Burnt Bridge Creek Fecal Coliform Bacteria, Dissolved Oxygen, and Temperature Total Maximum Daily Load

Water Quality Study Design (Quality Assurance Project Plan)

July 2008

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- BBCR28DO - Burnt Bridge Creek Dissolved Oxygen TMDL
- BBCR28FC - Burnt Bridge Creek Watershed Fecal Coliform TMDL
- BBCR28TM - Burnt Bridge Creek Watershed Temperature TMDL

2004 303(d) Listings Addressed in this Study

Waterbody: Burnt Bridge Creek	
Parameter	Listing ID
Fecal Coliform	7827, 7828, 7829, 7830, 7832, 7856, 7858
Dissolved Oxygen	7836, 7839, 7840, 7841, 7844
Temperature	7837, 7847, 7848, 7855

Waterbody Number: WA-28-1040

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Abstract

Burnt Bridge Creek was included on the Washington State 2004 303(d) list of impaired waterbodies for fecal coliform bacteria, dissolved oxygen, and temperature violations of water quality standards. Burnt Bridge Creek flows through the City of Vancouver in southwestern Washington.

The Washington State Department of Ecology (Ecology) is required under Section 303(d) of the federal Clean Water Act to develop and implement Total Maximum Daily Loads (TMDLs) for impaired waters of the state. As a part of the TMDL for Burnt Bridge Creek, this technical study will (1) evaluate the relevant water quality parameters within the watershed during 2008-2009 and (2) build on previous efforts conducted by a variety of government organizations. Data collected will form the basis for allocating contaminant loads to pollutant sources.

Each study conducted by Ecology must have an approved Quality Assurance (QA) Project Plan. This plan describes the objectives of the study and the procedures to be followed to achieve those objectives.

The goal of this TMDL project is to ensure that Burnt Bridge Creek and its tributaries attain water quality standards for fecal coliform, dissolved oxygen, and stream temperature. After completion of this 2008-2009 study, a final report describing the results will be posted to the Internet. Finally a water quality improvement report will be drafted using information provided by this study.

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. Under the Clean Water Act, each state is required to have 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, as well as criteria, usually numeric criteria, to achieve those uses.

Every two years, states are required to prepare 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. To develop the list, 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 the data are used to develop the 303(d) list.

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

Category 1 – Meets standards for the parameter (or parameters) for which it has been tested.

Category 2 – Waters of concern.

Category 3 – Waters with no data available.

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

- 4a. – Has a TMDL approved and it is being implemented.
- 4b. – Has a pollution control plan 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 – on the 303d list.

TMDL process overview

The Clean Water Act requires that a TMDL (cleanup plan) be developed for each waterbody on the 303(d) list. The TMDL identifies pollution problems in the watershed and specifies how much pollution must be reduced or eliminated to achieve clean water. Then Ecology works with the local community to develop an overall approach to control the pollution, called the implementation strategy, as well as a monitoring plan to assess effectiveness of the water quality improvement activities. Summarizing this effort, a *Water Quality Improvement Report* is prepared and submitted to the U.S. Environmental Protection Agency (EPA). Once EPA approval is given, a *Water Quality Implementation Plan* must be developed within one year. This Plan identifies specific tasks, responsible parties, and timelines for achieving clean water.

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 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 pollutant 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 the pollutant 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.

Identification of the contaminant loading capacity for a waterbody is an important step in developing a TMDL. 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, which must not exceed the loading capacity.

TMDL = Loading Capacity = sum of all wasteload allocations + sum of all load allocations + margin of safety.

What Part of the Process Are We In?

Certain parameters (e.g., fecal coliform, dissolved oxygen, and temperature) within the Burnt Bridge Creek watershed do not meet Washington State water quality standards. Currently, Ecology is assembling previous data and acquiring additional data necessary for the development of a TMDL.

Why is Ecology Conducting a TMDL Study in This Watershed?

Overview

Ecology is conducting a multiple parameter TMDL study on Burnt Bridge Creek because there are several stream reaches not meeting water quality standards. The parameters addressed in this study are fecal coliform, dissolved oxygen, and temperature.

There is a high level of interest in water quality issues in the watershed, demonstrated by cooperative sampling efforts, watershed management, and concerned citizens. Ecology hopes to build on previous data collection and watershed clean-up efforts. Ecology will work with the City of Vancouver and all contributing entities to better understand the water quality problems within the Burnt Bridge Creek watershed.

Ecology will organize and conduct field work from June 2008 through August 2009. The data collected will be used to establish loading capacity as well as load and wasteload allocations for fecal coliform bacteria, dissolved oxygen, and temperature.

Study area

The TMDL study area consists of the mainstem Burnt Bridge Creek watershed, all tributaries, and major stormwater inputs. Burnt Bridge Creek is located within Water Resource Inventory Area (WRIA) 28. The stream flows through the City of Vancouver and portions of unincorporated Clark County in southwestern Washington (Figure 1).

Pollutants addressed by this TMDL

The Burnt Bridge Creek TMDL addresses fecal coliform (FC) bacteria, dissolved oxygen, and temperature (Figure 1). Additional conventional parameters, such as pH, may be added if field investigations reveal impairments.

Impaired beneficial uses and waterbodies on Ecology's 303(d) List of impaired waters

The main beneficial uses to be protected by this TMDL include:

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

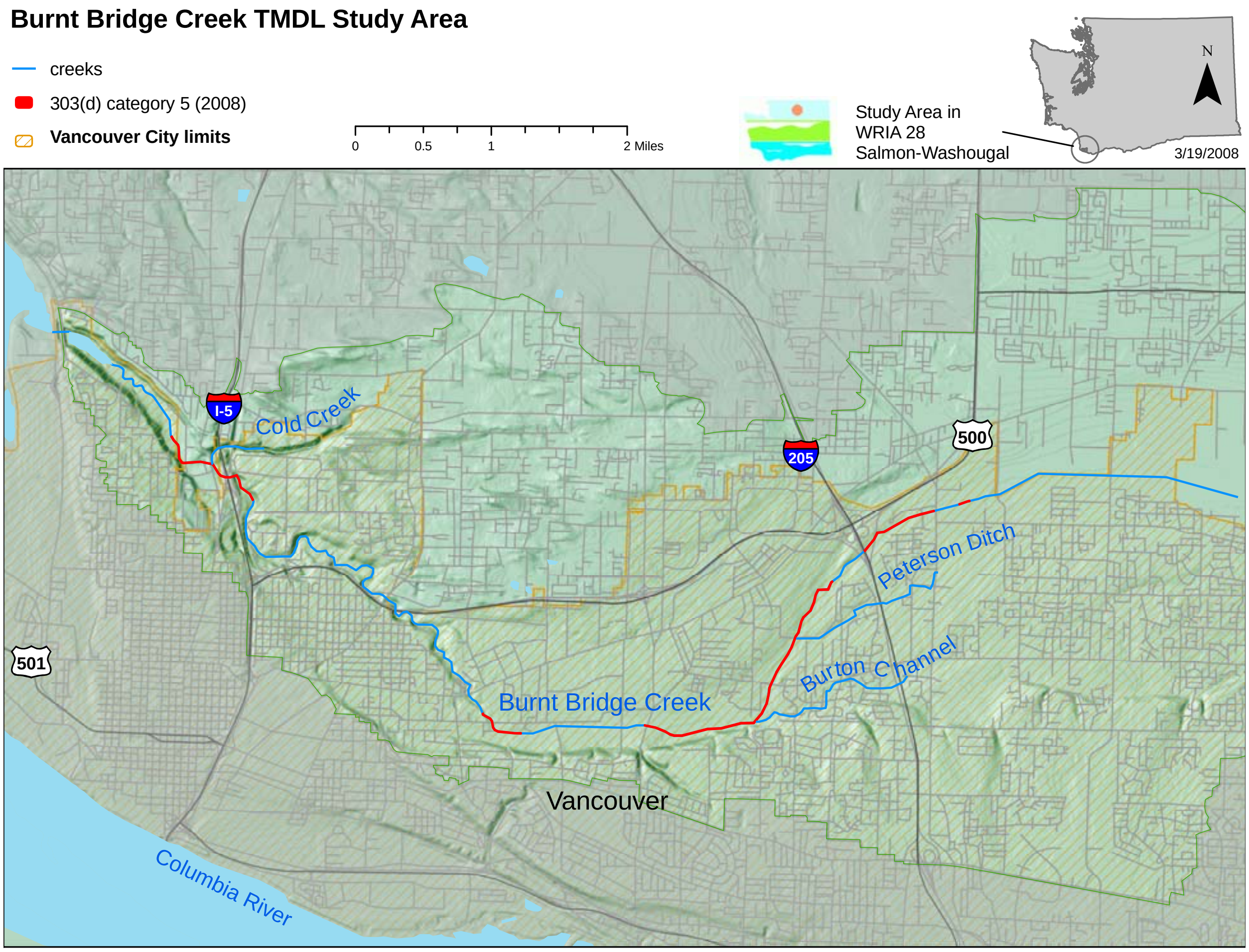

Figure 1. Study area for the Burnt Bridge Creek fecal coliform bacteria, dissolved oxygen, and temperature TMDL study in WRIA 28.

A presence/absence study of salmonids, performed in 2002-2003, found "…a few adult-sized trout, one possible adult salmon and less than a dozen juvenile trout and salmon combined…..The salmonids found in the creek were near pools and riffles and had good canopy cover" (Ehlke, 2003).

The City of Vancouver's watershed-wide management strategy to improve water quality in the Burnt Bridge Creek watershed includes an extensive greenway improvement and riparian restoration project, a targeted sewer construction and connection incentive program, enhanced stormwater treatment facilities, and an urban forestry plan designed to increase overall tree canopy cover to maximize benefits for wildlife habitat, aesthetics, and recreation.

Furthermore, the City of Vancouver drinking water is supplied by the Troutdale and Sandy River Mudstone aquifers. The Troutdale aquifer underlies the Burnt Bridge Creek watershed and was designated as a sole source aquifer in 2006 (City of Vancouver, 2006; EPA, 2006). The creek itself is not a known source of drinking water.

Washington State has established water quality standards to protect these beneficial uses. Table 1 lists the waterbodies within the study area that violate fecal coliform, dissolved oxygen, and temperature criterion established by the water quality standards. These impairments are addressed in this TMDL.

Table 1. Waterbodies in the Burnt Bridge Creek study area on the 2004 303(d) list for fecal coliform bacteria, dissolved oxygen, and temperature.

Waterbody	Parameter	Listing ID	Township	Range	Section
Burnt Bridge Creek	Dissolved oxygen	7836	02N	01E	38
		7839	02N	02E	60
		7840	02N	02E	67
		7841	02N	02E	56
		7844	02N	02E	69
	Fecal coliform	7827	02N	02E	60
		7828	02N	02E	66
		7829	02N	01E	15
		7830	02N	02E	69
		7832	02N	02E	56
		7856	02N	01E	38
		7858	02N	02E	67
	Temperature	7837	02N	01E	15
		7847	02N	01E	38
		7848	02N	02E	60
		7855	02N	02E	56

Table 2 summarizes the new listings that appear on the Draft 2008 303(d) list. This list is still under public review (comment period closed April 30, 2008); therefore, some of these listings may change/drop off depending on public comment. However, the 2008 Draft 303(d) list is being used in developing the sampling plan to target parameters and areas of concern.

Table 2. New waterbody segments in the Burnt Bridge Creek Watershed listed on the 2008 Draft 303(d) list.

Waterbody	Parameter	Listing ID	Township	Range	Section
Burnt Bridge Creek	Dissolved oxygen	7843	02N	02E	66
		47728	02N	02E	45
		47731	02N	02E	16
	Fecal coliform	45236	02N	02E	16
		46969	02N	02E	45
	Temperature	7851	02N	02E	66
		48686	02N	02E	45
		48689	02N	02E	16
	pH	7833	02N	01E	38
		7859	02N	02E	66
Peterson Ditch	Fecal Coliform	46972	02N	02E	67
	Temperature	48661	02N	02E	67

Why are we doing this TMDL now?

Ecology is initiating this TMDL for a number of reasons:

1. Since it flows through the heart of the City of Vancouver, there is much support from local agencies and citizens to improve water quality in Burnt Bridge Creek.
2. The Salmon-Washougal & Lewis Watershed Management Plan (WRIAs 27-28), adopted July 2006, recommended Burnt Bridge Creek as one of five priorities for a TMDL. The Burnt Bridge Creek recommendation was based on programs in place to address water quality impacts in the creek.
3. The Vancouver Lake Watershed Partnership was formed in 2004 to develop a strategy to improve water quality and recreational opportunities in Vancouver Lake. Burnt Bridge Creek is a tributary to the lake; therefore, information gained and clean-up activities implemented through this TMDL will benefit the Vancouver Lake Watershed Partnership effort.

How will the results of this study be used?

A TMDL study identifies how much pollution needs to be reduced or eliminated to achieve clean water. This is done by assessing the current water quality and then recommending management practices to reduce pollution, such as watershed management activities and establishing limits for facilities that have permits. Since the study may also identify the main sources or source areas of pollution, Ecology and local partners use these results to establish where to focus water quality improvement activities. Sometimes the study suggests areas for follow-up sampling to further pinpoint sources for cleanup.

Water Quality Standards and Beneficial Uses

The Washington State water quality standards, set forth in Chapter 173-201A of the Washington Administrative Code (WAC), include designated beneficial uses, waterbody classifications, and numeric and narrative water quality criteria for surface waters of the state. This section provides Washington State water quality information and those standards applicable to the Burnt Bridge Creek watershed.

In July 2003, Ecology made significant revisions to the state's surface water quality standards (Chapter 173-201A WAC). These changes included eliminating the classification system the state used for decades to designate uses for protection by water quality criteria (e.g., temperature, dissolved oxygen, turbidity, bacteria). Ecology also revised the numeric temperature criteria assigned to waters to protect specific types of aquatic life uses (e.g., native char, trout and salmon spawning and rearing, warm water fish habitat).

Ecology submitted the revised water quality standards regulation to the U.S. Environmental Protection Agency (EPA) for federal approval in July 2003. These standards were approved by EPA on February 11, 2008. The revisions to the existing standards are online at Ecology's water quality standards website: www.ecy.wa.gov/programs/wq/swqs.

The Burnt Bridge Creek watershed is listed on the 2004 303(d) list as impaired for fecal coliform bacteria, dissolved oxygen, and temperature. The applicable water quality criteria for these parameters are summarized in Table 3. pH criterion is included in the table because pH has been listed as a parameter of concern in previous state water quality assessments, and recent water quality monitoring showed some minor pH excursions. However, the pH listings will likely be excluded from the 2008 list based on recent evidence of supporting data not passing Quality Assurance analysis.

Table 3. Washington State water quality standards for impaired parameters in Burnt Bridge Creek including historical and present standards.

Water Quality Parameter	1997 Standards Classification	1997 Criteria [1]	2006 Use Classification	2006 Criteria [1]
Temperature	Class A	18°C 1-Dmax[2]	Salmonid Spawning, Rearing, and Migration	17.5°C 7-DADMax[3, 4]
Dissolved Oxygen		8.0 mg/L		8.0 mg/L 1-DMin[5]
pH		6.5 to 8.5 units		6.5 to 8.5 units
Fecal Coliform Bacteria		geomean: 100 cfu/100mL	Primary Contact Recreation	geomean: 100 cfu/100mL
		10% not to exceed: 200 cfu/100mL		10% not to exceed: 200 cfu/100mL

1. Criteria have been established in the existing water quality standards for specific waterbodies that differ from the general criteria shown in the above table. These special conditions can be found in WAC 173-201A-130 of the 1997 version, and WAC 173-201A-602 of the 2006 version of the standards.
2. 1-DMax means the highest annual daily maximum temperature occurring in the waterbody.
3. The 2006 corrected water quality standards rule contains supplemental spawning and incubation temperature criteria (13°C for salmon and trout, and 9°C for native char) that are to be applied to specific portions of many of these waters.
4. 7-DADMax means the highest annual running 7-day average of daily maximum temperatures.
5. 1-DMin means the lowest annual daily minimum oxygen concentration occurring in the waterbody.

Fecal Coliform Bacteria

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

Based on 2006 water quality standards, Burnt Bridge Creek and its tributaries are designated as protected for "Primary Contact Recreation." The *Primary Contact* use is intended for waters "where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and waterskiing." More to the point, however, the use is designated to any waters where human exposure is likely to include exposure of the eyes, ears, nose, and throat. Since children are also the most sensitive group for many of the waterborne pathogens of concern, even shallow waters may warrant primary contact protection.

To protect this *Primary Contact* use category: "Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200 colonies/100mL". [WAC 173-201A-200(2)(b), 2006 edition].

Compliance is based on meeting both the geometric mean criterion and the 10% of samples (or single sample if less than ten total samples) limit. In Washington State fecal coliform TMDL studies, the upper limit statistic (i.e., not more than 10% of the samples shall exceed) has been interpreted as a 90^{th} percentile value of the log-normalized values (Cusimano, 1997; Joy, 2000; Sargeant, 2002). 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. While some discretion exists for selecting sample-averaging periods, compliance will be evaluated for both monthly (if five or more samples exist) and seasonal (summer versus winter) data sets.

The criteria for fecal coliform are based on allowing no more than the pre-determined risk of illness to humans that work or recreate in a waterbody. Once the concentration of fecal coliform in the water reaches the numeric criterion, human activities that would increase the concentration above the criteria are not allowed. If the criterion is exceeded, the state will require that all known and reasonable technologies and targeted best management practices be implemented to reduce human impacts and bring fecal coliform concentrations into compliance with the standard.

