Squalicum Creek taken by Washington State Department of Ecology

Squalicum Creek Watershed Stormwater Pilot Total Maximum Daily Load

Quality Assurance Project Plan

United States Environmental Protection Agency

DEPARTMENT OF ECOLOGY
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Publication and Contact Information

This study represents a joint project between Washington State Department of Ecology (Ecology) and the U. S. Environmental Protection Agency (USEPA). This is a Quality Assurance Project Plan (QAPP) that describes the objectives of the study and the procedures to be followed to achieve those objectives. This QAPP has been approved by EPA and is represents a joint publication. Ecology is posting it to their website. After completing the study, Ecology will post the final report of the study to the Internet.

The plan for this study is available on the Department of Ecology's website at www.ecy.wa.gov/biblio/1203109.html.

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Authors: Brandi Lubliner and Bruce Cleland

Department of Ecology Communication Consultant: Phone 360-407-6834.

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Study Codes

Benthic and sediment data used for this project will be available on Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm. Search User Study ID, BRWA0007.

TMDL Study Code (Water Quality Program) is SqCk01IN.

Federal Clean Water Act 2008 303(d) Listings Addressed in this Study

Squalicum Creek Water Body Number: (WA-01-9100)

Cover photo: Squalicum Creek, Bellingham, Washington

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Approved by:

Signature: Helen Bresler, WQP, Lacey Headquarters	Date: June 2012
Signature: Steve Hood, WQP, Bellingham Field Office	Date: July 2012
Signature: Bruce Cleland, Project Manager, Tetra Tech Inc.	Date: June 2012
Signature: Amy King, Task Order Leader, Tetra Tech Inc.	Date: June 2012
Signature: John O'Donnell, Quality Assurance Officer, Tetra Tech Inc.	Date: July 2012
Signature: Brandi Lubliner, Project Manager, EAP	Date: June 2012
Signature: David Ragsdale, Project Technical Lead, USEPA	Date: June 2012
Signature: Will Kendra, Section Manager, EAP	Date: June 2012
Signature: Jayne Carlin, Task Order Manager, USEPA	Date: June 2012
Signature: Gina Grepo-Grove, Regional Quality Assurance Manager, USEPA	Date: June 2012

WQP: Water Quality Program, Washington State Department of Ecology
EAP: Environmental Assessment Program, Washington State Department of Ecology
USEPA: United State Environmental Protection Agency

Table of Contents

List of Figures

List of Tables

Abstract

Squalicum Creek and its major tributary Baker Creek do not meet Washington State water quality standards for low dissolved oxygen and high fecal coliforms. Additionally the creeks are listed as Waters of Concern for pH, zinc, pentachlorophenol, and low bioassessment scores.

The Washington State Department of Ecology and the U.S. Environmental Protection Agency (USEPA) are undertaking an innovative approach to control impacts and pollutants delivered from stormwater to the Squalicum Creek watershed. The pilot Total Maximum Daily Load (TMDL) study will include environmental assessment to address both the water quality listings and low bioassessment scores. Environmental assessment will include an evaluation of land use, impervious cover, macroinvertebrates, stream and storm flow metrics, and traditional water quality parameters.

To assist with this pilot stormwater TMDL, data pertinent to these parameters as well as benthic macroinvertebrate and GIS land use data will be compiled from the City of Bellingham, Whatcom County, and other sources. No sampling is planned under this study; however, a separate monitoring plan will collect benthic macroinvertebrate data for use under this TMDL. Data collection and environmental assessment will provide valuable information on the application of surrogate parameters for water quality listings or beneficial uses. Surrogates to be explored include stream and storm flow metrics, benthic macroinvertebrate health indicators, and land use indicators such as impervious cover.

Acknowledgements

The authors thank the City of Bellingham for generously sharing of water quality data, the flow model, GIS, benthic survey information, and fielding countless questions (Renee LaCroix, Sara Brooke Benjamin, and William Reilly). The Nooksack Salmon Enhancement Association also helped with data gathering.

What is a Total Maximum Daily Load (TMDL)?

Federal Clean Water Act Requirements

The Clean Water Act established a process to identify and clean up polluted waters. The Act requires each state to have its own water quality standards designed to protect, restore, and preserve water quality (RCW 90.48.260). Water quality standards consist of (1) designated uses for protection, such as cold water biota and drinking water supply, and (2) numeric or narrative criteria to achieve those uses.

The Water Quality Assessment (WQA) and the 303(d) List

Every two years, states are required to prepare a list of water bodies that do not meet water quality standards. This list is called the Clean Water Act 303(d) list. In Washington State, this list is part of the Water Quality Assessment (WQA) process authorized by the Washington State Administrative Code (WAC 173-201A).

To develop the WQA, the Washington State Department of Ecology (Ecology) compiles its own water quality data along with data from local, state, and federal governments, tribes, industries, and citizen monitoring groups. All data in this WQA are reviewed to ensure that they were collected using appropriate scientific methods before they are used to develop the assessment. The list of waters that do not meet standards [the 303(d) list] is the Category 5 part of the larger assessment.

The WQA divides water bodies into five categories. Those not meeting standards are given a Category 5 designation, which collectively becomes the 303(d) list].

Category 1 – Waters that meet standards for parameter(s) for which they have been tested.

Category 2 – Waters of concern.

Category 3 – Waters with no data or insufficient data available.

Category 4 – Polluted waters that do not require a TMDL because they:

- 4a. – Have an approved TMDL being implemented.
- 4b. – Have a pollution-control program in place that should solve the problem.
- 4c. – Are impaired by a non-pollutant such as low water flow, dams, culverts.

Category 5 – Polluted waters that require a TMDL – the 303(d) list.

Further information is available at Ecology's Water Quality Assessment website.

The Clean Water Act requires that a Total Maximum Daily Load (TMDL) be developed for each of the water bodies on the 303(d) list. A TMDL is a process which evaluates the 303(d) listed water body to derive a numerical value representing the highest pollutant load a surface water body can receive and still meet water quality standards. Any amount of pollution over the TMDL level needs to be reduced or eliminated to achieve clean water.

TMDL Process Overview

Ecology uses the 303(d) list to prioritize and initiate TMDL studies across the state. A TMDL is comprised of two parts: a study and implementation strategy. The TMDL technical study identifies pollution problems in the watershed, and specifies how much pollution needs to be reduced or eliminated to achieve clean water. This document will guide that technical study. Ecology, with the assistance of local governments, tribes, agencies, and the community then develops a strategy to control and reduce pollution sources and a monitoring plan to assess effectiveness of the water quality improvement activities. Together, the study and implementation strategy, comprise the *Water Quality Improvement Report* (WQIR).

Once the USEPA approves the WQIR, a *Water Quality Implementation Plan* (WQIP) is developed typically within one year. The WQIP identifies specific tasks, responsible parties, and timelines for reducing or eliminating pollution sources and achieving clean water.

Elements the Clean Water Act Requires in a TMDL

Loading Capacity, Allocations, Seasonal Variation, Margin of Safety, and Reserve Capacity

A water body's *loading capacity* is the amount of a given pollutant that a water body can receive and still meet water quality standards. The loading capacity provides a reference for calculating the amount of pollution reduction needed to bring a water body into compliance with the standards.

The portion of the receiving water's loading capacity assigned to a particular source is a *wasteload* or *load* allocation. If the pollutant comes from a discrete (point) source subject to a National Pollutant Discharge Elimination System (NPDES) permit, such as a municipal or industrial facility's discharge pipe, that facility's share of the loading capacity is called a *wasteload allocation*. If the pollutant comes from diffuse (nonpoint) sources not subject to an NPDES permit, such as general urban, residential, or farm runoff, the cumulative share is called a *load allocation*.

The TMDL must also consider *seasonal variations*, and include a *margin of safety* that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. A *reserve capacity* for future pollutant sources is sometimes included as well.

Therefore, a TMDL is the sum of the wasteload and load allocations, any margin of safety, and any reserve capacity. The TMDL must be equal to or less than the loading capacity.

What Does a "Stormwater Pilot TMDL" Mean?

Ecology and USEPA are working together to develop this "Stormwater Pilot TMDL". USEPA is providing funding to allow this project to go forward now and explore innovative ways to incorporate stormwater in TMDLs. When stormwater runoff is a source of pollutant loading which contributes to degraded water quality, the stormwater source must be assigned a wasteload allocation in the TMDL. This TMDL is considered a pilot project because it will use multiple lines of evidence to evaluate impairment associated with stormwater runoff and utilize the evaluation results to establish effective wasteload allocations. The multiple approaches are listed below:

- Traditional pollutant analysis
- Flow alteration estimations
- Benthic macroinvertebrate health and stressor causes
- Land use and land cover analysis

This study will explore each of the four above techniques to estimate what the allocation would be to protect water quality and beneficial uses. The implementation strategy will be developed based on the outcomes of the four techniques used to evaluate stormwater pollutant loads (like traditional TMDLs) and "non-pollutant" impacts such as an altered flow regime.

Pollutants bound and carried by stormwater or stormwater sediments are diverse, ranging from bacteria and nutrients to particulate-bound toxics. Stormwater volumes or flow rates can also cause impacts by eroding stream banks, scouring stream beds, flooding habitats, and dislodging aquatic life. For TMDLs, allocations to pollutant sources require evidence of either water quality samples exceeding criteria or evidence of unsupported beneficial uses. Historically, stormwater has been difficult for TMDL writers, because scant if any data are available on the pollutants carried by both the nonpoint and point sources' stormwater discharges for any given watershed. In addition, laying out TMDL studies to quantify stormwater pollutant loads by sampling from multiple jurisdictions or permittees within any given watershed is not only logistically difficult, but can also be cost-prohibitive. Devising an approach to quantify stormwater pollutants and stormwater "non-pollutant" impacts to beneficial uses is needed, and requires use of surrogate measures.

Surrogate Measures

To provide more meaningful and measurable pollutant loading targets, this TMDL will evaluate both 303(d) listings and potential *surrogate measures*. USEPA regulations [40 CFR 130.2(i)] allow the use of other appropriate measures in a TMDL. Potential surrogate measures for use in this TMDL, discussed below in more detail, will include flow duration curves, flow metrics, turbidity, benthic macroinvertebrate multimetrics, land use, and impervious cover. The ultimate need for, and the selection of, a surrogate measure for use in setting allocations depends on how well the proposed surrogate measure matches the impairment.

USEPA and Ecology are examining innovative TMDL development methods for water quality problems associated with urban stormwater. Specifically, this Stormwater Pilot TMDL will explore multiple lines of evidence to evaluate the stormwater impacts. The multiple approaches are listed below:

- Traditional pollutant analysis
- Flow alteration estimations
- Benthic macroinvertebrate health and stressor causes
- Land use and land cover analysis

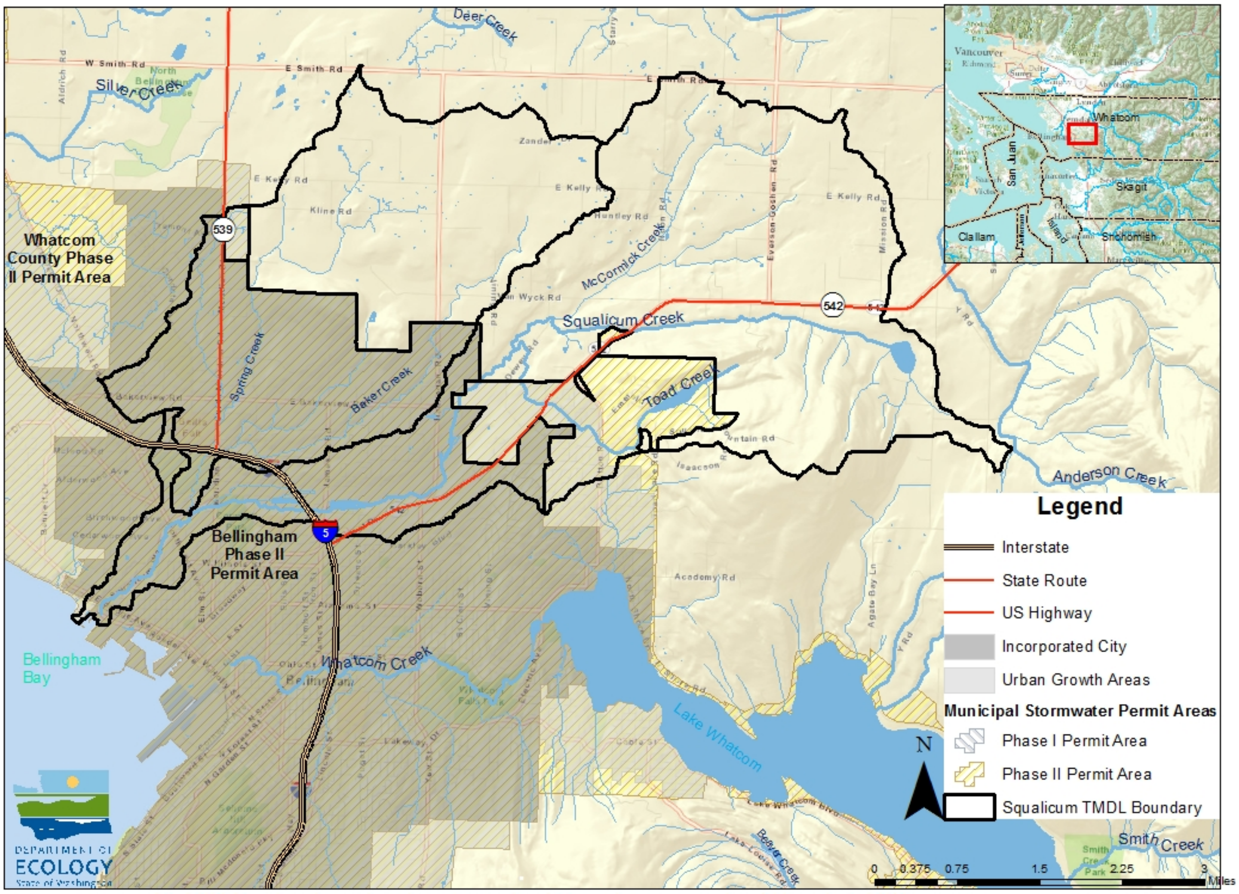
Flow will be explored as a primary surrogate measure to address the combination of water quality pollutants and stressors in stormwater that have an adverse effect on beneficial uses, notably aquatic biota. This includes the different ways that flow may be described (e.g., flow duration curves, flow volumes, normative flows, and / or flow regimes). Secondary lines of evidence and their fit as surrogates will also be evaluated for the relationship to water quality pollutants and biotic stressors will include pollutants such as turbidity or TSS, or land cover parameters such as land use or impervious cover. Surrogate appropriateness will be estimated and used if appropriate for meaningful TMDL allocations.

Benthic macroinvertebrate multimetric indices are quantitative measures for estimating impacts to Puget Lowland Streams. Scores from the multimetric indices will be coupled with EPA's diagnostic stressor identification framework to identify the stressors. This constitutes a defensible and effective monitoring and assessment program (USEPA, 2011).

Who Should Participate in This TMDL?

City of Bellingham, Whatcom County, Lummi Nation, Nooksack Tribe, Washington State Department of Transportation, and others should participate. These jurisdictions and permittees can assist by providing data, contributing their perspectives during TMDL development, and helping to identify implementation actions to improve water quality.

Nonpoint source pollutant load targets will likely be set in this TMDL. Because nonpoint pollution comes from diffuse sources, all upstream watershed areas have potential to affect downstream water quality. Therefore, all potential nonpoint sources in the watershed must use the best management practices to reduce impacts to water quality. Similarly, all point source dischargers in the watershed must also comply with the TMDL. The area that will be subject to the TMDL is shown in Figure 1.



The TMDL Boundary shows where the project applies. This map is a representation of this particular TMDL and does not replace the official version of the TMDL report approved by the U.S. EPA. Projects in development are subject to change before the report is finalized.

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Figure 1. Squalicum Creek watershed and tributaries.

Why is Ecology Conducting a Stormwater Pilot TMDL in this Watershed?

Background

Squalicum Creek, located in northwestern Washington, has been identified as a watershed that meets several conditions deemed suitable for a Stormwater Pilot TMDL effort. Current water quality impairments affecting Squalicum Creek are likely impacted by stormwater pollutant loads or aggravated by high stormwater flows. Existing local data show Squalicum Creek has a "flashy" hydrologic regime typical of urban development. In the lower Squalicum reaches, stream banks are steep and eroding, and threatening loss of property. Preliminary work shows that there is a relationship between flow metrics, water quality, and biological metrics indicators. These relationships are expected to support use of surrogate measures in the Stormwater Pilot TMDL.

Squalicum Creek and Baker Creek, a major tributary, are currently on Ecology's 2008 §303(d) list under Category 5 as impaired. Listings include temperature, fecal coliform bacteria, and dissolved oxygen. In 2011, Ecology developed a TMDL for temperature on Squalicum Creek that was approved by USEPA (Hood et al., 2011), which will remove the temperature listings in the next WQA. Because this pilot TMDL will focus primarily on stormwater loads, there exists potential that the fecal coliform and dissolved oxygen listings (typically found to be tied to summer low flow conditions) may not be completely addressed.

Additionally, Squalicum Creek is listed as a water of concern under Category 2 for pH, zinc, pentachlorophenol, and bioassessment. Category 2 listings do not require a TMDL. However, they (pH, zinc in sediments, pesticides in sediments) will at a minimum be screened as part of the bioassessment stressor identification process. This work is covered by a separate Quality Assurance Project Plan (QAPP).

The WAC 173-201A-602 lists Squalicum Creek Aquatic Life Uses as *core summer habitat*. The City of Bellingham has historic benthic macroinvertebrate and smolt trap survey data on Squalicum Creek. These data show that Squalicum Creek supports important food sources and four reproducing populations of salmonids (coho salmon, steelhead trout, cutthroat trout, and chum salmon).

The City of Bellingham has worked to restore riparian areas of Squalicum Creek with a focus on fish passage and bank stability improvements. Due to the high proportion of impervious surfaces in the lower watershed, stormwater runoff causes *flashy* flow conditions in Squalicum Creek. This means that the amount and velocity of water in the stream changes rapidly. As this stormwater rushes past backyards and roadways, it threatens to destabilize stream banks. The City of Bellingham undertook a large bank stabilization project downstream of West Street to protect Squalicum Parkway from erosion. In 2005 the City installed a series of large woody debris structures to stabilize the banks along Squalicum Creek in order to protect Squalicum Parkway and nearby homes from the effects of erosion, while at the same time improving in-stream habitat conditions.

This Stormwater Pilot TMDL is being undertaken to improve our understanding of stormwater impacts to water quality, stream ecology, and the beneficial uses of Washington's salmon-supporting streams. Outcomes of this particular TMDL may include a case example of stormwater pollutant loads and impacts directly being linked to benthic macroinvertebrate scores and surrogate measures such as impervious cover or similar land use metric, and flow metrics. This TMDL provides Ecology with innovative options for addressing stormwater in TMDLs.

This QAPP provides a general description of the analytical work to be performed for the Squalicum Creek Watershed Stormwater Pilot TMDL. This QAPP includes data quality objectives (DQOs) and quality control (QC) procedures to ensure that the final product satisfies user requirements. Secondary data (i.e., data collected for another purpose or collected by an organization or organizations not under the scope of this QAPP) will be the source of information for technical analyses conducted to support this project. This QAPP addresses the use of that secondary data.

