-deep storage tank. The total volume of the storage tank is 1.6 MG. During the November 2009 and January 2010 storm events, the storage capacity was entirely utilized. An overflow occurred in November 2009 but during the January 2010 event no overflow was reported.

The overflow weir for the NPDES168 Basin is a three-section weir, 223.25 inches long, located on the north and west end of the CSO Facility 2 chamber in MH 069-428. Once the level in the chamber reaches a depth of 381 inches and the offline storage tank is full, flow is diverted into a 30-inch-diameter CSO outfall pipe that discharges to Longfellow Creek.

NPDES169 Basin HydroBrake

Figure 3-19 shows the HydroBrake curve based upon monitoring data at an upstream meter and a downstream meter with respect to the HydroBrake location. The level data at upstream meter 076-367 were used for the HydroBrake 076-367 analysis. The level and flow data at downstream meter 076-362 were also used for the analysis. The HydroBrake manufacturer's curve was not available for this HydroBrake. Figure 3-19 shows October 2008 to May 2009 data (Phase 1 monitoring data), May 2009 data, and September 2009 through January 2010 data. The flat line of data at approximately 382 inches indicates the overflow height of the weir in the control chamber. The horizontal series of points at the 357.9-inch height indicate flow into the storage tank from the control chamber.

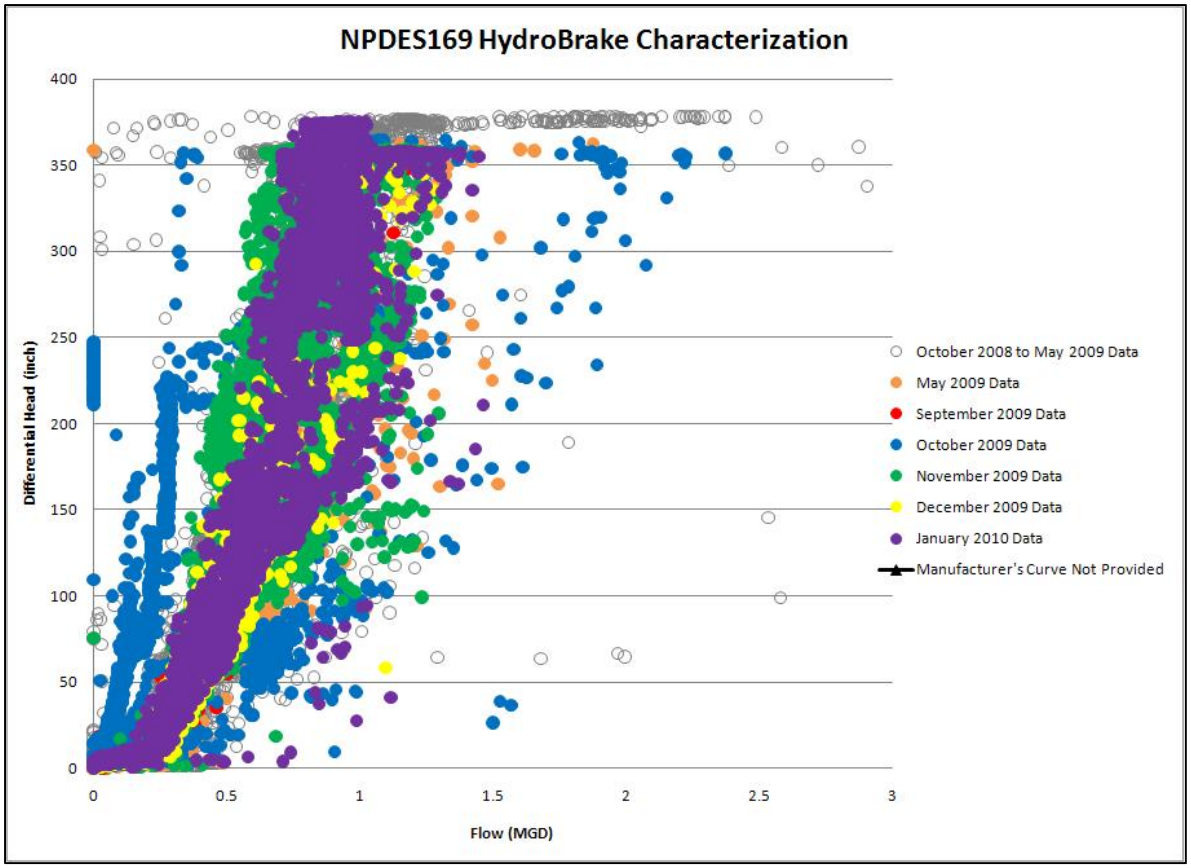

Figure 3-19. NPDES169 Basin HydroBrake characterization

The offline storage tank at MH 076-366 works in conjunction with HydroBrake 076-367. When the HydroBrake triggers during storm events, the tank fills. Temporary meter DEL169_076-366 measures the level in the storage tank during wet weather events. During large wet weather events, the flow begins to fill the 100-foot-diameter, 27-foot-deep storage tank. The total volume of the storage tank is 1.6 MG. During the January 2010 storm event, the storage capacity was almost entirely utilized and an overflow event occurred.

The overflow weir for NPDES169 Basin is a three-section weir, approximately 224 inches long, located on the north and west end of the CSO Facility 3 chamber in MH 076-367. Once the level in the chamber reaches a depth of 382 inches and the offline storage tank is full, flow is diverted into a 30-inch-diameter CSO outfall pipe which discharges to Longfellow Creek.

NPDES170 Basin HydroBrake

During Phase 2, meters were installed in December 2009 in the storage tank and in the HydroBrake chamber to provide characterization of the HydroBrake. Figure 3-20 shows December 2009 and January 2010 data for the HydroBrake. Because it was not possible to accurately measure the flow out of the HydroBrake at this location, the characterization curve was derived from a mass balance using measured inflow to the chamber together with depths measured in the HydroBrake chamber and storage tank. The horizontal series of points at 40 inches indicates flow into the storage tank from the control chamber.

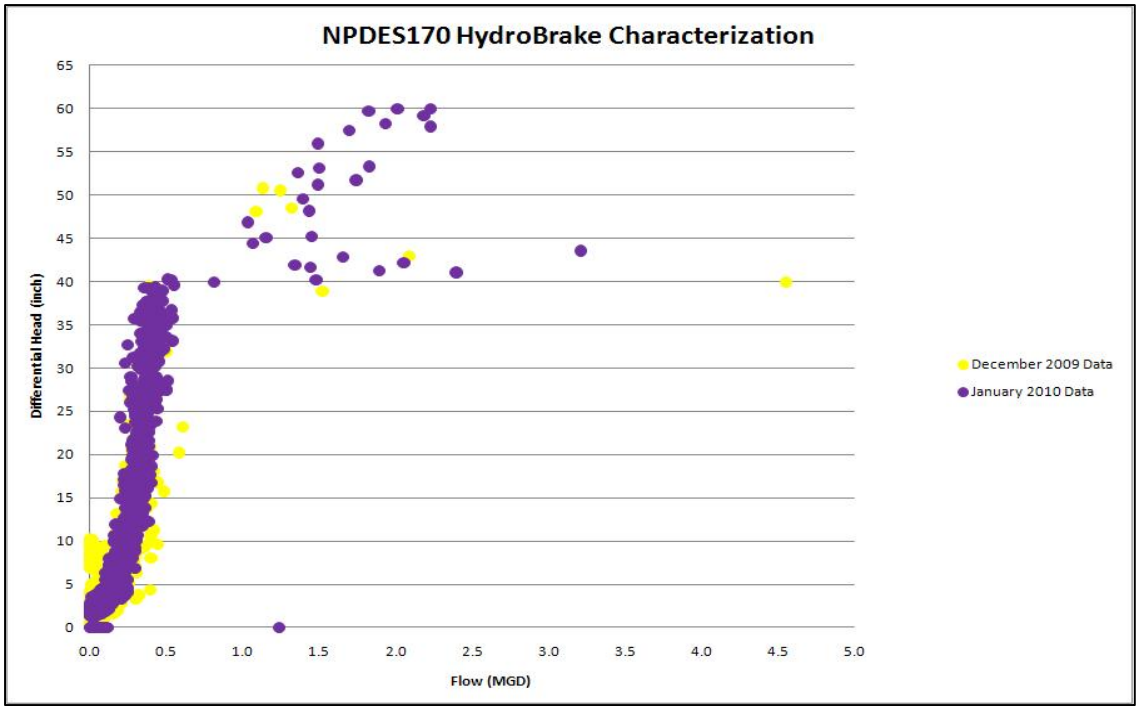

Figure 3-20. NPDES170 Basin HydroBrake characterization

The offline storage tank at the NPDES170 Basin is located at the intersection of 24th Avenue SW and SW Webster Street. The storage tank works in conjunction with a HydroBrake located in MH 069-146 downstream from the overflow weir. Temporary meter DEL170_069-146A measures the level in the storage tank during wet weather events. When the HydroBrake is activated during storm events, the flow is stored in the 8-foot-diameter, 521-foot-long storage tank at MH 069-146. An intermediate weir is located in the storage tank. If the tank capacity is exceeded during large wet weather events, a CSO occurs. The storage tank was never entirely utilized during Phases 2–3, although during the 10/26/2009 storm event it was close to capacity (approximately 95 percent full) and an overflow event occurred.

The NPDES170 Basin Overflow Structure is located on the northeast end of MH 069-144. Once the level in the storage pipe reaches a depth of 80 inches, flow is diverted into a 21-inch-diameter CSO outfall pipe which discharges to Longfellow Creek.

3.3.7 Recommendations for Additional Data Collection

At the conclusion of Phases 2–3, no additional data needed to be collected in the Delridge/Longfellow Basin for the purposes of model calibration. Two meters remained installed in the Delridge/Longfellow Basin to collect data for the CSO retrofit program.

3.4 Duwamish Basin

The Duwamish Basin, which consists of the NPDES107 and NPDES111 Basins, covers an area of approximately 585 acres.

One permanent meter monitors overflow events in the NPDES107 Basin. There were no suitable locations to measure flow throughout the NDPES107 Basin; therefore, no temporary meters were installed in the NPDES107 Basin. Overflows in the NPDES107 Basin flow into a storm drain that enters the East Waterway at the mouth of the Duwamish River.

The combined sewer flows in the NPDES111 Basin were monitored with temporary and permanent meters, and the combined sewage flows from east to west were monitored during Phases 2–3 monitoring with temporary meters at six locations. A total of eight overflow locations (111[A] through 111[H]) overflow to a large storm drain that flows into the Duwamish River.

Rainfall in the Duwamish Basin is monitored by RG 15, located at the Puget Sound Clean Air Monitor Station.

ADS monitored nine overflow points within the Duwamish Basin, and Stantec monitored seven temporary meters throughout Phases 2–3. At the conclusion of Phase 3 no temporary flow meters remained in the Duwamish Basin. The nine permanent flow meters remained.

Appendix E contains detailed information on each meter, and a basin schematic is located in Appendix B.

3.4.1 NPDES107 Basin

The Duwamish NPDES107 Basin, located due north of the NPDES111 Basin along the eastern shore of the Duwamish River, is approximately 51 acres in area. One permanent meter monitors the basin to verify overflows. It was found to be impossible to install a meter to collect reliable velocity data in this basin. Thus, there are no flow data with which to calibrate a model. The one overflow point within Duwamish NDPES107 Basin will continue to be monitored on a permanent basis.

NPDES107_MH056097

This permanent meter was installed on 7/26/2007 to measure depth at the NPDES107 Basin elevated overflow pipe. Overflows occur when the level at NPDES107_MH056097 reaches 65.4 inches.

The site is not expected to provide repeatable and reliable dry weather flow data and is classified as a wet weather site. During Phase 3, 14 overflows were reported at this location: 3 in October 2009, 5 in November 2009, 5 in January 2010, and 1 in April 2010. Depth data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

NPDES107_MH056097 is a permanent meter and will continue to be screened in the future.

3.4.2 NPDES111 Basin

The Duwamish NPDES111 Basin, located on the eastern shore of the Duwamish River, is approximately 534 acres in area. CSO Facility 35 is a CSS control facility located in the NPDES111(H) Basin. The facility contains three control structures: a 0.16 MG in-line storage pipe, a HydroBrake, and an overflow weir.

During Phases 2–3, eight permanent meters monitored the basin to verify overflows, and eight temporary monitoring sites were located in the NPDES111 Basin. At the conclusion of Phase 3 no temporary meters

remain in Duwamish NPDES111 Basin. The eight overflow points within Duwamish NDPES111 Basin will continue to be monitored on a permanent basis.

DUW111_056-166A

DUW111_056-166A was a temporary monitoring site that recorded both level and velocity. The meter was installed on 9/18/2008 to measure the combined flow to the King County pump station from the eastern part of the NPDES111 Basin. This meter is the most downstream temporary meter in the NPDES111 Basin.

The meter is located downstream from the 111(D), 111(E), 111(F), 111(G) and 111(H) overflow weirs and upstream from the 111(A), 111(B), and 111(C) overflow weirs and the King County Duwamish pump station. Data at the site captured a consistent diurnal dry weather flow pattern. Also, the data correlated well with the theoretical Manning's curve during storm flows. Depths of more than 70 inches were recorded in the 35-inch-diameter pipe. Tide signals were observed at this meter due to CSO flap gate leakage at 111(A), 111(B), and 111(C). Backwater effects were also caused by the closure of the sluice gate at the King County pump station. The site captured suitable data for Phases 2–3. The data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. For all monitoring periods, the tidal and backwater effects from the King County pump station will need to be accounted for. All data from Phases 2–3 are suitable for use in model calibration.

During Phases 2–3, an ADS FlowShark Pulse with a crown-mounted ultrasonic sensor was installed at the site. Velocity dropouts were edited by Stantec, and there is a data gap between 11/29/2009 and 12/2/2009 because the meter was not reporting data. The meter was replaced on 12/2/2009.

The meter was removed on 3/23/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DUW111_057-039A

DUW111_057-039A was a temporary monitoring site that recorded both level and velocity. The meter was installed on 9/22/2008 to measure the combined flows entering the basin from the easternmost portion of the basin. This meter is upstream of meter DUW111_056-166A and downstream of meter DUW111_057-229A.

The data at this location had a consistent diurnal dry weather flow pattern and correlated well with the theoretical Manning's curve during storm flows. The site captured suitable data for all wet weather events. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

During Phases 2–3, some velocity dropouts were edited by Stantec.

The meter was removed on 2/10/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DUW111_057-229A

DUW111_057-229A is a temporary monitoring site that recorded both level and velocity. The meter was installed on 10/1/2008 to measure the combined flows leaving the HydroBrake of that basin's CSO Facility 35 (overflow 111[H]).

Data from this site are used to characterize the HydroBrake. The data at this site had a consistent diurnal dry weather flow pattern. The data correlate well with the theoretical Manning's curve during storm flows. The site captured suitable data for Phases 2–3. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

During Phases 2–3, some level spikes were edited by Stantec.

The meter was removed on 2/10/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DUW111_057-350A

DUW111_057-350A was a temporary monitoring site that recorded level only. The meter was installed on 1/26/2009 to measure the water depth within the HydroBrake chamber in the NPDES111(H) Basin.

The pressure depth probe is mounted on the wall of the chamber 13 inches above the invert of the structure, which is just above the water surface during normal dry weather flow. The data together with flow from DUW111_057-229A were used for HydroBrake characterization. The mounting of the pressure probe above the invert was necessitated by the configuration of the structure. The lower range of the HydroBrake curve will be approximated. The data quality was classified as "Excellent" for Phases 2–3 because the meter captured suitable data throughout the monitoring periods. All data from Phases 2–3 are suitable for use in model calibration. The data were classified as "Good" for Phase 1 monitoring because the meter was installed on 1/26/2009 and did not capture the November 2008 and January 2009 storm events.

The meter was removed on 2/10/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DUW111_057-241A

DUW111_057-241A was a temporary monitoring site that recorded level and velocity. The meter was installed on 9/26/2008 to characterize hydrology of the residential area in the NPDES111 Basin upstream from that basin's 111(H) overflow weir and HydroBrake.

The data at this site captured a consistent diurnal dry weather flow pattern. The data correlated well with the theoretical Manning's curve during storm flows. The site captured suitable data for all wet weather events. The data quality was classified as "Good" for Phases 2–3 because of meter complications. Data collected during Phase 1 were classified as "Excellent." All data from Phases 2–3 are suitable for use in model calibration.

During Phases 2–3, velocity dropouts were edited by Stantec. The velocity data indicated that the meter was damaged during the October 2009 storm, and the meter was therefore replaced on 10/20/2009. There was a data gap from 11/6/2009 to 11/9/2009 because the meter was not reporting data. The meter was replaced on 11/9/2009. During the January 2010 storms the velocity meter range was switched from 10 to 15 fps; therefore, some velocity peaks were edited by Stantec.

The meter was removed on 2/10/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

DUW111_057-241B

DUW111_057-241B was a temporary monitoring site that recorded both level and velocity. The meter was installed on 9/26/2008 to characterize hydrology from the residential area of the NPDES111 Basin upstream from that basin's 111(H) overflow weir and HydroBrake.

The data at this site captured a consistent diurnal dry weather flow pattern, which is different than the pattern generated from meter DUW111_057-241A. Dry weather flow was typically 1 inch in depth, which affected dry weather data accuracy. Velocity and depth data correlated well with the theoretical Manning's curve during storm flows. The site captured suitable data for all wet weather events. The data quality was classified as "Good" for Phases 2–3 because of data gaps. Data collected during Phase 1 was classified as "Excellent." All data from Phases 2–3 are suitable for use in model calibration.

During Phase 3, there was a data gap from 11/4/2009 to 11/9/2009 because the meter was not reporting data. The meter was replaced on 11/9/2009. There was another data gap from 1/27/2010 to 2/3/2010 because the meter was not reporting data. The meter was replaced, again, on 2/3/2010.

The meter was removed on 2/10/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NPDES111A_MH056195

NPDES111A_MH056195 is a permanent monitoring site that records both level and velocity. The meter was installed on 8/16/2007 to measure depth at the NPDES111(A) overflow weir. Meters were installed in both the upstream and downstream CSO pipes. The site is not expected to provide repeatable and reliable dry weather flow data and is classified as a wet weather site. Overflows occur when the level in NPDES111A_MH056195 reaches 21.36 inches.

The site captured suitable data for all wet weather events. No overflows occurred during the review period. During Phase 1 monitoring it was found that the data at this site show backwater effects. These backwater effects are suspected to be caused by both the King County Duwamish pump station and high tide. When the pump station capacity was exceeded, or when flooding prevention was required, the sluice gate installed in the inflow line of the pump station is shut. In that case all of the CSO sites except 111H see backwater from the pump station. In addition, high tide can cause saltwater intrusion at this site because the flap gate is slightly leaky.

Previously during Phases 1 and 2, velocity and flow were monitored by the NPDES111(A) MP2 meter, which was removed in February 2010. During Phase 3 monitoring and in February 2010, velocity and flow were activated in the NPDES111(A) MP1 meter. The data quality was classified as "Excellent" for Phases 2–3 and all data from Phases 2–3 are suitable for use in model calibration. The data were classified as "Good" for Phase 1.

NPDES111A_MH056195 is a permanent meter and will continue to be screened in the future.

DUW111_DWF-056270

DUW111_DWF-056270 is a permanent monitoring site that records both level and velocity. The meter was installed on 8/20/2007 in the upstream pipe on the dry weather flow side of the NPDES111(B) overflow weir to measure the overflow volumes, and to provide dry weather flow data for basin characterization. Overflows occur when the level in DUW111_DWF-056270 reaches 27.12 inches.

The meter generally captured a consistent diurnal dry weather flow pattern. The data were consistent with expected backup conditions during storm flows. During Phase 1 a site visit photo indicated that there was backwatering from high tides. The site captured suitable data for all wet weather events. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

DUW111_DWF-056270 is a permanent meter and will continue to be screened in the future.

NPDES111C_MH056365

NPDES111C_MH056365 is a permanent monitoring site that records both level and velocity. The meter was installed on 8/16/2007 to measure depth at the NPDES111(C) overflow weir. Overflows occur when the level in NPDES111C_MH056365 reaches 21.84 inches.

The site is not expected to provide repeatable and reliable dry weather flow data and is classified as a wet weather site. The site captured suitable depth data for all wet weather events. During Phase 1 monitoring, the data indicated that there was backwatering and perhaps tidal flow into the structure during high tides. The

data quality was classified as "Excellent" for Phases 2–3, and all data from Phases 2–3 are suitable for use in model calibration. The data were classified as "Good" for Phase 1.

NPDES111C_MH056365 is a permanent meter and will continue to be screened in the future.

NPDES111D_MH057253

NPDES111D_MH057253 is a permanent monitoring site that records both level and velocity. This permanent meter was installed on 8/29/2007 to measure the overflow volumes at the NPDES111(D) overflow weir. Overflows occur when the level in NPDES111D_MH057253 reaches 22.25 inches.

The site is not expected to provide repeatable and reliable velocity data and is classified as a wet weather site. No overflows occurred at this location during Phases 2–3. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

NPDES111D_MH057253 is a permanent meter and will continue to be screened in the future.

NPDES111E_MH057065

NPDES111E_MH057065 is a permanent monitoring site that records both level and velocity. The permanent meter was installed on 7/23/2007 to measure the overflow volumes at the NPDES111(E) overflow weir. The sensors at this site were installed in the elevated overflow pipe; therefore, no dry weather flow data were to be collected at this site. Overflows occur when the level in NPDES111E_MH057065 reaches 23.88 inches.

The site is classified as a wet weather site, so velocity data are not considered reliable for basin characterization. No overflows occurred at this location during Phases 2–3. Depth data quality was classified as "Excellent" for Phases 2–3 and all data from Phases 2–3 are suitable for use in model calibration. The data were classified as "Good" for Phase 1.

NPDES111E_MH057065 is a permanent meter in an elevated CSO pipe. This site never overflowed during the entire monitoring period.

DUW111_DWF-057079

DUW111_DWF-057079 is a permanent monitoring site that records both level and velocity. The meter was installed on 8/7/2007 to measure the overflow volumes at the NPDES111(F) elevated overflow pipe and to measure dry weather flows for basin characterization. Overflows occur when the level in DUW111_DWF-057079 reaches 113.5 inches.

The site captured consistent dry weather flow patterns. The data correlated well with the theoretical Manning's curve during storm flows. The data reflected groundwater inflow into the combined system at this location. No overflows occurred at this location during Phases 2–3. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

DUW111_DWF-057079 is a permanent meter and will continue to be screened in the future.

NPDES111G_MH057513

NPDES111G_MH057513 is a permanent monitoring site that records both level and velocity. Three sets of sensors are installed on 7/25/2007 at this location. The first sensor set measures the upstream flow, the second set measures the stormwater flow diverted by the low-flow diversion structure into the CSS, and the

third set measures the overflow volumes at the NPDES111(G) overflow weir. Overflows occur when the level in NPDES111G_MH057513 reaches 38.16 inches.

The site is not expected to provide repeatable and reliable dry weather flow data and is classified as a wet weather site. The site captured suitable data for all wet weather events. No overflow events occurred at this site during Phases 2–3. Depth data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

NPDES111G_MH057513 is a permanent meter and will continue to be screened in the future.

NPDES111H_MH057347

NPDES111H_MH057347 is a permanent monitoring site that records both level and velocity. The meter was installed on 8/7/2007 to measure the depth at the NPDES111(H) overflow weir and HydroBrake (CSO Facility 35) to calculate overflow volumes. Overflows occur when the level in NPDES111H_MH057347 reaches 145.2 inches.

Depth data from this site were also used to characterize the HydroBrake. The site is not expected to provide repeatable and reliable dry weather flow data and is classified as a wet weather site. The site captured suitable depth data throughout Phases 2–3. Depth data quality was classified as "Excellent" for Phases 2–3 and all data from Phases 2–3 are suitable for use in model calibration. The data were classified as "Good" for Phase 1.

NPDES111H_MH057347 is a permanent meter and will continue to be screened in the future.

3.4.3 Combined Sewer Overflows

ADS reported that 19 CSOs occurred in the Duwamish Basin during the monitoring period. Table 3-6 lists the CSOs that occurred during Phases 2–3. Overflows reported for NPDES111 during 10/17/2009 were reported as one overflow, not the three shown below.

Table 3-6. 2009–2010 Combined Sewer Overflows in Duwamish Basin

NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
111A	--	--	--
111B	9/6/2009	0:20	16,132
	10/17/2009	1:00	30,937
111C	10/17/2009	0:15	6,506
111D	--	--	--
111E	--	--	--
111F	--	--	--
111G	--	--	--
111H	10/17/2009	0:35	62,369
	10/26/2009	0:20	10,435

Table 3-6. 2009–2010 Combined Sewer Overflows in Duwamish Basin			
NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
107	10/14/2009	18:00	12,772
	10/16/2009	20:00	239,803
	10/26/2009	12:00	486,610
	11/6/2009	23:12	146,038
	11/16/2009	0:48	418,365
	11/19/2009	21:36	183,001
	11/22/2009	15:12	785,230
	11/26/2009	0:48	295,660
	1/4/2010	1:18	79,758
	1/8/2010	1:38	49,692
	1/11/2010	6:06	868,057
	1/13/2010	1:02	28,842
	1/15/2010	1:40	20,952
	4/21/2010	1:08	20,883

Figure 3-21 shows the maximum water level recorded by ADS at each of the overflow structures in the basin as a percentage of the weir height.

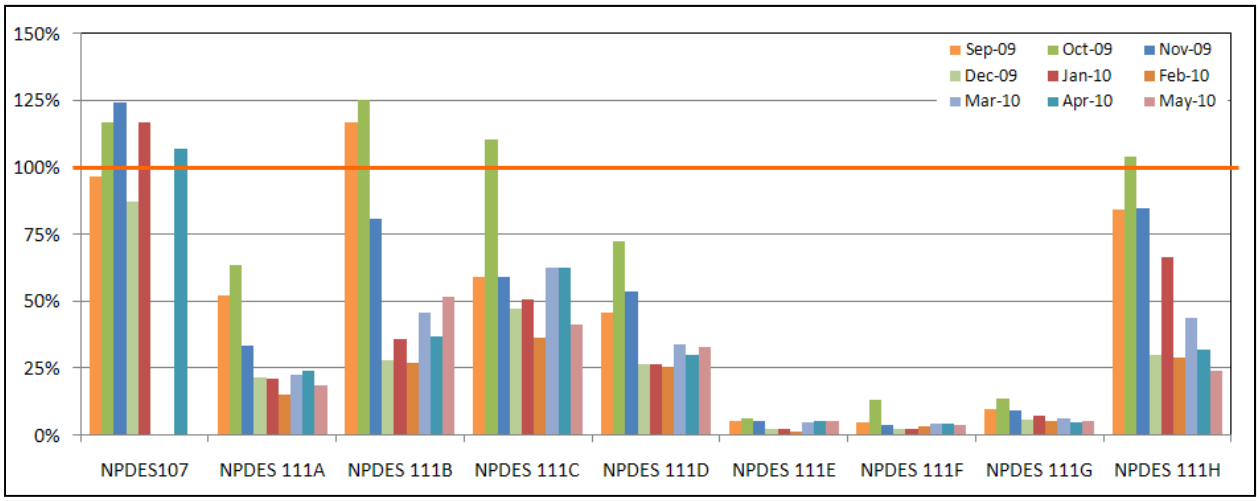

Figure 3-21. Maximum water level recorded in Duwamish Basin for major events

3.4.4 Facility Operations

The CSO facilities in the Duwamish Basin consist of the following:

- seven overflow weirs and two elevated overflow pipes as described in the sections above

- NPDES111(H), which includes CSO Facility 35: an in-line storage tank, HydroBrake, and overflow weir
- one pump station located in the Duwamish Basin; however, this is a King County pump station and was not monitored during this review period.

NPDES107

The overflow for NPDES107 is an elevated overflow pipe located on the east side of MH 056-097. Once the level in the storage pipe reaches a depth of 65.4 inches, flow is diverted into the elevated, 18-inch-diameter CSO outfall pipe which discharges to the Duwamish River.

NPDES111(A)

The overflow weir for NPDES111(A) is located on the west side of MH 056-195. Once the level in the storage pipe reaches a depth of 21.36 inches, flow is diverted into an overflow structure that discharges flow through a flap gate to the Duwamish/Diagonal storm drain.

NPDES111(B)

The overflow weir for the NPDES111(B) Basin is located on the north side of MH 056-270. Once the level in the storage pipe reaches a depth of 27.12 inches, flow is diverted into an overflow structure that discharges flow through a flap gate to the Duwamish/Diagonal storm drain.

NPDES111(C)

The overflow weir for the NPDES111(C) Basin is located on the east side of MH 056-365. Once the level in the storage pipe reaches a depth of 21.84 inches, flow is diverted into a CSO outfall pipe that discharges to the Duwamish/Diagonal storm drain.

NPDES111(D)

The overflow weir for the NPDES111(D) Basin is located on the west side of MH 057-253. Once the level in the storage pipe reaches a depth of 22.25 inches, flow is diverted into an overflow structure that discharges flow through a flap gate to the Duwamish/Diagonal storm drain.

NPDES111(E)

The overflow weir for the NPDES111(E) Basin is located through the center of MH 057-065. Once the level in the storage pipe reaches a depth of 23.88 inches, flow is diverted into a 16-inch-diameter CSO outfall pipe that discharges to the Duwamish/Diagonal storm drain.

NPDES111(F)

The overflow weir for the NPDES111(F) Basin is an elevated overflow pipe located on the north side of MH 057-079. Once the level in the storage pipe reaches a depth of 113.5 inches, flow is diverted into the elevated CSO outfall pipe that discharges to the Duwamish/Diagonal storm drain.

NPDES111(G)

The overflow weir for the NPDES111(G) Basin is located on the north side of MH 057-513. Once the level in the storage pipe reaches a depth of 38.16 inches, flow is diverted into two CSO outfall pipes, one 12-inch-diameter and one 8-inch-diameter. Both pipes discharge to the Duwamish/Diagonal storm drain.

NPDES111(H)

The overflow weir for the NPDES111(H) Basin is located on the northwest side of the MH 057-347. Once the level in the storage pipe reaches a depth of 176.8 inches, flow is diverted into a 30-inch-diameter CSO outfall pipe that discharges to the Duwamish/Diagonal storm drain.

Figure 3-22 below shows the HydroBrake curve based upon monitoring data at an upstream meter and a downstream meter with respect to the HydroBrake location. The level data at upstream meter 057-350 and downstream meter 057-229 were used to calculate the head at the HydroBrake. The level and flow data at downstream meter 057-229 were used to calculate the flow going through the HydroBrake. The HydroBrake manufacturer's curve was not available for this HydroBrake. Figure 3-22 shows January 2009 to May 2009 data (Phase 1 monitoring data), May 2009 data, and September 2009 through January 2010 data.

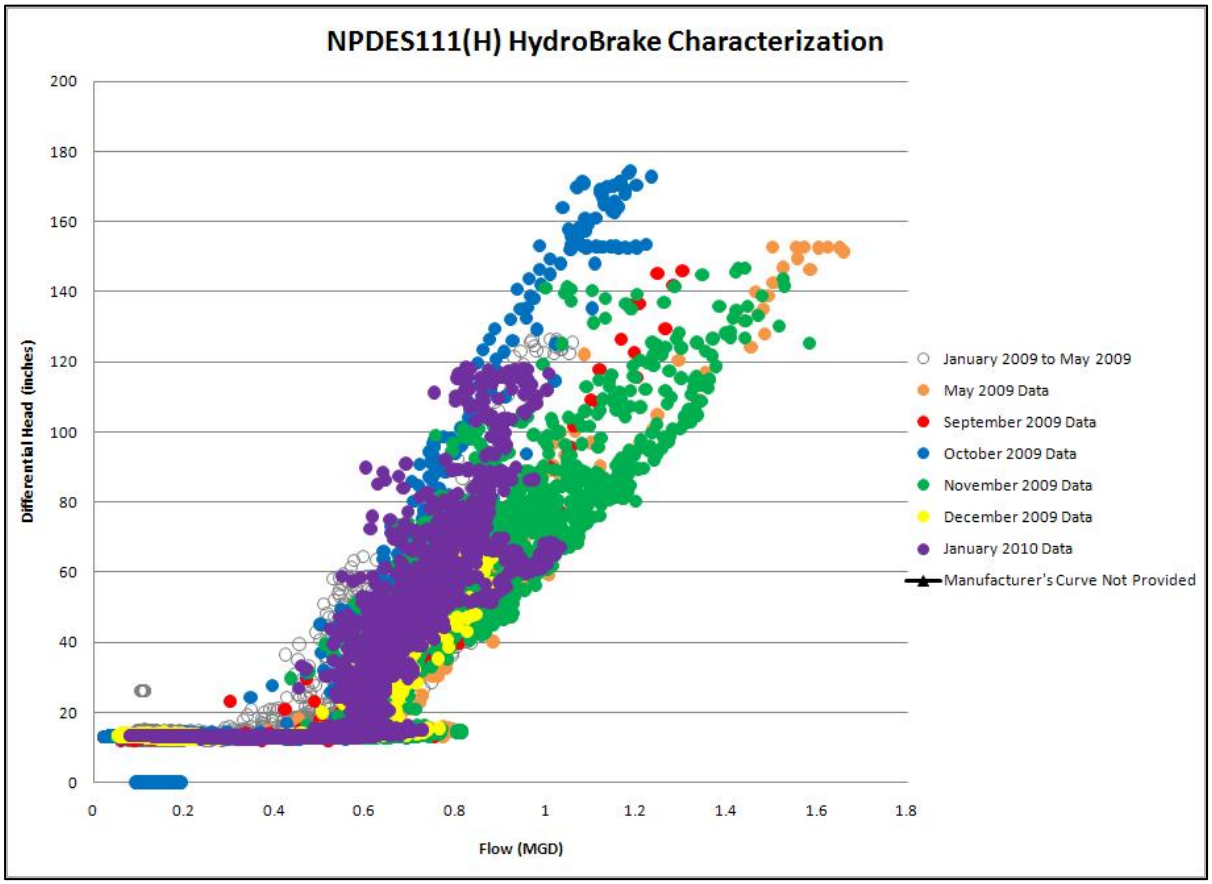

Figure 3-22. NPDES111(H) Basin HydroBrake characterization

The storage tank located at 057-348 is an in-line storage tank that works in conjunction with HydroBrake 057-350. When the HydroBrake causes sufficient backup during storm events, the tank fills.

During large wet weather events, the flow begins to fill the dual-tank system. Each tank is 64 feet long, 10.5 feet wide, and 12 feet deep. The storage was fully utilized during the two October 2009 overflow events as seen in Figure 3-23.

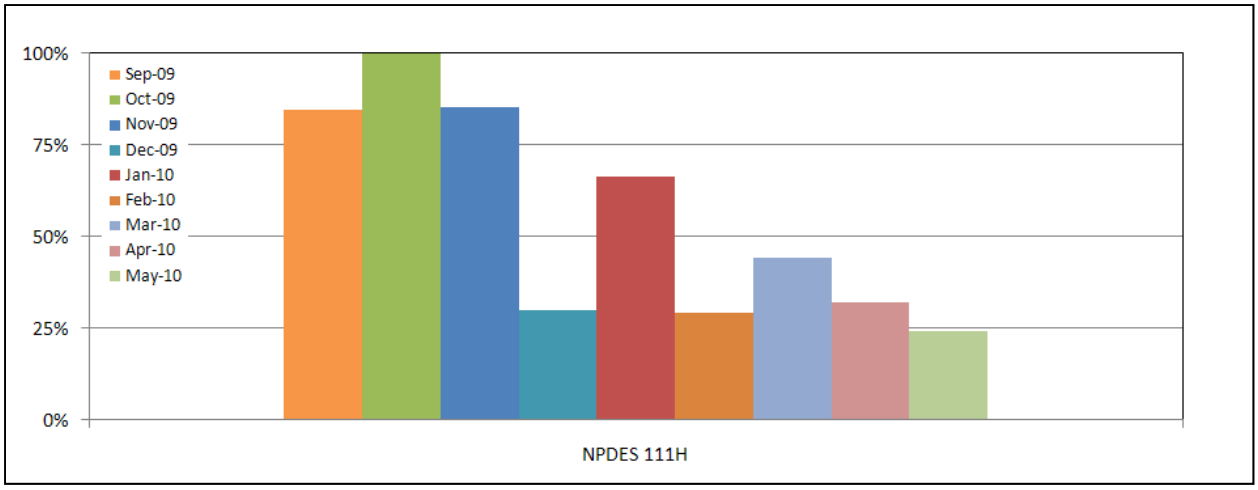

Figure 3-23. Duwamish Basin storage utilization

3.4.5 Recommendations for Additional Data Collection

At the conclusion of Phases 2–3, no additional data needed to be collected in the Duwamish Basin for the purposes of model calibration and development and all temporary meters were removed.

3.5 Fremont/Wallingford Basin

The Fremont/Wallingford Basin, which consists of the NPDES147, NPDES148, and NPDES174 Basins, is approximately 624 acres in area. The combined sewer flows from the NPDES147 Basin are broken up into two subcatchments: NPDES147(A) and NPDES147(B). Each subcatchment has its own overflow structure but the two share a common outfall. The NPDES147(A) Subcatchment is on the eastern side of the NPDES147 Basin, while the NPDES147(B) Subcatchment is on the western side. Flows from each subcatchment proceed from north to south by gravity to their respective overflow structures, then into the King County system. The NPDES148 Basin is a small 33-acre basin that flows into the NPDES174 Basin through PS 54. All monitoring sites in the NPDES148 Basin are discussed in Section 3.5.2 with sites from the NPDES174 Basin. The flow from the western and eastern parts of the NPDES174 Basin combines just north of the NPDES174 Overflow Structure, and flow into the King County system.

RG 09, located in the Woodland Park Zoo in the northern part of the NPDES174 Basin, monitors rainfall in the entire Fremont/Wallingford Basin.

ADS maintains three permanent monitoring sites at overflow structures within the Fremont/Wallingford Basin. Stantec maintained 15 temporary monitoring sites to monitor combined sewage flow during the Phases 2–3 monitoring period. At the end of Phase 3 one temporary flow meter and the three permanent monitoring sites remained in place.

Detailed information on the Fremont/Wallingford Basin can be found in Appendix F; a basin schematic is in Appendix B.

3.5.1 NPDES147 Basin

The NPDES147 Basin, the eastern basin in Fremont/Wallingford, is approximately 295 acres in area. The basin is located on the northern shore of the Lake Washington Ship Canal, west of Lake Union. The CSS control facilities in the NPDES147 Basin do not contain any storage or HydroBrakes.

The NPDES147 Basin has two permanent monitoring sites to verify overflows from the NPDES147(A) NPDES147(B) Overflow Structures. During the Phases 2–3 monitoring period seven temporary monitoring sites were located in the NPDES147 Basin. Following the end of Phase 3, one temporary monitoring site and all permanent monitoring sites remained in place.

FRE147B_022-118A

FRE147B_022-118A was a temporary hydrology monitoring site that recorded both level and velocity. The site was installed on 9/22/2008 to measure flow from the western part of the NPDES147(B) Subcatchment.

FRE147B_022-118A was located in the same maintenance hole as FRE147B_022-118B; FRE147B_022-118A was located in the pipe that enters the maintenance hole from the west. The data at the site captured a consistent dry weather pattern. During storm events, the velocity and level data responded consistently and no surcharged conditions occurred. The data quality was classified as "Good" for Phases 2–3 because the early morning low dry weather flows were overestimated due to water pooling in front of the velocity sensor, behavior that corresponds with data collected during Phase 1. All data from Phases 2–3, except early morning dry weather flows, are suitable for use in model calibration.

The site was removed on 2/23/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

FRE147B_022-118B

FRE147B_022-118B was a temporary hydrology monitoring site that recorded both level and velocity. The site was installed on 9/22/2008 to measure flow from the western part of the NPDES147(B) Subcatchment.

FRE147B_022-118B was located in the same maintenance hole as FRE147B_022-118A; FRE147B_022-118B is located in the pipe that enters the maintenance hole from the north. The data at the site captured a dry weather pattern that showed a fair amount of scatter and required frequent maintenance. During storm events, the velocity and level data responded consistently and no surcharged conditions occurred. The data quality was classified as "Good" for Phases 2–3 because the early morning low dry weather flows were overestimated due to water pooling in front of the velocity sensor, behavior that corresponds with data collected during Phase 1. All data from Phases 2–3, except early morning dry weather flows, are suitable for use in model calibration.

The site was removed on 2/23/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

FRE147_D022-146A

FRE147_D022-146A was a temporary hydrology monitoring site that recorded level and velocity. The site was installed on 9/2/2009 in the NPDES147 Basin stormwater system that discharges into Lake Union to the west of the NPDES CSO Outfall 147. This site will not be used in modeling of the CSO system. It was installed to provide an estimate of relative storm system flow, and to allow future modeling if required.

The data at FRE147_D022-146A did not capture a dry weather pattern because it was installed in the stormwater system. However, data collected during dry periods indicated a consistent flow in the stormwater system. The source(s) of the constant flow in the stormwater system is not known, and was not investigated as part of this project. The site captured a consistent pattern during storm events. The quality of the data was classified as "Excellent" for Phases 2–3. This site was not installed during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 2/4/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

FRE147B_022-152A

FRE147B_022-152A was a temporary hydrology monitoring site that recorded both level and velocity. The site was installed on 10/15/2008, and measured flow to characterize hydrology in the north part of the NPDES147(B) Subcatchment.

FRE147B_022-152A was located in the north-central portion of the NPDES147(B) Subcatchment from the NPDES147(B) Overflow Structure. The data at the site captured a consistent dry weather pattern. During storm events, the velocity and level data responded consistently and no surcharged conditions occurred. However, examination of spikes in the flow data by Stantec in data finalization indicated that the highest peak flows and velocity may be overestimated. At the end of October 2009, debris appeared to have accumulated on the sensor or immediately downstream, creating an unrepresentatively high flow depth and very low velocity. Additionally, there was a data gap from 11/23/2009 to 11/30/2009 during an important wet weather event. The data quality was therefore classified as "Some Limitations" for Phases 2–3. This classification matches the quality classification of the data collected during Phase 1 monitoring. All data, excluding flow spikes and data collected at the end of October and November 2009, are suitable for use in model calibration.

The site was removed on 2/23/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

FRE147_DWF-022160

FRE147_DWF-022160 is a permanent monitoring site that records both level and velocity at the NPDES147(B) Overflow Structure. The site, which was installed on 7/24/2007, has two monitors: MP1, located in the incoming 21-inch-diameter pipe, and MP2, located in the overflow line. The NPDES147(B) Subcatchment overflows when the depth at MP1 reaches 14.25 inches. Data from MP2 are used to compute CSO volumes and to alarm CSO events. MP1 is classified as a dry weather site, and is expected to provide high-quality level and velocity data. MP2 is classified as a wet weather site, and is not expected to provide high-quality level and velocity data, except when the level at MP1 exceeds 14.16 inches.

The monitoring site is located upstream of the King County system. The data at the site captured a consistent dry weather pattern at MP1. During storm events, the level data responded well and no surcharged conditions occurred. The data quality at MP1 was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All MP1 data from Phases 2–3 are suitable for use in model calibration. MP2 data from Phases 2–3 may not be suitable for use in model calibration due to stormwater entering the maintenance hole above the sensor and a difficult site configuration.

This monitoring site is a permanent site and will continue to be screened in the future.

FRE147B_022-174A

FRE147B_022-174A was a temporary monitoring site that recorded both level and velocity. The site was installed on 11/5/2008, and measured flow entering the King County interceptor from the west and southwest parts of the NPDES147(B) Subcatchment. The site was originally installed to measure flows that enter the King County interceptor that pass by the NPDES147(B) Overflow Structure, but it was found that only depth data were reliable at this site.

FRE147B_022-174A was located downstream of the NPDES147(B) Overflow Structure in a large pipe with a mild slope (0.22 percent), and thus was susceptible to siltation. The data at the site captured a dry weather pattern that showed significant scatter due to the siltation. During storm events, the velocity data frequently dropped out due to siltation. Level data responded consistently and indicated surcharged conditions. The quality of the level data was classified as "Good" for Phases 2–3 due to hydraulic shifting caused by siltation, which matches the quality classification of the data collected during Phase 1 monitoring. The level data provide a boundary condition for the model, reflecting the influence of the King County north interceptor, and are more important than velocity at this location. All level data from Phases 2–3 are suitable for use in model calibration. Velocity data from Phases 2–3 are not suitable for use in model calibration.

The site was removed on 3/19/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

FRE147_DWF-022187

FRE147_DWF-022187 is a permanent monitoring site that records both level and velocity at the NPDES147(A) Overflow Structure. The site, which was installed on 7/25/2007 upstream of the King County system, has two monitors: MP1, located in the incoming 30-inch-diameter pipe, and MP2, located in the overflow line. The NPDES147(A) Subcatchment overflows when the depth at MP1 reaches 14.0 inches. Data from MP2 are used to compute CSO volumes and to alarm CSO events. MP1 is classified as a dry weather site, and is expected to provide high-quality level and velocity data. MP2 is classified as a wet weather site, and is not expected to provide high-quality level and velocity data, except when the level at MP1 exceeds 14.5 inches.

Flow balancing was undertaken using the data from this permanent monitoring site during Phases 2–3. The total flow from two upstream temporary monitoring sites (FRE147A_022-306 and FRE147A_022-318) was compared to the downstream flow at FRE147_DWF-022187. The flow balance indicated that the calculated

flows from this permanent monitoring site were overestimated from 9/30/2009 through the end of Phase 3. Toward the end of Phase 3 it was determined that the incorrect flow data had been loaded into ZFM for FRE147_DWF-022187, which was being used to complete the flow balance. The correct data from FRE147_DWF-022187 was not overestimated.

The data at the site captured a consistent dry weather pattern. During storm events, the level data responded consistently and indicated frequent overflows. The data quality at MP1 was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data from Phases 2–3 are suitable for use in model calibration. MP2 data may not be suitable for use in model calibration, and should be used only to verify overflows.

This monitoring site is a permanent site and will continue to be screened in the future.

SPU_022-188A

SPU_022-188A was a temporary hydraulic monitoring site that recorded level only. The site was installed on 2/9/2009 to measure level downstream from the check valve that prevents backflow from the King County interceptor near the NPDES147(A) Overflow Structure.

SPU_022-188A was located downstream of the NPDES147(A) Overflow Structure. The data at the site captured a consistent dry weather pattern. During storm events, the level data responded consistently and frequently indicated surcharged conditions. The data quality was classified as "Excellent" for Phases 2–3, which is consistent with data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 4/2/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

FRE147A_022-306A

FRE147A_022-306A was a temporary hydrology monitoring site that recorded both level and velocity. The site was installed on 9/12/2008 to estimate flow from the western part of the NPDES147(A) Subcatchment.

FRE147A_022-306A was located upstream in the basin. The data at the site captured a consistent dry weather pattern. During storm events, the velocity and level data responded consistently and no surcharged conditions occurred. The data quality was classified as "Excellent" for Phases 2–3. The data gaps that were seen during Phase 1 monitoring, resulting in a data quality classification of "Good," were no longer seen in Phases 2–3. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 2/26/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

FRE147A_022-318A

FRE147A_022-318A was a temporary hydrology monitoring site that recorded both level and velocity. The site was installed on 10/1/2008 to estimate flow from the eastern part of the NPDES147(A) Subcatchment.

FRE147A_022-318A was located upstream in the basin. Pooling behind the velocity meter at night caused two flow regimes during dry weather. During storm events, the velocity and level data responded consistently and no surcharged conditions occurred. As shown in Figure 3-24, depth data collected between 12/11/2009 and 12/30/2009 showed unusual readings, which were eliminated following a meter replacement. During the calibration process it was determined that this monitoring site, in a very steep sewer, did not accurately report peak flows when compared with FRE147_DWF-022187. Because of these unusual and inaccurate readings during wet weather and pooling during low flows, the data quality was classified as "Poor" for Phases 2–3.

The rating of "Poor" is different from the "Excellent" data quality classification in Phase 1, which did not indicate unusual readings. None of the data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 2/4/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

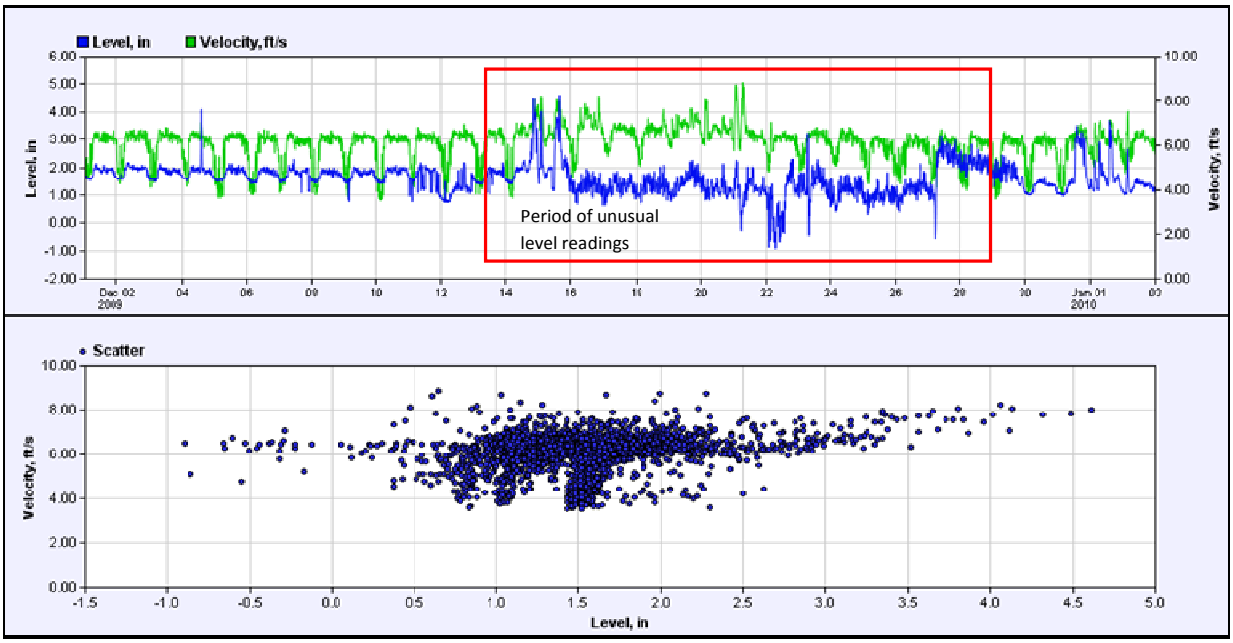

Figure 3-24. FRE147A_022-318A velocity and level hydrograph and scattergraph

FRE147A_022-187A

FRE147A_022-187A was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/20/2009 to evaluate the hydraulics around the flap gate between the NPDES147(A) Overflow Structure and the King County interceptor.

FRE147A_022-187A was located in the same maintenance hole as the permanent meter; however, FRE147A_022-187A was located in the dry weather pipe that leaves the maintenance hole to the southwest. The velocity sensor was installed in the downstream direction and therefore reported velocity as negative when flow moved toward the King County interceptor. The meters were intended to be installed to record bidirectional flow, which would provide positive velocity data if flow was backing up from the King County interceptor. The meter, however, was set to record only unidirectional for most of the Phase 3 monitoring period. Occurrences of negative differential head across the flap gate (level downstream of the flap gate higher than that in the overflow structure) occurred frequently during the monitoring period. This would suggest either flow passing from the King County interceptor to the overflow structure or at least zero flow toward the interceptor if the flap gate closed tightly. However, the meter data reported flow moving toward the interceptor during these periods. The data recorded when there was a positive head differential across the flap gate (level in overflow structure higher than that at the outlet of the flap gate) are considered suitable for model calibration. Data during negative differential head in October 2009 indicated flow from the interceptor toward the overflow structure and are suitable for model calibration. Data during negative differential head conditions that indicate flow toward the interceptor from the overflow structure are not considered reliable. Because of these observations, the data are classified as "Some Limitations."

After Phase 3 completion, the site remained in place to confirm backflow through the flap gate.

3.5.2 NPDES174 Basin

The NPDES174 Basin is the western basin in Fremont/Wallingford. Located on the northern shore of the Lake Washington Ship Canal and west of Lake Union, the basin is approximately 329 acres in area. The NPDES148 Basin, which is approximately 33 acres in area, flows into the NPDES174 Basin via PS 54. The CSS control facilities in the NPDES174 Basin do not contain any storage or HydroBrakes. Overflows in the NPDES148 Basin are monitored by the SCADA system recording of wet well level at PS 54. The NPDES148 Basin is considered to be controlled.

The NPDES174 Basin has one permanent monitoring site to verify overflows from the NPDES174 Overflow Structure. During Phases 2–3 eight temporary monitoring locations were installed in the NPDES174 Basin. Following the end of Phase 3, all temporary flow meters were removed, but the permanent monitoring site remained in place.

FRE174_013-115A

FRE174_013-115A was a temporary hydrology monitoring site that recorded both level and velocity. The site, which was installed on 9/11/2008, measured flow from the Woodland Park Zoo in the northern part of the NPDES174 Basin.

The monitoring site was upstream in the NPDES174 Basin near the Woodland Park Zoo. The flow from the Woodland Park Zoo typically adds a twice-daily industrial discharge (cleaning or tank water from the zoo is suspected). The timing and magnitude of the discharges are variable, as seen in Figure 3-25 below. These discharges exceed the wet weather response of the tributary area except in the most intense storm events. The flows from the zoo will require special handling in modeling the wet and dry weather flow, and data collected at this site will be used to develop an upstream boundary condition for the NPDES174 Basin. The data at the site captured a consistent dry weather pattern, with the exception of the timing and volume of the industrial discharge. During storm events, the level data responded well and no surcharging occurred. However, due to the variable timing and magnitude of the discharge, the data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 2/26/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

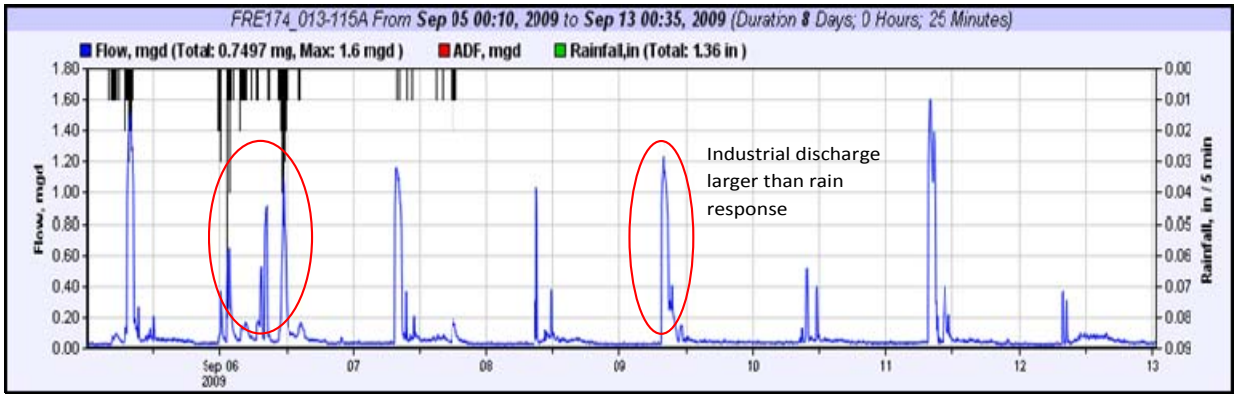

Figure 3-25. FRE174_013-115A flow hydrograph with Woodland Park Zoo industrial discharge

FRE174_021-044A

FRE174_021-044A was a temporary hydrology monitoring site that recorded both level and velocity. The site was installed on 9/19/2008, and measured flow from the northwest part of the NPDES174 Basin.

FRE174_021-044A was located downstream of PS 54. The data at the site captured a consistent dry weather pattern that was dominated by the influence of the pump station upstream. During storm events, the data responded consistently and no surcharging occurred. During Phase 3 it was determined that the velocity data were being over-predicted by up to 10 percent. Because of this, the data quality was classified as "Some Limitations" for Phases 2–3. Velocity data were likely over-predicted during Phase 1 monitoring as well, rendering the data classification of "Excellent" as inaccurate. All velocity data from Phases 1, 2, and 3 should be used with caution. Level data for all three phases are suitable for use in model calibration.

The site was removed on 2/23/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

FRE174_021-045B

FRE174_021-045B was a temporary hydrology monitoring site that recorded both level and velocity. The site was installed on 9/18/2008, and measured flow from the northwestern part of the NPDES174 Basin.

FRE174_021-045B was located in the northeast pipe that enters MH 021-045. The data at the site captured a dry weather pattern that oscillated between two signatures, as seen in Figure 3-26, due to pooling behind the meter at low flows. During storm events, the data responded consistently and no surcharging occurred. The data quality was classified as "Some Limitations" for Phases 2–3 because of the wide scatter and inconsistent signature at low flows, which matches the quality classification of the data collected during Phase 1 monitoring. All data from Phases 2–3 during storm events with depths above 3.5 inches are suitable for use in model calibration.