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

Dissolved oxygen

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

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

In the Washington State water quality standards, freshwater aquatic life use categories are described using key species (salmonid versus warm-water species) and life-stage conditions (spawning versus rearing). Minimum concentrations of dissolved oxygen are used as criteria to protect different categories of aquatic communities [WAC 173-201A-200; 2006 edition].

For the Burnt Bridge Creek TMDL, the following designated aquatic life use(s) and criteria are to be protected: “Salmonid Spawning, Rearing, and Migration” where the lowest 1-day minimum oxygen level must not fall below 8.0 mg/L more than once every ten years on average.

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

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

Temperature

Temperature affects the physiology and behavior of fish and other aquatic life. Temperature may be the most influential factor limiting the distribution and health of aquatic life and can be greatly influenced by human activities.

Temperature levels fluctuate over the day and night in response to changes in climatic conditions and river flows. Since the health of aquatic species is tied predominantly to the pattern of maximum temperatures, the criteria are expressed as the highest 7-day average of the daily maximum temperatures (7-DADMax) occurring in a waterbody.

In the state water quality standards, aquatic life use categories are described using key species (salmon versus warm water species) and life-stage conditions (spawning versus rearing) [WAC 173-201A-200; 2006 edition].

The temperature water quality standards for the Burnt Bridge Creek watershed protect the designated aquatic life uses of "Salmonid, Spawning, Rearing, and Migration, and Salmonid Rearing and Migration." For these waters, the highest 7-DADMax temperature must not exceed 17.5°C (63.5°F) more than once every ten years on average.

Washington State uses the criteria described above to ensure that where a waterbody is naturally capable of providing full support for its designated aquatic life uses, that condition will be maintained. The standards recognize, however, that not all waters are naturally capable of staying below the fully protective temperature criteria. When a waterbody is naturally warmer than the above-described criteria, the state provides an allowance for additional warming due to human activities. In this case, the combined effects of all human activities must not cause more than a 0.3°C (0.54°F) increase above the naturally higher (inferior) temperature condition.

In addition to the maximum criteria noted above, compliance must also be assessed against criteria that limit the incremental amount of warming of otherwise cool waters due to human activities. When water is cooler than the criteria noted above, the allowable rate of warming up to, but not exceeding, the numeric criteria from human actions is restricted to:

1. Incremental temperature increases resulting from individual point source activities must not, at any time, exceed 28/T+7 as measured at the edge of a mixing zone boundary (where "T" represents the background temperature as measured at a point or points unaffected by the discharge).
2. Incremental temperature increases resulting from the combined effect of all nonpoint source activities in the waterbody must not at any time exceed 2.8°C (5.04°F).

Special consideration is also required to protect spawning and incubation of salmonid species. Where Ecology determines the temperature criteria established for a waterbody would likely not result in protective spawning and incubation temperatures, the following criteria apply:

1. Maximum 7-DADMax temperatures of 9°C (48.2°F) at the initiation of spawning and at fry emergence for char.

2. Maximum 7-DADMax temperatures of 13°C (55.4°F) at the initiation of spawning for salmon and at fry emergence for salmon and trout.

Burnt Bridge Creek has not been identified as a waterbody requiring this designation under WAC 172-201A; therefore, these supplemental temperature criteria do not apply to this TMDL.

Global climate change

Changes in climate are expected to affect both water quantity and quality in the Pacific Northwest (Casola et al., 2005).

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

The predicted changes to our region's climate highlight the importance of protecting and restoring the mechanisms that help to cool stream temperatures. Stream temperature improvements obtained by growing mature riparian vegetation corridors along stream banks, reducing channel widths, and enhancing summer baseflows may all help to minimize the changes anticipated from global climate change. It will take considerable time, however, to reverse human actions that contribute to excess stream warming. The sooner such restoration actions begin and the more complete they are, the more effective we will be in offsetting some of the detrimental effects on our stream resources.

Restoration efforts may not cause streams to meet the numeric temperature criteria everywhere or in all years. However, they will maximize the extent and frequency of healthy temperature conditions, creating long-term and crucial benefits for fish and other aquatic species.

Ecology is writing this TMDL to meet Washington State's water quality standards based on current and recent climate patterns. Potential changes in stream temperature associated with global climate change may require further modifications to the human-source allocations at some future time. However, the best way to preserve our aquatic resources and to minimize future disturbance to human industry would be to begin now to protect as much of the thermal health of our streams as possible.

Watershed Description

Burnt Bridge Creek is located in Clark County in southwestern Washington. The basin comprises a small portion of the Salmon-Washougal WRIA 28. Burnt Bridge Creek flows from east to west through the City of Vancouver draining approximately 27.6 square miles. From its headwaters near NE 162nd Avenue, Burnt Bridge Creek flows 12.7 river miles to its confluence with Vancouver Lake near Interstate-5 (PBS, 2006). Vancouver Lake drains to the Columbia River through Lake River.

There are two minor tributaries that flow into Burnt Bridge Creek east of NE 86th Avenue. Peterson Channel conveys industrial discharge and urban stormwater runoff to Burnt Bridge Creek near the southern end of the Royal Oaks Country Club. Burton Channel, which also initiates east of Interstate-205, joins the creek south of Burton Road, near the southern end of Meadow Brook Marsh. A third tributary, Cold Creek, flows west through unincorporated Clark County and joins Burnt Bridge Creek approximately 2 miles upstream of Vancouver Lake west of I-5.

Prior to European settlement of the area, Burnt Bridge Creek emanated from a series of wetlands located near present day NE 18th Street, (at river mile 5.4). By the mid 1800s, many area wetlands had been drained and channelized to provide agricultural lands. The gradient for most of Burnt Bridge Creek is very low and naturally lends to the formation of wetlands. Downstream of NE 18th Street, the creek gradient becomes steeper and flows through a ravine. Below I-5, the stream gradient decreases again as it flows through a ditch across a broad plain before its confluence with Vancouver Lake (PBS, 2006).

Presently, the Burnt Bridge Creek watershed is highly urbanized, including little agriculture, industrial, commercial, and greenway spaces along the stream's riparian corridor (City of Vancouver, 2008). Vancouver is the largest urban center in WRIA 28, with a population of 160,800 (WA OFM, 2007). Roughly 80% of the tree canopy in the once forested watershed has been removed (City of Vancouver, 2007).

The City of Vancouver began the Burnt Bridge Creek Greenway Improvement Project (Greenway Project) in 2004. The Greenway Project was designed to enhance water quality, wildlife habitat, wetlands, riparian vegetation, and recreation with features such as infiltration basins, bioswales, vortexing manholes, water quality ponds, and wetlands. As part of the project, recent construction connected 3.5 miles of new trail to an existing 8-mile trail parallel to the river (Walsh, 2007).

Hydrology

Historically, Burnt Bridge Creek is a groundwater-fed system. Currently, streamflows from late fall through spring are predominantly influenced by precipitation. Summer flows are maintained by natural groundwater inflow coupled with substantial pumped groundwater discharges from an industrial facility located east of I-205 that feed Peterson Channel.

Continuous flow gages

The U.S. Geological Survey (USGS) operated three continuous streamflow gages on Burnt Bridge Creek from 1998 to 2000. As expected, the highest streamflows occurred during winter months, and the low-flow period occurred during the fall. Table 4 summarizes the maximum, minimum, and annual mean streamflow at each gaging station.

Table 4. Summary flow statistics (cfs) for USGS stations located on Burnt Bridge Creek.

USGS Station Number and Description	Flow (cfs)		
	Maximum	Minimum	Mean
14211902 Burnt Bridge Creek near mouth	149	5.4	24.8
14211898 Burnt Bridge Creek at 18th St	96	4.4	18.6
14211895 Burnt Bridge Creek at 112th Ave	29	0.89	7.52

Clark County collected continuous flow data from four gages between 1988 and 1998. The gages at Alki Point and 18th Street were operated for 10 consecutive years; therefore, 7Q-statistics were calculated for these stations. Table 5 summarizes the flow statistics for each gaging station.

Table 5. Summary flow statistics (cfs) for Clark County stations located on Burnt Bridge Creek.

Flow Statistics	Alki Pt (1988 - 1998)	18th St (1988 - 1998)	Royal Oaks (1988 - 1993)	Cold Creek (1995 - 1998)
Max. Avg. Daily	295.7	172.5	62.3	52.2
Min. Avg. Daily	0.1	1.3	0.6	0.1
Avg. Daily	24.8	13.8	9.2	2.8
7Q10 (all months)	0.4	1.4		
7Q2 (all months)	6.2	3.5		
7Q10 (July-Aug)	1.1	3.1		
7Q2 (July-Aug)	7.1	3.6		

Surface water rights

There are 24 surface water rights on record for Burnt Bridge Creek. However, only two water rights are greater than 0.25 cfs, such as 1.21 cfs and 2.5 cfs. The majority of the rights allow withdrawals of no more than 0.05 cfs. Many of these water rights may no longer be active.

Seepage surveys

The USGS conducted two seepage studies of Burnt Bridge Creek: one on September 15, 1987 and a second on October 7, 1988. Seepage studies are used to quantify groundwater and surface water interactions at a given time.

The seepage studies show that Burnt Bridge Creek gained water from groundwater inputs between river mile (RM) 8.9 (112th Avenue) and RM 5.0 (18th Street). However, from RM 5.0

(18th Street) to RM 2.2 (Leverich Park) the results from the two seepage studies differ. The September survey indicated a gain (upwelling) of 0.44 cfs from RM 5.0 to 3.6. The October survey indicated a loss of 0.04 cfs along the same reach. The September survey indicated a loss (downwelling) of 0.01 cfs from RM 3.6 to 2.2, and the October survey indicated a gain of 0.66 cfs. From RM 2.2 to 1.0 (Alki Road and 2nd Avenue), both seepage studies indicated downwelling (average of -0.18 cfs). The study concluded that groundwater discharge to the creek varies seasonally (McFarland and Morgan, 1996).

Geology

WRIA 28 primarily consists of continental sediments from the late Miocene, Pliocene, and Pleistocene eras. Eight hydrologic units make up three major subbasins. The youngest subbasin consists of unconsolidated sedimentary rock. The next oldest subbasin consists of sedimentary rock known as the Troutdale aquifer. The third subbasin includes older rocks from marine sediments, basalt, volcanic breccia, and volcaniclastic sediment.

During the late Pleistocene era, the Missoula floods deposited large quantities of sediments over the Troutdale Formation. Burnt Bridge Creek flows through these sediments consisting of basaltic boulders and cobbles with a matrix of silt, clay, gravels, and loam (Wade, 2001). These soils tend to drain at a fast rate creating groundwater infiltration (for example, the Burton sink located in the eastern portion of the watershed). Low lying portions of the broad creek channel, in the central portion of the watershed, developed lake and marsh conditions which accumulated deep peat and muck deposits over the centuries. The streambed itself is mostly covered with silt, leaving minimal areas of exposed gravel appropriate for salmonid redds.

Climate

Burnt Bridge Creek resides in the West Coast Marine Climate Region that includes the Pacific coast from southeastern Alaska to northern California (City of Vancouver, 2002). The Columbia River and Pacific Ocean (70 miles to the west) moderate temperatures lending to a maritime climate. As a result, Vancouver experiences mild, cool, wet winters, and relatively dry, warm summers. The Willapa Range to the west and the relatively taller Cascade Range to the east influence the climate as well. In Clark County, the average air temperatures range from 65°F to 40°F during the summer and winter, respectively. Severe temperature extremes are not common. Average annual rainfall for Vancouver is 41.3 inches (Wade, 2001).

Wildlife

Burnt Bridge Creek supports fish species such as coho salmon (*Oncorhynchus kisutch*), chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*Oncorhynchus mykiss*), cutthroat trout (*Oncorhynchus clarki*), sculpin (Family Cottidae), red-sided shiners (*Richardsonius balteatus*), sticklebacks (Family Gasterosteidae), leopard dace (*Rhinichthys falcatus*), and lamprey larvae (ammocoetes) (Family Petromyzontidae). These data are based on two fish surveys conducted by the Pacific States Marine Fisheries Commission for the City of Vancouver during the winter of 2002 and the spring of 2003 (Ehlke, 2003).

The Burnt Bridge Creek watershed provides habitat for many land species particularly along the riparian corridor and wetlands. Both resident and migratory birds rely on the area for food and raising their young. Mammals, amphibians, and reptiles also live in the watershed.

Vegetation

Historically, hardwood species such as alder (Alnus spp), cottonwood (*Populus balsamifera*), maple (*Acer macrophyllum*), and willow (Salix spp) dominated the canopy along the riparian corridor. Other tree species include western hemlock (*Tsuga heterophylla*), Douglas fir (*Pseudotsuga menziesii*), and western red cedar (*Thuja plicata*). Understory species include vine maple (*Acer circinatum*), huckleberry (Vaccinium spp), salal (*Gaultheria shallon*), ferns (Division Pteridophyta), and devil's club (*Oplopanax horridus*).

Humans have altered the vegetation dramatically along Burnt Bridge Creek. Exotic black berries (*Rubus armeniacus*) and reed canary grass (*Phalaris arundinacea*) are now very common (Wade, 2001).

Potential sources of contamination

Industrial Wastewater

SEH America manufactures single-crystal silicon ingots (CZ) and polished (CW/PW) and epitaxial (EPI) wafers. SEH America is part of Shin-Etsu Handotai, Ltd, the largest producer of semiconductor silicon in the world, headquartered in Tokyo.

All of the process wastewater generated at the facility, approximately 3.1 cfs or 2.0 million gallons per day (mgd), is collected and discharged to the City of Vancouver's Marine Park wastewater treatment facility (Industrial Pretreatment Permit Number 2004-03). Domestic wastewater generated at the plant is also discharged to the city treatment facility through a separate sanitary sewer connection. For the purpose of this TMDL study, the process and domestic wastewater is not considered a point source because it does not impact any surface waters within the Burnt Bridge Creek basin.

This TMDL study will assess non-process wastewaters that discharge to outfall 001 into Peterson Ditch, a tributary to Burnt Bridge Creek. Non-process wastewaters include non-contact cooling water, reverse osmosis reject water, stormwater, and multimedia and filter backwash water. The National Pollution Discharge Elimination System (NPDES) permit number WA0039616D also includes outfall 002 which discharges directly to groundwater. Current discharge to each outfall is approximately 2 cfs (1.3 mgd) and 1.1 cfs (0.9 mgd) to outfall 001 and 002, respectively. Finally, the current permit limits temperature for outfall 001 to a maximum of 21^{o}C.

At outfall 001 the SEH facility discharges surface wastewater to a series of retention ponds that flow into Peterson Ditch. The SEH discharge is the headwaters of Peterson Ditch, which then flows into Burnt Bridge Creek near Royal Oak Drive and NE 93rd Avenue at approximately RM 8.7. During low-flow events in the fall, Peterson Ditch (consisting almost entirely of SEH discharge flow) practically doubles the streamflow of Burnt Bridge Creek. SEH is considering increasing production capacity at the Vancouver facility to nearly double. Facility expansion would increase wastewater generation and increase discharge under the current permit. A portion of the increased non-process wastewater discharge would be directed to outfall 001 (SEH, 2007).

Wildlife and background sources

A variety of wildlife lives within the Burnt Bridge Creek watershed. Wildlife presents a potential source of fecal coliform bacteria, biological oxygen demand (BOD), and nutrients. Open fields, riparian areas, and wetlands provide feeding and roosting grounds for some birds whose presence can increase fecal coliform counts, BOD, and nutrients in runoff.

Usually these sources are dispersed and do not elevate fecal coliform counts or affect dissolved oxygen and pH in streams significantly enough to violate state criteria. Sometimes animal populations become concentrated and can cause water quality violations. Concentrated wildlife (for example, nutria (coypu), raccoons, beaver, and birds) in the watershed will be noted during sampling surveys.

Stormwater sources

During significant rain events, rainwater can wash the surface of the landscape, pavement, rooftops, and other impervious surfaces. This stormwater runoff can accumulate and transport pollutants and contaminants via stormwater drains to receiving waters and potentially degrade water quality.

Ecology issued the Western Washington Phase II Municipal Stormwater Permit in January 2007. Under the Phase II permit, the City of Vancouver must follow the prescribed guidelines to manage stormwater before it discharges to surface water. Permit requirements fall under five basic categories: public education and outreach, public involvement and participation, illicit discharge detection and elimination, the control of runoff from development, and pollution prevention. General information on the Phase II permit is available at www.ecy.wa.gov/programs/wq/stormwater/municipal/phase_II_ww/ww_ph_ii-permit.html.

The Washington State Department of Transportation (WSDOT) has a permit for stormwater management similar to Ecology's Stormwater Management Manual. Ecology's five-volume manual is available on the internet at www.ecy.wa.gov/programs/wq/stormwater/manual.html. WSDOT-maintained roads that potentially impact Burnt Bridge Creek through stormwater runoff include I-5 and I-205, and state highway 500.

In 1996, the City of Vancouver established a city-wide Surface Water Utility. The utility almost entirely manages the stormwater flowing into Burnt Bridge Creek. One significant exception with regard to this TMDL is the Cold Creek tributary, which collects the majority of its flow in Clark County.

At this time the Surface Water Utility is well established with an existing surface water utility rate structure, and the City of Vancouver has implemented the required NPDES Phase II Permit program elements. As part of the Phase II Permit, the city has developed a Stormwater Management Program. Documentation of the program and the annual report summarizing how the city is complying with each section of the Phase II Permit are available on the city web site. Outside of the city, Clark County must follow Phase I of the NPDES municipal stormwater guidelines to manage stormwater before it discharges to surface water.

Stormwater will be evaluated as part of the TMDL. The Ecology project team will attempt to capture 5 – 10 storm events during the winter season and one storm event during the summer, low-flow season in order to characterize the impact of these events. Winter storms will be sampled for bacteria only. The summer storm will include grab samples for nutrients, sediment, bacteria, and carbon. These data may be used to assign wasteload allocations to Vancouver's stormwater management system under the Phase II permit.

