

QUALITY ASSURANCE PROJECT PLAN

Kitsap County Stormwater Flow Monitoring Program



KITSAP COUNTY



July 2013

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Prepared by

Kitsap County Surface and Stormwater Management
614 Division Street, MS-26A
Port Orchard, Washington 98366

July 2013

Signature Page

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8/20/13

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Introduction

The monitoring of stormwater flow is an important tool to assess Kitsap County's expanded use of low impact development (LID) techniques for new and retrofit construction projects. In 2011, Kitsap County Surface and Stormwater Management (SSWM) installed stormwater flow monitoring stations in two communities, Manchester and Suquamish (Figure 1). Another two stations have been placed in Silverdale in 2013. These two stations will monitor adjacent basins (Figure 1) flows from highly developed sections of Silverdale. LID features, as well as traditional effective Best Management Practices (BMPs) will be added to each of these communities over the next several years. The stormwater flow monitoring stations will document the stormwater flow reductions in each stormwater system.

The goal of this Quality Assurance Project Plan (QAPP) is to document procedures used for data collection, processing, and analysis to ensure all results obtained from this monitoring program are scientifically and legally defensible. It was prepared in accordance with Ecology's *Guidelines for Quality Assurance Project Plans* (Ecology 2004), and includes the following major sections:

Background – An explanation of why the project is needed.

Project Description – Project goals and objectives, and the information required to meet the objectives.

Organization and Schedule – Project roles and responsibilities, and the schedule for completing the work.

Quality Objectives – Performance (or acceptance) thresholds for collected data.

Sampling Process Design – The sampling process design for the study, including sample types, monitoring locations, and sampling frequency.

Sampling Procedures – A detailed description of sampling procedures and associated equipment requirements.

Measurement Procedures – Procedures that will be performed in the field.

Quality Control – Quality control (QC) requirements for both laboratory and field measurements.

Data Management Procedures – How data will be managed from field or laboratory downloading to final use and archiving.

Audits and Reports – The process that will be followed to ensure this QAPP is being implemented correctly and the quality of the data is acceptable.

Data Verification and Validation – The data evaluation process, including the steps required for verification, validation, and data quality assessment.

Data Quality (Usability) Assessment – The procedures that will be used to determine if collected data are of the right type, quality, and quantity to meet project objectives.

Background

Stormwater runoff from impermeable surfaces, such as pavement and rooftops, often contain high levels of pollutants such as suspended solids, heavy metals, and petroleum products. Also, concentrated runoff from impermeable surfaces can increase erosion in nearby streams. Stormwater flow control has traditionally focused on end-of-pipe solutions, where flow is routed from impermeable surfaces via curbs, drains, and pipes to a structural best management practice (BMP) facility. These facilities (generally a pond, vault, or swale) are designed to attenuate or infiltrate flows to decrease discharge rates.

Recent research (Booth et al. 2002) suggests that traditional BMPs may be less effective at mitigating stormwater impacts than previously thought. In addition, numerous studies have indicated that Low Impact Development (LID) features that facilitate onsite infiltration offer superior runoff reduction in comparison to traditional BMPs (Dietz 2007). By mimicking natural hydrological processes, LID reduces both the rate and volume of peak flows. In areas characterized by an increase in impermeable surface, this can only be accomplished by increasing stormwater infiltration in those adjacent areas that remain permeable. Alternatively, practitioners may choose to install permeable alternatives to traditional impermeable surfaces, such as pervious pavement. Additionally, runoff water from permeable and impermeable surfaces may be directed to onsite, small-scale engineered water retention features called bioretention.

Permeable pavement systems installed on infiltrative soils have been shown to produce 93 percent less surface runoff relative to traditional impervious pavement systems (Dreelin et al. 2006). Rain gardens can reduce surface runoff by more than 98 percent (Dietz et al. 2005). Results such as these have contributed to an increasing interest in the use of LID features for treating stormwater runoff across the United States.

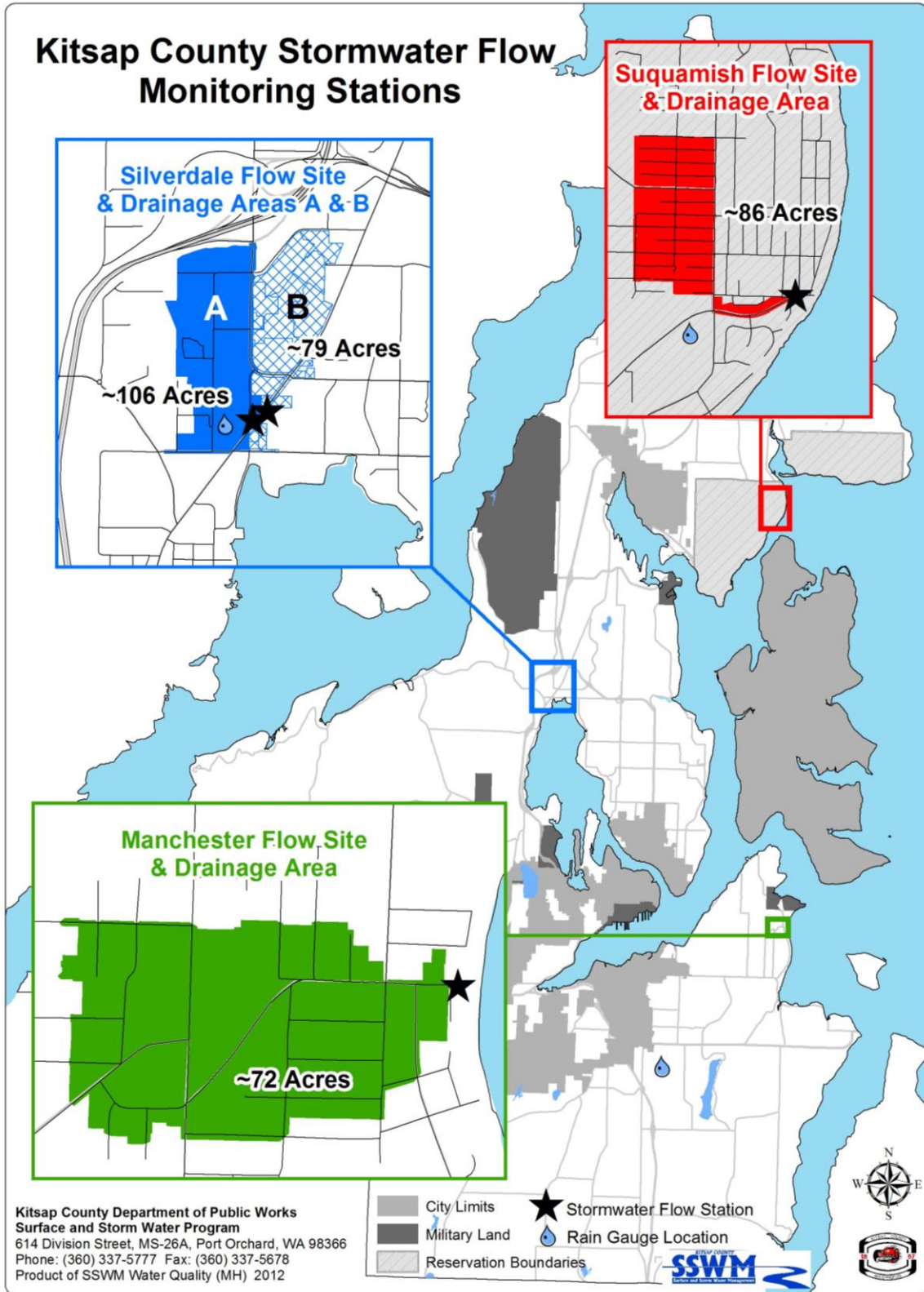
Program Description

This program will track the measured runoff characteristics in selected stormwater basins. For each basin, the following study questions will be answered:

- What are the compared measured runoff characteristics (i.e., storm event peak flow rates and runoff volumes) from the entire project site to modeled conditions for an equivalently sized forested area in the same location (i.e., a predevelopment scenario) during various storm event conditions?
- What are the compared measured runoff characteristics (i.e., storm event peak flow rates and runoff volumes) from the entire project site to modeled conditions for an equivalently sized area comprised entirely of impervious surfaces in the same location (i.e., a developed unmitigated scenario) during various storm event conditions?
- What are the compared measured runoff characteristics (i.e., storm event peak flow rates and runoff volumes) annually as LID facilities are installed (i.e. a retrofit scenario)?

To meet these objectives, the experimental design for this project requires monitoring of the hydrologic conditions of each site as well as computerized modeling. Discharge (runoff flow volume) will be continuously monitored over several years. Additionally the installation of LID facilities (whether for new development, re-development or retrofit) in each stormwater basin will be tracked by SSWM asset management personnel. Modeling output required to meet the project objectives identified above will be obtained from a continuous simulation hydrologic model (e.g., WWHM3 or the current standard practice).

Figure 1. Kitsap County map showing the first four flow monitoring locations.



Organization and Schedule

This section identifies key project participants, project funding sources, and the project schedule for implementation.

Project Organization and Key Personnel

As described above, this study is being conducted to characterize the stormwater treatment benefit(s) of LID features in basins where there will be significant Manchester, Suquamish, and Silverdale. The Kitsap County Surface and Storm Water Management (SSWM) Program will oversee the program and is responsible for developing and implementing this QAPP. Key personnel involved in this effort are identified below:

Kitsap County Surface and Stormwater Management
614 Division St., MS-26A
Port Orchard, Washington 98366
(360) 337-7066

Mindy Fohn, Water Quality Program Manager
Chris May, Senior Program Manager
Mauro Heine, Water Resources Coordinator
Renee Scherdnik, Water Resources Specialist
Randy Davis, Engineering Technician

Project Budget

Design and construction of the LID features at each project site are being constructed and supervised by SSWM. The County is conducting monitoring that will be performed pursuant to this QAPP. The County will also hire a consultant for data analysis and modeling. The monitoring equipment is funded by the Washington State Department of Ecology Grant G1100057.

Project Schedule

Monitoring associated with this study began in October 2011 in Manchester and Suquamish. Monitoring in Silverdale will begin in early 2013. Future basins may be added to the project as the need or opportunity arises. Reporting for this project will be organized to evaluate and present the results of data collected during a water year. In keeping with this schedule, the following project milestones have been identified:

July 2013—Final quality assurance project plan completed

August to September 2011—Monitoring equipment installation in Manchester and Suquamish

October 2011—Start of monitoring in Manchester and Suquamish

May 2013—Monitoring equipment installation at Silverdale.

June 2013—Begin monitoring in Silverdale

December 2013—Draft first Annual Data Summary report

January 2014—Revised draft Annual Data Summary report

February 2014—Final Annual Data Summary report

Quality Objectives

The primary goal of this QAPP is to ensure that the data collected for this study are scientifically and legally defensible. To meet this goal, the collected data will be evaluated based on the following data quality indicators:

Precision: A measure of the variability in the results of replicate measurements due to random error

Bias: The systematic or persistent distortion of a measurement process that causes errors in one direction (i.e., the measured mean is different from the true value)

Representativeness: The degree to which the data accurately describe the conditions being evaluated based on the selected sampling locations, sampling frequency and duration, and sampling methods

Completeness: The amount of data obtained from the measurement system

Comparability: The ability to compare data from the current project to data from other similar projects, regulatory requirements, and historical data

Measurement quality objectives (MQOs) are performance or acceptance criteria that are established for each of these data quality indicators. Monitoring for this project will involve water level and flow velocity measurements using an area velocity sensor in a stormwater pipe. The MQOs for these data are defined in subsections below. If the MQOs are not met, the data will be either flagged as an estimate (*J*) or rejected (*R*) (see *Data Verification and Validation* section).

Precision

The precision of each area velocity sensors' pressure transducer used in this study will be assessed after it is deployed. Precision will be assessed by calculating the coefficient of variation of 5 minute level readings during stable flow conditions having approximately two inches of flow (level) or more. The following equation will be used:

$$C_v = \frac{\sigma}{\mu} \times 100\%$$

Where: C_v = Coefficient of variation
 σ = Standard deviation
 μ = Average level reading

For each group of data the MQO will be a C_v of no more than 5 percent.

Bias

Bias associated with each pressure transducer will be assessed both in the laboratory before deployment and the field. In the laboratory, the sensor will be placed in a tub of water with at least 3 inches of water. The resultant level reading will be compared with the “true” measured values and the instrument will be set to this reading.

In the field, bias in the level readings will be assessed based on comparisons of monitoring equipment readings to an independently measured “true” value. In this case the true value will be derived from a manual measurement of water level at each monitoring location. If the monitoring equipment is not affected by drift or other operational problems, the difference between the equipment’s reading and the manual measurement of water level (“instrument drift”) should remain at zero over time and varying water depths. In reality the instruments will drift and equipment readings and manual readings will diverge. Therefore, bias in these data will be assessed based on the change in the instrument drift value relative to all previous measurements. Specifically, a change in the instrument drift value of plus or minus 2 standard deviations relative to the mean from all previous measurements will trigger an assessment of the monitoring equipment to determine proper functioning.

Bias in flow measurements may also result from manufacturing defects or installation discrepancies in the structures. Bias will be assessed by taking independent flow measurements during three separate storm events and three base flow periods. The MQO for level measurements will be a difference of no more than 20 percent between the instrument reading and an independently measured level values. Details on how these independent flow measurements will be performed are presented in the Field Quality Control Procedures section.

Representativeness

The representativeness of the hydrologic data for the flow monitoring will be ensured by the proper installation of the monitoring equipment. Additionally, monitoring will be conducted for at least 3 water years in order to capture a range of flow conditions.

Completeness

Completeness will be assessed on the basis of the occurrence of gaps in the data record for all monitoring equipment. The associated MQO is less than 5 percent of the total data record missing due to equipment malfunction or other operational problems. Completeness will be ensured through routine maintenance of all monitoring equipment and the immediate (within 72 hours) implementation of corrective actions if problems arise.

Comparability

Although there is no numeric MQO for this data quality indicator, standard monitoring procedures, units of measurement, and reporting conventions will be applied in this study to meet the quality indicator of data comparability.

Sampling Process Design

The experimental design for this project entails continuous monitoring of runoff volumes from stormwater systems in various communities of unincorporated Kitsap County.

The following subsection identify the initial monitoring stations that have been established to facilitate this monitoring, the data collection procedures that will be used in association with these stations, and the steps that will be followed in the analysis of the collected data. Future monitoring stations will be added via new updates and appendixes to this document.

