Clover Creek Watershed Fecal Coliform Bacteria, Dissolved Oxygen, and Temperature

Source Assessment Report

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Cover photo: Clover Creek at 25th Avenue East by Scott Groce

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by

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Water Resource Inventory Area (WRIA) and 8-digit Hydrologic Unit Code (HUC) number for the study area:

- WRIA: 12
- HUC number: 17110019

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Abstract

This report summarizes field measurements and laboratory data collected in Pierce County by the Washington State Department of Ecology from March 2013 to February 2014 for the *Clover Creek Dissolved Oxygen, Fecal Coliform, and Temperature TMDL Study* (Kardouni, 2013).

Concentrations of fecal coliform bacteria (FC) exceeded (did not meet) one or both *Primary Contact Recreation* criteria at 13 of 22 study sites. In addition, FC concentrations in stormwater samples exceeded the *Primary Contact Recreation* standard at 15 stream sites and 1 stormwater outfall.

Dissolved oxygen (DO) concentrations did not meet the minimum daily DO criterion of 8.0 mg/L at 4 of the 6 sites monitored during the summer (May through September) due to diurnal swings in DO concentrations. DO concentrations met the daily minimum DO water quality criterion in the winter at all 7 sites monitored.

The Clover Creek site at Canyon Road East met the 7-DADMax criterion (17.5°C) for water temperature throughout the summer. All other Clover Creek and tributary sites exceeded the 7-DADMax criterion.

The Department of Ecology compared the Benthic Index of Biological Integrity metrics for each of the 6 study sites to 12 reference sites. Based on this comparison, the biological condition was classified as *poor* at 2 sites and *very poor* at 4 sites. Periphyton collected at 7 study sites indicated nutrient enrichment, low DO conditions, reduced native taxa diversity, and siltation.

This project was originally conceived as a total maximum daily load (TMDL) study. However, after further consideration, TMDL staff decided to try a straight-to-implementation (STI) approach. This report includes implementation recommendations to help streams in the Clover Creek watershed meet Washington State water quality standards.

Executive Summary

The Clover Creek watershed is located in Pierce County, western Washington. The study area includes Clover Creek and its tributaries including North Fork Clover Creek (abbreviated as "North Fork" in this report), Morey Creek, and Spanaway Creek. The study area is primarily urban, surrounded by Tacoma, Lakewood, Parkland, and Spanaway, as well as Joint Base Lewis-McChord (JBLM).

The Washington State Department of Ecology (Ecology) conducted the Clover Creek study because water quality data show that portions of the watershed do not meet Washington State criteria WAC 173-201A for fecal coliform bacteria (FC), dissolved oxygen (DO), and temperature. Data were collected according to the *Clover Creek Dissolved Oxygen, Fecal Coliform, and Temperature Total Maximum Daily Load (TMDL) Water Quality Study Design Quality Assurance Project Plan* (Kardouni, 2013). This project was originally conceived as a total maximum daily load (TMDL) study. However, after further consideration, TMDL staff chose a straight-to-implementation (STI) approach.

Field sampling began in March 2013 and reoccurred roughly every other week for a total of 23 sampling events ending in February 2014. Most North Fork sites and the Clover Creek site at Spanaway Loop Road South went dry during the study period. Ecology was not able to collect as many samples at these sites, especially during the dry season. At Clover Creek and its tributaries (Spanaway, Morey, and North Fork), Ecology collected the following data:

- FC samples at 22 fixed-network sites.
- FC stormwater samples at 20 sites.
- Diurnal DO samples from 7 sites in the winter and 6 sites in the summer.
- Continuous temperature data from thermistors at 17 sites.
- Discharge measurements at 19 sites.
- Riparian shade estimates at 18 sites.
- Macroinvertebrate and periphyton samples at 6 sites.

Fecal Coliform Bacteria

Analysis of samples collected semimonthly at fix-network sites during the year-long study shows that FC concentrations violated both *Primary Contact Recreation* criteria at 7 sites (4 North Fork sites and 3 Clover Creek sites).

1. North Fork at 121st Street (NFCB1.1).
2. North Fork at B St S (NFC0.0).
3. Clover Creek at Spanaway Loop Rd S (CLO4.6).
4. Clover Creek at Gravelly Lake Dr SW (CLO0.4).
5. Stormwater Outfall to the North Fork on south side of 121st St, right bank (NFCB1.1RB).
6. North Fork at Aqueduct Dr, west branch (NFCB1.4W).
7. Clover Creek upstream of 138th St E (CLO7.1).

More than 10% of samples collected at 15 sites (9 North Fork sites and 6 Clover Creek sites) exceeded 200 cfu/100 mL. This list includes the previous 7 sites, plus:

8. Stormwater Outfall to the North Fork on south side of 121st St, left bank (NFCB1.1LB).
9. North Fork at Brookdale Rd E (NFCB0.0).
10. North Fork at Aqueduct Dr (NFCB1.4).
11. North Fork upstream of USGS staff gage Brookdale Rd (NFC1.0).
12. Clover Creek at 47th Ave SW (CLO1.9).
13. Clover Creek at 112th St (NFCB1.7).
14. Clover Creek at 152nd St N (CLO9.8).
15. Clover Creek at Pacific Hwy SW (CLO1.4).

The 90th percentile at the same 15 sites exceeded 200 cfu/100 mL.

Ecology collected samples during a single summer storm event. FC concentrations in stormwater samples exceeded *Primary Contact Recreation* standard (200 cfu/100 mL) at 16 of the 20 sites sampled. Only one stormwater outfall was sampled during storm event sampling on June 24, 2013−NFCB1.1RB, the outfall on the right bank on south side of 121st St. The FC concentration was 2900 cfu/100 mL, 14.5 times over the *Primary Contact Recreation* criterion for a single sample (200 cfu/100 mL).

Ecology collected all other samples during the storm event in the stream (not at stormwater outfalls) at fixed network sites during the summer storm event. Fifteen instream samples exceeded the *Primary Contact Recreation* criterion (200 cfu/100 mL). The highest FC concentrations (1300 to 1800 cfu/100 mL) in stormwater were found at 3 North Fork sites (NFC0.0, NFCB0.0, and NFCB1.1). FC concentrations were lower in Clover Creek samples (250 to 590 cfu/100 mL), but still exceeded 200 cfu/100 mL at 6 sites, from Clover Creek at 152nd St N (CLO9.8) downstream to Gravelly Lake Dr SW (CLO0.4). Most of the samples (4 out of 5) collected at Morey and Spanaway Creek sites exceeded the standard as well, but had lower concentrations (220 to 310 cfu/100 mL).

The *Primary Contact Recreation* standard (200 cfu/100 mL) was met for these stormwater sample locations: SPA1.4, CLO11.0, CLO7.1SC, and CLO12.0.

Ecology used the statistical rollback method (Ott, 1995) to calculate FC reduction targets. Target FC reductions are provided for segments of Clover Creek and the North Fork that exceeded the *Primary Contact Recreation* criteria. **Bolded sites** listed below have high concentrations of FC and contribute more to the FC load, so reduction in the reach upstream of these sites would help reduce the FC load downstream.

The following FC reductions are recommended during the dry season (May to September):

1. **CLO0.4 – 59%**
2. **CLO9.8 – 38%**
3. CLO7.1 – 45%

4. CLO1.4 – 40%
5. Morey Pond outlet to bypass at JBLM (MOR0.1) – 36%
6. Side Channel to Clover Creek upstream of 138th St E (CLO7.1SC) – 14%
7. Spanaway Creek at Spanaway Loop Rd S (SPA0.5) – 4%
8. Clover Creek 1980 feet downstream of Perimeter Rd at JBLM (CLO3.5) – 2%

Wet season (October to April) reduction is recommended at:

1. **CLO1.9 – 76%**
2. **NFC0.0 – 63%**
3. **CLO4.6 – 47%**
4. NFCB1.1RB – 76%
5. NFCB1.4 – 67%
6. NFCB1.4W – 60%
7. NFCB1.1LB – 36%
8. NFCB1.7 – 8%

Ecology recommends annual reductions (both wet and dry seasons) at:

- NFCB0.0 – wet 35% / dry 37%
- NFCB1.1 – wet 61% / dry 91%

Dissolved Oxygen

Dissolved oxygen (DO) concentration did not meet the minimum daily DO criterion of 8.0 mg/L at 4 out of 6 sites in the summer, due to diurnal swings in concentration. Ecology did not deploy multi-probes at the North Fork site (NFC0.0), because it was dry at the time of the diurnal survey.

DO fell below the minimum daily DO criterion at the following 4 sites:

- Clover Creek at 152nd St E (CLO9.8)
- Clover Creek upstream of 138th St E (CLO7.1)
- Clover Creek 1980 feet downstream of Perimeter Rd at JBLM (CLO3.5)
- Spanaway Creek at Spanaway Park (SPA1.8)

DO remained above the minimum daily DO criterion at the following 2 sites:

- Clover Creek at Canyon Rd E (CLO12.0)
- Clover Creek at Gravelly Lake Dr SW (CLO0.4)

In the winter, DO concentration met the daily minimum water quality criterion at all 7 sites (the 6 sites where DO was collected in the summer, plus one North Fork site at B St S - NFC0.0).

More information is needed to determine what is causing low DO concentrations and diurnal swings during the summer. Oxygen is less soluble in warmer water. Temperature exceedances in the summer were observed at all Clover Creek sites downstream of Canyon Road East and in all 3 tributaries: North Fork Clover Creek, Morey Creek, and Spanaway Creek. Periphyton metrics (see bioassessment section below) indicate potential nutrient enrichment at some locations. Information is not adequate to determine loading allocations and reductions that will fix the low DO conditions.

Temperature

All study sites except one exceeded the 7-DADMax water quality criterion of 17.5°C in the summer of 2013. The one exception was the Clover Creek upstream site CLO12.0 at Canyon Road East. The 7-DADMax water temperature was 12.5℃ at CLO12.0.

Water temperature exceeded 17.5°C in June and July at CLO11.0. The 7-DADMax water temperature increased over 6°C in one river mile from Canyon Rd E (CLO12.0) to Military Rd E (CLO11.0). Additional flow and temperature data is needed in this reach to determine if this much of an increase in temperature is typical in the summer, and if so, elucidate the causes.

The 7-DADMax temperature of Clover Creek continued to increase (19 to over 20℃) going downstream from Military Rd E to upstream of 138th St E (CLO7.1). The 7-DADMax temperature exceeded 17.5°C for a longer period of time (60 to 70 days) in the reach from 152nd St E (CLO9.8) to upstream of 138th St E. The highest Clover Creek 7-DADMax temperature (24.0℃) was measured at the side channel upstream of 138th St E (CLO7.1SC), where the 7-DADMax temperature exceeded 17.5°C for over 90 days from June to September.

Clover Creek at Spanaway Loop Rd S (CLO4.6) was dry during the summer data collection. Flow returned to Clover Creek downstream of the confluence of Spanaway Creek. The 7-DADMax temperature was 19.4 to 20.2℃ in lower Clover Creek, from downstream of Perimeter Rd at JBLM to Gravelly Lake Dr SW (CLO3.5 to CLO0.4). The 7-DADMax temperature exceeded 17.5ºC for over 30 days during the summer at downstream of Perimeter Rd at JBLM to Pacific Highway SW (CLO3.5, CLO1.9, and CLO1.4). At farthest downstream site at Gravelly Lake Dr SW (CLO0.4), the 7-DADMax temperature exceeded 17.5ºC for over 60 days.

All 3 North Fork sites exceeded the 7-DADMax temperature of 17.5°C, with water temperatures of 22.5 to 26.3℃. The highest 7-DADMax temperature (26.3℃) of all study sites was measured at the North Fork at B St S (NFC0.0). The North Fork became dry/sub-surface by mid-July. The 7-DADMax temperature exceeded 17.5ºC for 90 days at the branch of the North Fork at 121st St (NFCB1.1) from June until September. The North Fork at Brookdale Rd E (NFCB0.0) and at B St S did not flow the entire period, but 7-DADMax temperature exceeded 17.5º C for over 20 days from mid-June until July.

Both Morey Creek sites and all 3 Spanaway Creek sites exceeded the 7-DADMax temperature of 17.5°C. The 7-DADMax water temperature at Morey Creek was 22.5 to 24.8℃. At Spanaway

Creek, the 7-DADMax water temperature was 22.5 to 25.4°C. The 7-DADMax temperature exceeded 17.5°C at all Morey and Spanaway Creek sites for over 90 days.

Effective Shade and Canopy Cover

The following Clover Creek sites had the highest effective shade and canopy cover:

- Canyon Rd E (CLO12.0)
- Military Rd E (CLO11.0)
- Upstream of 138th St E (CLO7.1)
- 1980 feet downstream of Perimeter Rd at JBLM (CLO3.5)
- Gravelly Lake Dr SW (CLO0.4)

Clover Creek at Spanaway Loop Rd S (CLO4.6) had the lowest effective shade and canopy cover.

For the tributaries, the highest effective shade and canopy cover was measured at:

- North Fork branch at 121st St (NFCB1.1)
- Spanaway Creek at Spanaway Park (SPA1.8)
- Morey Creek at Spanaway Loop Rd S (MOR0.9)

Other tributary sites had lower effective shade and canopy cover. These sites at the North Fork include locations at Brookdale Rd E (NFCB0.0), B St S (NFC0.0), and upstream of the USGS gage at Brookdale Rd (NFC1.0). One site each on Morey Creek and Spanaway Creek had lower effective shade and canopy cover: Morey Pond outlet to bypass at JBLM (MOR0.1) and Spanaway Creek at 138th St S (SPA1.4).

Bioassessment

The biological condition was determined at 6 sites by comparing benthic macroinvertebrates and periphyton samples collected at study sites to reference sites**.** Based on the overall Benthic-Index of Biotic Integrity (B-IBI) scores, the biological condition was poor at 2 sites and very poor at 4 sites.

Two Clover Creek sites had **poor** biological condition:

- Canyon Rd E (CLO12.0)
- 1980 feet downstream of Perimeter Rd at JBLM (CLO3.5)

Four sites had **very poor** biological condition:

- Clover Creek at 25th Ave E (CLO8.7)
- Clover Creek at Pacific Hwy SW (CLO1.4)
- North Fork at B St S (NFC0.0)
- Spanaway Creek at Spanaway Park (SPA1.8)

Periphyton collected at study sites indicate low DO conditions, nutrient enrichment, reduced native taxa diversity, and siltation. A higher percentage of taxa tolerant of low DO conditions and nutrient enrichment were found at all 7 sample sites:

- Canyon Rd E (CLO12.0)
- Clover Creek at 25th Ave E midstream (CLO8.7) and on river-right (CLO8.7R)
- 1980 feet downstream of Perimeter Rd at JBLM (CLO3.5)
- Clover Creek at Pacific Hwy SW (CLO1.4)
- North Fork at B St S (NFC0.0)
- Spanaway Creek at Spanaway Park (SPA1.8)

Periphyton samples collected at the following sites had a reduced percentage of native taxa:

- CLO12.0
- CLO8.7
- CLO8.7R
- CLO3.5
- NFC0.0

These sites had a higher relative abundance of motile and siltation taxa:

- CLO12.0
- CLO3.5
- NFC0.0
- SPA1.8

Introduction

Ecology conducted the Clover Creek study because water quality data show that portions of the watershed (Figure 1) do not meet Washington State criteria for fecal coliform bacteria (FC), dissolved oxygen (DO), and temperature. This project was originally conceived as a total maximum daily load (TMDL) study. However, due to resource constraints, Ecology was forced to postpone the TMDL in favor of TMDL projects in other watersheds. Fortunately, Clover Creek has several active stakeholders already engaged in various water quality improvement projects.

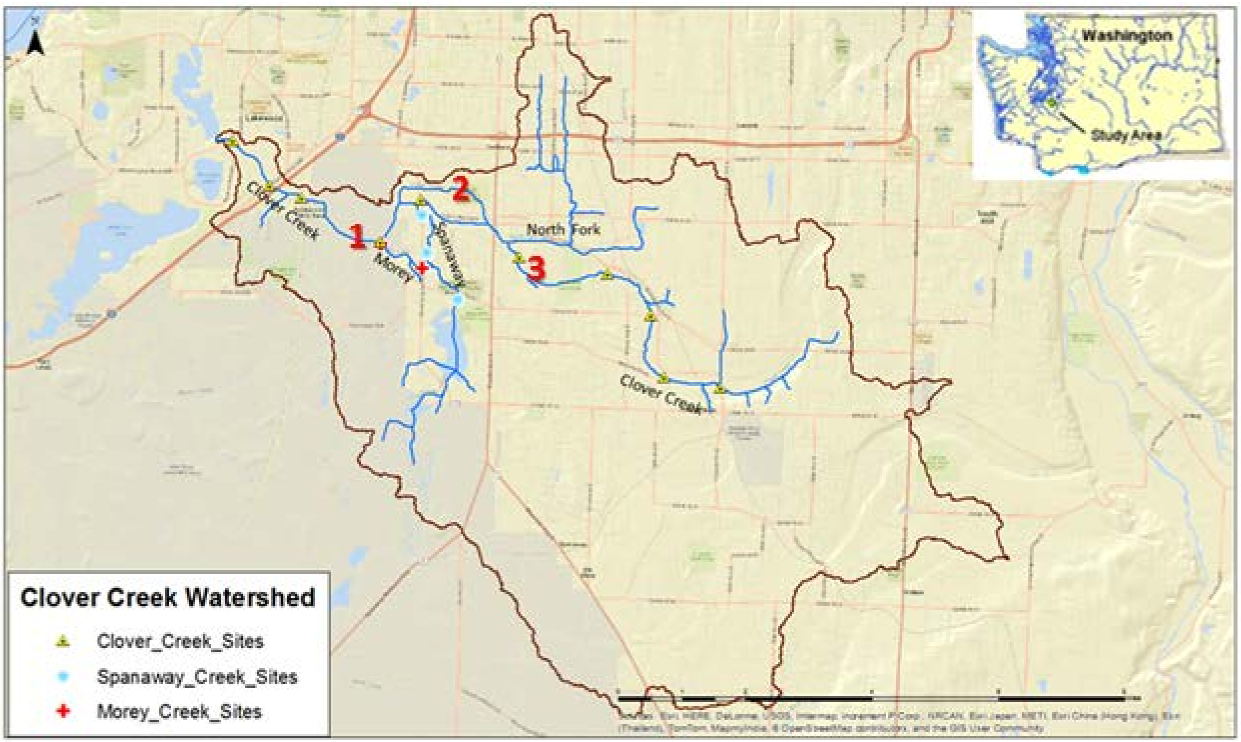


Figure 1. Clover Creek watershed and surrounding area.

While the TMDL is on hold, staff will work with these partners to pursue a straight-to-implementation (STI) approach in this watershed using data gathered in this assessment and other assessments to guide future action. Ecology and our partners will monitor water quality to quantify and track anticipated improvements to water quality and will then determine whether a TMDL is still warranted at a later date. This report is intended to help inform the STI strategy and will be used with other data, studies, and analyses by other partners within the watershed to determine restoration projects and actions.

The natural creek channels and drainage system have been extensively modified by man-made bypasses, irrigation channels, impoundments, dredging operations, collection systems, as well as infiltration and detention facilities (Pierce County, 2005).

Two large diversion projects near Joint Base Lewis McChord (JBLM) altered the location of the natural channel. First, Clover Creek was diverted underground where it crosses a section of JBLM (indicated by red number 1 on Figure 1). In 1939, Clover Creek was diverted into two 2,500-foot long metal pipe culverts under McChord Field (Pierce County, 2005).

The second project was upstream of McChord Field, where a bypass channel was constructed in the late 1960s, eliminating the natural channel to the north (shown on Figure 1 as the red number 2). Pierce County constructed the bypass channel to control floodwaters. The bypass is approximately one and a half miles long (Sinclair, 1986). It starts halfway between Pacific Avenue and C Street at 131st Street and flows toward McChord Field (Pierce County, 2005; Tobiason, 2003).

A third diversion project, this one for irrigation of a large hop farm, was completed prior to 1940 (red number 3 on the map). Approximately 1 mile of Clover Creek was rechanneled into two large irrigation channels, one on each side of the valley (Sinclair, 1986). The modified channels are located between 138th Street East and Brookdale Golf Course (Pierce County, 2005; Tobiason, 2003). For descriptions of additional modification projects in the Clover Creek watershed, see the Clover Creek Basin Plan (Pierce County, 2005), Tobiason (2003), and Sinclair (1986).

Figure 2 shows the category (color-coded) and listing identification number for water bodies in the Clover Creek watershed. This list of impaired waters is from Ecology's Water Quality Assessment submitted in 2015 and approved by the EPA in 2016. This information is available on Ecology's current assessment website and Water Quality Atlas.
http://www.ecy.wa.gov/programs/Wq/303d/currentassessmt.html

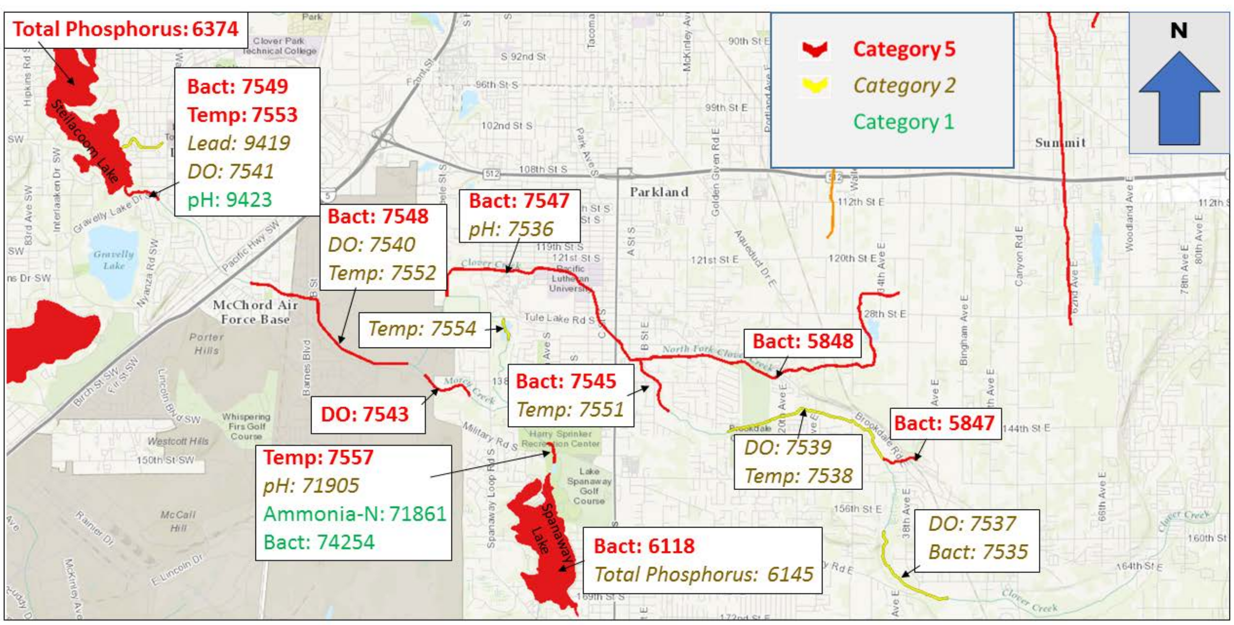


Figure 2. Portions of the Clover Creek watershed on the 303(d) list.

Table 1 details the Category 5 listings in the watershed addressed by this study. Most of the Category 5 listings are for bacteria. The unnamed tributary at Bigham Avenue is the upstream tributary to Clover Creek listed for bacteria (number 5847, on the right side of the Figure 2).

Spanaway Lake has a 303-(d) listing for bacteria, but this study did not address it. The scope was limited to flowing waterways; therefore, lakes, or impoundments were not addressed.

Table 1. Clover Creek Category 5 listed reaches investigated in this study.

Water body	Parameter	Category	Listing ID	Township - Range - Section
Clover Creek	Temperature	5	7553	19N - 2E - 11
Clover Creek	Bacteria	5	7549	19N - 2E - 11
Clover Creek	Bacteria	5	7548	19N - 2E - 48
Clover Creek	Bacteria	5	7547	19N - 3E - 42
Clover Creek	Bacteria	5	7545	19N - 3E - 47
Unnamed Tributary to Clover Creek at Bigham Ave	Bacteria	5	5847	19N - 3E - 23
North Fork Clover Creek	Bacteria	5	5848	19N - 3E - 48
Clover Creek	Dissolved Oxygen	5	7543	19N - 3E - 45
Spanaway Creek	Temperature	5	7557	19N - 3E - 49

Table 2 shows existing waters of concern (Category 2) in the Clover Creek watershed for fecal coliform bacteria (FC), dissolved oxygen (DO), and temperature. There are several reasons why a water body would be placed in this category:

- Pollution levels not quite high enough to violate the water criteria.
- Not enough violations to categorize as impaired in Category 5 according to Ecology's listing policy (Water Quality Policy 1-11).
- Data showing water quality violations not collected using appropriate scientific methods or under approved Quality Assurance (QA) Project Plan.

In all these situations, these waters need further investigation.

Table 2. Category 2 waters of concern for the Clover Creek watershed.

Water body	Parameter	Category	Listing ID	Township - Range - Section
Clover Creek	Bacteria	2	7535	19N - 3E - 25
Clover Creek	Dissolved Oxygen	2	7537	19N - 3E - 25
Clover Creek	Temperature	2	7538	19N - 3E - 48
Clover Creek	Dissolved Oxygen	2	7539	19N - 3E - 48
Clover Creek	Dissolved Oxygen	2	7540	19N - 2E - 48
Clover Creek	Dissolved Oxygen	2	7541	19N - 2E - 11
Clover Creek	Temperature	2	7551	19N - 3E - 47
Clover Creek	Temperature	2	7552	19N - 2E - 48
Clover Creek (Spanaway Creek)	Temperature	2	7554	19N - 3E - 42
Spanaway Creek	Temperature	2	7557	19N - 3E - 49

Water Quality Standards and Beneficial Uses

Specific water quality criteria for FC, DO, and temperature in the Clover Creek watershed are listed in Table 3.

Table 3. Water quality criteria and beneficial uses.

Clover Creek, North Fork Clover Creek, Spanaway Creek, and Morey Creek	
Salmonid Spawning, Rearing and Migration Habitat, Primary Contact Recreation	
Parameter	**Condition**
Fecal Coliform Bacteria	FC organism levels must not exceed a geometric mean value of 100 colonies/100 mL, with not more than 10% of all samples (or any single sample when less than 10 sample points exist) obtained for calculating the geometric mean value > 200 colonies/100 mL.
Dissolved Oxygen	8 mg/L Lowest 1-day minimum
Temperature	17.5º C Highest 7-DADMAX

The original QA Project Plan for this study (Kardouni, 2013) mistakenly reported the water quality criteria and beneficial uses for the North Fork and Morey Creek as *Extraordinary Primary Contact Recreation* and *Core Summer Salmonid Habitat*. The interpretation of GIS layers in the Water Quality Atlas and WAC 173-201A-600(1) was incorrect. The water quality criteria and beneficial uses for these 2 streams is listed in Table 3.

Watershed Description

The Clover Creek watershed is located in Pierce County, western Washington (Figure 1). The study area consists of Clover Creek and its tributaries: North Fork Clover Creek, Morey Creek, and Spanaway Creek. The headwaters originate from springs and groundwater discharges located 6 miles east of Spanaway. Clover Creek flows 13.8 miles through residential and commercial areas and empties into Steilacoom Lake. Other lakes in its 74-square-mile watershed include Spanaway Lake and Tule Lake (Pierce County, 2005).

Clover Creek drops approximately 150 feet in elevation over its length. The basin lies in the Puget Sound lowlands on an upland plain of moderate relief ranging in elevation from 200 to 600 feet above sea level. The plain contains numerous sub-parallel elongate hills or drumlins (Sinclair, 1986). Many small lakes in the basin are associated with underlying slow-draining substrates and gentle topography where wetlands tend to form. Seepage from lakes, wetlands, and springs contributes to the Clover Creek system and sustains baseflow during the summer months (Runge et al., 2003).

The North Fork flows approximately 3.2 miles before joining Clover Creek at river mile (RM) 12.25. Seasonal runoff provides flow to the headwaters of the North Fork. Urbanization has modified the natural creek channel into a series of interconnected roadside ditches, culverts, and stormwater retention ponds. The North Fork splits into 2 branches 1 river mile (RM) upstream of Clover Creek. One branch to the north and another to the east. Both branches are just over 2 miles in length.

Spanaway Creek originates from springs and wetlands upstream of Spanaway Lake in Joint Base Lewis-McChord (JBLM). These upper reaches are locally referred to as Coffee Creek (Runge et al., 2003). Spanaway Creek flows from the lake north through a wooded county park known as Bresemann Forest. Bresemann Dam is a 6-foot-high dam located approximately 2,200 feet downstream of the Spanaway Lake. The dam created a pond and fish habitat barrier (Runge et al., 2003). In 2007, the stream channel (260 feet) was restored to allow fish uninterrupted access upstream to Spanaway Lake and its tributaries. Approximately 1,800 feet downstream of the restored channel, Spanaway Creek forks, providing flow to Morey Creek. It then continues through Tule Lake before joining Clover Creek at RM 9.85.

Morey Creek originates from a branch of Spanaway Creek, flows for approximately 1 RM, and enters Clover Creek at RM 9.15. Morey Creek flows through associated wetlands and relatively undeveloped land with few houses and one small sub-division. Morey Creek Dam is located 115 feet upstream from the mouth of the creek; it impounds containing Morey Pond (Runge et al., 2003). In 2009, a new stream channel was constructed around the dam. This allowed continuous fish access upstream of the former barrier, opening approximately 6 miles of habitat.

Land use

Land use in the Clover Creek study area is primarily urban. Approximately 66% of the study area includes Tacoma, Lakewood, Parkland, and Spanaway (Kardouni, 2013). Land use in the watershed includes single- and multi-family residence, commercial, parks and recreation, golf courses, military reserves, rural, and agriculture (Figure 3).

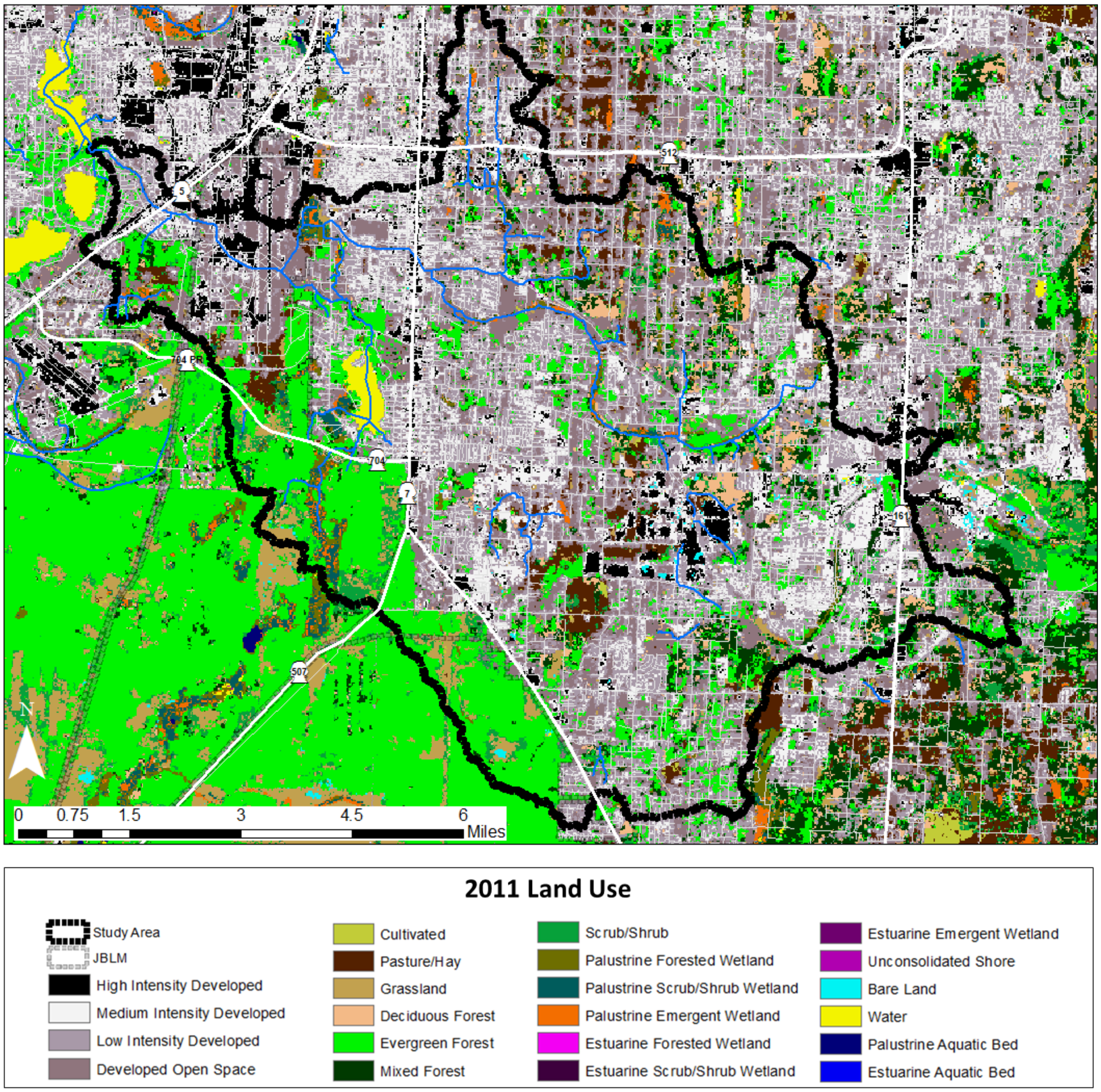


Figure 3. Land use in the Clover Creek watershed.

Clover Creek crosses McChord Air Force Base on the northern part of JBLM (Figure 4). JBLM is recognized as the largest military installation on the West Coast. The most recent human population estimate for the base was 95,000, including military personnel, military dependents residing on base, civilian employees, and visitors. The base area covers 142 square miles (EPA, 2013).

Figure 4 displays the density of on-site septic systems (OSS), as well as types of water quality permits, municipal stormwater permit areas, and stormwater outfalls in the study area. The density of OSS in the study area ranges from 0 to 1.60 per acre. The Pierce County Phase I Municipal Stormwater permit covers most of the study area. The City of Tacoma Phase I permit covers a small area in the headwaters of the North Fork. There are 71 general permits in the study area:

- 52 Construction Stormwater General Permits
- 10 Sand and Gravel General Permits
- 9 Industrial Stormwater General Permits

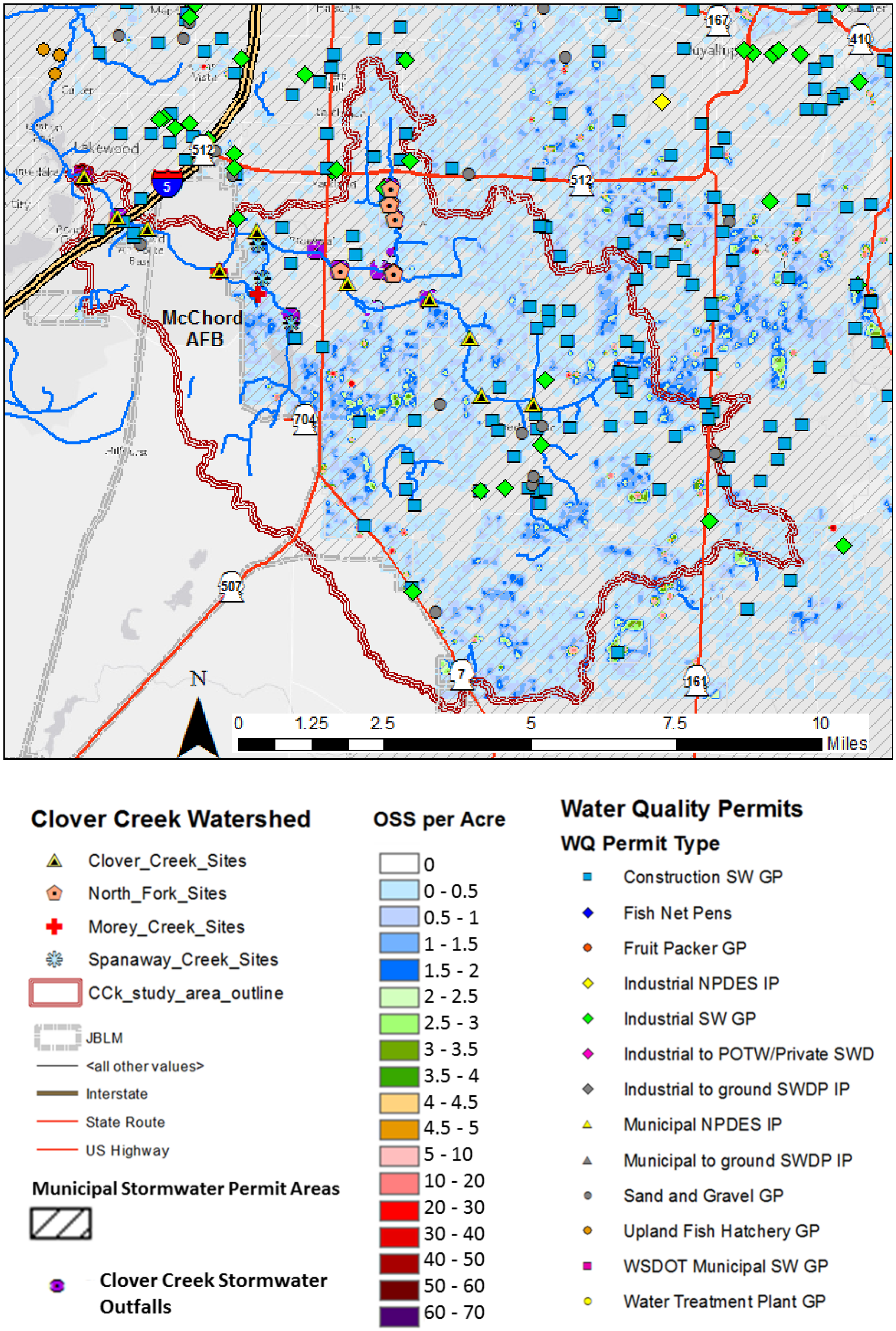


Figure 4. Density of on-site septic systems (OSS), stormwater outfalls, and water quality permits in the study area.

Table 4 lists the 9 businesses with Industrial Stormwater General Permits in the study area.

Table 4. Industrial Stormwater General Permits in the study area

Name	Description
Meridian Auto Wrecking	Auto Wrecking and Repair
Meridian Auto Wrecking	Auto Wrecking and Repair
idX Seattle	Wood Manufacturing and Distribution
Pearson Metal Salvage	Scrap Yard for Ferrous and Non-Ferrous Metals, Batteries, Motors
Zumar Industries	Sign Manufacturing
RW Rhine Inc.	Demolition
OK Grocery	Grocery Store and Gas Station
PSE	Frederickson Electrical Generating Station
Niagara Bottling Co.	Water Bottling

Study Design

Ecology monitored FC, DO, and temperature at sites in the Clover Creek watershed (Figure 5) from March 2013 to February 2014. Table 5 shows that Ecology collected:

- FC samples at 22 fixed-network sites.
- FC stormwater samples at 20 sites.
- Continuous temperature data (Temp) from thermistors at 17 sites.
- Diurnal DO concentrations from 7 sites in the winter (W) and 6 sites in the summer (S).
- Discharge measurements (Q) at 19 sites.
- Riparian shade estimates at 18 sites.
- Macroinvertebrate and periphyton (Bio) samples at 6 sites.

In this report, sites names were abbreviated by removing the WRIA number (12) from in front of the site name. For example, in EIM CLO11.0 is called 12CLO11.0.

Table 5. List of study sites in the Clover Creek watershed.

Site ID	Site Description	Latitude	Longitude	FC Fixed Site	FC Storm Site	Temp	DO	Q	Shade	Bio
CLO0.4	Clover Ck at Gravely Lk Dr SW	47.1560283	-122.5231217	X	X	X	S W	X	X	
CLO1.4	Clover Ck at Pacific Hwy SW	47.1459917	-122.5103583	X	X			X	X	X
CLO1.9	Clover Ck at 47th Ave SW	47.1433467	-122.4994567	X	X	X		X	X	
CLO3.5	Clover Ck 1980 ft. d/s of Perimeter Rd at JBLM	47.13367305	-122.472765	X	X	X	S W	X	X	X
CLO4.6	Clover Ck at Spanaway Loop Rd S	47.14345922	-122.4594648	X				X	X	
CLO7.1	Clover Ck u/s of 138th St E	47.13128465	-122.4263154	X	X	X	S W	X	X	
CLO7.1SC	Clover Ck side channel u/s of 138th St E	47.13128465	-122.4263154	X	X	X		X		
CLO8.7	Clover Ck at 25th Ave E	47.1277317	-122.396245	X	X	X		X	X	X
CLO9.8	Clover Ck at 152nd St E	47.1185067	-122.3814833	X	X	X	S W	X	X	
CLO11.0	Clover Ck at Military Rd E	47.10428904	-122.3766933	X	X	X		X	X	
CLO12.0	Clover Ck at Canyon Rd E near headwaters	47.1021316	-122.3573064	X	X	X	S W	X	X	X
MOR0.1	Morey Pond outlet to bypass at JBLM	47.13326896	-122.4727272	X	X	X		X	X	
MOR0.9	Morey Creek at Spanaway Loop Rd S	47.12778	-122.45866	X	X	X		X	X	
NFC0.0	NF Clover Ck at B St S	47.13446094	-122.4291162	X	X	X	W	X	X	X
NFC1.0	NF Clover Ck u/s of USGS gage Brookdale Rd	47.13395347	-122.4095402	X	X			X	X	
NFCB0.0	NF Clover Ck branch at Brookdale Rd E	47.13409742	-122.4095695	X	X	X		X	X	
NFCB1.1	NF Clover Ck branch at 121st	47.14737659	-122.4098005	X	X	X		X	X	
NFCB1.1LB	Left bank outfall to NF Clover Creek on south side of 121st	47.14737659	-122.4098005	X						
NFCB1.1RB	Right bank outfall to NF Clover Creek on south side of 121st	47.14737659	-122.4098005	X	X					
SPA0.5	Spanaway Ck at Spanaway Loop Rd S	47.1401477	-122.4592428	X	X	X				
SPA1.4	Spanaway Ck at 138 St S	47.1315217	-122.4572317	X	X	X		X	X	
SPA1.8	Spanaway Ck at Spanaway Park	47.1209117	-122.446315	X	X	X	S W	X	X	X

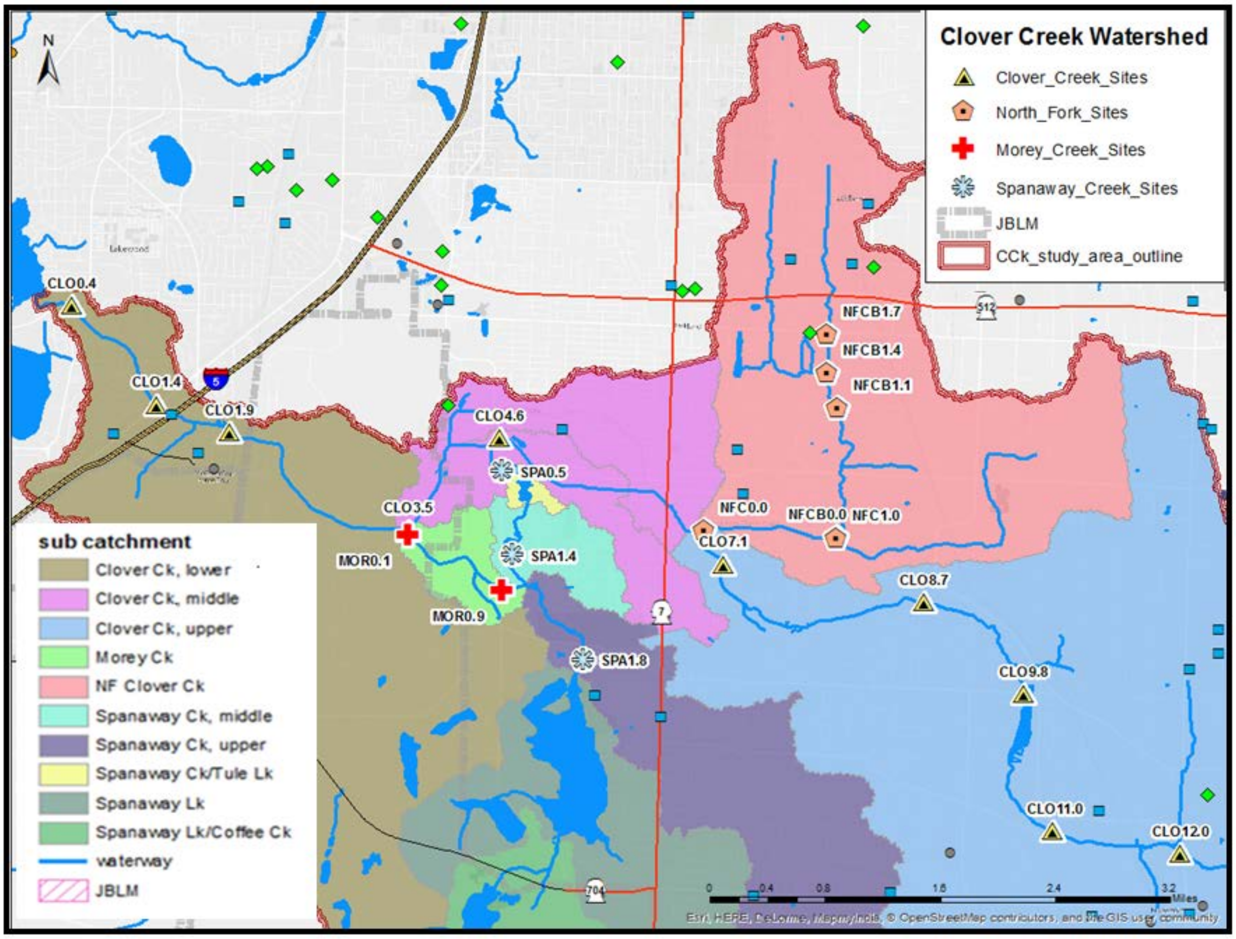


Figure 5. Water quality monitoring locations in the Clover Creek watershed.

A few sites are not shown in Figure 5.

- CLO7.1SC is a side channel that enters Clover Creek near CLO7.1, upstream of 138th Street.
- NFCB1.1LB and NFCB1.1RB are 2 stormwater outfalls downstream of NFCB1.1 on the south side of 121st Street. NFCB1.1LB is on the left bank (facing downstream). NFCB1.1RB is on the right bank.

Figure 6 shows FC investigatory sites, which included: NFCB1.4, NFCB1.4W, and NFCB1.7. Ecology selected investigatory sites upstream of locations with high FC concentrations. Staff collected samples at NFCB1.4 and NFCB1.4W from September to December 2013. Both sites are located at Aqueduct Drive. NFCB1.4W is the western branch. NFCB1.7, located at 112th Street, was monitored from October to December 2013.

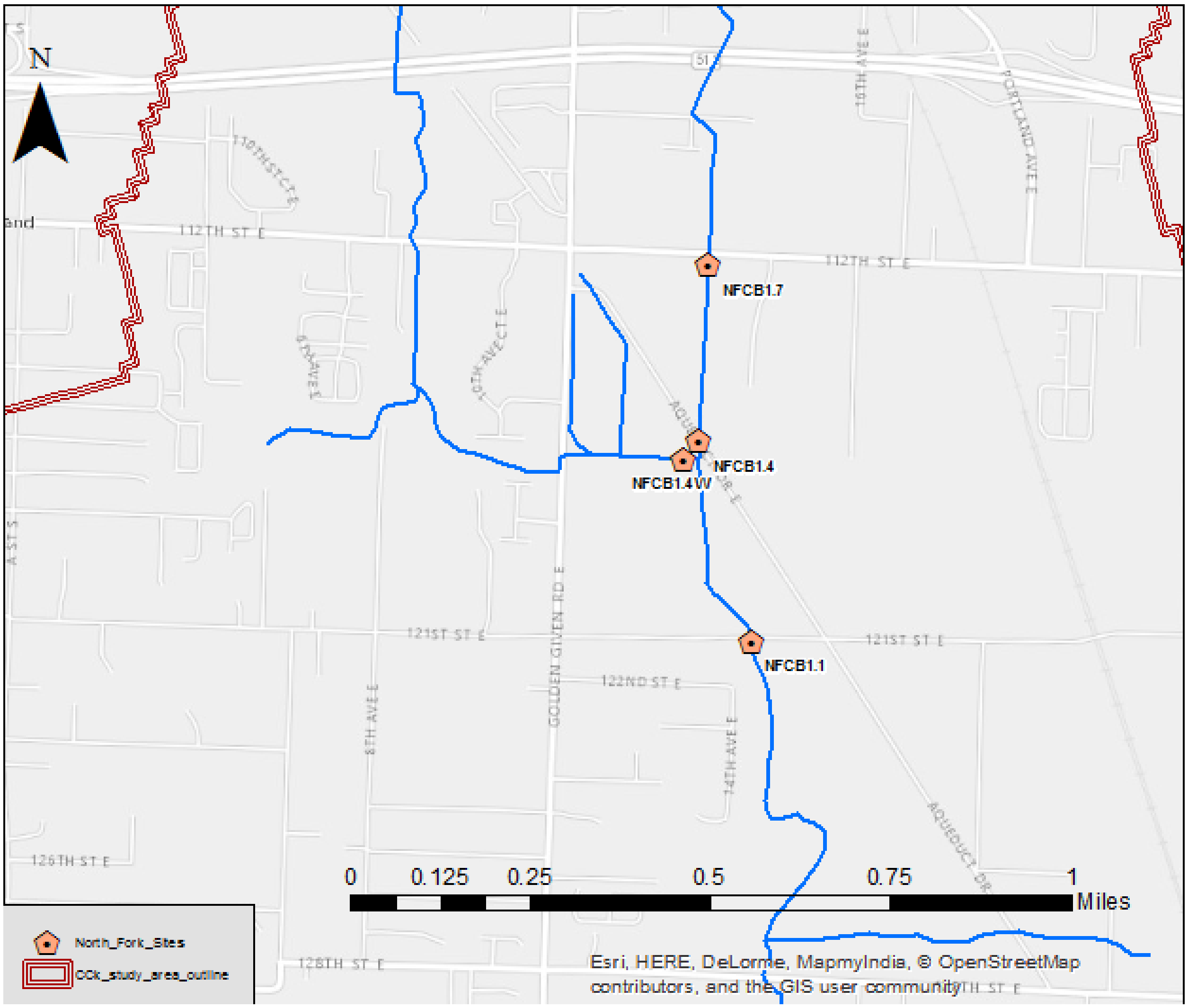


Figure 6. North Fork Clover Creek FC investigatory sites.

Methods

Field Methods

Field sampling began in March 2013 and reoccurred roughly every other week for a total of 24 sampling events ending in February 2014. Field parameters collected at each sampling site include FC grab samples, stream discharge, temperature, conductivity, pH, and DO. Stream discharge was not measured on Spanaway Creek at Spanaway Loop Rd. (SPA0.5) due to lack of proper fluvial dynamics. Methodology is described in the QA Project Plan (Kardouni, 2013)

DO Diurnal Surveys

For the summer diurnal survey, Ecology deployed 6 multi-probes logging temperature, conductivity, pH, and DO at half-hour intervals from August 26 to 29, 2013 at the following locations:

1. CLO0.4
2. CLO3.5
3. CLO7.1
4. CLO9.8
5. CLO12.0
6. SPA1.8

Ecology did not deploy multi-probes at the North Fork site (NFC0.0) because it was dry at the time of the diurnal survey.

For the winter diurnal survey, Ecology deployed 7 multi-probes logging temperature, conductivity, pH, and DO at half-hour intervals from December 16 to 19, 2013 at the 6 locations listed above plus NFC0.0.

Canopy Cover and Effective Shade

Ecology measured percent average canopy cover and effective shade using hemispherical photography.

Ecology took hemispherical digital photographs at 18 sites from July 22 to August 1, 2013. Photographs were taken looking upwards from beneath the plant canopy, using a 180° fish-eye lens and digital camera. Images were generally taken in the middle of a stream channel.

Ecology staff exported photos and data were documented into a library for analysis and future reference.

Canopy Cover is the percentage of the sky that is blocked by vegetation or topography. Unlike effective shade, this is a largely static quantity (assuming no wind) between full leaf expansion and leaf drop. The canopy cover was calculated for the time period in which the photographs were taken: July 22 to August 1, 2013. HemiView© software calculates canopy cover (1-VisSky value) with a grid on a hemispherical photograph (Figure 7).

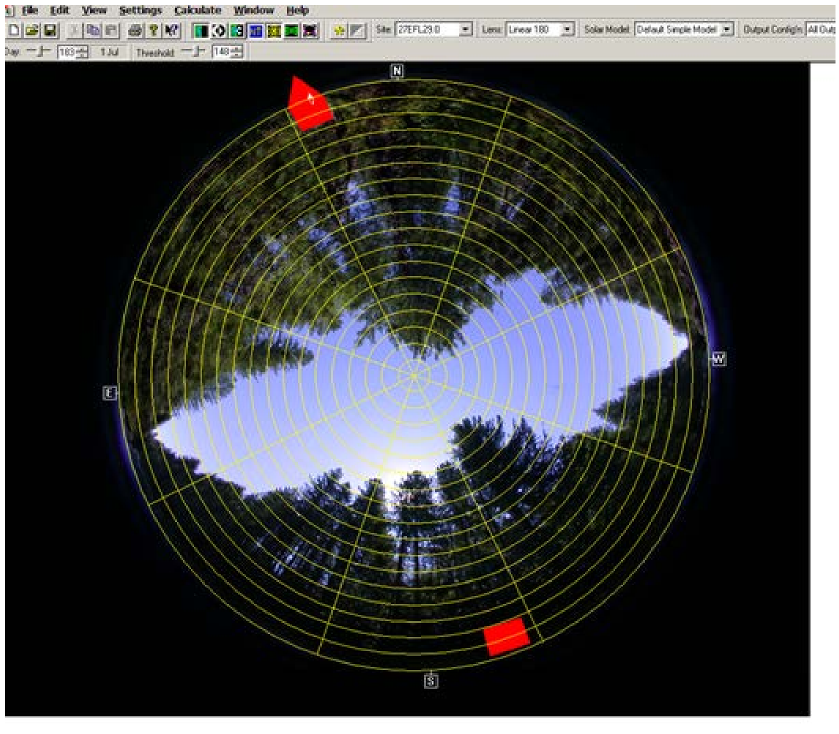


Figure 7. Hemispheric photograph showing grid for measuring canopy cover.

Effective Shade is the fraction of total possible solar radiation above the vegetation and topography that is blocked from reaching the surface of the stream and summed over a full day. Because the solar path across the sky changes each day, the solar exposure that a particular location receives will also change each day. The effective shade for each site was calculated, using HemiView©, for the May to September period.

Both of these methods for assessing potential shade incorporate both vegetative cover and topography.

Analytical Methods

Bacteria concentration targets for streams in the Clover Creek watershed were based on an analysis of FC data collected from 2013 to 2014. Excel® spreadsheets were used to evaluate the data.

Bacteria sources are quite variable, and different sources can cause water quality violations under different conditions (e.g., poor dilution of contaminated sources during low-streamflow

conditions or increased loading during runoff events). FC concentrations and percent reductions are the most practical for identifying trends and tracking implementation progress.
The water quality standards within the study area are:

- Geometric mean must not exceed 100 bacteria colonies per 100 milliliters of water (cfu/100 mL).
- No more than 10% of samples should exceed 200 cfu/100 mL. In this report, this is calculated as the 90th percentile of sample results.

The geometric mean is either the nth root of a product of n factors, or the antilogarithm of the arithmetic mean of the logarithms of the individual sample values.

The 90th percentile is a measure of statistical distribution. The 90th percentile tells you the value for which 90% of the data points are smaller and 10% are higher.

Comparisons of loads along a stream, or between seasons at a site, can be instructive for identifying changes in FC source intensity and for determining locations of bacteria load sources. The average bacteria load is the average mass of bacteria at a geographic location per unit of time. The units used in this report are a billion cfu/day.

Statistical Rollback Method

The statistical rollback method (Ott, 1995) was used to establish FC reduction targets for stream segments in the Clover Creek watershed. The rollback method simply compares monitoring data to standards, and the difference is the percentage change needed to meet the standards.

The method has been applied by Ecology in other bacteria evaluations (Cusimano and Giglio, 1995; Pelletier and Seiders, 2000; Joy, 2000; Coots, 2002; Joy and Swanson, 2005; Swanson, 2009).

Ideally, at least 20 samples taken throughout the year are taken from a broad range of hydrologic conditions to determine an annual FC distribution. If sources of bacteria vary significantly by season and create distinct critical conditions, seasonal targets may be required. Less data provide less confidence in bacteria reduction targets, but the rollback method is robust enough to provide general targets for planning implementation measures using smaller data sets. Compliance with the most restrictive of the dual bacteria standard criteria determines the bacteria reduction needed at a stream sampling site.

The rollback method is applied as follows:

> *The geometric mean (approximate median in a log-normal distribution) and 90th percentile statistics are calculated and compared to the FC criteria. If one or both do not meet the criteria, the whole distribution is "rolled-back" to match the more restrictive of the two criteria. The 90th percentile criterion usually is the most restrictive.*

The rolled-back geometric mean or 90th percentile FC value then becomes the recommended *target* FC value for the site. The term *target* is used to distinguish these estimated numbers from the actual water quality criteria. The degree to which the distribution of FC counts is *rolled-back* to the target value represents the estimated percent of FC reduction required to meet the FC water quality criteria and *Primary Contact Recreation* water quality standards.

The targets for bacteria are only in place to assist water quality managers in assessing the progress toward compliance with the bacteria water quality criteria. Compliance is ultimately measured as meeting both parts of the water quality standards criteria. Any water body with FC targets is expected to (1) meet both the applicable geometric mean and “not more than 10% of the samples” criteria, and (2) protect designated uses for the category.

Analysis of Distribution

The Shapiro-Wilk test was used to determine whether FC data were log-normally distributed. The Shapiro-Wilk test is one of the most powerful tests available for detecting departures from a hypothesized normal distribution for data sets less than or equal to 50.

The null-hypothesis of the Shapiro-Wilk Normality Test is that the population is normally distributed. The null hypothesis is rejected if the *p*-value is less than the chosen alpha level (0.05). Because the test is biased by sample size, a Q–Q plot is required for verification in addition to the test.

All data were $\log_{10}$ transformed before test unless otherwise stated.

H_0 = data come from a normal distribution
H_a = data do not come from a normal distribution

Wilcoxon Mann Whitney Test

Ecology used the Wilcoxon Mann Whitney test to determine if there was a significant difference between FC concentrations in dry and wet seasons. The Wilcoxon Mann Whitney is a non-parametric test used to determine if 2 independent samples of observations are drawn from the same distribution. The test uses the relative position of the data in a rank ordering.

- It must be reasonable to regard the data as a random sample from their respective populations.
- Observations within each sample must be independent of one another.
- The 2 samples must be independent of one another.

Data Quality

The QA Project Plan (Kardouni, 2013) for this study describes procedures used to collect and analyze field measurements and water samples. Ecology assessed all data used in this report for quality. Appendix B contains QA information.

Study Results and Discussion

Fecal Coliform Bacteria

Appendix C contains summaries of FC results.

Table 6 shows the geometric means for samples collected during the entire study period. The highest instream FC geometric mean (207 cfu/100 mL) and percentage of samples that exceeded *Primary Contact Recreation* criterion (74%) was at NFCB1.1. This site also had the highest 90^{th} percentile (1263 cfu/100 mL). Ecology collected samples at NFCB1.1 upstream of the 2 stormwater outfalls (NFCB1.1RB and NFCB1.1LB).