Nonpoint sources

Nonpoint sources and practices are dispersed and not controlled by discharge permits. Potential nonpoint sources within the Burnt Bridge Creek watershed include: residential properties adjacent to the creek, riparian residential development, some agricultural land, a golf course, wildlife, pet waste, human waste, and failing onsite septic systems. Nonpoint sources are important to understand due to their direct impact on creek water quality, but also as a major component of stormwater runoff.

Fecal coliform bacteria from nonpoint sources are transported to the creeks by direct and indirect means. For example, manure that is spread over fields during certain times of the year can enter streams via surface runoff or fluctuating water levels. Often livestock have direct access to water. Manure is deposited in the riparian area of the access points where fluctuating water levels, surface runoff, or constant trampling can transport the manure into the water.

Some residences may have wastewater illegally piped to waterways or may have malfunctioning on-site septic systems where effluent seeps to nearby waterways. Pet waste concentrated in public parks, on creekside trails, or private residences can be a source of contamination, particularly in urban areas. Swales, subsurface drains, and flooding through pastures and near homes can carry fecal coliform bacteria, nutrients, and BOD from sources to waterways. In Burnt Bridge Creek watershed, illegal campsites can also be a source of bacteria, nutrients, and BOD from human wastes.

Groundwater discharges can also affect dissolved oxygen levels and nutrient concentrations in streams. Information on groundwater inflows and water quality will be collected during this study to assess the potential influence of groundwater discharges on Burnt Bridge Creek.

Historical Data Review

Burnt Bridge Creek has been studied by the City of Vancouver, USGS, Clark County, and the Department of Ecology (Ecology) at various times since 1972. A summary of the available data and trends is provided below.

City of Vancouver

The City of Vancouver collected monthly water quality data at nine stations throughout the Burnt Bridge Creek watershed from 1998 to 1999, and from 2004 to 2007. Figure 2 and Table 6 display the sampling stations. Water quality parameters collected at the stations include fecal coliform, dissolved oxygen, pH, nitrate-nitrite, total kjeldahl nitrogen, orthophosphate, total phosphorus, and temperature.

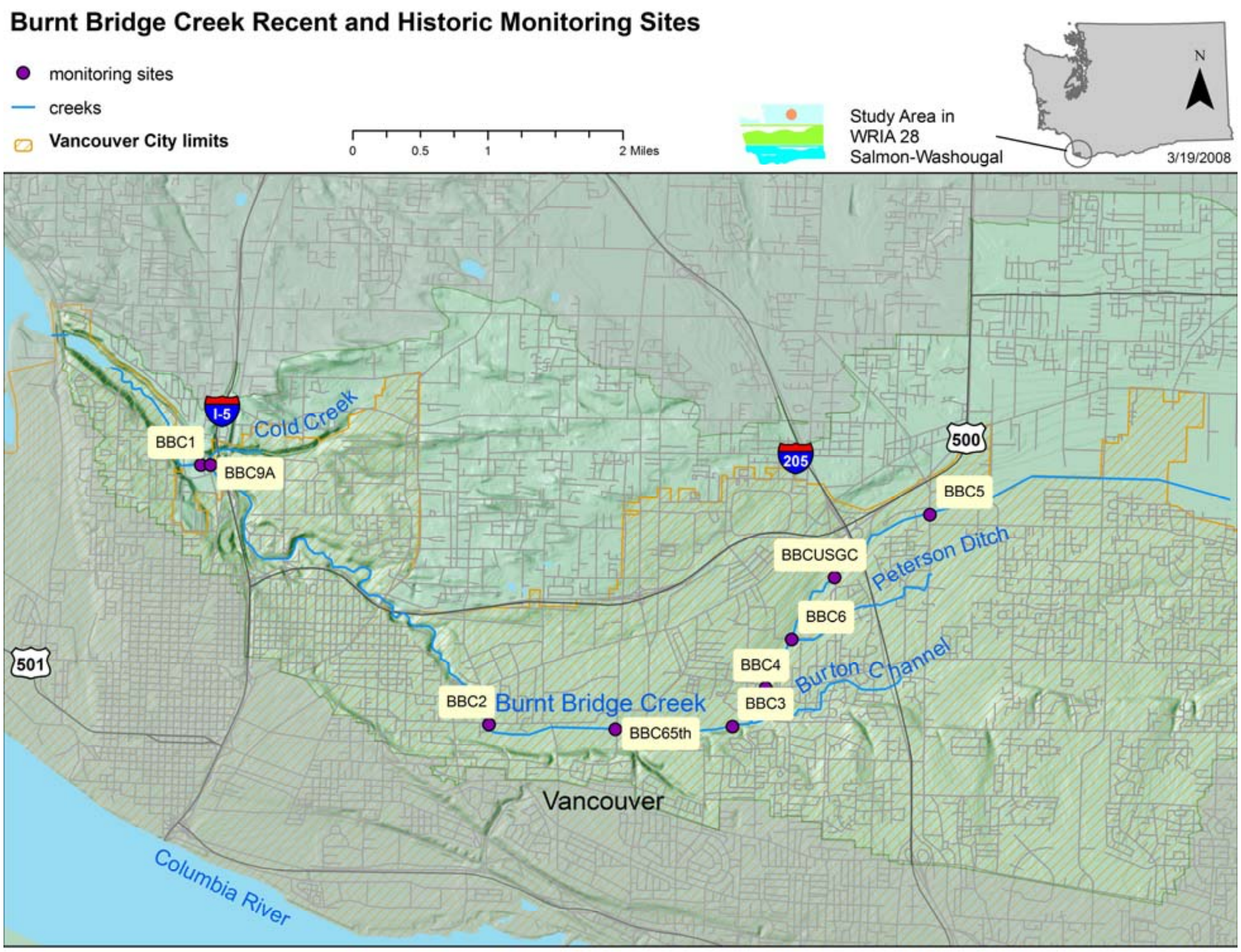

Figure 2. City of Vancouver recent and historic sampling locations.

Table 6. City of Vancouver sampling locations.

Site ID	Site Name and Description	Latitude	Longitude	Notes
BBC1	Burnt Bridge Creek at NW 2nd Avenue - NW Alki Road	45.66169	-122.66942	EPA Station 14211903. Ecology Station 28C070. BPA monitoring site BB-SW3.
BBC9A	Cold Creek at Burnt Bridge Creek	45.66172	-122.66796	Upstream of confluence with Burnt Bridge Creek, 75 feet upstream of stilling well. Same as BPA monitoring site C-SWI5.
BBC2	Burnt Bridge Creek at NE 18th Street	45.63467	-122.62428	
BBC65th	Burnt Bridge Creek at 65th Avenue	45.63453	-122.60496	
BBC3	Burnt Bridge Creek at NE 86th Avenue	45.63515	-122.58706	Sample site approximately 1 mile downstream of BBC4 after confluence of Burton Channel and Burnt Bridge Creek.
BBC4	Burnt Bridge Creek at Burton Road	45.63939	-122.58214	EPA Station 14211897. Ecology Station 28C110. SEH temperature monitoring site.
BBC6	Peterson Ditch at Burnt Bridge Creek	45.64464	-122.57835	
BBCUSGC	Burnt Bridge Creek upstream of Golf Course	45.65141	-122.57205	Access at intersection of NE 39th Street and NE 97th Avenue. Monitored this site and BBC at Royal Oak Dr to identify water quality changes occurring through the golf course
BBC5	Burnt Bridge Creek at 112th Avenue	45.65848	-122.55771	Sampled on downstream side of road until 1991 when sampling changed to upstream side of road.

BPA – Bonneville Power Administration.
SEH – SEH America.
BBC – Burnt Bridge Creek.

Burnt Bridge Creek is listed on the Washington State 303(d) list as impaired for fecal coliform, dissolved oxygen, and temperature. pH is also listed as a parameter of concern. Therefore, the following discussion focuses on these parameters in comparison to Washington State water quality criteria.

Figure 3 through Figure 6 illustrate the monthly water quality samples for fecal coliform, dissolved oxygen, pH, and temperature for data collected between 1998 and 2006. With the exception of pH, the figures illustrate that fecal coliform, dissolved oxygen, and temperature violated the water quality criterion at most sampling locations along Burnt Bridge Creek during the sampling period.

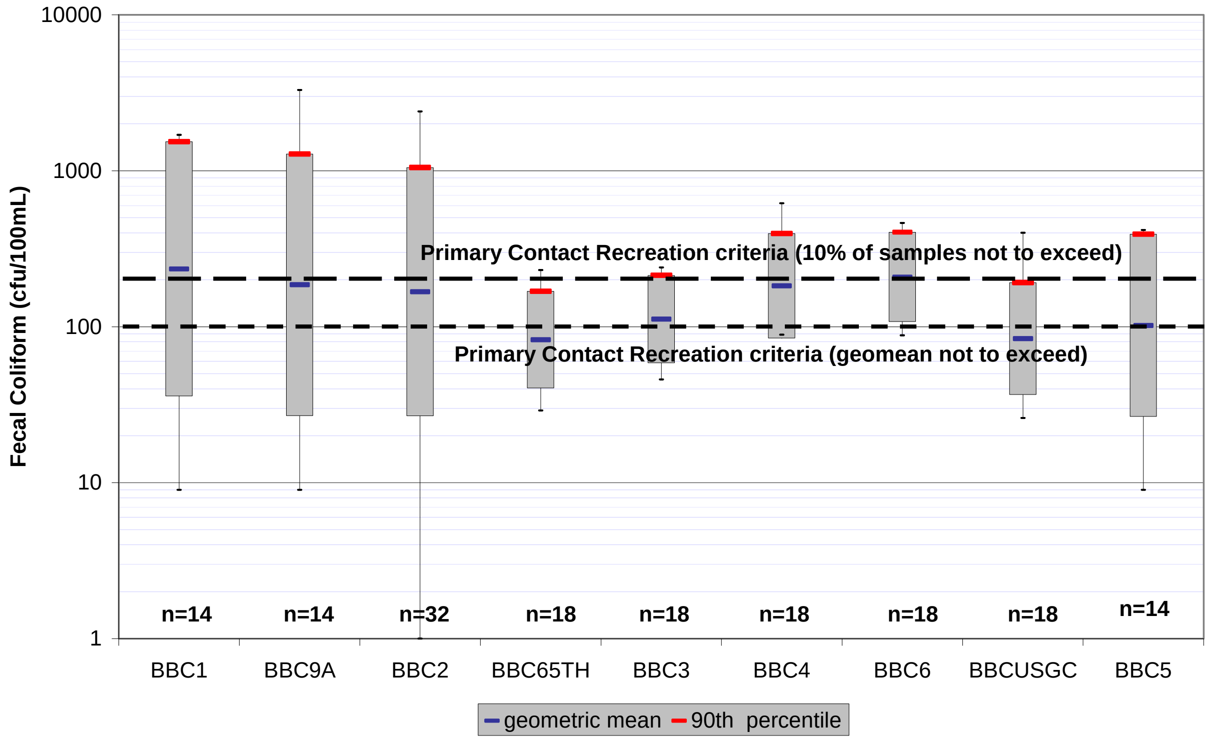

Figure 3. Fecal coliform statistics for City of Vancouver sampling locations.

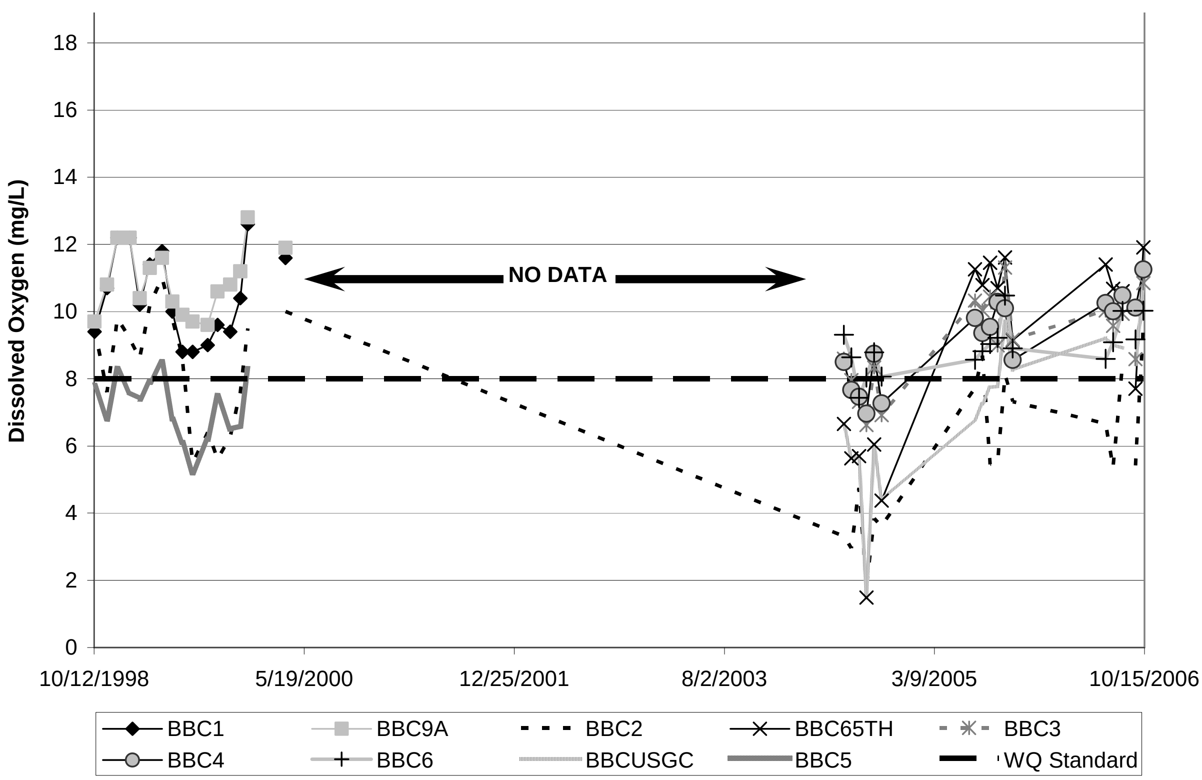

Figure 4. Dissolved oxygen measurements for City of Vancouver sampling locations.

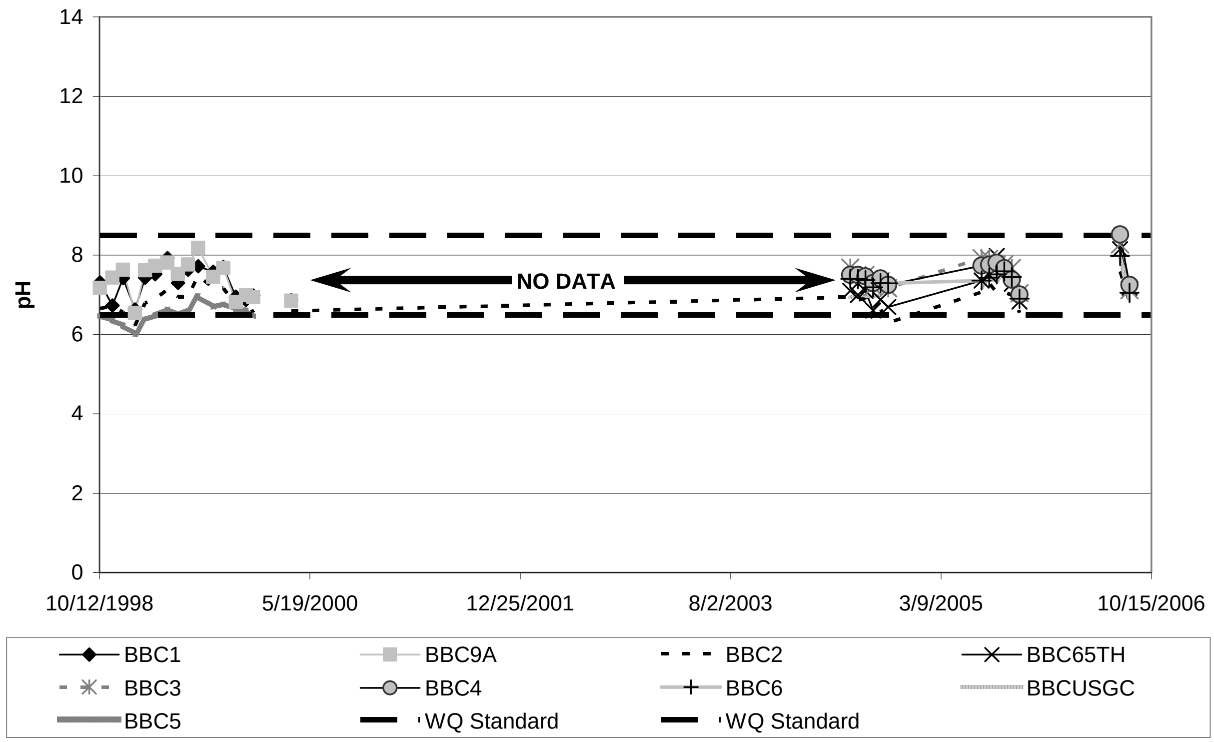

Figure 5. pH measurements for City of Vancouver sampling locations.