Monitoring Stations

To facilitate the monitoring described above, a total of four stations monitoring four basins will be established in connection with this project. The name and purpose of each station is presented in Appendix A with a short description of its location and associated monitoring equipment. Appendix A also includes four SSWM funded Kitsap County Public Utility (KPUD) rain gauge stations located near the flow monitoring stations. The specific location of each flow monitoring station and associated rain gauge station is shown in Figure 1 and Appendix A.

Data Collection

Data loggers will be installed at each location to facilitate the continuous collection of data from the stations identified in Appendix A. The data loggers will be programmed to record data every 5 minutes over the duration of a 1-year monitoring period extending from October 1 through September 30. The data loggers will be equipped with modem telecommunication hardware to allow remote access to the monitoring data. Power for the data loggers will be maintained using batteries, solar panel or an established 120-volt alternating current source.

Data from each monitoring station will be uploaded on a weekly basis to Flowlink LE. Flowlink LE will be located on a computer located in Kitsap County Public Works (KCPW) Annex Water Quality Laboratory. On a routine basis, the uploaded data will be transferred to the County's internal network and post-processed with Flowlink 5. Post-processing will include graphs and data summaries.

Data Analysis Overview

The continuous monitoring data that is collected from the stations identified in Appendix A will be used to evaluate the effectiveness of the LID features on the project sites at moderating the flow volumes and peak discharge rates. To perform this evaluation, the data from each individual monitoring station will be assessed to identify individual storm “events” based on measured rainfall amounts and defined limits for pre- and post-storm antecedent dry periods. Once these events are defined, summary statistics for each event (e.g., peak discharge, storm volume, rainfall total, flow duration, etc.) from the continuous monitoring data. Using these data, the following analyses will be performed:

Overall subbasin performance will be evaluated by comparing measured runoff characteristics (i.e.; storm event peak flow rates and runoff volumes) to modeled hydrographs for a predevelopment scenario, developed unmitigated scenario, and LID retrofit scenario.

Sampling Procedures

This section identifies the field sampling procedures that will be used to obtain the data described in the previous section

Discharge Monitoring

As described in the *Sampling Process Design* section, discharge will be continuously measured initially at four basins: Manchester, Suquamish and Silverdale (2 basins). Appendix A provides a description of the purpose of each station (and updated with any future stations), the equipment that will be installed to facilitate the discharge monitoring and the rain gauge location associated with each flow monitoring site.

Measurement Procedures

Discharge monitoring for this project will use an Isco area velocity sensor and data logger. The probe sensor uses Doppler technology to directly measure average velocity in the stormwater pipe and an integral pressure transducer to measure stormwater depth in the flow stream. The data logger calculates flow rate by multiplying the area of the flow stream by its average velocity (Walkowiak 2008).

Rainfall monitoring data used in this project will be supplied by Kitsap Public Utility District (KPUD). In some cases a Kitsap County facility will host the rain gauge and provide internet connectivity to KPUD's data management system. KPUD rain gauges include Stevens tipping bucket gauges and Stevens data loggers or equivalent. KPUD rain gauges are calibrated and maintained according to KPUD protocols. The rain gauge data can be viewed and downloaded from the following KPUD web site: http://kpudhydrodata.kpud.org/APS FED_RAIN.aspx.

Quality Control

The quality control procedures for this project will involve the following activities to ensure that data collected for this project are of a known and acceptable quality:

- Measurement validation checks
- Equipment calibration checks
- Equipment maintenance checks

The specific procedures that will be used during these activities are described in the following subsections.

Measurement Validation Checks

Measurement validation checks will be performed during a minimum of four site visits. The visits will be distributed across each 1-year monitoring period (October 1-September 30). Each check will be performed during storm events as well as base flows and be targeted to capture a range of storm event sizes to obtain validation measurements at different flow rates. During these checks, the discharge rate at each station will be manually measured and compared to the calculated discharge rate from the continuous monitoring equipment.

Discharge will be measured at these sites by one of two methods:

1. By catching water flowing over the lip of the pipe in a 5 gallon bucket. The time to fill the bucket to the 5 gallon mark will be measured with a stopwatch, and will be used to calculate the discharge rate in gallons per minute. This procedure will be conducted three times in succession and the average of the three times will be assumed to be the “true” discharge rate.
2. If there is insufficient room or flows are too high to capture the flow in a bucket then discharge will be calculated using a handheld velocity meter (Hach FH950, Swiffer or the like) and measured depth of flow in the pipe.

Note: A confined space entry may be necessary to access the location where discharge validation measurements will be conducted. In this case personnel who have received proper safety training in confined space entries will conduct the procedures.

Equipment Calibration Checks

A minimum of two site visits annually will be performed to check the calibration of the level measurement at each monitoring station. These checks will occur every other month during periods of dry weather. Calibration checks will be performed during a minimum of three site

visits during storm events. As with measurement validation checks calibration checks will be targeted to capture a range of storm event sizes.

Note: A confined space entry may be necessary to access the location where calibration checks will be conducted. In this case personnel who have received proper safety training in confined space entries will conduct the procedures.

Kitsap Public Utility District (KPUD) maintains the rain gauges associated with each flow instrument. The rain gauge is a robust instrument that will only require annual Maintenance. During these maintenance checks, the screen will be cleaned of any debris that has accumulated and the level of the instrument will also be checked. The calibration of the instrument will be verified by metering water into the rain gauge with a pipette until the tipping bucket mechanism triggers. This will be repeatedly conducted and adjustments on the rain gauge will be made until an equivalent volume of water triggers the tipping mechanism in either direction. Each bucket tip is calculated as equivalent to 0.01 inches of rain, consequently the volume of water that should initiate a bucket tip equals 0.01 inches multiplied by the area (in square inches) of the top of the rain gauge. This is the target volume that will be used when rain gauges are calibrated.

Equipment Maintenance Checks

In addition to the routine equipment validation and calibration measurements, the following equipment maintenance inspections will be carried out during all field visits:

- Check battery voltage and associated power connections weekly
- Inspect desiccant in data loggers enclosures monthly
- Remove any debris that may interfere with the sensor operation monthly
- Verify data logger time and proper functioning weekly

Results from these inspections will be documented in the field notebooks and transcribed to a Field Visit Log Sheet (see example in Appendix C) in the office.

Data Management Procedures

Data from the data loggers at each monitoring station in Appendix A will be remotely transferred to the Public Works Annex monitoring field computer. Data will be uploaded weekly via cellular modem to the Flowlink 5 program and then transferred for backed up to the County's network drive. The County will be able to access and manipulate the raw data from the network drive. These data will be routinely (monthly) checked for evidence of an equipment malfunction or other operational problem. To the extent possible, gaps in flow data will be interpolated and the data will be stored and presented in a manner that identifies the data that are from direct equipment measurements, and the data that are interpolated.

Audits and Reports

Audits will be performed to detect potential deficiencies in the hydrologic data collected for this project. Audits for hydrologic data will occur following at least one storm event per month or once every two months if there are no storm in the month. In connection with these audits, the data collected from each monitoring station over the sampled storm events will be examined in relation to data from prior storms and data from the rain gauge station to identify potential data quality issues. This audit will specifically include an examination of the data record for gaps, anomalies, or inconsistencies between the discharge and water level data from previous monitoring events. Any data generated from calibration checks that were performed at a particular monitoring station will also be entered into control charts and reviewed to detect potential instrument drift or other operational problems.