The site was removed on 2/1/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

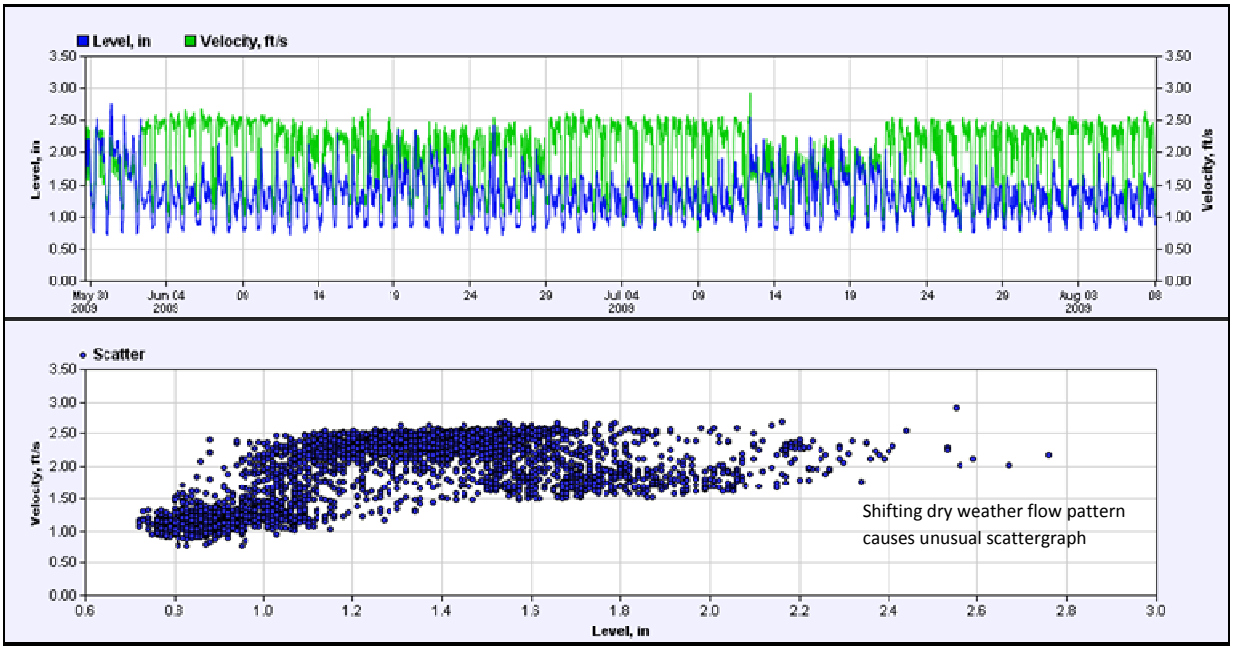

Figure 3-26. FRE174_021-045B dry weather flow hydrograph

FRE174_021-050A

FRE174_021-050A was a temporary hydrology monitoring site that recorded both level and velocity. The site was installed on 9/11/2008, and measured flow from the western part of the NPDES174 Basin.

FRE174_021-050A was downstream from PS 54, FRE174_021-044A, and FRE174_021-045B, and upstream from the NPDES174 Overflow Structure. The data at the site captured a dry weather pattern that saw occasional scatter and the influence of the upstream pump station. During storm events, the data responded consistently and no surcharging occurred. The data quality was classified as "Good" for Phases 2–3 due to the difficulties with capturing a consistent dry weather flow pattern, which matches the quality classification of the data collected during Phase 1 monitoring. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 2/23/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

FRE174_DWF-021052

FRE174_DWF-021052 is a permanent monitoring site that records both level and velocity. The site, which was installed on 7/25/2007, has two monitors: MP1, located in the incoming 48-inch-diameter pipe, and MP2, located in the overflow line. The NPDES174 Basin overflows when the depth at MP1 reaches 15.72 inches. Data from MP2 are used to compute CSO volumes and to alarm CSO events. MP1 is classified as a dry weather site, and is not expected to provide high-quality level and velocity data. MP2 is classified as a wet weather site, and is not expected to provide high-quality level and velocity data, except when the level at MP1 exceeds 15.72 inches.

The monitoring site is located upstream of the King County system. The data at the site showed the influence of the upstream industrial discharge from the zoo, as well as flow from the upstream PS 54. The data at the site captured a consistent dry weather pattern. During storm events, the data responded consistently and indicated occasional overflows. The data quality at MP1 was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All MP1 data from Phases 2–3 are suitable for use in model calibration. MP2 data may not be suitable for use in model calibration, and should be used only to verify overflows.

This monitoring site is a permanent site and will continue to be screened in the future.

KC_021-056B

KC_021-056B was a temporary monitoring site that recorded level only. The site was installed on 3/6/2009 to determine the hydraulic impact of the King County interceptor levels on NPDES174 Basin overflows. The level data recorded will be used as the downstream boundary condition for the NPDES174 Basin model.

KC_021-056B was located in the King County north interceptor immediately downstream from the connection from the NPDES174 Basin. The data at the site captured a consistent dry weather pattern. During storm events, the level data responded consistently and indicated frequent surcharged conditions. The site had several extended data gaps during late September and early October; however, the data gaps did not occur during critical wet weather events. Because of this, the data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 3/18/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

FRE174_021-066A

FRE174_021-066A was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/1/2008, and measured flow from the northeast part of the NPDES174 Basin.

FRE174_021-066A was downstream from sites FRE_013-115A and FRE_022-039A; therefore, it measured flows farther downstream from Woodland Park Zoo. The data showed the same industrial discharge from the zoo, as shown in Figure 3-27. The data at the site captured a dry weather pattern that showed significant scatter due to the industrial discharge. During storm events, the level data responded well and no surcharging occurred. The data quality was classified as "Good" for Phases 2–3 due to the wide scatter at low flows associated with the industrial discharge, which matches the quality classification of the data collected during Phase 1 monitoring. The upstream industrial discharge flow data will be used as an upstream boundary condition for calibration. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 2/4/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

Figure 3-27. FRE174_021-066A flow hydrograph with Woodland Park Zoo industrial discharge

FRE174_D021-083A

FRE174_D021-083A was a temporary hydrology monitoring site that recorded level and velocity. The site was installed on 10/6/2009 in the NPDES174 Basin stormwater system that discharges into Lake Union to the west of the NPDES CSO Outfall 174. This site will not be used in modeling of the CSO system; it was installed to provide an estimate of relative storm system flow, and to allow future modeling if required.

The data at FRE174_D021-083A did not capture a dry weather pattern because it was installed in the stormwater system. The site captured a consistent pattern during storm events. The quality of the data was classified as "Excellent" for Phase 3. This site was not installed during Phases 1 or 2. All data from Phase 3 are suitable for use in model calibration.

The site was removed on 2/23/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration

FRE174_022-039A

FRE174_022-039A was a temporary hydrology monitoring site that recorded both level and velocity. The site was installed on 11/11/2008, and measures flow from the northeastern part of the NPDES174 Basin.

The monitoring site was downstream from site FRE174_013-115A. The data exhibit the same industrial discharge from the zoo as the upstream site, as shown in Figure 3-28. The data at the site captured a

consistent dry weather pattern, with the exception of the timing and volume of the industrial discharge and possible pooling of water in front of the velocity meter at low flows. During storm events the site experienced rough flow conditions, causing an underestimation of velocity readings based on flow balances with data from surrounding meters. Because of this, the data quality was classified as "Some Limitations" for Phases 2–3. The data should be used with caution in model calibration.

The site was removed on 2/4/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

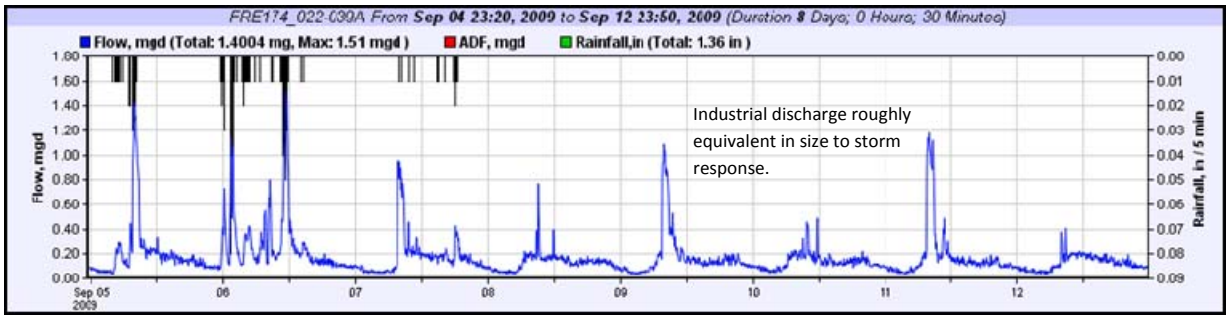

Figure 3-28. FRE174_022-039A flow hydrograph with Woodland Park Zoo industrial discharge

FRE174_022-043A

FRE174_022-043A was a temporary hydrology monitoring site that recorded both level and velocity. The site was installed on 9/29/2008, and measured flow from the middle part of the NPDES174 Basin.

FRE174_022-043A was located in the Fremont/Wallingford Basin, upstream of FRE174_012-066. The data at the site captured a dry weather pattern that indicated occasional hydraulic shifting caused by sediment, as well as pooling behind the velocity meter during low flows. During storm events, the level data responded well and no surcharged conditions occurred. Because of this and a variable diurnal pattern, the data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All wet weather data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 2/26/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

3.5.3 Combined Sewer Overflows

Table 3-7 shows overflows reported by ADS at each of the Fremont/Wallingford overflow points during Phases 2–3. The NPDES147(A) Subcatchment overflowed 49 times during Phases 2–3, while the NPDES147(B) Subcatchment overflowed 5 times. When overflows occurred at both NPDES147(A) and NPDES147(B) in response to the same storm event (e.g., on 11/22/2009, 11/26/2009, and 1/15/2010), a single overflow was reported. The NPDES174 Basin overflowed 18 times.

All three overflow points are affected by the flow levels in the King County north interceptor. In particular, the NPDES174 Basin was observed to overflow only when the interceptor level was above the weir level, closing the check valve to prevent backflow from the interceptor to the weir. Examination of the hydraulic conditions at the NPDES147(A) Subcatchment has shown that a hydraulic jump occurs upstream from the check valve, which prevents backflow from the interceptor. The hydraulic jump induced by the hydraulic restriction of the check valve results in overflows at this location during most storm events.

Figure 3-29 shows the maximum water level recorded at each of the overflow structures in the Fremont/Wallingford Basin as a percentage of the weir height.

Table 3-7. 2009–2010 Combined Sewer Overflows in Fremont/Wallingford Basin 6/1/2009 through 6/1/2010			
NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
147(A)	8/11/2009	0:10	1,858
	8/13/2009	0:50	210,486
	9/5/2009	29:06	728,139
	9/7/2009	0:40	34,667
	9/19/2009	2:30	151,646
	9/29/2009	0:45	74,885
	10/2/2009	0:11	9,740
	10/13/2009	17:00	480,378
	10/16/2009	32:00	1,800,000
	10/26/2009	5:34	696,278
	10/30/2009	0:42	124,094
	11/5/2009	49:27	1,686,163
	11/9/2009	2:46	27,234
	11/10/2009	2:07	136,188
	11/13/2009	1:58	15,352
	11/16/2009	75:57	1,724,728
	11/21/2009	16:26	2,331,179
	11/26/2009 [a]	15:16	2,338,437
	12/4/2009	0:09	1,001
	12/14/2009	49:00	296,672
	12/21/2009	7:30	413,688
	1/1/2010	1:25	4,913
	1/4/2010	6:45	377,174
	1/82010	25:07	1,232,794
	1/11/2010	107:07	3,946,578
	1/17/2010	0:28	28,297
	1/24/2010	3:42	88,061
	2/3/2010	10:57	48,322
	2/11/2010	36:28	98,693
	2/13/2010	19:17	214,660
	2/16/2010	4:42	54,647
	2/25/2010	0:07	924
	2/26/2010	0:53	9,728
	3/12/2010	5:24	167,517
	3/28/2010	42:39	421,100
	4/2/2010	3:05	181,933
	4/4/2010	0:22	22,765

Table 3-7. 2009–2010 Combined Sewer Overflows in Fremont/Wallingford Basin 6/1/2009 through 6/1/2010			
NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
147(A)	4/8/2010	1:05	113,467
	4/17/2010	1:22	145,961
	4/21/2010	6:35	481,692
	4/26/2010	13:54	6,606
	5/4/2010	0:40	107,896
	5/10/2010	0:32	58,392
	5/18/2010	0:11	51,156
	5/19/2010	1:58	149,523
	5/21/2010	33:10	208,619
	5/25/2010	13:58	26,682
	5/28/2010	0:05	1,440
	5/31/2010	1:11	80,407
147(B)	10/16/2009	0:35	131,969
	11/22/2009	0:18	1.758
	11/26/2009	0:52	18,729
	1/11/2010	1:08	4,076
	1/15/2010	0:12	757
174	9/6/2009	1:50	57,420
	10/14/2009	0:40	16,375
	10/17/2009	21:05	652,267
	10/26/2009	3:20	432,229
	11/7/2009	0:37	20,341
	11/16/2009	15:10	378,042
	11/19/2009	1:21	103,053
	11/22/2009	12:10	735,415
	11/26/2009	12:42	1,162,565
	12/21/2009	0:47	26,621
	1/4/2010	1:56	95,964
	1/8/2010	4:48	511,722
	1/11/2010	23:56	1,016,125
	1/13/2010	2:39	212,119
	1/15/2010	5:49	722,415
	4/17/2010	0:07	2,743
	4/21/2010	1:51	171,221
	5/21/2010	0:12	342

a. *The level on the outfall side of the overflow weir at NPDES147(A) was above the weir elevation, indicating a submerged flow condition over the weir.*

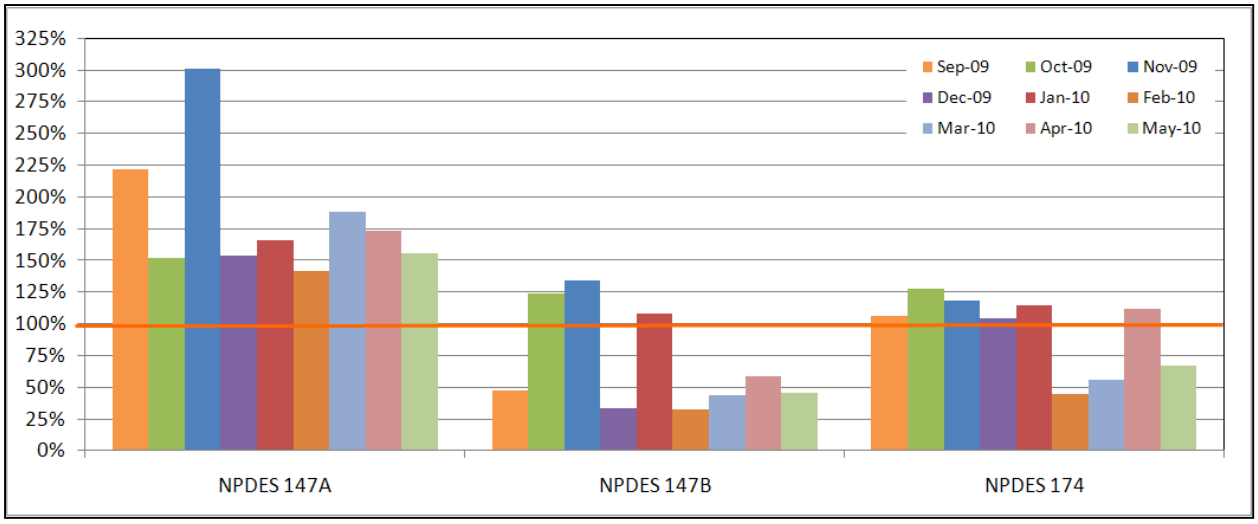

Figure 3-29. Maximum recorded levels in the Fremont/Wallingford Basin compared to weir heights for major events

3.5.4 Facility Operations

The CSS control facilities in the Fremont/Wallingford Basin consist of the three overflow weirs for each subcatchment. There are no HydroBrakes or storage structures. One pump station (PS 54) is located in the NPDES148 Basin.

NPDES147(A)

The overflow for NPDES147(A) is located on the southeast side of MH 022-187. Once the level in the pipe reaches a depth of 14.0 inches, flow is diverted into the CSO overflow pipe.

The NPDES147(A) Subcatchment contains a flap gate downstream of MH 022-187 to prevent backflow from the King County interceptor downstream, which has been known to create a hydraulic jump in the pipe.

NPDES147(B)

The overflow for NPDES147(B) is located on the southeast side of MH 022-160. Once the level in the pipe reaches a depth of 14.25 inches, flow is diverted into the CSO overflow pipe. Overflows at this site are affected by the flap gate downstream at the junction with the King County interceptor.

NPDES174

The overflow for NPDES174 is located on the west side of MH 021-052. Once the level in the pipe reaches a depth of 15.72 inches, flow is diverted into the CSO overflow pipe. Overflows at this site are affected by the flap gate downstream at the junction with the King County interceptor.

Pump Station 54

SPU monitors PS 54 via its SCADA system, recording wet well level and pump run times. The SCADA data will be used in model calibration to determine pump switch on and off levels and used in conjunction with drawdown test results to calculate the pump station flow rate.

Data collected during Phase 1 monitoring include the pump on-off states and the wet well depth. These data were plotted versus time. Review consisted of observing the normal rise and fall of wet well elevations with time during wet and dry weather. A change in signature was noted in May 2009 as well as September 2009.

The change could not be explained by maintenance or operational changes. Data from Phases 2–3 after October 2009 are considered suitable for use in model calibration.

3.5.5 Recommendations for Additional Data Collection

At the conclusion of Phase 2–3 monitoring, no further hydrology data are needed but hydraulics in the NPDES147(A) Subcatchment need to be confirmed. All temporary sites but one have been removed. The remaining site, FRE147A_022-187A, will remain to confirm backflow through the flap gate in NPDES147(A).

3.6 Interbay Basin

The Interbay Basin, located between Magnolia and Queen Anne, is approximately 287 acres in area. It consists of the NPDES068 Basin, which is divided into two subcatchments, NPDES068(A) in the north and NPDES068(B) in the south. These two subcatchments have separate overflow structures, but both overflow into the drainage system and share a common outfall, numbered NPDES068.

It is important to note that between the publishing of the 2001 CSO Reduction Plan and the LTCP Flow Monitoring Data Reports, documents regarding the Interbay Basin switched the (A) and (B) designation of the NPDES068(A) and NPDES068(B) Subcatchments, including the FO&M Blue Book. Uncontrolled CSO Basin Modeling Plans were written within this period. For consistency, the designation in this report will be as specified in the 2001 CSO Reduction Plan and as illustrated in the Interbay Basin schematic found in Appendix B. SPU will be making revisions to the next edition of the CSO Map Book.

The combined sewage in the NPDES068(A) Subcatchment flows from the north and a portion of the northeast part of the basin into the NPDES068(A) Overflow Facility 33A. The combined sewage from the NPDES068(B) Subcatchment flows from the southeastern and a portion of the northeastern part of the basin into the NPDES068(B) Overflow Facility 33B. The low flows from each overflow structure combine and proceed north, joining the King County north interceptor. Overflows from NPDES068(A) and NPDES068(B) are collected in the drainage system and discharge through a 96-inch-diameter pipe south into Elliot Bay.

RG 11, located in Myrtle Edwards Park, and RG 12, located at the Catherine Blaine K–8 School campus, monitor rainfall in the Interbay Basin. It was determined that the flow data in Interbay is better represented by RG 12.

Combined sewage was monitored at two permanent stations, located at each of the overflow facilities, and at 10 temporary monitoring locations. Only one temporary monitoring location was located in the NPDES068 Basin during Phase 1 monitoring. Most of the meters in the Interbay Basin remained installed at the end of Phase 3 but no additional information was required for model calibration, GSI, or retrofit purposes and all meters were recommended for removal.

Detailed information on Interbay monitoring locations can be found in Appendix G; a basin schematic is contained within Appendix B.

3.6.1 NPDES068(A) Subcatchment (North End of NPDES068)

The combined sewage from the NPDES068(A) Subcatchment flows into the NPDES068(A) Overflow Facility 33(A), which consists of an elevated pipe that receives only the overflows, a HydroBrake, and an offline 144-inch-diamater, 356-foot-long storage pipe. When the water level reaches the height of the elevated overflow line, excess flow is diverted to the storm drain system via a 24-inch overflow pipe.

INT68_021-364A

INT68_021-364A was a temporary monitoring site that recorded both level and velocity. The site was monitored using an ISCO 2150 meter installed on 2/8/2010 to monitor the flows entering the NPDES068(A) Subcatchment from the northeast.

INT68_021-364A is located upstream from the NPDES068(A) Overflow Structure. The data at this site captured a consistent dry weather flow pattern yet the scattergraph has less resolution at levels below 2 inches. The meter responded well to storm events. The data quality was classified as "Good" for Phase 3. All data for Phase 3 are suitable for model calibration.

The meter has met the project expectations and will be removed after the conclusion of Phase 3.

INT68_021-364B

INT68_021-364B is a temporary monitoring site that recorded level only. The site was monitored using an ISCO 2150 meter with the velocity sensor turned off and was placed offset in the pipe. It was installed on 2/8/2010 to verify the level readings at INT68_021-364A.

INT68_021-364B is located in MH 021-364, along with INT68_021-364A. During the May data review workshop it was decided that the level readings recorded by INT68_021-364A were reliable and that the meter was producing "Good" data. The level readings collected by INT68_021-364B were adjusted to match the level reading of meter INT68_021-364A. Therefore, the data quality for INT68_021-364B was classified as "Some Limitations" for Phase 3. Data should be used with caution during model calibration, according to screening notes.

The meter has met the project expectations and will be removed after the conclusion of Phase 3.

INT68_028-010A

INT68_028-010A was a temporary monitoring site that recorded both level and velocity. The site was installed on 11/16/2009 to monitor the flows entering the NPDES068(A) Subcatchment from the east part of the Basin and characterize its hydrology.

INT68_028-010A was located upstream from the NPDES068(A) Overflow Structure. The flow was fast and shallow, creating extremely difficult conditions for the velocity sensor to capture accurate readings (Figure 3-30). The meter was moved upstream to MH 028-517 to capture adequate data for the same purposes. The data quality was classified as "Poor" for Phase 3. Data are not suitable for model calibration.

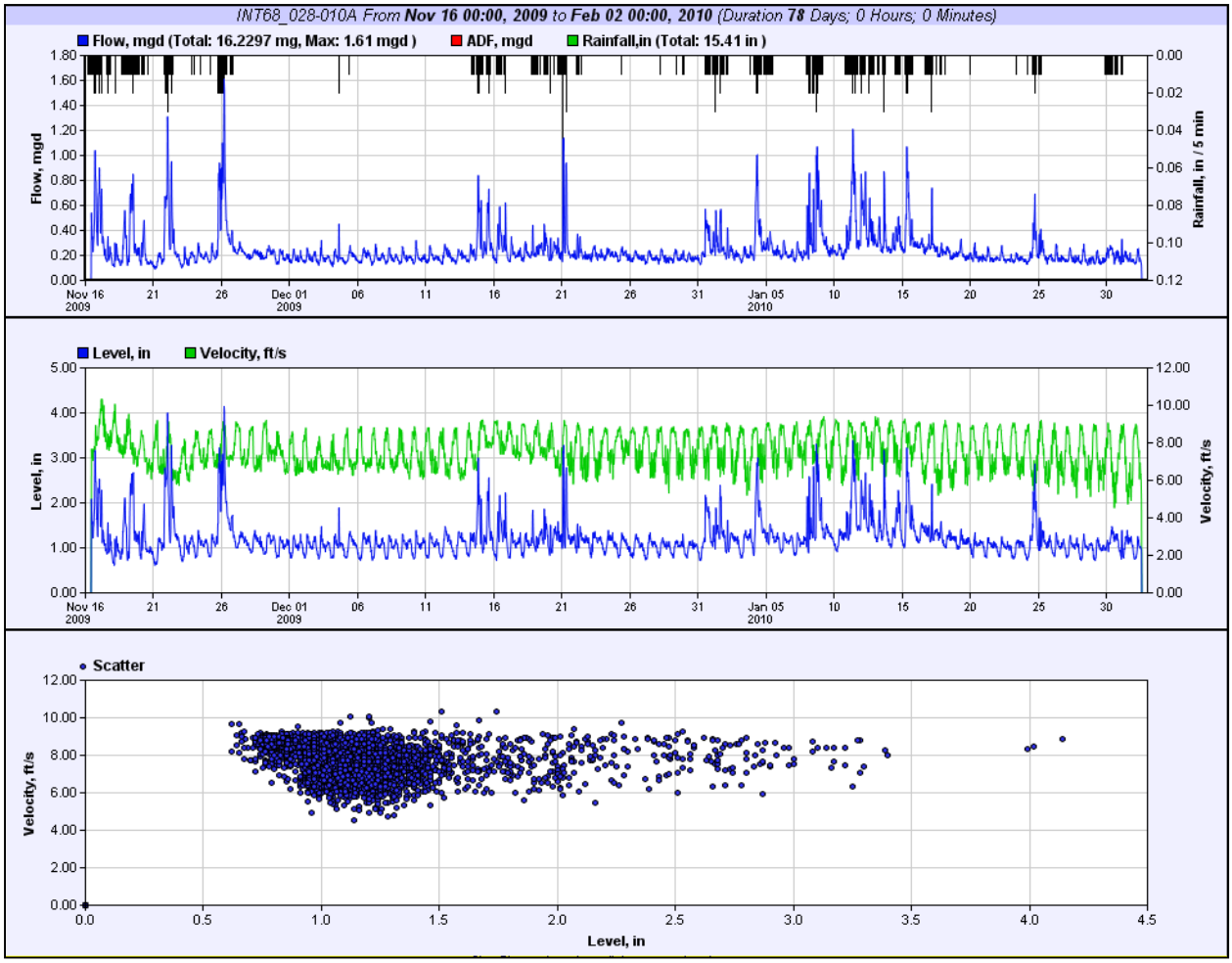

Figure 3-30. Data collected at INT68_028-010A presented no clear relationship between level and velocity

The meter was removed on 2/1/2010, during Phase 3 monitoring, as it was determined that the hydraulics of the site prevented the collection of reliable data and was moved upstream to MH 028-517.

INT68_028-188A

INT68_028-188A is a temporary monitoring site that recorded both level and velocity. The site was installed on 2/8/2010 to characterize the hydrology of the NPDES028 Basin.

The data at this site captured a clear and consistent dry weather flow pattern. The meter responded well during storm events. However, the velocity data required extensive editing as the site hydraulics were creating a jump over the velocity sensor (Figure 3-31). The data quality was classified as "Some Limitations" for Phase 3. Data should be used with caution during model calibration, according to the screening notes.

The meter has met the project expectations and will be removed after the conclusion of Phase 3.

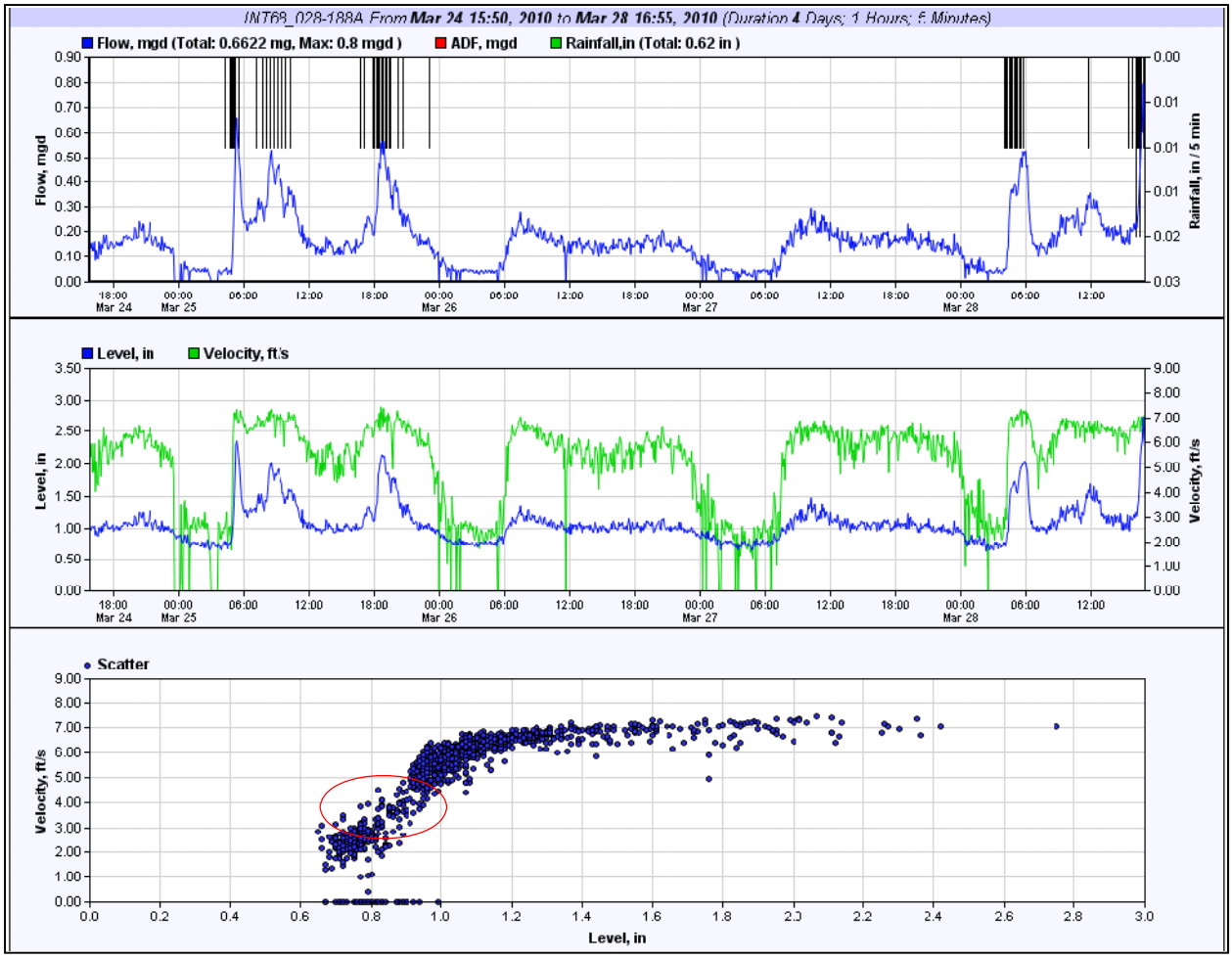

Figure 3-31. Data signature showed jumps over the velocity sensor at INT68_028-188A

INT68_028-422A

INT68_028-422A is a temporary monitoring site that initially recorded level only; after October 2009 it started recording both level and velocity. The site was installed on 1/13/2009 to monitor depth upstream from the HydroBrake and level on the weir to the offline storage pipe.

INT68_028-422A is located downstream of the overflow structure and just upstream of the HydroBrake in the NPDES068(A) Subcatchment. The site was surcharged during storm events due to the downstream HydroBrake (Figure 3-32). Velocity data are not suitable; only level will be used for model calibration purposes.

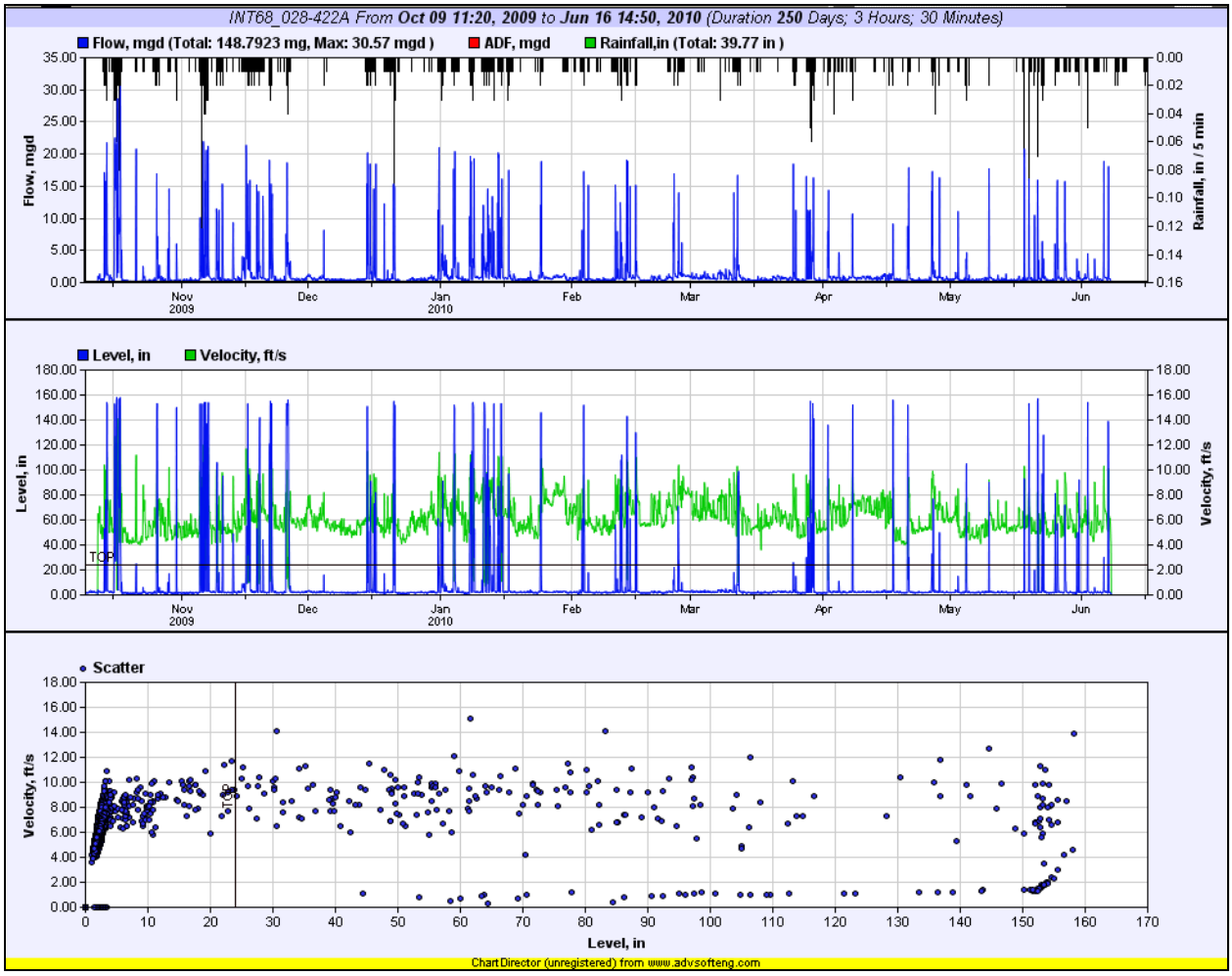

Figure 3-32. INT68_028-422A was surcharged during storm events

Level data quality was classified as "Good" for Phases 2–3, due to surcharges in the pipe. Level data for Phases 2–3 are suitable for model calibration. The quality of the data was classified as "Excellent" for Phase 1 monitoring.

The meter has met the project expectations and will be removed after the conclusion of Phase 3.

INT68_028-440A

INT68_028-440A is a temporary monitoring site that recorded level only. The site was installed on 2/19/2010 to monitor storage utilization of the offline storage pipe to the north in the NPDES068(A) Subcatchment.

INT68_028-440A is located in the offline 144-inch storage pipe in the NPDES068(A) Subcatchment. The meter collected suitable data during storm events. The level data quality was classified as "Excellent" for Phase 3. All data for Phase 3 are suitable for model calibration.

The meter has met the project expectations and will be removed after the conclusion of Phase 3.

INT68_028-517A

INT68_028-517A is a temporary monitoring site that recorded both level and velocity. The site was installed on 2/12/2010 to monitor the flows entering the NPDES068(A) Subcatchment from the east part of the basin. This meter was installed after site INT68_028-517A failed to record suitable data.

INT68_028-517A is located in MH 028-517 downstream from INT68_028-188A. The data at this site captured a clear and consistent dry weather flow pattern. During storm events the flow was fast, making it difficult to collect velocity readings, recording only spikes, which were later edited during data finalization. The quality of the finalized data was classified as "Good" for Phase 3. All data for Phase 3 are suitable for model calibration.

The meter has met the project expectations and will be removed after the conclusion of Phase 3.

NPDES068A_MH-028425

NPDES068A_MH-028425 is a permanent monitoring site that records both level and velocity. The site is classified as a wet weather site because it is not expected to provide high-quality velocity data; thus, only level data are finalized for the site. The site was installed on 8/13/2007 to identify and quantify CSO events occurring from the NPDES068 Basin. The velocity sensor is mounted in the overflow pipe and recordings are used to calculate overflow. Overflows occur when the level at NPDES068A_MH028425 reaches 108 inches.

NPDES068A_MH028425 is located at the NPDES068(A) Overflow Structure. The site responded well to storm events. Level data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All level data for Phases 2–3 are suitable for use in model calibration.

This monitoring site is a permanent site and will continue to be screened in the future.

3.6.2 NPDES068(B) Subcatchment (South End of NPDES068)

The combined sewage from the NPDES068(B) Subcatchment flows into the NPDES068(B) Overflow Facility NPDES068B_MH028431. This overflow facility contains an overflow weir, a HydroBrake, and an in-line storage pipe consisting of a 379-foot, 48-inch-diameter pipe followed by a 368-foot, 72-inch-diameter pipe. When the water reaches the level of the overflow weir, excess flow is diverted into the storm drain system via an 18-inch overflow line that interconnects the combined system and the storm drain system.

INT68_028-043A

INT68_028-043A is a temporary monitoring site. The site was installed on 8/10/2009 to monitor the flows entering the NPDES068(A) Subcatchment from the southeast part of the basin and characterize its hydrology.

INT68_028-043A is located upstream from the NPDES068(A) Overflow Structure, before flows enter the in-line storage pipe. The data at this site captured a consistent dry weather flow pattern with less resolution at levels below 1.5 inches. The site had some issues with high flows due to the steep slope but they were corrected by editing Vmax. The meter responded well to storm events. The data quality was classified as "Good" for Phases 2–3. All data for Phases 2–3 are suitable for model calibration.

The meter has met the project expectations and will be removed after the conclusion of Phase 3.

INT68_028-430A

INT68_028-430A is a temporary monitoring site. The site was monitored using an ADS FlowShark meter that was installed on 8/13/2009 to measure the flows from the NPDES068(A) Subcatchment and characterize the HydroBrake.

INT68_028-430A is located downstream from the HydroBrake. The data at this site captured a clear and consistent dry weather flow pattern. The scattergraph has lesser resolution at levels below 5 inches. The meter responded well to storm events and collected reliable peak flow data. The data quality was classified as "Good" for Phases 2–3. All data for Phases 2–3 are suitable for model calibration.

The meter has met the project expectations and will be removed after the conclusion of Phase 3.

INT68_028-430B

INT68_028-430B is a temporary monitoring site. The site was monitored using an ISCO 2150 meter installed on 2/19/2010 to verify the velocity data captured by INT68_028-430A.

INT68_028-430B is located downstream from the HydroBrake. The data at this site captured a clear and consistent dry weather flow pattern. The meter responded well to storm events. The data collected by this meter confirms the velocity collected by the ADS FlowShark installed at INT68_028-430A. The data quality was classified as "Excellent" for Phase 3. All data for Phase 3 are suitable for model calibration.

The meter has met the project expectations and will be removed after the conclusion of Phase 3.

NPDES068B_MH-028431

NPDES068B_MH-028431 is a permanent monitoring site that records both level and velocity. The site is classified as a wet weather site because it is not expected to provide high-quality velocity data; thus, only level data are finalized for the site. The site was installed on 8/15/2007 to identify and quantify CSO events occurring from the NPDES068(B) Subcatchment. The level data are used to calculate the volume of CSOs using a weir equation. Overflows occur when the level in NPDES068B_MH-028431 reaches 67.88 inches.

NPDES068B_MH-028431 is located at the NPDES068(B) Overflow Structure. The data at the site captured a consistent dry weather diurnal pattern. The site responded well to storm events. Level data quality was classified as "Excellent" for Phases 2–3, while the quality of the data collected during Phase 1 monitoring was classified as "Good." All level data for Phases 2–3 are suitable for use in model calibration.

This monitoring site is a permanent site and will continue to be screened in the future.

3.6.3 Combined Sewer Overflows

ADS reported no overflows in the Interbay Basin during Phases 2–3.

Figure 3-33 shows the maximum water level recorded by ADS at each of the overflow structures in the basin as a percentage of the weir height.

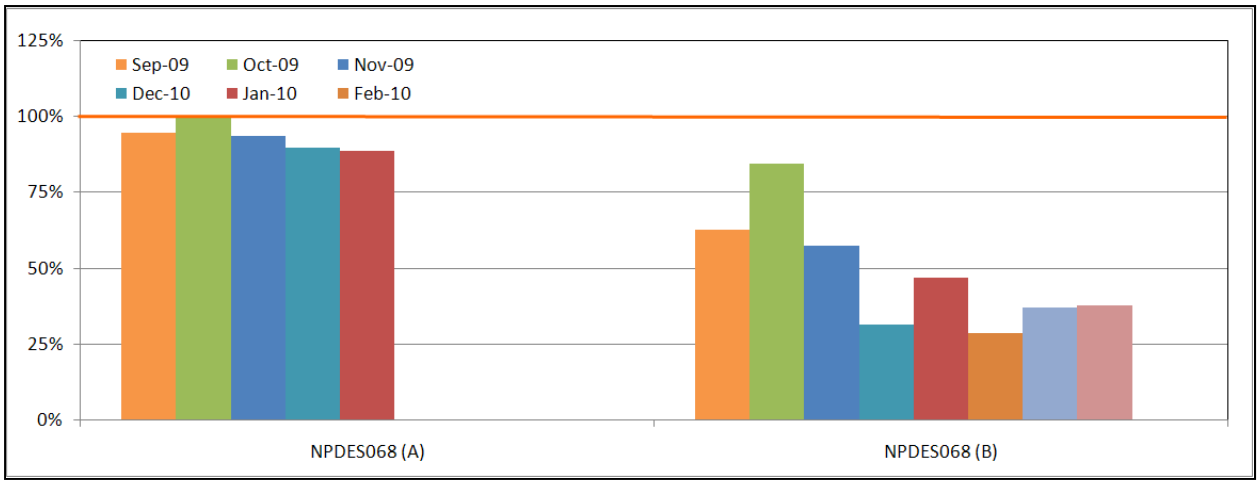

Figure 3-33. Maximum recorded levels compared to weir heights in Interbay for major events

3.6.4 Facility Operations

Two CSS control facilities are located in the Interbay Basin. The NPDES068(A) Subcatchment has CSO Facility 33(A). This facility consists of an elevated pipe that receives only the overflows, a HydroBrake, and an offline 144-inch-diameter, 356-foot-long storage pipe. The NPDES068(B) Subcatchment has CSO Facility 33(B). This facility contains an overflow weir, a HydroBrake, and an in-line storage pipe consisting of a 379-foot-long, 48-inch-diameter pipe followed by a 368-foot-long, 72-inch-diameter pipe. No pump stations are located in the NPDES068 Basin.

The estimated storage utilization in the Interbay Basin is shown in Figure 3-34. Storage utilization was estimated by using the maximum depth recorded at the permanent meter for the NPDES 68(B) Subcatchment and the depth recorded at INT68_028-440A for NPDES068(A). The water depth was compared to the invert level and crown level of the storage structure in order to estimate the percentage of the volume that was used

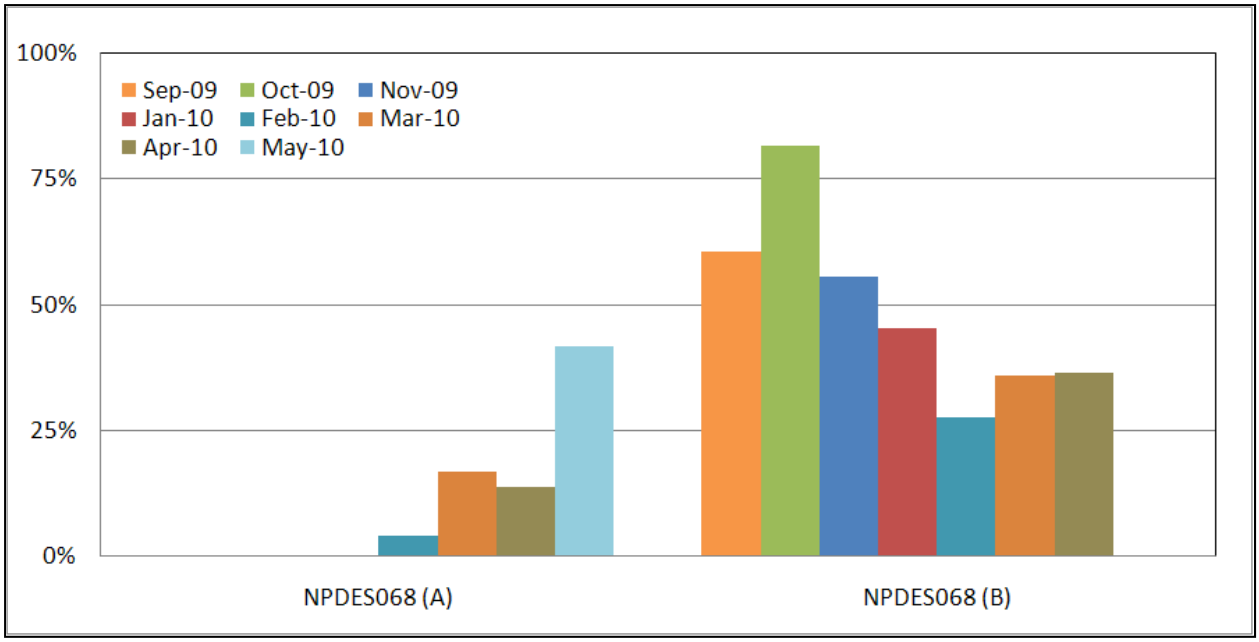

Figure 3-34. Storage utilization in Interbay Basin for major events

(Note: Meter in NPDES068 [A] was not installed until February 2010 and data for permanent meter at NPDES068 [B] does not have data available for May 2010 online)

3.6.4.1 NPDES068(A) Subcatchment

The CSS control facility in the NPDES068(A) Subcatchment consists of two overflow weirs, a HydroBrake, and an offline storage pipe. The overflow weirs are located at MH 028-422, which is the overflow to the offline storage pipe, and at MH 028-425, which is the overflow structure to Elliot Bay.

The storage pipe is located offline near MH 026-422 in CSO Facility 33A. The pipe works in conjunction with HydroBrake 028-422. During storm events the HydroBrake triggers and flow backs up and overflows a weir and begins to fill the offline 144-inch-diameter, 365-foot-long storage pipe. The total volume of the storage pipe is 308,708 gallons.

A drop structure downstream of HydroBrake 028-422 prevents the accurate measurement of flow leaving the HydroBrake. The HydroBrake characterization was created by performing a volumetric balance that uses the data from the monitoring sites upstream of the HydroBrake (Figure 3-35), an estimate of flow between these sites and the HydroBrake, the depth in the storage pipe, and the water level upstream of the HydroBrake. Figure 3-35 shows the configuration of the HydroBrake network and Figure 3-36 shows the characterization data.

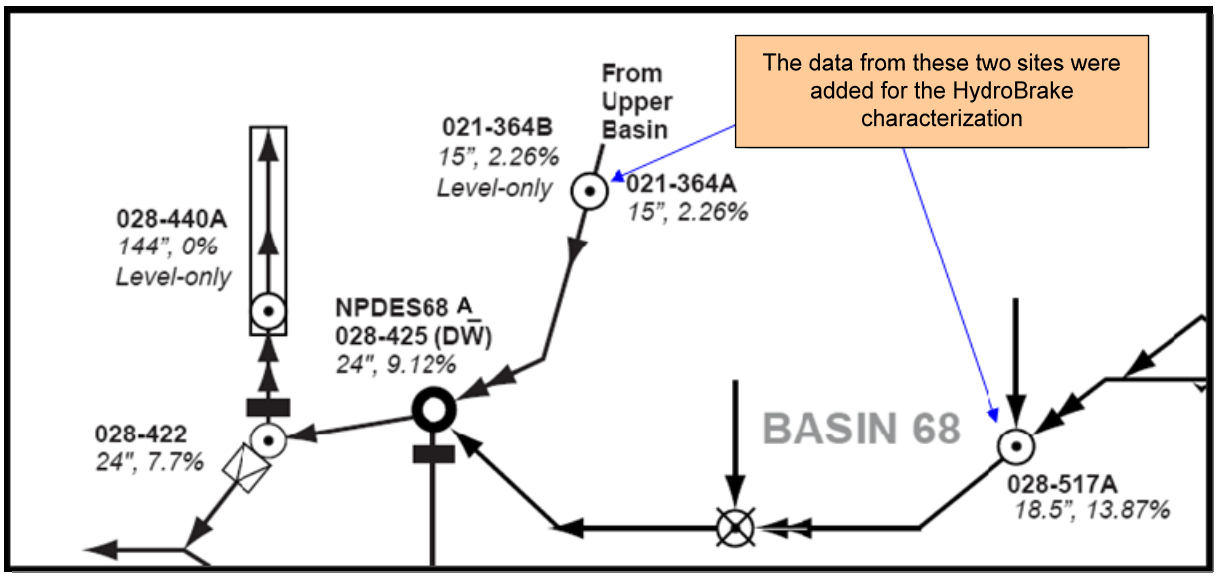

Figure 3-35. Schematic for the HydroBrake in the NPDES068(A) Subcatchment

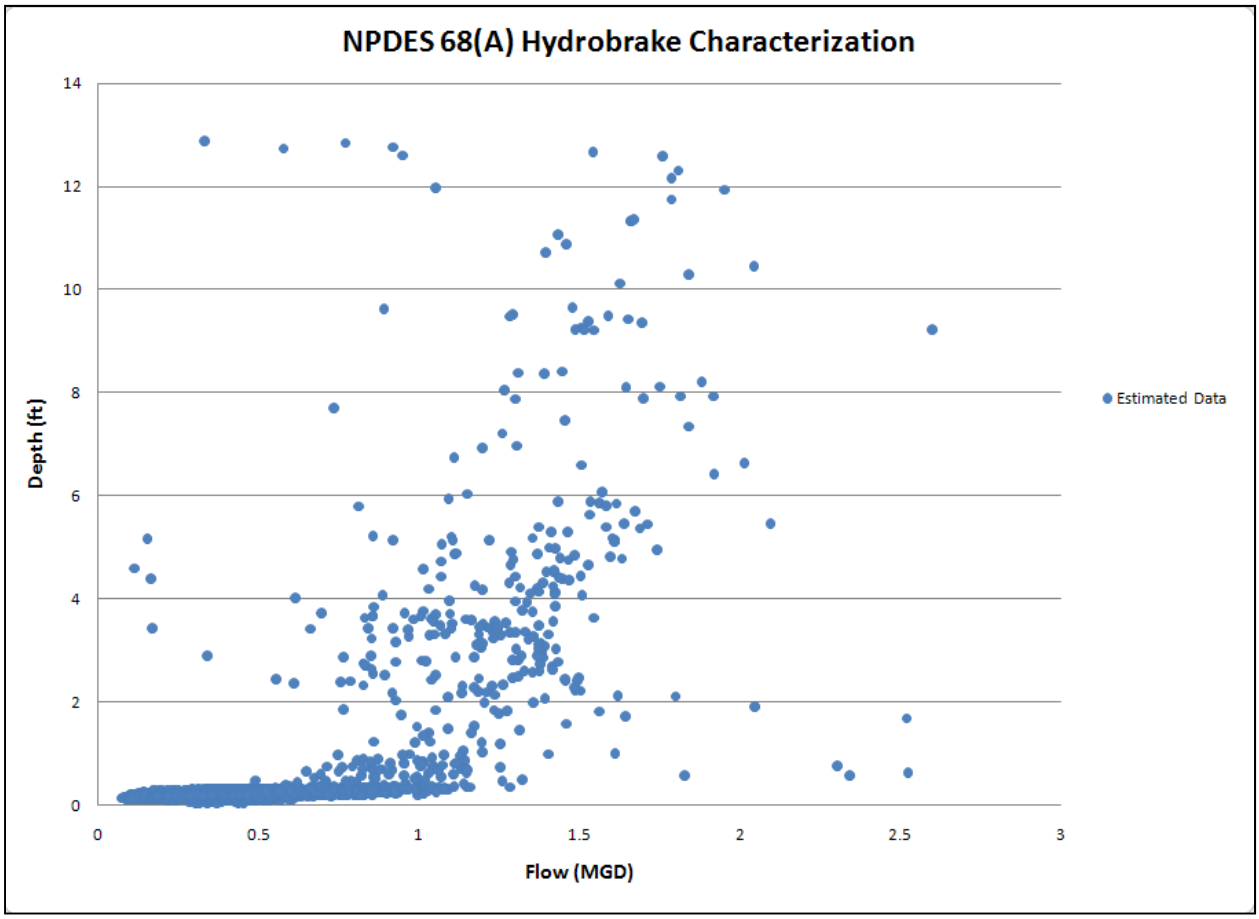

Figure 3-36. NPDES068(A) Subcatchment HydroBrake characterization

3.6.4.2 NPDES068(B) Subcatchment

The CSS control facility in the NPDES068(B) Subcatchment consists of one overflow weir, a HydroBrake, and an in-line storage pipe. The overflow weir is located at MH 028-431.

HydroBrake 028-431 is located downstream of the overflow structure in CSO Facility 33B. During storm events, the HydroBrake triggers and flows are stored in the 379-foot-long, 48-inch-diameter pipe and the 368-foot-long, 72-inch-diameter pipe upstream. The entire storage was utilized during the October 2009 storm event, which almost produced an overflow. Once the water level reaches the weir elevation at 108 inches above the invert, flows overflow into the drainage system and eventually to Elliot Bay. HydroBrake characterization for NPDES068(B) was performed using flow data collected at MH 028-430A and depth data from the permanent site at NPDES068(B). Data showed two distinct curves based on whether the downstream MH 028-430 was submerged as shown in Figure 3-37.

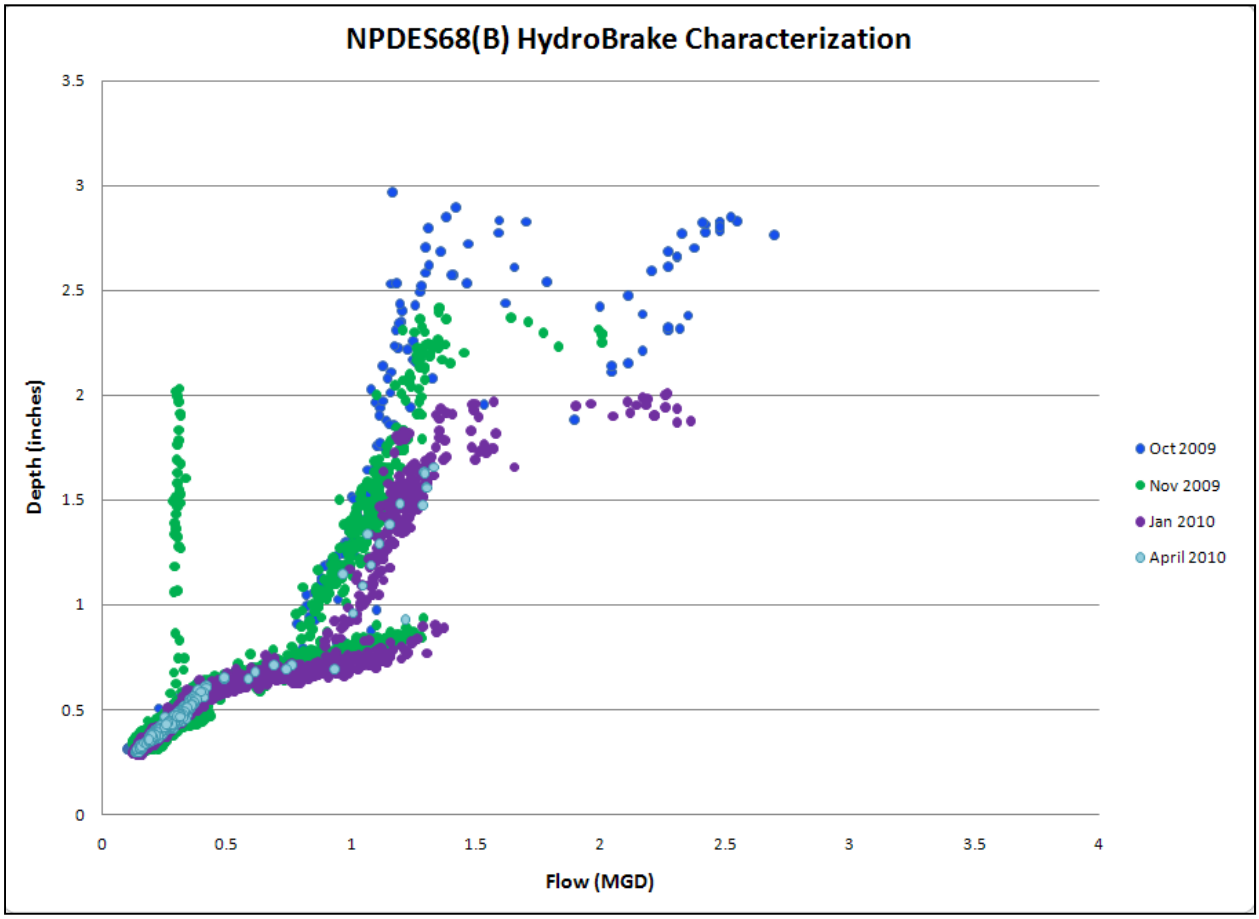

Figure 3-37. NPDES068(B) Subcatchment HydroBrake characterization

3.6.5 Recommendations for Additional Data Collection

At the conclusion of Phase 3 monitoring, no additional data needed to be collected in the Interbay Basin for model calibration and development, GSI, or retrofit purposes. All temporary meters were recommended for removal.

3.7 Leschi Basin

The Leschi Basin, located on the western shore of Lake Washington along Lake Washington Boulevard, extends from approximately S. McClellan Street to E. John Street. The Leschi Basin, which consists of the NPDES026–NDPES036 Basins, is approximately 425 acres in area. The total acreage includes 47 acres that divert flow only into the Leschi Basin, specifically the NPDES030 and NPDES036 Basins, during significant storm events. During development of the CSO LTCP project, the points of diversion were monitored to ascertain under what conditions flow is diverted to the NPDES basin. In the NPDES036 Basin it was determined that diversion of flow into the basin occurs only during very intense storm events, and only in very small volumes. In the NPDES030 Basin, flows were not diverted for the entire duration of the monitoring period.