NFC0.0 had the second highest geometric mean (126 cfu/100 mL), with 56% of the samples exceeding the *Primary Contact Recreation* criterion.

Ecology collected FC samples from 3 North Fork locations upstream of NFCB1.1 to investigate bacterial sources: NFCB1.4, NFCB1.4W, and NFCB1.7. From September to December 2013, Ecology collected 8 samples at NFCB1.4 and 7 samples at NFCB1.4W. NFCB1.4W, the west branch, exceeded both *Primary Contact Recreation* criteria. NFCB1.4 met the geometric mean criteria (99 cfu/100 mL), but 38% of the samples exceeded the *Primary Contact Recreation* criterion. Ecology investigated another site farther upstream at 112^{th} St. (NFCB1.7). Ecology collected 5 samples from October to December, 2013. The geometric mean met the *Primary Contact Recreation* criterion, but 20% of the samples and the 90^{th} percentile were over 200 cfu/100 mL.

Ecology collected samples from 2 stormwater outfalls, NFCB1.1LB and NFCB1.1RB, whenever they were flowing. Nine samples were collected from the right bank outfall (NFCB1.1RB). Samples collected at the right bank outfall exceeded both *Primary Contact Recreation* criteria. Six samples were collected from the left bank outfall (NFCB1.1LB), all during the wet season. The geometric mean met the *Primary Contact Recreation* criterion. However, 50% of the samples and the 90^{th} percentile for the left bank outfall were over 200 cfu/100 mL.

Table 6. FC (cfu/100mL) data for Clover Creek, North Fork Clover Creek, Spanaway Creek, and Morey Creek.

Station ID	Geometric Mean	90th Percentile	Percent Exceeding 200 cfu/100 mL	Total Number of FC Samples (Wet/Dry Season)
CLO12.0	22	95	4	23 (13/10)
CLO11.0	30	106	0	23 (13/10)
CLO9.8	81	**231**	**13**	23 (13/10)
CLO8.7	61	142	4	23 (13/10)
CLO7.1	**104**	**240**	**17**	23 (13/10)
CLO7.1SC	27	149	6	23 (13/10)
CLO4.6	**120**	**380**	**30**	10 (10/0)
CLO3.5	74	179	9	23 (13/10)
CLO1.9*	82	**412**	**22**	23 (13/10)
CLO1.4	71	**214**	**13**	23 (13/10)
CLO0.4	**117**	**340**	**26**	23 (13/10)
NFCB1.7	52	**216**	**20**	5 (5/0)
NFCB1.4	99	**955**	**38**	8 (6/2)
NFCB1.4W*	**106**	**328**	**71**	7 (5/2)
NFCB1.1	**207**	**1263**	**74**	23 (13/10)
NFCB1.1LB	26	**313**	**50**	6 (6/0)
NFCB1.1RB*	**113**	**880**	**44**	9 (6/3)
NFCB0.0	93	**302**	**14**	22 (13/9)
NFC1.0	73	**480**	**13**	16 (13/3)
NFC0.0	**126**	**564**	**38**	16 (12/4)
SPA1.8	18	102	4	23 (13/10)
SPA1.4	36	142	0	23 (13/10)
SPA0.5	50	161	9	23 (13/10)
MOR0.9	22	107	5	23 (13/10)
MOR0.1*	17	107	4	21 (11/10)

*Distribution is not normally distributed based on Shapiro-Wilk Normality Test.

The Shapiro-Wilk test was used to determine whether FC data were log-normally distributed. The FC data were not normally distributed at sites where H_0 was rejected: CLO1.9, MOR0.1, NFCB1.1RB, and NFCB1.4W. The first 2 sites, CLO1.9 and MOR0.1, had more extreme values than expected, which skewed their distributions. The 2 North Fork sites, NFCB1.4W and NFCB1.1RB, had less samples (only 7 and 9 samples, respectively). Skewed distributions and fewer data provide less confidence in bacteria reduction targets, but the Statistical Rollback Method is robust enough to provide general targets for planning implementation measures. See Q-Q plots of each site for visual display in Appendix C.

Figure 8 shows the stream segments that exceeded the *Primary Contact Recreation* geometric mean criteria in the study area.

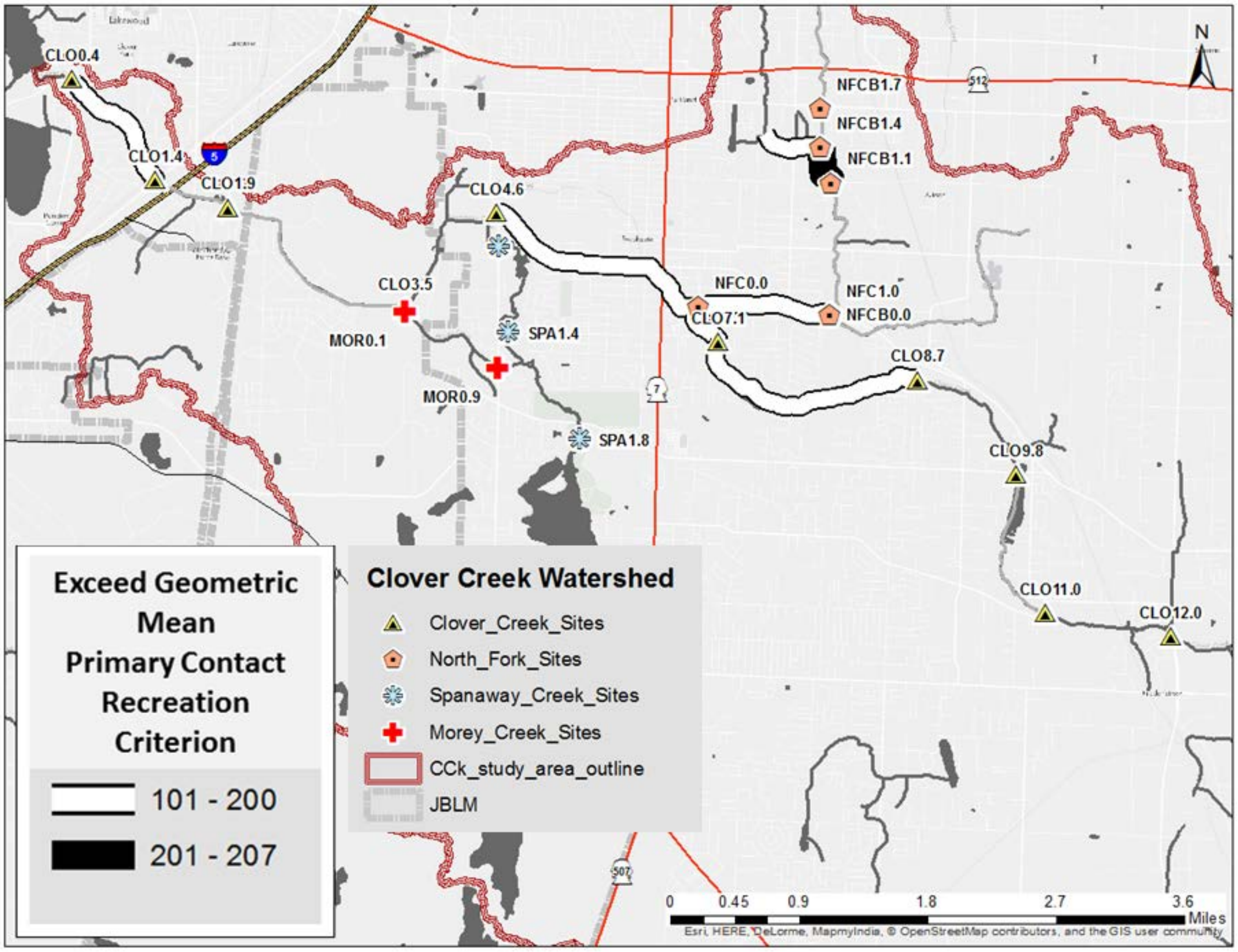


Figure 8. Stream segments that exceeded the *Primary Contact Recreation* geometric mean criteria in the watershed.

Figure 9 shows the stream segments with over 10% of samples that exceeded the *Primary Contact Recreation* criteria.

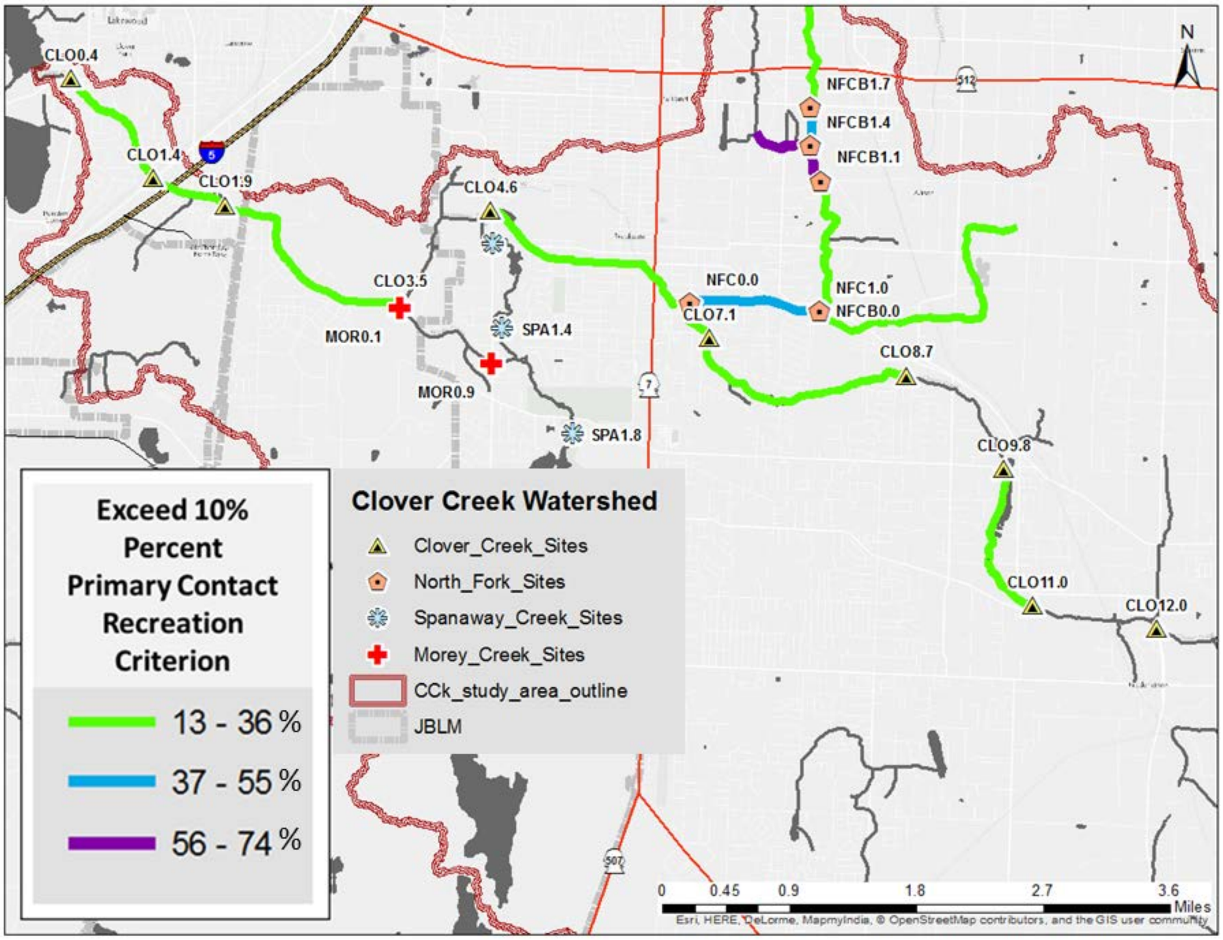


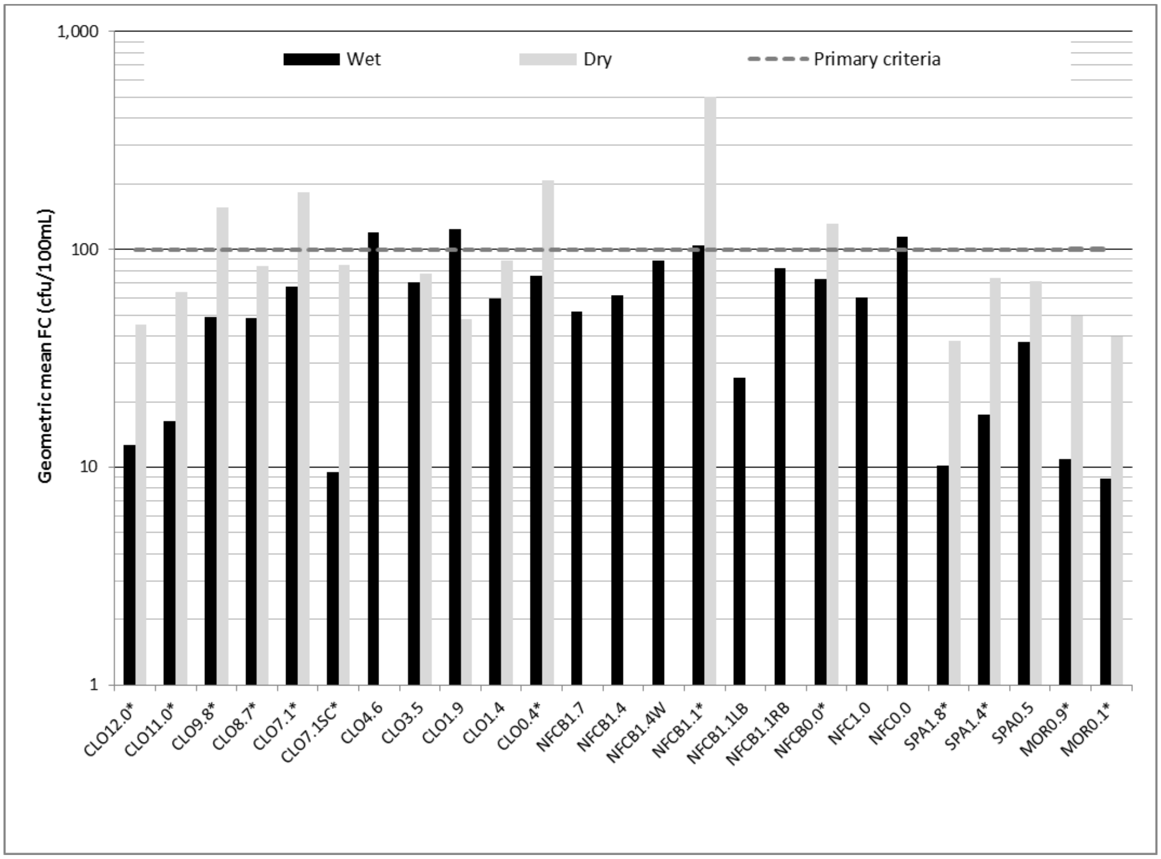
Figure 9. Stream segments where over 10% of samples exceeded the *Primary Contact Recreation* criteria.

Three Clover Creek sites, CLO4.6, CLO0.4, and CLO7.1, exceeded both *Primary Contact Recreation* criteria. CLO4.6 did not flow during 60% of the study period, so Ecology collected only 10 samples during the wet season.

The other 8 Clover Creek sampling locations listed in Table 6 met the *Primary Contact Recreation* geometric mean criterion. However, over 10% of samples collected at 3 sites (CLO9.8, CLO1.9, and CLO1.4) exceeded 200 cfu/100 mL.

Ten sites met both *Primary Contact Recreation* criteria. At these 10 sites, the geometric mean was 81 cfu/100 mL or less during the study period. The 10 sites include: CLO12.0, CLO11.0, CLO8.7, CLO3.5, all 3 Spanaway Creek sites, both Morey Creek sites, and the side channel CLO7.1SC. The left bank outfall to North Fork at 121st St (NFCB1.1LB) met the geometric mean criterion. Only 6 samples were collected at this outfall. Of these, 50% exceeded the *Primary Contact Recreation* criterion.

Figure 10 shows the geometric mean for each study site during the wet and dry seasons.



* significant difference between the seasons

Figure 10. Wet and dry season geometric means for the study sites.

Figures 11 and 12 display the FC distribution for study sites compared to the *Primary Contact Recreation* geometric mean criteria.

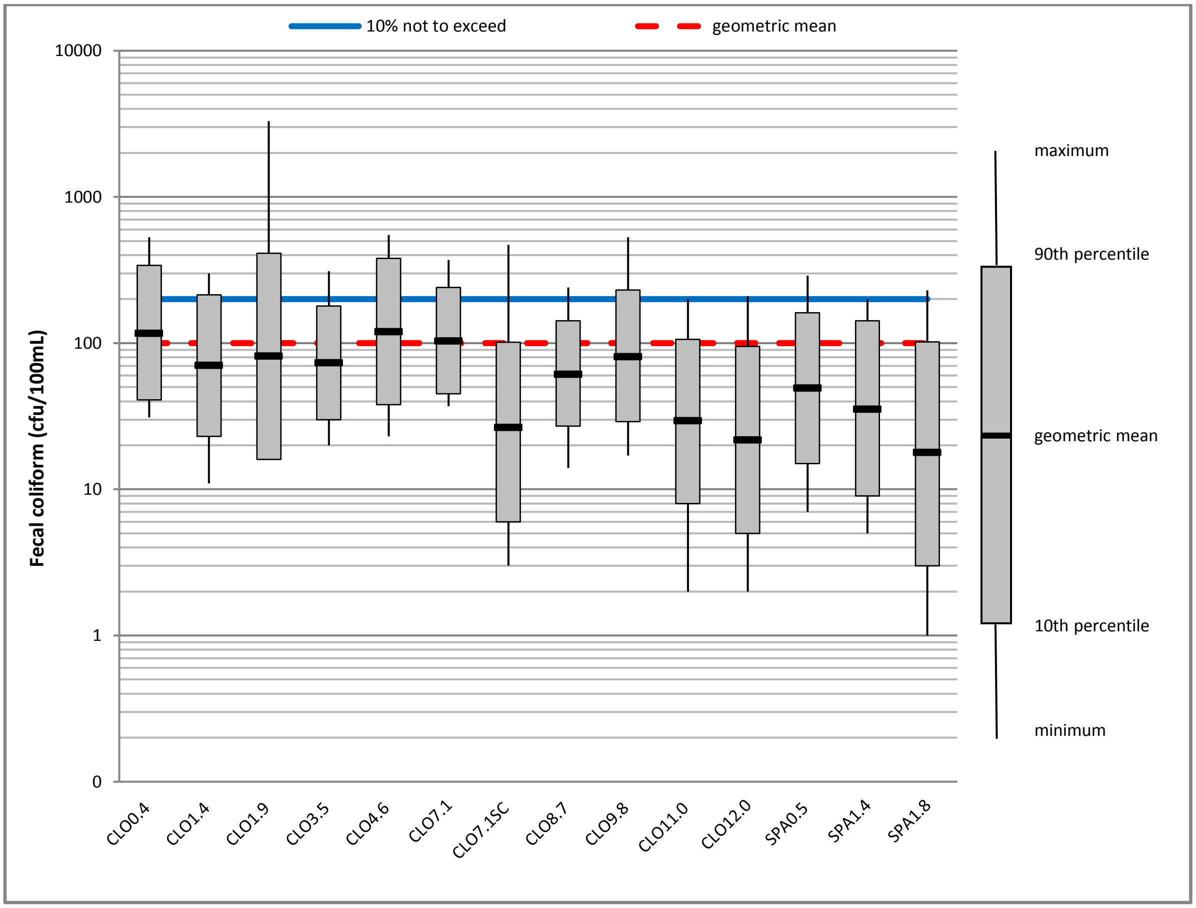


Figure 11. FC distributions for Clover Creek and Spanaway Creek sites compared to the *Primary Contact Recreation* criteria.

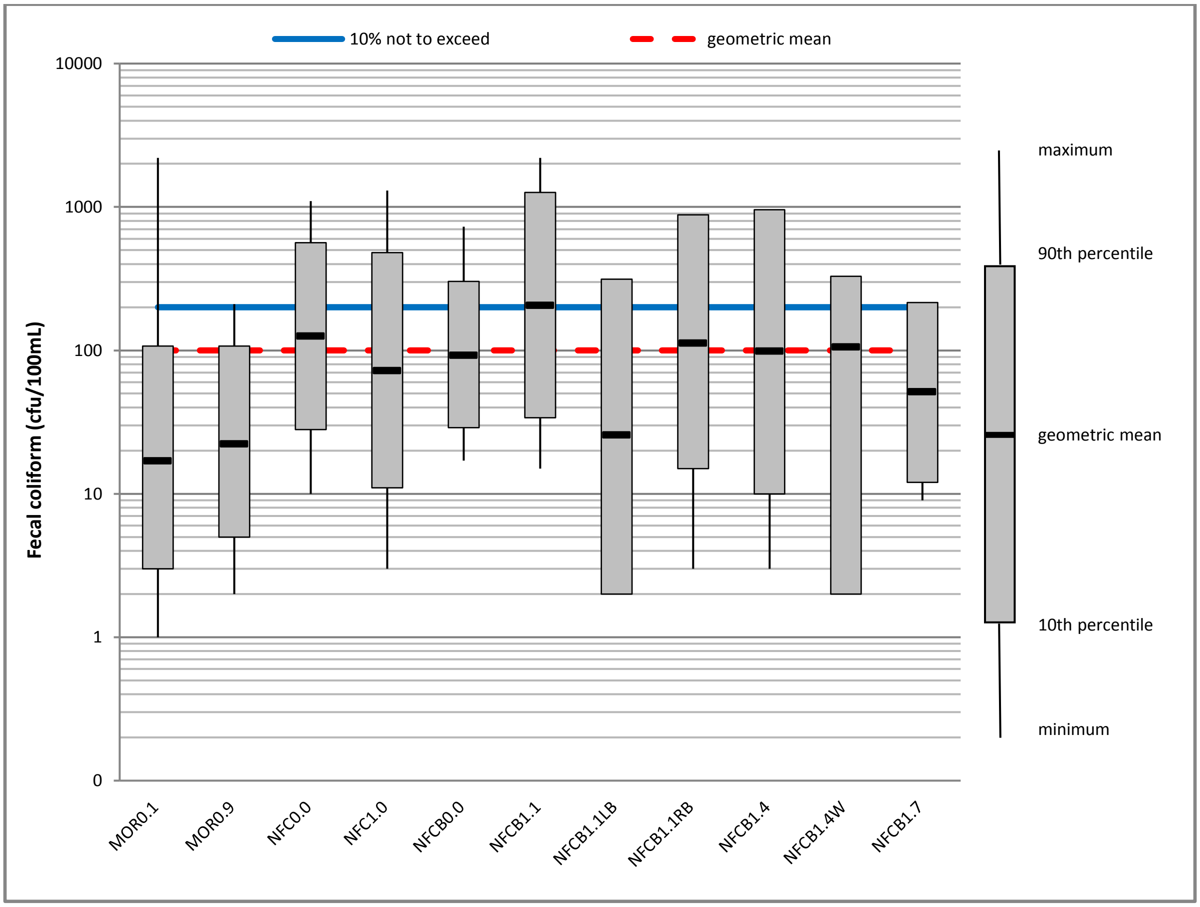


Figure 12. FC distributions for the Morey Creek and North Fork Clover Creek sites compared to the *Primary Contact Recreation* criteria.

Figure 13 shows the seasonal loading of bacteria in the watershed. All wet and dry season and annual loads shown in Figure 13 exceeded one or both parts of the *Primary Contact Recreation,* except MOR0.1, CLO3.5, and CLO12.0. The dry season load was significantly higher than the wet season load upstream of CLO9.8 and CLO7.1. Load is the mass of a substance that passes a particular stream location, in this case a monitoring site, in a specified amount of time (e.g., annually). The units used in this report are 1 billion cfu/day. However, the size of the loads at these 2 sites was very different. The load upstream of CLO9.8 was 43 billion cfu/day, compared to 5 billion cfu/day upstream of CLO7.1. The discharge at CLO9.8 was higher. Mathematically, load is essentially the product of the discharge and the concentration.

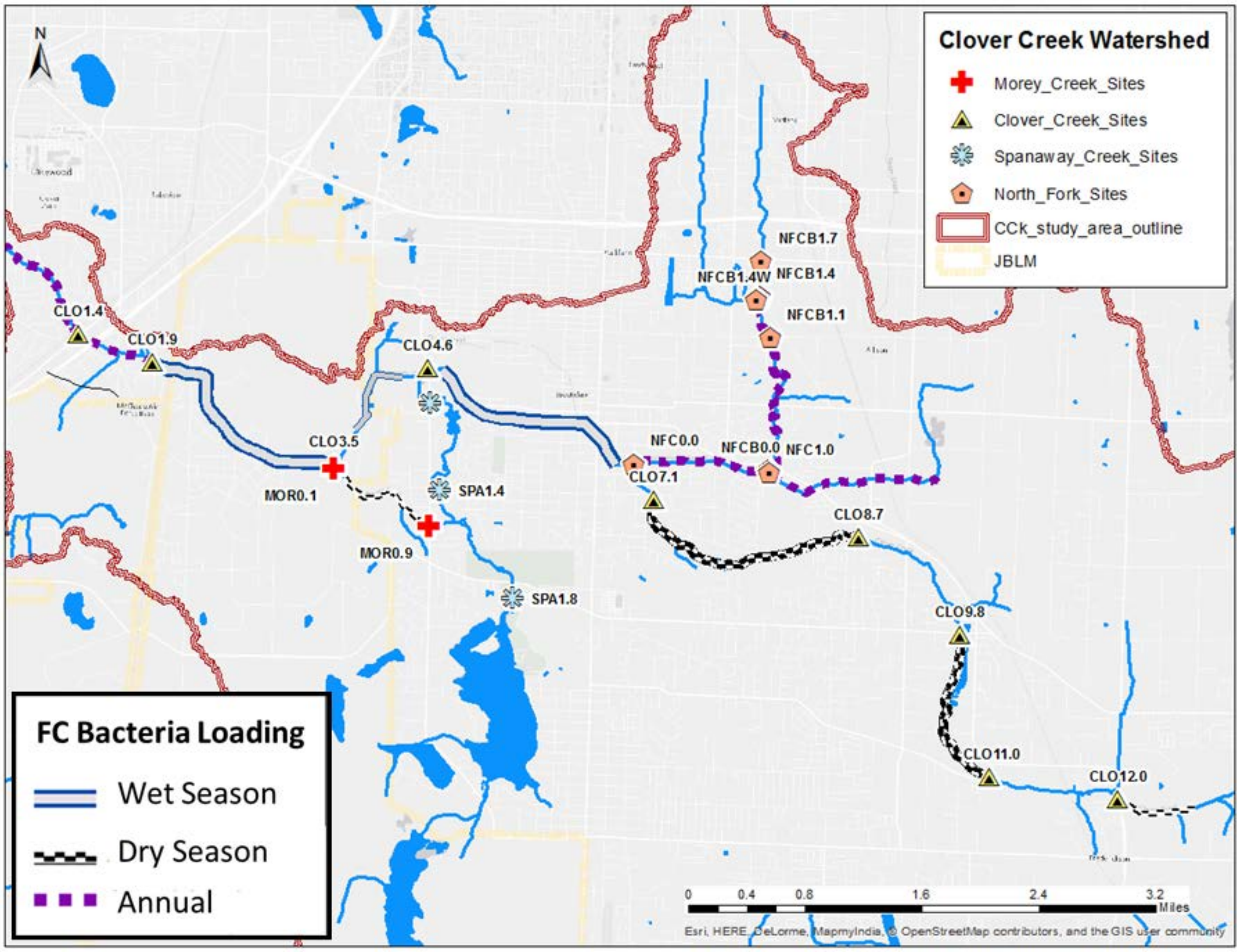
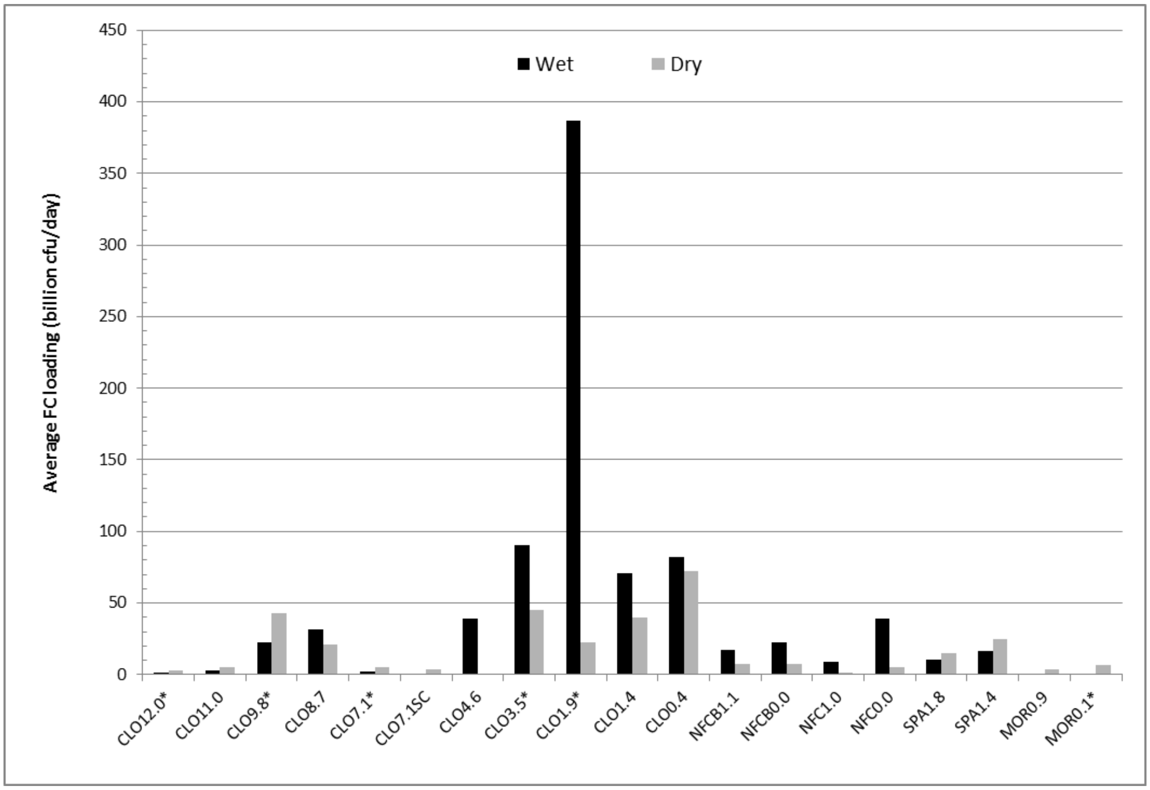


Figure 13. Map of FC loading in the study area.

Figure 14 shows that the wet season load was significantly higher than the dry season load upstream of CLO1.9. This load (387 billion cfu/day) was the highest wet season load of all study sites.



* significant difference between the season

Figure 14. Seasonal average FC loading (billion cfu/day) at study sites.

There was no significant difference between the wet and dry season loads at the 7 other sites that exceeded one or both *Primary Contact Recreation* criteria. The highest annual load of these 7 sites was 78 billion cfu/day at CLO0.4 (Table 7). Both CLO4.6 and NFC0.0 flowed intermittently during the study period. No dry season samples were collected at CLO4.6. Four dry season samples were collected at NFC0.0. Ecology did not collect sufficient bacteria and flow data at other sites to determine loads.

Table 7. Average FC loading (1 billion cfu/day).

Station ID	Average FC loading (billion cfu/day)		
	Annual	Wet	Dry
CLO12.0*	2	2	**3**
CLO11.0	4	3	5
CLO9.8*	31	23	**43**
CLO8.7	27	31	21
CLO7.1*	3	2	**5**
CLO7.1SC	2	1	3
CLO4.6	39	39	0
CLO3.5*	70	**90**	45
CLO1.9*	229	**387**	23
CLO1.4	57	71	40
CLO0.4	78	82	72
NFCB1.1	13	17	7
NFCB0.0	16	22	7
NFC1.0	6	9	2
NFC0.0	24	39	5
SPA1.8	13	11	15
SPA1.4	20	17	25
MOR0.9	2	1	4
MOR0.1*	3	0	**7**

***Difference between the seasons determined to be statistically significant.**
Light grey highlighted sites had more than 10% of samples exceed 200 cfu/100 mL.
Dark grey highlighted sites exceed both *Primary Contact Recreation* criteria.

Storm Sampling Event

One storm sampling event was captured on June 24, 2013. Ecology collected FC samples from fixed-network sites and one stormwater outfall (NFCB1.1RB). The samples collected in the stream at fixed-network sites illustrate how FC concentrations changed in the stream after a summer storm event. Unfortunately, the FC concentrations cannot be tied directly to any specific stormwater outfall, except NFCB1.1RB.

A total of 0.67 inches of precipitation fell from June 23 through June 24, starting and ending at 5:00 AM. An additional 0.23 inches of precipitation occurred over the course of sampling. There was no precipitation during the 48-hour antecedent period (McChord Airfield weather station ID KTCM). Figures 15 and 16 provide USGS hydrographs of Clover Creek and the North Fork, respectively, over the course of storm sampling.

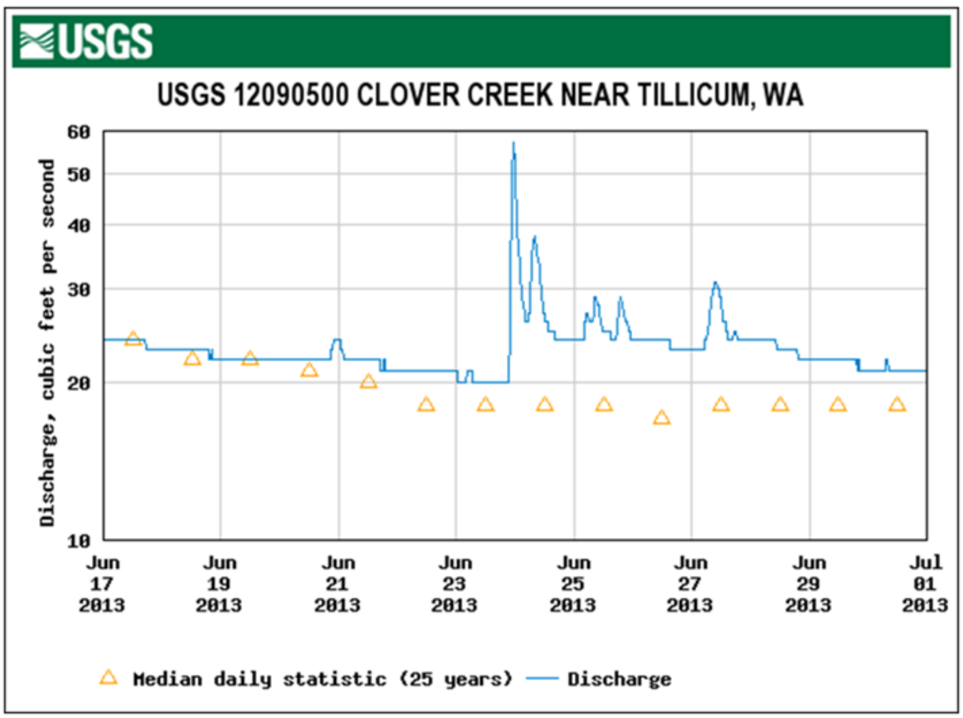


Figure 15. USGS discharge (cfs) data at Clover Creek at Pacific Highway during the June 24, 2013 storm sampling event.

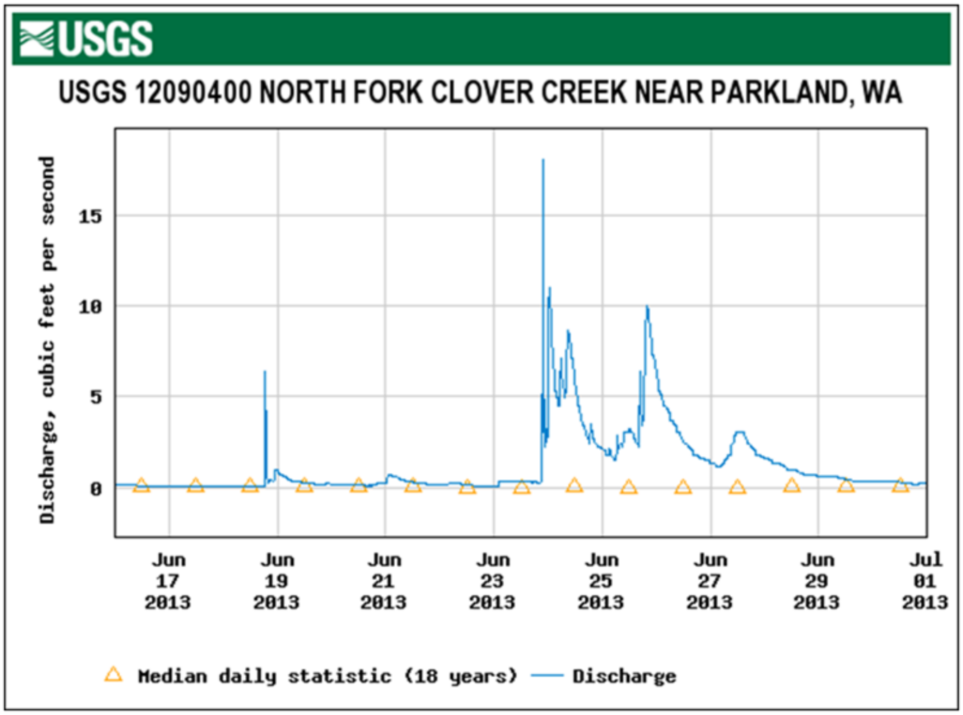


Figure 16. USGS discharge (cfs) data at North Fork Clover Creek at Golden Given Road during the June 24, 2013 storm sampling event.

Two hydrological peaks were observed from late hours of June 23 through the early hours of June 24. The first peak was slightly greater than the second peak. The first peak on the mainstem occurred on June 23 at 2315 hours with a discharge value of 57 ft^3/s, and the second peak occurred on June 24 at 0745 hours with a discharge value of 38 ft^3/s. The first peak on the North Fork occurred on June 24 at 0045 hours with a discharge value of 18 ft^3/s, and the second peak occurred on June 24 at 0900 hours with a discharge value of 8.6 ft^3/s.

Ecology staff observed stormwater in the system during sample collection. The storm event met the requirement in the QA Project Plan that at least 0.3 inches fell in the preceding 24 hours. Staff noted that:

- Stream discharge preceding the event was less than the stream discharge during the storm event.
- Sampling occurred at or near a hydrological peak, with little lag time.
- 0.9 inches of precipitation was observed within a 24-hour period and over the course of storm sampling.

However, after examining the hydrograph, it appears that storm sampling occurred during the second peak on its receding limb. Therefore the initial pulse of stormwater runoff from the first hydrographic peak may have not been captured while sampling. In fact, Ecology could not collect samples at 2 sites, the left bank stormwater outfall on 121st St (NFCB1.1LB) and Clover Creek at Spanaway Loop Rd S (CLO4.6) due to the lack of flow.

Elevated FC concentrations were observed at all sampling locations, particularly at the North Fork sites. Sixteen out of 20 sampling locations (80%) exceeded the *Primary Contact Recreation* criterion (200 cfu/100 mL) for a single sample.

Table 8 and Figure 17 show the FC results from the storm sampling event.

Table 8. FC geometric mean (cfu/100mL) results from June 13, 2013 storm event.

Site ID	FC (cfu/100mL)
CLO0.4	**490**
CLO1.4	**470**
CLO1.9	**440**
CLO3.5	**590**
CLO4.6	dry
CLO7.1	**510**
CLO7.1SC	120
CLO8.7	**440**
CLO9.8	**250**
CLO11.0	150
CLO12.0	92
MOR0.1	**310**
MOR0.9	**220**
NFC0.0	**1800**
NFC1.0	**210**
NFCB0.0	**1600**
NFCB1.1	**1300**
NFCB1.1LB	dry
NFCB1.1RB	**2900**
SPA0.5	**250**
SPA1.4	190
SPA1.8	**220**

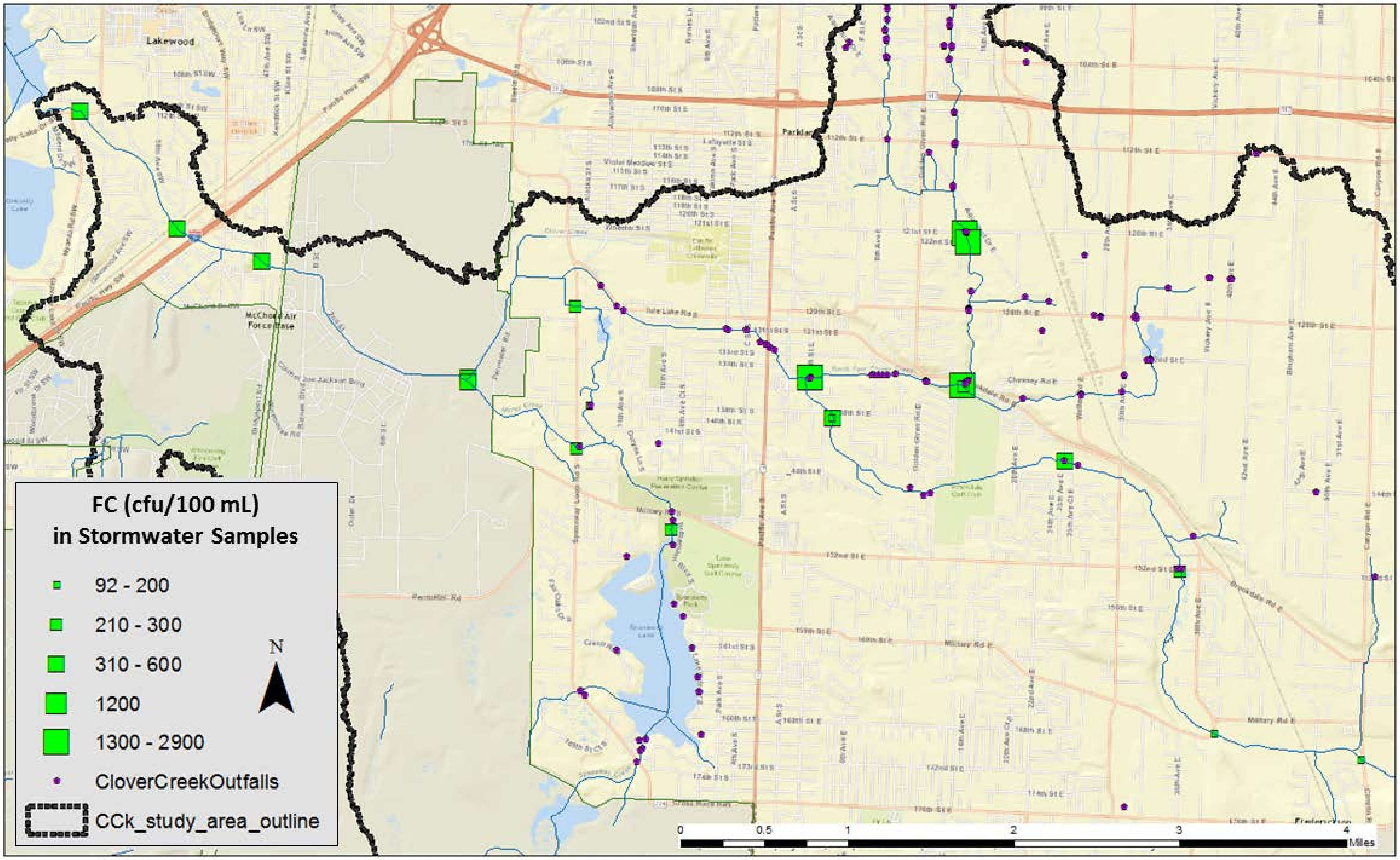


Figure 17. Range of FC concentrations at locations where stormwater samples were collected.

Hydrology

Ecology measured instantaneous stream discharge bi-weekly at the study sites from March 2013 to February 2014. Appendix A contains site specific information. Discharge data are located in Appendix D.

Clover Creek

Clover Creek gained mean streamflow from CLO12.0 to CLO8.7. Figure 18 shows that loss of mean streamflow began in the reach between CLO8.7 and CLO7.1. The loss of mean flow continued downstream to CLO4.6.

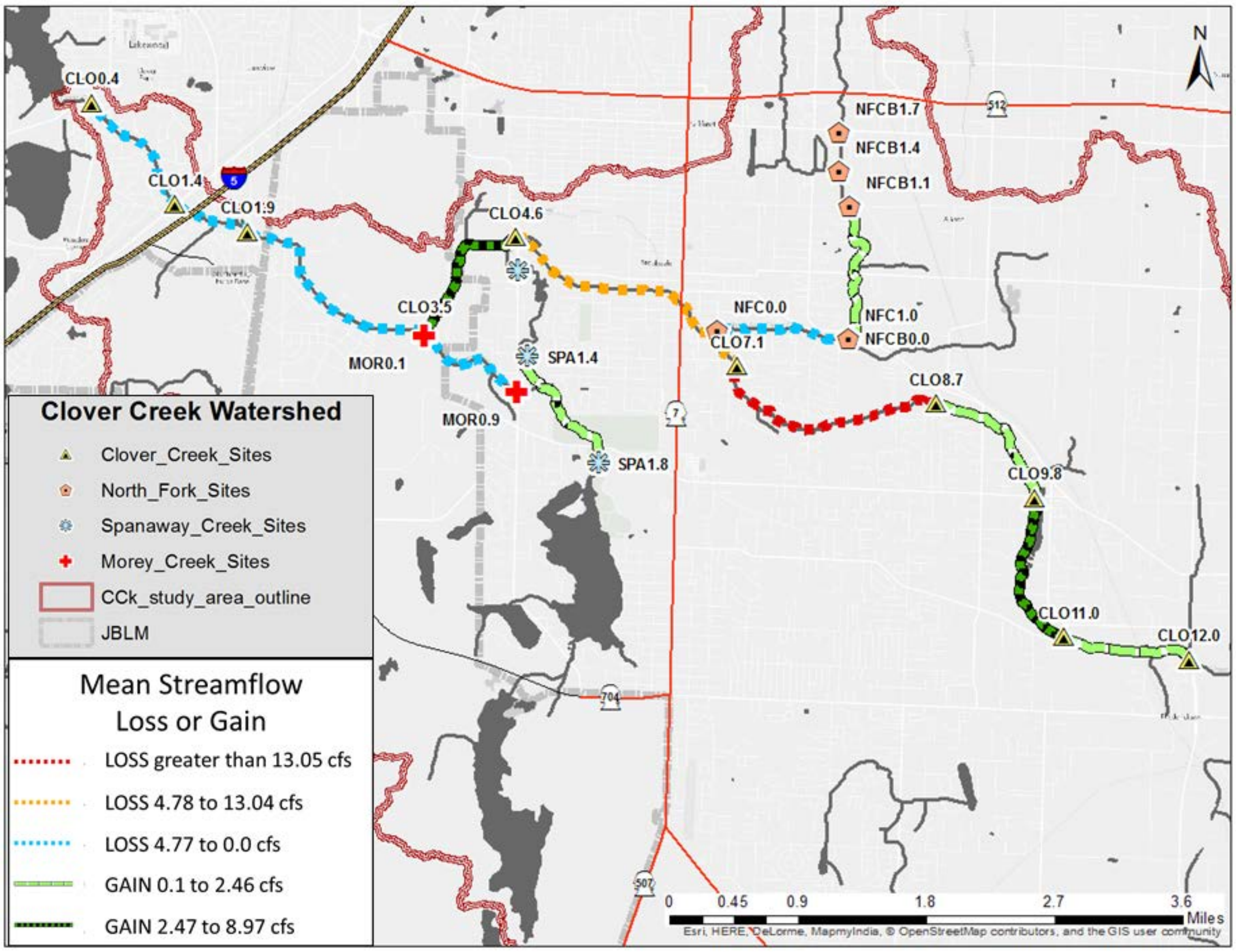


Figure 18. Mean loss or gain of streamflow (cfs) in the study area.

Clover Creek did not flow at CLO4.6 from May to November on sample days. Clover Creek gained streamflow in the reach between CLO4.6 and CLO3.5. Spanaway Creek, which discharges into Clover Creek in this reach, contributed over half the flow downstream to CLO3.5.

Clover Creek lost flow in the reach between CLO3.5 and CLO1.9 during mean and minimum flows. This reach is where the stream crosses JBLM.

Loss of flow continued downstream. In the reach between CLO1.9 to CLO1.4, the loss was less than 1 cfs, except at maximum flows when the loss was 6 cfs.

In the reach from CLO1.4 to CLO0.4, the mean and minimum loss was less than 1.5 cfs. There was no loss or gain during maximum flow.

Figure 19 summarizes the discharge statistics for Clover Creek sites.

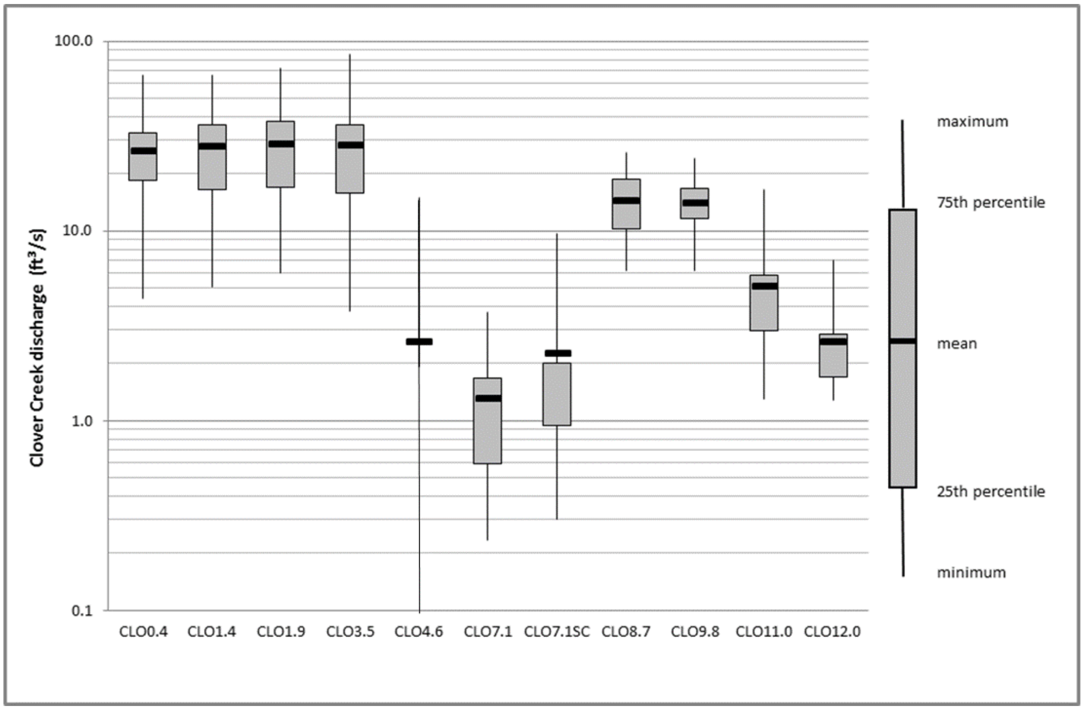


Figure 19. Distribution of instantaneous stream discharge (ft³/s) at Clover Creek sites.

Tributaries to Clover Creek

Tributaries to Clover Creek include North Fork Clover Creek, Spanaway Creek, and Morey Creek.

North Fork Clover Creek

Figure 20 shows that mean surface flow increased in the northern branch from NFCB1.1 to NFCB0.0.

Downstream of NFCB0.0 is the confluence with the eastern branch (NFC1.0). The eastern branch contributed a little over 2 cfs to the mean flow, but it was dry from June until September.

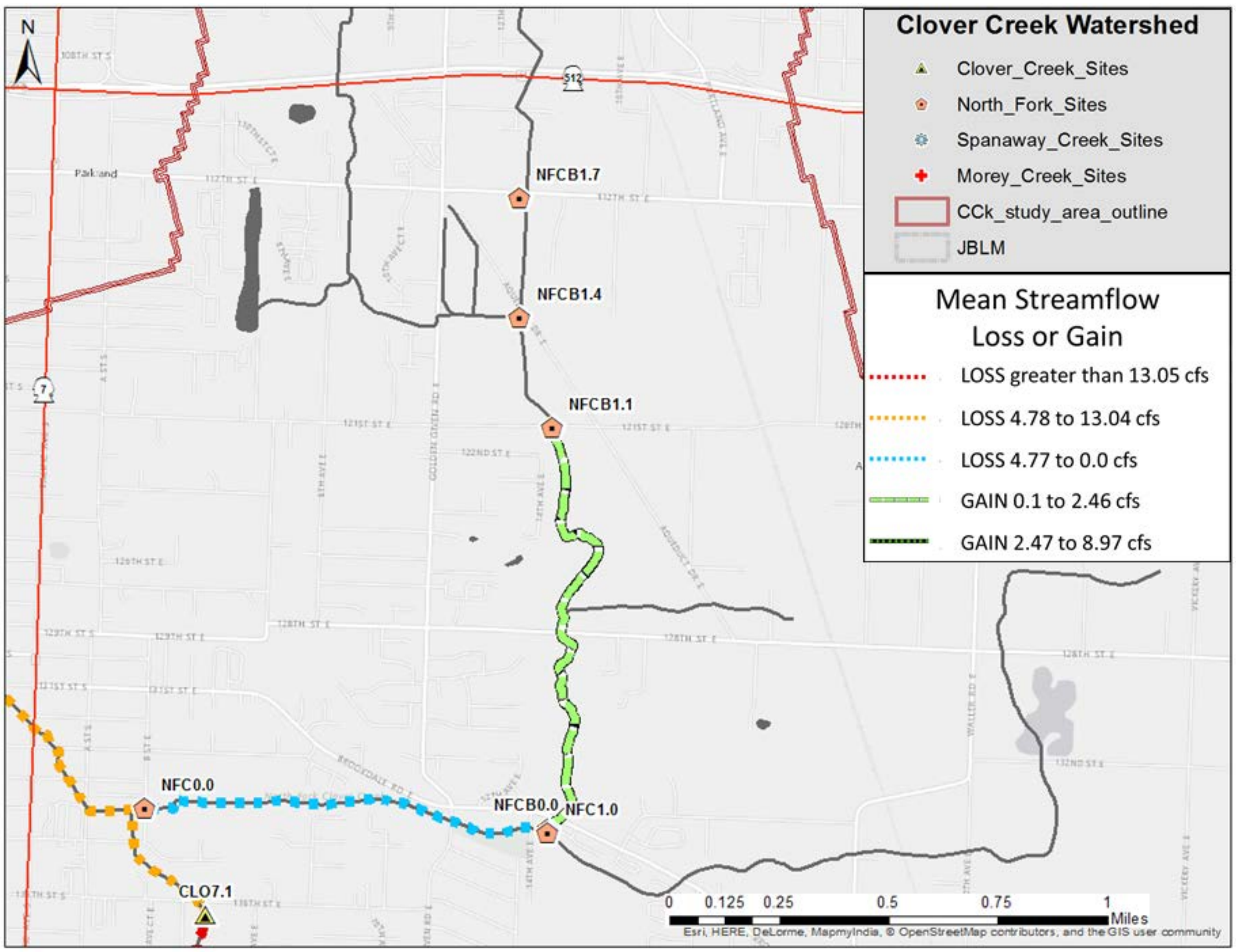


Figure 20. Mean loss or gain of streamflow (cfs) at North Fork Clover Creek sites.

The North Fork lost streamflow below the 2 branches. Flow was lost in the reach upstream of NFC0.0 for both the mean and maximum flows.

Spanaway Creek and Morey Creek

Figure 21 shows that Spanaway Creek gained mean flow in the reach between SPA1.8 and SPA1.4. Morey Creek lost flow in the reach from MOR0.9 to MOR0.1.

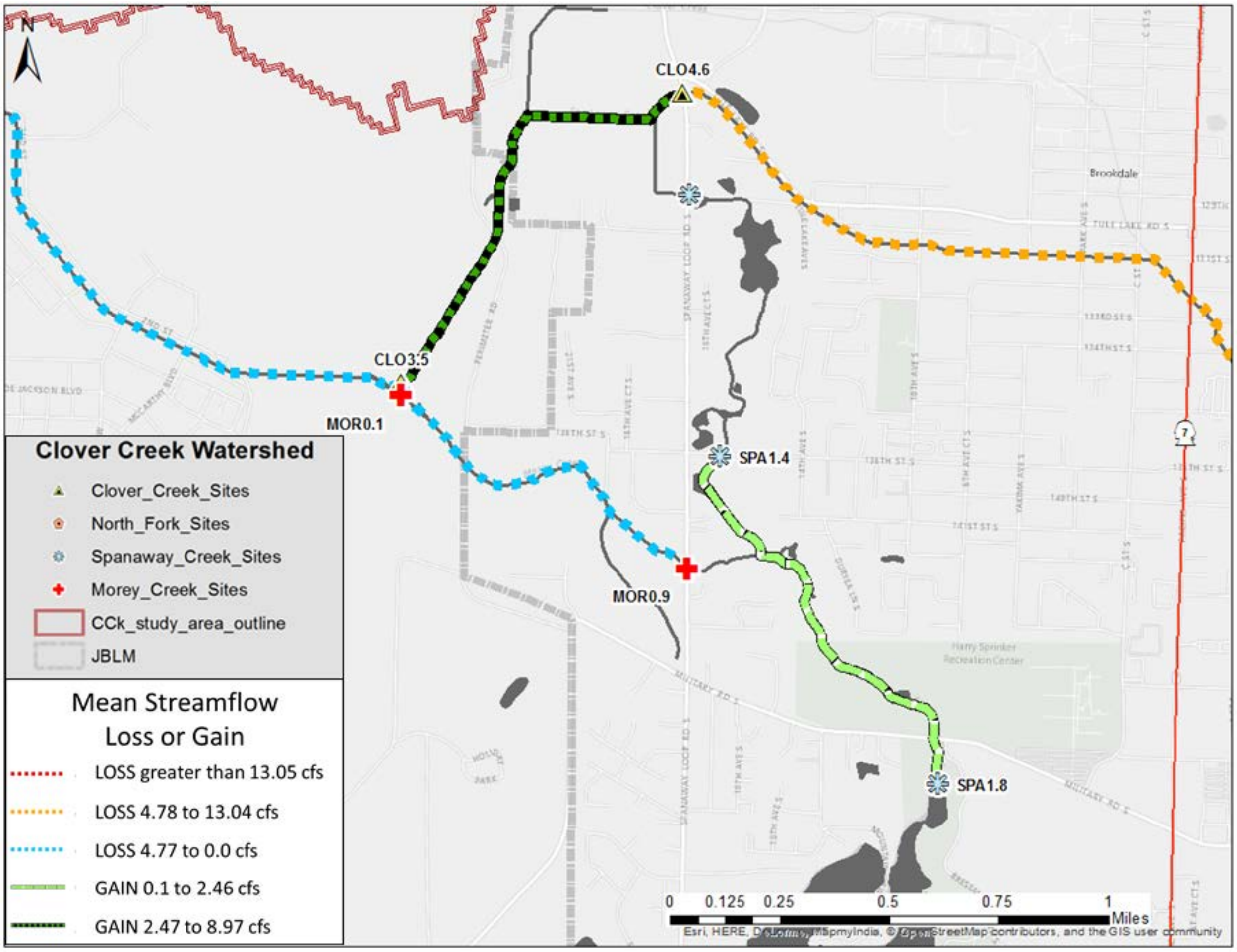


Figure 21. Mean loss or gain of streamflow (cfs) for Spanaway Creek and Morey Creek sites.

Figure 22 shows the distribution of instantaneous stream discharge (cfs) for the tributaries to Clover Creek.