If QA issues are identified on the basis of these audits, measures will be taken to troubleshoot the problem(s) and to implement corrective actions if possible. Further, if bias in the hydrologic record is detected, the data will be corrected to the extent possible based on the calibrations measurements from the associated station. All corrective actions or adjustments to the data will be documented in the database.

Reporting for this project will involve preparation of annual data summaries and periodically major reports. Major project reports will be produced with assistance from a consulting firm and will be performed after a significant amount of conversion of impervious surfaces to pervious surfaces is accomplished. Analysis for effectiveness of conversion of impervious to pervious surfaces may include: 1) scenario comparisons (predevelopment, developed unmitigated, and LID retrofit), and 2) alterations in the hydrology of the basin. The annual data summaries will consist of graphical and tabular representations of the compiled monitoring data. These reports will be reviewed by SSWM managers. The project reports will present and summarize all hydrologic data that were collected during this study. These reports will begin by identifying the specific goals of the monitoring program and then describe the monitoring procedures that were implemented to achieve those goals. It will then present and evaluate the compiled monitoring data using supporting graphical and/or tabular representations of the data as necessary. Results from any statistical analyses that were performed on these data will also be presented and discussed in detail. Finally, major conclusions from the monitoring program will be presented at longer intervals than the annual data summary reports. These major reports will involve modeling performed by a consulting firm. Appendices to the report will include tabular compilations of all raw monitoring data, field data sheets, and a data validation memorandum. All reports will be submitted to SSWM managers for review, comment, and approval.

Data Verification and Validation

Data collected for this project will be verified and validated before it is analyzed. The verification and validation process will include the following steps:

1. Precipitation data (collected by KPUD) for the study will be reviewed to identify any significant gaps. If possible, these gaps will be filled using data obtained from a nearby rain gauge.
2. The available discharge and water level data will be verified based on comparisons of the associated hydrographs to the hyetographs for individual storm events. Gross anomalies (e.g., data spikes), gaps, or inconsistencies that are identified through this review will be investigated to determine if there are quality assurance issues associated with the data that limit their usability.
3. Validation and calibration data collected during routine site visits will be reviewed to determine whether the specific MQOs specified in the *Quality Objectives* section have been met.
4. If minor quality assurance issues are identified in any portion of the discharge record or in the water level data from a particular station and storm event, the data from that station and event will be considered as an estimate and assigned a (*j*) qualifier. If major quality assurance issues are identified in any portion of the data from a particular station and /or storm event, the data from that station and event will be rejected and assigned an (*r*) qualifier. Estimated values will be used for evaluation purposes while rejected values will not.

Data Quality (Usability) Assessment

Procedures that will be used to assess the usability of the data and then analyze the data are presented in the following subsections.

Data Usability Assessment

Based on the results of the data verification and validation process described in the previous section, a data quality assessment will be included in the annual summary reports to summarize quality control results, identify when data quality objectives were not met, and discuss the resulting limitations, if any, on the use or interpretation of the data. The specific quality assurance information that will be noted in the data quality assessment report includes:

- Changes in and deviations from the monitoring and quality assurance plan
- Results of performance and/or system audits
- Significant quality assurance problems and recommended solutions
- Data quality assessment results in terms of precision, bias, representativeness, completeness, comparability, and reporting limits
- Discussion of whether the quality assurance objectives were met, and the resulting impact on decision-making
- Limitations on use of the measurement data

Data Analysis Procedures

The sections below present data analysis procedures. They will be used to evaluate the effectiveness of the LID features on the project basins at reducing flow volumes and peak discharge rates. Data pre-processing procedures for this analysis are described in the subsection below. Subsequent subsections then present the specific data analyses procedures that will be used to evaluate the performance of all LID features as a whole for the entire project site.

Data Pre-processing

The continuous monitoring data that is collected from the stations identified in Appendix A will be analyzed to evaluate the effectiveness of the LID features in the basin at reducing flow volumes and peak discharge rates. To perform this analysis, the data from each individual monitoring station will be processed using a computer algorithm to identify individual storm “events” based on measured rainfall amounts and user-defined limits for pre- and post-storm antecedent dry periods. Once these events are defined, the algorithm will automatically calculate

summary statistics for each event (e.g., peak discharge, storm volume, rainfall total, flow duration, etc.) from the continuous monitoring data. These data will then be used in the analyses described in the subsections below.

Entire Project Basin

Overall basin performance will be evaluated by comparing storm event characteristics (runoff volumes and peak discharge rates) measured for the entire basin to those from modeled hydrographs for a predevelopment scenario and developed unmitigated scenario on the same basin. The precipitation data gathered during the course of the study by KPUD will be formatted and imported into the model. Evaporation data for the study period will be estimated using Puyallup gage evaporation data or a closer dataset if available, adjusted for the project location. For the predevelopment scenario, a forested land cover will be assumed for the modeling. For the developed unmitigated scenario, the existing mix of impervious and landscaped areas will be modeled, excluding all LID measures. Again, separate model runs will be performed assuming till and saturated soil conditions, respectively, to provide a range of hydrographs for each scenario to quantify potential error in the analysis.

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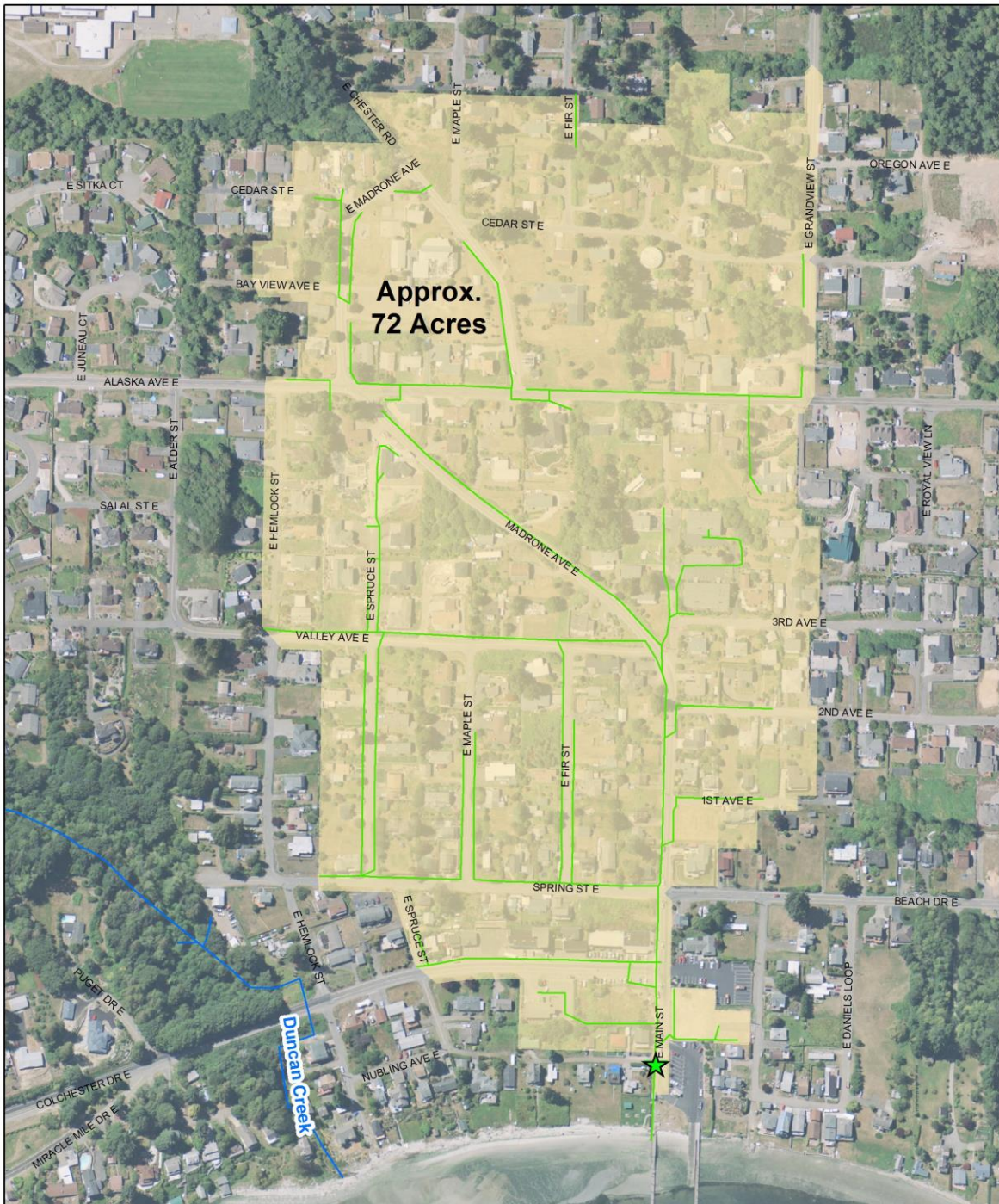
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Appendix A