Combined sewage flows south from the NPDES026 Basin and north from the NPDES036 Basin and collects at the East Pine Street pump station in the NPDES027 Basin. The flow is then pumped into the King County interceptor and flows toward the Montlake regulator. Flow is conveyed through the basins in a line that starts in the south as a 16-inch-diamater pipe and ends in the NPDES027 Basin as a 24-inch-diameter pipe. This line runs along the shoreline of Lake Washington and is referred to herein as the Leschi trunk sewer.

RG 20, located west of the Leschi Basin at the TT Minor Elementary campus, monitors rainfall in all of the NPDES basins within the Leschi Basin.

ADS maintains 12 permanent flow monitoring locations at overflow structures within the Leschi Basin. Stantec maintained 31 temporary flow monitoring locations to monitor combined sewage flow during the Phases 2–3 monitoring period. At the conclusion of Phase 3, five temporary meters remained installed in the Leschi Basin to collect post-construction data on the sluice gates for hydraulic analyses. No further data were required for the purposes of model calibration. The 12 permanent flow monitoring locations remained in place to monitor overflow events.

Detailed site information on Leschi monitoring locations can be found in Appendix H; a basin schematic is contained in Appendix B.

3.7.1 NPDES026 Basin

The NPDES026 Basin, located in the northernmost part of the Leschi Basin, is approximately 10 acres in area. Combined sewage from the NPDES026 Basin flows south and combines with the flows from the NPDES027 Basin before draining into the East Pine Street pump station. Overflows from this partially separated basin are directed to Lake Washington when water levels exceed the side-cast weir elevation located just east of Denny-Blaine Place in MH 038-081.

One permanent monitoring location to verify overflows, and one temporary monitoring location monitored the basin during Phases 1 and 2 of the monitoring period. The temporary monitoring location was removed toward the end of Phase 2 monitoring. The permanent meter will remain in place and continue to monitor for overflows.

LES26_042-270A

LES26_042-270A was a temporary monitoring site that recorded both level and velocity at the outlet of the NPDES026 Basin. The site was installed on 9/11/2008 to measure the flows from the NPDES026 Basin and characterize its hydrology.

LES26_042-270A was located downstream of the NPDES026 Overflow Structure. The collection of reliable data from this site was difficult due to a bump in the channel upstream of the meter (Figure 3-38). During storm events, the meter responded better and there are no data gaps during significant storms. The data quality was classified as "Some Limitations" for Phase 2, which matches the quality classification of the data collected during Phase 1 monitoring. The meter was removed at the end of Phase 2. A limited amount of data may be suitable for model calibration.

Figure 3-38. Bump upstream of meter at LES026_042-270

The monitor was removed on 9/17/2009, toward the end of Phase 2, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NPDES026_MH038081

NPDES026_MH038081 is a permanent monitoring site that records level and velocity. The site is classified as a wet weather site because it is not expected to provide high-quality velocity data; thus, only level data are finalized for the site. The site was installed on 8/22/2007 to identify and quantify CSO events occurring from the NPDES026 Basin. The level data are used to calculate the volume of CSOs using a weir equation. Overflows occur when the level in NPDES026_MH038081 reaches 11.4 inches.

NPDES026_MH038081 is located at the NPDES026 Overflow Structure. The site recorded suitable data during Phases 1. At the beginning of Phase 3 monitoring, the site was jet-cleaned to remove accumulated debris. As a result, the level dropped and conditions became more difficult for capturing reliable data by ultrasonic sensor (Figure 3-39). The data quality was classified as "Some Limitations" for Phase 3, whereas it was classified as "Good" during Phases 1 and 2. Data for Phase 3 should be used with caution during model calibration, according to the data screening notes.

NPDES026_MH038081 is a permanent meter and will continue to be screened in the future.

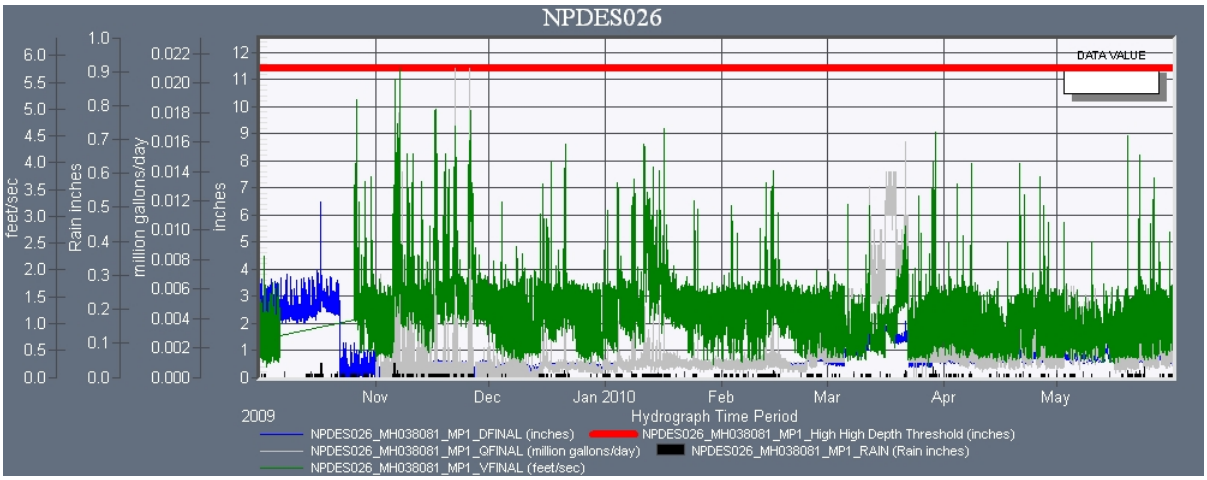

Figure 3-39. NPDES026_MH038081 data signature after cleanout performed by SPU in November 2009

3.7.2 NPDES027 Basin

The NPDES027 Basin, which extends along the east side of the Leschi Basin along Lake Washington, is approximately 39 acres in area. The partially separated basin drains to the King County East Pine Street pump station, which is located along the shore of Lake Washington. All of the flows from the Leschi Basin that do not overflow at the upstream overflow structures pass through the NPDES027 Basin.

One permanent monitoring location to verify overflows and one temporary monitoring location monitored the basin during the Phases 2–3 monitoring period. The temporary monitoring location was removed toward the end of Phase 2 monitoring. The permanent meter will remain in place and continue to monitor for overflows.

LES27_042-273A

LES27_042-273A was a temporary monitoring site that recorded level and velocity in the Leschi trunk sewer in the NPDES027 Basin. The site was installed on 9/16/2008 to characterize level in the Leschi trunk sewer just downstream from the overflow point in the NPDES028 Basin, and to confirm the flows measured at the NPDES027 permanent site just downstream.

LES27_042-273A was located upstream of the NPDES027 Basin Overflow Structure. Flows are regarded as overestimated due to silt in the line during Phase 1. The site was removed for line cleaning in June 2009. After the line cleaning the data captured showed no clear relationship between velocity and level at depths below about 11 inches (Figure 3-40). The data quality was classified as "Some Limitations" for Phase 2. Data for Phase 2 should be used with caution during model calibration, according to the data screening notes.

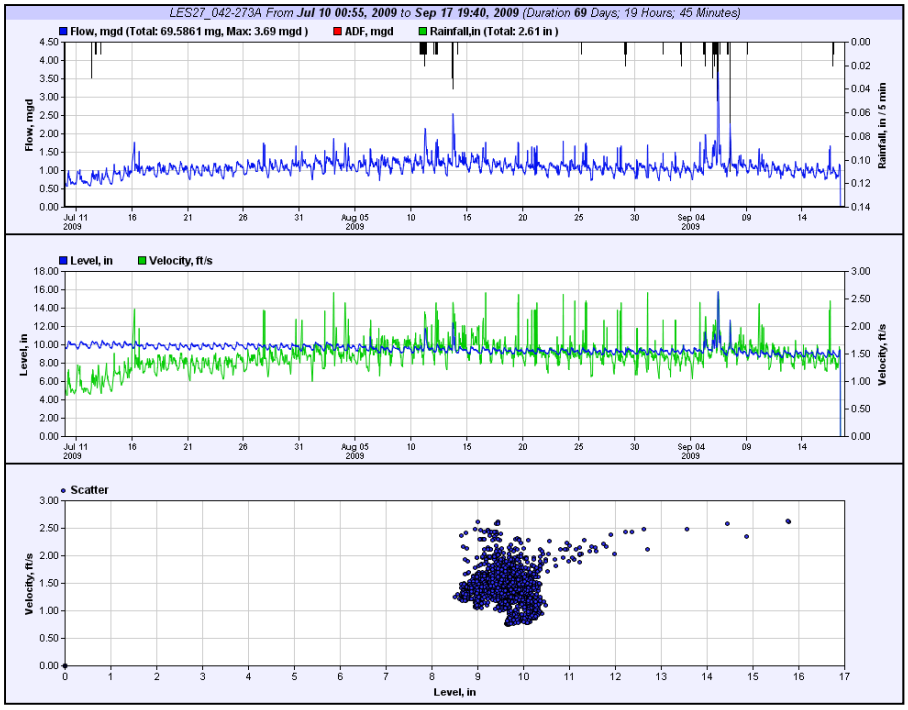

Figure 3-40. LES27_042-273A data signature captured during Phase 2 monitoring

The meter was removed on 9/17/2009, toward the end of Phase 2, as it was determined that the permanent meter (NPDES27_MH-042269) downstream of this site provides flow data suitable for model calibration.

LES27_DWF-042269

LES27_DWF-042269 is a permanent monitoring site that records both level and velocity. The site is classified as a dry weather flow site and therefore the site was expected to provide repeatable and reliable velocity data. The site was installed on 7/31/2007 to identify and quantify CSO events occurring from the NPDES027 Basin. The level data are used to calculate the volume of CSOs using a weir equation. Overflows occur when the level in LES27_DWF-042269 reaches 27.84 inches.

The data at the site captured a clear and consistent dry weather diurnal pattern. During all storm events the meter responded well. The scattergraph is clear and narrow during dry and wet weather periods. It was necessary to apply a depth offset correction to the data during finalization due to the configuration of the site. For this reason the data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for model calibration.

LES27_DWF-042269 is a permanent meter and will continue to be screened in the future.

3.7.3 NPDES028 Basin

The NPDES028 Basin, located in the northern part of the Leschi Basin, is approximately 20 acres in area. A side-cast overflow weir in MH 042-275 conveys the excess flows from this basin to Lake Washington through a 15-inch-diameter outfall pipe.

One permanent monitoring location to verify overflows and two temporary monitoring locations monitored the basin during the Phases 2–3 monitoring period. One temporary monitoring location was removed during Phase 2 and the other temporary monitor was removed at the conclusion of Phase 3 monitoring. The basin

overflowed four times during Phases 2–3. The permanent meter will remain in place and continue to monitor for overflows.

LES28_042-276A

LES28_042-276A was a temporary monitoring site that recorded both level and velocity in a small portion of the NPDES028 Basin. The site was installed on 9/11/2008 to calculate the flows from this subcatchment and characterize hydrology.

LES28_042-276A was located upstream of the NPDES028 Basin Overflow Structure. The data at the site captured a clear and repeatable dry weather level pattern. Below a level of 1 inch the scattergraph is thick, which is attributed to the velocity sensor detecting multiple velocities. During storm events, the meter responded well and there are no data gaps during significant storms. The data quality was classified as "Good" for Phase 2, which matches the quality classification of the data collected during Phase 1 monitoring. The meter was removed at the end of Phase 2. All data for Phase 2 are suitable for model calibration.

The monitor was removed on 9/17/2009, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

LES28_042-282A

LES28_042-282A was a temporary monitoring site that recorded both level and velocity from the south part of the NPDES028 Basin. The site was installed on 9/11/2008 to measure the flows from this subcatchment and characterize its hydrology. The flows from LES28_042-276A and this location characterize the majority of the flows within the NPDES028 Basin.

LES28_042-282A was located upstream of the NPDES028 Basin Overflow Structure. The data at the site captured a clear and repeatable dry weather pattern. Low nighttime dry weather flow may be overestimated. Below a level of 1.5 inches, a thick scatter of velocity data indicate that the velocity probe is detecting multiple velocities. During storm events, the meter responded well and there are no data gaps during significant storms. The data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for model calibration.

The monitor was removed on 2/11/2010, at the conclusion of Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NPDES028_MH042275

NPDES028_MH042275 is a permanent monitoring site that records both level and velocity using two monitoring locations for level; one pressure sensor is mounted on the inside pipe (MP2) and an ultrasonic sensor is mounted above the pipe to measure overflows (MP1). The site is classified as a wet weather site because it is not expected to provide high-quality velocity data; thus, only level data are finalized for the site. MP1 was installed on 8/1/2007 to identify and quantify CSO events occurring from the NPDES028 Basin. The level data are used to calculate the volume of CSOs using a weir equation. MP2 was installed on 1/28/2008 to verify the overflows measured by MP1. Overflows occur when the level in NPDES028_MH042275 reaches 13.63 inches prior to December 2009 and 16.38 inches after December 2009, when the weir level was raised.

NPDES028_MH042275 is located at the NPDES028 Overflow Structure. Both meters responded well to storm events and captured clear and consistent data. The data quality for both meters was classified as "Excellent" for Phases 2–3, whereas the data quality classification for Phase 1 was "Good." All data for Phases 2–3 are suitable for model calibration.

NPDES028_MH042275 is a permanent meter and will continue to be screened in the future.

3.7.4 NPDES029 Basin

The NPDES029 Basin, located near the center of the Leschi Basin, is approximately 21 acres in area. One CSO control facility is located within the NPDES029 Basin. CSO Facility 18 includes 300 feet of an in-line, 18-inch-diameter storage pipe, one HydroBrake, and two overflow structures. In addition to the 18-inch in-line storage, another 12-inch pipe is located to the north that provides additional storage.

The basin is monitored by five temporary meters and one permanent meter that collects both dry and wet weather data. The basin overflowed one time during Phases 2–3, during the October 2009 storm event. At the conclusion of Phase 3 no temporary meters remained in the NPDES029 Basin. The permanent meter location will continue to be monitored to verify overflows.

LES29_042-300A

LES29_042-300A was a temporary monitoring site that recorded both level and velocity. This site was installed on 9/11/2008 to characterize hydrology in the NPDES029 Basin.

LES29_042-300A was located upstream from the HydroBrake in the NPDES029 Basin. During large storm events, when storage backs up with flow, the data signature indicates backwater conditions at this site (Figure 3-41). The raw velocity during these large storm events drops out to zero; however, in reality this number may be a very small positive number or a negative number. Stantec edited the velocity data to follow previous patterns. Data from smaller storms will be used to characterize hydrology. The data quality was classified as "Some Limitations" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. Data collected during Phases 2–3 should be used with caution during model calibration; smaller storms, when the site did not surcharge, are recommended.

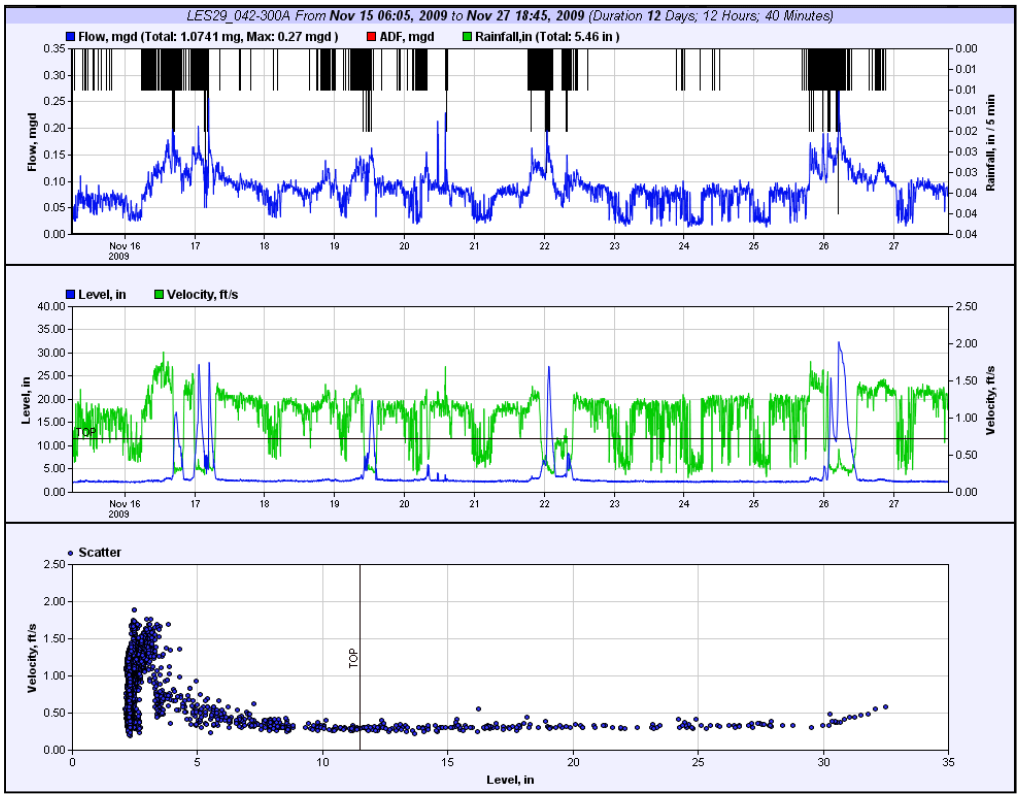

Figure 3-41. LES29_042-300A backs up during storm events, when storage is filled up

The meter was removed on 2/11/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

LES29_042-302A

LES29_042-302A was a temporary monitoring site that recorded level only. The site was installed on 9/16/2008 to measure level at the HydroBrake in the NPDES029 Basin.

LES29_042-302A was located just upstream from the HydroBrake in CSO Facility 18. The dry weather pattern was clear and repeatable and the meter responded well to storm events. However, due to battery failure the meter did not record data during the October 2009 storm. The site was surcharged during large storm events. The data quality was classified as "Good" for Phases 2–3, whereas data collected during Phase 1 were classified as "Excellent." Due to surcharged conditions, data for Phases 2–3 should be used with caution during model calibration.

The meter was removed on 2/4/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

LES29_042-305A

LES29_042-305A was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/30/2008 to measure the flow leaving the NPDES029 Basin and entering the Leschi trunk sewer and characterize the hydrology of the NPDES029 Basin.

LES29_042-305A was located downstream from the overflow structure in the NPDES029 Basin. Dry weather flow shows a clear and repeatable pattern and the meter showed a good response to storm events. There was a sudden increase in level and velocity on 7/7/2009, which remained until 8/11/2009. Verification readings taken during this time confirm that the readings are real. No explanation was established for the change in the data signature. The data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. During Phase 1, it was noted that the site experienced backwater conditions and reverse flow during large events. This pattern was not seen in Phases 2–3, likely due to Leschi trunk sewer cleaning. All data for Phases 2–3, with the exception of the period described above are suitable for model calibration.

The meter was removed on 2/4/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

LES29_042-305B

LES29_042-305B was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/30/2008 to measure the flow and level in the Leschi trunk sewer.

LES29_042-305B was in the Leschi trunk sewer at MH 042-305. Dry weather flow shows a clear and repeatable pattern and the meter showed a good response to storm events. The line was cleaned after March 2009 and data quality improved as a result. The data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. During Phase 1, it was noted that the site experienced backwater conditions and reverse flow during large events. All data for Phases 2–3 are suitable for model calibration.

The meter was removed on 2/4/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

LES29_042-306A

LES29_042-306A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/11/2008 to measure the flows in the south portion of the NPDES029 Basin and characterize its hydrology.

LES29_042-306A was located upstream from the HydroBrake before entering CSO Facility 18. Dry weather flow shows a clear and repeatable pattern. During storm events the velocity sensor recorded zero readings that were later edited to small positive values during data finalization. The site signature shows a backwater effect due to the downstream HydroBrake (Figure 3-42). The data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data are suitable for model calibration.

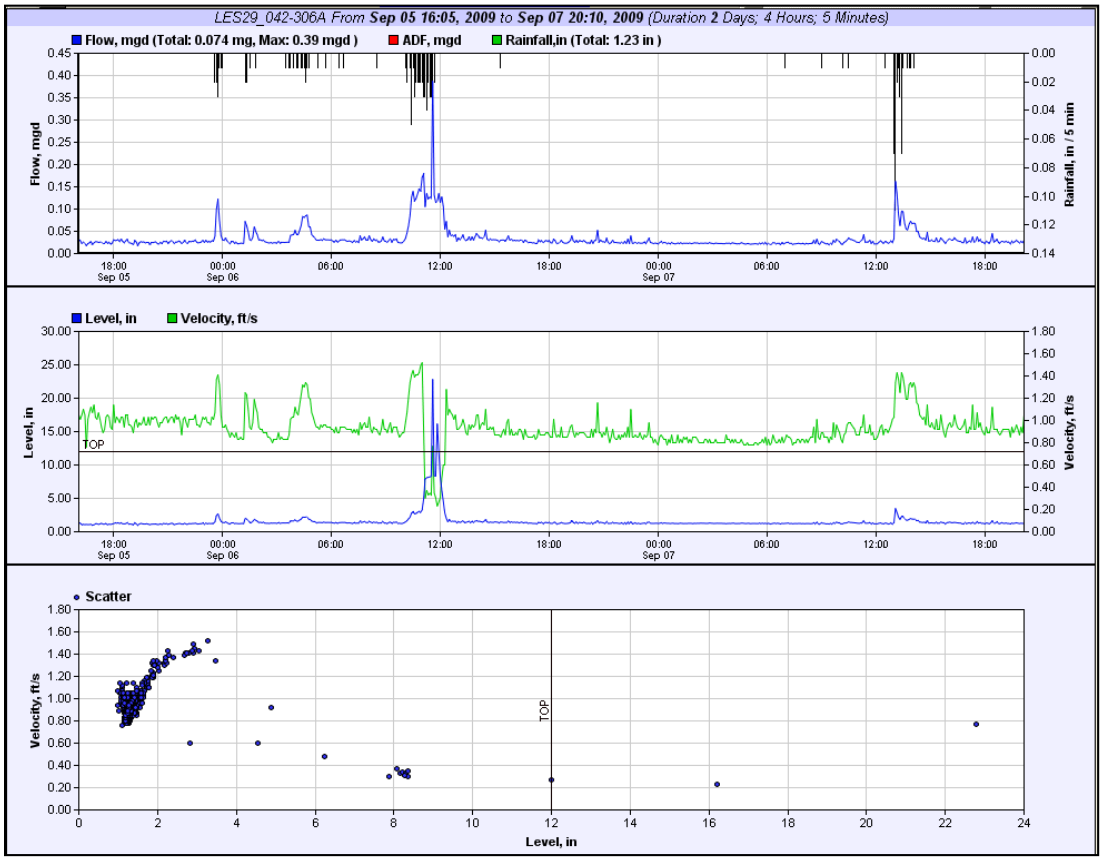

Figure 3-42. LES29_042-306A snapshot of surcharge signature

The meter was removed on 2/4/2010 toward the end of Phase 3 after sufficient suitable data had been collected for calibration purposes.

LES29_DWF-042303

LES29_DWF-042303 is a permanent monitoring site that records both level and velocity using two monitoring locations for level; a velocity and pressure sensor is mounted in the pipe (MP2) and an ultrasonic sensor is mounted above the pipe to measure overflows (MP1). The site was installed on 7/30/2007 to identify and quantify CSO events occurring from the NPDES029 Basin. The level data are used to calculate the volume of CSOs using a weir equation. Overflows occur when the level in LES29_DWF-042303 reaches 9.13 inches. MP1 was installed on 8/1/2007 to identify and quantify CSO events occurring from the

NPDES029 Basin. The level data are used to calculate the volume of CSOs using a weir equation. MP2 was installed on 9/1/2009 to verify the overflows measured by MP1.

LES29_DWF-042303 is located at the NPDES029 Overflow Structure. Data for both MP1 and MP2 show a clear dry weather flow pattern and the meter responded well to storm events. However, MP1 failed to record data during the October and November storm events. MP1 also shows backwater conditions during large storm events, which are caused by the Leschi trunk sewer backing up into the overflow control structure (Figure 3-43). The data quality for MP1 was classified as "Some Limitations" for Phases 2–3 and was classified as "Good" for Phase 1. The data quality for MP2 was classified as "Excellent." Data from MP1 should be used with caution during model calibration according to the data screening notes. All data from MP2 is suitable for model calibration purposes.

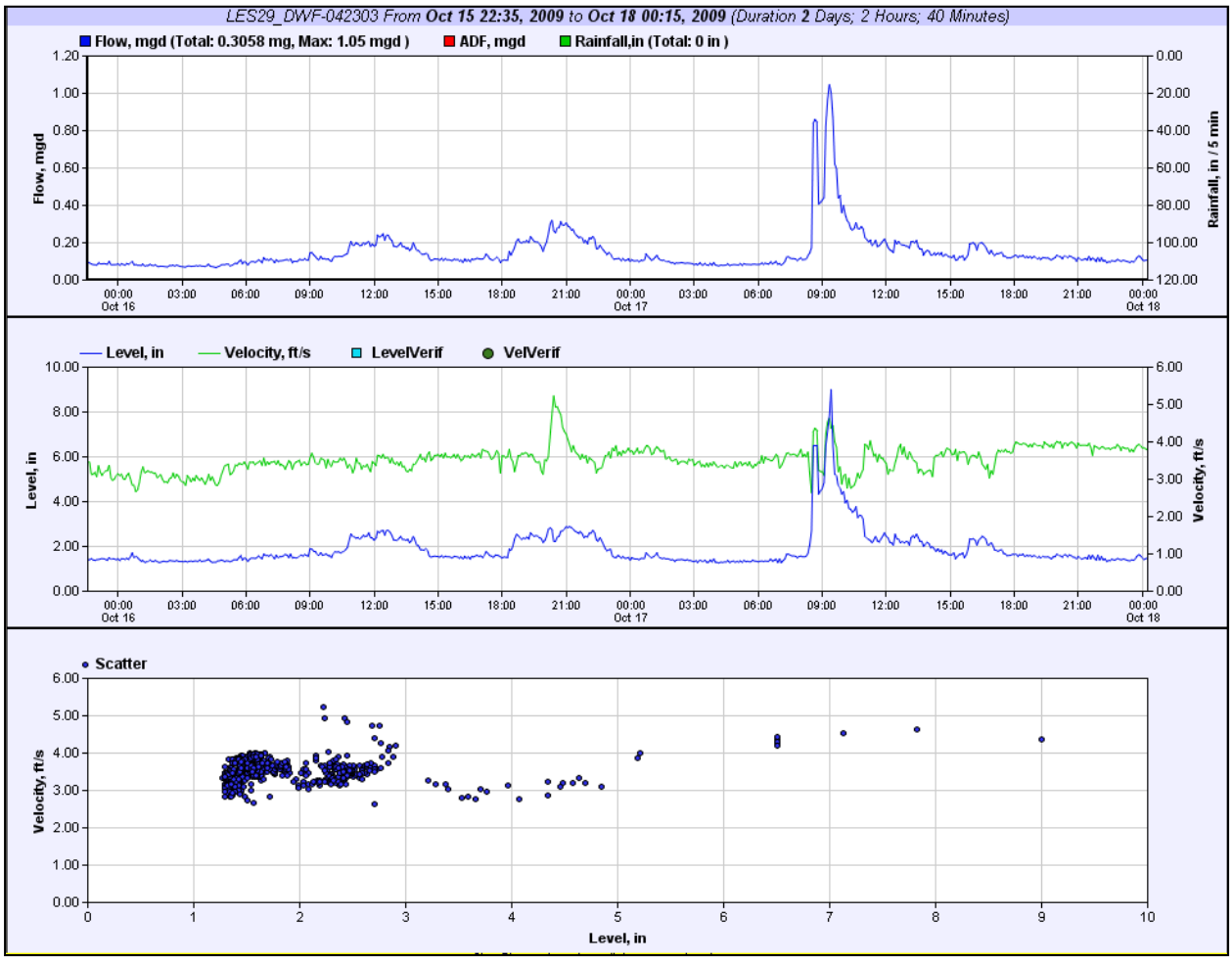

Figure 3-43. Backwater conditions captured at LES29_DWF-042303

LES29_DWF-042303 is a permanent meter and will continue to be screened in the future.

3.7.5 NPDES030 Basin

The NPDES030 Basin is approximately 60 acres in area. CSO Facility 17 is a control facility located in the NPDES030 Basin. The facility contains four control structures: an 18,000-gallon in-line storage tank with an overflow weir, a sluice gate, and two overflow weirs. In the western part of the basin, at MH 042-008, an overflow weir could allow flows from an additional 47 acres to flow into the NPDES030 Basin during

periods of extremely high flow or downstream blockages. During Phases 1 and 2 of monitoring, flows from the upper basin never reached the weir height at MH 042-008. As part of the retrofit program, this weir will be blocked, and will no longer allow flows into the NPDES030 Basin.

Seven temporary meters and one permanent meter monitor the basin. Two of the temporary meters in the western portion of the basin were removed during Phase 1. The permanent meter captures both dry and wet weather data. At the conclusion of Phase 3, two temporary meters remained for post-construction monitoring and hydraulic analysis of the sluice gate in the NPDES030 Basin. The overflow point in the Leschi NDPES030 Basin will continue to be monitored on a permanent basis.

LES30_042-008A

LES30_042-008A was a temporary monitoring site that recorded level in the western part of the NPDES030 Basin. The site was installed on 9/16/2008 to characterize the level in the pipe compared to the weir height to determine if the flow overtops the weir (any overflow would send flows through the overflow control structure at LES30_DWF-042322).

The site has a weir height of approximately 14 inches. Under normal conditions, the flow at this site proceeds northward away from the Leschi Basin. The dry weather pattern at this site shows a school flow contribution signature with higher flows during the weekdays and very small flows over the weekend. The quality of the level data collected during Phase 2 was classified as "Excellent," which matches the quality classification of the data collected during Phase 1 monitoring. All data from Phase 2 are suitable for use in model calibration.

The monitor was removed at the end of Phase 2 monitoring on 9/24/2009 as it was determined that suitable data had been collected for the purposes of model calibration. The level measured at this site never exceeded 2.5 inches.

LES30_042-202A

LES32_042-202A was a temporary monitoring site that recorded level and velocity upstream from the permanent meter in the NPDES030 Basin. The site was installed on 9/11/2008 to characterize hydrology in the NPDES030 Basin upstream from the permanent meter and sluice gate.

During Phases 2–3, data quality was classified as "Good," while Phase 1 classification was "Some Limitations." The meter was moved 12 inches upstream in the pipe on 8/6/2009 because it was found that flow was overestimated. Moving the meter upstream changed the site signature significantly; therefore, data after 8/6/2009 were considered more accurate. Data prior to 8/6/2009 were edited to have a similar site signature to the data after 8/6/2009. All data from Phases 2–3 are suitable for use in model calibration. During Phases 2–3, velocity spikes and dropouts were edited by Stantec. The depth sensor began to drift on 1/5/2010; therefore, Stantec needed to adjust the data during finalization.

The monitor was removed at the end of Phase 3 monitoring, on 2/4/2010 as it was determined that suitable data had been collected for the purposes of model calibration.

LES30_042-205A

LES30_042-205A was a temporary monitoring site that recorded level upstream from the sluice gate in the NPDES030 Basin. This site was installed on 1/22/2009 to characterize the storage utilization of the in-line storage pipe upstream from this meter.

Figure 3-44. LES30_042-205A covered by debris

During Phases 2–3, debris built up at the site, which appears to occur during high flows when the sluice gate is shut and water backs up into the storage pipe (Figure 3-44). The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data from Phases 2–3 are suitable for use in model calibration.

The meter remained installed at the conclusion of Phase 3 monitoring.

LES30_042-206B

LES30_042-206B was a temporary monitoring site that recorded level and velocity in the outlet pipe of the NPDES030 Basin to the Leschi trunk sewer. The site was installed on 1/22/2009 to characterize the sluice gate in the NPDES030 Basin and to provide level data in the Leschi trunk sewer.

The depth data should be relied upon more than the velocity data because the site was heavily influenced by the Leschi trunk sewer and was in a backwater condition during storm events, which made conditions difficult to capture accurate velocity data. The velocity readings appear to be from the Leschi trunk sewer water washing over the probe, creating a false reading (Figure 3-45). The data quality was classified as "Some Limitations" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. Data for Phases 2–3 should be used with caution for model calibration according the data screening notes.

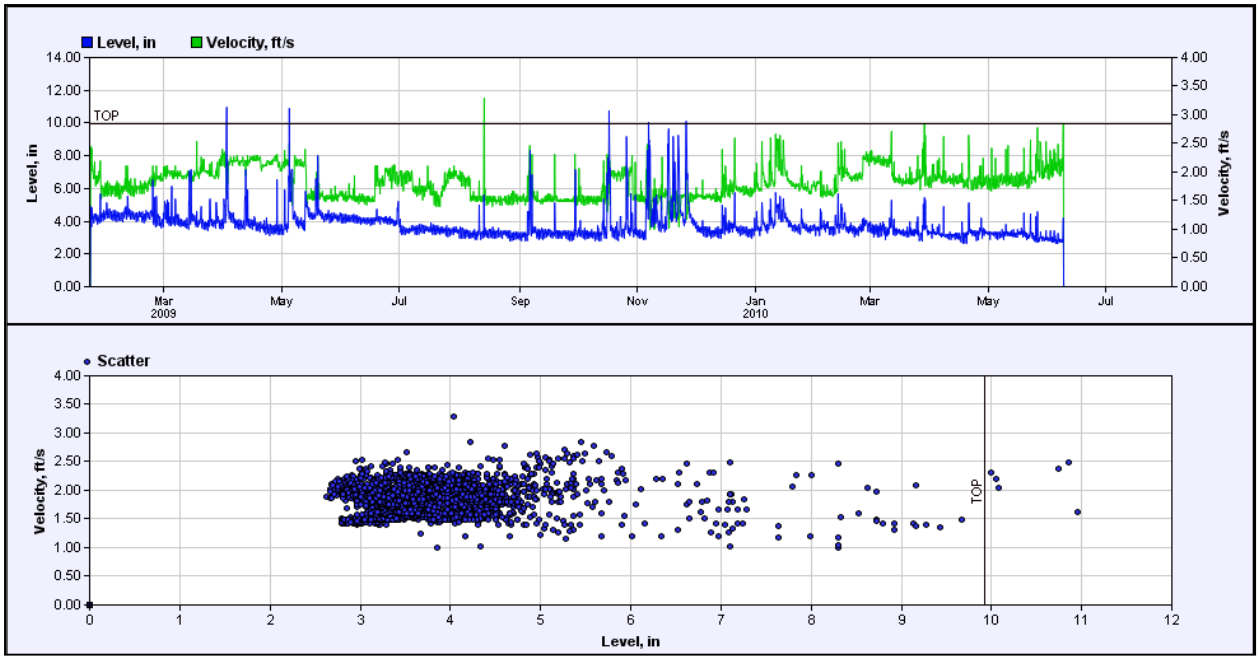

Figure 3-45. LES30_042-206B data signature; velocity was edited heavily during data finalization

The meter remained installed at the conclusion of Phase 3 monitoring.

LES30_046-015A

LES30_046-015A was a temporary monitoring site that recorded level and velocity upstream from the in-line storage pipe in the NPDES030 Basin. The site was installed on 9/11/2008 to characterize hydrology in the NPDES030 Basin.

During Phase 2, the data were classified as "Good" because under a level of about 0.6 inch, the site shows signs of ramping over the meter. This matches the quality classification of the data collected during Phase 1 monitoring. All data from Phase 2 are suitable for use in model calibration.

The monitor was removed at the end of Phase 2 monitoring on 9/24/2009 as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

LES30_DWF-042322

LES30_DWF-042322 is a permanent monitoring site that records both level and velocity. The site was installed on 8/1/2007 to identify and quantify CSO events occurring from the NPDES030 Basin. Overflows occur when the level in LES30_DWF-042322 reaches 12.36 inches.

The permanent site was classified as a dry weather site; therefore, the site was expected to provide repeatable and reliable velocity data. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. Level data are more reliable than velocity data. All level data from Phases 2–3 are suitable for use in model calibration. Velocity data should be used with caution during model calibration according to data screening notes.

LES30_DWF-042322 is a permanent meter and will continue to be screened in the future.

3.7.6 NPDES031 Basin

The NPDES031 Basin is approximately 6 acres in area; overflows from this partially separated basin are directed to Lake Washington. The NPDES031 Basin contains one control structure: an overflow weir. There is no storage in the NPDES031 Basin.

One temporary site and one permanent site monitor the basin. At the conclusion of Phase 3 no temporary meters will remain in the Leschi NPDES031 Basin. The overflow point within the Leschi NDPES031 Basin will continue to be monitored on a permanent basis.

LES31_046-042A

LES31_046-042A was a temporary monitoring site that recorded level in the Leschi trunk sewer near the permanent meter in the NPDES031 Basin. This site was installed on 10/15/2008 to compare the level in the Leschi trunk sewer to the elevation of the overflow weir at the permanent site.

The site is not conducive to accurate velocity measurement due to siltation in the Leschi trunk sewer. The quality of the level data was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. During Phases 2–3, velocity spikes and dropouts were edited by Stantec. The meter was replaced by Stantec on 12/15/2009 because the meter was malfunctioning. The site was susceptible to debris buildup. All depth data from Phases 2–3 are suitable for use in model calibration.

The meter was removed on 2/5/2010 during Phase 3 monitoring, as it was determined that suitable data had been collected for the purposes of model calibration.

LES31_DWF-046033

LES31_DWF-046033 is a permanent monitoring site that records both level and velocity. The site was installed on 8/21/2007 to identify and quantify CSO events occurring from the NPDES031 Basin. Overflows occur when the level in LES31_DWF-046033 reaches 9.63 inches.

The permanent site was classified as a dry weather site; therefore, the site was expected to provide repeatable and reliable velocity data. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The data quality was classified as "Excellent" for Phases 2–3. All data from Phases 2–3 are suitable for use in model calibration. During Phase 1 monitoring the data were classified as "Good" because some of the data for the January 2009 storm event were missing.

LES31_DWF-046033 is a permanent meter and will continue to be screened in the future.

3.7.7 NPDES032 Basin

The NPDES032 Basin, which consists of two hydraulically separate subcatchments that share one outfall, is approximately 40 acres in area. The first subcatchment, NPDES032(A), comprises the majority of area and flow. The second subcatchment, NPDES032(B), has a contributing area of less than 1 acre and contains only three houses. CSO Facility 16 is a control facility located in the NPDES032 Basin. The facility contains four control structures: a 6,000-gallon in-line storage tank, a HydroBrake, and two overflow weirs. Low flows in the NDPES032(B) Subcatchment are directed to the 18-inch-diameter Leschi trunk sewer and low flows in NPDES032(A) are conveyed through a HydroBrake into the 18-inch Leschi trunk sewer. The Leschi trunk sewer then conveys flows to the East Pine Street pump station. Overflows from both NPDES032(A) and NPDES032(B) are directed to the 12-inch-diameter outfall pipe to Lake Washington. NPDES032(A) overflowed once during Phases 2–3, while NPDES032(B) overflowed three times.

Three temporary sites and two permanent sites monitor the NPDES032 Basin. The permanent site at NPDES032(A) collects dry and wet weather data. The permanent site at NPDES032(B) collects depth data

only to quantify overflows. At the conclusion of Phase 3 no temporary meters remained in the Leschi NPDES032 Basin. The two overflow points within the Leschi NDPES032 Basin will continue to be monitored on a permanent basis.

LES32_046-084A

LES32_046-084A was a temporary monitoring site that recorded both level and velocity upstream from the permanent meter in the NPDES032(A) Subcatchment. The site was installed on 9/12/2008 to characterize hydrology in the NPDES032(A) Subcatchment.

The data showed a clear relationship between level and velocity above a level of 0.8 inch. At depths recorded below 0.8 inch there was a thick scatter of velocity data, indicating that the velocity probe was picking up multiple velocities. The low, nighttime, dry weather flow may be overestimated. The data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data from Phases 2–3 are suitable for use in model calibration.

During Phase 2–3, velocity spikes and dropouts were edited by Stantec.

The meter was removed on 2/4/2010 during Phase 3 monitoring, as it was determined that suitable data had been collected for the purposes of model calibration.

LES32_046-156A

LES32_046-156A was a temporary monitoring site that recorded level upstream of the HydroBrake located in the NPDES032(A) Subcatchment. The site was installed on 10/24/2008 to characterize the HydroBrake.

The quality of the level data was classified as "Good" for Phases 2–3, as the response to rainfall was not as consistent as during Phase 1. During Phase 1 the data were classified as "Excellent." The depth data from Phases 2–3 are suitable for use in model calibration.

The meter was removed on 2/4/2010 during Phase 3 monitoring, as it was determined that suitable data had been collected for the purposes of model calibration.

LES32_046-163A

LES32_046-163A was a temporary monitoring site that recorded level and velocity downstream from the HydroBrake in the NPDES032(A) Subcatchment. The site was installed on 10/24/2008 to characterize the HydroBrake.

Although the quality of the level data for Phases 2–3 was classified as "Excellent," the quality of the velocity data was classified as "Some Limitations." The site experiences reverse flow through the HydroBrake from the Leschi trunk sewer into the basin storage and heavy silt in the Leschi trunk sewer prevented collection of good velocity data. Consequently, the quality of the velocity and calculated flow data was classified as "Some Limitations" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. Although periods of data are suitable for model calibration, these data must be selected carefully.

During Phases 2–3, the site would surcharge often with little to no velocity; therefore, velocity data are unreliable. Some storms appear to have reliable velocity data, including the storm event of 10/26/2009. Many of the smaller storms could be accurate but the large influence of the pump station makes it difficult to be sure. Debris buildup was prevalent at the site.

The meter was removed on 2/4/2010 during Phase 3 monitoring, as it was determined that suitable data had been collected for the purposes of model calibration.

LES32_DWF-046157

LES32_DWF-046157 is a permanent monitoring site that records both level and velocity. The site was installed on 8/22/2007 to identify and quantify CSO events occurring from the NPDES032(A) Subcatchment. Overflows occur when the level in LES32_DWF-046157 reaches 32.75 inches.

The permanent site was classified as a dry weather site; therefore, the site was expected to provide repeatable and reliable velocity data. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The data quality was classified as "Some Limitations" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. This is because it was determined through flow balances with upstream meter at LES32_046-084A that the velocity was overestimating. All data from Phases 2–3 are suitable for use in model calibration.

LES32_DWF-046157 is a permanent meter and will continue to be screened in the future.

NPDES032B_MH046078

NPDES032B_MH046078 is a permanent monitoring site that records both level and velocity. The site was installed on 7/30/2007 to identify and quantify CSO events occurring from the NPDES032(B) Subcatchment. Overflows occur when the level in NPDES032B_MH046078 reaches 12.75 inches.

The permanent site was classified as a wet weather site; the site was not expected to provide repeatable and reliable velocity data. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The quality of the depth data was classified as "Excellent" for Phases 2–3. All data from Phases 2–3 are suitable for use in model calibration.

NPDES032B_MH046078 is a permanent meter and will continue to be screened in the future.

3.7.8 NPDES033 and NPDES034 Basins

The NPDES033 and NPDES034 Basins have a combined area of 76 acres. During periods of high flow, both basins act as one CSS control facility. CSO Facility 15 stores combined flow from both basins. This CSS control facility includes 122 feet of 84-inch-diameter offline storage pipe, two HydroBrakes, two overflow weirs, and one pump station (PS 2). A weir located in MH 046-172A directs excess flow in the NPDES033 Basin to a large HydroBrake also located in MH 046-172A, and then into the offline 84-inch-diameter storage pipe associated with SPU PS 2. When the level behind the other HydroBrake in the overflow control structure at MH 046-171A for the NPDES033 Basin reaches the level of the overflow weir, overflow is conveyed to Lake Washington through the 20-inch-diameter outfall pipe. The NPDES034 Basin contributes partially separated flow from the north and south of CSO Facility 15, which is conveyed to PS 2. During high-flow periods, when the capacity of PS 2 is exceeded, flow overtops a weir in MH 046-176 and is sent to the offline, 84-inch-diameter storage pipe. When the storage pipe is full, water continues to rise above the weir until it reaches the invert of the NPDES034 Overflow Structure, which is approximately 1.4 feet above the MH 046-176 weir. Overflow from the NPDES034 Basin is conveyed to Lake Washington through a 15-inch-diameter outfall pipe.

During Phases 2–3 six temporary meters and one permanent meter monitored the flows at the NPDES033 Basin and one temporary meter and one permanent meter monitored the flows at the NPDES034 Basin. The permanent meters at both basins collect dry and wet weather flow data. Each basin reported one overflow during Phase 3 monitoring, during the October 2009 storm event. At the conclusion of Phase 3 no temporary meters remained in the NPDES033 and NPDES034 Basins. The two permanent meters will remain in place to continue monitoring for overflows.

LES33_046-120A

LES33_046-120A was a temporary monitoring site that recorded both level and velocity. The site was monitored using an ADS FlowShark meter installed on 9/12/2008, to characterize the hydrology in most of the NPDES033 Basin.

LES33_046-120A was located upstream of overflow structure in the NPDES033 Basin. The data collected during Phases 2–3 show a clear and consistent dry weather flow pattern. The meter responded well during storm events and collected reliable data. The quality of the level data was classified as "Excellent" for Phases 2–3, which is an improvement from the "Good" classification during Phase 1. All data for Phases 2–3 are suitable for model calibration.

The meter was removed on 4/1/2010 during Phase 3 monitoring, as it was determined that suitable data had been collected for the purposes of model calibration.

LES33_046-120B

LES33_046-120B was a temporary monitoring site that recorded both level and velocity. The site was monitored using an ISCO 2150 meter installed at the beginning of Phase 3 monitoring, on 10/7/2009, to gather data about the flow magnitude passing through this site and to characterize the hydrology in the NPDES033 Basin.

LES33_046-120B was located upstream of the storage pipe in CSO Facility 15. The data collected during Phase 3 showed that the site had very poor hydraulics due to upstream tap and an offset pipe (Figure 3-46). No clear relationship between level and velocity was achieved. The quality of the level data was classified as "Poor" for Phase 3. Data for Phase 3 are not suitable for model calibration.

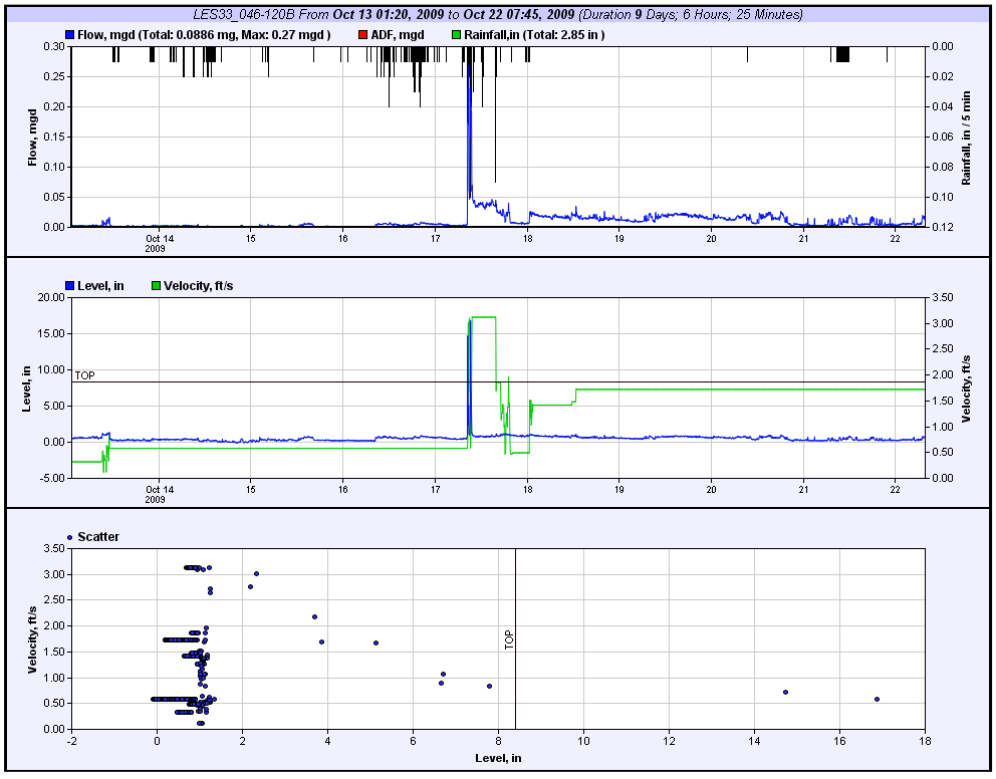

Figure 3-46. LES33_046-120B data signature collected during a Phase 3 storm event

The meter was removed on 11/19/2010 after it was determined that the site hydraulics would not allow for the collection of suitable data.

LES33_046-121A

LES33_046-121A was a temporary monitoring site that recorded both level and velocity. The site was monitored using an ISCO 2150 installed at the beginning of Phase 3 monitoring, on 10/7/2009, to gather data about the flow magnitude passing through this site and to characterize the hydrology in the NPDES033 Basin.

LES33_046-121A was located upstream of CSO Facility 15 in the NPDES033 Basin. The data collected during Phase 3 showed that the site presented very low flows that led to erratic velocity readings (Figure 3-47). The LES33_046-121A velocity probe showed poor response to storm events. The quality of the level data was classified as "Poor" for Phase 3. Data for Phase 3 should be used with caution during model calibration according to the data screening notes.

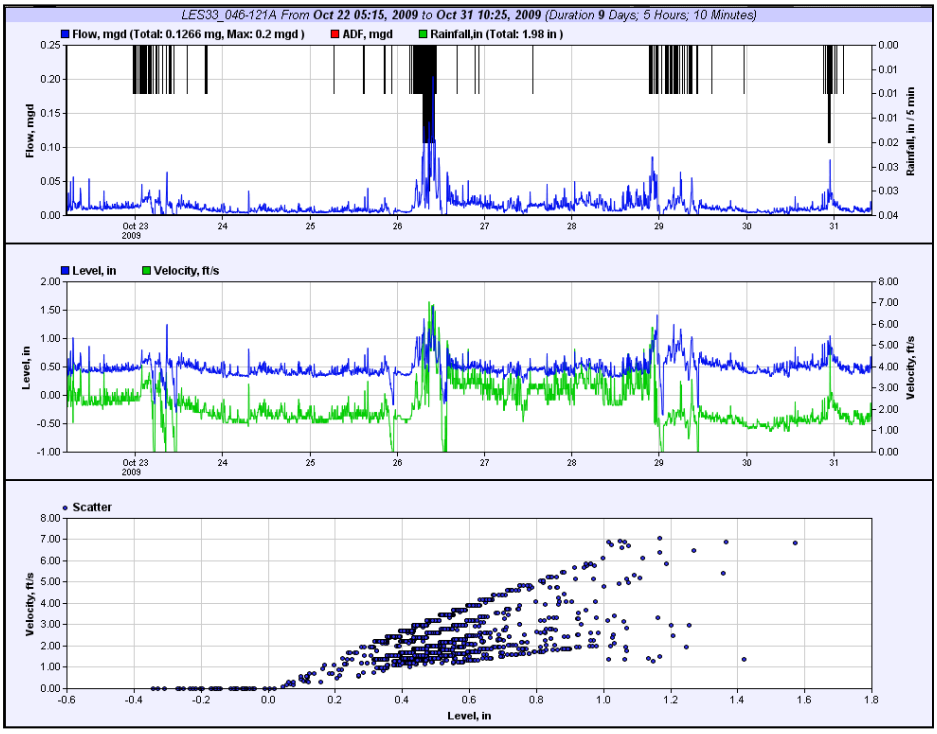

Figure 3-47. LES33_046-121A velocity probe showed poor response to storm events

The meter was removed on 11/20/2009 after it was determined that the site hydraulics would not allow for the collection of suitable data.

LES33_046-129A

LES33_046-129A was a temporary monitoring site that recorded both level and velocity. The site was monitored using an ISCO 2150 installed at the beginning of Phase 3 monitoring, on 10/7/2009, to gather data about the flow magnitude passing through this site and to characterize the hydrology in the NPDES033 Basin.

LES33_046-129A was located upstream of CSO Facility 15 in the NPDES033 Basin. The data collected during Phase 3 showed that the site presented very low flows. There was not enough water depth to cover the velocity sensor resulting in the type of step readings shown in Figure 3-48. No clear relationship between level and velocity was achieved. The quality of the level data was classified as "Poor" for Phase 3. Data for Phase 3 are not suitable for model calibration.

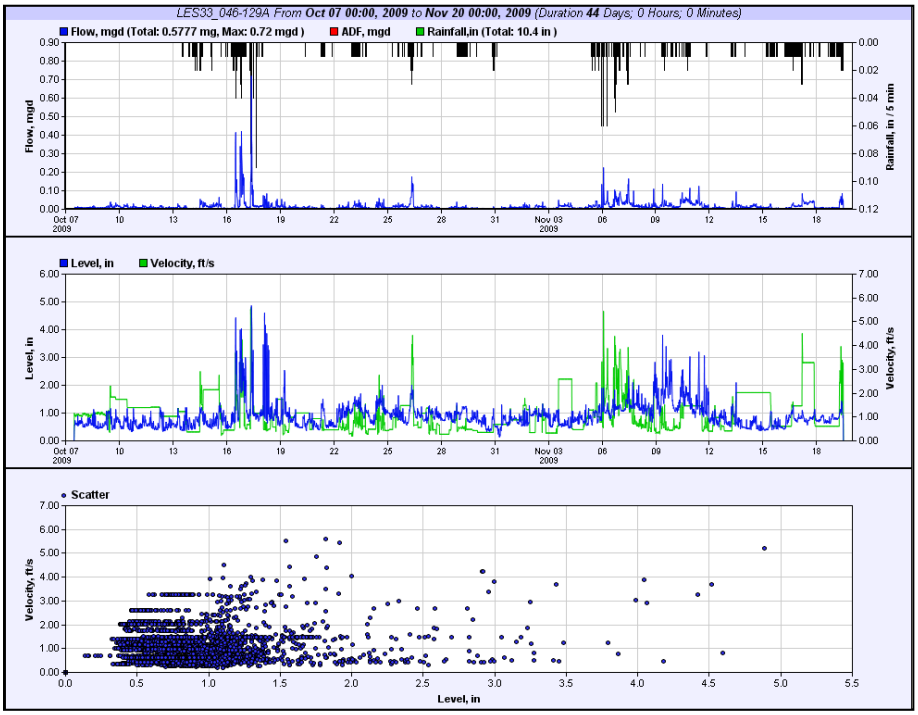

Figure 3-48. LES33_046-121A data signature; velocity readings jump erratically due to low flows

The meter was removed on 11/19/2010 after it was determined that the site hydraulics would not allow for the collection of suitable data.

LES33_046-171A

LES33_046-171A was a temporary monitoring site that recorded level and velocity. The site was monitored using an ISCO 2151 meter installed on 12/3/2009 to capture flow data at the permanent site to verify the accuracy of the permanent meter NPDES033_MH046171.

LES33_046-171A was located in the NPDES033 Basin Overflow Structure. The data at the site captured a clear and repeatable dry weather flow pattern. During storm events, the site surcharged (Figure 3-49). The data quality was classified as "Excellent" for Phase 3. All data for Phase 3 are suitable for model calibration.

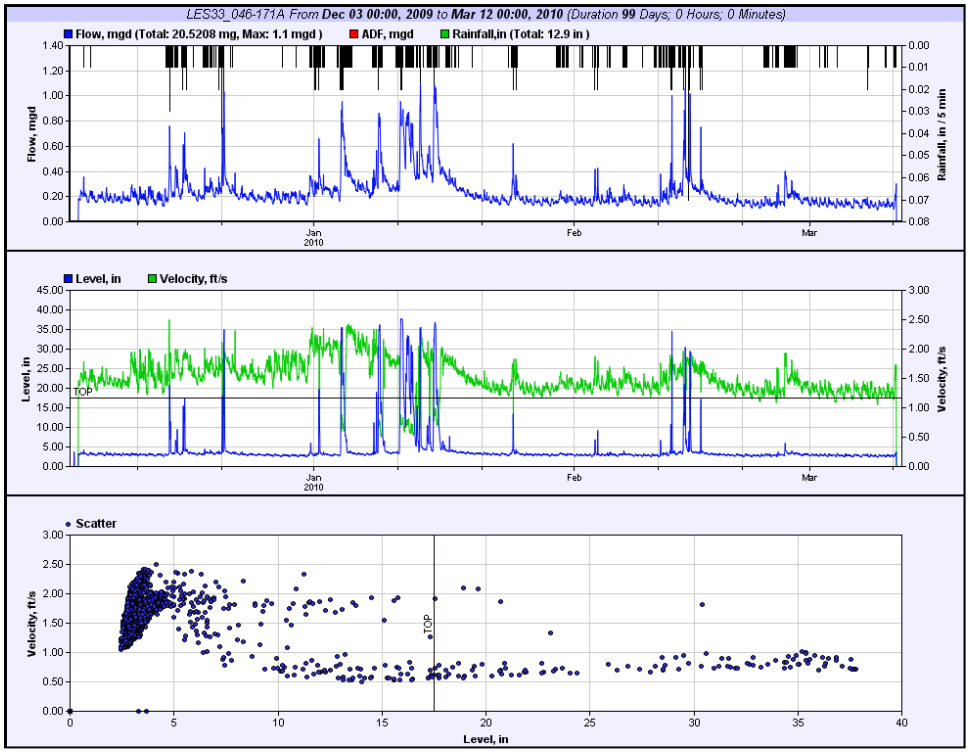

Figure 3-49. LES33_046-171A data signature for Phase 3 showed site surcharged during large storm events

The meter was removed on 3/11/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NPDES033_MH046171

NPDES033_MH046171 is a permanent monitoring site that records both level and velocity. The site is classified as a wet weather site because the addition of meter LES33_046-171 at the same location may have interfered with accurate velocity measurements; thus, only level data are finalized for the site. The site was installed on 7/30/2007 to identify and quantify CSO events occurring from the NPDES033 Basin and was initially a dry weather flow site until the addition of the temporary meter. The level data are used to calculate the volume of CSOs using a weir equation. Overflows occur when the level in NPDES033_MH046171 reaches 42.9 inches.