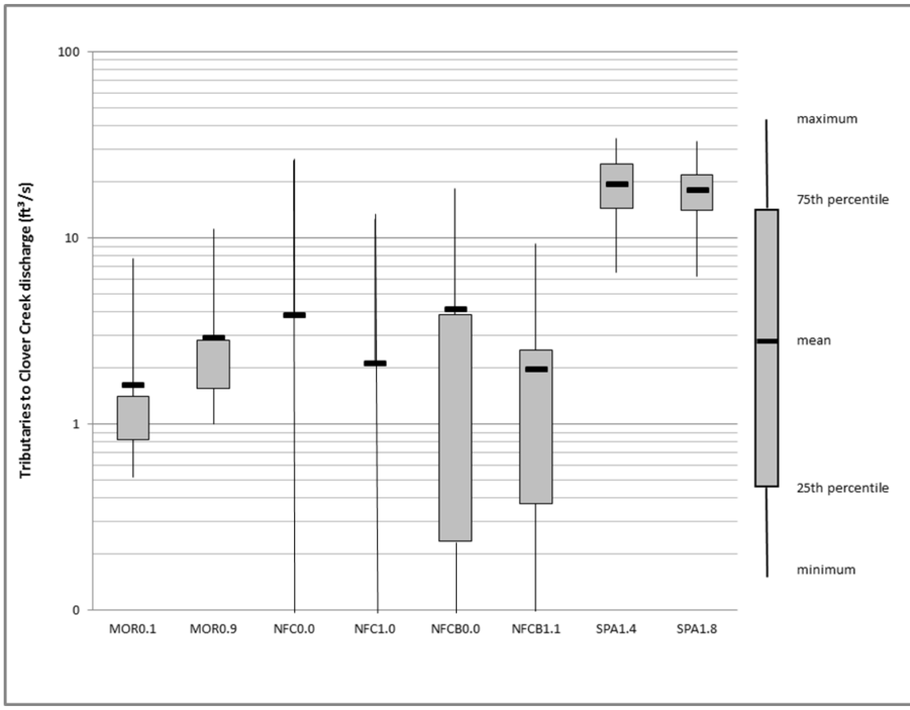


Figure 22. Distribution of instantaneous stream discharge (cfs) for the tributaries to Clover Creek.

Temperature Data

Ecology deployed temperature data loggers (thermistors) at 17 sampling locations where there was streamflow from May to September 2013. Staff downloaded loggers approximately every 4 weeks. Ecology recovered all thermistors in late September. Thermographs were developed for selected locations (Appendix E).

Clover Creek

The temperature of Clover Creek increased from upstream (CLO12.0) to downstream (CLO0.4). Only the upstream site (CLO12.0) met the temperature criterion throughout the deployment period. All other sites exceeded the 7-day average of the daily maximum temperatures (7-DADMax) water quality criterion of 17.5º C (Tables 9 and 10).

Table 9. Seven-day average of daily maximum temperatures (°C) for Clover Creek sites upstream of the confluence with the North Fork Clover Creek.

Site ID	Date	7-DADMax
CLO12	9/9/13	12.7
CLO11	7/1/13	19.0
CLO9.8	7/1/13 and 8/7/13	19.8
CLO8.7	7/1/13	20.6
CLO7.1	7/1/13	20.2
CLO7.1SC	7/1/13	24.0

The 7-DADMax water temperature increased over 6°C in one river mile from CLO12.0 to CLO11.0. No significant change in riparian cover was observed. Additional flow and temperature data are needed to determine why temperature increased in this reach.

The temperature of Clover Creek continued to increase going downstream from CLO11.0 to CLO7.1 (7-DADMax from 19.0 to 20.2°C). The 7-DADMax temperature exceeded 17.5°C for 12 days during June and July at CLO11.0. Temperature was exceeded more often in the reach downstream from CLO9.8 to CLO7.1. The 7-DADMax temperature exceeded the criterion for 60 to 70 days from June to September. The highest Clover Creek 7-DADMax temperature (24.0°C) was measured at the side channel CLO7.1SC, where the 7-DADMax temperature exceeded 17.5°C for over 90 days from June to September.

Table 10. Seven-day average of daily maximum temperatures (°C) for Clover Creek sites downstream of Spanaway Creek.

Site ID	Date	7-DADMax
CLO3.5	7/1/13	20.2
CLO1.9	7/1/13	19.4
CLO1.4	7/1/13	19.6
CLO0.4	7/1/13	20.2

Downstream of Spanaway Creek, 7-DADMax temperature exceeded the criterion at 3 Clover Creek sites for over 30 days during the summer (CLO3.5, CLO1.9, and CLO1.4). The farthest downstream site, CLO0.4 exceeded 17.5ºC for over 60 days.

Tributaries to Clover Creek

North Fork Clover Creek

The North Fork exceeded the 7-DADMax of 17.5ºC (Table 11). Ecology observed that the North Fork became dry/sub-surface by mid-July (these data were not included in the thermographs). The 7-DADMax temperature exceeded 17.5ºC for 90 days at NFCB1.1 from June until September. NFCB0.0 and NFC0.0 did not flow the entire period, but 7-DADMax temperature exceeded 17.5ºC for over 20 days from mid-June until July.

Table 11. Seven-day average of daily maximum temperatures (°C) for sites on the North Fork Clover Creek.

Site ID	Date	7-DADMax
NFCB1.1	7/1/13	22.5
NFCB0.0	7/27/13	24.7
NFC0.0	6/28/13	26.3

Spanaway Creek

All 3 Spanaway Creek monitoring sites exceeded the 7-DADMax of 17.5ºC (Table 12). The 7-DADMax temperature exceeded 17.5ºC for over 90 days at all 3 sites.

Table 12. Seven-day average of daily maximum temperatures (°C) for Spanaway Creek.

Site ID	Date	7-DADMax
SPA1.8	7/1/13 and 7/3/13	25.3
SPA1.4	7/1/13	22.6
SPA0.5	7/1/13	25.4

Morey Creek

Both Morey Creek monitoring sites exceeded the 7-DADMax of 17.5ºC (Table 13). The 7-DADMax temperature exceeded 17.5ºC for over 90 days at both sites.

Table 13. Seven-day average of daily maximum temperatures (°C) for Morey Creek.

Site ID	Date	7-DADMax
MOR0.9	7/1/13	22.5
MOR0.1	7/1/13	24.8

Temperature measurement data collected during site visits are given in Appendix E.

Riparian Assessment

Percent Effective Shade and Canopy Cover

Figures 23 and 24 summarize percent average effective shade and canopy cover for 18 monitoring sites in the Clover Creek watershed.

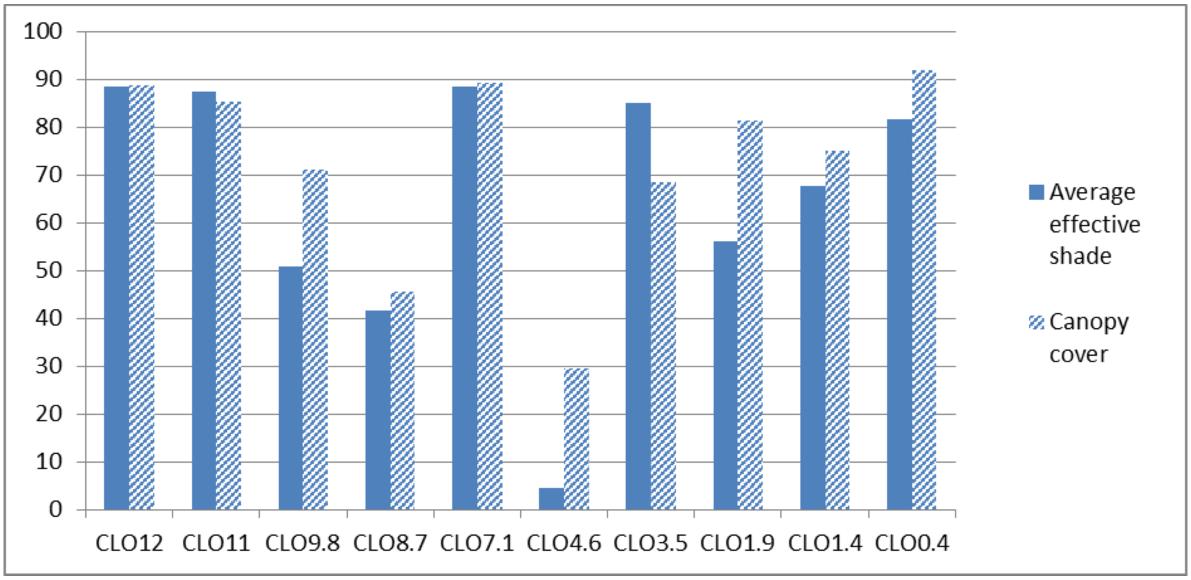


Figure 23. Percent average effective shade and percent canopy cover for Clover Creek.

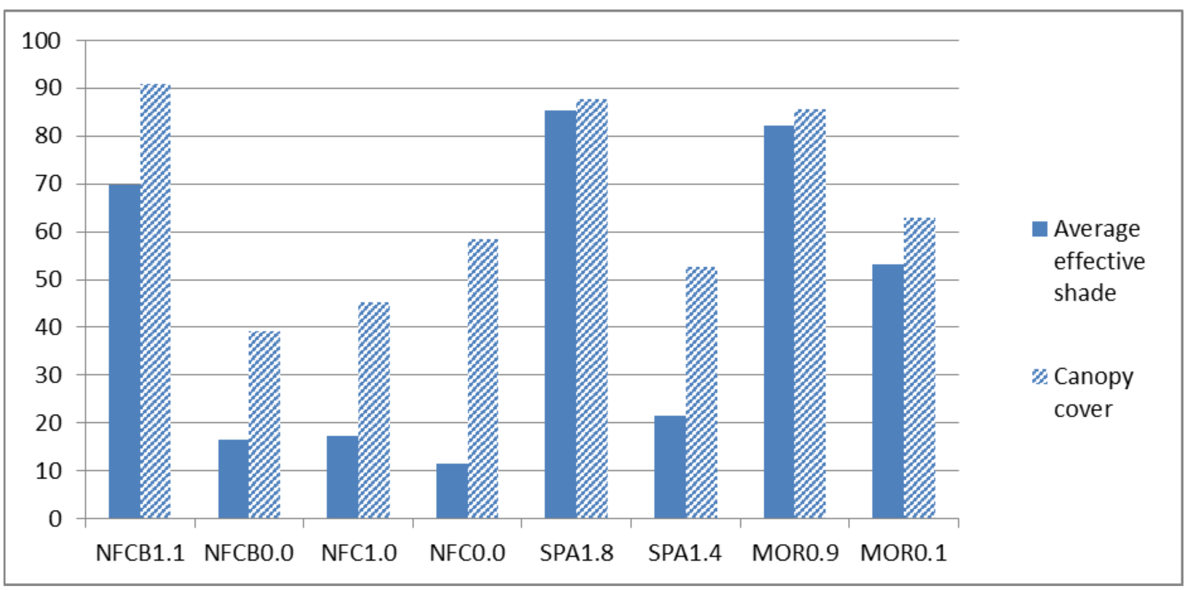


Figure 24. Percent average effective shade and percent canopy cover for North Fork Clover Creek and Spanaway Creek.

The following Clover Creek sites had the highest effective shade: CLO12.0, CLO11.0, CLO7.1, CLO3.5, and CLO0.4. CLO4.6 had the lowest effective shade.

For the tributaries, NFCB1.1, SPA1.8, and MOR0.9 had the highest effective shade.

Additional Riparian Canopy Assessment

Digital photos were taken at each fixed-network site using both the HemiView© and SunEye™ methods.

The Solmetric SunEye™ is a handheld unit with integrated 360° camera lens (fish-eye lens). Its processing software can determine annual, seasonal, monthly, and quarter-hourly shading percentages (Solmetric Corporation, 2010).

Both methods can assess and report effective shade. Effective shade was expressed as a shading percentage (percent effective shade) for the months of June, July, August, and September. Ecology compared the 2 methods using the monthly percent effective shade (Kardouni, 2013).

Precision is a measure of the variability in the results of replicate measurements due to random error (Lombard and Kirchmer, 2004). Comparing the precision of the SunEye™ method to the HemiView© method, the average RPD is 43.3% and the average RSD is 30.6%.

Bias is the difference between the population mean and the true value. Comparing the SunEye™ method to the HemiView© method, the SunEye™ method was biased low (32.1% RPD).

See Appendix F for additional riparian data.

Diurnal Surveys for Dissolved Oxygen

August 2013 Survey

The DO criterion for Clover and Spanaway Creeks is 8.0 mg/L. The following 4 sites fell below the daily minimum DO water quality criterion: CLO9.8, CLO7.1, CLO3.5, and SPA1.8. Two sites on Clover Creek met the water quality criterion: the farthest upstream site (CLO12.0) and the farthest downstream site (CLO0.4). CLO3.5 was at least 2 mg/L below the water quality criterion over the course of the diurnal survey. The diurnal fluctuation was most pronounced at SPA1.8, CLO9.8, and CLO3.5.

Figure 25 shows DO concentrations from the diurnal survey conducted from August 26 – 29.

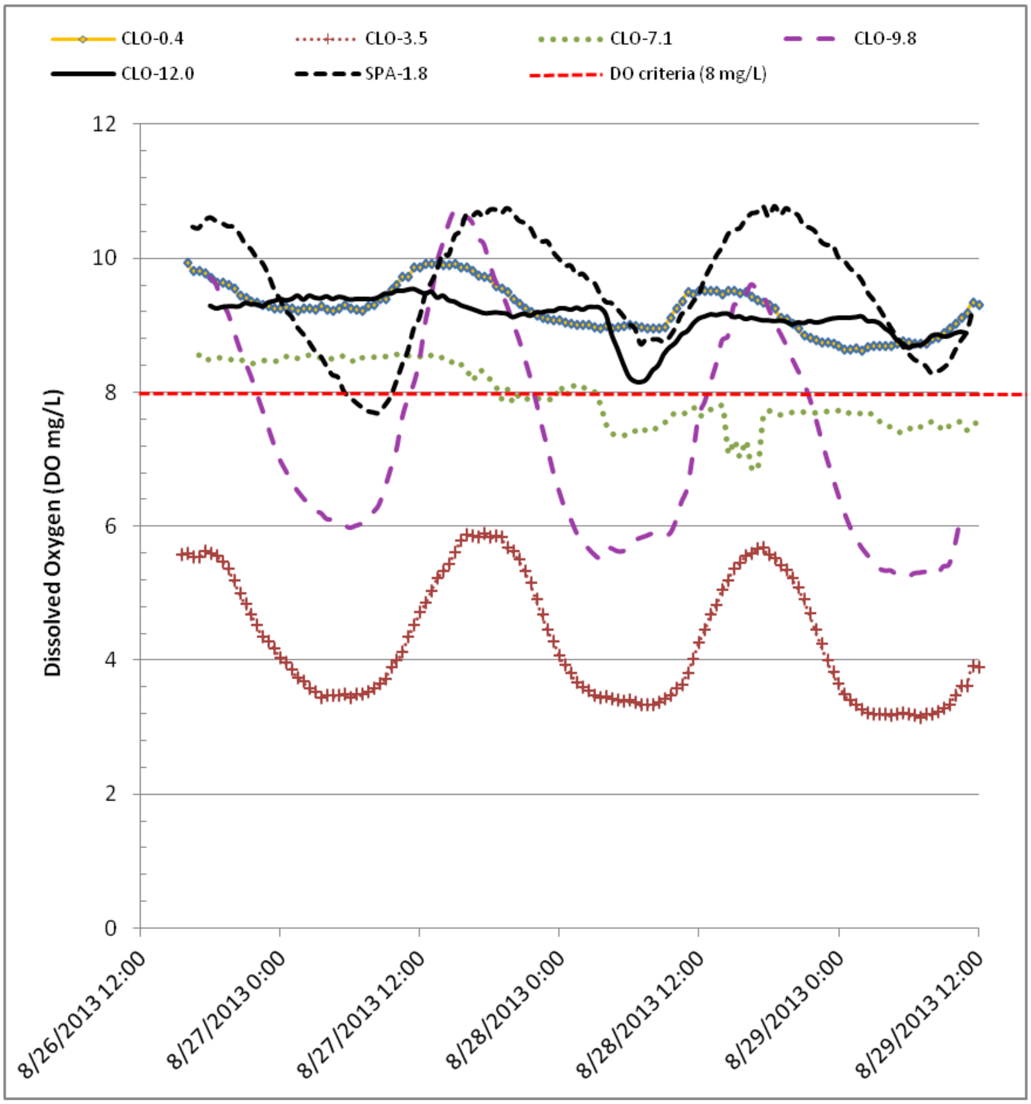


Figure 25. August 26 through 29, 2013 time series dissolved oxygen in the Clover Creek watershed.

December 2013 Survey

Ecology deployed 7 multi-probes logging temperature, conductivity, pH, and DO at half-hour intervals from December 16 through 19 at the following locations:

- CLO0.4
- CLO3.5
- CLO7.1
- CLO9.8
- CLO12.0
- NFC0.0
- SPA1.8

Figure 26 shows DO concentrations from the diurnal survey. The DO criterion is 8.0 mg/L. All monitoring locations met the water quality criteria.

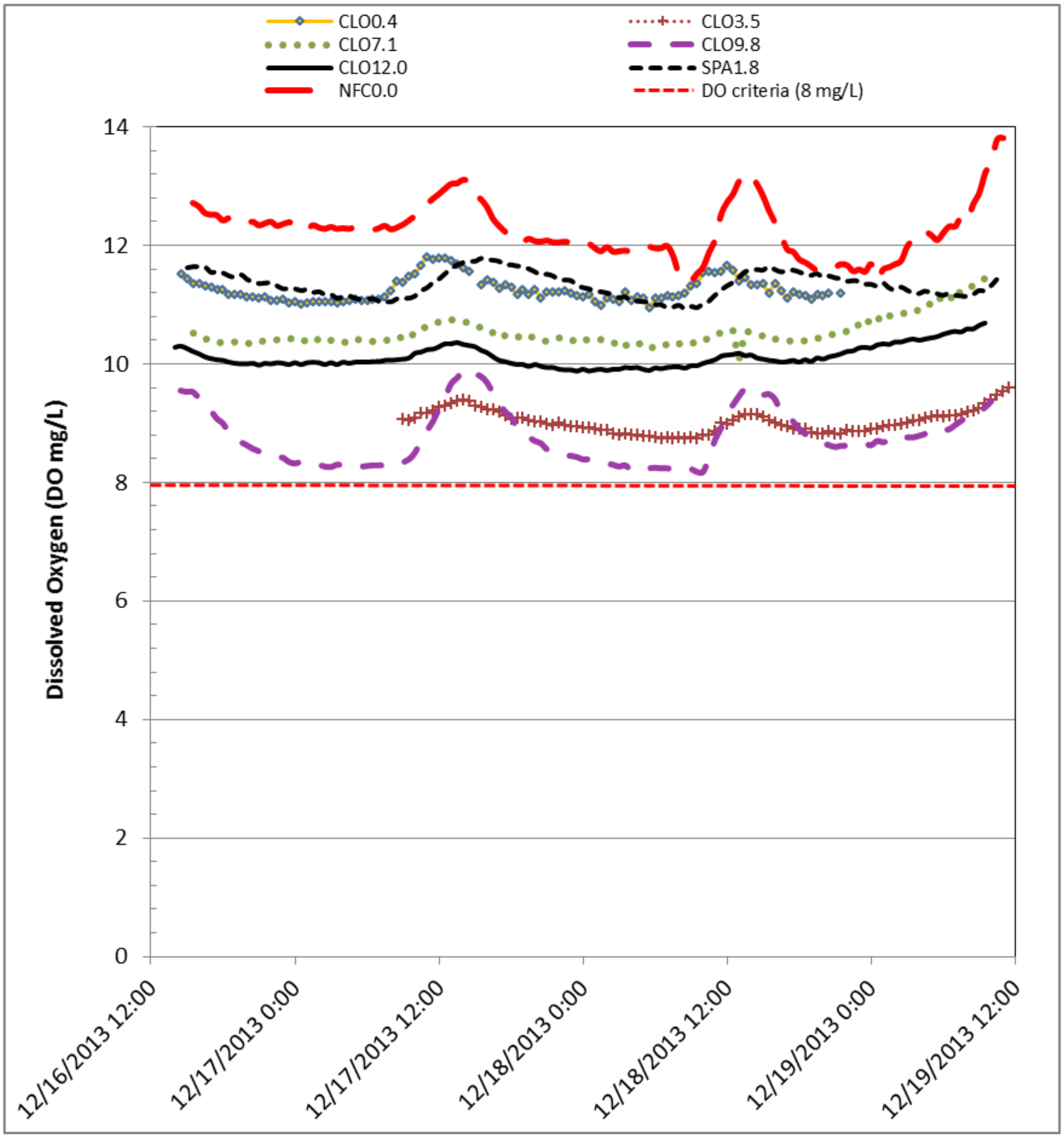


Figure 26. December 16 through 19, 2013 time series dissolved oxygen in the Clover Creek watershed.

In addition, Ecology collected DO measurements biweekly at each monitoring site from March 2013 to February 2014 during sample collection. DO data are in Appendix G.

Bioassessment Methods

Bioassessment methods can detect physical habitat-related or chemical impairments that cannot be detected by chemical and physical measurements alone. Stream organisms are continuously exposed to conditions in the stream and respond to physical and chemical changes in the environment.

Bioassessment information, lists of reference sites, scores, and data are located in Appendix H.

Ecology collected benthic macroinvertebrate and periphyton samples during the first 2 weeks of October 2013 at the following 6 sites in the Clover Creek watershed (Figure 27):

- Clover Creek at Canyon Rd. (CLO12.0)
- Clover Creek at 25th Ave. (CLO8.7) and on river-right for periphyton (CLO8.7R)
- North Fork Clover Creek at B St. (NFC0.0)
- Spanaway Creek at Military Rd. (SPA1.8)
- Clover Creek at JBLM (CLO3.5)
- Clover Creek at Pacific Hwy SW (CLO1.4)

Benthic Index of Biotic Integrity

The Benthic-Index of Biotic Integrity (B-IBI) scoring system is a quantitative method for determining and comparing the biological conditions of streams. Ecology currently uses the Puget Sound Lowlands B-IBI. The B-IBI is based on the scaled response of community attributes to a range of changes in environmental conditions. The B-IBI score is a composite score from 10 individual metrics associated with the macroinvertebrate community. It can be used to assess the biological integrity of a particular stream reach. Macroinvertebrate data and more information about the Puget Sound Lowlands B-IBI and the scoring process can be found at: http://pugetsoundstreambenthos.org/.

The B-IBI index is composed of 10 individual metrics that can be examined to make inferences about stressors influencing macroinvertebrate communities. Ecology used the 10-50 scale, which is the scale currently used to assess and list water bodies. Each individual metric is given a score of either 1, 3, or 5, with a score of 1 for conditions indicating impairment, a score of 5 for conditions representative of streams least impacted by anthropogenic influences, and a score of 3 for intermediate conditions (Appendix H contains scores based on 0 -100 scale).

These scores are added together for the single, integrated overall B-IBI score. The overall score is associated with one of the biological condition categories shown in Table 14. More information on the condition value ranges for each scoring method and its metric is available here: http://pugetsoundstreambenthos.org/BIBI-Scoring-Types.aspx.

Table 14. B-IBI biological condition categories modified from Karr et al., 1986 and Morley, 2000.

Biological Condition	Description	10-50 B-IBI	0-100 B-IBI
Excellent	Comparable to least disturbed reference condition; overall high taxa diversity, particularly of mayflies, stoneflies, caddis flies, long-lived, clinger, and intolerant taxa. Relative abundance of predators high.	[46, 50]	[80, 100]
Excellent/Good	....	(44, 46)	
Good	Slightly divergent from least disturbed condition; absence of some long-lived and intolerant taxa; slight decline in richness of mayflies, stoneflies, and caddis flies; proportion of tolerant taxa increases	[38, 44]	[60, 80)
Good/Fair	....	(36, 38)	
Fair	Total taxa richness reduced – particularly intolerant, long-lived, stonefly, and clinger taxa; relative abundance of predators declines; proportion of tolerant taxa continues to increase	[28, 36]	[40, 60)
Fair/Poor	....	(26, 28)	
Poor	Overall taxa diversity depressed; proportion of predators greatly reduced as is long-lived taxa richness; few stoneflies or intolerant taxa present; dominance by three most abundant taxa often very high	[18, 26]	[20, 40)
Poor/Very Poor	....	(16, 18)	
Very Poor	Overall taxa diversity very low and dominated by a few highly tolerant taxa; mayfly, stonefly, caddis fly, clinger, long-lived, and intolerant taxa largely absent; relative abundance of predators very low	[10, 16]	[0, 20)

The biological data collected at Clover Creek were identified to Species-Family (fine resolution) and was compared to data collected at 12 reference sites in the Puget Lowlands ecoregion (see Appendix H for the list of reference sites). Reference sites are intended to represent one of 2 reference stream conditions: (1) minimally disturbed, or (2) least disturbed. Minimally disturbed conditions exist at sites with very little historical activity that alters stream integrity. Least disturbed sites may have been degraded historically, but show some level of recovery. Comparison with reference sites allows biological data collected at Clover Creek to be interpreted relative to sites representing minimally or least disturbed conditions.

Figure 27 shows the biological condition (color-coded as orange for *Poor* and red for *Very Poor*) for the study sites compared to reference sites. The Clover Creek overall scores were much lower than all the reference sites (Appendix H). All sites scored lower than 28. B-IBI scores lower than 28 on the 10-50 scale indicate considerable biological impairment. Two sampling events with a score lower than 28 will lead to a stream segment being included on the state's 303(d) list for biological impairment.

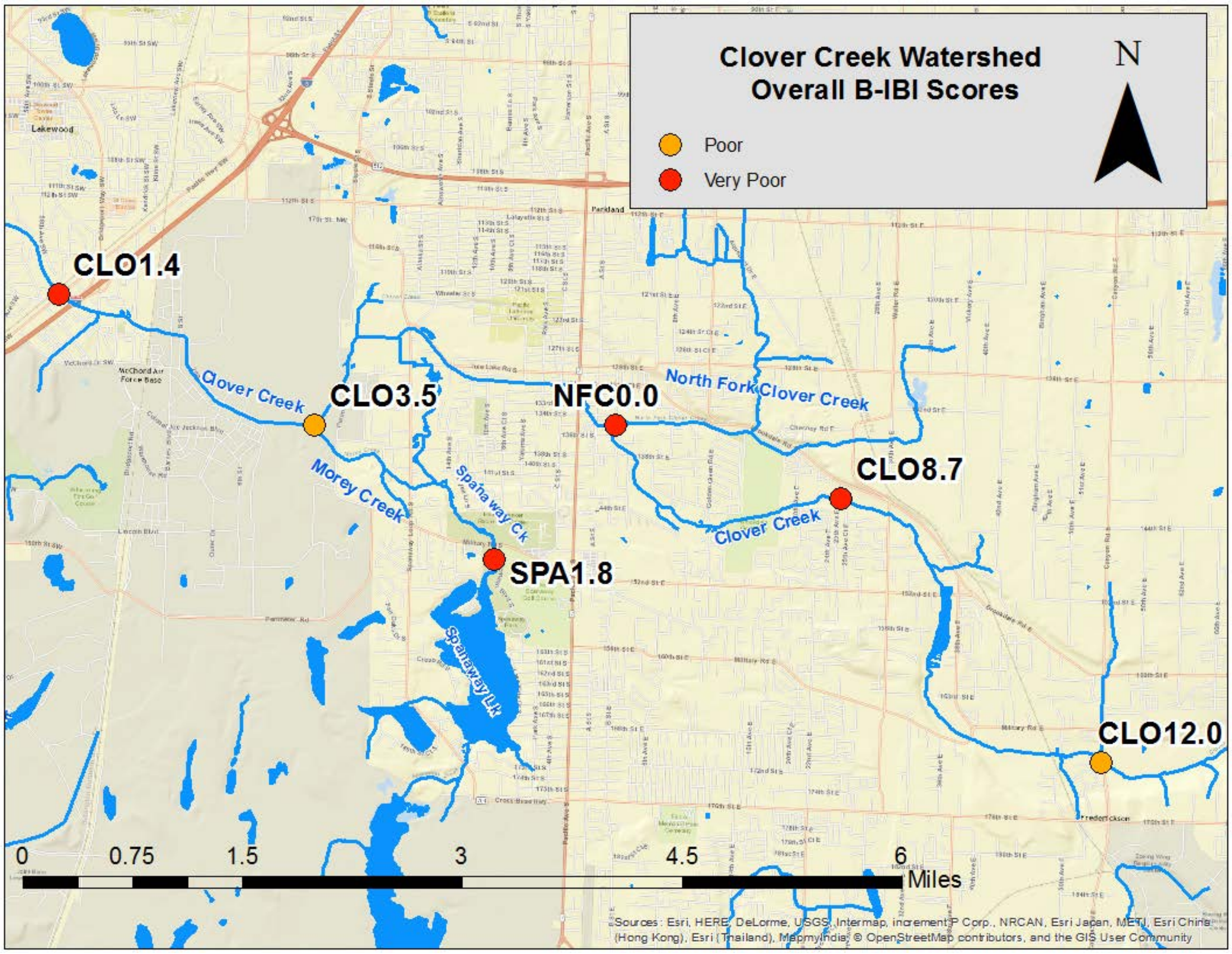


Figure 27. Location of bioassessment sites and overall B-IBI biological condition at 6 sites in the Clover Creek watershed.

Table 15 shows the comparison of B-IBI metrics to the reference sites.

Table 15. Clover Creek study sites B-BI metrics compared to reference sites.

B-IBI Metric	Indicates	CLO12.0	CLO8.7	CLO3.5	CLO1.4	NFC0.0	SPA1.8
Taxa Richness	biodiversity	**Lower**	**Lower**	**Lower**	**Lower**	**Lower**	**Lower**
EPT Richness	sensitive species	**Lower**	**Lower**	**Lower**	**Lower**	**Lower**	**Lower**
Ephemeroptera Richness	sensitive species	**Lower**	**Lower**	**Lower**	**Lower**	**None**	**Lower**
Plecoptera Richness	sensitive species	**Lower**	**None**	**None**	**None**	**None**	**Lower**
Trichoptera Richness	sensitive species	**Lower**	**None**	**Lower**	**Lower**	**Lower**	**Lower**
Clinger Richness	sedimentation	**Lower**	**Lower**	**Lower**	**Lower**	**Lower**	**Lower**
Long-Lived Richness	stable conditions	**None**	**Lower**	**Lower**	**Lower**	**None**	**Lower**
Intolerant Richness	stable conditions vs. disturbance	**Lower**	**None**	**None**	**None**	**None**	**None**
Percent Predator	habitat diversity	Higher	**Lower**	**Lower**	**Lower**	**Lower**	**Lower**
Percent Dominant	sensitive species and biodiversity	Similar	**Higher**	**Higher**	**Higher**	**Higher**	**Higher**
Percent Tolerant	disturbance	Lower	**Higher**	Similar	**Higher**	**Higher**	**Higher**

Highlighted/bold text indicates impairment compared to the reference sites.
EPT: Ephemeroptera, Plecoptera, and Trichoptera taxa.

See Appendix H for comparison of study sites to reference sites for each metric.

Periphyton

Periphyton are important primary producers and chemical modulators in stream ecosystems. As such, periphyton can be more sensitive to certain stressors such as nutrients, salts, sediment, and temperature compared to other aquatic organisms. Measures of periphyton structure, diversity, and density are useful in the assessment of biological condition for surface waters (Barbour et al., 1999; Stevenson et al., 1996).

Table 16 shows the comparison of periphyton metrics to the reference sites.

Study sites had higher Shannon Diversity and species richness, which mean the study sites had a high number of algal species. However, given the higher percentage of taxa that indicate nutrient enrichment and low DO conditions, the high number of algal species may indicate nutrient enrichment.

Table 16. Clover Creek study sites periphyton metrics compared to reference sites.

Periphyton Metric	Indicates	CLO12.0	CLO8.7	CLO8.7R	CLO3.5	CLO1.4	NFC0.0	SPA1.8
Shannon Diversity	biodiversity or nutrient enrichment	**Higher**	**Higher**	**Higher**	**Higher**	**Higher**	**Higher**	**Higher**
Species Richness	biodiversity or nutrient enrichment	**Higher**	**Higher**	**Higher**	**Higher**	**Higher**	**Higher**	**Higher**
Percent Dominant Taxa	degree of impairment	Lower	Similar	Lower	Lower	Lower	Lower	Lower
Percent Native Taxa	native biodiversity	**None**	**Lower**	**Lower**	**Lower**	Similar	**Lower**	Higher
Rare Mountain Brackish Taxa	native biodiversity	Similar	Higher	Higher	**Lower**	**Lower**	Similar	**Lower**
Rare Plains Brackish Taxa	native biodiversity	Higher	Similar	Similar	Higher	Similar	**Lower**	Higher
Eutraphentic taxa	inorganic nutrient enrichment	Similar	Lower	Lower	**Higher**	**Higher**	Similar	**Higher**
Nitrogen Autotroph Taxa	inorganic nutrient enrichment	Similar	**Higher**	**Higher**	Lower	Lower	Similar	Lower
Facultative Nitrogen Heterotroph Taxa	organic nutrient enrichment	**Higher**	**Higher**	Similar	**Higher**	**Higher**	**Higher**	**Higher**
Percent Low DO Taxa	organic nutrient enrichment and low DO	**Higher**	**Higher**	**Higher**	**Higher**	**Higher**	**Higher**	**Higher**
Polysaprobous Taxa	organic nutrient enrichment and low DO	**Higher**	Similar	Similar	**Higher**	Similar	**Higher**	Similar
Pollution Tolerance Index	lower value for more tolerant species	**Lower**	Similar	Similar	**Lower**	**Lower**	**Lower**	Similar
Percent Motile Taxa	increased sedimentation	**Higher**	Similar	Similar	**Higher**	**Higher**	**Higher**	**Higher**
Percent Siltation Taxa	increased sedimentation	**Higher**	Similar	Similar	**Higher**	Similar	**Higher**	**Higher**
Percent Metal Tolerant Taxa	less sensitivity to metals contamination	**Higher**	Similar	Similar	**Higher**	Similar	**Higher**	Similar
Percent Acidophilous Taxa	less sensitive to acidic environment	**Higher**	**Higher**	Similar	**Higher**	Similar	None	Similar

Highlighted/bold text indicates impairment compared to the reference sites.

See Appendix H for comparison of periphyton collected at study sites to reference sites for each of the listed metrics.

Conclusions

The study conducted by the Washington State Department of Ecology (Ecology) from March 2013 to February 2014 found that fecal coliform bacteria (FC), dissolved oxygen (DO), and temperature in Clover Creek and its tributaries often exceeded (did not meet) Washington State standards.

Fecal Coliform Bacteria

FC concentrations exceeded one or both *Primary Contact Recreation* criteria at the Clover Creek and North Fork Clover Creek sites.

FC concentrations violated both *Primary Contact Recreation* criteria at 7 sites (4 at North Fork and 3 at Clover Creek).

More than 10% of samples collected at 15 sites (9 at North Fork and 6 at Clover Creek) exceeded 200 cfu/100 mL.

The 90th percentile at 15 sites (9 at North Fork and 6 at Clover Creek) exceeded 200 cfu/100 mL.

FC concentrations in stormwater samples exceeded *Primary Contact Recreation* standard (200 cfu/100 mL) at 16 sites. Four sites met the standard. Only 1 stormwater outfall was sampled−NFCB1.1RB−where the FC concentration was 14.5 times over the *Primary Contact Recreation* criterion for a single sample (200 cfu/100 mL).

Dissolved Oxygen

The DO concentration does not meet the minimum daily DO criterion of 8.0 mg/L at most sites in the summer, due to diurnal swings in concentration. However, the DO concentration meets the daily minimum DO water quality criterion in the winter.

- 4 of the 6 monitoring locations (CLO9.8, CLO7.1, CLO3.5, and SPA1.8) fell below the daily minimum DO water quality criterion during the summer diurnal survey.
- Diurnal variation in DO concentration was most pronounced in CLO3.5, CLO9.8, and SPA1.8. CLO3.5 was 2 mg/L under the state standard during the entire summer study period. The North Fork was dry during diurnal study.
- All monitoring sites (5 on Clover Creek and 1 each on Spanaway Creek and the North Fork) met the water quality criteria during the December 2013 diurnal survey.

Temperature

Water temperature was high throughout the watershed in the summer months. Only the upstream site (CLO12.0) met the 7-DADMax criterion (17.5°C) throughout summer (May through September).

- The temperature of Clover Creek increases from CLO12.0 to CLO7.1. All sites downstream of CLO12.0 exceeded the 7-DADMax water quality criterion of 17.5°C.
- The 3 North Fork sites exceeded the temperature 7-DADMax temperature of 17.5°C. The North Fork became dry/sub-surface by mid-July.
- Both Morey Creek sites and all 3 Spanaway Creek sites exceeded the 7-DADMax temperature of 17.5°C.

Bioassessment Methods

Bioassessment methods can detect physical habitat-related or chemical impairments that cannot be detected by chemical and physical measurements alone. The overall Benthic-Index of Biotic Integrity (B-IBI) scores reveal that:

- The upstream site on Clover Creek (CLO12.0) had the highest overall score. The biological condition was ranked as Poor.
- The Clover Creek site downstream from the confluence with Spanaway Creek (CLO3.5) had the next highest overall score. The biological condition was also classified as Poor.
- The other 4 sites had lower overall scores. The biological condition was considered to be Very Poor.
- All sites scored less than 28 for the overall B-IBI metric, which indicates considerable impairment.

Recommendations

Conduct Additional Monitoring for Fecal Coliform Bacteria, Dissolved Oxygen, Temperature, and Streamflow

Ecology recommends additional monitoring for fecal coliform bacteria (FC) in the reaches with high FC concentrations to narrow down the location of potential sources. Once locations in these reaches have been identified, potential sources should be investigated.

All stormwater conveyance systems in the watershed should be assessed to determine where stormwater may be delivering pollutants to the stream and where to apply best management practices (BMPs). Ecology collected samples during one summer storm event. FC concentrations were high at most instream sites. Ecology only collected one stormwater sample at an outfall on the North Fork. The FC concentration was 2900 cfu/100 mL. Sampling at additional stormwater outfalls in the watershed is necessary to determine which outfalls contribute to high FC during stormwater runoff.

Ecology recommends additional monitoring to determine the causes of low DO concentrations and large diurnal variation in DO concentrations. Four sites fell below 8.0 mg/L during the summer diurnal study: CLO9.8, CLO3.5, CLO7.1, and SPA1.8. The diurnal fluctuation was most pronounced in CLO9.8, CLO3.5, and SPA1.8. Water temperature, nutrients, flow, and groundwater discharge may be affecting DO concentration in the summer.

Ecology recommends additional temperature and streamflow monitoring at tributaries not sampled during this study to determine if they are contributing warm water to Clover Creek, in particular in the reach from CLO12.0 to CLO11.0. Water temperature increased 6.5°C in that one river mile.

Also, additional flow monitoring may help to determine the effects of groundwater and wetlands on temperature regimes and loading of other pollutants. These pieces of information would facilitate planning where riparian restoration would be most beneficial.

Reduce Fecal Coliform Bacteria and Improve Water Quality

The streams in this watershed run through parkland, residential areas, and commercial areas. Children were observed playing in Clover Creek at 25th Street, where the stream runs through a neighborhood. As sources are located and corrected, water quality should improve. Also, eliminating larger bacteria sources will make small sources more apparent.

To ensure Clover Creek and its tributaries meet *Primary Contact Recreation* criteria, unnatural sources need to be corrected.

Ecology calculated target FC reductions for water bodies that violated water quality standards. The water quality standards within the study area require that:

- Geometric mean should not exceed 100 cfu/100 mL.
- No more than 10% of samples should exceed 200 cfu/100 mL. In this report, this is calculated as the 90th percentile of sample results.

Ecology determined FC load reduction targets, based on abatements needed to meet *Primary Contact Recreation* criteria. The target is expressed as a percent reduction from FC concentration levels collected during this study. Targets are set for geographic areas upstream of each study site (Table 17).

The FC concentration was significantly higher in the dry season for the first 8 sites listed on Table 17. The targets given were rolled back to the most restrictive of the dual FC criteria for the dry season.

The wet season geometric mean and 90^{th} percentile at CLO1.9 exceeded FC criteria. The wet season load was the highest of all study sites at 387 billion cfu/day. Ecology recommends a 76% reduction in the wet season based on a rollback to the 90^{th} percentile.

CLO4.6 was not flowing during the dry season, so all 10 samples are from the wet season. No comparison between the seasons was possible. The target was rolled-back to the 90^{th} percentile for that site and is listed under the wet season.

Like CLO4.6, the North Fork flowed intermittently during the summer. Ecology collected less samples at intermittent North Fork sites. Ecology collected 5 to 16 total samples (with fewer samples collected during the dry season) at 6 North Fork sites. Ideally, at least 20 samples taken throughout the year are needed from a broad range of hydrologic conditions to determine an annual FC distribution. With fewer samples, there is less confidence in bacteria reduction targets. Ecology calculated the target reductions for these sites to provide general targets for planning implementation measures.

Table 17. FC reductions for water bodies in the study area.

Station ID	Total Number of Samples (Wet/Dry)	Observed FC (cfu/100mL)		FC Reduction	FC Target Capacity (cfu/100mL)	
		Geo-mean	90th Percentile		Geo-mean	90th Percentile
Sites with Targets for Dry Season (May 2013 to September 2013)						
CLO9.8	23 (13/10)	**156**	**323**	38	97	200
CLO7.1	23 (13/10)	**182**	**292**	45	100	161
CLO7.1SC	17 (9/8)	85	**231**	14	73	200
CLO3.5	23 (13/10)	78	**205**	2	76	200
CLO1.4	23 (13/10)	89	**334**	40	53	200
CLO0.4	23 (13/10)	**207**	**483**	59	86	200
MOR0.1	23 (13/10)	40	**315**	36	25	200
SPA0.5	23 (13/10)	71	**208**	4	69	200
Sites with Targets for Wet Season (March to April 2013; October 2013 to February 2014)						
CLO1.9	23 (13/10)	**124**	**832**	76	30	200
CLO4.6*	10 (10/0)	**120**	**380**	47	63	200
NFCB1.1RB	9 (6/3)	82	**824**	76	20	200
NFCB1.1LB*	6 (6/0)	26	**313**	36	17	200
NFCB1.4	8 (6/2)	62	**605**	67	20	200
NFCB1.4W	7 (5/2)	89	**496**	60	36	200
NFCB1.7*	5 (5/0)	52	**216**	8	48	200
NFC0.0	16 (12/4)	**114**	**544**	63	42	200
Sites with Targets for Both Dry and Wet Seasons						
Dry Season (May 2013 to September 2013)						
NFCB0.0	22 (13/9)	**132**	**317**	37	83	200
NFCB1.1	23 (13/10)	**501**	**2130**	91	47	*200*
Wet Season (March to April 2013; October 2013 to February 2014)						
NFCB0.0	22 (13/9)	73	**265**	25	55	200
NFCB1.1	23 (13/10)	**105**	**515**	61	41	200

*No dry season samples collected due to lack of flow or reduced sampling at bacteria investigatory sites.

Onsite-Septic Systems (OSS)

Septic systems are potential sources of FC. Improperly maintained septic systems can fail and lead to pollutants entering waterways. Untreated or partially treated sewage can leach into the groundwater and accumulate on the ground and flow into nearby streams.

Information about the proper inspection and maintenance of OSS should be provided to owners of OSS. This information should include the negative effects of garbage disposals and provide a list of substances that should not be poured down the drain.

Reaches with consistent year-round loading should be further investigated for failing or improperly constructed septic systems. Once the source area is narrowed down with additional sampling, Ecology recommends inspecting septic systems closest to the stream first. Many OSS in this watershed are located within 200 feet of the stream.

Sanitary and Storm Sewer Inspection and Repair

Ecology recommends continued inspection of the sanitary and storm systems. Ruptures, leaks, or overflows from sanitary sewers in the vicinity of surface water bodies can have a direct impact on FC concentrations and potentially harmful pathogens in those water bodies. Standing water and accumulated sediment in stormwater catch basins and manholes can be a potential significant source of FC. It is recommended that catch basins and manholes be inspected frequently and catch basins be cleaned out twice a year.

Stormwater

All stormwater conveyance systems in the watershed should be assessed to determine where stormwater may be delivering pollutants to the stream and where to apply BMPs.

Many BMPs exist to reduce runoff that can transport bacteria and sediment to streams via stormwater, the main strategies include: infiltration, pollution prevention/source control, and improving operation and maintenance of stormwater conveyance systems.

Table 18 and Figure 28 shows the instream sites that exceeded *Primary Contact Recreation* criterion (200 cfu/100 mL) during the summer stormwater event.

Table 18. Instream sites where FC concentrations in stormwater exceeded the *Primary Contact Recreation* (PCR) of 200 cfu/100mL (for a single sample).

Exceed PCR	cfu/100 mL
NFC0.0	1800
NFCB0.0	1600
NFCB1.1	1300
CLO3.5	590
CLO7.1	510
CLO0.4	490
CLO1.4	470
CLO1.9	440
CLO8.7	440
MOR0.1	310
CLO9.8	250
SPA0.5	250
MOR0.9	220
SPA1.8	220
NFC1.0	210

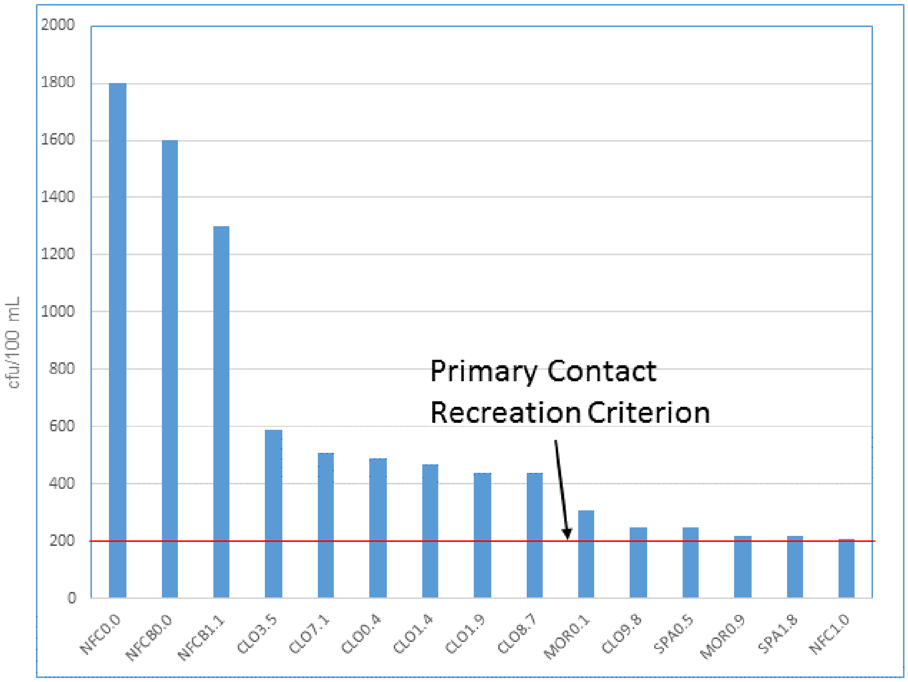


Figure 28. Instream sites where FC concentrations in stormwater exceeded 200 cfu/100 mL.

Infiltration

Ecology recommends increasing infiltration of runoff in the stream reaches that lose streamflow: upstream of CLO7.1 to downstream of CLO4.6 and the North Fork. Infiltration is a passive means of treatment, where existing or amended soils collect and treat the stormwater. Increasing infiltration of stormwater into the soil reduces transportation of pollutants to area streams.

Stormwater Source Control

Controlling the source and preventing bacteria and sediment from entering stormwater or MS4s can reduce transportation to area streams.

Fecal waste left on the ground can be transported into stream with stormwater. Pet waste is an important source of fecal contamination, especially in residential areas where many people have pets. If restroom facilities are not available to individuals camping in riparian areas, they could also be contributing fecal waste near the stream.

Although livestock are not common in the watershed, they are present. Cattle were observed next to Spanaway Creek at 138th Street and next to the North Fork at 121st Street. A fenced pasture with water troughs, sparse ground cover, and manure was observed near Clover Creek near the intersection of Brookdale and Waller Roads. Sites downstream of SPA1.5, SPA0.5, and

CLO8.7 met the *Primary Contact Recreation* criteria during the study period. The North Fork site at 121st Street (NFCB1.1) exceeded both parts of the *Primary Contact Recreation* criteria. The geometric mean was 207 cfu/100 mL, and 74% of the samples exceeded 200 cfu/100 mL.

Ecology recommends that riparian areas be fenced off to exclude livestock. Livestock deposit fecal matter, trample vegetation, and break up the soil. When vegetation is removed and the soil is loosened, the filtering capacity of the soil is reduced and erosion potential increases.

Wildlife also contribute to bacteria in water bodies. This bacteria is usually considered part of natural background levels. An exception is made when a pollutant source is created by man-made alterations to the environment. By eliminating food sources and habitats used by rodents and raccoons, such as patches of invasive plants and debris piles, we could reduce bacteria contamination in some areas.

Restore Streams

Hydrology

Changes in stream hydrology play a great role in the water quality in urban and suburban areas. Conveyance systems that shunt stormwater runoff directly to the nearest stream lead to sudden increases in flow. High peak flows accelerate the natural bank scouring processes and increase sedimentation. This same runoff, which would naturally infiltrate into the ground or be stored in a wetland, is no longer available in the summer months when there is not as much rainfall. Additionally, loss of summer base flows concentrated pollutants.

Appendix A shows areas affected by loss of summer baseflow and high dry-season FC loads, as well as areas affected by stormwater runoff. Projects to reduce stormwater runoff into area streams, increase infiltration of precipitation into the ground, and restore wetlands and riparian buffers would benefit the stream hydrology, water quality, and physical habitats.

Riparian Plantings

Lack of shading and degradation of the riparian micro-environment can cause stream temperatures to increase and reduce DO. Ecology recommends that a detailed plan be developed for the watershed to reduce the proliferation of invasive plants and to establish native vegetation in areas lacking native riparian vegetation. Preferred species include smaller hydrophytic trees and shrubs that are native to the area. Red alders interspersed with native willows will grow quickly under existing conditions. Table 19 shows the species list that Pierce County Conservation District provided.

Recommendations for some specific locations are shown in Appendix A. However, feasibility of various locations will depend on land ownership and site characteristics. Sites with flow during the summer would benefit most by planting riparian vegetation to reduce temperature.

Table 19. Native trees and shrubs that are suitable for riparian restoration in the Tacoma area.

Common Name	Botanical Name
Western red cedar	*Thuja plicata*
Douglas fir	*Pseudotsuga menziesii*
Grand fir	*Abies grandis*
Western hemlock	*Tsuga heterophylla*
Black cottonwood	*Populus trichocarpa*
Vine maple	*Acer circinatum*
Beaked hazelnut	*Corylus cornuta*
Salmonberry	*Rubus spectabilis*
Snowberry	*Symphoricarpos albus*
Coastal black gooseberry	*Ribes divaricatum*
Indian plum	*Oemleria cerasiformis*
Red elderberry	*Sambucus racemosa*

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Appendices

Appendix A. Clover Creek Subbasin Summaries

Each subbasin (Figure A-1) of the watershed is discussed below.

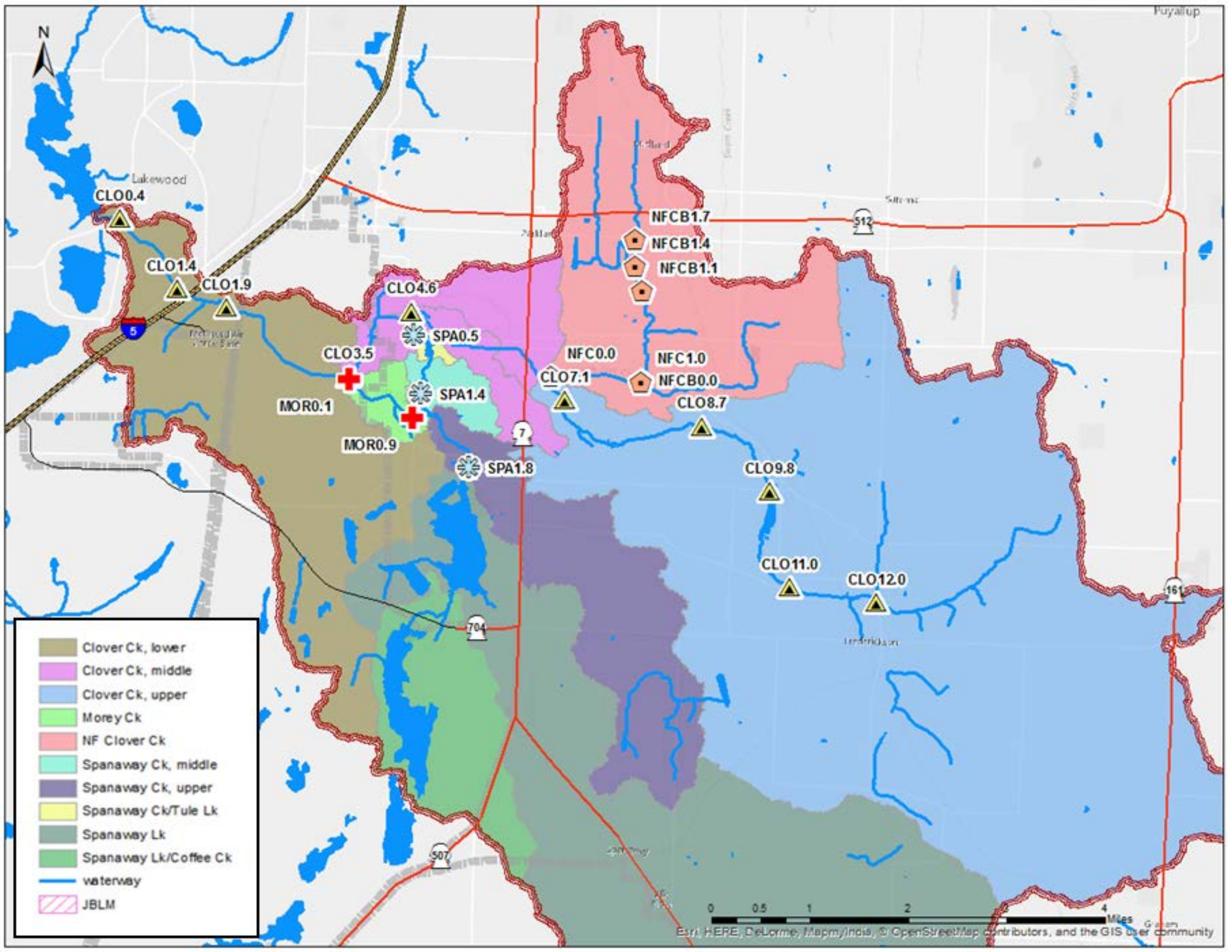


Figure A-1. Subbasins in the Clover Creek watershed study area.

Upper Clover Creek

Fecal Coliform Bacteria (FC)

Table A-1 summarizes FC data for the 6 monitoring sites in the upper Clover Creek subbasin.

One site exceeded (did not meet) all the bacteria numeric criteria – CLO7.1.

Thirteen percent of samples collected at CLO9.8 exceeded the *Primary Contact Recreation* bacteria criterion. The 90th percentile at both sites was above 200 cfu/100 mL. Samples collected during the dry season at both of these sites had significantly higher FC geometric means and loads.

Table A-1. FC data for the 6 monitoring sites in the upper Clover Creek subbasin.

Site	FC Geometric Mean (cfu/100 mL)	FC 90th Percentile (cfu/100 mL)	Percent FC Exceeding WQ Criterion	Stormwater FC (cfu/100 mL)
CLO12.0	22	95	4	92
CLO11.0	30	106	0	150
CLO9.8	81	**231**	**13**	**250**
CLO8.7	61	142	4	**440**
CLO7.1	**104**	**240**	**17**	**510**
CLO7.1SC	27	149	6	120

Bold/highlighted values exceeded standards or, for the critical season, there was a significant difference between the seasons.

CLO7.1 was intermittent. In contrast, CLO9.8, gained streamflow. Upstream of CLO9.8, there are tributaries and wetlands.

CLO7.1 exceeded both *Primary Contact Recreation* criteria. A higher percentage of samples from CLO7.1 exceeded 200 cfu/100 mL, where low flows may have concentrated the bacteria. The FC concentration was lower at CLO9.8, but it had a higher mean discharge. The average annual load at CLO9.8 was 31 billion cfu/day, compared to 7 billion cfu/day at CLO7.1. Based on rollback to the 90^{th} percentile for the dry period, Ecology recommends the following FC reductions for the dry season: 45% at CLO7.1 and 38% at CLO9.8.

Sites CLO9.8 and CLO7.1 had the higher FC concentrations and loads in the dry season, suggesting onsite septic systems (OSS) could be contributing to FC contamination upstream of these areas. Priority should be given to investigating sources upstream of these sites to determine if OSS are contributing to the bacterial contamination.

Figure A-2 shows the locations of the 6 sites (CLO7.1SC is the side channel that enters Clover Creek at CLO7.1) in relation to the density of OSS and some stormwater outfalls. Pierce County provided the point files of stormwater outfalls and OSS in the area. The kernel density was produced from the OSS point-file. Some of the highest density OSS per acre were plotted with a single point in this file (red bull's-eye polygons on the map).

In the reach in-between CLO12.0 and CLO8.7, Clover Creek flows through an area with mostly 0 to 0.5 OSS per acre. Many OSS are located within 200 feet of the stream. Areas with higher density OSS (1 to 3 per acre) are located 100 to 2000 feet from the stream.

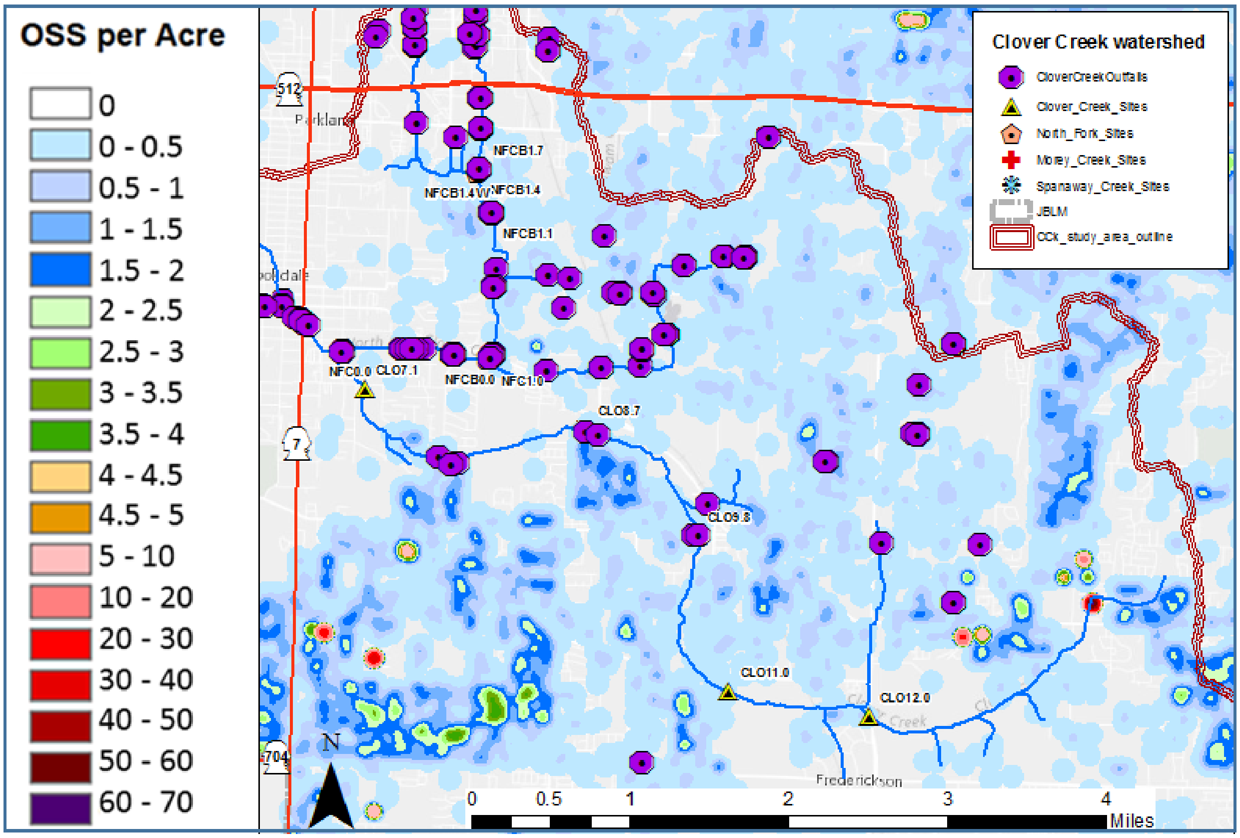


Figure A-2. Map of upper Clover Creek OSS and stormwater outfalls.

