Union River Watershed Fecal Coliform Total Maximum Daily Load

Water Quality Effectiveness Monitoring Report

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Cover photo: Direct discharge of domestic sewage to Belfair Creek; this was corrected in 2004.

Union River Watershed
Fecal Coliform
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Water Quality
Effectiveness Monitoring Report

by

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Waterbody Number: WA-15-2010

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Abstract

Under Section 303(d) of the federal Clean Water Act and U.S. Environmental Protection Agency (EPA) regulations, the Washington State Department of Ecology (Ecology) is required to develop and implement Total Maximum Daily Loads (TMDLs; cleanup plans) for impaired waters. After TMDL recommendations have been implemented, data are collected to determine if the TMDL targets and water quality standards have been met.

In 2001, Ecology published the results of a 1999 TMDL study of the Union River. The study showed that Washington State surface water quality standards for fecal coliform bacteria (FC) were not met at five monitoring locations. The 1999 study identified percent reductions needed to achieve FC water quality standards at five compliance sites on the Union River and one of its tributaries (Bear Creek).

In 2002, Ecology submitted a TMDL report to EPA to address FC in the Union River watershed. Since then, several pollution reduction actions have been implemented. These include (1) decommissioning of high-risk, on-site sewage treatment systems, (2) installing riparian fencing and plantings, and (3) completing stormwater improvement projects.

This current report presents the results of an effectiveness monitoring study conducted by Ecology in 2008-2009. The primary goal of this study is to evaluate attainment of the TMDL targets (load allocations) for FC at several compliance stations identified in the 1999 TMDL study. A secondary goal is to evaluate attainment of water quality standards for FC at five additional stations in the study area.

This evaluation shows that FC concentrations in the Union River and its tributaries have not yet shown significant improvement at target locations since the 1999 TMDL study. Sampling at new monitoring sites shows that two of the five additional sites met water quality standards for FC while three did not.

Acknowledgements

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    - Dave Garland provided logistical support and organized the entire effort.
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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 in the United States. Under the Clean Water Act, every state has its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of designated uses for protection, such as cold water biota and drinking water supply, and criteria, usually numeric criteria, to achieve those uses.

Every two years, states are required to update a list of waterbodies – lakes, rivers, streams, or marine waters – that do not meet water quality standards. This list is called the 303(d) list or water quality assessment. To develop the list for Washington State, the Washington State Department of Ecology (Ecology) compiles its own water quality data along with data submitted by local, state, and federal governments, tribes, industries, and citizen monitoring groups. All data are reviewed to ensure that they were collected using appropriate scientific methods before they are used to develop the 303(d) list.

TMDL process overview

The Clean Water Act requires that a Total Maximum Daily Load (TMDL) be developed for each of the waterbodies on the 303(d) list composed of water segments in Category 5 of the Water Quality Assessment. A TMDL identifies how much pollution needs to be reduced or eliminated to achieve clean water. Then the local community works with Ecology to develop a strategy to control the pollution and a monitoring plan to assess the effectiveness of the water quality improvement activities.

Elements required in a TMDL

The goal of a TMDL is to ensure the impaired water will attain water quality standards. A TMDL includes a written, quantitative assessment of water quality problems and of the known pollutant sources that cause the problem. The TMDL determines the amount of a given pollutant that can be discharged to the waterbody and still meet standards (the loading capacity) and allocates that load among the various sources.

If the pollutant comes from a discrete (point) source such as a municipal or industrial facility's discharge pipe, that facility's share of the loading capacity is called a *wasteload allocation*. If it comes from a set of diffuse (nonpoint) sources 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 loads from growth pressures is sometimes included as well. The sum of the wasteload and load allocations, the margin of safety, and any reserve capacity must be equal to or less than the loading capacity.

Water quality assessment / Categories 1-5

The 303(d) list identifies polluted waters in Washington State. The Water Quality Assessment is a list that tells a more complete story about the condition of Washington State's surface water. This list divides waterbodies into five categories:

- Category 1 – Meets tested standards for clean water.
- Category 2 – Waters of concern.
- Category 3 – Insufficient data available, so will be largely empty.
- Category 4 – Polluted waters that do not require a TMDL since the problems are being solved in one of three ways:
    - 4a – Has an approved TMDL and it is being implemented
    - 4b – Has a pollution control project in place that should solve the problem
    - 4c – Is impaired by a non-pollutant such as low water flow, dams, culverts
- Category 5 – Polluted waters that require a TMDL – the 303(d) list.

TMDL analyses: Loading capacity

Identification of the contaminant loading capacity for a waterbody is an important step in developing a TMDL. The U.S. Environmental Protection Agency (EPA) defines the loading capacity as "the greatest amount of loading that a waterbody can receive without violating water quality standards" (EPA, 2001). The loading capacity provides a reference for calculating the amount of pollution reduction needed to bring a waterbody into compliance with standards. The portion of the receiving water's loading capacity assigned to a particular source is a load or wasteload allocation. By definition, a TMDL is the sum of the allocations and an explicit margin of safety, which must not exceed the loading capacity.

Background

What is effectiveness monitoring?

An effectiveness monitoring evaluation determines if the interim or final targets and water quality standards have been met. This is an essential component of any restoration or implementation activity since it measures to what extent the work performed or recommended has attained the watershed restoration objectives or goals.

The benefits of effectiveness monitoring evaluations include:

- More efficient allocation of funding.
- Optimization in planning/decision-making (i.e., program benefits).
- Watershed recovery status (i.e., how much restoration has been achieved, how much more effort is required).
- Adaptive management or technical feedback to refine restoration treatment design and implementation.
- Determining the progress of individual segments (and the watershed as a whole) towards meeting water quality standards.

The effectiveness evaluation may address four fundamental questions with respect to restoration or implementation activity:

1. Is the restoration or implementation work achieving the desired objectives or goals (significant improvement)?
2. How can restoration or implementation techniques be improved?
3. Is the improvement sustainable?
4. How can the cost-effectiveness of the work be improved?

Study area

The study area for this TMDL is the Union River watershed which is located on the southern Kitsap Peninsula in Kitsap and Mason Counties. The study area is southeast of the Olympic National Park and near Belfair, Washington (Figure 1).

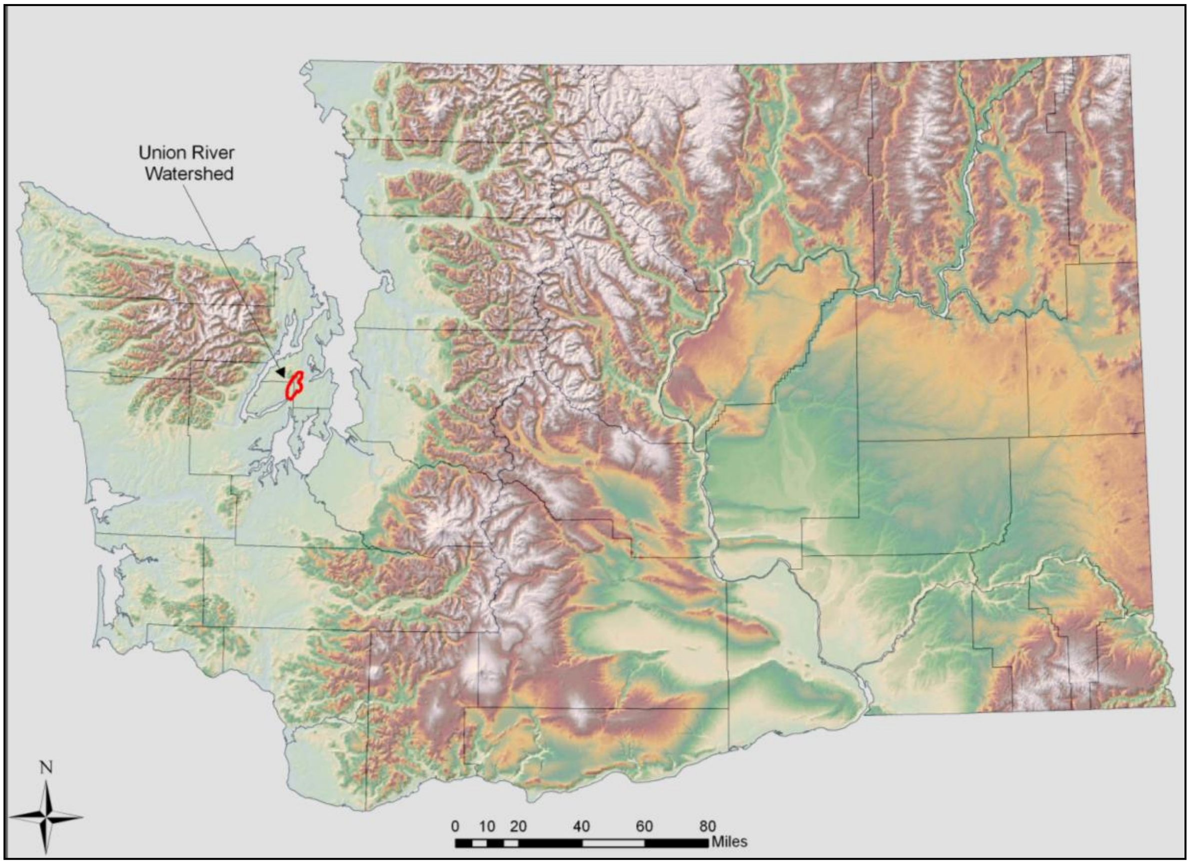

Figure 1. Location of the Union River Watershed within Washington State (Cadmus, Inc.).

The river and its tributaries drain approximately 23 square miles (14,500 acres) and flow into Lynch Cove, which is the furthest extent of Hood Canal. The largest tributaries to the river are the East Fork, Northeast Fork, Bear Creek, and Hazel Creek.

The evaluation also includes two streams outside of the Union River watershed. These two streams (Mission Creek and Little Mission Creek), like the Union River, drain to Lynch Cove which has been closed to shell fishing due to excessive FC levels suspected to originate from its freshwater tributaries. Figure 3 displays the location of these streams relative to the Union River watershed.

The headwaters of the Union River begin several miles west of Bremerton at an elevation of 1,500 feet. Although the river gradients are high at the headwaters, the river is mostly in a broad river valley with stream gradients near three percent. Basin soils are made up of a highly erodible mix of glacial outwash silt, sand, and gravel. Because of the low stream gradient in the lower river basin, the river has only minor erosion problems. Most eroded material is deposited near the river mouth as alluvial floodplain and mudflat sediments.

Casad Dam, located above McKenna Falls (a natural fish barrier), impounds the headwaters of the Union River. The reservoir created by the dam provides 65% of the drinking water for the City of Bremerton. The city maintains very strict water quality controls at the reservoir because it is one of the few unfiltered systems in the country. No public access is allowed to the watershed above the reservoir and the access roads are gated and patrolled.

The Union River basin is located in a largely rural setting with few prominent urban areas or major point sources of pollution. Figure 2 provides a map of the study area, including the Union River monitoring sites. Belfair, an unincorporated city located near the mouth, is the largest urban area in the basin.

The most common land uses in the basin include forestry and small agricultural or livestock operations. Other land uses include the City of Bremerton domestic water supply reservoir, a county landfill, an airport, and several sand and gravel operations. Managed forests and the restricted access area for the water supply reservoir dominate the upper basin. The lower Union River contains salmon habitat for small runs of chum, chinook, coho, cutthroat, and steelhead.

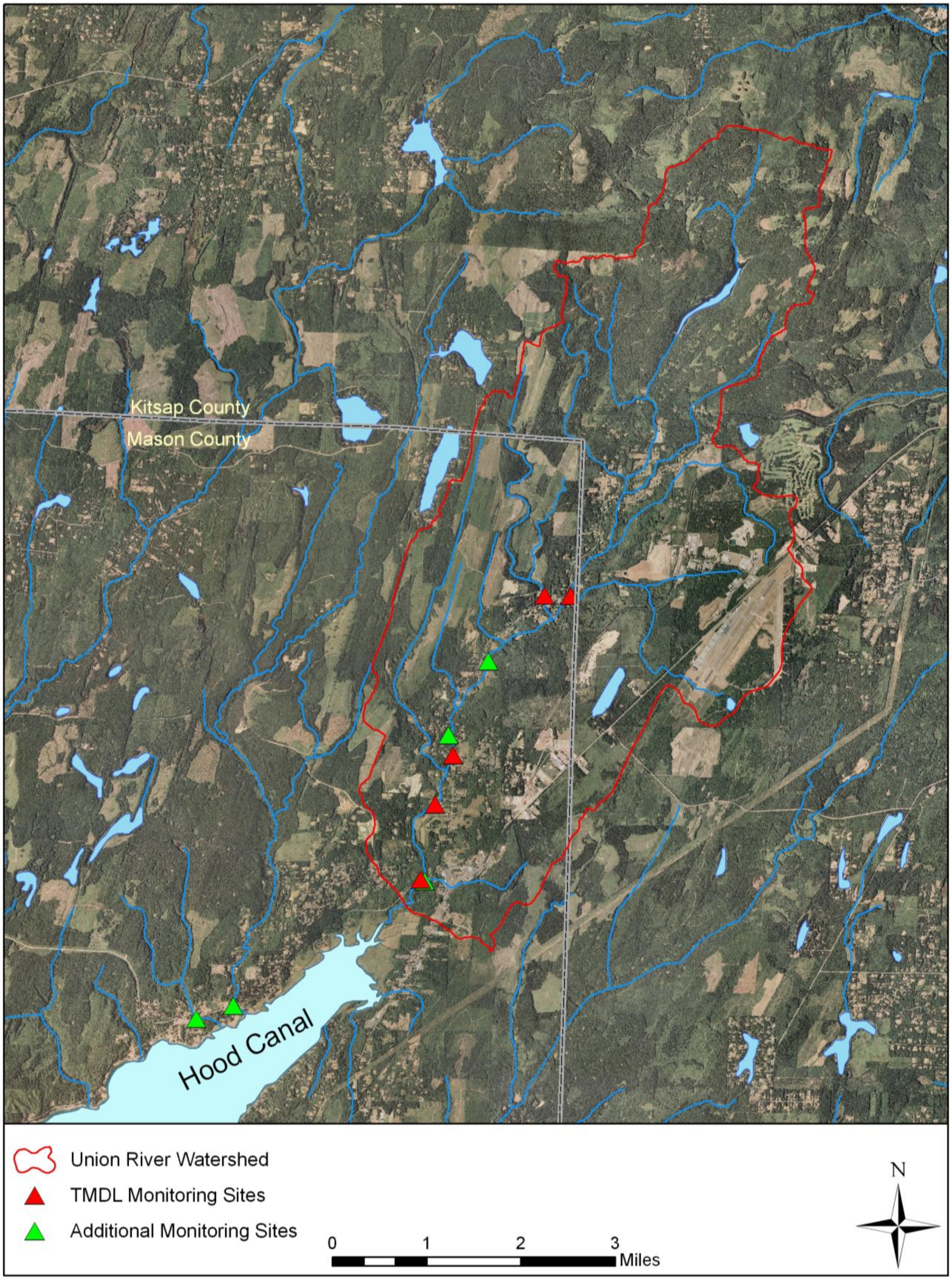

Figure 2. Union River Watershed and Monitoring Sites (Cadmus, Inc.).

Pollutant addressed by this TMDL: fecal coliform bacteria

Since 1990, water quality sampling in the Union River has shown that fecal coliform bacteria (FC) levels do not meet (exceed) Washington State's *Extraordinary Primary Contact Recreation* Standards at several sampling locations. Starting in 1987, portions of shellfish beds in Lynch Cove, adjacent to the mouth of Union River, have been closed due to FC contamination. The Mason County Department of Health Services (MCDHS) has created a shellfish protection district and programs as required by RCW 90.72.045 to address the shellfish closure problem. MCDHS initiated water quality sampling and sanitary surveys to track down sources of FC in Lynch Cove in the early 1990s.

As part of the shellfish closure response, MCDHS sampled the lower Union River at the bridge of Highway 300 between August 1990 and August 1991 and found FC excursions above the standard. These data resulted in listing the lower mainstem of the Union River on Washington State's 1996 Section 303(d) list for FC.

Ecology's Environmental Assessment Program and the Bremerton-Kitsap County Health District have collected data after 1999 showing that the Union River exceeds FC standards at several sampling stations. Excursions were found at stations from the mouth of Union River to river mile 4.5 at the Kitsap/Mason County line and in the Bear Creek Tributary.

Excessive bacteria concentrations expose the public to an increased risk of illness after primary contact with the receiving waters. Consumption of bacteria-contaminated shellfish also confers an increased health risk. Lynch Cove is a commercial shellfish harvest area and one of the state's largest recreational shellfish areas. Shellfish are filter feeders that pump large amounts of water through their bodies. This process can concentrate bacteria in their tissues, which causes little or no harm to the animal, but may pose health risks for human consumers. The Union River is one of many contributors of bacteria to Lynch Cove.

