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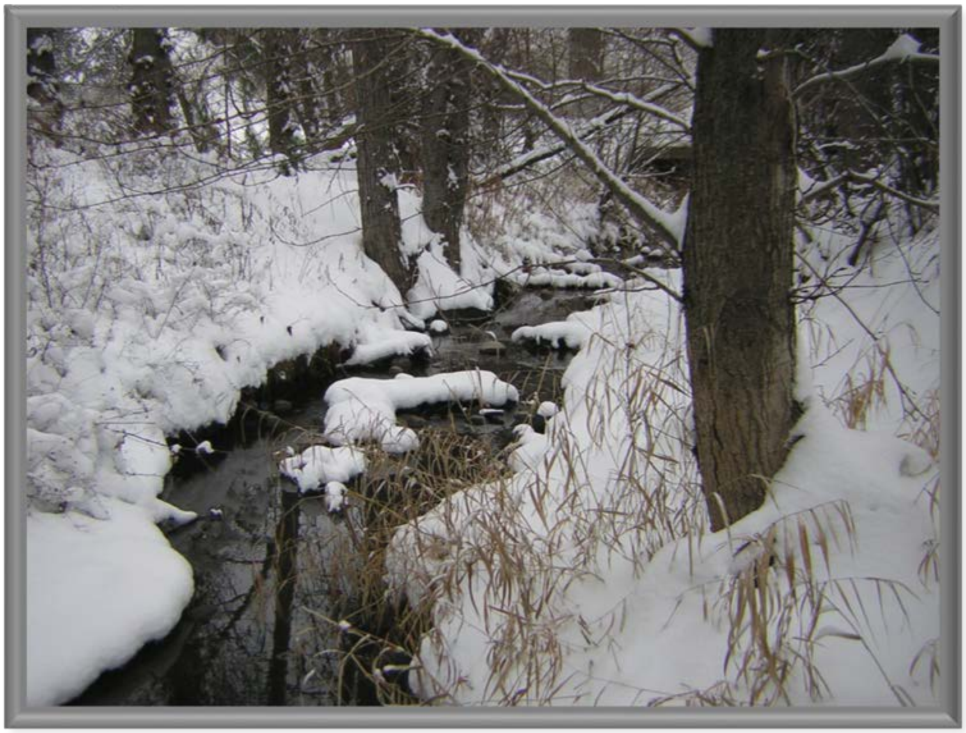

Crystal Creek Multi-Parameter Total Maximum Daily Load

Water Quality Effectiveness Monitoring Report

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Cover photo: Crystal Creek, near Cle Elum, WA

Crystal Creek
Multi-Parameter
Total Maximum Daily Load

Water Quality
Effectiveness Monitoring Report

by

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Water Body ID: WA-39-1037
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Table of Contents

List of Figures and Tables

Page

Figures

Tables

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Abstract

This study monitors the effectiveness of the Crystal Creek Total Maximum Daily Load (TMDL) for ammonia-nitrogen (ammonia-N), total residual chlorine (TRC), five-day biochemical oxygen demand (BOD_5) and fecal coliform bacteria (FCB). The study compares contaminant concentrations in water samples collected in 1985 and 1990 against a similar data set collected in 2009, 2010 and 2014. Samples were collected from three sites along Crystal Creek, a small creek in central Washington State. Crystal Creek originates in the hills above the city of Roslyn, runs along the historic Coal Mine Trail, through the city of Cle Elum, and then joins the Yakima River.

The most significant improvements that occurred over the last 20 years was the construction of a new community wastewater treatment plant, allowing the former Roslyn wastewater treatment plant to shut down and thereby stopping all discharges to Crystal Creek.

Results of the 2009-10 sampling showed that BOD_5 targets and ammonia-N criteria were always met during this period.

During the 2009-10 sampling events, it appeared that TRC occasionally did not meet criteria, which may have been due to manganese interference. However, after correcting for manganese interference in 2014, TRC samples always met state water quality criteria.

FCB levels generally met criteria, except for a slight exceedance at site CRY2 (the most downstream site) found in samples collected after the creek had dried up in some sections.

As a result of this study, the Washington State Department of Ecology (Ecology) recommends:

- Water Quality Assessment listings for BOD_5, TRC, and ammonia-N in Crystal Creek should be changed from Category 4A (has a TMDL) to Category 1 (meets water quality standards).
- Identify possible FCB sources between the two most downstream sampling sites.
- Collect additional FCB samples near to and/or within the city of Roslyn, to expand the FCB study. Work with the Washington State Department of Transportation (WSDOT) to reduce the impact of stormwater flows from Highway I-90 into Crystal Creek.

Acknowledgements

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- Jake Kleinknecht (Water Quality) and Kristen Carmack (Environmental Assessment) for their expert assistance with uploading data to the Environmental Information Management (EIM) database.

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, every state has its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of designated uses for protection, such as cold water biota and drinking water supply, and criteria, usually numeric criteria, to achieve those uses.

Every two years, all states are required to perform a Water Quality Assessment of the quality of surface waters in the state, including all the rivers, lakes, and marine waters where data were available. To develop the list, Ecology compiles its own water quality data, and invites other groups to submit water quality data they have collected. All data submitted needs to be collected using appropriate scientific methods.

Waters whose beneficial uses (such as drinking, recreation, aquatic habitat, and so on) are impaired by pollutants are placed in the “polluted” category on the water quality assessment. The 303(d) list, so called because the process is described in Section 303(d) of the Clean Water Act, comprises waters in the polluted water category.

TMDL process overview

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

Elements required in a TMDL

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

If the pollutant comes from a discrete (point) source such as a municipal or industrial facility’s discharge pipe, that facility’s share of the loading capacity is called a *wasteload allocation*. If it comes from a set of diffuse (nonpoint) sources such as general urban, residential, or farm runoff, the cumulative share is called a *load allocation.*

The TMDL must also consider seasonal variations and include a margin of safety that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. A reserve capacity for future loads from growth pressures is sometimes included as well. The sum of the wasteload and load allocations, the margin of safety, and any reserve capacity must be equal to or less than the loading capacity.

Water Quality Assessment / Categories 1 to 5

The 303(d) list identifies the most polluted waters in Washington State. However, the Water Quality Assessment is a list that tells a more complete story about the condition of Washington's water.

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

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

Category 2 – Waters of concern.

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

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

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

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

TMDL analyses

Loading capacity

Identification of the contaminant loading capacity for a water body is an important step in developing a TMDL. The U.S. Environmental Protection Agency (EPA) defines the loading capacity as "the greatest amount of loading that a water body 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 water body into compliance with standards. The portion of the receiving water's loading capacity assigned to a particular source is a load allocation (LA) or wasteload allocation (WLA). By definition, a TMDL is the sum of the allocations, which must not exceed the loading capacity.

Load and wasteload allocations

In this effectiveness monitoring study, the LA is considered to be equal to the loading capacity for Crystal Creek. The original TMDL determined both LAs and WLA for all TMDL parameters; however, since the sole permitted point source (the Roslyn POTW (wastewater treatment plant or "publicly owned treatment works") was removed from service, the related WLA was also removed.

Background

What is effectiveness monitoring?

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

The benefits of effectiveness evaluation include:

- More efficient allocation of funding.
- Optimization in planning/decision-making (i.e., program benefits).
- Watershed recovery status (i.e., how much restoration has been achieved, how much more effort is required).
- Adaptive management or technical feedback to refine restoration treatment design and implementation.

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

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

Study area

Crystal Creek is located near the cities of Roslyn and Cle Elum in central Washington State. Crystal Creek is part of the upper Yakima River watershed, in water resource inventory area (WRIA) 39.

Crystal Creek is a tributary of the Yakima River, entering the Yakima River at river mile (RM) 183.1 near Cle Elum. Crystal Creek drains over eight square miles of forested foothills in its four-mile course through a small valley, which is bounded by the Cle Elum ridge to the northeast and Easton ridge to the west.

Crystal Creek averages two to six feet wide, with an average depth of 0.5 foot. Winter flows can be quite high: in January 2009, Crystal Creek overtopped its banks and flooded several nearby homes. However, this creek often dries up in several sections in late summer through early fall.

According to the Washington State water quality standards, this creek is a primary contact recreation stream and is protected for salmonid spawning, rearing, and migration.

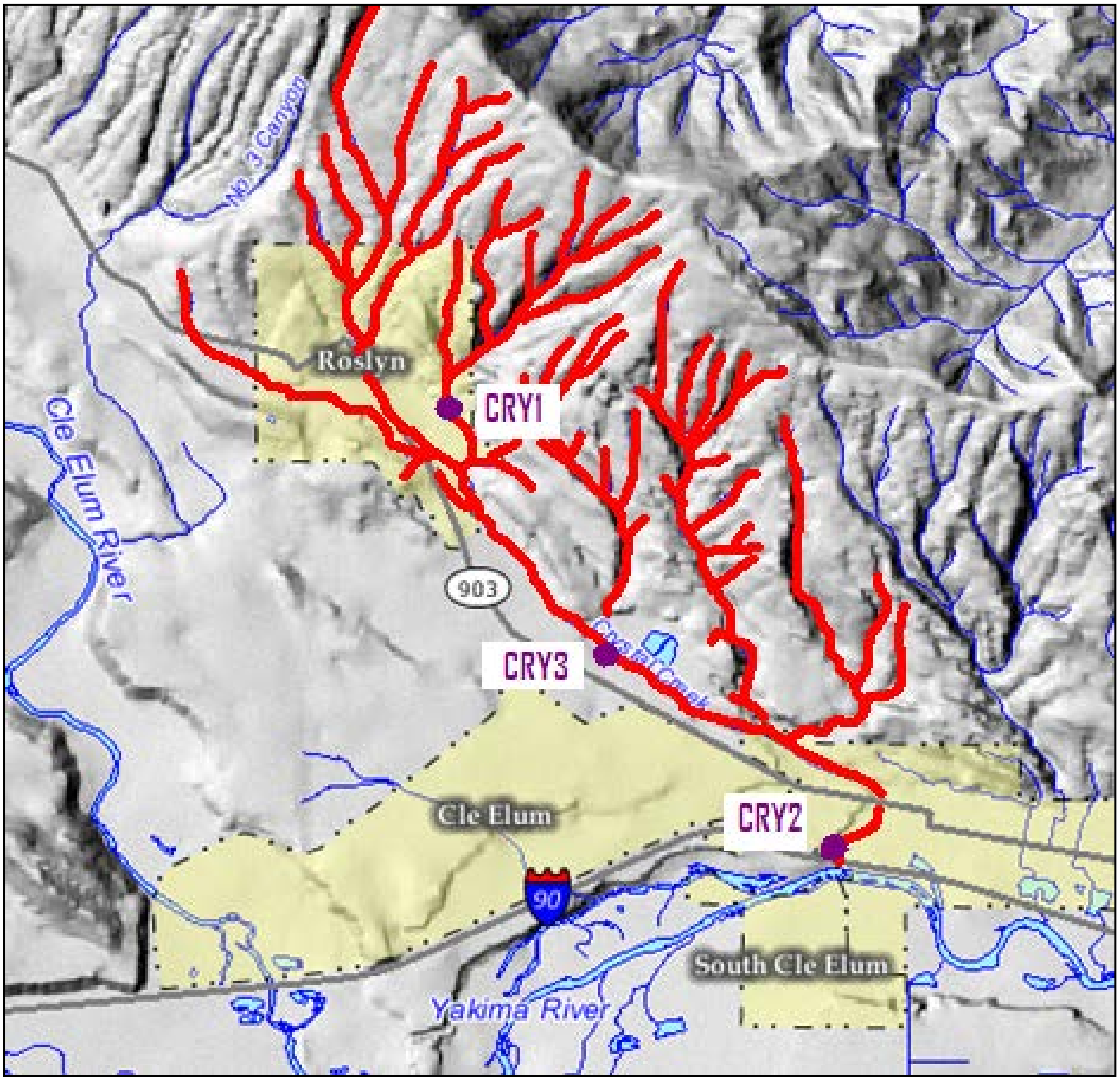

Figure 1: Map of Crystal Creek. Sampling locations in purple. Crystal Creek and tributaries outlined in red.

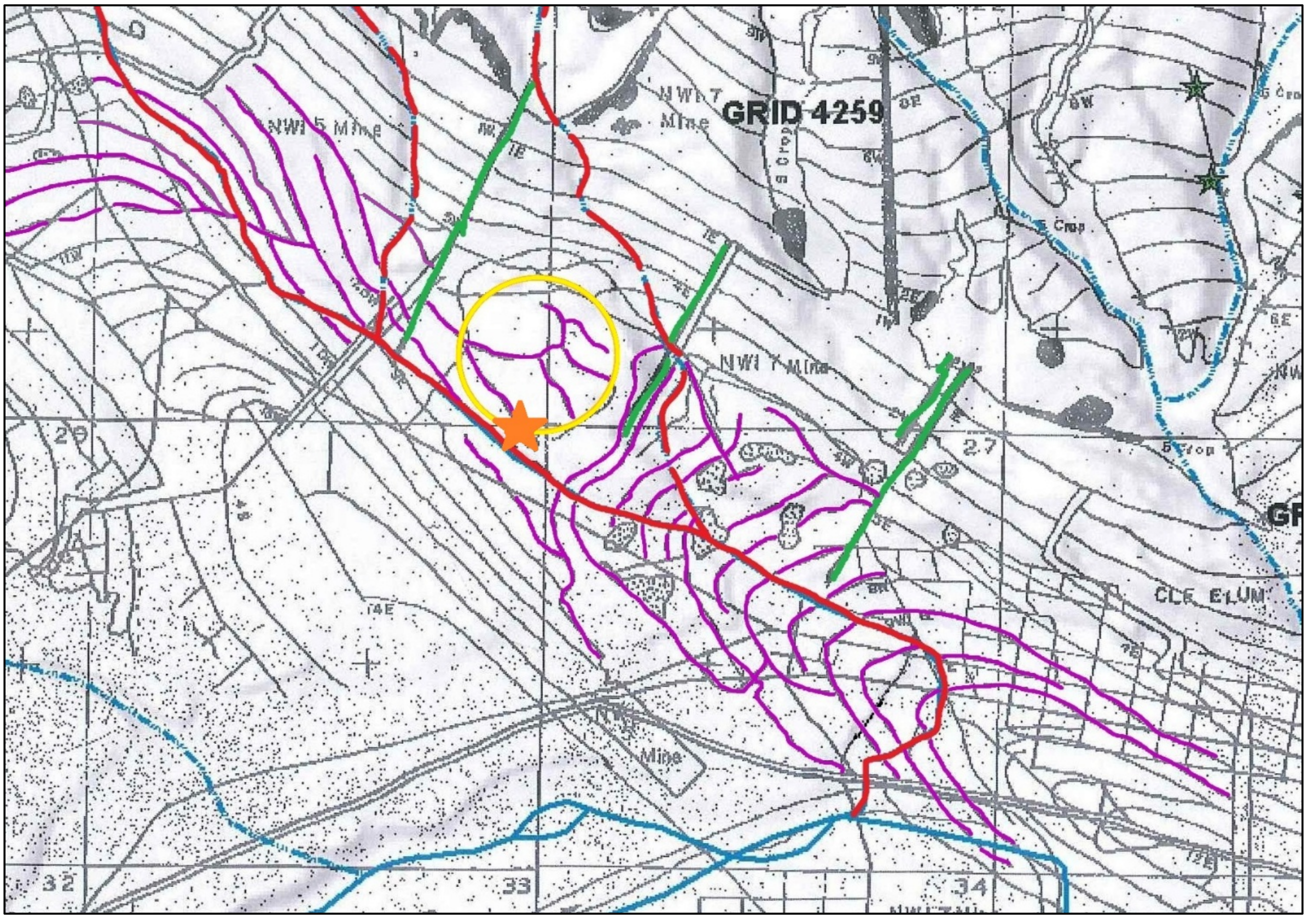

Figure 2: Map showing coal mines and tunnels near the lower section of Crystal Creek.

(Crystal Creek in red, Yakima River in solid blue, mine adits in green, selected laterals in purple. Area of former Roslyn POTW in yellow circle. Orange star indicates location of former POTW effluent discharge and one point of entry of mine drainage into creek.)

Pollutants addressed by this TMDL

Pollutants addressed by this TMDL are fecal coliform bacteria (FCB), total residual chlorine (TRC), five-day biochemical oxygen demand (BOD_5), and ammonia nitrogen (ammonia-N). The latter three parameters were primarily associated with discharges from the former Roslyn POTW (wastewater treatment plant or "publicly owned treatment works"), while the FCB had numerous suspected sources. See the later section on "water quality standards and beneficial uses" for more information about these parameters.

Project history

In the 1980's and '90's, Ecology conducted TMDL studies on Crystal Creek, to evaluate water pollution levels and to identify possible sources of pollution. During these assessments, Ecology determined that FCB, TRC, BOD_5, and ammonia-N represented water quality impairments in Crystal Creek. The TMDL identified the "critical condition" to be the low-flow period of the year.

The first receiving water study on the Roslyn POTW (Joy, 1985) found that principal pollutant sources were effluent from the city's sewage treatment lagoons and leaking sewer lines in the city of Roslyn. Discharge from an old coal mine was also investigated, but it did not appear to impact stream water quality. Possible additional pollutant sources were identified as pasture areas, spring sources, and sewage leaks from the town of Ronald. However, a subsequent receiving water study (Willms, 1991) focused primarily on the Roslyn POTW and the Roslyn sewer collection system as significant pollutant sources; possible mine drainage was not addressed. Both of the studies were used to support the TMDL.