NPDES033_MH046171 is located at the NPDES033 Overflow Structure downstream from CSO Facility 15. The data at the site show an overestimation of flows due to overestimated velocity data. During storm events the level sensor responded well. Level data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All level data for Phases 2–3 are suitable for model calibration.

This monitoring site is a permanent site and will continue to be screened in the future.

LES33_046-173A

LES33_046-173A was a temporary monitoring site that recorded both level and velocity. The site was installed on 12/9/2009 to capture data on storage utilization and to indicate overflows from the NPDES033 Basin into the storage tank associated with PS 2.

LES33_046-173A was located in the in-line storage pipe in CSO Facility 15. The data are useful only during storm events. Velocity data were unstable but level data were consistent. The quality of the level data was classified as "Good" for Phase 3. Level data responded well to storm events and there are no data gaps during significant storms. All level data collected during Phase 3 can be used for model calibration.

The meter was removed on 3/11/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

LES33_046-174A

LES33_046-174A was a temporary monitoring site that recorded level only. The site was installed on 9/24/2008 to capture data on storage utilization in the 84-inch offline storage pipe. The meter was removed in 4/2/2009 but later reinstalled on 11/19/2009 to capture wet weather data during Phase 3.

LES33_046-174A was located upstream from PS 2 in the CSO Facility 15. Level data respond well to storm events and there are no data gaps during significant storms for the period it was installed during Phases 3 monitoring. The quality of the level data was classified as "Excellent" for Phase 3, which matches the quality classification of the data collected during Phase 1 monitoring. All level data for Phase 3 are suitable for model calibration.

The meter was removed on 3/11/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

LES34_DWF-046054

LES34_DWF-046054 is a permanent monitoring site that records both level and velocity. The site is classified as a dry weather flow site; therefore, the site was expected to provide repeatable and reliable velocity data. The site was installed on 7/30/2007 to identify and quantify CSO events occurring from the NPDES034 Basin. The level data are used to calculate the volume of CSOs using a weir equation. Overflows occur when the level in LES34_DWF-046054 reaches 27.75 inches.

LES34_DWF-046054 is located at the NPDES034 Overflow Structure, downstream from CSO Facility 15. The data at this site captured a consistent dry weather diurnal pattern. The data show a distinct relationship above about 2 inches of water. Below a level of 2 inches in the pipe, the scattergraph is wide, which indicates that the meter is picking up multiple velocities at a given depth. For wet weather flow the data captured a clear scatter. After November 2009 storm, the data signature at this site changed significantly (Figure 3-50). The data quality was classified as "Some Limitations" for Phases 2–3, whereas it was classified as "Good" for Phase 1. All data for Phases 2–3 are suitable for model calibration.

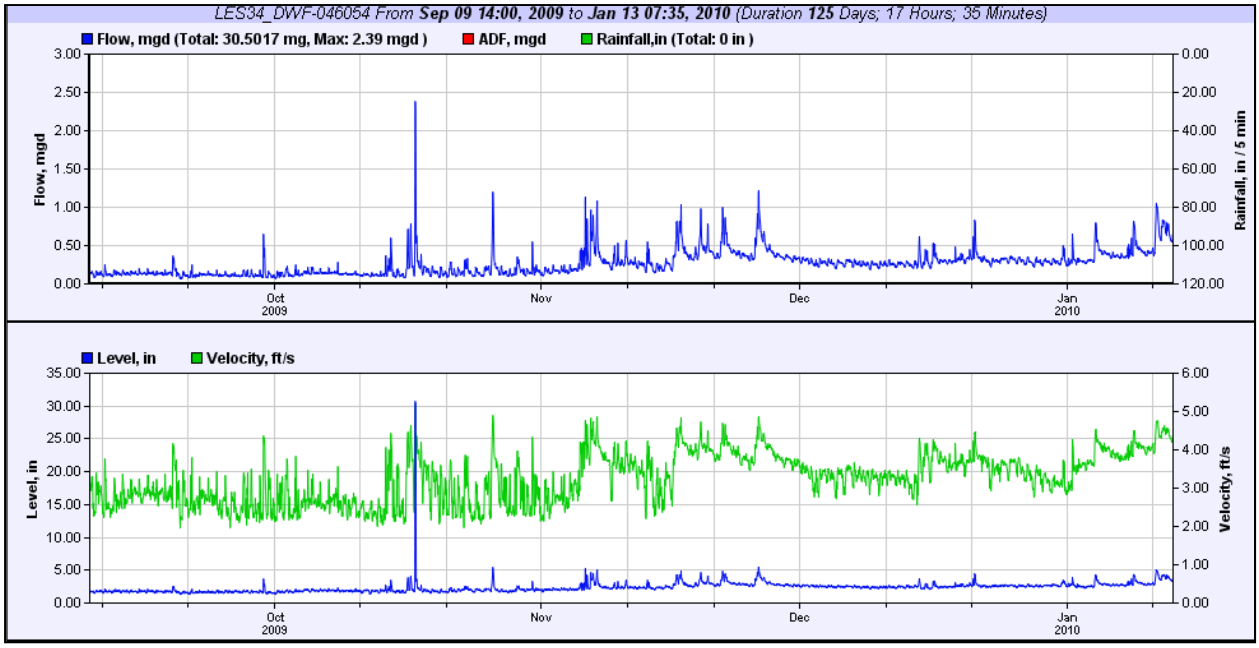

Figure 3-50. Data signature significantly changed after the November 2009 storm

This monitoring site is a permanent site and will continue to be screened in the future.

3.7.9 NPDES035 Basin

The NPDES035 Basin is a 60-acre basin with one CSS control facility. CSO Facility 14 includes 65 feet of an offline, 72-inch-diameter storage pipe, one sluice gate, one flap valve, three weirs, and one HydroBrake. The HydroBrake and an overflow structure are located in MH 046E-138 at the intersection of Lakeside Avenue South and South Massachusetts Street. A sluice gate controls the flows and during high flow will close partially to fill the storage pipe in CSO Facility 14. Once the storage pipe is filled, flows will overflow the bypass weir over the sluice gate and proceed to the overflow structure where the HydroBrake controls flow. Once the HydroBrake backs up the upstream line to the level of the overflow weir, flows are discharged into Lake Washington at the NPDES035 Outfall.

Seven temporary meters and one permanent meter monitored the NPDES035 Basin. The permanent meter is classified as a wet weather site and is used only to verify overflows; it does not monitor dry weather flows. The NPDES035 Basin did not overflow during Phases 2–3. Three of the temporary meters remained in place at the conclusion of Phase 3 monitoring for post-construction monitoring and hydraulic analysis of the sluice gate.

LES35_046-139A

LES35_046-139A was a temporary monitoring site that recorded both level and velocity. The site was installed on 1/8/2009 to characterize the sluice gate hydraulics in the NPDES035 Basin. The meter was installed to characterize the sluice gate in CSO Facility 14.

LES35_046-139A was located downstream of the sluice gate in the NPDES035 Basin. The data at the site captured a repeatable dry weather flow pattern. During storm events the meter responded well, with the exception of the December 2009 to January 2010 storm, when it failed to collect some of the data. The quality of the level and velocity data was classified as "Some Limitations" for Phases 2–3, whereas

classification for Phase 1 was "Good." Data should be used with caution during model calibration, according to screening notes.

The meter was removed on 2/4/2010 as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

LES35_046-188A

LES35_046-188A is a temporary monitoring site that records both level and velocity. Even though the meter records both level and velocity, only level will be used for model calibration. The site was monitored using an ADS FlowShark meter installed on 1/8/2009 to measure depth upstream from the sluice gate.

LES35_046-188A was installed as a dual meter with LES35_046-188B recording depth in the adjacent offline storage pipe. Most of the storms during Phases 2–3 were not successfully captured by the meter. A few storms were missed due to abnormal sluice gate behavior/operation. Data should be used with caution during model calibration according to the data screening notes.

Figure 3-51 and Figure 3-52 show the regular and abnormal data signature resulting from the sluice gate operation, respectively. The normal operation of the sluice gate is to shut to a 2-inch closing. The abnormal operation of the sluice gate had the gate shut fully closed. The November 2009 storm showed excellent response by the meter. The quality of the overall level and velocity data was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All level data for Phases 2–3 are suitable for model calibration.

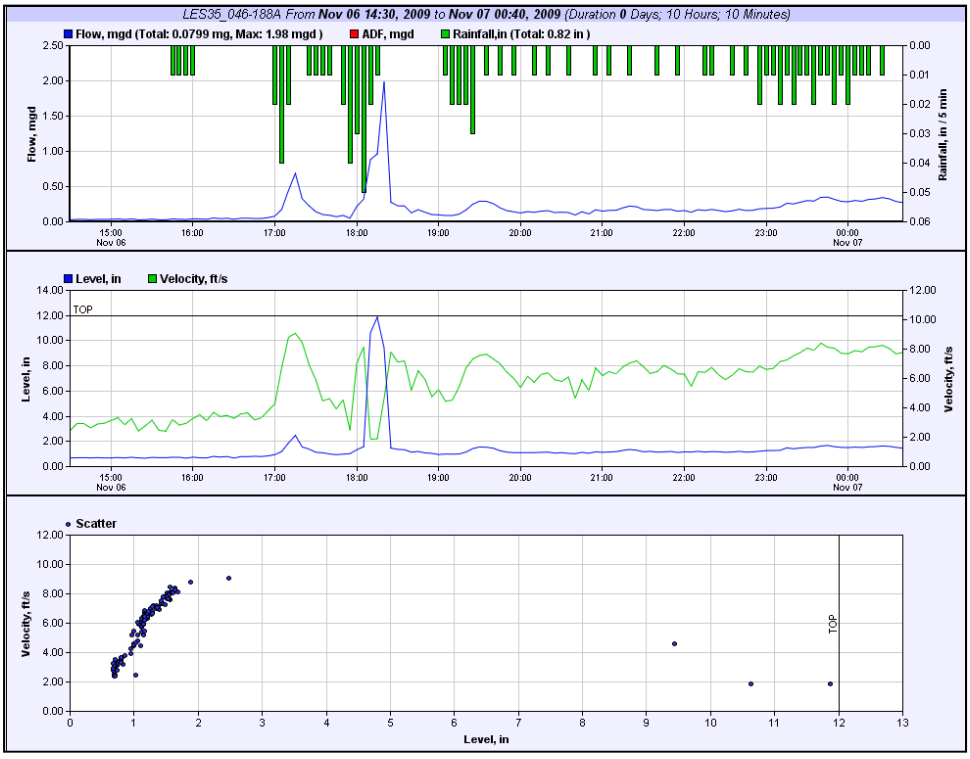

Figure 3-51. LES35_046-188A data signature for regular sluice gate operation expected at this site

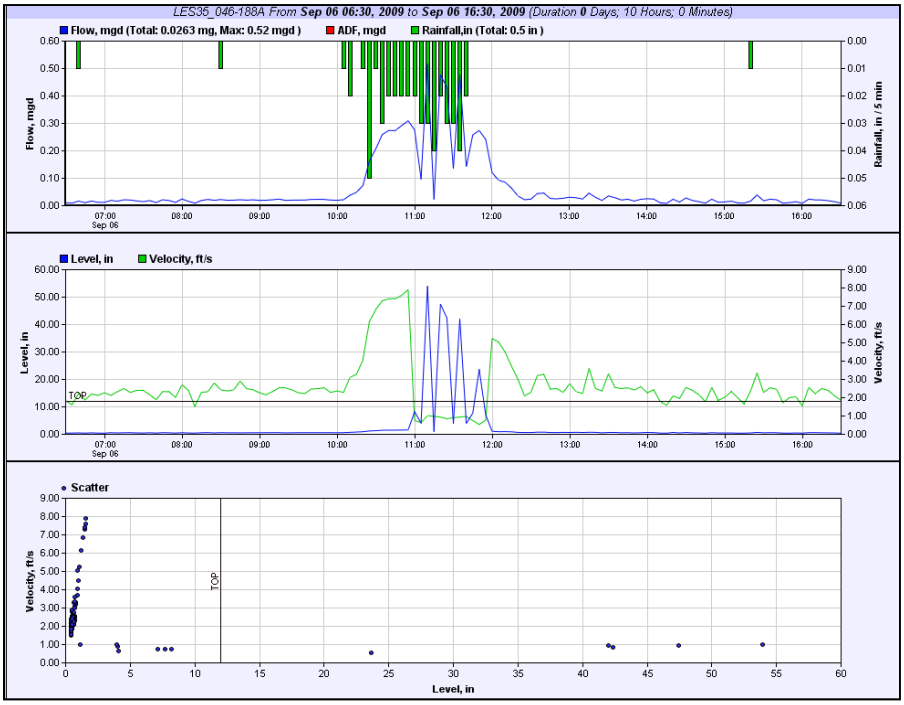

Figure 3-52. LES35_046-188A data signature for abnormal sluice gate operation

This temporary monitoring site remained installed after the completion of Phase 3 monitoring to continue collecting post-construction data to be used for hydraulic analyses.

LES35_046-188B

LES35_046-188B is a temporary monitoring site that records level only. The site was monitored using an ADS FlowShark installed on 1/8/2009 to measure depth in the storage tank in CSO Facility 14.

LES35_046-188B was installed in the offline storage pipe in the NPDES035 Basin. Level data were collected during significant storm events. The data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data are suitable for model calibration.

This temporary monitoring site remained installed after the completion of Phase 3 monitoring to continue collecting post-construction data to be used for hydraulic analyses.

LES35_046E-017A

LES35_046E-017A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/19/2008 to characterize the hydrology of the NPDES035 Basin.

LES35_046E-017A was located upstream of the sluice gate in CSO Facility 14. The data at the site captured a clear and consistent dry weather flow pattern. The meter responded well to storm events. The data quality was classified as "Good" for Phases 2–3, whereas the Phase 1 classification was "Excellent." This is due to lower resolution of the scattergraph than that collected during Phase 1. All data for Phases 2–3 are suitable for model calibration.

The meter was removed on 2/4/2010 during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

LES35_046E-026A

LES35_046E-026A is a temporary monitoring site that records level and velocity. The site was installed on 9/12/2008 to measure the flows from the NPDES035 Basin and the flows leaving the NPDES036 Basin. The data will also be used to characterize the HydroBrake in the NPDES035 Basin.

LES35_046E-026A is located downstream from the HydroBrake in the NPDES035 Basin. The meter was removed on 9/18/2009 for site cleaning and reinstalled on 9/22/2009. Flow prior to 9/22/2009 is overestimated due to silt sedimentation, which increases the apparent depth. After 9/22/2009 the replacement of the meter allowed for the capturing of data with a clear and repeatable dry weather flow pattern. During the remainder of the storm events in Phase 3, the meter responded well. The quality of the level and velocity data was classified as "Good" for Phase 3 and "Poor" for Phase 2. The quality classification for data collected during Phase 1 was "Poor." All data for Phase 3 are suitable for model calibration.

The meter was removed on 6/2/2010 soon after the completion of Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

LES35_046E-031A

LES35_046-031A was a temporary monitoring site that recorded both level and velocity. The site was monitored using an ADS FlowShark Pulse installed on 10/6/2009 to verify the flows that were collected at the permanent site at MH 046E-138.

LES35_046-031A was located upstream from the HydroBrake in the NPDES035 Basin. Dry weather flows were affected by silt sedimentation, which caused velocity dropouts as shown in Figure 3-53. The meter responded well to the October 2009 storm event but not to the rest of Phase 3 storm events. Stantec edited the data based on the data signature of storms prior to November 2009. The quality of the level and velocity data was classified as "Some Limitations" for Phases 2–3. Data for Phases 2–3 are not suitable for model calibration.

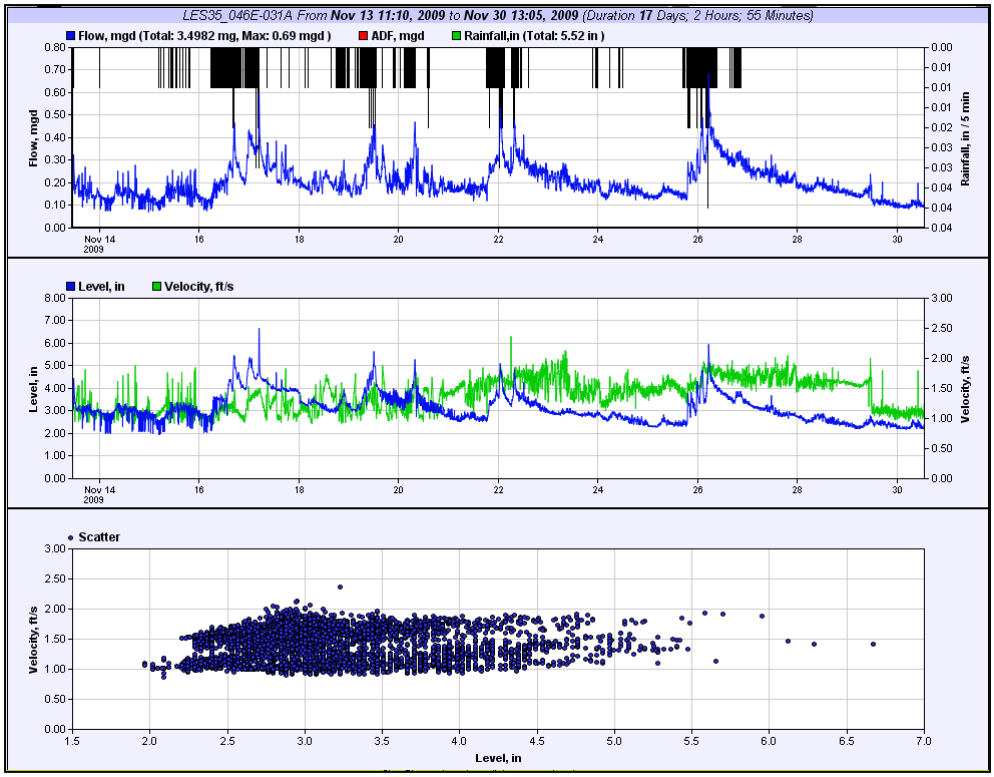

Figure 3-53. LES35_046E-031 data signature; velocity appears affected by siltation problems

The meter was removed on 2/4/2010 as it was determined that no reliable data could be collected due to site hydraulics.

LES35_046E-138A

LES35_046E-138A was a temporary monitoring site that recorded level above the HydroBrake at the overflow site in the NPDES035 Basin. Because the permanent monitor at this site is not at the same elevation as the HydroBrake, this site was installed on 4/6/2009 to better characterize the level just upstream from the HydroBrake.

LES35_046E-138A was mounted on the NPDES035 Overflow Structure 11 inches above the low flow water level. When the meter recorded flows of 26.44 inches, flows were overtopping the weir at the permanent site. The quality of the level data was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for use in model calibration.

On 10/9/2009, the cleanout gate on the HydroBrake was permanently opened to simplify the understanding of this structure (Figure 3-54).

Figure 3-54. LES35_046E-138 HydroBrake cleanout gate open

The meter was removed on 2/4/2010 as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NPDES035_MH046E138

NPDES035_MH046E138 is a permanent monitoring site that records level. The site was installed on 7/26/2007 to identify and quantify CSO events occurring from the NPDES035 Basin. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. Overflows occur when the level in NPDES035_MH046E138 reaches 20.04 inches.

NPDES035_MH046E138 is located at the NPDES035 Overflow Structure downstream from CSO Facility 14. The data at the site captured a consistent dry weather diurnal pattern. During storm events the meter responded well. Level data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All level data are suitable for model calibration.

This monitoring site is a permanent site and will continue to be screened in the future.

3.7.10 NPDES036 Basin

The NPDES036 Basin, located in the southern part of the Leschi Basin, is approximately 45 acres in area. This basin has one CSS control facility. CSO Facility 13 includes 1,200 feet of an in-line, 16-inch-diameter storage pipe (the original drainage for the Basin), one HydroBrake, and an overflow structure.

Three temporary meters and one permanent meter monitored the basin. The permanent meter is classified as a wet weather site and is used only to verify overflows; it does not monitor dry weather flows. The NPDES036 Basin overflowed once during Phases 2–3, in October 2009. All temporary meters were removed prior to the conclusion of Phase 3.

LES36_046E-044A

LES36_046E-044A was a temporary monitoring site that recorded both level and velocity in an area that under low flow conditions does not contribute flows to the NPDES036 Basin. The site was monitored using an ISCO 2150 meter installed on 9/12/2008 to characterize flows and to measure levels that overtop the weir, sending flow to the NPDES036 Basin. The meter was removed toward the end of Phase 2 monitoring after the September 2009 storm event, but was reinstalled on 11/19/2009 to continue collecting data during the second wet weather season.

LES36_046E-044A was located in an 8-inch pipe having just over 900 feet of upstream pipe length. A small weir about 2.5 inches high connects this small system to the NPDES036 Basin. The meter did not capture a clear and consistent pattern during Phases 2 and 3 monitoring (Figure 3-55). Due to the site hydraulics, the velocity data captured is "Poor" and should not be used for modeling. The level data responded well to rainfall. The quality of the level data was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. Level data can be used for model calibration.

The meter was removed on 3/11/2010 during Phase 3 monitoring as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

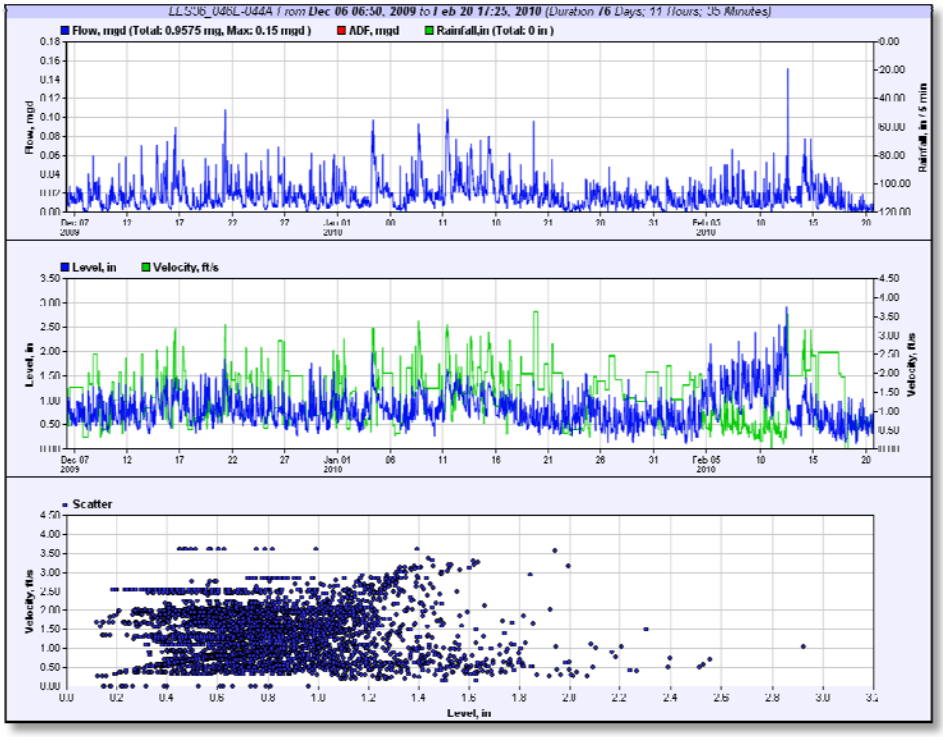

Figure 3-55. LES36_046E-044 data signature; velocity data poor due to site hydraulics, level data are good

LES36_046E-141A

LES36_046E-141A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/12/2008 to characterize the HydroBrake in the NPDES036 Basin. Because of the failure to locate a suitable hydrology monitoring site upstream from the HydroBrake conducive to collection of accurate data, this meter will also be used together with depth recorded at the upstream meter to characterize the basin hydrology.

LES36_046E-141A was located downstream from the HydroBrake in the NPDES036 Basin. Velocity dropouts occurred regularly but were edited during data finalization. The data captured periods of suitable dry weather flow. The quality of the level and velocity data was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for model calibration purposes.

The meter was removed on 2/5/2010 as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

LES36_046E-142A

LES36_046E-142A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/12/2009 to characterize the HydroBrake performance in the NPDES036 Basin, providing depth upstream of the HydroBrake in the storage pipe. The depth data at this location served as the critical parameter for HydroBrake characterization.

LES36_046E-142A was located upstream from the HydroBrake in the NPDES036 Basin. The meter at this location was replaced several times before Phase 2 monitoring. An ISCO 2150 meter was used throughout Phases 2–3. The site presented low flows and debris accumulation. Storm events in which the HydroBrake was clogged should not be used for model calibration. During storm events, the site was surcharged (Figure 3-56). The quality of the depth data was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. Velocity data are not considered suitable.

The meter was removed on 2/4/2010 after sufficient suitable data had been collected for calibration purposes.

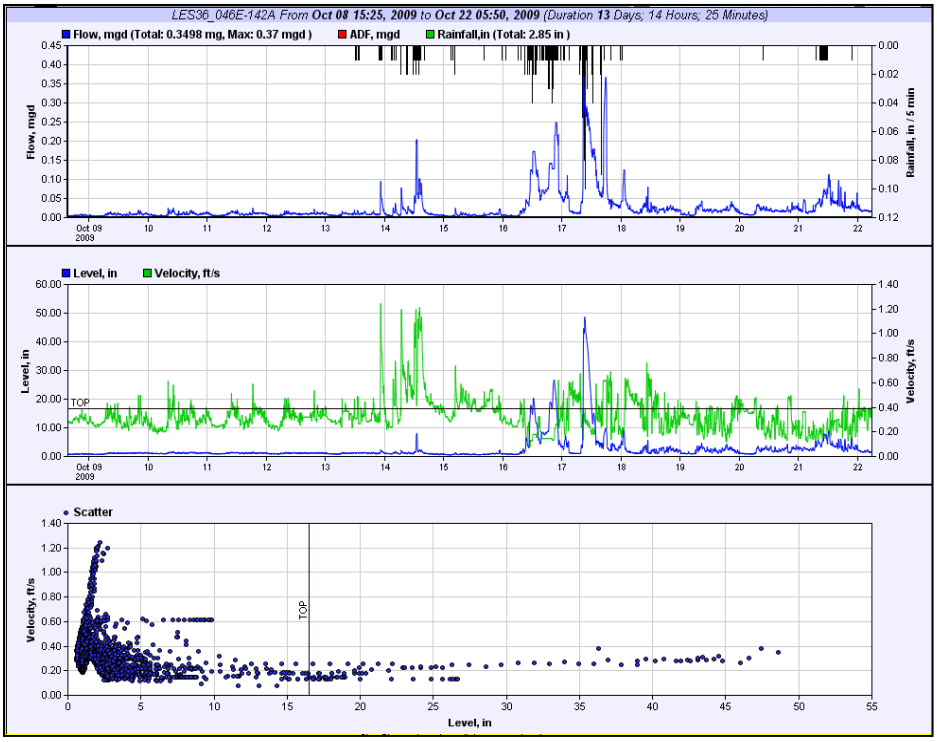

Figure 3-56. LES36_046E-142A surcharge signature during storm events

NPDES036_MH046E150

NPDES036_MH046E150 is a permanent monitoring site that records level only. The site was initially installed on 7/26/2007 and was later removed and reinstalled in February 2009, prior to the end of Phase 1. The site is classified as a wet weather site because it is not expected to provide high-quality velocity data; thus, only level data are finalized for the site. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. Overflows occur when the level in NPDES036_MH046E150 reaches 6.72 inches.

NPDES036_MH046E150 is located at the NPDES036 Overflow Structure. During dry weather flows, the site does not experience any flow. During storm events, the downstream HydroBrake at MH 046E-142 restricts and controls flows from the NPDES036 Basin to the downstream system. When storage is exceeded at the NPDES036 Basin, flow is diverted over the weir to the NPDES036 Outfall. A fold in the pipe liner caused a puddle under the level sensor. Therefore, the quality of the level data was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. The level data have a consistent repeatable pattern and lack of data gaps, and are suitable for use in model calibration. All data for Phases 2–3 are suitable for model calibration.

This monitoring site is a permanent site and will continue to be screened in the future.

3.7.11 Meters outside Leschi Basin

No peripheral meters remained installed after the conclusion of Phase 1 monitoring; therefore, no data were monitored during Phases 2–3 of the monitoring program.

3.7.12 Combined Sewer Overflows

ADS reported that 27 CSOs occurred in the Leschi Basin during Phases 2–3. Table 3-8 lists the CSOs reported during the monitoring period.

Table 3-8. 2009–2010 Combined Sewer Overflows in Leschi Basin
6/1/2009 through 5/31/2010

NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
26	--		--
27	--		--
28	9/6/2009	0:30	51.27
	9/7/2009	0:05	213.29
	9/19/2009	0:30	0.0
	10/16/2009	13:29	8,442.57
	11/6/2009	0:08	894.19
29	10/17/2009	0:18	2,863
30	--		--
31	9/6/2009	1:05	23,222
	10/17/2009	3:20	58,753
	10/26/2009	2:41	42,144
	11/6/2009	33:40	41,315
	11/16/2009	12:10	16,240
	11/19/2009	0:58	4,544
	11/22/2009	1:23	14,810
	11/26/2009	6:46	81,781
	1/11/2010	5:38	88,313
	1/13/2010	2:20	17,552
	1/15/2010	5:35	57,641
	3/29/2010	0:28	3,735
	4/21/2010	2:15	106

Table 3-8. 2009–2010 Combined Sewer Overflows in Leschi Basin 6/1/2009 through 5/31/2010			
NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
	5/23/2010	1:05	15,395
32(A)	10/17/2009	0:20	7,995
32(B)	9/6/2009	0:40	5,250
	10/17/2009	2:18	32,028
	11/26/2009	2:42	12,642
33	10/17/2009	0:05	7,875
34	10/17/2009	0:32	8,590
35	--	-	-
36	10/17/2009	1:20	37,666

Figure 3-57 shows the maximum water level recorded by ADS at each of the overflow structures in the basin as a percentage of the weir height.

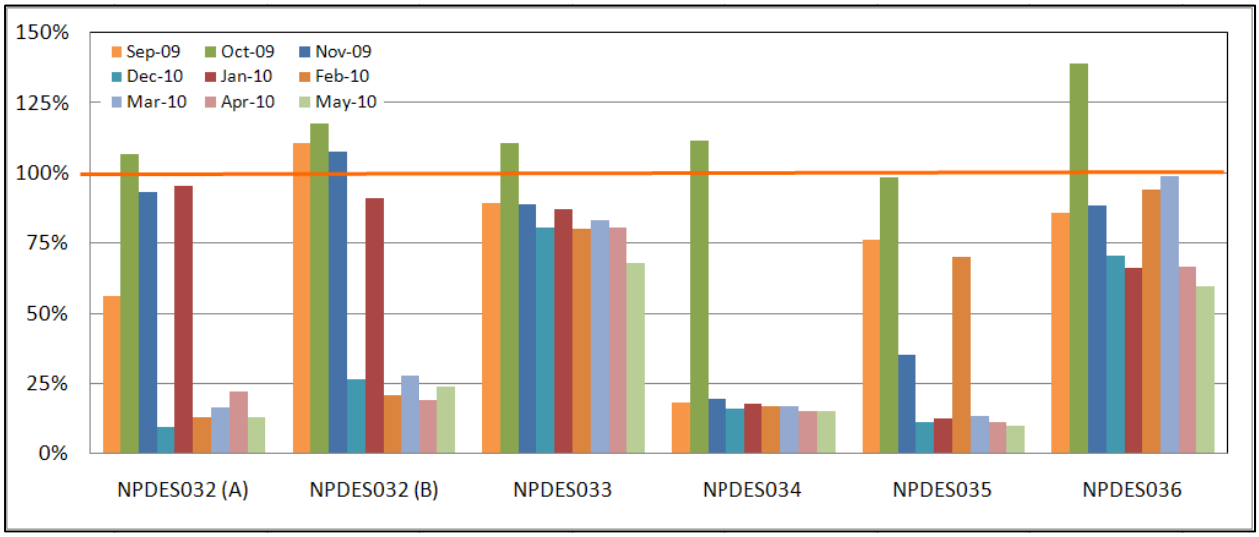

Figure 3-57. Maximum recorded levels over weir heights in Leschi Basin for major events

3.7.13 Facility Operations

Eleven permitted outfalls are located in Leschi Basin; all discharge excess combined sewer flows to Lake Washington. Eleven CSS control facilities are located within the Leschi Basin as well. The CSS facilities in the NPDES026, NPDES027, NPDES028, NPDES031 Basins, and NPDES032(B) Subcatchment consist only of overflow structures with no storage pipes or HydroBrakes. The CSS control facilities in the NPDES029, NPDES033, NPDES034, NPDES036 Basins and the NPDES032(A) Subcatchment consist of an overflow structure, storage, and a HydroBrake. The CSS control facilities in the NPDES030 and NPDES035 Basins consist of an overflow structure, storage, HydroBrake, and sluice gate.

Two sluice gates, which are retrofit projects that were once HydroBrakes, are located upstream of the NPDES030 and NPDES035 Overflow Structures. HydroBrake characterization curves for the Leschi Basin were created using data collected during major storm events; these facilities are further described below.

Figure 3-58 shows the estimated storage utilization at all the Leschi NPDES basins that have storage pipes. Storage utilization was estimated by using the maximum depth recorded at the closest monitoring locations within these basins. The water depth was compared to the invert level and crown level of the storage pipe in order to estimate the percentage of the volume that was used. As depicted in Figure 3-57 and Figure 3-58, during all overflow events at these NPDES basins, the storage was fully utilized, with the exception of the storage at NPDES033 and NPDES034, where there may be opportunity for retrofit projects. The meter used to calculate storage usage in the NPDES033 and NPDES034 Basins was not installed for the September and October 2009 storm events.

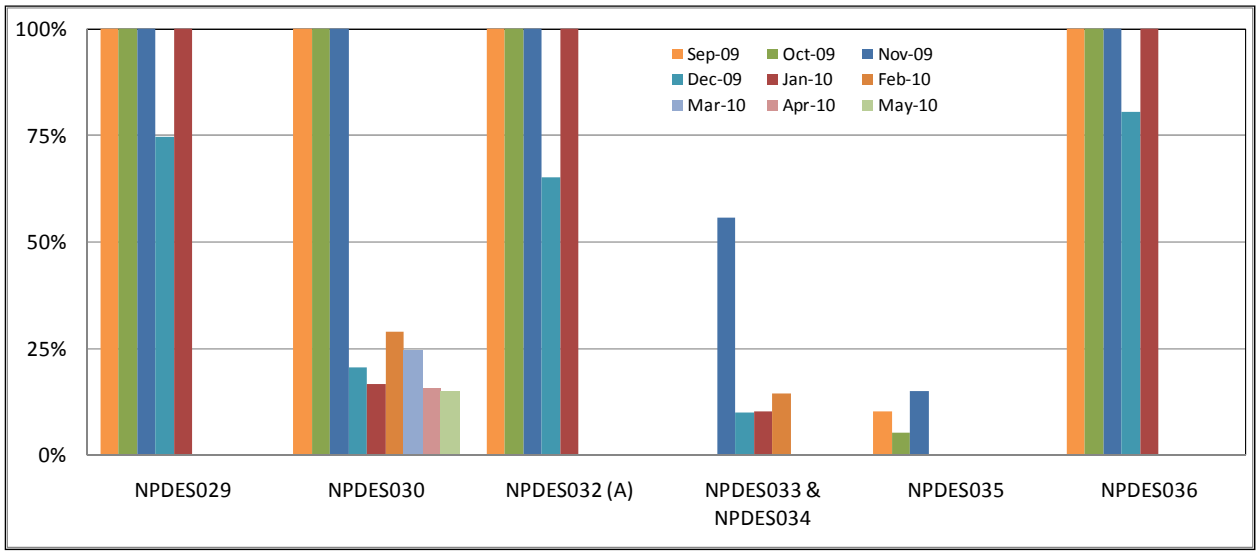

Figure 3-58. Storage utilization for the Leschi Basin

NPDES026 Basin

The NPDES026 Basin includes only one overflow structure. Overflows from this partially separated basin are directed to Lake Washington when flow depths exceed the side-cast weir elevation located just east of Denny-Blaine Place in MH 038-081. The highest recorded level at the 11.4-inch-high weir was 6.47 inches during the October 2009 storm event (less than 60 percent of the weir height). No overflows were recorded in the monitoring period. There is no storage in the NPDES026 Basin.

NPDES027 Basin

The NPDES027 Basin includes only one overflow structure. An overflow weir designed to protect the King County East Pine pump station from flooding is located in MH 042-269, just east of the pump station. If the capacity of the pump station is exceeded, the weir allows overflows to discharge into a 24-inch-diameter outfall pipe (NPDES027 Outfall). The highest recorded level at the 27.72-inch-high weir was 16.38 inches during the October 2009 storm event (less than 60 percent of the weir height). No overflows were observed during the monitoring period. There is no storage in the NPDES027 Basin. Both SPU and King County have permits for this outfall.

NPDES028 Basin

The NPDES028 Basin includes only one overflow structure, a side-cast overflow weir in MH 042-275 that conveys overflows from the basin to Lake Washington through a 15-inch-diameter outfall pipe. During Phases 1 and 2 and the beginning of Phase 3 the weir height was 13.63 inches. In December 2009, the weir height was raised to 16.38 inches. The highest recorded level recorded at this site was 19.62 inches during the October 2009 storm; the NDPES028 Basin overflowed during this storm event.

NPDES029 Basin

One CSS control facility is located within the NPDES029 Basin. CSO Facility 18 includes 300 feet of the original sewer system used as an in-line, 18-inch-diameter storage pipe that was fully utilized during each of the major storm events during the Phases 2–3 monitoring period. The HydroBrake in MH 042-302 at the intersection of Lake Washington Boulevard and Fullerton Avenue is located at the downstream end of the storage pipe. Flows pass through the HydroBrake, through the overflow structure (MH 042-303) to an 8-inch-diameter pipe, and eventually to the East Pine Street pump station through a 21-inch-diameter pipe that runs along Lake Washington.

Level data collected at MH 042-302 and flow data collected at the downstream permanent meter characterize the HydroBrake. Figure 3-59 shows the HydroBrake characterization. Three curves that represent behavior when the downstream outlet from the HydroBrake is submerged, not submerged, and then both submerged and overflowing are shown. The fourth curve, from the October 2009 storm event, was not used as the data collected from the meter at MH 042-302 were poor. The model curve was developed relying on the storm data from the November 2009 storm event as it was determined to be the most representative storm for the basin.

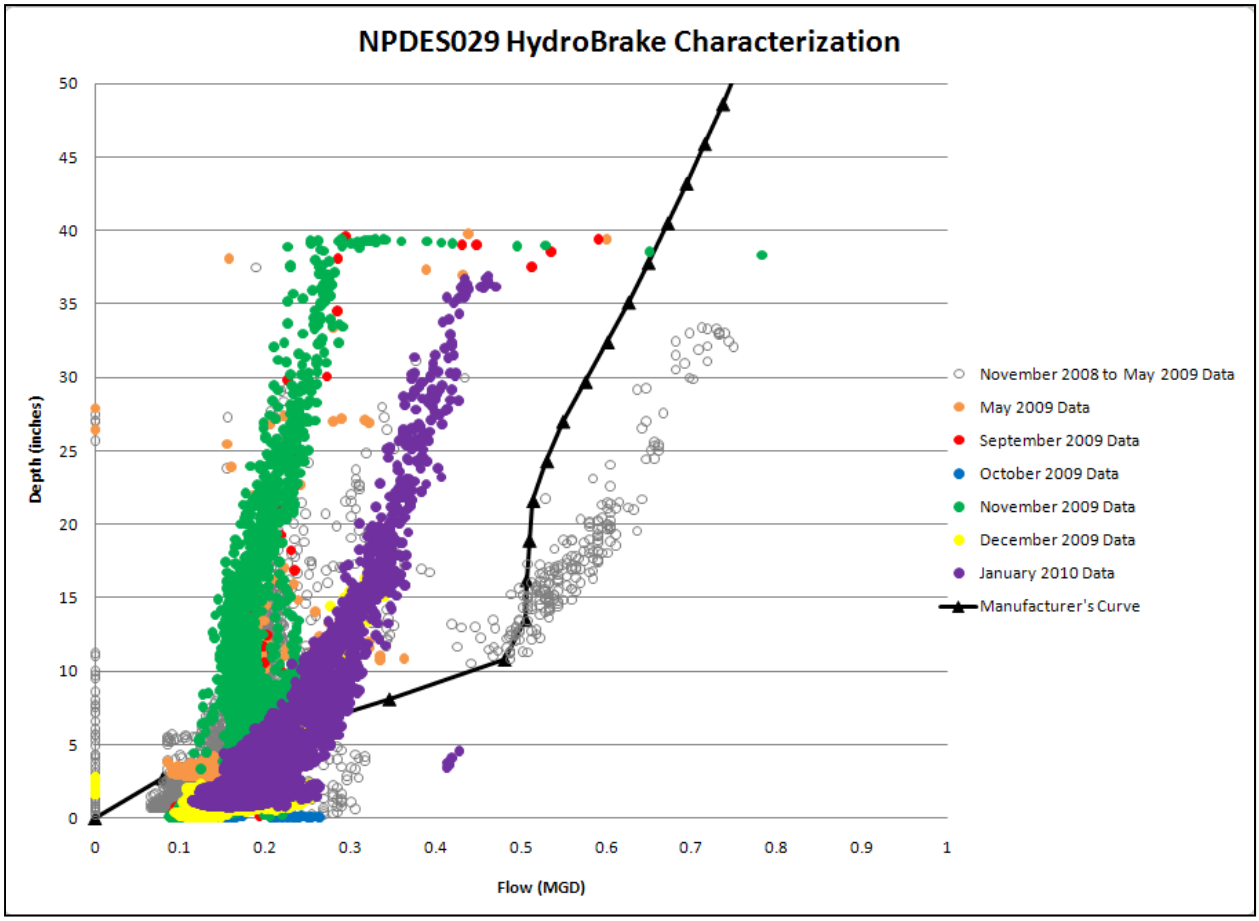

Figure 3-59. NPDES029 Basin HydroBrake characterization

Flows pass through the HydroBrake, then through the overflow maintenance hole (MH 042-303) to an 8-inch-diameter pipe, and eventually to the East Pine Street pump station through the 21-inch-diameter Leschi trunk sewer that runs along Lake Washington. The highest recorded level on the 8.5-inch-high weir was 10.37 inches during the October 2009 storm event. When the capacity of the HydroBrake is exceeded, flows are stored in the in-line storage pipes. The in-line storage pipes upstream from the HydroBrake were fully utilized during all three major storm events. A weir in MH 042-325 diverts flow around the HydroBrake when storage is filled to the overflow weir located in MH 042-303. The level in the Leschi trunk sewer was observed to be above the overflow weir during overflow conditions.

NPDES030 Basin

Under normal operating conditions, low flows in the western part of the NDPES030 Basin are directed to the north and away from the NPDES030 Outfall. During periods of extremely high flow, wastewater might discharge over weirs located in MH 041-386 and MH 042-008 to the east into the NPDES030 Basin; however, this was not observed during any of the monitoring phases.

One CSS control facility is located in the NPDES030 Basin. CSO Facility 17 includes 250 feet of an in-line, 42-inch-diameter storage pipe. A sluice gate in MH 042-205 at the intersection of Lake Washington Boulevard and East Alder Street is located at the downstream end of the storage pipe and upstream from the overflow weir. Flow passes under the sluice gate, through the overflow MH 042-322 to a 10-inch-diameter pipe, and eventually to the East Pine Street pump station through the 21-inch-diameter Leschi trunk sewer that runs along Lake Washington.

When a downstream control is activated in MH 042-206, the sluice gate shuts to an opening of 2.5 inches and stores flow in the in-line storage pipe. A weir in MH 042-324 diverts flow around the sluice gate when storage is filled to the overflow weir located in MH 042-322. During the monitoring period, the highest level recorded on the 12.36-inch-high weir was 11.47 inches during the November 2009 storm event.

NPDES031 Basin

Overflows from this partially separated basin are directed to Lake Washington when flow depths exceed the side-cast weir elevation located just north of South Leschi Place in MH 046-033. The level in the Leschi trunk sewer was observed to be higher than the NPDES031 Basin overflow weir during overflow conditions. No storage, pump stations, or HydroBrakes are located in the NPDES031 Basin. The highest recorded level on the 9.63-inch-high weir was 10.87 inches during the October 2009 storm event.

NPDES032 Basin

The NPDES032 Basin consists of two hydraulically separate subcatchments that share one outfall. The first subcatchment, NPDES032(A), comprises the majority of area and flow, and is approximately 39 acres. The second subcatchment, NPDES032(B), has a contributing area of less than 1 acre and contains only three houses. CSO Facility 16 is a control facility located in the NPDES032(A) Subcatchment. The facility contains three control structures: a 6,000-gallon in-line storage tank, a HydroBrake, and one overflow weir. Meters in MH 046-156 and MH 046-163 characterize the HydroBrake in NPDES032(A). The HydroBrake experiences reverse flow from the Leschi trunk sewer. Therefore, the HydroBrake will be modeled as an orifice.

Low flows in the NDPES032(B) Subcatchment are directed to the 18-inch-diameter Leschi trunk sewer that conveys flows to the East Pine Street pump station. Overflows are directed over the overflow weir in MH 046-078 to the 12-inch-diameter outfall pipe that is shared with the NPDES032(A) Subcatchment. When the capacity of the HydroBrake is exceeded, flows are stored in the storage pipe between the HydroBrake and the NPDES032(A) Overflow Structure. The storage pipe was fully utilized in the Phases 2–3 storm events. A weir in MH 046-157 at the upstream end of the storage discharges to the 12-inch-diameter outfall pipe that is shared with the NPDES032(B) overflow structure. This highest recorded level on the 32.75-inch-high weir was 34.94 inches during the October 2009 storm event.

NPDES034 and NPDES033 Basins

During periods of high flow, CSO Facility 15 acts as the control facility for both the NPDES033 and NPDES034 Basins. CSO Facility 15 is able to store excess flow from these basins. CSO Facility 15 includes 122 feet of 84-inch-diameter storage pipe, two HydroBrakes, an offline storage pipe, and a pump station (PS 2).

During dry periods, wastewater flows from the NPDES033 Basin (conveyed along Parkland Place) enter a HydroBrake in MH 046-171 and continue through it, bypassing the pump station. Downstream of the HydroBrake, in MH 046-050, flow combines with the discharge from SPU PS 2, which collects the flows from the NPDES034 Basin. These combined flows are then conveyed through an 18-inch-diameter sanitary mainline to the north and eventually to the East Pine Street pump station.

During storm events, a weir located in MH 046-172 directs excess flow in the NPDES033 Basin to a large HydroBrake (also located in MH 046-172) and then into the offline, 84-inch-diameter storage pipe associated with SPU PS 2. Eventually SPU PS 2 pumps out the stored flow. When the level behind the downstream HydroBrake (MH 046-171) reaches the level of the NPDES033 Basin Overflow Structure (also located in MH 046-171 and approximately 0.3 foot higher than the weir elevation in MH 046-172), overflow is conveyed to Lake Washington through the 20-inch-diameter outfall pipe.

The highest recorded level upstream from the overflow weir at the NPDES033 Basin was 47.5 inches on the 42.96-inch-high weir. The permanent meter (NPDES033_MH046171), the temporary ISCO meter at MH

046-171, and temporary meter at MH 046-050 characterize the HydroBrake at MH 046-171. Because the ISCO meter was not installed at the same time as the temporary meter in MH 046-050, the ISCO meter was used to correct the data at the permanent site that was thought to be overestimated. Figure 3-60 shows the HydroBrake characterization based on the flow monitoring data collected during Phase 1. No additional data were collected during Phases 2–3 for the characterization of this HydroBrake.

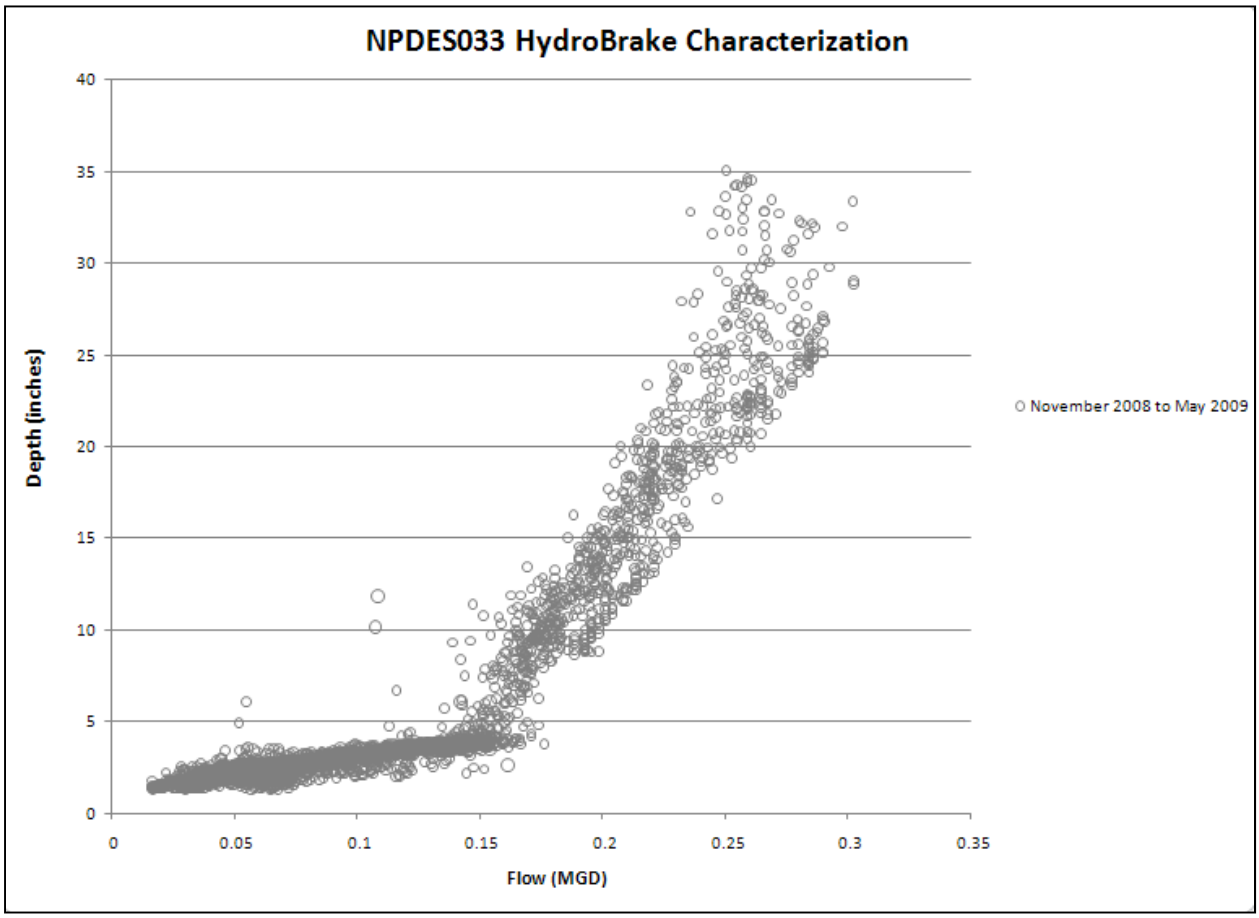

Figure 3-60. NPDES033 Basin HydroBrake characterization

The NPDES034 Basin contributes partially separated flow from the north and south of CSO Facility 15, which is conveyed to SPU PS 2. The 8-inch-diameter pump station force main discharges to an 18-inch-diameter sanitary mainline (at the same location as the NPDES033 Basin low flows, MH 046-050). During high-flow periods, when the capacity of PS 2 is exceeded, flow overtops a weir in MH 046-176 and is sent to the offline, 84-inch-diameter storage pipe. During Phases 2–3, the storage pipe was not fully utilized, even though an overflow was reported during October 2009. When the storage pipe is full, water continues to rise above the weir until it reaches the invert of the NPDES034 Outfall pipe, which is approximately 1 foot above the MH 046-176 weir. Overflow from the NPDES034 Basin is conveyed to Lake Washington through a 16-inch-diameter outfall pipe. The highest recorded level upstream from the overflow weir at 046-054 in the NPDES034 Basin was 47.5 inches during the October 2009 storm event.

SCADA Data: SPU Pump Station 2

SPU PS 2 is located at 901 Lakeside Drive South in the NPDES034 Basin. The pump station collects flows from the NPDES036, NPDES035, and NPDES034 Basins, and storm flows from the NPDES033 Basin (dry weather flows from NPDES033 bypass the pump station). The station pumps flows to the NPDES032 Basin to the north via a force main (approximately 66 feet long by 8 inches in diameter). The station includes two pumps.

SPU monitors PS 2 via its SCADA system, which records wet well level and pump run times. Data are available at 90- to 120-second resolution. The SCADA data will be used in model calibration to determine the pump switch on and off levels. The data collected were consistent through the monitoring period. The data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for model calibration.

NPDES035 Basin

One CSS control facility is located within the NPDES035 Basin. CSO Facility 14 includes a HydroBrake, a sluice gate, and a storage pipe. Under normal dry weather operating conditions, flow passes through the sluice gate, located in MH 046-188, and proceeds down to Lakeside Avenue South, then south toward the lower part of the NPDES035 Basin located at South Massachusetts Street. During periods of wet weather flow when the sluice gate in MH 046-188 is shut to an opening of 2 inches, excess flow is diverted over a weir to the offline storage pipe. If the storage tank fills completely, backwater behind the sluice gate continues to rise until it reaches a bypass weir over the sluice gate approximately 2 feet higher than the overflow weir to the storage. Flow over this bypass weir is routed over the sluice gate and conveyed to the lower part of CSO Facility 14 and subsequently to the NPDES035 Basin Overflow Structure.

The offline, 72-inch-diameter storage pipe also includes a sluice gate and a flap gate. The sluice gate always remains closed and is used for maintenance and emergencies (for example, if the flap gate gets stuck in the closed position). The flap gate allows for the release of flow out of the storage pipe when conditions downstream allow (i.e., there is a positive head out of the storage pipe). During the monitoring period, the highest level recorded in the storage was 54.93 inches during the January 2010 storm event.

The lower part of CSO Facility 14 includes a HydroBrake and the overflow weir. The HydroBrake cleanout gate was opened in October 2009 and left open, allowing it to function as an orifice.

NPDES036 Basin

The NPDES036 Basin has one CSS control facility: CSO Facility 13 includes 1,200 feet of an in-line, 16-inch-diameter storage pipe. A HydroBrake in MH 046E-142 is located at the downstream end of the storage pipe. Dry weather flows pass through the HydroBrake and continue to the north through the 16-inch-diameter pipe along Lakeside Avenue South. The HydroBrake causes flow to back up and be stored in the in-line storage pipe during larger storm events. During all major storm events of Phases 2–3, with the exception of the December storm, 100 percent of the storage was utilized. A weir in MH 046E-150 diverts flow to the 21-inch-diameter outfall pipe to Lake Washington. The highest level recorded over the 6.72-inch weir was 9.33 inches during the October 2009 storm event.

Level data collected at MH 046E-142 and flow data collected at the MH 046E-141 were used to characterize HydroBrake 046E-142. Figure 3-61 depicts several distinct curves for the different storm events. The data to the left of the manufacturer's curve occurred when the HydroBrake was clogged. The data suggest that the HydroBrake is very sensitive to clogging and thus acts differently depending on the amount of debris buildup. Curves developed from all data groups potentially will be used during model calibration.