Sources of fecal coliform bacteria

As determined by Ecology in the *Union River Fecal Coliform TMDL Study* (Ward et al., 2001) and suggested by Kitsap and Mason Counties, the most probable sources of contamination to Union River are on-site sewage system failures, inadequate agricultural and livestock practices, pet wastes, wildlife, and runoff from homes, highways, and commercial businesses. Potential sources are further discussed below.

Commercial and residential on-site sewage systems

On-site sewage systems can be a source of pollutants to the river if they are sub-standard, failing, or located adjacent to a waterbody. Potential sources of bacteria and other contaminants include sewage from failing residential on-site sewage systems, inadequate community wastewater treatment systems, and accidental spills or illegal dumping from sewage collection.

According to the Bremerton-Kitsap County Health District, greywater discharges to Union River have been detected. Greywater is a potential source of bacteria and other contaminates. Greywater is wastewater from bathtubs, showers, sinks, washing machines, and dishwashers. The Washington State Department of Health (DOH) regulates the use of greywater for subsurface irrigation. DOH stresses that greywater can contain harmful bacteria, viruses, and chemicals that pose a risk to public health and the environment if mishandled. Greywater cannot be discharged to the groundwater or surface water in the state. A wastewater permit must be obtained from a county health agency in order to use greywater for subsurface discharges.

Small-scale farming or commercial horticultural activities

Small-scale or hobby farms make up a significant portion of land in the Union River watershed. Small-scale farming and commercial horticulture typically involve fertilizers, pesticides, and animal wastes that can impact nearby waterbodies. Homeowner use of fertilizers and pesticides can also impact waterbodies. Runoff from feedlots and manure piles, common in many agricultural areas, can be significant sources of bacteria, nitrogen, and phosphorus pollution to surface water and groundwater. Bacterial pollution from agricultural runoff is implicated in many shellfish bed closures nationwide.

Pet wastes

Pet wastes deposited on curbs and paved surfaces may enter surface waters via runoff during storm events and contribute to shellfish bed bacterial contamination and excessive nutrient pollution (Horner et al., 1994).

Wildlife

Wildlife may contribute bacteria, nutrients, and particulate organic material to surface waters, occasionally in significant amounts. Wildlife activity can increase in riparian areas in the fall when animals feed on spawned-out salmon.

Urban and semi-urban stormwater runoff

The unincorporated city of Belfair and the Port of Bremerton facilities generate significant stormwater runoff. Insufficient stormwater control and treatment can result in excessive sedimentation and erosion, increased stream temperatures, and decreased dissolved oxygen levels. It can introduce bacteria, toxic chemicals, metals, and other contaminants into receiving waters. (Horner et al., 1994.)

City of Bremerton biosolids land application program

The City of Bremerton applies biosolids from its wastewater treatment plant to approximately 470 acres in the upper Union River watershed. Biosolids are organic, semi-solid material derived from municipal sewage sludge that can be beneficially recycled but must meet strict quality standards for pathogens, animal attraction, and pollutant concentrations. Regulations found in RCW 70.95J provide Ecology and local governments with the authority and direction to meet federal regulatory requirements for managing municipal sewage sludge. Ecology and Bremerton-Kitsap County Health District provide oversight cooperatively for biosolids management in Kitsap County.

The Bremerton biosolids permit allows land application of Class B treated biosolids on city-owned forested areas between State Highway 3 and Old Belfair Highway, adjacent to the Gold Mountain Golf Course. Bremerton monitors its biosolids land application site for groundwater and surface water impacts and provides quarterly and annual reports. Local groundwater meets drinking water standards, and surface water immediately downstream of the land application site had FC levels of 4 cfu/100 mL in 2001 (City of Bremerton, 2002). Therefore, the Bremerton biosolids program is not considered a source of FC contamination to the Union River.

Olympic View Sanitary Landfill

Olympic View Sanitary Landfill is located in the Union River basin approximately 10 miles southwest of the City of Bremerton. It was the only operating solid waste landfill in Kitsap County up through 2001. An extensive wetland complex of over 130 acres of freshwater wetlands is located north and west of the landfill and includes portions of the floodplain of the East Fork of the Union River.

Landfilling at the site began in 1963, at which time the total landfill area was about 25 acres. After 1975, the site accepted mixed municipal solid waste, industrial waste, demolition waste, and other special waste. The active landfill area grew through the 1980s and 1990 to approximately 65 acres of the total 500-acre tract owned and operated by Olympic View Sanitary Landfill, Inc. The landfill closed in 2001.

In its post-closure status, Olympic View Landfill leachate is collected and pre-treated in the on-site lagoon system, and the pre-treated leachate is trucked to the Bremerton Sewage Treatment Plant. Stormwater runoff at the landfill is collected in a separate stormwater lagoon system, which is regulated under State Waste Discharge Permit #7271. Ecology requires implementation of technology-based pollution controls for stormwater from the landfill through the Stormwater Pollution Prevention Plan associated with Permit #7271.

Past surface water monitoring at Olympic View landfill has included quarterly sampling, individual wetland monitoring, and off-site monitoring events (Parametrix, 1992). Fecal coliform was measured in water samples collected at both background (run-on) and receiving water (run-off) sampling stations around the landfill. Fecal coliform pollution was documented as leaving the landfill site; however, many of the sampling results at background stations also exceeded standards indicating other sources were involved as well.

Since the landfill began the closure process, surface water sampling was not considered useful for evaluating potential impacts of the landfill and was discontinued after 1998 (Geomatrix, 2001). While the landfill is considered a potential source of FC to the Union River, closure and post-closure monitoring of the site will help ensure that the Union River is not being contaminated from this potential source.

Watershed implementation or restoration activities

In a 2002 report, Ecology discussed, in general, the agencies and activities that would contribute to clean-up efforts for meeting TMDL target limits for FC in the Union River watershed (Sweet et al., 2002). Additional information on responsible agencies and activities was provided in Ecology's 2003 Detailed Implementation Plan for the Union River watershed (Garland and Lawrence, 2003).

The Union River cleanup effort involves reducing FC pollution that originates exclusively from nonpoint (diffuse) sources. Control measures focus on:

1. Reducing the amount of animal waste entering the river.
2. Locating and eliminating sources of human FC contamination.
3. Reducing and controlling sources of stormwater runoff entering the river.

Agencies responsible for helping the Union River meet Washington State water quality standards include:

- Kitsap County Surface and Stormwater Management
- Kitsap County Public Works
- Kitsap County Health District
- Kitsap Conservation District
- Mason Conservation District
- Mason County Department of Health Services
- Mason County Department of Utilities/Waste Management
- Mason County Public Works
- Lower Hood Canal Watershed Coalition
- Washington State Department of Ecology
- Washington State Departments of Health
- City of Bremerton
- Port of Bremerton

Businesses and residents in the watershed are also responsible for helping to prevent Union River FC contamination.

Other groups playing a role in Union River cleanup include:

- University of Washington Sea Grant Program
- Hood Canal Salmon Enhancement Group
- Washington State University Cooperative Extension
- Hood Canal Coordinating Council
- Hood Canal Watershed Project
- Other citizen groups and volunteers

A list and map of specific TMDL implementation actions that have occurred since the 1999 TMDL (Ward et al., 2001) was approved is provided in Appendix B.

Water Quality Standards and Beneficial Uses

Washington State Surface Water Quality Standards (WAC 173-201A) have recently changed. In November 2006, Ecology adopted revised surface water quality standards, which were approved by EPA (Ecology, 2006a). As a result, the standards have changed since the 1999 TMDL study (Ward et al., 2001). The historic standards were based on the class designation of each waterbody. The revised standards are based on designated beneficial uses of the waterbody. These changes do not, however, change the criteria for FC in the waters addressed by the TMDL.

Fecal coliform bacteria

Bacteria criteria are set to protect people who work and play in and on the water from water-borne illnesses. Ecology's water quality standards use FC as an "indicator bacteria" for the state's freshwaters (i.e., 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 FC criteria are set at levels that are shown to maintain low rates of serious intestinal illness (gastroenteritis) in people.

WAC Chapter 173-201A designates all waterbodies into categories. Since Hood Canal is designated as *extraordinary quality marine waters*, freshwater tributaries to Hood Canal (except those specified in Table 602 of WAC 173-201A) are designated for FC standards as *Extraordinary Primary Contact Recreation*. Therefore, the Union River watershed is designated as *Extraordinary Primary Contact Recreation*. The characteristic beneficial uses and the FC water quality criteria for this classification are listed below.

Use designations — Fresh waters.

(1) All surface waters of the state not named in Table 602 are to be protected for the designated uses of: Salmonid spawning rearing, and migration; primary contact recreation; domestic, industrial, and agricultural water supply; stock watering; wildlife habitat; shellfish harvesting; commerce and navigation; boating; and aesthetic values.

(a) Additionally, the following waters are also to be protected for the designated uses of:

Core summer salmonid habitat; and extraordinary primary contact recreation:

(i) All surface waters lying within national parks, national forests, and/or wilderness areas.

(ii) All lakes and all feeder streams to lakes (reservoirs with a mean detention time greater than fifteen days are to be treated as a lake for use designation).

(iii) All surface waters that are tributaries to waters designated core summer salmonid habitat; or extraordinary primary contact recreation.

(iv) All fresh surface waters that are tributaries to extraordinary quality marine water

[WAC 173-201A-610 through 173-201A-612]

Fecal coliform organism levels must not exceed a geometric mean value of 50 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 100 colonies/100 mL

[WAC 173-201A-200, Table 200 2(b)]

The criteria for FC are based on allowing no more than the pre-determined acceptable risk of illness to humans who work or recreate in a waterbody. 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 FC 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 FC concentrations back into compliance with the standard.

Compliance with the criteria for FC 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 waterbody will be maintained at levels that will not cause a greater risk to human health than intended.

Waterbodies that do not meet the applicable water quality standards for fecal coliform, despite the presence of technology-based pollutant controls, are listed as impaired under Section 303(d) of the Clean Water Act. The listing requires development of a TMDL intended to provide guidance for the protection of beneficial uses within the basin. Table 1 lists the Union River study areas that were listed on the 2008 303(d) list for FC.

Table 1. Union River Study Area Waterbodies on the 2008 303(d) List for Fecal Coliform.

Waterbody	Listing ID	Township	Range	Section
Union River	6958	23N	01W	29
	9888	23N	01W	29
	16729	23N	01W	20
	38899	23N	01W	10
Union River, East Fork	45445	23N	01W	03

Listing/delisting methodology

Ecology's Water Quality Program Policy (2006b) along with the applicable water quality standards for FC (WAC-173-201A-200) constitute the listing methodology used to evaluate data collected at eight monitoring stations within the Union River watershed and two stations in the Mission Creek watershed. Both the Union River and Mission Creek segments have a designated use of *Extraordinary Primary Contact Recreation*. This use has a two-part numeric water quality standard: Not to exceed a geometric mean value of 50 cfu/100 mL and not more than 10% of values used to calculate the geometric mean exceeding 100 cfu/100 mL. A minimum of five samples are required for calculation of the geometric mean, and averaging beyond a 30-day period is not permitted when such averaging masks non-compliance periods.

A segment may be placed in Category 5 when either the calculated geometric mean of all samples from that segment exceeds the geometric mean criterion of 50 cfu/100 mL or more than 10% of all sample values exceed the percent criterion of 100 cfu/100 mL (Ecology 2006b). In practice, the percent criterion is calculated as the 90th percentile value based on the mean, standard deviation, and Z-score of the collected data (Ward et al., 2001).

The Water Quality Program Policy (2006) states that a segment will be placed in Category 4a when a TMDL for bacteria has been approved by EPA. The Policy also states that data from a more recent reporting period may allow a previous Category 5 listing to be moved to another category (e.g., Category 1).

Goals and Objectives

Project goals

This project has two goals:

- Gather support for the FC bacteria TMDL implementation actions.
- Support systematic review and improvement of water quality.

Study objectives

This study has two objectives:

- Determine if FC targets set by the 1999 TMDL study (Ward et al., 2001) and described in the 2003 Detailed Implementation Plan (Garland and Lawrence, 2003) have been met.
- Determine if Washington State water quality standards for FC are being met in select freshwater streams.

Methods

Monitoring of FC is used to assess (1) how the Union River's conditions match the temporal and spatial goals set by the TMDL and (2) the status of nearby waters of concern. To meet these needs, FC concentrations were estimated monthly from all sites from May 2008 – April 2009. Geometric means and 90th percentiles were calculated from the monthly data at each station. These statistics are reported on both an annual and seasonal basis. The following summarizes the methods used for this project.

Field and laboratory

Fecal coliform data were collected as part of a number of monitoring programs and special studies. Washington State Department of Ecology (Ecology) analyzed these samples with the Most Probable Number (MPN) method in 1999 as part of the Union River TMDL Study. Ecology analyzed routine ambient monitoring data, collected between 2002 and 2007, with the Membrane Filtration (MF) method.

Ecology collected monthly samples in 2008 and 2009 to evaluate TMDL effectiveness. Mason County collected monthly samples at five sites in 2003 and 2004 as part of the Lower Union River Restoration Study. The Kitsap County Health District collected samples from 2001 to 2004 at one station. Ecology approved a Quality Assurance Project Plan for the TMDL Study, Lower Union River Restoration Study, and Effectiveness Monitoring Study (Merritt, 2008).

All laboratory tests were performed at Ecology's Manchester Environmental Laboratory, accredited by Ecology.

Bacterial methodologies

Ecology used two methods to determine FC concentrations at stations identified in this report.

- The MPN method was used in the 1999 TMDL evaluation of the Union River main stem (Ward et al., 2001). For consistency in evaluating against the 1999 TMDL, the 2008-09 effectiveness monitoring study used the MPN method for all five of the TMDL stations.
- In 2008-09, Ecology sampled two sites located on Mission and Little Mission Creeks, as well as three additional sites within the Union River watershed, using the MF method. Between 2002 and 2007, Ecology collected data within the Union River watershed using the MF method.

Although data collected using the MF method were not used to compare TMDL stations with FC standards and TMDL target limits, the data were used in the trends-over-time analysis.

Data analysis

Field and laboratory data were compiled and organized using Excel® spreadsheet software (Microsoft, 2006). Statistical analyses, plots, and data calculations were performed using Excel®. Data collected from 2008-09 were compared against both the TMDL target limits and state water quality standards.

Geometric means and percentile values of FC concentrations were calculated using Excel® formulas. A geometric mean is calculated by taking the mean of log-transformed values and then back-transforming that mean to its standard scale. The 90^{th} percentile, as used here, is calculated as the 90^{th} percentile of a lognormal distribution, whose mean and standard deviation are estimated from the log-transformed data.

Trend analysis

Analyses of trends in FC concentration over time were conducted using the KENDALL program, developed by the U.S. Geological Survey (Helsel et al., 2006). KENDALL is a software package used for the calculation of annual, seasonal, and regional trend statistics. The procedure is based on the Mann-Kendall test (a non-parametric trend test) with modifications to account for seasonal and regional variations. This test identifies whether or not a statistically significant trend exists in a time-series dataset. The absolute values of Z statistics are compared to a table of critical values to determine if there is a trend at the selected level of significance (α). A positive value of Z indicates an upward trend, while a negative Z value indicates a downward trend. With α=0.1, Z scores greater than 1.64 indicate a significant increasing trend, while Z scores less than -1.64 indicate a significant decreasing trend.

General linear model

A general linear model was performed using MINITAB 13.30 to evaluate the effects of year, month, and site and their interactions on FC concentrations. The primary objective of this test is to evaluate differences between the two time periods (1999 and 2008-09), after accounting for variations in FC concentrations among months and sites. If $p<0.05$ for a model term, there are significant differences in FC concentrations among samples with different values of that term. In particular, if $p<0.05$ for year, we would conclude that FC concentrations changed over the monitoring period. Because this is a parametric test, FC concentrations are log-transformed to satisfy the assumption of normality. In the model, year and month were treated as fixed factors, and site was treated as a random factor.

TMDL Summary

In 2001, Ecology completed a TMDL study (Ward et al., 2001); the TMDL analysis was performed using data collected by Ecology in 1999. In 2002, Ecology completed a TMDL submittal report for FC in the Union River watershed (Sweet et al., 2002).

There was not enough available information on the relative contributions from the various nonpoint sources contributing to exceedance of the FC standards in the Union River to develop load allocations by source type. However, the most probable sources of contamination were identified as agricultural and livestock practices, septic tank failures, and stormwater runoff from highways and commercial businesses.

Ecology developed load allocations as percent FC reductions within each segment of the river and its tributaries. Ecology compared the percent reductions required by each part of the criteria, and the most restrictive criterion was used to establish the recommended target level or load allocation.

Although a FC TMDL can be presented as a load (cfu/day), the resulting numbers are of little value from a management perspective. For fecal coliform, it is more appropriate to represent the loading capacity as a distribution of concentrations and load reductions. Defining the loading capacity in these surrogate terms will allow monitoring data to be used to verify effectiveness of meeting the TMDL targets.