Monitoring Stations

Station Name	Drainage Basin Area	Station Purpose	Station Description	KPUD Rain Gauge Site
Manchester:	Approximately 72 Acres (Note: project area may change when final storm system design is complete)	This station will be used to continuously monitor the combined flow volume of all sources discharging into the Main Street storm system.	Isco 4250 with standard area velocity sensor and rain gauge	Kitsap County South Road Shed
Suquamish:	Approximately 86 Acres (Note: project area may change when final storm system design is complete)	This station will be used to continuously monitor the flow volume of runoff from Division Avenue.	Isco 4250 with low profile area velocity sensor	Suquamish Village
Silverdale: Basin A Poplars-0001	Approximately 106 Acres	This station will collect continuous flow from the area between Kitsap Mall Blvd NW and NW Randall Way.	Isco 2150's with area velocity sensor	Silverdale Sheriff's Office
Silverdale: Basin B Mall-0002	Approximately 79 Acres	This station will collect continuous flow from the area between Kitsap Mall Blvd NW and Silverdale Way NW	Isco 2150's with area velocity sensor	Silverdale Sheriff's Office

Manchester Storm Flow Monitoring & Approximate Drainage Area



- Manchester Main St Drainage Systems
- Manchester Main St Drainage Parcels
- ★ Flow Monitoring Station

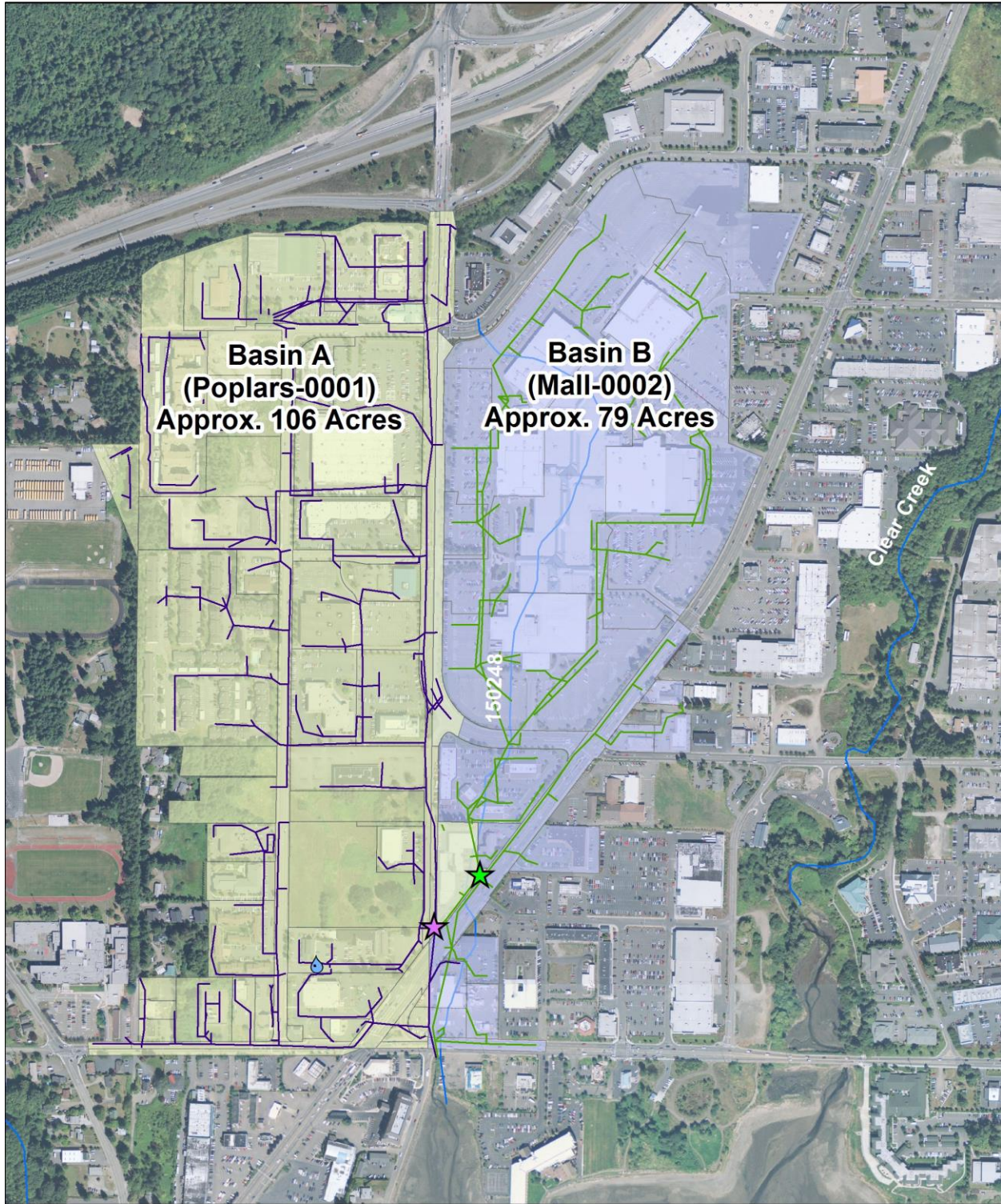


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 Product of SSWM Water Quality (MH) July 2013

Suquamish Storm Flow Monitoring & Approximate Drainage Area



Silverdale Storm Flow Monitoring & Approximate Drainage Areas



- Basin A Drainage System
- Basin A Approximate Flow Drainage
- Basin B Drainage System
- Basin B Approximate Flow Drainage
- ★ Basin A (Poplars-0001)
- ★ Basin B (Mall-0002)
- 💧 Rain Gauge Site



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 Product of SSWM Water Quality (MH) Jun 2013
 (storm flow/Silverdale flow Drainages.mxd)