The reach in-between CLO8.7 and CLO7.1 has a lower density of OSS (0 to 2 per acre). Several OSS and stormwater outfalls are located within 200 feet of the stream in this reach.

FC Storm Event

Ecology collected samples during one storm event. These samples were collected in the stream at study sites, not at stormwater outfalls. Samples collected at CLO9.8, CLO8.7, and CLO7.1 exceeded 200 cfu/100 mL. The FC concentration increased going downstream from 250 cfu/100 mL at CLO9.8, to 440 at CLO8.7, to 510 at CLO7.1. Ecology did not collect samples at stormwater outfalls in this reach. More stormwater monitoring is required to determine sources in upper Clover Creek.

Hydrology

Figure A-3 shows that Clover Creek gained surface flow from CLO12.0 to CLO8.7. Many wetlands and a few tributaries provide baseflow to Clover Creek in this reach.

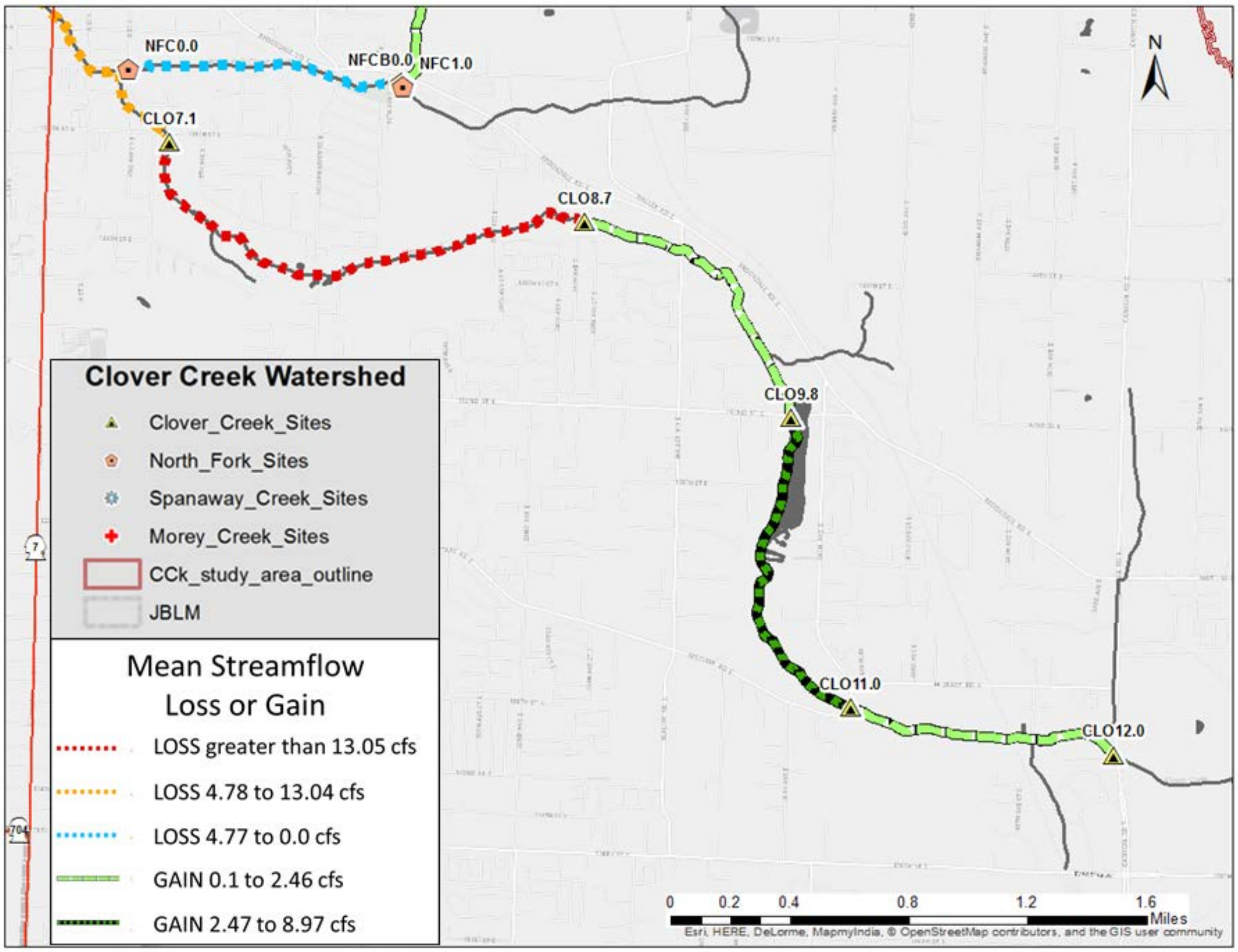


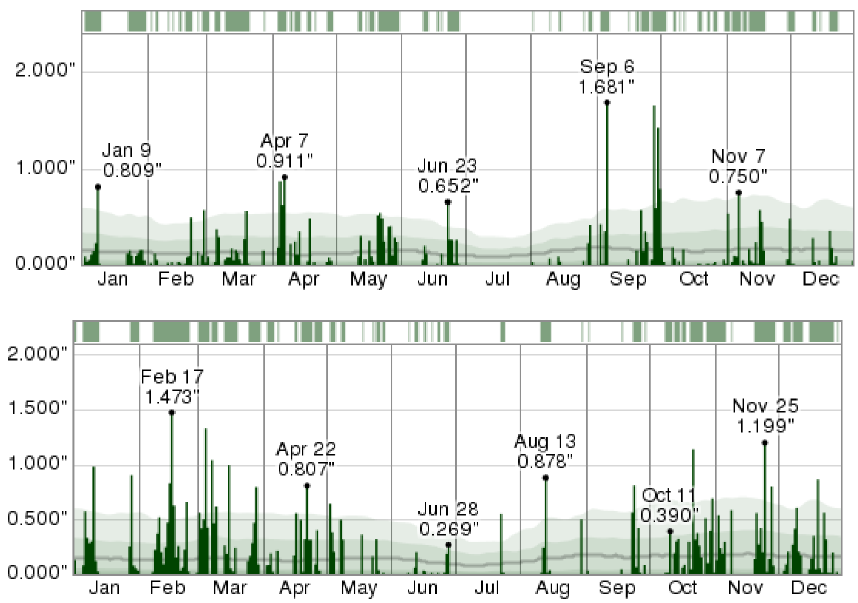
Figure A-3. Loss or gain of streamflow (cfs) at upper Clover Creek.

At CLO7.1 surface flow was lost. CLO7.1 had the lowest mean and maximum flows compared to other Clover Creek sites.

Monthly Discharge

Figure A-4 shows monthly instantaneous discharge measurements at CLO12.0 (the upstream station) and CLO 11.0, 1 river mile (RM) downstream. The stream gained flow at CLO11.0. The most gain was during high flows (over 9 cfs). CLO11.0 was flashier than the upstream site, with significantly higher flows after precipitation events and a rapid return to pre-rain conditions, like the rise seen after the rain events in late June, 2013 (Figure A-5).

Figure A-4. Instantaneous discharge measurements by Ecology from March 2013 to February 2014. Horizontal lines show minimum, mean, and maximum values from bottom to top.



*The thick gray line shows the median non-zero quantity, and the shaded areas are the 10th, 25th, 75th, and 90th non-zero percentiles. The bar at the top of the graph is green if any precipitation was measured that day, and white otherwise.

Figure A-5. Daily measured precipitation during 2013 (top) and 2014 (bottom) in the project area. The graph from the weather station at McChord Air Force Base in Tacoma, Washington.

Small gains were observed from CLO9.8 to CLO8.7 during maximum (approximately + 2.0 cfs) and average (approximately + 0.3 cfs) flows. The stream gained nothing during minimum flow conditions (Figure A-6).

Figure A-6. Instantaneous discharge measurements by Ecology from March 2013 to February 2014. Horizontal lines show minimum, mean, and maximum values from bottom to top.

Clover Creek lost streamflow from CLO8.7 to CLO7.1, the greatest loss during maximum and mean discharges. Streamflow at CLO7.1 dropped to a minimum of 1.3 cfs during the low-flow period from September to December. Some flow was contributed by the side channel CLO7.1SC (Figure A-7). Approximately 0.9 cfs was contributed to the mean flow. Maximum flows added even more, approximately + 6.0 cfs.

Figure A-7. Instantaneous discharge measurements by Ecology from March 2013 to February 2014. Horizontal lines show minimum, mean, and maximum values from bottom to top.

Dissolved Oxygen

Based on the 2 diurnal DO studies, all sites met the water quality criterion (8.0 mg/L) for DO in the winter. In the summer, only the upper site (CLO12.0) met the water quality criteria for DO. DO measured during site visits reveal similar results: CLO12.0 was the only site consistently above the water quality criterion.

Temperature

Only the upper site (CLO12.0) met the water quality criterion for temperature (17.5°C) using the temperature logger data. Temperature data collected during site visits reveal similar results: CLO12.0 was the only site that met the water quality criterion.

Water temperature increased 6.5°C in one river mile from CLO12.0 to CLO11.0. No large change in effective shade or canopy cover was observed between these 2 sites. The aerial imagery does not show any substantial change in riparian buffer in this reach. Also, this reach gained flow during the study. Collecting additional flow and temperature measurements would be informative within the reach from CLO12.0 to CLO11.0.

Riparian Corridor

Average effective shade was relatively high (87 to 88%) at the 2 sites in upper Clover Creek (Figure A-8). The riparian corridors around CLO12.0 and upstream of CLO11.0 were still in a somewhat natural condition during the study period. Both sites are located in a growing commercial and residential area, with new construction nearby.

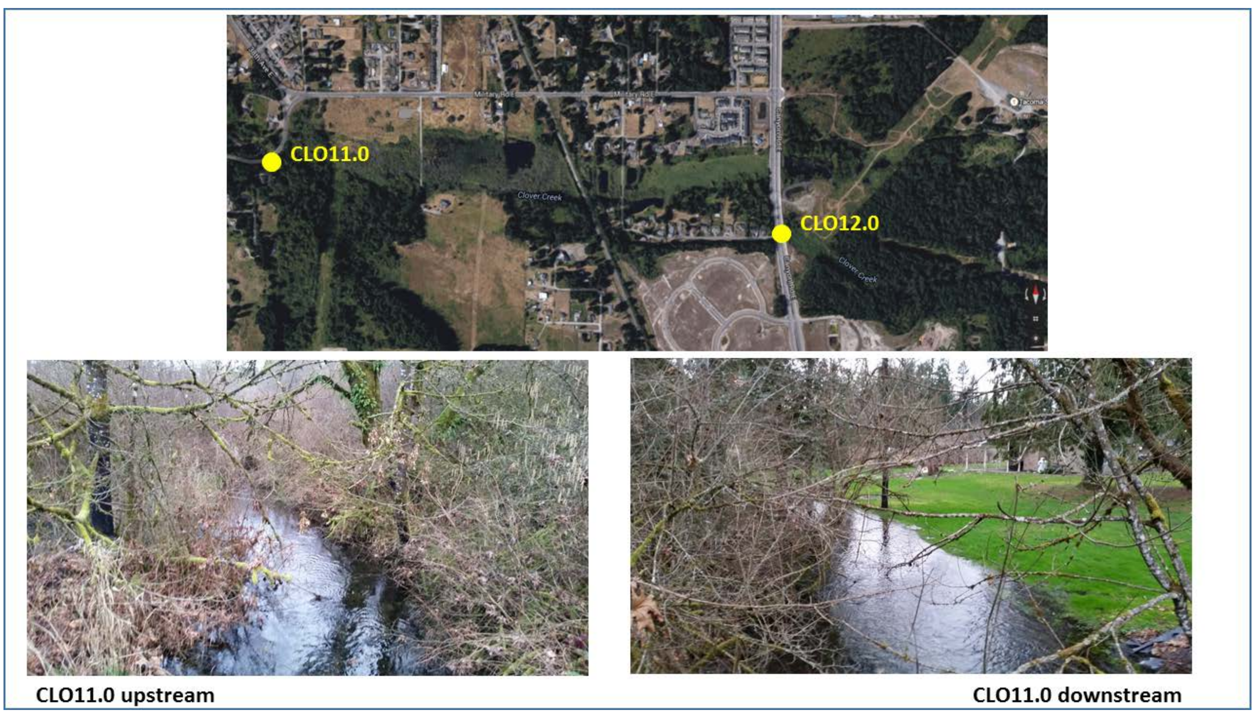


Figure A-8. Photographs of CLO12.0 and CLO11.0

The percentage of average effective shade drops to 42 to 51% at sites CLO9.8 and CLO8.7 in the middle reaches. There may be opportunities to increase buffer widths and increase shade by planting native trees and shrubs in these areas (Figures A-9 to A-10).

Figure A-9. Photographs of CLO9.8.

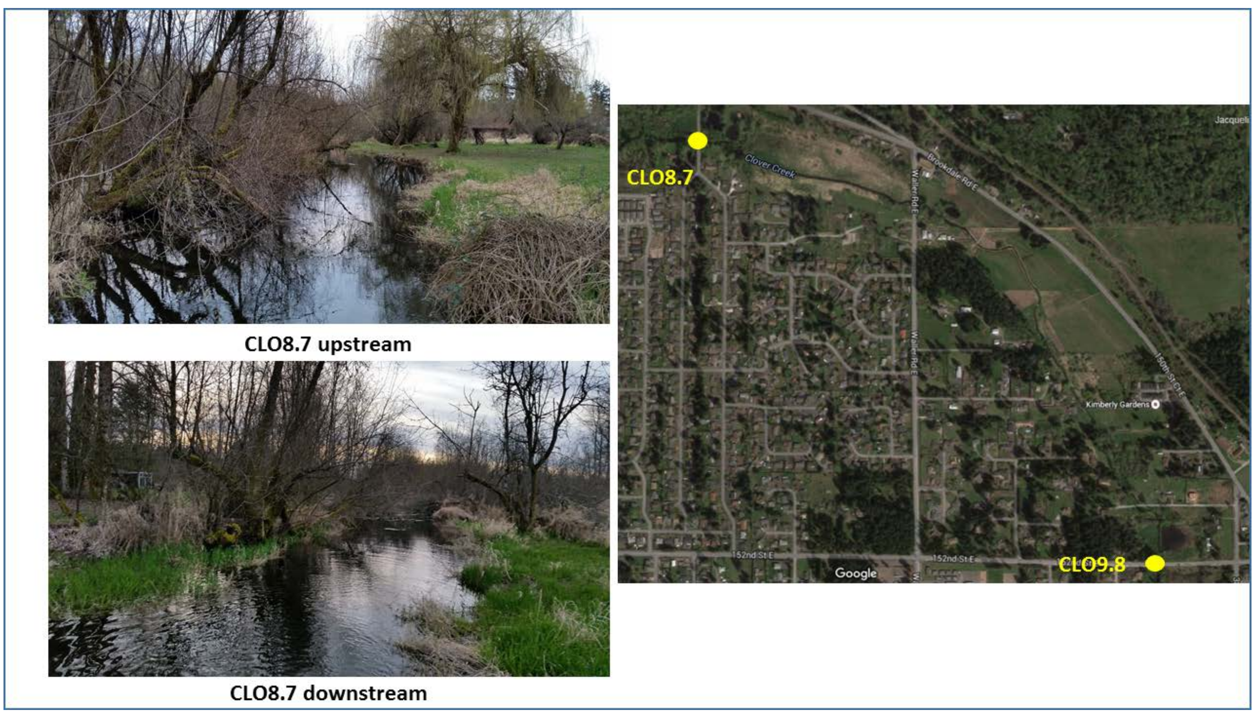


Figure A-10. Photographs of CLO8.7.

Of all the study sites where hemispheric photographs were taken, CLO7.1 had the second highest effective shade (Figure A-11).

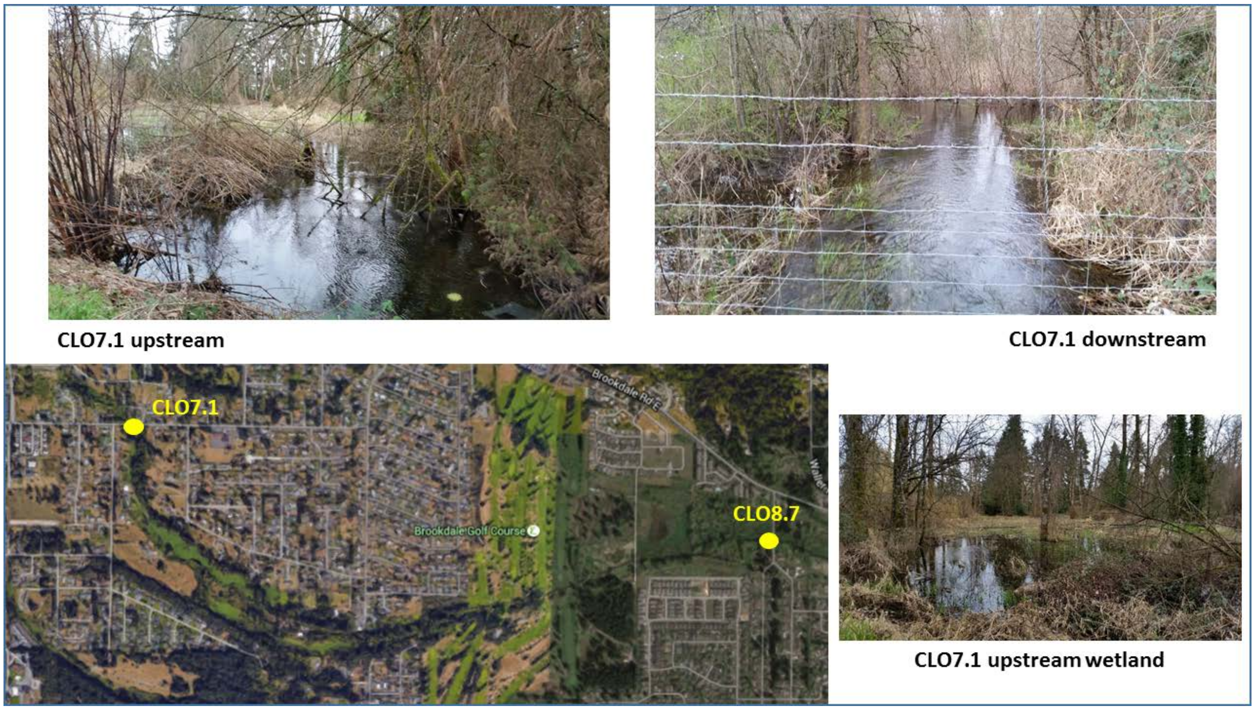


Figure A-11. Photographs of CLO7.1.

Bioassessment

Ecology collected benthic macroinvertebrates and periphyton samples at CLO12.0 and CLO8.7.

Based on the B-IBI scores, the biological condition of CLO12.0 was Poor. Compared to the reference sites (see Appendix G), CLO12.0 had reduced richness of total taxa. Specific taxa with reduced richness included long-lived, stonefly, clinger, and intolerant taxa.

The biological condition at CLO8.7 was Very Poor, with reduced taxa richness. Richness of Ephemeroptera, clinger, and predator taxa was also reduced compared to the reference sites. Samples collected at CLO8.7 did not have any Plecoptera, Trichoptera, long-lived, or intolerant taxa. This site had a much greater percentage of tolerant and dominant taxa.

See the *Bioassessment* section of this report and Appendix G for a comparison of periphyton metrics for CLO12.0, CLO8.7, and CLO8.7R to the reference sites. The higher percentages of some taxa in samples collected at these sites indicate nutrient enrichment, such as the higher percentages of low DO, facultative nitrogen heterotroph, and nitrogen autotroph taxa. Also, all 3 sites had higher Shannon Diversity and species richness values. Nutrient enrichment can increase the number of algal species.

Middle Clover Creek

Fecal Coliform Bacteria (FC)

Table A-2 summarizes FC data for the 2 sites in the middle Clover Creek subbasin.

Table A-2. Summary of FC data for sites in the middle section of Clover Creek.

Site	FC Geometric Mean (cfu/100 mL)	FC 90th Percentile (cfu/100 mL)	Percent FC Exceeding WQ Criterion	Stormwater FC (cfu/100 mL)
CLO4.6	**120**	**380**	**30**	dry
CLO3.5	74	179	9	**590**

Bold/highlighted values exceeded standards or, for the critical season, there was a significant difference between the seasons.

CLO4.6 exceeded both *Primary Contact Recreation* bacteria criteria. Also, the 90th percentile was over 200 cfu/100 mL. Since CLO4.6 was dry 60% of the study period, all samples were collected during the wet season. CLO4.6 had relatively high FC and low flow. Ecology recommends a 47% reduction of FC during the wet season to meet the standard.

Storm-Event FC

Ecology collected a sample in the stream at CLO3.5 during one storm event in June 2013. The FC concentration was almost 3 times the standard (200 cfu/100 mL). Also, the FC load was significantly higher during the wet season at CLO3.5. Investigations into stormwater contributions in this reach may help identify the source(s).

Unfortunately, Ecology did not collect a sample at CLO4.6 because it was dry during the storm event. The precipitation began on June 23 at 0500 and ended June 24 at 0500. Ecology collected samples on June 24 during the second hydrological peak. The second peak was lower than the first. In addition, samples were collected on the receding limb. Therefore, much of the stormwater from this event had already flowed downstream.

Hydrology

Figure A-12 shows that surface flow was lost from CLO7.1 to CLO4.6.

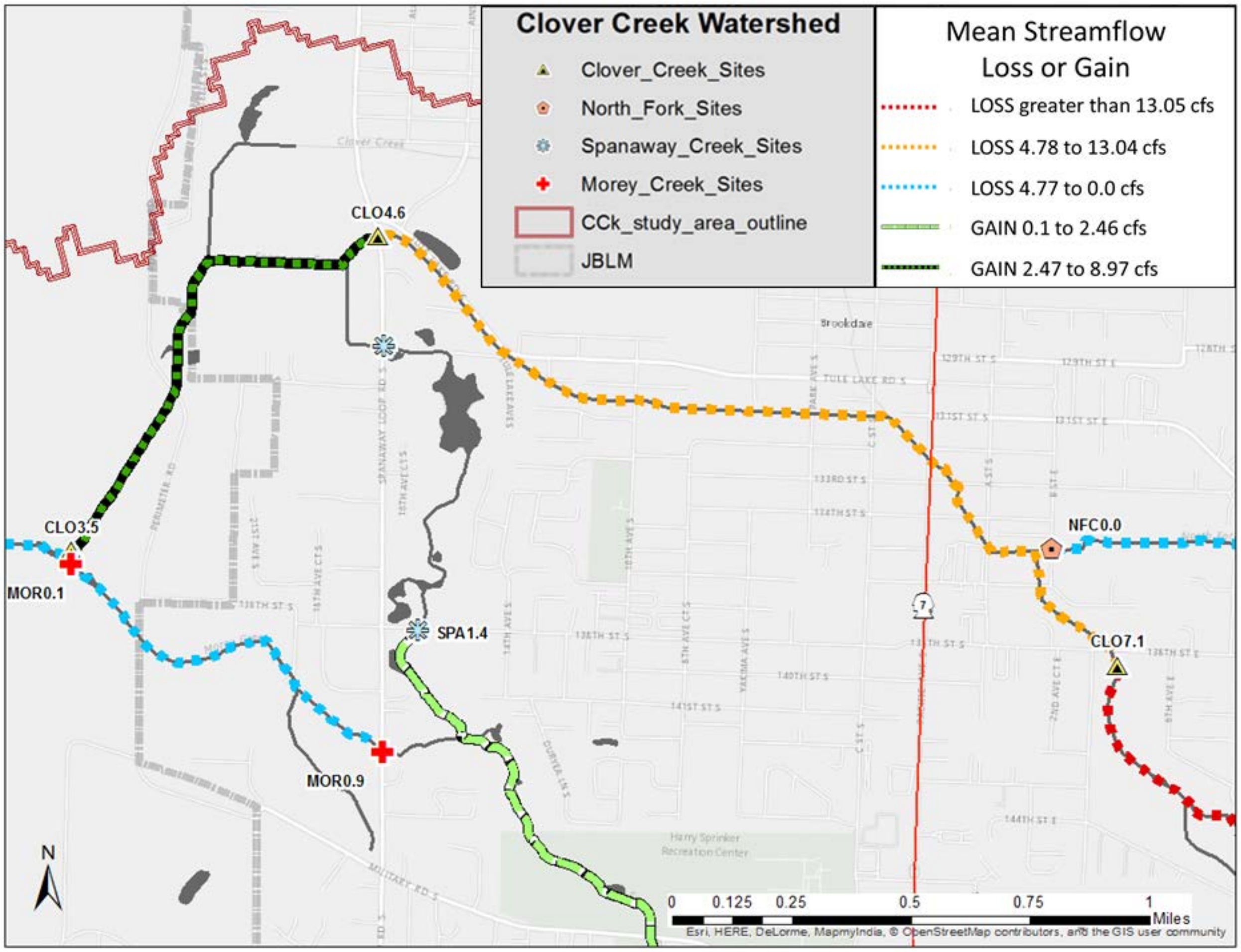


Figure A-12. Mean streamflow loss or gain.

Monthly Discharge

Field staff observed that flow became subsurface in this reach. CLO4.6, which has a concrete channel bed, was dry 60% of the time. Streamflow was reduced at CLO4.6 at minimum, mean, and maximum flow levels. Figure A-13 shows that this site was dry all summer, and the rest of the year the flow increased after rain events and then quickly returned to very low flow.

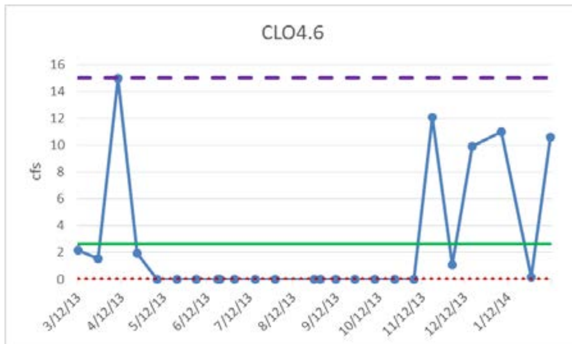


Figure A-13. Instantaneous discharge measurements by Ecology from March 2013 to February 2014. Horizontal lines show minimum, mean, and maximum values from bottom to top.

CLO3.5 is located in the mainstem of Clover Creek, downstream from Spanaway Creek. During the study period, Spanaway Creek contributed most of the flow downstream to CLO3.5 – 100% of the minimum, over 80% of the mean, and nearly 70% of the maximum. Clover Creek at CLO3.5 gained streamflow during both maximum and average flows. The most was gained during high flow (over 30 cfs), with less gained during mean (over 6 cfs) flow. The site flowed the entire sample period (minimum flow 3.8 cfs), despite a loss of over 2 cfs at minimum flow (Figure A-14).

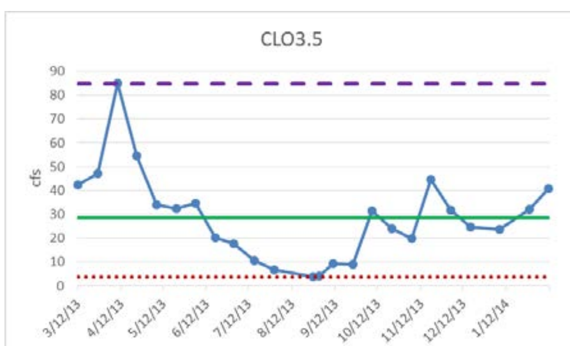


Figure A-14. Instantaneous discharge measurements by Ecology from March 2013 to February 2014. Horizontal lines show minimum, mean, and maximum values from bottom to top.

Dissolved Oxygen

CLO3.5 met the water quality criterion (8.0 mg/L) for DO in the winter, but not in the summer based on diurnal data. The mean of DO measurements taken during site visits was below the water quality standard at CLO3.5, but above at CLO4.6. Ecology did not collect diurnal data at CLO4.6.

Temperature

Based on temperature logger data, CLO3.5 did not meet the water quality criteria for temperature (17.5°C). The temperature measurements taken during site visits at CLO4.6 were above the water quality criterion (see Appendix D), but no continuous temperature data is available for this site.

Riparian Corridor

CLO4.6 had the lowest percentage of effective shade (4.4%) in the watershed (Figure A-15). This site has a concrete channel bed and was dry 60% of the time (during the warmer summer months). If the flow regime observed during this study is typical, adding shade in this location may not affect water temperature in the summer. Restoration of the riparian buffer downstream of the Spanaway Creek confluence, where surface flow is more reliable, could lower temperatures by proving shade in the summer.

Figure A-15. Photographs of CLO4.6

Bioassessment

Ecology collected benthic macroinvertebrates and periphyton at CLO3.5.

Based on B-IBI scores, the biological condition of CLO3.5 is ranked as Poor. Taxa richness was lower than the reference sites. Also, the richness of all EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa, as well as clinger, predator, and long-lived taxa, was reduced compared to the reference sites. A higher percentage of dominant taxa was found at CLO3.5 compared to the reference sites. No intolerant species were collected.

Comparing the periphyton metrics for the sample collected at CLO3.5 to the reference sites, CLO3.5 had higher Shannon diversity and species richness values. Higher numbers of algal species are often linked to nutrient enrichment. The sample collected at CLO3.5 also had higher percentages of 2 other indicators of elevated nutrients: eutraphentic and facultative nitrogen heterotroph taxa. Eutraphentic taxa are periphyton with preferences for nutrient-enriched, eutrophic water. Facultative nitrogen heterotrophs are periphyton taxa that can tolerate periodic elevated concentrations of organically bound nitrogen and generally increase with episodic nutrient enrichment.

High percentages of 2 types of taxa collected at CLO3.5 are indicators of low dissolved oxygen (DO): low DO taxa and polysaprobous. Low DO taxa can tolerate low levels of DO. Polysaprobous taxa are indicative of depressed DO levels and elevated biological oxygen demand. Saprobity is a measure of nutrient enrichment characterized by the combination of DO, organic matter, products of septic decay, and mineralization within the water.

Compared to the reference sites, samples collected at CLO3.5 had a higher percentage of 2 taxa that indicate excess sedimentation: mobile and siltation taxa. The percent of motile taxa increases in response to excess sediment. Percent siltation taxa is the relative abundance of several periphyton groups known to increase in response to increased sedimentation.

Samples collected at CLO3.5 also had a higher percentage of metal tolerance and acidophilous taxa. Metals tolerant taxa are less sensitive to metals contamination. Acidophilous taxa have the ability to survive and reproduce in a relatively acidic environment.

Lower Clover Creek

Fecal Coliform Bacteria (FC)

Table A-3 summarizes FC data for the 3 sites in the lower Clover Creek subbasin.

Table A-3. Summary of FC data for the lower Clover Creek subbasin.

Site	FC Geometric Mean (cfu/100 mL)	FC 90th Percentile (cfu/100 mL)	Percent FC Exceeding WQ Criterion	Stormwater FC (cfu/100 mL)
CLO1.9*	82	**412**	**22**	**440**
CLO1.4	71	**214**	**13**	**470**
CLO0.4	**117**	**340**	**26**	**490**

Bold/highlighted values exceeded standards.

*indicates CLO1.9 is not normally distributed.

CLO1.4 and CLO1.9 met the *Primary Contact Recreation* FC criteria for the geometric mean. However, 13 to 22% of samples and the 90th percentiles exceeded 200 cfu/100 mL.

CLO1.9 had relatively high FC and flow, so it contributed more to the FC load. In fact, CLO1.9 had the highest annual and wet season loads compared to all other sites. Ecology recommends a 76% FC reduction during the wet season in this reach based on the high geometric mean (124 cfu/100 mL) and load (387 billion cfu/day) during the wet season.

CLO1.4 had relatively high flow, but somewhat lower FC. Ecology recommends a 40% FC dry season reduction at this site to meet the *Primary Contact Recreation* standard for bacteria.

FC exceeded both *Primary Contact Recreation* FC criteria at CLO0.4. CLO0.4 had relatively high FC and flow, so it contributed more to the FC load. Samples collected during the dry season had significantly higher concentrations of FC. In order to meet the bacteria standard for *Primary Contact Recreation*, Ecology recommends a 59% reduction of FC during the dry season at CLO0.4.

Storm-Event FC

Stormwater samples from all 3 sites exceeded the *Primary Contact Recreation* bacteria criterion (200 cfu/100 mL for a single sample). The FC concentration increased going downstream, from 2.2 times the standard at CLO1.9 to 2.5 times the standard at CLO0.4.

Figure A-16 shows the location of some stormwater outfalls and density of OSS in the lower Clover Creek subbasin. The density of OSS was low (0 to 1 per acre) in the area surrounding lower Clover Creek.

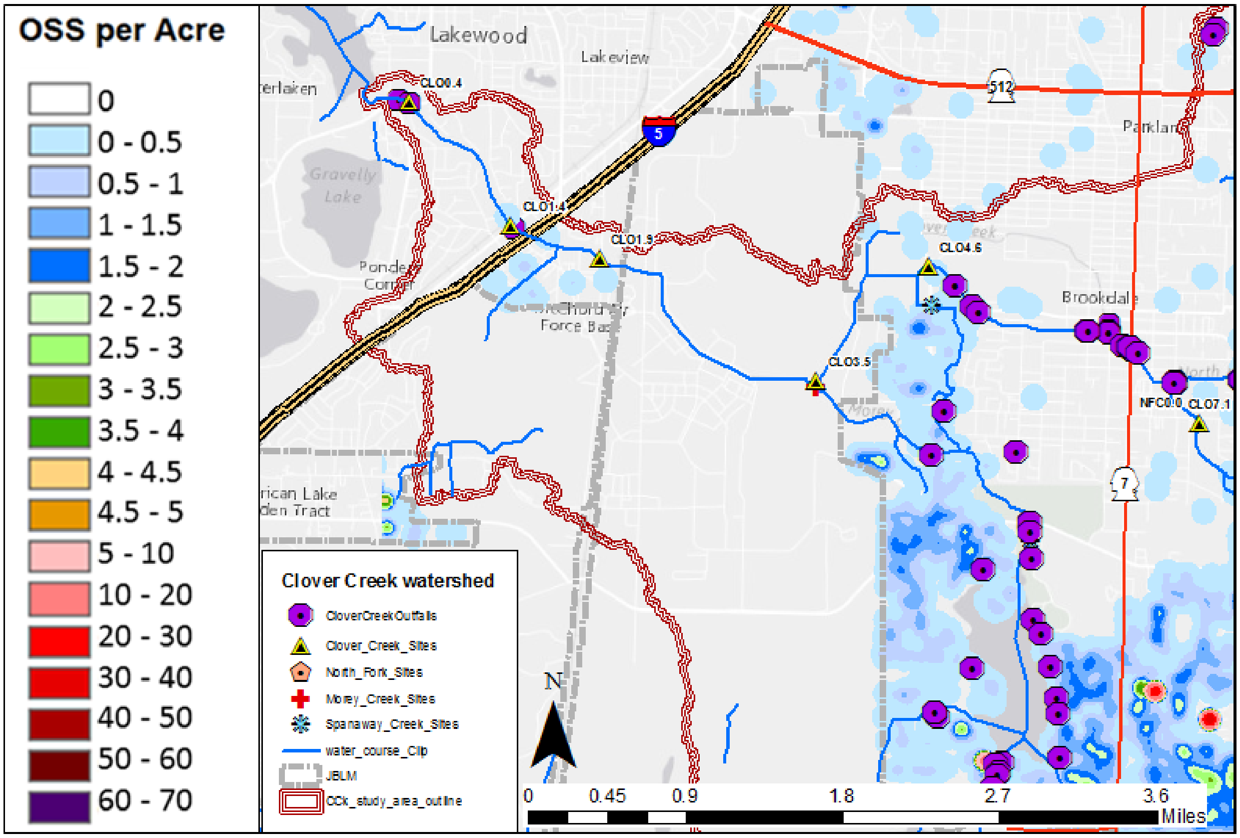


Figure A-16. Map of lower Clover Creek OSS and stormwater outfalls.

Hydrology

Figures A-17 and A-18 show that lower Clover Creek tended to lose flow during the study period. Streamflow was lost between CLO3.5 and CLO1.9 during maximum and average flows. A small amount of flow was gained during minimal flows. Clover Creek continued to lose streamflow between CLO1.9 and CLO1.4. It lost the most during maximum flows, with smaller losses during minimum and average flows. Water loss continued from CLO1.4 to CLO0.4, where flow was reduced during average and minimum flows. There was no observed gain or loss of maximum flow between CLO1.4 and CLO0.4.

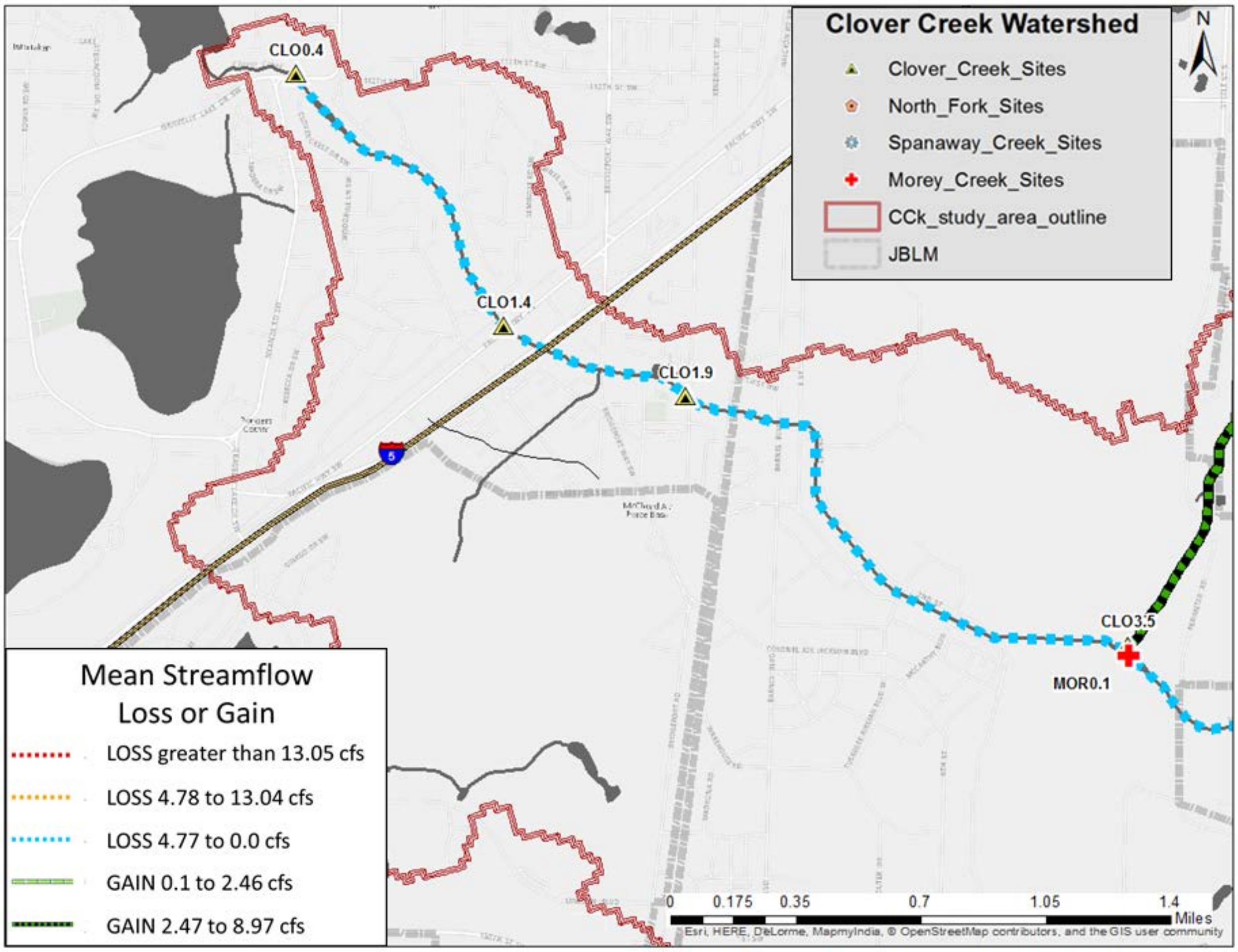


Figure A-17. Mean streamflow loss or gain in the lower Clover Creek subbasin.

Figure A-18. Instantaneous discharge measurements by Ecology from March 2013 to February 2014. Horizontal lines show minimum, mean, and maximum values from bottom to top.

Dissolved Oxygen

Based on diurnal data, CLO0.4 met the water quality criterion (8.0 mg/L) for DO in both the winter and summer. All DO measurements taken during site visits at CLO0.4 were above the water quality criteria, as well. Ecology did not collect diurnal data at CLO1.9 and CLO1.4. The DO concentration at these sites fell below the water quality criteria for some measurements taken during site visits. At CLO1.4, the DO concentration was below 8.0 mg/L during July and from late August until late September. At CLO1.9, the DO concentration was below 8.0 mg/L during July and again from mid-August until mid-October.

Temperature

All 3 sites exceeded the water quality criterion for temperature (17.5°C) for both temperature logger and temperature measurements taken during site visits.

Riparian Corridor

Percent effective shade, which is shade provided by both vegetation and topography, increased from the upstream site (CLO1.9) to the 2 downstream sites (56.2 to 81.7%). Ecology did not take hemispheric photographs at CLO3.5 on Joint Base Lewis-McChord (JBLM), where the riparian buffer is largely absent (Figure A-19).

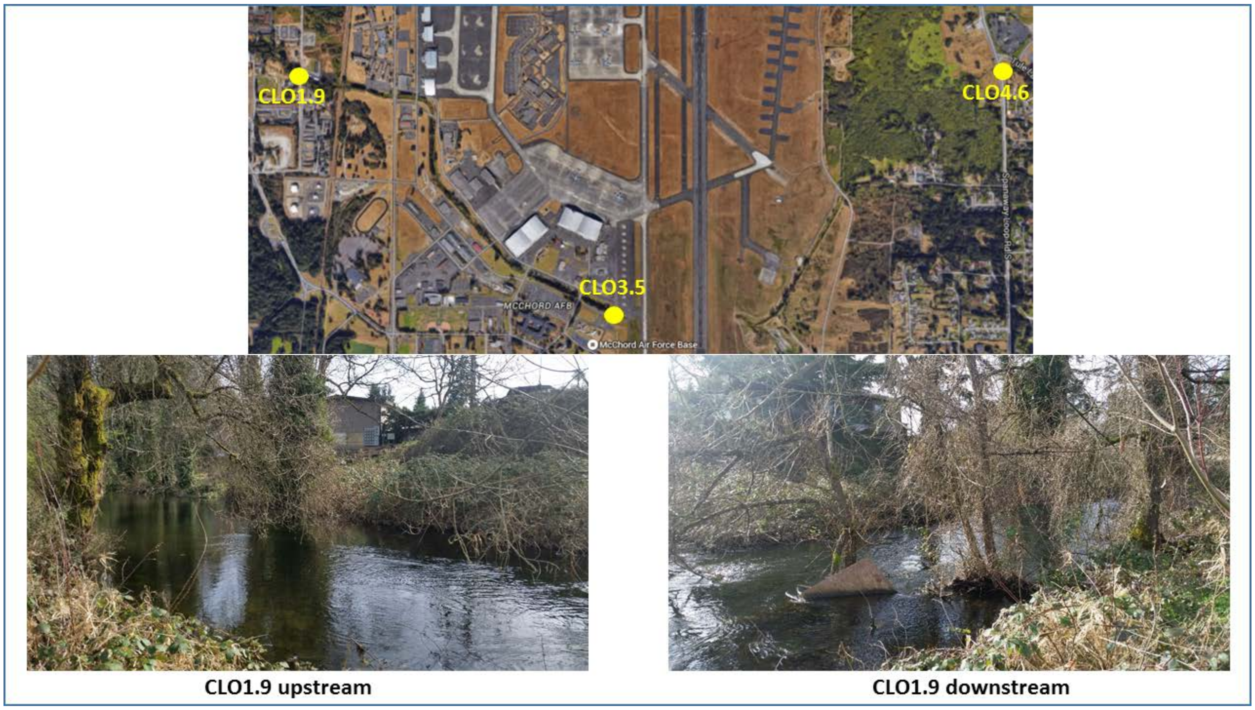


Figure A-19. Photographs of CLO1.9.

The riparian buffer is narrow in lower Clover Creek, but scattered tall trees provide shade, and shrubs and vines line the bank. Native and invasive vegetation provide cover for wildlife and for people to camp (Figure A-20).

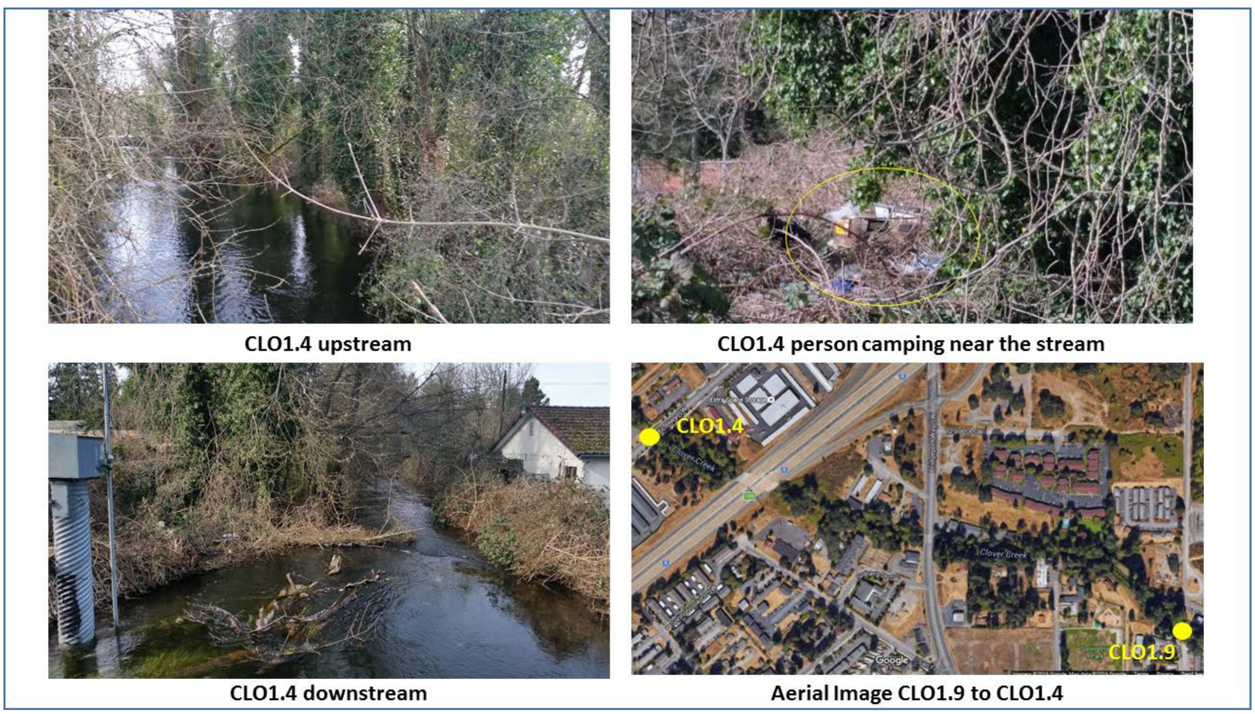


Figure A-20. Photographs of CLO1.4.

The stream is channelized at CLO0.4. Figure A-21 show that maintained lawn borders the right bank upstream of CLO0.4. Downstream of Gravelly Lake Road, a narrow band of trees provides canopy above the modified channel.

Figure A-21. Photographs of CLO0.4.

Bioassessment

Ecology collected benthic macroinvertebrates and periphyton at CLO1.4.

According to the B-IBI, the biological condition at CLO1.4 was Very Poor, which is characterized by overall very low taxa diversity. Compared to the reference sites, taxa richness was reduced. Also, richness of EPT, Ephemeroptera, Trichoptera, clinger, long-lived, and predator taxa was reduced. No Plecoptera or intolerant taxa were collected. A higher percentage of tolerant and dominant taxa were found at CLO1.4 compared to the reference sites.

Comparing the periphyton metrics for the reference sites to CLO1.4, CLO1.4 had higher Shannon Diversity and taxa richness. Nutrient enriched sites often have large numbers of algal species. CLO1.4 also had higher percentages of eutraphentic and facultative nitrogen autotroph taxa. Eutraphentic taxa are periphyton with preferences for nutrient-enriched, eutrophic water. Facultative nitrogen heterotrophs are periphyton taxa that can tolerate periodic elevated concentrations of organically bound nitrogen.

CLO1.4 had a higher percentage of low DO taxa than the reference sites. These taxa are tolerant of low levels of DO.

CLO1.4 had a higher percentage of motile taxa. The percent of motile taxa increases in response to excess sediment.

Upper North Fork of Clover Creek

Fecal Coliform Bacteria (FC)

Table A-4 summarizes FC data for the 6 monitoring sites in the upper North Fork subbasin.

Table A-4. Summary of FC data for the upper North Fork subbasin.

Site	FC Geometric Mean (cfu/100 mL)	FC 90th Percentile (cfu/100 mL)	Percent FC Exceeding WQ Criterion	Stormwater FC (cfu/100 mL)
NFCB1.7	**52**	**216**	**20**	NA
NFCB1.4	**99**	**955**	**38**	NA
NFCB1.1	**207**	**1263**	**74**	**1300**
NFCB1.4W*	**106**	**328**	**71**	NA
NFCB1.1LB	26	**313**	**50**	dry
NFCB1.1RB*	**113**	**880**	**56**	**2900**

Bold/highlighted values exceeded standards.

*Distribution is not normally distributed based on Shapiro-Wilk Normality Test.

Two bacteria investigatory sites, NFCB1.7 and NFCB1.4, and the stormwater outfall NFCB1.1LB met the *Primary Contact Recreation* bacteria geometric mean criterion. However, over 10% of samples and the 90th percentiles for all 3 sites exceeded 200 cfu/100 mL.

Three sites exceed both *Primary Contact Recreation* criteria: NFCB1.1, the investigatory site NFCB1.4W, and the stormwater outfall NFCB1.1RB.

NFCB1.1, the stream site located upstream of the stormwater outfalls (NFCB1.1LB and RB), had the highest geometric mean and 90th percentile. Seventy-four percent of samples exceeded the *Primary Contact Recreation* criterion. The FC concentration was higher in the dry season. NFCB1.1 had relatively high FC, but low flow. Ecology recommends reducing FC at NFCB1.1 by 91% during the dry season and 61% during the wet season.

Figure A-22 shows locations of stormwater outfalls and the density of OSS in the upper North Fork subbasin.

The density of OSS was relatively low (0 to 2 per acre) in most of the area around the North Fork. Some OSS are located within 300 feet of the stream in the reach between NFCB1.4 and NFCB1.1.

The stormwater outfall point file provided by Pierce County shows 28 stormwater outfalls in the upper North Fork area. Two stormwater outfalls are at 121st Street (NFCB1.1RB and NFCB1.1LB). Ecology collected samples at both NFCB1.1 stormwater outfalls when they were running. NFCB1.1 stormwater outfalls did not flow from mid-June to mid-September. By late September and early October, discharge resumed. When flow was measured at these sites, it was less than 0.1 cfs at each.

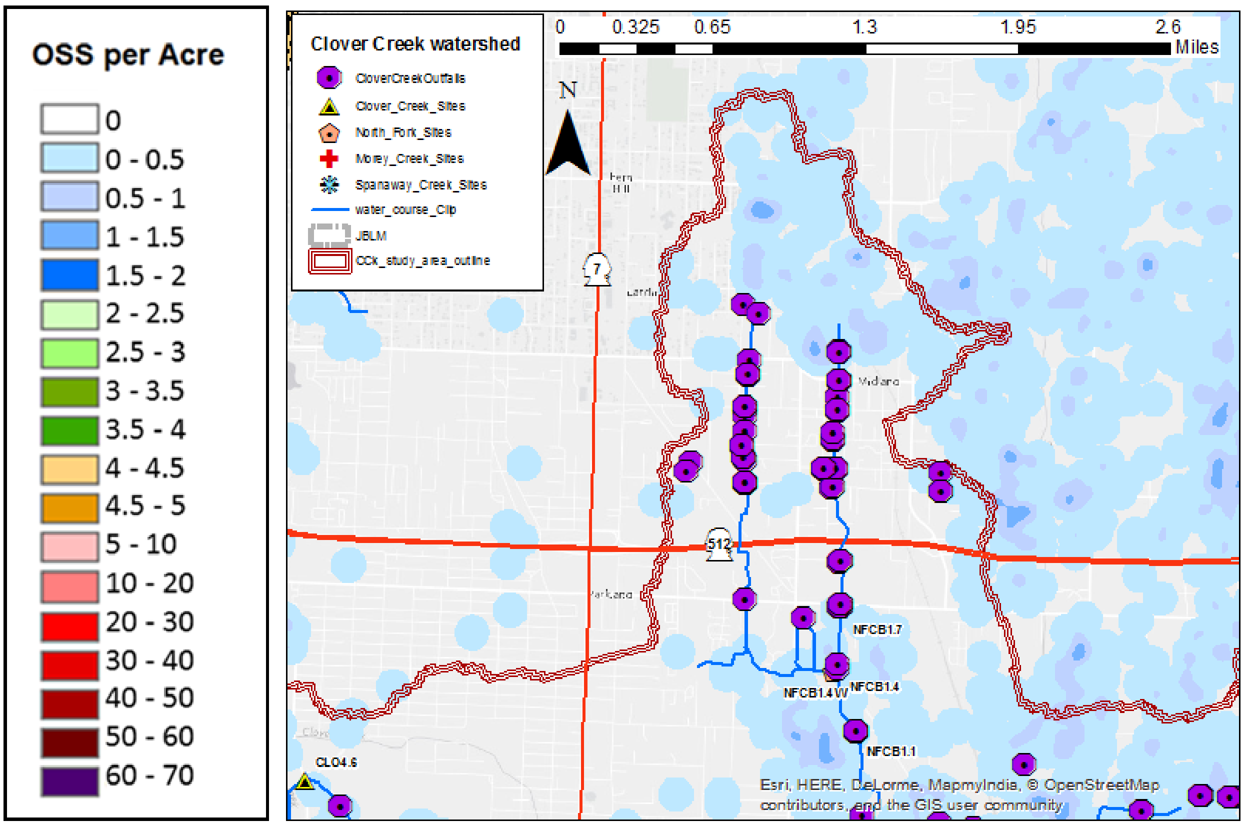


Figure A-22. Map of the upper North Fork Clover Creek percent OSS per acre and locations of OSS and stormwater outfalls.

Storm-Event FC

Ecology collected 2 stormwater samples in this reach, one in the stream at the fixed-site NFCB1.1 and another at a stormwater outfall. Both samples exceeded the water quality standard (200 cfu/100 mL). The sample collected at NFCB1.1 was 6.5 times the standard. The sample collected at the outfall NFCB1.1RB was 14.5 times the standard.

Hydrology

The mean flow at NFCB1.1 was almost 2 cfs (minimum flow less than 0.1, maximum flow over 9 cfs). The flow at NFCB1.1 dropped below 1 cfs intermittently in May and June. From July to September, flow remained consistently below 1 cfs. NFCB1.7 and 1.4 were added later in the study as bacteria investigatory sites with no regular flow measurements.

Dissolved Oxygen

No diurnal DO data were collected in the upper North Fork. Ecology collected DO measurements during site visits at NFCB1.1. The mean DO concentration (8.77 mg/L) was above the water quality criterion of 8.0 mg/L. The minimum and 10th percentile DO concentrations were below 8.0 mg/L.

Temperature

NFCB1.1 exceeded the 7-DADMax temperature (17.5°C) based on temperature logger data. The maximum and 90th percentile temperature measurements collected during site visits exceeded 17.5°C. Restoration of the riparian buffer in this area may not reduce temperatures directly by providing shade. During the study period, streamflow was low and intermittent during the warmest time of the year (May to September). However, improving buffers and infiltration of water into the soil could reduce stormflow and improve baseflow, which could help reduce stream water temperatures.

Lower North Fork of Clover Creek

Fecal Coliform Bacteria (FC)

Table A-5 summarizes data for the 3 monitoring sites in the lower North Fork subbasin.

Table A-5. Summary of FC data for the lower North Fork subbasin.

Site	FC Geometric Mean (cfu/100 mL)	FC 90th Percentile (cfu/100 mL)	Percent FC Exceeding WQ Criterion	Stormwater FC (cfu/100 mL)
NFCB0.0 northern branch	**93**	**302**	**41**	**1600**
NFC1.0 eastern branch	**73**	**480**	**31**	**210**
NFC0.0 downstream of confluence	**126**	**564**	**56**	**1800**

Bold/highlighted values exceeded standards.

Both sites on the northern and eastern branches (NFCB0.0 and NFC1.0) met the *Primary Contact Recreation* for the geometric mean. However, over 10% of samples collected at these sites exceeded 200 cfu/100 mL, as did the 90th percentiles. The FC concentration was significantly higher during the dry season at NFCB0.0. Ecology recommends a 37% reduction during the dry season and 25% reduction during the wet season.

NFC0.0 exceeded both parts of the *Primary Contact Recreation* bacteria criteria. Also, the 90th percentile exceeded 200 cfu/100 mL. Ecology recommends a 63% reduction in FC during the wet season.

Figure A-23 shows the density of OSS and some of the stormwater outfalls in the area around NFCB1.1 to NFC0.0. The density of OSS was relatively low (0 to 1.5 per acre) in most of the lower subbasin of the North Fork. According to the Pierce County point file, 44 stormwater outfalls are located in the lower North Fork (below NFCB1.1) and in the eastern branch. Ecology did not collect samples from the stormwater outfalls.