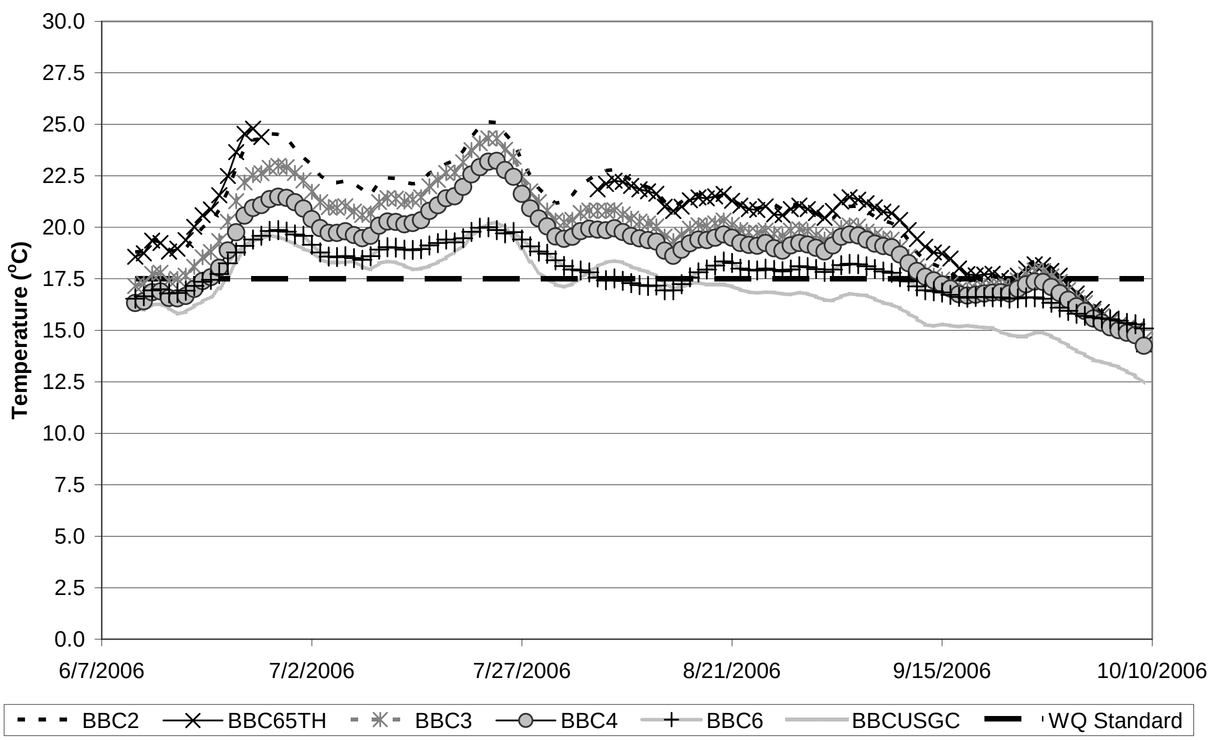

Figure 6. 7-DADMax temperatures for City of Vancouver sampling locations.

A summary of the percent of samples that do not meet the water criterion for dissolved oxygen, pH, and temperature is provided in Table 7. The table indicates that temperature is a problem at all sample locations in the basin. Dissolved oxygen seems to violate criteria more frequently in the central and upper portions of the stream. Only 3 locations do not comply with the pH criteria during data collection.

Table 7. Percent exceedance of water quality criteria.

Station location description	Percent Exceedance of Water Quality Standards		
	DO	pH	Temperature
(sample periods)			(2006 data only)
BBC1 at NW Alki Rd (10/1998-3/2000)	0%	0%	- -
BBC9A Cold Creek (10/1998-3/2000)	0%	0%	- -
BBC2 at NE 18th St (10/1998-10/2006)	58%	10%	88%
BBC65TH at 65th Ave (6/2004-10/2006)	41%	0%	87%
BBC3 at NE 86th Ave (6/2004-10/2006)	24%	0%	79%
BBC4 at Burton Rd (6/2004-10/2006)	24%	7%	71%
BBC6 Peterson Ditch (6/2004-10/2006)	6%	0%	60%
BBCUSGC above golf course (6/2004-10/2006)	59%	0%	40%
BBC5 at 112th Ave (10/1998-3/2000)	75%	44%	- -

The City of Vancouver and the Southwest Washington Health District contracted Mansour Samadpour to conduct a Microbial Source Tracking Study on Burnt Bridge Creek in 1999. The draft report identifies humans, pets, dogs and cats, migratory birds, urban wildlife, and livestock as the major sources of microbial pollution in Burnt Bridge Creek. Additionally, the report recommends:

- Reducing the number of septic systems in the watershed.
- Pet owner education on proper waste disposal.

- Discouraging the formation of resident bird populations of migratory birds.
- Population control of urban wildlife.
- Livestock managed under best management practices.
- Tree planting along the streambeds to reduce elevated stream temperatures (Samadpour et al., 1999).

Ecology ambient monitoring station

Ecology established an ambient monitoring station on Burnt Bridge Creek near the mouth at Alki Road in October 1972. This station (28C070) was established at the same location as the City of Vancouver's station BBC1. Ecology's ambient monitoring program collected twice-monthly water quality samples at the site during water year (WY) 1973 and monthly water quality grab samples at the site during WY 2004 – WY 2005 and starting again in WY 2008. Figure 7 through Figure 9 display the data for the station for temperature, dissolved oxygen, and pH, respectively. These figures indicate that temperature is elevated above the water quality criteria at this site, but dissolved oxygen and pH are in compliance.

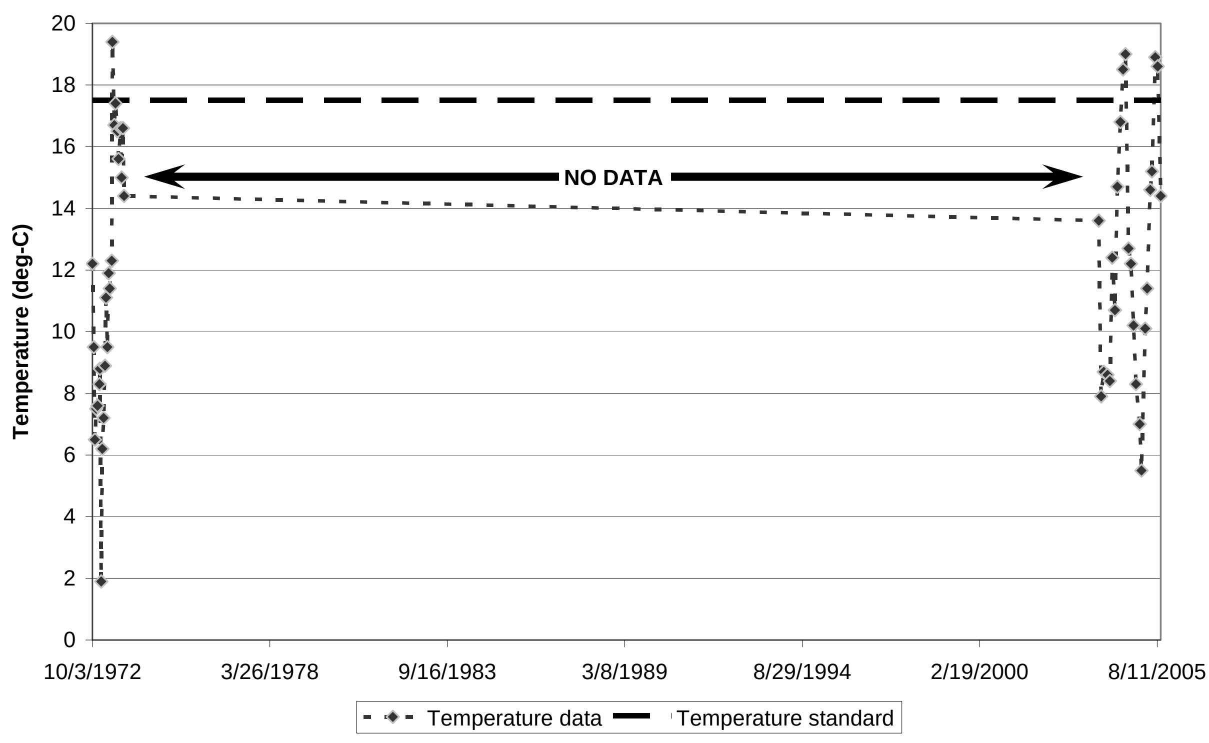

Figure 7. Temperature measurements collected at Ecology's ambient monitoring station 28C070.

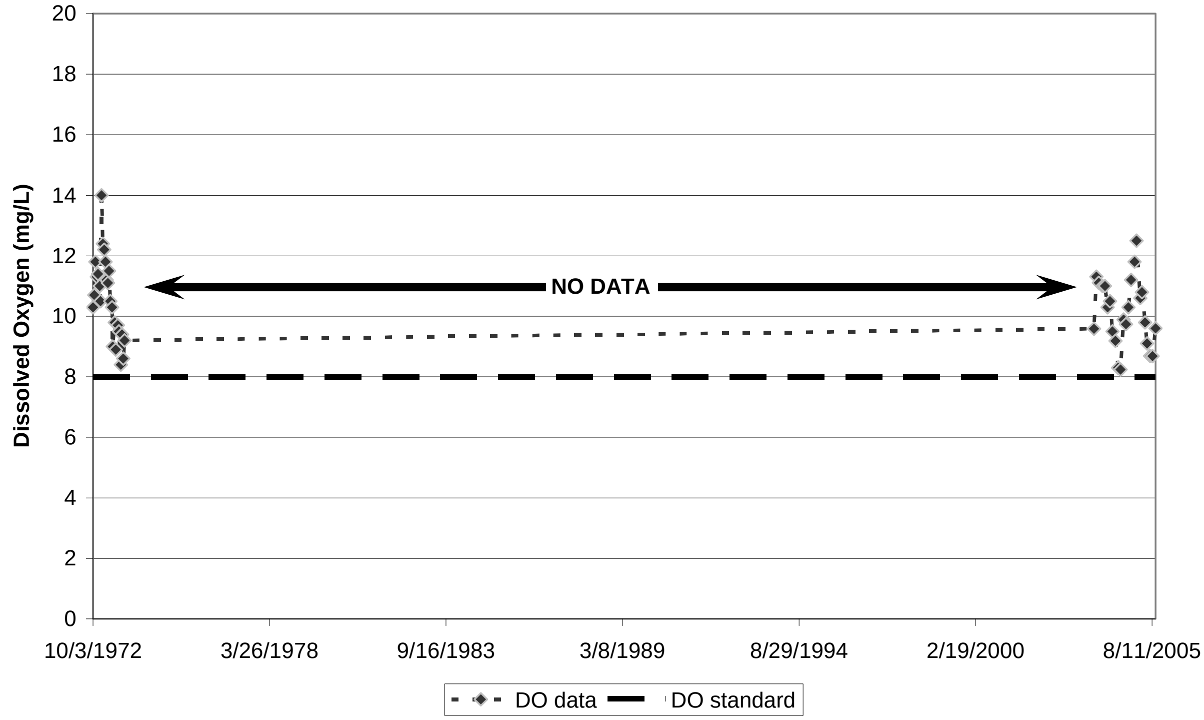

Figure 8. Dissolved oxygen measurements collected at Ecology's ambient monitoring station 28C070.

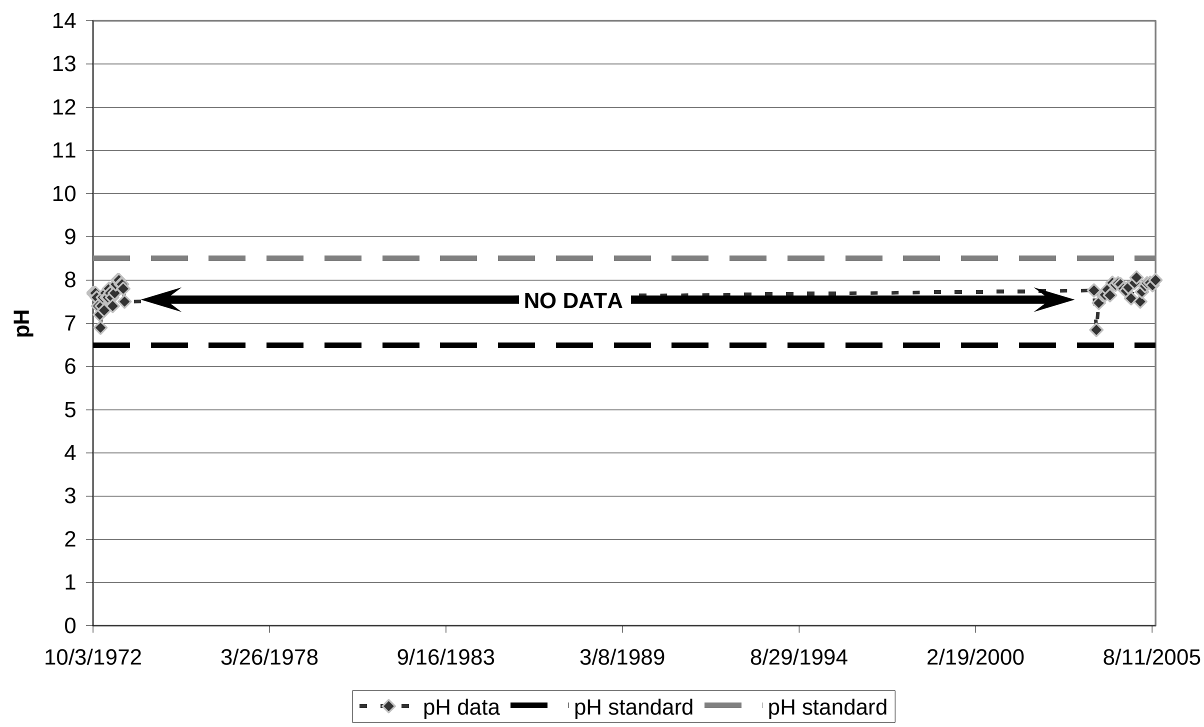

Figure 9. pH measurements collected at Ecology's ambient monitoring station 28C070.

Fecal coliform was collected at the site between 2003 and 2005. These data are summarized in Table 8. At this station, fecal coliform does not meet the geometric mean and "10% of samples" not to exceed criteria.

Table 8. Summary statistics for fecal coliform data collected at Ecology's ambient monitoring station 28C070 (data collected during 2003 - 2005).

Statistics	Fecal coliform (cfu/100mL)
10th percentile	54
Minimum	29
Geometric Mean	194
Maximum	1200
90th percentile	703
Percent of samples that exceed 200 cfu/100mL	54%
Sample size	24

Trend analysis

The ambient monitoring station 28C070, combined with the City of Vancouver station BBC1, has a record of monthly dissolved oxygen, temperature, and pH data from 1972 through 2007. There are fecal coliform data available for the location from 1998 through 2007.

A Seasonal Kendall (SKWOC) trend analysis was performed using WQHydro software (Aroner, 2003) to determine the historic trend for each of these 4 parameters for 1998 - 2007. Each of the parameters were analyzed by performing the test on all of the data available, on dry season (June – October) and wet season (November – May) data, and on summer season (June – September) and winter season (October – May) data.

Results of the trend analysis indicate that dissolved oxygen, temperature, and fecal coliform have not significantly changed over time. However, the trend analysis for pH (Figure 10) has a slope of 0.06 and a significance of 99%. These results indicate a statistically significant increase in pH levels over the period of record (1998-2007), although pH is meeting state water quality criterion at this site.

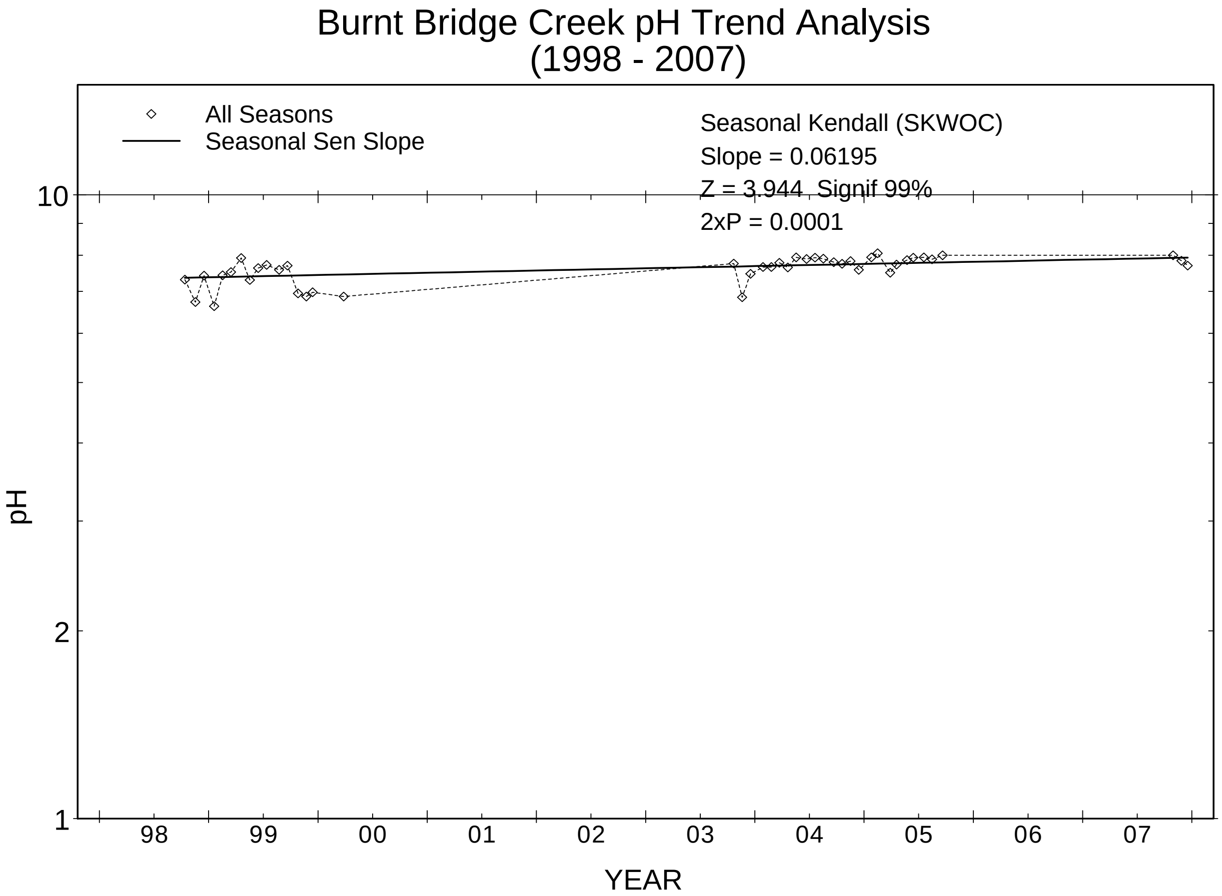

Figure 10. pH trend analysis for data collected at Ecology's ambient monitoring station 28C070 (also City of Vancouver station BBC1).