Existing (or secondary) data collected primarily by the City of Bellingham will constitute the measured data used in this TMDL. Other sources of data will be sought, such as the U.S. Geological Survey (USGS), Lummi Nation, Nooksack Tribe, Whatcom County, Western Washington University, and the Nooksack Salmon Enhancement Association. Data will be reviewed according to Ecology's and EPA's quality assurance policies, which are discussed more in the Data Quality section of this QAPP.

Study Area

Squalicum Creek originates in the Cascade foothills east of Bellingham and north of Lake Whatcom (Figure 2). The watershed drains an area of 24.7 square miles. Squalicum Creek flows through agricultural, wooded, industrial, commercial, and residential areas before discharging into Bellingham Bay (City of Bellingham, 2011). Major tributaries include Baker Creek, Spring Creek, Toad Creek, and McCormick Creek. Baker Creek, the major contributor to Squalicum Creek, drains nearly 12 square miles, also flowing through agricultural, wooded, industrial, commercial, and residential areas.

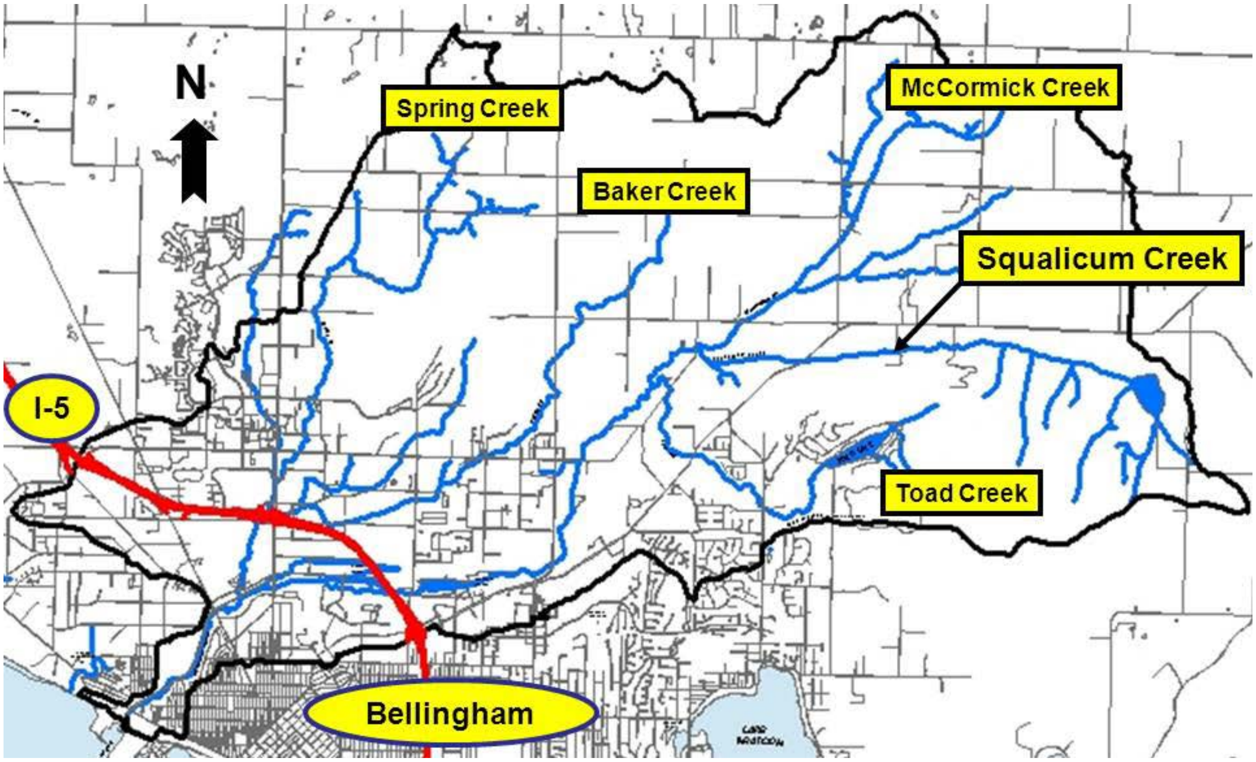


Figure 2. TMDL boundaries in Squalicum Creek watershed

Impairments Addressed by This TMDL

The main beneficial use to be protected by this TMDL is "Aquatic Life Use for Core Summer Salmonid Habitat" in Squalicum Creek watershed. Other beneficial uses that may be included by this TMDL include:

- *Primary Contact Recreation.*
- *Water Supply Uses* for domestic consumption, industrial production, and agriculture or hobby farm livestock.
- *Miscellaneous Uses* for wildlife habitat, harvesting, commerce/navigation, boating, and aesthetics (WAC 173-201A-600).

Washington State has established water quality standards to protect these beneficial uses. Ecology has included domestic water as a use for Squalicum Creek in WAC 173-201A-602, so that is a use that must be protected.

Table 1 lists the water bodies within the study area that violate water quality standards, and the state must develop TMDLs to address them. Additionally, when biological impairments are a concern the state will develop TMDLs to identify pollutant(s) or stressor(s) adversely affecting the aquatic community. The listings in Table 1 show both Category 5 303 (d) listings, as well as listings for waters of concern (Category 2). Although a TMDL is only required for the Category 5 listings by law, the goal is to address water quality impairments that are identified as part of this Stormwater Pilot TMDL technical study.

Table 1. Water bodies requiring TMDLs (Category 5) and waters of concern (Category 2) in the Squalicum Creek watershed (Ecology, 2009a).

Water body	Category	Parameter	Medium	Listing ID	Township	Range	Section
Squalicum Creek	5	Dissolved Oxygen	Water	39019	38N	3E	9
	5	Dissolved Oxygen	Water	39020	38N	3E	16
	5	Dissolved Oxygen	Water	39021	38N	3E	18
	5	Fecal Coliform	Water	39150	38N	3E	9
	5	Fecal Coliform	Water	39151	38N	3E	16
	5	Fecal Coliform	Water	39152	38N	3E	18
	5	Fecal Coliform	Water	39153	38N	2E	43
	5	Temperature*	Water	39239	38N	3E	9
	5	Temperature*	Water	39241	38N	3E	18
	2	Temperature*	Water	14001	38N	2E	43
	2	pH	Water	14007	38N	2E	43
	2	Dissolved Oxygen	Water	14013	38N	2E	43
	2	Bioassessment	Other	22282	38N	2E	13
	2	Temperature*	Water	39240	38N	3E	16
	2	pH	Water	39317	38N	3E	9
	2	pH	Water	39319	38N	3E	18
	2	Pentachlorophenol	Water	41334	38N	3E	10
	2	Zinc	Water	41776	38N	3E	18
	2	Zinc	Water	41778	38N	3E	10
Baker Creek	5	Dissolved Oxygen	Water	38950	38N	2E	24
	5	Fecal Coliform	Water	39037	38N	2E	13
	5	Fecal Coliform	Water	39038	38N	2E	24
	2	Temperature*	Water	39169	38N	2E	24
	2	pH	Water	39262	38N	2E	24

* A TMDL for temperature was approved by USEPA in 2011 (Hood et al., 2011); therefore, these listings will be moved to Category 4a in the next WQA.

Figure 3 shows the three common pathways by which aquatic life can be affected by stressors from stormwater runoff VDEC, 2006.

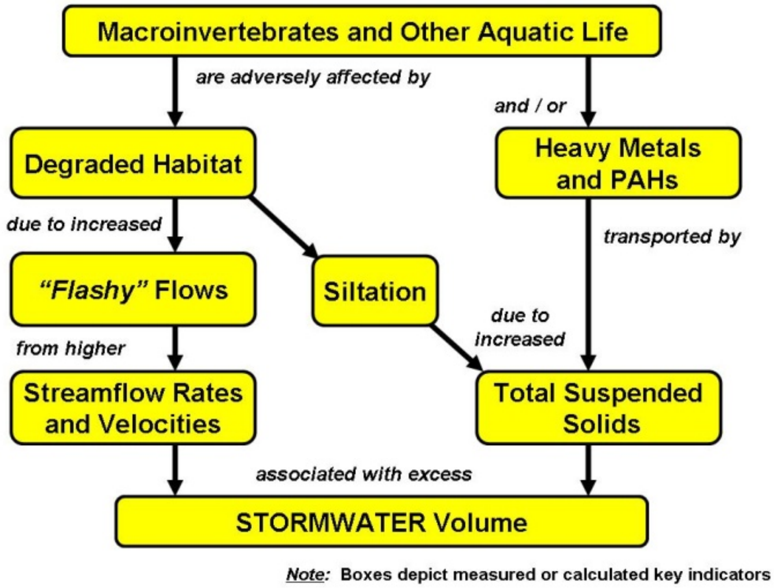


Figure 3. Example stormwater TMDL key indicators and relationships.

We will be looking at this watershed more thoroughly and may find other impaired reaches for bioassessment.

How Will the Results of This Study be Used?

A TMDL study identifies how much pollution needs to be reduced or eliminated to achieve clean water. This is done by assessing the situation and then recommending practices to reduce pollution, and by establishing limits for permitted stormwater sources.

Typically a TMDL study conducts further sampling to pinpoint source areas of pollution. In this TMDL existing and ongoing data collection by the City of Bellingham will be used in conjunction with benthic macroinvertebrate monitoring to identify reaches of the stream that are impaired. Squalicum Creek does not have major point source discharges such as wastewater treatment plants. Ecology and local partners will use these results to figure out where to focus water quality improvement activities. Or they may suggest areas for follow-up sampling to further pinpoint sources for cleanup.

Water Quality Standards and Numeric Targets

Data collection and analysis of water quality standards will begin with the parameters in Table 1, Category 5 303 (d) listing and waters of concern. Results from the Stressor Identification process may lead us to evaluate other parameters (if exiting data exist). This would possibly include turbidity, other toxics, or suspended sediment.

The Washington State water quality standards include designated beneficial uses, water body classifications, and numeric and narrative water quality criteria for surface waters of the state. This section provides Washington State surface water quality information and the criteria (set forth in Chapter 173-201A of the WAC), that may or may not be used to evaluate Squalicum Creek watershed data. Data from the station at the mouth of Squalicum Creek will be evaluated against marine criteria.

Dissolved Oxygen

Aquatic organisms are very sensitive to reductions in the level of dissolved oxygen in the water. The health of fish and other aquatic species depends on maintaining an adequate supply of oxygen dissolved in the water. Oxygen levels affect growth rates, swimming ability, susceptibility to disease, and the relative ability to endure other environmental stressors and pollutants. While direct mortality due to inadequate oxygen can occur, the state designed the criteria to maintain conditions that support healthy populations of fish and other aquatic life.

Oxygen levels can fluctuate over the day and night in response to changes in climatic conditions as well as the respiratory requirements of aquatic plants and algae. Since the health of aquatic species is tied predominantly to the pattern of daily minimum oxygen concentrations, the criteria are the lowest 1-day minimum oxygen concentrations that may occur in a water body.

Fresh Waters

In the state water quality standards, freshwater aquatic life use categories are described using key species (salmonid versus warm-water species) and life-stage conditions (spawning versus rearing). Minimum concentrations of dissolved oxygen are used as criteria to protect different categories of aquatic communities [WAC 173-201A-200; 2003 edition]. In this TMDL the following designated aquatic life use(s) and criteria are to be protected:

(1) To protect the designated aquatic life use of "Core Summer Salmonid Habitat," the lowest 1-day minimum oxygen level must not fall below 9.5 mg/L more than once every ten years on average.

The criteria described above are used to ensure that where a water body is naturally capable of providing full support for its designated aquatic life uses, that condition will be maintained. The standards recognize, however, that not all waters are naturally capable of staying above the fully protective dissolved oxygen criteria. When a water body is naturally lower in oxygen than the criteria, the state provides an additional allowance for further depression of oxygen conditions due to human activities. In this case, the combined effects of all human activities must not cause more than a 0.2 mg/L decrease below that naturally lower (inferior) oxygen condition. Whether or not the water body is naturally low in oxygen is often determined using a model. The model roughly approximates natural conditions, and is appropriate for determining the implementation of the dissolved oxygen criteria.

While the numeric criteria generally apply throughout a water body, they are not intended to apply to discretely anomalous areas such as in shallow stagnant eddy pools where natural features unrelated to human influences are the cause of not meeting the criteria. For this reason, the standards direct that one take measurements from well-mixed portions of rivers and streams. For similar reasons, do not take samples from anomalously oxygen-rich areas. For example, in a slow moving stream, sampling on surface areas within a uniquely turbulent area would provide data that are erroneous for comparing to the criteria.

The state treats lakes differently for protecting dissolved oxygen conditions. For all lakes, and for reservoirs with a mean annual retention time of greater than 15 days, human actions considered cumulatively may not decrease the 1-day minimum oxygen concentration more than 0.2 mg/L below the modeled approximation of natural conditions.

Fecal Coliform Bacteria

Fresh Waters

Bacteria criteria are set to protect people who work and play in and on the water from waterborne illnesses. In Washington State, the Department of Ecology's (Ecology) water quality standards use fecal coliform as indicator bacteria for the state's freshwaters (e.g., lakes and streams). Fecal coliform in water indicates the presence of waste from humans and other warm-blooded animals. Waste from warm-blooded animals is more likely to contain pathogens that will cause illness in humans than waste from cold-blooded animals. The fecal coliform criteria are set at levels that are shown to maintain low rates of serious intestinal illness (gastroenteritis) in people.

(1) The *Primary Contact* use is intended for waters "where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and waterskiing." More to the point, however, the use is designated to any waters where human exposure is likely to include exposure of the eyes, ears, nose, throat, and urogenital system. Since children are also the most sensitive group for many of the waterborne pathogens of concern, even shallow waters may warrant primary contact protection. To protect this use category: "Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies /100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200 colonies /100 mL." [WAC 173-201A-200(2)(b), 2006 edition].

Compliance is based on meeting both the geometric mean criterion and the 10% of samples (or single sample if less than ten total samples) limit. These two measures used in combination ensure that bacterial pollution in a water body will be maintained at levels that will not cause a greater risk to human health than intended. While some discretion exists for selecting sample averaging periods, compliance will be evaluated for both monthly (if five or more samples exist) and seasonal (summer versus winter) data sets.

The criteria for fecal coliform are based on allowing no more than the pre-determined risk of illness to humans that work or recreate in a water body. The criteria used in the state standards are designed to allow seven or fewer illnesses out of every 1,000 people engaged in primary contact activities. Once the concentration of fecal coliform in the water reaches the numeric criterion, human activities that would increase the concentration above the criteria are not allowed. If the criterion is exceeded, the state will require that human activities be conducted in a manner that will bring fecal coliform concentrations back into compliance with the standard.

If natural levels of fecal coliform (from wildlife) cause criteria to be exceeded, no allowance exists for human sources to measurably increase bacterial pollution. While the specific level of illness rates caused by animal versus human sources has not been quantitatively determined, warm-blooded animals (particularly those that are managed by humans and thus exposed to human-derived pathogens as well as those of animal origin) are a common source of serious waterborne illness for humans.

Marine Waters

The Squalicum Creek watershed is listed on the 2008 303(d) as impaired for fecal coliform bacteria. Squalicum Creek discharges directly to Bellingham Bay. The beneficial uses of Bellingham Bay, particularly the shellfish harvesting use, require a more restrictive standard for fecal coliform bacteria. Therefore at the mouth of Squalicum Creek, the more restrictive marine water quality standards for Bellingham Bay would apply and freshwater bacteria levels may need to be lower than freshwater criteria.

In marine waters, bacteria criteria are set to protect shellfish consumption and people who work and play in and on the water. Ecology uses two separate bacterial indicators in the state's marine waters. In waters protected for both primary contact recreation and shellfish harvesting, the state uses fecal coliform bacteria as indicator bacteria to gage the risk of waterborne diseases. In water protected only for secondary contact, enterococci bacteria are used as the indicator bacteria. The presence of these bacteria in the water indicates the presence of waste from humans and other warm-blooded animals. Waste from warm-blooded animals is more likely to contain pathogens that will cause illness in humans than waste from cold-blooded animals.

(1) To protect either *Shellfish Harvesting* or *Primary Contact Recreation* (swimming or water play): "Fecal coliform organism levels must not exceed a geometric mean value of 14 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 43 colonies/100 mL" [WAC 173-201A-210(3)(b), 2006 edition].

(2) The criterion level set to protect shellfish harvesting and primary contact recreation is consistent with federal shellfish sanitation rules. Fecal coliform concentrations in our marine waters that meet shellfish protection requirements also meet the federal recommendations for protecting people who engage in primary water contact activities. Thus, Ecology uses the same criterion to protect both "shellfish harvesting" and "primary contact" uses in the state standards.

Compliance is based on meeting both the geometric mean criterion and the 10% of samples (or single sample if less than ten total samples) limit. These two measures must be used in combination to ensure that the bacterial pollution in a water body will be maintained at levels that will not cause a greater risk to human health. While some discretion exists for selecting sample averaging periods, compliance will be evaluated for both monthly (if five or more samples exist) and seasonal (summer versus winter) data sets.

Once the concentration of fecal coliform in the water reaches the numeric criterion, the state does not allow human activities that would increase the concentration above that criterion. If the criterion is exceeded, the state requires that human activities are conducted in a manner that will bring bacterial concentrations back into compliance with the standards.

If natural levels of bacteria (from wildlife) cause criteria to be exceeded, no allowance exists for human sources to measurably increase bacterial pollution. While the specific level of illness rates caused by animal versus human sources has not been quantitatively determined, warm-blooded animals (particularly those humans manage and thus exposed to human-derived pathogens as well as those of animal origin) are a common source of serious waterborne illness for humans.

pH

The pH of natural waters is a measure of acid-base equilibrium achieved by the various dissolved compounds, salts, and gases. pH is an important factor in the chemical and biological systems of natural waters. pH both directly and indirectly affects the ability of waters to have healthy populations of fish and other aquatic species. Changes in pH affect the degree of dissociation of weak acids or bases. This effect is important because the toxicity of many compounds is affected by the degree of dissociation. While some compounds (e.g., cyanide) increase in toxicity at lower pH, others (e.g., ammonia) increase in toxicity at higher pH.

While there is no definite pH range within which aquatic life is unharmed and outside which it is damaged, there is a gradual deterioration as the pH values are further removed from the normal range. However, at the extremes of pH lethal conditions can develop. For example, extremely low pH values (<5.0) may liberate sufficient CO_2 from bicarbonate in the water to be directly lethal to fish.

The state established pH criteria in the state water quality standards primarily to protect aquatic life, but the standards also serve to protect waters as a source for domestic water supply. Water supplies with either extreme pH or that experience significant changes of pH even within otherwise acceptable ranges are more difficult and costly to treat for domestic water purposes.

pH also directly affects the longevity of water collection and treatment systems, and low pH waters may cause compounds of human health concern to be released from the metal pipes of the distribution system.

In the state's water quality standards, two different pH criteria are established to protect six different categories of aquatic communities [WAC 173-201A-200; 2003 edition].

To protect the designated aquatic life uses of core summer salmonid habitat" pH must be kept within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.2 units.

Toxics

The state applies toxics criteria (e.g., arsenic, mercury, chromium, lead, ammonia, etc.) to waters of the state to protect aquatic life and human health. In some cases, the state designs criteria to protect wildlife that are drinking water and eating fish contaminated with the toxins.