Appendix B

Equipment Specifications

Specifications

2150 Flow Module	
Size (HxWxD):	2.9 x 11.3 x 7.5 in (74 x 287 x 191 mm)
Weight:	2.0 lb (0.9 kg)
Materials of construction:	High-impact polystyrene, stainless steel
Enclosure (self-certified):	NEMA 4X, 6P (IP68)
Temperature Range:	-40° to 140° F (-40° to 60° C) operating and storage
Power Required:	12 VDC nominal (7.0 to 16.6 VDC), 100 mA typical, 1 mA standby
Power Source:	Typically, an Isco 2191 Battery Module, containing 2 alkaline or 2 rechargeable lead-acid batteries. (Other power options are available; ask for details.)
Typical Battery Life:	Using 15-minute data storage interval Energizer® Model 529 alkaline - 15 months Isco rechargeable lead-acid - 2.5 months
Program Memory:	Non-volatile programmable flash; can be updated using PC without opening enclosure; retains user program after updating.
Built-in Conversions	
Flow Rate Conversions:	Up to 2 independent level-to-area conversions and/or level-to-flow rate conversions.
Level-to-Area Conversions:	Channel Shapes - round, U-shaped, rectangular, trapezoidal, elliptical, with silt correction; Data Points - Up to 50 level-area points.
Level-to-Flow Conversions:	Most common weirs and flumes; Manning Formula; Data Points (up to 50 level-flow points); 2-term polynomial equation
Total Flow Calculations:	Up to 2 independent, net, positive or negative, based on either flow rate conversion
Data Handling and Communications	
Data Storage:	Non-volatile flash; retains stored data during program updates. Capacity 395,000 bytes (up to 79,000 readings, equal to over 270 days of level and velocity readings at 15-minute intervals, plus total flow and input voltage readings at 24-hour intervals)
Data Types:	Level, velocity, flow rate 1, flow rate 2, total flow 1, total flow 2, input voltage, temperature
Storage Mode:	Rollover; 5 bytes per reading.
Storage Interval:	15 or 30 seconds; 1, 2, 5, 15, or 30 minutes; or 1, 2, 4, 12, or 24 hours Storage rate variable based on level, velocity, flow rate, total flow, or input voltage
Data Retrieval:	Serial connection to PC or optional 2101 Field Wizard module; optional modules for spread spectrum radio; land-line or cellular modem; 1xRTT. Modbus and 4-20 mA analog available.
Software:	Isco Flowlink for setup, data retrieval, editing, analysis, and reporting
Multi-module networking:	Up to four 2100 Series Flow Modules, stacked and/or remotely connected. Max distance between modules 3300 ft (1000 m).
Serial Communication Speed:	38,400 bps

2150 Area Velocity Sensor	
Size (HxWxD):	0.75 x 1.3 x 6.0 in (19 x 33 x 152 mm)
Cable (Length x Diameter):	33 ft x 0.37 in (10 m x 9 mm) standard. Custom lengths available on request.
Weight (including cable):	2.2 lbs (1 kg)
Materials of construction:	Sensor - Epoxy, chlorinated polyvinyl chloride (CPVC), stainless steel Cable - Polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC)
Operating Temperature:	32° to 140° F (0° to 60° C)
Level Measurement:	Method - Submerged pressure transducer mounted in the flow stream Transducer Type - Differential linear integrated circuit pressure transducer Range (standard) 0.033 to 10 ft (0.010 to 3.05 m); (optional) up to 30 ft (9.15 m). Maximum Allowable Level 34 ft (10.5 m) Accuracy ±0.01 ft from 0.033 to 10 ft, (±0.003 m from 0.01 to 3.05 m.) Long-Term Stability ±0.023 ft/yr (±0.007 m/yr) Compensated Range 32° to 122°F (0° to 50° C)
Velocity Measurement:	Method - Doppler ultrasonic, frequency 500 kHz Typical Minimum Depth 0.08 ft (25 mm) Range -5 to +20 ft/s (-1.5 to +6.1 m/s) Accuracy (in water with uniform velocity profile, speed of sound = 4850 ft/s, for indicated velocity range) ±0.1 ft/s from -5 to 5 ft/s (±0.03 m/s from -1.5 to +1.5 m/s) ±2% of reading from 5 to 20 ft/s (1.5 to 6.1 m/s)
Temperature Measurement:	Accuracy ±3.6° F (±2° C)
2191 Battery Module	
Size (HxWxD):	6.0 x 9.6 x 7.6 in (152 x 244 x 193 mm)
Weight (without batteries):	3.2 lb (1.4 kg)
Materials of construction:	High-impact polystyrene, stainless steel
Enclosure (self certified):	NEMA 4X, 6P, (IP68)
Batteries:	Two 6-volt Energizer Model 529* alkaline (25 Ahrs capacity) or Isco Rechargeable Lead-acid (5 Ahrs capacity) recommended. *Note - Energizer 529 ER does not give specified life.

2150 Ordering Information

Contact your Teledyne Isco representative for complete ordering details and information on other 2100 Series Modules.

Description	Part No.
2150 with AV sensor, 2191 Battery Module, and Handle	68-2050-002
2150 Module with AV sensor (only)	68-2050-001
Isco Flowlink® 5 Software	68-2540-200
Energizer® Model 529 Alkaline Lantern Battery (2 required)	340-2006-02
Isco Rechargeable Lead-acid Battery (2 required)	60-2004-041
Charger for Lead-acid Batteries (holds 2 batteries)	60-2004-040



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Isco 2103ci CDMA Cellular Phone Modem

This cellular modem module is factory-configured to deliver Isco 2100 Series flow meter data to an identified, remote server database. Data can also be downloaded from the server using an internet connection. The 2103ci modem module uses Serial Over Internet Protocol (SOIP), so a landline modem is not required.

This ability virtually eliminates the need for routine site visits, time-consuming (and potentially dangerous) confined space entry, as well as costly installation of land lines.

Improved efficiency in I&I studies, cMOM, SSO, and CSO

The 2103ci stacks together with up to three other Isco 2100 Series flow modules of your choice, giving you a compact, integrated system for open channel flow data collection and management. Features include:

- ◆ Automatic dial-out alarm messaging to pagers or cell phones
- ◆ Resistance to lightning damage
- ◆ Compatibility with Isco Flowlink® Data Management Software, allowing sophisticated analysis, editing, graphing, reporting, and archiving.

Long battery life

Pre-set dial-out conditions automatically cause the 2103ci to power up, but the user may program specific "on times" for dial-in communication, significantly extending battery life.

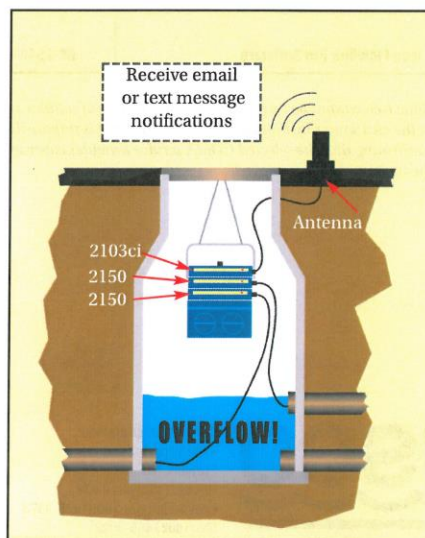
* Contact the factory for additional information regarding service providers.