The target limits developed for FC at the five 1999 Union River monitoring stations are listed in Table 2. The locations of these five sites are displayed in Figure 3.

Table 2. Union River Watershed TMDL Monitoring Stations and Target Limits.

Station	Station Description	Agency	Reach	Latitude, Longitude (NAD83)	Limit for Geometric Mean (cfu/100 mL)	Limit for 90th Percentile (cfu/100 mL)
UR1HY300	Union River at Highway 300	Ecology	Mouth to RM 1.3	47.4522 -122.8339	44	100
UR2Tmbr	Union River at Timberline Dr	Ecology	RM 1.3 to 1.8	47.4638 -122.8312	50	54
UR3River	Union River at Old Belfair Hwy	Ecology	RM 1.8 to 4.5	47.4714 -122.8275	50	51
UR4Arch	Union River at Archery Range	Ecology	RM 4.5 to Headwaters	47.4964 -122.8019	50	57
UR5Bear	Bear Creek at Bear Creek Rd	Ecology	Bear Creek	47.4964 -122.8078	50	62

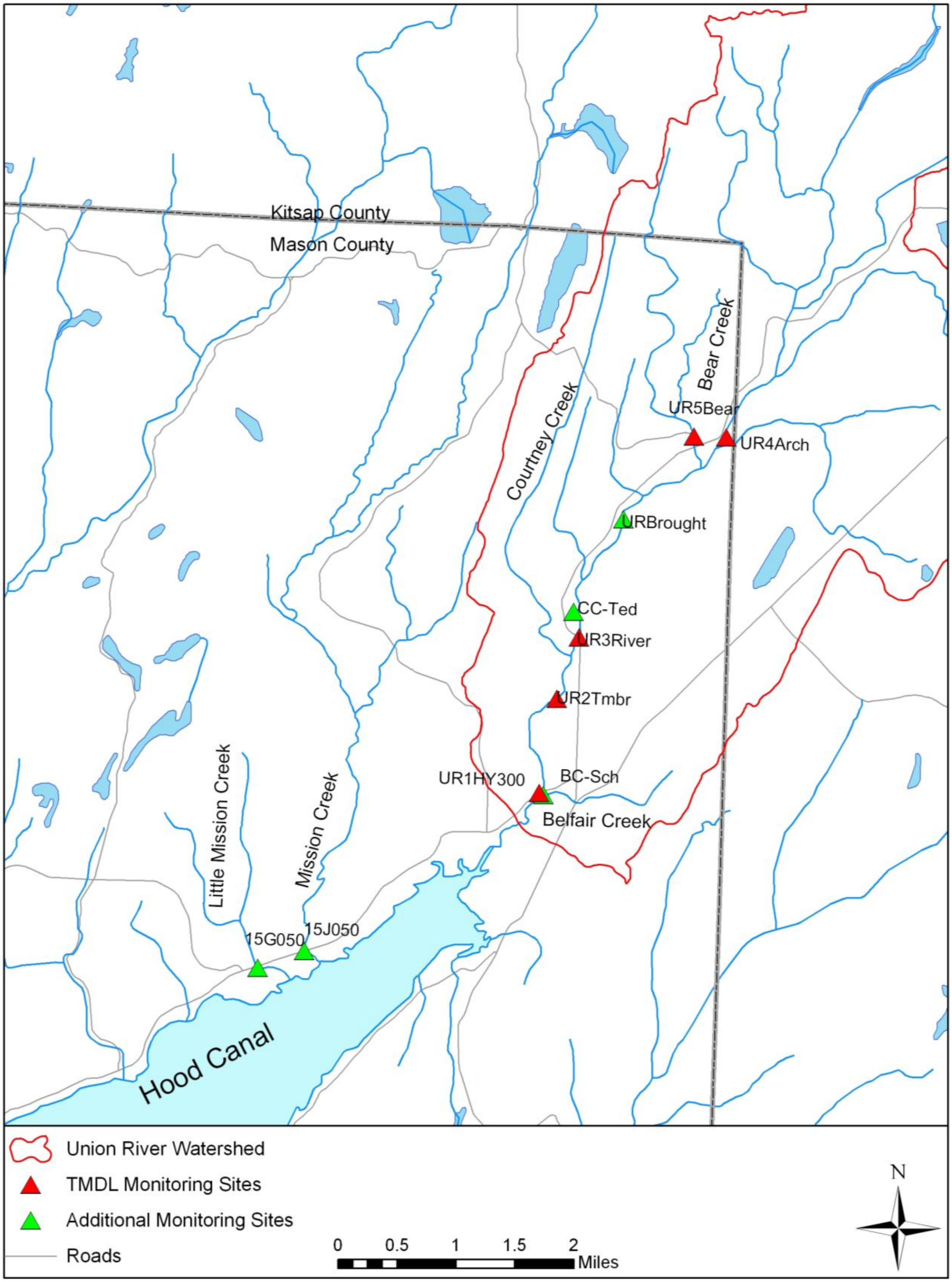

Figure 3. Location of TMDL Monitoring Stations and Additional Stations within the Union River TMDL Study Area (Cadmus Inc.).

Five additional sites, three in the Union River watershed and two in the Mission Creek watershed, were also sampled and evaluated against water quality standards. These sites and the applicable water quality standards are listed in Table 3. The locations of these sites are displayed in Figure 3.

Table 3. Additional Monitoring Stations and Applicable Water Quality Standards.

Station	Station Description	Agency	Latitude, Longitude (NAD83)	Limit for Geometric Mean (cfu/100 mL)	Limit for 90th Percentile (cfu/100 mL)
URBROUGHT	Union River at private bridge (T23N,R1W,Sec16, SW of NW)	Ecology	47.4860 -122.8201	50	100
CC-TED	Courtney Creek at mouth	Ecology	47.4745 -122.8286	50	100
BC-Sch	Belfair Creek at mouth	Ecology	47.4520 -122.8331	50	100
15G050	Little Mission Creek at Highway 300	Ecology	47.4298 -122.8838	50	100
15J050	Big Mission Creek at Highway 300	Ecology	47.4320 -122.8755	50	100

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Results and Discussion

Summary of historical data

During the 1990s, monitoring by several agencies indicated that the Union River violated the Washington State water quality standard for fecal coliform (Ward et al., 2001; Sweet et al., 2002; Garland and Lawrence, 2003). This resulted in the addition of the river to the state's 303(d) list of impaired waters. In response to the 303(d) listing, Ecology collected water quality data at approximately monthly intervals between January and December 1999 for the five Lower Union River basin stations to support development of a TMDL. Figure 4 displays the 1999 TMDL study data relative to Washington State water quality standards.

Since 1999, additional data have been collected by Ecology, Mason County, and Kitsap County.

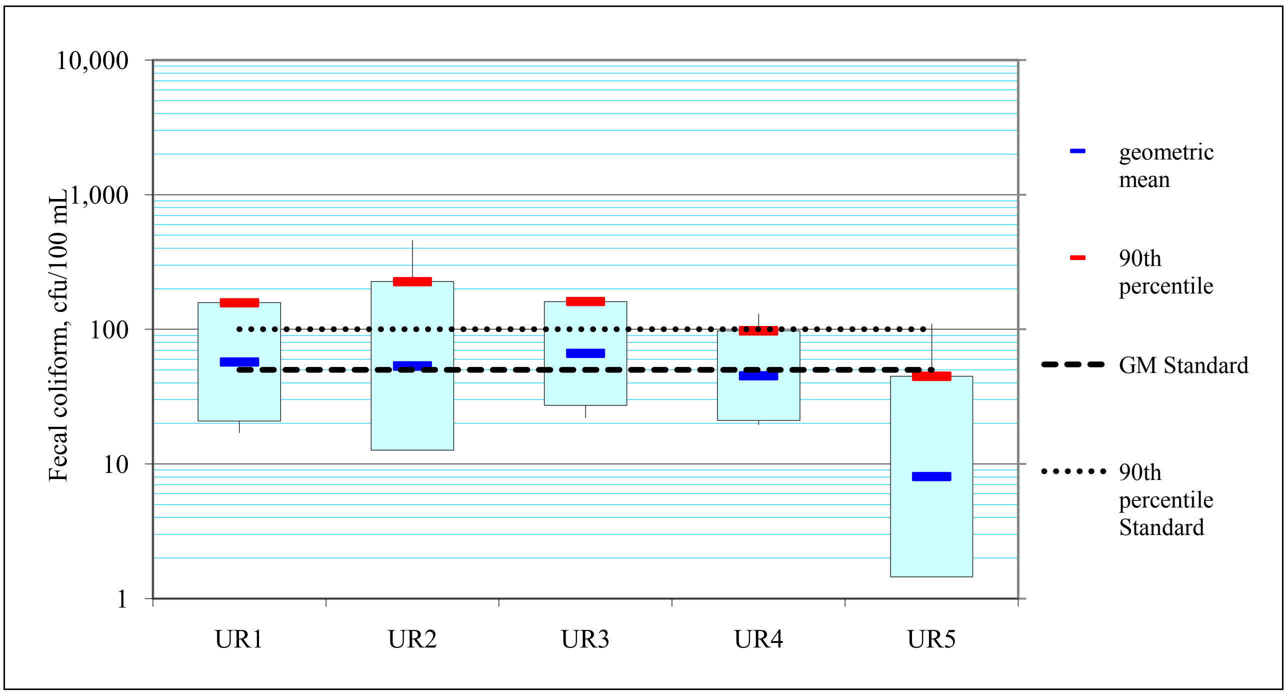

Figure 4. Annual Fecal Coliform Data from the 1999 TMDL Study (Ward et al., 2001).

Summary of effectiveness monitoring data

To evaluate the effectiveness of the implementation of nonpoint source management actions following the 1999 TMDL study, Ecology collected data between May 2008 and April 2009 at the five Union River stations. These data were compared against both the TMDL targets and state water quality standards.

Figure 5 displays these data relative to water quality standards, and Figure 6 displays the data relative to TMDL targets. Tables 4 and 5 also summarize this information. As shown in Figure 5, only one station (UR5) is meeting the 90th percentile standard. Three of the five stations are meeting the geometric mean water quality standards. However, only the Bear Creek station (UR5) is meeting both water quality standards. Therefore, Bear Creek carries over its previous Category 1 status. The other four Union River segments remain in Category 4a due to their continued exceedance of water quality standards.

The TMDL study identifies May through December as the critical period due to the elevated FC levels during the summer and a secondary increase in November and December. Due to FC exceedance at all five stations, the Detailed Implementation Plan identified the 90th percentile during the critical period as the primary criteria for performance tracking. As shown in Figure 6, during the critical period all stations are still exceeding their respective 90th percentile targets, and four of the five stations are still exceeding their respective geometric mean TMDL targets.

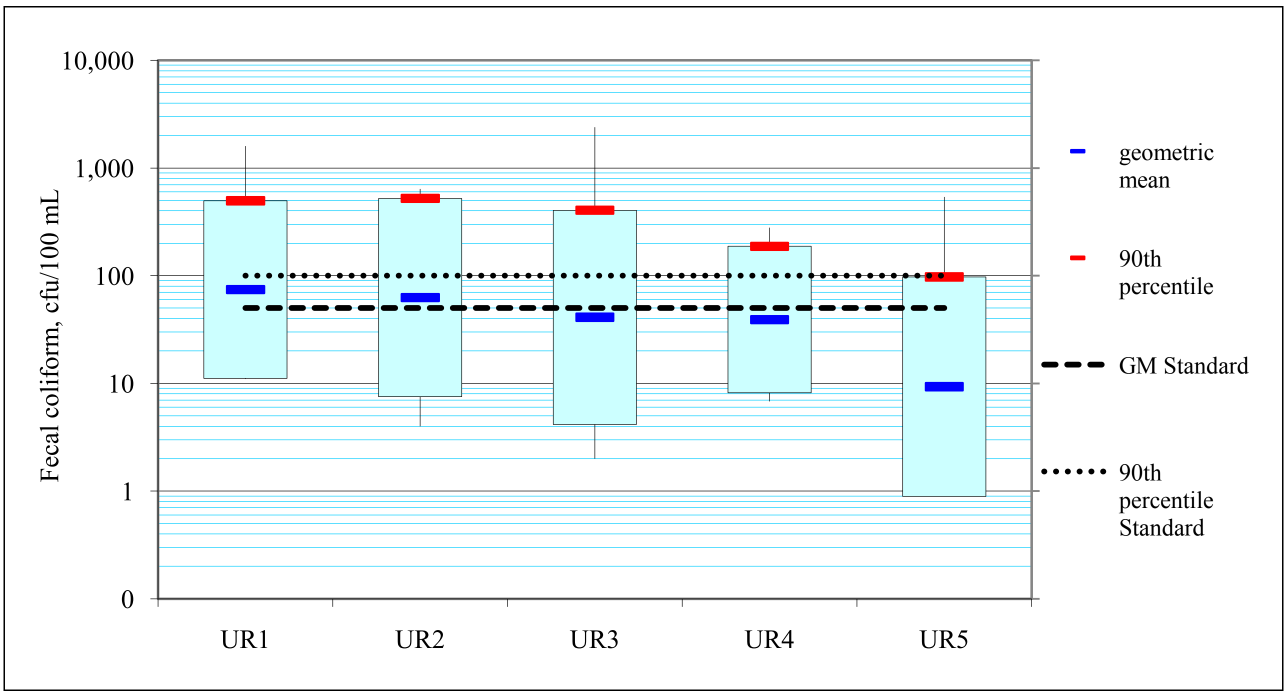

Figure 5. Comparison of Annual Fecal Coliform Data from the 2008-09 Effectiveness Monitoring Study to Washington State Water Quality Standards (Ecology, 2006a).

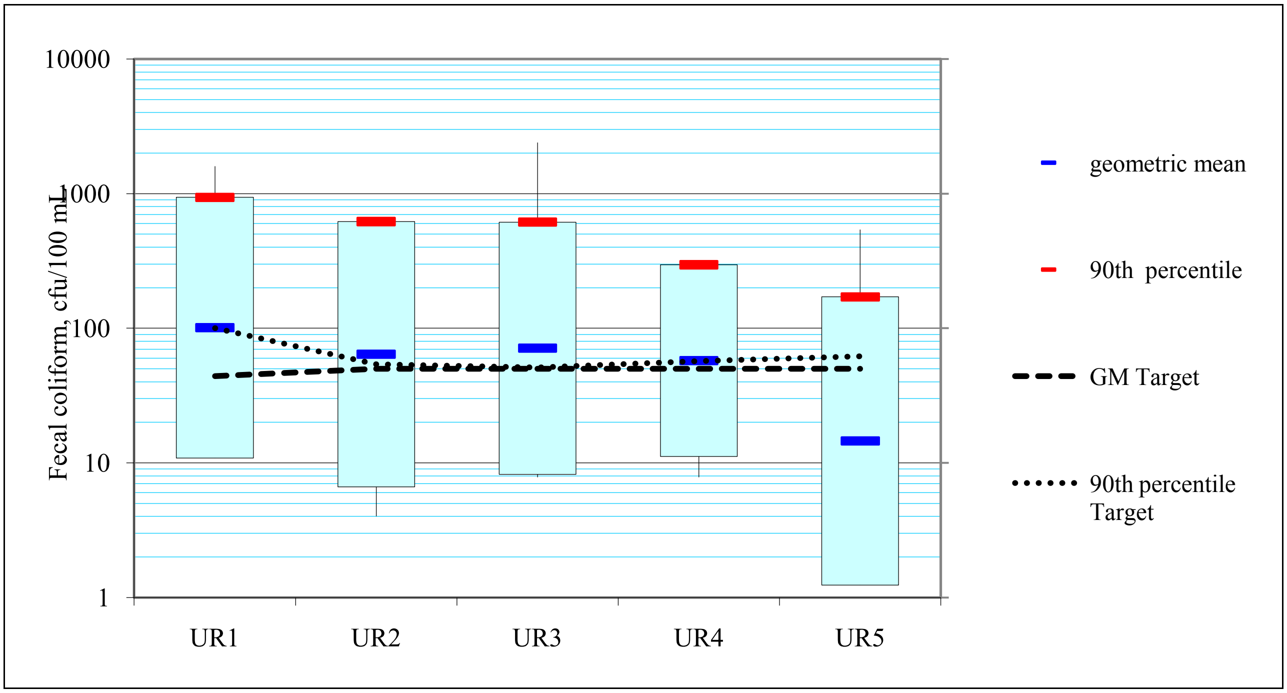

Figure 6. Comparison of Fecal Coliform Data from the 2008-09 Effectiveness Monitoring Study to the TMDL Targets for the Critical Period (May – December).

Table 4. Comparison of Annual Fecal Coliform Data from the 2008-09 Effectiveness Monitoring Study to Washington State Water Quality Standards.