In the mid-1990's, sewage from the town of Ronald was piped to, and treated at, the Roslyn POTW. Roslyn had significant inflow and infiltration (I&I) [1] problems during this period, and made numerous upgrades and repairs to their sewer collection system. By this time, the Roslyn POTW consisted of three five-acre lagoons, two aeration basins and a chlorine contact chamber. Under a National Pollution Discharge Elimination System (NPDES) permit, the Roslyn POTW discharged to Crystal Creek until 2006.

In 2006, the city of Roslyn and the town of Ronald connected their sewer mains to the new Upper Kittitas County Regional Wastewater Treatment Facility, located in Cle Elum, and the Roslyn POTW was closed.

Because the Roslyn POTW has ceased operations, there is no longer any effluent discharged to Crystal Creek from this facility. The earlier studies indicated that the effluent represented about 20% to 50% of the flow in creek, during low-flow periods.

In 2009, Ecology decided that it would be appropriate to review the water quality in Crystal Creek with an effectiveness monitoring project. Staff drafted a quality assurance project plan (QAPP) (Appendix A), and then followed the QAPP to produce the information found in this report.

[1] Inflow and infiltration (I&I) are terms that describe the ways that groundwater and stormwater enter into dedicated wastewater or sanitary sewer systems. Inflow is stormwater that enters into sanitary sewer systems at points of direct connection to the systems. Infiltration is groundwater that enters sanitary sewer systems through cracks and/or leaks in the sanitary sewer pipes. Some neglected or poorly built wastewater collection systems can have I&I problems during the wet time of the year, and then leak sewage during the dry time of the year. Usually, I&I inspections and correction projects can help with both I&I and leakage issues..

Watershed implementation or restoration activities

New wastewater treatment facility

In the mid-1990s, sewage from the city of Roslyn and the town of Ronald was treated at the Roslyn POTW, with POTW effluent discharged to Crystal Creek.

In 2006, the city of Roslyn and the town of Ronald connected to the new Upper Kittitas County Regional Wastewater Treatment Facility. After they connected to the new treatment plant, the Roslyn POTW was closed, and all discharges of effluent from the Roslyn POTW to Crystal Creek ceased. The Roslyn POTW discharges had historically been identified as the primary cause of the water quality violations in Crystal Creek, so elimination of this discharge to the creek is the most significant management change implemented following development of the TMDL. This is a cost-effective, sustainable pollution reduction activity.

Additional water quality improvement activities

The I&I improvements made by the city of Roslyn during the 1990's have reduced the potential (and the observation) of leaks from its sewer collection system throughout the city.

Beginning in 2008, the city of Cle Elum has been working with the Kittitas County Conservation District to map and digitize their stormwater system, so that the city can better control stormwater runoff and prevent pollution of Crystal Creek.

In 2011, both the city of Cle Elum and the City of Roslyn passed municipal ordinances regarding disposal of pet waste. Enforcement of these laws will help prevent future contamination of Crystal Creek by animal waste.

In 2014, the city of Roslyn completed a comprehensive stormwater management plan. One of the goals of the plan is to reduce polluted stormwater runoff from entering Crystal Creek.

How can restoration or implementation techniques be improved?

Future TMDL implementation activities should focus on reduction of FCB[2]. Additional actions that will further reduce FCB include:

- Conduct additional sampling for FCB in Crystal Creek, including all tributaries, from within the city of Roslyn to the creek's confluence with the Yakima River. Use results from this sampling to determine where additional FCB reduction activities should occur.
- Work with Kittitas County Environmental Health Department to identify potential leaking on-site septic systems. Work with property owners to correct problems, by providing financial and technical assistance.
- Identify properties that are near (or drain to) Crystal Creek that graze livestock. Work with property owners to prevent runoff from livestock areas, if the runoff enters Crystal Creek.

[2] Total residual chlorine, BOD_5 and ammonia met TMDL targets. Therefore, reduction of FC bacteria should be the focus of additional water quality improvement activities.

Water Quality Standards, TMDL Targets, and Beneficial Uses

This TMDL protects two key beneficial uses: primary contact recreation and aquatic life use for spawning and rearing of salmonids.

Crystal Creek runs through two small cities (Roslyn and Cle Elum), and is immediately adjacent to many homes. Because it is a small creek with low flows in the summer, children find the creek inviting to play in during the warm weather. By reducing FCB levels to amounts safe for primary contact recreation, this use will be protected.

Crystal Creek is also home to several kinds of resident fish, including rainbow trout, and is a good spawning and rearing location for salmon. Additionally, salmon smolts often enter lower Crystal Creek, as a resting spot as they move down river. TMDL parameters that affect aquatic species include BOD_5, ammonia-N, and TRC. BOD_5 limits are set to improve dissolved oxygen (DO) concentrations.

Target levels in the original TMDL were set to comply with 1992 state water quality standards[3]. However, target levels for this effectiveness monitoring project have been updated, where necessary, to comply with the latest version (2006) of the state water quality standards. See Table 1 for specific targets.

Because Washington State does not have numeric water quality criteria for BOD_5, this effectiveness monitoring project will continue to use the original TMDL limits as BOD_5 targets for this project. The 1993 TMDL set the loading capacity to Crystal Creek for BOD_5 at 116 lbs/day (12 mg/L). The TMDL wasteload allocation for BOD_5 was set at 113 lbs/day (11 mg/L in effluent) and a BOD_5 load allocation of 1 mg/L (3 lbs/day BOD_5 instream). The loading capacity for BOD_5 was determined to be consistent with the state water quality criterion for DO (Joy, 1985; Willms, 1991). The BOD_5 level is determined by measuring the amount that DO is reduced in a five-day period; in this case, the instream DO will still meet state DO criterion after exposure to the allowed (loading capacity) amount of BOD_5. The state water quality criterion for DO in Crystal Creek is the same now (8.0 mg/L) as it was in 1992, so the original BOD_5 loading capacity will still ensure compliance with the current DO criterion.

[3] The Crystal Creek TMDL technical study was completed in 1990, and the TMDL was submitted to EPA in 1991, using proposed 1992 water quality standards. The TMDL was approved by EPA in 1993.

Table 1: Effectiveness Monitoring Targets for the *Crystal Creek TMDL*

Parameter	Current Classification Category / Beneficial Use (most stringent)	Target
Fecal Coliform Bacteria	Primary Contact Recreation	Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies /100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200 colonies /100 mL .
BOD_5	Aquatic Life Use: Spawning/Rearing	12 mg/L (116 lbs/day in 1.76 cfs flow (0.53 cfs stream + 1.23 cfs effluent from former POTW))
Total Residual Chlorine	Aquatic Life Use: Spawning/Rearing	ACUTE: 19.0 ug/L A 1-hour average concentration not to be exceeded more than once every three years on the average. CHRONIC: 11.0 ug/L A 4-day average concentration not to be exceeded more than once every three years on the average.
Ammonia	Aquatic Life Use: Spawning/Rearing	ACUTE: Shall not exceed the numerical value total ammonia nitrogen (mg N/L) given by: For salmonids present: $\frac{0.275}{1 + 10^{7.204 - pH}} + \frac{39.0}{1 + 10^{pH - 7.204}}$ A 1-hour average concentration not to be exceeded more than once every three years on the average. CHRONIC: Shall not exceed the numerical concentration calculated as follows: **Un-ionized ammonia concentration for waters where salmonid habitat is an existing or designated use:** $0.80 \div (FT)(FPH)(RATIO)$ where: $RATIO = 13.5; 7.7 \leq pH \leq 9$ $RATIO = (20.25 \times 10^{(7.7-pH)}) \div (1\ 10^{(7.4-pH)}); 6.5 \leq pH \leq 7.7$ $FT = 1.4; 15 \leq T \leq 30$ $FT = 10^{[0.03(20-T)]}; 0 \leq T \leq 15$ $FPH = 1; 8 \leq pH \leq 9$ $FPH = (1 + 10^{(7.4-pH)}) \div 1.25; 6.5 \leq pH \leq 8.0$ A 4-day average concentration not to be exceeded more than once every three years on the average.

The EPA approved the Crystal Creek TMDL in 1993. Following this approval, Water Quality Assessment listings for FCB, TRC and ammonia-N in Crystal Creek were changed to Category 4A, meaning that a TMDL has been approved for these water quality parameters. Additionally, DO in Crystal Creek was moved to Category 2, Waters of Concern. See Table 2.

Table 2: Current water quality assessment listings for Crystal Creek. From the 2014 EPA-approved Washington State Water Quality Assessment.

Listing ID	Category	WRIA	Water Body Name	Parameter	Medium
6720	4A	39	CRYSTAL CREEK	Fecal Coliform	Water
8937	4A	39	CRYSTAL CREEK	Chlorine	Water
8938	4A	39	CRYSTAL CREEK	Ammonia-N	Water
8353	2	39	CRYSTAL CREEK	Dissolved Oxygen	Water

Fecal coliform bacteria

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

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 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 mL" [WAC 173-201A-200(2)(b), 2003 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)" criterion. These two measures, used in combination, ensure that bacterial pollution in a water body will be maintained at levels that will not cause a greater risk to human health than intended. While some discretion exists for selecting sample averaging periods, compliance will be evaluated for both monthly (if five or more samples exist) and seasonal (summer versus winter) data sets.

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

If natural levels of FCB (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 (DO)

BOD_5, rather than DO, is one of the original TMDL parameters. However, because increased BOD_5 results in reduced DO, the following discussion of DO is included. Aquatic organisms are very sensitive to reductions in the level of DO in the water. The health of fish and other aquatic species depends on maintaining an adequate supply of oxygen dissolved in the water. DO 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, Washington State designed the DO criteria to maintain conditions that support healthy populations of fish and other aquatic life.

DO 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 corresponds predominantly to the pattern of daily minimum DO concentrations, the criteria are the lowest 1-day minimum DO concentrations that occur in a water body.

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

> To protect the designated aquatic life use of "Salmonid Spawning, Rearing, and Migration," the lowest 1-day minimum DO level must not fall below 8.0 mg/l more than once every ten years on average. To achieve this criterion, a maximum BOD_5 target of 12 mg/L is part of this TMDL.

Toxics

Washington State applies criteria for toxics (e.g., ammonia-N and TRC) to waters of the state to protect aquatic life and human health. In this TMDL, criteria for ammonia-N and TRC are set to protect aquatic life, at the chronic exposure level.

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

Goals and Objectives

Goal

The goal of this monitoring project is to track changes in water quality by monitoring concentrations of BOD_5, TRC, ammonia-N, and FCB in Crystal Creek, to verify management activities are effective and to support the systematic review and improvement of water quality. In particular, this project aims to determine the water quality improvements resulting from the (1) bacteria-reduction improvements made in the city of Roslyn, and (2) closure of the former Roslyn POTW and the resulting cessation of effluent entering Crystal Creek.

Objectives

Objectives of the proposed study are as follows:

- Collect water data from selected locations in Crystal Creek, over a calendar year, to assess water quality to:
  - Further characterize the current water quality of the creek, and
  - Use these data in evaluation of other TMDL criteria (i.e., ammonia-N)
- Determine if targets for BOD_5, TRC, ammonia-N, and FCB set by the 1990 TMDL study have been met.
- Determine if Washington State water quality standards for TRC, ammonia-N and FCB have been met.

Methods

Sampling Locations

Sampling sites were selected relative to importance to the project and ease of access. In particular, access during heavy winter snowfall was considered, as was avoidance of private property. A single background site (CRY1) was originally selected, since this was a small project – the headwater site was selected on a fork of Crystal Creek with relatively little human contact (the east fork), to give a better depiction of the changes caused by the closure of the Roslyn POTW. The targets identified in the original TMDL were at a site that is difficult to access during the winter. For this reason, a sampling site about ½ mile further downstream was used for this study (CRY2). Except for the period when the creek is dried-up, the water quality at site CRY2 should be very similar to the original target site. The *background* site from the original TMDL was retained (site CRY3).

The most downstream sampling location (CRY2), placed about 100 yards up from the confluence with the Yakima River, was selected to show the water quality after all potential influences were included. However, toward the end of the data collection phase of the project, staff discovered that an additional pollution source was caused by runoff from Highway I-90 during heavy rains – the high runoff levels added significant turbidity just below the sampling location. During this period, samples were collected further downstream from the original CRY1 sampling site, in order to evaluate the increased turbidity levels.

In early summer, site (CRY3) was added. CRY3 was located just downstream from the Alliance Road crossing, just downstream from confluence of the all forks of Crystal Creek in the Roslyn area. Data from CRY3 was useful in determining the FCB levels from the city of Roslyn, rather that sampling the individual urban tributaries as seen in the original TMDL sampling regimen.

Sampling Procedures

Sampling proceeded much as planned in the quality assurance project plan (QAPP) designed for this effectiveness monitoring project (Creech, 2009).

The majority of samples were collected by Jane Creech, from May 2009 through August 2010, with some follow-up sampling in 2014. The main analytical lab used was Cascade Analytical in Union Gap, Washington. However, Cascade Analytical in Wenatchee was used occasionally to accommodate lab schedules. Additionally, Analytical Resources Incorporated lab in Seattle was used to ensure that the detection limits for ammonia samples were below criteria. All of these labs are certified by Ecology for the parameters analyzed. Labs used for each sampling event are identified in Appendix A, which shows all laboratory analytical results.

Samples were collected at least once a month, over a fourteen-month period (in 2009-10), with additional samples collected in 2014. The 2014 samples were analyzed in the field.

Since the creek now dries up during the period identified as the critical condition in the original TMDL[4], samples were collected during the rest of the year to assess stream condition.

The supply list outlined in the QAPP was followed closely, with minor changes. Staff found that the depth integrated hand sampler was not needed, as the creek allowed wading and collecting grab samples by hand. In 2014, only four follow-up samples were collected for TRC (instead of the five estimated in the QAPP), as the creek dried up earlier in 2014. The creek also had very low flows in 2015 and dried up very early in the year.

Flow meters were checked for calibration per the manufacturer’s recommended schedules and methods. The pH/temperature probe was calibrated before each round of sampling, using current pH standards. The chlorine tester was checked for calibration, using standards prior to each sampling event.

Field procedures that were used in this project were based on standard operating procedures developed by Ecology’s EAP program (Nipp, 2006; Mathieu, 2006; Joy, 2006; Sullivan, 2007;

[4] Following the closure of the Roslyn POTW, stream flow levels are now much lower, especially during the summer and fall when the stream dries up in many sections.

Ward, 2007). EAP also provided guidance regarding the collection of TRC data in the field. Field staff used a Hach Cl_2 field tester (Model 46700-00) for TRC, provided by EAP's Manchester Lab.

During one sampling excursion (March 3, 2010), field blanks were created by filling a 125 mL sterilized poly container and a 16-ounce poly sample container with de-ionized (or distilled) water just before collection of the first sample. The field blanks were clearly marked as BLANKS, including each parameter name, to avoid use for analytical duplicates or matrix spikes. The field blanks were placed in the ice chest and transported by the sampler throughout the sampling event.

Staff collected replicate samples for quality control. During one sampling excursion, replicates were collected for all samples; each replicate was collected immediately after each original sample. During a later sampling excursion, replicates were again collected for bacteria samples, using the same procedures.

Entries in a field notebook were added as needed at each of the monitoring sites. The entries included the date, time of sampling, personnel present, name of person doing the water collection, general weather conditions and any comments pertinent to the event. Also, any field data was entered into the notebook immediately as the data was collected.

All surface-water samples collected in the field were immediately sealed, labeled, and stored in ice for transport to the lab. Field blanks were stored and transported along with the collected samples. Water samples were transported as soon as realistically possible after sampling and stored in a cooler or refrigerator unit at the lab at 4ºC or less until analysis. Analysis by the lab were completed within the holding time for each sample.

Table 3: Collection, preservation and handling of samples in the field.

Parameter	Container Type	Sample Volume	Preservation	Holding Time
Fecal Coliform Bacteria	Sealed sterile single use polycarbonate containers	100 mL	Cool <4ºC	24 hrs
Ammonia-N	Poly	125 mL	Cool <4ºC	48 hrs
BOD_5	Poly	16 oz.	Cool <4ºC	48 hrs
Total Residual Chlorine	Poly	1,000 mL	N/A	15 minutes*

*Total residual chlorine must be analyzed in field, due to very short holding time

Adjustments made to study design

As projects progress, changes must be made to a sampling plan if problems or unexpected events arise. In this case, a few changes were necessary to add to the success of the project. These changes are also described in the addendum to the QAPP.

Stream flow monitoring

In July 2009, the background site near Roslyn (CRY1) dried up completely. Site CRY3 was established just downstream from the Alliance Road crossing. This site had been used during the original TMDL study. While the stream geometry was not ideal at this site (numerous large boulders throughout this reach made flow sampling difficult and unreliable), the site was easily accessed and good for historical comparison. Staff continued to collect samples and field data at Site CRY3 for the duration of the project as well.

In January 2010, some flowing water could be heard under deep snow at site CRY1. By February, field staff were able to see the flowing water and estimate the flow. Flow was estimated by comparing current flow to the lowest flow that could be measured with a flow meter.