Pushed-data capability

The 2103ci can automatically send data via the internet to a designated server running Isco Flowlink Pro software, using economical 1xRTT packet-switched data transmission. The user-specified primary data transmission interval (from 5 minutes to 24 hours) can automatically change to a secondary interval when specific site conditions occur at the monitoring site.

An Oracle® or Microsoft® SQL database is required to use this feature. Contact the factory for additional information.



The 2103ci dial-out feature enables it to transmit a text message alarm to your digital cell phone or pager.

Specifications

2103ci CDMA Cellular Phone Modem	
Size: (H x W x D)	2.9 x 10.5 x 7.5 in (7.3 x 26.7 x 19 cm)
Weight:	2.0 pounds (9 kg)
Enclosure:	NEMA 4X, 6P (IP 68)
Material:	High-impact polystyrene
Power:	Provided by Isco 2191 Battery Module
Operating Temperature:	-4° to 140° F (-20° to 60°C)
Storage Temperature:	-40° to 140° F (-40° to 60°C)
Setup and data retrieval:	Via PC with Isco Flowlink Software

2191 Battery Module	
Size: (H x W x D)	6.0 x 9.6 x 7.6 in (15 x 22 x 19 cm)
Weight: (w/o batteries)	3.2 lbs (1.45 kg)
Enclosure: (self-certified)	NEMA 4X, 6P (IP 68)
Material:	High-impact polystyrene
Batteries:	Two 6V alkaline or lead-acid lantern
Alkaline	25 Ahr capacity
Lead-acid	5 Ahr capacity

Ordering Information

Isco will consult with customer at time of order to select CDMA service provider, install the phone number per customer's service contract, and make test calls in and out, normally providing plug-and-play startup when modem is delivered.

Description	Part Number
2103ci CDMA Digital Cell Phone package with magnetic-mount antenna	68-2000-098
Magnetic-mount antenna Includes 10-foot (3-meter) cable	60-2004-550
Isco Flowlink Software	68-2540-200
Isco Flowlink Pro Software	68-2540-270



Magnetic-mount antenna, for elevated placement to extend range and avoid signal obstruction, e.g., where modem is inside a steel enclosure or steel-framed building.

Note: Isco cannot be responsible for availability of cellular service at the customer's installation site. The customer is responsible for confirming that the selected CDMA service provides coverage where the modem will be deployed.

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4250 Area Velocity Flow Meter

The sensor on the Isco 4250 uses patented* Doppler technology to directly measure average velocity in the flow stream. An integral pressure transducer measures liquid depth to determine flow area. The 4250 then calculates flow rate by multiplying the area of the flow stream by its average velocity.

The 4250 gives you greater accuracy in applications where weirs or flumes are not practical, or where submerged, full pipe, surcharged, and reverse flow conditions may occur. And you don't have to estimate the slope and roughness of the channel.

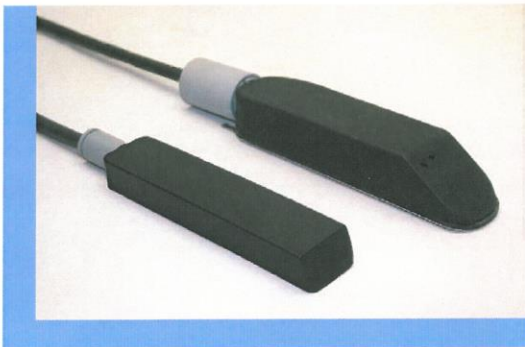
Easy Setup

The 4250's Doppler system continuously profiles the flow stream. This saves you time by eliminating profiling and calibration required by electromagnetic systems.

Maintenance-free

The streamlined 4250 sensor sheds debris and withstands corrosive flow stream chemicals. And, unlike electromagnetic probes, the sealed Isco sensor resists fouling by oil and grease, so you're not bothered with frequent cleanings. You can count on the Isco 4250 for long-term, dependable operation.

*US Patent Nos. 5,371,686 and 5,557,536



The 4250 Area Velocity Flow Meter is ideal for sites where submerged, full pipe, surcharged, or reverse flows may occur.

Isco offers both Standard and Low Profile Area Velocity Sensors to meet your specific needs. The Standard Sensor (right) is more suitable for use in larger pipes and in turbid flows with high concentrations of suspended solids and entrained air, and may be less susceptible to silting.

The Low Profile Sensor senses velocity in flows typically down to 1" (25 mm) in depth, while its streamlined design minimizes flow stream obstruction. In addition, encapsulation in epoxy provides improved chemical compatibility.

Please refer to literature on the Low Profile Area Velocity Sensor for specifications.