Station	Water Quality Standards		2008 – 2009 Data		Meets WQS?	Category
	90th Percentile	Geometric Mean	90th Percentile	Geometric Mean		
UR1HY300	100	50	496	74	No	4a
UR2Tmbr	100	50	522	63	No	4a
UR3River	100	50	405	41	No	4a
UR4Arch	100	50	187	39	No	4a
UR5Bear	100	50	97	9	Yes	1

Table 5. Comparison of Fecal Coliform Data from the 2008-09 Effectiveness Monitoring Study to the TMDL Targets for the Critical Period (May – December).

Station	TMDL Targets		2008 – 2009 Data		Meets Target?
	90th Percentile	Geometric Mean	90th Percentile	Geometric Mean	
UR1HY300	100	44	938	101	No
UR2Tmbr	54	50	620	64	No
UR3River	51	50	615	71	No
UR4Arch	57	50	296	58	No
UR5Bear	62	50	171	15	No

As part of the effectiveness monitoring study, five additional stations were sampled to determine compliance with state water quality standards (i.e., geometric mean of 50 cfu/100 mL and 90^{th} percentile of 100 cfu/100 mL). Two of these five sites show attainment of water quality standards while three do not. This information is summarized in Table 6 and further discussed below.

Table 6. Fecal Coliform Concentrations at Additional Sample Sites During the 2008-09 Effectiveness Monitoring Study.

Station	Water Quality Standards		2008 – 2009 Data		Meets WQS?	Category
	90^{th} Percentile	Geometric Mean	90^{th} Percentile	Geometric Mean		
URBROUGHT	100	50	134	26	No	4a
CC-TED	100	50	223	21	No	4a
BC-Sch	100	50	205	21	No	4a
15G050	100	50	51	11	Yes	1
15J050	100	50	59	13	Yes	1

Stations 15G050 and 15J050, both of which are in compliance with standards, are located on the north shore of Lynch Cove, outside of the Union River watershed. Station 15J050 is not currently listed in a category, but should be listed in Category 1 since it is currently in compliance with standards. Station 15G050 was previously placed in Category 5, requiring a TMDL. Ecology's Water Quality Program Policy (2006b) states that data from the most recent reporting period may allow a previous Category 5 listing to be moved to another category. Since the 2008-09 sampling effort is comparable to the 1999 sampling effort that resulted in the Category 5 listing, Station 15G050 should now be listed in Category 1.

Stations URBROUGHT, CC-TED, and BC-Sch are not meeting (exceeding) water quality standards; however, they are located within the Union River watershed which already has a TMDL. Therefore, stream segments associated with these sites should remain in Category 4a and continue to be evaluated for compliance against the state standards. Alternatively, a TMDL target specific for these stations can be established if deemed necessary by Ecology.

Summary of water quality trends

Figure 7 shows the general relationship between precipitation and streamflow in the Union River watershed. Average streamflow data are from the gage at UR2Tmbr and contain averaged data from January to December 2007 and May to December 2008. Precipitation data are from a rainfall gage (Illahee) in Bremerton and contain averaged daily data from January 2007 to November 2009 (Weather Underground, 2009).

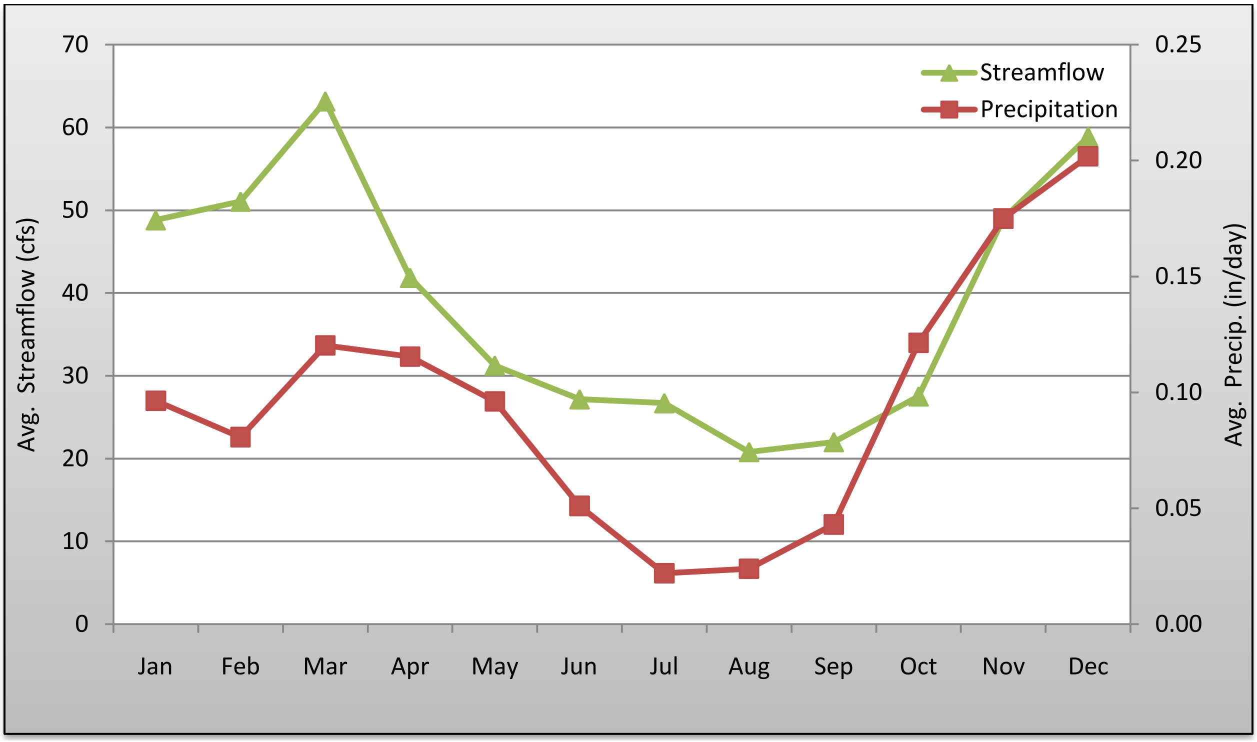

Figure 7. Average Daily Precipitation and Streamflow by Month at Bremerton, WA.

From 1999 to 2008-09, four of the five original TMDL monitoring stations show an overall increase in the 90th percentile FC concentration during the TMDL critical period (May through December). While the highest values in 1999 were primarily in the summer (Figure 8), the 2008-09 effectiveness monitoring data collected show the highest values occurring in November for all stations except UR4Arch (Figure 9).

Average streamflow on the November sampling date was about 35 cfs, within the top 15% of all available streamflow data. However, this is only slightly higher than the 31 cfs (top 23%) recorded during the December sampling event, which had very low FC levels. Streamflow was also comparable on the days preceding these sampling events. However, there was little precipitation during and preceding the December sampling event, suggesting that December's high streamflows may have been the result of releases from the Casad Dam at the Union Reservoir in the upper reaches of the watershed. Therefore, the high FC levels in November may be attributable to stormwater or agricultural runoff sources.

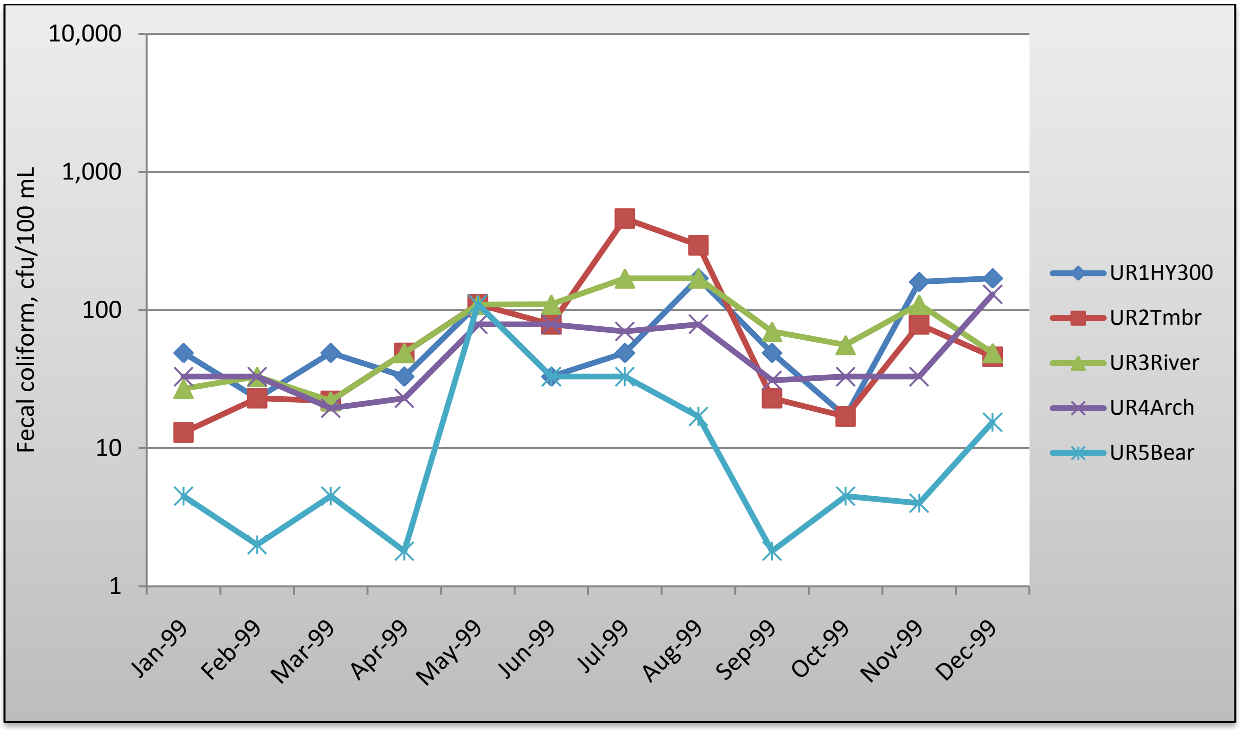

Figure 8. Monthly Fecal Coliform Data from the 1999 TMDL Study.
Note the high values during the low flow months of May - August.

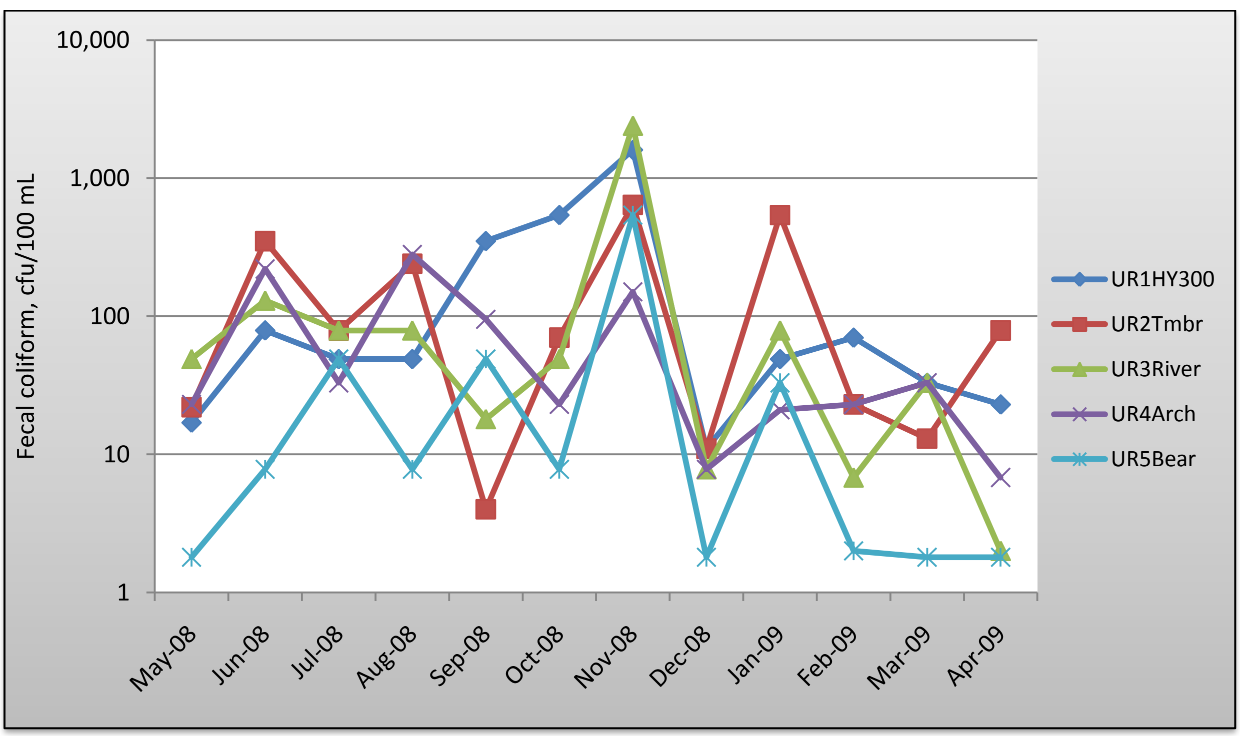

Figure 9. Monthly Fecal Coliform Data from the 2008-09 Effectiveness Monitoring Study.
Note the high values during the month of November.

Table 7 displays the results of the Seasonal Kendall test for trend at each of the five Union River TMDL monitoring stations for all years of data between 1999 and 2009. This test evaluates trends based on the raw data (i.e., individual samples, not geometric means or percentiles) for all critical period months, after accounting for differences among months, thus avoiding the identification of false trends based on monthly variability.

Additionally, a Regional Kendall test for trend was conducted on the geometric mean and 90th percentile values of the five Union River TMDL stations for all years of data between 1999 and 2009. This test evaluates watershed-wide trends, after accounting for differences among sites.

The Regional Kendall test for trend requires a summary statistic (such as geometric mean or 90th percentile), while the Seasonal Kendall test uses raw data for every month.

Table 7. Results of 1999-2008 Fecal Coliform Seasonal and Regional Trend Tests for the TMDL Critical Period.

Station	Z-Score	Trend	Statistically Significant?
UR1HY300	0.439	↑	No
UR2Tmbr	0.34	↑	No
UR3River	-0.376	↓	No
UR4Arch	0	↓	No
UR5Bear	0	↓	No
Regional geometric mean	-0.22	↓	No
Regional 90th percentile	2.348	↑	Yes (98%)

Zcrit= ±1.64.
Positive Z-Scores and "up" arrows indicate an increasing trend in FC levels and, therefore, no improvement in water quality and possible worsening of conditions.
Negative Z-Scores and "down" arrows indicate a decreasing trend and possible improvement in water quality.

The results of the Regional test show that while the geometric mean FC concentration has not significantly changed, the 90th percentile concentration has significantly increased ($p=0.02$). This result is probably mostly due to the very high sample values obtained during the November sampling event.

While the Seasonal and Regional Kendall trend tests can account for trends across a series of years, their power to detect changes is limited because differences among sites and months cannot be evaluated simultaneously. A general linear model can evaluate the effects of year, month, and site and their interactions on FC concentrations simultaneously. Its weakness is that it can only evaluate differences among years, and cannot specifically evaluate trends when more than two years of data are available.

A general linear model analysis was conducted for the Union River data (detailed results are provided in Appendix C). After accounting for the influence of site and month, there is no significant difference in the geometric mean FC level at all the sites between 1999 and 2008-09.

However, FC concentrations are significantly different *among* months and sites. In addition, monthly patterns are different in 1999 and 2008-09. These results indicate that mean FC concentrations have not changed, but that their temporal distribution among months may be changing. Additional sampling data would be useful in further evaluating whether the monthly pattern observed in 2008-09 is now typical, or whether the monthly pattern changes from year to year.

Another set of general linear models was used to evaluate differences in mean FC levels between 1999 and 2008-09 for each site independently (detailed results are provided in Appendix C). No statistically significant differences were detected. As a whole, these analyses suggest that FC levels did not change between 1999 and 2008-09. However, a power analysis indicates that concentrations would have had to decrease by 52% and 87% to be reliably detected by the all-site and individual-site analyses, respectively. For purpose of illustration, if the geometric mean FC levels were actually reduced by 25%, the all-site analysis would only have a 28% chance of detecting this change. A larger number of samples would decrease the size of the minimum detectable reductions, so additional sampling could help reduce uncertainty about whether or not reductions actually occurred.

Kernel density estimation

Kernel density estimation was used to spatially quantify areas of land-use intensity in relation to FC monitoring station locations for this 2008-09 *Union River Watershed Fecal Coliform Effectiveness Monitoring Study*. A simple hypothesis was derived on the notion that areas indicating high land-use intensity would have a significant impact on FC results. For example, land parcels are single data-point values representing the total number of land parcels along a longitudinal stream corridor from UR4Arch to UR1HY300. The Kernel density function creates a distribution of the land parcels over stream corridor areas that indicate high or low parcel intensity. The Kernel function is based on the quadratic kernel function described in Silverman (1986; p. 76, equation 4.5).