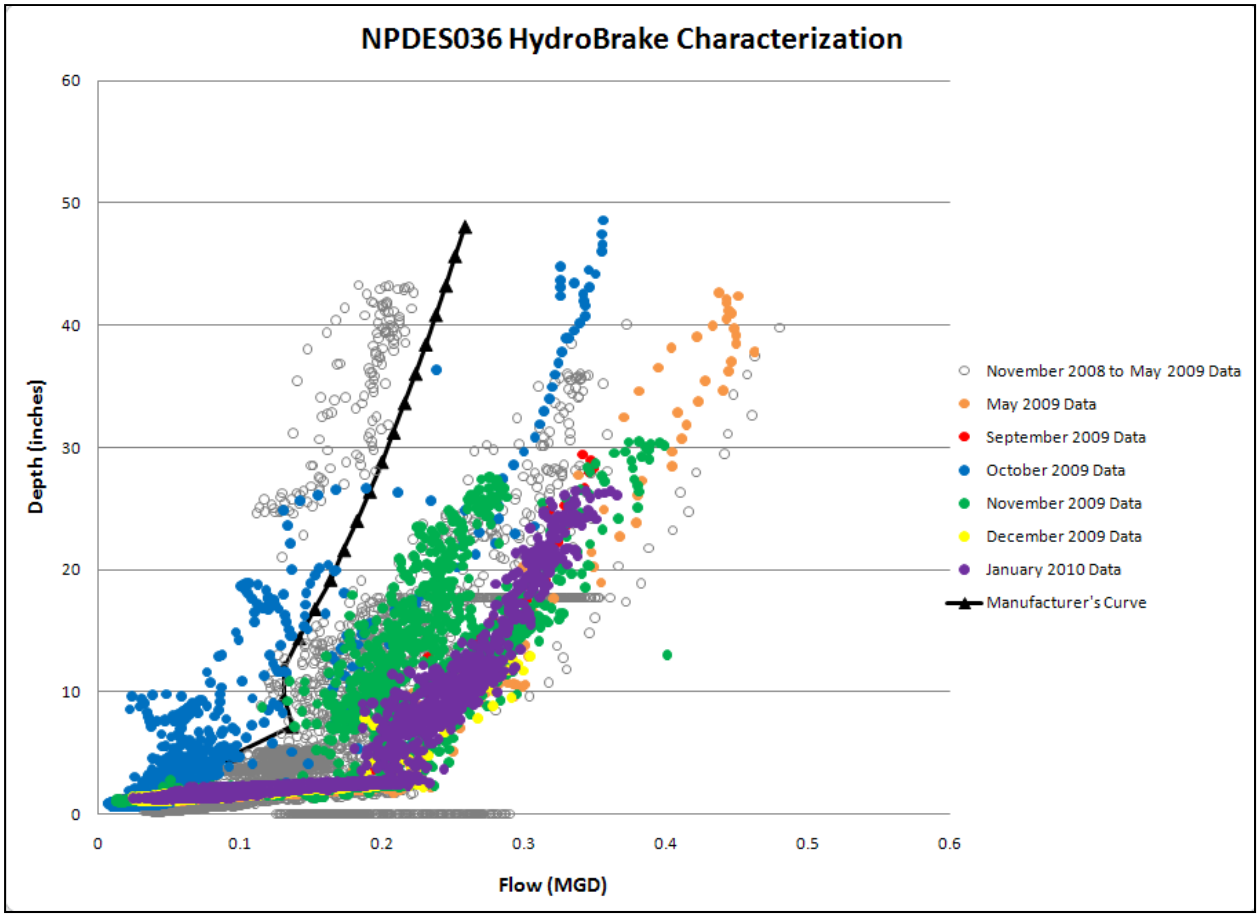

Figure 3-61. NPDES036 Basin HydroBrake characterization

3.7.14 Recommendations for Additional Data Collection

At the conclusion of Phase 3 monitoring, no additional data needed to be collected in the Leschi Basin for the purposes of model calibration and development. All temporary meters are recommended for removal.

3.8 Madison Park/Union Bay Basin

The Madison Park/Union Bay Basin, located on the western shore of Lake Washington, consists of the NPDES022, NPDES024, and NPDES025 Basins and is approximately 240 acres in area. Flows from the NPDES022 Basin in the north are pumped to the NPDES025 Basin via PS 50. Flows from the NPDES024 and NPDES025 Basins combine at PS 7, and then are pumped to the King County system.

RG 3, located to the northwest of the Madison Park/Union Bay Basin on the University of Washington south campus, monitors rainfall in the NPDES022 Basin and the north of the NPDES024 and NPDES025 Basins. RG 20, located southwest of the Madison Park/Union Bay Basin at the TT Minor Elementary campus, monitors the rainfall in the south end of the NPDES024 and NPDES025 Basins.

ADS monitors three permanent flow monitoring locations at the overflow structures within the Madison Park/Union Bay Basin. Stantec maintained seven temporary flow monitoring locations to monitor combined sewage flow during the Phases 2–3 monitoring period. At the end of Phase 3 no temporary flow meters remained in the Madison Park/Union Bay Basin. The three permanent flow meters remained in place to verify overflows.

Detailed site information on the Madison Park/Union Bay Basin can be found in Appendix G; a basin schematic is in Appendix B.

3.8.1 NPDES022 Basin

The NPDES022 Basin, the farthest basin to the north in Madison Park, is located on the southern shore of Union Bay and is approximately 9 acres in area. Flows from the NPDES022 Basin are collected in PS 50 and pumped to the NPDES025 Basin.

During the Phases 2–3 monitoring period, one permanent meter monitored the basin to verify overflows. No temporary monitoring locations were installed in the NPDES022 Basin as there is no suitable site for flow measurement. The permanent meter will remain in place and continue to monitor for overflows.

NPDES022_MH-032014

NPDES022_MH-032014 is a permanent monitoring site that records both level and velocity. The site is classified as a wet weather site because it is not expected to provide high-quality velocity data. Therefore, only level data are finalized for the site. The site was installed on 7/31/2007 to identify and quantify CSO events in the NPDES022 Basin. The level data are used to calculate the volume of CSOs using a weir equation. Overflows are reported when the level in NPDES022_MH-032014 reaches 123.38 inches.

NPDES022_MH-032014 is located adjacent to PS 50. The site has two sensor locations: one in the maintenance hole and one in the elevated overflow pipe. The level data captured at this site had a consistent and repeatable response with no data gaps during the Phases 2–3 monitoring period. The level data are suitable for use in model calibration. The velocity data are not suitable for use in model calibration due to the site hydraulics and pump station influence. Flows in this basin will be estimated from PS 50 operations and data from the monitoring location downstream at UB25_032-044A. Level data quality for Phases 2–3 was classified as "Excellent," whereas Phase 1 data quality was classified as "Good" due to data gaps during significant storms. All data for Phases 2–3 are suitable for model calibration.

NPDES022_MH-032014 is a permanent site and it will continue to be screened in the future.

3.8.2 NPDES024 Basin

The NPDES024 Basin, located on the western shore of Lake Washington immediately north of the Leschi Basin, is approximately 50 acres in area. Flows from the NPDES024 Basin are collected in PS 7, where they are combined with the flows from the NPDES025 Basin. The combined flows then are pumped into the King County system.

During the Phases 2–3 monitoring period, two temporary meters and one permanent meter monitor this basin to verify overflows. One of the temporary meters was located on the downstream side of the overflow weir to confirm the data from the permanent meter. At the conclusion of Phase 3 monitoring no temporary meters remained in the NPDES024 Basin.

UB24_038-141A

UB24_038-141A was a temporary monitoring site that recorded both level and velocity in the southern part of the NPDES024 Basin just upstream from SPU PS 7. The site was installed on 10/20/2008 to measure the flows from the southern part of the NPDES024 Basin and characterize its hydrology.

UB24_038-141A was located upstream of PS 7 in the NPDES024 Basin. The data collected at this site captured a consistent dry weather flow pattern. During large storm events the velocity data have dropouts at peak flows. During Phase 2 monitoring the site responded well to the early September storm and was removed soon after obtaining satisfactory storm data. The data quality was classified as "Good" for Phase 2 monitoring, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phase 2 are suitable for model calibration.

The site was removed on 9/16/2009, during Phase 2 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

UB24_038-283A

UB24_038-283A was a temporary monitoring site that recorded level data only. The site was monitored using an ISCO 2150 meter. The site was installed on 2/11/2009 to verify the data from the permanent monitoring site in NPDES024_PS7 and to provide a boundary condition for overflow calculations.

UB24_038-283A was located in MH 038-283, which is downstream from the NPDES024 Overflow Structure at PS 7. The data at the site captured a consistent and repeatable dry weather flow pattern. The meter did not record data during two significant events in Phase 3 monitoring. During the storm event in October 2009, where an overflow occurred at the NPDES024 Basin, the meter failed to record data. As a result, the data quality was classified as "Some Limitations" for Phases 2–3 as a result of the data gaps. During Phase 1 the site's data quality was classified as "Good." Data for Phases 2–3 should be used with caution during model calibration according to data screening notes.

The meter was removed on 3/18/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NPDES024_PS7

NPDES024_PS7 is a permanent monitoring site that records level data only and is classified as a wet weather site. The site was installed on 3/18/2009 to identify and quantify CSO events occurring from the NPDES024 Basin. The level data are used to calculate the volume of CSOs using a weir equation. Overflows occur when the sensor records a level in NPDES024_PS7 of 33.88 inches.

NPDES024_PS7 is located on the inlet pipe to SPU PS 7, in the structure that was previously the grit chamber. The data at the site captured a consistent and repeatable dry weather flow pattern. The meter did

not record data during the first half of the November 2009 storm event, but all other storms were captured satisfactorily. The data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for use during model calibration.

NPDES024_PS7 is a permanent site and it will continue to be screened in the future.

3.8.3 NPDES025 Basin

The NPDES025 Basin, located between the NPDES022 and NPDES024 Basins on the western shore of Lake Washington, is approximately 183 acres in area. The flows from the NPDES025 Basin drain into PS 7 and are pumped into King County's arboretum trunk. Excess flows overflow into the NPDES025 Basin Overflow Structure.

Five temporary meters and one permanent meter to verify overflows monitored this basin during Phases 2 – 3 monitoring. One of the temporary meters was located on the downstream side of the overflow structure to confirm the data from the permanent meter. At the conclusion of Phase 3 monitoring no temporary meters remained in the NPDES025 Basin.

UB25_032-044A

UB25_032-044A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/13/2008 to measure the flows from the NPDES022 Basin and to characterize the hydrology of the northern part of the NPDES025 Basin.

UB25_032-044A was located just downstream from SPU PS 50. The data at the site captured a consistent dry weather diurnal pattern. The meter responded well to the early September storm event. The data quality was classified as "Excellent" for Phase 2, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phase 2 are suitable for model calibration.

The meter was removed on 9/16/2009, during Phase 2 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

UB25_032-078A

UB25_032-078A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/13/2008 to measure the flows from the upper part of the NPDES025 Basin and characterize its hydrology.

UB25_032-078A was located in MH 032-078. The data collected at this site required a high degree of editing, as shown in Figure 3-62 and Figure 3-63 for raw and finalized data, respectively. Velocity was being overestimated due to small hydraulic jump occurring 3 to 4 joints upstream of this site. However, flow balancing with upstream and downstream sites indicated that the finalized data are within the expected range. The finalized data captured a consistent dry weather flow pattern. The meter responded well to storm events. The quality classification of the finalized data was classified as "Good" for Phase 2, which matches the quality classification of the data collected during Phase 1 monitoring. All finalized data for Phase 2 are suitable for model calibration.

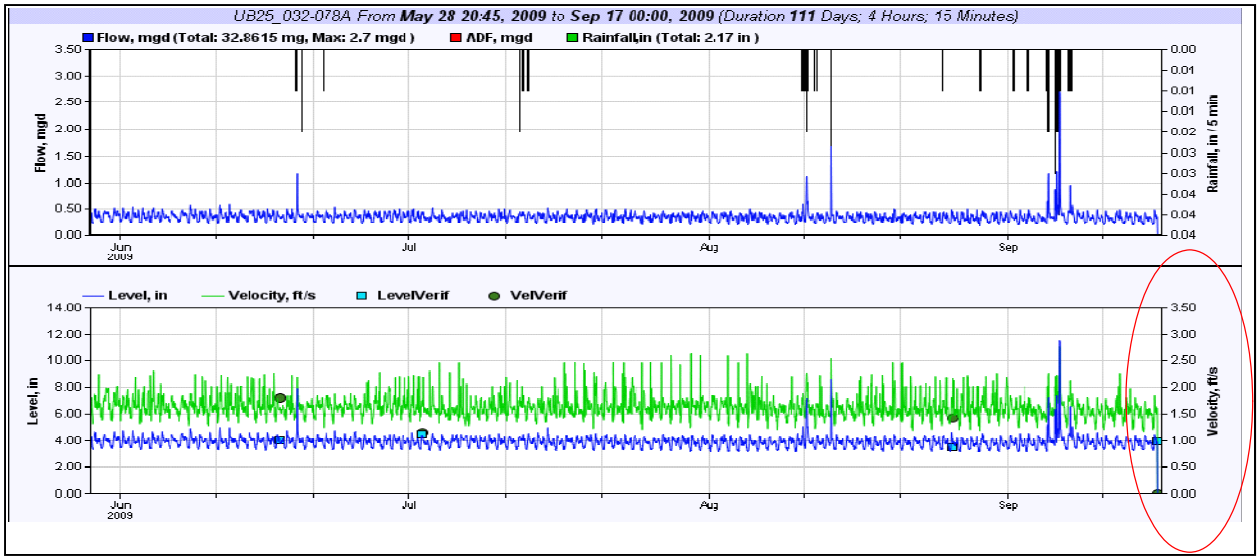

Figure 3-62. Raw data showing the velocity as recorded by the meter at UB25_032-078A

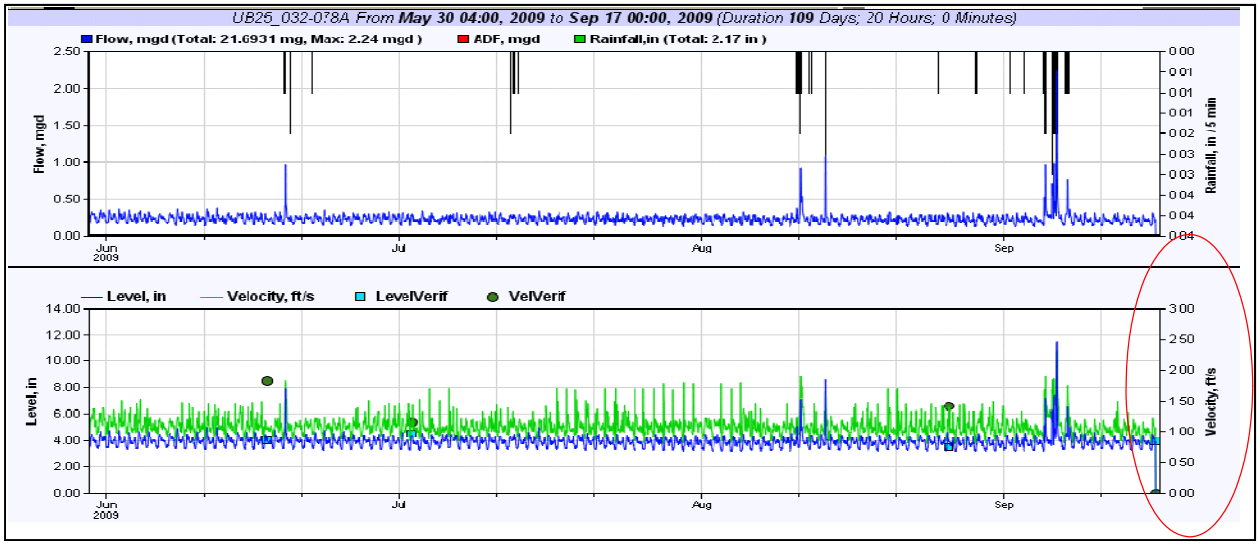

Figure 3-63. Finalized data showing the velocity as recorded by the meter at UB25_032-078A

The site was removed on 9/16/2009, during Phase 2 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

UB25_032-188A

UB25_032-188A was a temporary monitoring site that recorded both level and velocity. The site was installed on 4/15/2009 to measure the flows from the NPDES025 Basin and characterize its hydrology.

UB25_032-188A was located in MH 032-188A. The data collected at this site captured a consistent dry weather diurnal pattern. The site was surcharged during storm events (Figure 3-64). However, periods of suitable data exist for each storm. Small waves were created by the downstream pump station, which made field verification data not reliable. Therefore, finalized data were not edited to match field verification readings. The quality of the finalized data was classified as "Some Limitations" for Phases 2–3, which

matches the quality classification of the data collected during Phase 1 monitoring. Data for Phases 2–3 should be used with caution during model calibration, according to data screening notes.

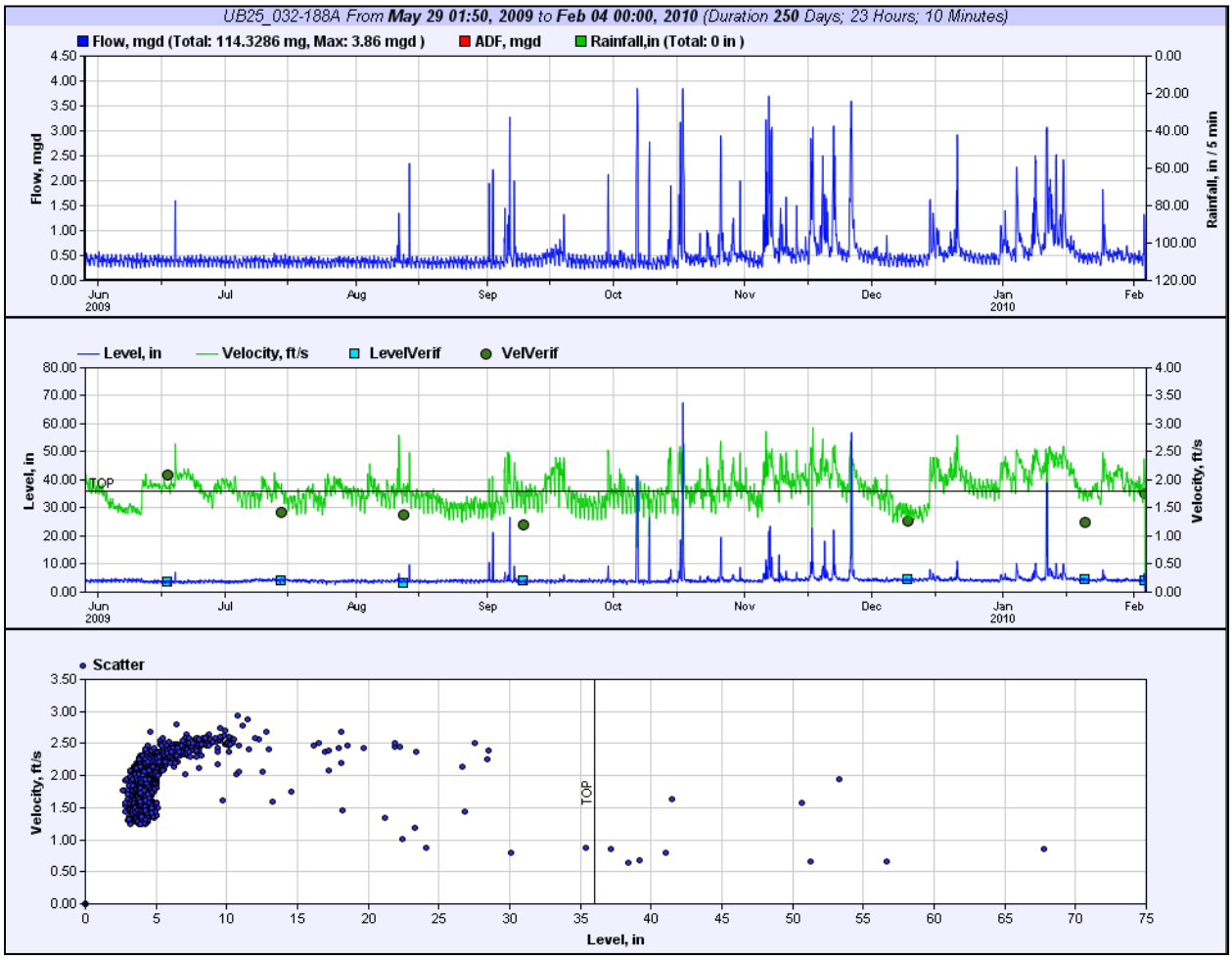

Figure 3-64. Surcharging and apparent flow overestimation at UB25_032-188A.
Overestimation of velocity could be a result of waves caused by downstream pump station.

The site was removed on 2/3/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

UB25_038-149A

UB25_038-149A was a temporary monitoring site that recorded level only. The site was installed on 1/21/2009 to confirm overflows indicated by the permanent monitoring site in the NPDES025 Basin and to provide a boundary condition for overflow calculations.

UB25_038-149A was originally located upstream of the weir at the NPDES025 Overflow Structure; however, it should have been located on the downstream side of the weir. It was moved to the downstream side of the weir wall on 11/19/2009. Thus, the entire Phase 1 and Phase 2 data as well as some of the Phase 3 data are not usable for their intended purpose. The data are usable only for confirmation of the depth reading of the permanent meter in the same maintenance hole. The quality of the level data was classified as "Some Limitations" for Phase 2 and "Good" for Phase 3 after being moved downstream of the weir. Data quality

for Phase 1 was classified as "Some Limitations." Data for Phases 2–3 should be used with caution during model calibration, according to data screening notes.

The site was removed on 3/18/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

UB25_038-285A

UB25_038-285A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/13/2008 to measure the flows from the western part of the NPDES025 Basin and characterize its hydrology.

UB25_038-285A was located upstream of NPDES025_038-149 and PS 7. The data collected at this site captured a consistent dry weather flow pattern and responded well to smaller storm events. PS 7 influenced the velocity data during peak storm events. Backwater effect was evident during peak flows. The data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. Smaller storm data for Phases 2–3 are suitable for model calibration.

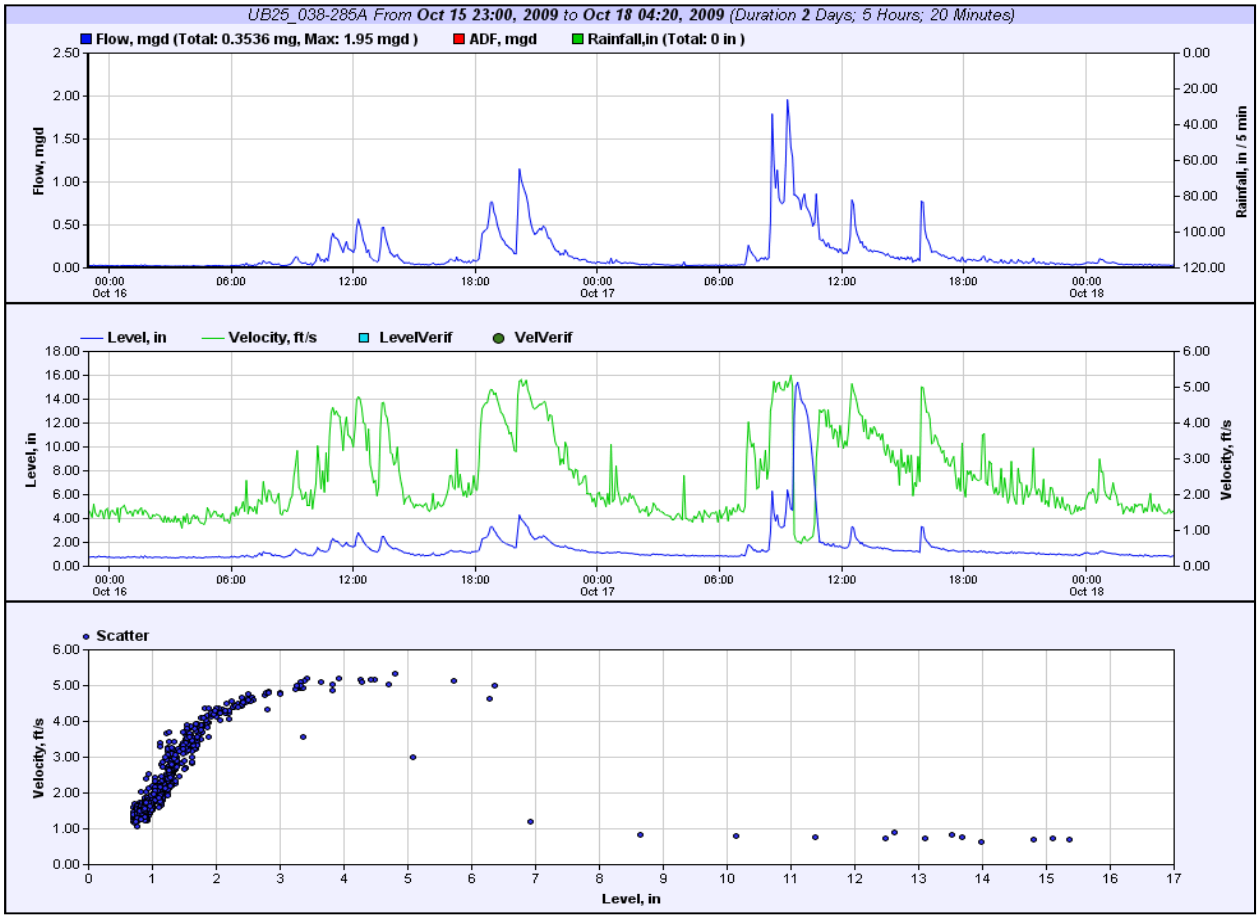

Figure 3-65. Backwater effect during peak flows at UB25_038-285A

The site was removed on 2/3/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NPDES025_038-149

NPDES025_038-149 is a permanent monitoring site that records both level and velocity. The monitoring location was initially classified as a dry weather site but after Phase 1 monitoring it was decided that velocity data were not suitable for model calibration due to the influence of the pump station and the cunette in the inlet pipe. The site was reclassified as a wet weather site and only level data were finalized. The site was installed on 8/23/2007 to identify and quantify CSO events occurring from the NPDES025 Basin. The level data are used to calculate the volume of CSOs using a weir equation. Overflows are reported when the level in NPDES025_038-149 reaches 80.16 inches.

NPDES025_038-149 is located upstream of PS 7. During storm events the level data responded well and indicated overflows. The level data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for model calibration.

This monitoring site is a permanent site and will continue to be screened in the future.

3.8.4 Meters outside Madison Park/Union Bay Basin

KC_031-053A

KC_031-053A was a temporary monitoring site that recorded both level and velocity. The site was installed on 11/3/2008 to estimate the flows from the Madison Park Basin, Leschi Basin, and an area outside the uncontrolled basins, which contribute directly to the King County system and will be used for the calibration of the system-wide hydraulic model.

KC_031-053A was located in the King County system, near the end of the King County Southwest Lake Washington trunk. The data at this site captured a consistent and repeatable dry weather flow pattern. During storm events the meter responded well and exhibited a narrow scattergraph. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for model calibration.

The site was removed on 3/23/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

3.8.5 Combined Sewer Overflows

ADS reported that two CSOs occurred in the Madison Park/Union Bay Basin during the Phases 2–3 monitoring period. The overflows occurred at the NPDES024 and NPDES025 Basins during the 10/17/2009 storm event. Table 3-9 lists the overflow duration and volumes reported during this monitoring period.

Figure 3-66 shows the maximum water level recorded by ADS at each of the overflow structures in the basin as a percentage of the weir height.

Table 3-9. 2009–2010 Combined Sewer Overflows in Madison Park/Union Bay Basin
6/1/2009 through 5/31/2010

NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
22	--		--
24	10/17/2009	0:44	41,390

Table 3-9. 2009–2010 Combined Sewer Overflows in Madison Park/Union Bay Basin 6/1/2009 through 5/31/2010			
NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
25	10/17/2009	0:28	6,637.2

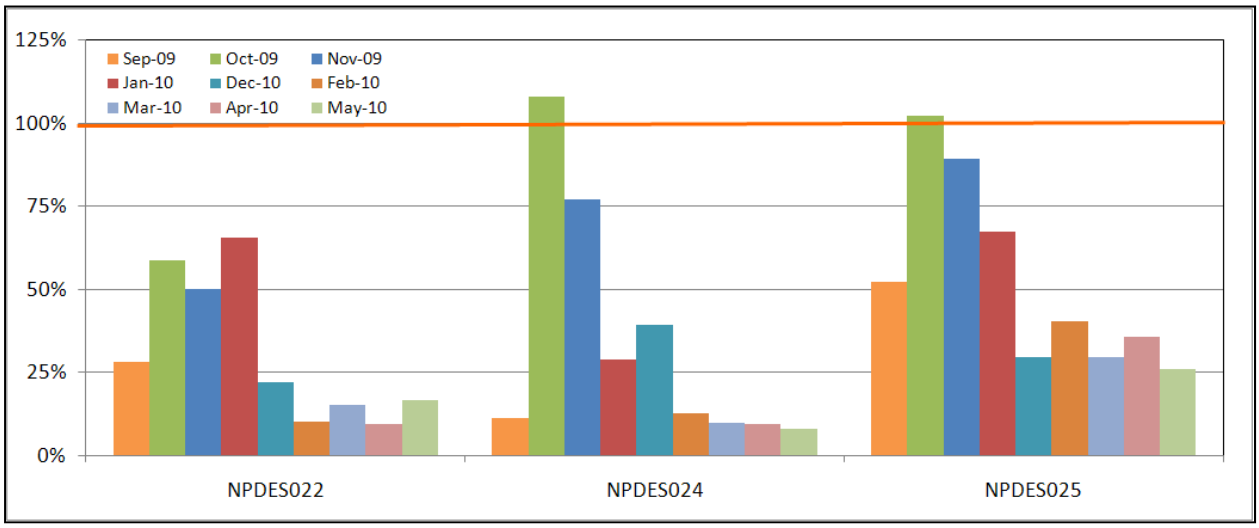

Figure 3-66. Maximum water level in Madison Park/Union Bay Basin overflow structures in relation to weir height for major events

3.8.6 Facility Operations

The CSO facilities in the Madison Park/Union Bay Basin consist of three overflow structures. There are no HydroBrakes within the basin. One inline storage structure is located in the NPDES025 Basin. There are two pump stations in the Madison Park/Union Bay Basin. PS 50 is located in the NPDES022 Basin and PS 7 is located in the NPDES024 Basin.

NPDES022 Basin

The CSS control facility in the NPDES022 Basin consists of an overflow structure at MH 032-014. This maintenance hole is located at the north end of 39th Avenue East, which is one joint upstream from PS 50. MH 032-014 is 149 inches deep, and the overflow line is elevated 123.38 inches from the invert of the maintenance hole. When the inflow to the pump station exceeds the pump station capacity, the flows back up in the gravity main system. Once the water level in MH 032-014 reaches a height of 123.38 inches above the invert, wastewater spills into a storm drain leading to Union Bay via a 20-foot-long, 8-inch-diameter overflow line.

SCADA Data: Pump Station 50

PS 50 is located in the NPDES022 Basin at the northern end of 39th Avenue E. The pump station collects flows from this basin and pumps them to the NPDES025 Basin via a short length of force main (approximately 400 feet long and 4 inches in diameter).

SPU monitors PS 50 via its SCADA system, which records pump run times. Wet well level is not recorded at this site. Data are available at 90- to 120-second resolution.

SPU operations staff indicated that PS 50 is an air-lift pump station and has two 50-gallon cans that can be cycled on a 60-second cycle yielding a maximum pumping rate of 50 gallons per minute. Operations were consistent throughout the monitoring period. The data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data for Phases 2–3 are suitable for model calibration

NPDES024 Basin

The CSS control facility in the NPDES024 Basin consists of an overflow structure at PS 7, located in East Lee Street between Knox Place East and 42nd Avenue East. Flows typically enter PS 7 via a 24-inch-diameter pipe that runs through a chamber (previously the grit chamber) separated from the wet well by a concrete wall. Once the water level in the chamber increases, flows can also enter the wet well through a cut-out in the wall. An overflow weir is located at 33.88 inches above the base of the chamber. If the flow continues to increase the water level above the height of the weir wall, excess flows are diverted to Lake Washington via a 21-inch-diameter overflow line.

SCADA Data: Pump Station 7

PS 7 is located in the NPDES024 Basin in East Lee Street between Knox Avenue E and 42nd Avenue E. The pump station collects flows from both the NPDES024 and NPDES025 Basins and pumps them to the 48-inch-diameter King County main line that runs toward the King County Montlake regulator station.

The pump station has two parallel force mains, each approximately 1,025 feet long. One of the force mains is 12 inches in diameter; the other is 16 inches. A transfer valve between the parallel force mains is currently closed, and all flow is conveyed through the 16-inch force main. SPU monitors PS 7 via its SCADA system, which records wet well level and pump run times. Data are available at 90- to 120-second resolution. The SCADA data will be used in model calibration to determine the pump switch on and off levels and used in conjunction with drawdown test results to calculate the pump station flow rate.

Operations were consistent throughout the Phases 2–3 monitoring period. The data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data for Phases 2–3 are suitable for model calibration.

NPDES025 Basin

The CSS control facility in the NPDES025 Basin consists of an overflow structure at MH 038-149, located upstream from PS 7 in East Lee Street, and an inline storage structure.

The inline storage in the NPDES025 Basin consists of approximately 675 feet of 54-inch-diameter main that extends from MH 038-149 to MH 023-187. Field inspections indicated that this pipe segment has a cunette.

When the inflows to PS 7 exceed the pumping capacity, the flows back up in the gravity main system. MH 038-149 is 129 inches deep and the weir wall is elevated 85.2 inches from the invert of the maintenance hole. When the water level in MH 038-149 reaches a height of 85.2 inches above the invert, combined sewage overflows into Lake Washington via a 24-inch-diameter overflow line.

3.8.7 Recommendations for Additional Data Collection

At the conclusion of Phase 3 monitoring, no additional data needed to be collected in the Madison Park/Union Bay Basin for the purposes of model calibration and development. All temporary meters are recommended for removal.

3.9 Montlake Basin

The Montlake Basin, which consists of the NPDES020, NPDES139, and NPDES140 Basins, is approximately 120 acres in area. Flows from the NPDES020 Basin are pumped via PS 13 into the King County mainline upstream from the Montlake regulator. The flows from both the NPDES139 and NPDES140 Basins are collected in PS 25, which pumps them to the Montlake gravity basin.

RG 03, located north of the Montlake Basin on the University of Washington south campus, monitors rainfall in the Montlake Basin.

ADS maintains three permanent flow monitoring locations at the overflow structures within the Montlake Basin. Stantec maintained seven temporary flow monitoring locations to measure combined sewage flow and two to measure level on the downstream side of overflow weirs during the Phases 2–3 monitoring period.

Detailed information on the Montlake Basin can be found in Appendix J; a basin schematic is in Appendix B.

3.9.1 NPDES020 Basin

The NPDES020 Basin is located farthest to the east in Montlake, with the Lake Washington Ship Canal to the north. The basin is approximately 60 acres in area. Flows from the NPDES020 Basin are pumped into the King County mainline upstream from the Montlake regulator. CSO Facility 26 is a control facility located in the NPDES020 Basin. The facility includes two offline 72-inch storage pipes, an overflow structure, and a pump station.

One permanent meter to verify overflows, and two temporary monitoring locations monitored the basin during Phases 2–3. At the conclusion of Phase 3 no temporary monitoring locations remained in the Montlake NPDES20 Basin. The permanent monitoring location will remain in place and continue to monitor for overflows.

MON020_031-037A

MON20_031-037A was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/13/2008 to measure the flows from most of the NPDES20 Basin and characterize its hydrology.

MON20_031-037A was located upstream of CSO Facility 26. The data at this site captured a consistent dry weather diurnal pattern. The meter responded well to storm events and collected suitable level and velocity data. The scattergraph is clear during dry and wet weather flows. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for model calibration.

The meter was removed on 2/25/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

MON020_031-381A

MON20_031-381A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/18/2008 to measure the flows from the NPDES020 Basin upstream of the overflow structure and PS 13 and characterize the hydrology of the NPDES020 Basin.

MON20_031-381A was located upstream of PS 13. A flow and volume balance performed with the data collected at this site, and data collected from both MON20_031-037A and MON20_031-027A, indicated that the velocity at this location was overestimated. The site data signature also presented backwater conditions

during large storm events. The data quality was classified as "Poor" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring (Figure 3-67). The data are not suitable for model calibration.

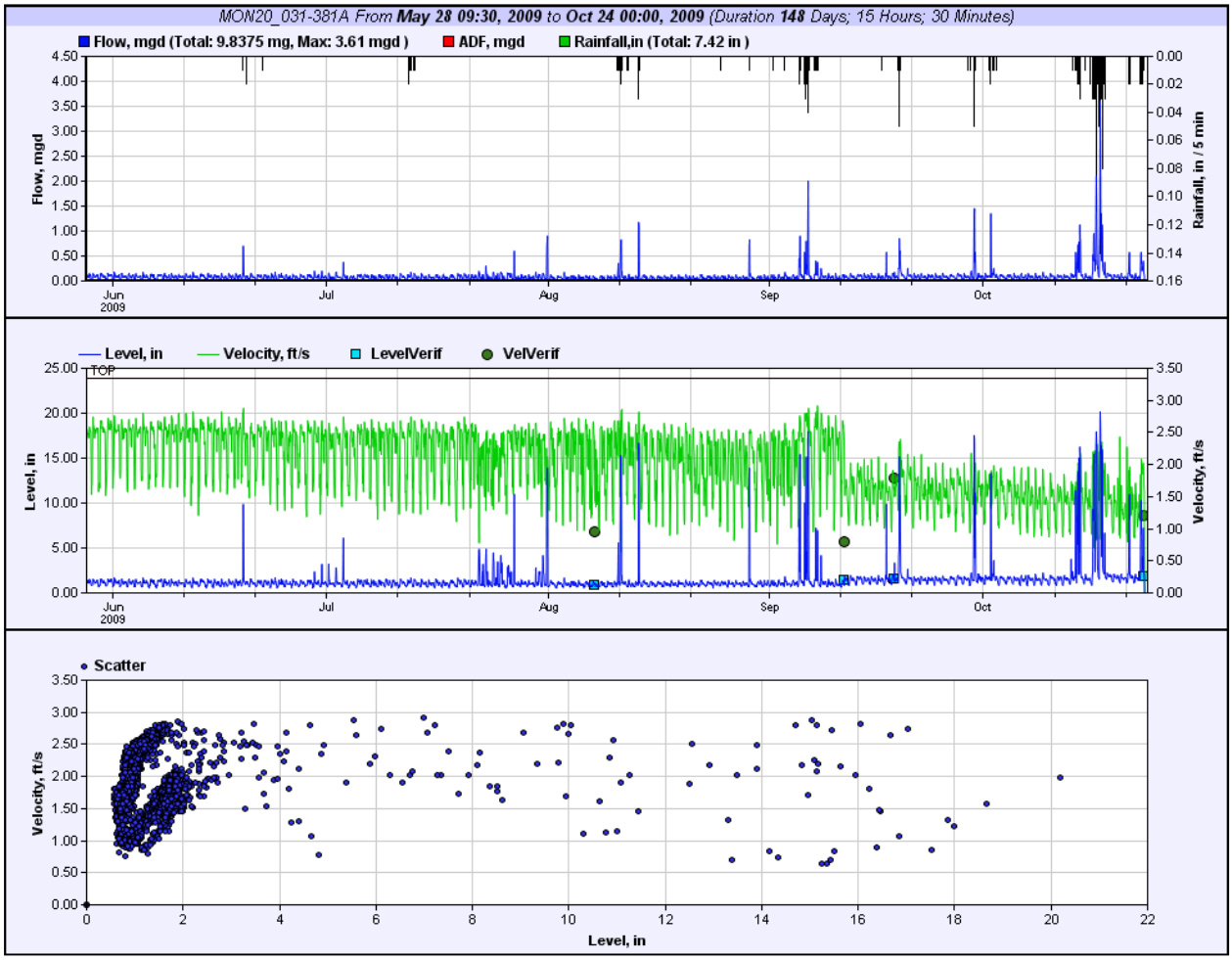

Figure 3-67. Data collected during Phases 2–3 at MON20_032-381A

The meter was removed on 10/23/2009, during Phase 3 monitoring, as it was determined that the site presented poor hydraulic conditions and no reliable data could be collected.

NPDES020_MH031382

NPDES020_ MH031382 is a permanent monitoring site that records both level and velocity. The site is classified as a wet weather site because it is not expected to provide high-quality velocity data; thus, only level data are finalized for the site. The site was installed on 7/18/2007 to identify and calculate the volume of CSOs using a weir equation. Overflows occur when the level in NPDES020_ MH031382 reaches 49.88 inches.

The meter is located on the downstream side of a weir that diverts excess flow to the offline storage in the NPDES020 Basin. Therefore, level and velocity data are captured only when flows are diverted to offline storage facilities. The level data have a consistent and repeatable response. During storm events, the velocity and level data responded well and consistently. The quality of the level data was classified as "Excellent" for

Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for modeling.

NPDES020_MH031382 is a permanent site and will continue to be screened in the future.

3.9.2 NPDES139 Basin

The NPDES139 Basin, located farthest to the south and west in Montlake on the southern shore of Portage Bay, is approximately 46 acres in area. Flows from the NPDES139 Basin are collected in PS 25 and pumped in the Montlake gravity basin. The CSO control facility in the NPDES139 Basin consists of an overflow structure that discharges into the Lake Washington Ship Canal.

During the Phases 2–3 monitoring period, two temporary meters and one permanent meter to verify overflows monitored the basin. At the conclusion of Phase 3 no temporary meters remained in the Montlake NPDES139 Basin. The permanent meter will remain in place and continue to monitor for overflows.

MON0139_031-310A

MON139_031-310A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/16/2008 to measure the flows from the NPDES139 Basin upstream of the overflow weir and characterize the hydrology of the basin.

MON139_031-310A was located upstream of the NPDES139 Overflow Structure. The data collected at this meter show ramping at depths below 2.5 inches. However, periods of suitable dry weather flow exist. During storm events the velocity presented dropouts at peak flows. The data quality was classified as "Some Limitations" for Phases 2–3. The data collected during Phase 1 was classified as "Good" as most of the storm data were captured. Data at peak flows should be used with caution during model calibration.

The meter was removed on 3/22/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

MON139_031-313A

MON139_031-313A was a temporary monitoring site that recorded level only. The site was installed on 1/23/2009 to provide a boundary condition of depth for the model to account properly for any submergence of the weir during a CSO event, and to provide an indication of whether reverse flow occurs over the weir from the storm drain system to the CSS.

MON139_031-313A was located on the downstream side of the weir in the NPDES139 Basin, which overflows to a storm drain. The meter successfully recorded the overflow that occurred at NPDES139 during Phase 3 monitoring and level data were consistent during storm events when no overflow occurred. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for model calibration.

The meter was removed on 2/25/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

MON139_DWF-031313

MON139_DWF-031313 is a permanent monitoring site that records both level and velocity. The site is classified as a wet weather site because it is not expected to provide high-quality velocity data; thus, only level data are finalized for the site. The site was installed on 7/18/2007 to identify and calculate the volume of CSOs using a weir equation. Overflows occur when the level sensor in MON139_DWF-031313 records a level of 75.48 inches.

MON139_DWF-031313 is located at the NPDES139 Overflow Structure. The data captured a consistent and repeatable dry weather flow pattern. During storm events, the level data responded well and consistently. The data quality based on level-only data was classified as "Excellent" during the Phases 2–3 monitoring period, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for model calibration.

MON139_DWF-031313 is a permanent site and it will continue to be screened in the future.

3.9.3 NPDES140 Basin

The NPDES140 Basin, located west of the NPDES020 Basin on the southern side of the Lake Washington Ship Canal between Portage Bay and Union Bay, is approximately 14 acres in area. The flows from the NPDES140 Basin are collected in PS 25 and pumps in the Montlake gravity basin. CSO Facility 31 is located in the NPDES140 Basin and it includes one offline storage tank, one HydroBrake, an overflow structure, and PS 15. The overflows from the NPDES140 Basin discharge into the Lake Washington Ship Canal.

During the Phases 2–3 monitoring period, two temporary meters and one permanent meter monitor the basin to verify overflows monitored the basin. The permanent site depth data are also used to characterize the HydroBrake, but the velocity data are not finalized. At the conclusion of Phase 3 no temporary meters remained in the Montlake NPDES140 Basin. The permanent meter will remain in place and continue to monitor for overflows.

MON140_031-001A

MON140_031-001A was a temporary monitoring site that recorded level data only. The site was installed on 1/23/2009 to confirm the data from the permanent meter and to develop a boundary condition for depth at the outfall.

MON140_031-001A was located on the downstream side of the NPDES140 Basin Overflow Structure. The meter responded well during storm events, recording suitable level data for developing boundary conditions. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for model calibration.

The meter was removed on 2/25/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

MON0140_031-002A

MON140_031-002A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/18/2008 to characterize the hydraulics of the HydroBrake and provide information on the influence of PS 25.

MON140_031-002A was located downstream of the HydroBrake in CSO Facility 31. The meter captured consistent and repeatable dry weather flow patterns. During storm events, the velocity and level data captured a consistent and clear response. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data for Phases 2–3 are suitable for model calibration.

The meter was removed on 2/25/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NPDES140_MH031001

NPDES140_MH031001 is a permanent monitoring site that records both level and velocity. The site is classified as a wet weather site because it is not expected to provide high-quality velocity data; thus, only level data are finalized for the site. The site was installed on 7/18/2007 to alarm for overflow events, calculate the volume of CSOs using a weir equation, and characterize the HydroBrake at MH 031-002. Overflows occur when the level in NPDES140_MH031001 reaches 26.64 inches.

NPDES140_MH031001 is located at the NPDES140 Overflow Structure downstream from CSO Facility 31. The meter captured a consistent and repeatable response of level data to overflows. During storm events, the level data responded well and consistently indicated overflows when the water level exceeded 26.64 inches. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for model calibration.

NPDES140_ MH031001 is a permanent site and will continue to be screened in the future.

3.9.4 Meters outside Montlake Basin

Three temporary monitoring sites were installed outside the Montlake Basin, in the area referred to as the Montlake graivtry basin. This area contributes flow directly to the King County mainline, upstream of the Montlake regulator. Data from these three meters will be used for calibration of the system-wide model.

SPU_031-143A

SPU_031-143A was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/22/2008 to measure the flows from the NPDES139 and NPDES140 Basins, and the Montlake gravity basin directly tributary to the King County system.

SPU_031-143A was located downstream from PS 25 and the temporary monitoring sites at SPU_032-231A and SPU_031-227A. The data at SPU_031-143A captured a consistent dry weather diurnal pattern. The meter captured backwater conditions during the peak of storm events caused by the King County trunk sewer downstream (Figure 3-68). The data quality was classified as "Good" during Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phases 2–3 are suitable for model calibration.

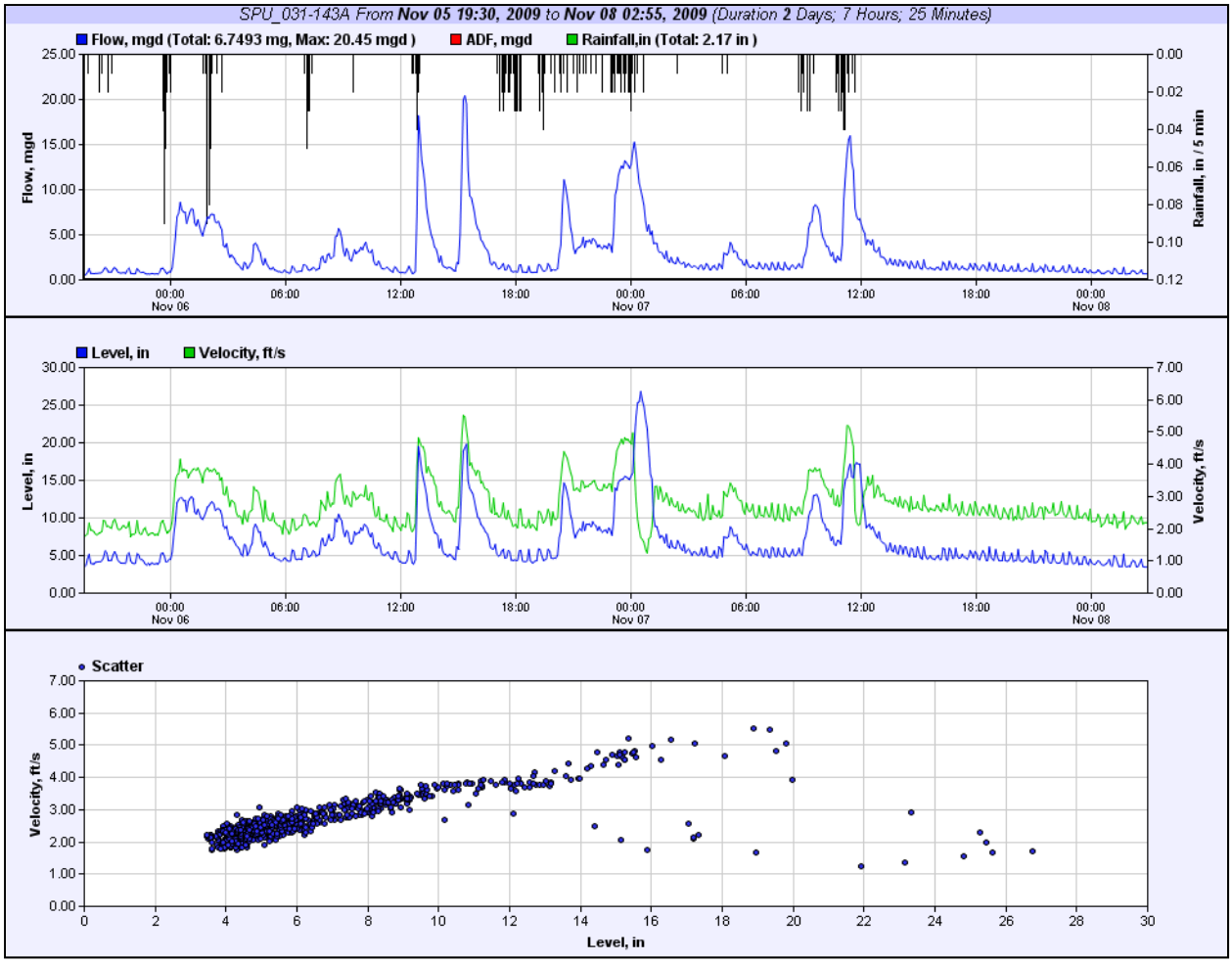

Figure 3-68. Backwater conditions during peak of storm events at SPU_031-143A

The meter was removed on 3/22/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

SPU_031-227A

SPU_031-227A was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/6/2008 to measure the flows in the southern part of the Montlake gravity basin directly tributary to the King County system.

SPU_031-227A was located upstream from the temporary monitoring site at SPU_031-143A. The data at SPU_031-227A captured a consistent dry weather diurnal pattern. The scattergraph was slightly thick during storm events, attributed to the egg-shape of the pipe, but suitable level and velocity data were captured. The data quality was classified as "Good" during Phase 2, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phase 2 are suitable for model calibration.

The meter was removed on 8/20/2009, during Phase 2 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

SPU_031-231A

SPU_031-231A was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/20/2008 to measure the flows in the northern part of the Montlake gravity basin directly tributary to the King County system.

SPU_031-231A was located upstream from the temporary monitoring site at SPU_031-143A. The data at SPU_031-231A captured a consistent dry weather diurnal pattern. The meter responded well to storm events, capturing suitable level and velocity data. The data quality was classified as "Excellent" during Phase 2, which matches the quality classification of the data collected during Phase 1 monitoring. All data for Phase 2 are suitable for model calibration.

The meter was removed on 8/20/2009, during Phase 2, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

3.9.5 Combined Sewer Overflows

ADS reported that eight CSOs occurred in the Montlake Basin during Phases 2–3. Table 3-10 lists the CSOs reported during the monitoring period. Two overflows occurred at the NPDES020 Basin, one at NPDES139, and five at NPDES140. Table 3-10 also lists the overflow duration and volume of each CSO during this monitoring period.

Table 3-10. 2009–2010 Combined Sewer Overflows in Montlake Basin
6/1/2009 through 5/31/2009

NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
20	10/17/2009	0:40	9,693
	11/26/2009	0:10	55
139	10/17/2009	0:10	2,884
140	09/29/2009	0:05	1,643
	10/16/2009	14:05	21,045
	11/6/2009	0:05	109
	11/26/2009	0:08	561
	05/18/2010	0:02	423

Figure 3-69 shows the maximum water level recorded by ADS at each of the overflow structures in the basin as a percentage of the weir height.

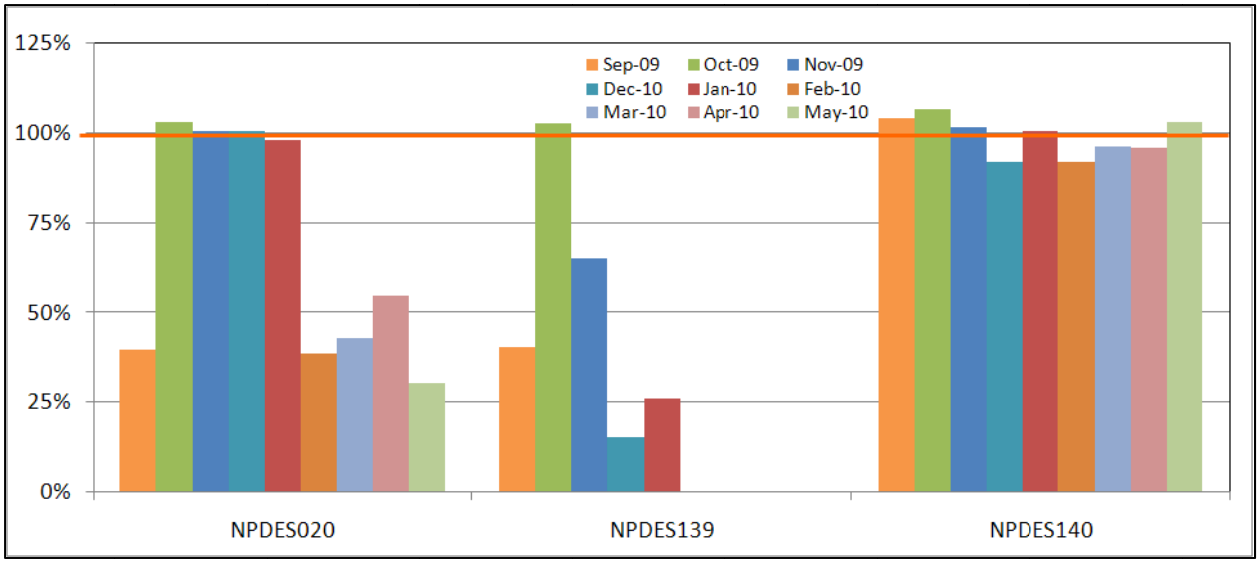

Figure 3-69. Maximum recorded levels compared with weir heights in Montlake Basin for major events

3.9.6 Facility Operations

Three CSS control facilities are located within the Montlake Basin. CSO Facility 26, located in the NPDES020 Basin, includes one pump station, two offline storage pipes, and an overflow structure. CSO Facility 31, located in the NPDES140 Basin, includes one pump station, one offline storage tank, one HydroBrake, and an overflow structure. The CSS control facility in the NPDES139 Basin consists of one overflow structure.

The estimated storage utilization in the Montlake Basin is shown in Figure 3-70. Storage utilization was estimated by using the maximum depth recorded at the permanent monitors and assuming that the same depth was reached in the storage facility. The water depth was compared to the invert level and crown level of the storage structure in order to estimate the percentage of the volume that was used.

Two overflow events were recorded at the NPDES020 Basin during the Phases 2–3 monitoring period. Figure 3-70 indicates that the full capacity of the detention pipes was not utilized. There may be opportunities for retrofit in this basin. The detention tanks in the NPDES140 Basin were completely full when the CSOs occurred in that basin.

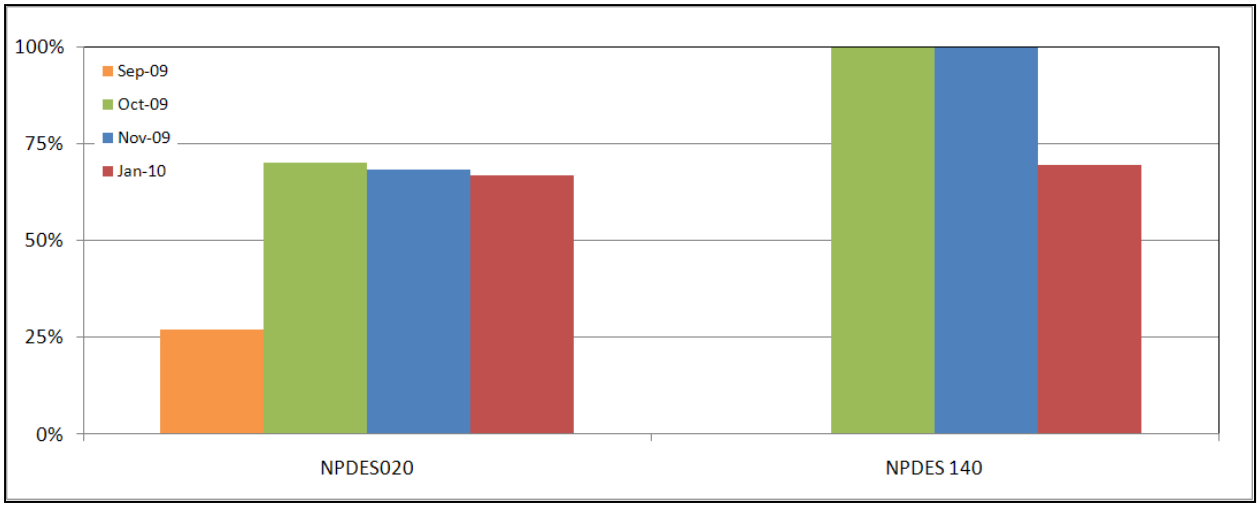

Figure 3-70. Storage utilization in Montlake Basin for major events

NPDES020 Basin

CSO Facility 26 in the NPDES020 Basin consists of overflow weirs at MH 031-381 and MH 038-149, and parallel offline 72-inch detention pipes near the intersection of Shelby Street and 24th Avenue East. When the inflow to PS 13 exceeds the pumping capacity, the flows back up in the gravity main system. The overflow weir located at MH 031-381 diverts these excess flows into the offline detention pipes. The detention pipes continue to fill until the water level in the pipes exceeds the weir level at the second overflow location, MH 031-382, the location of the permanent meter. The weir height is 49.88 inches above the invert level of the maintenance hole. Flows overflow to the Lake Washington Ship Canal via a 21-inch-diameter overflow line.

SCADA Data: Pump Station 13

PS 13 is located in the NPDES020 Basin near the intersection of Shelby Street and 24th Avenue E at MH 031-383. The pump station lifts flows from the NPDES020 Basin to the King County north trunk main at MH 031-026 south of the Montlake Bridge.

SPU monitors PS 13 via its SCADA system, which records wet well level and pump run times. Data are available at 90- to 120-second resolution. The SCADA data will be used in model calibration to determine the pump switch on and off levels and used in conjunction with drawdown test results to calculate the pump station flow rate. Operations were consistent throughout the Phases 2–3 monitoring period.