Isco 4250 Specifications

Size (H x W x D) (without power source)	15.5 in x 11.5 in x 10.5 in	39.4 cm x 29.2 cm x 26.7 cm	Voice Messaging (with optional internal telephone modem)	Calls up to 5 telephone numbers with programmable delay between calls, activated based on AND and OR combinations of any two of level, velocity, flow rate, rainfall, pH, DO, conductivity, and temperature																
Weight (without power source)	17.3 lbs	7.81 kg	Analog Outputs (optional)	Up to 3 isolated internal outputs, 0 to 20 mA or 4 to 20 mA, scalable based on level, velocity, flow rate, pH, DO, conductivity, or temperature, into a maximum of 750 ohms each																
Material	High-impact molded polystyrene structural foam		Relay Outputs	2 form C relays with field selectable trip points based on flow rate (with optional High/Low Alarm Relays)																
Enclosure (self-certified)	NEMA 4X	IP65	Serial Output	Current status and readings, in response to command or automatically at selectable time intervals, ASCII comma separated values at 1200, 2400, 4800, or 9600 bps																
Power	12 to 14V DC, 14 mA average at 12.5V DC (printer set at 1 in/hr (2.5 cm/hr), 1 minute level reading interval, and 5 minute velocity reading interval)		Operating Temperature	0° to 140°F																
Typical Battery Life	(printer set at 1 in./hr (2.5 cm/hr), 1 minute level reading, interval, 5 minute velocity reading interval)		Storage Temperature	-40° to 140°F																
934 Nickel-Cadmium Battery	8 to 11 days		Area Velocity Sensor (see separate data sheet for low-profile sensor)																	
946 Lead-Acid Battery	12 to 16 days		Length	6.6 in																
948 Lead-Acid Battery	75 to 90 days		Width	1.6 in																
Program Memory	Non-volatile, programmable flash; can be updated via interrogator port without opening the enclosure		Height	1.2 in																
Display	Backlit LCD, 2-line, 80-character		Nose Angle	35° from horizontal																
Level-to-Area Conversions	Backlit LCD, 2-line, 80-character		Cable Length																	
Channel shapes	Round, U-shaped, rectangular, trapezoidal		Standard range probe	25 ft																
Data points	Four sets of 50 level-area points		Extended range probe	50 ft																
Level-to-Flow Rate Conversions			Cable Diameter																	
Weirs	V-notch, rectangular, and Cipolletti		(including cable)																	
Flumes	Parshall, Palmer-Bowlus, Leopold-Lagoo, Trapezoidal, H, HS, HL		Standard range probe	0.37 in																
Manning formula	Round, U-channel, rectangular, trapezoidal		Extended range probe	0.37 in																
Data Points	Four sets of 50 level-flow rate points		Weight (including cable)																	
Equation	Two-term polynomial		Standard range probe	2.1 lbs																
Totalizers			Extended range probe	3.9 lbs																
LCD	Total, forward, and reverse flow; 9 digits each, floating decimal point, resettable		Level Measurement																	
Mechanical (optional)	Total flow, 7 digits, non-resettable		Method	Submerged pressure transducer mounted in the flow stream																
Rain Gauge Input	Contact closure, normally open		Transducer Type	Differential linear integrated circuit pressure transducer																
Resolution	0.01 or 0.004 in	0.25 or 0.1 mm	Range																	
Parameter Inputs	pH, dissolved oxygen, conductivity, and temperature (with optional YSI 600 Multi-Parameter Water Quality Monitor); pH and temperature (with optional Isco 201 Parameter Module)		Standard range probe	0.05 to 10 ft																
Sampler Activation Conditions	Enabled, disabled, AND and OR combinations of any two of level, velocity, flow rate, rainfall, pH, DO, conductivity, and temperature		Extended range probe	0.05 to 30 ft																
Sampler Pacing Output	12V pulse		Maximum Allowable Level																	
Sampler Input	Event mark, bottle number		Standard range probe	20 ft																
Printer			Extended range probe	40 ft																
Recording Modes	Up to 3 graphs of level, velocity, flow rate, pH, DO, conductivity, and temperature vs time; includes totalized flow, Rainfall and sampler events (time and bottle number) are also recorded		Accuracy	Non-linearity, repeatability, and hysteresis at 25°C (77°F) (does not include temperature coefficient)																
Speed	Off, 0.5, 1, 2, 4 in/hr	Off, 1.25, 2.5, 5, 10 cm/hr	Standard range probe	<table border="1"> <thead> <tr> <th>Level*</th> <th>Error</th> <th>Level*</th> <th>Error</th> </tr> </thead> <tbody> <tr> <td>0.033 to 5.0 ft</td> <td>±0.008 ft/R</td> <td>0.01 to 1.52 m</td> <td>±0.008 m/m</td> </tr> <tr> <td>> 5.0 ft</td> <td>±0.012 ft/R</td> <td>> 1.52 m</td> <td>±0.012 m/m</td> </tr> </tbody> </table>	Level*	Error	Level*	Error	0.033 to 5.0 ft	±0.008 ft/R	0.01 to 1.52 m	±0.008 m/m	> 5.0 ft	±0.012 ft/R	> 1.52 m	±0.012 m/m				
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Recording Span	User selectable with multiple over- and under-ranges		Extended range probe	<table border="1"> <thead> <tr> <th>Level*</th> <th>Error</th> <th>Level*</th> <th>Error</th> </tr> </thead> <tbody> <tr> <td>0.05 to 15 ft</td> <td>±0.03 ft</td> <td>0.015 to 4.57 m</td> <td>±0.009 m</td> </tr> <tr> <td>0.05 to 21 ft</td> <td>±0.09 ft</td> <td>0.015 to 6.40 m</td> <td>±0.027 m</td> </tr> <tr> <td>0.05 to 30 ft</td> <td>±0.30 ft</td> <td>0.015 to 9.14 m</td> <td>±0.09 m</td> </tr> </tbody> </table>	Level*	Error	Level*	Error	0.05 to 15 ft	±0.03 ft	0.015 to 4.57 m	±0.009 m	0.05 to 21 ft	±0.09 ft	0.015 to 6.40 m	±0.027 m	0.05 to 30 ft	±0.30 ft	0.015 to 9.14 m	±0.09 m
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Resolution	1/240 of recording span		Temperature Coefficient	Maximum error within compensated temperature range (per degree of temperature change)																
Reports Printed	Flow meter program, 2 independent time interval reports, flow meter history, sampler history		Standard range probe	<table border="1"> <thead> <tr> <th>Level*</th> <th>Error</th> <th>Level*</th> <th>Error</th> </tr> </thead> <tbody> <tr> <td>0.05 to 4.0 ft</td> <td>±0.005ft/°F</td> <td>0.015 to 1.22m</td> <td>±0.0027m/°C</td> </tr> <tr> <td>4.0 to 10 ft</td> <td>±0.007ft/°F</td> <td>1.22 to 3.05 m</td> <td>±0.0038m/°C</td> </tr> </tbody> </table>	Level*	Error	Level*	Error	0.05 to 4.0 ft	±0.005ft/°F	0.015 to 1.22m	±0.0027m/°C	4.0 to 10 ft	±0.007ft/°F	1.22 to 3.05 m	±0.0038m/°C				
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Interval Report Contents	Site number; time interval; total, forward and reverse flow; minimum, maximum, and average flow rate, level, velocity, pH, DO, conductivity, and temperature, and time of occurrence; interval flow; total rainfall; number of samples, flow meter history and sampler history		Extended range probe	<table border="1"> <thead> <tr> <th>Level*</th> <th>Error</th> <th>Level*</th> <th>Error</th> </tr> </thead> <tbody> <tr> <td>0.05 to 30 ft</td> <td>±0.008ft/°F</td> <td>0.015 to 9.14 m</td> <td>±0.0044m/°C</td> </tr> </tbody> </table>	Level*	Error	Level*	Error	0.05 to 30 ft	±0.008ft/°F	0.015 to 9.14 m	±0.0044m/°C								
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Character Size	0.09 in high x 0.07 in wide (2.4 mm x 1.7 mm), 12 pitch		Velocity Measurement																	
Paper	4.5 in wide x 58 ft (11.4 cm x 17.7 m) plain white paper, replaceable roll		Method	Doppler ultrasonic																
Ribbon	19.7 ft (6.0 m) black nylon, replaceable		Frequency	500 kHz																
Data Storage Memory	80,000 bytes (approximately 40,000 readings) divided into a maximum of 12 memory partitions; equal to 60 days of level, velocity, rainfall, pH, DO, conductivity, and temperature readings at 15 minute intervals, plus 3,000 sample events.		Typical minimum depth for velocity measurement	0.25 ft																
Capacity			Range	-5 to +20 ft/s																
Setup and Data Retrieval	Isco Flowlink® software		Accuracy (Uniform velocity profile)	<table border="1"> <thead> <tr> <th>Velocity</th> <th>Error</th> <th>Velocity</th> <th>Error</th> </tr> </thead> <tbody> <tr> <td>-5 to +5 ft/s</td> <td>±0.1 ft/s</td> <td>-1.5 to +1.5 m/s</td> <td>±0.03 m/s</td> </tr> <tr> <td>5 to 20 ft/s</td> <td>±2% of reading</td> <td>1.5 to 6.1 m/s</td> <td>±2% of reading</td> </tr> </tbody> </table>	Velocity	Error	Velocity	Error	-5 to +5 ft/s	±0.1 ft/s	-1.5 to +1.5 m/s	±0.03 m/s	5 to 20 ft/s	±2% of reading	1.5 to 6.1 m/s	±2% of reading				
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Communication	Direct connection, optional internal 2400 bps telephone modem with voice messaging, or optional spread spectrum wireless module		Resolution	±0.024 ft/s																
Data Retrieval (optional)	Isco 581 Rapid Transfer Device (RTD)		Operating Temperature	32° to 160°F																
			Compensated Temperature	32° to 100°F																
			Materials																	
			Sensor	Polybutadiene-based polyurethane, stainless steel																
			Cable	Polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC)																

* Actual vertical distance between the area velocity sensor and the liquid surface

Appendix C

Field Visit Log Sheet