Another finding related to flow was the discovery that the stream was never observed to cease flowing at site CRY2, just upstream from the confluence of Crystal Creek and the Yakima River. This was in spite of the fact that a long reach of the creek, only about 500' upstream, completely dried up from August through December. This observation – the drying-up of a large portion of the lower creek – had not been noted during previous studies, since the very low flows were masked by POTW effluent. Two possible causes were identified for the uninterrupted flow just downstream from the long dry reach: (1) connectivity between the creek and extensive flooded underground coal mines in the area, and (2) subsurface flows from a small irrigated pasture just upstream from the always-flowing reach. Because the constant disconnected flow was unanticipated, samples were inadvertently collected from Site CRY2 during a period when much of the rest of the creek may have actually dried up. The data collected after the creek had dried up were not included in the statistical results for this study, since the study was to look at the water quality of the flowing stream, not pools.

Additional checks at Site CRY3 indicate that that this site might also have persistent (year-round) flows, although this site was not checked as often as Site CRY2. The persistent flows at Site CRY3 are also likely due, at least in part, to drainage from old mines.

Total residual chlorine monitoring

In order to measure TRC levels in a water body, samples must be analyzed within 15 minutes of sample collection. For this project, the water had to be analyzed in the field, since no water quality labs are reachable within a 15-minutes delivery time from the project area.

Ecology's Manchester Lab supplied a Hach field chlorine test kit for this purpose. After collecting numerous samples that appeared to show TRC contamination, staff learned that naturally-occurring manganese can mimic the presence of TRC when using this field analytical equipment. Additional samples were collected in 2014 and treated to eliminate manganese interference prior to TRC analysis. See Appendix B for more detail on the test to eliminate manganese interference. When the samples were tested in the colorimeter after treatment, it became apparent that TRC levels did meet state water quality criteria.

TMDL Summary

In 1993, the EPA approved Ecology's TMDLs on Crystal Creek for FCB, TRC, BOD_5, and ammonia-N. The related TMDL technical assessments identified the critical condition to be the low-flow period of the year.

The TMDL assessments also found that principal pollutant sources were effluent from the town's sewage treatment lagoons, leaking sewer collection system in the city of Roslyn, and discharge from old coal mines. Other possible pollutant sources were identified as pasture areas, spring sources, and sewage leaks from the town of Ronald.

During the TMDL studies, researchers found that typical low flows in Crystal Creek were approximately 1-2 cfs and the 7Q10 low flow was 0.53 cfs. In June 1985, the POTW discharged about 0.2 cfs of effluent into the creek, which then had a flow of about 1.1 cfs, resulting in an approximate 5:1 water-to-effluent ratio. Similar results were found in September 1990. POTW records indicate that these were typical findings for early summer flows. [5]

Wasteload allocations (WLAs) and load allocations (LAs) set by the TMDL are shown in Table 4.

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[5] Before the Roslyn POTW was closed, local reports indicated that annual low stream flow levels were about 1 to 2 cfs, and the creek flowed year-round (Joy, 1985). However, in more recent years, the creek has been observed drying up in several sections each year, during late summer and early autumn. One possibility is that, during the operation of the Roslyn POTW, flow levels in the creek were augmented by more than just the POTW effluent to the creek. For instance, leakage from the POTW lagoons (three five-acre converted coal-washing ponds, each located about 90 meters uphill from the creek) could have previously interacted with the extensive coal tunnel network to recharge the creek during the dry season. Climate change may also be contributing to lower flows in recent years.

Table 4: Recommended WLAs and LAs for Crystal Creek during the low-flow season (June - October) – from original TMDL (Willms, 1991).

	Total Residual Chlorine		Total NH3-N		Fecal Coliform		BOD-5		
	Conc. mg/L	Load lbs/day	Conc. mg/L	Load lbs/day	Conc. cfu/100 mL	Load cfu/sec	Conc. mg/L	Load lbs/day	Effluent Discharge (MGD)
Water Quality Criterion									
Acute toxicity (1Q10)	0.019	--	6.90	--	--	--	--	--	--
Chronic toxicity (7Q10)	0.011	--	1.33	--	--	--	--	--	--
Class A	--	--	--	--	100	--	8.0 *	--	--
Crystal Creek TMDL	0.011	0.08	1.330	9.75	100	49,900	12	116	--
Crystal Creek LA (background)	0.00	0.00	0.017	0.05	59	8,800	1	3	--
Roslyn WLA (WTP)	0.012	0.08	1.461	9.70	118	41,100	17	113	--
Recommended Roslyn WTP Permit Limits									
Daily	0.019	0.126	2.400	15.92	--	--	--	--	--
Weekly	--	--	--	--	118	--	17	113	--
Monthly	0.008	0.053	1.197	7.94	59 **	--	11 ***	75 ***	0.80

* Dissolved oxygen concentration (mg/L).

** Monthly fecal coliform permit limit based on 1/2 of the weekly limit.

*** Monthly BOD-5 permit limit based on 2/3 of the weekly limit.

Results and Discussion

Data for the original TMDL study was collected on June 11 and 12, 1985 and September 11 and 12, 1990, from numerous sites in Crystal Creek and adjacent waters, above and below the former discharge point of the Roslyn POTW. Samples were also collected directly from the POTW effluent.

In general, the earlier data showed that the water quality was impaired by the discharge from the POTW.

This effectiveness monitoring study found that, in general, most TMDL targets and water quality criteria are now met, with slight exceedances of FCB.

Also, while data occurred on only four days (two two-day periods) for the original TMDL, most data was collected at regular intervals over a fourteen-month period for this follow-up study. Additional sampling for TRC was necessary in 2014.

See Table 5 and discussions of specific parameters on following pages.

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Table 5: Summary of analytical results for TMDL parameters.

Parameter	Site	Type of Data Analysis	Result	Range	TMDL Target*	**Comparison with TMDL target**
Ammonia-N: *Acute* (total ammonia nitrogen)	CRY2	Lab	Max = 0.044 mg/L	<0.01 mg/L to 0.044 mg/L	• Varies with temperature and pH, see Appendix C. • Only one exceedance (1-hr-avg) every 3 years for acute criteria	Meets targets in all samples
Ammonia-N: *Chronic* (un-ionized ammonia)	CRY2	Lab	Max = 0.000533 mg/L (using calculations as shown in state WQ standards)	0.0000553 mg/L to 0.000533 mg/L	• Varies with temperature and pH, see Appendix C. • Only one exceedance (4-day-avg) every 3 years for chronic criteria	Meets targets in all samples
BOD_5*	CRY2	Lab	Max = <5.0 mg/L	<2.0 mg/L to <5.0 mg/L	12 mg/L	Meets targets in all samples
Fecal Coliform bacteria	CRY1	Lab	Geometric mean = 1.47 cfu/100 mLmL	0 cfu/100 mLmL to 8.0 cfu/100 mLmL	Geometric mean ≤ 100 cfu/100 mLmL and 90th percentile ≤ 200 cfu/100 mLmL	Meets targets
	CRY2	Lab	Geometric mean = 17.96 cfu/100 mLmL; ***90th percentile = 200.60 cfu/100 mLmL***	1.0 cfu/100 mLmL to 1470 cfu/100 mLmL		Meets geometric mean; ***slight exceedance of 90th percentile***
	CRY3	Lab	Geometric mean = 14.66 cfu/100 mLmL	0 cfu/100 mLmL to 86.7 cfu/100 mLmL		Meets targets
Total residual chlorine	CRY2	Field	Max = 0.010 mg/L	0.00 mg/L to 0.010 mg/L (excursion averages)	11.0 µg/L (0.011 mg/L) – chronic exposure.	Meets targets in all samples

*Target for BOD_5 from original TMDL. All other targets = current water quality criteria (chlorine shows most stringent only)

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TMDL Parameters

Ammonia

During the data collection for the 1985 TMDL study, levels of ammonia-N were found to be in compliance in Crystal Creek. However, ammonia-N levels did exceed water quality standards in the effluent from the former POTW, and modeling showed that ammonia-N criteria would likely be exceeded downstream from the discharge point during future low-flow periods.

Water quality criteria for ammonia-N are dependent on stream temperature and pH at the time of the sample collection. See Appendix C. To assess variations in ammonia-N concentrations, we compared the change in the relationship between the criteria and the results. See Figure 3. Note that the high, low and median values, as compared to criteria, have decreased since the original TMDL data was collected.

The 2009/2010 samples were collected at site CRY2, about a mile downstream from the 1985/1990 sampling site. The site had to be moved downstream due to changes in property ownership and site access.

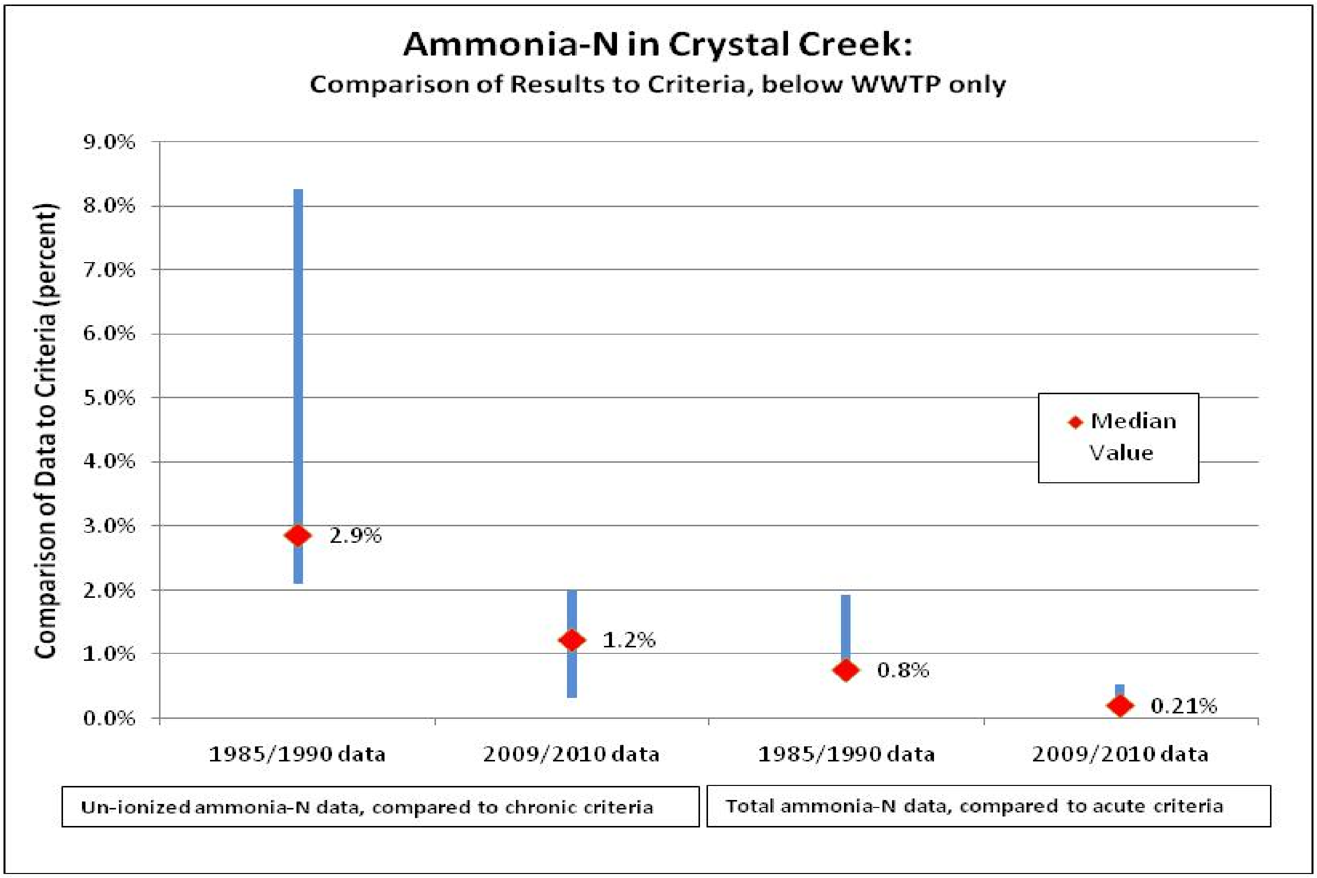

Figure 3: Change in ammonia-N levels in Crystal Creek, as compared to criteria, from 1985/1991 to 2009/2010. Points in chart represent data divided by criteria, shown as percent.

Five-Day Biochemical Oxygen Demand (BOD_5)

BOD_5 in Crystal Creek decreased after the old Roslyn POTW stopped discharging effluent. While earlier results met DO water quality criteria for the creek, modeling showed that DO criteria might have been violated during very low flows. See Appendix D for BOD_5 data.

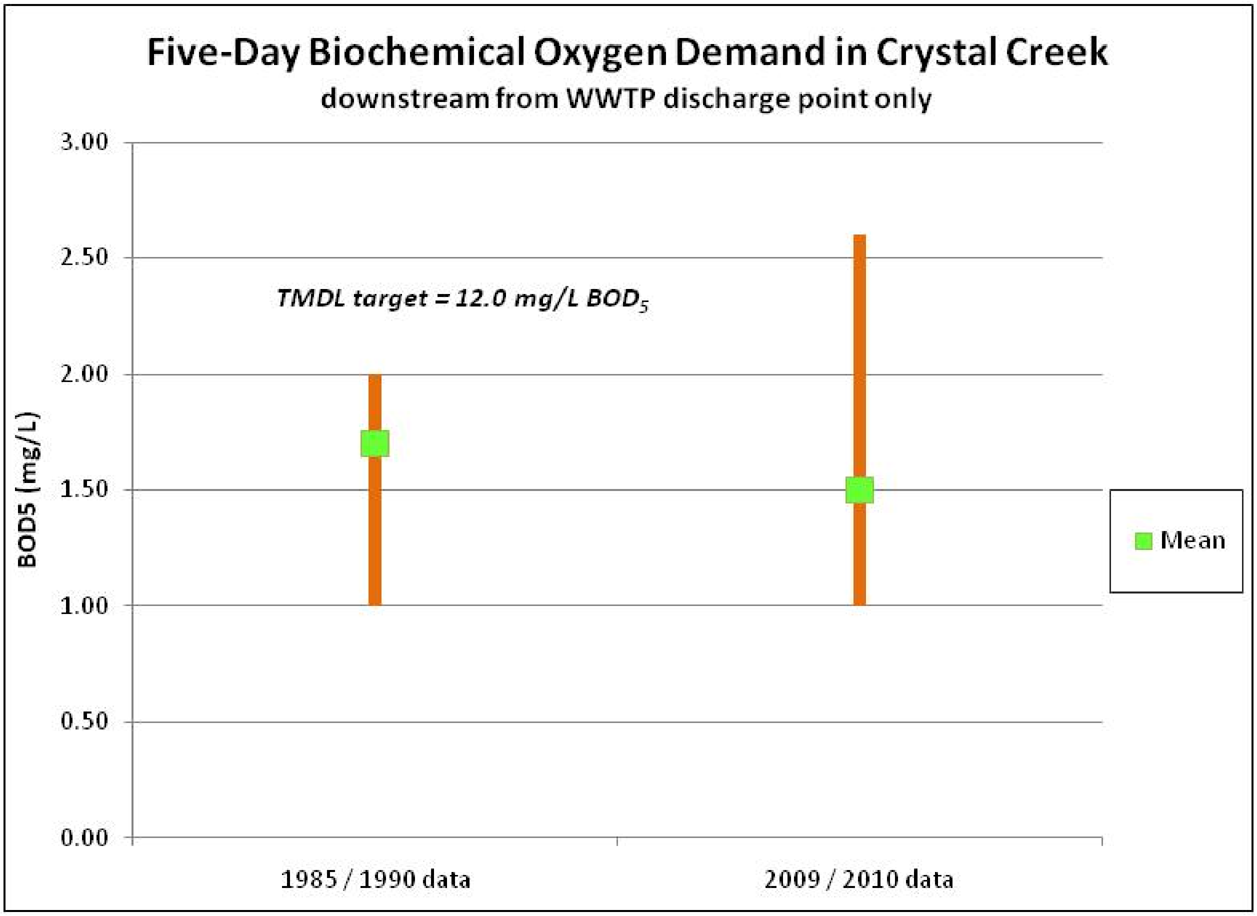

Figure 4: Five-day biochemical oxygen demand, Crystal Creek

Fecal Coliform Bacteria

FCB levels were assessed in samples collected from sites CRY1, CRY2 and CRY3.

Lab data showed that water samples from sites CRY1 and CRY3 met all targets and criteria. However, while sample results from CRY2 met the 100 cfu/100 mL geometric mean target and criteria, this site did not meet the 200 cfu/100 mL criteria and target in August 2009, when the creek had dried up[6] a short distance upstream from the sampling site. See Tables 6, 7 and 8.

[6] Water in Crystal Creek at sites CRY2 and CRY3 was observed to be flowing on all sampling excursions (although flows were quite low at times), even large sections upstream in the creek had dried up. These persistent flows may have been caused by runoff from irrigated pastures and/or by drainage from flooded underground coalmine shafts.

For all sites, the recent results were a significant improvement over findings in the earlier studies of Crystal Creek.

See Appendix E for details on data points and calculation of geometric means.