The data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. Data from Phases 2–3 are considered suitable for use in model calibration.

NPDES139 Basin

The CSS control facility in the NDPES139 Basin consists of an overflow structure at MH 031-313, located in the parking lot at the intersection of 16th Avenue E and E Calhoun Street. The overflow structure is several pipe lengths upstream from PS 25. When the inflow to PS 25 exceeds the pumping capacity, the flows back up in the gravity main system. MH 031-313 is approximately 155 inches deep; ADS reported that the meter read 75.48 inches when the weir crest elevation is reached. The overflow line is a 24-inch-diameter pipe, which then connects into a 42-inch storm drain. The NPDES139 Basin overflows into Portage Bay.

SCADA Data: Pump Station 25

PS 25 is located in the NPDES139 Basin. The pump station receives flow from the NPDES139 and NPDES140 Basins and pumps to the Montlake gravity basin via a short length of 8-inch-diameter force main.

SPU monitors PS 25 via its SCADA system, which records wet well level and pump run times. Data are available at 90- to 120-second resolution. The SCADA data will be used in model calibration to determine the pump switch on and off levels and will be used in conjunction with drawdown test results to calculate the pump station flow rate. Operations were consistent throughout the Phases 2–3 monitoring period.

The data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. Data from Phases 2–3 are considered suitable for use in model calibration.

NPDES140 Basin

The CSS control facility in the NPDES140 Basin consists of two overflow weirs, a HydroBrake, an offline detention tank, and PS 15. The overflow weirs are located at MH 031-419, which is the overflow to the offline detention tank, and at MH 031-001, which is the overflow to the Lake Washington Ship Canal.

The HydroBrake is located at MH 031-002 in an 8-inch-diameter pipe. The HydroBrake limits the flow to PS 25 from the NPDES140 Basin. When the water level increases on the upstream side of the HydroBrake and exceeds the level of the weir at MH 031-419, flows are diverted to the detention tank. The storage tank fills by gravity with flows pumped back to the system. Once the detention tank level exceeds the height at the overflow weir at MH 031-001, an overflow occurs and flows enter Lake Washington via an 18-inch-diameter overflow line. MH 031-001 is approximately 42 inches deep, and the weir wall height is 26.64 inches above the invert level of the maintenance hole.

The HydroBrake at MH 031-002 was characterized using depth data from the permanent meter at NPDES140_MH031001 and flow data from the temporary meter MON140_031-002A. Figure 3-71 shows the head-discharge data pairs collected during the review period. The data exhibit two regions that are associated with downstream surcharge and vortex collapse. PS 25 influences the HydroBrake. The levels at the pump station rise during wet weather, causing surcharge in the sewer line between the pump station and the HydroBrake.

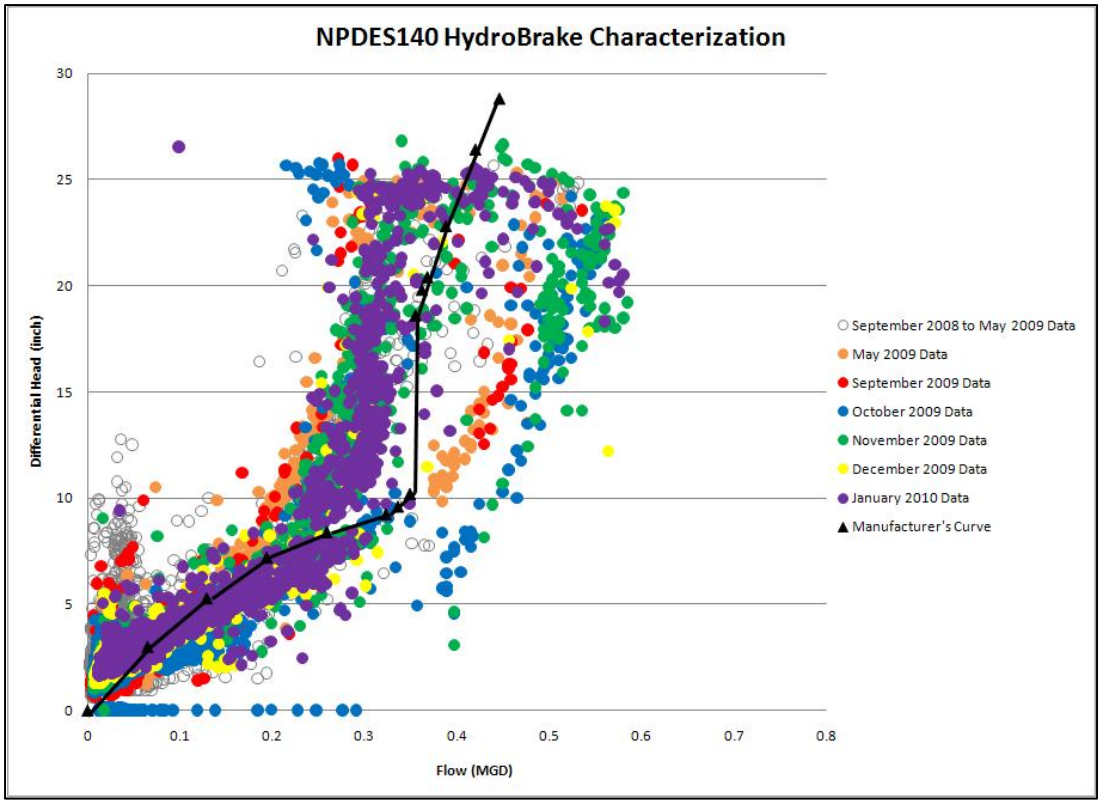

Figure 3-71. NPDES140 Basin HydroBrake curve

SCADA Data: Pump Station 15

PS 15 is located in the NPDES140 Basin. This offline pump station is connected to a large-diameter storage pipe. The pump station pumps flow from the offline storage pipe back into the combined sewer system at MH 031-420.

SPU monitors PS 15 via its SCADA system, which records wet well level and pump run times. Data are available at 90- to 120-second resolution. The SCADA data will be used in model calibration to determine the pump switch on and off levels. Operations were consistent throughout the Phases 2–3 monitoring period.

The data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. Data from Phases 2–3 are considered suitable for use in the model.

3.9.7 Recommendations for Additional Data Collection

At the conclusion of Phase 3 monitoring, no additional data needed to be collected in the Montlake Basin for the purposes of model calibration and development. All temporary meters are recommended for removal.

3.10 North Union Bay Basin

The North Union Bay Basin, which consists of the NPDES018 and NPDES019 Basins, is approximately 988 acres in area. The combined sewer flows from the NPDES018 Basin are broken up into two subcatchments: NPDES018(A) and NPDES018(B). Each subcatchment has its own overflow structure but shares a common outfall. Flow originates in the northern part of the NPDES018(B) Subcatchment and flows southwest toward the King County system. A weir located between the NPDES018(A) and NPDES018(B) Subcatchments provides a hydraulic connection between the two subcatchments. The NPDES018(A) Subcatchment is located in the southern part of the NPDES018 Basin, and flows southwest through CSO Facility 25 into the King County system west of the Windermere Basin. Flows from the Windermere Basin and the NPDES018(A) Subcatchment flow northwest through the King County 30th Avenue PS, and then join with flows from the NPDES018(B) Subcatchment and pumped flows from the NPDES019 Basin.

RG 02, located to the east of the North Union Bay Basin in Warren G. Magnuson Park, monitors rainfall in the NPDES018(B) Subcatchment. RG 03, located to the southwest of the North Union Bay Basin on the University of Washington south campus, monitors rainfall in the NPDES019 Basin and the NPDES018(B) Subcatchment.

ADS maintains three permanent monitoring sites at overflow structures within the North Union Bay Basin. Stantec maintained 18 temporary monitoring sites to measure combined sewage flow during the Phases 2–3 monitoring period. At the end of Phase 3 one temporary monitoring site remained in the North Union Bay Basin. The three permanent monitoring locations remained in place to verify overflows.

Detailed information on the North Union Bay Basin can be found in Appendix K; a basin schematic is in Appendix B.

3.10.1 NPDES018 Basin

The NPDES018 Basin, which contains the majority of the area of the North Union Bay Basin, is approximately 914 acres in area. The NPDES018 Basin is broken up into two subcatchments: NPDES018(A), which is 142 acres in area and located in the southern part of the NPDES018 Basin, and NPDES018(B), which is 769 acres in area and located in the northern part of the NPDES018 Basin. A weir is located between the two subcatchments in MH 016-197. Flow from The NPDES018(B) Subcatchment can overflow to the NPDES018(A) Subcatchment at this point. The NPDES018 Basin contains two CSS control facilities: CSO Facility 24 and CSO Facility 25.

Fifteen temporary monitoring sites and two permanent monitoring sites monitored the NPDES018 Basin during Phases 2–3. Following the end of Phase 3, one temporary monitoring site and the two permanent monitoring locations remained in the NPDES018 Basin.

NUB18_016-078C

NUB18_016-078C was a temporary monitoring site that recorded level only. The site was installed on 10/24/2008 to measure level at the high-flow bypass weir that diverts flow into CSO Facility 24, and to characterize the upstream hydrology.

NUB18_016-078C was upstream from CSO Facility 24, and is set to read a level of zero inches when flow is going over the diversion weir. The data at the site captured a consistent dry weather pattern. During storm events, the velocity and level data responded consistently and did not result in surcharged conditions. The data quality was classified as "Some Limitations" for Phases 2–3 due to the level readings being relative to the diversion weir. All data from Phases 2–3 are suitable for use in model calibration, provided that they are converted into levels relative to the invert elevation of the outgoing pipe.

The site was removed on 10/14/2009, at the end of Phase 2, as it was determined that sufficient suitable data had been collected for the purposes of model calibration. It was also determined that the downstream NUB016-508B sufficiently monitored the amount of flow diverted into CSO Facility 24, which remained in the North Union Bay Basin until 3/18/2010.

NUB18_016-197A

NUB18_016-197A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/22/2008 to calculate flows leaving the NPDES018(B) Subcatchment and to detect when flow was diverted from the NPDES018(B) Subcatchment into the NPDES018(A) Subcatchment.

The monitor was downstream from the HydroBrake in CSO Facility 24 and NUB18_016-518A. A weir is located in the structure just downstream from the location of the monitor, and is overtopped when the depth at this site reaches 11 inches. The weir diverts high flows into the NPDES018(A) Subcatchment; the weir is the only hydraulic connection between the two NPDES018 Subcatchments. The site captured a consistent dry weather flow pattern. The flow data indicated that high flows surcharged the weir causing a siphon effect until depth of flow dropped below the top of the weir, as shown in Figure 3-72. However, despite this effect the overall data quality was classified as "Good" for Phases 2–3, as shown in Figure 3-73. This data classification matches the quality classification of the data collected during Phase 1 monitoring. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 3/17/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

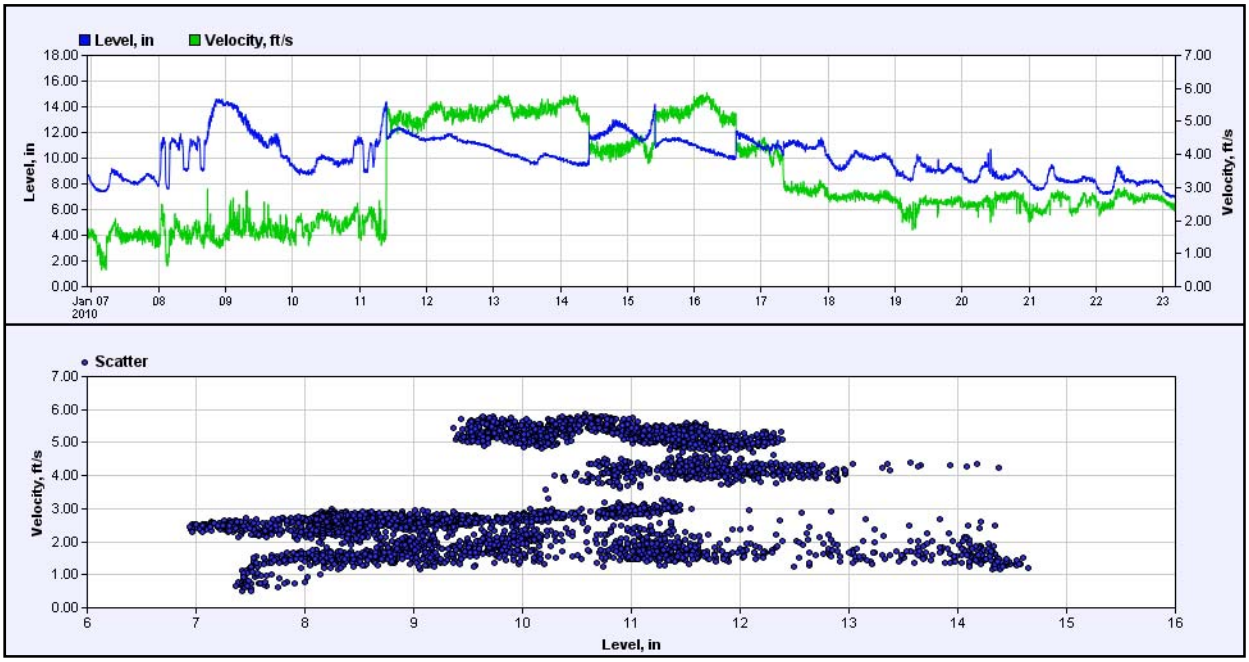

Figure 3-72. Siphon effect at NUB18_016-197A hydrograph and scattergraph from 1/7/2010 to 1/23/2010

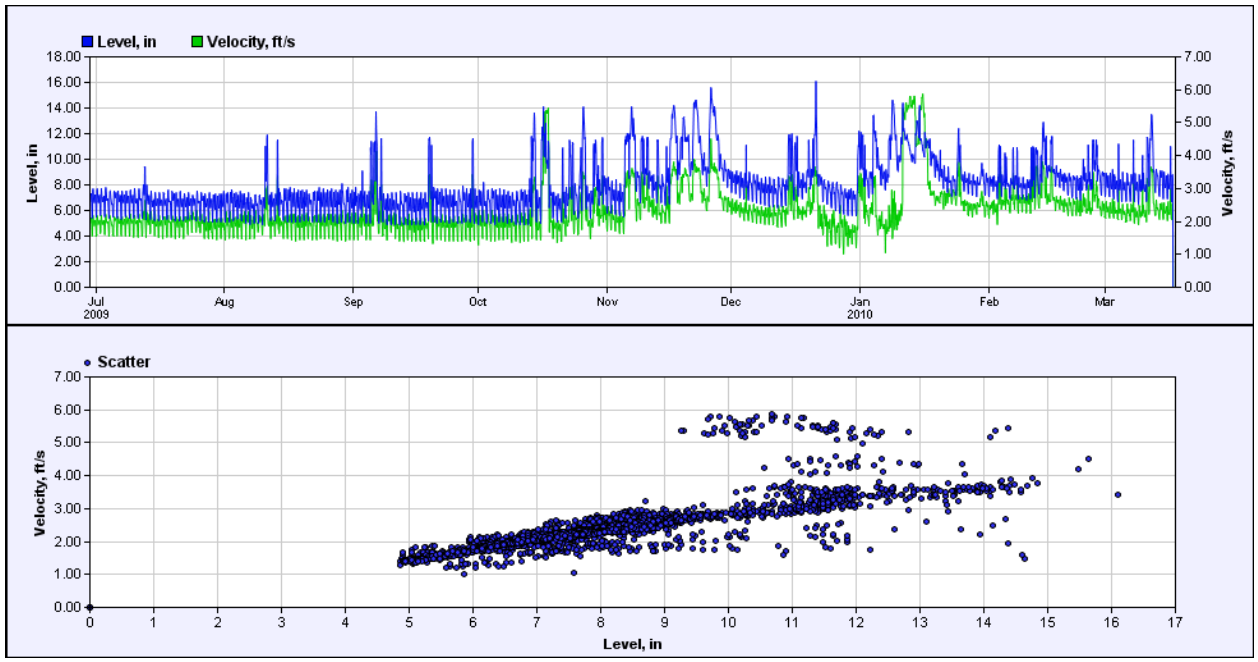

Figure 3-73. Hydrograph and scattergraph of NUB18_016-197A from 7/1/2009 through 3/2010

NUB18_016-505A

NUB18_016-505A was a temporary monitoring site that recorded level only. The site was installed on 11/18/2008 to characterize the HydroBrake and storage utilization at CSO Facility 24.

The depth meter at NUB18_016-505A was located on the bench of the maintenance hole, 17.5 inches above the entrance to the HydroBrake in CSO Facility 24. Because of this, the site did not record depths below 17.5 inches and did not capture depth during dry weather flow. During storm events, the level data were consistent with the levels seen at the north end of the storage tank. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data from Phases 2–3 are suitable for model calibration.

The site was removed on 2/3/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NUB18_016-508A

NUB18_016-508A was a temporary monitoring site that recorded both level and velocity. The site was installed on 2/25/2009 to characterize the hydraulics of the weir at MH 016-510 and to characterize utilization of the storage tanks at CSO Facility 24.

NUB18_016-508A was located on the storage side of the storage diversion weir located in upstream MH 016-510. The data at the site did not capture a dry weather pattern; there is no flow in this pipe under low-flow conditions. During storm events, the velocity and level data responded well and surcharged conditions did not occur. The infrequent flow in the pipe made the verification of the meters difficult. However, the monitor correctly indicated occurrence and magnitude of flows in this branch. Therefore, the data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data collected during Phases 2–3 are suitable for model calibration.

The site was removed on 3/17/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NUB18_016-508B

NUB18_016-508B was a temporary monitoring site that recorded both level and velocity. The site was installed on 2/25/2009 to characterize the hydraulics of the weir at MH 016-078 and, in conjunction with NUB18_016-505A, to characterize utilization of the storage tanks at CSO Facility 24.

NUB18_016-508B was located on the storage side of the storage diversion weir located in upstream MH 016-078. The data at the site did not capture a dry weather pattern; there is no flow in this pipe under low-flow conditions. During storm events, the velocity and level data responded well and surcharged conditions did not occur. Backup caused by filling of the downstream storage tank did occur. The infrequent flow in the pipe made the verification of the meters difficult. Therefore, the data quality was classified as "Some Limitations" for Phases 2–3. This data quality rating is different from the rating of "Excellent" from Phase 1. During Phase 1 only 3 months of data had been collected at this site, and monitoring issues had yet to be discovered. All data collected during Phases 2–3 should be used with caution due to difficulty calibrating the meters.

The site was removed on 3/17/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NUB18_016-510A

NUB18_016-510A was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/15/2008 to characterize the hydrology for the northern part of the NPDES018(B) Subcatchment.

NUB18_016-510A was downstream from MH 016-078; it was located in the main sewer pipe that directs dry weather flow around the storage tank to the HydroBrake on the south end of CSO Facility 24. An overflow pipe is located on the shelf of the maintenance hole that is overtopped when the depth reaches 21 inches. The overflow pipe diverts flows to the north end of the storage tank when the HydroBrake starts to back up flows in the system. As shown in Figure 3-74, the data at the site captured two dry weather diurnal signatures—one during the dry weather days over the summer months, and a slightly different one during dry weather days over the winter months. During storm events, the downstream HydroBrake in MH 016-505 frequently caused surcharged conditions at NUB018_016-510A. The data quality was classified as "Good" for Phases 2–3, whereas the quality of the data collected during Phase 1 was rated "Excellent" before the change in signature was identified. All data collected during Phases 2–3 are suitable for model calibration. Model developers should recognize the change in signature.

The site was removed on 2/3/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

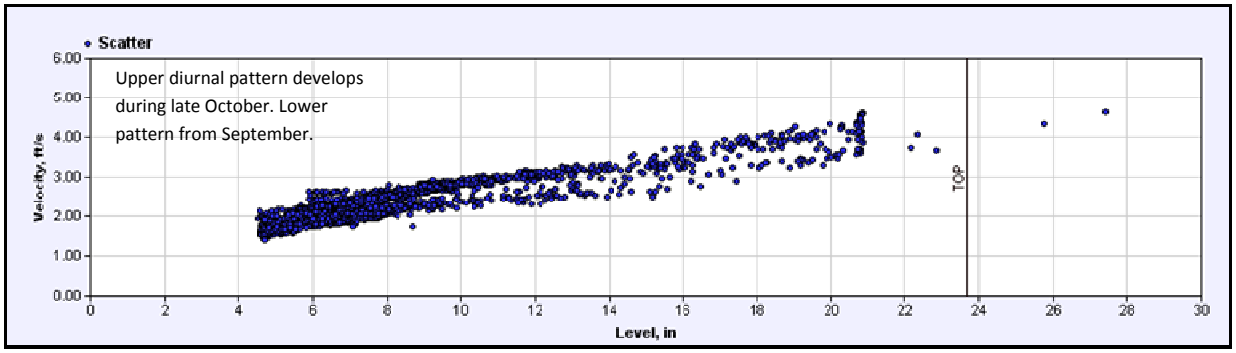

Figure 3-74. NUB18_016-510A scattergraph from 9/13/2009 to 11/23/2009

NUB18_016-518A

NUB18_016-518A was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/21/2008 to characterize the HydroBrake at the CSO Facility 24.

NUB18_016-518A was located downstream from the HydroBrake at CSO Facility 24. The data at the site captured a dry weather pattern that showed occasional scatter caused by debris in the pipe. During storm events, the site showed consistent flow patterns, resulting from its location downstream from the HydroBrake. The data quality was classified as "Good" for Phases 2–3 due to hydraulic shifting during low flows, which matches the quality classification of the data collected during Phase 1 monitoring. All data from Phases 2–3 are suitable for use in characterizing the HydroBrake.

The site was removed on 2/3/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NUB18_024-059A

NUB18_024-059A was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/16/2008 to characterize the flow within the King County CSS line downstream from the Belvoir pump station and upstream from the connection from the NPDES018(A) Subcatchment.

NUB18_024-059A was located in the same maintenance hole as NUB18_024-059B; it was placed in the pipe that enters the maintenance hole from the east. The data at NUB18_024-059A captured a dry weather diurnal pattern that showed a fair amount of scatter. The site responded consistently to storm events and was not surcharged. The data quality was classified as "Good" for Phases 2–3 due to the scatter at low flows, which matches the quality classification of the data collected during Phase 1 monitoring. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 3/17/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NUB18_024-059B

NUB18_024-059B was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/16/2008 to characterize the hydraulics of the HydroBrake located in CSO Facility 25.

NUB18_024-059B was located in the same maintenance hole as NUB18_024-059A; it was placed in the pipe that enters the structure from the northeast. The site was directly downstream from the HydroBrake at CSO Facility 25. The data at the site captured a consistent dry weather diurnal pattern. During storm events the site was not surcharged, but showed a backwater condition with decreasing velocity with increasing depth at depths above 3 inches due to the downstream King County pipe. The data quality was classified as "Excellent" for Phases 2–3, which is different from the data classification of "Good" for Phase 1. This difference is due to improvements in low-flow measuring during Phases 2–3. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 3/17/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NUB18_024-072A

NUB18_024-072A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/25/2008 to characterize both the HydroBrake hydraulics and storage utilization for CSO Facility 25.

NUB18_024-072A was located upstream from the HydroBrake in CSO Facility 25. The data at the site captured a consistent dry weather pattern. During storm events, the level and velocity data indicated that the HydroBrake was backing up flow into storage in CSO Facility 25, resulting in frequent velocity dropouts which required significant velocity data finalization. Level data also corresponded with the CSO weir overflowing. The level data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. Velocity data from Phases 2–3 are not suitable for model calibration. Level data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 3/18/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NUB18_D025-009A

NUB18_D025-009A was a temporary hydrology monitoring site that recorded level and velocity. The site was installed on 8/18/2009 in the NPDES018 Basin stormwater system downstream of Overflow Structure 18B at MH 016-509 and upstream of Overflow Structure 18A at MH 025-380. This site will not be used in modeling of the CSO system. It was installed to provide an estimate of relative storm system flow, and to allow future modeling if required.

The data at NUB18_D025-009A did not capture a dry weather pattern because it was installed in the stormwater system, but it did show a constant flow of 0.2 mgd during dry periods. The site captured a consistent pattern during storm events. The data quality was classified as "Excellent" for Phase 3. This site was not installed during Phases 1 or 2. All data from Phase 3 are suitable for use in model calibration.

The site was removed on 2/3/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NUB18_025-018A

NUB18_025-018A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/22/2008 to characterize hydrology for the northwestern part of the NPDES018(A) Subcatchment.

NUB18_025-018A was located upstream from CSO Facility 25 and downstream of the weir transferring flows from the NPDES018(B) Subcatchment. The data at the site captured a dry weather pattern that showed a fair amount of scatter at low flows, possibly due to a hydraulic jump as the level rises. During storm events, the velocity and level data also showed a fair amount of scatter, and did not result in surcharged conditions. The data quality was classified as "Good" for Phases 2–3 due to the scatter at low flows, which matches the quality classification of the data collected during Phase 1 monitoring. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 3/17/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NUB18_025-025A

NUB18_025-025A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/22/2008 to characterize hydrology for the northeastern part of the NPDES018(A) Subcatchment.

NUB18_025-025A was located upstream from CSO Facility 25. The data at the site captured a consistent dry weather pattern that included a small and consistent industrial discharge from Children's Hospital every morning, as seen in the hydrograph in Figure 3-75 below. During storm events, the velocity and level data responded consistently and did not result in surcharged conditions. The data quality was classified as "Good"

for Phases 2–3, due to a 7-day-long data gap from 11/4/2009 to 11/11/2009 during a large storm event. The data quality classification during Phase 1 was also classified as "Good." All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 3/17/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

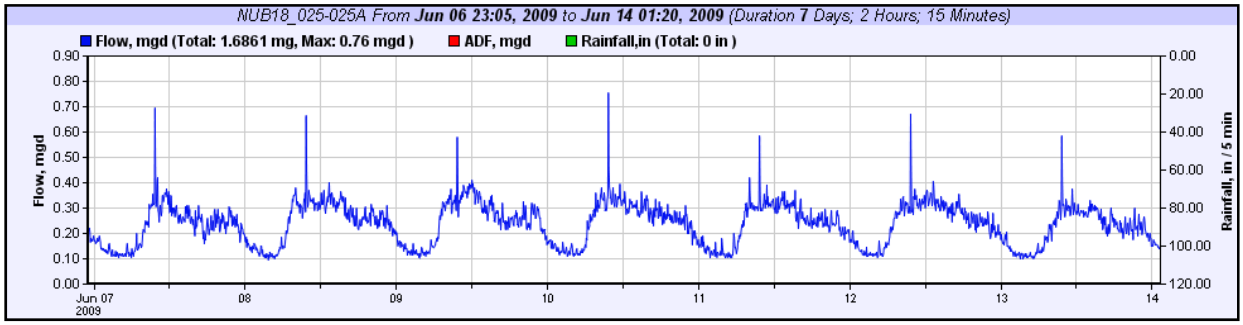

Figure 3-75. NUB18_025-025A flow hydrograph with Children's Hospital industrial discharge

NUB18_025-034A

NUB18_025-034A was a temporary monitoring site that recorded both level and velocity. The site was installed on 2/11/2010 to characterize the hydrology for the northwestern part of the NPDES018(A) Subcatchment. The site was also installed in order to evaluate the feasibility of a GSI (Green Stormwater Infrastructure) installation in the North Union Bay Basin.

NUB18_025-034A was located in the same maintenance hole as NUB18_025-034B; it was placed in the pipe that enters the maintenance hole from the north. NUB18_025-34A was located upstream from CSO Facility 25 and NUB18_025-025A. The data at the site captured a consistent dry weather pattern. During storm events, the velocity and level data responded consistently and did not result in surcharged conditions. The data quality was classified as "Excellent" for Phase 3, and was not installed during Phases 1 and 2. All data from Phase 3 are suitable for use in model calibration.

The site was removed on 3/17/2010, during Phase 3 monitoring.

NUB18_025-034B

NUB18_025-034B was a temporary monitoring site that recorded both level and velocity. The site was installed on 2/11/2010 to characterize the hydrology for the northwestern part of the NPDES018(A) Subcatchment. The site was also installed in order to evaluate the feasibility of a GSI installation in the North Union Bay Basin.

NUB18_025-034B was located in the same maintenance hole as NUB18_025-034A; it was placed in the pipe that enters the maintenance hole from the north. NUB18_025-34B was located upstream from CSO Facility 25 and NUB18_025-025A. The data at the site captured a dry weather pattern that showed a significant amount of scatter. During storm events, the velocity and level data responded well and did not result in surcharged conditions. The data quality was classified as "Good" for Phase 3 due to scatter at low flows, and was not installed during Phases 1 and 2. All data from Phase 3 are suitable for use in model calibration.

The site was removed on 3/17/2010, during Phase 3 monitoring.

KC_025-050A

KC_025-050A was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/21/2008 to calculate flows going to the Belvoir pump station.

NUB18_025-050A was located upstream from the King County Belvoir pump station. The data at the site captured a consistent dry weather pattern. During storm events, the velocity and level data responded consistently and did not result in surcharged conditions. The data quality was classified as "Excellent" for Phases 2–3, which is consistent with data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

This site remained in the North Union Bay Basin at the end of Phase 3 for use in evaluating the effect of changes made in the Windermere Basin to the east on the King County system.

NPDES018A_MH025380

NPDES018A_MH025380 is a permanent monitoring site that records both level and velocity. The site is classified as a wet weather site because it is expected to provide high-quality level data only; thus, only level data are finalized for the site. The site was installed on 7/16/2007 to quantify CSO events occurring from the NPDES018(A) Subcatchment. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The NPDES018(A) Subcatchment overflows when the level in NPDES018A_MH025380 exceeds 24.50 inches.

NPDES018A_MH025380 is located at the upstream end of the storage tank within CSO Facility 25. The data captured a consistent dry weather pattern. During storm events, the velocity and level data responded consistently. Surcharged conditions were frequently measured at this site, due to the HydroBrake downstream. Level data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data from Phases 2–3 are suitable for use in model calibration.

This monitoring site is a permanent site and will continue to be screened in the future.

NPDES018B_MH016509

NPDES018B_MH016509 is a permanent monitoring site that records both level and velocity. The site, which was installed on 12/8/2006 in CSO Facility 24, has two monitors: MP1, located in the incoming pipe, and MP2, located in the overflow line. MP1 is classified as a dry weather site, and is expected to provide high-quality level and velocity data. The level data from MP1 are used to alarm for CSO events from the NPDES018(B) Subcatchment and calculate the volume of CSOs using a weir equation. MP2 is classified as a wet weather site, and is not expected to provide high-quality level or velocity data. The data from MP2 are used only to verify overflows. The NPDES018(B) Subcatchment overflows when the depth at MP1 reaches 44.89 inches.

During the January 2010 flow monitoring review meeting, it was determined that MP1 was located on the wrong side of the NPDES018(B) Overflow Structure. The meters were intended to be installed on the non-overflow side of the weir, and they were instead installed on the overflow side of the weir. As a result, CSOs from the NPDES018(B) Subcatchment were not reported from the meter's site through 2/8/2010, when the meters were moved to their intended location. As of the writing of this report, ADS has updated the CSO volumes and durations for data collected prior to 2/8/2010.

The data quality was classified as "Some Limitations" for Phases 2–3 due to the placement of the meters discussed above. Data prior to 2/8/2010 should not be used for model calibration. Data after 2/8/2010 are suitable for use in model calibration.

This monitoring site is a permanent site and will continue to be screened in the future.

3.10.2 NPDES019 Basin

The NPDES019 Basin is located outside of the North Union Bay modeling basin as it is considered controlled. Data from the basin were screened in the monitoring program in case it was necessary to include it in the hydraulic boundary condition for long-term simulation modeling of the NPDES018 Basin.

One permanent monitoring site verifies overflows in the approximately 74-acre basin. No CSS control facilities are located within this basin; however, PS 35 drains the basin into the King County system downstream of the King County 30th Avenue pump station.

NPDES019_MH015237

NPDES019_MH015237 is a permanent monitoring site that records both level and velocity. The site is classified as a wet weather site because it is expected to provide high-quality level data only; thus, only level data are finalized for the site. The site was installed on 7/24/2008 to quantify CSO events from PS 35. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The NPDES019 Subcatchment overflows when the level in NPDES019_MH015237 exceeds 47.5 inches.

The site is located upstream from PS 35. The data at the site captured a consistent dry weather pattern. During storm events, the level data responded well and did not result in surcharged conditions. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1 monitoring. All data from Phases 2–3 are suitable for use in model calibration.

This monitoring site is a permanent site and will continue to be screened in the future.

3.10.3 Combined Sewer Overflows

ADS reported that during Phases 2–3, five CSOs occurred in the NPDES018(A) Subcatchment, while one CSO occurred in the NPDES018(A) Subcatchment. No CSOs occurred in the NPDES019 Subcatchment during Phases 2–3. Table 3-11 lists the CSOs that occurred during the monitoring period.

Table 3-11. 2009–2010 Combined Sewer Overflows in North Union Bay Basin
6/1/2009 through 6/1/2010

NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
18(A)	9/6/2009	0:25	4,162
	10/17/2009	1:12	115,334
	10/26/2009	0:34	5,712
	11/26/2009	4:28	221,242
18(B)	9/22/2009	2:10	99,611
	11/26/2009	8:05	1,486,787
19	--		--

Figure 3-76 shows the maximum water level recorded at each of the overflow structures in the basin as a percentage of the weir height. As noted above, the depth on the upstream side of the overflow weir at NPDES018(B) was not available. Overflows were computed using the measured depth and velocity on the downstream side of the weir.

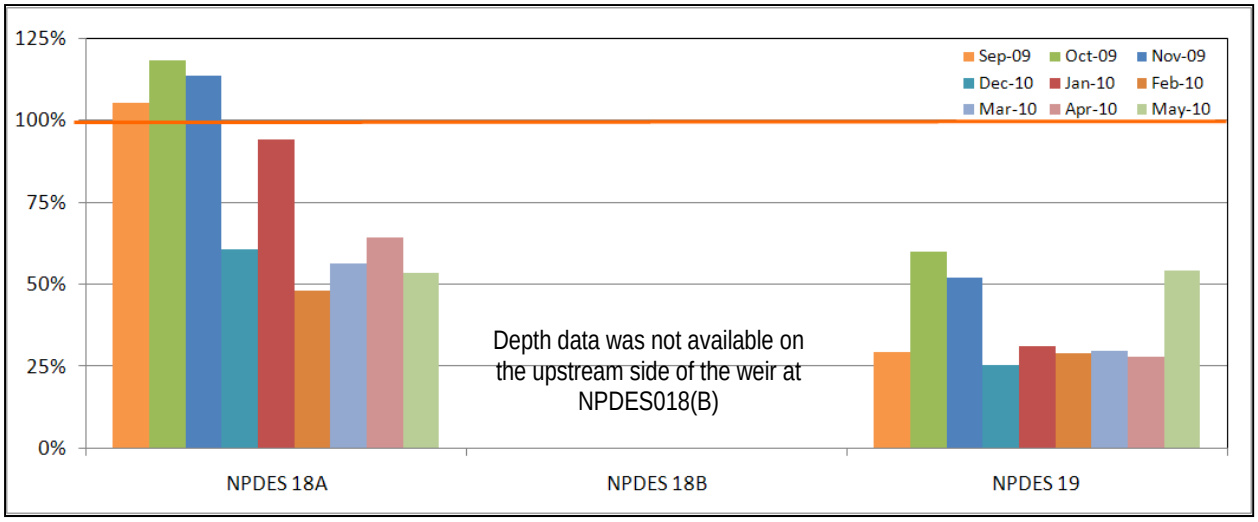

Figure 3-76. Maximum recorded levels in the North Union Bay Basin compared to weir heights for major events

3.10.4 Facility Operations

The NPDES018 Basin contains the following CSS control structures:

- CSO Facility 24: offline storage, HydroBrake, and NPDES018(B) Overflow Structure
- CSO Facility 25: in-line storage, HydroBrake, and NPDES018(A) Overflow Structure.

The NPDES019 Basin does not contain any CSS control facilities; it contains only the NPDES019 Overflow Structure associated with PS 35.

NPDES018(A)

CSO Facility 25 is located within the NPDES018(A) Subcatchment. The facility consists of a HydroBrake located at MH 024-072 at the intersection of NE 41st Street and University Bay Circle N, a 20,000-gallon in-line storage tank that runs along NE 41st Street, and the NPDES018(B) Overflow Structure located in MH 016-509.

Figure 3-77 shows the monitor data for the HydroBrake using data collected from NUB18_024-072A and NUB18_024-059B. The structure has an emergency bypass weir located at the HydroBrake, which is set at an elevation lower than the overflow weir in the NPDES018(A) Subcatchment.

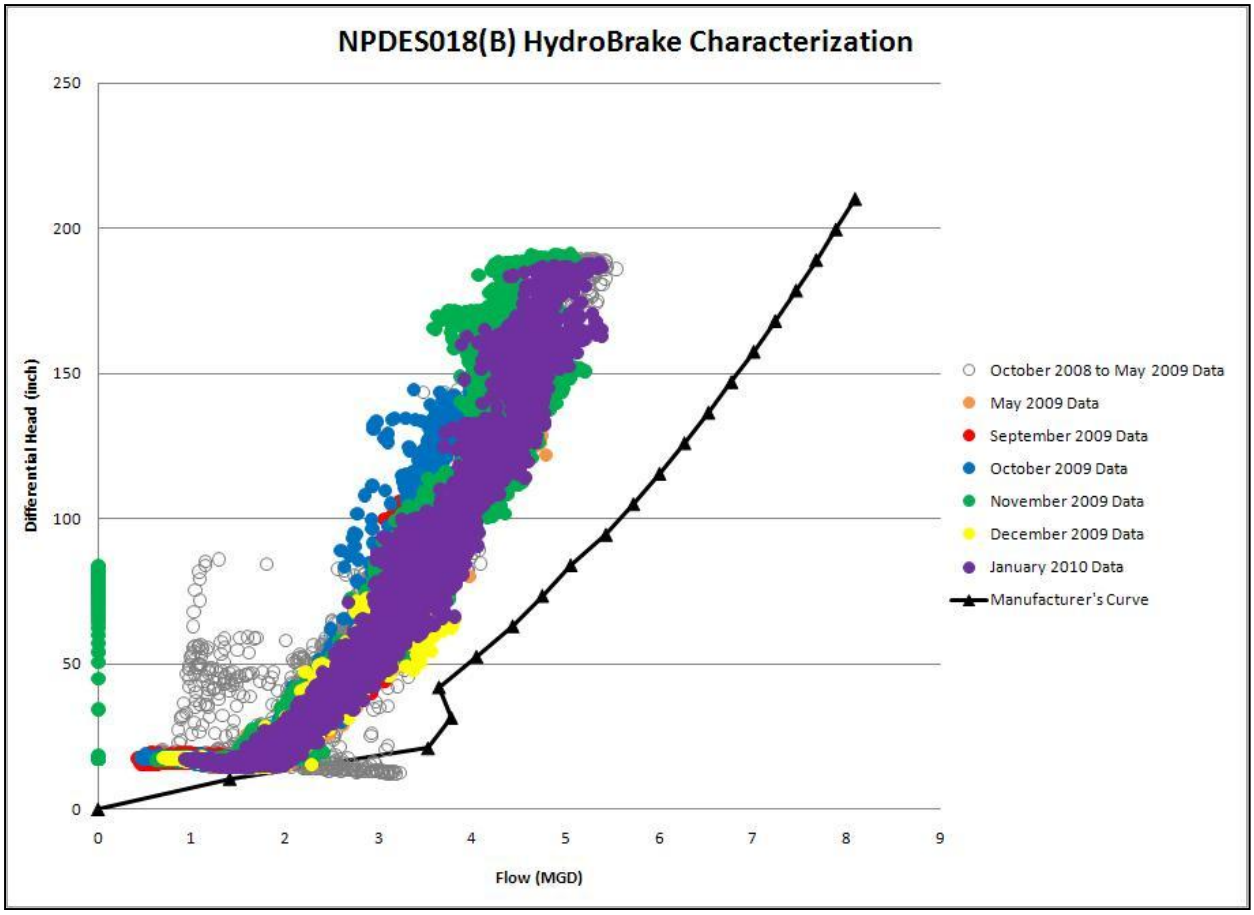

Figure 3-77. NPDES018(A) Subcatchment HydroBrake characterization

The storage tanks in the control facility consist of one 72-inch-diameter storage pipe with a cunette at the bottom. NUB18A_024-072A was used to determine utilization for the storage pipe. The overflow weir for the structure is at the upstream side of the storage tank. The overflow weir is set at an elevation that allows the tank to be filled only to 60 percent prior to overflowing into Lake Washington.

The overflow structure for the NPDES018(A) Subcatchment is located on the east end of the storage pipe at MH 025-380. Once the level at the upstream end of the storage pipe reaches a depth of 21.50 inches, flow is diverted into the 54-inch-diameter CSO outfall pipe into the storm drain system, which discharges to Lake Washington.

NPDES018(B)

CSO Facility 24 is located within the NPDES018(B) Subcatchment. The facility consists of a HydroBrake located at MH 016-505 at 4875 39th Avenue NE, and two offline storage pipes with a combined storage volume of 200,000 gallons, located along 39th Avenue NE. Figure 3-78 shows the monitor data for the HydroBrake using data collected from MH 016-505A and MH 016-518A. The structure has an emergency bypass weir located at the HydroBrake; the data indicate that this weir was not overtopped during the review period, suggesting that the bypass weir is higher than the overflow weir.

The storage pipes in the control facility consist of two square 10-by-10-foot pipes. NUB18B_016-505A was used to determine the utilization of the storage pipes. If the storage tank fills up and is unable to overtop the

overflow weir, flow overtops the emergency bypass weir at the HydroBrake and continues downstream to MH 016-518.

Under normal flow conditions, the storage tank fills up from the HydroBrake (south end of storage pipes) back into the storage pipe. In high-flow conditions, the storage pipes start filling from the north as weirs at MH 016-078 and MH 016-510 are overtopped and direct flow toward the storage tank. The NPDES018(B) Overflow Structure is located on the north end of the storage tanks at MH 016-509, and discharges into a storm drain leading to Lake Washington.

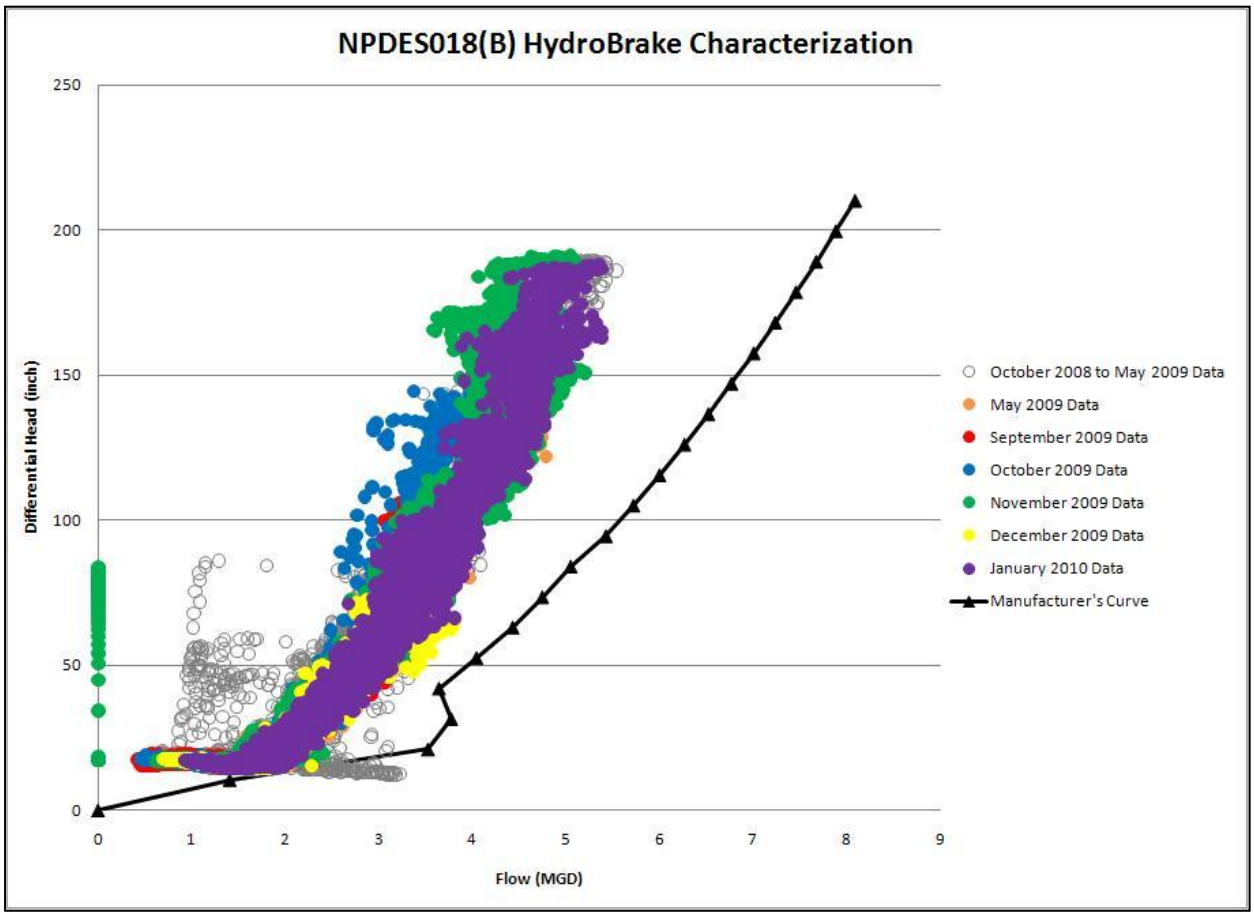

Figure 3-78. NPDES018(B) Subcatchment HydroBrake characterization

NPDES019

The overflow for the NPDES019 Basin is an elevated pipe located on the west side of MH 015-237. Once the level in the pipe reaches a depth of 47.5 inches, flow is diverted into the CSO overflow pipe.

Pump Stations 35, 48, and 55

SPU monitors PS 35, PS 48, and PS 55 via its SCADA system, which records wet well level and pump run times. Data are available at 90- to 120-second resolution. The pump stations will not be included in the North Union Bay model.

Data collected during Phase 2 monitoring included the pump on-off states and the wet well depth at PS 35 and PS 55. These data were plotted versus time for review. Review consisted of observing the normal rise and fall of wet well elevation with time during wet and dry weather. In general, no anomalies in operation were

noted that could not be explained by response to rainfall. Data were not reviewed at PS 35 and PS 55 during Phase 3 because it was decided that pump stations would not be included in the North Union Bay Basin model. Data were not reviewed at PS 48 during Phases 2–3 because it was decided that pump stations would not be included in the North Union Bay Basin model.

3.10.5 Recommendations for Additional Data Collection

At the conclusion of the Phase 2–3 monitoring period, no additional data needed to be collected in the North Union Bay Basin for the purposes of model calibration and development. All temporary meters were removed except for KC025-050A, which remained in place to monitor flows from the Windermere Basin.

3.11 Portage Bay/Lake Union Basin

The Portage Bay/Lake Union Basin, approximately 233 acres in area, consists of six NPDES basins: NPDES127, NPDES130, NPDES132, NPDES135, NPDES138, and NPDES175. Flow originates in the NPDES138 Basin and is pumped north toward the NPDES135 Basin via the Shelby Street pump station (PS 20). At the NPDES135 Overflow Structure, dry weather flow changes direction and flows south. As the flow heads south, the NPDES132, NPDES130, NPDES175, and NPDES127 Basins all contribute flow to the trunk line heading toward the King County system. Under normal flow conditions, the flow collected within the basin discharges into the system that runs west along Mercer Street and flows into the Elliott West CSO tunnel. Under high-flow conditions, CSOs flow through CSO outfalls into Portage Bay and Lake Union via the six overflow structures located in the Portage Bay/Lake Union Basin.

RG 03, located at the University of Washington Hydraulics Lab, measures rainfall in the NPDES138, NPDES135, NPDES132, and NPDES130 Basins. RG 20, located at TT Minor Elementary School on Capitol Hill, monitors rainfall for the NPDES175 and NPDES127 Basins.

ADS maintains six permanent flow monitoring sites at overflow structures within the Portage Bay/Lake Union Basin. Stantec maintained 17 temporary monitoring sites at various key locations throughout the basin during Phases 2–3. At the end of Phase 3 no temporary flow meters remained in the Portage Bay/Lake Union Basin. The six permanent monitoring sites remained in place.

Detailed information on the Portage Bay/Lake Union Basin can be found in Appendix L; a basin schematic is in Appendix B.

3.11.1 NPDES127 Basin

The NPDES127 Basin, located downstream from the NPDES175 Basin and upstream from the King County system, is approximately 13 acres in area. Flows from the basin are pumped into the main sewer trunk line, leaving the Portage Bay/Lake Union Basin through PS 62. No CSS control facilities are located within this basin.

The basin contains one permanent monitoring site to verify overflows.

NPDES127_036-146

NPDES127_036-146 is a permanent monitoring site that records level only. The site is classified as a wet weather site because it is expected to provide high-quality level data only; thus, only level data are finalized for the site. The site was installed on 7/19/2007 to determine when CSO events were occurring and to quantify the overflow volumes from the NPDES127 Basin. The level data are used to alarm for CSO events and to calculate the volume of CSOs. The NPDES127 Basin overflows when the level in NPDES127_036-146 exceeds 36.13 inches.

The site is located downstream from the NPDES175 Basin, but it is not located within the main combined sewer trunk line for the basin. The data at the site do not capture a dry weather diurnal pattern due to the small size and commercial land use of the tributary area. During storm events, the scattergraph indicated a consistent response with no evidence of surcharging. The quality of the level data was classified as "Excellent" for Phases 2–3, which matches the quality of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

This monitoring site is a permanent site and will continue to be screened in the future.

3.11.2 NPDES130 Basin

The NPDES130 Basin, located downstream from the NPDES132 Basin and upstream from the NPDES175 Basin, is approximately 36 acres in area. No CSS facilities are located in the basin.

One temporary monitoring site and one permanent monitoring site measured flows in the basin during Phases 2–3. Following the end of Phase 3, only the permanent monitoring location remained in the basin.

PB130_030-133A

PB130_030-133A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/20/2008 to characterize the hydrology for the NPDES130 Basin.

PB130_030-133A was located downstream from PB130_DWF-030410 on a side line that enters the main basin sewer. The data at the site captured a consistent dry weather diurnal pattern. During storm events, the site showed a consistent and repeatable response, and did not result in surcharged conditions. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data are suitable for use in model calibration.

The site was removed on 3/23/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

PB130_DWF-030410

PB130_DWF-030410 is a permanent monitoring site that records both level and velocity. The site is classified as a dry weather site because it is expected to provide high-quality velocity and level data; thus, both level and velocity data are finalized for the site. The site was installed on 7/31/2007 to determine if CSO events are occurring from the NPDES130 Basin and to quantify them. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The NPDES130 Basin overflows when the level in PB130_DWF-030410 reaches 56.13 inches.

PB130_DWF-030410 is located in the main combined sewer pipe downstream from MH 030-416. Flow balancing was undertaken during Phases 2–3 as described in the section for PB132_DWF-030416. The data at the site captured a consistent dry weather diurnal pattern. During storm events, the site showed a consistent and repeatable response, and did not result in surcharged conditions. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

This monitoring site is a permanent site and will continue to be screened in the future.

3.11.3 NPDES132 Basin

The NPDES132 Basin, located downstream from the NPDES135 Basin and upstream from the NPDES130 Basin, is approximately 36 acres in area. PS 65 pumps combined flows from the NPDES134 Basin into the main combined sewer line that passes through the NPDES132 Basin. No CSS facilities are located in the basin.

Four temporary monitoring sites and one permanent monitoring site measured flows in the basin during Phases 2–3. Following the end of Phase 3, only the permanent monitoring site remained in the basin.

PB132_030-178A was located upstream from PB132_DWF-030416. The data at the site captured a consistent dry weather diurnal pattern. During storm events the site showed a consistent response, and did not indicate surcharged conditions. There was an 8-day-long data gap from 1/7/2010 to 1/15/2010; consequently, the data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 2/5/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

PB132_030-179A

PB132_030-179A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/24/2008 to characterize the hydrology for the southwest part of the NPDES132 Basin.

PB132_030-179A was located upstream from PB132_DWF-030416. The data at the site captured a consistent dry weather diurnal pattern. However, the calculated daily minimum dry weather flow is overestimated due to pooling in front of the meters. During storm events the site showed a consistent response, and did not result in surcharged conditions. The site also had an extended data gap from 1/7/2010 to 1/15/2010 due to a meter malfunction. Because of the data gap and over-predicted low flows, the data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. Wet weather data and dry weather diurnal peak flows for Phases 2–3 are suitable for model calibration.

The site was removed on 2/5/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

PB132_030-194A

PB132_030-194A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/24/2008 to characterize the hydrology for the northeastern part of the NPDES132 Basin.

PB132_030-194A was located upstream from PB132_030-426A. The data at the site captured a consistent dry weather diurnal pattern. During storm events the site responded well and showed a consistent pattern. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 3/22/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

PB132_030-426A

PB132_030-426A was a temporary monitoring site that recorded both level and velocity. The site was installed on 11/5/2008 to characterize the hydrology for the northern part of the NPDES132 Basin.

PB132_030-426A was located in the main drainage line that originates at the NPDES138 Basin. The data reflect the upstream PS 20 and PS 65. The data at the site captured a consistent dry weather diurnal pattern that was dominated by pumped flow from upstream, as shown in Figure 3-79 below. The site was also prone to ramping at low flows. During storm events the site responded well and showed a consistent pattern. Due to the low flow ramping, the data quality was classified as "Good" for Phases 2–3. Data collected during Phase 1 were classified as "Excellent" because ramping was not observed. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 3/22/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

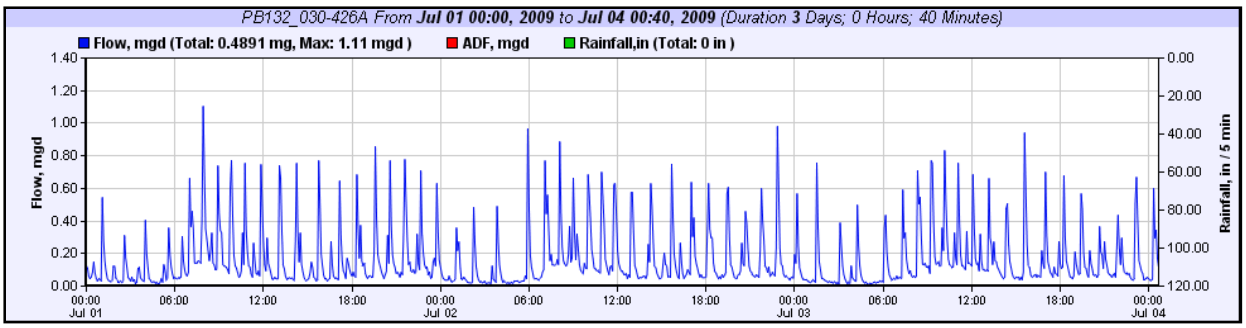

Figure 3-79. PB132_030-426A dry weather flow hydrograph reflecting PS 20 and PS 65 discharges

PB132_DWF-030416

PB132_DWF-030416 is a permanent monitoring site that records both level and velocity. The site is classified as a dry weather site because it was expected to provide high-quality velocity and level data; thus, both level and velocity data are finalized for the site. The site was installed on 7/19/2007 to determine if CSO events were occurring from the NPDES132 Basin and to quantify them. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The NPDES132 Basin overflows when the level in PB132_DWF-030416 reaches 40.0 inches.

PB132_DWF-030416 is located at the NPDES132 Overflow Structure, which consists of an overflow pipe located on the maintenance hole bench. The site is located within the main combined sewer line downstream from the NPDES135 Overflow Structure. Upstream PS 20 and PS 65 influence the site.

Flow balancing was undertaken using the data from this permanent monitoring site during Phases 2–3. The following flow balancing occurred at this location:

- The total flow from three upstream temporary monitoring sites (PB132_030-426A, PB132_030-178A, and PB132_030-179A) was compared to the downstream flow at PB132_DWF-030416. The flow balance indicated that the calculated flows from this permanent monitoring site were underestimated.
- The total flow from PB132_DWF-030416 was compared to the downstream flow at PB130_DWF-030410. The flow balance also indicated that the calculated flows from PB132_DWF-030416 were underestimated.
- Another flow balance was performed using the same total flow from three upstream temporary monitoring sites (PB132_030-426A, PB132_030-178A, and PB132_030-179A); however, this time the flows were compared to the downstream flow at PB130_DWF-030410. This flow balance determined that the calculated flows from PB130_DWF-030410 were within the correct range.

Based on the flow balances, it was determined that the data from PB132_DWF-030416 should be used for level only, and that PB130_DWF-030410 should be used to calculate the flow and characterize hydrology for both the NPDES130 and NPDES132 Basins.

The site showed a consistent dry weather flow pattern that is dominated by the upstream pump station flow. During storm events the site showed a fairly consistent and repeatable response that indicated that flow was backing up along the main Portage Bay pipe that flows into the King County system. The data quality was classified as "Some Limitations" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. The level data from Phases 2–3 are suitable for use in model calibration. The velocity data from Phases 2–3 are underestimating flows based on the flow balances and are not suitable for use in model calibration.

This monitoring site is a permanent site and will continue to be screened in the future.

3.11.4 NPDES135 Basin

The NPDES135 Basin, the northernmost basin in the Portage Bay/Lake Union Basin, is approximately 18 acres in area. Flows from the NPDES138 Basin are pumped northwest into the NPDES135 Basin. As the flows pass through the basin, they are redirected south toward the King County system at Mercer Street. No CSS facilities are located in the basin.