Kernel density analysis for the effectiveness monitoring study was performed within ArcView 9.3. Land-use parcels were clipped according to modified Union River HUC 6^{th} boundaries prior to Kernel density analysis. Density gradients where delineated into three classes (low, medium, high) by using the natural breaks function. A secondary Kernel density analysis was performed using R statistical software for the distribution of the land-use parcel kernel density proportion (y) along a longitudinal gradient (x). Land-use parcel data sets were imported into R from ArcView, and calculations where performed using an R library (Duong, 2008).

Laboratory analysis indicated that stations URTMBR and UR1HY300 had higher FC concentrations than the stations in the upper areas of the Union River corridor. Figure 10 represents a watershed overview based on Kernel density estimation of land-use parcels within the Union River HUC 6^{th} boundary. Figure 11 represents a 2D graph portraying the proportion of land-use parcels (land-use intensity) within the area of magnitude along the Union River stream corridor. Longitudinal coordinates were delineated from -122.78 to -122.84. FC monitoring stations were labeled along the longitudinal gradient ***x*** axis to view the spatial relationship of station locations to land-use density concentrations.

Based on the examination of the Kernel density profiles for Figures 10 and 11, stronger FC concentrations reside at stations within the proximity of higher land-use intensity between -122.83 and -122.84 than stations located between -122.79 and -122.82. High land-use areas may have an influence on FC results due to increased stormwater run-off potential by impervious surface concentrations between -122.83 and -122.84. A closer examination of stormwater inputs may provide additional evidence for possible correlation between land-use intensity and FC results.

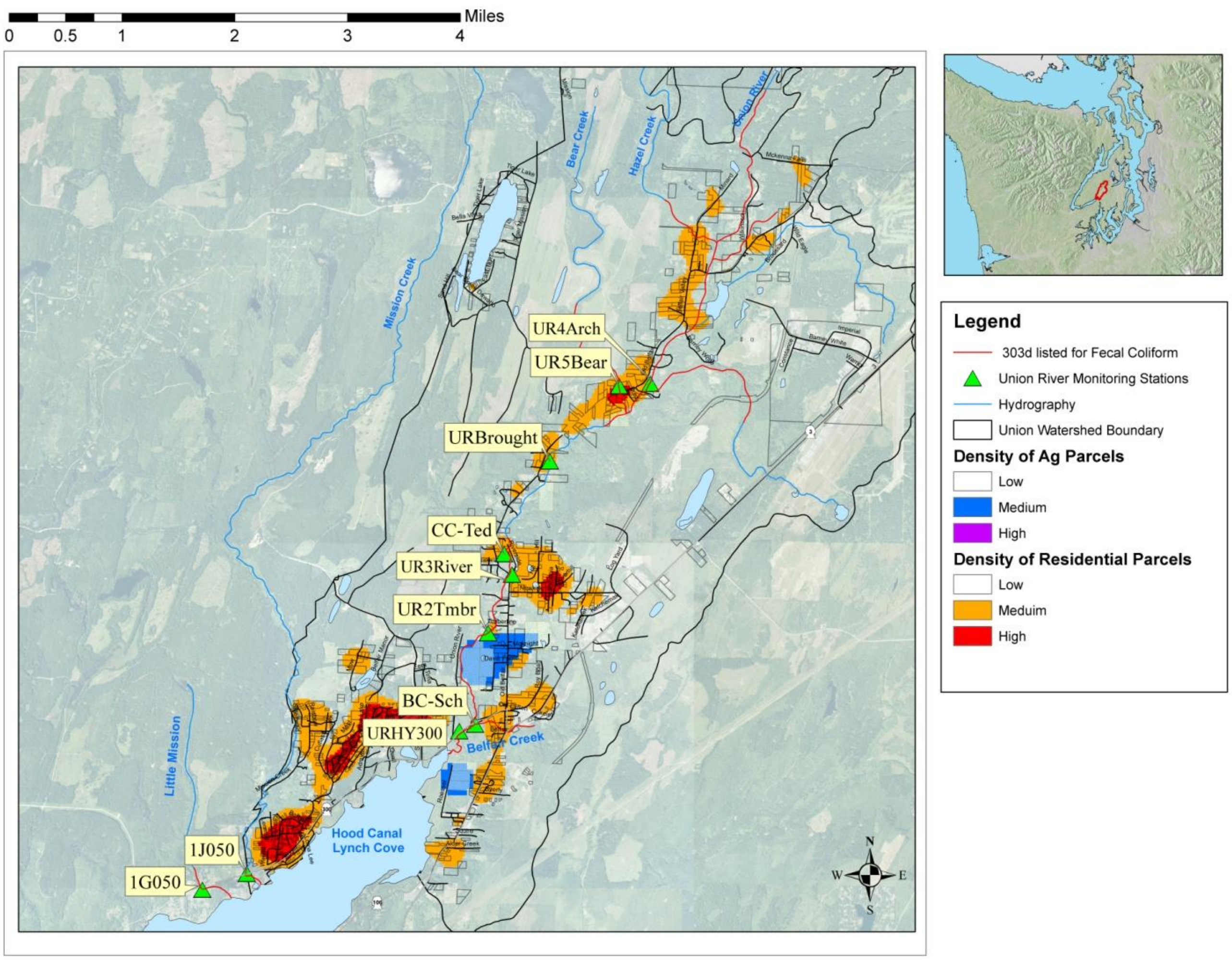

Figure 10. Kernel Density Analysis of Agricultural and Residential Land Parcels in the Union River Watershed.

Darker shades indicate the highest density of land-use parcels.

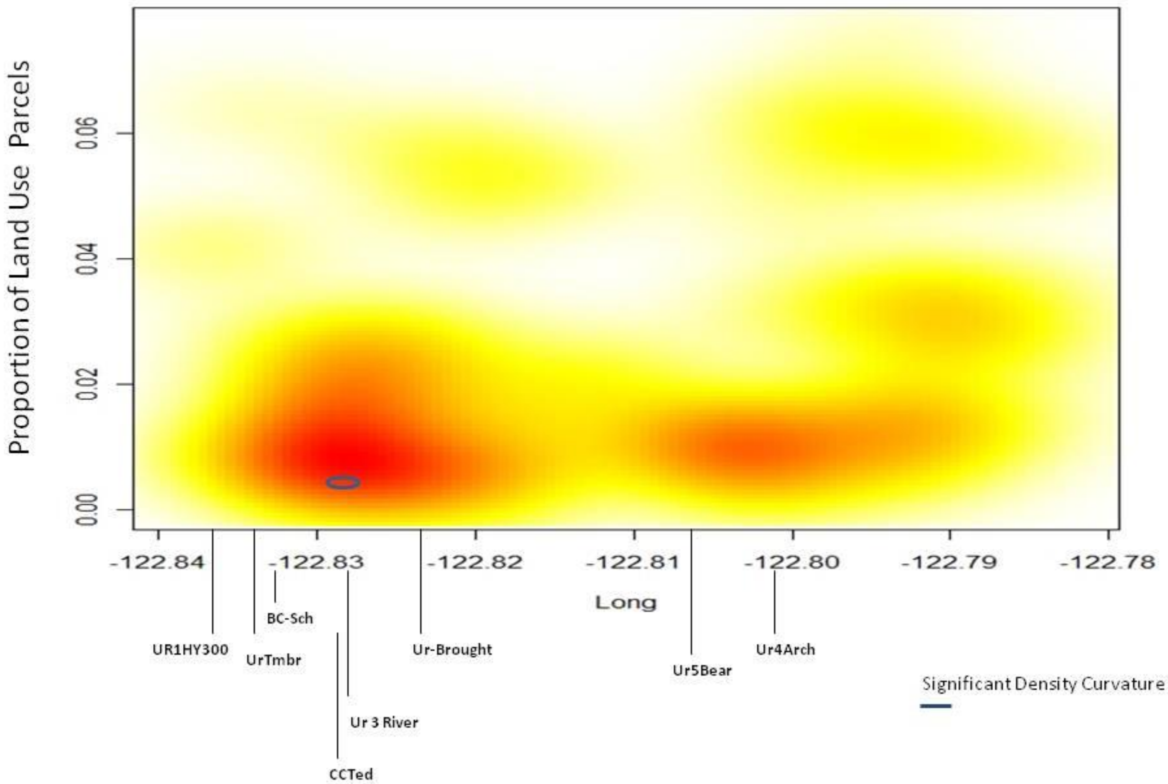

Figure 11. Proportion of Land-Use Parcels in Relation to the Longitudinal Stream Corridor on the Union River.

The blue area indicates the highest parcel density along the Union River mainstem.

National Water Program Guidance Measures

Measures SP-12 and WQ-10

The Government Performance and Results Act requires that EPA develop a 5-year strategic plan every three years. The current plan calls for the improvement of water quality in 250 watersheds using the watershed approach (Measure SP-12) and the full or partial restoration of 250 primarily nonpoint source (NPS)-impaired waterbodies nationwide (Measure WQ-10). The strategic plan refers to these targets as National Water Program Guidance Measures.

Measure SP-12 is a "demonstration" measure, used to document water quality successes that result from application of the watershed approach; the intent is not to inventory all instances where success has occurred or is underway in a state. Measure WQ-10 is the main long-term environmental results measure for the NPS program and requires that a designated use be restored or that one or more pollutants causing impairment of a designated use meet applicable criteria.

For a watershed to be counted under SP-12, states can use one of three options for demonstrating water quality improvement.

- Option 1: States must demonstrate improvement as the removal of one or more of the impairment causes identified in 2002 for at least 40% of the impaired waterbodies or impaired miles/acres.
- Option 2a: States must use valid scientific information and statistical procedures to demonstrate that significant improvement has occurred with a 90% or greater level of confidence. *Improvement* is defined as a significant watershed-wide improvement in one or more water quality parameters associated with the impairments.
- Option 2b: States can use a multiple lines of evidence approach to demonstrate watershed improvement. A "multiple lines of evidence approach" means that the cumulative weight of several lines of evidence is used to assess whether a watershed-wide improvement has occurred.

Union River watershed evaluated against Measures SP-12 and WQ-10

As part of this 2008-09 effectiveness evaluation, the Union River watershed was evaluated against requirements for Measures SP-12 and WQ-10. Based on the results of the data analysis, the watershed is neither in attainment with water quality standards nor showing an improving trend in FC levels sufficient for a WQ-10 or SP-12 recommendation.

Fecal coliform data in the Union River watershed collected between 1999 and 2009 do not demonstrate removal of impairment for at least 40% of the impaired waterbodies or impaired miles, do not demonstrate significant improvement with a 90% or greater level of confidence, and do not contain a cumulative weight of several lines of evidence to demonstrate watershed improvement. Thus, the Union River watershed does not qualify for an SP-12 recommendation. The data also do not demonstrate full or partial restoration of any 303(d) listed segments in the watershed. Thus, the watershed also does not qualify for a WQ-10 recommendation.

Results

Figure 12 displays a summary of monthly data collected in 1999 and 2008-09 relative to the two-part Washington State water quality standards for the *Extraordinary Primary Contact Recreation* designated use. These standards consist of a geometric mean criterion of 50 cfu/100 mL and a 90th percentile criterion of 100 cfu/100 mL. The geometric mean must be calculated based on at least five sample values. The 90th percentile criteria state that 10% of samples must not exceed 100 cfu/100 mL. As Figure 12 shows, none of the segments listed as impaired in 1999 are meeting water quality standards in 2008-09.

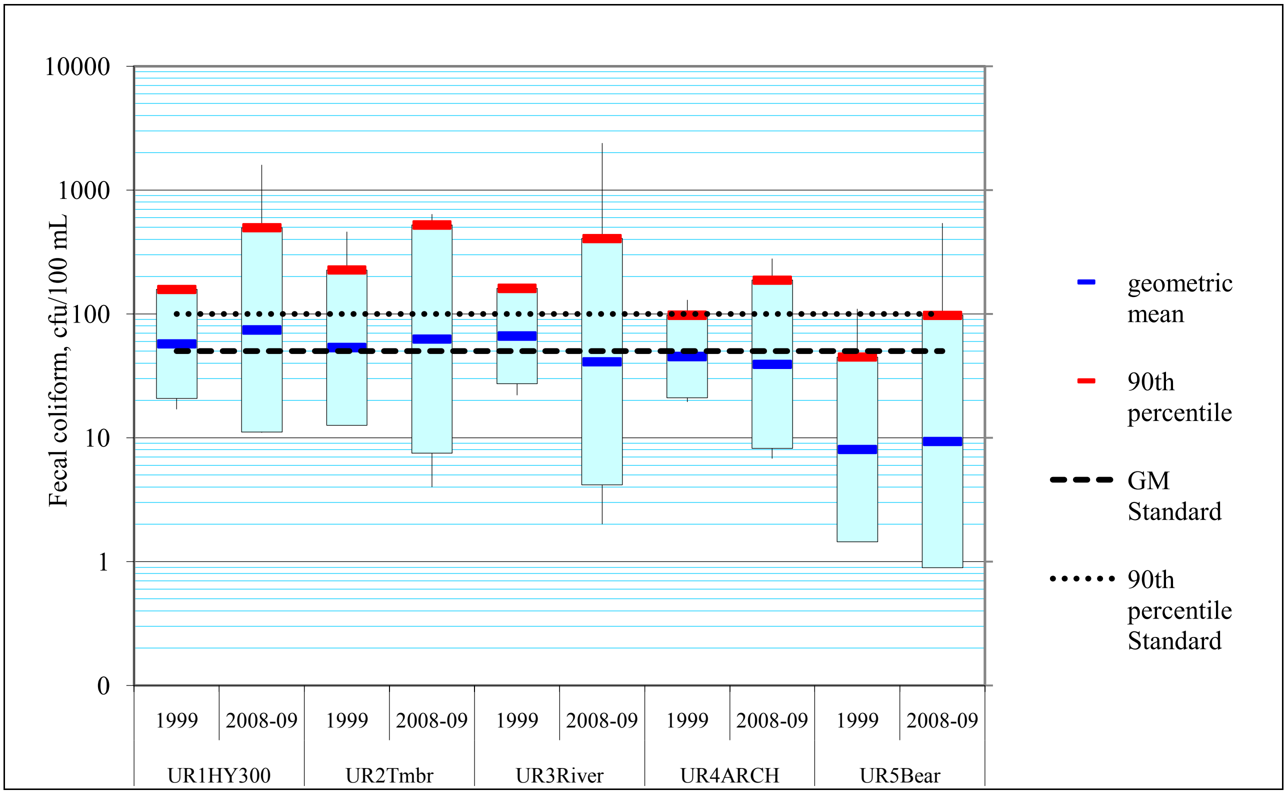

Figure 12. Fecal Coliform Sampling Results for the Critical Period (May-December) in 1999 and 2008-09 at the Five Union River TMDL Monitoring Stations.

The 1999 TMDL Study (Ward et al., 2001) and the 2003 Detailed Implementation Plan (Garland and Lawrence, 2003) identified May – December as the critical period for tracking improvements. A trend analysis was conducted on data from this critical period for all years between 1999 and 2009 for which there were data. Table 7 in the previous section displays the results of the trend analysis. The results show that there was not a significant improving trend at any of the five sampling sites or for the watershed as a whole.

Conclusions

Both TMDL targets and water quality standards are not being met in the Union River watershed. Despite the concerted efforts of numerous stakeholders in the watershed, fecal coliform bacteria (FC) levels in the river have not improved significantly.

However, a noticeable change in the timing of yearly maximum FC levels (from low-flow summer months in 1999 to high-flow winter months in 2008) suggests that the numerous on-site sewage system upgrades may be having a positive effect on water quality. Nevertheless, exceedances are still common in the summer, underlining the importance of continued on-site system upgrades and sewer connections.

The high FC levels in November 2008 are likely the result of wet-weather events, suggesting stormwater or agricultural runoff sources of FC.

The unincorporated city of Belfair and the Port of Bremerton facilities generate significant stormwater runoff, which is likely a major source of FC. For example, pet wastes deposited on curbs and paved surfaces may enter surface waters via runoff during storm events and contribute to shellfish bed FC contamination.

Recommendations

The following recommendations are suggested based on the results of this 2008-09 TMDL effectiveness monitoring study of the Union River watershed:

- Ecology should continue to monitor fecal coliform bacteria (FC) levels at all 10 current mainstem and tributary sites in the Union River watershed on at least a monthly basis. Continued sampling will allow for consistent comparison to both the 1999 TMDL study data and the 2008-09 effectiveness monitoring data. Identification of water quality trends in the presence of seasonal variation is greatly facilitated by monthly data collected over the course of multiple years.

- Two additional sites should be added to the monthly monitoring for FC.
    - The Northeast Fork of the Union River. The majority of the stormwater outfalls from the Bremerton National Airport are located on this segment. Part of the Olympic View Sanitary Landfill is also located within the drainage area for this segment.
    - The East Fork Union River. This is an impaired segment in the Union River watershed. The remainder of the Landfill is located within the drainage area of the East Fork Union River, which also contains the area where the City of Bremerton municipal biosolids are applied to forest land.