Aquatic Life Criteria

Criteria in 173-201A WAC are designed to protect aquatic life from both short-term (acute) and long-term (chronic) effects. The state designs aquatic life criteria primarily to avoid direct lethality to fish and other aquatic life within the exposure periods specified for the specific criteria. The exposure periods assigned to the acute criteria are expressed as: (a) instantaneous concentrations not to be exceeded at any time, or (b) a 1-hour average concentration not to be exceeded more than once every three years on the average. The exposure periods assigned to the chronic criteria are expressed as either: (1) a 24-hour average not to be exceeded at any time, or (2) a 4-day average concentration not to be exceeded more than once every three years on the average.

Human Health Criteria

Criteria for the protection of human health are applied to the state through a federal rule [40 CFR 131.36(14)]. In fresh waters, human health criteria take into account the combined exposure of both drinking the water and eating fish and shellfish that live in the water. In marine waters, human health criteria only consider the effect of eating fish and shellfish that live in the water.

Washington State established criteria to protect against non-carcinogenic illness and to keep the risk of developing cancer to a pre-specified level. In Washington, the cancer risk is set such that no more than 1 in 1,000,000 people with full exposure would be likely to develop cancer in response to that exposure. Full exposure is defined by set assumptions on body weight, fish and water consumption, and the number of years exposed. For example, in Washington the risk is correlated to an average-weight man consuming 6.5 grams per day of fish (approximately 5 pounds per year), drinking 2 liters of water per day (if a freshwater body), and continuing this pattern for 70 years. People with higher or lower exposure patterns would face higher or lower risks. This basic exposure pattern is the same for both cancer-causing and non-cancer-causing chemicals.

Turbidity

Turbidity is a measure of light refraction in the water and one uses it to control the amount of sediment and suspended solids. Suspended solids in the water column and sediment that has settled out on the bottom of the water body affect fish and other aquatic life. Effects are similar for both fresh and marine waters.

The effects of suspended solids on fish and other aquatic life can be divided into four categories:

1. Acting directly on the fish swimming in the water and either killing them or reducing their growth rate, resistance to disease, etc.
2. Preventing the successful development of fish eggs and larvae.
3. Modifying natural movements and migrations.
4. Reducing the abundance of available food.

Suspended solids may also serve to transmit attached chemical and biological contaminants to water bodies where they can be taken up in the tissue of fish. This can affect the health of humans or wildlife that eat the fish.

Turbid waters also interfere with the treatment and use of water as potable water supplies, and can interfere with the recreational use and aesthetic enjoyment of the water.

The state established turbidity criteria in the state water quality standards primarily to protect aquatic life. Two different turbidity criteria are established to protect six different categories of aquatic communities [WAC 173-201A-200; 2003 edition].

(1) To protect the designated aquatic life uses of "Core Summer Salmonid Habitat," turbidity must not exceed: (A) 5 NTU over background when the background is 50 NTU or less; or (B) a 10% increase in turbidity when the background turbidity is more than 50 NTU.

Global Climate Change

Changes in climate are expected to affect both water quantity and quality in the Pacific Northwest (Casola et al., 2005). Studies of the region's hydrology indicate a declining tendency in snow water storage coupled with earlier spring snowmelt and earlier peak spring streamflows (Hamlet et al., 2005). Factors affecting these changes include climate influences at both annual and decadal scales, and air temperature increases. Increases in air temperatures result in more precipitation falling as rain rather than snow and earlier melting of the winter snowpack.

Ten climate change models were used to predict the average rate of climatic warming in the Pacific Northwest (Mote et al., 2005). The average warming rate is expected to be in the range of 0.1-0.6°C (0.2-1.0°F) per decade, with a best estimate of 0.3°C (0.5°F) (Mote et al., 2005). Eight of the ten models predicted proportionately higher summer temperatures, with three indicating summer temperature increases at least two times higher than winter increases. Summer streamflows are also predicted to decrease as a consequence of global climate change (Hamlet and Lettenmaier, 1999).

The expected changes coming to our region's climate highlight the importance of protecting and restoring the mechanisms that help keep stream temperatures cool, DO capacity stable and provide habitat for aquatic life. Habitat improvements obtained by growing mature riparian vegetation corridors along stream banks, reducing channel widths, and enhancing summer baseflows may all help offset the changes expected from global climate change – keeping conditions from getting worse. It will take considerable time, however, to reverse those human actions that exacerbate stream habitat degradation. Changes in stream conditions associated with global climate change may require further modifications to the human-source allocations at some time in the future. However, the best way to preserve our aquatic resources and to minimize future disturbance to human industry would be to begin now to protect as much of the thermal health of our streams as possible.

Watershed Description

Geographic Setting

Squalicum Creek originates in the Cascade foothills east of Bellingham and north of Lake Whatcom and stretches west to Bellingham Bay. The watershed lies partially within the city of Bellingham with its headwaters in the unincorporated area of Whatcom County. The 24.7 square mile watershed drains Squalicum and Toad Lakes, and areas of agricultural, wooded, industrial, commercial, and residential areas before discharging into Bellingham Bay. Tributaries include Toad Lake and Creek, and Baker, Spring, and McCormick Creeks. Baker Creek, the major contributor to Squalicum Creek, drains nearly 12 square miles, also flowing through agricultural, wooded, industrial, commercial, and residential areas.

Whatcom County (2006) describes land uses within the Squalicum Creek watershed as residential, forestry, commercial, agricultural, industrial, and some mining. Residential development and industrial zoning are prevalent through the length of the creek with scattered pockets of commercial, service, and industrial uses. Second-growth forests dominate the upper watershed and are primarily deciduous. Much of the riparian zone is forested in the upper watershed. The lower watershed (incorporated Bellingham) is developed with high levels of impervious area (Whatcom County, 2006).

Within the incorporated city, Squalicum Creek maintains a vegetated riparian buffer for most of the stream length despite the urban character of the landscape. Transportation corridors and utilities parallel the creek along many of the reaches. Several major arterials and Interstate-5 cross Squalicum Creek; however, crossings decrease within the County. A larger percentage of the undeveloped land along Squalicum within the city is zoned industrial or planned for a new hospital. Several large parcels are also in public ownership.

Geology

Squalicum Creek is a glacially formed stream that flows through a valley with a width of less than one-quarter mile in most places (City of Bellingham, 2004). Local geology is primarily glacial outwash and glacial drift. The creek valley is dominated by glacial outwash in the upper reaches and glacial drift in the lower reaches. The uplands surrounding the stream valley are characterized by un-stratified glacial drift. The mouth of Squalicum Creek is artificial fill.

The valley walls in the lower reaches rise approximately 60 feet from the valley floor with the south wall being much steeper than the north wall. Soils in the watershed are dominated by Group D hydrologic soils which tend to have very slow infiltration rates and high runoff potential. Group B and C soils are also mapped in the valley, which tend to have moderate to slow infiltration and moderate runoff potential (City of Bellingham, 2004).

Hydrology

The City of Bellingham states that there is not one identifiable source of water for the creek, but rather precipitation, natural springs, wetlands, and small lakes feed the creek and minor tributaries in the upper watershed (City of Bellingham, 2004). Nearly half of the Squalicum Creek drainage is forested; however, the forest age is immature and dominated by deciduous vegetation.

Surface water storage is expected to be less than mature pre-European fir forests that would have existed historically. Whatcom County (2006) finds that significant wetland and water storage areas have been lost, altered, or otherwise affected throughout the watershed. The area of highest wetland loss is located within the upper Squalicum Creek drainage. Most of the wetlands identified as important for water quality remain intact in lower McCormick Creek and lower Squalicum Creek. The Whatcom County Shoreline Master Program identifies large contiguous tracts of wetlands along lower Squalicum Creek and McCormick Creeks and around Squalicum Lake. The City of Bellingham does not extract water from the Squalicum Creek drainage. The drainage is closed to further water rights allocations (WAC 173-501-040), which indicates insufficient base flow to support fish and wildlife and additional consumptive use.

Wildlife

At least 62 animal species inhabit Squalicum Creek watershed, including 36 types of birds, as well as 15 mammal, 6 fish, 3 amphibian, and 2 reptile species (Nooksack Salmon Enhancement Association, 2009).

Chum salmon and coho salmon spawn and rear in Squalicum Creek. Winter steelhead and sea-run cutthroat trout have been documented in Squalicum Creek by the City of Bellingham. The Washington State Administrative Code lists Squalicum Creek (WAC 173-201A-602) Aquatic Life Uses as *core summer habitat*. Large concentrations of wintering waterfowl are found at Toad Lake (Whatcom County, 2006).

The City of Bellingham shoreline characterization survey found that, although habitat is generally impaired throughout the creek, the potential for habitat connectivity along the entire length of the creek still exists due to undeveloped property in the creek valley and floodplain. Future restoration activities by the City are planned to secure some of these undeveloped tracts of land to improve Squalicum creek meanders by re-routing the channel around Sunset pond.

Potential Pollutant Sources

Permits

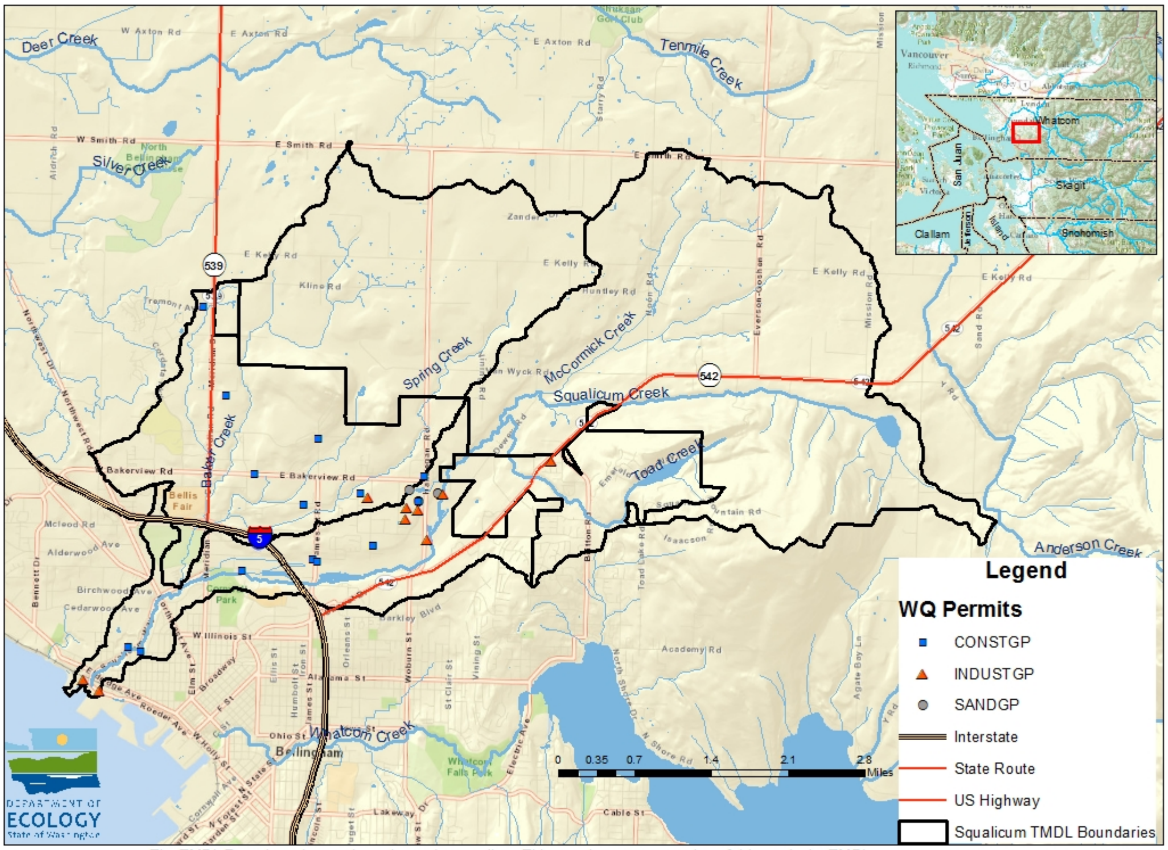
On-site septic tank use is prevalent; forestry and agricultural operations, residents and businesses throughout the watershed use individual on-site septic tanks. City of Bellingham provides sewer service to several neighborhoods and the commercial and industrial centers along the Guide Meridian. There are no direct discharges from wastewater treatment plants (WWTPs) to the creek. Several sand and gravel operations and multiple industrial operations are permitted in the watershed. Table 2 lists the permitted entities and Figure 4 shows their locations.

Table 2. Wastewater, stormwater, and other facilities with permits in the Squalicum Creek watershed.

Permit Number	Permit Holder	Permit Type
WAR005085	Strider Industrial Park	Construction SW GP
WAR125394	Razz Storage Yard	
WAR007242	Meadow Ridge Park Plat	
WAR007552	Emerald Cottages	
WAR124839	James Street Fire Flow Upgrades Phase 1 & 2	
WAR010024	H & H Properties Lot A Irongate	
WAR010743	Orchard Drive Storage	
WAR005980	Lewsader Const Country Plat Condos	
WAR004006	Irongate Storage H&H Properties	
WAR012126	Willow Spring at Squalicum	
WAR010625	Cottages at Landon	
WAR125059	Auxiliary Services Building	
WAR004469	Cowden Batch Plant	
WAR011119	Squalicum Creek Medical Arts Centre	
WAR125335	Emerald Cottages	
WAR004695	Point Whitehorn Cordata Park PL	
WAR004242	Gundies Inc	Industrial SW GP
WAR001392	Mt. Baker Products Inc	
WAR000439	UPS Bellingham	
WAR000694	MAAX US Corp	
WAR005570	WTA Maintenance Base	
WAR010593	Irongate Machine Inc	
WAR002167	Henifin Construction LLC	
WAR012122	Hunnicutts Inc	
WAR000596	Bellingham Cold Storage Roeder	
WAG503343	Cowden Batch Plant	Sand and Gravel GP
WAG507196	Granite Precasting & Concrete Inc	
WAG503261	Granite Northwest Hannegan Plant	
WAR04300A	Washington State Department of Transportation	Municipal SW
Western Washington Phase II Municipal NPDES and State Waste Discharge General Permit	City of Bellingham	
	Whatcom County	

SW = Stormwater
GP = General Permit
LLC = Limited Liability Corporation.

Whatcom County describes the upper watershed as impaired due to agricultural encroachment on the riparian zones in upper Squalicum Creek and to a lesser extent in the Baker and Spring Creek headwaters (Whatcom County, 2006). The creek is more intensely developed within the incorporated city and has numerous road crossings. Urbanization is likely a primary basis for stormwater pollution (both point and nonpoint) such as decreased forest, wetlands, and buffers, increased sedimentation and pollutants such as metals, organics, and nutrients.



The TMDL Boundary shows where the project applies. This map is a representation of this particular TMDL and does not replace the official version of the TMDL report approved by the U.S. EPA. Projects in development are subject to change before the report is finalized.

Published by the Water Quality Program
Map Print Date: 4/3/2012

Figure 4. Locations of permitted facilities within the Squalicum Creek watershed.

Baker, McCormick, and Spring Creeks become more urbanized as they approach the City of Bellingham. Toad Lake is surrounded by residential development, but returns to forest not far from the lake shore. Bellingham and surrounding suburbs in Whatcom County have stormwater treatment systems, and the city and county have municipal stormwater permits (Table 2). Even residential and urbanized areas set back from the creek require protection from stormwater effects. The Washington State Department of Transportation (WSDOT) holds a stormwater permit in the watershed and is required to manage stormwater from their jurisdictions within the City and County. WSDOT discharges are primarily associated with Interstate-5, Highway 539, Highway 542, and a maintenance facility near I-5 and Squalicum Creek.

Land Use

The City of Bellingham has developed a very extensive Geographic Information System (GIS). Included in the GIS coverage is a significant amount of data that can be used to support development of the Squalicum Creek stormwater TMDL. Some of the available GIS data layers include impervious coverages, parcels, and land use types. Roads and building outlines are shown in Figure 5, which illustrates that the impervious area is concentrated in the lower watershed. These coverages, coupled with parking areas, represent a significant amount of the impervious cover that drains to Squalicum Creek.

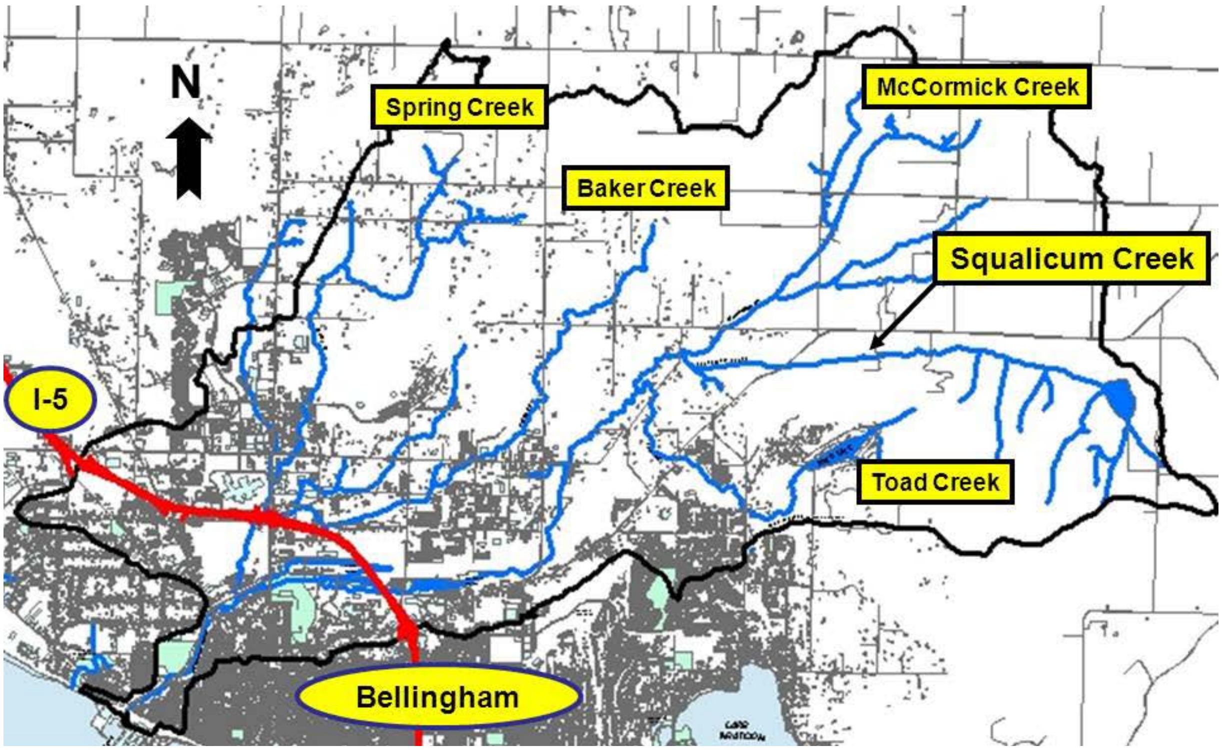


Figure 5. Land use and impervious area of Squalicum Creek sub-watersheds

In addition, the City of Bellingham has delineated Squalicum Creek into sub-watershed units that could be used to provide a refined analysis that highlights priority areas using a watershed modeling framework. Sub-watershed units are resolved in more detail in the lower watershed where greater amounts of impervious cover are found, particularly lower Spring Creek and lower Baker Creek along the Meridian corridor near the intersection with Interstate 5.