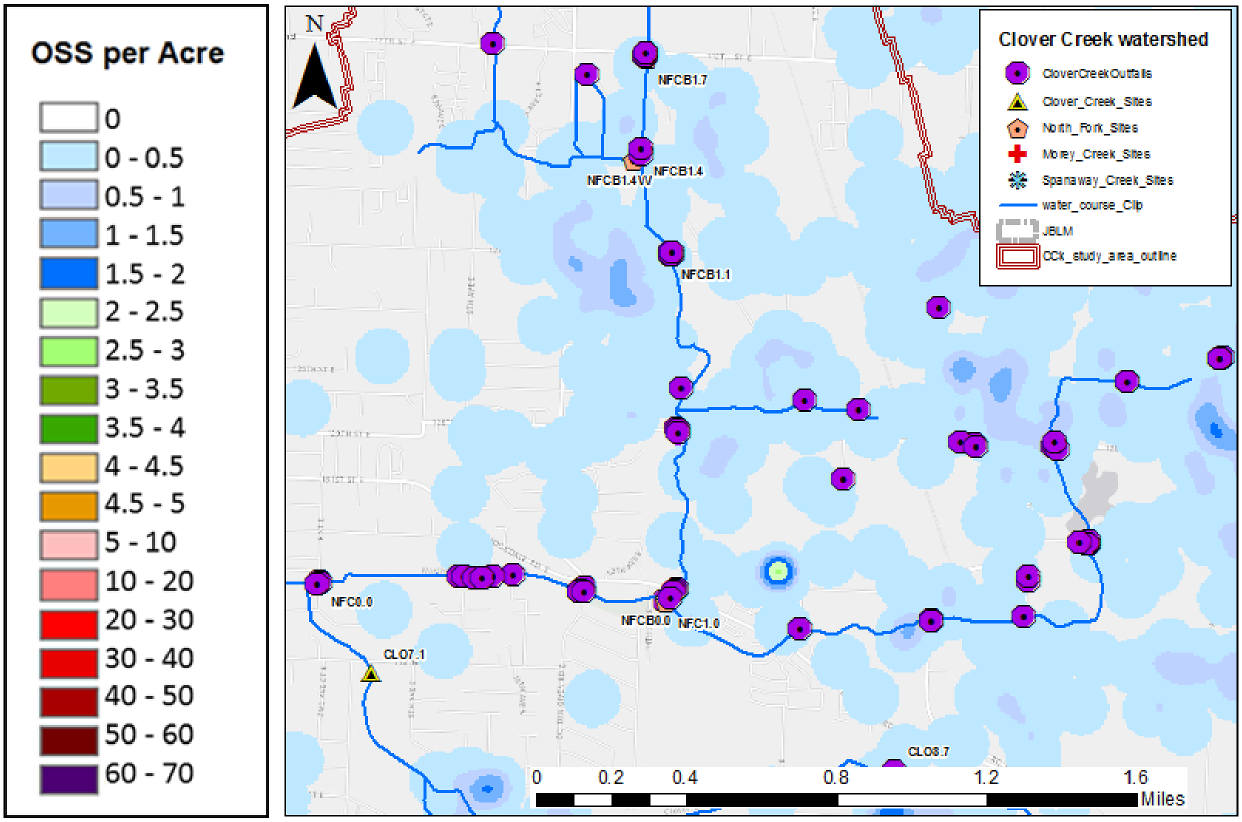


Figure A-23. Map showing the OSS per acre and locations of OSS and stormwater outfalls in the lower North Fork subbasin.

Storm-Event FC

Ecology collected stormwater samples in the stream at 3 sites. The stormwater sample collected from the northern branch had a higher FC concentration (1600 cfu/100 mL) compared to in the eastern branch (210 cfu/100 mL). The stormwater sample collected at NFC0.0 (1800 cfu/100 mL) was higher than both upstream sites.

Hydrology

Figure A-12 shows that surface flow increased in the northern branch from NFCB1.1 to NFCB0.0 during mean flows. Downstream toward the confluence with Clover Creek, the North Fork lost mean surface flow.

Monthly Discharge

Ecology monitored discharge at 4 sites on the North Fork. NFCB0.0 (the northern branch) gained the most at the maximum flow (9 cfs) and a smaller amount during average flow (a little over 2 cfs). Both sites monitored at the north branch tended to increase in flow after precipitation and then swiftly drop back to low flow (Figure A-24). The flow at NFCB1.1 dropped below 1 cfs intermittently in May and June. From July to September, flow remained consistently below 1 cfs. Downstream at NFCB0.0, flow was below 1 cfs from July to September.

The culvert outfalls at 121st (NFCB1.1RB and NFCB1.1LB) were intermittent. Both had no flow from mid-June to mid-September. By late September and early October, discharge resumed. When flow was measured at these sites, it was less than 0.1 cfs at each.

Figure A-24. Instantaneous discharge measurements by Ecology from March 2013 to February 2014. Horizontal lines show minimum, mean, and maximum values from bottom to top.

NFC1.0 (on the eastern branch) was intermittent from early May to early June, with flows from 0 to less than 1 cfs (Figure A-26). It was dry from mid-June to mid-September. It began to flow again in late September, but flows remained below 1 cfs until mid-November.

The North Fork lost streamflow below the 2 branches (Figure A-25). The sum of the minimum, mean, and maximum flow for the northern and eastern branches was: 0 cfs, over 6 cfs, and 31 cfs. Flow was lost in the reach upstream of NFC0.0 during both the average (approximately 2.5 cfs) and maximum (approximately 4.4 cfs) flow conditions.

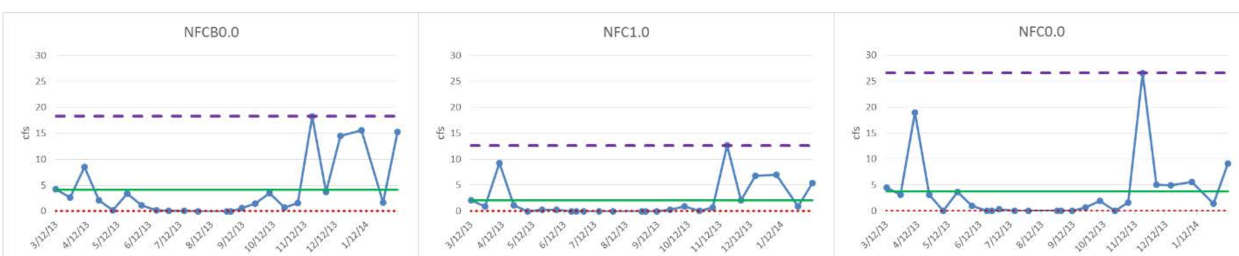


Figure A-25. Instantaneous discharge measurements by Ecology from March 2013 to February 2014. Horizontal lines show minimum, mean, and maximum values from bottom to top.

Dissolved Oxygen

NFC0.0 was above the water quality criteria in the winter based on diurnal DO measurements. NFC0.0 was dry in the summer. Ecology did not collect diurnal measurements at the other 2 sites. No DO measurements taken during sites visits were below 8.0 mg/L.

Temperature

Both NFCB0.0 and NFC0.0 exceeded the 7-DADMax temperature (17.5°C) based on temperature logger data. The maximum and 90th percentile of temperature measurements collected during site visits exceeded 17.5°C.

Ecology did not deploy a temperature logger at NFC1.0. Temperature measurements collected at NFC1.0 during site visits exceeded 17.5°C in June.

Riparian Corridor

Percent average effective shade (11.6 to 17.2%) was very low at all 3 sites (Figures A-26 to A-27). Given the low and intermittent flow in the upper North Fork, restoration of these riparian buffers may not reduce temperatures directly by providing shade. However, projects to increase infiltration of stormwater into the soil could improve baseflow.

Figure A-26. Aerial photograph of confluence of northern and eastern branches of the North Fork Clover Creek.

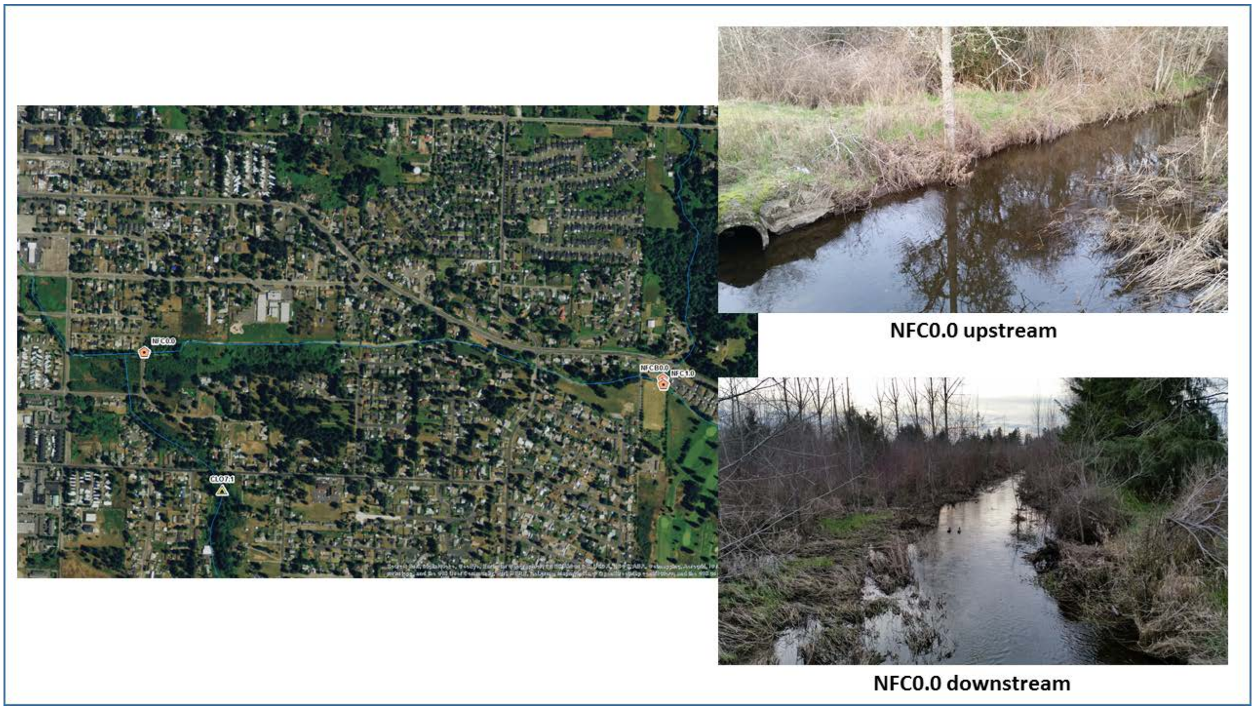


Figure A-27. Photographs at NFC0.0.

Bioassessment

The biological condition at NFC0.0 was Very Poor, which is characterized by overall very low taxa diversity. The benthic community was dominated by a few highly tolerant taxa. Taxa richness was reduced compared to the reference sites, as was EPT, Ephemeroptera, Trichoptera, clinger, and predator taxa. No Plecoptera, long-lived, or intolerant taxa were collected. The proportion of tolerant and dominant taxa was higher than the reference sites.

Comparing the periphyton metrics for the reference sites to NFC0.0, higher percentages of 3 metrics indicate elevated nutrients and depressed DO at NFC0.0: facultative nitrogen heterotroph, low DO, and polysaprobous taxa. Facultative nitrogen heterotroph taxa can tolerate periodic elevated concentrations of organically bound nitrogen and generally increase with episodic nutrient enrichment. Low DO taxa can tolerate low levels of DO. A high percentage of polysaprobous taxa indicate depressed DO levels and elevated biological oxygen demand.

NFC0.0 had higher percentages of motile and siltation taxa compared to the reference sites. Both of these types of taxa tend to increase in response to increased sedimentation

NFC0.0 also had a higher percentage of metals tolerant taxa, which are less sensitive to metals contamination.

Spanaway Creek

Fecal Coliform Bacteria (FC)

Table A-6 summarizes FC data for the 3 monitoring sites in the Spanaway Creek subbasin.

Table A-6. Summary of FC data for the Spanaway Creek subbasin.

Site	FC Geometric Mean (cfu/100 mL)	FC 90th Percentile (cfu/100 mL)	Percent FC Exceeding WQ Criterion	Stormwater FC (cfu/100 mL)
SPA1.8	18	102	4	**220**
SPA1.4	36	142	0	190
SPA0.5	50	161	9	**250**

Bold/highlighted values exceeded standards.

FC met the water quality criteria for *Primary Contact Recreation* at Spanaway Creek. The lowest geometric mean at all Ecology sites in the watershed was at SPA1.8. None of the samples collected at SPA1.4 exceeded the water quality standard. The site with the highest bacteria levels was SPA0.5, which met standards except for the one sample collected during the storm event.

Storm-Event FC

Ecology collected samples in the stream (not from outfalls) during one storm event. Two of the samples (at SPA1.8 and SPA0.5) exceeded the criterion for a single sample (200 cfu/100 mL).

Hydrology

Spanaway Creek gained streamflow from SPA1.8 to SPA1.4 (Figure A-12). Flow was not measured at SPA0.5 because the site was a wetland without a discernible channel and flow direction. Permission to access another more suitable site was denied.

Monthly Discharge

Spanaway Creek gained the most during average (almost 1.5 cfs) and maximum (approximately 1 cfs) flow conditions. A small amount was gained during minimum flow (approximately 0.3 cfs). Spanaway Creek flowed during the entire sampling period and appeared less flashy than other parts of the watershed (Figure A-28).

Figure A-28. Instantaneous discharge measurements by Ecology from March 2013 to February 2014. Horizontal lines show minimum, mean, and maximum values from bottom to top.

Dissolved Oxygen

Diurnal DO measurements reveal that SPA1.8 was above the water quality criterion in the winter and below in the summer. DO measurements taken during sample collection were above the 8.0 mg/L criterion at all sites.

Temperature

All 3 sites exceeded the water quality criterion for temperature (17.5°C) according to the temperature logger data. Temperature measurements taken during site visits exceeded 17.5°C from June to September at SPA0.5 and SPA1.4. At SPA1.8, temperature exceeded the criterion from May to September.

Riparian Corridor

Figures A-29 to A-31 show sites at Spanaway Creek. The percent average effective shade was relatively low at SPA1.4 (21.6%). Enhancement of the riparian buffer along Spanaway Creek could reduce water temperature by providing shade. Spanaway Creek provides a significant amount of flow to Clover Creek. Reducing water temperatures in Spanaway Creek would benefit Clover Creek downstream.

Figure A-29. Photographs of SPA1.8 at the park, where there are walking paths and ducks swimming on the lake.

Figure A-30. Photographs of SPA1.4 showing flooded fields both upstream (in the cow pasture) and downstream.

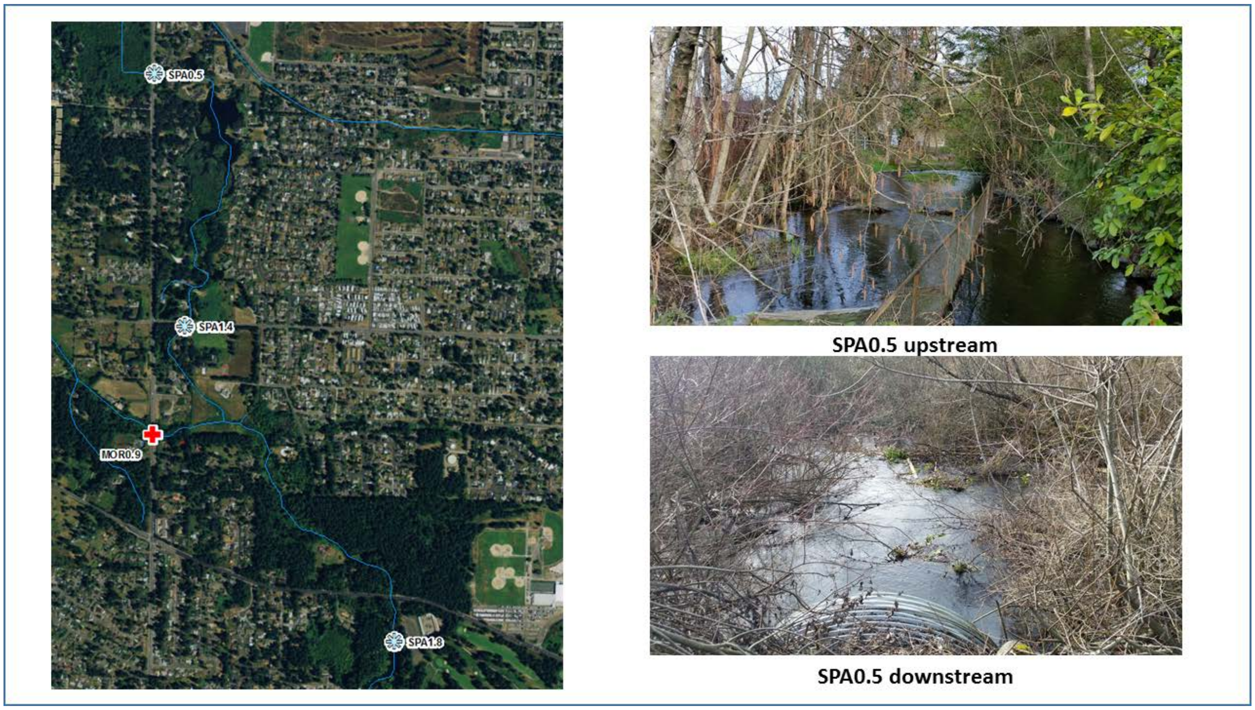


Figure A-31. Photographs of SPA0.5.

Bioassessment

According to the B-IBI, the biological condition at SPA1.8 was Very Poor. Taxa richness was reduced at SPA1.8 compared to the reference sites, as was richness of all EPT taxa. Clinger, long-lived, predator, dominant, and nitrogen autotroph taxa richness was also reduced. The proportion of dominant and tolerant species was higher at SPA1.8. No intolerant taxa were collected at SPA1.8.

Comparing the periphyton metrics for SPA1.8 to the reference sites, SPA1.8 had higher Shannon diversity and taxa richness values. Nutrient enrichment can cause an increased number of algal species. Compared to the reference sites, SPA1.8 had a higher percentage of 2 taxa groups that are indicators of elevated nutrient levels. The samples had a higher percentage of facultative nitrogen heterotroph taxa, which can tolerate periodic elevated concentrations of organically bound nitrogen. Also the samples contained higher percentages of eutraphentic taxa, which prefer nutrient-enriched, eutrophic water.

Furthermore, SPA1.8 had a higher percentage of low DO than the reference sites. This taxa can tolerate low levels of DO.

SPA1.8 had higher percentages of motile and siltation taxa compared to the reference sites. Both of these taxa increase in response to excess sediment.

SPA1.8 also had a higher percentages of metals tolerant and acidophilous taxa. Metals tolerant taxa are less sensitive to metals contamination. Acidophilous taxa have the ability to survive and reproduce in a relatively acidic environment.

Morey Creek

Fecal Coliform Bacteria (FC)

Table A-7 summarizes FC data for the 2 monitoring sites in the Morey Creek subbasin.

Table A-7. Summary of FC data for the Morey Creek subbasin.

Site	FC Geometric Mean (cfu/100 mL)	FC 90th Percentile (cfu/100 mL)	Percent FC Exceeding WQ Criterion	Stormwater FC (cfu/100 mL)
MOR0.9	22	**107**	5	**220**
MOR0.1*	17	**107**	4	**310**

*Distribution is not normally distributed based on Shapiro-Wilk Normality Test.

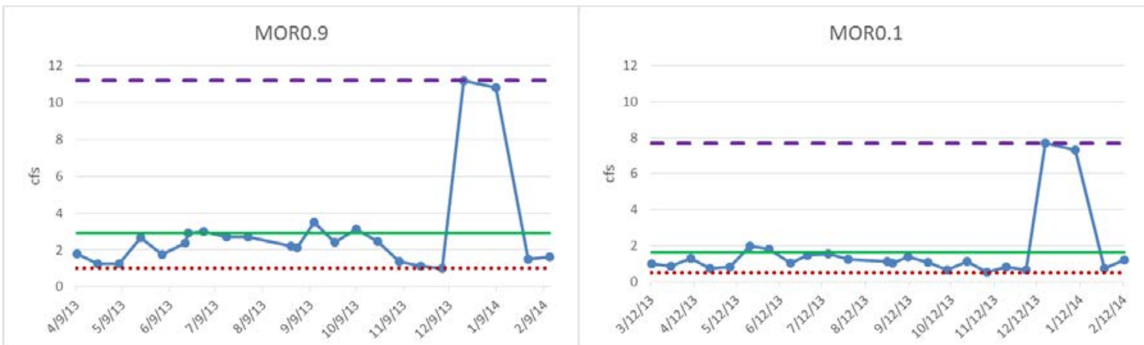
Both Morey Creek sites met both *Primary Contact Recreation* criteria. Both sites had low FC and flow.

Storm-Event FC

Samples collected from Morey Creek during the storm event exceeded the water quality criterion of 200 cfu/100 mL.

Hydrology

Figure A-12 shows that Morey Creek lost streamflow going downstream. Figure A-32 shows that streamflow was higher at MOR0.9, near where it branched off from Spanaway Creek. Morey Creek lost at minimum (approximately 0.5 cfs), average (approximately 1.3 cfs), and maximum (approximately 3.5 cfs) flows. Morey Creek enters Clover Creek downstream from CLO3.5. Morey Creek contributed an average of over 1.5 cfs (minimum approximately 0.5, maximum over 7.5 cfs) to Clover Creek.



*No flows were taken at MOR0.9 in March 2013

Figure A-32. Instantaneous discharge measurements by Ecology from March 2013 to February 2014. Horizontal lines show minimum, mean, and maximum values from bottom to top.

Dissolved Oxygen

No diurnal DO data were collected in Morey Creek. The minimum and 10th percentile of DO concentration collected during site visits were below the criterion of 8.0 mg/L for both sites. During site visits, DO at MOR0.1 was below 8.0 mg/L from July to September. At MOR0.9, the DO was below 8.0 mg/L from June to December.

Temperature

Both sites exceeded the 7-DADMax temperature (17.5°C) based on both temperature logger data. The maximum and 90th percentile of temperature data collected during site visits exceeded 17.5°C.

Riparian Corridor

Percent average effective shade was higher at the upstream site (82.1%) than at the downstream site (53.2%). Much of the riparian buffer, especially the right bank, could be enhanced along Morey Creek.

Appendix B. Quality Assurance

Hydrology

Ecology collected streamflow data with a Marsh McBirney Flow-Mate flow meter. All procedures and protocols for flow complied with the QA Project Plan.

USGS data for Clover Creek and the North Fork Clover Creek are available at https://www2.usgs.gov/water/. Data available at that site are presented in Figures B-1 and B-2, respectively.

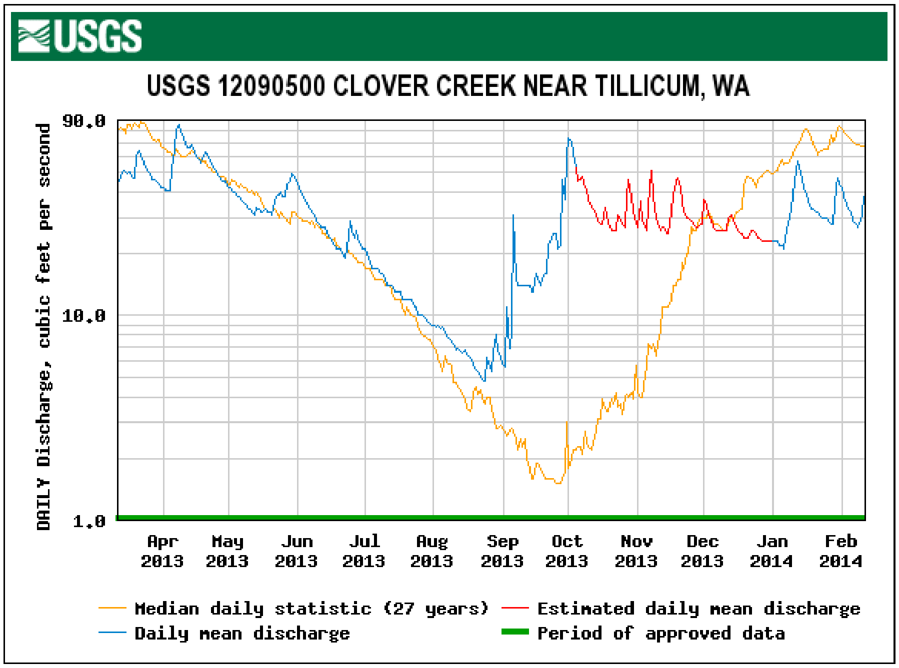


Figure B-1. USGS discharge (cfs) data at Clover Creek at Pacific Highway.

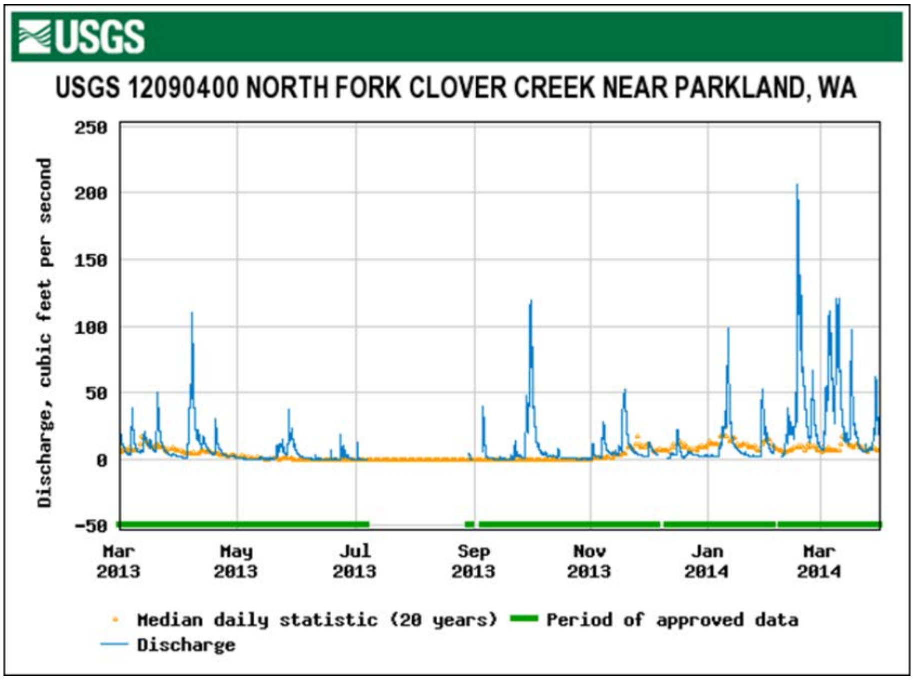


Figure B-2. USGS discharge (cfs) data at North Fork Clover Creek at Golden Given Road.

In order to compare Ecology's instantaneous discharge measurements at CLO0.4 to the mean daily discharge from the USGS site (12090500), the relative percent difference (RPD) was calculated using the formula:

$$RPD = \frac{(G_i - E_i) * 2}{(G_i + \mathrm{E}_i)}$$

Where:

G = USGS Stream Gage daily mean

E = Ecology instantaneous flow

This formula does not take the absolute value of the error, to retain the sign and indicate the direction of bias. Table B-1 shows the RPD for each sample day. The larger differences between the 2 measurements may have been caused by:

- Comparison of instantaneous measurements with the mean daily flow. Changes in the daily flow from precipitation was not captured in Ecology's instantaneous flow measurement (e.g. in April, September, November, and January).
- Conditions that may have prevented good instantaneous flow measurements, such as low or high flows.
- Estimation of USGS mean discharge measurements from mid-October 2013 to January 2014.

Table B-1. Comparison of discharge measurements at USGS site 12090500 and Ecology site CLO1.4 at Pacific Hwy SW.

Date	CLO1.4	Gage 12090500	RPD
3/12/2012	39.9	45	0.12
3/26/2013	42.5	49	0.14
4/9/2013	66	79	0.18
4/23/2013	47.8	55	0.14
5/7/2013	34.7	36	0.04
5/21/2013	35.8	36	0.01
6/4/2013	33.5	36	0.07
6/18/2013	22.5	21	-0.07
7/1/2013	20.9	21	0.00
7/16/2013	13	13	0.00
7/30/2013	9	9.1	0.01
8/13/2013	7.1	6.7	-0.06
8/27/2013	5.1	5.3	0.04
9/10/2013	10.8	14	0.26
9/24/2013	10.1	25	0.85
10/22/2013	23	26	0.12
11/5/2013	20	26	0.26
11/19/2013	36.7	47	0.25
12/3/2013	29.7	31	0.04
12/17/2013	29.6	25	-0.17
1/7/2014	29.5	26	-0.13
1/28/2014	32.1	28	-0.14
2/11/2014	41.5	38	-0.09

Water Quality

Ecology calibrated Hydrolab® multiprobes with certified standards before each sampling trip following the SOP EAP033. Ecology also collected DO grab samples for quality assurance (QA). The samples were analyzed using the Winkler Method (Azide-Modification from APHA, 2005). The average difference between the Hydrolab® DO probe and the Winkler values was -0.17.

Table B-2. Comparison of Hydrolab DO measurements to Winkler values.

Site ID	Date and Time	DO (mg/l)	DO Winkler (mg/L)	Difference
CLO0.4	8/26/2013 16:00	9.92	10.18	-0.26
CLO0.4	8/27/2013 10:00	9.6	9.74	-0.14
CLO0.4	8/29/2013 13:30	9.52	9.28	0.24
CLO3.5	8/26/2013 15:30	5.57	5.66	-0.09
CLO3.5	8/27/2013 8:00	3.57	3.9	-0.33
CLO3.5	8/29/2013 1:00	3.4	4.15	-0.75
CLO7.1	8/26/2013 17:00	8.55	8.64	-0.09
CLO7.1	8/27/2013 14:30	8.49	8.61	-0.12
CLO7.1	8/29/2013 12:00	7.6	7.52	0.08
CLO9.8	8/27/2013 8:00	3.57	3.9	-0.33
CLO9.8	8/29/2013 10:30	6.15	6.36	-0.21
CLO12.0	8/27/2013 17:00	9.21	9.28	-0.07
CLO12.0	8/29/2013 11:00	8.88	8.89	-0.01
SPA1.8	8/27/2013 13:30	9.83	11.4	-1.57
SPA1.8	8/29/2013 11:30	9.2	9.31	-0.11
CLO0.4	12/16/2013 16:30	11.52	11.4	0.12
CLO0.4	12/17/2013 10:30	11.39	11.37	0.02
CLO0.4	12/19/2013 12:00	9.06	9.2	-0.14
CLO3.5	12/17/2013 9:00	9.6	9.7	-0.1
CLO3.5	12/19/2013 11:30	10.52	10.6	-0.08
CLO7.1	12/16/2013 15:30	10.54	10.75	-0.21
CLO7.1	12/18/2013 12:00	11.53	11.58	-0.05
CLO7.1	12/19/2013 10:30	9.55	9.54	0.01
CLO9.8	12/16/2013 14:30	8.42	8.65	-0.23
CLO9.8	12/18/2013 10:30	9.37	9.5	-0.13
CLO9.8	12/19/2013 10:00	10.28	10.39	-0.11
CLO12.0	12/16/2013 14:00	9.97	9.99	-0.02
CLO12.0	12/18/2013 9:00	10.69	10.74	-0.05
CLO12.0	12/19/2013 9:30	10.69	10.74	-0.05

Tables B-3 to B-8 show the Hydrolab® post-check criteria and values.

Table B-3. Hydrolab® post-check criteria.

Post-Calibration Evaluation Criteria
pH
≤ ±0.25 = accept
> ±0.25 and ≤ ±0.5 = estimate
> ±0.5 = reject
DO Percent Saturation
≤ ±5% = pass*
> ±5% and ≤ ±15% = estimate
> ±15% = reject*
Specific Conductance
≤ ±5% = pass
> ±5% and ≤ ±10% = estimate
> ±10% = reject

Table B-4. Hydrolab® post-check DO values.

Field Use Date(s)	Post-Check Date	Sonde #	Reference standard value	Hydrolab DO post-check value	Difference	*Conclusion*
3/12/13	3/13/13	42	100%	99.4%	-0.6%	*Pass*
3/26/13	3/27/13	42	100%	97.2%	-2.8%	*Pass*
4/9/13	4/10/13	17	100%	Membrane problem		*NA*
4/23/13	4/24/13	17	100%	98.5%	-1.5%	*Pass*
5/7/13	5/8/13	40	100%	100.5%	0.5%	*Pass*
5/21/13	5/22/13	40	100%	100.4%	0.4%	*Pass*
6/4/13	6/5/13	40	100%	100.8%	0.8%	*Pass*
6/18/13	6/20/13	40	100%	99.7%	-0.3%	*Pass*
6/19/13	6/20/13	36	100%	99.4%	-0.6%	*Pass*
6/24/13	6/25/13	40	100%	99.5%	-0.5%	*Pass*
7/1/13	7/2/13	40	100%	101.0%	1.0%	*Pass*
7/16/13	7/17/13	40	100%	101.0%	1.0%	*Pass*
7/30/13	8/1/13	43	100%	99.2%	-0.8%	*Pass*
8/13/13	8/13/13	43	100%	99.5%	-0.5%	*Pass*
8/26/13 -8/27/13, 8/29/13	8/29/13	17	100%	101.7%	1.7%	*Pass*
8/26/13 - 8/29/13	8/29/13	43	100%	99.0%	-1.0%	*Pass*
8/26/13 - 8/29/13	8/29/13	26	100%	99.8%	-0.2%	*Pass*
8/26/13 - 8/29/13	8/29/13	36	100%	99.0%	-1.0%	*Pass*
8/26/13 - 8/29/13	8/29/13	37	100%	100.7%	0.7%	*Pass*
8/26/13 - 8/29/13	8/29/13	40	100%	99.8%	-0.2%	*Pass*
8/26/13 - 8/29/13	8/29/13	42	100%	99.9%	-0.1%	*Pass*
9/10/13	9/11/13	43	100%	103.5%	3.4%	*Pass*
9/24/13-9/25/13	9/25/13	43	100%	99.3%	-0.7%	*Pass*
10/2/13	10/3/13	43	100%	100.4%	0.4%	*Pass*
10/7/13-10/10/13	10/10/13	43	100%	99.6%	-0.4%	*Pass*
10/22/13 - 10/23/13	10/23/13	43	100%	98.9%	-1.1%	*Pass*
11/05/13 - 11/06/13	11/6/13	43	100%	100.5%	0.5%	*Pass*
11/19/13 - 11/20/13	11/20/13	43	100%	101.5%	1.5%	*Pass*
12/3/13 - 12/4/13	12/5/13	43	100%	100.5%	0.5%	*Pass*
12/17/13 - 12/18/13	12/19/13	36	100%	98.6%	-1.4%	*Pass*
12/17/13 - 12/18/13	12/19/13	43	100%	99.4%	-0.6%	*Pass*
12/17/13 - 12/18/13	12/19/13	18	100%	99.1%	-0.9%	*Pass*
12/17/13 - 12/18/13	12/19/13	42	100%	100.3%	0.3%	*Pass*
12/17/13 - 12/18/13	12/19/13	40	100%	98.2%	-1.8%	*Pass*
12/17/13 - 12/18/13	12/19/13	37	100%	98.9%	-1.1%	*Pass*
12/17/13 - 12/18/13	12/19/13	41	100%	99.1%	-0.9%	*Pass*
12/17/13 - 12/18/13	12/19/13	33	100%	99.7%	-0.3%	*Pass*
1/7/14 - 1/8/14	1/9/14	43	100%	0.0%	-200.0%	*Reject*
1/28/14 - 1/29/14	1/30/14	40	100%	97.8%	-2.2%	*Pass*
2/11/14 - 2/12/14	2/12/14	40	100.00%	99.0%	-1.0%	*Pass*

Table B-5. Hydrolab® post-check specific conductance values.

Field Use Date(s)	Post-Check Date	Sonde #	Reference standard value	Conductivity post-check value	Difference	*Conclusion*
3/12/13	3/13/13	42	100.0	89.4	-11.2%	*Reject*
3/26/13	3/27/13	42	100.0	99.5	-0.5%	*Pass*
4/9/13	4/10/13	17	100.0	89.9	-10.6%	*Reject*
4/23/13	4/24/13	17	100.0	73.9	-30.0%	*Reject*
5/7/13	5/8/13	40	100.0	132.4	27.9%	*Reject*
5/21/13	5/22/13	40	100.0	96.8	-3.3%	*Pass*
6/4/13	6/5/13	40	100.0	Not Used	NA	*NA*
6/18/13	6/20/13	40	100.0	103.9	3.8%	*Pass*
6/19/13	6/20/13	36	100.0	94.7	-5.4%	*Estimate*
6/24/13	6/25/13	40	100.0	71.3	-33.5%	*Reject*
7/1/13	7/2/13	40	100.0	99.0	-1.0%	*Pass*
7/16/13	7/17/13	40	100.0	143.0	35.4%	*Reject*
7/30/13	8/1/13	43	100.0	92.9	-7.4%	*Estimate*
8/13/13	8/13/13	43	200.0	199.6	-0.2%	*Pass*
8/26/13 -8/27/13, 8/29/13	8/29/13	17	200.0	196.1	-2.0%	*Pass*
8/26/13 - 8/29/13	8/29/13	43	200.0	195.8	-2.1%	*Pass*
8/26/13 - 8/29/13	8/29/13	26	200.0	198.8	-0.6%	*Pass*
8/26/13 - 8/29/13	8/29/13	36	200.0	201	0.5%	*Pass*
8/26/13 - 8/29/13	8/29/13	37	200.0	201	0.50%	*Pass*
8/26/13 - 8/29/13	8/29/13	40	200.0	190	-5.13%	*Estimate*
8/26/13 - 8/29/13	8/29/13	42	200.0	187	-6.72%	*Estimate*
9/10/13	9/11/13	43	200.0	195.2	-2.43%	*Pass*
9/24/13-9/25/13	9/25/13	43	200.0	197.4	-1.31%	*Pass*
10/2/13	10/3/13	43	200.0	200.2	0.10%	*Pass*
10/7/13-10/10/13	10/10/13	43	200.0	198.8	-0.60%	*Pass*
10/22/13 - 10/23/13	10/23/13	43	200.0	199.8	-0.10%	*Pass*
11/05/13 - 11/06/13	11/6/13	43	200.0	197.7	-1.16%	*Pass*
11/19/13 - 11/20/13	11/20/13	43	200.0	162.3	-20.81%	*Reject*
12/3/13 - 12/4/13	12/5/13	43	200.0	201.2	0.60%	*Pass*
12/17/13 - 12/18/13	12/19/13	36	200.0	180.9	-10.03%	*Reject*
12/17/13 - 12/18/13	12/19/13	43	200.0	177	-12.20%	*Reject*
12/17/13 - 12/18/13	12/19/13	18	200.0	176	-12.77%	*Reject*
12/17/13 - 12/18/13	12/19/13	42	200.0	182.6	-9.10%	*Estimate*
12/17/13 - 12/18/13	12/19/13	40	200.0	186	-7.25%	*Estimate*
12/17/13 - 12/18/13	12/19/13	37	200.0	183.7	-8.50%	*Estimate*
12/17/13 - 12/18/13	12/19/13	41	200.0	192.5	-3.82%	*Pass*
12/17/13 - 12/18/13	12/19/13	33	200.0	194.4	-2.84%	*Pass*
1/7/14 - 1/8/14	1/9/14	43	200.0	199.7	-0.15%	*Pass*
1/28/14 - 1/29/14	1/30/14	40	200.0	197.7	-1.16%	*Pass*
2/11/14 - 2/12/14	2/12/14	40	200.0	199.5	-0.25%	*Pass*

Table B-6. Hydrolab® post-check pH 4.00 values.

Field Use Date/s	Post-Check Date	Reference standard value	Hydrolab post-check value	Difference	Conclusion
3/12/13	3/13/13	4.00	3.88	-0.12	*Pass*
3/26/13	3/27/13	4.00	3.98	-0.02	*Pass*
4/9/13	4/10/13	4.00	4.00	0	*Pass*
4/23/13	4/24/13	4.00	4.04	0.04	*Pass*
5/7/13	5/8/13	4.00	4.13	0.13	*Pass*
5/21/13	5/22/13	4.00	4.08	0.08	*Pass*
6/4/13	6/5/13	4.00	4.07	0.07	*Pass*
6/18/13	6/20/13	4.00	4.70	0.7	*Reject*
6/19/13	6/20/13	4.00	4.06	0.06	*Pass*
6/24/13	6/25/13	4.00	4.19	0.19	*Pass*
7/1/13	7/2/13	4.00	4.32	0.32	*Estimate*
7/16/13	7/17/13	4.01	4.18	0.17	*Pass*
7/30/13	8/1/13	4.00	4.03	0.03	*Pass*
8/13/13	8/13/13	4.01	4.11	0.1	*Pass*
8/26/13 -8/27/13, 8/29/13	8/29/13	4.00	4.05	0.05	*Pass*
8/26/13 - 8/29/13	8/29/13	4.00	4.00	0	*Pass*
8/26/13 - 8/29/13	8/29/13	4.00	4.01	0.01	*Pass*
8/26/13 - 8/29/13	8/29/13	4.00	3.97	-0.03	*Pass*
8/26/13 - 8/29/13	8/29/13	4.00	3.97	-0.03	*Pass*
8/26/13 - 8/29/13	8/29/13	4.00	4.10	0.1	*Pass*
8/26/13 - 8/29/13	8/29/13	4.00	4.05	0.05	*Pass*
9/10/13	9/11/13	4.00	4.02	0.02	*Pass*
9/24/13-9/25/13	9/25/13	4.00	4.11	0.11	*Pass*
10/2/13	10/3/13	4.00	3.99	-0.01	*Pass*
10/7/13-10/10/13	10/10/13	4.00	4.05	0.05	*Pass*
10/22/13 - 10/23/13	10/23/13	4.00	4.03	0.03	*Pass*
11/05/13 - 11/06/13	11/6/13	4.00	4.33	0.33	*Pass*
11/19/13 - 11/20/13	11/20/13	4.00	4.20	0.2	*Pass*
12/3/13 - 12/4/13	12/5/13	4.00	4.22	0.22	*Pass*
12/17/13 - 12/18/13	12/19/13	4.00	3.79	-0.21	*Pass*
12/17/13 - 12/18/13	12/19/13	4.00	4.12	0.12	*Pass*
12/17/13 - 12/18/13	12/19/13	4.00	4.34	0.34	*Estimate*
12/17/13 - 12/18/13	12/19/13	4.00	4.07	0.07	*Pass*
12/17/13 - 12/18/13	12/19/13	4.00	4.08	0.08	*Pass*
12/17/13 - 12/18/13	12/19/13	4.00	4.01	0.01	*Pass*
12/17/13 - 12/18/13	12/19/13	4.00	3.95	-0.05	*Pass*
12/17/13 - 12/18/13	12/19/13	4.00	4.04	0.04	*Pass*
1/7/14 - 1/8/14	1/9/14	4.00	4.12	0.12	*Pass*
1/28/14 - 1/29/14	1/30/14	4.00	4.08	0.08	*Pass*
2/11/14 - 2/12/14	2/12/14	4.00	4.15	0.15	*Pass*

Table B-7. Hydrolab® post-check pH 7.00 values.

Field Use Date/s	Post-Check Date	Sonde #	Reference standard value	Hydrolab post-check value	Difference	Conclusion
3/12/13	3/13/13	40	7.00	7.03	0.03	*Pass*
3/26/13	3/27/13	0	7.02	7.02	0	*Pass*
4/9/13	4/10/13	0	7.02	7.02	0	*Pass*
4/23/13	4/24/13	17	7.01	7.05	0.04	*Pass*
5/7/13	5/8/13	0	7.01	7.14	0.13	*Pass*
5/21/13	5/22/13	0	7.00	7.08	0.08	*Pass*
6/4/13	6/5/13	0	7.02	7.08	0.06	*Pass*
6/18/13	6/20/13	0	7.02	7.79	0.77	*Reject*
6/19/13	6/20/13	0	7.02	7.02	0	*Pass*
6/24/13	6/25/13	0	7.02	7.23	0.21	*Pass*
7/1/13	7/2/13	0	7.01	7.34	0.33	*Estimate*
7/16/13	7/17/13	0	7.01	7.23	0.22	*Pass*
7/30/13	8/1/13	0	7.02	7.07	0.05	*Pass*
8/13/13	8/13/13	0	7.01	7.1	0.09	*Pass*
8/26/13 -8/27/13, 8/29/13	8/29/13	0	7.00	7.05	0.05	*Pass*
8/26/13 - 8/29/13	8/29/13	0	7.00	7.01	0.01	*Pass*
8/26/13 - 8/29/13	8/29/13	0	7.00	6.99	-0.01	*Pass*
8/26/13 - 8/29/13	8/29/13	0	7.00	7	0	*Pass*
8/26/13 - 8/29/13	8/29/13	0	7.00	6.99	-0.01	*Pass*
8/26/13 - 8/29/13	8/29/13	0	7.00	7.09	0.09	*Pass*
8/26/13 - 8/29/13	8/29/13	0	7.00	7.12	0.12	*Pass*
9/10/13	9/11/13	0	7.02	7.1	0.08	*Pass*
9/24/13-9/25/13	9/25/13	0	7.01	7.14	0.13	*Pass*
10/2/13	10/3/13	0	7.02	7.03	0.01	*Pass*
10/7/13-10/10/13	10/10/13	0	7.02	7.07	0.05	*Pass*
10/22/13 - 10/23/13	10/23/13	0	7.02	7.03	0.01	*Pass*
11/05/13 - 11/06/13	11/6/13	0	7.02	7.36	0.34	*Estimate*
11/19/13 - 11/20/13	11/20/13	0	7.02	7.27	0.25	*Pass*
12/3/13 - 12/4/13	12/5/13	0	7.02	7.27	0.25	*Pass*
12/17/13 - 12/18/13	12/19/13	0	7.02	6.93	-0.09	*Pass*
12/17/13 - 12/18/13	12/19/13	0	7.02	7.14	0.12	*Pass*
12/17/13 - 12/18/13	12/19/13	0	7.02	7.63	0.61	*Pass*
12/17/13 - 12/18/13	12/19/13	0	7.02	7.08	0.06	*Pass*
12/17/13 - 12/18/13	12/19/13	0	7.02	7.20	0.18	*Pass*
12/17/13 - 12/18/13	12/19/13	0	7.02	6.96	-0.06	*Pass*
12/17/13 - 12/18/13	12/19/13	0	7.02	7.19	0.17	*Pass*
12/17/13 - 12/18/13	12/19/13	0	7.02	7.07	0.05	*Pass*
1/7/14 - 1/8/14	1/9/14	43	7.02	7.15	0.13	*Pass*
1/28/14 - 1/29/14	1/30/14	40	7.02	7.1	0.08	*Pass*
2/11/14 - 2/12/14	2/12/14	40	7.02	7.17	0.15	*Pass*

Table B-8. Hydrolab® post-check pH 10.00 values.

Field Use Date/s	Post-Check Date	Reference standard value	Hydrolab post-check value	Difference	Conclusion
3/12/13	3/13/13	10.01	9.92	-0.09	*Pass*
3/26/13	3/27/13	10.03	9.97	-0.06	*Pass*
4/9/13	4/10/13	10.03	10.00	-0.03	*Pass*
4/23/13	4/24/13	10.02	10.03	0.01	*Pass*
5/7/13	5/8/13	10.02	10.10	0.08	*Pass*
5/21/13	5/22/13	10.03	10.08	0.05	*Pass*
6/4/13	6/5/13	10.03	10.06	0.03	*Pass*
6/18/13	6/20/13	10.03	10.75	0.72	*Reject*
6/19/13	6/20/13	10.03	10.06	0.03	*Pass*
6/24/13	6/25/13	10.05	10.19	0.14	*Pass*
7/1/13	7/2/13	10.02	10.30	0.28	*Estimate*
7/16/13	7/17/13	10.03	10.15	0.12	*Pass*
7/30/13	8/1/13	10.04	10.09	0.05	*Pass*
8/13/13	8/13/13	10.03	10.07	0.04	*Pass*
8/26/13 -8/27/13, 8/29/13	8/29/13	10.00	10.01	0.01	*Pass*
8/26/13 - 8/29/13	8/29/13	10.00	10.01	0.01	*Pass*
8/26/13 - 8/29/13	8/29/13	10.00	9.92	-0.08	*Pass*
8/26/13 - 8/29/13	8/29/13	10.00	10.08	0.08	*Pass*
8/26/13 - 8/29/13	8/29/13	10.00	9.93	-0.07	*Pass*
8/26/13 - 8/29/13	8/29/13	10.00	10.05	0.05	*Pass*
8/26/13 - 8/29/13	8/29/13	10.00	10.08	0.08	*Pass*
9/10/13	9/11/13	10.04	10.06	0.02	*Pass*
9/24/13-9/25/13	9/25/13	10.04	10.06	0.02	*Pass*
10/2/13	10/3/13	10.05	9.98	-0.07	*Pass*
10/7/13-10/10/13	10/10/13	10.05	9.94	-0.11	*Pass*
10/22/13 - 10/23/13	10/23/13	10.03	9.95	-0.08	*Pass*
11/05/13 - 11/06/13	11/6/13	10.05	10.27	0.22	*Pass*
11/19/13 - 11/20/13	11/20/13	10.06	10.16	0.1	*Pass*
12/3/13 - 12/4/13	12/5/13	10.05	10.13	0.08	*Pass*
12/17/13 - 12/18/13	12/19/13	10.03	10.30	0.27	*Estimate*
12/17/13 - 12/18/13	12/19/13	10.03	10.02	-0.01	*Pass*
12/17/13 - 12/18/13	12/19/13	10.03	10.70	0.67	*Reject*
12/17/13 - 12/18/13	12/19/13	10.03	10.08	0.05	*Pass*
12/17/13 - 12/18/13	12/19/13	10.03	10.02	-0.01	*Pass*
12/17/13 - 12/18/13	12/19/13	10.03	9.84	-0.19	*Pass*
12/17/13 - 12/18/13	12/19/13	10.03	10.33	0.30	*Estimate*
12/17/13 - 12/18/13	12/19/13	10.03	9.97	-0.06	*Estimate*
1/7/14 - 1/8/14	1/9/14	10.05	10.01	-0.04	*Pass*
1/28/14 - 1/29/14	1/30/14	10.05	9.90	-0.15	*Pass*
2/11/14 - 2/12/14	2/12/14	10.04	9.97	-0.07	*Pass*

Table B-9 shows point measurements to check the accuracy of the Hydrolab during the 2 diurnal studies.

Table B-9. Point measurements to check diurnal water quality data.

Site ID	Date and Time	Temp (°C)	pH (Units)	SpCond (µS/cm)	DO% (Sat)	DO (mg/l)	DO Winkler (mg/L)
CLO0.4	8/26/2013 16:00	16.87	7.56	136	103.1	9.92	10.18
CLO0.4	8/27/2013 10:00	15.62	7.58	139	97.2	9.6	9.74
CLO0.4	8/29/2013 13:30	17.05	7.57	136	99.3	9.52	9.28
CLO3.5	8/26/2013 15:30	15.41	6.61	145	56.2	5.57	5.66
CLO3.5	8/27/2013 8:00	13.89	6.56	148	34.8	3.57	3.9
CLO3.5	8/29/2013 1:00	15.48	6.55	147	34.3	3.4	4.15
CLO7.1	8/26/2013 17:00	17	7.5	186	89.1	8.55	8.64
CLO7.1	8/27/2013 14:30	17.24	7.6	187	89	8.49	8.61
CLO7.1	8/29/2013 12:00	18.01	7.48	184	80.9	7.6	7.52
CLO9.8	8/26/2013 17:30						9.7
CLO9.8	8/26/2013 18:00	16.49	6.24	182	100.3	9.72	
CLO9.8	8/27/2013 8:00	13.89	6.56	148	34.8	3.57	3.9
CLO9.8	8/29/2013 10:30	13.79	6.34	182	59.8	6.15	6.36
CLO12.0	8/26/2013 17:00						9.91
CLO12.0	8/26/2013 18:00	11.85	7.25	192	86.6	9.29	
CLO12.0	8/27/2013 17:00	12.2	7.33	194	86.6	9.21	9.28
CLO12.0	8/29/2013 11:00	11.57	7.18	195	82.3	8.88	8.89
SPA1.8	8/26/2013 16:15						10.11
SPA1.8	8/26/2013 16:30	22.54	8.63	134	121.9	10.47	
SPA1.8	8/27/2013 13:30	22.91	8.35	135	115.3	9.83	11.4
SPA1.8	8/29/2013 11:30	22.47	7.98	135	106.9	9.2	9.31
CLO0.4	12/16/2013 16:30	8.12	7.46	128	96.4	11.52	11.4
CLO0.4	12/17/2013 10:30	7.48	7.27	127	93.8	11.39	11.37
CLO0.4	12/19/2013 12:00	6.26	7.4	129			12.19
CLO3.5	12/17/2013 9:00	7.22	6.96	131	74.1	9.06	9.2
CLO3.5	12/19/2013 11:30	5.65	6.92	133	75.5	9.6	9.7
CLO7.1	12/16/2013 15:30	7.74	7.33	166	87.2	10.52	10.6
CLO7.1	12/18/2013 12:00	7.6	7.54	167	87.1	10.54	10.75
CLO7.1	12/19/2013 10:30	4.8	7.54	167	88.7	11.53	11.58
CLO9.8	12/16/2013 14:30	8.88	6.75	181	81.4	9.55	9.54
CLO9.8	12/18/2013 10:30	8.45	6.78	181	71.1	8.42	8.65
CLO9.8	12/19/2013 10:00	6	6.83	180	74.4	9.37	9.5
CLO12.0	12/16/2013 14:00	9.11	6.89	169	88.1	10.28	10.39
CLO12.0	12/18/2013 9:00	8.99	7.13	169	85.2	9.97	9.99
CLO12.0	12/19/2013 9:30	7.05	7.21	169	87.1	10.69	10.74

Temperature

Onset Hobo© continuously logging thermistors were calibrated before deployment and checked after recovery with a NIST (National Institute of Standards and Technology) thermometer (Table B-10). The average post-calibration difference between the thermistors and NIST thermometer was 0.05. Thermistors were deployed May 2013. All were recovered on September 2013, except 2 removed early because the stream had stopped flowing and the thermistors were out of the water. All thermistors met the post-deployment calibration check QA criterion, as outlined in the QA Project Plan.

Table B-10. Thermistor calibration results (absolute differences).

Pre-Deployment Calibration					
Thermister Number	**1000383**	**1157506**	**1157534**	**1157547**	**1157549**
Average Difference	0.23	0.20	0.29	0.25	0.24
Ice Average Difference	0.05	0.05	0.07	0.03	0.02
Ambient Average Difference	0.39	0.33	0.48	0.46	0.44
Post-Deployment Calibration					
Thermister Number	**1000383**	**1157506**	**1157534**	**1157547**	**1157549**
Average Difference	0.05	0.04	0.05	0.02	0.02
Ice Average Difference	0.04	0.04	0.04	0.01	0.02
Ambient Average Difference	0.05	0.03	0.05	0.03	0.03
Pre-Deployment Calibration					
Thermister Number	**1157550**	**1157563**	**1157570**	**1157583**	**1157601**
Average Difference	0.27	0.31	0.40	0.16	0.40
Ice Average Difference	0.10	0.07	0.18	0.00	0.18
Ambient Average Difference	0.41	0.52	0.59	0.30	0.59
Post-Deployment Calibration					
Thermister Number	**1157550**	**1157563**	**1157570**	**1157583**	**1157601**
Average Difference	0.07	0.05	0.16	0.03	0.08
Ice Average Difference	0.05	0.04	0.14	0.03	0.06
Ambient Average Difference	0.09	0.06	0.16	0.03	0.10

Pre-Deployment Calibration					
Thermister Number	**1246843**	**1246850**	**1246852**	**1246861**	**1246866**
Average Difference	0.27	0.26	0.23	0.16	0.20
Ice Average Difference	0.07	0.08	0.05	0.03	0.05
Ambient Average Difference	0.44	0.42	0.38	0.27	0.34
Post-Deployment Calibration					
Thermister Number	**1246843**	**1246850**	**1246852**	**1246861**	**1246866**
Average Difference	0.04	0.06	0.03	0.06	0.02
Ice Average Difference	0.04	0.07	0.01	0.07	0.01
Ambient Average Difference	0.04	0.06	0.04	0.05	0.03

Pre-Deployment Calibration					
Thermister Number	**1246884**	**1246894**	**1246903**	**1246928**	**1246929**
Average Difference	0.14	0.27	0.22	0.25	0.30
Ice Average Difference	0.00	0.05	0.07	0.03	0.13
Ambient Average Difference	0.26	0.46	0.35	0.44	0.45
Post-Deployment Calibration					
Thermister Number	**1246884**	**1246894**	**1246903**	**1246928**	**1246929**
Average Difference	0.04	0.03	0.03	0.05	0.12
Ice Average Difference	0.05	0.01	0.04	0.07	0.11
Ambient Average Difference	0.04	0.04	0.02	0.04	0.12

Pre-Deployment Calibration					
Thermister Number	**1246941**	**1246943**	**1252370**	**1252379**	**10332784**
Average Difference	0.24	0.27	0.19	0.31	0.08
Ice Average Difference	0.05	0.07	0.01	0.08	0.02
Ambient Average Difference	0.41	0.44	0.37	0.50	0.13
Post-Deployment Calibration					
Thermister Number	**1246941**	**1246943**	**1252370**	**1252379**	**10332784**
Average Difference	0.04	0.07	0.04	0.07	0.03
Ice Average Difference	0.04	0.06	0.05	0.06	0.03
Ambient Average Difference	0.03	0.06	0.02	0.07	0.03

Pre-Deployment Calibration			
Thermister Number	**10332804**	**10332813**	**10332818**
Average Difference	0.13	0.08	0.21
Ice Average Difference	0.03	0.02	0.02
Ambient Average Difference	0.22	0.13	0.37
Post-Deployment Calibration			
Thermister Number	**10332804**	**10332813**	**10332818**
Average Difference	0.07	0.03	0.02
Ice Average Difference	0.07	0.03	0.01
Ambient Average Difference	0.06	0.04	0.03

*Hobo Water Temperature post-calibration evaluation MQO criteria: ± 0.21°C

Fecal Coliform Bacteria (FC)

FC were analyzed in the Manchester Environmental Laboratory (MEL) located in the town of Manchester near Port Orchard. All sampling procedures and protocols for bacteria complied with the QA Project Plan.

FC samples collected on May 7 were incubated at a temperature too high for accurate FC laboratory analysis. The FC were over-heated and therefore produced unusable results. These data were not used in the analyses.

FC Laboratory Duplicates

Duplicate laboratory analysis refers to analyzing duplicate aliquots in the lab taken from a single sample container. The results for laboratory duplicates provide an estimate of lab analytical precision, including the homogeneity of the sample matrix (MEL, 2008). The measurement quality objective (MQO) used by Ecology's MEL for membrane filtered bacteria duplicates is 40% average relative percent difference (RPD). The average RPD value for lab duplicate FC samples in the Clover Creek watershed was 33.7%, thus this study met the MEL MQO for lab duplicates (Table B-11). For the 31 lab duplicates with greater than 20 cfu/mL, 6 samples (19.4%) were above 40 RSD.

Table B-11. Duplicate laboratory sample statistics.

Parameter	Total Number of Samples Including Lab Duplicates	Total Number of Samples Less Lab Duplicates	Total Number of Lab Duplicates	Percent of Samples Duplicated	MQO Precision standard (RPD)	Average RPD	Meets MQO Criteria?
FC	619	579	40	6.5%	< 40	33.7	YES

FC Field Replicates

Field replicate samples are 2 samples collected from the same location at the same time and submitted to MEL as blind pairs (no identification provided). Collecting field replicates is a method of looking at the precision of the entire process of sampling and analysis. Differences between the results of replicate samples can arise from variations in the sample location, collection process, sample containers, and/or analytical procedures (MEL, 2008).

The Clover Creek QA Project Plan (Kardouni, 2013) MQOs for analyzing precision in replicated bacteria samples requires that at least 50% of the samples be below a 20% relative standard deviation (RSD) and that at least 90% of the samples be below a 50% RSD (Mathieu, 2006). The RSD is the absolute value of the coefficient of variation for the replicated QA samples. None of the samples used to assess the MQO should have a mean concentration of 20 cfu/ 100 mL or less.

Ecology collected 96 FC field replicates in 2013 to 2014 for the Clover Creek TMDL project. Of these 96 samples, 80 had a mean concentration above 20 cfu/100 mL and were therefore used to assess if the MQO was met. A total of 14.6% of the replicate pairs were below 20% RSD and 38.2% were below 50% RSD. Membrane filtered FC samples met Ecology's MQO QA precision criteria (Table B-12).

Table B-12. Field replicate sample statistics.