- Stakeholders should continue to support operation and maintenance of the continuous flow gage at site UR2Tmbr, operated by the Hood Canal Salmon Enhancement Group. Flow data can be helpful in evaluating the influence of rainfall on FC levels in the stream. This is useful in identifying potential FC sources.

- Stakeholders should continue to identify and correct failing on-site sewage systems.

- Stakeholders should continue outreach and education efforts to reduce FC loading from agricultural animal waste and pet waste.

- Ecology should continue to evaluate and assess the unincorporated city of Belfair and the Port of Bremerton compliance with their stormwater permits. Further, Ecology should work with each of the municipalities to evaluate the effectiveness of their Stormwater Management Programs. Ecology may want to consider revising the municipalities' permits (i.e., during the next cycle or sooner if deemed appropriate) to require implementation of more effective and/or more targeted stormwater best management practice (BMPs) to further efforts to restore water quality in the Union River watershed.

- If resources permit, Ecology should consider carrying out a wet-weather and dry-weather monitoring study of stormwater outfalls in the basin. Data obtained during wet weather storm events may help provide a better understanding of the amount of FC transported via stormwater. This can help to identify more appropriate BMPs to improve stormwater quality. Data obtained during dry-weather sampling may help to identify potential illegal or illicit discharges or connections to the municipal storm sewer systems.

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Appendices

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Appendix A. Glossary and Acronyms

Glossary

303(d) List: Section 303(d) of the federal Clean Water Act requires Washington State periodically to 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 waterbodies (ocean waters, estuaries, lakes, and streams) that fall short of state surface water quality standards, and are not expected to improve within the next two years.

Clean Water Act: 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 period: In this study, the critical period is May through December.

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

Effectiveness monitoring: Monitoring to determine whether the recommended *Detailed Implementation Plan*, after a significant portion of the recommendations or prescriptions have been implemented, is adequate in meeting (1) the goals and objectives for the TMDL project or (2) other desired outcomes over long temporal scales.

Extraordinary primary contact: Waters providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas.

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 + or - 0.2 ° Celsius.
FC 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 (GM): 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 ten 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 waters' 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 waterbody 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 waterbody.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities. This includes, but is 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 National Pollutant Discharge Elimination System Program. Generally, it refers to any unconfined and diffuse source of contamination. Legally, it refers to any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Nutrient: Substances such as carbon, nitrogen, and phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms.

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

Point source: Sources 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: Such 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 is 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: Any fish that belong to the family *Salmonidae*. Basically, any species of salmon, trout, or char. www.fws.gov/le/ImpExp/FactSheetSalmonids.htm

Spatial: How concentrations differ among various parts of the river.

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, saltwaters, wetlands and all other surface waters and water courses within the jurisdiction of the State of Washington.

Temporal trends: Characterize trends over time.

Total Maximum Daily Load (TMDL): A distribution of a substance in a waterbody designed to protect it from 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 allocation constitutes 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

Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FC	(See Glossary above)
GM	(See Glossary above)
RM	river mile
TMDL	(See Glossary above)
WAC	Washington Administrative Code

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cfu	coliform units

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Appendix B. Implementation Activities, 2004-14 and Ongoing

Table B-1. Union River Implementation Activities, 2004-14 and Ongoing.

Implementation Project	Description of Implementation Activity	Responsible Parties	Completion Date
Kitsap County			
Upper Union River Restoration Project	Through funding from Kitsap County SSWM and an Ecology CCWF Grant, the Kitsap County Health District (KCHD) conducted the Upper Union River Restoration Project. This project addressed FC contamination related to failing on-site sewage systems (OSS) and inadequately managed animal wastes through intensive site-by-site property parcel visits and inspections. KCHD is employing its proven "Pollution Identification and Correction" (PIC) protocol to identify and correct FC sources on each property parcel. FC sources were corrected through water quality/OSS information and education, and through enforcement of local OSS and solid waste regulations. KCHD sub-contracted with Kitsap Conservation District (KCD) to provide animal waste management information, education, and technical assistance. Both KCHD and KCD have loan monies and cost-share opportunities available to assist eligible property owners with financial assistance to correct FC sources.	SSWM KCHD KCD	December 2004
Port of Bremerton Industrial Stormwater Permit and Stormwater Improvements	The Port of Bremerton (POB) General Industrial Stormwater Permit will help ensure that stormwater from the airport and industrial park does not convey pollutants to the Union River. Under the permit, POB conducts quarterly monitoring of stormwater leaving the airport and industrial park. Kitsap County SSWM has an interlocal agreement to assist POB in construction and maintenance of regional stormwater facilities at the airport and industrial park. Ecology manages the State General Industrial Stormwater Permit and awarded a FY 2003 CCWF grant to POB for a stormwater management study for its business park extension.	POB SSWM Ecology	Ongoing
Port of Bremerton Large On-Site Sewage Treatment Permit	The Port of Bremerton (POB) Large On-Site Sewage System (LOSS) serves Bremerton National Airport and Olympic View Industrial Park and is operated under State Waste Discharge Permit No. ST 7390. The Port maintains the system which includes aerated treatment lagoons, a gravel berm filter, and 13-acre drainfield. The port conducts limited environmental monitoring in the vicinity of its LOSS.	POB Ecology	Ongoing
Olympic View Sanitary Landfill Closure	Closure of Olympic View Sanitary Landfill, and environmental monitoring associated with the landfill closure, are helping to ensure that landfill leachate and other landfill-associated contamination do not migrate to surface water and groundwater resources contiguous with the Union River.	KCHD-Solid Waste Division, Ecology	June 2005
Bremerton Biosolids Application Permit	Extensive environmental monitoring associated with the Bremerton Biosolids application permit will help ensure that surface and groundwater resources are not adversely affected by the project. Upgrading biosolids treatment to Class A will provide further protection.	Bremerton KCHD Ecology	Ongoing

Implementation Project	Description of Implementation Activity	Responsible Parties	Completion Date
South Kitsap Industrial Area Sewer Service	The extensive 3,400-acre industrial and business park development planned around the existing Port of Bremerton-Olympic View Industrial Park complex will ultimately be served by the Port Orchard sewer system.	Port of Bremerton	Ongoing
Kitsap Self-Help On-Site Sewage Repair Program	On a selective ongoing basis, the Kitsap Self-Help On-Site Sewage Repair Program will work with low-income applicants to diagnose and repair failing on-site systems in Kitsap County.	WOSSA volunteers	Ongoing
Mason County			
Lower Union River Restoration Study	The Mason Conservation District (MCD) received a $246,580 CCWF grant for the Lower Union River Restoration Study in 2002. The goals of the project were to identify sources of FC pollution and contaminants toxic to salmon and shellfish in the lower Union River and its estuary, implement remediation measures, develop a stormwater runoff and control plan for the Belfair Urban Growth Area, and establish a community-based watershed stewardship program. Sources of FC contamination were determined by bimonthly water quality measurements at control points over the length of the river followed by inspection and dye tests of suspected sites. Remediation actions were coordinated with property owners, and repairs were monitored. The stormwater runoff and potential pollution from the Belfair Urban Growth area will be determined by analysis, inspection, and tests. A concept plan for the stormwater management and control will be developed for future implementation by Mason County.	MCD HCSEG MCDHS Ecology, UW Sea Grant	September 2005
Belfair Sanitary Sewer Improvements	Mason County is currently planning to sewer the Belfair area via a force main to the existing North Bay-Case Inlet water reclamation facility in Allyn.	BSPG MCUWM Ecology	2012
Belfair Stormwater Improvements	MCPW is contributing to the stormwater sampling characterization for the Lower Union River Restoration Study and is committed to implementation of whatever stormwater solutions are determined for Belfair.	BSPG MCPW Ecology	2014
Hood Canal Watershed Project	Environmental science and water-quality-related education projects conducted by the Hood Canal Watershed Project will help call attention to Belfair stormwater contamination issues and ecosystem impacts of environmental pollution. The projects will also help future generations obtain ecosystem understanding and environmental appreciation.	NMSD	Ongoing
WSU Cooperative Extension Educational Programs	The WSU Cooperative Extension Program in Mason County will continue to provide environmental and water quality-related educational programs to various groups such as elementary schools and real estate professionals in the Lower Hood Canal area.	WSU	Ongoing
Road Runoff Stormwater Management	The Washington State Department of Transportation, Mason County Public Works, and Kitsap County Public Works will be responsible for implementing stormwater recommendations on SR3, Hwy 300, and county-maintained roads within the watersheds.	WSDOT KCPW MCPW	Ongoing

Acronyms in Table B-1

BSPG	Belfair Subarea Planning Group
CCWF	Centennial Clean Water Fund
DOH	Washington State Department of Health
Ecology	Washington State Department of Ecology
FY	Fiscal year
HCCC	Hood Canal Coordinating Council
HCSEG	Hood Canal Salmon Enhancement Group
KCD	Kitsap Conservation District
KCHD	Kitsap County Health District
KCPW	Kitsap County Public Works
LHCWC	Lower Hood Canal Watershed Coalition
MCD	Mason Conservation District
MCDHS	Mason County Department of Health Services
MCPW	Mason County Public Works
MCUWM	Mason County Department of Utilities/Waste Management
NMSD	North Mason School District
POB	Port of Bremerton
PSAT	Puget Sound Action Team
SSWM	Kitsap County Surface and Stormwater Management
UW Sea Grant	University of Washington Sea Grant Program
WOSSA	Washington On-Site Sewage System Association
WSDOT	Washington State Department of Transportation
WSU	Washington State University Cooperative Extension

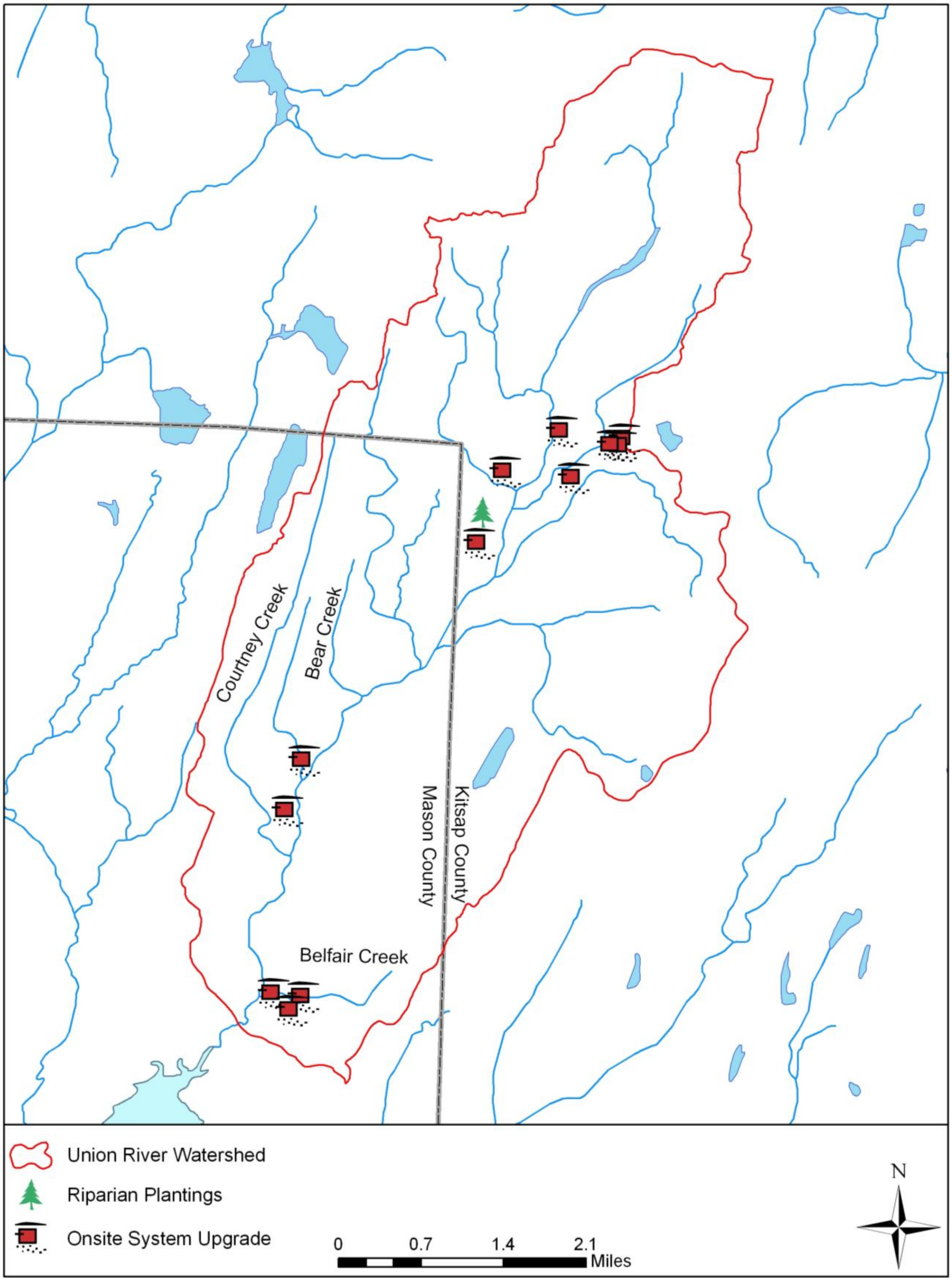

Figure B-1. Locations of Confirmed Implementation Actions.

Appendix C. General Linear Model Results

Because this is a parametric test, FC concentrations were log-transformed to satisfy the assumption of normality. In the model, year and month were treated as fixed factors and site as a random factor.

Table C-1. General Linear Model Results for All Five Sites Combined (Annual Data).

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Year	1	0.0491	0.0491	0.0491	0.35	0.586
Month	11	12.8318	12.8318	1.1665	7.73	0
Site	4	12.0858	12.0858	3.0215	21.54	0.006
Year*Month	11	9.2091	9.2091	0.8372	5.55	0
Year*Site	4	0.5612	0.5612	0.1403	0.93	0.451
Error	88	13.2805	13.2805	0.1509		
Total	119	48.0176				

Table C-2. General Linear Model Results for All Five Sites Combined (Critical Period Data).

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Year	1	0.0623	0.0623	0.0623	0.79	0.424
Month	7	6.709	6.709	0.9584	5.29	0
Site	4	6.5657	6.5657	1.6414	20.81	0.006
Year*Month	7	8.2194	8.2194	1.1742	6.48	0
Year*Site	4	0.3156	0.3156	0.0789	0.44	0.782
Error	56	10.1407	10.1407	0.1811		
Total	79	32.0126				

Table C-3. General Linear Model Results for Site UR1HY300 (Annual Data).

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Year	1	0.0541	0.0541	0.0541	0.12	0.734
Month	7	1.7854	1.7854	0.2551	0.59	0.750
Error	7	3.0389	3.0389	0.4341		
Total	15	4.8785				

Table C-4. General Linear Model Results for Site UR2Tmbr (Annual Data).

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Year	1	0.0555	0.0555	0.0555	0.27	0.620
Month	7	2.8875	2.8875	0.4125	2.00	0.191
Error	7	1.4444	1.4444	0.2063		
Total	15	4.3874				

Table C-5. General Linear Model Results for Site UR3River (Annual Data).

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Year	1	0.2583	0.2583	0.2583	0.75	0.414
Month	7	3.7145	3.7145	0.5306	1.55	0.289
Error	7	2.3975	2.3975	0.3425		
Total	15	6.3704				

Table C-6. General Linear Model Results for Site UR4ARCH (Annual Data).

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Year	1	0.0081	0.0081	0.0081	0.04	0.848
Month	7	0.9902	0.9902	0.1415	0.69	0.680
Error	7	1.4283	1.4283	0.2040		
Total	15	2.4265				

Table C-7. General Linear Model Results for Site UR5Bear (Annual Data).

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Year	1	0.0018	0.0018	0.0018	0	0.963
Month	7	1.7108	1.7108	0.2444	0.30	0.932
Error	7	5.6716	5.6716	0.8102		
Total	15	7.3842				

Table C-8. General Linear Model Results for Site UR1HY300 (Critical Period Data).

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Year	1	0.0441	0.0441	0.0441	0.15	0.704
Month	11	2.4395	2.4395	0.2218	0.76	0.669
Error	11	3.1944	3.1944	0.2904		
Total	23	5.6780				

Table C-9. General Linear Model Results for Site UR2Tmbr (Critical Period Data).

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Year	1	0.0095	0.0095	0.0095	0.04	0.841
Month	11	3.6893	3.6893	0.3354	1.49	0.260
Error	11	2.4784	2.4784	0.2253		
Total	23	6.1773				

Table C-10. General Linear Model Results for Site UR3River (Critical Period Data).

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Year	1	0.4840	0.4840	0.4840	1.56	0.238
Month	11	5.6957	5.6957	0.5178	1.66	0.206
Error	11	3.4221	3.4221	0.3111		
Total	23	9.6018				

Table C-11. General Linear Model Results for Site UR4ARCH (Critical Period Data).