Historical Data Review

Flow

This section provides an analysis of flow information gathered to date for the area. Total runoff, for example, often represents a starting point to understand key hydrologic processes in any given drainage. Common units are cubic feet per square mile or depth of runoff expressed as inches. Watershed specific differences can reflect factors such as increased impervious cover or diversions / withdrawals, as well as the influence of groundwater, wetlands, or lakes. The percentage of total runoff, which is either base flow or surface runoff, is another metric that can be used to evaluate the potential effect of stormwater in a watershed.

The City of Bellingham maintains one flow station at West Street near the mouth of Squalicum Creek that has been recording flow data (15 minute intervals) from 2005 to present with minor interruptions *(Table 3)*. The same site was gauged by Ecology from 2003 to 2009 (data not shown) and will be used to extend the data record. The City of Bellingham also has gages on Padden, Whatcom, and Chuckanut Creeks. These data records will also be collected and compared to the Squalicum creek flows, model results and flow duration curve analyses.

USGS operates a number of gages in the Bellingham area *(Table 3 and Figure 6)*. Several have been established to evaluate inputs to Lake Whatcom. Two other gages (Fishtrap Creek and Samish River) are included to examine longer-term hydrologic patterns in the area. The *"Base"* and *"Surface"* flow percentages of annual runoff were determined using the USGS hydrograph separation method (Sloto and Crouse, 1996).

Table 3. Flow data – Squalicum Creek and other potentially useful sites.

Gage ID	Location	Area (mi.^{2})	Average Annual Flow (cfs/mi.^{2})	Annual Runoff		
				Total (in.)	Base (%)	Surface (%)
01S070	Squalicum Creek at West Street	24.7	1.351	18.3	*67%*	*33%*
12201500	Samish River near Burlington	87.8	2.789	37.9	*74%*	*26%*
12201950	Anderson Creek near Bellingham**	4.13	5.377	73.0	*82%*	*18%*
12201960	Brannian Creek near Wickersham**	3.36	3.019	41.0	*75%*	*25%*
12202300	Olsen Creek near Bellingham**	3.78	2.615	35.5	*65%*	*35%*
12202310	Carpenter Creek near Bellingham**	1.17	1.557	21.1	*71%*	*29%*
12202400	Euclid Creek at Euclid Avenue**	0.54	1.004	13.6	*69%*	*31%*
12202420	Mill Creek near Bellingham**	0.79	1.339	18.2	*75%*	*25%*
12202450	Silver Beach Creek at Maynard Pl.**	1.20	1.113	15.1	*69%*	*31%*
12212050	Fishtrap Creek at Lynden	37.8	1.910	25.9	*72%*	*28%*

** Lake Whatcom tributary monitoring gage

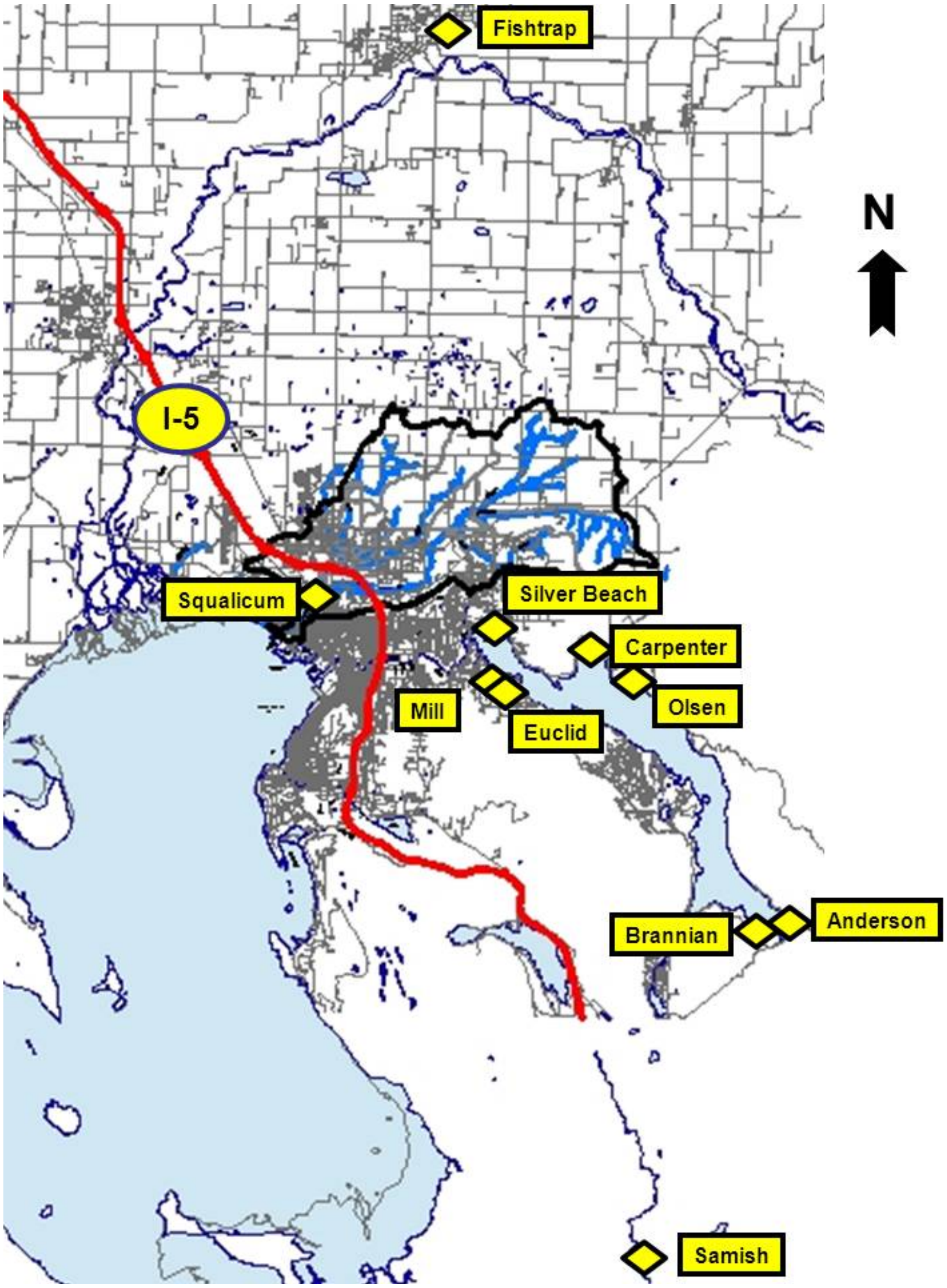


Figure 6. Location of gages used in area.

Flow duration curves are an effective method to characterize hydrologic conditions and are an important component of an overall hydrologic analysis. Duration curves provide a quantitative summary that represents the full range of flow conditions, including both magnitude and frequency of occurrence (USEPA, 2007a,b). Development of a flow duration curve is typically based on daily average stream discharge data. A typical curve runs from high flows to low flows along the x-axis.

Figure 7 depicts flow duration curves for Squalicum Creek and other local streams. These duration curves are expressed as unit area flows (i.e., cfs/sq. mi.) for direct comparison between sites. Note the flow duration interval of "40" is associated with a stream discharge of 0.9 cfs/sq. mi. (i.e., 40% of all observed stream discharge values equal or exceed 0.9 cfs/sq. mi.).

Flow duration curve intervals can be grouped into several broad categories or zones. These zones provide additional insight about conditions and patterns associated with water quality impairments where hydrology may play a major role. One common way to look at the duration curve is by dividing it into five zones: one representing *high flows (0-10%)*, another for *moist conditions (10-40%)*, one covering *mid-range flows (40-60%)*, another for *dry conditions (60-90%)*, and one representing *low flows (90-100%)*.

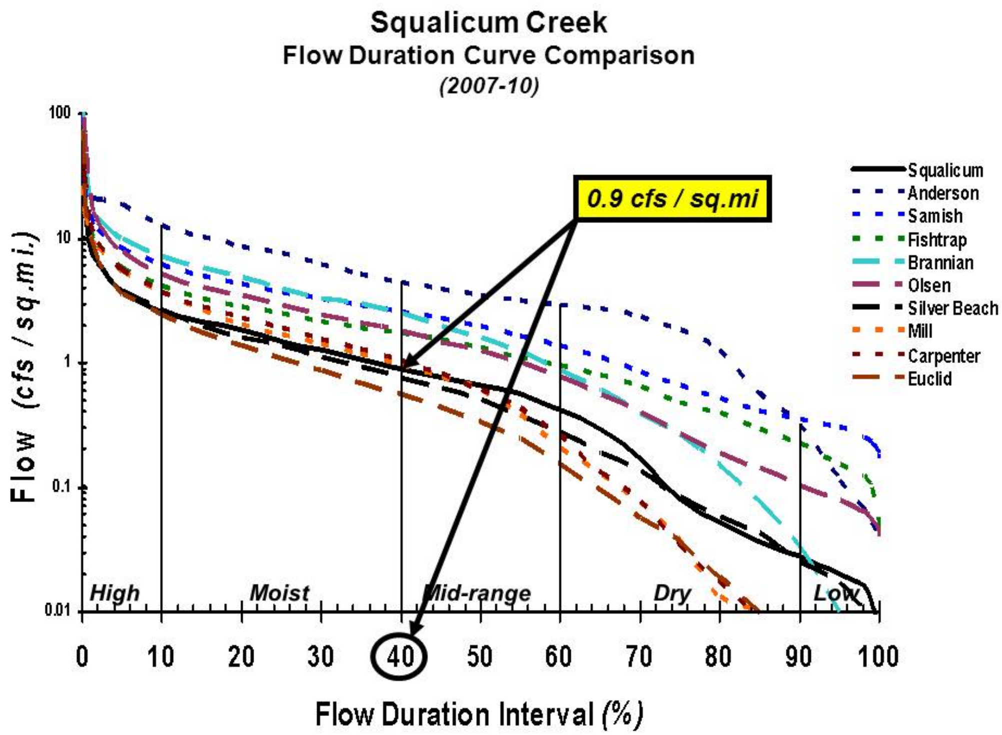


Figure 7. Flow duration curves for several USGS gages in the Bellingham area.

Figure 7 shows that the flow duration curve for Squalicum Creek generally falls within the range of all other local streams in the Bellingham area. Padden, Whatcom, and Chuckanut Creeks flow records will be added to flow duration curve analyses.

Figure 8 demonstrates how using a logarithmic scale to evaluate differences under high flow conditions for Squalicum and Fishtrap Creeks shows an increase in high flow volumes.

Nearby local creeks' flow records will be compared to the full record of Squalicum creek flows. Flashiness metrics, hydrological characteristics, and the possibility for a data record extension. For example, Fishtrap Creek has been monitored by the USGS from 1998 to the present. This would provide a greater period of record that reflects longer-term patterns. Also, Fishtrap Creek is closer in size to Squalicum Creek than other gages listed in Table 3. This minimizes the potential effect of differences in watershed size on the duration curves. Under high flow conditions, the unit area flows for Squalicum Creek are greater than those in Fishtrap Creek. This may be an indication of increased impervious cover over the primarily agricultural basin of Fishtrap Creek. Flow duration curves for Padden, Whatcom, Chuckanut, and other local creeks with gage data will be compared to the full record of Squalicum creek as part of the technical TMDL study.

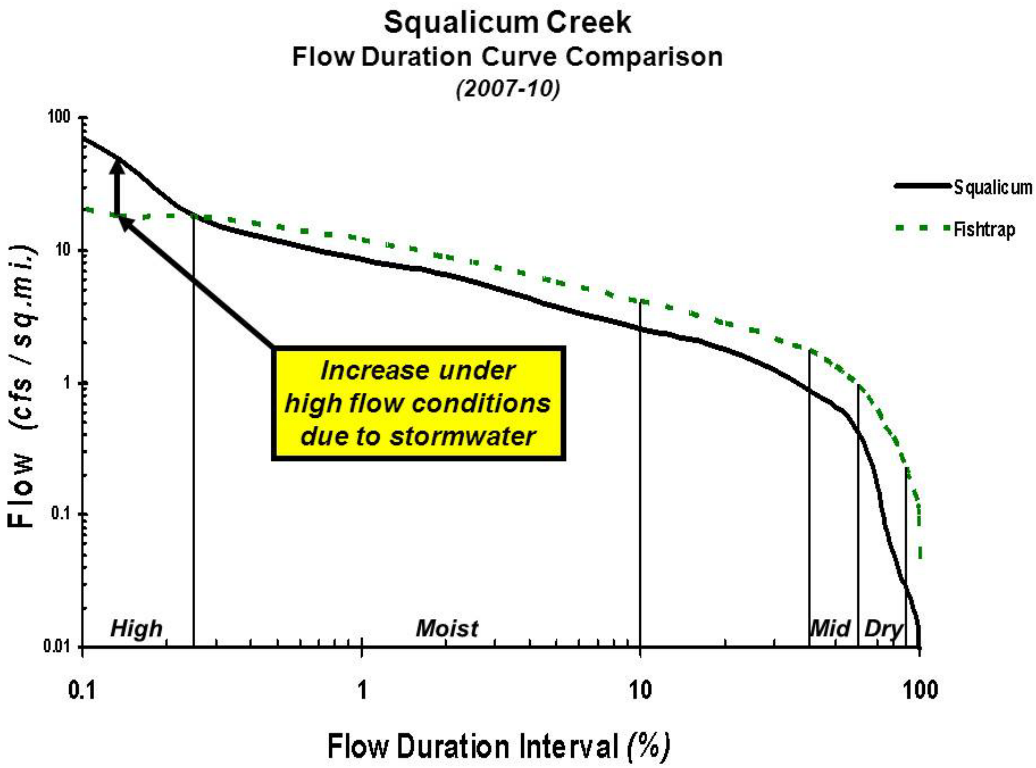


Figure 8. Flow duration curves for Squalicum Creek (log scale).

Two other metrics (T_{Qmean} and Richards – Baker Flashiness Index (Baker et al., 2004)) will be examined to understand changes in the flow regime that are often associated with urbanization (Table 4). These flow metrics have been used in Washington studies (Konrad and Booth, 2002) that focused on evaluating regional patterns and trends in flow flashiness related to changes in land cover/land use. T_{Qmean} represents the percentage of time that daily average flows exceed the annual average flow. A higher value represents hydrologic conditions that are closer to being normally distributed (generally, an indication of stable flow regimes). Conversely, lower T_{Qmean} values are typically associated with watersheds that may subjected to rapid changes. T_{Qmean} has been used to detect trends in flow flashiness related to basin urbanization in the Puget Lowland (Konrad and Booth, 2002).

R-B Flashiness is an indicator of the frequency and rapidity of short-term changes in stream flow. Higher scores represent flashier systems. It is often a function of watershed size and the usefulness of the metric for larger watersheds is diminished. Reasons for differences in these two flashiness metrics shown in Table 4 will be considered in the TMDL development process for Squalicum Creek.

Table 4. Metric comparison of Squalicum Creek to several USGS gages in the area.

Gage ID	Location	Area (mi.^{2})	Flow (cfs/mi.^{2})		Metric Comparison	
			Median	Average	T_{Qmean}	R-B Flashiness
01S070	Squalicum Creek	24.7	0.628	1.351	*30.1*	*0.408*
12201500	Samish River near Burlington	87.8	1.925	2.789	*35.9*	*0.203*
12201950	Anderson Creek near Bellingham	4.13	3.390	5.377	*32.8*	*0.209*
12201960	Brannian Creek near Wickersham	3.36	1.577	3.019	*32.7*	*0.300*
12202300	Olsen Creek near Bellingham	3.78	1.217	2.615	*27.7*	*0.438*
12202310	Carpenter Creek near Bellingham	1.17	0.607	1.557	*29.3*	*0.377*
12202400	Euclid Creek at Euclid Avenue	0.54	0.333	1.004	*26.4*	*0.495*
12202420	Mill Creek near Bellingham	0.79	0.595	1.339	*31.1*	*0.340*
12202450	Silver Beach Creek at Maynard Pl.	1.20	0.500	1.113	*29.1*	*0.425*
12212050	Fishtrap Creek at Lynden	37.8	1.323	1.910	*34.8*	*0.230*

Flow characteristics, substrate size, water and sediment chemistry, and a host of other factors influence the benthic community. "*Flashy*" flows tend to disrupt aquatic community structure in a number of ways. DeGasperi et al. (2009) found in King County that eight hydrologic metrics that were significantly correlated with benthic macroinvertebrate scores (Low Pulse Count and Duration; High Pulse Count, Duration, and Range; Flow Reversals, T_{Qmean}, and R-B Index). "Clinger" type benthic macroinvertebrates can tolerate high flows and more pollution tolerant organisms, such as worms, can become more established as they can burrow into the substrate. Smaller substrate particle sizes are often found to contain larger pollutant concentrations than larger gravelly substrates. Less pollution-tolerant organisms, such as EPT (mayflies, stoneflies, caddisflies), are typically "*washed out*" from increased stream velocities and flow volumes.

Characteristics associated with stormwater impacts (pollution or hydrologic) will be examined more carefully for contribution to reducing the more intolerant, "pollution-sensitive" taxa and for promoting the more "opportunistic" benthic taxa. Hydrologic conditions can be characterized by primary factors in select stream reaches:

1. Higher gradients (>5%) = high water velocity
2. Moderate gradients (>2 and <5%) = flood with moderate fine sediment deposition
3. Low gradient (<2%) = (flood/ebb), high sedimentation rates; dominated by fine substrate

High gradient streams would normally be associated with larger substrate sizes so the primary impact to intolerant organisms would be flashiness accompanied by high water velocity. Moderate gradient streams would normally be associated with flooding and some fine sediment deposition (interstitial spaces of existing coarse substrate would begin to fill) and patchiness of substrate type (habitat type) would increase. Low gradient streams would normally be dominated by more fine sediment, but the primary impact from stormwater would be shifting shallow substrate and pollutants (e.g., metals, organics) concentrated in portions of the low-gradient habitat. Ultimately, a matrix of condition expectations can be constructed and expected changes to community type can be predicted.

Benthic Macroinvertebrates

Benthic macroinvertebrates (BMI) are widely used to determine biological condition of streams. Because they are relatively stationary and subject to pollution and altered flow regimes, macroinvertebrate communities integrate the effects of stressors over time (i.e., pollution-tolerant species will survive in degraded conditions, and pollution-intolerant species will die). These communities are also critically important to fish and higher trophic animals as food sources.

BMI data for Squalicum Creek and tributaries comes from several sources. Ecology sampled a station near the mouth of Squalicum Creek (station 121) just once in 1996 as part of the ambient monitoring program (Ecology, 2012). A screening survey was conducted on Squalicum Creek in October 2000, 2002, and 2010 by the City of Bellingham (personal communication with Renee LaCroix, 2011). The October 2000 samples were collected by the Nooksack Salmon Enhancement Association, from four sites in Squalicum Creek and one site in Baker Creek. See Table 5 and Figure 9 (Nooksack Salmon Enhancement Association, 2002).

Table 5. Squalicum Creek – October 2000 macroinvertebrate summary.

(Nooksack Salmon Enhancement Association, 2002, unpublished notes)

Site ID	Location	Notes
1	Squalicum Creek at Highway 542	Highest population (399 organisms; 20 families). Stoneflies were dominant (34%), followed by mayflies (23.6%) and caddisflies (10%).
2	Squalicum Creek below I-5 (Bug Lake)	Relatively sparse population (58 organisms; 11 families). Dominated by scuds, along with a few aquatic worms and fingernail clams.
B	Squalicum Creek below Meridian	High population with lower diversity (501 organisms; 14 families). Dominated by scuds (41.9%), followed by broadback stoneflies (22.6%). Small minnow mayflies, common netspinner caddisflies, and aquatic earthworms also present in considerable numbers.
C	Baker Creek	Moderate population present (308 organisms; 15 families). Dominated by scuds (52.9%), followed by small minnow mayflies (19.8%) and leeches.
D	Squalicum Creek below Baker Creek	No information presented in summary report.