USGS

USGS operated 3 continuous flow gages on Burnt Bridge Creek during 1998 – 2000. Information about these gages was provided earlier in this report under the *Watershed Description* section.

Clark County

Clark County operated 4 continuous flow gages on Burnt Bridge Creek during 1988 – 1998. Summary statistics for these gages were provided in the *Hydrology* section of this report.

Clark County operated 2 weather stations within the City of Vancouver from 1988 - 1998. The stations were located at Ft. Vancouver and Orchard Elementary. Table 9 provides a summary of the data.

Table 9. Summary statistics for precipitation data (in inches) collected at two locations by Clark County.

Year	Ft. Vancouver		Orchard Elementary School	
	Total Rainfall	One Day Maximum	Total Rainfall	One Day Maximum
1988	28	1.5	32	1.3
1989	25	1.4	25	1.4
1990	26	1.2	34	1.2
1991	30	1.6	18	1.1
1992	24	1.7	26	1.2
1993	22	1.2	31	1.1
1994	33	3.0	32	1.8
1995	43	2.1	48	2.5
1996	60	3.3	62	3.0
1997	35	1.7	48	1.7
1998	37	2.0	39	1.5
Average	33		36	
Maximum	60	3.3	62	3.0

Project Goal and Study Objectives

Goal

The goal of the proposed TMDL study is to ensure that Burnt Bridge Creek and its tributaries attain Washington State water quality standards.

Objectives

Objectives of the study are as follows:

- Characterize fecal coliform bacteria concentrations and loads from all major tributaries, point sources, and drainages into Burnt Bridge Creek under various seasonal or hydrological conditions.
- Calculate percent reductions needed from sources and establish fecal coliform load allocations (for nonpoint sources) and wasteload allocations (for point sources). Load and wasteload allocations protect the primary contact beneficial uses of Burnt Bridge Creek.
- Identify relative contributions of fecal coliform loading to Burnt Bridge Creek based on source areas so clean-up activities can focus on the largest sources.
- Characterize processes governing dissolved oxygen in Burnt Bridge Creek including the influence of tributaries, nonpoint sources, point sources, and groundwater.
- Develop a model to simulate biochemical processes and productivity in Burnt Bridge Creek. Using critical conditions in the model, determine the capacity to assimilate BOD and nutrients. Nutrient data may be used to assist the Vancouver Lake Partnership in determining nitrogen and phosphorus loads to the lake.
- Characterize stream temperatures and processes governing the thermal regime in Burnt Bridge Creek. This would include the influence of tributaries, point sources, and groundwater/surface water interactions on the heat budget.
- Develop a predictive temperature model for Burnt Bridge Creek. Using critical conditions in the model, determine the creek's capacity to assimilate heat. Evaluate the system potential temperature (approximated natural temperature conditions) for Burnt Bridge Creek.
- Establish load allocations for nonpoint sources and wasteload allocations for point sources to meet temperature and dissolved oxygen water quality standards and protect beneficial uses.
- Use the calibrated model to evaluate future water quality management decisions for the Burnt Bridge Creek watershed.

Study Design

Overview

The study objectives for Burnt Bridge Creek will be met by (1) characterizing annual and seasonal fecal coliform bacteria loads in the basin and (2) developing a numerical water quality model for dissolved oxygen and temperature. This effort will rely on data collected by Ecology during the 2008-2009 project as well as existing data collected by the City of Vancouver, USGS, Ecology and others.

Fecal coliform, dissolved oxygen, temperature, and associated conventional parameters will be monitored at a fixed network of sampling sites. These sites include locations at the mouths of all tributaries, point sources, significant drainage/discharges, and key locations along Burnt Bridge Creek. Flow will be measured at all sites at the time of sampling.

The water quality model will be calibrated to field data. The calibrated model will then be used to evaluate the water quality in Burnt Bridge Creek in response to various alternative scenarios of pollutant loading. The loading capacity of Burnt Bridge Creek will be evaluated. In addition, wasteload allocations for point sources and load allocations for nonpoint sources will be evaluated. The model will be used to determine (1) how much nutrients and BOD need to be reduced to meet dissolved oxygen water quality standards and (2) how much effective shade is necessary to bring stream temperature into compliance with water quality standards. Components and descriptions of the models are summarized in Appendix B.

Fecal coliform TMDL allocations will be set based on applying a statistical method to measured data (the numeric water quality model will not be used). The statistical roll-back method, described in Appendix B, will be used to determine how much (in terms of percent) fecal coliform concentrations need to be reduced at each sampling site.

Details

Fixed-network sampling

The following describes the study design for each 303(d)-listed parameter covered by this TMDL. Streamflow, time-of-travel, and groundwater sampling will also be discussed. Figure 11 and Table 10 show the fixed-network of sampling locations. Stations were selected based on historical site locations, fecal coliform results, spatial resolution, and location of tributaries.

Sites may be added or removed from the sampling plan depending on access and new information provided during the field observation and preliminary data analysis.

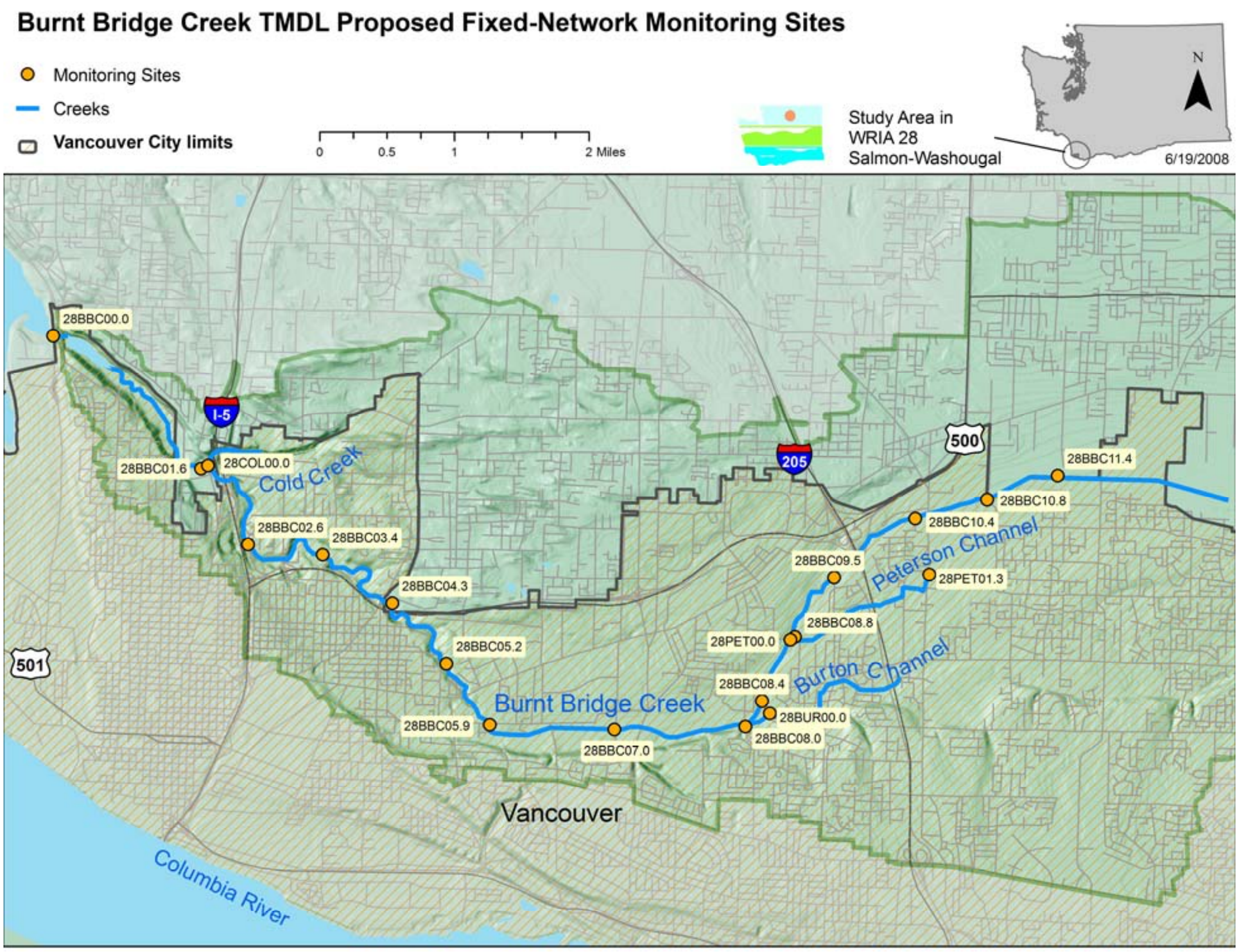

Figure 11. Fixed-network sampling locations in the Burnt Bridge Creek watershed.

Table 10. Ecology's Fixed-network sampling locations in the Burnt Bridge Creek watershed.

Site ID	Description	NAD 83	
		Latitude	Longitude
28BBC00.0	Burnt Bridge Creek downstream of Fruit Valley Rd	45.67520	-122.69253
28BBC01.6	Burnt Bridge Creek at 2nd Ave near Alki Rd	45.66137	-122.66934
28COL00.0	Cold Creek at Hazel Dell Ave BBC RM 1.6	45.66174	-122.66827
28BBC02.6	Burnt Bridge Creek at Leverich Park	45.65339	-122.66180
28BBC03.4	Burnt Bridge Creek near SR 500 at 41st Circle	45.65250	-122.65034
28BBC04.3	Burnt Bridge Creek upstream of Saint Johns Blvd	45.64745	-122.63946
28BBC05.2	Burnt Bridge Creek at Rossiter Ln	45.64112	-122.63094
28BBC05.9	Burnt Bridge Creek at NE 18th St	45.63469	-122.62405
28BBC07.0	Burnt Bridge Creek at NE 65th Ave	45.63456	-122.60497
28BBC08.0	Burnt Bridge Creek at NE 86th Ave, downstream of Burton Ch.	45.63523	-122.58489
28BUR00.0	Burton Channel at BBC RM 8.3, 19th Circle & 92nd Ave	45.63672	-122.58121
28BBC08.4	Burnt Bridge Creek at NE Burton Rd, below Peterson Ditch	45.63802	-122.58246
28PET00.0	Peterson Ditch confluence at 93rd Ave, BBC RM 8.8	45.64501	-122.57767
28PET01.3	Peterson Ditch at SEH outfall 001	45.65207	-122.55736
28BBC08.8	Burnt Bridge Creek above Peterson Ditch at NE 93rd Ave	45.64468	-122.57837
28BBC09.5	Burnt Bridge Creek at 98th, upstream of Royal Oaks Dr	45.65148	-122.57191
28BBC10.4	Burnt Bridge Creek at NE 110th Ave	45.65809	-122.55974
28BBC10.8	Burnt Bridge Creek at NE 121st Ave	45.66031	-122.54881
28BBC11.4	Burnt Bridge Creek at 131st Ave	45.66308	-122.53808

Fecal coliform bacteria

Data from the fixed-network will provide fecal coliform bacteria data sets to meet the following needs:

- Provide an estimate of the annual and seasonal geometric mean and 90^{th} percentile statistics fecal coliform counts. The schedule should provide 28 to 30 samples per site to develop the annual statistics. This will include 16 samples per site during the dry season (June - October), and 14 samples per site during the wet season (November - May).
- Provide reach-specific fecal coliform load and concentration comparisons to define areas of fecal coliform loading increases (e.g., malfunctioning on-site systems, livestock, wildlife, or manure spreading) or decreases (e.g., settling with sediment, die-off, or dilution). With accurate streamflow monitoring, tributary and source loads also can be estimated.
- Identify if certain land uses affect instream changes in fecal coliform loads.

The fixed-network sites will be sampled twice monthly from June 2008 to August 2009. During the wet season (November – May), the field crew will try to sample 5 - 10 storm events.

Dissolved oxygen and synoptic surveys

Dissolved oxygen and associated conventional parameter data will be collected synoptically [1] from the fixed-network of stations (Table 10 and Figure 11). Field teams will record in-situ parameters (temperature, dissolved oxygen, pH, and conductivity) and collect representative grab samples for laboratory analysis early in the morning and late in the afternoon. Synoptic surveys will be conducted at least 2 times throughout the course of the project to provide calibration and corroboration data sets.

The fixed-network synoptic sampling will occur during the summer low-flow months (June to October 2008) to capture critical conditions. Synoptic sampling will include grab samples of dissolved oxygen [2], chloride, total suspended solids, total non-volatile suspended solids, turbidity, ammonia, nitrite/nitrate, orthophosphate, total phosphorous, total persulfate nitrogen, dissolved and total organic carbon, alkalinity, and chlorophyll-*a*.

Continuous diel monitoring for pH, DO, conductivity, and temperature will be conducted at several fixed-network sites with the Hydrolab DataSonde® (Table 10 and Figure 11). Sediment oxygen demand will be characterized by installing sediment flux chambers in 4 representative reaches along the creek during the synoptic surveys (Roberts, 2007). The benthic chambers will remain in place for at least 24 hours. Once deployed, grab samples will be taken for Winkler titration of dissolved oxygen at dawn and dusk. Phytoplankton and periphyton sampling will be conducted at each fixed network sampling site to determine biomass and chlorophyll-*a* levels.

Macrophytes, phytoplankton, and periphyton are photosynthetic primary producers in aquatic systems. Increased primary production may increase pH due to uptake of CO_2. When photosynthetic organisms decompose or reduce productivity, CO_2 is released or no longer used

[1] all stations sampled over a short period of time
[2] Winkler dissolved oxygen samples for lab check of field measurements

and a decrease in pH may occur. Dissolved oxygen is also influenced by primary production. Primary production activity emits oxygen thus temporarily increasing dissolved oxygen in aquatic systems. Primary production die-off is oxygen-demanding, as aquatic bacteria use oxygen while decomposing the carbon-based plant matter.

Diel (24-hr period) fluctuations may occur with pH and dissolved oxygen. Typically during daylight hours, an increase in dissolved oxygen and pH occurs as primary producers emit oxygen, and take in CO_2. At night, pH and dissolved oxygen levels decrease as primary producers engage in photo respiration by taking in oxygen. Excessive nutrients and biomass, and large diel chemical fluctuations, are characteristic of a eutrophic (nutrient-rich) condition.

Phytoplankton and periphyton life cycles potentially affect pH, dissolved oxygen, dissolved organic carbon, and nutrient uptake such as phosphorus and nitrogen. Factors that potentially influence phytoplankton and periphyton include light, temperature, water chemistry, current, substrate, scouring effects of floods, and grazing by macroinvertebrates. Streams and rivers with a healthy biotic structure have a proper balance of these factors so that photosynthetic organisms are neither over-productive nor under-productive (Allan, 1995).

Temperature

Continuous temperature data loggers (thermistors) will be deployed at each fixed-network site (Table 10 and Figure 11). Each site will have at least two thermistors; one to measure water temperature and another to measure air temperature. The thermistors will measure temperature at 30-minute intervals. Instream thermistors are deployed in the thalweg of a stream such that they are suspended off the stream bottom and in a well-mixed portion of the stream, typically in riffles or swift glides. Some sites may also have a data logger measuring relative humidity.

The temperature assessment of Burnt Bridge Creek will use effective shade as a surrogate measure of heat flux. Effective shade is defined as the fraction of the potential solar shortwave radiation that is blocked by vegetation and topography before it reaches the stream surface. Effective shade accounts for the interception of solar radiation by vegetation and topography.

Heat loads to the stream will be calculated using a heat budget that accounts for surface heat flux and mass transfer processes. Heat loads are of limited value in guiding management activities needed to solve identified water quality problems. Shade will be used as a surrogate to thermal load as allowed under EPA regulations (defined as “other appropriate measure” in 40 CFR § 130.2(i)). A decrease in shade due to inadequate riparian vegetation causes an increase in solar radiation and thermal load upon the affected stream section. Other factors influencing the distribution of the solar heat load also will be assessed, including increases in streamflow and groundwater interactions.

Groundwater and synoptic surveys

For this study, groundwater and surface-water interactions will be assessed via a combination of common field techniques. Instream piezometers will be installed beginning in May 2008 at the majority of the fixed-network sites (Table 10 and Figure 11). The piezometers will be used to monitor surface water and groundwater head relationships, streambed water temperatures, and groundwater quality at discrete points along the creek.

Two groundwater sampling events (scheduled to coincide with synoptic surface-water sampling events) will be conducted to assess the quality of groundwater discharging to the creek. During the synoptic surveys, groundwater samples will be collected from those piezometers located along gaining stream reaches. The samples will be submitted to the laboratory for subsequent analysis of fecal coliform, alkalinity, chloride, orthophosphate, total phosphorus, nitrate/nitrite, ammonia, total persulfate nitrogen, dissolved organic carbon, and iron concentrations. Temperature, water level, conductivity, pH, and dissolved oxygen will also be measured in the piezometers during the surveys.