Table 6: FCB data analysis, for site CRY1 (E. Fork Crystal Creek, Roslyn)

Data Set Characteristics (Site CRY1: East Fork, Roslyn)	Number of data points ("n")	Geometric Mean	Number of samples exceeding 200 cfu/100 mL	Does data set meet TMDL targets and WQ criteria?
All data points	9	1.47	0	Yes

Table 7: FCB data analysis, for site CRY3 (Alliance Road, about ½ mile upstream from old POTW discharge point)

Data Set Characteristics (Site CRY3: Alliance Road)	Number of data points ("n")	Geometric Mean	Number of samples exceeding 200 cfu/100 mL	Does data set meet TMDL targets and WQ criteria?
All data points	10	14.66	0	Yes

Table 8: FCB data analysis, for Site CRY2 (Cle Elum, about mile downstream from old POTW discharge point)

Data Set Characteristics (Site CRY2: Cle Elum)	Number of data points ("n")	Geometric Mean	Number of samples exceeding 200 cfu/100 mL	Does data set meet TMDL targets and WQ criteria?
All data points	17	17.96	2	**No**

Total Residual Chlorine

The original TMDL study showed exceedances of TRC criteria downstream from the old Roslyn POTW discharge site. Due to a change in creek accessibility following closure of the POTW, this monitoring project collected TRC samples about a mile downstream from the original site. Results from this effectiveness monitoring study found that the TRC data met criteria[7]. See Appendix F.

[7] The first rounds of data collection for this effectiveness monitoring project appeared to show that TRC levels exceeded state water quality criteria. We later learned that manganese commonly causes interference with testing for

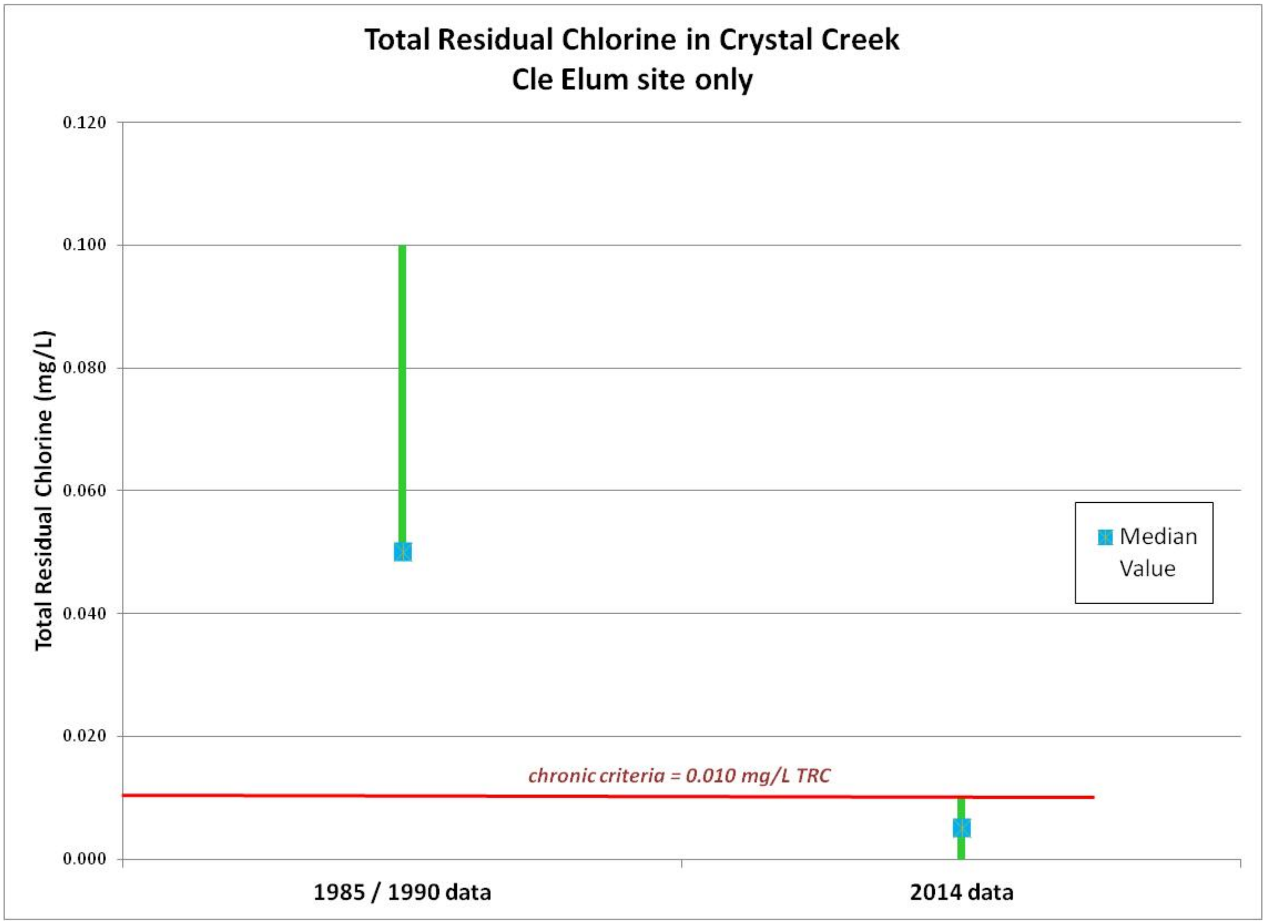

Figure 5: TRC in Crystal Creek

Data Quality Analysis

Duplicate samples, or duplicate field measurements, were collected for all parameters of interest. The data from the duplicate samples was compared for each relevant excursion. Finally, these statistics were compared to the measurement quality objectives (MQOs) in the QAPP. See Table 9 for data quality analysis findings.

TRC. Following the testing equipment manufacturer's instructions on how to reduce or eliminate manganese interference, we found that TRC never exceeded state criteria. See Appendixes B for more detail on this procedure, and see Appendix F for resulting data.

Table 9: Data quality assurance - study data compared to measurement quality objectives (MQOs). Data from Site CRY2 (Cle Elum).

Measurement	Lowest Concentration of Interest	Precision MQO - Duplicate Samples (%RSD)*	Study Findings for Duplicate Samples (%RSD)	Were MQOs met?
Field Measurement				
Discharge	0.1 cubic foot per second (cfs)	0.1 cfs**	0.04 cfs	Yes
Total Residual Chlorine	0.01 mg/L	± 10%	141.4%***	No
Water Temperature	0.1^{o} C	± 10%	0.9%	Yes
pH	0.01 pH units	± 10%	0.2%	Yes
Laboratory Analyses				
Fecal Coliform Bacteria	1 colony forming unit (cfu/100 mL)	± 40%	11.2%	Yes
Ammonia-N	0.01 mg/L	± 10%	0%	Yes
Biochemical Oxygen Demand	2 mg/L	± 15%	0%	Yes

* %RSD = Percent relative standard deviation
** As unit of measurement, not percent
***Unusually high RSD because results compared are (very) small numbers. See discussion.

Comparison of duplicate sample/measurement data shows that all parameters other than TRC met the MQOs. In the case of TRC, the high RSD value is likely due to the fact that the result numbers were quite small (0.003 mg/L compared to 0.0 mg/L), so that even tiny variations in results can cause very large changes in RSD. It also could be that our precision MQO for TRC RSD should have been much higher to begin with.

Other water quality findings

In addition to collecting new data about the TMDL parameters, this study looked at several other related water quality parameters, including turbidity and stream flow. Temperature and pH data collection was also necessary to determine ammonia-N criteria on each sampling day.

Turbidity

In general, the entire stream had low turbidity during all months. The main exception to this was isolated instances of increased turbidity at Site CRY3, during periods that crews and equipment were working on nearby roads and discharging silt.

Stream flow

Stream flow data on Crystal Creek had not been collected since the Roslyn POTW ceased operations. During this study, stream flow data was collected only at sites CRY1 (Roslyn) and CRY2 (Cle Elum); stream flow data was not collected at site CRY3 (Alliance Road) since the channel geometry did not lend itself well to flow monitoring.

In general, the streamflow data showed that:

- Crystal Creek at site CRY1 dried up during the summer of every year of the study.

- Flowing water was always present at both sites CRY2 and CRY3; however, beginning in August during each year of the study, several sections of the creek in between these two sites had completely dried up.
- The highest flows recorded were 6.2 cfs at Site CRY2 (Cle Elum, near mouth), in March 2001.
- At times, flow levels were too low to calculate using the Marsh-McBirney flow meter. In these cases, the flows were estimated by visually comparing the flow level to the lowest metered flow.

Conclusions

Results of this study support the following conclusions:

- Removal of a major pollution source, as well as implementation of best management practices (BMPs), has resulted in improved water quality in Crystal Creek. The creek now meets TMDL targets for ammonia-N, TRC, and BOD_5, and is close to meeting targets for fecal coliform bacteria (FCB).

- Due to lack of effluent being discharged from the old Roslyn POTW, Crystal Creek now dries up in several locations during the low-flow time of the year (usually mid-August through mid-October), stranding salmonids in several pools along the length of the stream. Ironically, this period was identified in the original TMDL as the critical condition - but without the effluent from the former POTW, there is no water in much of the creek during the critical period.

- Results of the 2014 sampling showed that TRC criteria were always met.

- Results of the 2009-10 sampling showed that BOD_5 targets and ammonia-N criteria were always met during this period.

- FCB levels generally met criteria, except for a slight exceedance at site CRY2 (the most downstream site), from two samples collected after the creek was partially dried up in places.

Recommendations

Regarding the follow-up work for this project, Ecology recommends:

- Water Quality Assessment listings for BOD_5, TRC, and ammonia-N in Crystal Creek should be changed from Category 4A (has a TMDL) to Category 1 (meets water quality standards).

- Collect additional FCB samples near to and/or within the city of Roslyn, to expand the FCB study.

- Work with the Washington State Department of Transportation (WSDOT) to reduce the impact of stormwater flows from Highway I-90 into Crystal Creek.

- Conduct additional sampling for FCB in Crystal Creek, including all tributaries, from within the city of Roslyn to the creek's confluence with the Yakima River. Use results from this sampling to determine where additional FCB reduction activities should occur.
- Work with Kittitas County Environmental Health Department to identify potential leaking on-site septic systems. Work with property owners to correct problems, by providing financial and technical assistance.
- Identify properties near Crystal Creek that graze or house livestock. Work with property owners to prevent livestock pollution to Crystal Creek.

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Appendices

Appendix A. Quality Assurance Project Plan

Quality Assurance Project Plan for Total Maximum Daily Load Effectiveness-Monitoring Project in Crystal Creek

May 2009 – February 2010

Prepared By:

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Washington State Dept. of Ecology
April 2009

_approval email on file____________________________ Date_______________
Ryan Anderson, CRO Regional TMDL Coordinator, WA Dept. of Ecology

_approval email on file___________________________ Date_______________
Jon Merz, Acting CRO Water Quality Program Manager, WA Dept. of Ecology

_signature on file ______________________________ Date_______________
Mike Herold, Quality Assurance Coordinator, Water Quality Program, WA Dept. of Ecology

_verbal approval with witnesses____________________ Date_______________
Gary Arnold, Eastside Operations Section Mgr., Env. Assessment Program, WA Dept. of Ecology

_signature on file ______________________________ Date_______________
Chris Coffin, Environmental Assessment Program, WA Dept. of Ecology

_signature on file ______________________________ Date_______________
Laura Mrachek, President, Cascade Analytical Laboratory

_signature on file ______________________________ Date_______________
Jane Creech, TMDL Lead, WA Dept. of Ecology

Introduction

This project is a portion of the effectiveness monitoring phase of the *Crystal Creek Total Maximum Daily Load (TMDL)*. The original objective of this TMDL was to reduce fecal coliform bacteria (FC), total residual chlorine (TRC), 5-day biochemical oxygen demand (BOD_5), and ammonia-nitrogen (ammonia-N) in Crystal Creek.

In this effectiveness monitoring project, all water quality parameters in the original TMDL project will be evaluated. Because treated wastewater is no longer discharged to Crystal Creek, ammonia-N, BOD_5, and TRC levels are now expected to meet water quality standards. However, potential FC sources still exist, so FC levels will be monitored more extensively during this project.

Background and Problem Statement

Crystal Creek is located near the towns of Roslyn and Cle Elum in central Washington State. This creek is considered a primary contact stream in the Washington State water quality standards.

Crystal Creek is a tributary of the Yakima River, entering the Yakima River at river mile (RM) 183.1 near Cle Elum. Crystal Creek drains 7.7 miles of forested foothills in its three mile course through a small valley, which is bounded by the Cle Elum ridge to the northeast and Easton ridge to the west.

Crystal Creek averages two to six feet wide, with an average depth of 0.5 foot. Winter flows can be quite high: in January 2009, Crystal Creek overtopped its banks and flooded several nearby homes. However, this creek can become virtually dry in late summer or early fall.

The Clean Water Act directs the Washington State Department of Ecology (Ecology) to perform a TMDL analysis for contaminated waters on the state's 303(d) list of impaired water bodies.

In the early 1990's, Ecology conducted a TMDL on Crystal Creek, to evaluate water pollution levels and to identify possible sources of pollution. During this assessment, Ecology determined that FC, TRC, BOD_5, and ammonia-N represented significant water quality impairments in Crystal Creek.

Ecology's original TMDL assessments (Joy, 1985; Willms, 1991) found that principal pollutant sources were leaking sewer lines in the town of Roslyn, effluent from the town's sewage treatment lagoons, and discharge from an old coal mine (contributed primarily inorganic nitrogen). Possible additional pollutant sources were identified as pasture areas, spring sources, and sewage leaks from the town of Ronald.

In the mid-1990's, sewage from the town of Ronald was piped to, and treated at, the Roslyn wastewater treatment plant (WWTP). The Roslyn WWTP consisted of three five-acre lagoons, two aeration basins and a chlorine contact chamber. The Roslyn WWTP discharged to Crystal Creek until 2006.

In 2006, the cities of Roslyn and Ronald then connected to the new Upper Kittitas County Regional Wastewater Treatment Facility, and the Roslyn WWTP was closed.

During the original TMDL study, researchers found that typical low flows in Crystal Creek were approximately 2 cfs, and the 7Q10 flow was 0.53 cfs. However, stream flows in Crystal Creek have not been measured since the Roslyn wastewater treatment plant stopped discharging effluent to this creek in 2006.

Because the Roslyn WWTP is no longer operating, there is no longer any effluent discharged to Crystal Creek from this facility. However, some water samples will be analyzed for BOD_5, TRC and ammonia-N to confirm that they are no longer a problem.

High FC levels may still be a problem, due to the possibility of multiple sources that were not necessarily addressed by connecting the towns of Roslyn and Ronald to the Upper Kittitas County Regional Wastewater Treatment Facility. These sources may include leaking sewer lines, spring sources and pastures adjacent to the creek.

Therefore, this sampling plan will focus on evaluating levels of FC, BOD_5, TRC, and ammonia-N in Crystal Creek, to assess compliance with the earlier TMDL.

Project Description

This study will measure TRC, BOD_5, ammonia-N and FC levels in Crystal Creek to determine whether the creek is meeting the targets set by the Crystal Creek TMDL.

Sampling sites for the earlier TMDL study were located just above and below the discharge point for the Roslyn WWTP. Because this WWTP is no longer operating, the sampling sites for this project have been moved upstream and downstream, respectively, of the former sites. Expanding the sampled area will allow a better evaluation of current FC levels.

The upstream site will be located near where Whitehead Road in Roslyn crosses Crystal Creek. This site will serve as a background site for this study.

The downstream site will be located where 1st Street West in Cle Elum crosses Crystal Creek. This site is about 1/3 mile from the confluence of Crystal Creek with the Yakima River.

See Figure A-1 (below) for location Crystal Creek and location of sampling sites.

Figure A-1: Aerial view of Crystal Creek. Proposed sampling locations marked in blue.

No critical period was specifically identified in the original TMDL, although the report inferred that low-flow periods would be most susceptible to pollution from sewage treatment plant discharges. Therefore, sampling will occur every two weeks for about ten months (the lowest flow periods), but only when there is enough water in the stream to collect a sample. Stream flows drop considerably in late summer and early fall – during this period, the stream appears completely dry in places.

If monitoring indicates that water quality standards for any of the TMDL parameters are not met in Crystal Creek, Ecology and community stakeholders will jointly evaluate what additional implementation activities may be necessary to meet water quality standards. Results from this monitoring study will help Ecology coordinate implementation activities.

Project Goals

The goals for this effectiveness monitoring project in Crystal Creek include:

1) Determining whether water quality targets for TRC, BOD_5, ammonia-N and FC are now met, and
2) Assess and quantify implementation of pollution-reduction BMPs in the last five years.

Target levels in the original TMDL were set to comply with 1992 state water quality standards. However, target levels for this effectiveness monitoring project have been updated, where necessary, to comply with the latest version of the state water quality standards. See Table 1 for specific targets.

Because Washington State does not have a water quality standard for BOD_5, this effectiveness monitoring project will continue to use the original TMDL limits as BOD_5 targets for this project. The 1993 TMDL set the loading capacity for BOD_5 at 116 lbs/day (12 mg/L). The TMDL wasteload allocation for BOD_5 was set at 113 lbs/day (11 mg/L in effluent) and a BOD_5 load allocation of 1 mg/L (3 lbs/day BOD_5 instream). The loading capacity for BOD_5 was determined to be consistent with the state water quality standard for DO (Joy, 1985; Willms, 1991). The BOD_5 level is determined by measuring the amount that DO is reduced in a five day period; in this case, the instream DO will still meet state DO standards after exposure to the allowed (loading capacity) amount of BOD_5. The state standard for DO in Crystal Creek is the same now as it was in 1992 (8.0 mg/L), so the original BOD_5 loading capacity will still ensure compliance with current DO standards.