In 2002 and 2003, the City of Bellingham collected additional benthic macroinvertebrate samples from three sites in Squalicum Creek and one site in Baker Creek, a tributary to Squalicum Creek. A detailed analysis of this information was conducted by Western Washington University (Vandersypen et al., 2006). A brief summary of quantitative results from this assessment report are presented in Table 6.

Although the uppermost Squalicum Creek site had slightly better macroinvertebrate indices, all sites contained low numbers of sensitive organisms and were dominated by pollution-tolerant taxa, including amphipods, chironomids, and worms. Pollution-tolerant mayflies *(Baetis tricaudatus)* were also observed in higher numbers than normally expected.

Table 6. Squalicum Creek – 2002-03 macroinvertebrate summary.

(Vandersypen et al., 2006)

General Group	**Site A** WWU-HEC*	**Site B** above Baker Cr	**Site C** Baker Cr	**Site D** below Baker Cr
Ephemeroptera (mayflies)	0%	9%	8%	12%
Plecoptera (stoneflies)	6%	2%	0%	1%
Trichoptera (caddisflies)	0%	1%	1%	3%
EPT (total)	7%	12%	9%	16%
Amphipoda (scuds)	8%	64%	60%	38%
Oligochaeta (worms)	4%	2%	16%	9%
Diptera (true flies)	57%	19%	8%	31%
Gastropoda (snails, limpets)	1%	1%	5%	1%

* WWU-HEC = Western Washington University's Hannegan Environmental Center.

In 2011, the City monitored for benthic macroinvertebrates in the Squalicum Creek watershed at Irongate Rd. This most recent sampling and data will be used in the TMDL study (not shown). Figure 9 shows all sites historically monitored by the City.

In terms of data needs, the existing information provides a good starting point. However, to be able to identify stressors and develop TMDL targets, additional benthic macroinvertebrate data is needed. Particularly data from reaches that represent land uses and reaches that are both impacted and un-impacted by stormwater sources. Un-impacted sites will serve as "reference locations". USEPA supports additional benthic monitoring for this TMDL. A separate QAPP will be developed by USEPA's contractor for monitoring to support use of the RIVPACS model for Western Washington and diagnostic use of USEPA's Stressor Identification program.

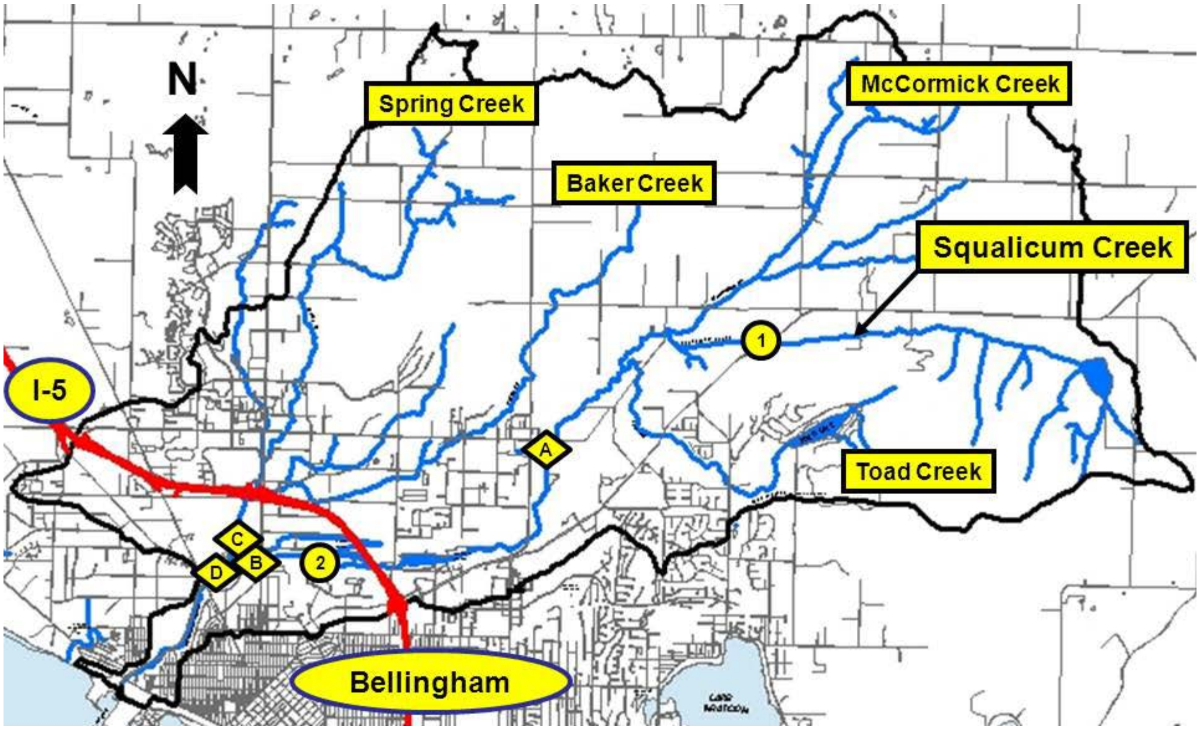


Figure 9. Location of Squalicum bioassessment sites.

Water Quality

The City of Bellingham Urban Streams Monitoring Program has developed the most extensive water quality data set for Squalicum Creek. This program has conducted monthly monitoring at four stations in the watershed that has conducted monthly monitoring from 2002 to 2012 for conventional water quality parameters. There are also monthly data from 1990 to 2001 from these four stations with some minor interruptions. In 2010 the City of Bellingham conducted additional monitoring in the Squalicum Creek basin from May 1 to October 1. The Meridian and Mouth sites were sampled weekly for fecal coliform. In addition, an in-situ sonde (temperature, dissolved oxygen) was placed at the Meridian site to log data at 15-minute intervals.

The Lummi Nation has conducted random grab sampling in the Squalicum Creek watershed.

Ecology conducted a toxics screening study between November 2002 and June 2003 in the Squalicum Creek watershed (Anderson and Roose, 2004). Water and sediment from both the creek and stormwater catch basins were monitored for a wide variety of conventional parameters, metals, and organic pollutants. Metals, pesticides, and semi-volatile organic compounds were found to be exceeding state criteria. The study identified stormwater as a transport mechanism for toxics. By focusing on wet weather events, the study isolated areas of the watershed to target source control efforts for cleanup. Study recommendations highlighted the need for education and source control in the urbanized lower portion of the watershed, specifically land uses around the Meridian and Irongate areas (Anderson and Roose, 2004).

Existing monitoring studies, stations, timeframe, and the responsible agency are described in Table 7.

Table 7. Water quality data – Squalicum Creek and other potentially useful sites.

Sites	Location	Agency	Period of Record
4 Sites	Squalicum Cr - at East Bakerview Squalicum Cr - at Meridian Baker Cr - at Squalicum Parkway Squalicum Cr - above mouth	City of Bellingham, Urban Streams Monitoring Program	2002-2012, Monthly 1990-2001, Intermittent Pre-2001
16 Sites	Throughout Squalicum Cr watershed	Lummi Nation (LUMMINSN)	2007-2008, random dates
7 Sites	Seven sites along Squalicum Cr (SQ1-SQ7)	Ecology's Squalicum Creek Toxics Study (Anderson and Roose, 2004)	2002-2003, 3 sampling events

One method to evaluate water quality data is through the use of water quality duration curves, where a water quality parameter concentration is plotted against the cumulative exceedance value of the flow at the time of sampling. The primary benefit of water quality duration curves in this Stormwater TMDL development is to provide insight regarding patterns associated with hydrology and water quality concerns. The duration curve approach is applicable because water quality is often a function of stream flow.

For instance, turbidity or DO concentrations may increase with rising flows as a result of turbulence, higher velocities, and/or channel scour. Loads of pollutants (e.g., fecal coliforms, metals, toxics) will be plotted and the pattern of exceedances may show a strong high flow association. The use of duration curves in water quality assessment creates a framework that enables data to be characterized by flow conditions. The method provides a visual display of the relationship between stream flow and water quality. This concept is illustrated by using turbidity data collected at the City of Bellingham's fixed station monitoring sites (A, B, C, and D) as identified in Tables 5 and 6.

Figures 10 - 13 illustrate that turbidity concentrations are the greatest under high flow conditions at each site. The display also shows that the highest levels are generally associated with runoff events (as indicated by the shaded diamonds). These events are days when surface runoff constitutes more than half of the daily average flow, as determined through hydrograph separation.

Washington State water quality standards provide a frame of reference for examining turbidity data patterns [WAC-173-201A-200(1)(e)]. Specifically, the standard for applicable aquatic life criteria for core summer salmonid habitat states:

Turbidity shall not exceed:

- *5 NTU over background when the background is 50 NTU or less; or*
- *A 10 percent increase in turbidity when the background turbidity is more than 50 NTU.*

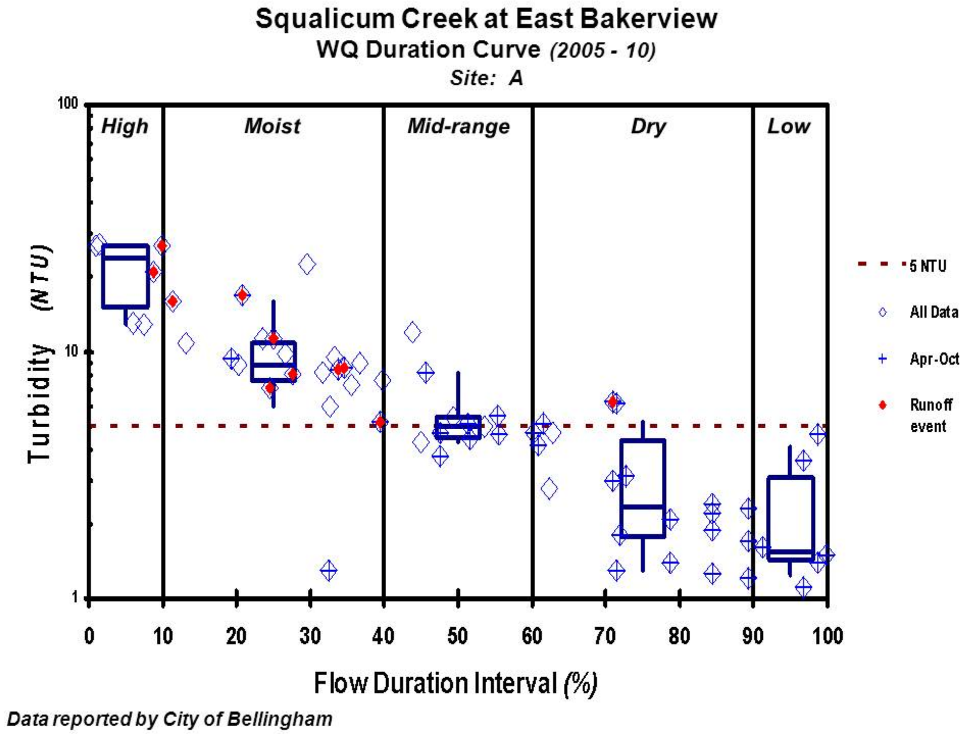


Figure 10. Relationship between flow and turbidity -- Squalicum Creek at East Bakerview.

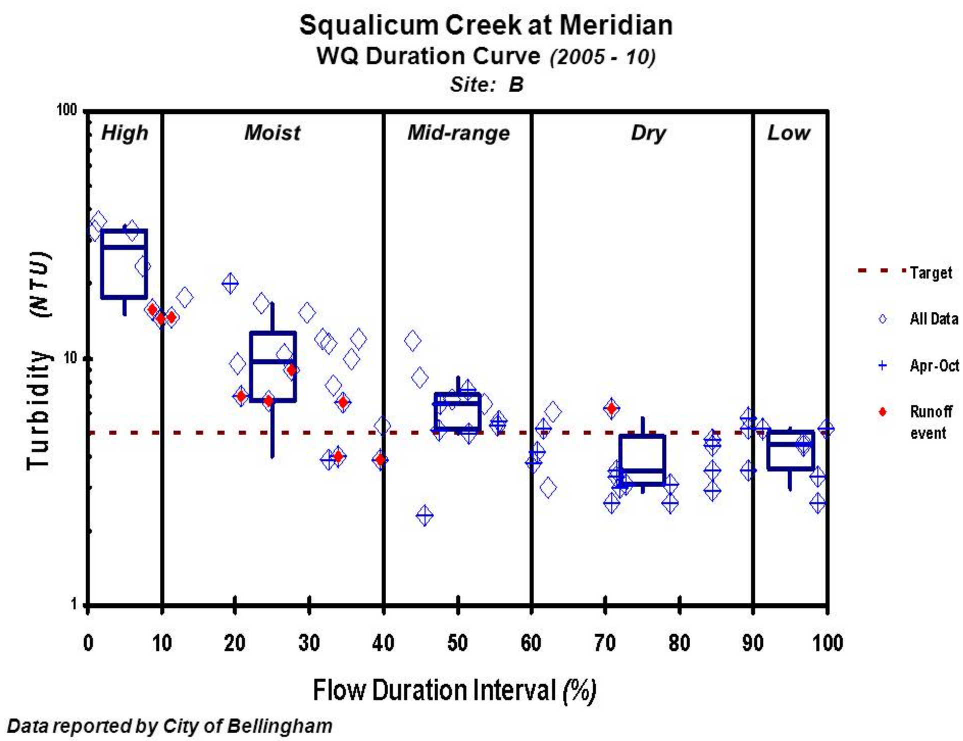


Figure 11. Relationship between flow and turbidity -- Squalicum Creek at Meridian.

Figures 10 and 11 show the same patterns: higher turbidity measurements are generally associated with higher flow conditions in Squalicum Creek at the Meridian monitoring site. One interesting observation is that turbidity levels in the *moist* zone associated with storm events tend to be lower (Figure 11) for Squalicum at Meridian. This site is located below two ponds: Heron Pond and Sunset Pond. These ponds act as settling basins, which could provide a partial explanation to this observation. Table 8 summarizes median turbidity values at each station.

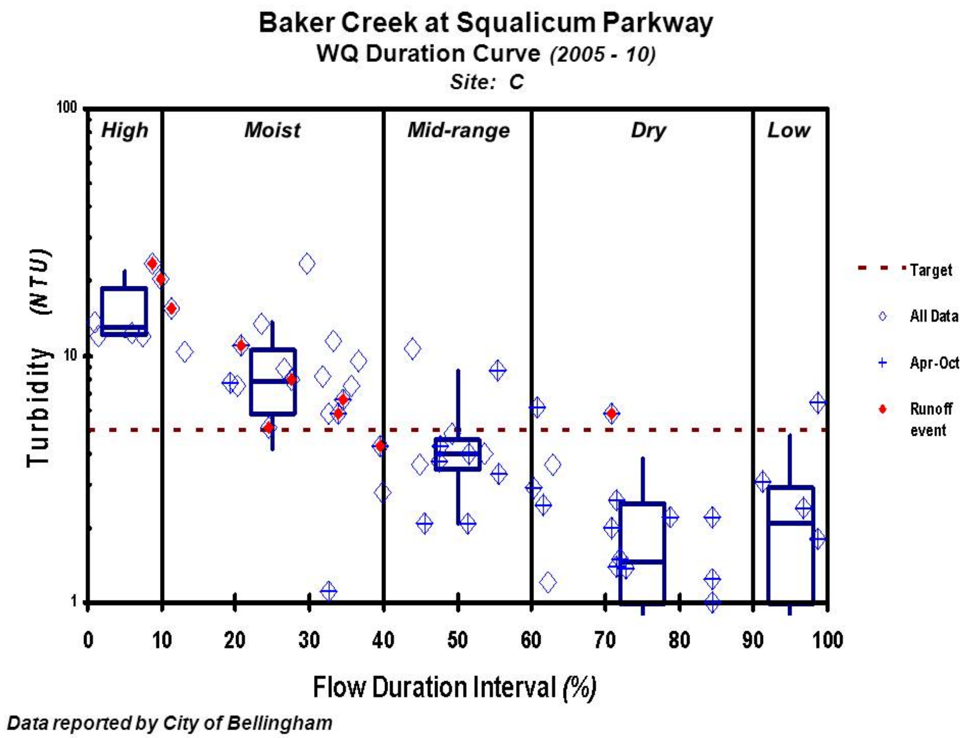


Figure 12. Relationship between flow and turbidity -- Baker Creek at Squalicum Parkway.

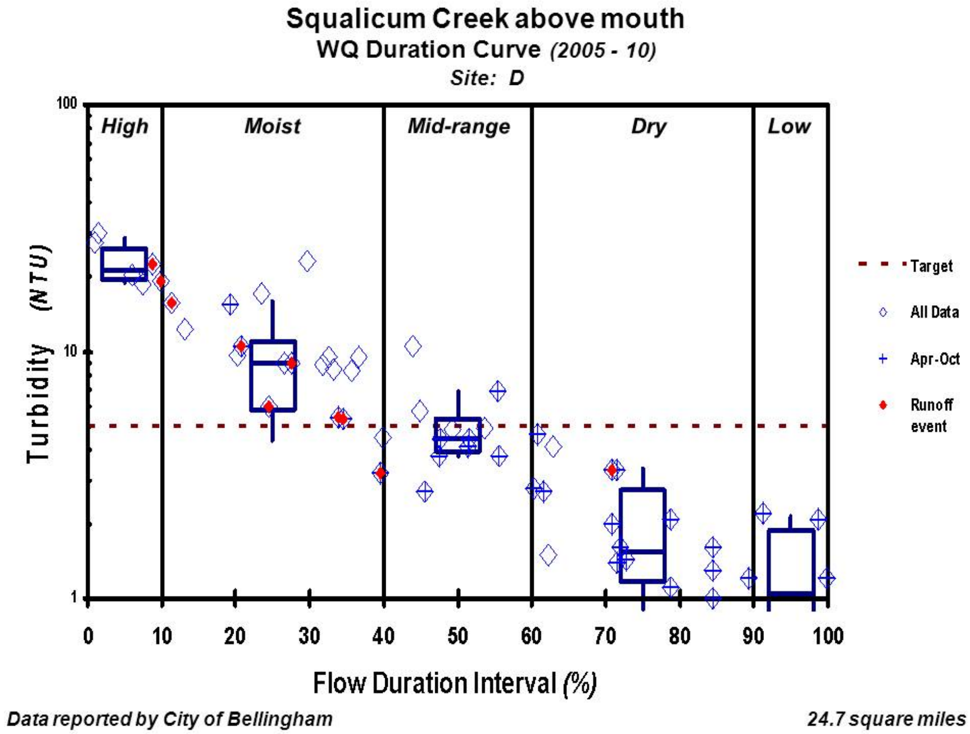


Figure 13. Relationship between flow and turbidity -- Squalicum Creek above mouth.

Another pattern of interest is that a *baseflow* zone of turbidity can be seen for low and dry conditions. Then turbidity rises in the mid-range and moist zones, likely reflecting runoff and re-suspension processes. In the high zone turbidity jumps again, likely reflecting additional contributions of sediment from bank and bed erosion processes.

Table 8. Water quality duration curve summary for turbidity.