The piezometers for this study will consist of a five-foot length of a 1.5-inch diameter galvanized pipe, one end of which is crimped and slotted. The upper end of each piezometer will be fitted with a standard pipe coupler to provide a robust strike surface for piezometer installation and to enable the piezometers to be securely capped between sampling events. The piezometers will be driven into the streambed (within a few feet of the shoreline) to a maximum depth of approximately 5 feet. Keeping the top of the piezometer underwater and as close to the streambed as possible will reduce the influence of heat conductance from the exposed portion of the pipe. Following installation, the piezometers will be developed using standard surge and pump techniques to assure a good hydraulic connection with the streambed sediments.

Each piezometer will be instrumented with up to three thermistors for continuous monitoring of streambed water temperatures (Figure 12). In a typical installation, one thermistor will be located near the bottom of the piezometer, one will be located at a depth of approximately 0.5 feet below the streambed, and one will be located roughly equidistant between the upper and lower thermistors. The piezometers will be accessed monthly to download thermistors and to make spot measurements of stream and groundwater temperature for later comparison against and validation of the thermistor data. The monthly spot measurements will be made with properly maintained and calibrated field meters in accordance with standard Ecology Environmental Assessment (EA) Program methodology (Ward, 2007).

During the monthly site visits, surface water stage and instream piezometer water levels will be measured using a calibrated electric well probe, a steel tape, or a manometer board (as appropriate) in accordance with standard EA Program methodology. The water level (head) difference between the piezometer and the creek provides an indication of the vertical hydraulic gradient and the direction of flow between the creek and groundwater. When the piezometer head exceeds the creek stage, groundwater discharge into the creek can be inferred. Similarly, when the creek stage exceeds the head in the piezometer, loss of water from the creek to groundwater storage can be inferred.

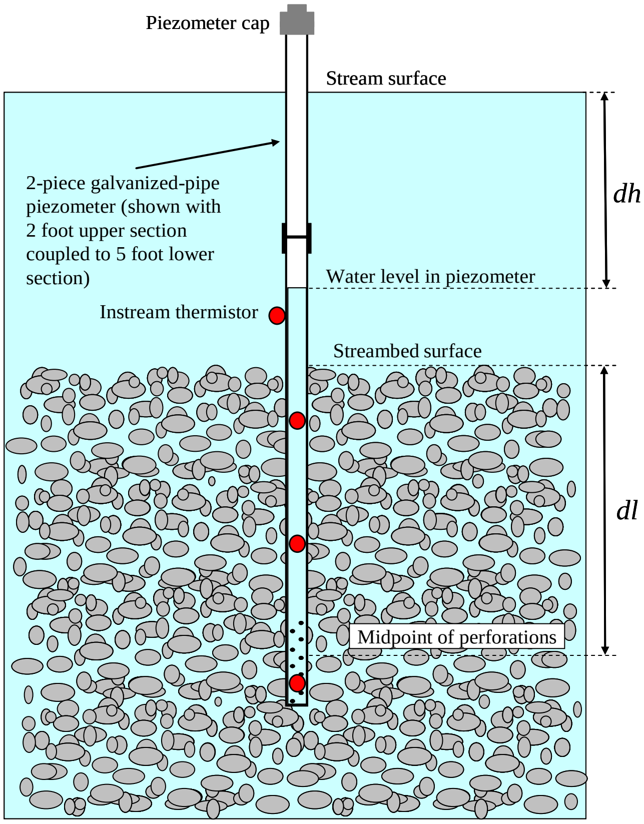

Figure 12. Instream piezometer conceptual diagram.
(diagram not to scale).

To provide a secondary confirmation of the instream piezometer dataset, Ecology will also attempt to arrange access to a tandem network of shallow off-stream domestic wells which will be used to monitor "regional" groundwater levels, temperatures, and groundwater quality. When selecting wells, preference will be given to shallow, properly documented wells in close proximity to Burnt Bridge Creek. Wells selected for monitoring will be visited monthly during the 2008-2009 study to measure groundwater levels. Where owner permission is granted, and site conditions allow, recording thermistors will be deployed in the wells. We also hope to sample a subset of the off-stream wells during each of the two instream piezometer sampling events described above.

Time of travel to determine average stream velocities

Time-of-travel studies will use a fluorescent dye (20% Rhodamine WT) to trace the movement of a dye cloud from an upstream point to a downstream point to calculate the average velocity of that body of water. Rhodamine WT dye is used by Ecology, the USGS, and others to provide safe and effective time-of-travel measurements. The methods and protocols used in this survey will follow those prescribed by Kilpatrick and Wilson (1982).

Field measurements of dye concentration in the stream will be made using a Hydrolab DataSonde® equipped with a rhodamine fluorometer recording measurements every 5-10 minutes at key locations downstream from the initial point of dye release. Over a period of time in the stream, the dye will dissipate becoming visually undetectable. These studies will take place at different streamflow regimes during summer and fall. Furthermore, these studies will coincide with the synoptic surveys.

Ecology will notify the Ecology Vancouver Field Office, the City of Vancouver Surface Water Management Department, and local emergency contacts before injecting the dye. Announcing the dye studies will prevent unnecessary emergency actions in the event a spills complaint is submitted (i.e., someone calls the sheriff or Ecology spills hotline because the river just turned red).

Establish a continuously recording stream gage network to measure streamflows

Ecology's Freshwater Monitoring Unit (FMU) will install and maintain up to two continuous streamflow gages. These gages will help quantify streamflow conditions on Burnt Bridge Creek. The proposed gage locations are 2nd Avenue near Alki Road (28BBC01.2) and 110th Avenue (28BBC10.2) (Table 10 and Figure 11). Piezometers instrumented with water level loggers may be co-located with the stream gages to facilitate the development of continuous vertical hydraulic gradient profiles for each location.

Continuously recorded streamflow data, instantaneous streamflow measurements conducted during baseflow conditions, piezometer vertical hydraulic gradient measurements, and the resulting flow mass balance will be used to determine surface water and groundwater interactions. The major surface water inputs to Burnt Bridge Creek, including tributaries and point discharges, will be measured during each field visit, if possible. Surface water withdrawals will be estimated based on water right certificates and claims or by surveying those users to determine how much water they are withdrawing during low-flow conditions.

Riparian habitat and channel geometry surveys

Effective shade inputs to the water quality model (QUAL2Kw) require an estimate of the aerial density of vegetation shading the stream. Ground truthing is necessary, so a hemispherical lens and digital camera will be used to take 360° pictures of the sky to calculate the shade provided by vegetation and topography at the center of the stream. Digital photographs will be taken at each fixed-network site and at a few reference reaches to verify existing riparian vegetation compared to aerial photos. The digital images will be processed and analyzed using the HemiView© software program (Stohr, 2008).

Ecology will follow Timber-Fish-Wildlife stream temperature survey methods for the collection of data during thermal reach surveys (Schuett-Hames et al., 1999). The surveys will be conducted during the summer of 2008 at the fixed-network sites (Table 10 and Figure 11). Depending on stream access, field measurements will be taken at 10 locations per site. Measurements will consist of bankfull width and depth, wetted width and depth, substrate composition, canopy density, and channel type.

Riparian habitat field data collection includes 150 feet on both banks of Burnt Bridge Creek (Johnston et al., 2005). Vegetation heights will be measured in the field using a laser range/ height finder. Comparing the field data collected to an aerial photo, a GIS map layer will be made including vegetation type, general height class, and vegetation density. Additional, Riparian Management Zone characteristics, such as active channel width, effective shade, bank incision, and bank erosion, will be recorded during the thermal reach surveys.

Stormwater monitoring

The purpose of storm monitoring is to better characterize potential sources of fecal coliform loading to Burnt Bridge Creek. During rain events, greater than average fecal coliform loading may occur when urban surface water flushes into the creeks. Ecology will attempt to capture five to ten storm events between June 2008 and August 2009. For this TMDL, a storm event is defined as a minimum of 0.3 inches of rainfall in a 24-hour period preceded by no more than trace rainfall in the previous 24 hours. Daily rainfall data will be obtained from local sources, such as Vancouver's Pearson Field Airport weather station # KVUO and Burnt Bridge Creek weather station # KWAVANCO4.

During the wet season, Ecology will try to sample all sites twice during one storm event. However, the majority of sites will be sampled for bacteria only once during the duration of the storm. When grab samples are collected, streamflow will be (1) measured with a flow meter, or (2) estimated using stage and rating curves, relationships with other monitoring locations, or filling a known volume over a certain amount of time. Local weather forecasts will allow anticipation of significant storm events suitable for sampling.

Ecology will attempt to sample one summer storm event. During this storm event, sites and representative outfalls will be monitored for bacteria, total organic carbon (TOC), dissolved organic carbon (DOC), total suspended solids (TSS), and nutrients (ammonia, nitrite-nitrate, total persulfate nitrogen, orthophosphate, and total phosphorus).

The stormwater sampling sites will include all fixed network sites plus approximately 10 representative outfalls under NPDES. Stormwater NPDES permits are required to have corresponding wasteload allocations set in TMDL studies.

Sampling Procedures

Field sampling and measurement protocols will follow those listed by Ecology's EA Program quality assurance guidance and methodology procedures www.ecy.wa.gov/programs/eap/quality.html.

Grab samples will be collected directly into pre-cleaned containers supplied by Ecology's Manchester Environmental Laboratory (MEL) and described in the MEL User's Manual (2005). Dissolved oxygen grab samples will be collected and field processed according to the SOP for the Collection and Processing of Stream Samples (Ward, 2007). Sample parameters, containers, volumes, preservation requirements, and holding times are listed in Table 11. All samples for laboratory analysis will be stored on ice and delivered to MEL within 24 hours of collection via Greyhound and Ecology courier.

A minimum of 10% of the samples will be field duplicates used to assess total (field and lab) variability. Samples will be collected in the thalweg and just under the water's surface.

Periphyton field sampling protocols are adapted from the USGS protocols (Porter et al., 1993).

Temperature monitoring stations and piezometers will be checked monthly to make field measurements and to clear accumulated debris away from the instruments. Documentation of the temperature monitoring stations will include:

- GPS coordinates and a sketch of the site (during installation only).
- Depth of the instream temperature instrument (TI) under the water surface and height off the stream bottom.
- Stream temperature.
- Serial number of each instrument and the action taken with the instrument (i.e., downloaded data, replaced TI, or noted any movement of the TI location to keep it submerged in the stream).
- The date and time before the dataloggers are installed or downloaded, and the date and time after they have been returned to their location. All timepieces and PC clocks should be synchronized to the atomic clock using Pacific Daylight Savings Time. Pacific Standard Time will be reported if instruments are still in place during the time change.

Table 11. Containers, preservation requirements, and holding times for samples collected (MEL, 2005).

Parameter	Sample Matrix	Container	Preservative	Holding Time
Fecal Coliform	Surface water, groundwater, effluent, & runoff	250 or 500 mL glass/poly autoclaved	Cool to 4ºC	24 hours
Dissolved Oxygen	Surface water, effluent	300 mL BOD bottle & stopper	2 mL manganous sulfate reagent + 2 mL alkaline-azide reagent	4 days
Chloride	Surface water, groundwater, effluent, & runoff	500 mL poly	Cool to 4ºC	28 days
Total Suspended Solids; TNVSS[1]	Surface water, effluent, & runoff	1000 mL poly	Cool to 4ºC	7 days
Turbidity	Surface water, effluent, & runoff	500 mL poly	Cool to 4ºC	48 hours
Alkalinity	Surface water, groundwater, effluent, & runoff	500 mL poly – No Headspace	Cool to 4°C; Fill bottle *completely*; Don't agitate sample	14 days
Ammonia	Surface water, groundwater, effluent, & runoff	125 mL clear poly	H_2SO_4 to pH<2; Cool to 4ºC	28 days
Dissolved Organic Carbon	Surface water, groundwater, effluent, & runoff	60 mL poly with: Whatman Puradisc™ 25PP 0.45um pore size filters	Filter in field with 0.45um pore size filter; 1:1 HCl to pH<2; Cool to 4°C	28 days
Nitrate/Nitrite	Surface water, groundwater, effluent, & runoff	125 mL clear poly	H_2SO_4 to pH<2; Cool to 4ºC	28 days
Total Persulfate Nitrogen	Surface water, groundwater, effluent, & runoff	125 mL clear poly	H_2SO_4 to pH<2; Cool to 4ºC	28 days
Orthophosphate	Surface water, groundwater, effluent, & runoff	125 mL amber poly w/ Whatman Puradisc™ 25PP 0.45um pore size filters	Filter in field with 0.45um pore size filter; Cool to 4°C	48 hours
Total Phosphorous	Surface water, groundwater, effluent, & runoff	60 mL clear poly	1:1 H_2SO_4 to pH<2; Cool to 4°C	28 days
Total Organic Carbon	Surface water, effluent, & runoff	60 mL clear poly	1:1 HCl to pH<2; Cool to 4°C	28 days
Dissolved Metals	Groundwater	500 mL HDPE[2] bottle	Filter; then HNO_3 to pH<2 3, Cool to 4°C	6 months
Chlorophyll a	Surface water & periphyton	1000 mL amber poly	Cool to 4ºC; 24 hrs to filtration	28 days after filtering

TNVSS[1] = Total Nonvolatile Suspended Solids.
HDPE[2] = high-density polyethylene.

Measurement Procedures

Field

Field measurements will include conductivity, temperature, pH, and dissolved oxygen using a calibrated Hydrolab DataSonde® or MiniSonde®. Dissolved oxygen will also be collected and analyzed using the Winkler titration method (www.ecy.wa.gov/programs/eap/quality.html).

Measurement of relative head conditions between the piezometer and the creek will be accomplished by direct comparison measurements using standard procedures for calibrated electric well probes (Stallman, 1983). Temperature data loggers will also be downloaded monthly or bi-monthly using protocols established in SOP EAP044 (Bilhimer and Stohr, 2007).

Instantaneous flow measurements will follow the EA Program protocol (Ecology, 2006). Flow volumes will be calculated from continuous stage height records and rating curves developed during the project at two locations on Burnt Bridge Creek. Stage height will be measured by pressure transducer and recorded by a datalogger every 15 minutes. All dataloggers will be downloaded monthly or bi-monthly to reduce potential data loss due to vandalism/theft. Staff gages or tape-down measurements will be established at other selected sites. During the field surveys, staff gage/tape-down readings will be recorded at all stations, and streamflow will be measured when possible. A flow rating curve will be developed for sites with a staff gage or tape-down reference point so gage readings can be converted to a discharge value.

All continuously recording dataloggers will be synchronized to official U.S. time. The official time can be found at: www.time.gov/timezone.cgi?Pacific/d/-8/java. This information is available through (1) a Department of Commerce agency, the National Institute of Standards and Technology (NIST) and (2) the U.S. Naval Observatory (military counterpart of NIST). All date and time stamps will be recorded in Pacific Daylight Savings Time.

Laboratory

Measurement quality objectives state the level of acceptable error in the measurement process. Precision is a measure of the variability in the results of replicate measurements due to random error (Lombard and Kirchmer, 2004). This random error includes error inherently associated with field sampling and laboratory analysis. Field and laboratory errors are minimized by adhering to strict protocols for sampling and analysis.

Data Quality Objectives

Field sampling procedures and laboratory analysis inherently have associated error. Measurement quality objectives state the allowable error for a project. Precision and bias are data quality criteria used to indicate conformance with measurement quality objectives.

Precision is defined as the measure of variability in the results of replicate measurements due to random error. Random error is imparted by the variation in concentrations of samples from the environment as well as other introduced sources of variation (e.g., field and laboratory procedures). Precision for replicates will be expressed as percent relative standard deviation (%RSD).

Bias is defined as the difference between the population mean and true value of the parameter being measured. Bias affecting measurement procedures can be inferred from the results of quality control procedures involving the use of blanks, check standards, and spiked samples. Bias in field measurements will be minimized by strictly following sampling and handling protocols, and will be assessed by submitting field blanks.

Temperature and flow

Table 12 summarizes the accuracy and reporting limits of the equipment used. Certain instruments are used exclusively for water temperature and others for air as noted in the table. A WTW 340i multi-meter will be used to measure water conductivity and temperature of groundwater in piezometers. A Hydrolab DataSonde may be used to measure temperature and conductivity of surface waters.

Table 12. Summary of measurement quality objectives and manufacturer measurement limits of field equipment.

Measurement/ Instrument Type	Accuracy (% Deviation from True Value)	Required Resolution
Stream velocity/ Marsh McBirney Flo-Mate model 2000	±2% of reading; 0.1 ft/s 5%-8% measurement error	0.05 ft/s
Continuous temperature/ Hobo Water Temp Pro	±0.2°C at 0 to 50°C (± 0.36°F at 32° to 122°F)	0.2°C for water temperature
Continuous temperature/ StowAway Tidbits -5°C to +37°C model	±0.4°F (±0.2°C) at +70°F	0.2°C for water temperature
Continuous temperature / StowAway Tidbits -20°C to +50°C model	±0.8°F (±0.4°C) at +70°F	0.4°C for air temperature
Continuous water levels/ Hobo Water Level Logger U-20-001-01	±2.1 cm (0.07 ft) and ±0.37°C at 20°C (0.67°F at 68°F);	0.01 ft
Hobo Pro Relative Humidity	±3% RH	n/a
Instantaneous conductivity and temp./ TetraCon 325C probe and WTW 340i multi-meter	±1% of value (conductivity) 0.2°C (temperature)	0.2°C for temperature
Water Temperature and Specific Conductivity/Hydrolab MiniSonde®	+/- 0.1°C (temp) +/- 0.5% (conductivity)	0.1°C (temp) 0.1 umhos/cm (conductivity)

Groundwater

Two groundwater sampling events (one in mid summer and one in early fall, 2008) will be conducted to assess the quality of groundwater discharging to the creek along gaining stream reaches. The samples will be evaluated for the parameters shown in Table 13.