Table A-1: Effectiveness Monitoring Targets for the *Crystal Creek TMDL*

Parameter	Current Classification Category (most stringent)	Target
Fecal Coliform Bacteria	Primary Contact Recreation	Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies /100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200 colonies /100 mL .
BOD_5	Aquatic Life Use: Spawning/Rearing	12 mg/L (116 lbs/day in 1.76 cfs flow (0.53 cfs stream + 1.23 cfs effluent from former WWTP))
Total Residual Chlorine	Aquatic Life Use: Spawning/Rearing	ACUTE: 19.0 ug/L A 1-hour average concentration not to be exceeded more than once every three years on the average. CHRONIC: 11.0 ug/L A 4-day average concentration not to be exceeded more than once every three years on the average.
Ammonia	Aquatic Life Use: Spawning/Rearing	ACUTE: Shall not exceed the numerical value total ammonia nitrogen (mg N/L) given by: For salmonids present: $\frac{0.275}{1 + 10^{7.204 - pH}} + \frac{39.0}{1 + 10^{pH - 7.204}}$ A 1-hour average concentration not to be exceeded more than once every three years on the average. CHRONIC: Shall not exceed the numerical concentration calculated as follows: **Unionized ammonia concentration for waters where salmonid habitat is an existing or designated use:** $0.80 \div (FT)(FPH)(RATIO)$ where: $RATIO = 13.5;\ 7.7 \le pH \le 9$ $RATIO = (20.25 \times 10^{(7.7-pH)}) \div (1\ 10^{(7.4-pH)});\ 6.5 \le pH \le 7.7$ $FT = 1.4;\ 15 \le T \le 30$ $FT = 10^{[0.03(20-T)]};\ 0 \le T \le 15$ $FPH = 1;\ 8 \le pH \le 9$ $FPH = (1 + 10^{(7.4-pH)}) \div 1.25;\ 6.5 \le pH \le 8.0$ A 4-day average concentration not to be exceeded more than once every three years on the average.

The US Environmental Protection Agency approved the Crystal Creek TMDL in 1993. Following this approval, water quality assessment listings for FC, TRC and ammonia-N in Crystal Creek were changed to Category 4A, meaning that a TMDL has been approved for these water quality parameters. Additionally, DO in Crystal Creek was moved to Category 2, Waters of Concern. See Table 2.

Table A-2: Current water quality assessment listings for Crystal Creek.

Listing ID	Category	WRIA	Water Body Name	Parameter	Medium
6720	4A	39	CRYSTAL CREEK	Fecal Coliform	Water
8937	4A	39	CRYSTAL CREEK	Chlorine	Water
8938	4A	39	CRYSTAL CREEK	Ammonia-N	Water
8353	2	39	CRYSTAL CREEK	Dissolved Oxygen	Water

Schedule and Organization

Personnel and Organization

Ecology staff will conduct the sample collection and field analyses for this effectiveness monitoring project. The groups and participating staff members are outlined below.

The main group that will be collecting samples will be staff from Ecology's Water Quality Program from the Central Regional Office in Yakima. Jane Creech will be the lead sampler and project manager, and will be responsible for data analysis and composition of the final report. Ryan Anderson and Bryan Neet will be backup samplers.

Tasks

One set of FC samples will be taken from both sampling sites every two weeks during the project. Staff will collect samples and perform field analyses during a total of 15 sampling events. One set of BOD_5 and ammonia-N samples will be taken from both sampling sites every four weeks.

Note that 22 weeks are identified as sampling dates; however, sampling will not occur on all these dates. Sampling will continue as scheduled until 15 sampling events have occurred. Extra dates have been planned in case Crystal Creek goes dry in late summer/early fall, as has happened in the past. If some weeks are missed due to very low stream flows, then staff will sample on later dates.

Most sampling will be conducted on a Monday, Tuesday, or Wednesday – ideally Tuesday (as indicated in Table 3). The specific weekday will be selected to accommodate shipment and lab schedule.

Samples to be analyzed for TRC have a very short holding time (15 minutes), so will be analyzed in the field using an Ecology-approved field testing kit and using Ecology-approved procedures.

Other field analyses will include stream flow measurement, water temperature and pH.

Water sample collection and field analyses will be conducted by Ecology. Each sample collection will take 54 miles round-trip, from Ellensburg to the farthest sampling site.

Laboratory analyses will be conducted by Cascade Analytical Laboratory, with locations in Wenatchee and Yakima, WA. Both labs are accredited by Ecology for all analyses required for this project, except the Yakima lab is not accredited for ammonia-N.

Sample bottles and coolers will be provided by the lab prior to sampling events. Cascade Analytical Lab's courier will pick up samples in Ellensburg on the day of sampling, for transport to the labs. FC and BOD_5 will usually be analyzed in Yakima, ammonia-N in Wenatchee.

Table A-3: Sampling schedule. Sampling will continue until 15 sampling events have occurred. Extra dates are planned in case stream dries up in late summer/early fall.

Sampling Event No.	FC Samples Collected	BOD_5 and Ammonia-N Samples Collected	Date (all Tuesdays)
1	X		5-May-09
2	X	X	19-May-09
3	X		2-Jun-09
4	X	X	16-Jun-09
5	X		30-Jun-09
6	X	X	14-Jul-09
7	X		28-Jul-09
8	X	X	11-Aug-09
9	X		25-Aug-09
10	X	X	8-Sep-09
11	X		22-Sep-09
12	X	X	6-Oct-09
13	X		20-Oct-09
14	X	X	3-Nov-09
15	X		17-Nov-09
16	X	X	1-Dec-09
17	X		15-Dec-09
18	X	X	29-Dec-09
19	X		12-Jan-10
20	X	X	26-Jan-10
21	X		9-Feb-10
22	X	X	23-Feb-10

If possible, staff gages will be installed at both sampling sites. If it is not possible to install staff gages, then a stable point will be used to measure from each time. A tape-down method can also be used. Additionally, at these staff gage sites, instantaneous flows will be collected when possible and new rated charts established.

Table 1. Crystal Creek Average Daily Streamflow (cfs) Upper Yakima River TMDL 1999

Day	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	19.5	5.7	1.0	0.5	0.3	0.5	0.6	0.9	1.3
2	19.2	5.3	1.0	0.5	0.3	0.5	0.5	0.8	1.6
3	18.3	5.0	0.9	0.6	0.3	0.5	0.5	0.8	1.5
4	17.8	4.7	0.9	0.5	0.3	0.5	0.5	1.0	1.4
5	15.7	4.0	0.9	0.5	0.3	0.5	0.6	0.9	1.4
6	14.4	3.7	0.9	0.5	0.3	0.5	0.6	1.1	1.4
7	14.2	3.5	0.8	0.5	0.3	0.5	0.6	1.0	1.5
8	13.7	3.2	0.8	0.5	0.3	0.5	0.6	1.0	1.3
9	13.1	3.0	0.8	0.5	0.3	0.5	0.5	0.9	1.2
10	12.3	2.9	0.8	0.5	0.3	0.6	0.7	0.9	1.2
11	11.5	2.8	0.7	0.4	0.3	0.5	0.7	1.1	3.8
12	12.1	2.6	0.7	0.4	0.3	0.5	0.6	1.5	3.6
13	11.3	2.3	0.7	0.5	0.3	0.5	0.7	1.3	2.8
14	11.4	2.1	0.8	0.5	0.3	0.5	0.6	1.0	2.7
15	11.6	1.9	0.8	0.5	0.3	0.5	0.6	0.9	3.2
16	12.4	1.8	0.6	0.4	0.3	0.4	0.6	0.9	-
17	14.0	1.8	0.8	0.8	0.3	0.4	0.6	0.9	-
18	16.8	1.8	5.8	0.5	0.3	0.5	0.6	0.8	-
19	19.9	1.6	18.3	0.4	0.3	0.4	0.6	0.7	-
20	19.4	1.5	18.6	0.4	0.3	0.4	0.7	0.8	-
21	17.4	1.3	7.3	0.5	0.3	0.5	0.7	0.8	-
22	14.9	1.3	1.5	0.4	0.3	0.5	0.7	0.8	-
23	13.1	1.2	0.6	0.4	0.4	0.5	0.7	0.8	-
24	11.8	1.2	0.9	0.3	0.3	0.5	0.9	1.0	-
25	11.2	1.1	5.5	0.3	0.3	0.5	1.2	7.4	-
26	11.0	1.2	23.9	0.3	0.4	0.5	1.1	4.6	-
27	10.4	1.1	23.7	0.3	0.4	0.6	0.8	2.3	-
28	9.1	1.0	15.0	0.3	0.4	0.6	1.3	1.8	-
29	7.6	1.0	0.9	0.3	0.4	0.5	1.1	1.5	-
30	6.3	0.9	0.5	0.3	0.4	0.5	0.9	1.4	-
31	-	0.9	-	0.3	0.5	-	0.9	-	-

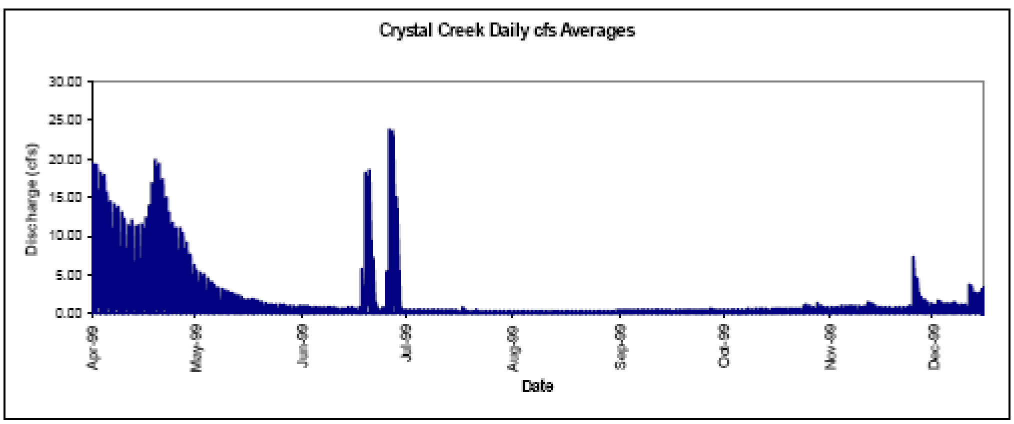

Figure A-2: 1999 flow data for Crystal Creek, collected just upstream of Site #2 for this project.

As part of this evaluation project, Ecology staff will meet with stakeholders and organizations throughout the project area to describe and quantify the best management practices (BMPs) for FC reduction that have been implemented during the life of this TMDL. This information will be included in the final report as well.

The Kittitas County Conservation District (KCCD) is currently working on a stormwater program for the City of Cle Elum, which includes lower Crystal Creek. The KCCD and City of Cle Elum will act in an advisory role. The City of Roslyn will also act in an advisory role as needed.

Project Budget

Table A-3: Project budget.

Parameter	No. of Sampling Events	No. of Sites*	A: Total No. of "Regular" Samples	B: No. of Replicate Samples Over Life of Project	C: No. of Field Blanks, Over Life of Project	Total Number of Samples (A+B+C)	Lab Analysis Cost Per Sample	Total Cost
FC	15	2	30	4	0	34	$25.00	$850.00
BOD_5	5	1	5	1	1	7	$45.00	$315.00
Ammonia-N	5	1	5	1	1	7	$26.50	$185.50
Total Residual Chlorine	5	1	5	1	0	6	$0.00	$0.00
								$1,350.50

* BOD_5, TRC and ammonia-N will only be sampled at lower site

Lab Costs including sample analysis and QA….$1,351
Shipping costs …………………………………..…..$120
Vehicle Expenses (15 trips x $32/trip)…..………$480
Personnel……………………………………..….0.1 FTE, for 15 months

Project Schedule

Upon completion of the monitoring portion of this project and the associated data analyses, a report will be completed detailing the information collected for surface-water quality in Crystal Creek. The report, prepared by Ecology, will specifically indicate (1) whether Crystal Creek meets water quality standards for all TMDL parameters and (2) if standards are *not* met, a list of possible sources.

The report findings will be reviewed by Ecology's Environmental Assessment Program (EAP), Ecology's Water Quality (WQ) Program, KCCD, and the Cities of Cle Elum and Roslyn before presenting them to stakeholders in Roslyn and Cle Elum. The final report should be ready in 2010.

Table A-4: Project schedule

Sample collection	May 2009 – February 2010
Data compilation, verification, and validation	April 2010
Data review and analysis	May 2010
Draft report completed by Ecology	June 2010
EIM entry complete	May 2010
Final report	September 2010

Data Quality Objectives

Water quality data will be collected and analyzed to assess the quality of the water resources in Crystal Creek and to assist in understanding and quantifying impacts to water quality from adjacent land and water uses. Results from the measurements of FC levels will be compared to state water quality standards to determine compliance with the targets for the *Crystal Creek TMDL Effectiveness Monitoring Project* (Table 1).

All data will be collected with the highest accuracy practicable. The protocols for sample collection and measurements will be standardized for all monitoring sites.

Duplicate field samples will be used to estimate total variation (field and laboratory), expressed as the percent relative standard deviation (RSD).

Measurement quality objectives (MQOs) and analytical methods are included in Table 5 below.

Table A-5: Measurement Quality Objectives (MQOs)

Measurement	Method of Analysis Used	Lowest Concentration of Interest	Precision MQO - Duplicate Samples (Relative Standard Deviation)
Field Measurement			
Discharge	Flow meter	0.1 cubic foot per second (cfs)	0.1 cfs*
Total Residual Chlorine	Pocket colorimeter (adapted SM 10070)	0.01 mg/L	± 10%
Water Temperature	Temperature probe	0.1° C	± 10%
pH	pH probe	0.01 pH units	± 10%
Laboratory Analyses			
Fecal Coliform Bacteria	SM 9222D	1 colony forming unit (cfu/100 mL)	± 40%
Ammonia-N	SM 4500-NH3 H	0.01 mg/L	± 10%
Biological Oxygen Demand	SM 5210 B	2 mg/L	± 15%

*As unit of measurement, not percent

The total accuracy figures are reflective of the reported precision and bias limitations of the respective analytical methods (Lombard and Kirchmer, 2003). Standard field methods will be used throughout this project to minimize measurement bias (systematic error) and to improve precision (random error). All laboratory-bound samples will be collected, stored, and otherwise managed using accepted procedures for maintaining sample integrity prior to analysis.

The precision and bias routinely obtained by Ecology for the parameters of interest to this project will be adequate. Detection limits for all analyses are adequate to evaluate whether or not TMDL targets are met.

Sampling Process Design

Study design

Two locations on Crystal Creek will be monitored from April 2009 through February 2010. These sampling sites were selected based on information from the original TMDL study. If sampling opportunities are limited, additional monitoring may be required to ensure adequate data is obtained for analyses.

Both sampling sites are on Crystal Creek. The upstream (background) site (marked as “1” on Figure 1) is within the city limits of Roslyn, just downstream from where Whitehead Road crosses Crystal Creek (where two small tributaries join). The upstream sampling site may be accessed from the portion of the Coal Mines Trail at this location.

The downstream sampling site (marked as "2" on Figure 1) is within the city limits of Cle Elum, near South Cle Elum Way, just upstream of the culvert that goes under Highway I-90. The downstream site is within 100 yards of the confluence with the Yakima River.

Sample collection will be conducted biweekly throughout the monitoring period. Sampling will continue until fifteen sampling events have occurred; it may be necessary to stop sampling for a period if and when the creek dries up in late summer.

Flow rate, TRC, pH and water temperature will be measured in the field. No other field measurements or analyses will be conducted.

Assumptions underlying design

Representativeness: Both the sampling schedule and the monitoring site location should accurately describe the conditions to be evaluated by this project. Samples will be collected every two weeks. The stream should be well-mixed due to its small size.

All samples will be collected from the middle of the stream, at the center of the water column, to the extent this is possible even during very low stream flows. Bacteria samples will be collected directly into a bacteria bottle. BOD_5 and ammonia-N samples will be collected directly into a one-liter poly sample bottle on a sampling rod, using an integrated sampler.

Completeness: The main factors that could possibly affect completeness are 1) weather that presents safety concerns and 2) unforeseen equipment failure. These factors will be anticipated to the maximum extent possible. All sampling surveys are expected to be completed with usable high quality data. The sampling staff is well trained and experienced, and all sampling excursions will be well organized. Transportation of samples to the laboratory is consistent and well organized as well, with backup plans in case of emergency.

Comparability: All sampling and analysis will be accomplished using standardized procedures, to ensure comparability to data collected from Crystal Creek in earlier studies. The same standard operating procedures will be used for all sampling and analysis.

However, only Ecology will collect samples during this project, so we will not need to compare the data from this project with data sets from other concurrent sampling groups. In other words, comparison between concurrent sampling groups will not be needed during this project, because Ecology is doing all the sampling. Additionally, two well-established locations of a well-established laboratory will be used during this project (with one location used solely for one parameter, the other location used solely for the other parameters), so MQOs and quality control criteria should be consistent within those laboratories.