Location	Median Turbidity (NTU) Duration Curve Zone				
	High	Moist	Mid	Dry	Low
Squalicum Creek at East Bakerview	23.9	8.8	5.0	2.4	1.6
Squalicum Creek at Meridian	28.2	9.7	6.5	3.5	4.5
Baker Creek at Squalicum Parkway	13.0	7.9	4.0	1.5	2.1
Squalicum Creek at mouth	19.9	9.5	4.5	1.7	1.2

Goals and Objectives

Project Goals

This Stormwater Pilot TMDL will be developed using a weight of evidence approach (multiple lines of evidence) because stormwater delivers both pollutant loads and non-pollutant impacts to receiving waters. This TMDL is a pilot project to explore how to identify *surrogates* that best describe stormwater pollution and impacts to water quality and aquatic life.

The ultimate objective is to ensure that Squalicum Creek and its tributaries attain Washington State narrative aquatic life beneficial uses and numeric water quality standards for fecal coliform and dissolved oxygen. Squalicum Creek discharges directly to the eastern side of Bellingham Bay; therefore, the beneficial uses of the bay will also be considered in this Squalicum Creek study.

The goal of the proposed study is to provide the best estimate of the total maximum daily load of pollutants or surrogates that are protective of water quality and aquatic life. This will consist of evaluating the relationships between changes in the landscape, hydrologic regime of the creek, water quality, and benthic macroinvertebrate health.

Study Objectives

Objectives of the TMDL study are as follows:

- Build the continuous simulation hydrology model (LSPC) for Squalicum Creek so that flows at higher points in the watershed and sub-watershed can be evaluated.
- Characterize existing data on fecal coliform and dissolved oxygen concentrations and determine the critical period. Evaluate if this Stormwater Pilot TMDL will be able to address these listings and to what capacity.
  - For fecal coliforms build load duration curves for all major tributaries, point sources, and drainages into Squalicum and Baker Creeks.
  - Calculate percent reductions and establish fecal coliform load and wasteload allocations.
  - Identify relative contributions of fecal coliform loading to Squalicum and Baker Creeks based on source areas so that cleanup activities can focus on the largest sources.
- Utilize results from the benthic macroinvertebrate stressor identification report (separate report yet to be developed) to chart impaired biology reaches.
- Statistically evaluate the relationships between:
  - Pollutant concentrations and stormwater flows
  - Land use, impervious cover, and flow metrics
  - Land use, impervious cover, and pollutant loads
  - BMI metrics and flow metrics
  - BMI metrics and pollutant concentrations

- Determine the suitable and appropriate surrogate measures for TMDL development.
- Develop appropriate targets for pollutants and surrogate measures.
- Establish allocations for land uses and sources, including nonpoint sources to meet water quality standards and protect beneficial uses.
- Use the LSPC model to evaluate future water quality management alternatives for the Squalicum Creek watershed.

Study Design

Watershed Characterization and Source Assessment

The study covered under this QAPP will work entirely with secondary data available at the time of the study, with the exception of macroinvertebrate data. This project will involve collection, evaluation, and analysis of existing data. Evaluation of secondary data will be conducted based on USEPA guidance documents USEPA QA/G-5, USEPA QA/G-9R and USEPA QA/G-9S (USEPA, 2002 and 2006a,b) and as described in the *Quality Objectives for Existing Data and Modeling* section of this QAPP.

Data from an additional primary data collection effort, July 2012, to support the benthic macroinvertebrate assessment and stressor identification work for this Stormwater Pilot TMDL is covered by a separate QAPP (Tetra Tech, Inc., 2012). Under the macroinvertebrate QAPP, monitoring and data reporting will be done for 6 additional sites on Squalicum and Baker Creeks by EPA's contractor Tetra Tech, Inc. The results from this additional data collection effort will be incorporated in the Stormwater Pilot TMDL Report as described in this QAPP.

The Stormwater Pilot TMDL will provide information and documentation sufficient to support the watershed characterization, identify pollutants of concern, describe applicable water quality standards, and define the numeric water quality target elements of a TMDL. This task will also identify all potential sources at the watershed scale, as well as provide quantitative source load estimates for significant sources within the Squalicum Creek watershed and tributaries at the sub-watershed scale.

Target Development

This TMDL will explore two distinct approaches to quantifying stormwater pollution and impacts in Squalicum Creek. Using each approach alone may be insufficient for the TMDL study design; therefore, the two approaches used together will likely support a weight of evidence TMDL.

The first approach, called the *Hydrology-based Reference Site Approach*, is to use hydrologic metrics that relate water quality, storm flows, and the landscape condition. The second approach is called the *Biological Reference Site Approach* and uses the benthic macroinvertebrates, periphyton, water quality, and aquatic life health models. Established local relationships such as flow metrics and benthic macroinvertebrate scores will be used to pull the two approaches together. Utility of additional surrogates such as impervious area, percent forest conversion, or a landscape development index may be explored.

Hydrology-based Reference Site Approach

The hydrology-based reference site approach employs a continuous simulation flow model to simulate flows for the sub-basins and upper watershed. At a minimum the mouth of each tributary and five stations in the mainstem will be selected for flow duration curve analysis. The mainstem stations will be co-located with the benthic monitoring sites planned for the summer of 2012. The model and flow duration framework will be used to understand the hydrology for each of the tributaries and mainstem stations. Water quality criteria for fecal coliforms and DO (and other parameters if found to be stressors for the benthic macroinvertebrates) will be used to develop loading capacities that extend across the full range of flow conditions.

This approach builds on the use of flow duration curves, which are based on hydrologic data that describe the cumulative frequency of historic flow data over a specified period. A water quality criterion or other target concentration can then be multiplied by observed flow duration intervals to create a curve that represents the distribution of allowable loads as a function of daily flow (i.e., the loading capacity of the stream). Thus, the entire curve represents flow-variable loading capacities. Allowable loads are identified for specified flow intervals, which can be used as a general indicator of hydrologic condition (e.g., wet versus dry and to what degree).

Steps needed to apply the hydrology-based reference site approach to Squalicum Creek include:

- Collect and analyze additional flow and water quality data for the Squalicum Creek watershed (including 2011-12 data from the City of Bellingham, as well as modeled flow data for tributaries and upper Squalicum Creeks)
- Conduct detailed evaluation of available flow and water quality information
- Select appropriate indicator(s) and reference site(s)
- Identify target values
- Determine degree of impairment, as well as critical conditions and location(s)
- Document linkage analysis (connect target to sources and water quality response)
- Develop TMDL components (loading capacity, waste load allocations, load allocation, margin of safety

Rainfall and Runoff

The underlying premise behind the hydrologic-based approach using a duration curve framework is to determine the rainfall and runoff patterns that should occur at a given site prior to degradation. This task involves an expanded, detailed analysis of information collected by the City of Bellingham (e.g., flow and rainfall) as well as other data if available from sources such as Western Washington University, Whatcom County, Lummi Nation, and information used to support development of the Lake Whatcom TMDL.

Select Appropriate Indicator(s) and Reference Site(s)

These examples are simply to highlight factors that must be considered in reviewing other potential sites. This task is designed to conduct similar analyses using other available data in the Bellingham area (e.g., information collected on tributary streams to Lake Whatcom). Again, the intent is to locate good reference sites that could be used to develop hydrology-based targets for Squalicum Creek.

Potential indicators related to flow include key points on the duration curve, such as the flow or volume associated with the 1-day recurrence interval (i.e., the 1-day divided by 365 days or the 0.274 percentile). This was used in the Potash Brook, VT stormwater TMDL because it connects to a daily maximum value. Other potential flow-related indicators include T_{Qmean}, Richards – Baker Flashiness Index, and two flow metrics used by King County, High Pulse Count and High Pulse Range *(*Cassin et al., 2005).

A comparison of Squalicum Creek flow data with stream discharge information for Fishtrap Creek will allow flow records to be extended. Fishtrap Creek has been monitored by the USGS from 1998 to the present, providing a greater period of record that reflects longer-term patterns. Fishtrap Creek is also closer in size to Squalicum Creek than other gages examined. A regression analysis, depicted in Figure 14, was used to examine the validity of pursuing a relationship between the two sites. This graph shows a fairly reasonable correlation between flows in Squalicum and Fishtrap Creeks.

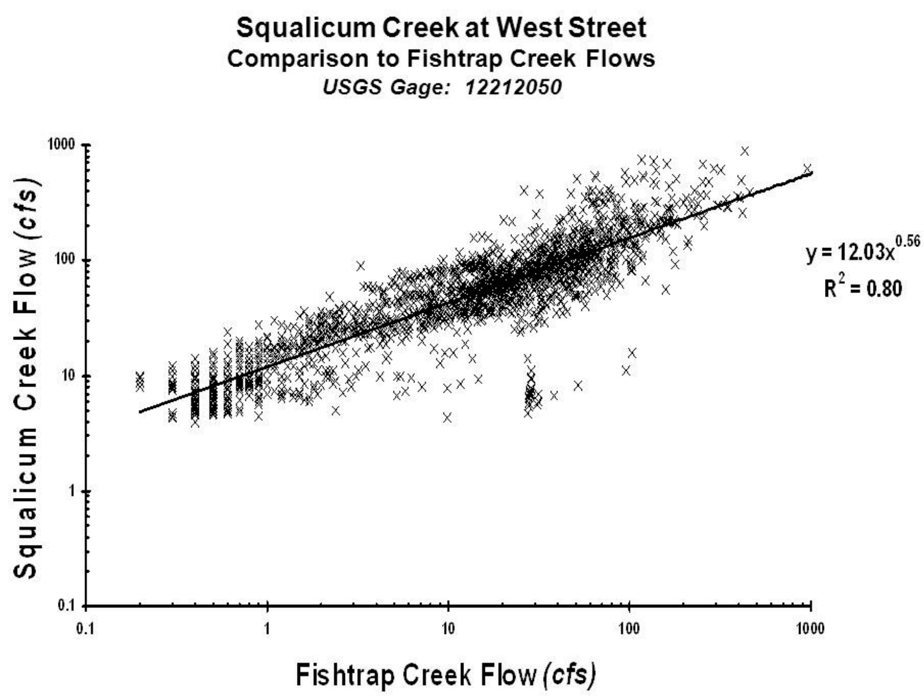


Figure 14. Correlation between Squalicum and Fishtrap Creek flow data.

This method is generally more appropriate when the shape of the unit area duration curves is similar. Figure 15 shows that the two curves are noticeably different. The validity of this method is further tested by comparing water quality patterns using both the *pre-extended* and the extended flow record. This is illustrated in Figure 16.

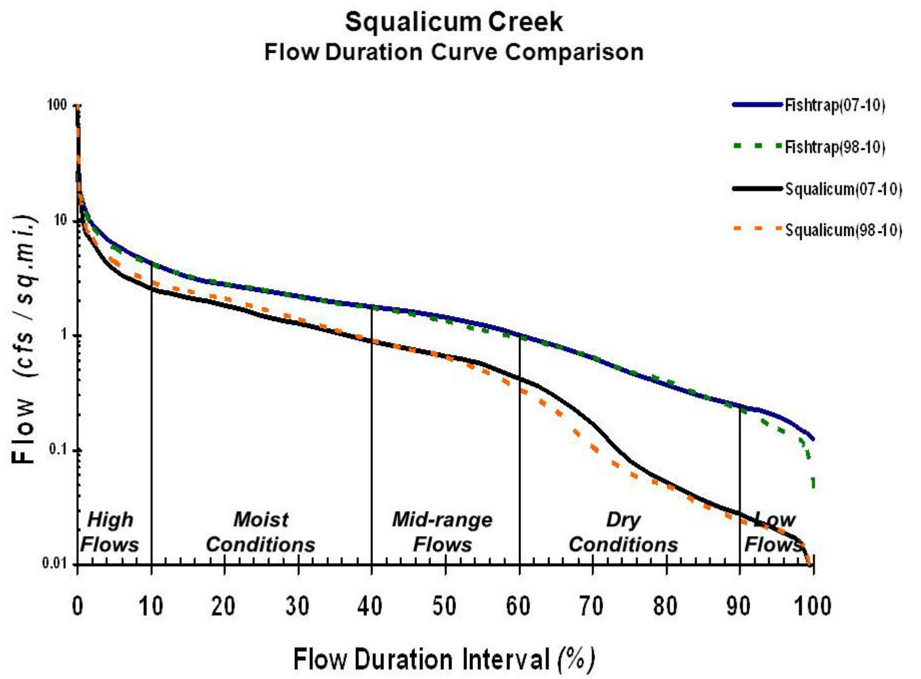


Figure 15. Flow duration curve comparison for Squalicum and Fishtrap Creeks.

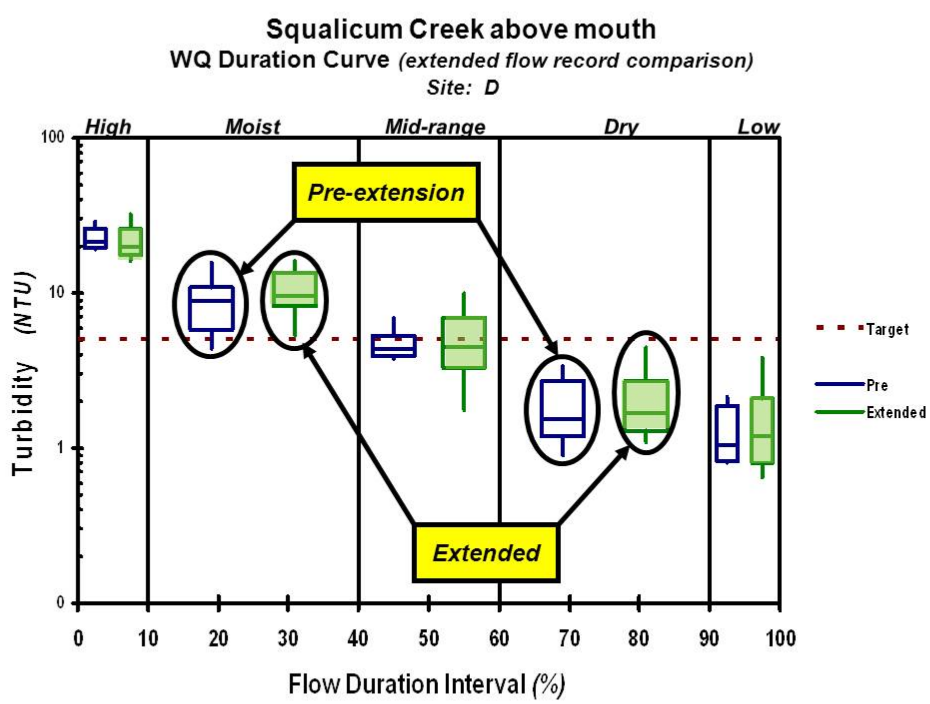


Figure 16. Squalicum Creek turbidity pattern comparison using extended flow record.

Hydrologic Model

In 2007 Clear Creek Solutions, Inc. developed a comprehensive stormwater plan which included building a version 3 Western Washington Hydrology Model (WWHM3) for six Bellingham watersheds. WWHM3, originally developed for Ecology, uses USEPA Hydrologic Simulation Program Fortran (HSPF) as its computational engine to compute stormwater runoff. WWHM3's HSPF hydrology parameter values are based on regional watershed calibrations performed by the USGS. The City of Bellingham Central Shop hourly precipitation records were used.

Runoff was then routed using HSPF's RCHRES algorithms and/or SWMM's Transport algorithms. Basins, sub-basins, and their boundaries in each watershed study area were checked and revised, as needed, using the City of Bellingham's GIS data. GIS stormwater conveyance system data were used to model the stormwater pipe systems (Clear Creek Solutions, 2007). As part of the WWHM model development two of the City of Bellingham's watersheds, Silver Beach Creek and Whatcom Creek, were calibrated to determine appropriate HSPF parameter values that best represented the hydrology of the city's watersheds. The hydrologic and hydraulic modeling for the current City of Bellingham Comprehensive Stormwater Plan was based on continuous simulation methodology used in the WWHM3 model. Critical locations in each basin were identified by comparing existing facility capacity with generated stormwater flows.

This Stormwater Pilot TMDL will build off of the existing WWHM3 model and create a distinct model for Squalicum Creek watershed using the LSPC model (USEPA, 2003a). Both the WWHM3 and LSPC models use continuous simulations of water balance and pollutant generation, transformation, and transport based on HSPF. LSPC is a component of the EPA's TMDL Modeling Toolbox, which has been developed through a joint effort between USEPA and Tetra Tech, Inc. (USEPA, 2003b).

Pollutants that influence water quality are often derived from the land surface. A modeling system may be utilized to simulate land-use based sources of pollutants and the hydrologic and hydraulic processes that affect delivery. Understanding and modeling of these processes provides the necessary decision support for TMDL development and allocation of loads to sources. The Squalicum Creek watershed LSPC model will be used to simulate water quantity and quality for a wide range of pollutants from the Squalicum Creek watershed. Time series of the runoff flow rate, sediment yield, and user-specified pollutant concentrations can be generated at any point in the watershed. The model has been used extensively in other studies for both screening level and detailed analyses. The model will be used to develop flows for the tributaries and upper drainage area of Squalicum Creek.

Figure 17 shows that flow rates are relatively low coming out of the summer months (typical for the Pacific Northwest). The onset of fall storms shows an increase in the base flow that carries through the remainder of fall and into winter. This highlights the importance of using a model that adequately accounts for subsurface processes. Use of the LSPC model provides flexibility in simulating subsurface interactions through storage and infiltration variables.

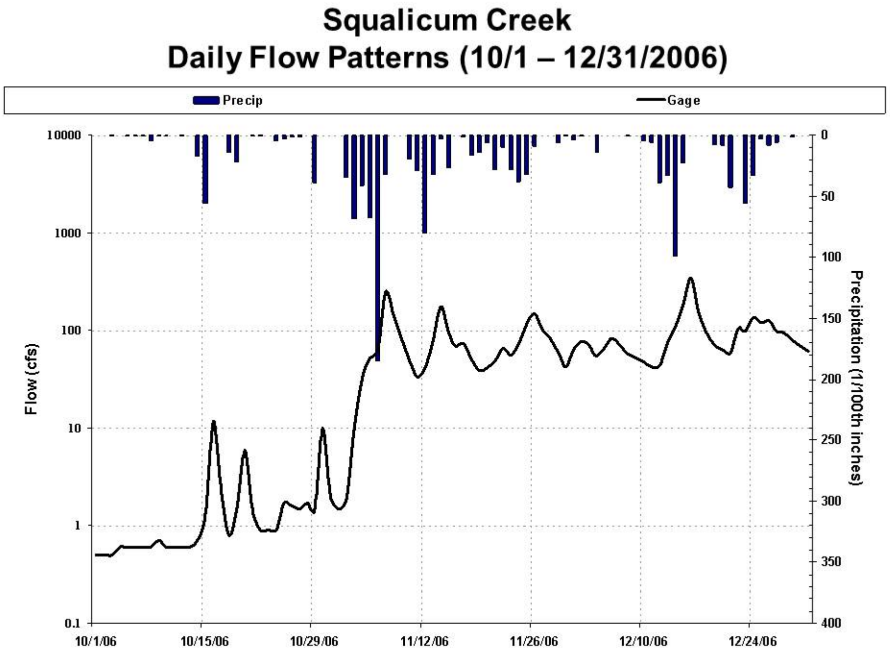


Figure 17. Squalicum Creek temporal rainfall and flow patterns.

The range of land use patterns in the Squalicum Creek drainage will be represented by the model. The lower part of the watershed is developed as residential, commercial, and industrial whereas the upper watershed has large tracts of forest, light residential, or pasture. LSPC offers a GIS interface and flexibility to represent the diverse land use patterns in Squalicum Creek.