FC Count	MQO	Total Number of Samples Including Replicates	Number of Replicates	Total Number of Samples Less Replicates	Percentage of Samples Replicated	Average Percentage RSD	Meets MQO Criteria?
FC ≤ 20 cfu/100 mL	50% of replicate pairs < 20%	579	16	563	2.8%	30.7%	YES
	90% of replicate pairs < 50%					47.1%	YES
FC ≥ 20 cfu/100 mL	50% of replicate pairs < 20%	579	80	499	13.8%	14.6%	YES
	90% of replicate pairs < 50%					38.2%	YES

References for Appendix B

APHA (American Public Health Association), 2005. Standard Methods for the Examination of Water and Wastewater, 21st ed. American Water Works Association, American Public Health Association, and Water Environment Federation, Philadelphia, PA.

Kardouni, J., 2013. Clover Creek Dissolved Oxygen, Fecal Coliform, and Temperature Total Maximum Daily Load Water Quality Study Design (QAPP), 2013. Washington State Department of Ecology, Olympia, WA. Publication No. 13-03-109. 90 pp. https://fortress.wa.gov/ecy/publications/SummaryPages/1303109.html

Mathieu, N., 2006. Replicate precision for 12 Total Maximum Daily Load (TMDL) Studies and Recommendations for Precision Measurement Quality Objectives for Water Quality Parameters. Washington State Department of Ecology, Olympia, WA. Publication No. 06-03-044. https://fortress.wa.gov/ecy/publications/SummaryPages/0603044.html

MEL, 2008. Manchester Environmental Laboratory, Lab Users Manual, Ninth Edition. Washington State Department of Ecology, Manchester, WA.

Appendix C. Fecal Coliform Bacteria Data

Tables C-1 to C-3 provide fecal coliform bacteria (FC) data.

Table C-1. FC data for March to August, 2013.

Station ID	3/12/2013	3/26/2013	4/9/2013	4/23/2013	5/7/2013	5/21/2013	6/4/2013	6/18 and 19/13	7/1/2013	7/16/2013	7/30/2013	8/13/2013
CLO12.0	10	2	25	6	-	31	14	26	57	9	49	66
CLO11.0	12	2	21	12	-	**140**	17	26	84	92	**130**	60
CLO9.8	47	17	56	20	-	89	**120**	100	**220**	**200**	**110**	100
CLO8.7	39	32	84	14	-	**130**	88	**120**	**130**	80	57	66
CLO7.1	28	37	84	55	-	**180**	**140**	**120**	**220**	**110**	**150**	**170**
CLO7.1SC							88	**110**	**470**	96	51	
CLO4.6	60	**110**	**260**	**130**	-	-	-	-	-	-	-	-
CLO3.5	43	57	**130**	67	-	**310**	43	29	88	54	60	63
CLO1.9	35	29	**250**	41	-	**120**	17	26	46	29	37	63
CLO1.4	52	19	**160**	27	-	**110**	11	49	92	34	63	**130**
CLO0.4	49	47	**140**	31	-	**140**	**130**	84	100	**130**	**450**	**300**
NFCB1.7												
NFCB1.4												
NFCB1.4W												
NFCB1.1	**110**	16	**300**	**120**	-	**660**	**180**	**1700**	**740**	**1800**	**2200**	**320**
NFCB1.1LB	**200**	2	27	-	-	**-**		-	-	-	-	
NFCB1.1RB	**420**	96	87			**500**	**320**	-	-	-	-	
NFCB0.0	55	27	**140**	68	-	**730**	100	**110**	89	**180**	88	**110**
NFC1.0	23	36	**180**	35	-	**1100**	3	-	-	-	-	
NFC0.0	75	10	**240**	44	-	**440**	**190**	-	37	-	-	
SPA1.8	10	1	5	2	-	52	14	26	17	11	**230**	57
SPA1.4	13	11	47	5	-	69	20	49	63	**140**	43	69
SPA0.5	17	15	21	7	-	100	37	26	46	37	34	80
MOR0.9	-	-	23	2	-	84	49	17	84	37	26	60
MOR0.1	10	10	11	1	-	28	6	63	60	11	20	23

Table C-2. FC data for August 2013 to February 2014.

Station ID	8/27/2013	9/10/13-9/11/13	9/24/13-9/25/13	10/8/13-10/9/13	10/22/13-10/23/13	11/5/13-11/6/13	11/19/13-11/20/13	12/3/13-12/4/13	12/17/13-12/18/13	1/7/14-1/8/14	1/28/14-1/29/14	2/11/14-2/12/14
CLO12.0	88	**210**	100	29	31	9	9	26	3	51	26	9
CLO11.0	57	57	96	37	31	9	23	17	17	14	40	26
CLO9.8	**530**	**260**	**120**	63	51	92	31	46	77	71	**140**	34
CLO8.7	100	60	54	83	17	31	80	40	43	69	**240**	54
CLO7.1	**370**	**250**	**230**	**140**	84	94	57	40	66	92	**120**	71
CLO7.1SC	40	66	46	6	6	40	11	14	3	14	11	6
CLO4.6	-	-	-	-	-	-	**160**	88	63	**550**	23	**250**
CLO3.5	51	88	**260**	**140**	49	20	**170**	37	80	83	46	**200**
CLO1.9	60	92	71	**210**	74	**780**	**3300**	26	40	**530**	57	**120**
CLO1.4	**250**	**300**	**260**	80	80	49	**170**	43	46	57	29	**160**
CLO0.4	**290**	**530**	**350**	**180**	71	43	**270**	80	88	32	60	**140**
NFCB1.7					84	96	**150**	34	9			
NFCB1.4		**260**	**670**	**740**	96	60	100	43	3			
NFCB1.4W		**110**	**250**	**220**	29	**260**	**220**		15			
NFCB1.1	69	**240**	**320**	**900**	54	**210**	**150**	15	77	**180**	23	**390**
NFCB1.1LB				**120**	3		77					
NFCB1.1RB			63	69	3		**410**					
NFCB0.0		80	**120**	60	46	20	**150**	88	17	**300**	60	**540**
NFC1.0			**1300**	100	100	37	**140**	46	37	**200**	37	40
NFC0.0			**290**	**1100**		**150**	**120**	89	46	**210**	71	**490**
SPA1.8	40	37	94	54	83	3	34	3	14	11	11	51
SPA1.4	**150**	**170**	**110**	**120**	92	9	20	14	6	9	20	14
SPA0.5	**220**	**120**	**290**	**120**	**170**	63	69	29	66	66	23	31
MOR0.9	46	26	**210**	96	26	3	20	11	3	6	17	11
MOR0.1	20	71	**2200**	9	17	11	37	9	6	3	11	17

Table C-3. FC data summary.

Station ID	Number of samples (n)	Geometric mean	Exceed WQ Criterion (%)	90th percentile
CLO12.0	23	22	4	95
CLO11.0	23	30	0	106
CLO9.8	23	81	**13**	**231**
CLO8.7	23	61	4	142
CLO7.1	23	**104**	**17**	**240**
CLO7.1SC	17	27	6	149
CLO4.6	10	**120**	**30**	**380**
CLO3.5	23	74	9	179
CLO1.9	23	82	**22**	**412**
CLO1.4	23	71	**13**	**214**
CLO0.4	23	**117**	**26**	**340**
NFCB1.7	5	52	**20**	**216**
NFCB1.4	8	99	**38**	**955**
NFCB1.4W	7	**106**	**71**	**328**
NFCB1.1	23	**207**	**74**	**1263**
NFCB1.1LB	6	26	**50**	**313**
NFCB1.1RB	9	**113**	**56**	**880**
NFCB0.0	22	93	**41**	**302**
NFC1.0	16	73	**31**	**480**
NFC0.0	16	**126**	**56**	**564**
SPA1.8	23	18	4	102
SPA1.4	23	36	0	142
SPA0.5	23	50	9	161
MOR0.9	21	22	5	107
MOR0.1	23	17	4	107

Figures C-1 to C-9 are Q-Q plots of FC data. All data were log_{10} transformed, unless otherwise stated.

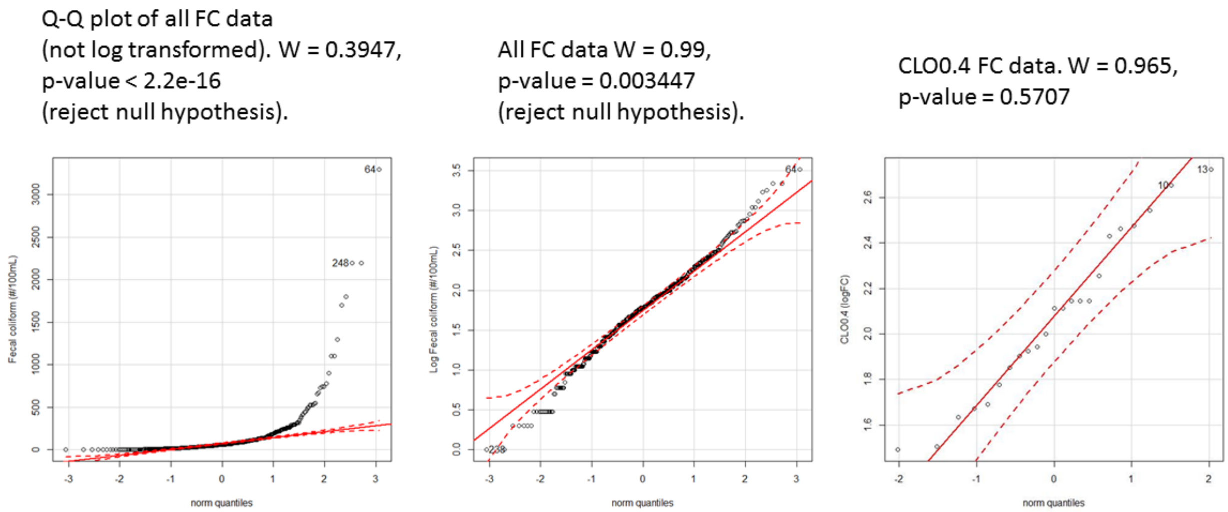


Figure C-1. Q-Q plots of all FC data and CLO0.4.

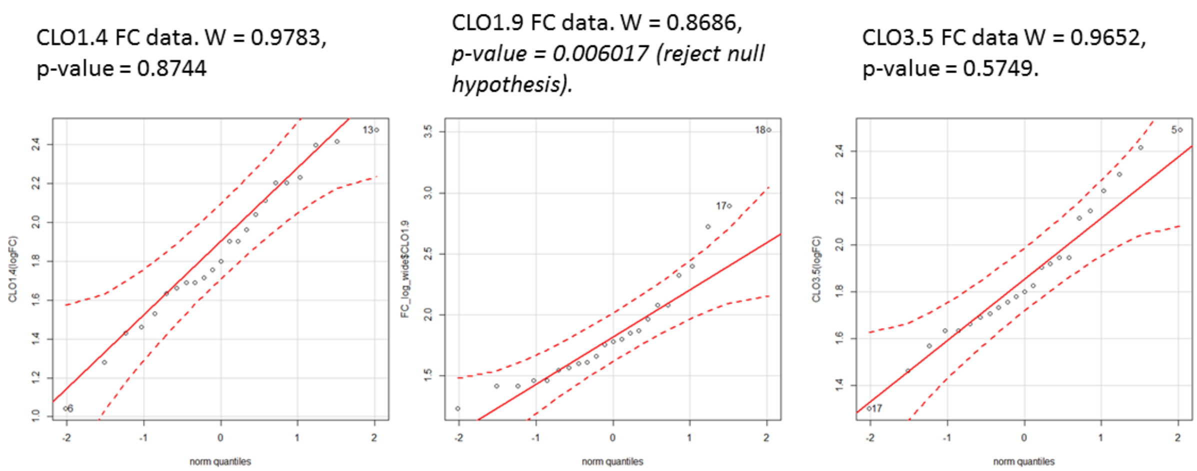


Figure C-2. Q-Q plots of CLO1.4, CLO1.9, and CLO3.5.

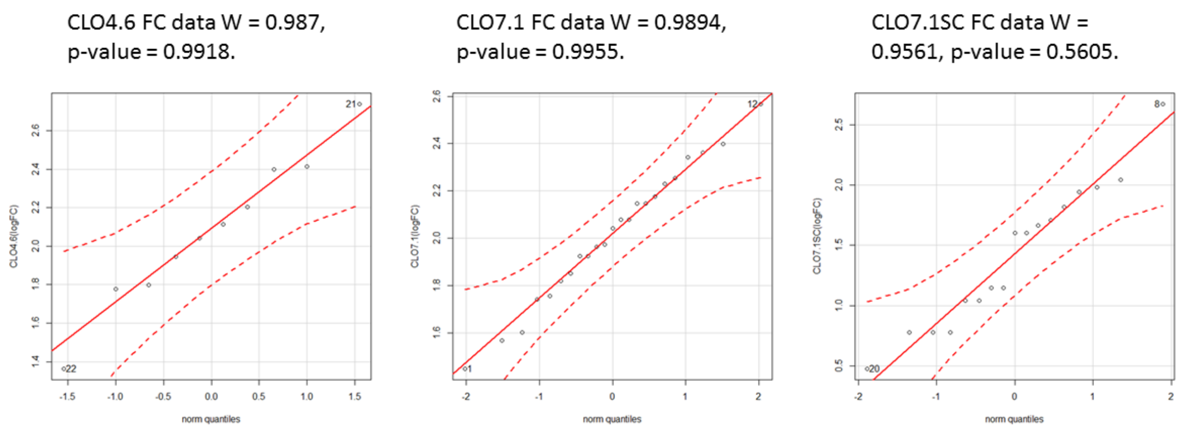


Figure C-3. Q-Q plots of CLO4.6, CLO7.1, and CLO7.1SC.

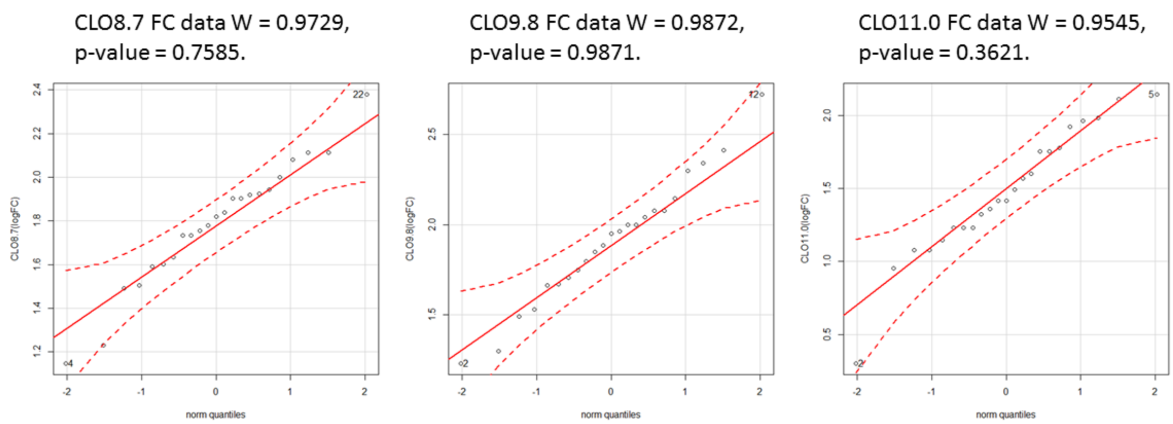


Figure C-4. Q-Q plots of CLO8.7, CLO9.8, and CLO11.0.

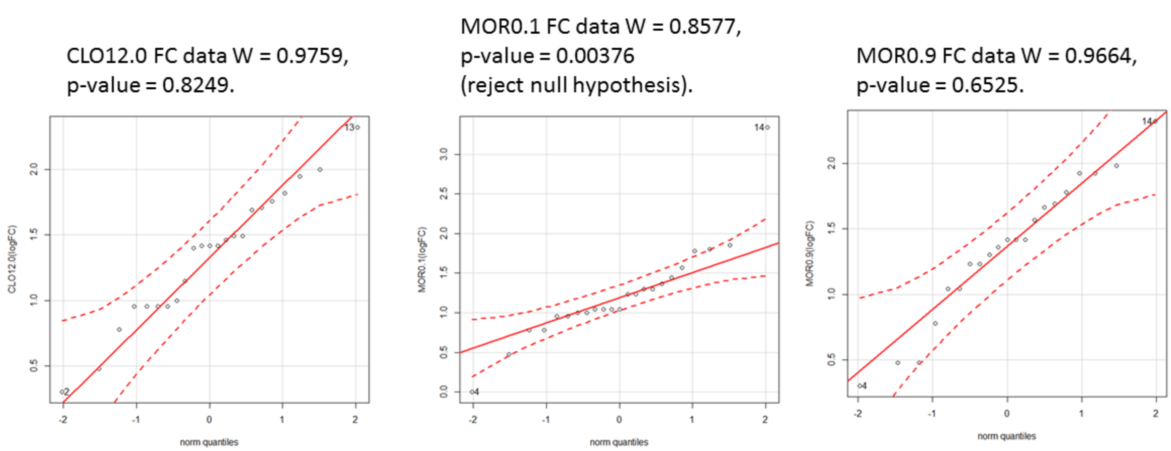


Figure C-5. Q-Q plots of CLO12.0, MOR0.1, and MOR0.9.

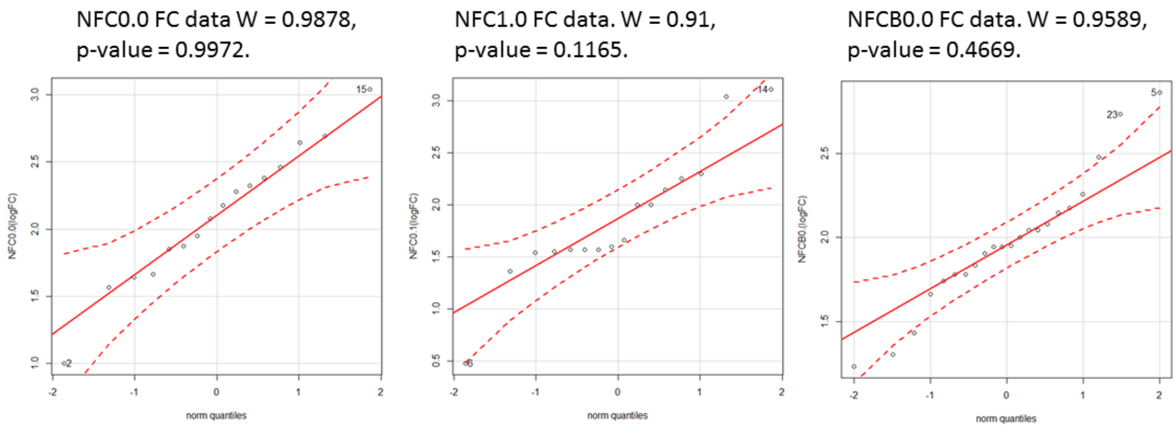


Figure C-6. Q-Q plots of NFC0.0, NFC1.0, and NFCB0.0.

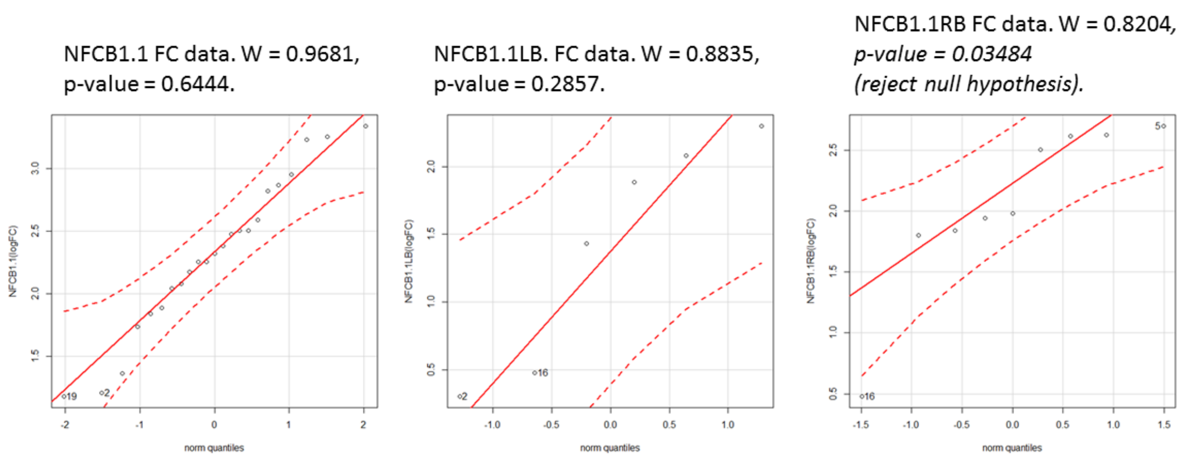


Figure C-7. Q-Q plots of NFCB1.1, NFC1.1LB, and NFCB1.1RB.

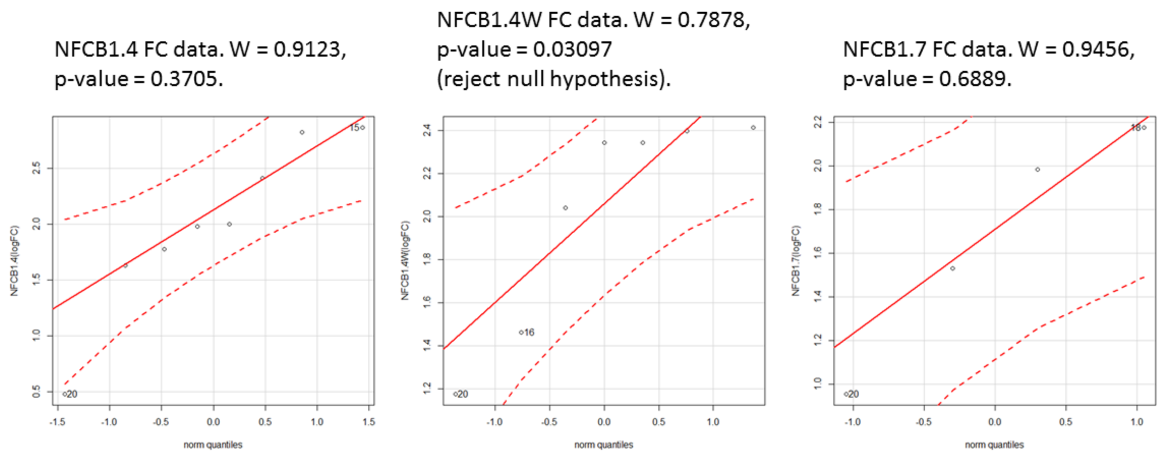


Figure C-8. Q-Q plots of NFCB1.4, NFC1.4W, and NFCB1.7.

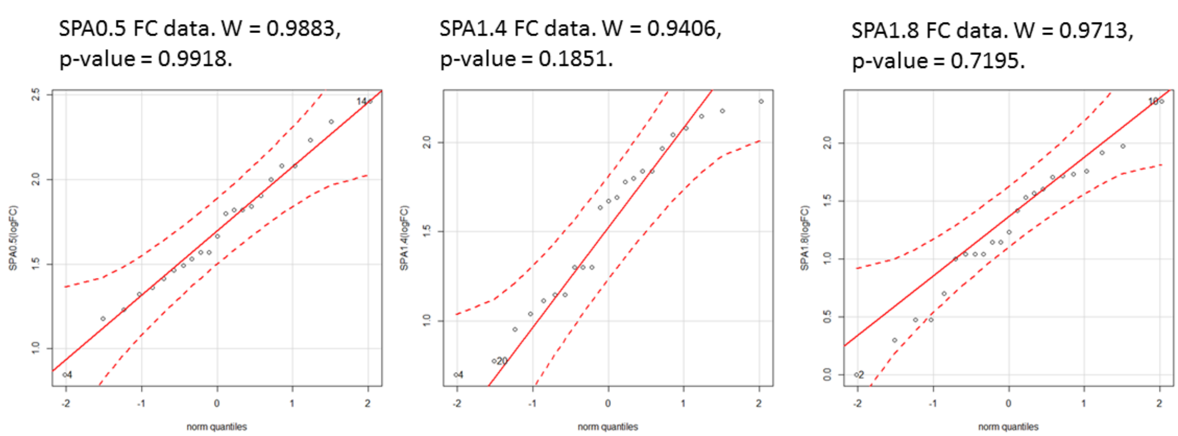


Figure C-9. Q-Q plots of SPA0.5, SPA1.4, and SPA1.8.

Appendix D. Hydrology

Table D-1. Stream discharge (cfs) measurements in the Clover Creek watershed.

Station ID	n	Avg	Max	Min	3/12/13	3/26/13	4/9/13	4/23/13	5/7/13	5/21/13	6/4/13	6/18 & 19 2013
CLO0.4	25	26	66	4.4	37	41	66	49	32	32	33	21
CLO1.4	23	28	66	5.1	40	43	66	48	35	36	33	22
CLO1.9	23	29	72	6.0	41	45	72	49	35	32	32	22
CLO3.5	24	28	85	3.8	42	47	85	54	34	32	35	20
CLO4.6	25	2.6	15	0.0	2.2	1.6	15	1.9	0.0	0.0	0.0	0.0
CLO7.1	23	1.3	3.7	0.2	1.4	1.5	1.7	1.9	1.9	1.8	1.7	1.5
CLO7.1SC	22	2.2	10	0.3	-	-	1.5	1.7	0.97	3.2	1.7	1.8
CLO8.7	24	14	26	6.2	16	19	26	19	13	12	13	12
CLO9.8	24	14	24	6.2	17	20	24	20	14	14	15	14
CLO11.0	25	5.1	16	1.3	5.3	7.3	7.8	6.3	4.4	4.1	4.5	3.8
CLO12.0	25	2.6	7.0	1.3	2.6	2.5	3.6	2.8	2.2	2.5	2.5	2.3
MOR0.1	24	1.6	7.7	0.5	1.0	0.87	1.3	0.75	0.8	2.0	1.8	1.0
MOR0.9	23	2.9	11	1.0	-	-	1.8	1.2	1.2	2.6	1.7	2.4
NFC0.0	24	3.8	27	0.0	4.5	3.2	19	3.2	0.02	3.6	1.0	0.0
NFC1.0	24	2.1	13	0.0	2.1	1.0	9.3	1.1	0.0	0.26	0.3	0.0
NFCB0.0	24	4.2	18	0.0	4.2	2.6	8.5	2.1	0.24	3.4	1.1	0.2
NFCB1.1	25	2.0	9.3	0.0	2.5	1.4	5.0	1.3	0.30	1.7	0.9	0.4
SPA0.5	0	-	-	-	-	-	-	-	-	-	-	-
SPA1.4	24	19	34	6.5	26	28	34	28	23	24	19	16
SPA1.8	24	18	33	6.2	21	23	31	21	19	20	19	16
NFCB1.1LB*	12	-	-	-	-	-	-	-	-	-	0.0	0.0
NFCB1.1RB*	11	-	-	-	-	-	-	-	-	-	0.002	-

11/19 & 20 2013	11/5 & 6 2013	10/22 & 23 2013	10/8 & 9 2013	9/24 & 25 2013	9/10 & 11 2013	8/27/13	8/13/13	7/30/13	7/16/13	7/1/13	6/24/13 S	Station ID
33	18	23	26	8.9	9.7	4.4	5.7	8.9	12	20	29	CLO0.4
37	20	23	-	10	11	5.1	7.1	9	13	21	-	CLO1.4
41	22	26	-	11	10	6.0	7.9	10	13	21	-	CLO1.9
45	20	24	31	9.0	9.2	3.8	4.1	6.8	11	18	-	CLO3.5
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CLO4.6
0.2	0.2	0.5	0.5	0.5	0.7	0.8	-	1.4	1.4	1.4	-	CLO7.1
1.6	1.0	0.9	0.9	0.4	0.5	0.3	-	0.7	1.0	1.5	1.9	CLO7.1SC
18	11	12	16	6.9	6.6	6.2	6.7	8.3	10	10	-	CLO8.7
17	12	12	16	7.7	6.8	6.2	7.9	9.3	10	13	-	CLO9.8
5.8	3.2	3.0	4.3	1.7	1.7	1.3	1.4	2.0	2.5	3.5	16	CLO11.0
3.0	1.6	1.5	2.0	1.3	1.3	1.3	1.7	1.7	2.0	2.2	2.6	CLO12.0
0.8	0.5	1.1	0.6	1.1	1.4	1.1	1.0	1.3	1.6	1.5	-	MOR0.1
1.1	1.4	2.4	3.1	2.4	3.5	2.2	2.1	2.7	2.7	3.0	2.9	MOR0.9
27	1.7	0.0	2.0	0.6	0.0	0.0	0.0	0.0	0.0	0.3	-	NFC0.0
13	0.7	0.1	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	-	NFC1.0
18	1.6	0.7	3.5	1.4	0.6	0.0	0.01	0.01	0.1	0.1	-	NFCB0.0
9.3	0.9	0.6	2.7	1.6	0.61	0.01	0.02	0.01	0.08	0.3	1.3	NFCB1.1
-	-	-	-	-	-	-	-	-	-	-	-	SPA0.5
24	18	20	20	11	11	6.6	6.5	7.4	10	16	-	SPA1.4
19	15	15	16	10	12	6.2	7.4	9.0	10	16		SPA1.8
-	-	0.0	0.013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NFCB1.1LB*
-	-	0.016	0.095	0.051	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NFCB1.1RB*

Station ID	12/3 & 4 2013	12/17 & 18 2013	1/7 & 8 2014	1/28 & 29 2014	2/11 & 12 2014
CLO0.4	29	25	25	31	42
CLO1.4	30	30	30	32	41
CLO1.9	33	26	25	33	44
CLO3.5	32	25	24	32	41
CLO4.6	1.1	9.9	11	0.2	11
CLO7.1	0.3	3.5	3.7	0.9	0.9
CLO7.1SC	2.0	9.0	9.7	3.4	3.7
CLO8.7	15	22	22	22	23
CLO9.8	15	15	15	17	18
CLO11.0	4.6	11	11	4.8	5.5
CLO12.0	1.9	7.0	6.8	3.0	3.3
MOR0.1	0.6	7.7	7.3	0.7	1.2
MOR0.9	1.0	11	11	1.5	1.6
NFC0.0	5.0	5.0	5.6	1.4	9.1
NFC1.0	2.1	6.8	7.0	1.0	5.4
NFCB0.0	3.8	15	16	1.6	15
NFCB1.1	2.3	5.0	4.9	0.5	5.3
SPA0.5	-	-	-	-	-
SPA1.4	23	19	19	28	31
SPA1.8	17	33	33	23	25
NFCB1.1LB*	-	-	-	-	-
NFCB1.1RB*	-	-	-	-	-

* Outfalls to North Fork Clover Creek at 121st Street
S Storm event
"-" No measurement taken

Two USGS gage stations exist in the watershed, providing continuous (time-series) stream discharge data (Figure D-1). One is located on Clover Creek at Pacific Highway SW (station ID 12090500), at the same location as Ecology site CLO1.4. The other is located on North Fork Clover Creek at Golden Given Rd. E (station ID 12090400).

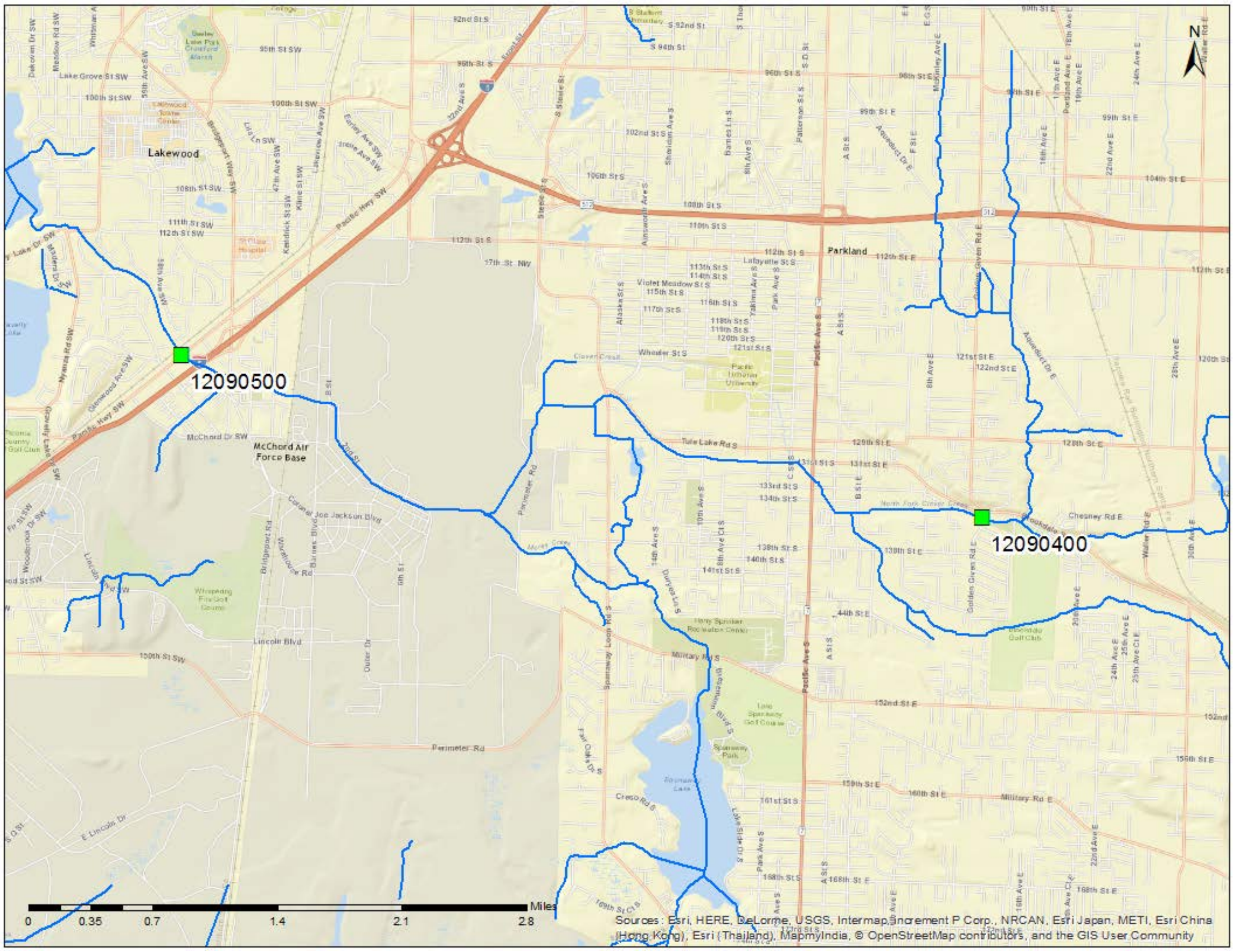


Figure D-1. Location of USGS stream gages in the Clover Creek watershed.

USGS data for Clover Creek and the North Fork Clover Creek are available at http://www.usgs.gov/water/. Data available at these site are presented in Figures D-2 and D-3, respectively.

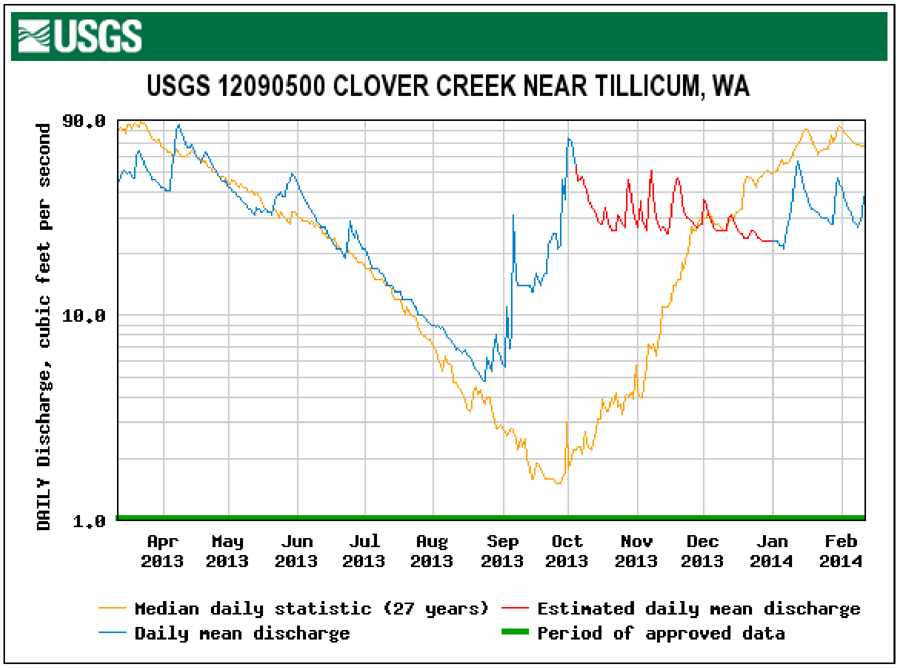


Figure D-2. USGS discharge (cfs) data at Clover Creek at Pacific Highway.

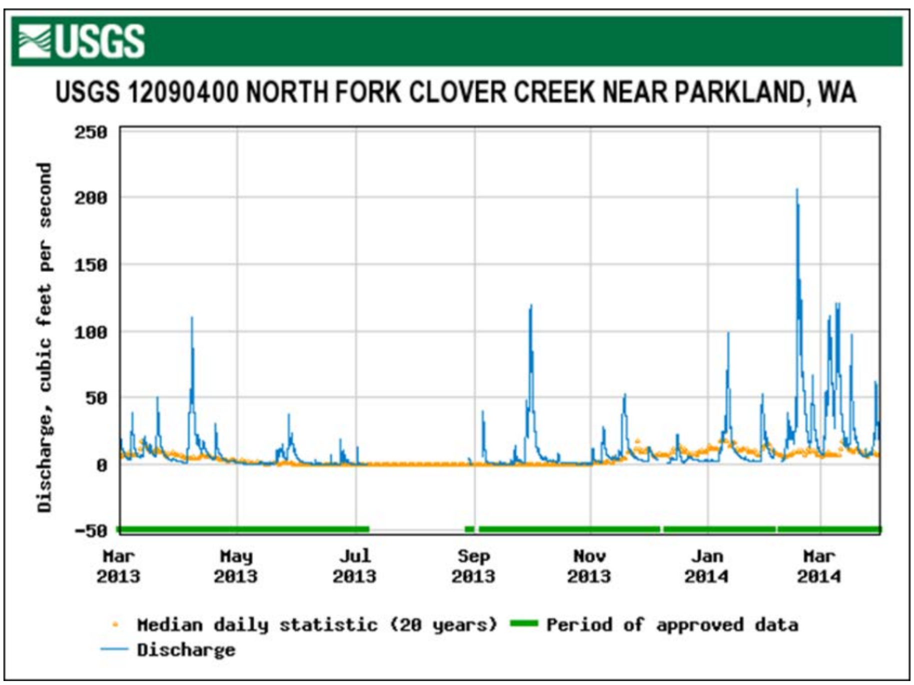


Figure D-3. USGS discharge (cfs) data at North Fork Clover Creek at Golden Given Road.

Appendix E. Temperature Data

Ecology collected temperature measurements biweekly at each fixed monitoring station during sample collection (Table E-1, Figure E-1). Temperature measurements were not collected at the same time of day and do not account for diurnal changes in temperature. Table E-1 shows the temperature measurements taken during sample collection.

Bolded and highlighted temperatures exceeded the 7-day average of the daily maximum temperatures (7-DADMax) water quality criterion of 17.5º C.

Table E-1. Temperature measurements taken during sample collection at the study sites.

Site	Mean	10th Percentile	90th Percentile	Minimum	Maximum	Number
CLO0.4	12.25	6.52	16.97	5.68	**19.76**	28
CLO1.4	12.05	6.78	16.34	5.78	**19.49**	25
CLO1.9	12.19	6.99	16.41	5.94	**19.82**	25
CLO11.0	12.12	7.36	16.59	4.85	**20.22**	25
CLO12.0	10.30	7.77	12.10	5.73	12.84	28
CLO3.5	11.91	6.22	16.19	5.18	**19.77**	28
CLO4.6	7.02	3.55	9.86	3.12	11.30	10
CLO7.1	12.22	6.70	**17.67**	3.29	**20.15**	27
CLO7.1SC	13.48	6.70	**20.52**	2.98	**24.36**	20
CLO8.7	12.52	7.87	16.97	4.48	**20.36**	25
CLO9.8	12.90	8.21	**18.71**	5.58	**21.22**	28
MOR0.1	13.17	4.38	**19.86**	4.12	**23.12**	25
MOR0.9	14.11	7.37	**18.93**	5.01	**21.94**	23
NFC0.0	12.57	4.64	**24.67**	2.34	**31.82**	19
NFC1.0	11.43	4.49	17.20	4.27	**28.85**	17
NFCB0.0	12.93	5.52	**21.15**	4.84	**26.05**	23
NFCB1.1	13.74	5.79	**19.83**	5.48	**25.03**	25
SPA0.5	14.19	6.42	**21.53**	4.98	**25.10**	25
SPA1.4	13.81	7.46	**19.89**	6.25	**22.63**	24
SPA1.8	14.99	5.84	**23.12**	4.70	**25.53**	27

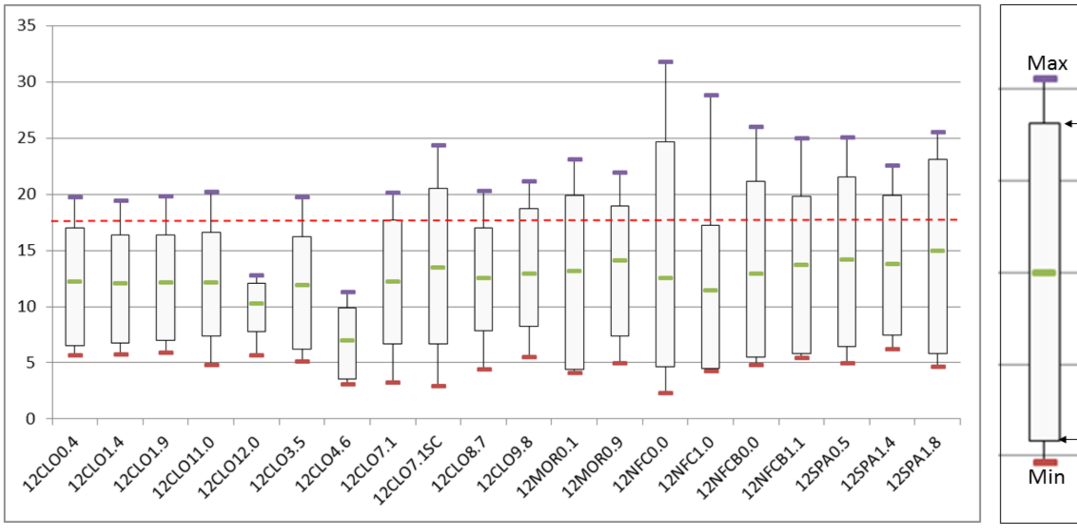


Figure E-1. Temperature distribution from measurements taken during sample collected at Clover Creek sites.

Sites that exceeded (did not meet) the water quality criteria for the 90th percentile include:

- CLO7.1
- CLO7.1SC
- CLO9.8
- All stations on Morey Creek
- All stations on the North Fork Clover Creek
- All stations on Spanaway Creek

All sites, except CLO12.0 and CLO4.6, exceeded the water quality criterion for the maximum value. Two sites on the North Fork (NFC0.0 and NFC1.0) had the greatest range in temperatures.

Figures E-2 to E-10 show water and air temperature thermographs for study sites where Ecology deployed thermistors.

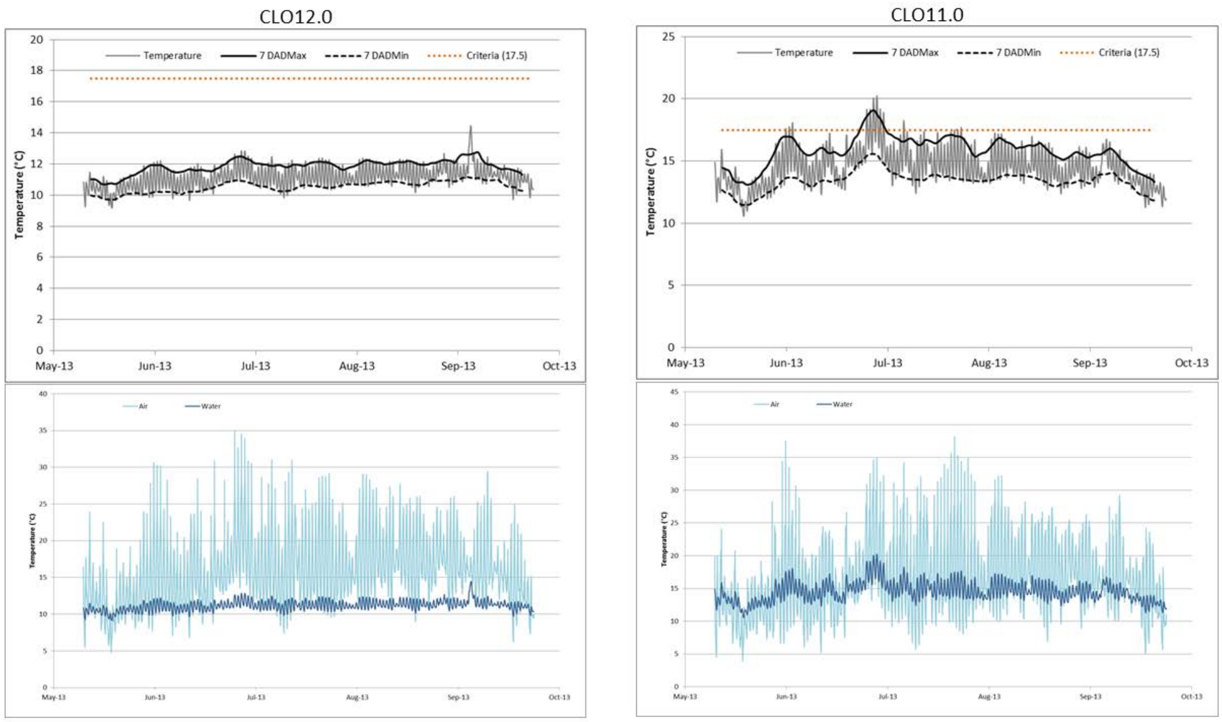


Figure E-2. Water and air temperatures during summer 2013 at CLO12.0 and CLO11.0.

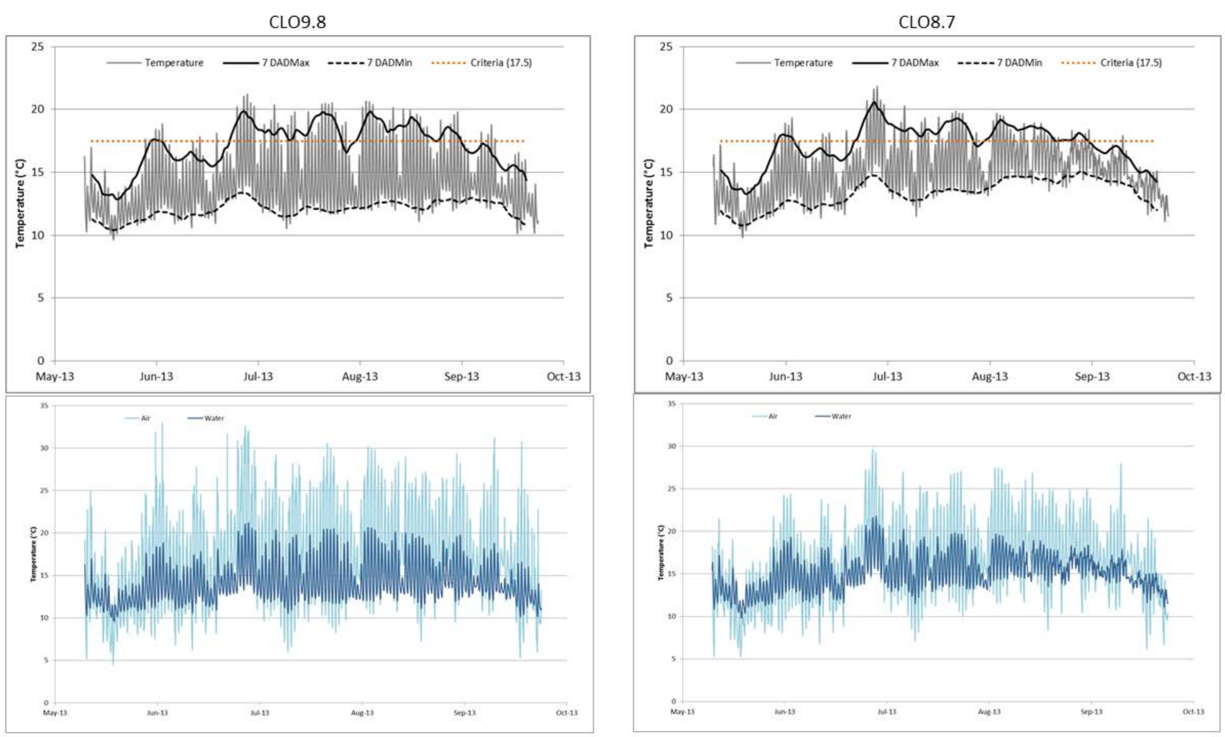


Figure E-3. Water and air temperatures during summer 2013 at CLO9.8 and CLO8.7.

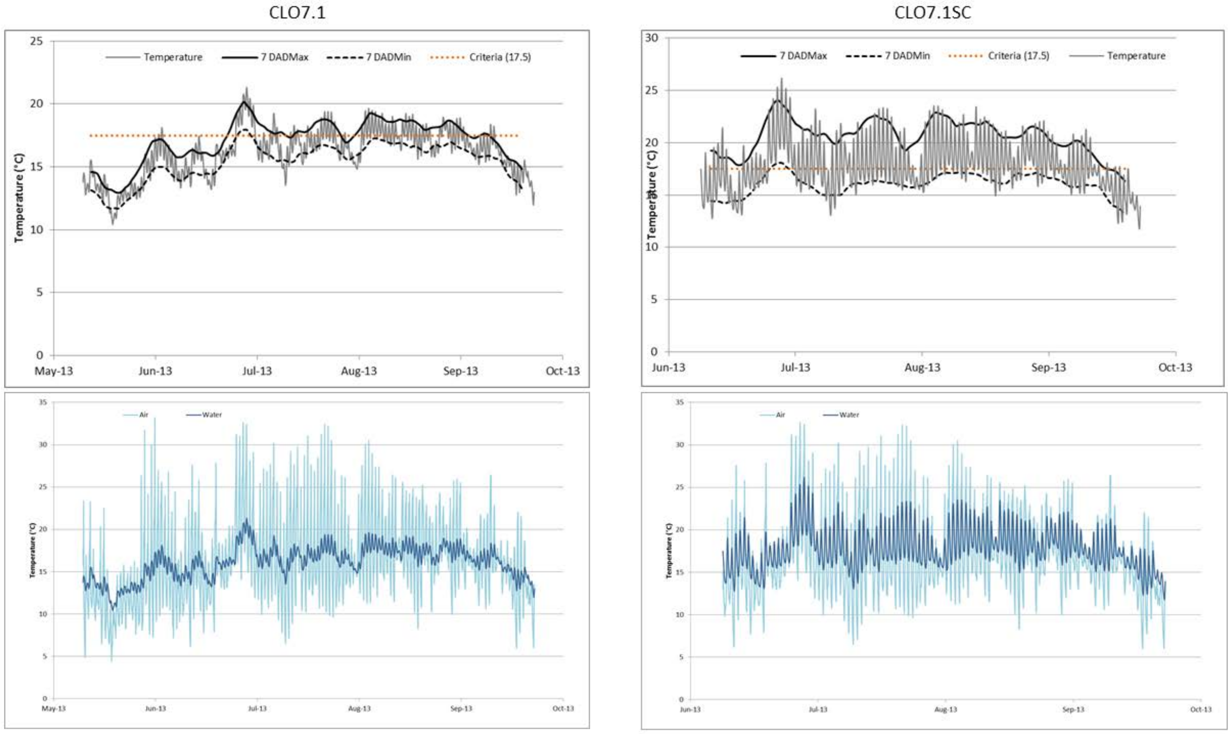


Figure E-4. Water and air temperatures during summer 2013 at CLO7.1 and CLO7.1SC.

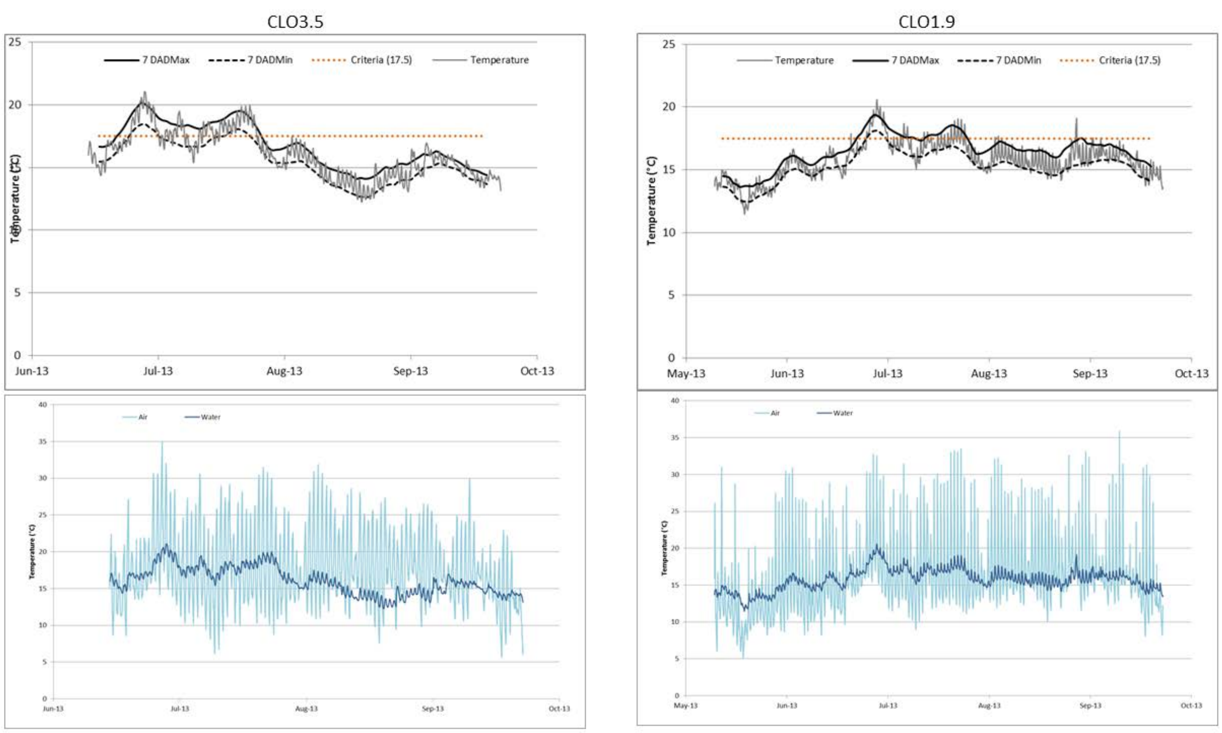


Figure E-5. Water and air temperatures during summer 2013 at CLO3.5 and CLO1.9.

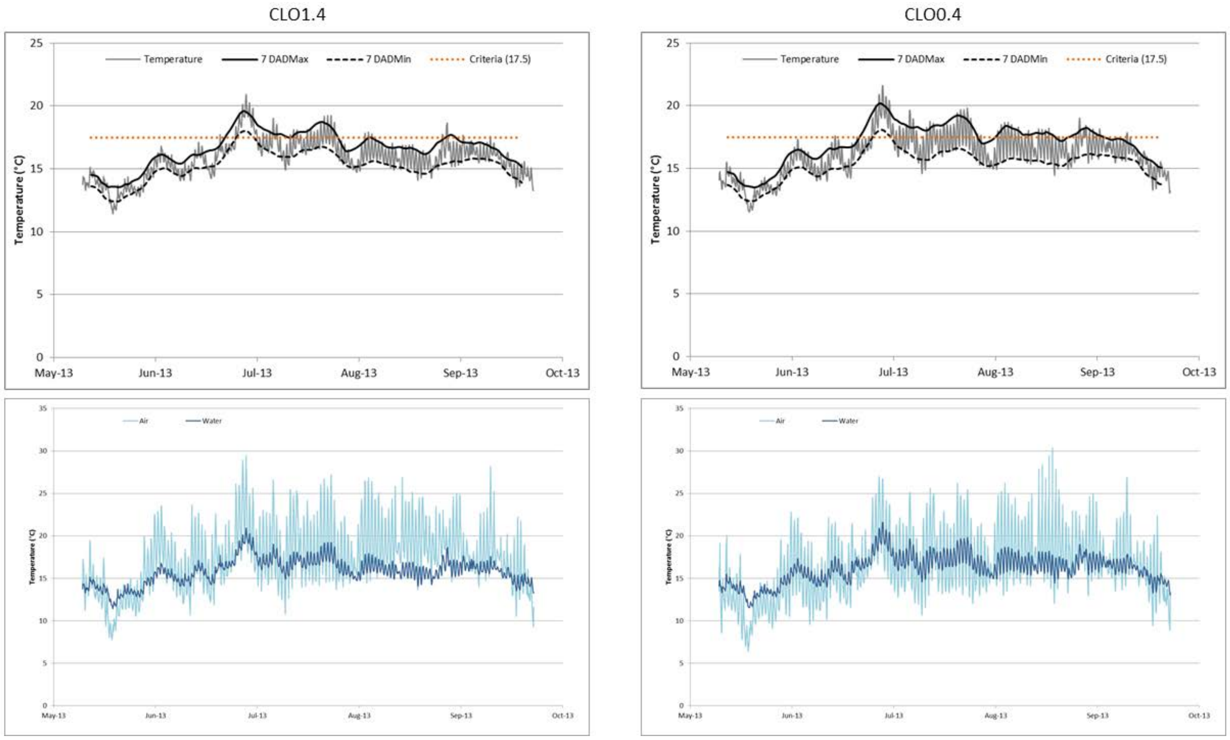


Figure E-6. Water and air temperatures during summer 2013 at CLO1.4 and CLO0.4.

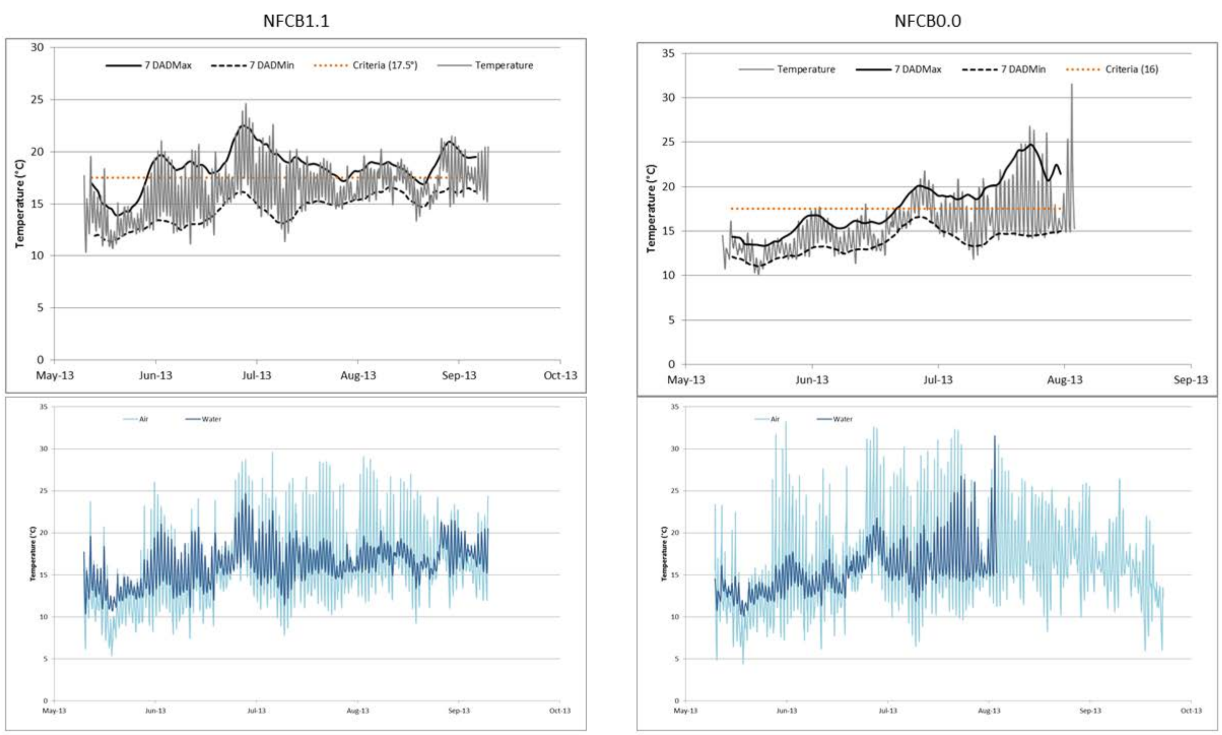


Figure E-7. Water and air temperatures during summer 2013 at NFCB1.1 and NFCB0.0.