Table A-6: Project monitoring sites

Site No.	Monitoring Sites	Field ID	Sampler	Water Sampling Access	Inst. Flow Sampler
1	Crystal Creek at Whitehead Road, Roslyn (park at intersection with Coal Mine Trail, walk up trail about 50 feet')	01-CRY	Ecology	Culvert	Ecology
2	Crystal Creek near S. Cle Elum Way (just before creek enters culvert under I-90), in Cle Elum	02-CRY	Ecology	Culvert	Ecology

Sampling Procedures

Supplies

- 16 ounce sterilized plastic bottles (for BOD_5 analysis), supplied by lab
- 125 mL sterilized plastic bottles (for ammonia-N analysis), supplied by lab
- Sealed sterile single use polycarbonate containers (for bacteria analysis), supplied by lab
- Coolers for sample shipment, supplied by lab
- Ice for coolers
- DH-81 Depth Integrated Hand Sampler (*or integrated sampler similar to the DH series)*
- Sampling Rod
- Hach Cl_2 test kit – Model 46700-00 (for field TRC tests)
- pH/temperature probe (WTW Multi 340i)
- Marsh-McBirney flow meter
- Paper towels
- Gallon jug(s) of distilled water
- Anti-bacterial hand sanitizer or soap
- Latex gloves
- Bridge traffic cones
- Lab forms
- Field notebook and pens
- Sample tags
- Clean 5-gallon buckets to carry stuff in

Instrument Calibration

Flow meters will be checked for calibration per the manufacturer's recommended schedules and methods. pH/temperature probe will be calibrated before each round of sampling, using pH standards. Chlorine tester will be calibrated per manufacturer's recommended schedules.

Field Procedures

Ecology's EAP program has developed standard operating procedures for field procedures used in this project (see Table 7 below). Details of these procedures are available on the Internet at https://ecology.wa.gov/About-us/How-we-operate/Scientific-services/Quality-assurance.

Table A-7: Standard operating procedures (SOPs) for sample collection and field data collection.

No. of SOP	Title	Author	Approval Date
EAP011	Standard Operating Procedure for Instantaneous Measurements of Temperature in Water	Brenda Nipp	4/26/06
EAP012	Standard Operating Procedure for Sampling Bacteria in Water	Nuri Mathieu	6/26/06
EAP015	Standard Operating Procedure for Manually Obtaining Surface Water Samples	Joe Joy	10/24/06
EAP024	Standard Operating Procedure for Estimating Streamflow	Lawrence Sullivan	2/20/07
EAP031	Standard Operating Procedures for the Collection and Analysis of pH Samples	William J. Ward	6/14/07 (provisional approval)

EAP has also offered guidance regarding the collection of TRC data in the field. Staff will use a Hach Cl_2 field tester (Model 46700-00) for TRC, provided by EAP's Manchester Lab.

Field Blanks

During one sampling excursion, field blanks will be created by filling a 125 mL sterilized poly container and a 16-ounce poly sample container with deionized (or distilled) water just before collection of the first sample. The field blanks will be clearly marked as **blanks**, including the parameter of interest that relates to the blank, to avoid use for analytical duplicates or matrix spikes. The field blanks will be placed in the ice chest and transported by the sampler throughout the sampling event.

Field Replicates

Staff will collect replicate samples as needed for quality control. During one sampling excursion, replicates will be collected for all samples. Replicates will be collected immediately after collection of the each sample. During a subsequent sampling excursion, replicates will only be collected for bacteria samples. Again, replicates will be collected immediately following collection of the each sample.

Field Data Recording

A field data sheet will be completed at each of the monitoring sites. The sheet will record the date, time of sampling, personnel present, name of person doing the water collection, general weather conditions and any comments pertinent to the event.

Storage and Shipping

All surface-water samples collected in the field will be immediately sealed, labeled, and stored in ice for transport to the lab. Field blanks will be stored and transported along with the collected samples. Water samples will be transported as soon as realistically possible after sampling and stored in a cooler or refrigerator unit at the lab at 4°C or less until analysis. Analysis by the lab will be completed within the holding time for each sample.

Table A-8: Collection, preservation and handling of samples in the field.

Parameter	Container Type	Sample Volume	Preservation	Holding Time
Fecal Coliform Bacteria	Sealed sterile single use polycarbonate containers	100 mL	Cool <4°C	24 hrs
Ammonia-N	Poly	125 mL	Cool <4°C	48 hrs
BOD_5	Poly	16 oz.	Cool <4°C	48 hrs
Total Residual Chlorine	Poly	1,000 mL	N/A	15 minutes*

*Total residual chlorine will be analyzed in field, due to very short holding time

Laboratory Analysis

Ecology will use the Cascade Analytical Laboratory for this project, with locations in Yakima and Wenatchee. These labs are accredited by the state of Washington for all lab procedures to be performed, except only the Wenatchee lab is certified for ammonia-N analysis. All samples will be cooled to 4°C immediately after collection and will be left at this temperature until analysis is performed at the lab.

On each day of sample collection, Cascade Analytical's courier will pick up samples in Ellensburg for transport to the lab. The courier will transport the FC and BOD_5 samples to Cascade Analytical's Yakima lab, and then take the ammonia-N samples to Cascade Analytical's Wenatchee lab. Occasionally, depending on courier and lab circumstances, the courier may need to take FC and BOD_5 samples to the Wenatchee lab for analysis.

If determined necessary by Ecology, Cascade Analytical may sub-contract analysis of ammonia-N samples to the Aquatic Research, Inc. laboratory in Seattle. If this occurs, Cascade Analytical Lab will preserve the ammonia-N samples and send via UPS in a chilled cooler (at 4°C) to Seattle at their earliest convenience. Chain-of-custody paperwork for the sample transfer will be initiated by Cascade Analytical. Aquatic Research is accredited by Ecology for all relevant analyses.

The lab(s) will analyze water samples using methods identified in Table A-9.

Table A-9: Laboratory procedures.

Parameter	Sample Matrix	No. Of Samples Per Daily Event	Expected Range of Results	Reporting Limit	Sample Prep Method	Analytical Method
Fecal coliform bacteria	Whole water	2 or 3	1 to 1000 cfu/100 mL	1 cfu/100 mL	Hold @ 4ºC up to 24 hours	SM 9222D
Ammonia-N	Whole water	2 or 3	0.1 to 100 mg/L	0.01 mg/L	Hold @ 4ºC up to 48 hours	SM 4500-NH3
BOD_5	Whole water	2 or 3	2 to 40 mg/L	2 mg/L	Hold @ 4ºC up to 48 hours	SM 5210 B G

Quality Control

All equipment used in the field will be inspected, cleaned, and calibrated before use. Faulty equipment will be replaced or repaired if required. Sample bottles are cleaned by the lab before use, and supplied by the lab for sampling. The integrated sampler is stored to prevent contamination or damage.

Field QC will consist of collecting replicate samples during two monitoring events. Replicates consist of a full sampling of all of the monitoring sites. Ten percent or more of the total number of water quality samples collected for this project will be replicated in order to assess variability in field sampling.

Ten percent or more of the sample analyses will also be replicated in the lab to assess analytical variability.

Table A-10: Quality control schedule for each sampling event

Parameter	Field		Laboratory			
	Blanks	Replicates	Check Against Standards	Method Blanks	Analytical Duplicates	Matrix Spikes
FC	N/A	1/8 samples	N/A	2/batch	N/A	N/A
BOD_5	1/5 samples	1/5 samples	N/A	1/day	N/A	None
Ammonia-N	1/5 samples	1/5 samples	N/A	1/day	1/batch	None
Total Residual Chlorine*	1/5 samples	1/site	N/A	N/A	N/A	N/A
Stream flow	N/A	1/5 samples	N/A	N/A	N/A	N/A
pH	N/A	1/site	As needed	N/A	N/A	N/A
Water temperature	N/A	1/site	N/A	N/A	N/A	N/A

*Total residual chlorine will be analyzed in the field, so no lab procedures needed

The precision statistic used in this project is the *percent difference in relative standard deviation (RSD)* between replicate or duplicate pairs. Percent RSD is the standard deviation divided by the mean multiplied by one hundred.

Standard deviation is a simple measure of the variability or statistical dispersion of a data set. A low standard deviation indicates that all of the data points are very close to the same value (the mean) while high standard deviation indicates that the data are spread out over a large range of values. The lower a standard deviation of a set of repeat measurements, the better is the precision of those measurements.

For ammonia-N, Ecology's Ambient Monitoring Program has a quality assurance goal of 7% RSD between replicate or duplicate pairs (Hallock and Ehinger, 2003). This TMDL effectiveness monitoring project will also use the goal of 10% RSD for both ammonia-N and TRC.

This project will use a precision goal of 40% RSD for bacteria, as suggested in the quality assurance program plan (QAPP) guidance (Lombard and Kirchmer, 2004). This higher level is suggested as expected FC levels are low, which can increase RSD between samples.

Analysis of BOD_5 is a bioassay technique and is not as precise as most instrumental techniques. Therefore, this project will use a precision goal of RSD ± 15%.

Data Acquisition Requirements

The data analyses from this effectiveness-monitoring project will be comparable to the 1993 TMDL evaluation. Historical data will be collected as needed. Reference material will be collected from the TMDL and other Ecology reports.

Data Management

All field notes are recorded during sample collection, on field data sheets. Data sheets include information of date, time, location, staff, and water quality parameters being collected. Notes are recorded for weather conditions and any other specific information needed for sample analysis or data interpretation. Data is stored in spreadsheet format on a personal computer using Microsoft Excel© software. The original field data sheets and photo copies will be preserved and kept on file by Ecology.

After review, the data will be analyzed and summarized accordingly as required to complete reports. Ecology staff will be responsible for entering all data from this project into Ecology's Environmental Information Management (EIM) system.

Collect BMP Information

The most significant BMP is the construction of the new Upper Kittitas County Regional Wastewater Treatment Facility, and the piping of all of Roslyn's sewage waste to the new plant. These actions resulted in a complete halt to the earlier practice of treated WWTP plant waste (from the old Roslyn plant) to Crystal Creek.

Non-point BMPs will also be evaluated. Ecology will work closely with the KCCD and other stakeholders throughout the project area to describe and (where possible) quantify the pollution-reduction BMPs that have been implemented during the life of this TMDL. Specifically, Ecology WQP staff will interview stakeholders participating in TMDL implementation, and collect general information regarding the types and quantities of BMP implementation. Some examples of successful BMPs may include dog waste pickup programs, stormwater treatment, evaluation and repair of failing on-site septic systems, livestock fencing, and the like.

This information will be included in the final report.

Audits and Reports

This project will include a written report, prepared by Ecology staff (Jane Creech) to address whether TMDL targets have been met. It will describe the project and include:

- A map of the study area showing sampling sites,
- Descriptions of field and laboratory methods,
- A discussion of data quality, estimates of precision and bias, and the significance of any problems encountered,
- A comparison with earlier studies and findings,
- An evaluation of significant finding including whether targets are being met,
- Description and (where possible) quantification of the pollution-reduction BMPs that have been implemented during the life of this TMDL, and,
- Recommendations for follow-up, as warranted.

A draft of the final report will be reviewed by staff from the WQ program at the Central Regional Office in Yakima, as well as by staff from Ecology's EAP program.

Assessment and Response Actions

The project manager will observe and assess team performance and will address any deviations in protocol and/or quality control measures. Any suspected deviations in data results will be investigated on a case-by-case basis to make a determination if it is a result of an analytical error, data management error or an error in the sample collection process.

If errors in sampling techniques are identified, they will be addressed by the project manager and adjustments will be made. Adjustments made in the field or deviations from established protocols will be noted on the field data sheets.

Analytical errors in data management will be addressed by the project manager and the quality assurance coordinator. Recalculation of data will result if necessary.

Data Review, Validation, and Verification

All field notes will be reviewed internally by the project manager. Input into database will be compared to that on field sheets to insure that:

- Information has been accurately transcribed.
- Established protocols have been followed.

The lab will verify all data before reporting the results to the project manager. The project manager will be responsible for the review of lab data and narratives for errors or omissions. Data validation will be done by the project lead using professional judgment as to whether the lab followed the procedures in this QAPP and the laboratory Quality Assurance Manual and that the requirements for this project have been met.

Data Quality Assessment

After the data have been validated, the following steps will be conducted to assess the data quality prior to preparing the report:

- Review of the data quality objectives and the sampling design
- Conduct a preliminary data review
- Apply statistical tests as needed to assess quality assurance
- Draw conclusions from the data

It is possible – in fact likely – that some sampling and data analysis will result in non-detects. In other words, some parameters of interest may not be found in measurable amounts during field or lab analysis. Because WWTP effluent is no longer discharged to Crystal Creek, we do not expect to find much, if any, TRC and ammonia-N in the creek. BOD_5 levels may also be quite low. However, frequent non-detects during FC analysis may indicate an error in quality control and may prompt further sampling for this parameter.

Reconciliation with Data Quality Objectives

A final quality assurance section will be included in the final report providing a project summary of the Quality Assurance/Quality Control (QA/QC) including accomplishments, results of performance, quality control checks, and any significant problems encountered. In addition, the final report will provide a data quality assessment in terms of precision, accuracy, and comparability as well as a discussion regarding whether the QA objectives were met.

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Appendix B. Addendum to Quality Assurance Project Plan

Stream flow monitoring

In July 2009, the background site near Roslyn (CRY1) dried up completely. As a backup, site CRY3 was established just downstream from the Alliance Road crossing. This site had been used during the original TMDL study. While the stream geometry was not ideal at this site (numerous large boulders throughout this reach made flow sampling difficult and unreliable), the site was easily accessed and good for historical comparison. Staff continued to collect samples and field data at Site CRY3 for the rest of the project as well.

At site CRY2 (just upstream from the confluence of Crystal Creek and the Yakima River) stream flow continued during all sampling exursions. The contiuous flow as surprise considering that a long reach of the creek, only about 500’ upstream from CRY2, completely dried up from August through December. The drying up of a large portion of the lower creek had not been observed during previous studies of Crystal Creek, since the very low flows were masked by POTW effluent. Two possible causes were identified for the current uninterrupted flow just downstream from the long dry reach: (1) connectivity between the creek and extensive flooded underground coal mines in the area, and (2) subsurface flows from a small irrigated pasture just upstream from the always-flowing reach.

Additional checks at Site CRY3 indicate that that this site might also have persistent (year-round) flows, although this site was not checked as often as Site CRY2. The persistent flows at Site CRY3 are also likely due, at least in part, to drainage from old mines.

Total residual chlorine monitoring

During 2009/2010 sampling events, staff used a Hach pocket colorimeter supplied by Ecology’s Manchester Lab to test for total residual chlorine (TRC). Because TRC has a 15-minute holding time, staff had to do these tests in the field. After several sampling events, it appeared that the samples regularly exceeded state water quality criteria for TRC even though there was no known source for chlorine in the creek.

Staff later learned that manganese (Mn) occurs naturally in many Washington State streams, and that Mn interference can interfere during field TRC tests. Consequently, staff learned that steps should be taken to eliminate the Mn interference in these situations, and these extra steps can be an important part of the correct analytical procedure for TRC.

The method of eliminating Mn interference during TRC analysis appears in the owner’s manual for the Hach pocket colorimeter, and is copied below:

Table B-1: Method to eliminate Mn interference from TRC results

Interfering substance	Interference level
Manganese, Oxidized (Mn^{4+}, Mn^{7+})	Pre-treat the sample as follows: **1.** Adjust the sample pH to 6–7. **2.** Add 3 drops of Potassium Iodide (30-g/L) to 10 mL of sample. **3.** Mix and wait 1 minute. **4.** Add 3 drops of Sodium Arsenite (5-g/L) and mix. **5.** Use the test procedure to measure the concentration of the treated sample. **6.** Subtract this result from the result without the treatment to obtain the correct chlorine concentration.

TRC samples were collected and analyzed on 1/14/14, 2/27/14, 5/30/14, and 6/4/14 (2 reps on 6/4/14).

In 2014, only four follow-up samples and one set of replicates were collected for TRC (instead of the five estimated in the QAPP), as the creek dried up earlier than expected in 2014. The creek also had historically low flows in 2015 and dried up in late spring.

Data from the additional TRC analysis is in Appendix F.

Appendix C: Ammonia calculations

Table C-1: Specific criteria and analytical results for ammonia-N. Sampling site #2 (Cle Elum) only.

Date	pH	Stream Temp. (ºC)	Acute Criteria (**Total Ammonia-N**, in mg/L)	Chronic Criteria (**Un-ionized ammonia** conc., in mg/L)	Fraction Of Total Ammonia Present As Un-ionized (%)	Lab Result, **Total Ammonia-N** (in mg/L)	**Un-ionized ammonia** in actual sample, in mg/L (un-ionized fraction X lab result)	Comment
6/29/09	7.80	12.8	8.11	0.0322	1.440%	0.037	0.0005328	
7/15/09	7.14	13.7	21.06	0.0088	0.341%	0.044	0.00015004	
8/11/09	7.08	12.1	22.38	0.0069	0.263%	0.021	0.000055251	
12/7/09	7.78	2.7	8.40	0.0158	0.620%	0.017	0.0001054	
2/2/10	8.40	3.8	2.59	0.0194	2.769%	0.014	0.00038766	
3/3/10	8.02	6.2	5.41	0.0228	1.42%	*0.005**	0.0000711	
3/3/10	8.02	6.2	5.41	0.0228	1.42%	*0.005**	0.0000711	REPLICATE SAMPLE

*Lab result for total ammonia-N in these samples was <0.010 (detection limit = 0.010); used ½ detection limit for calculations.

Appendix D: Five-day biochemical oxygen demand

Table D-1: Analytical results for five-day biochemical oxygen demand (BOD_5). Sampling site #CRY2 (Cle Elum) only.