Table 13. Groundwater sampling parameters including test methods and detection limits.

Parameter	Equipment Type and Test Method	Reporting limit
Field Measurements		
Water level	Calibrated E-tape	0.01 foot
Temperature	Sentix® 41-3 probe[2]	0.1°C
Specific Conductance	Tetracon® 325 probe[2]	1 µS/cm
pH	Sentix® 41-3 probe[2]	0.1 SU
Dissolved Oxygen	Cellox® 325 probe[2]	0.1 mg/L
Laboratory Analyses		
Coliform, fecal (MF)	SM 9222D	1 CFU/100 mL
Alkalinity	SM 2320B	5 mg/L
Chloride	EPA 300.0	0.1 mg/L
Orthophosphate[1]	SM 4500-P G	0.003 mg/L
Total phosphorus[1]	SM 4500-P F	0.005 mg/L
Nitrate+nitrite-N[1]	SM 4500 NO_3^- I	0.01 mg/L
Ammonia[1]	SM 4500-NH_3^-H	0.01 mg/L
Total persulfate nitrogen-N[1]	SM 4500NB	0.025 mg/L
Dissolved organic carbon[1]	EPA 415.1	1 mg/L
Iron[1]	EPA 200.7	0.05 mg/L

[1] Dissolved fraction.
[2] Probe used with a WTW multiline P4 meter.
MF: Membrane filter method.
SU: Standard units.

Fecal coliform bacteria and dissolved oxygen

Microbiological and analytical methods, expected precision of sample replicates, and method reporting limits and resolution are given in Table 14. The targets for analytical precision of laboratory analyses are based on historical performance by MEL for environmental samples taken around the state by the EA Program (Mathieu, 2006). The reporting limits of the methods listed in the table are appropriate for the expected range of results and the required level of http://aww.ecology/programs/eap/Publications/ea_pub1.htmsensitivity to meet project objectives. The laboratory's measurement quality objectives and quality control procedures are documented in the MEL Lab Users Manual (MEL, 2005).

Table 14. Targets for precision and reporting limits for measurement systems.

Analysis	Equipment Type and Method	Duplicate Samples Relative Standard Deviation (RSD)	Method Reporting Limits and/or Resolution
Field Measurements			
Water Temperature[1]	Hydrolab MiniSonde®	+/- 0.1° C	0.01° C
Specific Conductivity[2]	Hydrolab MiniSonde®	+/- 0.5%	0.1 umhos/cm
pH[1]	Hydrolab MiniSonde®	0.05 SU	1 to 14 SU
Dissolved Oxygen[1]	Hydrolab MiniSonde®	10% RSD	0.1 mg/L
Dissolved Oxygen[1]	Winkler Titration	10% RSD	0.1 mg/L
Laboratory Analyses			
Fecal Coliform – MF	SM 9222D	30% RSD[3]	1 cfu/100 mL
Chloride	EPA 300.0	5% RSD[4]	0.1 mg/L
Total Suspended Solids	SM 2540D	15% RSD[4]	1 mg/L
Total Non-Volatile Suspended Solids	SM 2540 D, E	15% RSD[4]	1 mg/L
Turbidity	SM 2130	10% RSD[4]	1 NTU
Alkalinity	SM 2320B	10% RSD[4]	5 mg/L
Ammonia	SM 4500-NH_3^-H	10% RSD[4]	0.01 mg/L
Dissolved Organic Carbon	EPA 415.1	10% RSD[4]	1 mg/L
Nitrate/Nitrite	SM 4500 NO_3^- I	10% RSD[4]	0.01 mg/L
Total Persulfate Nitrogen	SM 4500 NO_3^-B	10% RSD[4]	0.025 mg/L
Orthophosphate	SM 4500-PG	10% RSD[4]	0.003 mg/L
Total Phosphorous	SM 4500-PF	10% RSD[4]	0.005 mg/L
Total Organic Carbon	EPA 415.1	10% RSD[4]	1 mg/L
Chlorophyll-*a*	SM 10200H(3)	20% RSD[4]	0.05 ug/L

[1] as units of measurement, not percentages.
[2] as percentage of reading, not RSD.
[3] replicate results with a mean of less than or equal 20 cfu/100 mL will be evaluated separately.
[4] replicate results with a mean of less than or equal to 5X the reporting limit will be evaluated separately.

SM = Standard Methods for the Examination of Water and Wastewater, 20th Edition (APHA, AWWA and WEF, 1998).
EPA = EPA Method Code.

Quality Control

Total variability for field sampling and laboratory analysis will be assessed by collecting replicate samples. Replicate samples are a type of quality assurance/quality control (QA/QC). Sample precision will be assessed by collecting replicates for 10-20% of samples in each survey. MEL routinely duplicates sample analyses in the laboratory to determine laboratory precision. The difference between field variability and laboratory variability is an estimate of the sample field variability.

Laboratory

All samples will be analyzed at MEL. The laboratory's measurement quality objectives and quality control procedures are documented in the MEL Lab Users Manual (MEL, 2005). MEL will follow standard quality control procedures (MEL, 2005). Field sampling and measurements will follow QC protocols described in Ecology (1993). If any of these QC procedures are not met, the associated results may be qualified by MEL or the project manager and used with caution, or not used at all.

Bacteria samples tend to have a high relative standard deviation (RSD) between replicates compared to other water quality parameters. Bacteria sample precision will be assessed by collecting replicates for approximately 20% of samples in each survey.

Standard Methods (APHA, AWWA, and WEF, 1998) recommends a maximum holding time of eight hours for microbiological samples (six hours transit and two hours laboratory processing) for non-potable water tested for compliance purposes. MEL has a maximum holding time for microbiological samples of 24 hours (MEL, 2005). Standard Methods (APHA, AWWA, and WEF, 1998) recommends a holding time of less than 30 hours for drinking water samples and less than 24 hours for other types of water tested when compliance is not an issue. Microbiological samples analyzed beyond the 24-hour holding time are qualified as estimates with a *J* qualifier code. MEL accepts samples Monday through Friday, which means Ecology can sample Sunday through Thursday.

To identify any problems with holding times, two comparison studies were conducted during the Yakima Area Creeks TMDL (Mathieu, 2005). A total of 20 fecal coliform samples were collected in 500-mL bottles and each split into two 250-mL bottles. The samples were driven to MEL within 6 hours. One set of the split samples was analyzed upon delivery. The other set was stored overnight and analyzed the next day. Both sets were analyzed using the membrane filter (MF) method. Replicates were compared to the measurement procedures in Table 14.

The combined precision results between the different holding times yielded a mean RSD of 19%. This is comparable to the 23% mean RSD between field replicates for 12 EA Program TMDL studies using the MF method, suggesting that a longer (i.e., 24-hour) holding time has little effect on fecal coliform results processed by MEL. Samples with longer holding times did not show a significant tendency towards higher or lower fecal coliform counts compared to the samples analyzed within 6-8 hours.

Field

Another type of QA/QC is the calibration check for data loggers. The Onset StowAway Tidbits©, Hobo Water Temp Pro©, and Hobo Water Level Logger© instruments will have a calibration check both pre- and post-study in accordance with Ecology Temperature Monitoring Protocols (Ward, 2003). This check will be to document instrument bias or performance at representative temperatures. A NIST certified reference thermometer will be used for the calibration check. The calibration check may show that the temperature datalogger differs from the NIST-certified thermometer by more than the manufacturer-stated accuracy of the instrument (range greater than ±0.2°C or ±0.4°C).

A datalogger that fails pre-study calibration check will not be used. If the temperature datalogger fails the post-study calibration check, then the actual measured value will be reported along with its degree of accuracy based on the calibration check results. As a result, these data may be rejected.

Variation for field sampling of instream temperatures and potential thermal stratification will be addressed with a field check of stream temperature at all monitoring sites upon deployment, during regular site visits, and during instrument retrieval at the end of the 2008 study period. Air temperature data and instream temperature data for each site will be compared to determine if the instream TI was exposed to the air due to stream stage falling below the installed depth of the stream TI.

The Onset Hobo Water Level Logger© pressure transducers will be checked for accuracy both before and after deployment using a graduated vertical water column that is capable of simulating the range of water depths the instruments will likely encounter during deployment. Water levels both in the piezometer and at the stream stage reference point will be measured in the field with an e-tape and steel engineers tape. Barometric pressure will be recorded at representative stations to compensate for atmospheric pressure effects on the water level loggers.

The WTW 340i multi-meter will be calibrated at the beginning of each sampling day using commercially prepared conductivity standards and reference solutions in accordance with the manufacturer's calibration procedures. The calibration will be rechecked at the end of each sample day.

Data Management Procedures

Field measurement data will be entered into a field book with waterproof paper in the field and then entered into EXCEL® spreadsheets (Microsoft, 2001) as soon as practical after returning from the field. This database will be used for preliminary analysis and to create a table to upload data into Ecology's Environmental Information Management (EIM) System.

Sample result data received from MEL by Ecology's Laboratory Information Management System (LIMS) will be exported prior to entry into EIM and added to a cumulative spreadsheet for laboratory results. This spreadsheet will be used to informally review and analyze data during the course of the project.

All continuous data will be stored in a project database that includes station location information and data quality assurance information. This database will facilitate summarization and graphical analysis of the temperature data and also create a data table to upload temperature data to the EIM geospatial database.

An EIM user study ID (STEB0002) has been created for this TMDL. All monitoring data will be available via the internet once the project data have been validated. The URL address for this geospatial database is: apps.ecy.wa.gov/eimreporting. All data will be uploaded to EIM by the EIM data engineer after all data have been reviewed for quality assurance and finalized.

All final spreadsheet files, paper field notes, and final GIS products created as part of the data analysis and model building will be kept with the project data files.

Audits and Reports

The project manager will submit quarterly reports and the final technical study report to Ecology's Water Quality Program client (TMDL coordinator) for this project according to the project schedule (Table 16). The project field lead will complete the bacteria section of the quarterly report.

Data Verification

Both data verification and validation require adequate documentation of the process.

Laboratory-generated data reduction, review, and reporting will follow the procedures outlined in the MEL Lab Users Manual (MEL, 2005). Lab results will be checked for missing and improbable data. Variability in lab duplicates will be quantified using the procedures outlined in the Users Manual (MEL, 2005). Any estimated results will be qualified and their use restricted as appropriate. A standard case narrative of laboratory QA/QC results will be sent to the project manager for each set of samples.

Field notebooks will be checked for missing or improbable measurements before leaving each site. The EXCEL® Workbook file containing field data will be labeled Draft until data verification and validation is complete. Data entry will be checked against the field notebook data for errors and omissions. Missing or unusual data will be brought to the attention of the project manager for consultation. Valid data will be moved to a separate file labeled FINAL.

As soon as fecal coliform data are verified by MEL, the laboratory microbiologist will notify the field lead about results greater than 200 cfu/100 mL. The field lead will then notify the Southwest Regional Office (SWRO) client staff contact and Water Quality Program section manager of these elevated counts in accordance with EA Program Policy 1-03. The TMDL coordinator will notify local authorities or permit managers as appropriate.

Data received from LIMS will be checked for omissions against the Request for Analysis forms by the field lead. Data can be in EXCEL® spreadsheets (Microsoft, 2001) or downloaded tables from EIM. These tables and spreadsheets will be located in a file labeled Draft until data verification and validation is completed. Field replicate sample results will be compared to quality objectives in Table 11. Data requiring additional qualifiers will be reviewed by the project manager.

Data for instream temperature monitoring stations will be verified against the corresponding air temperature station to ensure the stream temperature record represents water temperatures and not temperatures recorded during a time the instream TI was dewatered. Measurement accuracy of individual TIs is verified using a NIST-certified reference thermometer and field measurements of stream temperature at each TI location several times during the study period.

Data validation is the next step following verification. Data validation involves a detailed examination of the data package to determine whether the method quality objectives (MQOs) have been met. The project manager examines the complete data package to determine compliance with procedures outlined in the QA Project Plan and SOPs. The project manager is also responsible for data validation by ensuring that the MQOs for precision, bias, and sensitivity are met.

After data verification and data entry tasks are completed, all field, laboratory, and flow data will be entered into a file labeled FINAL and then into EIM. Ten percent of the project data in EIM will be independently reviewed by another EA Program field assistant for errors. If significant entry errors are discovered, a more intensive review will be undertaken.

During periods of active data collection, quarterly progress reports will be prepared and distributed by the project manager to the Technical Advisory Committee. At the end of the field study, the data will be compiled in a formal data summary report.

Data Quality (Usability Assessment)

The field lead will verify that all measurement and other data quality objectives have been met for each monitoring station. The field lead will make this determination by examining the data and all of the associated QC information. Data that does not meet the project data quality criteria will be qualified or rejected as appropriate. The field investigator will produce a station QA report that will include site descriptions, data QA notes, and graphs of all continuous data.

Project Organization

The roles and responsibilities of Ecology staff are provided in Table 15.

Table 15. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Tonnie Cummings WQP, SWRO (360) 690-4664	Overall Project Lead	Acts as point of contact between EAP staff and interested parties. Coordinates information exchange. Forms technical advisory team and organizes meetings. Reviews the QAPP and technical section of the joint TMDL report. Prepares and implements the joint TMDL report for submittal to EPA.
Kim McKee WQP, SWRO (360) 407-6407	Unit Supervisor of Project Lead	Approves TMDL report for submittal to EPA.
Stephanie Brock Western DSU/EAP (360) 407-6498	Project Manager	Defines project objectives, scope, and study design. Co-authors the QAPP. Develops TMDLs for temperature, bacteria and DO, including model development and writing the technical section of the joint TMDL report.
James Kardouni Western DSU/EAP (360) 407-6517	Field Lead/EIM Engineer	Co-authors QAPP. Manages the data collection program under the supervision of the project manager. Coordinates and conducts field survey and data collection. Enters project data into the EIM system and conducts data quality review.
Kirk Sinclair Groundwater/Forest and Fish Unit/EAP (360) 407-6557	Hydrogeologist	Provides hydrogeologic assistance with study design including interpretation of historical geology and groundwater data in the basin, groundwater data collection, data analysis, and report writing.
Chuck Springer FMU, WOS/EAP (360) 407-6997	Hydrogeologist	Deploys and maintains continuous flow gages and staff gages. Produces records of streamflow data at sites selected for this study.
George Onwumere Western DSU/EAP (360) 407-6730	Unit Supervisor of Project Manager	Reviews and approves the QAPP, staffing plan, technical study budget, and the technical sections of the joint TMDL report.
Bob Cusimano WOS/EAP (360) 407-6596	Section Manager of Project Manager	Approves the QAPP and technical sections of the joint TMDL report.
Stuart Magoon EAP, Manchester Environmental Laboratory (360) 871-8801	Director	Provides laboratory staff and resources, sample processing, analytical results, laboratory contract services, and quality assurance/quality control (QA/QC) data. Approves the QAPP.
William R. Kammin EAP (360) 407-6964	Ecology Quality Assurance Officer	Provides technical assistance on QA/QC issues. Reviews the d QAPP and approves the final QAPP.

DSU – Directed Studies Unit
EAP – Environmental Assessment Program
EIM – Environmental Information Management system
FMU – Freshwater Monitoring Unit
QAPP – Quality Assurance Project Plan
SWRO – Southwest Regional Office
WOS – Western Operations Section
WQP – Water Quality Program

Project Schedule

Table 16. Proposed schedule and assignments for completing field work, laboratory work, report writing, and data entry into EIM.

Field and laboratory work	
Field work completed	August 2009
Laboratory analyses completed	September 2009
Environmental Information System (EIM) system	
EIM data engineer	James Kardouni
EIM user study ID	STEB0002
EIM study name	Burnt Bridge Creek Fecal Coliform Bacteria, Dissolved Oxygen, and Temperature TMDL Technical Study
Data due in EIM	December 2010
Quarterly/annual reports	
Author lead	Stephanie Brock
Schedule	
1st quarterly/annual report	November 2008
2nd quarterly/annual report	February 2009
3rd quarterly/annual report	May 2009
4th quarterly/annual report	August 2009
Groundwater report	
Project Tracker code	08-029-02
Author lead	Kirk Sinclair
Schedule	
Draft due to supervisor	November 2010
Draft due to client/peer reviewer	December 2010
Draft due to external reviewer	March 2011
Final report due on web	December 2012
Final report	
Author lead	Stephanie Brock
Schedule	
Draft due to supervisor	November 2010
Draft due to client/peer reviewer	December 2010
Draft due to external reviewer	March 2011
Final report due on web	December 2012

Laboratory Budget

Table 17 presents the laboratory budget for this study. The estimated budget and lab sample load is based on (1) sampling bacteria at each fixed-network site twice per month (including QA/QC replicates), (2) one periphyton assessment, (3) two synoptic surface water surveys (including QA/QC replicates), (4) two groundwater quality surveys (including QA/QC replicates), and (5) one summer storm sampling event for bacteria, nutrients, TSS + TNVSS, TOC and DOC. Since all months have more than one survey that occur on different weeks, monthly and weekly laboratory sample loads should not overload the microbiological units at MEL.

The greatest uncertainty in the laboratory load and cost estimate is with the synoptic storm survey work. Efforts will be made to keep the submitted number of samples within the estimate; however, because the storm sites have not been selected yet, this is an estimate only.