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Year	1	0.0560	0.0560	0.0560	0.39	0.547
Month	11	2.1076	2.1076	0.1916	1.32	0.326
Error	11	1.5955	1.5955	0.1450		
Total	23	3.7590				

Table C-12. General Linear Model Results for Site UR5Bear (Critical Period Data).

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Year	1	0.0167	0.0167	0.0167	0.03	0.866
Month	11	4.5945	4.5945	0.4177	0.75	0.677
Error	11	6.1046	6.1046	0.5550		
Total	23	10.7157				

Abbreviations in Appendix C tables

DF	degrees of freedom
Seq SS	sequential sums of squares
Adj SS	adjusted sums of squares
Adj MS	adjusted mean of squares
F	F-statistic
P	p-value

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Appendix D. Fecal Coliform Sampling Data, 1999-2009

Table D-1. Union River FC Sampling Data, 1999-2009.

Qualifier Codes: U – below detection limit, G – above detection limit; J – estimate.

Site	Value	Units	Quali-fier	Date	Method
Ecology TMDL study, 1999					
UR1HY300	49	MPN/100mL		1/26/1999	SM16-908C
UR1HY300	23	MPN/100mL		2/23/1999	SM16-908C
UR1HY300	49	MPN/100mL		3/30/1999	SM16-908C
UR1HY300	33	MPN/100mL		4/27/1999	SM16-908C
UR1HY300	110	MPN/100mL		5/18/1999	SM16-908C
UR1HY300	33	MPN/100mL		6/29/1999	SM16-908C
UR1HY300	49	MPN/100mL		7/27/1999	SM16-908C
UR1HY300	170	MPN/100mL		8/24/1999	SM16-908C
UR1HY300	49	MPN/100mL		9/28/1999	SM16-908C
UR1HY300	49	MPN/100mL		9/28/1999	SM16-908C
UR1HY300	17	MPN/100mL		10/26/1999	SM16-908C
UR1HY300	160	MPN/100mL		11/30/1999	SM16-908C
UR1HY300	170	MPN/100mL		12/14/1999	SM16-908C
UR2TMBR	13	MPN/100mL		1/26/1999	SM16-908C
UR2TMBR	23	MPN/100mL		2/23/1999	SM16-908C
UR2TMBR	22	MPN/100mL		3/30/1999	SM16-908C
UR2TMBR	49	MPN/100mL		4/27/1999	SM16-908C
UR2TMBR	110	MPN/100mL		5/18/1999	SM16-908C
UR2TMBR	79	MPN/100mL		6/29/1999	SM16-908C
UR2TMBR	460	MPN/100mL		7/27/1999	SM16-908C
UR2TMBR	240	MPN/100mL		8/24/1999	SM16-908C
UR2TMBR	350	MPN/100mL		8/24/1999	SM16-908C
UR2TMBR	23	MPN/100mL		9/28/1999	SM16-908C
UR2TMBR	17	MPN/100mL		10/26/1999	SM16-908C
UR2TMBR	79	MPN/100mL		11/30/1999	SM16-908C
UR2TMBR	46	MPN/100mL		12/14/1999	SM16-908C
UR3RIVER	27	MPN/100mL		1/26/1999	SM16-908C
UR3RIVER	33	MPN/100mL		2/23/1999	SM16-908C
UR3RIVER	22	MPN/100mL		3/30/1999	SM16-908C
UR3RIVER	49	MPN/100mL		4/27/1999	SM16-908C
UR3RIVER	49	MPN/100mL		5/18/1999	SM16-908C
UR3RIVER	170	MPN/100mL		5/18/1999	SM16-908C
UR3RIVER	110	MPN/100mL		6/29/1999	SM16-908C

Site	Value	Units	Quali-fier	Date	Method
UR3RIVER	170	MPN/100mL		7/27/1999	SM16-908C
UR3RIVER	170	MPN/100mL		8/24/1999	SM16-908C
UR3RIVER	70	MPN/100mL		9/28/1999	SM16-908C
UR3RIVER	33	MPN/100mL		10/26/1999	SM16-908C
UR3RIVER	79	MPN/100mL		10/26/1999	SM16-908C
UR3RIVER	110	MPN/100mL		11/30/1999	SM16-908C
UR3RIVER	49	MPN/100mL		12/14/1999	SM16-908C
UR4ARCH	33	MPN/100mL		1/26/1999	SM16-908C
UR4ARCH	33	MPN/100mL		2/23/1999	SM16-908C
UR4ARCH	22	MPN/100mL		3/30/1999	SM16-908C
UR4ARCH	17	MPN/100mL		3/30/1999	SM16-908C
UR4ARCH	23	MPN/100mL		4/27/1999	SM16-908C
UR4ARCH	79	MPN/100mL		5/18/1999	SM16-908C
UR4ARCH	79	MPN/100mL		6/29/1999	SM16-908C
UR4ARCH	70	MPN/100mL		7/27/1999	SM16-908C
UR4ARCH	79	MPN/100mL		8/24/1999	SM16-908C
UR4ARCH	31	MPN/100mL		9/28/1999	SM16-908C
UR4ARCH	33	MPN/100mL		10/26/1999	SM16-908C
UR4ARCH	33	MPN/100mL		11/30/1999	SM16-908C
UR4ARCH	130	MPN/100mL		12/14/1999	SM16-908C
UR5Bear	4.5	MPN/100mL		1/26/1999	SM16-908C
UR5Bear	2	MPN/100mL		2/23/1999	SM16-908C
UR5Bear	4.5	MPN/100mL		3/30/1999	SM16-908C
UR5Bear	1.8	MPN/100mL	U	4/27/1999	SM16-908C
UR5Bear	110	MPN/100mL		5/18/1999	SM16-908C
UR5Bear	33	MPN/100mL		6/29/1999	SM16-908C
UR5Bear	33	MPN/100mL		7/27/1999	SM16-908C
UR5Bear	17	MPN/100mL		8/24/1999	SM16-908C
UR5Bear	1.8	MPN/100mL	U	9/28/1999	SM16-908C
UR5Bear	4.5	MPN/100mL		10/26/1999	SM16-908C
UR5Bear	4	MPN/100mL		11/30/1999	SM16-908C
UR5Bear	7.8	MPN/100mL		12/14/1999	SM16-908C
UR5Bear	23	MPN/100mL		12/14/1999	SM16-908C
Mason County Lower Union River Restoration Study, 2003-04					
UR1HY299	170	MPN/100mL		6/24/2003	SM19-9221E
UR1HY300	300	MPN/100mL		7/21/2003	SM19-9221E
UR1HY300	50	MPN/100mL		8/18/2003	SM19-9221E
UR1HY300	80	MPN/100mL		9/19/2003	SM19-9221E
UR1HY300	500	MPN/100mL		10/21/2003	SM19-9221E

Site	Value	Units	Quali-fier	Date	Method
UR1HY300	130	MPN/100mL		11/18/2003	SM19-9221E
UR1HY300	9	MPN/100mL		12/9/2003	SM19-9221E
UR1HY300	13	MPN/100mL		1/20/2004	SM19-9221E
UR1HY300	27	MPN/100mL		2/9/2004	SM19-9221E
UR1HY300	30	MPN/100mL		3/8/2004	SM19-9221E
UR1HY300	30	MPN/100mL		4/8/2004	SM19-9221E
UR1HY300	500	MPN/100mL		5/26/2004	SM19-9221E
UR2TMBR	90	MPN/100mL		6/24/2003	SM19-9221E
UR2TMBR	170	MPN/100mL		7/21/2003	SM19-9221E
UR2TMBR	110	MPN/100mL		8/18/2003	SM19-9221E
UR2TMBR	90	MPN/100mL		9/19/2003	SM19-9221E
UR2TMBR	300	MPN/100mL		10/21/2003	SM19-9221E
UR2TMBR	130	MPN/100mL		11/18/2003	SM19-9221E
UR2TMBR	8	MPN/100mL		12/9/2003	SM19-9221E
UR2TMBR	17	MPN/100mL		1/20/2004	SM19-9221E
UR2TMBR	2	MPN/100mL		2/9/2004	SM19-9221E
UR2TMBR	8	MPN/100mL		3/8/2004	SM19-9221E
UR2TMBR	50	MPN/100mL		4/8/2004	SM19-9221E
UR2TMBR	170	MPN/100mL		5/26/2004	SM19-9221E
UR3RIVER	50	MPN/100mL		6/24/2003	SM19-9221E
UR3RIVER	240	MPN/100mL		7/21/2003	SM19-9221E
UR3RIVER	170	MPN/100mL		8/18/2003	SM19-9221E
UR3RIVER	130	MPN/100mL		9/19/2003	SM19-9221E
UR3RIVER	130	MPN/100mL		10/21/2003	SM19-9221E
UR3RIVER	130	MPN/100mL		11/18/2003	SM19-9221E
UR3RIVER	7	MPN/100mL		12/9/2003	SM19-9221E
UR3RIVER	17	MPN/100mL		1/20/2004	SM19-9221E
UR3RIVER	8	MPN/100mL		2/9/2004	SM19-9221E
UR3RIVER	8	MPN/100mL		3/8/2004	SM19-9221E
UR3RIVER	23	MPN/100mL		4/8/2004	SM19-9221E
UR3RIVER	130	MPN/100mL		5/26/2004	SM19-9221E
URBROUGHT	65	MPN/100mL		6/24/2003	SM19-9221E
URBROUGHT	350	MPN/100mL		7/21/2003	SM19-9221E
URBROUGHT	240	MPN/100mL		8/18/2003	SM19-9221E
URBROUGHT	80	MPN/100mL		9/19/2003	SM19-9221E
URBROUGHT	95	MPN/100mL		11/18/2003	SM19-9221E
URBROUGHT	2	MPN/100mL		12/9/2003	SM19-9221E
URBROUGHT	4	MPN/100mL		1/20/2004	SM19-9221E
URBROUGHT	11	MPN/100mL		2/9/2004	SM19-9221E
URBROUGHT	8	MPN/100mL		3/8/2004	SM19-9221E

Site	Value	Units	Quali-fier	Date	Method
URBROUGHT	13	MPN/100mL		4/8/2004	SM19-9221E
URBROUGHT	130	MPN/100mL		5/26/2004	SM19-9221E
CC-TED	500	MPN/100mL		6/24/2003	SM19-9221E
CC-TED	500	MPN/100mL		7/21/2003	SM19-9221E
CC-TED	300	MPN/100mL		8/18/2003	SM19-9221E
CC-TED	130	MPN/100mL		9/19/2003	SM19-9221E
CC-TED	30	MPN/100mL		10/21/2003	SM19-9221E
CC-TED	65	MPN/100mL		11/18/2003	SM19-9221E
CC-TED	30	MPN/100mL		12/9/2003	SM19-9221E
CC-TED	130	MPN/100mL		1/20/2004	SM19-9221E
CC-TED	13	MPN/100mL		2/9/2004	SM19-9221E
CC-TED	30	MPN/100mL		3/8/2004	SM19-9221E
CC-TED	270	MPN/100mL		4/8/2004	SM19-9221E
CC-TED	280	MPN/100mL		5/26/2004	SM19-9221E
BC-SCH	1600	MPN/100mL	G	6/24/2003	SM19-9221E
BC-SCH	1600	MPN/100mL	G	7/21/2003	SM19-9221E
BC-SCH	1600	MPN/100mL	G	8/18/2003	SM19-9221E
BC-SCH	1600	MPN/100mL	G	9/19/2003	SM19-9221E
BC-SCH	1600	MPN/100mL	G	10/21/2003	SM19-9221E
BC-SCH	1600	MPN/100mL	G	11/18/2003	SM19-9221E
BC-SCH	17	MPN/100mL		12/9/2003	SM19-9221E
BC-SCH	50	MPN/100mL		1/20/2004	SM19-9221E
BC-SCH	23	MPN/100mL		2/9/2004	SM19-9221E
BC-SCH	1600	MPN/100mL	G	3/8/2004	SM19-9221E
BC-SCH	80	MPN/100mL		4/8/2004	SM19-9221E
BC-SCH	390	MPN/100mL		5/26/2004	SM19-9221E
Ecology monitoring data, 2002-07					
UR1HY299	230	cfu/100 ml		11/6/2002	SM9222D
UR1HY300	79	cfu/100 ml		1/29/2003	SM9222D
UR1HY300	54	cfu/100 ml		5/5/2003	SM9222D
UR1HY300	170	cfu/100 ml		7/8/2003	SM9222D
UR1HY300	24	cfu/100 ml		10/28/2003	SM9222D
UR1HY300	23	cfu/100 ml		5/4/2004	SM9222D
UR1HY300	94	cfu/100 ml		8/3/2004	SM9222D
UR1HY300	89	cfu/100 ml		10/4/2004	SM9222D
UR1HY300	73	cfu/100 ml		3/1/2005	SM9222D
UR1HY300	60	cfu/100 ml		6/6/2005	SM9222D
UR1HY300	55	cfu/100 ml		9/12/2006	SM9222D
UR1HY300	110	cfu/100 ml		12/19/2006	SM9222D

Site	Value	Units	Quali-fier	Date	Method
UR1HY300	22	cfu/100 ml		3/6/2006	SM9222D
UR1HY300	86	cfu/100 ml		6/20/2006	SM9222D
UR1HY300	96	cfu/100 ml		9/12/2006	SM9222D
UR1HY300	9	cfu/100 ml		12/19/2006	SM9222D
UR1HY300	19	cfu/100 ml		3/20/2007	SM9222D
UR1HY300	71	cfu/100 ml		6/12/2007	SM9222D
UR2TMBR	300	cfu/100 ml		11/6/2002	SM9222D
UR2TMBR	53	cfu/100 ml		1/29/2003	SM9222D
UR2TMBR	69	cfu/100 ml		5/5/2003	SM9222D
UR2TMBR	1200	cfu/100 ml		7/8/2003	SM9222D
UR2TMBR	22	cfu/100 ml		10/28/2003	SM9222D
UR2TMBR	100	cfu/100 ml		5/4/2004	SM9222D
UR2TMBR	110	cfu/100 ml		8/3/2004	SM9222D
UR2TMBR	29	cfu/100 ml		10/4/2004	SM9222D
UR2TMBR	80	cfu/100 ml		3/1/2005	SM9222D
UR2TMBR	44	cfu/100 ml		6/6/2005	SM9222D
UR2TMBR	60	cfu/100 ml		9/12/2006	SM9222D
UR2TMBR	51	cfu/100 ml		12/19/2006	SM9222D
UR2TMBR	6	cfu/100 ml		3/6/2006	SM9222D
UR2TMBR	36	cfu/100 ml		6/20/2006	SM9222D
UR2TMBR	105	cfu/100 ml		9/12/2006	SM9222D
UR2TMBR	16	cfu/100 ml		12/19/2006	SM9222D
UR2TMBR	40	cfu/100 ml		3/20/2007	SM9222D
UR2TMBR	92	cfu/100 ml		6/12/2007	SM9222D
URBROUGHT	160	cfu/100 ml		1/29/2003	SM9222D
URBROUGHT	53	cfu/100 ml		5/5/2003	SM9222D
URBROUGHT	120	cfu/100 ml		7/8/2003	SM9222D
URBROUGHT	110	cfu/100 ml		10/28/2003	SM9222D
URBROUGHT	3	cfu/100 ml		3/2/2004	SM9222D
URBROUGHT	36	cfu/100 ml		5/4/2004	SM9222D
URBROUGHT	94	cfu/100 ml		8/3/2004	SM9222D
URBROUGHT	42	cfu/100 ml		10/4/2004	SM9222D
URBROUGHT	48	cfu/100 ml		3/1/2005	SM9222D
URBROUGHT	57	cfu/100 ml		6/6/2005	SM9222D
URBROUGHT	62	cfu/100 ml		9/12/2006	SM9222D
URBROUGHT	18	cfu/100 ml		12/19/2006	SM9222D
URBROUGHT	6	cfu/100 ml		3/6/2006	SM9222D
URBROUGHT	70	cfu/100 ml		6/20/2006	SM9222D
URBROUGHT	310	cfu/100 ml		9/12/2006	SM9222D
URBROUGHT	7	cfu/100 ml		12/19/2006	SM9222D