Sample Date	Sample ID	Result	Units	Comments
5/20/09	CRY2-02-BOD	2.6	mg/L	
6/15/09	CRY2-04-BOD	<2	mg/L	
7/15/09	CRY2-06-BOD	<2	mg/L	
8/11/2009	*CRY2-08-BOD*	*<2*	*mg/L*	Stream probably not continuous
12/7/09	CRY2-11-BOD	<2	mg/L	
2/2/10	CRY2-14-BOD-A	<5	mg/L	
2/2/10	CRY2-14-BOD-B	<5	mg/L	replicate
3/3/10	CRY2-16-BOD	<2	mg/L	

Appendix E: Fecal Coliform Bacteria Calculations

FCB samples were taken at three sites: CRY1 (Roslyn – east fork Crystal Creek), CRY2 (Cle Elum), and CRY3 (Alliance Road). No samples collected from north or west forks of Crystal Creek.

Site CRY2 (Cle Elum)

Sample Date	Sample ID	Result	Units	Comments
5/7/09	CRY2-01	143.0	cfu/100 mL	
5/20/09	CRY2-02-FC	6.0	cfu/100 mL	
6/2/09	CRY2-03-FC	13.0	cfu/100 mL	
6/15/09	CRY2-04-FC	153.0	cfu/100 mL	
6/29/09	CRY2-05-FC	272.0	cfu/100 mL	
7/15/09	CRY2-06-FC	60.0	cfu/100 mL	
8/3/09	CRY2-07-FC	10.0	cfu/100 mL	
8/11/09	CRY2-08-FC	1470.0	cfu/100 mL	Stream probably not continuous
8/25/09	CRY2-09-FC	130.0	cfu/100 mL	Stream not continuous
11/18/09	CRY2-10-FC	34.0	cfu/100 mL	
12/7/09	CRY2-11-FC	2.0	cfu/100 mL	
12/16/09	CRY2-12-FC-AB	1.0	cfu/100 mL	A=1, B=1, this is an average
1/12/10	CRY2-13-FC	1.0	cfu/100 mL	
2/2/10	CRY2-14-FC	1.0	cfu/100 mL	
2/17/10	CRY2-15-FC	4.0	cfu/100 mL	
3/3/10	CRY2-16-FC	10.0	cfu/100 mL	
4/6/10	CRY2-17-FC-AB	14.5	cfu/100 mL	A=11, B=18, this is an average

Geomean	**17.96**

Site CRY3 (Alliance Road)

Sample Date	Sample ID	Result	Units	Comments
7/15/09	CRY3-06-FC	22.0	cfu/100 mL	
8/5/09	CRY3-07-FC	86.7	cfu/100 mL	
8/11/09	CRY3-08-FC	68.9	cfu/100 mL	Stream probably not continuous
8/25/09	CRY3-09-FC	60.0	cfu/100 mL	Stream not continuous
11/18/09	CRY3-10-FC	56.0	cfu/100 mL	
12/7/09	CRY3-11-FC	13.0	cfu/100 mL	
12/16/09	CRY3-12-FC-AB	4.0	cfu/100 mL	
12/16/09	CRY3-12-FC-B	4.0	cfu/100 mL	
1/12/10	CRY3-13-FC	5.0	cfu/100 mL	
2/17/10	CRY3-15-FC	1.0	cfu/100 mL	actual value = 0.0, but changed to 1.0 so that GEOMEAN formula would work

Geomean	**14.68**

Site CRY1 (Roslyn)

Sample Date	Sample ID	Result	Units	Comments
5/7/09	CRY1-01	1.0	cfu/100 mL	actual result = 0, changed to 1 to make GEOMEAN work
5/20/09	CRY1-02-FC	1.0	cfu/100 mL	
6/2/09	CRY1-03-FC	1.0	cfu/100 mL	actual result = 0, changed to 1 to make GEOMEAN work
6/15/09	CRY1-04-FC	8.0	cfu/100 mL	
6/29/09	CRY1-05-FC	1.0	cfu/100 mL	actual result = 0, changed to 1 to make GEOMEAN work
2/2/10	CRY1-14-FC	1.0	cfu/100 mL	actual result = 0, changed to 1 to make GEOMEAN work
2/17/10	CRY1-15-FC	2.0	cfu/100 mL	
3/3/10	CRY1-16-FC	2.0	cfu/100 mL	
4/6/10	CRY1-17-FC-AB	1.0	cfu/100 mL	A=0, B=0, avg=0, changed to 1 to make GEOMEAN work

Geomean	**1.47**

Appendix F: Total Residual Chlorine Data

Table F-1: Total residual chlorine data. Collected in 2014 at site CRY2 (Cle Elum) only.

Sample Date	Sample number, for that day	Treated with NaAs02 and KI before testing?	Run number †, if from same sample (U = untreated, T = treated*)	Result (mg/L)	Average of runs for that sample (mg/L)	Calculated "true" TRC concentration (difference between T and U, for that sample) (mg/L)
1/14/14	Sample 1	No	U-1	0.04	0.030	0.010
1/14/14		No	U-2	0.02		
1/14/14		Yes	T-1	0.02	0.020	
1/14/14		Yes	T-2	0.02		
2/27/14	Sample 1	No	U-1	0.04	0.040	0.010
2/27/14		No	U-2	0.04		
2/27/14		Yes	T-1	0.03	0.030	
2/27/14		Yes	T-2	0.03		
5/30/14	Sample 1	No	U-1	0.04	0.040	0.000
5/30/14		No	U-2	0.04		
5/30/14		Yes	T-1	0.04	0.040	
5/30/14		Yes	T-2	0.04		
6/4/14	Sample 1	No	U-1	0.03	0.030	0.000
6/4/14		No	U-2	0.03		
6/4/14		Yes	T-1	0.03	0.030	
6/4/14		Yes	T-2	0.03		

Sample Date	Sample number, for that day	Treated with NaAs02 and KI before testing?	Run number †, if from same sample (U = untreated, T = treated*)	Result (mg/L)	Average of runs for that sample (mg/L)	Calculated "true" TRC concentration (difference between T and U, for that sample) (mg/L)
6/4/14	Sample 2	No	#REP-U-1	0.02	0.023	0.003
6/4/14		No	REP-U-2	0.03		
6/4/14		No	REP-U-3	0.02		
6/4/14		Yes	REP-T-1	0.02	0.020	
6/4/14		Yes	REP-T-2	0.02		
6/4/14		Yes	REP-T-3	0.02		

†The "run number" shows how many times a portion of the sample was analyzed within the 15 minute holding time. Typically, a portion of the sample would be analyzed in untreated form, then treatment added, then the sample would be analyzed again. For a second run, the process would be repeated, using the same sample.
*To determine if manganese interference is the source of the apparent TRC contamination, both treated and untreated samples were analyzed using a hand-held field colorimeter. (Note that is equipment manufacturer requires this method). True TRC values were determined by finding the difference between the treated and untreated results.
#A replicate sample was collected on 6/4/14.

Appendix G. Laboratory Data

Three laboratories were used for data analysis in this study: The main analytical lab used was Cascade Analytical in Union Gap, Washington (near Yakima). However, Cascade Analytical's lab in Wenatchee was used occasionally to accommodate their lab schedules. Additionally, Analytical Resources Incorporated lab in Seattle was used to ensure that the detection limits for ammonia samples were below criteria.

Lab abbreviations in table below are:

- Cascade Analytical Laboratory-Union Gap : *Cascade/UG*
- Cascade Analytical Laboratory-Wenatchee : *Cascade/Wen*
- Analytical Resources Incorporated : *ARI*

Table G-1: Laboratory analysis data.

Sample Date	Time	Sampling Site	Location	Lab	Parameter	Sample ID	Result	Units	Comments
5/7/09	1145	CRY2	Cle Elum	Cascade/UG	FC	CRY2-01	143.0	cfu/100 mL	
5/7/09	1218	CRY1	Roslyn	Cascade/UG	FC	CRY1-01	0.0	cfu/100 mL	
5/20/09	1121	CRY2	Cle Elum	Cascade/UG	FC	CRY2-02-FC	6.0	cfu/100 mL	
5/20/09	1125	CRY2	Cle Elum	Cascade/UG	BOD_5	CRY2-02-BOD	2.6	mg/L	
5/20/09	1240	CRY1	Roslyn	Cascade/UG	FC	CRY1-02-FC	1.0	cfu/100 mL	
6/2/09	954	CRY2	Cle Elum	Cascade/UG	FC	CRY2-03-FC	13.0	cfu/100 mL	
6/2/09	1046	CRY1	Roslyn	Cascade/UG	FC	CRY1-03-FC	0.0	cfu/100 mL	
6/15/09	1020	CRY2	Cle Elum	Cascade/UG	FC	CRY2-04-FC	153.0	cfu/100 mL	
6/15/09	1021	CRY2	Cle Elum	Cascade/UG	BOD_5	CRY2-04-BOD	<2	mg/L	
6/15/09	1112	CRY1	Roslyn	Cascade/UG	FC	CRY1-04-FC	8.0	cfu/100 mL	
6/29/09	1048	CRY2	Cle Elum	Cascade/Wen	FC	CRY2-05-FC	272.0	cfu/100 mL	
6/29/09	1049	CRY2	Cle Elum	ARI	Ammonia-N	CRY2-05-NH4	0.037	mg/L	
6/29/09	1212	CRY1	Roslyn	Cascade/Wen	FC	CRY1-05-FC	0.0	cfu/100 mL	

Sample Date	Time	Sampling Site	Location	Lab	Parameter	Sample ID	Result	Units	Comments
7/15/09	1203	CRY2	Cle Elum	Cascade/UG	FC	CRY2-06-FC	60.0	cfu/100 mL	Site CRY1 (Roslyn) dry. Added site CRY3, creek flowing below this pt.
7/15/09	1204	CRY2	Cle Elum	ARI	Ammonia-N	CRY2-06-NH4	0.044	mg/L	
7/15/09	1205	CRY2	Cle Elum	Cascade/UG	BOD_5	CRY2-06-BOD	<2	mg/L	
7/15/09	1308	CRY3	Alliance Rd	Cascade/UG	FC	CRY3-06-FC	22.0	cfu/100 mL	
8/5/09	1230	CRY2	Cle Elum	Cascade/UG	FC	CRY2-07-FC	10.0	cfu/100 mL	stream still flowing at lower sites; unknown if continuous between CRY3 and CRY1.
8/5/09	1255	CRY3	Alliance Rd	Cascade/UG	FC	CRY3-07-FC	86.7	cfu/100 mL	
8/11/09	1113	CRY2	Cle Elum	Cascade/UG	FC	CRY2-08-FC	1470	cfu/100 mL	stream likely not continuous on this date, sections still flowing, prob. with groundwater input.
8/11/09	1114	CRY2	Cle Elum	ARI	Ammonia-N	CRY2-08-NH4	0.021	mg/L	
8/11/09	1115	CRY2	Cle Elum	Cascade/UG	BOD_5	CRY2-08-BOD	<2	mg/L	
8/11/09	1205	CRY3	Alliance Rd	Cascade/UG	FC	CRY3-08-FC	68.9	cfu/100 mL	
8/25/09	1110	CRY2	Cle Elum	Cascade/UG	FC	CRY2-09-FC	130	cfu/100 mL	stream not continuous - walked entire lower creek.
8/25/09	1230	CRY3	Alliance Rd	Cascade/UG	FC	CRY3-09-FC	60	cfu/100 mL	

Sample Date	Time	Sampling Site	Location	Lab	Parameter	Sample ID	Result	Units	Comments
11/18/09	1110	CRY2	Cle Elum	Cascade/Wen	FC	CRY2-10-FC	34.0	cfu/100 mL	creek flowing again, from at least Alliance Rd to confluence with river
11/18/09	1050	CRY3	Alliance Rd	Cascade/Wen	FC	CRY3-10-FC	56.0	cfu/100 mL	
12/7/09	1250	CRY2	Cle Elum	Cascade/UG	FC	CRY2-11-FC	2.0	cfu/100 mL	
12/7/09	1251	CRY2	Cle Elum	Cascade/UG	BOD_5	CRY2-11-BOD	<2	mg/L	
12/7/09	1253	CRY2	Cle Elum	ARI	Ammonia-N	CRY2-11-NH4	0.017	mg/L	sent to correct lab
12/7/09	1345	CRY3	Alliance Rd	Cascade/UG	FC	CRY3-11-FC	13.0	cfu/100 mL	
12/16/09	1233	CRY2	Cle Elum	Cascade/UG	FC	CRY2-12-FC-A	1.0	cfu/100 mL	
12/16/09	1234	CRY2	Cle Elum	Cascade/UG	FC	CRY2-12-FC-B	1.0	cfu/100 mL	replicate
12/16/09	1146	CRY3	Alliance Rd	Cascade/UG	FC	CRY3-12-FC-A	4.0	cfu/100 mL	
12/16/09	1147	CRY3	Alliance Rd	Cascade/UG	FC	CRY3-12-FC-B	4.0	cfu/100 mL	replicate
1/12/10	1205	CRY2	Cle Elum	Cascade/UG	FC	CRY2-13-FC	1.0	cfu/100 mL	
1/12/10	1235	CRY3	Alliance Rd	Cascade/UG	FC	CRY3-13-FC	5.0	cfu/100 mL	
2/2/10	1055	CRY2	Cle Elum	Cascade/UG	FC	CRY2-14-FC	1.0	cfu/100 mL	
2/2/10	1100	CRY2	Cle Elum	Cascade/UG	BOD5	CRY2-14-BOD-A	<5	mg/L	
2/2/10	1101	CRY2	Cle Elum	Cascade/UG	BOD_5	CRY2-14-BOD-B	<5	mg/L	replicate
2/2/10	1102	CRY2	Cle Elum	ARI	Ammonia-N	CRY2-14-NH4-A	0.014	mg/L	
2/2/10	1103	CRY2	Cle Elum	ARI	Ammonia-N	CRY2-14-NH4-B	0.014	mg/L	replicate
2/2/10	1224	CRY1	Roslyn	Cascade/UG	FC	CRY1-14-FC	0.0	cfu/100 mL	
2/17/10	1255	CRY1	Roslyn	Cascade/UG	FC	CRY1-15-FC	2.0	cfu/100 mL	

Sample Date	Time	Sampling Site	Location	Lab	Parameter	Sample ID	Result	Units	Comments
2/17/10	1225	CRY2	Cle Elum	Cascade/UG	FC	CRY2-15-FC	4.0	cfu/100 mL	
2/17/10	1245	CRY3	Alliance Rd	Cascade/UG	FC	CRY3-15-FC	0.0	cfu/100 mL	
3/3/10	1205	CRY2	Cle Elum	ARI	Ammonia-N	Field Blank NH4	<0.010	mg/L	field blank
3/3/10	1210	CRY2	Cle Elum	ARI	Ammonia-N	CRY2-16-NH4	<0.010	mg/L	
3/3/10	1205	CRY2	Cle Elum	Cascade/UG	BOD_5	Field Blank BOD	<2	mg/L	field blank
3/3/10	1211	CRY2	Cle Elum	Cascade/UG	BOD_5	CRY2-16-BOD	<2	mg/L	
3/3/10	1212	CRY2	Cle Elum	Cascade/UG	FC	CRY2-16-FC	10.0	cfu/100 mL	
3/3/10	1250	CRY1	Roslyn	Cascade/UG	FC	CRY1-16-FC	2.0	cfu/100 mL	
4/6/10	1144	CRY2	Cle Elum	Cascade/UG	FC	CRY2-17-FC-A	11.0	cfu/100 mL	
4/6/10	1145	CRY2	Cle Elum	Cascade/UG	FC	CRY2-17-FC-B	18.0	cfu/100 mL	replicate
4/6/10	1233	CRY1	Roslyn	Cascade/UG	FC	CRY3-17-FC-A	0.0	cfu/100 mL	
4/6/10	1234	CRY1	Roslyn	Cascade/UG	FC	CRY3-17-FC-B	0.0	cfu/100 mL	replicate

Appendix H: Raw Field Data

A variety of field data was collected, including stream flow discharge levels (Q), turbidity, and total residual chlorine (TRC). TRC findings are included only for 2014, as TRC data was collected incorrectly prior to 2014 (see report text). pH and temperature data was collected when needed to evaluate ammonia samples.

Table H-1: Field data collected for this monitoring project.