Table 17. Laboratory budget.[3]

Parameter	Cost/ Sample	Number of Sites	Number of Samples (including field QA)	Subtotal Cost	Number of Surveys	Total Cost
Turbidity	11	19	42	462	2	924
Total Suspended (TSS) + TNVSS	35	19	42	1470	2	2940
Alkalinity	17	19	63	1071	2	2142
Chloride	13	19	63	819	2	1638
Chlorophyll-a (lab filtered)	55	19	42	2310	2	4620
Ammonia (NH3)	13	19	63	819	2	1638
Nitrite-Nitrate (NO2/NO3)	13	19	63	819	2	1638
Total Persulfate Nitrogen (TPN)	17	19	63	1071	2	2142
Orthophosphate (OP)	15	19	63	945	2	1890
Total Phosphorus (TP)	18	19	63	1134	2	2268
Periphyton (biovolume, ID)	77	19	21	1617	1	1617
Dissolved Organic Carbon (DOC)	35	19	63	2205	2	4410
Total Organic Carbon (TOC)	33	19	42	1386	2	2772
Iron	38	19	21	798	2	1596
Fecal Coliform	23	19	23	529	32	16928
One summer storm sampling event for bacteria, nutrients, TSS + TNVSS, DOC, and TOC						5728
Additional samples (e.g., for unknown sources)						7374
					Total:	$62,265

TNVSS - Total Nonvolatile Suspended Solids.

[3] Costs include 50% discount for Manchester Laboratory.

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Appendix A. Glossary and Acronyms

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

1-DMax or 1-day maximum temperature: The highest water temperature reached on any given day. This measure can be obtained using calibrated maximum/minimum thermometers or continuous monitoring probes having sampling intervals of thirty minutes or less.

7-DADMax or 7-day average of the daily maximum temperatures: The arithmetic average of seven consecutive measures of daily maximum temperatures. The 7-DADMax for any individual day is calculated by averaging that day's daily maximum temperature with the daily maximum temperatures of the three days prior and the three days after that date.

7Q2 flow: A typical low-flow condition. The 7Q2 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every other year on average. The 7Q2 flow is commonly used to represent the average low-flow condition in a waterbody and is typically calculated from long-term flow data collected in each basin. For temperature TMDL work, the 7Q2 is usually calculated for the months of July and August as these typically represent the critical months for temperature in our state.

7Q10 flow: A critical low-flow condition. The 7Q10 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every ten years on average. The 7Q10 flow is commonly used to represent the critical flow condition in a waterbody and is typically calculated from long-term flow data collected in each basin. For temperature TMDL work, the 7Q10 is usually calculated for the months of July and August as these typically represent the critical months for temperature in our state.

90th percentile: A statistical number obtained from a distribution of a data set, above which 10% of the data exists and below which 90% of the data exists.

Bankfull stage: Formally defined as the stream level that "corresponds to the discharge at which channel maintenance is most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels (Dunne and Leopold, 1978).

Char: Char (genus *Salvelinus*) are distinguished from trout and salmon by the absence of teeth in the roof of the mouth, presence of light colored spots on a dark background, absence of spots on the dorsal fin, small scales, and differences in the structure of their skeleton. (Trout and salmon have dark spots on a lighter background.)

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

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

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

Diel: Of, or pertaining to, a 24-hour period.

Diurnal: Of, or pertaining to, a day or each day; daily. (1) Occurring during the daytime only, as different from nocturnal or crepuscular, or (2) Daily; related to actions which are completed in the course of a calendar day, and which typically recur every calendar day (e.g., diurnal temperature rises during the day, and falls during the night).

Effective shade: The fraction of incoming solar shortwave radiation that is blocked from reaching the surface of a stream or other defined area.

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 twenty-four hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform bacteria are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

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

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

Loading capacity: The greatest amount of a substance that a 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.

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

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

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 of 5 or more acres.

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

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

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

System potential: The design condition used for TMDL analysis.

System potential temperature: An approximation of the temperatures that would occur under natural conditions. System potential is our best understanding of natural conditions that can be supported by available analytical methods. The simulation of the system potential condition uses best estimates of *mature riparian vegetation, system potential channel morphology, and system potential riparian microclimate* that would occur absent any human alteration.

Thalweg: the deepest and fastest moving portion of a stream.

Thermistor: temperature data logger, also known as a temperature instrument (TI).

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. As a margin of safety, a reserve for future growth is also generally provided.

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

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

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

BBC	Burnt Bridge Creek
BOD	biological oxygen demand
cfs	cubic feet per second
cfu	colony forming units
EAP	Environmental Assessment Program
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management
EPA	U.S. Environmental Protection Agency
FC	fecal coliform bacteria
GIS	Geographic Information System software
GPS	Global Positioning System
I-205	Interstate 205
I-5	Interstate 5
MEL	Manchester Environmental Laboratory
NIST	National Institute of Standards and Technology
QA/QC	quality assurance/quality control
RM	river mile
RSD	relative standard deviation
SOP	standard operating procedure
TI	temperature instrument
TMDL	Total Maximum Daily Load (water cleanup plan)
USGS	United States Geological Survey
WAC	Washington Administrative Code
WRIA	Water Resources Inventory Area

Appendix B. Data Analysis and Modeling Procedures

Fecal Coliform

Data analysis will include evaluation of data distribution characteristics and, if necessary, appropriate distribution of transformed data. Streamflow data will be frequently reviewed during the field data survey season to check longitudinal water balances. Fecal coliform mass balance calculations will be performed on a reach basis. Estimation of univariate statistical parameters and graphical presentation of the data (box plots, time series, and regressions) will be made using WQHYDRO (Aroner, 2003) and EXCEL® (Microsoft, 2001) software.

The statistical rollback method (Ott, 1995) will be applied to determine the necessary reduction for both the geometric mean value (GMV) and 90^{th} percentile bacteria concentration (Joy, 2000) to meet water quality standards. Ideally, at least 20 data are needed from a broad range of hydrologic conditions to determine an annual fecal coliform distribution. If sources of fecal coliform vary by season and create distinct critical conditions, seasonal targets may be required. Fewer data will provide less confidence in fecal coliform reduction targets, but the rollback method is robust enough to provide general targets for planning implementation measures. Compliance with the most restrictive of the dual fecal coliform criteria determines the bacteria reduction needed.

The rollback method uses the statistical characteristics of a known data set to predict the statistical characteristics of a data set that would be collected after pollution controls have been implemented and maintained. In applying the rollback method, the target fecal coliform GMV and the target 90^{th} percentile are set to the corresponding water quality standard. The reduction needed for each target value to be reached is determined. The rollback factor, $f_{rollback}$, is

$$f_{rollback} = \text{minimum} \{ (100/\text{sample GMV}), (200/\text{sample } 90^{th} \text{ percentile}) \}$$

The percent reduction ($f_{reduction}$) needed is

$$f_{reduction} = (1 - f_{rollback}) \times 100\%$$

which is the percent reduction that allows both GMV and 90^{th} percentile target values to be met. The result is a revised target value for either the GMV or the 90^{th} percentile. In most cases, a reduction of the 90^{th} percentile is needed, and application of this reduction factor to the study GMV yields a target GMV that is usually less (i.e., more restrictive) than the water quality criterion. The 90^{th} percentile is used as an equivalent expression to the "no more than 10%" criterion found in the second part of the water quality standards for fecal coliform bacteria.

Modeling Procedures

Means, maximums, minimums, and 90th percentiles will be determined from the raw data collected at each monitoring location. For temperature, the maximum, minimum, and daily average will be determined. Estimates of groundwater inflow will be calculated by constructing a water mass balance from continuous and instantaneous streamflow data and piezometer studies.

A model will be developed for observed and critical conditions. Critical conditions for temperature and dissolved oxygen are characterized by a period of low-flow and high-water temperatures. Sensitivity analysis will be run to assess the variability of the model results. Model resolution and performance will be measured using the root-mean-square-error (RMSE), a commonly used measure of model variability (Reckhow, 1986). The RMSE is defined as the square root of the mean of the squared difference between the observed and simulated values.

Temperature

The QUAL2Kw model (Chapra and Pelletier, 2003; Ecology, 2003b) or similar modeling framework will be used to evaluate the system potential temperature in the river. The model will be used to evaluate various heat budget scenarios for future water quality management decisions in the Burnt Bridge Creek basin.

GIS coverage of riparian vegetation in the Burnt Bridge Creek study area will be created from information collected during the 2008 temperature field study and the 2007 Clark County digital aerial orthophotographs. Riparian vegetation coverage will be created by qualifying four attributes: vegetation height, general species type or combinations of species, percent vegetation overhang, and the average canopy density of the riparian vegetation.

Data collected during this TMDL effort will allow the development of a temperature simulation methodology that is both spatially continuous and spans full-day lengths. The model will be calibrated to current (2008) conditions measured by this study design. The GIS and modeling analysis will be conducted using specialized software tools:

- Ecology's Ttools extension for ArcView will be used to sample and process GIS data for input to the shade and temperature models.
- Ecology's shade calculator (Ecology, 2003a) will be used to estimate effective shade along Burnt Bridge Creek. Effective shade will be calculated at 50- to 100-meter intervals along the streams, and then averaged over 500- to 1000-meter intervals for input to the temperature model.
- The QUAL2Kw model (Chapra and Pelletier, 2003; Ecology, 2003b) or GEMMS model (Edinger and Buchak, 1995) will be used to calculate the components of the heat budget and simulate water temperatures. Both temperature models simulate diurnal variations in stream temperature using the kinetic formulations for the components of the surface water heat budget that are described in Chapra (1997).

Model resolution and performance will be measured using the root-mean-square-error (RMSE), a commonly used measure of model variability (Reckhow, 1986). The RMSE is defined as the square root of the mean of the squared difference between the observed and simulated values.

QUAL2K will be applied by assuming that flow remains constant (i.e., steady flows) for a given condition such as a 7-day or 1-day period (using daily average flows), but key variables other than flow will be allowed to vary with time over the course of a day. For QUAL2K temperature simulation, the solar radiation, air temperature, relative humidity, headwater temperature, and tributary water temperatures are specified or simulated as diurnally varying functions.

Dissolved Oxygen and pH

Water quality modeling will be conducted using QUAL2Kw (Chapra and Pelletier, 2003) or a similar biogeochemical modeling framework. The specific modeling framework is expected to be QUAL2Kw, although an alternative framework may be used instead, depending on a review of available frameworks at the time when modeling tasks will be conducted. The water quality model will use kinetic formulations for simulating dissolved oxygen and pH in the water column similar to those shown in Figure B-1.

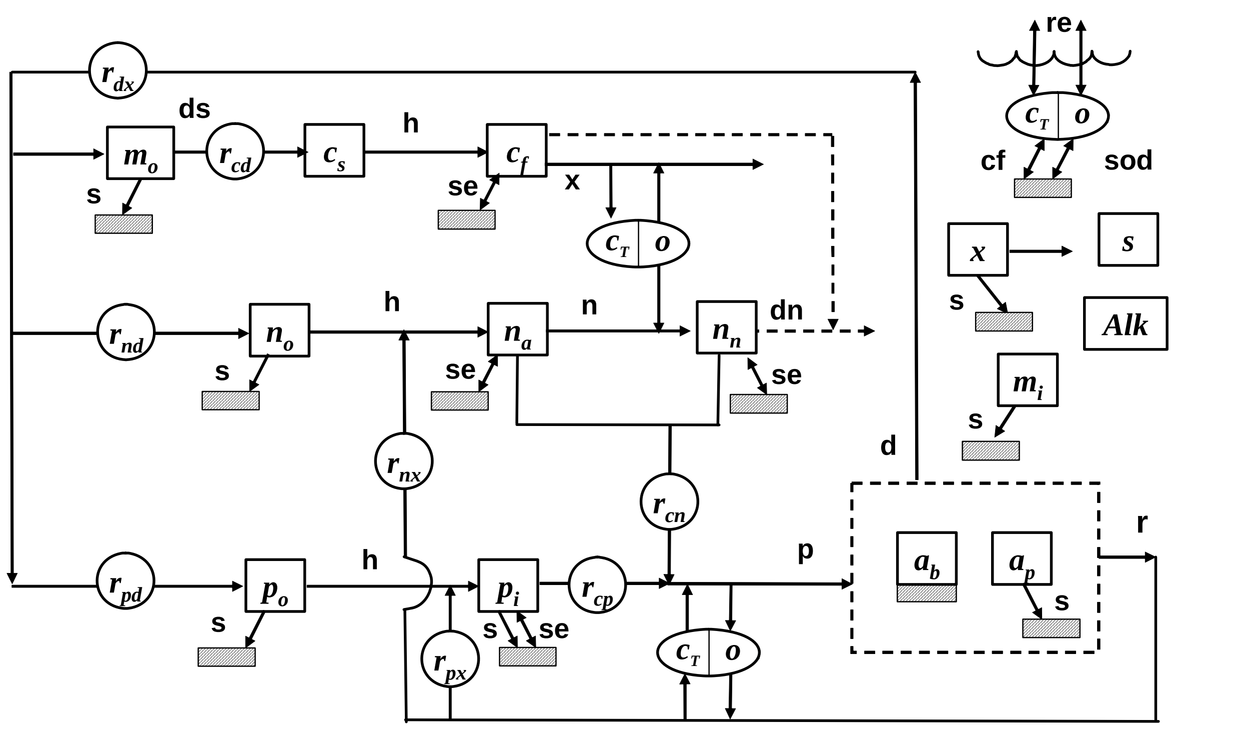

Figure B-1. Model kinetics and mass transfer processes in QUAL2Kw. The state variables are defined in Table B-1.

QUAL2K, or a similar model (e.g., WASP EUTRO) will be used to analyze the fate and transport of water quality variables relating to nutrients, periphyton, dissolved oxygen, and pH interactions in the water column. The water quality model will be developed to simulate dynamic variations in water quality of Burnt Bridge Creek. The water quality model will be calibrated and corroborated using data collected during the synoptic surveys and historical data to the extent possible.

Table B-1. Model state variables.

Variable	Symbol	Units*	Measured as
Conductivity	S	μmhos	COND
Inorganic suspended solids	m_i	mgD/L	TSS-VSS
Dissolved oxygen	O	mgO_2/L	DO
Slow-reacting CBOD	c_s	mgO_2/L	-
Fast-reacting CBOD	$c_{f,}$	mgO_2/L	r_{oc} * DOC or dissolved CBODU
Organic nitrogen	n_o	μgN/L	TN – NO3N NO2N– NH4N
Ammonia nitrogen	n_a	μgN/L	NH4N
Nitrate nitrogen	n_n	μgN/L	NO3N+NO2N
Organic phosphorus	p_o	μgP/L	TP - SRP
Inorganic phosphorus	p_i	μgP/L	SRP
Phytoplankton	a_p	μgA/L	CHLA
Detritus	m_o	mgD/L	r_{dc} (TOC – DOC)-r_{da}*CHLA
Alkalinity	*Alk*	$mgCaCO_3/L$	ALK
Total inorganic carbon	c_T	mole/L	Calculation from pH and alkalinity
Bottom algae biomass	a_b	gD/m^2	Periphyton biomass dry weight
Bottom algae nitrogen	IN_b	mgN/m^2	Periphyton biomass nitrogen
Bottom algae phosphorus	IP_b	mgP/m^2	Periphyton biomass phosphorus

* mg/L = g/m$^{3;}$ D = dry weight; A = chlorophyll a
r_{oc} = stoichiometric ratio of oxygen for hypothetical complete carbon oxidation (2.69)
CBOD – carbon biological oxygen demand

Kinetic processes are dissolution (ds), hydrolysis (h), oxidation (x), nitrification (n), denitrification (dn), photosynthesis (p), death (d), and respiration/excretion (r). Mass transfer processes are reaeration (re), settling (s), sediment oxygen demand (SOD), sediment exchange (se), and sediment inorganic carbon flux (cf).

Note that the subscript x for the stoichiometric conversions stands for chlorophyll a (a) and dry weight (d) for phytoplankton and bottom algae, respectively. For example: rpx and rnx are the ratio of phosphorus and nitrogen to chlorophyll *a* for phytoplankton, or the ratio of phosphorus and nitrogen to dry weight for bottom algae; rdx is the ratio of dry weight to chlorophyll *a* for phytoplankton or unity for bottom algae; rnd, rpd, and rcd are the ratios of nitrogen, phosphorus, and carbon to dry weight.

The following are measurements that are needed for comparison with model output:

TEMP =	temperature (^oC)
TKN =	total kjeldahl nitrogen (μgN/L) or TN = total nitrogen (μgN/L)
NH4N =	ammonium nitrogen (μgN/L)
NO2N =	nitrite nitrogen (μgN/L)
NO3N =	nitrate nitrogen (μgN/L)
CHLA =	chlorophyll *a* (μgA/L)
TP =	total phosphorus (μgP/L)
SRP =	soluble reactive phosphorus (μgP/L)
TSS =	total suspended solids (mgD/L)
VSS =	volatile suspended solids (mgD/L)
TOC =	total organic carbon (mgC/L)
DOC =	dissolved organic carbon (mgC/L)
DO =	dissolved oxygen (mgO_2/L)
PH =	pH
ALK =	alkalinity ($mgCaCO_3/L$)
COND =	specific conductance (μmhos/cm)

The model state variables can then be related to these measurements as follows:

s = COND

m_i = TSS – VSS or TSS – r_{dc} (TOC – DOC)

o = DO

n_o = TKN – NH4 – r_{na} CHLA or n_o = TN – NO2 – NO3 – NH4 – r_{na} CHLA

n_a = NH4

n_n = NO2 + NO3

p_o = TP – SRP – r_{pa} CHLA

p_i = SRP

a_p = CHLA

m_o = VSS – r_{da} CHLA or r_{dc} (TOC – DOC) – r_{da} CHLA

pH = PH

Alk = ALK