Site	Value	Units	Quali-fier	Date	Method
URBROUGHT	15	cfu/100 ml		3/20/2007	SM9222D
URBROUGHT	77	cfu/100 ml		6/12/2007	SM9222D
CC-TED	490	cfu/100 ml		11/6/2002	SM9222D
CC-TED	21	cfu/100 ml		1/29/2003	SM9222D
CC-TED	24	cfu/100 ml		5/5/2003	SM9222D
CC-TED	210	cfu/100 ml		7/8/2003	SM9222D
CC-TED	31	cfu/100 ml		10/28/2003	SM9222D
CC-TED	81	cfu/100 ml		3/2/2004	SM9222D
CC-TED	590	cfu/100 ml		5/4/2004	SM9222D
CC-TED	280	cfu/100 ml		8/3/2004	SM9222D
CC-TED	71	cfu/100 ml		10/4/2004	SM9222D
CC-TED	19	cfu/100 ml		3/1/2005	SM9222D
CC-TED	12	cfu/100 ml		6/6/2005	SM9222D
CC-TED	68	cfu/100 ml		12/19/2006	SM9222D
CC-TED	3	cfu/100 ml		3/6/2006	SM9222D
CC-TED	48	cfu/100 ml		6/20/2006	SM9222D
CC-TED	360	cfu/100 ml		9/12/2006	SM9222D
CC-TED	6	cfu/100 ml		12/19/2006	SM9222D
CC-TED	4	cfu/100 ml		3/20/2007	SM9222D
CC-TED	69	cfu/100 ml		6/12/2007	SM9222D
BC-SCH	890	cfu/100 ml		11/6/2002	SM9222D
BC-SCH	2100	cfu/100 ml		1/29/2003	SM9222D
BC-SCH	9800	cfu/100 ml		5/5/2003	SM9222D
BC-SCH	8900	cfu/100 ml		7/8/2003	SM9222D
BC-SCH	4200	cfu/100 ml		10/28/2003	SM9222D
BC-SCH	49	cfu/100 ml		3/2/2004	SM9222D
BC-SCH	1	cfu/100 ml		5/4/2004	SM9222D
BC-SCH	2500	cfu/100 ml		8/3/2004	SM9222D
BC-SCH	28	cfu/100 ml		10/4/2004	SM9222D
BC-SCH	14	cfu/100 ml		3/1/2005	SM9222D
BC-SCH	27	cfu/100 ml		6/6/2005	SM9222D
BC-SCH	65	cfu/100 ml		9/12/2006	SM9222D
BC-SCH	60	cfu/100 ml		12/19/2006	SM9222D
BC-SCH	120	cfu/100 ml		3/6/2006	SM9222D
BC-SCH	100	cfu/100 ml		6/20/2006	SM9222D
BC-SCH	60	cfu/100 ml		6/12/2007	SM9222D
15J050	2	cfu/100ml		3/11/2004	SM9222D
15J050	40	cfu/100ml		3/25/2004	SM9222D
15J050	6	cfu/100ml		4/1/2004	SM9222D
15J050	292	cfu/100ml		7/9/2004	SM9222D

Site	Value	Units	Quali-fier	Date	Method
15J050	56	cfu/100ml		7/28/2004	SM9222D
15J050	58	cfu/100ml		8/18/2004	SM9222D
15J050	64	cfu/100ml		9/8/2004	SM9222D
Kitsap County Health District					
UR4ARCH	4	MPN/100mL		7/5/2001	SM9221E
UR4ARCH	17	MPN/100mL		7/31/2001	SM9221E
UR4ARCH	30	MPN/100mL		9/4/2001	SM9221E
UR4ARCH	900	MPN/100mL		10/2/2001	SM9221E
UR4ARCH	130	MPN/100mL		10/30/2001	SM9221E
UR4ARCH	13	MPN/100mL		11/27/2001	SM9221E
UR4ARCH	1	MPN/100mL		1/10/2002	SM9221E
UR4ARCH	4	MPN/100mL		1/29/2002	SM9221E
UR4ARCH	2	MPN/100mL		3/5/2002	SM9221E
UR4ARCH	8	MPN/100mL		4/2/2002	SM9221E
UR4ARCH	13	MPN/100mL		5/2/2002	SM9221E
UR4ARCH	23	MPN/100mL		6/4/2002	SM9221E
UR4ARCH	220	MPN/100mL		7/17/2002	SM9221E
UR4ARCH	50	MPN/100mL		8/15/2002	SM9221E
UR4ARCH	50	MPN/100mL		9/5/2002	SM9221E
UR4ARCH	300	MPN/100mL		10/2/2002	SM9221E
UR4ARCH	50	MPN/100mL		10/29/2002	SM9221E
UR4ARCH	4	MPN/100mL		11/26/2002	SM9221E
UR4ARCH	70	MPN/100mL		1/22/2003	SM9221E
UR4ARCH	110	MPN/100mL		2/19/2003	SM9221E
UR4ARCH	17	MPN/100mL		3/5/2003	SM9221E
UR4ARCH	22	MPN/100mL		4/1/2003	SM9221E
UR4ARCH	7	MPN/100mL		5/1/2003	SM9221E
UR4ARCH	80	MPN/100mL		6/18/2003	SM9221E
UR4ARCH	30	MPN/100mL		7/15/2003	SM9221E
UR4ARCH	300	MPN/100mL		8/27/2003	SM9221E
UR4ARCH	50	MPN/100mL		9/24/2003	SM9221E
UR4ARCH	22	MPN/100mL		10/29/2003	SM9221E
UR4ARCH	11	MPN/100mL		11/19/2003	SM9221E
UR4ARCH	2	MPN/100mL		12/23/2003	SM9221E
UR4ARCH	1	MPN/100mL		1/21/2004	SM9221E
UR4ARCH	13	MPN/100mL		2/3/2004	SM9221E
UR4ARCH	4	MPN/100mL		3/2/2004	SM9221E
UR4ARCH	4	MPN/100mL		4/6/2004	SM9221E
UR4ARCH	13	MPN/100mL		5/5/2004	SM9221E

Site	Value	Units	Quali-fier	Date	Method
UR4ARCH	50	MPN/100mL		6/1/2004	SM9221E
UR4ARCH	8	MPN/100mL		7/8/2004	SM9221E
UR4ARCH	70	MPN/100mL		8/11/2004	SM9221E
UR4ARCH	30	MPN/100mL		9/21/2004	SM9221E
Ecology EM study					
UR1HY299	17	MPN/100mL		5/5/2008	SM16-908C
UR1HY300	15	cfu/100 ml		5/5/2008	SM9222D
UR1HY300	79	MPN/100mL		6/2/2008	SM16-908C
UR1HY300	49	MPN/100mL		7/2/2008	SM16-908C
UR1HY300	49	MPN/100mL		8/4/2008	SM16-908C
UR1HY300	350	MPN/100mL		9/8/2008	SM16-908C
UR1HY300	55	cfu/100 ml		9/8/2009	SM9222D
UR1HY300	540	MPN/100mL		10/6/2008	SM16-908C
UR1HY300	1600	MPN/100mL		11/3/2008	SM16-908C
UR1HY300	11	MPN/100mL		12/1/2008	SM16-908C
UR1HY300	49	MPN/100mL		1/5/2009	SM16-908C
UR1HY300	37	cfu/100 ml		1/5/2009	SM9222D
UR1HY300	70	MPN/100mL		2/2/2009	SM16-908C
UR1HY300	33	MPN/100mL		3/9/2009	SM16-908C
UR1HY300	23	MPN/100mL		4/10/2009	SM16-908C
UR2TMBR	22	MPN/100mL		5/5/2008	SM16-908C
UR2TMBR	14	cfu/100 ml		5/5/2008	SM9222D
UR2TMBR	350	MPN/100mL		6/2/2008	SM16-908C
UR2TMBR	110	cfu/100 ml		6/2/2008	SM9222D
UR2TMBR	79	MPN/100mL		7/2/2008	SM16-908C
UR2TMBR	80	cfu/100 ml		7/2/2008	SM9222D
UR2TMBR	240	MPN/100mL		8/4/2008	SM16-908C
UR2TMBR	69	cfu/100 ml		8/4/2008	SM9222D
UR2TMBR	4	MPN/100mL		9/8/2008	SM16-908C
UR2TMBR	28	cfu/100 ml		9/8/2008	SM9222D
UR2TMBR	70	MPN/100mL		10/6/2008	SM16-908C
UR2TMBR	640	MPN/100mL		11/3/2008	SM16-908C
UR2TMBR	200	cfu/100 ml	J	11/3/2008	SM9222D
UR2TMBR	11	MPN/100mL		12/1/2008	SM16-908C
UR2TMBR	5	cfu/100 ml		12/1/2008	SM9222D
UR2TMBR	540	MPN/100mL		1/5/2009	SM16-908C
UR2TMBR	120	cfu/100 ml	J	1/5/2009	SM9222D
UR2TMBR	23	MPN/100mL		2/2/2009	SM16-908C
UR2TMBR	26	cfu/100 ml		2/2/2009	SM9222D
UR2TMBR	13	MPN/100mL		3/9/2009	SM16-908C

Site	Value	Units	Quali-fier	Date	Method
UR2TMBR	27	cfu/100 ml		3/9/2009	SM9222D
UR2TMBR	79	MPN/100mL		4/10/2009	SM16-908C
UR2TMBR	26	cfu/100 ml		4/10/2009	SM9222D
UR3RIVER	49	MPN/100mL		5/5/2008	SM16-908C
UR3RIVER	130	MPN/100mL		6/2/2008	SM16-908C
UR3RIVER	140	cfu/100 ml		6/2/2008	SM9222D
UR3RIVER	79	MPN/100mL		7/2/2008	SM16-908C
UR3RIVER	79	MPN/100mL		8/4/2008	SM16-908C
UR3RIVER	18	MPN/100mL	U	9/8/2008	SM16-908C
UR3RIVER	49	MPN/100mL		10/6/2008	SM16-908C
UR3RIVER	2400	MPN/100mL	G	11/3/2008	SM16-908C
UR3RIVER	7.8	MPN/100mL		12/1/2008	SM16-908C
UR3RIVER	79	MPN/100mL		1/5/2009	SM16-908C
UR3RIVER	67	cfu/100 ml		1/5/2009	SM9222D
UR3RIVER	6.8	MPN/100mL		2/2/2009	SM16-908C
UR3RIVER	10	cfu/100 ml		2/2/2009	SM9222D
UR3RIVER	33	MPN/100mL		3/9/2009	SM16-908C
UR3RIVER	2	MPN/100mL		4/10/2009	SM16-908C
UR4ARCH	23	MPN/100mL		5/5/2008	SM16-908C
UR4ARCH	220	MPN/100mL		6/2/2008	SM16-908C
UR4ARCH	33	MPN/100mL		7/2/2008	SM16-908C
UR4ARCH	27	cfu/100mL		7/2/2008	SM9222D
UR4ARCH	280	MPN/100mL		8/4/2008	SM16-908C
UR4ARCH	95	MPN/100mL		9/8/2008	SM16-908C
UR4ARCH	23	MPN/100mL		10/6/2008	SM16-908C
UR4ARCH	150	MPN/100mL		11/3/2008	SM16-908C
UR4ARCH	33	cfu/100mL		11/3/2008	SM9222D
UR4ARCH	8	MPN/100mL		12/1/2008	SM16-908C
UR4ARCH	21	MPN/100mL		1/5/2009	SM16-908C
UR4ARCH	12	cfu/100mL		1/5/2009	SM9222D
UR4ARCH	23	MPN/100mL		2/2/2009	SM16-908C
UR4ARCH	33	MPN/100mL		3/9/2009	SM16-908C
UR4ARCH	27	cfu/100mL		3/9/2009	SM9222D
UR4ARCH	7	MPN/100mL		4/10/2009	SM16-908C
UR5Bear	1.8	MPN/100mL	U	5/5/2008	SM16-908C
UR5Bear	7.8	MPN/100mL		6/2/2008	SM16-908C
UR5Bear	49	MPN/100mL		7/2/2008	SM16-908C
UR5Bear	7.8	MPN/100mL		8/4/2008	SM16-908C
UR5Bear	4	cfu/100mL		8/4/2008	SM9222D
UR5Bear	49	MPN/100mL		9/8/2008	SM16-908C

Site	Value	Units	Quali-fier	Date	Method
UR5Bear	7.8	MPN/100mL		10/6/2008	SM16-908C
UR5Bear	540	MPN/100mL		11/3/2008	SM16-908C
UR5Bear	1.8	MPN/100mL	U	12/1/2008	SM16-908C
UR5Bear	1	cfu/100mL	U	12/1/2008	SM9222D
UR5Bear	33	MPN/100mL		1/5/2009	SM16-908C
UR5Bear	32	cfu/100mL		1/5/2009	SM9222D
UR5Bear	2	MPN/100mL		2/2/2009	SM16-908C
UR5Bear	1.8	MPN/100mL	U	3/9/2009	SM16-908C
UR5Bear	1.8	MPN/100mL	U	4/10/2009	SM16-908C
URBROUGHT	14	cfu/100 ml		5/5/2008	SM9222D
URBROUGHT	92	cfu/100 ml		6/2/2008	SM9222D
URBROUGHT	48	cfu/100 ml		7/2/2008	SM9222D
URBROUGHT	210	cfu/100 ml		8/4/2008	SM9222D
URBROUGHT	20	cfu/100 ml		9/8/2008	SM9222D
URBROUGHT	83	cfu/100 ml		10/6/2008	SM9222D
URBROUGHT	29	cfu/100 ml		11/3/2008	SM9222D
URBROUGHT	8	cfu/100 ml		12/1/2008	SM9222D
URBROUGHT	17	cfu/100 ml		1/5/2009	SM9222D
URBROUGHT	10	cfu/100 ml		2/2/2009	SM9222D
URBROUGHT	60	cfu/100 ml		3/9/2009	SM9222D
URBROUGHT	2	cfu/100 ml		4/10/2009	SM9222D
CC-TED	440	cfu/100 ml		5/5/2008	SM9222D
CC-TED	71	cfu/100 ml		6/2/2008	SM9222D
CC-TED	95	cfu/100 ml		7/2/2008	SM9222D
CC-TED	100	cfu/100 ml		8/4/2008	SM9222D
CC-TED	31	cfu/100 ml	J	9/8/2008	SM9222D
CC-TED	19	cfu/100 ml		10/6/2008	SM9222D
CC-TED	18	cfu/100 ml		11/3/2008	SM9222D
CC-TED	5	cfu/100 ml		12/1/2008	SM9222D
CC-TED	48	cfu/100 ml		1/5/2009	SM9222D
CC-TED	1	cfu/100 ml		2/2/2009	SM9222D
CC-TED	8	cfu/100 ml		3/9/2009	SM9222D
CC-TED	1	cfu/100 ml	U	4/10/2009	SM9222D
BC-SCH	3	cfu/100 ml		5/5/2008	SM9222D
BC-SCH	11	cfu/100 ml	J	6/4/2008	SM9222D
BC-SCH	27	cfu/100 ml		7/2/2008	SM9222D
BC-SCH	48	cfu/100 ml		8/4/2008	SM9222D
BC-SCH	14	cfu/100 ml		9/8/2008	SM9222D
BC-SCH	69	cfu/100 ml	J	10/6/2008	SM9222D
BC-SCH	260	cfu/100 ml		11/3/2008	SM9222D

Site	Value	Units	Quali-fier	Date	Method
BC-SCH	3	cfu/100 ml		12/1/2008	SM9222D
BC-SCH	360	cfu/100 ml		1/5/2009	SM9222D
BC-SCH	18	cfu/100 ml		2/2/2009	SM9222D
BC-SCH	40	cfu/100 ml		3/9/2009	SM9222D
BC-SCH	1	cfu/100 ml	U	4/10/2009	SM9222D
15G050	10	cfu/100 ml		5/5/2008	SM9222D
15G050	21	cfu/100 ml		6/4/2008	SM9222D
15G050	110	cfu/100 ml		7/2/2008	SM9222D
15G050	72	cfu/100 ml		8/4/2008	SM9222D
15G050	7	cfu/100 ml		9/8/2008	SM9222D
15G050	6	cfu/100 ml	J	10/6/2008	SM9222D
15G050	4	cfu/100 ml		11/3/2008	SM9222D
15G050	12	cfu/100 ml		12/1/2008	SM9222D
15G050	16	cfu/100 ml		1/5/2009	SM9222D
15G050	4	cfu/100 ml		2/2/2009	SM9222D
15G050	2	cfu/100 ml		3/9/2009	SM9222D
15G050	12	cfu/100 ml		4/10/2009	SM9222D
15J050	7	cfu/100 ml		5/5/2008	SM9222D
15J050	44	cfu/100 ml		6/2/2008	SM9222D
15J050	23	cfu/100 ml		7/2/2008	SM9222D
15J050	32	cfu/100 ml		8/4/2008	SM9222D
15J050	35	cfu/100 ml		9/8/2008	SM9222D
15J050	24	cfu/100 ml		10/6/2008	SM9222D
15J050	44	cfu/100 ml	J	11/3/2008	SM9222D
15J050	4	cfu/100 ml		12/1/2008	SM9222D
15J050	35	cfu/100 ml		1/5/2009	SM9222D
15J050	3	cfu/100 ml		2/2/2009	SM9222D
15J050	2	cfu/100 ml		3/9/2009	SM9222D
15J050	5	cfu/100 ml		4/10/2009	SM9222D

MPN Most Probable Number.
SM Standard Method.