Sample Date	Sample Time (military)	Site	Near ...?	Parameter	Finding	Units	Tester Used	Notes
5/7/09	1145	CRY2	Cle Elum	turbidity	4.64	NTU	turbidimeter	
5/7/09	1218	CRY1	Roslyn	turbidity	1.41	NTU	turbidimeter	
5/8/09	1026	CRY1	Roslyn	Q	1.66	cfs	flow meter	
5/8/09	1131	CRY2	Cle Elum	Q	4.30	cfs	flow meter	
5/20/09	1135	CRY2	Cle Elum	turbidity	3.42	NTU	turbidimeter	
5/20/09	1245	CRY1	Roslyn	turbidity	1.45	NTU	turbidimeter	flow in creek now intermittent:
5/22/09	1003	CRY2	Cle Elum	Q	2.21	cfs	flow meter	
5/22/09	1040	CRY1	Roslyn	Q	0.87	cfs	flow meter	
6/2/09	954	CRY2	Cle Elum	turbidity	1.65	NTU	turbidimeter	
6/2/09	1032	CRY2	Cle Elum	Q	1.54	cfs	flow meter	
6/2/09	1045	CRY1	Roslyn	turbidity	1.26	NTU	turbidimeter	still flowing at sample site
6/2/09	1116	CRY1	Roslyn	Q	0.23	cfs	flow meter	
6/15/09	1030	CRY2	Cle Elum	turbidity	7.23	NTU	turbidimeter	
6/15/09	1118	CRY1	Roslyn	turbidity	2.86	NTU	turbidimeter	creek dry at 1st Street
6/15/09	1143	CRY1	Roslyn	Q	0.06	cfs	flow meter	
6/15/09	1230	CRY2	Cle Elum	Q	1.13	cfs	flow meter	

Sample Date	Sample Time (military)	Site	Near ...?	Parameter	Finding	Units	Tester Used	Notes
6/29/09	1105	CRY2	Cle Elum	pH	7.80	pH units	pH/temp probe	
6/29/09	1105	CRY2	Cle Elum	water temp	12.8	°C	pH/temp probe	
6/29/09	1110	CRY2	Cle Elum	turbidity	3.53	NTU	turbidimeter	
6/29/09	1150	CRY2	Cle Elum	Q	0.27	cfs	flow meter	
6/29/09	1215	CRY1	Roslyn	turbidity	1.41	NTU	turbidimeter	• wet, pools along Coal Mine Trail
6/29/09	1220	CRY1	Roslyn	Q	*est <0.1*	cfs		
7/15/09	1215	CRY2	Cle Elum	turbidity	1.51	NTU	turbidimeter	
7/15/09	1240	CRY2	Cle Elum	pH	7.14	pH units	pH/temp probe	
7/15/09	1240	CRY2	Cle Elum	Q	*est <0.2*	cfs		
7/15/09	1240	CRY2	Cle Elum	water temp	13.7	°C	pH/temp probe	
7/15/09	1308	CRY3	Alliance Rd	Q	*est <0.2*	cfs		
7/15/09	1308	CRY3	Alliance Rd	turbidity	3.53	NTU	turbidimeter	
7/15/09	1401	CRY2	Cle Elum	pH	7.22	pH units	pH/temp probe	
7/15/09	1401	CRY2	Cle Elum	water temp	14.9	°C	pH/temp probe	
8/5/09	1235	CRY2	Cle Elum	Q	*est <0.1*	cfs		
8/5/09	1235	CRY2	Cle Elum	turbidity	*est <2.0*	NTU	turbidimeter	
8/5/09	1300	CRY3	Alliance Rd	Q	*est <0.2*	cfs		
8/5/09	1300	CRY3	Alliance Rd	turbidity	*est <4.0*	NTU	turbidimeter	
8/5/09	1340	CRY1	Roslyn	Q	***0.00***	cfs	flow meter	
8/11/09	1118	CRY2	Cle Elum	turbidity	1.96	NTU	turbidimeter	
8/11/09	1120	CRY2	Cle Elum	pH	7.08	pH units	pH/temp probe	
8/11/09	1120	CRY2	Cle Elum	Q	*est <0.1*	cfs		

Sample Date	Sample Time (military)	Site	Near ...?	Parameter	Finding	Units	Tester Used	Notes
8/11/09	1120	CRY2	Cle Elum	water temp	12.1	° C	pH/temp probe	
8/11/09	1210	CRY3	Alliance Rd	turbidity	*2.90*	NTU	turbidimeter	
8/11/09	1211	CRY3	Alliance Rd	Q	*est <0.1*	cfs		
8/25/09	1125	CRY2	Cle Elum	turbidity	1.31	NTU	turbidimeter	
8/25/09	1128	CRY2	Cle Elum	Q	*est <0.1*	cfs		
8/25/09	1240	CRY3	Alliance Rd	turbidity	2.07	NTU	turbidimeter	
8/25/09	1245	CRY3	Alliance Rd	Q	*est <0.1*	cfs		
11/18/09	1052	CRY3	Alliance Rd	Q	*est <0.5*	cfs		
11/18/09	1052	CRY3	Alliance Rd	turbidity	8.71	NTU	turbidimeter	
11/18/09	1112	CRY2	Cle Elum	Q	*est <0.5*	cfs		
11/18/09	1112	CRY2	Cle Elum	turbidity	3.89	NTU	turbidimeter	
12/5/09	1258	CRY2	Cle Elum	turbidity	2.24	NTU	turbidimeter	
12/5/09	1310	CRY2	Cle Elum	pH	7.78	pH units	pH/temp probe	
12/5/09	1310	CRY2	Cle Elum	Q	*est <0.1*	cfs		
12/5/09	1310	CRY2	Cle Elum	water temp	2.7	° C	pH/temp probe	
12/5/09	1355	CRY3	Alliance Rd	turbidity	2.27	NTU	turbidimeter	
12/5/09	1357	CRY3	Alliance Rd	Q	*est <0.1*	cfs		
12/16/09	1150	CRY3	Alliance Rd	turbidity	1.87	NTU	turbidimeter	
12/16/09	1210	CRY3	Alliance Rd	Q	*est <1.0*	cfs		
12/16/09	1235	CRY2	Cle Elum	turbidity	10.1	NTU	turbidimeter	
12/16/09	1250	CRY2	Cle Elum	Q	*est <1.0*	cfs		
1/12/10	1211	CRY2	Cle Elum	turbidity	0.98	NTU	turbidimeter	
1/12/10	1247	CRY3	Alliance Rd	turbidity	1.76	NTU	turbidimeter	
1/12/10	1248	CRY3	Alliance Rd	Q	*est <0.5*	cfs		
1/12/10	1326	CRY2	Cle Elum	Q	0.41 (actual)	cfs	flow meter	

Sample Date	Sample Time (military)	Site	Near ...?	Parameter	Finding	Units	Tester Used	Notes
2/2/10	1110	CRY2	Cle Elum	pH	8.40	pH units	pH/temp probe	
2/2/10	1110	CRY2	Cle Elum	water temp	3.8	° C	pH/temp probe	
2/2/10	1159	CRY2	Cle Elum	turbidity	3.02	NTU	turbidimeter	
2/2/10	1222	CRY1	Roslyn	Q	*est <0.2*	cfs		
2/2/10	1225	CRY1	Roslyn	turbidity	1.70	NTU	turbidimeter	• still flowing at Alliance Rd
2/2/10	1255	CRY3	Alliance Rd	Q	*est <0.5*	cfs		
2/2/10	1255	CRY3	Alliance Rd	turbidity	3.58	NTU	turbidimeter	
2/2/10	1335	CRY2	Cle Elum	Q	2.64 (actual)	cfs	flow meter	
2/17/10	1230	CRY2	Cle Elum	turbidity	4.70	NTU	turbidimeter	
2/17/10	1245	CRY3	Alliance Rd	Q	*est <1.0*	cfs		
2/17/10	1245	CRY3	Alliance Rd	turbidity	6.16	NTU	turbidimeter	
2/17/10	1300	CRY1	Roslyn	Q	*est <0.5*	cfs		
2/17/10	1300	CRY1	Roslyn	turbidity	8.45	NTU	turbidimeter	
2/18/10	1405	CRY2	Cle Elum	Q	3.91 (actual)	cfs	flow meter	
3/3/10	1220	CRY2	Cle Elum	pH	8.02	pH units	pH/temp probe	
3/3/10	1220	CRY2	Cle Elum	water temp	6.2	° C	pH/temp probe	
3/3/10	1225	CRY2	Cle Elum	turbidity	13.50	NTU	turbidimeter	
3/3/10	1256	CRY1	Roslyn	turbidity	5.24	NTU	turbidimeter	
3/3/10	1258	CRY1	Roslyn	Q	*est ~1.5*	cfs		
3/3/10	1406	CRY2	Cle Elum	Q	6.21	cfs	flow meter	
4/6/10	1151	CRY2	Cle Elum	turbidity	3.87	NTU	turbidimeter	
4/6/10	1220	CRY2	Cle Elum	Q	3.00	cfs	flow meter	
4/6/10	1245	CRY1	Roslyn	turbidity	1.49	NTU	turbidimeter	

Sample Date	Sample Time (military)	Site	Near ...?	Parameter	Finding	Units	Tester Used	Notes
4/6/10	1255	CRY1	Roslyn	Q	0.99	cfs	flow meter	
4/6/10	1318	CRY3	Alliance Rd	turbidity	13.60	NTU	turbidimeter	
4/27/10	1243	CRY2	Cle Elum	turbidity	3.16	NTU	turbidimeter	
5/19/10	1652	CRY1	Roslyn	turbidity	1.02	NTU	turbidimeter	
5/19/10	1740	CRY2	Cle Elum	turbidity	4.68	NTU	turbidimeter	UPSTREAM from stormwater runoff site
5/19/10	1742	CRY2	Cle Elum	turbidity	125	NTU	turbidimeter	DOWNSTREAM from stormwater runoff site
6/3/10	1255	CRY1	Roslyn	turbidity	1.40	NTU	turbidimeter	
6/3/10	1310	CRY1	Roslyn	Q	*est < 0.2*	cfs		
6/3/10	1344	CRY2	Cle Elum	turbidity	4.88	NTU	turbidimeter	
6/4/10	1245	CRY2	Cle Elum	Q	2.35	cfs	flow meter	
6/4/10	1259	CRY2	Cle Elum	Q	2.29	cfs	flow meter	**REPLICATE - 2.6% diff, good**
6/24/10	1440	CRY2	Cle Elum	turbidity	3.16	NTU	turbidimeter	
6/24/10	1519	CRY2	Cle Elum	Q	0.54	cfs	flow meter	
6/24/10	1530	CRY2	Cle Elum	Q	0.56	cfs	flow meter	**REPLICATE - 3.6% diff, good**
7/9/10	1250	CRY2	Cle Elum	turbidity	3.48	NTU	turbidimeter	
7/13/10	1525	CRY2	Cle Elum	turbidity	3.32	NTU	turbidimeter	
7/13/10	1522	CRY2	Cle Elum	Q	*est ~0.15*	cfs		
7/13/10	1542	CRY3	Alliance Rd	turbidity	2.49	NTU	turbidimeter	
7/13/10	1544	CRY3	Alliance Rd	Q	*est <0.5*	cfs		
7/13/10	1608	CRY1	Roslyn	turbidity	1.03	NTU	turbidimeter	
7/13/10	1611	CRY1	Roslyn	Q	*est <0.1*	cfs		barely trickling
7/21/10	1445	CRY2	Cle Elum	turbidity	5.14	NTU	turbidimeter	
7/21/10	1450	CRY2	Cle Elum	Q	*est < 0.2*	cfs		very low flow

Sample Date	Sample Time (military)	Site	Near ...?	Parameter	Finding	Units	Tester Used	Notes
1/14/14	1443	CRY2	Cle Elum	TRC	0.010	mg/L	chlorine test kit	Sample data is difference between treated and untreated samples
2/27/14	1306	CRY2	Cle Elum	TRC	0.010	mg/L	chlorine test kit	Sample data is difference between treated and untreated samples
5/30/14	1404	CRY2	Cle Elum	TRC	0.000	mg/L	chlorine test kit	Sample data is difference between treated and untreated samples
6/4/14	1539	CRY2	Cle Elum	TRC	0.000	mg/L	chlorine test kit	Sample data is difference between treated and untreated samples
6/4/14	1558	CRY2	Cle Elum	TRC	0.000	mg/L	chlorine test kit	**REPLICATE**

Appendix I: Flow Data

The flow levels at several sites were very low during the late summer and early fall, and one site (CRY1) dried up completely for several months. When the flow were very low, it was not possible to use the flow meter to measure flows due to limitations of the equipment. As a result, rough estimates of flow levels were made in some cases. Additionally, the channel geometry made sampling difficult at another site (CRY3), so flow at this site was always estimated.

The flow estimates were based on the judgment of the sampler, and so should not be entered into a database. However, the estimates are included in the table below to help characterize the sites.

Table I-1: Flow data, collected and/or estimated at three sites

Sample Date	Site	Near	Finding*	Units	Source of Data	Notes
5/8/09	CRY1	Roslyn	1.66	cfs	flow meter	
5/22/09	CRY1	Roslyn	0.87	cfs	flow meter	
6/2/09	CRY1	Roslyn	0.23	cfs	flow meter	
6/15/09	CRY1	Roslyn	0.06	cfs	flow meter	
6/29/09	CRY1	Roslyn	*est <0.1*	cfs	estimate only	
8/5/09	CRY1	Roslyn	0.00	cfs	flow meter	Creek dry at this location from mid-July through early winter; snow too deep in Jan to collect a sample
2/2/10	CRY1	Roslyn	*est <0.2*	cfs	estimate only	
2/17/10	CRY1	Roslyn	*est <0.5*	cfs	estimate only	
3/3/10	CRY1	Roslyn	*est ~1.5*	cfs	estimate only	
4/6/10	CRY1	Roslyn	0.99	cfs	flow meter	
6/3/10	CRY1	Roslyn	*est < 0.2*	cfs	estimate only	
7/13/10	CRY1	Roslyn	*est <0.1*	cfs	estimate only	
5/8/09	CRY2	Cle Elum	4.30	cfs	flow meter	
5/22/09	CRY2	Cle Elum	2.21	cfs	flow meter	
6/2/09	CRY2	Cle Elum	1.54	cfs	flow meter	
6/15/09	CRY2	Cle Elum	1.13	cfs	flow meter	
6/29/09	CRY2	Cle Elum	0.27	cfs	flow meter	
7/15/09	CRY2	Cle Elum	*est <0.2*	cfs	estimate only	
8/5/09	CRY2	Cle Elum	*est <0.1*	cfs	estimate only	
8/11/09	CRY2	Cle Elum	*est <0.1*	cfs	estimate only	
8/25/09	CRY2	Cle Elum	*est <0.1*	cfs	estimate only	Creek observed to always flow at this location (never dried up); however, stopped sampling when upstream became discontinuous
11/18/09	CRY2	Cle Elum	*est <0.5*	cfs	estimate only	
12/5/09	CRY2	Cle Elum	*est <0.1*	cfs	estimate only	
12/16/09	CRY2	Cle Elum	*est <1.0*	cfs	estimate only	
1/12/10	CRY2	Cle Elum	0.41	cfs	flow meter	
2/2/10	CRY2	Cle Elum	2.64	cfs	flow meter	
2/18/10	CRY2	Cle Elum	3.91	cfs	flow meter	
3/3/10	CRY2	Cle Elum	6.21	cfs	flow meter	

4/6/10	CRY2	Cle Elum	3.00	cfs	flow meter	
6/4/10	CRY2	Cle Elum	2.32	cfs	flow meter	Replicate – avg of both runs
6/24/10	CRY2	Cle Elum	0.55	cfs	flow meter	Replicate – avg of both runs
7/13/10	CRY2	Cle Elum	*est ~0.15*	cfs	estimate only	
7/21/10	CRY2	Cle Elum	*est < 0.2*	cfs	estimate only	
7/15/09	CRY3	Alliance Rd	*est <0.2*	cfs	estimate only	Established this site when CRY1 dried up in July '09
8/5/09	CRY3	Alliance Rd	*est <0.2*	cfs	estimate only	
8/11/09	CRY3	Alliance Rd	*est <0.1*	cfs	estimate only	
8/25/09	CRY3	Alliance Rd	*est <0.1*	cfs	estimate only	
11/18/09	CRY3	Alliance Rd	*est <0.5*	cfs	estimate only	
12/5/09	CRY3	Alliance Rd	*est <0.1*	cfs	estimate only	
12/16/09	CRY3	Alliance Rd	*est <1.0*	cfs	estimate only	
1/12/10	CRY3	Alliance Rd	*est <0.5*	cfs	estimate only	
2/2/10	CRY3	Alliance Rd	*est <0.5*	cfs	estimate only	
2/17/10	CRY3	Alliance Rd	*est <1.0*	cfs	estimate only	
7/13/10	CRY3	Alliance Rd	*est <0.5*	cfs	estimate only	

Appendix J. Glossary and Acronyms

Glossary

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

Analyte: Water quality constituent being measured (parameter).

Anthropogenic: Human-caused.

Best management practices (BMPs): Physical, structural, and/or operational practices that, when used singularly or in combination, prevent or reduce pollutant discharges.

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

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

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

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

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

Effluent: An outflowing of water from a natural body of water or from a man-made structure. For example, the treated outflow from a wastewater treatment plant.

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

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

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 ten to 10,000 fold over a given period. The calculation is performed by either: (1) taking the nth root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

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

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

National Pollutant Discharge Elimination System (NPDES): National program for issuing and revising permits, as well as imposing and enforcing pretreatment requirements, under the Clean Water Act. The NPDES permit 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. This includes, but is not limited to, atmospheric deposition, surface-water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the National Pollutant Discharge Elimination System Program. Generally, 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.

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

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

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

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

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

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

Salmonid: Any fish that belong to the family *Salmonidae*. Basically, any species of salmon, trout, or char.

Sediment: Soil and organic matter that is covered with water (ex. river or lake bottom).

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

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

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

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

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

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

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

BMP	Best management practice
BOD_5	Five-day biochemical oxygen demand
DO	Dissolved oxygen
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FC	Fecal coliform (bacteria)
NPDES	National Pollutant Discharge Elimination System
POTW	Publicly-owned treatment works
RM	River mile
TRC	Total residual chlorine
TMDL	Total maximum daily load
WRIA	Water Resource Inventory Area

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cfu	colony forming unit
cfu/100 mL	colony forming units per 100 milliliter sample
ft	feet
g	gram, a unit of mass
m	meter
mg	milligram
mg/L	milligrams per liter (parts per million)
ng/L	nanograms per liter (parts per trillion)
NTU	nephelometric turbidity units
ug/L	micrograms per liter (parts per billion)