One temporary monitoring site and one permanent monitoring site measured flows in the basin during Phases 2–3. Following the end of Phase 3, only the permanent monitoring site remained in the basin.

PB135_023-239A

PB135_023-239A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/23/2008 to characterize the hydraulics of PS 20 and the area between the NPDES135 and NPDES138 Basins.

PB135_023-239A was located within the NPDES135 Basin downstream from PS 20 and upstream from the NPDES135 Overflow Structure. The data at the site correlated with the flow pulses from the upstream pump station. The meter captured a consistent dry weather diurnal pattern that was dominated by the upstream pump station, as seen in Figure 3-80. During storm events the data showed a consistent response. The data indicate several extended dropouts:

- 7/24/2009 to 10/16/2009: The site was removed because suitable data had been collected to characterize the hydraulics in the NPDES135 Basin. However, it was determined that the monitoring site was useful in confirming data collected at the permanent site downstream, and the monitoring site was subsequently reinstalled.
- 2/5/2010 to 3/7/2010: Meter malfunction resulted in loss of data. However, because the site was scheduled to be removed following the January 2010 flow data review workshop, the data collected after that date are not critical for model calibration. Thus, this data gap was not considered in the data quality classification for this monitoring location.

The data quality was classified as "Excellent" for Phases 2–3. All level data collected during Phases 2–3 are suitable for use in model calibration.

The site was removed on 3/22/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

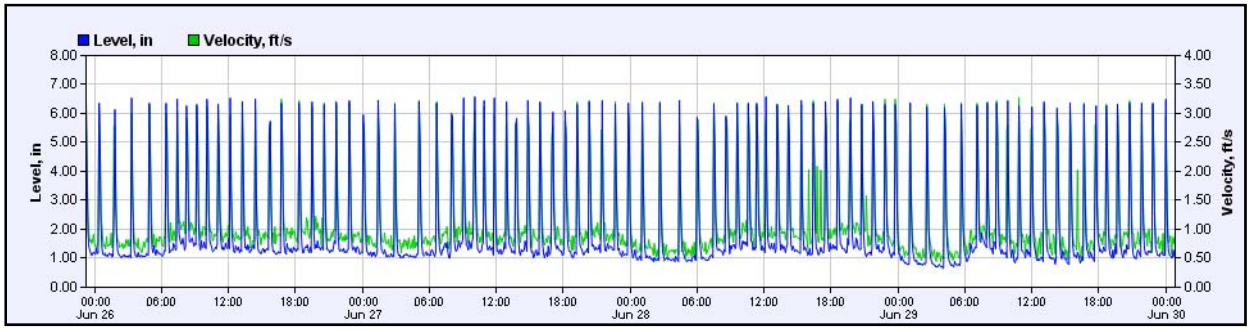

Figure 3-80. PB135_023-239A dry weather flow hydrograph reflecting PS 20 discharge

NPDES135_MH023208A

NPDES135_023-208A is a permanent monitoring site that records both level and velocity. The site is classified as a wet weather site because it is not expected to provide high-quality velocity data; thus, only level

data are finalized. The site was installed on 8/27/2007 to quantify CSO events occurring from the NPDES135 Basin. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The NPDES135 Basin overflows when the level in NPDES135_023-208A reaches 9.63 inches.

NPDES135_023-208A is located at the NPDES135 Overflow Structure, which is downstream from the PS 20 force main discharge. Upstream pump operations directly influence the site. Flow enters the site from the southeast through an 18-inch-diameter pipe, and exits heading toward the southwest. The meter captured a consistent dry weather diurnal pattern that was dominated by the upstream pump station flow. During storm events the data showed a consistent but scattered response due to the pump station flow from upstream. Level data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All level data from Phases 2–3 are suitable for use in model calibration.

This monitoring site is a permanent site and will continue to be screened in the future.

3.11.5 NPDES138 Basin

The NPDES138 Basin, located in the northeastern part of the Portage Bay/Lake Union Basin on the western shore of Portage Bay, is approximately 36 acres in area. The basin is downstream from the NPDES136 Basin and upstream from the NPDES135 Basin. The NPDES138 Basin contains CSO Facility 36 and two pump stations: PS 20 and PS 67.

Six temporary monitoring sites and one permanent monitoring site measured flows in the basin during Phases 2–3. Following the end of Phase 3, only the permanent monitoring location remained in the basin.

PB138_023-188B

PB138_023-188B was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/26/2008 to characterize the hydrology for the western part of the NPDES138 Basin.

PB138_023-188B was located in the same maintenance hole as PB138_023-188C; it was placed in the pipe that enters the structure from the west. The structure is upstream from the HydroBrake in CSO Facility 36. Only an ultrasonic meter was used at this monitoring location to measure level. The data show a consistent surcharge relationship between large storm events. The site did not capture a consistent dry weather flow pattern, due to wide scatter at very low flow depths (below 1 inch) caused by ramping. Because of this, the data quality was classified as "Good" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data collected during Phases 2–3 are suitable for use in model calibration. Smaller storm events with peak flow data that do not cause surcharging at the site will be used for hydrology model calibration. The larger storm event data will be used to calibrate the hydraulics of the storage facility.

The site was removed on 3/22/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

PB138_023-188C

PB138_023-188C was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/26/2008 to characterize the hydrology of the north part of the NPDES138 Basin.

PB138_023-188C was located in the same maintenance hole as PB138_023-188B; the site was placed in the pipe that enters the structure from the north. The structure is upstream from the HydroBrake located in CSO Facility 36. The data at the site captured a dry weather diurnal pattern that showed a significant amount of scatter during low flows due to ramping. During storm events, the site became surcharged and the velocity dropped to near zero as the flow backed up at the HydroBrake. The data show a consistent surcharge relationship between large storm events. The data quality was classified as "Good" for Phases 2–3 due to the

scatter at low flows, which matches the quality classification of the data collected during Phase 1. All data collected during Phases 2–3 are suitable for use in model calibration. Smaller storm events with peak flow data that do not cause surcharging at the site will be used for hydrology model calibration. The larger storm event data will be used to calibrate the hydraulics of the storage facility.

The site was removed on 3/22/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

PB138_023-191A

PB138_023-191A was a temporary monitoring site that recorded both level and velocity. The site was installed on 3/23/2010 to characterize the hydraulics of CSO Facility 36.

PB138_023-191A was located on the downstream side of the HydroBrake at CSO Facility 36. The primary purpose for the monitoring location was to characterize the HydroBrake at MH 023-434. Four hydraulic conditions are occurring simultaneously within the structure:

- The structure receives flow from the upstream HydroBrake.
- The structure receives flow from the PS 67 force main.
- Under normal conditions the structure directs flow toward PS 20.
- Under high-flow conditions flow is also diverted over the high-flow bypass weir and directed toward the NPDES138 Overflow Structure.

Flows that go over the high-flow bypass weir and flow toward the NPDES138 Overflow Structure are initially redirected back toward PS 67; however, when the pump station is inundated overflows into Portage Bay occur. Two scenarios can cause the high-flow bypass weir in MH 023-191 to overflow. First, PS 20 can malfunction, causing the depth of flow in the structure to rise and go over the weir. Second, the storage tank high-flow bypass weir at structure 023-434 can overflow, sending excess flow toward the structure. If PS 20 can retain the excess flow, no overflow over the weir in MH 023-191 occurs; however, if the excess flow cannot be retained by the pump station, the weir overflows.

The data at the site captured a dry weather diurnal pattern that showed occasional fluctuations and showed scatter due to the PS 67 discharge. During storm events, the site showed consistent flow patterns resulting from the downstream HydroBrake and the upstream pump station. The data quality was classified as "Good" for Phases 2–3; the site captured the different hydraulic conditions occurring within the structure. This classification matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 3/22/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

PB138_023-434A

PB138_023-434A was a temporary monitoring site that recorded level only. The site was installed on 9/24/2008 to characterize the HydroBrake at CSO Facility 36 and to be used in conjunction with upstream meters to develop hydraulics for the storage tank weirs.

PB138_023-434A was located upstream of the HydroBrake at CSO Facility 36. The site captured a consistent dry weather level pattern. During storm events, the level data were consistent and corresponded with the storage tank weir and the high-flow bypass weir overflowing. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 3/22/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

PB138_023-438A

PB138_023-438A was a temporary monitoring site that recorded level only. The site was installed on 9/24/2008 to characterize storage utilization during storm events in CSO Facility 36.

PB138_023-438A was located within the storage tanks at CSO Facility 36; thus, no dry weather levels were recorded at the site. During storm events, the level data were consistent and corresponded with the meters in MH 023-434. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 3/22/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

PB138_030-352A

PB138_030-352A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/20/2008 to measure flows and characterize hydrology for the southern part of the NPDES138 Basin.

PB138_030-352A was located upstream from the HydroBrake located in CSO Facility 36 and south of the meters located at MH 023-188. The data at the site captured a dry weather diurnal pattern that showed periodic scatter. During storm events the meters became surcharged, and the velocity dropped to near zero as the flow backed up at the HydroBrake. The data show a consistent depth-velocity relationship at depths between 2 and 5 inches, and a variable relationship at higher and lower depths. The data quality was classified as "Good" for Phases 2–3 due to the scatter at low and high flows, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration. Smaller storm events with peak flow data that do not cause surcharging at the site will be used for hydrology model calibration. The larger storm event data will be used to calibrate the hydraulics of the storage facility.

The site was removed on 2/5/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NPDES138_MH023192

NPDES138_MH023192 is a permanent monitoring site that records both level and velocity. The site is classified as a wet weather site because it is not expected to provide high-quality velocity data; thus, only level data are finalized for the site. The site was installed on 7/25/2007 to identify and quantify CSO events occurring from the NPDES138 Basin. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. Overflows occur when the level in NPDES138_MH023192 reaches 73.25 inches.

NPDES138_MH023192 is located at the NPDES138 Overflow Structure downstream from CSO Facility 36. The data at the site captured a consistent dry weather diurnal pattern. During storm events the data showed very little response unless the diversion weir in MH 023-191 was overtopped. When this occurred, the data responded well. Level data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All level data from Phases 2–3 are suitable for use in model calibration.

This monitoring site is a permanent site and will continue to be screened in the future.

3.11.6 NPDES175 Basin

The NPDES175 Basin, located upstream from the King County system and downstream from the NPDES129, NPDES130, and NPDES131 Basins, is approximately 94 acres in area. No CSS facilities are located in the basin.

Five temporary monitoring locations and one permanent monitoring location measure flows in the NPDES175 Basin during Phases 2–3. Following the end of Phase 3, only the permanent monitoring location remained in the basin.

PB175_030-074A

PB175_030-074A was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/7/2008 to characterize the hydrology for the northeastern part of the NPDES175 Basin.

PB175_030-074A was located upstream from PB175_030-072A. The data at the site captured a dry weather diurnal pattern that indicated a fair amount of scatter, due to very low flow depths (< 1 inch) and ramping. A hydraulic jump occurs around 2.5 inches of flow depth, resulting in a slightly unusual scattergraph as seen in Figure 3-81 below. Storm data showed a consistent and repeatable response. The data quality was classified as "Good" for Phases 2–3 due to the wide scatter at low flows, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 3/23/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

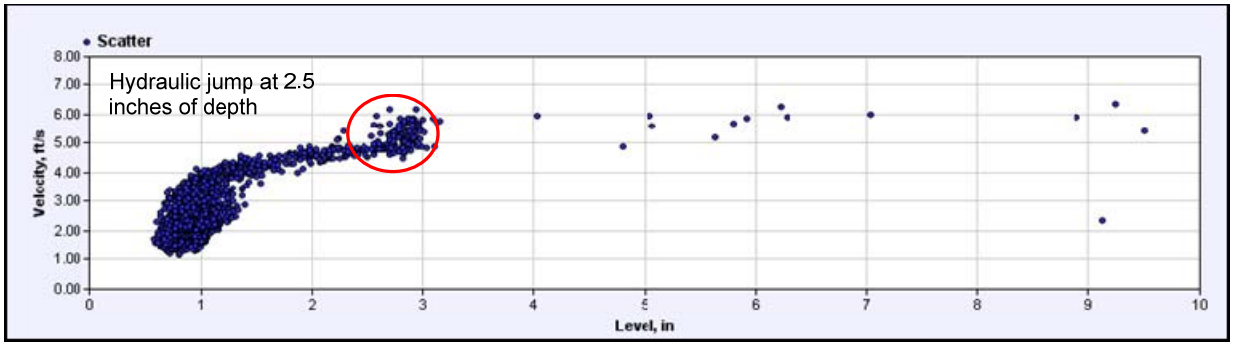

Figure 3-81. PB175_030-074A scattergraph from 9/2009 to 12/2009

SPU_030-080A

SPU_030-080A was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/16/2008 to characterize the hydrology in the NPDES175 Basin and to calculate flows in the parallel sewer trunk line leaving the Portage Bay/Lake Union Basin.

SPU_030-080A was located in East Lake Avenue on a line parallel to the main sewer trunk line for the Portage Bay/Lake Union Basin. The data at the site captured a consistent dry weather diurnal pattern. During storm events, the scattergraph indicated a consistent response with no evidence of surcharging. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

The site was removed on 2/4/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

PB175_030-096A

PB175_030-096A was a temporary monitoring site that recorded both level and velocity. The site was installed on 1/16/2009 to characterize the hydrology for the northeastern part of the NPDES175 Basin.

PB175_030-096A was located upstream from site PB175_030-074B. The data at the site captured a consistent dry weather diurnal pattern. During storm events, the site showed a consistent and repeatable response with no evidence of surcharged conditions. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data are suitable for use in model calibration.

The site was removed on 3/22/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

SPU_030-358A

SPU_030-358A was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/21/2008 to calculate flows in the main sewer trunk line leaving the Portage Bay/Lake Union Basin for comparison with the permanent site at the NPDES175 Overflow Structure, and to estimate flow split between this line and the parallel that runs along the main Portage Bay line.

SPU_030-358A was located in East Lake Avenue on the main sewer trunk line leaving the Portage Bay/Lake Union Basin. The data at the site captured a consistent dry weather diurnal pattern. During storm events, the scattergraph indicated a consistent response with no evidence of surcharging. The data quality was classified as "Excellent" for Phases 2–3, which is different from the Phase 1 classifications of "Poor" and "Good." During Phase 1 the type of meter was changed, resulting in two different data quality classifications. Problems during Phase 1 were caused by silt, but frequent maintenance and installing an ADS FlowShark reduced the problems during Phases 2–3. All data collected during Phases 2–3 are suitable for use in data calibration.

The site was removed on 2/4/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

PB175_036-581A

PB175_036-581B was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/29/2008 to calculate flows entering the NPDES175 Basin from the NPDES128 Basin.

PB175_036-581B was located downstream from the meters at PB175_036-046A/B. PB175_036-581B was placed in a 30-inch-diameter pipe upstream from an 18-inch-diameter pipe. The data at the site captured a dry weather diurnal pattern that showed significant scatter, likely due to debris and sediment. During storm events, the scattergraph indicated a downstream flow constriction that resulted in a flat scattergraph, as seen in Figure 3-82. The data quality was classified as "Good" for Phases 2–3 due to the wide scatter at low flows, which matches the quality classification of the data collected during Phase 1. All data are suitable for use in model calibration.

The site was removed on 3/23/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

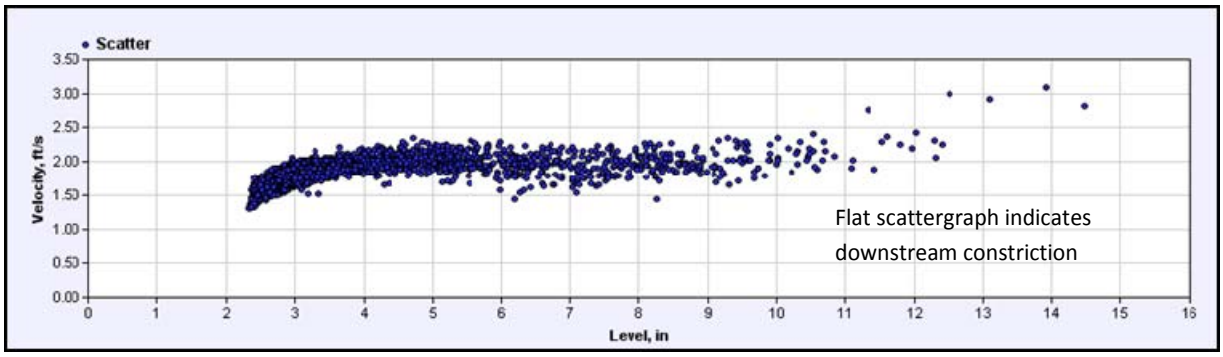

Figure 3-82. PB175_030-074A scattergraph from 9/2009 to 12/2009

PB175_DWF-030348

PB175_DWF-030348 is a permanent monitoring site that records both level and velocity. The site is classified as a dry weather site because it is expected to provide high-quality velocity and level data; thus, both level and velocity data are finalized for the site. The site was installed on 8/28/2007 to determine if CSO events were occurring and to quantify overflow volumes from the NPDES175 Basin. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The NPDES175 Basin overflows when the level in PB175_DWF-030348 exceeds 42.13 inches.

The site is located within the main sewer trunk line directly downstream from PB130_DWF-030410. The data at the site captured a consistent dry weather diurnal pattern. During storm events, the scattergraph indicated a consistent response with no evidence of surcharging. The data quality was classified as "Excellent" for Phases 2–3, which matches the quality classification of the data collected during Phase 1. All data from Phases 2–3 are suitable for use in model calibration.

This monitoring site is a permanent site and will continue to be screened in the future.

3.11.7 Combined Sewer Overflows

ADS reported that two CSOs occurred in the Portage Bay/Lake Union Basin during Phases 2–3: one in the NPDES132 Basin, and the other in the NPDES175(B) Subcatchment. Table 3-12 lists the CSOs reported during the monitoring period. Figure 3-83 shows the maximum water level recorded by ADS at each of the overflow structures in the basin as a percentage of the weir height.

Table 3-12. 2008–2009 Combined Sewer Overflows in Portage Bay/Lake Union Basin
6/1/2009 through 6/1/2010

NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
127	--	--	--
130	--	--	--
132	--	--	--
135	--	--	--
138	11/26/2009	1:45	133,059
175B	10/17/2009	0:05	269

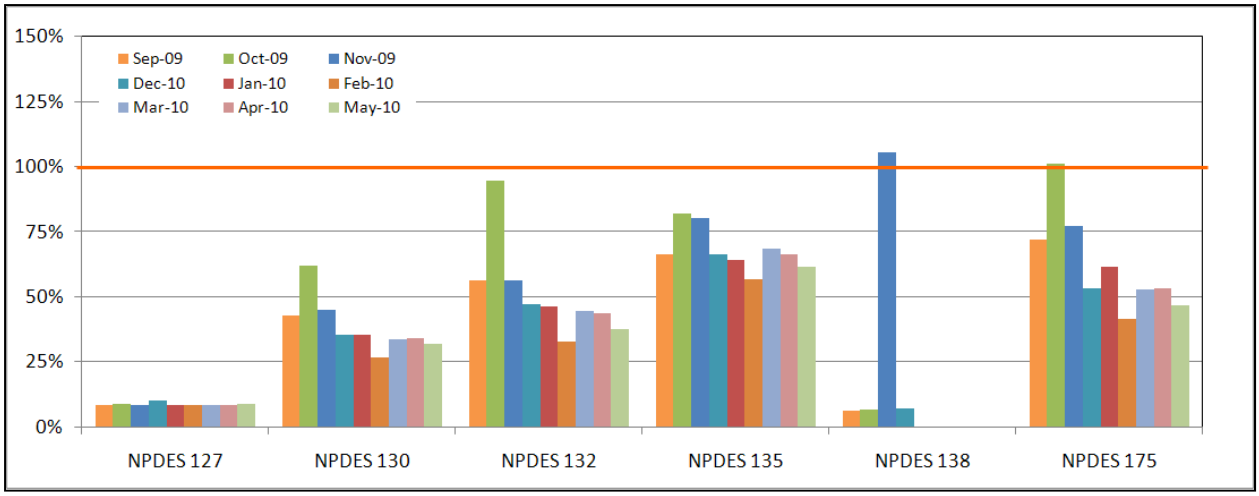

Figure 3-83. Maximum water level as percent of overflow weir height in Portage Bay/Lake Union Basins

3.11.8 Facility Operations

The CSO facilities in the Portage Bay/Lake Union Basin consist of one overflow weir in each NPDES basin and CSO Facility 36. The Portage Bay/Lake Union Basin also contains PS 20, PS 62, and PS 67.

NPDES127

The overflow for the NPDES127 Basin is located on the northern side of MH 036-146. Once the level in the pipe reaches a depth of 36.13 inches, flow is diverted into the CSO overflow pipe.

NPDES130

The overflow for the NPDES130 Basin is located on the western side of MH 030-410. Once the level in the pipe reaches a depth of 56.13 inches, flow is diverted into the CSO overflow pipe.

NPDES132

The overflow for the NPDES132 Basin is located on the northwestern side of MH 030-381. Once the level in the pipe reaches a depth of 40.0 inches, flow is diverted into the CSO overflow pipe.

NPDES135

The overflow for the NPDES135 Basin is located on the northern side of MH 023-208. Once the level in the pipe reaches a depth of 9.63 inches, flow is diverted into the CSO overflow pipe.

NPDES138

CSO Facility 36 is located within the NPDES138 Basin. The facility consists of a HydroBrake and 12,000 gallons of offline storage, located at MH 023-434 at the dead-end roadway of Shelby Street. Figure 3-84 shows the monitor data for the HydroBrake, which was created using data from PB138_023-434A and PB138_023-191A. A manufacturer's curve is not available for this HydroBrake.

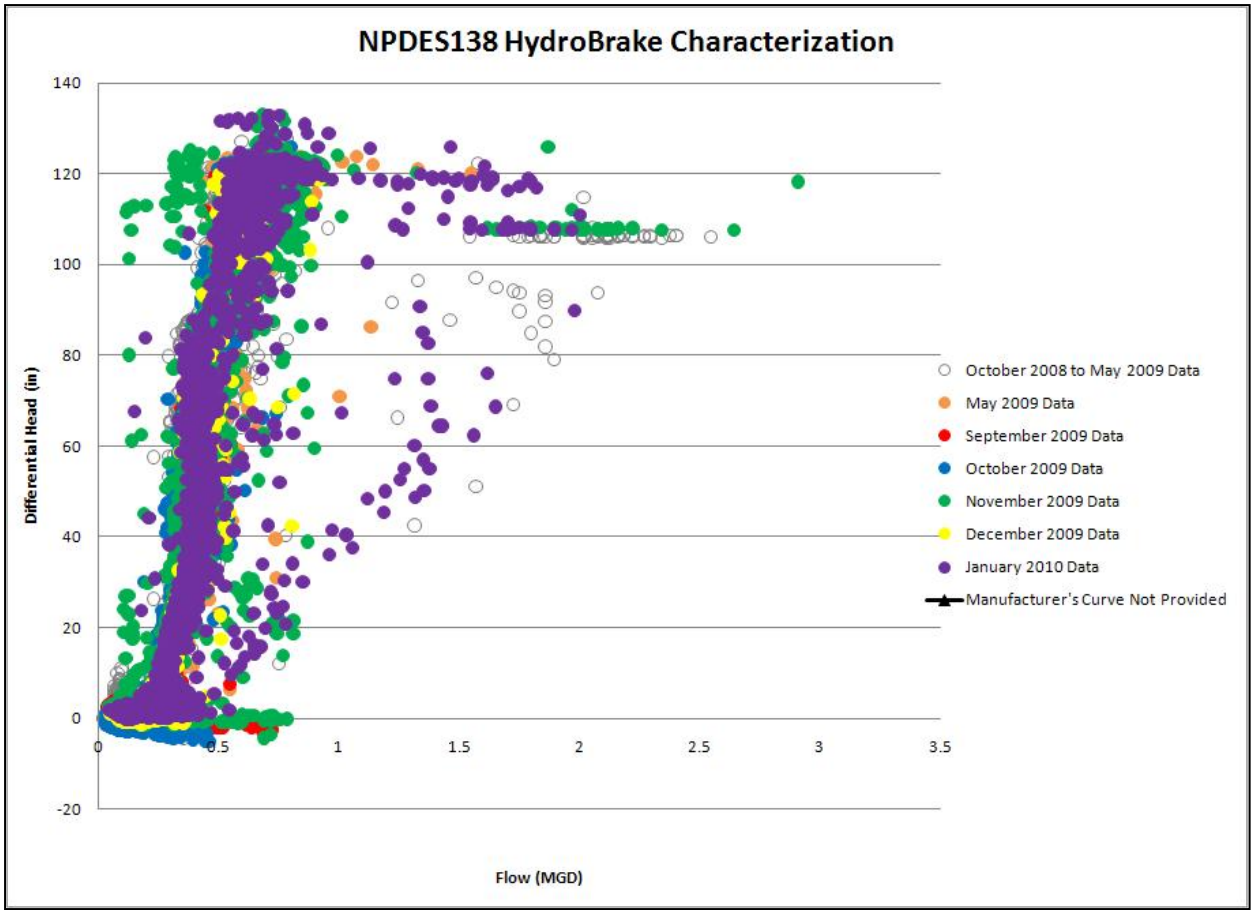

Figure 3-84. NPDES138 Basin HydroBrake characterization

As shown in Figure 3-85, a storage weir and an emergency bypass weir are located within the same structure as the HydroBrake. The flow backs up within the pipe network until the storage weir is overtopped and the flow is diverted into the storage tanks. MH 023-438 measures the depth of storage within the storage tanks. A flap gate installed at the outflow from the storage tank prevents flow from entering the storage tank prior to overtopping the weir. If the storage tank fills up, flow overtops the emergency bypass weir at the HydroBrake and continues downstream to MH 023-191.

MH 023-191 is located downstream from the HydroBrake structure. Under normal flow conditions, the HydroBrake directs flow toward PS 20. Under high-flow conditions, an emergency bypass weir in this structure is overtopped, and flow is diverted toward the NPDES138 Overflow Structure. Flow in this structure is initially directed to PS 67, which pumps flows back up into MH 023-191. If the pump station is unable to keep up with the incoming flows, the pump station backs up and discharges over the overflow weir into Portage Bay.

The overflow for the NPDES138 Basin is located on the eastern side of MH 023-192. Once the level in the pipe reaches a depth of 73.25 inches, flow is diverted into the CSO overflow pipe.

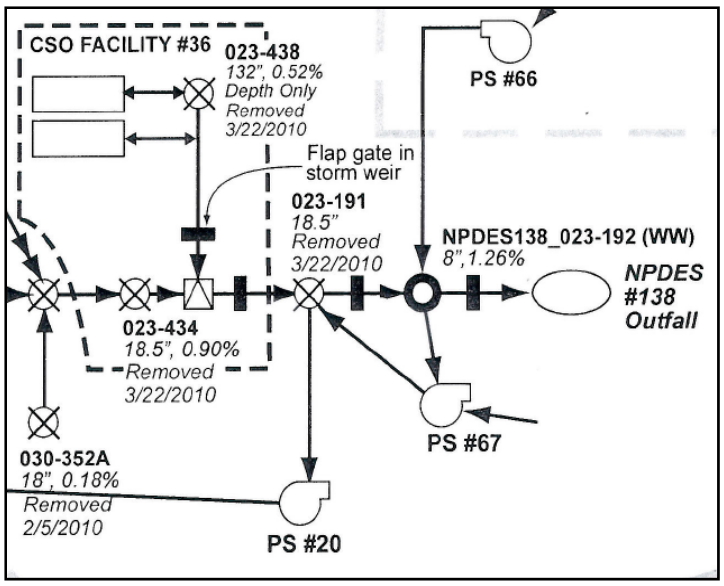

Figure 3-85. Flow schematic of CSO Facility 36

NPDES175

The overflow for the NPDES175 Basin is located on the western side of MH 030-348. Once the level in the pipe reaches a depth of 42.13 inches, flow is diverted into the CSO overflow pipe.

Pump Stations 20, 62, and 67

SPU monitors PS 20, PS 62, and PS 67 via its SCADA system, which records wet well level and pump run times. Data are available at 90- to 120-second resolution. The SCADA data will be used in model calibration to determine the pump switch on and off levels and used in conjunction with drawdown test results to calculate the pump station flow rate.

Data collected during Phases 2–3 included the pump on-off states and the wet well depth. These data were plotted versus time for review. Review consisted of observing the normal rise and fall of wet well elevation with time during wet and dry weather. In general, no anomalies in operation were noted that could not be explained by response to rainfall.

3.11.9 Recommendations for Additional Data Collection

At the conclusion of Phases 2–3 monitoring, no additional data needed to be collected in the Portage Bay/Lake Union Basin for the purposes of model calibration and development and all temporary meters were removed.

3.12 System-Wide Monitoring Locations

The system-wide monitoring locations were selected to capture the flows from the City's CSS before draining into King County's CSS in areas not covered by the CSO basin-specific model. In addition, system-wide monitoring locations were placed in King County's system in areas that the County identified as having data gaps, and to support assessment of system capacity. The system-wide model basins were previously delineated by Aqualyze by tracing pipes upstream from the manhole connecting the last pipe to the King County interceptor system. A total of 53 monitoring locations were selected to provide flow data in the system-wide model basins. The data collected at the system-wide monitoring locations will be used for the following purposes:

- to provide flow data for the calibration of a system-wide model
- to provide flow data required in the assessment of GSI pilot studies performed by the City such as Ballard GSI retrofits
- to support analysis of capacity problems in the City's sewer network
- to obtain data in areas where the County has insufficient CSS data.

The quality of the data collected during the Phases 2–3 monitoring period for each of these locations is described in more detailed in the following sections.

Detailed information for each of the system-wide meter sites can be found in Appendix M. A basin schematic can be found in Appendix B. The meter locations and system-wide model basins are shown on Figure 1-5, Figure 1-6, and Figure 1-7 of Section 1.

ALK_059-162A

ALK_059-162A is a temporary monitoring site that records both level and velocity. The site was installed on 10/29/2009 to characterize the hydrology of the system-wide model basin 059-164 in Genesee. Rainfall at this site was monitored by RG 18, which is stationed in the Aki Kurose Middle School campus.

ALK_059-162A is sited in the City's CSS upstream of the King County Rainier pump station that pumps the combined sewage into King County's Hanford trunk. The meter captured a consistent dry weather diurnal pattern and collected suitable wet weather data during the majority of storm events, with the exception of the November 2009 storm, when it failed to record data from 11/12/2009 to 11/18/2009. The data quality was classified as "Good" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

The meter remained installed after the end of Phase 3 monitoring to continue collecting data for the system-wide model calibration purposes.

BAL_012-127A

BAL_012-127A was a temporary monitoring site that recorded both level and velocity. The site was installed on 8/19/2009 to characterize the hydrology of the system-wide model basin 012-172 in Ballard. Rainfall at this site was monitored by RG 08, which is stationed at the Hiram M. Chittenden Locks.

BAL_012-127A was located in the City's CSS upstream of the confluence with King County's Ballard trunk. The meter readings at this site were affected by heavy debris deposited upstream. Debris appeared to be cleared out with storms. Figure 3-86 shows a snapshot of the data signature typical of this site leaving a dry weather period into a storm event. As a result, wet weather flow data are more suitable for model calibration than those for dry weather flows. Nevertheless, there are sufficient dry weather flow periods that captured a

consistent pattern. The meter failed to record data from 12/31/2009 to 1/4/2010. The data quality was classified as "Good" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

The meter was removed on 3/22/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

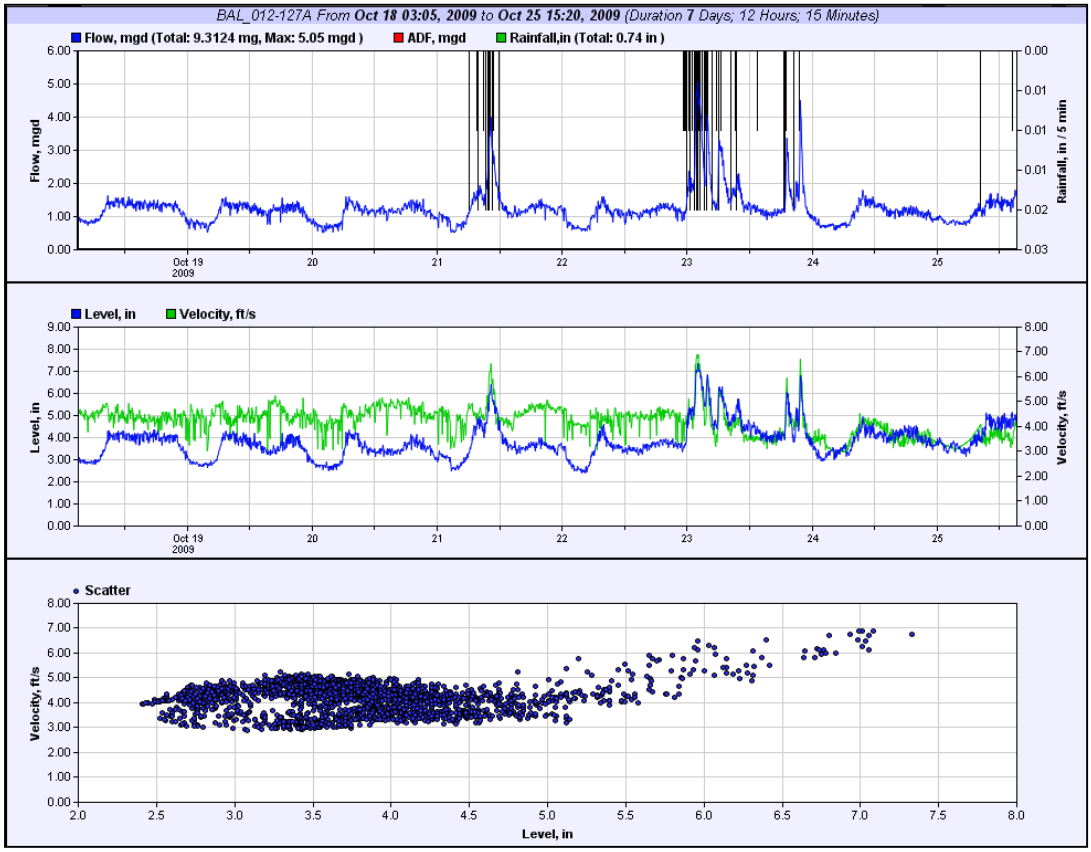

Figure 3-86. BAL_012-127 data signature showing indication of debris accumulation

BAL_012-373A

BAL_012-373A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/24/2009, during Phase 2 monitoring, to characterize the hydrology of the system-wide model basin 012-165 in Ballard as well as flows from the King County Carkeek Park pump station. Rainfall was monitored by RG 08, which is stationed at the Hiram M. Chittenden Locks.

BAL_012-373A was located in the King County CSS upstream of the King County 11th Avenue NW CSO and the Ballard regulator station. The meter captured a consistent dry weather diurnal pattern. During the majority of storm events the meter responded well, with the exception of the October 2009 storm, when it failed to record data from 10/16/2009 to 10/19/2009. The data quality was classified as "Good" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

The meter was removed on 3/29/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

BV_224-071A

BV_224-071A is a temporary monitoring site that records both level and velocity. The site was installed on 2/1/2010 to assess capacity issues of sewers in 12th Avenue NW in the Broadview area. The site is classified as a capacity meter but will potentially be used in system-wide model calibration. Rainfall was monitored by RG 07, which is stationed in the Whitman Middle School campus.

BV_224-071A is located within the system-wide model basin 223-001N. BV_224-071A was a low-flow site. The meter collected suitable dry and wet weather data through Phase 3 monitoring. The meter responded well and consistently during storm events (Figure 3-87). No data gaps occurred during Phase 3 monitoring. The scattergraph is clear and narrow. The data quality was classified as "Excellent" for Phase 3.

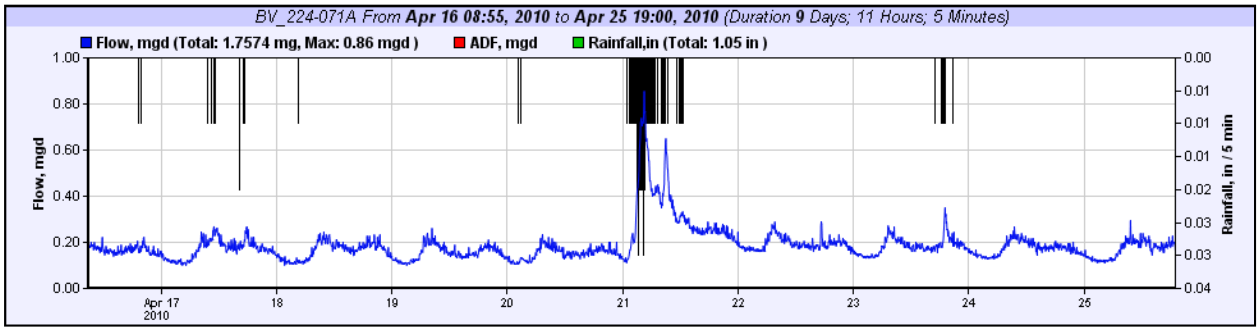

Figure 3-87. BV_224-071A hydrograph shows diurnal pattern and wet weather response

The meter remained in place at the conclusion of Phase 3 monitoring to continue collecting data for capacity assessment purposes.

BV_224-104A

BV_224-104A is a temporary monitoring site that records both level and velocity. The site was installed on 11/4/2009, to assess capacity issues in the Broadview area. The site is classified as a capacity meter but will potentially be used in system-wide model calibration. Rainfall was monitored by RG 07, which is stationed in the Whitman Middle School campus. The meter was initially installed in the east pipe entering the maintenance hole. On 3/25/2010, it was moved to the north pipe in the maintenance hole.

BV_224-104A is located within the system-wide model basin 223-001N. When the meter was installed in the east pipe, it responded well during storm events (Figure 3-88). No data gaps occurred during Phase 3 monitoring. The scattergraph is clear and narrow. The data quality was classified as "Excellent" for Phase 3 prior to 3/25/2010. When the meter was moved to the north pipe, the site characteristics did not allow collection of accurate data. The data quality was therefore ranked as "Poor" following 3/25/2010.

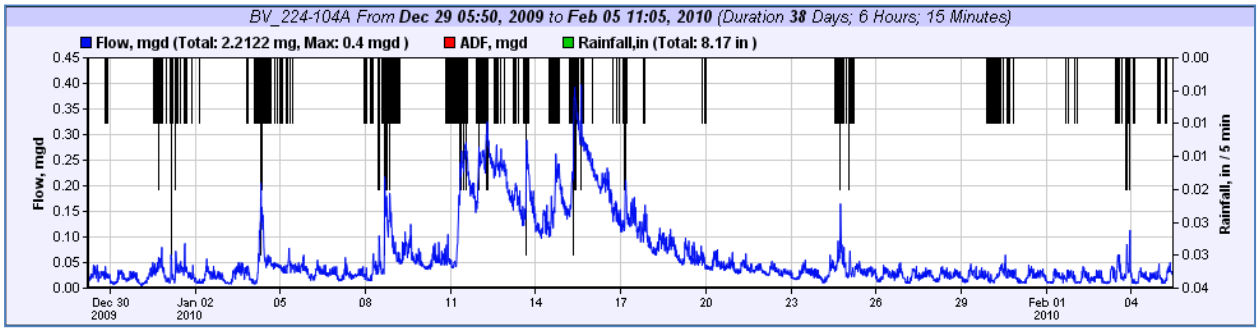

Figure 3-88. BV_224-104A hydrograph shows diurnal pattern and wet weather response

The meter remained in place at the conclusion of Phase 3 monitoring to continue collecting data for capacity assessment purposes. It is recommended that the meter be moved to MH 224-103 to improve data quality and to monitor flows from both the east and north pipes at MH 224-104.

CAP_036-343A

CAP_036-343A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/28/2009 during Phase 2 to characterize the hydrology of the system-wide model basin 035-307 in Capitol Hill. Rainfall was monitored by RG 20, which is located at the TT Minor Elementary campus.

CAP_036-343A was located in the City's CSS upstream of King County's Lake Union tunnel. The site measures low flows only, as high flows are diverted west toward King County's central trunk immediately upstream (see CAP_036-387A). The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. No significant data gap occurred during Phases 2–3. The scattergraph is clear and narrow. The data quality was classified as "Excellent" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

The meter was removed on 4/1/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

CAP_036-387A

CAP_036-387A was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/27/2009 to measure the high flows diverted from the system-wide model basin 035-307 in Capitol Hill and characterize its hydrology. Rainfall was monitored by RG 20, which is stationed in the TT Minor Elementary campus.

CAP_036-387A was located in the City's CSS upstream of the confluence with King County's central trunk. The data collected at this site did not capture dry weather flow. During storm events the meter responded well. No significant data gap occurred during Phase 3 monitoring. The scattergraph is clear and narrow. The data quality was classified as "Excellent" for Phase 3. All Phase 3 data are suitable for model calibration.

The meter was removed on 4/1/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

COM_020-073A

COM_020-073A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/24/2009 near the end of Phase 2 to characterize the hydrology of the system-wide model basin 011-299 in Magnolia. Rainfall was monitored by RG 08, which is stationed at the Hiram M. Chittenden Locks.

COM_020-073A was located in the City's CSS upstream of the confluence with King County's north interceptor. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. No significant data gap occurred during Phases 2–3. The scattergraph is clear and narrow. The data quality was classified as "Excellent" for Phases 2–3. The data are suitable for model calibration.

The meter was removed on 3/23/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

COM_020-212A

COM_020-212A was a temporary monitoring site that recorded both level and velocity. The site was installed on 8/17/2009 to characterize the hydrology of the system-wide model basin 011-170 in Magnolia. Rainfall was monitored by RG 08, which is stationed at the Hiram M. Chittenden Locks.

COM_020-212A was located in the City's CSS upstream of the confluence with King County's north interceptor. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. No significant data gap occurred during Phases 2–3. However, the data signature changed after 3/9/2010, as the level went down (Figure 3-89).

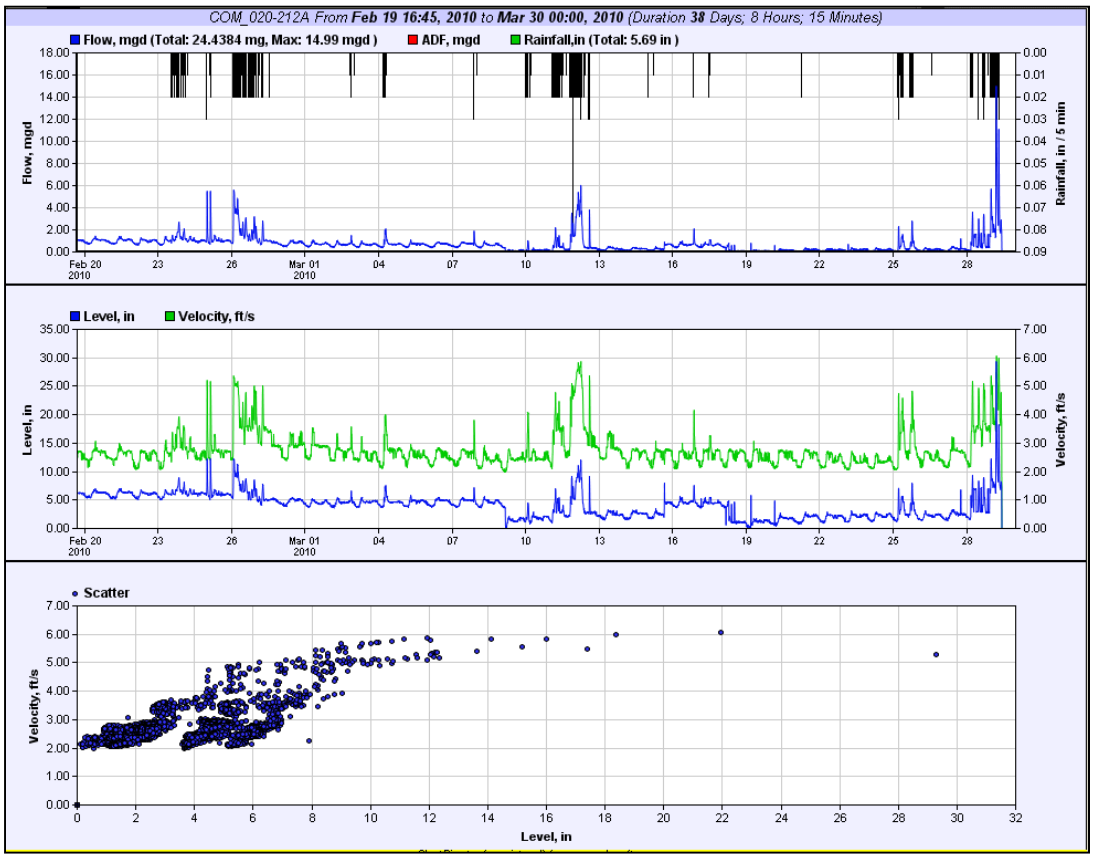

Figure 3-89. COM_020-212A data signature change

The quality of the data for this site was classified as "Good" through the signature change. Data after 3/9/2010 should not be used for model calibration. The data should be used with caution during model calibration, according to data screening notes.

The meter was removed on 3/29/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

DAY_225-072A

DAY_225-072A is a temporary monitoring site that records both level and velocity. The site was installed on 2/12/2010 to provide supporting data for capacity assessments and it is classified as a capacity meter. Rainfall was monitored by RG 01, which is located at the Haller Lake Shop.

DAY_225-072A is located within the system-wide model basin 223-001N at the intersection of Dayton Avenue North and North 115th Street. The meter is mounted on the north pipe. The data collected at this site captured two data signatures (Figure 3-90), which suggest debris downstream that raises the depth while decreasing the velocity. The meter responded well during storm events. No significant data gap occurred during Phase 3. The data quality was classified as "Good" for Phase 3.

The meter remained in place at the conclusion of Phase 3 monitoring to continue collecting data for capacity assessment purposes.

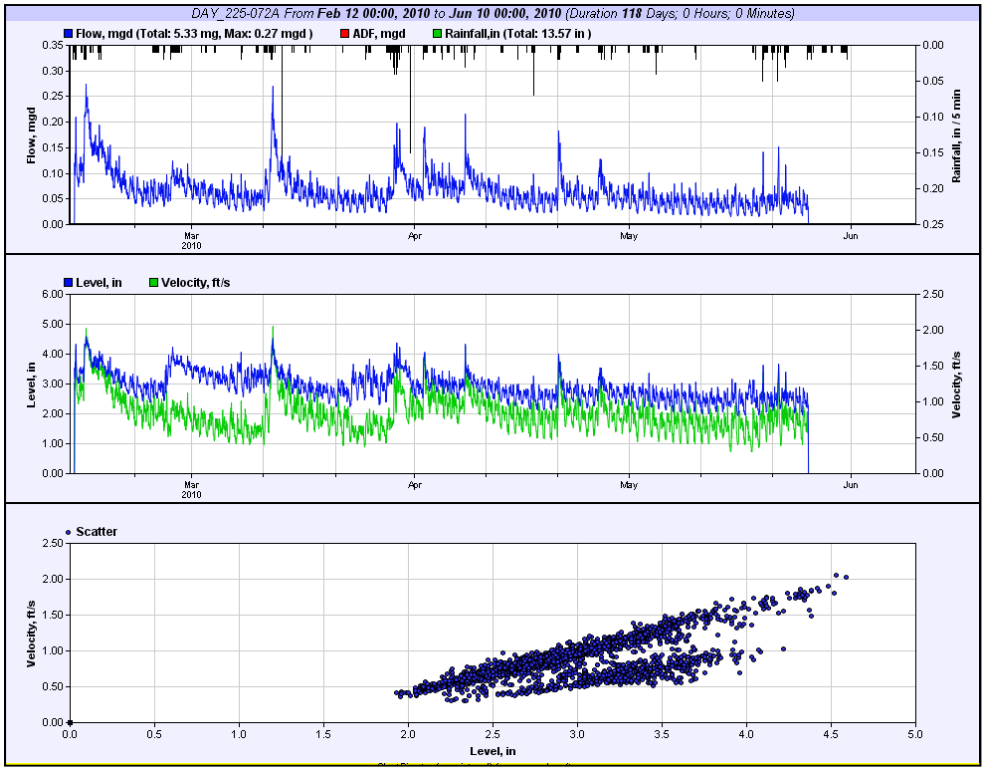

Figure 3-90. DAY_225-072B shows two data signatures suggesting debris accumulation downstream

DAY_225-072B

DAY_225-072B is a temporary monitoring site that records both level and velocity. The site was installed on 2/13/2010 to provide supporting data for capacity assessments and it is classified as a capacity meter site. Rainfall was monitored by RG 01, which is located at the Haller Lake Shop.

DAY_225-072B is located within system-wide model basin 223-001N at the intersection of Dayton Avenue North and North 115th Street. The meter is mounted on the east pipe. The data collected at this site collected a consistent dry weather flow pattern, with the exception of the period between 4/18/2010 and 4/30/2010 (Figure 3-91), where debris in the line affected the data readings. This period will be excluded from model

calibration efforts. The scattergraph presents lower resolution at low flows. The meter responded well during storm events. The data quality was classified as "Some Limitations" for Phase 3. Data should be used with caution during model calibration according to data screening notes.

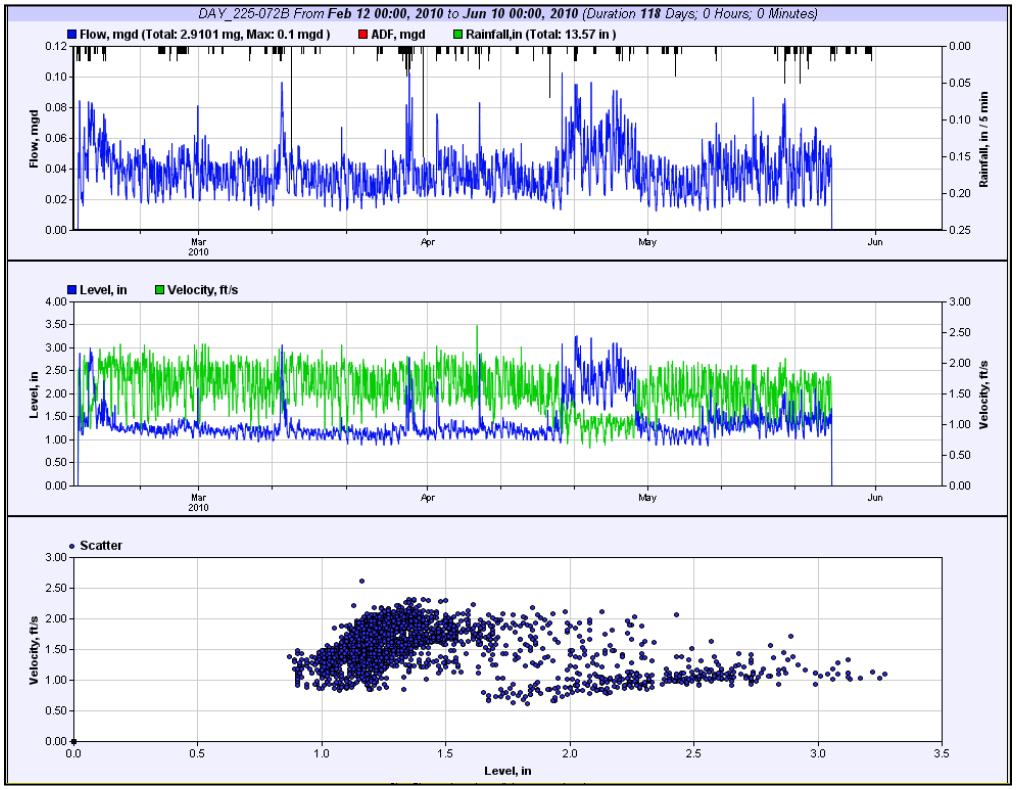

Figure 3-91. DAY_225-072B shows poor relationship between velocity and level

The meter remained in place at the conclusion of Phase 3 monitoring.

DEL_055-142A

DEL_055-142A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/18/2009, near the end of Phase 2, to characterize the hydrology of the system-wide model 055-136 in Delridge and flow in the King County Delridge trunk. Rainfall is monitored by RG 15, which is located in the Puget Sound Clean Air Monitor Station.

DEL_055-142A was located in King County's Delridge trunk upstream of the King County Chelan regulator station. The meter captured a consistent dry weather diurnal pattern. During the majority of storm events the meter responded well, with the exception of the October 2009 storm, when it failed to record data from 10/13/2009 to 10/18/2009. Therefore, data quality was classified as "Good" for Phases 2–3. The data are suitable for model calibration.

The meter was removed on 4/6/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

DEL_055-208A

DEL_055-208A is a temporary monitoring site that records both level and velocity. The site was installed on 2/9/2009 to characterize the hydraulics of the leaping weir diversion structure in the system-wide model

basin 076-218 that diverts high flows to the storage tank in the NPDES169 Basin, and to define any additional capacity to divert less flow to storage. Rainfall is monitored by RG 17, which is located at the West Seattle reservoir.

DEL_055-208A is located in the City's CSS upstream of the confluence with King County's Delridge trunk. High flows are diverted upstream to SPU's Delridge storage tank located in the NPDES169 Basin. The data collected at this site captured a consistent dry weather flow pattern. During storm events the meter had a minimal response, due to the diversion of high flows. The meter presented a suspicious signature during the period of 3/17/2010 to 3/24/2010. Figure 3-92 shows a snapshot of this signature. This period will be excluded from model calibration. Therefore, the data quality was classified as "Good" for Phases 2–3. The data should be used with caution during model calibration, according to data screening notes.

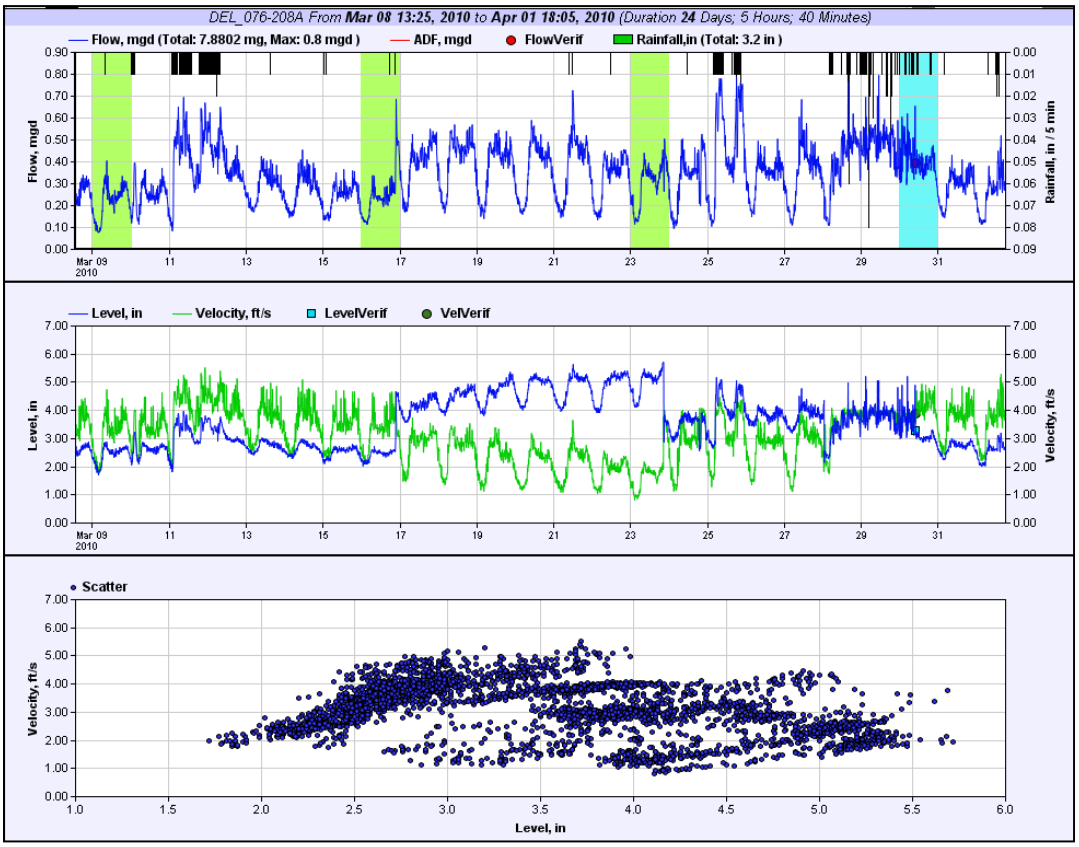

Figure 3-92. DEL_076-208 signature during Phase 3 monitoring

The meter remained in place at the conclusion of Phase 3 monitoring to continue collecting data for use in examining retrofit opportunities for the NPDES169 Basin.

DEL_D055-172A

DEL_D055-172A was a temporary monitoring site that recorded both level and velocity. The site was installed on 8/14/2009 to characterize the stormwater flow in the system-wide model basin 055-136 in Delridge. Rainfall was monitored by RG 15, which is located in the Puget Sound Clean Air Monitor Station.

The flows measured at this site are routed to the City's drainage system. During storm events the meter responded well. No significant data gap occurred during Phase 3 monitoring. The data quality was classified as "Excellent" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

The meter was removed on 3/16/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

DEX_035-241A

DEX_035-241A was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/22/2009 to characterize the hydrology of the system-wide model basin 035-205 in Westlake. Rainfall was monitored by RG 11, which is located at King County's Denny Way regulator station.

DEX_035-241A was located in the City's CSS upstream of the confluence with King County's central trunk. The flows measured at this site drain downstream of the Broad Street siphon. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. No significant data gap occurred during Phases 2–3. The data quality was classified as "Excellent" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

The meter was removed on 4/1/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

DEX_035-241B

DEX_035-241B was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/22/2009 to characterize the hydrology of the system-wide model basin 035-205 in Westlake. Rainfall was monitored by RG 11, which is located in King County's Denny Way regulator station.