Estimate Degree of Impairment

Hydrologic flows over time and from nearby streams will be used to gain an understanding of the degree of hydrologic alteration. Information from "reference" sites will be used to identify targets that will protect aquatic life uses. This task is dependent on indicator or flow metrics selected to best describe Squalicum and Baker Creeks' impairments. For example, if a duration curve is used, reduction targets could be used (similar to Potash Brook, VT), as illustrated in Figure 18. Factors to also consider include adequate information on other parameters for reference sites used (either bioassessment or water quality data). For example, a hypothetical example of this concept related to sediment is shown in Figure 19, which shows the corresponding total suspended solids loading of the hypothetical impaired and attainment flow scenarios. Target development will be explored using duration curves (Figure 18) or rating curves (Figure 19).

An emphasis on hydrology and LID is consistent with the National Research Council stormwater study (2008) that encourages a focus towards controlling stormwater volume. The National Research Council study states that efforts to reduce stormwater volume will also achieve reductions in pollutant loading. A watershed model approach would emphasize hydrologic or volume-based targets.

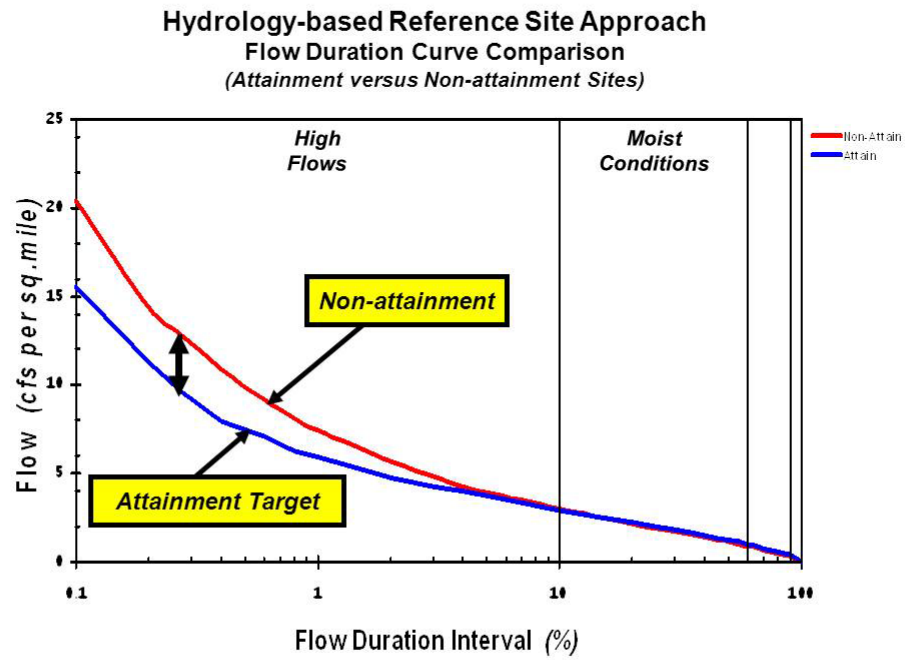


Figure 18. TMDL target development using flow duration curve.

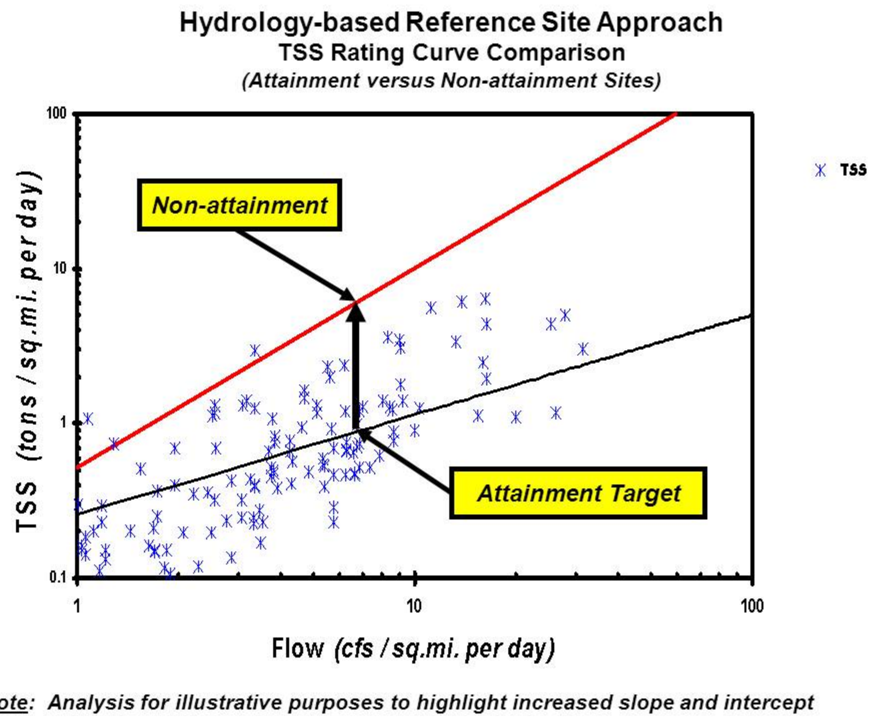


Figure 19. Example TSS rating curves for attainment and non-attainment streams.

The strength of a watershed modeling approach relative to target setting is the ability to examine pre- and post-development hydrology and water quality, as shown by the example in Figure 20. This provides a connection to Stormwater Management Programs (SWMPs) developed under the MS4 NPDES program. In particular, the low impact development requirements proposed in Ecology's draft municipal stormwater permits are part of the adaptive process to improve stormwater management and protect surface waters from degradation.

Biological Reference Site Approach

The second approach is called the *Biological Reference Site Approach*. An advantage of using bioassessment information is the ability to examine metric and taxonomic signals to identify key potential stressors (e.g., sediment deposition, metals contamination, hydrologic alteration, habitat degradation, thermal stress). Macroinvertebrate assemblage attributes will be evaluated for evidence of water quality and/or habitat integrity problems. Recent work conducted for the City of Bellevue provides a good starting framework. The focus of that effort was to consider assemblage attributes individually so information is not maximized by relying on a single cumulative score, which may mask stress on the biota (Rhithron Associates, 2009).

A common method for applying biological data in the TMDL process is through a reference site approach using the Western Washington River Invertebrate Prediction and Classification System (RIVPACS) model. Although biological assessments are critical tools for evaluating the condition of aquatic life uses, they do not identify the cause or causes of impairment. USEPA developed a stressor identification (SI) process to assist water resource professionals in identifying stressors or combinations of stressors that cause biological impairment *(*USEPA, 2000*)*. EPA's SI process is often also called the Casual Analysis Diagnosis/Decision Information System (CADDIS) Model. Elements of the SI process have been used to evaluate and identify the primary stressors of the benthic community in other TMDLs. Examples include Eagleville Brook, Connecticut and Accotink Creek, Virginia (CT DEP, 2007 and USEPA, 2010).

The SI process or CADDIS Model involves a critical review of available information, forming possible stressor scenarios that might explain the impairment, analyzing those scenarios, and producing conclusions about which stressor or stressors are causing the impairment *(*USEPA, 2000; USEPA, 2011). Ecology also encourages the use of SI for addressing biological impairments in Washington's water bodies (Adams, 2010). SI typically consists of three steps (Figure 20) that include: (1) listing candidate causes, (2) analyzing evidence, and (3) characterizing causes.

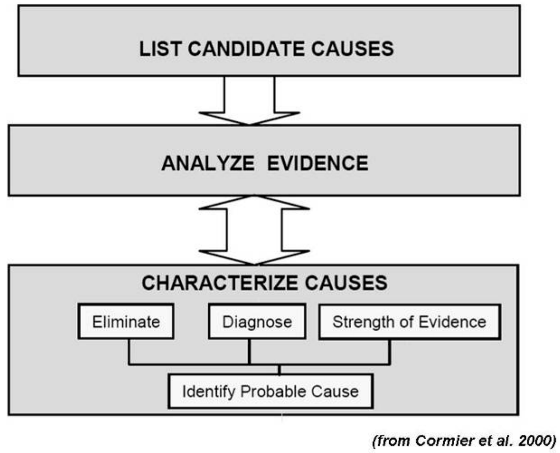


Figure 20. Overview of stressor identification process.

At a minimum three models will be used to evaluate the health of the benthic macroinvertebrate community in Squalicum and Baker Creeks. In all cases, existing data from the City of Bellingham and new data collected during the summer of 2012 will be used.

- The Benthic Index of Biotic Integrity (B-IBI) is composed of ten metrics that measure different aspects of stream biology, including taxonomic richness and composition, tolerance and intolerance, habit, reproductive strategy, feeding ecology, and population structure.
- (RIVPACS) Model is a multivariate predictive model that can be used to measure biological condition in any wadeable Western Washington stream. The RIVPACs score is ratio of the observed taxa over the expected. The tool predicts the expected taxa based on 300 reference sites built into the model.
- EPA's CADDIS Model is a process to identify likely stressors for impairments seen in the biological community. This approach is often called the "Stressor Identification".

Information derived from the two multimetric models (B-IBI and RIVPACS) will play an important role in developing a list of candidate causes (or stressors) and also in analyzing the evidence. The use of RIVPACS data can accomplish this by carefully describing the effect that is prompting the overall analysis (e.g., unexplained absence of mayflies, stoneflies, and caddisflies). Following a description of the biological concern, available information relevant to the situation is gathered and potential causes identified.

Evidence for RIVPACS is based on biological information from a *Reference Site*. Such a site may not necessarily be a pristine location. Site selection can either be within the Squalicum Creek watershed or from another representative location. However, the location must be in attainment of the aquatic life beneficial use in order to serve as a *Reference Site*. A key piece of information to be documented is a careful description of the effect that prompted the evaluation. Whenever possible, the impairment should be described in terms of its nature, magnitude, and spatial and temporal extent. Making inferences about causes is easier when the impairment is defined in terms of a specific effect, or when the response is quantified as a count (e.g., abundance of isopods, snails, and leeches).

These multimetric scores will determine degree of impairment and critical location(s) in the Squalicum Creek watershed and the USEPA CADDIS process will ascertain likely stressors to the benthic community. Biological assessment on Squalicum Creek for this stormwater pilot TMDL will use existing and new data collected during July 2012. As already mentioned a separate QAPP is being written for the biological monitoring to be conducted in the summer of 2012.

Linkage Analysis Framework

The basic objective of the linkage analysis is to understand the cause-and-effect relationships governing water quality, such that management alternatives can be explored that will bring water quality back into compliance with water quality standards. The linkage analysis examines connections between water quality targets, available data, and potential sources. This provides a framework for connecting information on biological impairment(s) to other key indicators at a watershed scale.

Hydrology and Water Quality

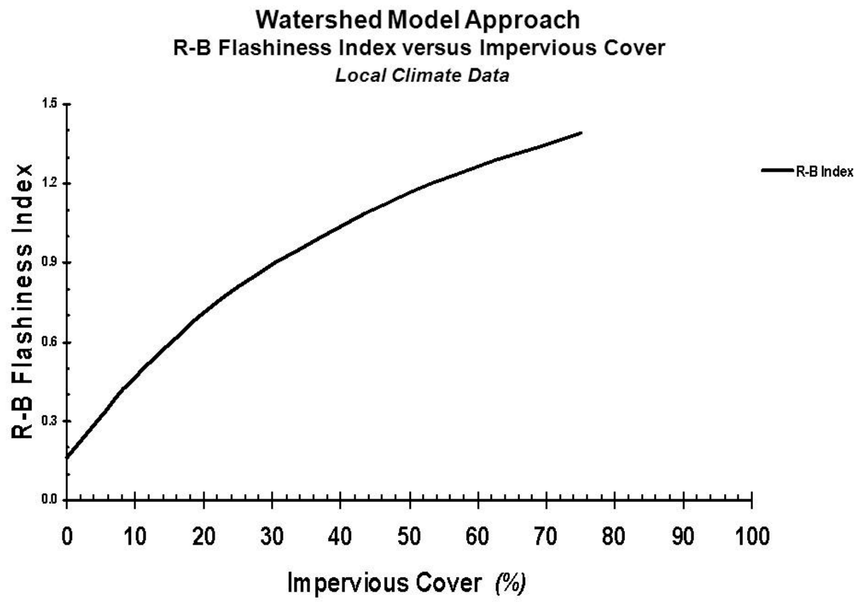
An examination of Squalicum Creek's overall response to watershed loading is a key part of the linkage analysis. This evaluation should recognize the varied nature of the drainage. Different land use patterns and source areas across the watershed contribute to the spatial variation observed in the monitoring data. The linkages documented in this step will highlight the importance of the parameters and targets selected to address biological impairments in Squalicum Creek. A summary of major considerations and concerns by location across the watershed will be presented. Combined, the linkages and the array of concerns will help identify and guide the range of different management strategies to address problems causing non-attainment of Washington's aquatic life use in the Squalicum Creek watershed.

A starting point for Squalicum Creek is to use the watershed model coupled with local meteorological data to examine the effect of land use on the flow duration curve. Land uses have different levels of impervious cover, which in turn exerts a major effect on watershed hydrology. The LSPC model will be built to reflect the current land uses in the Squalicum Creek watershed and various scenarios of decreased and increased levels of impervious cover for urban land uses (e.g., low density residential, high density residential, commercial) evaluated. A watershed model can also be used to estimate the degree of impairment for other key indicators that might be used in the TMDL.

Specific activities to be included in the linkage analysis include:

- Identify locations where duration curves are to be developed.
- Explore approaches for developing duration curves on ungaged reaches.
- Evaluate water quality, flow relationships, metrics; ensure key parameters – such as bacteria, turbidity, or total suspended solids – are addressed in the linkage analysis.
- Recommend critical conditions for targets, examining relationships causing differences in observed longitudinal, seasonal, and year-to-year patterns (magnitude, frequency, and duration).

Figure 21 illustrates an example of using model output to depict the effect of impervious cover on the Richards-Baker Flashiness Index. This graph was developed using a set of daily flow time series generated by LSPC. It demonstrates the utility of a watershed model in quantifying the relationship between urbanization (reflected through impervious cover), the effect of stormwater runoff on stream flow, and an indicator (*"flashiness"*) known to affect aquatic life uses.



LSPC Output

Figure 21. Example change in R-B Flashiness Index related to increased impervious cover.

For watersheds experiencing rapid growth and development, stormwater has often been identified as a contributing factor to biological impairments. In many cases, it is difficult to identify a specific component of stormwater that is responsible for reduced macroinvertebrate or fish populations. Because hydrologic indicators and/or impervious cover are used to guide stormwater management programs, they have also been used as surrogate measures for TMDLs intended to address urban runoff concerns.

Innovative approaches have been used for TMDL development in other states that were based on *weight of the evidence* or stressor identification methods. This activity will explore the use of stressor identification and surrogate measures to connect key pieces in the linkage analysis. The Squalicum Creek watershed is comprised of multiple habitats that will require the application of several types of linkage analyses depending on the habitat.

TMDL Development

The purpose of this task is to calculate the TMDLs and to allocate loads to sources. This involves establishing loading capacities for each pollutant that meet applicable water quality standards, evaluating options that reduce source loads to those loading capacities, identifying a *margin of safety*, developing allocations, and preparing the TMDL document.

Loading Capacity

Under the current regulatory framework for development of TMDLs, calculation of the loading capacity for impaired segments identified on the §303(d) list is an important step. USEPA's regulation defines loading capacity as *"the greatest amount of loading that a water can receive without violating water quality standards"*. The loading capacity provides a reference, which helps guide pollutant reduction efforts needed to bring a water into compliance with standards. Once the existing conditions and the cause-and-effect relationship between sources and water quality are established for the Squalicum Creek watershed, loading capacities for pollutants or surrogates can be determined.

TMDL Report

The TMDL report will include a compilation of all analyses (e.g., watershed characterization, source assessment, linkage analysis). The report will comply with the elements needed for TMDL approval identified by USEPA Region 10. After determining the loading capacity and evaluating options, development of the report will involve coordination with EPA, Ecology, and watershed stakeholders to allocate to sources. Individual waste load allocations will be allocated to regulated stormwater sources, and a general load allocation will be assigned to all unregulated nonpoint sources. Waste load allocations will also be developed for any other NPDES sources as deemed necessary.

Stormwater permits in Washington require permittees to comply with TMDL requirements. For this reason, it is important that the TMDLs are clear about stormwater requirements. The TMDL technical team will ensure coordination between Ecology's stormwater permit managers and TMDL policy managers.

Sampling Procedures

There is no sampling or primary data collection by Ecology planned under this QAPP. The vast majority of data to be used for this Stormwater Pilot TMDL is secondary data collected by City of Bellingham and other local entities under their ambient monitoring programs. A small amount of additional sampling for benthic macroinvertebrates will occur under a USEPA contract to augment the City of Bellingham data set for use in the Stormwater Pilot TMDL. A separate QAPP is currently being developed by EPA's contractor Tetra Tech, Inc. for the bioassessment work.

Measurement Procedures

Field

This section is not applicable.

Laboratory

This section is not applicable.

Quality Control Objectives

Quality control objectives expressed in this QAPP are for use of secondary data to meet the project goals.

Quality Objectives for Existing Data and Modeling

Quality Control Guidance

Existing data used for this project will need to meet Ecology's Credible Data Policy 1-11 (Ecology, 2009b), and USEPA guidance documents. The additional primary benthic monitoring data collection efforts in July 2012 for this Stormwater Pilot TMDL will be addressed by a subsequent QAPP. USEPA provides guidance for projects using existing data in their 2002 publication entitled *Guidance for Quality Assurance Project Plans, USEPA QA/G-5.* The guidance specifies that the limitations and quality of the data should be explored and understood for use on a secondary project. Figure 22 shows the USEPA QA/G-5 process (EPA, 2002).

Figure 22. Process in determining whether or not to use existing data (USEPA, 2002).

The first two steps in Figure 22, data needs and identifying sources, are addressed by this QAPP. Several sources of existing data on Squalicum Creek are identified and shown in Table 9. The third and fourth steps in Figure 22 are discussed below in the Data Verification section.

Project Data Quality Review

Secondary data will be evaluated to assess the quality of the data. This will consist of evaluating the water quality and benthic data and, where appropriate, flow and rainfall records.

Table 9. Types, sources, and understood quality issues for data to be used in this project.

Project Data Needs	Source of Data	Data Type	Application	Known Data* Quality Issues
GIS Layers for land use, impervious cover, building outlines, parking areas, stormwater network, streams, lakes, jurisdictional boundaries, roads, permitted areas, and natural resources	Ecology, City of Bellingham, Whatcom County	Shapefile layers and planning documents.	Analytical tool, source assessment	None known
Benthic macroinvertebrate survey data	City of Bellingham	Taxa, water quality, habitat metrics, and other single metric data	Analytical tool	None, collected following Ecology protocols (Plotnikoff and Wiseman, 2001).
Water quality measurement	Ecology, City of Bellingham, Whatcom County, and Lummi Nation	Single event and in-situ measurement data	Analytical tool	Bellingham data is collected under a QAPP and analyzed by a state accredited lab. Other data availability or quality unknown.
Water flow measurement	Ecology, City of Bellingham, Whatcom County	Single daily average data	Analytical tool	A few data points are highlighted as not usable due to gage error.
Continuous simulation flow models	City of Bellingham and Contractor	WWHM3 model of Squalicum Creek watershed	Analytical tool, source assessment	Unknown
Discharge monitoring reports	Ecology	Event measurement data	Source assessment, analytical tool	None

* Data quality comments are from the data sources, and the secondary data have not yet been fully evaluated.