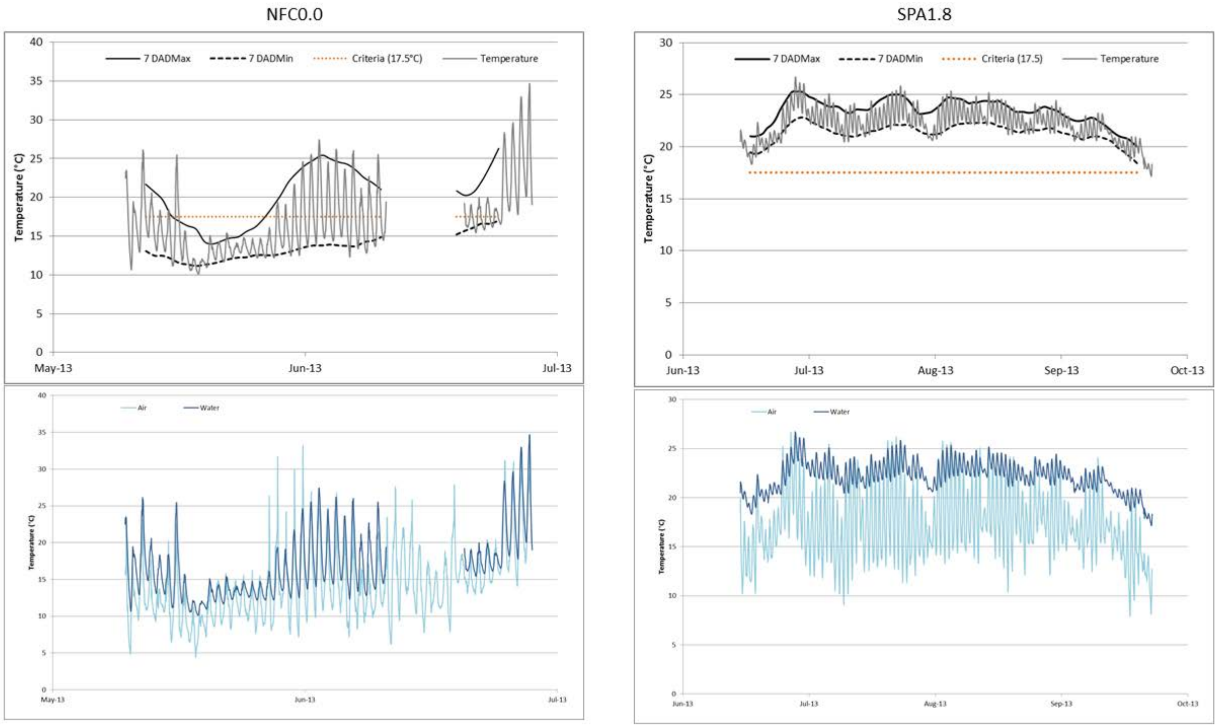


Figure E-8. Water and air temperatures during summer 2013 at NFC0.0 and SPA1.8.

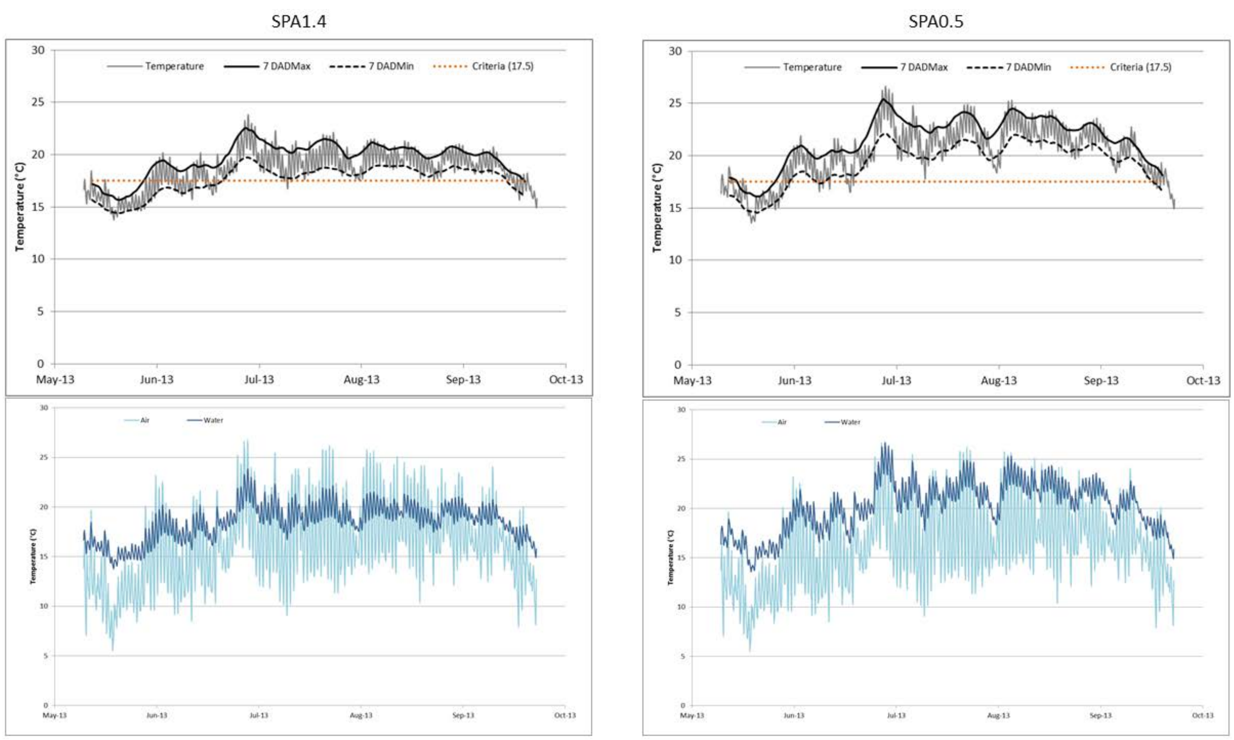


Figure E-9. Water and air temperatures during summer 2013 at SPA1.4 and SPA0.5.

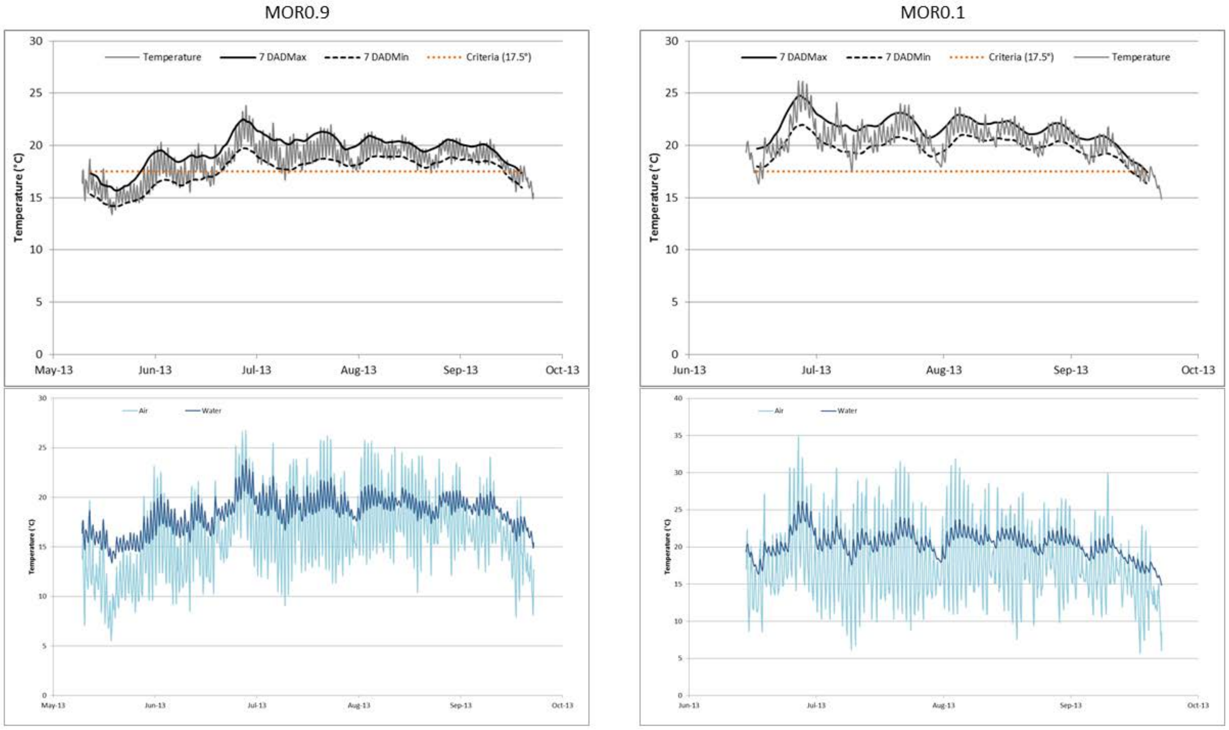


Figure E-10. Water and air temperatures during summer 2013 at MOR0.9 and MOR0.1.

Appendix F. Riparian Data

Table F-1. Effective shade and canopy cover calculated from HemiView® photographs for the Clover Creek watershed.

Site ID	Average effective shade* (%)	Canopy cover (%)
CLO0.4	81.7	91.9
CLO1.4	67.6	75.1
CLO1.9	56.2	81.3
CLO3.5	85	68.5
CLO4.6	4.4	29.6
CLO7.1	88.4	89.3
CLO8.7	41.7	45.5
CLO9.8	50.9	71.1
CLO11	87.4	85.3
CLO12	88.5	88.8
MOR0.1	53.2	62.8
MOR0.9	82.1	85.7
NFC0.0	11.6	58.4
NFC1.0	17.2	45.3
NFCB0.0	16.5	39.1
NFCB1.1	69.9	91
SPA1.4	21.6	52.6
SPA1.8	85.4	87.6

*Average includes May through September

Table F-2. Comparison of monthly percent effective shade calculated with HemiView® (percent Effective Shade) and Solmetric SunEye™ (percent Effective Shade Suneye).

Site	Month	% Effective Shade	% Effective Shade Suneye	RSD (%)	RPD (%)
CLO0.4	*5 (May)*	80	46	38.3	54.2
CLO0.4	*6 (June)*	94	85	7.1	10.1
CLO0.4	*7 (July)*	94	66	24.6	34.8
CLO0.4	*8 (Aug)*	79	28	67.4	95.3
CLO0.4	*9 (Sept)*	61	18	77.3	109.3
CLO1.4	*5 (May)*	70	44	32	45.3
CLO1.4	*6 (June)*	66	43	30.2	42.7
CLO1.4	*7 (July)*	67	45	27.4	38.7
CLO1.4	*8 (Aug)*	69	39	39.7	56.2
CLO1.4	*9 (Sept)*	66	42	31.2	44.2
CLO1.9	*5 (May)*	56	43	18.2	25.8
CLO1.9	*6 (June)*	58	38	29.6	41.9
CLO1.9	*7 (July)*	58	41	24.3	34.3
CLO1.9	*8 (Aug)*	55	40	22.8	32.2
CLO1.9	*9 (Sept)*	54	38	24.5	34.6
CLO1.9_RB	*5 (May)*	78	51	30	42.5
CLO1.9_RB	*6 (June)*	80	56	24.7	35
CLO1.9_RB	*7 (July)*	80	54	27.3	38.6
CLO1.9_RB	*8 (Aug)*	78	47	35.1	49.6
CLO1.9_RB	*9 (Sept)*	67	35	44.1	62.4
CLO3.5	*5 (May)*	86	72	12.8	18
CLO3.5	*6 (June)*	80	68	11.4	16.1
CLO3.5	*7 (July)*	80	68	11.4	16.2
CLO3.5	*8 (Aug)*	87	82	4	5.7
CLO3.5	*9 (Sept)*	92	95	2.3	-3.2
CLO3.5_LB	*5 (May)*	91	83	6.7	9.4
CLO3.5_LB	*6 (June)*	85	77	6.7	9.5
CLO3.5_LB	*7 (July)*	85	79	4.9	7
CLO3.5_LB	*8 (Aug)*	92	91	0.5	0.7
CLO3.5_LB	*9 (Sept)*	91	98	5.3	-7.6
CLO4.6	*5 (May)*	5	8	28.2	-39.9
CLO4.6	*6 (June)*	4	4	6	-8.4
CLO4.6	*7 (July)*	4	5	21.7	-30.6
CLO4.6	*8 (Aug)*	5	6	8.1	-11.4
CLO4.6	*9 (Sept)*	4	3	19.2	27.1
CLO4.6_LB	*5 (May)*	4	6	32.3	-45.6
CLO4.6_LB	*6 (June)*	4	5	13.6	-19.3
CLO4.6_LB	*7 (July)*	4	5	13.1	-18.5

Site	Month	% Effective Shade	% Effective Shade Suneye	RSD (%)	RPD (%)
CLO4.6_LB	*8 (Aug)*	4	4	6	-8.5
CLO4.6_LB	*9 (Sept)*	2	2	14.1	-20
CLO4.6_RB	*5 (May)*	2	3	19.4	-27.4
CLO4.6_RB	*6 (June)*	1	2	33.7	-47.7
CLO4.6_RB	*7 (July)*	1	2	34.3	-48.5
CLO4.6_RB	*8 (Aug)*	2	4	33.3	-47.1
CLO4.6_RB	*9 (Sept)*	3	4	20.4	-28.8
CLO7.1	*5 (May)*	90	12	108.1	152.8
CLO7.1	*6 (June)*	87	13	104.6	148
CLO7.1	*7 (July)*	87	11	109.7	155.1
CLO7.1	*8 (Aug)*	90	9	115.8	163.7
CLO7.1	*9 (Sept)*	88	6	123.4	174.5
CLO7.1_LB	*5 (May)*	86	26	75.7	107.1
CLO7.1_LB	*6 (June)*	87	30	68.8	97.2
CLO7.1_LB	*7 (July)*	87	28	72.3	102.3
CLO7.1_LB	*8 (Aug)*	86	26	75.9	107.3
CLO7.1_LB	*9 (Sept)*	91	14	103.6	146.5
CLO7.1_RB	*5 (May)*	93	100	5	-7.1
CLO7.1_RB	*6 (June)*	91	100	6.7	-9.4
CLO7.1_RB	*7 (July)*	91	100	6.6	-9.4
CLO7.1_RB	*8 (Aug)*	93	100	4.9	-6.9
CLO7.1_RB	*9 (Sept)*	93	100	5.2	-7.4
CLO8.7	*5 (May)*	45	49	6.6	-9.4
CLO8.7	*6 (June)*	37	33	7.3	10.3
CLO8.7	*7 (July)*	36	39	4.7	-6.7
CLO8.7	*8 (Aug)*	45	50	7.4	-10.4
CLO8.7	*9 (Sept)*	46	56	14	-19.8
CLO8.7_RB	*5 (May)*	35	33	3.4	4.8
CLO8.7_RB	*6 (June)*	23	24	2.9	-4.1
CLO8.7_RB	*7 (July)*	23	28	13.1	-18.6
CLO8.7_RB	*8 (Aug)*	35	39	7.2	-10.2
CLO8.7_RB	*9 (Sept)*	44	53	13.3	-18.8
CLO9.8	*5 (May)*	48	44	6.5	9.1
CLO9.8	*6 (June)*	57	41	22.6	32
CLO9.8	*7 (July)*	56	43	19.1	27
CLO9.8	*8 (Aug)*	48	38	15.9	22.5
CLO9.8	*9 (Sept)*	45	33	22.5	31.8
CLO9.8_RB	*5 (May)*	34	44	17.9	-25.4
CLO9.8_RB	*6 (June)*	31	39	17.1	-24.2
CLO9.8_RB	*7 (July)*	31	44	25.3	-35.8

Site	Month	% Effective Shade	% Effective Shade Suneye	RSD (%)	RPD (%)
CLO9.8_RB	*8 (Aug)*	34	38	7.4	-10.4
CLO9.8_RB	*9 (Sept)*	31	33	5.2	-7.3
CLO11	*5 (May)*	89	83	5.2	7.4
CLO11	*6 (June)*	86	74	10.2	14.5
CLO11	*7 (July)*	85	76	8.1	11.5
CLO11	*8 (Aug)*	90	92	1.8	-2.6
CLO11	*9 (Sept)*	87	98	8.4	-11.8
CLO11_LB	*5 (May)*	95	100	3.3	-4.6
CLO11_LB	*6 (June)*	96	100	2.7	-3.9
CLO11_LB	*7 (July)*	96	100	2.7	-3.8
CLO11_LB	*8 (Aug)*	95	100	3.3	-4.6
CLO11_LB	*9 (Sept)*	96	100	3.1	-4.4
CLO11_RB	*5 (May)*	85	6	122.8	173.6
CLO11_RB	*6 (June)*	86	8	117.4	166
CLO11_RB	*7 (July)*	86	8	117.4	166
CLO11_RB	*8 (Aug)*	85	6	122.7	173.6
CLO11_RB	*9 (Sept)*	83	3	131.6	186.1
CLO12	*5 (May)*	88	8	117.9	166.7
CLO12	*6 (June)*	93	9	116.4	164.6
CLO12	*7 (July)*	92	9	116.3	164.5
CLO12	*8 (Aug)*	88	6	123.3	174.4
CLO12	*9 (Sept)*	82	4	128.2	181.3
CLO12_LB	*5 (May)*	84	64	18.8	26.6
CLO12_LB	*6 (June)*	80	51	31.2	44.1
CLO12_LB	*7 (July)*	80	58	22.5	31.9
CLO12_LB	*8 (Aug)*	84	80	3.3	4.7
CLO12_LB	*9 (Sept)*	86	78	7.3	10.3
CLO12_RB	*5 (May)*	95	19	94.2	133.2
CLO12_RB	*6 (June)*	93	20	91.2	129
CLO12_RB	*7 (July)*	93	15	102.1	144.3
CLO12_RB	*8 (Aug)*	95	26	80.6	114
CLO12_RB	*9 (Sept)*	94	33	68.1	96.3
MOR0.1	*5 (May)*	60	53	8.5	12
MOR0.1	*6 (June)*	33	32	1.5	2.2
MOR0.1	*7 (July)*	33	42	16.6	-23.5
MOR0.1	*8 (Aug)*	61	73	12.8	-18
MOR0.1	*9 (Sept)*	80	98	14.6	-20.6
MOR0.9	*5 (May)*	83	39	50.9	72
MOR0.9	*6 (June)*	80	34	57	80.5
MOR0.9	*7 (July)*	80	36	53.5	75.7
MOR0.9	*8 (Aug)*	83	50	35	49.5

Site	Month	% Effective Shade	% Effective Shade Suneye	RSD (%)	RPD (%)
MOR0.9	*9 (Sept)*	85	67	16.7	23.5
MOR0.9_LB	*5 (May)*	83	53	31.3	44.2
MOR0.9_LB	*6 (June)*	82	45	41.6	58.8
MOR0.9_LB	*7 (July)*	83	49	36.1	51
MOR0.9_LB	*8 (Aug)*	83	59	23.9	33.8
MOR0.9_LB	*9 (Sept)*	87	72	13.2	18.6
MOR0.9_RB	*5 (May)*	86	46	42.9	60.7
MOR0.9_RB	*6 (June)*	82	45	41.4	58.5
MOR0.9_RB	*7 (July)*	82	43	44.2	62.5
MOR0.9_RB	*8 (Aug)*	86	48	40.4	57.1
MOR0.9_RB	*9 (Sept)*	84	44	43.8	62
NFC0.0	*5 (May)*	9	7	20.6	29.1
NFC0.0	*6 (June)*	10	8	14.7	20.8
NFC0.0	*7 (July)*	10	8	14.8	20.9
NFC0.0	*8 (Aug)*	9	6	31.2	44.1
NFC0.0	*9 (Sept)*	20	24	13.9	-19.6
NFC0.0_LB	*5 (May)*	51	44	10.9	15.4
NFC0.0_LB	*6 (June)*	52	45	10.8	15.3
NFC0.0_LB	*7 (July)*	52	44	12.1	17.1
NFC0.0_LB	*8 (Aug)*	52	44	11.9	16.9
NFC0.0_LB	*9 (Sept)*	65	72	6.9	-9.8
NFC0.0_RB	*5 (May)*	34	22	30.3	42.9
NFC0.0_RB	*6 (June)*	40	27	27.2	38.4
NFC0.0_RB	*7 (July)*	40	23	38.1	53.8
NFC0.0_RB	*8 (Aug)*	34	20	35.7	50.5
NFC0.0_RB	*9 (Sept)*	30	17	40.2	56.8
NFC1.0	*5 (May)*	12	6	46.9	66.3
NFC1.0	*6 (June)*	10	3	73.6	104.2
NFC1.0	*7 (July)*	10	3	73.8	104.4
NFC1.0	*8 (Aug)*	12	10	14.5	20.5
NFC1.0	*9 (Sept)*	43	63	27.4	-38.7
NFCB0.0	*5 (May)*	17	19	9.7	-13.8
NFCB0.0	*6 (June)*	18	19	2	-2.8
NFCB0.0	*7 (July)*	18	18	1.7	2.3
NFCB0.0	*8 (Aug)*	17	19	9.8	-13.9
NFCB0.0	*9 (Sept)*	13	12	3.6	5
NFCB1.1	*5 (May)*	67	40	35.9	50.8
NFCB1.1	*6 (June)*	69	42	34.2	48.4
NFCB1.1	*7 (July)*	69	39	39.3	55.6
NFCB1.1	*8 (Aug)*	67	37	40.8	57.6

Site	Month	% Effective Shade	% Effective Shade Suneye	RSD (%)	RPD (%)
NFCB1.1	*9 (Sept)*	77	35	53.4	75.6
SPA1.4	*5 (May)*	20	24	11.5	-16.3
SPA1.4	*6 (June)*	23	23	0.3	-0.5
SPA1.4	*7 (July)*	23	24	3.5	-5
SPA1.4	*8 (Aug)*	20	21	2.7	-3.8
SPA1.4	*9 (Sept)*	22	27	15	-21.2
SPA1.4_LB	*5 (May)*	30	35	10.1	-14.3
SPA1.4_LB	*6 (June)*	33	35	3.1	-4.5
SPA1.4_LB	*7 (July)*	33	36	5.3	-7.5
SPA1.4_LB	*8 (Aug)*	30	31	1.8	-2.5
SPA1.4_LB	*9 (Sept)*	24	29	13.9	-19.7
SPA1.4_RB	*5 (May)*	16	20	15.3	-21.7
SPA1.4_RB	*6 (June)*	14	13	3.2	4.5
SPA1.4_RB	*7 (July)*	14	13	2.7	3.8
SPA1.4_RB	*8 (Aug)*	17	24	25.4	-35.9
SPA1.4_RB	*9 (Sept)*	31	41	18.9	-26.7
SPA1.8	*5 (May)*	85	69	14.7	20.8
SPA1.8	*6 (June)*	86	69	15.9	22.5
SPA1.8	*7 (July)*	86	68	16.9	23.8
SPA1.8	*8 (Aug)*	85	62	22.1	31.2
SPA1.8	*9 (Sept)*	84	54	31.1	44
SPA1.8_LB	*5 (May)*	92	100	6	-8.4
SPA1.8_LB	*6 (June)*	92	92	0.4	-0.5
SPA1.8_LB	*7 (July)*	92	94	1.8	-2.6
SPA1.8_LB	*8 (Aug)*	92	99	5.3	-7.5
SPA1.8_LB	*9 (Sept)*	87	100	9.6	-13.6
SPA1.8_RB	*5 (May)*	76	60	17	24
SPA1.8_RB	*6 (June)*	86	53	33.4	47.3
SPA1.8_RB	*7 (July)*	86	56	29.6	41.9
SPA1.8_RB	*8 (Aug)*	76	59	18	25.4
SPA1.8_RB	*9 (Sept)*	77	58	19.6	27.7

Appendix G. Dissolved Oxygen Data

Ecology collected DO measurements biweekly at each monitoring site from March 2013 to February 2014. These DO measurements did not occur at the same time of day and do not account for diurnal fluctuations in DO.

Table G-1 shows the DO measurements taken at study sites during sample collection. Bolded and highlighted DO values are below the 8.0 mg/L criterion.

Table G- 1. DO measurements (mg/L) taken during site visits.

Site	Mean	10th Percentile	90th Percentile	Min	Max	n
CLO0.4	10.47	9.47	11.83	8.61	12.4	62
CLO1.4	8.95	**7.60**	10.53	**7.47**	11	46
CLO1.9	8.80	**6.89**	10.56	**6.38**	11.15	49
CLO11.0	8.09	**6.58**	9.58	**6.3**	11.25	48
CLO12.0	9.62	8.95	10.49	8.45	10.8	60
CLO3.5	**7.21**	**4.84**	9.80	**4.05**	10.3	55
CLO4.6	13.19	10.87	15.30	10.61	16.15	18
CLO7.1	9.64	8.41	11.27	**4.11**	12.16	54
CLO7.1SC	**7.74**	**5.35**	10.72	**4.44**	11.52	36
CLO8.7	10.63	9.47	11.95	8.43	12.39	51
CLO9.8	9.50	8.08	11.25	**6.36**	11.8	60
MOR0.1	11.04	**6.75**	16.69	**5.66**	19.2	49
MOR0.9	9.06	**6.49**	11.48	**5.81**	12	49
NFC0.0	12.25	10.29	13.70	9.33	14.82	37
NFC1.0	11.66	9.50	13.05	9.22	13.5	28
NFCB0.0	10.48	9.07	12.16	8.56	12.55	44
NFCB1.1	8.77	**6.48**	10.83	**6.09**	12.2	44
SPA0.5	9.78	8.56	11.44	8.09	12	34
SPA1.4	10.61	9.36	11.92	8.74	12.2	48
SPA1.8	11.13	9.60	12.90	8.66	13.3	54

Clover Creek

The mean DO concentration at 2 Clover Creek stations (CLO3.5 and CLO7.1SC) fell below the water quality criterion. The minimum and 10th percentile DO concentration fell below 8.0 mg/L at 5 sites. The minimum DO concentration fell below 8.0 mg/L at 2 sites.

Spanaway Creek

All 3 sites on Spanaway Creek had DO concentrations above water quality criteria of 8.0 mg/L for all measurements.

Morey Creek

The DO concentration fell below 8.0 mg/L for the minimum and 10th percentile at both Morey Creek sites.

North Fork Clover Creek

All of the North Fork sites, except NFCB1.1, had DO concentrations above 8.0 mg/L. The minimum and 10th percentile DO concentrations fell below 8.0 mg/l at NFCB1.1.

Figure G-1 displays the distribution of DO concentrations measured during site visits.

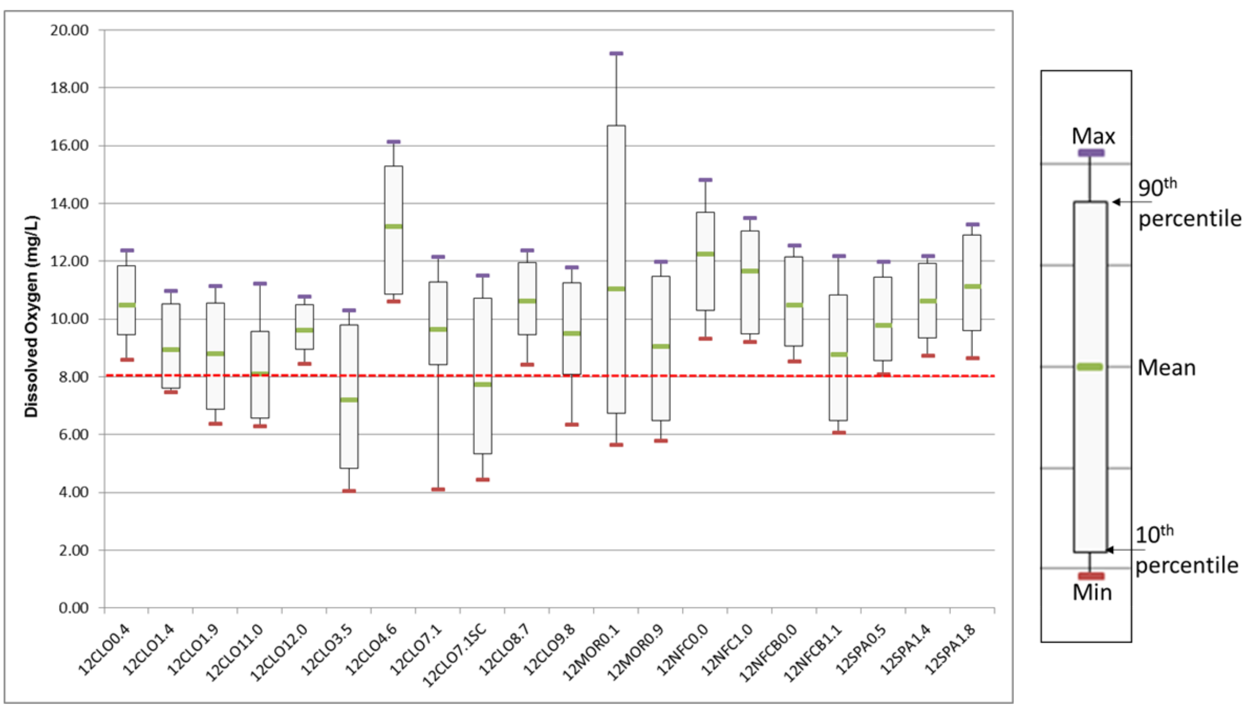


Figure G- 1. Dissolved oxygen (mg/L) measurements taken during sample collection at Clover Creek sites.

Appendix H. Bioassessment

Table H-1 lists reference sites used for B-IBI assessment.

Table H-1. Reference sites used for B-IBI assessment.

WRIA #	WRIA	Basin	Subbasin	Stream	Site ID	Data Collection Event
1	Nooksack	Whatcom-Chuckanut	Lake Whatcom	Austin Creek	BIO06600-AUST02	BIO06600-AUST02-DCE-2013-0904-13:30
1	Nooksack	Whatcom-Chuckanut	Bellingham Bay	Chuckanut Creek	EPA06600-CHUC01	EPA06600-CHUC01-DCE-2013-0801-15:30
7	Snohomish	Skykomish	Elwell Creek	Youngs Creek	BIO06600-YOUN02	BIO06600-YOUN02-DCE-2013-0731-12:00
7	Snohomish	Lower Snoqualmie	Griffin Creek	Griffin Creek	SEN06600-GRIF09	SEN06600-GRIF09-DCE-2013-0808-09:30
7	Snohomish	Lower Snoqualmie	Griffin Creek	Griffin Creek	SEN06600-GRIF09	SEN06600-GRIF09-DCE-2012-0807-11:25
8	Cedar-Sammamish	Sammamish	Issaquah Creek	Holder Creek	BIO06600-HOLD02	BIO06600-HOLD02-DCE-2013-0717-10:20
15	Kitsap	Hood Canal	W Kitsap	Big Anderson Creek	BIO06600-BIGA02	BIO06600-BIGA02-DCE-2013-0730-11:45
15	Kitsap	Hood Canal	W Kitsap	Boyce Creek	BIO06600-BOYC02	BIO06600-BOYC02-DCE-2013-0729-12:30
15	Kitsap	Hood Canal	W Kitsap	Seabeck Creek	BIO06600-SEAB02	BIO06600-SEAB02-DCE-2013-0710-12:30
15	Kitsap	Hood Canal	W Kitsap	Seabeck Creek	BIO06600-SEAB02	BIO06600-SEAB02-DCE-2013-1007-10:30
18	Elwha-Dungeness	Dungeness River	Lower Dungeness River	Canyon Creek (Dungeness)	BIO06600-CANY02	BIO06600-CANY02-DCE-2013-0715-13:08
18	Elwha-Dungeness	Port Angeles	Port Angeles Bay	Tumwater Creek	BIO06600-TUMW02	BIO06600-TUMW02-DCE-2013-0705-09:22

Table H-2 lists B-IBI metrics (0-100 scale) quantities calculated for study sites.

Table H-2. B-IBI metrics (0-100 scale) quantities calculated for 5 sites in Clover Creek watershed.

Site ID	Quantities											
	Taxa Richness Quantity	Ephemeroptera Richness Quantity	Plecoptera Richness Quantity	Trichoptera Richness Quantity	EPT Richness Quantity	Clinger Richness Quantity	Long-Lived Richness Quantity	Intolerant Richness Quantity	Percent Dominant Quantity	Predator Percent Quantity	Tolerant Percent Quantity	Number of Organisms
CLO12.0	42	2	2	4	8	10	5	0	0.4	0.4	0.0	246
CLO8.7	16	1	0	0	1	3	5	0	0.8	0.0	0.2	110
NFC0.0	18	0	0	1	1	1	1	0	0.7	0.1	0.1	191
SPA1.8	32	2	1	1	4	10	5	0	0.6	0.1	0.1	500
CLO3.5	39	1	0	7	8	14	4	1	0.8	0.1	0.1	500
CLO1.4	30	2	0	3	5	7	3	0	0.6	0.0	0.3	500

Table H-3 provides B-IBI metric scores (0-100 scale) for study sites.

Table H-3. B-IBI metrics scores (0-100 scale) calculated for 5 sites in the Clover Creek watershed.

Site ID	Scores										
	Overall Score	Taxa Richness Score	Ephemeroptera Richness Score	Plecoptera Richness Score	Trichoptera Richness Score	Clinger Richness Score	Long-Lived Richness Score	Intolerant Richness Score	Percent Dominant Score	Predator Percent Score	Tolerant Percent Score
CLO12.0	44.2	5.2	1.4	1.4	3.8	1.8	3.8	0	7.8	10	9.1
CLO8.7	10.2	0	0	0	0	0	3.8	0	0	1.3	5.1
NFC0.0	9.7	0	0	0	0	0	0	0	0.2	2.4	7.1
SPA1.8	22	1.7	1.4	0	0	1.8	3.8	0	3.5	2.1	7.7
CLO3.5	30.6	4.1	0	0	7.5	4.1	2.5	1.4	0	3.1	7.9
CLO1.4	9.7	1	1.4	0	2.5	0	1.2	0	1.1	0.2	2.1

Figure H-1 compares overall B-IBI scores of 12 reference sites with sites in the Clover Creek watershed.

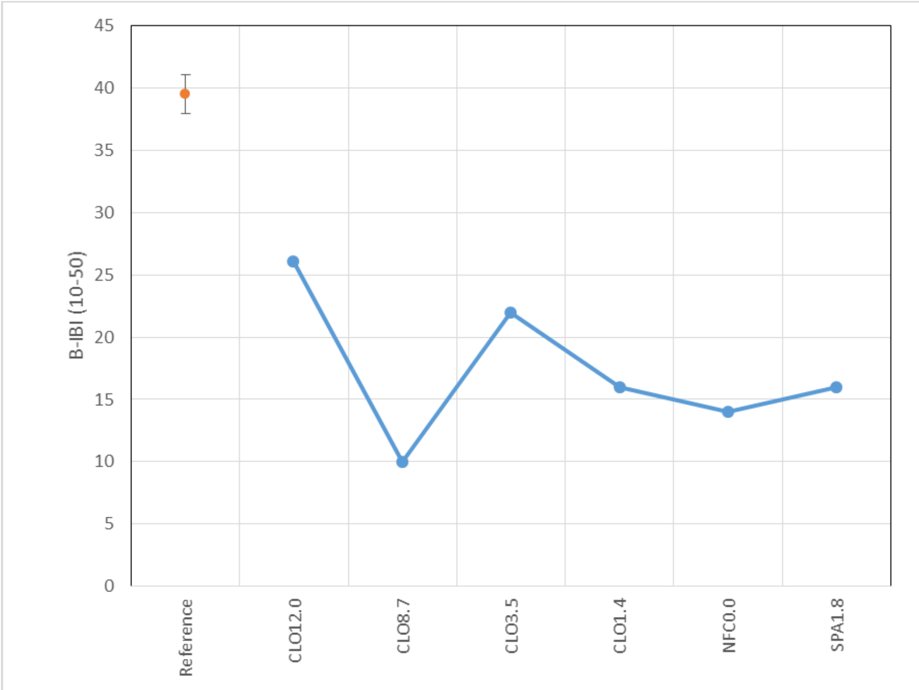


Figure H-1. Overall B-IBI scores of 12 reference sites and sites in the Clover Creek watershed. Error bars ± 1 standard error.

Taxa richness is a measure of biodiversity, which can be affected by human disturbances such as changes to flow and degradation of water quality. It includes all invertebrates collected from a stream site. Figure H-2 shows that taxa richness was lower at all Clover Creek watershed sites (16 – 42 taxa) compared to the reference sites (mean 53.2 taxa).

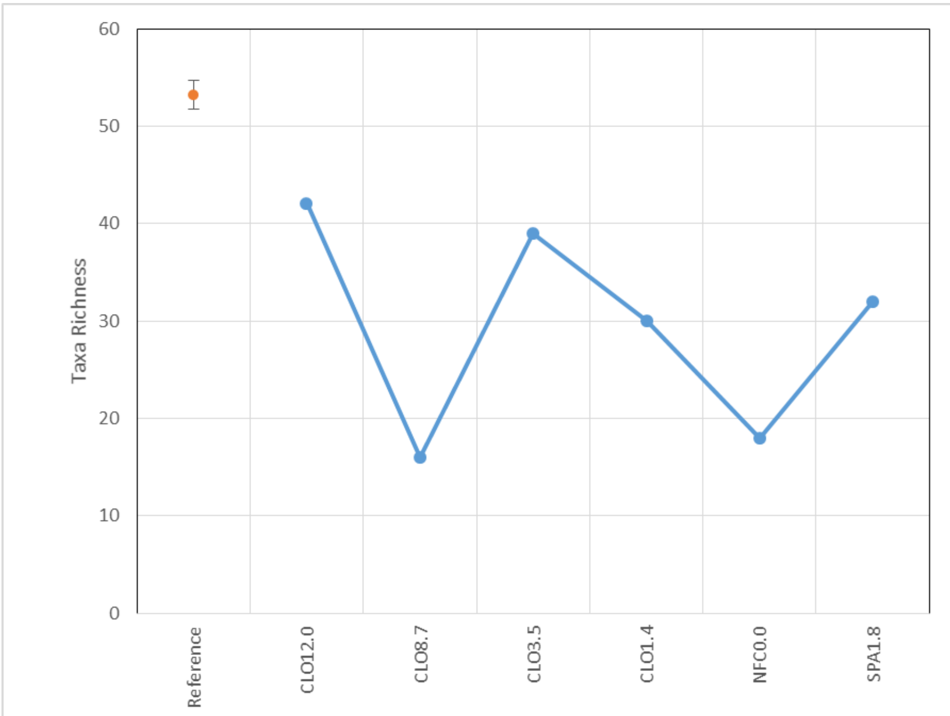


Figure H-2. Comparison of taxa richness at reference sites to sites in the Clover Creek watershed. Error bars ± 1 standard error.

The next 4 charts (Figure H-3) compare richness of 3 orders of benthic macroinvertebrates: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).

The EPT metric is the combined number of Ephemeroptera, Plecoptera, and Trichoptera taxa found in the sample. EPT richness was very low at all sites in the Clover Creek watershed (number of taxa ranged from 1 to 8) compared to the reference sites (mean 23.9). CLO12.0 and CLO3.5 had the highest number of EPT taxa (8 taxa). The lowest EPT richness was at CLO8.7 and NFC0.0 (1 taxa each).

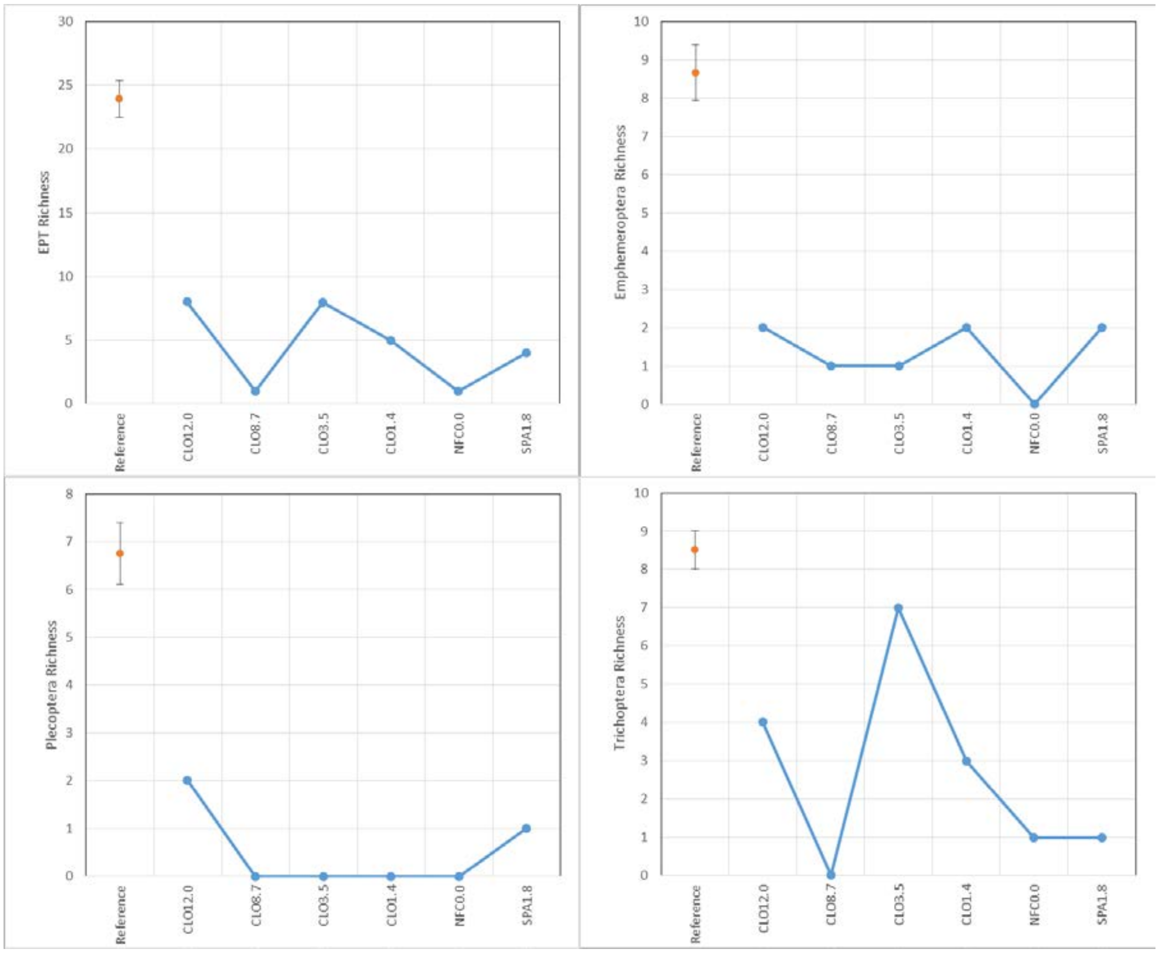


Figure H-3. Comparison of EPT, Ephemeroptera, Plecoptera, and Trichoptera richness at reference sites to sites in the Clover Creek watershed. Error bars ± 1 standard error of the mean.

The next 3 charts (Figure H-3) show the number of taxa in each of these orders separately, since each order may respond differently to various impacts.

- Ephemeroptera diversity is affected by human disturbance. Some mayfly taxa are sensitive to chemical pollution and nutrient enrichment. Ephemeroptera richness was very low at all sites (0 to 2 species) compared to the reference sites (mean 8.7).
- Stoneflies require cool water with high DO to complete their life cycle. They are often the first group of invertebrates to disappear in disturbed streams. Plecoptera richness was very low (0 to 2 species) at all sites compared to the reference sites (mean 6.8). No stoneflies were collected at 4 out of 6 sites.
- Trichoptera taxa are diverse, with varied foraging strategies and materials for construction of cases. As the complexity of stream habitats is reduced with disturbance, so are the number of different types of Trichoptera taxa present. Trichoptera richness was low (0 - 7 taxa) at all sites compared to the reference sites (mean 8.5 taxa). Richness was highest at CLO3.5, where 7 caddisfly species were collected.

Clingers are macroinvertebrates typically occupying interstitial spaces between rocks. They have physical structures and adaptations allowing them to cling onto substrates in fast water. These taxa are particularly sensitive to flow modification and fine sediment deposition which reduce interstitial habitat. Richness of clinger taxa was low at all sites compared to the reference sites (Figure H-4). The most clinger taxa were collected at CLO3.5, where Clover Creek gained streamflow downstream of Spanaway Creek.

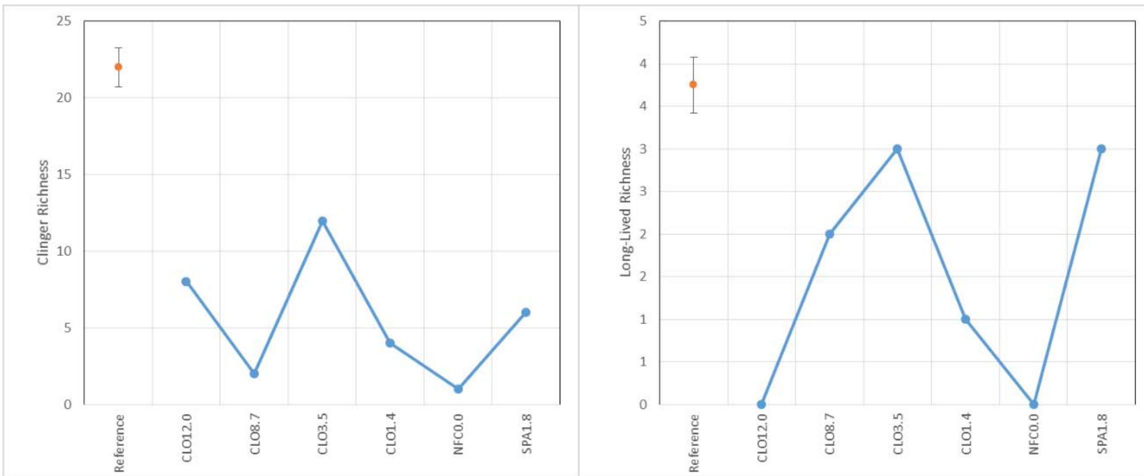


Figure H-4. Comparison of clinger and long-lived richness at reference sites to sites in the Clover Creek watershed. Error bars ± 1 standard error.

Long-lived taxa require more than one year to complete their life cycle. The presence of long-lived taxa suggests relatively stable conditions. In contrast, reduced richness indicates that the life cycle of long-lived taxa is interrupted. It could be a periodic disturbance that affects one life stage or a more chronic problem that repeatedly interrupts the life cycle. Richness of long-lived taxa was low compared to the reference sites. Long-lived richness was highest at CLO3.5 and SPA1.8, suggesting relatively stable conditions at these sites (Figure H-4). All other sites showed reduced richness of long-lived taxa, indicating the possibility of disturbance events at these sites.

Intolerant taxa are the most sensitive to disturbance. They represent only 5 to 10% of all the taxa present and are the first to disappear when a stream is disturbed. As Figure H-5 shows, no intolerant species were collected at 5 out of 6 sites. One intolerant taxon was collected at CLO12.0, which is low compared to the reference sites (mean 4.3 taxa).

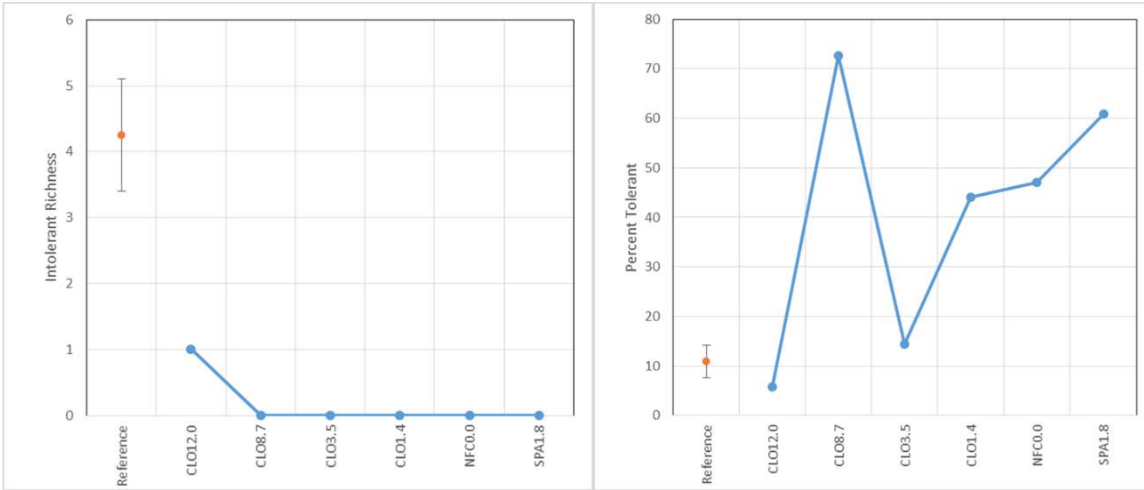


Figure H-5. Comparison of intolerant and tolerant richness at reference sites to sites in the Clover Creek watershed. Error bars ± 1 standard error.

In contrast to intolerant taxa richness is the percentage of tolerant taxa, which represent 5 to 10% of the most tolerant taxa in the region. They can be present at many streams sites; however, as disturbance increases, they may increase in number and represent a larger percentage of the community. The percentage of tolerant taxa was much higher at 4 out of 6 sites (44.0 to 72.7%) compared to the reference sites (mean 10.9%). CLO12.0 (5.7%) and CLO3.5 (14.4%) had the lowest percentages of tolerant species (Figure H-5).

Predators rely on a diverse source of invertebrate prey items, which are found at less impacted sites with greater habitat diversity. The percent of obligate predators is a measure of trophic complexity supported by the site. Figure H-6 shows that the percentage of predators was higher at CLO12.0 (39.0%) but lower at all other sites (1.0 to 5.2%) compared to the reference sites (mean 15.5%).

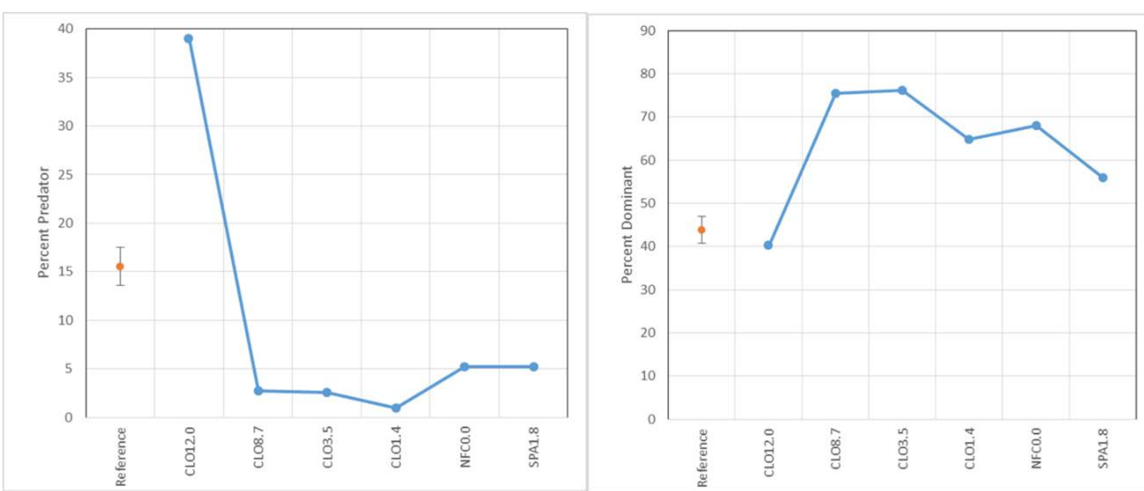


Figure H-6. Comparison of percent predator and percent dominant taxa at reference sites to sites in the Clover Creek watershed. Error bars ± 1 standard error.

The percentage dominant taxa is measured by adding the number of individuals in the most common taxa and dividing it by the total number of individuals collected at a site. Opportunistic species that have less particular life history requirements can replace more sensitive species in disturbed environments, leading to a reduction in biodiversity. The percentage dominant taxa at CLO12.0 (40.2%) was comparable to the reference sites (mean 43.9%). All other sites had a higher proportion of dominant taxa (Figure H-6).

Periphyton Results

Table H-4 provides the diatom attribute key. Table H-5 provides the diatom attributes.

Table H-4. Diatom attribute key.

PTC	Pollution Tolerence Class	Tolerance to organic pollution according to Lange-Bertalot 1979; 1=most tolerant of pollution; 2=tolerant of pollution; 3=sensitive to pollution
Hab.	Habitat	A = aerophile; P = planktonic
pH	pH	1 acidobiontic, optimum pH <5.5; 2 acidophilous, pH <7; 3 circumneutral, pH ~7; 4 alkaliphilous, mainly pH >7; 5 alkalibiontic, exclusively pH >7; 6 indifferent, no apparent optimum
H	Salinity	1 fresh; 2 fresh brackish; 3 brackish fresh; 4 brackish; 5 marine (see Van Dam et al. 1994 for criteria)
N	Nitrogen Uptake Metabolism	1 nitrogen autotroph tolerating very small concentrations of organic nitrogen; 2 nitrogen autotroph tolerating elevated concentrations of organic nitrogen; 3 facultative nitrogen heterotroph; 4 obligate nitrogen heterotroph
O	Oxygen requirements	1 continuously high (~100% saturation); 2 high (>75%); 3 moderate (>50%); 4 low (>30%); 5 very low (~10% saturation)
S	Saprobity	1 oligosaprobous; 2 beta-mesosaprobous; 3 alpha-mesosaprobous; 4 alpha-meso-/polysaprobous; 5 polysaprobous (see Van Dam et al. 1994 for criteria)
T	Tropic State	1 oligotraphentic; 2 oligo-mesotraphentic; 3 mesotraphentic; 4 meso-eutraphentic; 5 eutraphentic; 6 hypereutraphentic; 7 oligo- to eutraphentic (variable); 8 dystrophic
M	Moisture	1 rarely occurs outside water bodies; 2 mainly in water but sometimes on wet places; 3 mainly in water but regularly on wet or moist places; 4 mainly on wet, moist, or temporarily dry places; 5 occurs almost exclusively outside water bodies
Motility	Motility	H = highly motile; M = moderately motile (diatoms with raphes but not highly motile); N = not motile; V = variable motility (source: Jan Stevenson)
Dist.	Distribution	N = North American endemics; C = cosmopolitan in temperate regions, broad ecological niche,generally aggressive and opportunistic species that develop large populations in response to disturbance and may exclude native species (**, Lange-Bertalot 1996)
Rare	Rare Taxa	M = Mountains Rare Taxa; P = Plains Rare Taxa; C = Mountains and Plains Rare Taxa

Table H-5. Diatom attributes.