DEX_035-241B was located in the City's CSS upstream of the confluence with King County's central trunk. The flows measured at this site drain downstream of the Broad Street siphon. The data collected at this site captured a repeatable dry weather flow pattern but with a wide scattergraph at low flows (Figure 3-93). The meter responded well during storm events. The data quality for this site was classified as "Good" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

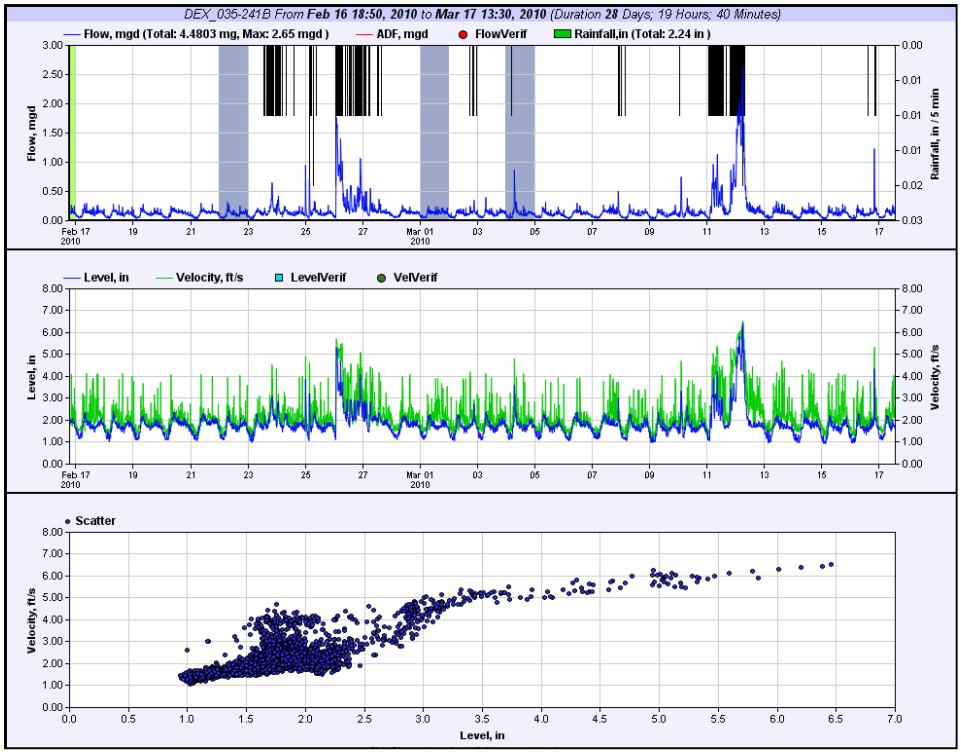

Figure 3-93. DEX_035-241B low resolution scattergraph at low flows

The meter was removed on 4/1/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

DEX_035-300A

DEX_035-300A is a temporary monitoring site that records both level and velocity. The site was installed on 9/15/2009, near the end of Phase 2 to characterize the hydrology of the system-wide model basins 035-307 and 035-584 in Westlake. Rainfall was monitored by RG 11, which is located at King County's Denny Way regulator station.

DEX_035-300A is located in King County's central trunk, upstream of the Broad Street siphon. The dry weather flow scattergraph is thick (perhaps due to influence from the siphon downstream), but periods of suitable data were captured. The meter responded well during storm events. Data are missing from 12/31/2009 to 1/6/2010. The data quality for this site was classified as "Good" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

The meter remained in place at the conclusion of Phase 3 monitoring to continue collecting data for system-wide model calibration purposes.

DIAG_D057-015A

DIAG_D057-015A is a temporary monitoring site that records both level and velocity. The site was monitored using an ISCO 2150 meter installed on 10/29/2009 to monitor the storm drain in the Diagonal Avenue storm drain. The data collected at this site will also serve to create the boundary conditions for the Duwamish Basin model. Rainfall was monitored by RG 16, which is located at King County's East Marginal pump station.

DIAG_D057-015A was located in the Diagonal Avenue storm drain system. When the site was installed in October 2009, the meter recorded level data only. The velocity meter was then installed on 1/13/2010. The data show a clear tidal effect during dry weather and wet weather flows and the flow data are suitable for calibration only during outgoing tides. Figure 3-94 shows a snapshot of the tidal effect evident in the data. The quality of the level data was classified as "Excellent" for Phases 2–3, while the velocity data was classified as "Some Limitations." All level data are suitable for model calibration. Velocity data should be used with caution during model calibration according to data screening notes.

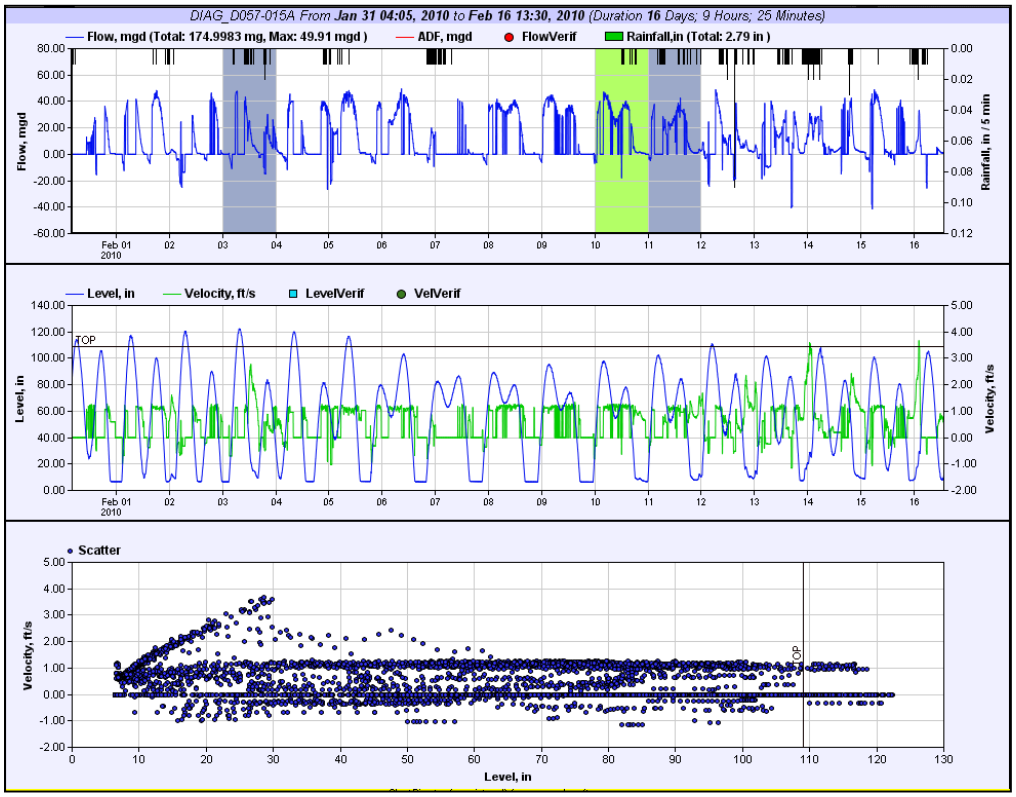

Figure 3-94. DIAG_D057-015A typical data signature exhibiting a tidal effect

The meter was removed on 3/30/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

DIAG_D057-015B

DIAG_D057-015B was a temporary monitoring site that recorded both level and velocity. The site was monitored using an ISCO 2150 meter installed on 1/12/2009 as a redundant meter to DIAG_D057-015A, to confirm the velocity readings of that site from the other side of the wall. Rainfall was monitored by RG 16, which is located at King County's East Marginal pump station.

DIAG_D057-015B was located in the Diagonal Avenue storm drain system. The data show a clear tidal effect during dry weather and wet weather flows and the flow data are suitable for calibration only during outgoing tides. Flow is useful only for model calibration on outgoing tides. The data recorded by the "B" meter matched that recorded by meter "A." The data quality for this site was classified as "Some Limitations"

for Phases 2–3. The data should be used with caution during model calibration according to data screening notes.

The meter was removed on 4/1/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

GEN_059-442A

GEN_059-442A is a temporary monitoring site that records both level and velocity. The site was installed on 10/21/2009 to characterize the hydrology for the system-wide model basin 059-445 and provide additional data for calibration of the SPU Genesee system model. Rainfall was monitored by RG 18, which is located at Aki Kurose Middle School.

GEN_059-442A is located in King County's Charlestown trunk. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. Toward the end of April 2010, the site started to collect debris, which affected the readings at this site. Figure 3-95 shows a snapshot of the data signature change. The data quality for this site was classified as "Some Limitations" for Phases 2–3. Peak flows are usable. The data should be used with caution during model calibration according to data screening notes.

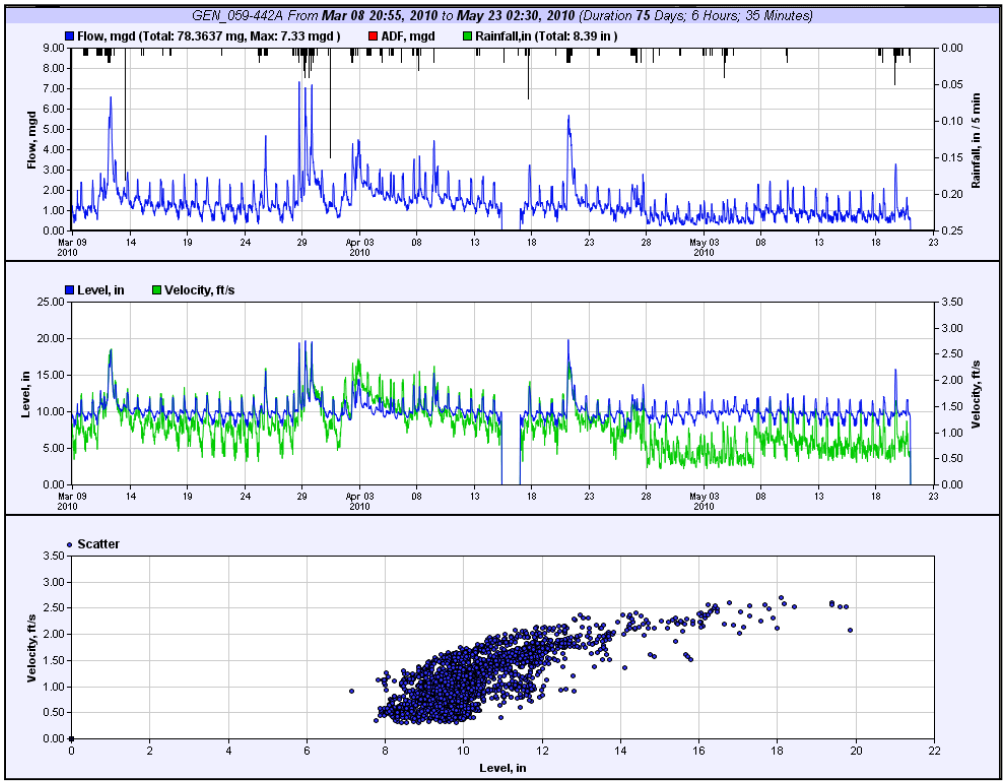

Figure 3-95. GEN_059-442A data signature change at the end of April 2010

The meter remained in place at the conclusion of Phase 3 monitoring to continue collecting data for system-wide model calibration purposes.

GLK_004-219A

GLK_004-219A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/28/2009, at the end of Phase 2 to characterize the hydrology for the system-wide model basin 004-315. Rainfall was monitored by RG 09, which is located in the Woodland Park Zoo.

GLK_004-219A was located in the City's CSS upstream of the confluence with King County's Green Lake/Ravenna trunk. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. However, the resolution of the scattergraph was lower at levels below 5 inches. The data quality was classified as "Excellent" for Phase 3. All Phase 3 data are suitable for model calibration.

The meter was removed on 2/2/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

GLK_005-095A

GLK_005-095A is a temporary monitoring site that records both level and velocity. The site was installed on 9/30/2009, at the end of Phase 2 to characterize the hydrology for the system-wide model basin 024-017. Rainfall is monitored by RG 09, which is located in the Woodland Park Zoo.

GLK_005-095A is located in King County's Green Lake/Ravenna trunk. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. No significant data gap occurred during Phase 3. The data quality was classified as "Excellent" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

The meter remained in place at the conclusion of Phase 3 monitoring to continue collecting data for system-wide model calibration purposes.

GLK_005-117A

GLK_005-117A was a temporary monitoring site that recorded both level and velocity. The site was installed on 8/27/2009 to characterize the hydrology for the system-wide model basin 024-017. Rainfall was monitored by RG 09, which is located in the Woodland Park Zoo.

GLK_005-117A was located in the City's CSS upstream of the confluence with King County's Green Lake/Ravenna trunk. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. The scattergraph shows lower resolution during low flows. No significant data gap occurred during Phases 2–3. The data quality was classified as "Excellent" for Phases 2–3. The data are suitable for model calibration.

The meter was removed on 11/17/2009, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

GLK_005-154B

GLK_005-154B was a temporary monitoring site that recorded both level and velocity. The site was installed on 8/13/2009 to monitor the inflow from Green Lake into the CSO system. Rainfall was monitored by RG 09, which is located in the Woodland Park Zoo.

GLK_005-154B was located in a wooden pipe and there was a 5/8-inch gap between the sensor and the pipe invert. This configuration is expected to overestimate flow. The invert of GLK_005-154B was approximately 24 inches above the mainline invert. The velocity was affected by the mainline during large storms. Figure

3-96 shows the data signature for this site throughout Phases 2–3. The data quality was classified as "Poor" for Phases 2–3. The data are not suitable for model calibration.

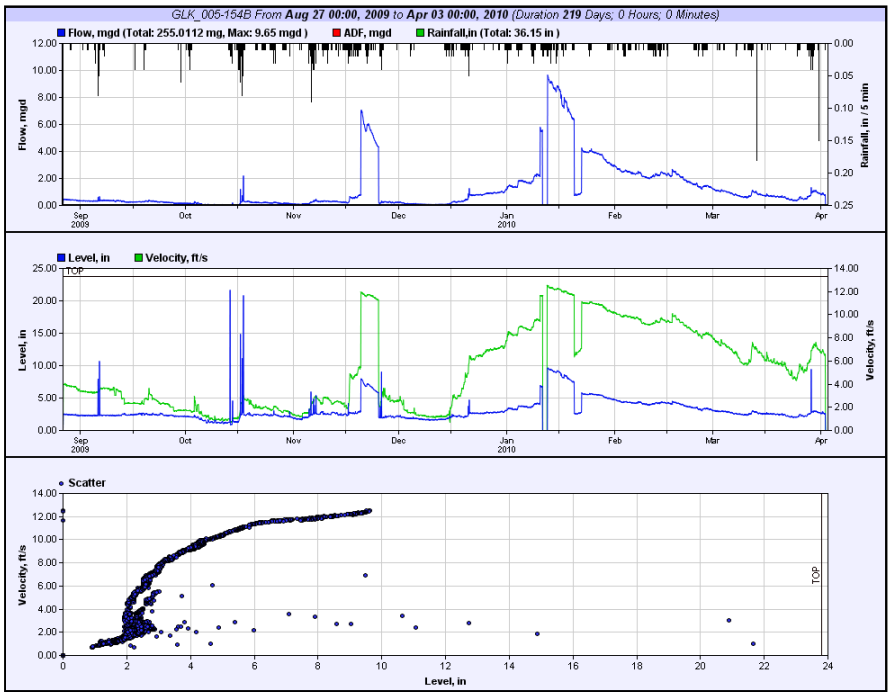

Figure 3-96. GLK_005-154B data signature for Phases 2–3

The meter was removed on 4/2/2010, during Phase 3 as it was determined that site hydrology did not allow for the collection of suitable data for model calibration.

GLK_005-157A

GLK_005-157A was a temporary monitoring site that recorded both level and velocity. The site was installed on 8/12/2009 to characterize the hydrology for the system-wide model basin 005-116. Rainfall was monitored by RG 09, which is located in the Woodland Park Zoo.

GLK_005-157A was located in the City's CSS upstream of the confluence with King County's Green Lake/Ravenna trunk. The data collected at this site captured a consistent dry weather flow pattern but had lower resolution when the water level was below 8 inches. This is attributable to the velocity sensor capturing multiple velocities at the same depth of water. The meter responded well during storm events. The data quality was classified as "Good" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

The meter was removed on 4/2/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

GLK_005-157B

GLK_005-154B was a temporary monitoring site that recorded both level and velocity. The site was installed on 8/27/2009 to measure the inflow from Green Lake into the CSO system. Rainfall was monitored by RG 09, which is located in the Woodland Park Zoo.

GLK_005-154B was located on the inlet pipe from Green Lake. The data at this site capture hydraulic jumps during large storm events (Figure 3-97). Level dropped during November 2009 and no explanation for this

signature change was identified (Figure 3-98). The data quality was classified as "Poor" for Phases 2–3. The data are not suitable for model calibration.

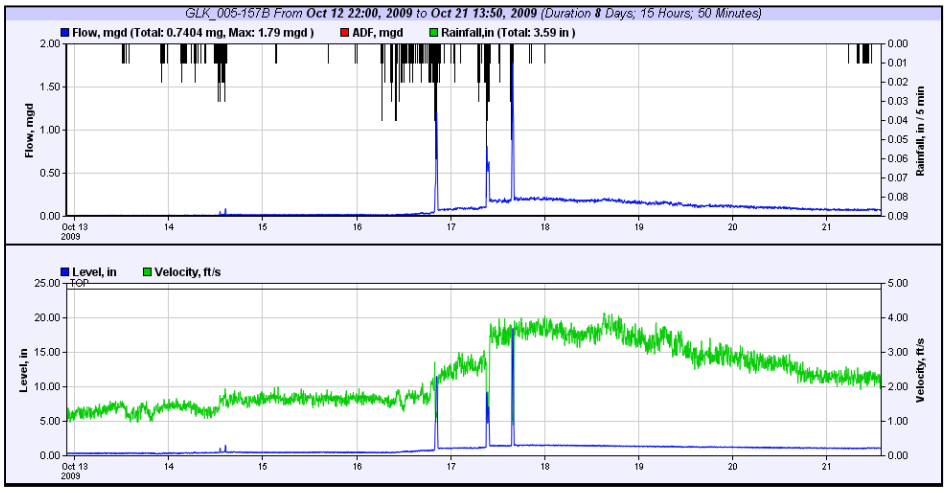

Figure 3-97. GLK_005-157B recorded hydraulic jumps during large storm events

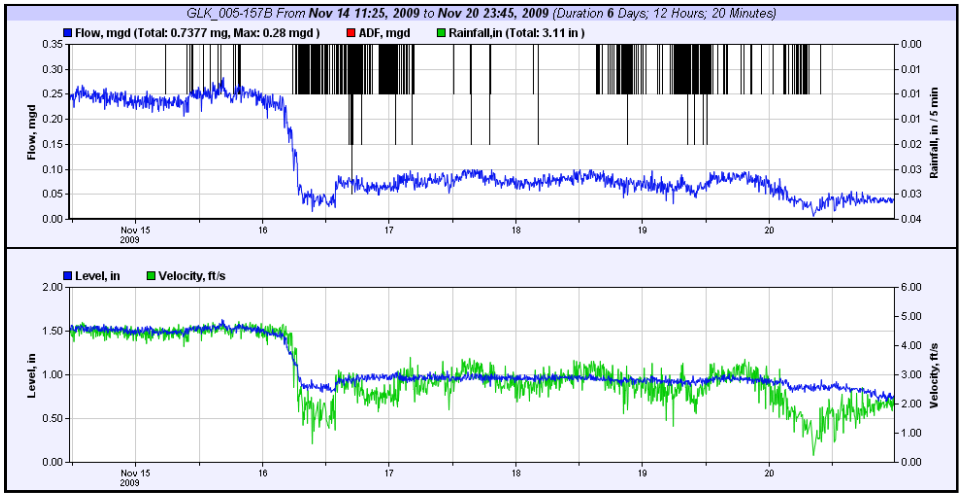

Figure 3-98. GLK_005-157B data signature change during the November 2009 storm event

The meter was removed on 4/2/2010, during Phase 3 as it was determined that site hydrology did not allow for the collection of suitable data for model calibration.

GWD_231-434A

GWD_231-434A was a temporary monitoring site that recorded both level and velocity. The site was installed on 11/20/2009 to measure the flows tributary to King County's Carkeek Park CSO treatment facility and to assess capacity issues in the Greenwood area. Rainfall is monitored by RG 07, which is located at the Whitman Middle School campus.

GWD_231-434A was located within the system-wide model basin 223-001S in the City's CSS upstream of the confluence with King County's Pipers Creek trunk. The meter responded well during storm events. The dry weather data pattern was inconsistent, sometimes showing two velocity signatures at levels below 6 inches. However, periods of suitable DWF data were captured. No significant data gap occurred during Phases 2–3.

The data quality was classified as "Good" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

The meter was removed on 3/23/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

HAN_052-172A

HAN_052-172A was a temporary monitoring site that recorded both level and velocity. The site was installed on 8/18/2009 to characterize the hydrology for the system-wide model basin 052-087. Rainfall was monitored by RG 15, which is located in the Puget Sound Clean Air Monitor Station.

HAN_052-172A was located in the City's CSS upstream of the confluence with King County's Hanford trunk at the Pepsi Bottling Group. The DWF pattern is not consistent and the meter failed to record during every storm while it was installed. The data quality was classified as "Poor" for Phases 2–3. The data not are suitable for model calibration.

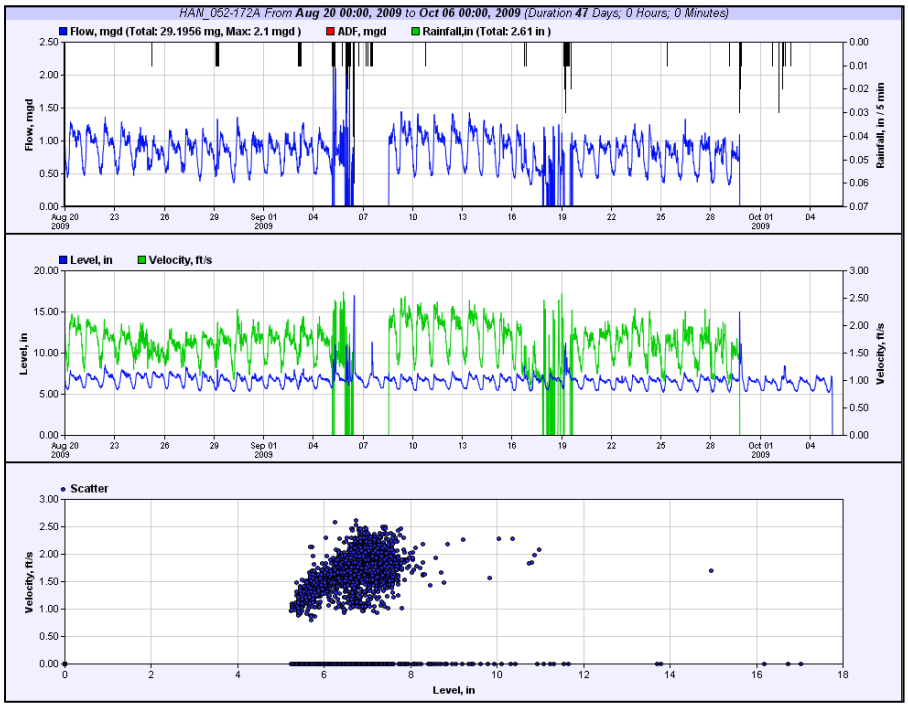

Figure 3-99. HAN_052-172A data signature throughout Phases 2–3

The meter was removed on 10/5/2009, at the beginning of Phase 3 as it was determined that site hydraulics did not allow for the collection of suitable data for model calibration.

HAN_052-318A

HAN_052-318A was a temporary monitoring site that recorded both level and velocity. The site was installed on 7/28/2009 to characterize the hydrology for the system-wide model basin 052-109. Rainfall was monitored by RG 15, which is located in the Puget Sound Clean Air Monitor Station.

HAN_052-318A was located in the City's CSS upstream of the confluence with King County's Hanford trunk. The data collected at this site failed to capture a clear and consistent dry weather and wet weather flow

pattern. The scattergraph is thick. This is a high velocity site. The data quality was classified as "Some Limitations" for Phases 2–3. The data should be used with caution during model calibration according to the data screening notes.

The meter was removed on 3/12/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

HAN_058-106A

HAN_058-106A was a temporary monitoring site that recorded both level and velocity. The site was installed on 8/18/2009 to characterize the hydrology for the system-wide model basin 052-104. Rainfall was monitored by RG 15, which is located in the Puget Sound Clean Air Monitor Station.

HAN_058-106A was located in the City's CSS upstream of the confluence with King County's Hanford trunk. The data collected at this site captured a consistent dry weather flow pattern with less resolution at water levels below 5 inches. During dry weather flows the velocity measurements were unstable. The meter responded well during storm events. The data quality was classified as "Some Limitations" for Phases 2–3. The data should be used with caution during model calibration, according to the screening notes.

The meter was removed on 3/12/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

HAN_D052-137A

HAN_D052-137A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/11/2009 to characterize the hydrology of the upper portion of the Diagonal Avenue stormwater drain system. Rainfall was monitored by RG 15, which is located in the Puget Sound Clean Air Monitor Station.

HAN_D052-137A was located in the City's CSS upstream of the confluence with King County's Hanford trunk. The data collected at this site will be used only to calibrate storm events. The meter responded well to rainfall and captured clear relationships between level and velocity data. The data quality was classified as "Excellent" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

The meter was removed on 3/12/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

HEN_306-242A

HEN_306-242A was a temporary monitoring site that recorded both level and velocity. The site was installed on 10/21/2009 to characterize the hydrology for the system-wide model basin 081-348-a in the Henderson Basin. Rainfall was monitored by RG 30, which is located at the Seattle Public Library Rainier branch.

HEN_306-242A is located in the City's CSS upstream of the confluence with King County's Henderson Street trunk. The data collected at this site captured two data signatures due to a change in operations of the Henderson pump station that occurred on 11/31/2009 (Figure 3-100). Nevertheless, all data present a clear and consistent pattern during dry weather flows and showed a good response to rainfall. There are no gaps in the data during significant storm events. The data quality was classified as "Good" for Phases 2–3. The data are suitable for model calibration but the pump station operations need to be accounted for in the model.

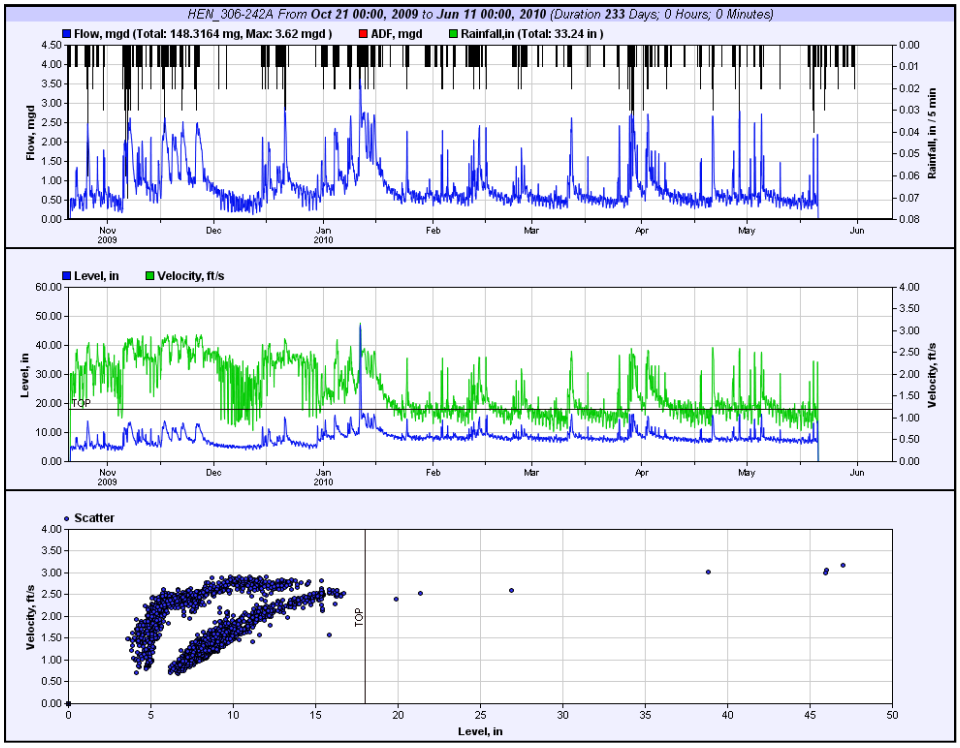

Figure 3-100. HEN_306-242A shows two data signatures associated with a change in operations of the Henderson pump station

The meter remained in place at the conclusion of Phase 3 monitoring to continue collecting data for system-wide model calibration purposes.

KCNI_022-185A

KCNI_022-185A is a temporary monitoring site that records both level and velocity. The site was installed on 9/10/2009 to characterize the hydrology of basins flowing into King County's north interceptor and the system-wide model basin 021-056. Rainfall was monitored by RG 03, which is located at the University of Washington Hydrology Laboratory campus.

KCNI_022-185A is located in King County's north interceptor line that runs along the Lake Washington Ship Canal in Fremont/Wallingford. The site recorded flow rates up to 200 mgd in magnitude. The quality of the data is rated "Excellent" based on the meter response. A comparison of the data with King County's calibrated model output indicated that the peak flows recorded by the meter are significantly lower than the model results.

The meter remained in place at the conclusion of Phase 3 monitoring to continue collecting data for system-wide model calibration purposes.

LIN_225-095A

LIN_225-095A was a temporary monitoring site that recorded both level and velocity. The site was installed on 8/21/2009 to characterize the hydrology of basins flowing into King County's Green Lake trunk and the system-wide model basin 232-385. Rainfall was monitored by RG 01, which is located at the Haller Lake Shop.

KCNI_022-185A is located in King County's Green Lake trunk and is the most upstream site of the system-wide meters located in this trunk. This monitoring location captures the majority of the flows coming into the Green Lake Trunk. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. The scattergraph showed less resolution at water levels below 6 inches. No significant data gap occurred during Phases 2–3. The data quality was classified as "Good" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

The meter was removed on 2/26/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

LP_055-387A

LP_055-387A was a temporary monitoring site that recorded both level and velocity. The site was installed on 8/18/2009 to characterize the hydrology for the system-wide model basin 055-136 in Luna Park. Rainfall was monitored by RG 14, which is located at the Lafayette Elementary School campus.

LP_055-387A was located in the City's CSS upstream of the confluence with King County's Harbor regulator station. The data collected at this site captured a consistent dry weather flow pattern. Wet weather flow scattergraphs showed lower resolution during the September 2009 and October 2009 storm events. The data quality was classified as "Good" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

The meter was removed on 3/30/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

LQA_034-026A

LQA_034-026A was a temporary monitoring site that recorded both level and velocity. The site was installed on 8/14/2009 to characterize the hydrology for the system-wide model basin 034-283. Rainfall was monitored by RG 11, which is located in King County's Denny Way regulator station.

LQA_034-026A was located in the City's CSS upstream of the confluence with King County's Denny Way regulator station. The meter captured a consistent dry weather diurnal pattern. However, during storm events, the meter surcharged. The data quality was classified as "Good" for Phases 2–3. The operation of the County's regulator should be accounted for when using these data for calibration. Figure 3-101 shows a snapshot of the daily backup on the site due to the regulator's operation.

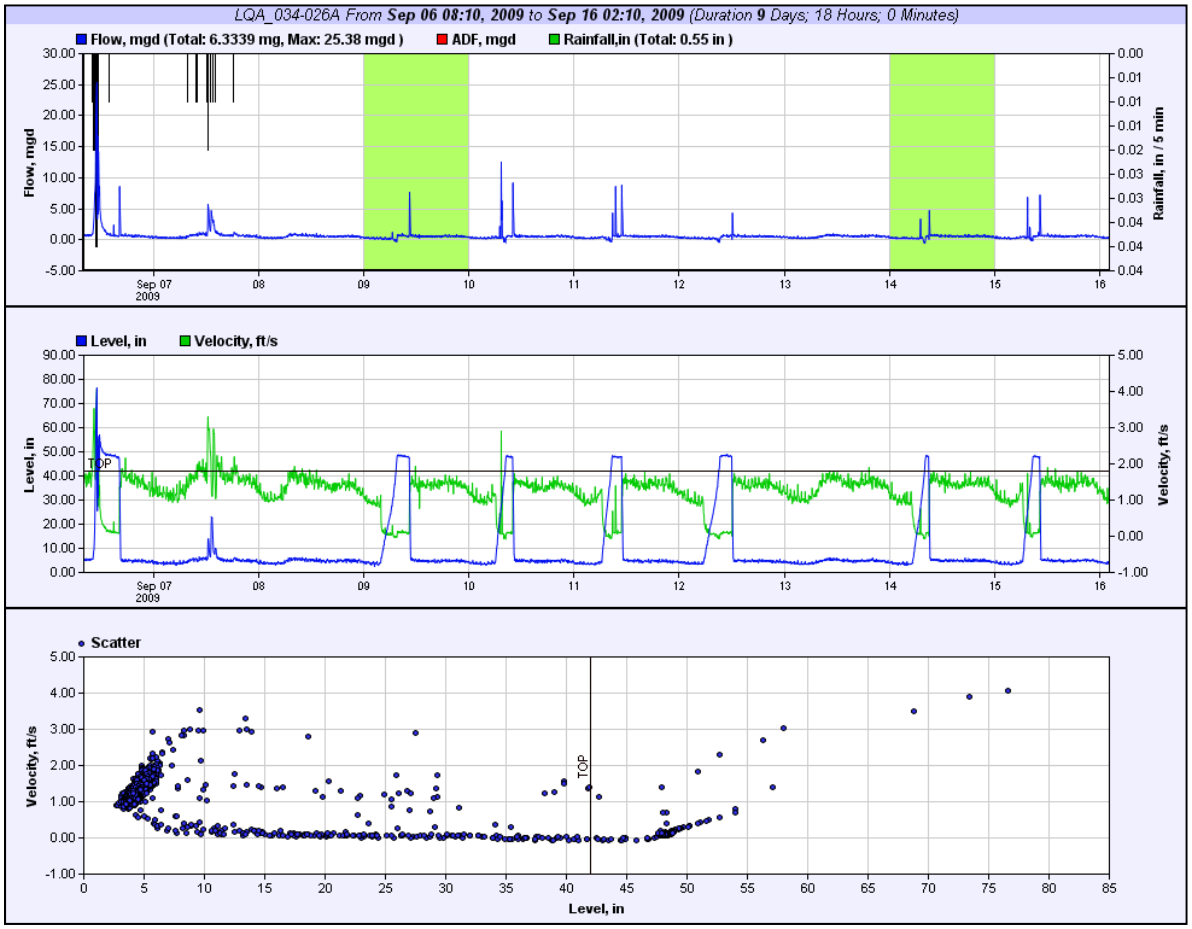

Figure 3-101. LQA_034-026A daily backup due to operation of King County's Denny Way regulator

The meter was removed on 4/1/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

MICH_065-398A

MICH_065-398A was a temporary monitoring site that recorded both level and velocity. The site was monitored using an ADS FlowShark installed on 8/21/2009 to characterize the hydrology for the system-wide model basin 064-188-a. Rainfall was monitored by RG 16, which is located in King County's East Marginal pump station.

MICH_065-398A was located in the City's CSS upstream of the confluence with King County's Michigan regulator station. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. There was a change in the velocity data signature during October 2009 (Figure 3-102). As a result, a redundant meter was installed at MH 065-398 to verify correct velocity range. After review of the second meter's data it was determined that the velocity data were accurate. The data quality was classified as "Good" for Phases 2–3. All Phases 2–3 data are suitable for model calibration purposes.

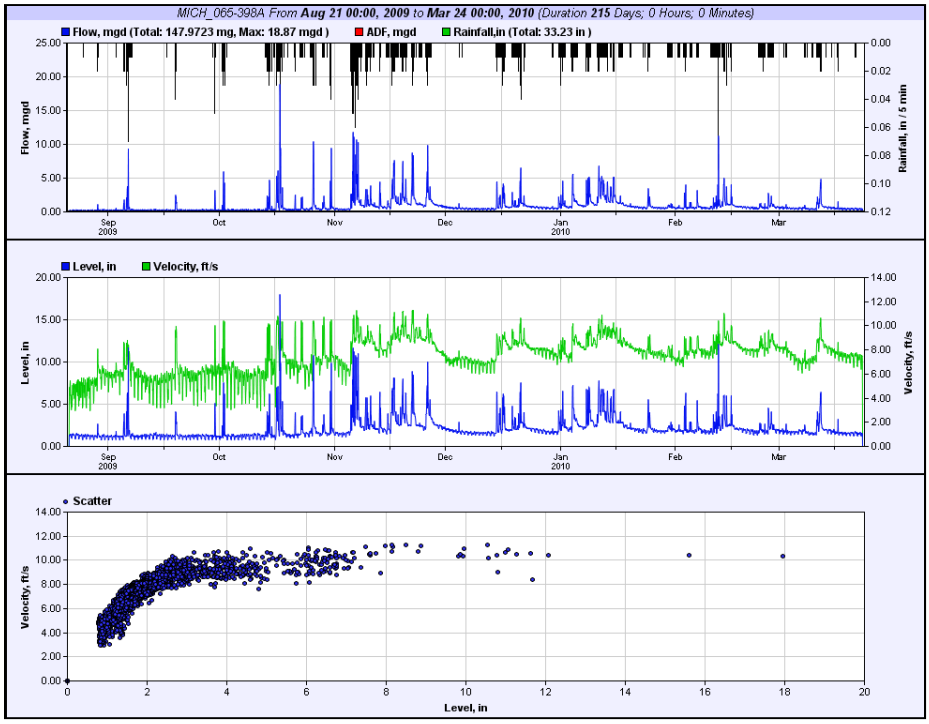

Figure 3-102. MICH_065-398A presented a change in velocity signature during October 2009

The meter was removed on 3/30/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

MICH_065-398B

MICH_065-398B was a temporary monitoring site that recorded both level and velocity. The site was monitored using an ISCO 2150 meter installed on 12/10/2009 to verify the velocity data recorded by MICH_065-398A. Rainfall was monitored by RG 16, which is located in King County's East Marginal pump station.

MICH_065-398B was located in the City's CSS upstream of the confluence with King County's Michigan regulator station, which is upstream of MICH_065-398A. The data collected were within the same range as those for meter "A." The data from this site will not be used in model calibration.

The meter was removed on 2/10/2010, during Phase 3 as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

MLKKC_080-169A

MLKKC_080-169A is a temporary monitoring site that records both level and velocity. The site was installed on 8/10/2009 to characterize the hydrology for the system-wide model basins 305-021 and 073-125. Rainfall was monitored by RG 18, which is located at the Aki Kurose Middle School campus.

MLKKC_080-169A is located in King County's Empire Way/Martin Luther King Way trunk. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. The meter responded well during storm events collecting suitable wet weather data. The scattergraph is clear and narrow. No significant data gap occurred during Phases 2–3. The data quality was classified as "Excellent" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

The meter remained in place at the conclusion of Phase 3 monitoring to continue collecting data for system-wide model calibration purposes.

MTB_052-254A

MTB_052-254A was a temporary monitoring site that recorded both level and velocity. The site was installed on 8/18/2009 to characterize the hydrology for the system-wide model basin 058-094. Rainfall was monitored by RG 20, which is located at the TT Minor Elementary School campus.

MTB_052-254A was located in the City's CSS upstream of the confluence with King County's Hanford trunk. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. No significant data gap occurred during Phases 2–3. The data quality was classified as "Good" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

The meter was removed on 3/12/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

MTWPK_227-185A

MTWPK_227-185A was a temporary monitoring site that recorded both level and velocity. The site was installed on 11/4/2009 to characterize flows from the system-wide model basin 228-243 NE and to assess capacity issues. The site is classified as a capacity meter site but will potentially be used for system-wide model calibration. Rainfall was monitored by RG 01, which is located at the Haller Lake Shop.

MTWPK_227-185A was located in the City's CSS upstream of the confluence with King County's Thornton Creek trunk. The data collected at this site show multiple velocities when water levels were below 3.8 inches (Figure 3-103). The meter responded well during storm events. The data of larger-duration storms present a clearer pattern than those of short duration and high intensities. All wet weather data are suitable for model calibration. The data quality was classified as "Good" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

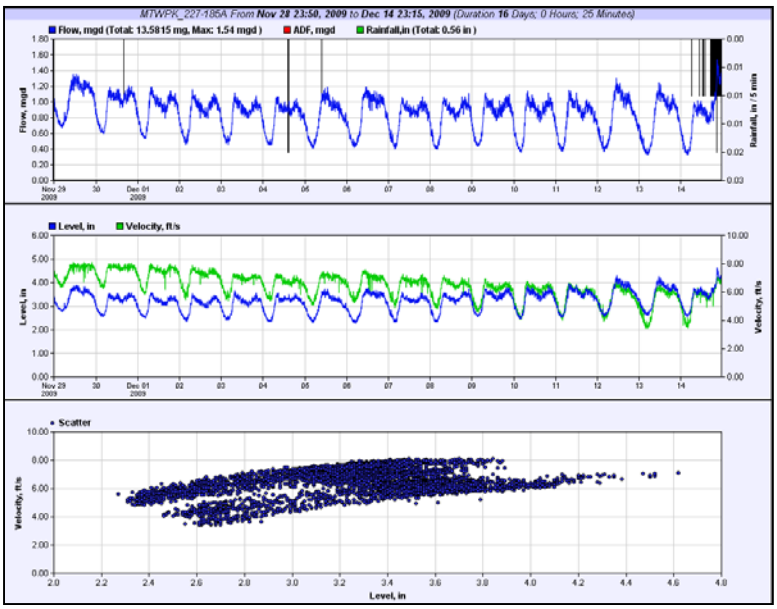

Figure 3-103. MTWPK_227-185A shows three data signatures at water levels below 3.8 inches

The meter was removed on 2/26/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

MV_037-421A

MV_037-421A is a temporary monitoring site that records both level and velocity. The site is an MGD meter previously monitored by Taylor and Associates. On 11/1/2009 Stantec took over the monitoring of this site. The data at this site will be used to characterize flows from Madison Valley (system-wide model basin 031-062). Rainfall is monitored by RG 03, which is located at the University of Washington Hydrology Laboratory.

MV_037-421A was located in the City's CSS upstream of the confluence with King County's Arboretum trunk. Several problems were encountered with the meter. There were also several data gaps through Phase 3 monitoring. The data quality was classified as "Poor" for Phase 3. Good data were obtained with this meter in 2004 through 2007 during calibration of the SPU Madison Valley model. The earlier data should be used for further calibration.

The meter remained installed at the conclusion of Phase 3 monitoring.

MV_D037-160I

MV_D037-160I is a temporary monitoring site that records both level and velocity. The site was installed on 1/9/2010 to calculate flows on the upstream side of the stormwater control gates in Madison Valley. Rainfall is monitored by RG 03, which is located at the University of Washington Hydrology Laboratory.

MV_D037-160I is located in the inlet pipe of the stormwater tank. The data collected at this site showed a clear response to storm events. No significant data gap occurred during Phases 2–3. The effect of the gates is evident in the data (Figure 3-104). The data quality was classified as "Excellent" for Phase 3. All Phase 3 data are suitable for model calibration.

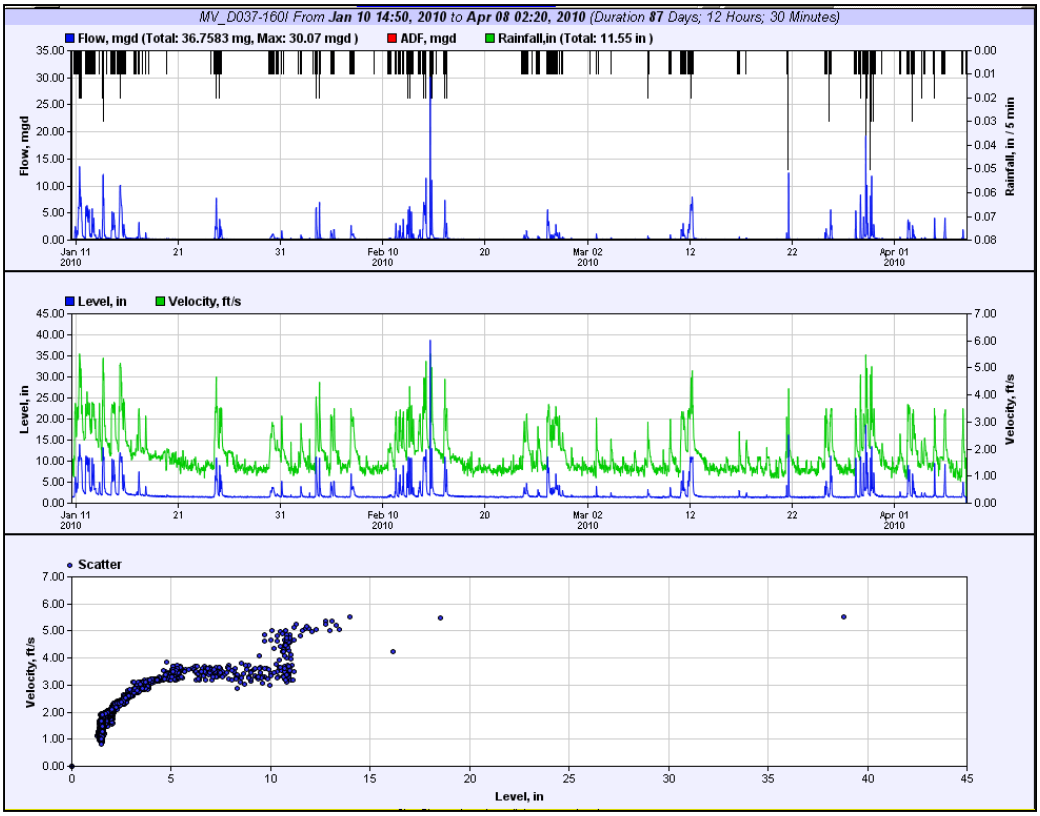

Figure 3-104. MV_D037-160I data show the effect of the gates operations

The meter remained in place at the conclusion of Phase 3 monitoring to continue collecting data for system-wide model calibration purposes.

MV_D037-160O

MV_D037-160O is a temporary monitoring site that records level only. The site was installed on 1/11/2010 to estimate the storage tank utilization and the operation of the stormwater control gates in Madison Valley. Rainfall is monitored by RG 03, which is located at the University of Washington Hydrology Laboratory.

MV_D037-160O is located in the outlet pipe of the stormwater tank. The meter recorded a water level during all significant storm events. The data quality was classified as "Excellent" for Phases 2–3. The data are suitable for model calibration.

The meter remained in place at the conclusion of Phase 3 monitoring to continue collecting data for system-wide model calibration purposes.

NQA_021-245A

NQA_021-245A is a temporary monitoring site that records both level and velocity. The site was installed on 8/13/2009 to characterize the hydrology for the system-wide model basin 021-406 in North Queen Anne. Rainfall is monitored by RG 09, which is located in the Woodland Park Zoo.

NQA_021-245A is located in King County's central trunk just upstream of King County's Third Avenue West CSO. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. The scattergraph is clear and narrow. Only one data gap occurred during Phases 2–3,

from 3/9/2010 to 3/13/2010. However, this gap was not within a storm event relevant for model calibration purposes. The data quality was classified as "Excellent" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

The meter remained in place at the conclusion of Phase 3 monitoring to continue collecting data for system-wide model calibration purposes.

RAN_045-469A

RAN_045-469A was a temporary monitoring site that recorded both level and velocity. The site was installed on 9/25/2009 to characterize the hydrology for the system-wide model basin 052-440 SW. Rainfall was monitored by RG 15, which is located in the Puget Sound Clean Air Monitor Station.

RAN_045-469A was located in the City's CSS upstream of the confluence with King County's Rainier Avenue trunk. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. The scattergraph is clear and narrow. No significant data gap occurred during Phases 2 and 3. The data quality was classified as "Excellent" for Phases 2 and 3. All Phases 2 and 3 data are suitable for model calibration.

The meter was removed on 3/23/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

RAN_052-417A

RAN_052-417A was a temporary monitoring site that recorded both level and velocity. The site was installed on 7/28/2009 to characterize the hydrology for the system-wide model basin 052-440 SW. Rainfall was monitored by RG 15, which is located in the Puget Sound Clean Air Monitor Station.

RAN_045-417A was located in the City's CSS upstream of the confluence with King County's Rainier Avenue trunk. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. No significant data gap occurred during Phases 2–3. The data quality was classified as "Excellent" for Phases 2–3. The data are suitable for model calibration.

The meter was removed on 3/12/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

RAV_014-126A

RAV_014-126A was a temporary monitoring site that recorded both level and velocity. The site was installed on 7/28/2009 to characterize the hydrology for the system-wide model basin 024-017 N. Rainfall was monitored by RG 04, which is located in the Maple Leaf reservoir.

RAV_014-126A was located in the City's CSS upstream of the confluence with King County's Green Lake trunk. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. The data exhibited lower resolution at low flows. The data quality was classified as "Good" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

The meter was removed on 2/26/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

RAV_015-104A

RAV_015-104A was a temporary monitoring site that recorded both level and velocity. The site was installed on 8/19/2009 to characterize the hydrology for the system-wide model basin 015-272 SW. Rainfall was monitored by RG 04, which is located in the Maple Leaf reservoir.

RAV_015-104A was located in the City's CSS upstream of the confluence with King County's Laurelhurst trunk. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. The data quality was classified as "Excellent" for Phases 2–3. All Phases 2–3 data are suitable for model calibration.

The meter was removed on 3/23/2010, during Phase 3 monitoring, as it was determined that sufficient suitable data had been collected for system-wide model calibration purposes.

RSD_221-139A

RSD_221-139A is a temporary monitoring site that records both level and velocity. The site was installed on 2/12/2010 to provide supporting data for capacity assessments. The site is classified as a capacity meter but will potentially be used in system-wide model calibration. Rainfall was monitored by RG 01, which is located at the Haller Lake Shop.

RSD_221-139A is located within the system-wide model basin 228-243 and monitors flow from the Ronald Sewer District as well as areas in the City's CSS. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. No significant data gap occurred during Phase 3. The data quality was classified as "Excellent" for Phase 3. All Phase 3 data are suitable for use in capacity assessments and model calibration.

The meter remained in place at the conclusion of Phase 3 monitoring to continue collecting data for system-wide model calibration purposes.

RSD_221-171A

RSD_221-171A is a temporary monitoring site that records both level and velocity. The site was installed on 2/12/2010 to provide supporting data for capacity assessments. The site is classified as a capacity meter but will potentially be used in system-wide model calibration. Rainfall was monitored by RG 01, which is located at the Haller Lake Shop.

RSD_221-171A is located within the system-wide model basin 228-243 and monitors flow from the Ronald Sewer District as well as from areas in the City's CSS. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. No significant data gap occurred during Phase 3. The scattergraph showed lower resolution during low flows. The data quality was classified as "Good" for Phase 3. All Phase 3 data are suitable for use in GSI efforts, capacity assessments, and model calibration purposes.

The meter remained in place at the conclusion of Phase 3 monitoring to continue collecting data for system-wide model calibration purposes.

UNIV_024-018A

UNIV_024-018A is a temporary monitoring site that records both level and velocity. The site was monitored using an ISCO 2150 meter installed on 2/19/2010 to characterize the flow in the King County University trunk. Rainfall is monitored by RG 03, which is located at the University of Washington Hydrology Laboratory.

UNIV_024-018A is located in the City's CSS upstream of King County's University regulator station. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. No significant data gap occurred during Phase 3. The data quality was classified as "Excellent" for Phase 3. All Phase 3 data are suitable for model calibration purposes.

The meter remained in place at the conclusion of Phase 3 monitoring to continue collecting data for system-wide model calibration purposes.

UNIV_024-018B

UNIV_024-018B is a temporary monitoring site that records both level and velocity. The site was monitored using an ISCO 2150 meter installed on 2/19/2010 to characterize flow in the King County University trunk. Rainfall is monitored by RG 03, which is located at the University of Washington Hydrology Laboratory.

UNIV_024-018B is located in the same maintenance hole as UNIV_024-018A. It was installed to provide a redundant measurement. The data collected at this site captured a consistent dry weather flow pattern and responded well during storm events. No significant data gap occurred during Phase 3. The data at this meter are within the same range as those of meter "A." The data quality was classified as "Excellent" for Phase 3. All Phase 3 data are suitable for model calibration.

The meter remained in place at the conclusion of Phase 3 monitoring to continue collecting data for system-wide model calibration purposes.

3.12.1 System-Wide Monitoring Locations within NPDES Basins

In addition to the monitoring locations described above, a few monitoring locations located within the uncontrolled NPDES basins will potentially be used for system-wide model calibration purposes. These monitoring locations were screened as part of the NPDES basin in which they are located and their site narrative can be found under the specific basin section (i.e., Ballard, Montlake, etc). Table 3-13 references these meters and their locations.

Table 3-13. System-Wide Model Supporting Monitoring Locations

Meter ID	Basin name
BAL150_011-241A	Ballard NPDES150 Basin
KC_021-056B	Fremont/Wallingford NPDES174 Basin
KC_025-050A	North Union Bay NPDES018 Basin
KC_025-053A	Madison Park/Union Bay NPDES025 Basin
NUB18_024-059A	North Union Bay NPDES018 Basin
SPU_022-188A	Fremont/Wallingford NPDES147 Basin
SPU_030-080A	Portage Bay/Lake Union NPDES175 Basin
SPU_030-358A	Portage Bay/Lake Union NPDES175 Basin
SPU_031-143A	Montlake Basin
SPU_031-227A	Montlake Basin
SPU_031-231A	Montlake Basin
SPU_038-353A	Leschi NPDES026 Basin
SPU_042-231A	Leschi NPDES026 Basin
SPU_069-198A	Delridge/Longfellow NPDES168 Basin
SPU_069-242A	Delridge/Longfellow NPDES168 Basin
SPU_076-217A	Delridge/Longfellow NPDES169 Basin

4. SUITABILITY OF DATA FOR HYDROLOGIC AND HYDRAULIC MODELING EFFORTS

This section presents an assessment as to whether the data collected during Phases 2–3 are sufficient for model calibration purposes. The data were assessed according to the Quality Assurance Project Plan (QAPP), December 2009.

4.1 Wet Weather Model Calibration Periods

The monitoring period rainfall can be characterized generally as above average in volume and number of events at most gauges. Figure 3-3 shows the monthly long-term Sea-Tac International Airport average rainfall together with the observed rainfall at RG 05, (RG 03 and RG 09. June through August 2009 showed minimal rainfall. Significant events occurred in October and November 2009 and in the second week of January 2010. February through April 2010 had average total rainfall, while May 2010 was above average due to two large events.

As described in Chapter 3, all objectives for rainfall monitoring were exceeded in Phases 2–3 at all LTCP gauges. Ten events were identified as useful for model calibration. These events cover a variety of antecedent moisture conditions, rainfall intensities, and volumes that will enhance the model calibrations.

4.2 Dry Weather Model Calibration Periods

Dry weather flow data collected during the Phases 2–3 flow monitoring period (6/1/2009 to 5/31/2010) are suitable for estimating dry weather flow and diurnal patterns using ZFM2 supplementing data collected in Phase 1. Dry weather periods occur in the late spring and summer. Preference should be given to data collected in September and early October when groundwater flow is reduced to a minimum.

Where the meter data are unavailable or do not provide suitable dry weather flow patterns, estimates will be used with a suitable addition for dry weather infiltration estimated from other meters in the basin.

4.3 Future Flow Monitoring

At the conclusion of Phase 3, all flow monitoring goals and objectives were achieved, as described in Section 4 of the QAPP, December 2009. No additional flow monitoring is required for the purposes of model calibration.

4.4 Data Quality Summary

The data obtained from each of the monitoring locations were assessed and classified for their suitability for use in model calibration as described in Section 14 of the QAPP, December 2009. A detailed description of the data quality per monitoring site can be found in Section 3.

In summary, the data at the majority of monitors were rated either "Good" or "Excellent." In cases where data were rated "Some Limitations," portions of the data still can be used for the modeling, either to confirm or supplement other data. This together with the desirable rainfall patterns captured provides a solid foundation for model calibration.

4.5 Use of Data in Model Calibration

The data collected during Phases 2–3 of the flow monitoring program will serve the following uses during model calibration:

- determine the wet weather hydrology of each meter basin
- determine dry weather flows and associated diurnal patterns
- develop HydroBrake head-discharge relationships
- confirm hydraulic performance of structures.

5. REFERENCES

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Seattle Public Utilities. Quality Assurance Project Plan (QAPP). Long Term Control Plan: Flow Monitoring Plan 2009–2010. December 2009.

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APPENDIX A: PRECIPITATION ANALYSIS

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APPENDIX B: BASIN SCHEMATICS

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APPENDIX C: BALLARD DATA SITE SHEETS

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APPENDIX D: DELRIDGE/LONGFELLOW DATA SITE SHEETS

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APPENDIX E: DUWAMISH DATA SITE SHEETS

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APPENDIX F: FREMONT/WALLINGFORD DATA SITE SHEETS

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APPENDIX G: INTERBAY DATA SITE SHEETS

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APPENDIX H: LESCHI DATA SITE SHEETS

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APPENDIX I: MADISON PARK/UNION BAY SITE SHEETS

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APPENDIX J: MONTLAKE DATA SITE SHEETS

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APPENDIX K: NORTH UNION BAY DATA SITE SHEETS

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APPENDIX L: PORTAGE BAY/LAKE UNION DATA SITE SHEETS

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APPENDIX M: SYSTEM-WIDE DATA SITE SHEETS

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APPENDIX N: RAIN GAUGE ADJUSTMENT REPORT

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APPENDIX O: DATA REVIEW WORKSHOPS

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