Water Quality

Water quality data from Bellingham are collected under a QAPP. Data will be evaluated for their appropriate use during development of the TMDL.

Benthic Macroinvertebrates

Benthic macroinvertebrates have always been and continue to be collected using Ecology protocols. With the exception of different field sites, there are no known data quality issues for use of the data.

Meteorology

Meteorological data are a critical component of any water resource analysis. Appropriate representation of precipitation, wind speed, potential evapotranspiration, cloud cover, temperature, and dew point is required to develop estimates of streamflow for un-gaged sites. This is particularly important given the focus on hydrology in the Squalicum Creek Stormwater Pilot TMDL development project.

Meteorological data will be obtained from a number of sources in an effort to develop the most representative data set for the watershed. In general, hourly precipitation data are recommended for rainfall-runoff analysis. Data available from the local weather stations distributed throughout the watershed are the primary source. The City laboratory collects rainfall data from 21 separate locations. Locations of interest to this project may include: (1) Van Wyck and Mt Baker Hwy, (2) 4059 Bakerview Valley Road, (3) Sunset Pond, and (4) 851 Coho Way (Roeder Ave area).

Flow

In preparation for TMDL development, EPA's Contractor Tetra Tech, Inc. will collect flow records for Squalicum Creek. Additional data relevant to the effort may be available from other agencies such as the USGS, Ecology, Whatcom County, or local environmental groups. The City of Bellingham maintains a flow gaging station which logs data in 15-minute intervals at Squalicum and West Street. These data will be assembled and documented on an as-needed basis.

Example questions, such as those shown in Table 10, will be asked to evaluate the quality of the secondary data. The organizations that collected the data will provide metadata to help answer these questions. The answers will be documented in the final report.

If gaps are found in the quality requirements for data used in the project, Tetra Tech, Inc. will provide justification for the appropriate use of the data and will include a statement to this effect in the final TMDL report. The potential impact of using the data in the TMDL will also be estimated through an uncertainty analysis.

Table 10. Examples of potential data sources and related questions.

Potential Data Sources	Example Questions
Data from handbooks, the scientific literature, or websites[1]	Are the data correct for the problem, or can they be transformed so that they are? What are the assumptions implicit in the data? What are the limitations of the data?
Model outputs[1]	What are the assumptions that these estimates are based upon? Has the quality of the modeling effort been evaluated? What are the limitations of the data?

Measurement data sets	Period of Record
	    Age of data – flow records are the only data that will be considered suitable if older than 15 years.
	    Are the data up to date?
	    Seasonality of the data record
	    Data record in relation to hydrological modifications in the river channel.
	Site Locations
	    Have the sites used for water quality, rainfall measurements, or flow measurements changed over time?
	    Have the sites undergone significant changes that would affect the data? In what way?
	Methods for Data Collection
	    What methods for data collection were used?
	    Are data methods comparable to methods used by others, including Ecology?
	    If methods were changed over the period of record, are the older data comparable to the newer data?
	    Was data analyzed by an accredited laboratory and/or calibrated measuring device?
	Data Quality Assessment
	    Were the data collected under any quality controls?
	    Have the data been reviewed for quality assurance?
	    What are the limitations of the data (for example, uncertainty, representativeness, QC flags)?
	    What are the results of the quality assessment done on the data?
	    Were blanks, replicates, or splits done as part of the data set for estimates of variability, precision, bias, or accuracy?

[1] Example questions from EPA, 2002.

Data Verification and Usability

Tetra Tech, Inc. will review reports or metadata to evaluate measurement performance criteria associated with the data that would be relevant to the Squalicum Stormwater Pilot TMDL. Tetra Tech, Inc. will also perform general quality checks on the transfer of data from any source databases to another database, spreadsheet, or document.

Audits, Deficiencies, Nonconformities, and Corrective Actions

Quality assurance (QA) will be applied to the acceptance of secondary data, data analysis, and data modeling. This includes surveillance, as well as internal and external testing of the software application. Performance and system audits are key to ensuring compliance. The essential steps in audits for the QA program are as follows:

- Identify and define the problem
- Investigate and determine the cause of the problem
- Implementing appropriate corrective action
- Verify that the corrective action has eliminated the problem
- Verify that QA procedures called for in this QAPP are properly followed and executed
- Confirm that appropriate documents are properly completed and kept current and orderly

Many technical problems can be solved on the spot by the staff members involved. Tetra Tech, Inc. will determine whether acceptable quality is met. The Tetra Tech Task Order Leader (TOL) (or designee) has responsibility for assuring credible data are used for the project. Identifying problems with data quality such as deficiencies in the data record or nonconformities in the model will require acknowledgement, investigation, and corrective action if appropriate. Corrective actions may include the following:

- Reemphasizing to staff the project objectives, the limitations in scope, the need to adhere to the agreed-upon schedule and procedures, and the need to document QC and QA activities
- Securing additional commitment of staff time to devote to the project

The Tetra Tech, Inc. Quality Control Officer (QCO) will perform or oversee the following qualitative and quantitative assessments of model performance to ensure that models are performing the required tasks while meeting the quality objectives:

- Data acquisition assessments
- Secondary data quality assessments
- Analytical tool testing studies
- Model evaluations *(if applicable)*
- Internal peer reviews

Tetra Tech, Inc. will review staff performance during each phase of the project to ensure adherence to project protocols. Quality assessment is defined as the process by which QC is implemented in the model development task. All technical analysts will conform to the following guidelines:

- All technical assessment activities including data interpretation, load calculations, or other related computational activities are subject to audit or peer review. Thus, the technical analysts are instructed to maintain careful written and electronic records for all aspects of the assessment and linkage analysis process.
- The location of these records will be noted and maintained in the project files.
- If new theory is incorporated into the linkage analysis framework, references for the theory and how it is implemented in any electronic spreadsheet or analytical tool will be documented.

The Tetra Tech, Inc. Task Order Leader (TOL) or deputy will make detailed documentation available to members of the project work group.

Usability of Results from Modeling or Other Analysis

The study covered under this QAPP will work entirely with secondary data. This project will involve collection, evaluation, and analysis of existing data. Evaluation of secondary data will be conducted based on USEPA guidance documents USEPA QA/G-9R and USEPA QA/G-9S (USEPA, 2006a, b). Summary plots, graphs, and maps of the relevant flow and water quality information will be created to help identify the problem areas, assess trends, compare data to water quality standards, and assist in the source assessment process. Plots and graphs of the data, as well as data interpretation, will be included in the water quality data section of the report. Other data that may be included and summarized are: habitat data, stream channel measurements, and/or any other physical data related to identified water quality concerns.

The Squalicum Creek Stormwater Pilot TMDL will investigate sources of pollutant loads using flow duration curves. Potential sources that deliver pollutants or that could contribute to water quality impairments will be identified by land use type. Available source location information, organized by sub-watershed, will be compiled. Potentially significant sources will be identified, both in tabular form and as geographic information system (GIS) data layers.

Data Usability Statement

Water quality data from outside this study used in the TMDL analysis must meet the requirements of Ecology's credible data policy (Ecology, 2009b). Note that the standards set in this policy do not apply to non-quality data such as flow or meteorological data, although the quality of these data will still be evaluated.

Documentation of the QA assessment must consider whether the data, in total, fairly characterize the quality of the water body at that location at time of sampling. Also the original intended use of the information gathered (e.g., chemical/physical data for TMDL analyses) and any limitations on use of the data (e.g., if measurements only represent storm-event conditions) will be known. Data sets must be complete, that is, not censored to include only part of the data results from the project.

Although a substantial amount of data has been collected and reports prepared for the Squalicum Creek watershed, it is not clear at the outset of this project which data will be used to support TMDL decision-making. The Linkage Analysis described in this QAPP is a critical task that describes the connection between stormwater sources and their effect on water quality. Results of the Linkage Analysis will guide allocation decisions in the TMDL process.

To ensure that the secondary data and other supporting studies are appropriate to the use for which they will be applied, a separate appendix in the TMDL Report called the Data Usability will be prepared. This appendix will identify the secondary data, modeling results, and reports used in the Linkage Analysis, the rationale for their inclusion and a discussion on the data quality, deficiencies, corrective actions, and results. The Data Usability Appendix will include a summary table with the following elements:

- Secondary data, model, or report name
- Data source (originating organization, report title or study identifier, date)
- Data type (parameters included, date range or period covered)
- How data was used to support decisions
- Limitations on data use

Data Management

Secondary data collected as part of this project will be maintained as printed copy only, both printed and electronic, or electronic only, depending on their nature. Software to be used for this project includes publicly available Microsoft Office (specifically Excel, Access, and Word), and the LSPC continuous simulation model. Tetra Tech, Inc. may also use spreadsheet analysis tools created for similar projects by staff. The GIS software that Tetra Tech, Inc. will use for this project is Environmental Systems Research Institute's ArcGIS Desktop platform, and the primary program to be used will be ArcMap 9.3. The software to be used for the project operates on standard Pentium-class microcomputers under the Windows operating system.

Tetra Tech, Inc. will maintain and provide the final version of all technical analysis tools to USEPA and Ecology for archiving at the completion of the project. Electronic copies of the data, GIS, LSPC model, and other supporting documentation will be supplied to USEPA with the final report. Tetra Tech, Inc. will maintain copies in a project subdirectory (subject to regular system backups) and on disk for a maximum period of five years after project termination, unless otherwise directed by the client.

Ecology will keep all final spreadsheet files, paper notes, photographs, final GIS products, and final LSPC model created as part of the data analysis and model building with the project data files. Ecology will not enter secondary data into EIM.

Reports

The Tetra Tech, Inc. TOL will submit the draft and final technical study report to Ecology's TMDL lead for this project, Steve Hood (Bellingham Field Office, Water Quality Program), according to the project schedule

Project Organization

Table 11 lists the people involved in this project.

Table 11. Organization of project staff and responsibilities.

Name/Contact	Title/Role	Responsibilities
United States Environmental Protection Agency (USEPA) Region 10		
Dave Ragsdale USEPA Region 10 300 Desmond Drive, NE Olympia, WA 98504-7600 Phone: 360-407-6598	Technical Lead	Provide project oversight for this study as the USEPA Region 10 technical lead. The USEPA Region 10 Task Order Manager (TOM) will work with the Tetra Tech, Inc. Task Order Leader (TOL), Amy King, to ensure that project objectives are attained. The USEPA Region 10 TOM will also have the following responsibilities: • Providing oversight for selection of analytical tools used to support TMDL development, data selection, and adherence to project objectives • Maintaining the official approved QAPP • Facilitating participation of the Ecology, Nooksack Tribe, Lummi Nation, USEPA, and other key participants on the project workgroup
Jayne Carlin, USEPA, Region 10 1200 6th Avenue, Seattle, WA 206-553-8512	Task Order Manager	USEPA Region 10 TOM. She will provide coordination of the technical and QA resources of the Agency and its contractors in executing this project.
Gina Grepo-Grove USEPA, Region 10 1200 6th Avenue, Seattle, WA 206-553-1632	Regional Quality Assurance Manager	USEPA Region 10 Quality Assurance Manager (QAM), or her designee, will be responsible for reviewing and approving the QAPP and any other deliverables, as requested by the TOM.
Washington State Department of Ecology (Ecology)		
Helen Bresler Water Quality Program Lacey Headquarters Phone: 360-407-6180	Watershed Planning Unit	Review QAPP, TMDL technical report and TMDL implementation plan. Serves as policy review TMDL reports.
Steve Hood Water Quality Program Bellingham Field Office Phone: 360-715-5211	TMDL Lead	Acts as point of contact between EAP staff, tribes, stakeholders, and other interested parties. Coordinates information exchange. Forms technical advisory team and organizes meetings. Reviews the QAPP and technical report. Prepares and implements TMDL report for submittal to EPA.
Brandi Lubliner EAP, Toxics Studies Unit PO Box 47600 Olympia, WA 98504-7600 Phone: 360-407-7140	Project Manager (QAPP Author)	Co-author of the QAPP with Bruce Cleland. Oversee information exchange. Review intermediary technical products, and model. Review draft report and final TMDL report.

Name/Contact	Title/Role	Responsibilities
Will Kendra EAP, Statewide Coordination Section PO Box 47600 Olympia, WA 98504-7600 Phone: 360- 407-6698	Section Manager of Author	Approves the QAPP and technical sections of the TMDL report.
Tetra Tech, Inc.		
Bruce Cleland 25919 – 99th Avenue S.W. Vashon, WA 98070 Phone: 206- 463-2596	Project Manager	Co-author the QAPP. Lead the development of the Squalicum Creek Stormwater Pilot TMDL. Additional responsibilities of the Tetra Tech, Inc. Project Manager include the following: • Coordinating project assignments, establishing priorities, and scheduling • Ensuring completion of high-quality products within established budgets and time schedules • Acting as primary point of contact for the USEPA Region 10 TOM • Prepare TMDL project deliverables, including the draft report, final report, and other materials developed to support the project • Providing support to USEPA in interacting with the project team, technical reviewers, workgroup participants, and others to ensure that technical quality requirements of the study design objectives are met
Amy King 350 Indiana Street, Suite 500 Golden, CO 80401 Phone: 720-881-5874	Task Order Leader (TOL)	Tetra Tech, Inc.'s Project Manager (Bruce Cleland) is authorized to commit resources to meet project objectives and requirements. The TOL's primary function is to achieve technical, financial, and scheduling objectives. Additional responsibilities of the Tetra Tech, Inc. TOL include the following: • Providing guidance, technical advice, and performance evaluations to those assigned to the project • Implementing corrective actions and providing professional advice to staff • Review QAPP
John O'Donnell 10306 Eaton Place, Suite 340 Fairfax, VA 22030 Phone: 703-385-6000	Quality Assurance Officer	Quality Assurance Officer, or his designee, will be responsible for reviewing and approving the QAPP and any other deliverables, as requested by the TOL.

Project Schedule

Table 12. Proposed schedule for completing TMDL technical study and WQIR.

Model Development	
Project manager	Tetra Tech, Inc. - Bruce Cleland
Squalicum LSPC model	July 2012
Final TMDL (WQIR) Report	
EAP review lead (for entry in Activity Tracker)	Brandi Lubliner (Ecology)
TMDL technical report schedule:	
Tetra Tech, Inc. develops LSPC model.	July – September 2012
Tetra Tech, Inc. conducts additional benthic monitoring and prepares stressor identification study report (covered by separate QAPP).	July – September 2012
Tetra Tech, Inc. draft TMDL technical study findings reported in WQIR format -- Due to EPA.	December 2012
EAP and WQP review of draft TMDL technical findings. WQP policy review if warranted.	February 2013
Anticipated schedule for completion of the WQIR:	
WQP, EAP, and potentially Tetra Tech, Inc. develop implementation strategy.	Spring 2013
WQP policy review.	Spring 2013
Report draft WQIR for external review.	Spring/Summer 2013
Draft WQIR complete.	Summer 2013
Final WQIR posted on web by WQP.	Date unknown – anticipated Fall 2013

WQIR: Water Quality Improvement Report.
EAP: Environmental Assessment Program, Washington State Department of Ecology
WQP: Water Quality Program, Washington State Department of Ecology
USEPA: U.S. Environmental Protection Agency

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Appendix. Glossary, Acronyms, and Abbreviations

Glossary

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited estuaries, lakes, and streams that fall short of state surface water quality standards and are not expected to improve within the next two years.

Analyte: Water quality constituent being measured (parameter).

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Critical condition: When the physical, chemical, and biological characteristics of the receiving water environment interact with the effluent to produce the greatest potential adverse impact on aquatic biota and existing or designated water uses. For steady-state discharges to riverine systems, the critical condition may be assumed to be equal to the 7Q10 flow event unless determined otherwise by the department.

Designated uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each water body or segment, regardless of whether or not the uses are currently attained.

Dilution factor: The relative proportion of effluent to stream (receiving water) flows occurring at the edge of a mixing zone during critical discharge conditions as authorized in accordance with the state's mixing zone regulations at WAC 173-201A-100.
http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-020

Existing uses: Those uses actually attained in fresh and marine waters on or after November 28, 1975, whether or not they are designated uses. Introduced species that are not native to Washington, and put-and-take fisheries comprised of non-self-replicating introduced native species, do not need to receive full support as an existing use.

Fecal coliform (FC): That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform bacteria are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

Geometric mean: A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from 10 to 10,000 fold over a given period. The calculation is performed by either: (1) taking the nth root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

Load allocation: The portion of a receiving water's loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

Loading capacity: The greatest amount of a substance that a water body can receive and still meet water quality standards.

Margin of safety: Required component of TMDLs that accounts for uncertainty about the relationship between pollutant loads and quality of the receiving water body.

Municipal separate storm sewer systems (MS4): A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains): (1) owned or operated by a state, city, town, borough, county, parish, district, association, or other public body having jurisdiction over disposal of wastes, stormwater, or other wastes and (2) designed or used for collecting or conveying stormwater; (3) which is not a combined sewer; and (4) which is not part of a Publicly Owned Treatment Works (POTW) as defined in the Code of Federal Regulations at 40 CFR 122.2.

National Pollutant Discharge Elimination System (NPDES): National program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface-water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Parameter: Water quality constituent being measured (analyte).

Pathogen: Disease-causing microorganisms such as bacteria, protozoa, viruses.

Phase I stormwater permit: The first phase of stormwater regulation required under the federal Clean Water Act. The permit is issued to medium and large municipal separate storm sewer systems (MS4s) and construction sites of five or more acres.

Phase II stormwater permit: The second phase of stormwater regulation required under the federal Clean Water Act. The permit is issued to smaller municipal separate storm sewer systems (MS4s) and construction sites over one acre.

Point source: Source of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Primary contact recreation: Activities where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and water skiing.

Riparian: Relating to the banks along a natural course of water.

Salmonid: Fish that belong to the family *Salmonidae*. Basically, any species of salmon, trout, or char. www.fws.gov/le/ImpExp/FactSheetSalmonids.htm

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and water courses within the jurisdiction of Washington State.

Total Maximum Daily Load (TMDL): A distribution of a substance in a water body designed to protect it from not meeting (exceeding) water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a margin of safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Wasteload allocation: The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. Wasteload allocations constitute one type of water quality-based effluent limitation.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

BMP	Best management practice
CADDIS	Casual Analysis Diagnosis/Decision Information System
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
EPT	Pollution-sensitive benthic macroinvertebrate groups, e.g., stoneflies mayflies (ephemeroptera) (plecoptera), and caddisflies (trichoptera)
GIS	Geographic Information System software
HSPF	Hydrologic Simulation Program Fortran
LSPC	Loading Simulation Program C++
NPDES	(See Glossary above)
NTU	Nephelometric turbidity units
QAPP	Quality Assurance Project Plan
QA	Quality assurance
QC	Quality control
RIVPACS	Western Washington River Invertebrate Prediction and Classification System
TMDL	(See Glossary above)
USGS	United States Geological Survey
WAC	Washington Administrative Code
WQA	Water Quality Assessment
WQIR	Water Quality Improvement Report
WWHM3	Version 3 Western Washington Hydrology Model
WWTP	Wastewater treatment plant

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
ft	feet
m	meter
mg	milligrams
mg/L	milligrams per liter (parts per million)
NTU	nephelometric turbidity units
sq. mi.	square mile