Taxon	PTC	Hab.	pH	H	N	O	S	T	M	Motility	Dist.	Rare
Achnanthes	3									N		
Achnanthes conspicua	3		3	1	1	2	1	7	1	N	C	
Achnanthes oblongella	3		3	2	1	1	1	1	3	N		
Achnanthes subhudsonis v. kraeuselii	3									N		
Achnanthidium deflexum	3		4	2				3		N	C	P
Achnanthidium exiguum	3		4	2	2	1	2	7	3	N	C	
Achnanthidium gracillimum	3											
Achnanthidium minutissimum	3		3	2	2	1	2	7	3	N	C	
Achnanthidium pyrenaicum	3		4	2				3		N	N	
Achnanthidium rivulare	3		3							N	N	M
Adlafia minuscula	2	A	4	1			2	1	4	M		
Amphora copulata	2		4	2	2	2	2	5	1	M	C	
Amphora inariensis	3			2				1		M		
Amphora pediculus	3		4	2	2	2	2	5	3	M	C	
Aulacoseira	3	P								N		
Aulacoseira crenulata	3	P	3	1	1	1	1	1	2	N		
Brachysira microcephala	3		4	2	1	2	1	2	2	M		
Caloneis bacillum	2	A	4	2	1	2	2	4	2	M		

Taxon	PTC	Hab.	pH	H	N	O	S	T	M	Motility	Dist.	Rare
Cocconeis neodiminuta	3			2						N		
Cocconeis neothumensis	3		5	1			1			N		
Cocconeis placentula	3		4	2	2	3	2	5	2	N	C	
Cocconeis placentula v. euglypta	3		4	2	2	3	2	5	2	N	C	
Cocconeis placentula v. lineata	3		4	2	2	3	2	5	2	N	C	
Cosmarium	2											
Cyclostephanos tholiformis	2	P								N		
Cyclotella bodanica	3	P	3	1	1	1	1	1	1	N		
Cyclotella ocellata	3	P	4	1	1	1	1	4	1	N		
Cymatopleura solea	2		4	2	2	3	2	5	1	H	C	
Cymbella affinis	3		4	2	1	1	2	5	2	V		
Cymbopleura subrostrata	3		4	2	2					V		
Diatoma mesodon	3		3	1	1	1	1	3	2	N		
Diatoma tenuis	2		4	3	2	3	3	5	1	N	C	
Diatoms	2											
Diploneis ovalis	3		4	2	1	1	1		4	M		
Encyonema auerswaldii	2			2			3	7		V	C	
Encyonema minutum	2		3	2	2	3	3	7	1	V	C	

Taxon	PTC	Hab.	pH	H	N	O	S	T	M	Motility	Dist.	Rare
Encyonema silesiacum	2		3	2	2	3	3	7	1	V	C	
Encyonopsis microcephala	3		4	2	1	1	1	4	3	V		
Encyonopsis subminuta	3									V		
Eolimna minima	1		4	2	3	4	4	5	3	M	C	
Epithemia adnata	2		5	2	1	2	2	4	2	M	C	
Epithemia turgida	3		5	2	1	2	2	4	3	M		
Eunotia	3									V		
Eunotia bilunaris v. bilunaris	2		6	2	2	2	2	7	3	V	C	
Eunotia formica	3		2	2	1	1	1	3	2	V		
Eunotia implicata	3									V		
Eunotia minor	2	A	2	1			1		4	V	C	
Fragilaria	3									N		
Fragilaria bicapitata	3		3	2	1	1	2	7	1	N		
Fragilaria capucina	2		3	2			2	3		N	C	
Fragilaria capucina v. gracilis	2		3	2	1	1	1	2		N		
Fragilaria capucina v. mesolepta	2		4	2						N	C	
Fragilaria crotonensis	3	P	4	2	2	2	2	3	1	N	C	
Fragilaria vaucheriae	2	A	4	2	2	3	3	5	3	N	C	

Taxon	PTC	Hab.	pH	H	N	O	S	T	M	Motility	Dist.	Rare
Fragilariforma bicapitata	3		3	2	1	1	2	7	1	N		
Fragilariforma nitzschioides	3		4	1	1					N		
Fragilariforma virescens	3		3	1	1	1	1	2	3	N		
Frustulia	3											
Geissleria	2									M		
Geissleria acceptata	2			1		1	2		4	M		
Geissleria decussis	3		4	2	1		1	4	3	M	C	
Gomphonema	3									N		
Gomphonema acuminatum	3		4	2	1	2	2	5	2	N	C	
Gomphonema exilissimum	2											
Gomphonema gracile	2		3	2	1	1	1	3	3	N		
Gomphonema kobayasii	3			2				7		N	N	P
Gomphonema lagenula	2											
Gomphonema minutum	3		3	2			2	5		N	C	
Gomphonema olivaceum	3		5	2	2	2	2	5	1	N	C	
Gomphonema parvulum	1		3	2	3	4	4	5	3	N	C	
Gomphonema rhombicum	3									N	N	
Gomphonema truncatum	3		4	2	1	2	2	4	2	N		

Taxon	PTC	Hab.	pH	H	N	O	S	T	M	Motility	Dist.	Rare
Halamphora veneta	1		5	3	2	3	4	5	3	M	C	
Hippodonta capitata	2		4	2	2	3	3	4	3	M		
Homeothrix	2											
Karayevia	3											
Karayevia clevei	3		4	2	2	2	2	4	1	N		
Karayevia laterostrata	3		3	1	1	1	1	1	3	N		
Karayevia suchlandtii	3		3	1	1	1	1	1	2	N		
Komvophoron	2											
Lemnicola hungarica	2		4	2	2	4	3	6	1	N	C	
Mayamaea atomus	1	A	4	2	4	2	4	6	4	M	C	
Melosira varians	2		4	2	3	3	3	5	2	N	C	
Meridion circulare	3		4	2	2	2	2	7	1	N	C	
Meridion circulare v. constrictum	3		4	2	2	2	2	7	2	N	C	
Navicula	2									M		
Navicula antonii	2		4	2			2	5		M	C	
Navicula cryptocephala	3		3	2	2	3	3	7	2	M	C	
Navicula cryptotenella	2		4	2			2	7	2	M	C	
Navicula cryptotenelloides	2									M	C	

Taxon	PTC	Hab.	pH	H	N	O	S	T	M	Motility	Dist.	Rare
Navicula gregaria	2		4	3	2	4	3	5	3	M	C	
Navicula lanceolata	2		4	3	2	3	3	5	3	M	C	
Navicula medioconvexa	3		3	1						M		
Navicula pseudoventralis	2		4	2	1	1	1	2	3	M		
Navicula recens	2		4	3			3	5	3	M		
Navicula rhynchocephala	3		4	2	2	4	2	7	2	M	C	
Navicula schadei	3											
Navicula tenelloides	1	A	4	3	1	1	1	5	4	M		
Navicula trivialis	2	A	4	3	2	3	3	5	3	M	C	
Navicula veneta	1	A	4	3	2	4	4	5	3	M	C	
Nitzschia	2									H		
Nitzschia acidoclinata	3		3	1	1	1	2	3	3	H		
Nitzschia amphibia	2		4	2	3	3	3	5	3	H		
Nitzschia archibaldii	2		3	2	2	2	2	5		H		
Nitzschia dissipata	3		4	2	2	2	2	4	3	H	C	
Nitzschia frustulum	2		4	3	4	3	2	5	3	H	C	
Nitzschia heufleriana	3		4	2			2			H	C	
Nitzschia incognita	2			4						H		

Taxon	PTC	Hab.	pH	H	N	O	S	T	M	Motility	Dist.	Rare
Nitzschia inconspicua	2		4	3	3	3	3	5	3	H	C	
Nitzschia linearis	2		4	2	2	2	2	4	3	H	C	
Nitzschia palea	1	A	3	3	4	4	5	6	3	H	C	
Nitzschia paleacea	2		4	3	4	3	3	5	2	H	C	
Nitzschia perminuta	3		4	2	1	1	1	2	3	H		
Nitzschia pusilla	1		3	3	2	2	2	7	3	H	C	
Nitzschia recta	3		4	2	2	2	2	7	1	H	C	
Opephora olsenii	2									N	C	
Phormidium	1											
Planothidium	2									N		
Planothidium calcar	2		3	1	1					V		
Planothidium dubium	2									N		
Planothidium frequentissimum	2		4	2	2	3	4	7		N	C	
Planothidium granum	3		2	1	1	2	1	2	3	N	N	
Planothidium haynaldii	2											
Planothidium lanceolatum	2		4	2	2	3	3	5	3	N	C	
Planothidium peragalli	3		3	1	1	1	2	1	2	N		
Planothidium rostratum	2		4	2	2	3	3	5	3	N		

Taxon	PTC	Hab.	pH	H	N	O	S	T	M	Motility	Dist.	Rare
Psammothidium	3											
Psammothidium subatomoides	3		2	1	1	1	1	2	1	N		
Pseudanabaena	2											
Pseudostaurosira brevistriata	3		4	2	1	1	1	7	2	N	C	
Pseudostaurosira parasitica	2		4	2	1	1	2	4	2	N	C	
Pseudostaurosira robusta	3									N		
Reimeria sinuata	3		3	2	2	1	2	3	3	M	C	
Rhoicosphenia abbreviata	3		4	2	2	2	2	5	2	N	C	
Sellaphora pupula	2		3	2	2	3	3	4	2	M	C	
Sellaphora seminulum	1		3	2	3	4	4	5	3	M	C	
Stauroneis kriegeri	3		3	2	2	2	2	4	3	M	N	
Staurosira construens	3		4	2	1	1	2	4	1	N	C	
Staurosira construens v. venter	3		4	2	2	1	2	4	1	N	C	
Staurosirella leptostauron	3		4	2	1	1	1	4	2	N	C	
Staurosirella pinnata	3		4	2	2	1	2	7	3	N	C	
Stephanocyclus meneghiniana	2		4	3	3	5	4	5	2	N	C	
Stephanodiscus minutulus	2	P	5	2	2	3	3	6	2	N	C	
Stigeoclonium	1											

Taxon	PTC	Hab.	pH	H	N	O	S	T	M	Motility	Dist.	Rare
Surirella angusta	1		4	2	2	2	2	5	3	H		
Synedra ulna	2		4	2	2	3	4	7	2	N	C	
Synedra ulna v. contracta	2		4	2	2	3	4	7	2	N		
Tabularia fasciculata	2		4	4	2	3	3	5	3	N	C	

Table H-6 provides the Clover Creek diatom metric values.

Table H-6. Clover Creek diatom metric values.

Monitoring Site	Sample ID	Heading	Group	Metric	Value
CLO1.4	WADOE13CCP001	Community Structure	Distribution	Cosmopolitan Taxa Percent	52.33%
CLO1.4	WADOE13CCP001	Community Structure	Distribution	Native Taxa Percent	10.33%
CLO1.4	WADOE13CCP001	Community Structure	Diversity	Shannon H (log2)	3.867
CLO1.4	WADOE13CCP001	Community Structure	Diversity	Species Richness	38
CLO1.4	WADOE13CCP001	Community Structure	Dominance	Dominant Taxon Percent	28.33%
CLO1.4	WADOE13CCP001	Community Structure	Rare Taxa	Mountains Rare Taxa Percent	9.67%
CLO1.4	WADOE13CCP001	Community Structure	Rare Taxa	Plains Rare Taxa Percent	0.67%
CLO1.4	WADOE13CCP001	Inorganic Nutrients	Rhopalodiales	Rhopalodiales Percent	0.00%
CLO1.4	WADOE13CCP001	Inorganic Nutrients	Autotrophism	Nitrogen Autotroph Taxa Percent	48.00%
CLO1.4	WADOE13CCP001	Inorganic Nutrients	Trophic State	Eutraphentic Taxa Percent	39.33%
CLO1.4	WADOE13CCP001	Metals	Abnormality	Abnormal Cells Percent	0.00%
CLO1.4	WADOE13CCP001	Metals	Acid Tolerance	Acidophilous Taxa Percent	0.67%
CLO1.4	WADOE13CCP001	Metals	Disturbance	Disturbance Taxa Percent	0.67%
CLO1.4	WADOE13CCP001	Metals	Metals Tolerance	Metals Tolerant Taxa Percent	7.00%
CLO1.4	WADOE13CCP001	Organic Nutrients	Heterotrophism	Nitrogen Heterotroph Taxa Percent	7.67%
CLO1.4	WADOE13CCP001	Organic Nutrients	Oxidation	Low DO Taxa Percent	4.67%
CLO1.4	WADOE13CCP001	Organic Nutrients	Pollution	Pollution Index	2.763
CLO1.4	WADOE13CCP001	Organic Nutrients	Saprobity	Polysaprobous Taxa Percent	11.67%
CLO1.4	WADOE13CCP001	Sediment	Brackishness	Mountains Brackish Taxa Percent	56.33%
CLO1.4	WADOE13CCP001	Sediment	Brackishness	Plains Brackish Taxa Percent	2.00%
CLO1.4	WADOE13CCP001	Sediment	Motility	Motile Taxa Percent	21.33%
CLO1.4	WADOE13CCP001	Sediment	Siltation	Siltation Taxa Percent	9.00%

Monitoring Site	Sample ID	Heading	Group	Metric	Value
CLO3.5	WADOE13CCP002	Community Structure	Distribution	Cosmopolitan Taxa Percent	71.00%
CLO3.5	WADOE13CCP002	Community Structure	Distribution	Native Taxa Percent	6.83%
CLO3.5	WADOE13CCP002	Community Structure	Diversity	Shannon H (log2)	4.568
CLO3.5	WADOE13CCP002	Community Structure	Diversity	Species Richness	57
CLO3.5	WADOE13CCP002	Community Structure	Dominance	Dominant Taxon Percent	15.83%
CLO3.5	WADOE13CCP002	Community Structure	Rare Taxa	Mountains Rare Taxa Percent	6.00%
CLO3.5	WADOE13CCP002	Community Structure	Rare Taxa	Plains Rare Taxa Percent	0.00%
CLO3.5	WADOE13CCP002	Inorganic Nutrients	Rhopalodiales	Rhopalodiales Percent	0.00%
CLO3.5	WADOE13CCP002	Inorganic Nutrients	Autotrophism	Nitrogen Autotroph Taxa Percent	65.17%
CLO3.5	WADOE13CCP002	Inorganic Nutrients	Trophic State	Eutraphentic Taxa Percent	43.33%
CLO3.5	WADOE13CCP002	Metals	Abnormality	Abnormal Cells Percent	0.00%
CLO3.5	WADOE13CCP002	Metals	Acid Tolerance	Acidophilous Taxa Percent	2.67%
CLO3.5	WADOE13CCP002	Metals	Disturbance	Disturbance Taxa Percent	0.33%
CLO3.5	WADOE13CCP002	Metals	Metals Tolerance	Metals Tolerant Taxa Percent	20.33%
CLO3.5	WADOE13CCP002	Organic Nutrients	Heterotrophism	Nitrogen Heterotroph Taxa Percent	13.50%
CLO3.5	WADOE13CCP002	Organic Nutrients	Oxidation	Low DO Taxa Percent	11.67%
CLO3.5	WADOE13CCP002	Organic Nutrients	Pollution	Pollution Index	2.568
CLO3.5	WADOE13CCP002	Organic Nutrients	Saprobity	Polysaprobous Taxa Percent	23.83%
CLO3.5	WADOE13CCP002	Sediment	Brackishness	Mountains Brackish Taxa Percent	81.17%
CLO3.5	WADOE13CCP002	Sediment	Brackishness	Plains Brackish Taxa Percent	7.00%
CLO3.5	WADOE13CCP002	Sediment	Motility	Motile Taxa Percent	22.50%
CLO3.5	WADOE13CCP002	Sediment	Siltation	Siltation Taxa Percent	15.50%

Monitoring Site	Sample ID	Heading	Group	Metric	Value
CLO8.7	WADOE13CCP003	Community Structure	Distribution	Cosmopolitan Taxa Percent	87.83%
CLO8.7	WADOE13CCP003	Community Structure	Distribution	Native Taxa Percent	2.00%
CLO8.7	WADOE13CCP003	Community Structure	Diversity	Shannon H (log2)	3.575
CLO8.7	WADOE13CCP003	Community Structure	Diversity	Species Richness	44
CLO8.7	WADOE13CCP003	Community Structure	Dominance	Dominant Taxon Percent	35.50%
CLO8.7	WADOE13CCP003	Community Structure	Rare Taxa	Mountains Rare Taxa Percent	1.67%
CLO8.7	WADOE13CCP003	Community Structure	Rare Taxa	Plains Rare Taxa Percent	0.00%
CLO8.7	WADOE13CCP003	Inorganic Nutrients	Rhopalodiales	Rhopalodiales Percent	0.00%
CLO8.7	WADOE13CCP003	Inorganic Nutrients	Autotrophism	Nitrogen Autotroph Taxa Percent	89.33%
CLO8.7	WADOE13CCP003	Inorganic Nutrients	Trophic State	Eutraphentic Taxa Percent	18.83%
CLO8.7	WADOE13CCP003	Metals	Abnormality	Abnormal Cells Percent	0.00%
CLO8.7	WADOE13CCP003	Metals	Acid Tolerance	Acidophilous Taxa Percent	0.17%
CLO8.7	WADOE13CCP003	Metals	Disturbance	Disturbance Taxa Percent	0.00%
CLO8.7	WADOE13CCP003	Metals	Metals Tolerance	Metals Tolerant Taxa Percent	7.17%
CLO8.7	WADOE13CCP003	Organic Nutrients	Heterotrophism	Nitrogen Heterotroph Taxa Percent	4.67%
CLO8.7	WADOE13CCP003	Organic Nutrients	Oxidation	Low DO Taxa Percent	3.33%
CLO8.7	WADOE13CCP003	Organic Nutrients	Pollution	Pollution Index	2.795
CLO8.7	WADOE13CCP003	Organic Nutrients	Saprobity	Polysaprobous Taxa Percent	12.67%
CLO8.7	WADOE13CCP003	Sediment	Brackishness	Mountains Brackish Taxa Percent	93.50%
CLO8.7	WADOE13CCP003	Sediment	Brackishness	Plains Brackish Taxa Percent	1.83%
CLO8.7	WADOE13CCP003	Sediment	Motility	Motile Taxa Percent	9.17%
CLO8.7	WADOE13CCP003	Sediment	Siltation	Siltation Taxa Percent	6.67%

Monitoring Site	Sample ID	Heading	Group	Metric	Value
NFC0.0	WADOE13CCP006	Community Structure	Distribution	Cosmopolitan Taxa Percent	86.00%
NFC0.0	WADOE13CCP006	Community Structure	Distribution	Native Taxa Percent	7.17%
NFC0.0	WADOE13CCP006	Community Structure	Diversity	Shannon H (log2)	3.825
NFC0.0	WADOE13CCP006	Community Structure	Diversity	Species Richness	46
NFC0.0	WADOE13CCP006	Community Structure	Dominance	Dominant Taxon Percent	37.33%
NFC0.0	WADOE13CCP006	Community Structure	Rare Taxa	Mountains Rare Taxa Percent	7.17%
NFC0.0	WADOE13CCP006	Community Structure	Rare Taxa	Plains Rare Taxa Percent	0.00%
NFC0.0	WADOE13CCP006	Inorganic Nutrients	Rhopalodiales	Rhopalodiales Percent	0.00%
NFC0.0	WADOE13CCP006	Inorganic Nutrients	Autotrophism	Nitrogen Autotroph Taxa Percent	72.50%
NFC0.0	WADOE13CCP006	Inorganic Nutrients	Trophic State	Eutraphentic Taxa Percent	32.50%
NFC0.0	WADOE13CCP006	Metals	Abnormality	Abnormal Cells Percent	0.00%
NFC0.0	WADOE13CCP006	Metals	Acid Tolerance	Acidophilous Taxa Percent	0.00%
NFC0.0	WADOE13CCP006	Metals	Disturbance	Disturbance Taxa Percent	0.00%
NFC0.0	WADOE13CCP006	Metals	Metals Tolerance	Metals Tolerant Taxa Percent	18.67%
NFC0.0	WADOE13CCP006	Organic Nutrients	Heterotrophism	Nitrogen Heterotroph Taxa Percent	17.33%
NFC0.0	WADOE13CCP006	Organic Nutrients	Oxidation	Low DO Taxa Percent	12.17%
NFC0.0	WADOE13CCP006	Organic Nutrients	Pollution	Pollution Index	2.553
NFC0.0	WADOE13CCP006	Organic Nutrients	Saprobity	Polysaprobous Taxa Percent	32.33%
NFC0.0	WADOE13CCP006	Sediment	Brackishness	Mountains Brackish Taxa Percent	83.83%
NFC0.0	WADOE13CCP006	Sediment	Brackishness	Plains Brackish Taxa Percent	0.50%
NFC0.0	WADOE13CCP006	Sediment	Motility	Motile Taxa Percent	28.67%
NFC0.0	WADOE13CCP006	Sediment	Siltation	Siltation Taxa Percent	26.67%

Monitoring Site	Sample ID	Heading	Group	Metric	Value
CLO8.7	WADOE13CCP003	Community Structure	Distribution	Cosmopolitan Taxa Percent	87.83%
CLO8.7	WADOE13CCP003	Community Structure	Distribution	Native Taxa Percent	2.00%
CLO8.7	WADOE13CCP003	Community Structure	Diversity	Shannon H (log2)	3.575
CLO8.7	WADOE13CCP003	Community Structure	Diversity	Species Richness	44
CLO8.7	WADOE13CCP003	Community Structure	Dominance	Dominant Taxon Percent	35.50%
CLO8.7	WADOE13CCP003	Community Structure	Rare Taxa	Mountains Rare Taxa Percent	1.67%
CLO8.7	WADOE13CCP003	Community Structure	Rare Taxa	Plains Rare Taxa Percent	0.00%
CLO8.7	WADOE13CCP003	Inorgainc Nutrients	Rhopalodiales	Rhopalodiales Percent	0.00%
CLO8.7	WADOE13CCP003	Inorganic Nutrients	Autotrophism	Nitrogen Autotroph Taxa Percent	89.33%
CLO8.7	WADOE13CCP003	Inorganic Nutrients	Trophic State	Eutraphentic Taxa Percent	18.83%
CLO8.7	WADOE13CCP003	Metals	Abnormality	Abnormal Cells Percent	0.00%
CLO8.7	WADOE13CCP003	Metals	Acid Tolerance	Acidophilous Taxa Percent	0.17%
CLO8.7	WADOE13CCP003	Metals	Disturbance	Disturbance Taxa Percent	0.00%
CLO8.7	WADOE13CCP003	Metals	Metals Tolerance	Metals Tolerant Taxa Percent	7.17%
CLO8.7	WADOE13CCP003	Organic Nutrients	Heterotrophism	Nitrogen Heterotroph Taxa Percent	4.67%
CLO8.7	WADOE13CCP003	Organic Nutrients	Oxidation	Low DO Taxa Percent	3.33%
CLO8.7	WADOE13CCP003	Organic Nutrients	Pollution	Pollution Index	2.795
CLO8.7	WADOE13CCP003	Organic Nutrients	Saprobity	Polysaprobous Taxa Percent	12.67%
CLO8.7	WADOE13CCP003	Sediment	Brackishness	Mountains Brackish Taxa Percent	93.50%
CLO8.7	WADOE13CCP003	Sediment	Brackishness	Plains Brackish Taxa Percent	1.83%
CLO8.7	WADOE13CCP003	Sediment	Motility	Motile Taxa Percent	9.17%
CLO8.7	WADOE13CCP003	Sediment	Siltation	Siltation Taxa Percent	6.67%

Monitoring Site	Sample ID	Heading	Group	Metric	Value
CLO12.0	WADOE13CCP005	Community Structure	Distribution	Cosmopolitan Taxa Percent	80.83%
CLO12.0	WADOE13CCP005	Community Structure	Distribution	Native Taxa Percent	0.00%
CLO12.0	WADOE13CCP005	Community Structure	Diversity	Shannon H (log2)	4.693
CLO12.0	WADOE13CCP005	Community Structure	Diversity	Species Richness	72
CLO12.0	WADOE13CCP005	Community Structure	Dominance	Dominant Taxon Percent	29.50%
CLO12.0	WADOE13CCP005	Community Structure	Rare Taxa	Mountains Rare Taxa Percent	0.00%
CLO12.0	WADOE13CCP005	Community Structure	Rare Taxa	Plains Rare Taxa Percent	0.00%
CLO12.0	WADOE13CCP005	Inorgainc Nutrients	Rhopalodiales	Rhopalodiales Percent	0.50%
CLO12.0	WADOE13CCP005	Inorganic Nutrients	Autotrophism	Nitrogen Autotroph Taxa Percent	77.17%
CLO12.0	WADOE13CCP005	Inorganic Nutrients	Trophic State	Eutraphentic Taxa Percent	33.50%
CLO12.0	WADOE13CCP005	Metals	Abnormality	Abnormal Cells Percent	0.00%
CLO12.0	WADOE13CCP005	Metals	Acid Tolerance	Acidophilous Taxa Percent	2.17%
CLO12.0	WADOE13CCP005	Metals	Disturbance	Disturbance Taxa Percent	0.00%
CLO12.0	WADOE13CCP005	Metals	Metals Tolerance	Metals Tolerant Taxa Percent	21.00%
CLO12.0	WADOE13CCP005	Organic Nutrients	Heterotrophism	Nitrogen Heterotroph Taxa Percent	14.33%
CLO12.0	WADOE13CCP005	Organic Nutrients	Oxidation	Low DO Taxa Percent	17.67%
CLO12.0	WADOE13CCP005	Organic Nutrients	Pollution	Pollution Index	2.468
CLO12.0	WADOE13CCP005	Organic Nutrients	Saprobity	Polysaprobous Taxa Percent	31.33%
CLO12.0	WADOE13CCP005	Sediment	Brackishness	Mountains Brackish Taxa Percent	87.33%
CLO12.0	WADOE13CCP005	Sediment	Brackishness	Plains Brackish Taxa Percent	10.67%
CLO12.0	WADOE13CCP005	Sediment	Motility	Motile Taxa Percent	27.00%
CLO12.0	WADOE13CCP005	Sediment	Siltation	Siltation Taxa Percent	24.83%

Table H-7 provides list of non-diatom algae collected at Clover Creek.

Table H-7. Clover Creek non-diatom algae.

Sample_ID	Sample_Station_Name	Sample_Client_ID	Sample_Date_Collected	Taxon	Count	Portion	mLs_Counted
1	Clover Creek	CLO1.4	10/10/2013	Diatoms	174	Algae	0.0040524
1	Clover Creek	CLO1.4	10/10/2013	cells	60	Algae	0.0040524
1	Clover Creek	CLO1.4	10/10/2013	Stigeoclonium	120	Algae	0.0040524
1	Clover Creek	CLO1.4	10/10/2013	Homeothrix	6	Algae	0.0040524
2	Clover Creek	CLO3.5	10/8/2013	Diatoms	96	Algae	0.0014736
2	Clover Creek	CLO3.5	10/8/2013	cells	38	Algae	0.0014736
2	Clover Creek	CLO3.5	10/8/2013	Stigeoclonium	180	Algae	0.0014736
2	Clover Creek	CLO3.5	10/8/2013	Homeothrix	4	Algae	0.0014736
2	Clover Creek	CLO3.5	10/8/2013	Pseudanabaena	20	Algae	0.0014736
3	Clover Creek	CLO8.7	10/10/2013	Diatoms	250	Algae	0.0003684
3	Clover Creek	CLO8.7	10/10/2013	cells	150	Algae	0.0003684
3	Clover Creek	CLO8.7	10/10/2013	Phormidium	50	Algae	0.0003684
4	Clover Creek	CLO8.7R	10/10/2013	Diatoms	260	Algae	0.0004912
4	Clover Creek	CLO8.7R	10/10/2013	cells	230	Algae	0.0004912
4	Clover Creek	CLO8.7R	10/10/2013	Phormidium	28	Algae	0.0004912
4	Clover Creek	CLO8.7R	10/10/2013	Komvophoron	7	Algae	0.0004912
4	Clover Creek	CLO8.7R	10/10/2013	Homeothrix	5	Algae	0.0004912
5	Clover Creek	CLO12.0	10/9/2013	Diatoms	178	Algae	0.0008596
5	Clover Creek	CLO12.0	10/9/2013	cells	260	Algae	0.0008596
5	Clover Creek	CLO12.0	10/9/2013	Phormidium	118	Algae	0.0008596
5	Clover Creek	CLO12.0	10/9/2013	Homeothrix	4	Algae	0.0008596
6	N.F. Clover Ck	NFC0.0	10/7/2013	Diatoms	282	Algae	0.0058944
6	N.F. Clover Ck	NFC0.0	10/7/2013	cells	150	Algae	0.0058944
6	N.F. Clover Ck	NFC0.0	10/7/2013	Homeothrix	12	Algae	0.0058944
6	N.F. Clover Ck	NFC0.0	10/7/2013	Cosmarium	6	Algae	0.0058944
7	Spanaway Ck	SPA1.8	10/2/2013	Diatoms	56	Algae	0.0019648
7	Spanaway Ck	SPA1.8	10/2/2013	cells	18	Algae	0.0019648
7	Spanaway Ck	SPA1.8	10/2/2013	Stigeoclonium	156	Algae	0.0019648
7	Spanaway Ck	SPA1.8	10/2/2013	Homeothrix	2	Algae	0.0019648
7	Spanaway Ck	SPA1.8	10/2/2013	Cosmarium	14	Algae	0.0019648
7	Spanaway Ck	SPA1.8	10/2/2013	Phormidium	72	Algae	0.0019648

Note: Equation used to determine mL's counted ([FieldsOfView]*0.307*0.4)*0.001)

- area of field of view = 0.307
- depth of counting cell = 0.4
- convert mm3 to mL = 0.001

Community Structure

Shannon Diversity (Shannon H) is a function of both the number of species in a sample and the distribution of individuals among those species (Klemm et al., 1990). Shannon Diversity scores range from 0, where all individual are the same taxon, to a maximum value that is dependent on the number of taxa in a sample. Patterns of Shannon Diversity are generally dependent on surrounding land use type (Petersen and Femmer, 2010). All Clover Creek watershed sites had higher Shannon Diversity values than the reference sites (Figure H-7). Nutrient enrichment can increase the number of algal species.

Species richness is an estimate of the number of algal species (diatoms, soft algae, or both) in a sample. All sites had higher numbers of algal species than the reference sites, which is not uncommon for nutrient-enriched sites (Figure H-7).

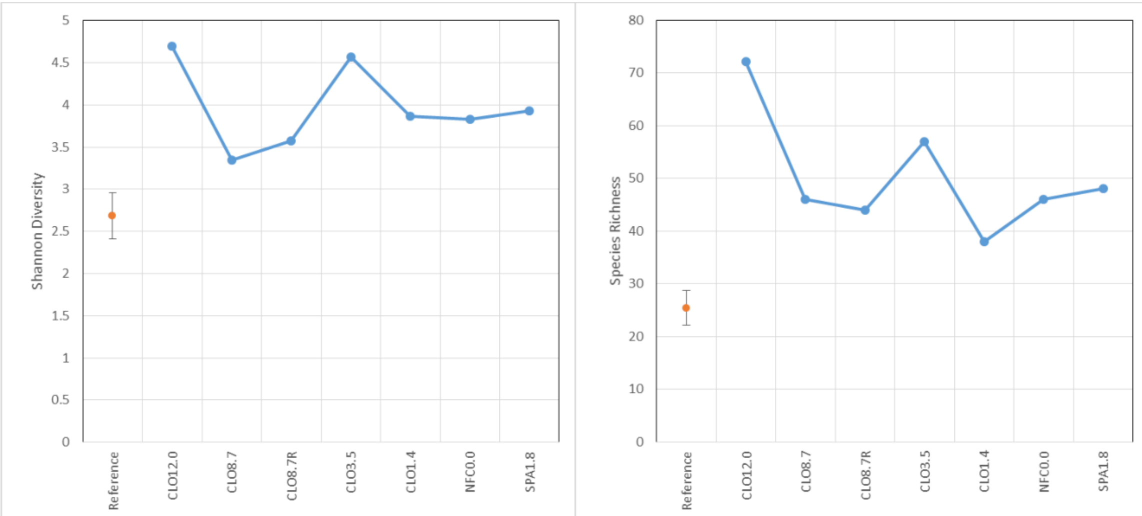


Figure H-7. Shannon Diversity scores and species richness for sites in the Clover Creek watershed. Error bars ± 1 standard error.

Percent dominant taxon is the percent composition of the single most abundant taxon in a sample. The greater percentage contributed by a single dominant species, the greater the degree of impairment (Weber, 1978). CLO8.7 was within one standard error of the reference sites (Figure H-8). All other sites had a lower percentage of dominant taxa.

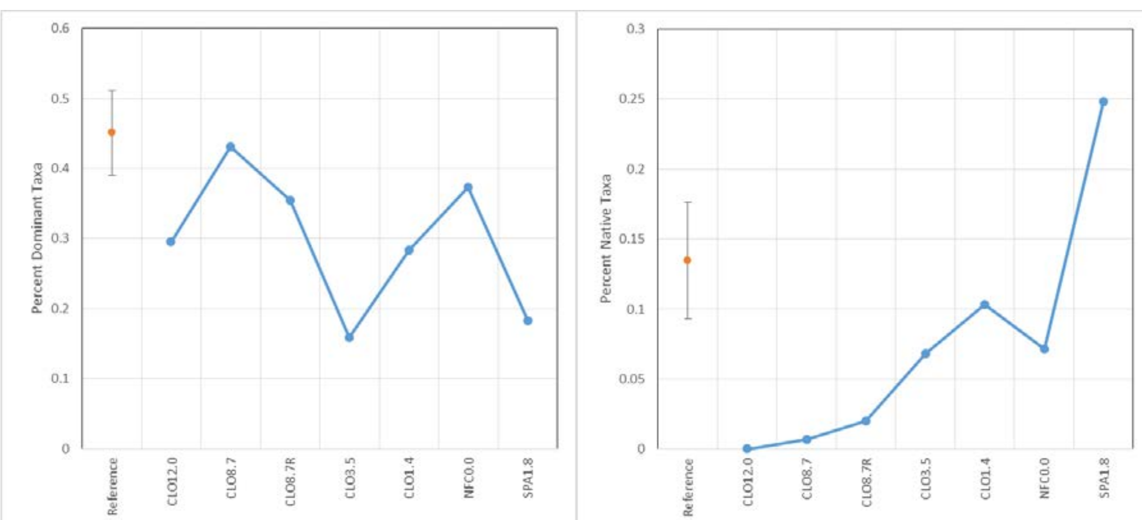


Figure H-8. Percent native and dominant taxa for sites in the Clover Creek watershed. Error bars ± 1 standard error.

Native taxa are endemic to the Puget Sound Lowlands. The percentage of native taxa collected at CLO1.4 was within one standard error of the reference sites. All other sites had a lower percentage of native taxa, except for SPA1.8. SPA1.8 had a higher percentage of native taxa than the reference sites (Figure H-8).

Rare taxa often have low abundance and/or relatively small range sizes. CLO3.5 had a similar percentage of rare mountain taxa to the reference sites (within one standard error). SPA1.8 and CLO1.4 had higher percentages of rare mountain taxa compared to all other sites. Rare plains taxa were collected at only 2 sites, CLO1.4 and SPA1.8 (Figure H-9). The percentage of rare plains taxa at SPA1.8 was within one standard error of the reference sites.

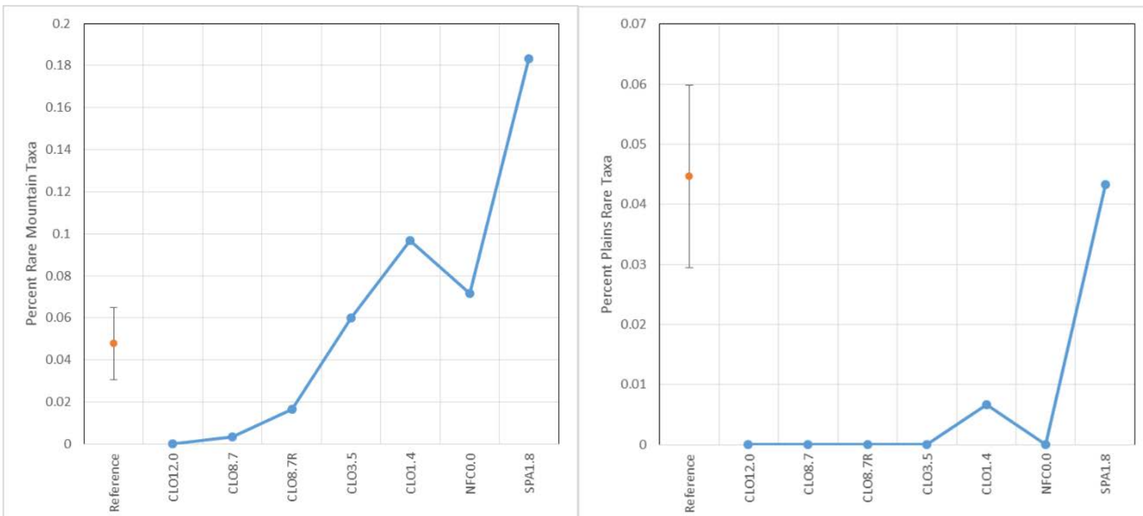


Figure H-9. Percent rare mountain and plains taxa for sites in the Clover Creek watershed. Error bars ± 1 standard error.

Inorganic Nutrients

Eutraphentic taxa are periphyton with preferences for nutrient-enriched, eutrophic water. These taxa are normally used in the identification and assessment of sites impacted by nutrients. The percentage of eutraphentic taxa at CLO12.0 and NFC0.0 were within one standard error of the reference sites. The 3 sites with the highest percentage eutraphentic taxa were CLO3.5, CLO1.4, and SPA1.8 (Figure H-10). CLO8.7 and CLO8.7R had the lowest percentage of eutraphentic taxa.

Percent nitrogen autotroph taxa are periphyton that use light energy to convert inorganic sources of nitrogen to organic nitrogen. CLO12.0 and NFC0.0 had percentages of nitrogen autotroph taxa within one standard error of the reference sites (Figure H-10). CLO8.7 and CLO8.7R had higher percentages of this taxa than the reference sites. The lowest percentage of nitrogen autotroph taxa in the watershed was at CLO1.4, which was also lower than the reference sites.

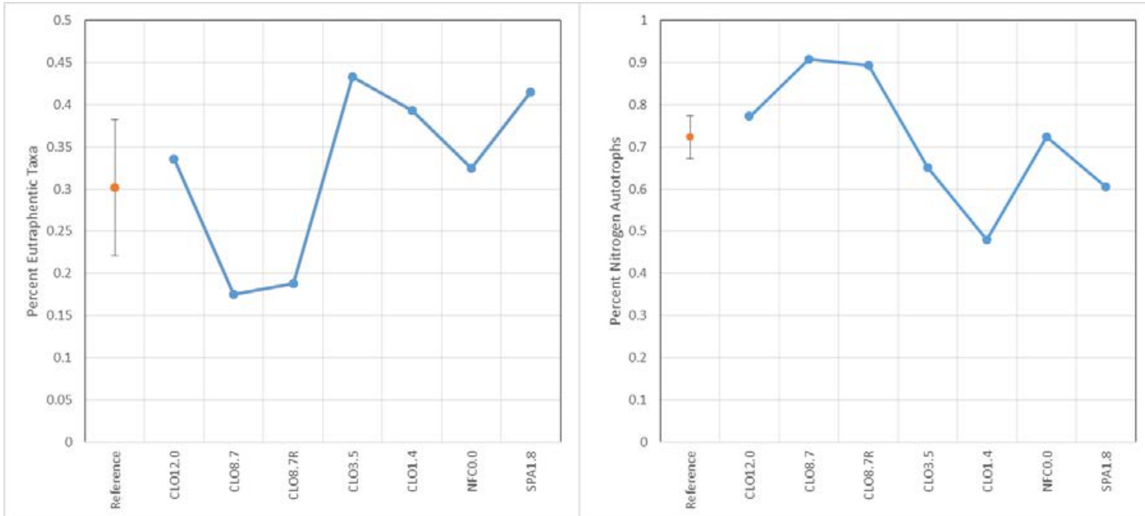


Figure H-10. Percent eutraphentic and nitrogen autotroph taxa for sites in the Clover Creek watershed. Error bars ± 1 standard error.

Organic Nutrients

Facultative nitrogen heterotrophs are periphyton taxa that can tolerate periodic elevated concentrations of organically bound nitrogen and generally increase with episodic nutrient enrichment (Fore, 2003; Van Dam et al., 1994). All sites except 8.7R had higher percentages of facultative nitrogen heterotrophs than the reference sites (Figure H-11). NFC0.0 and CLO12.0 had higher percentages compared to other sites in the watershed. The lowest percentages of facultative nitrogen heterotrophs were at CLO8.7 and CLO8.7R.

Percent of low DO taxa is equal to the proportion of organisms in the sample that can tolerate low levels of DO. Elevated relative abundances of periphyton taxa that can tolerate low DO (i.e., minimum of 30% saturation) generally increase in response to organic nutrient enrichment (Fore, 2003; Van Dam et al., 1994). All sites had a higher percentage of low DO taxa compared to the reference sites. CLO12.0 had the highest percentage of low DO taxa, followed by NFC0.0 and CLO3.5 (Figure H-11). The lowest percentage was at CLO8.7R.

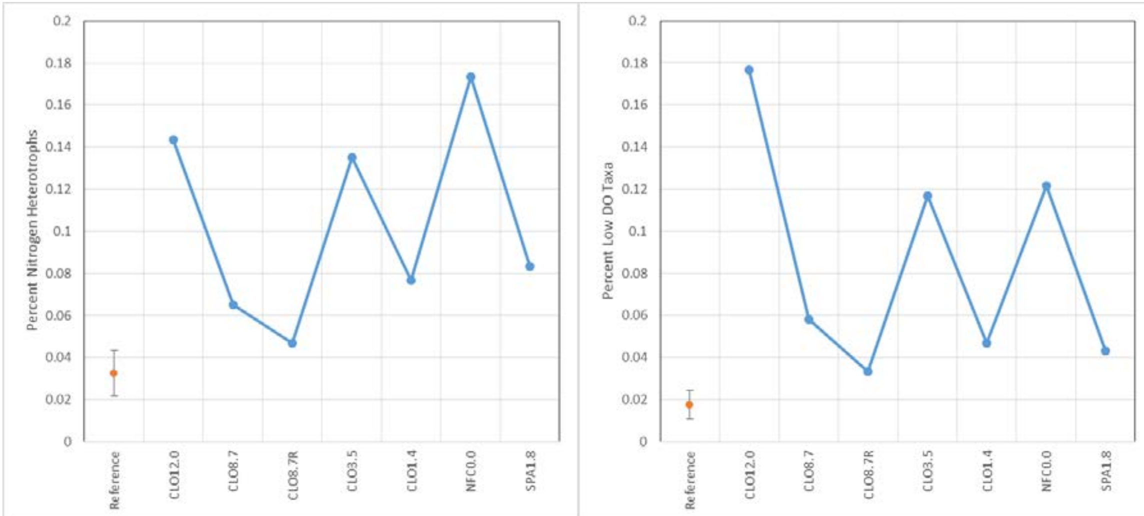


Figure H-11. Percent facultative nitrogen heterotrophs and low DO taxa at sites in the Clover Creek watershed. Error bars ± 1 standard error.

Polysaprobous taxa are indicative of depressed DO levels and elevated biological oxygen demand (BOD). Saprobity is a measure of nutrient enrichment characterized by the combination of DO, organic matter, products of septic decay, and mineralization within the water. Polysaprobous diatoms occur in waters with very low DO saturation of <10% and/or high BOD concentrations >22 mg/L. This diatom group normally increases in relative abundance in response to inorganic and organic nutrient enrichment, elevated ammonia, and/or hydrogen sulfide production (Van Dam et al., 1994). The 3 sites, CLO12.0, NFC0.0, and CLO3.5, had higher percentages of polysaprobous taxa than the reference sites (Figure H-12). The 4 other sites fell within one standard error of the reference sites.

The pollution tolerance index categorizes periphyton according to their tolerance to increased pollution. Lower values are given to more tolerant species. Higher values are assigned to more sensitive species. More pollution tolerant species were collected at CLO12.0, CLO3.5, and NFC0.0, which had lower values than the reference sites (Figure H-12). Three sites, CLO8.7, CLO8.7R, and SPA1.8, were comparable to the reference sites (within one standard error).

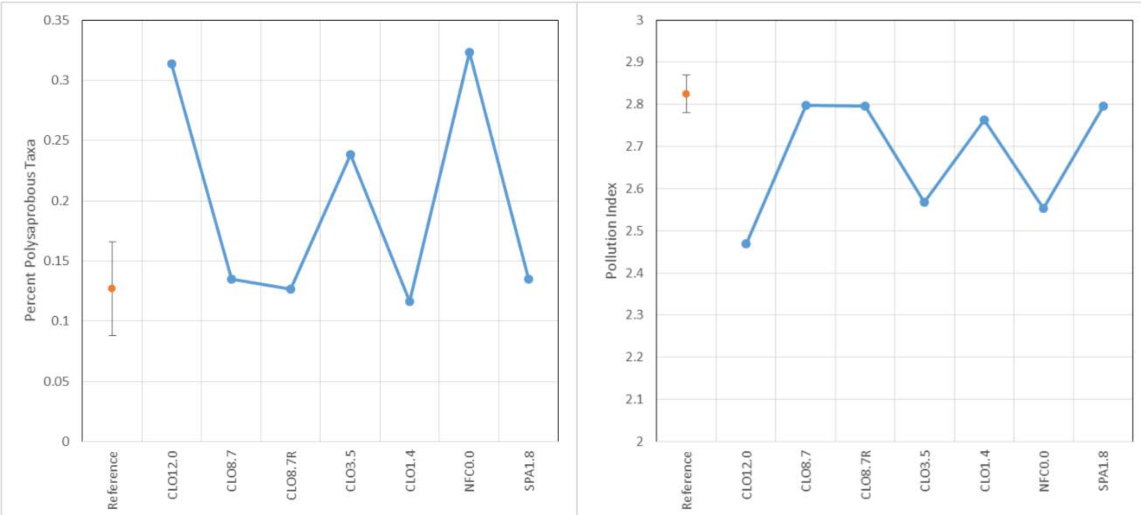


Figure H-12. Percent polysaprobous taxa and the pollution index for sites in the Clover Creek watershed. Error bars ± 1 standard error.

Sediment

Percent motile taxa is the relative abundance of motile diatoms in a sample. The percent of motile taxa increases in response to excess sediment (Barbour et al., 1999). Five out of 7 sites had a higher percentage of motile taxa than the reference sites. The 2 sites with the highest percentage motile taxa (Figure H-13) were CLO12.0 and NFC0.0. CLO8.7 and 8.7R had the lowest percentage compared to other sites in the Clover Creek watershed. These 2 sites had similar percentages of motile taxa to the reference sites (within one standard error).

Percent siltation taxa is the relative abundance of several periphyton groups known to increase in response to increased sedimentation (Bahls, 1993; Fore and Graph, 2002). A higher proportion of these taxa indicates increased sedimentation. The 2 sites with the highest percentage of siltation taxa (Figure H-13) were CLO12.0 and NFC0.0. Three sites, CLO8.7, CLO8.7R, and CLO1.4, had percentages within one standard error of the reference sites.

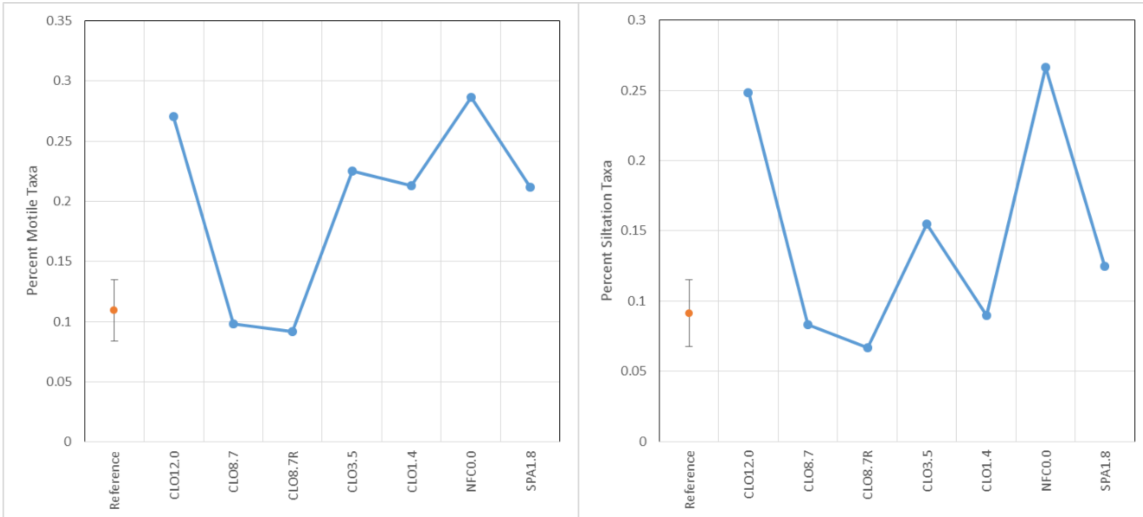


Figure H-13. Percent motile and siltation taxa at sites in the Clover Creek watershed. Error bars ± 1 standard error.

Mountain and plains brackish taxa are able to tolerate higher salinities than typical freshwater taxa. CLO12.0 had similar percentage of brackish mountain taxa to the reference sites. Percentages of brackish plains taxa at CLO8.7, CLO8.7R, and CLO1.4 were within one standard error of the reference sites (Figure H-14). CLO12.0 and CLO3.5 had larger percentages of plains brackish taxa than all other sites, including the reference sites.

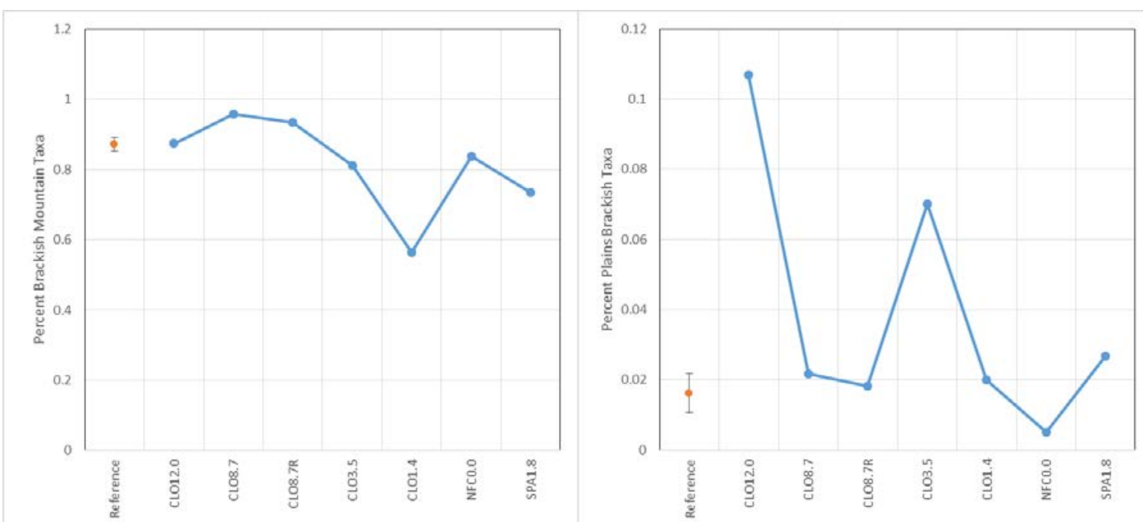


Figure H-14. Percent brackish mountain and brackish plains taxa at sites in the Clover Creek watershed. Error bars ± 1 standard error.

Metals

Metals tolerant taxa are less sensitive to metals contamination. Four sites, CLO8.7, CLO8.7R, CLO1.4, and SPA1.8, had similar percentages of metals tolerant taxa to the reference sites (within one standard error). Three sites, CLO12.0, CLO3.5, and NFC0.0, had higher percentages than the reference sites (Figure H-15).

Acidophilous taxa have the ability to survive and reproduce in a relatively acidic environment. The percentages of acidophilous taxa at CLO8.7, SPA1.8, and CLO1.4 were within one standard error of the reference sites (Figure H-15). All other sites had higher percentages of acidophilous taxa, except NFC0.0 where no acidophilous taxa were collected.

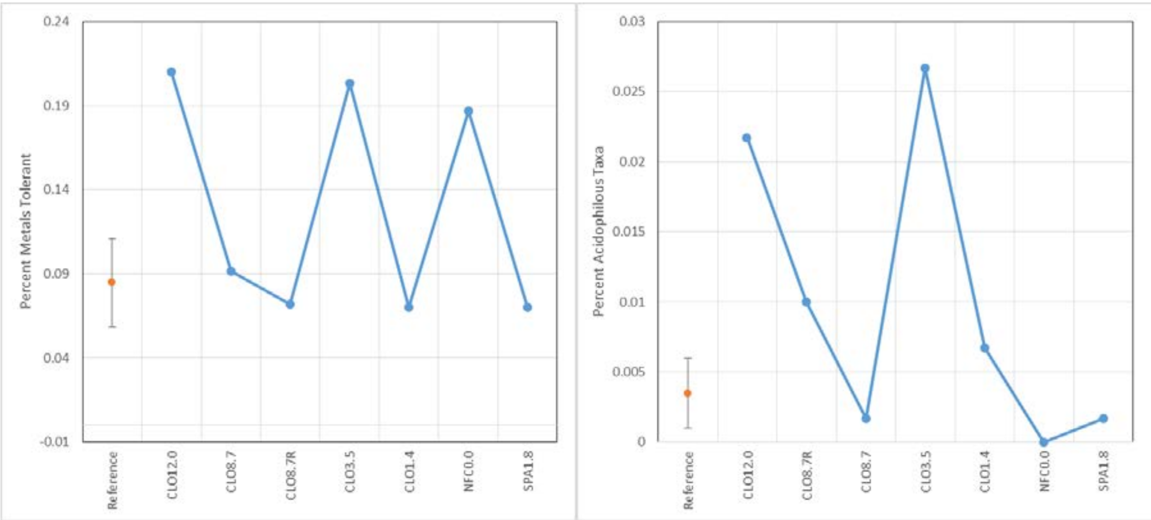


Figure H-15. Percent metals tolerant and acidophilous taxa at sites in the Clover Creek watershed. Error bars ± 1 standard error.

References for Appendix H

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Appendix I. Pierce County Comments

Figure I-1 is the September 2, 2016 letter from Pierce County providing comments to Ecology on the July 8, 2016 draft of this report.

Bullet #1 and #2
Pierce County requested that Ecology use more specific language in regard to Ecology's position on the STI as a TMDL alternative STI and the purpose of this document. Ecology clarified language in the Introduction regarding the STI approach.

Bullet #3
Ecology clarified that only one stormwater outfall (NFCB1.1RB) was sampled during the storm event that occurred on June 24, 2013.

Bullet #4
The stormwater outfalls NFCB1.1RB and NFCB1.1LB are located on the south side (downstream) of 121st Street.

Bullet #5, 6, and 7
Ecology updated several maps with the current Water Quality Assessment data (approved by the EPA in 2016) and stormwater outfall location information provided by Pierce County (July 2016).

Bullet #8
Ecology used a well-established and regionally calibrated B-IBI for Puget Sound Lowland streams. Ecology used 4 broad classes of metrics which reflect the functional and ecological attributes of the component invertebrate communities. These biological metrics have been shown to respond to gradients of human influence and successfully distinguish least- and most-disturbed sites (Fore et al., 1996; Karr, 1998). These 4 classes are:

- Taxa richness and composition
- Tolerant and intolerant taxa
- Feeding ecology
- Population attributes

The B-IBI for Puget Sound Lowland streams uses regionally appropriate metrics in each of those 4 classes (Karr, 1998). Comparison of Clover Creek samples to regional reference sites helped to put results from the Clover Creek samples into greater context. Using metrics in each of the 4 classes shows that Clover Creek had:

- Lower taxa richness for multiple metrics (Taxa, EPT, Ephemeroptera, Plecoptera, Trichoptera, long-lived, and clingers) at all 6 sites.
- A much higher percentage of tolerant taxa at 4 sites. No intolerant taxa at 5 sites. For the one remaining site with some organisms classified as intolerant taxa, a much lower percentage of intolerant taxa than observed under 'least impacted' condition.

- Lower proportion of predators at 5 sites.
- Higher proportion of dominant taxa at 5 sites.

Multiple studies of Puget Sound Lowland streams have found that B-IBI scores decline as the percentage of urban land cover increases. Biological condition has also been shown to be related to hydrologic alteration and stream substrate (Morley et al., 2002; DeGasperi et al., 2009). Given the extensive urban development in the watershed and history of modifications to the natural stream system, the Poor to Very Poor biological condition at these sites is most likely a reflection of impaired habitat, streamflow, and water quality.

Bullet # 9
Comments noted.

Bullet #10
Ecology clarified the target reduction recommendation for site CLO1.9. The 76% reduction in the wet season is based on the higher concentration and load compared to the dry season (Table I-1).

Table I-1. CLO1.9 FC geometric mean (GM) and load for the wet and dry seasons.

Season	GM (cfu/100 mL)	Load (billion cfu/day)
Wet	124	387
Dry	48	23

Bullet #11
Statistical rollback continues to be an EPA accepted methodology for analysis of FC contamination in a stream system. Ecology provides target reductions for bacteria to assist water quality managers in assessing the progress toward compliance with the bacteria water quality criteria. Compliance is ultimately measured as meeting both parts of the water quality standards criteria. Any water body with FC targets is expected to (1) meet both the applicable geometric mean and “not more than 10% of the samples” criteria, and (2) protect designated uses for the category.

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September 2, 2016
WP61584

Donovan Gray
Department of Ecology
PO BOX 47600
Olympia, WA 98504-7600

Dear Donovan,

Thank you for the opportunity to comment on the Clover Creek Source Assessment report. Pierce County appreciates the Department of Ecology working with partners in the watershed to address the unique challenges there. In particular, we appreciate and commend Ecology recognizing that, given the unique hydrology, soils, role of groundwater, presence of established partnerships, and history of development that a traditional multi-year sampling and modeling TMDL project is not appropriate for the Clover Creek watershed. Pierce County supports Ecology's decision to proceed with a Straight to Implementation strategy instead and we acknowledge and appreciate Ecology keeping this process open and transparent.

Pierce County generally agrees with the conclusions in the Clover Creek Source Assessment and offer the following comments:

- Pierce County requests more specific language in regards to the agency's position on the selection of a STI as a TMDL alternative. Specifically, replace the following language on pg. 13, "*However after further consideration, TMDL staff chose to try a straight-to-implementation (STI) approach*" with a statement similar to "In this watershed, Ecology has determined a TMDL is not appropriate and an STI would be more effective."
- Pierce County requests clarifying language in regards to the purpose of this document, given its determination above. Specifically, replace language on pg. 13 "*This report includes implementation recommendations to help streams in this watershed meet water quality standards*" with a statement similar to "This report is intended to help inform the STI strategy and will be used with other data, studies, and analyses by other partners within the watershed to determine restoration projects and actions."
- On Pg. 8, the report states that only one stormwater outfall (NFCB1.1RB) was sampled, however, on Pg. 30 the report states that both stormwater outfalls were sampled.
- It is unclear which stormwater outfall is represented by sampling sites NFCB1.1LB and NFCB1.1RB. Please add a description that clearly explains which side of the street and

which side of the bank the sample was taken from (i.e. North side of 121st ST E, left side of bank looking downstream).

- On Pg.14, please replace *Figure 2. Portions of the Clover Creek watershed on the 303(d) list and monitoring sites* with a more current map which displays 303(d) listed stream segments based on reaches identified in the National Hydrography Dataset (NHD). This map should match Ecology's Water Quality Atlas map of the 303(d) listed segments in the watershed.
- Figure A-2 does not reflect outfalls that Pierce County identified for Ecology.
- Figure A-22 and Figure A-23 do not show known Pierce County stormwater outfalls. A shapefile of stormwater outfalls was provided 7/19/2016.
- Pg 56. Bioassessment: The B-IBI methodology used to assess macroinvertebrate community health was developed and calibrated using certain Puget Sound lowland stream morphology (pool, riffle, glide). The method is not the most appropriate way to assess aquatic biological community health in groundwater dominated, low gradient streams like Clover Creek. Therefore, B-IBI scores may not accurately reflect the health of the stream's biological community. Recovery targets that use B-IBI scores for decision making should consider the natural conditions and the intrinsic potential for improvement of aquatic macroinvertebrate communities.
- Pg. 69 Restoration; Hydrology: There are still programmatic actions that can be taken by the County and State that would predictably improve DO, but those investments would not be confirmed as the correct priorities given what is known about the source of the impairment. I believe the effects of hydromodification are the most substantive source of this watersheds impairments and will therefore be the most difficult to address. Hydromodification management has emerged as a prominent issue because degradation of the physical structure of a channel is often indicative of and associated with broader impacts to many beneficial uses, including water supply, water quality, habitat, and public safety. Hydromodification by definition results from alteration of watershed processes; therefore, correcting the root causes of hydromodification ought to be most effective if based on integrated watershed-scale solutions. Long-term reversal of hydromodification effects, however, will require movement away from reliance on such site-based approaches to more integrated watershed-based strategies.
- Pg. 89 *"Although there was no significant difference between the seasons at CLO1.9, based on the high FC concentration and load during the wet season, Ecology recommends a 76% reduction during the wet season at this reach."* Is Ecology referring to a lack of significant difference in flow between seasons? Please be more specific.
- Pierce County has provided comments on other methodologies used by Ecology in the past it does not support (such as the statistical rollback method of determining FC load reductions), which still exist. While those concerns remain, in this case we are confident the STI strategy will result in more achievable and practical outcomes in the Watershed.

Pierce County looks forward to working with the Department of Ecology and other stakeholders in the execution of a STI and we thank Ecology for its willingness to apply that technique to this unique watershed. Feel free to contact Anthea Aasen (aaasen@co.pierce.wa.us or 253-798-3719) with questions.

Sincerely,

for Dan Wrye

Dan Wrye
Water Quality Manager
Pierce County Surface Water Management

DW:kj

cc: File

Figure I-1. September 2, 2016 letter from Pierce County.

References for Appendix I

DeGasperi, C.L., H.B. Berge, K.R. Whiting, J.J. Burkey, J.L. Cassin, and R.R. Fuerstenberg. 2009. Linking hydrologic alteration to biological impairment in urbanizing streams of the Puget Lowland, Washington, USA. Journal of the American Water Resources Association 45(2): 512–533.

Fore, L.S., J.R. Karr, and R.W. Wisseman, 1996. Assessing invertebrate responses to human activities: evaluating alternative approaches. Journal of the North American Benthological Society 15:212-231.

Karr, J.R., 1998. Rivers as sentinels: Using the biology of rivers to guide landscape management. Pages 502-528 in R.J. Naiman and R.E. Bilby, editors. *River Ecology and Management: Lessons from Pacific Coastal Ecosystems*. Springer, New York.

Morley, S.A. and J.R. Karr, 2002. Assessing and restoring the health of urban streams in the Puget Sound Basin. Conservation Biology 16: 1498-1509.

Appendix J. Glossary, Acronyms, and Abbreviations

Glossary

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

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

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

Parameter: Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

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

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

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.

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.

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.

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

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

Acronyms and Abbreviations

7-DADMax	7-DAD Maximum
B-IBI	Benthic-Index of Biotic Integrity
BMP	Best management practices
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, and Trichoptera taxa
FC	Fecal coliform bacteria
GIS	Geographic Information System software
JBLM	Joint Base Lewis-McChord
MEL	Manchester Environmental Laboratory
MQO	Measurement Quality Objectives
NF	North Fork
OSS	Onsite sewage systems
QA	Quality Assurance
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
STI	Straight-to-implementation
TMDL	(See Glossary above)
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WRIA	Water Resource Inventory Area

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
ft	feet
g	gram, a unit of mass
m	meter
mg	milligram
mL	milliliters

NTU	nephelometric turbidity units
psu	practical salinity units
s.u.	standard units
umhos/cm	micromhos per centimeter
uS/cm	microsiemens per centimeter, a unit of conductivity