DEPARTMENT OF
ECOLOGY
State of Washington

Addendum to

Colville River Fecal Coliform Total Maximum Daily Load Report

September 2015
Publication No. 15-10-036

Publication and Contact Information

This addendum is available on the Department of Ecology's website at
https://fortress.wa.gov/ecy/publications/SummaryPages/1510036.html

The original report, *Colville River Fecal Coliform Total Maximum Daily Load: Submittal Report - Amended*, is available at
https://fortress.wa.gov/ecy/publications/SummaryPages/0310030.html

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Data for this project are available at Ecology's Environmental Information Management (EIM) website www.ecy.wa.gov/eim/index.htm. Search Study ID RCOO0002.

The Activity Tracker Code for this study is 13-054.

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

WRIA: 59 - Colville

HUC number: 17020003

Addendum to

Colville River Fecal Coliform Total Maximum Daily Load Report

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Abstract

This report is an addendum to the 2002 report, *Colville River Fecal Coliform Total Maximum Daily Load Report*. Stevens County Conservation District data collection efforts identified federal Clean Water Act 303(d) listings for fecal coliform bacteria that were not addressed in the original TMDL. These 303(d) listings are located within four tributaries to the Colville River (Hoffman Creek, Paye Creek, Bulldog Creek, and Sheep Creek). Hoffman Creek is excluded from the TMDL study and report because Ecology could not gain access from local landowners for sampling. Hoffman Creek will have to be addressed in the future when permission to access can be acquired.

This report includes a study of the bacteria impairment, indicates how much the bacteria needs to be reduced to meet Washington State water quality standards, and describes activities to achieve those reductions.

The Washington State Department of Ecology collected bacteria and streamflow data from nine sites throughout the study area from July 2012 to July 2013. This data was analyzed to determine the level of bacteria reduction needed to meet water quality standards.

Paye Creek, Bulldog Creek, and Sheep Creek are required to have a geometric mean of less than 100 colony forming units/100 milliliters (100 cfu/100 mL). Also, no more than 10 percent of the samples used to calculate the geometric mean can exceed 200 cfu/100 mL.

Executive Summary

In 2002 the Washington State Department of Ecology (Ecology) issued the *Colville River Fecal Coliform Total Maximum Daily Load* (TMDL) *Study*. This study established loadings to the Colville River for bacteria, ultimately establishing discharge criteria for Chewelah and Colville wastewater treatment facilities. Watershed monitoring efforts by Stevens County Conservation District (SCCD) identified additional tributaries of concern, with fecal coliform levels warranting consideration for 303(d) listing. The data for these additional tributaries was apparently omitted from consideration in the original study, and consequently the need for an addendum was considered and adopted. All of the listings considered in this addendum are within the existing TMDL footprint. This addendum goes no further than to provide statistical targets for meeting the requirements of the existing TMDL.

The tributaries identified as having elevated bacteria included Hoffman, Paye, Bulldog and Sheep Creeks. Ecology's Environmental Assessment Program (EAP) were requested by the Water Quality section to sample these creeks, with the intention of creating an addendum to the original TMDL study should the data show continued justification for concern.

In July 2012, EAP began sampling on three of the creeks. Hoffman Creek was not sampled due to denial of access (Hoffman Creek is surrounded by private land, and has no publicly accessible points that are suitable for monitoring). Consequently, impacts from Hoffman Creek were not verified by EAP, and therefore consideration for Hoffman Creek is absent in this addendum. Impacts to the Colville River from this tributary will remain a concern, and the issue is likely to be revisited. In the meantime, Ecology nonpoint staff in the Water Quality Program will try to identify sources of potential pollution on Hoffman Creek with a view to proactively dealing with sources of bacteria from this creek.

The monitoring efforts of EAP continued through July 2013, at which point monitoring ceased, and data analysis and report writing continued. The EAP report was finalized at the end of March, 2015. The following report provides details of how EAP conducted sampling, the quality assurance protocols adhered to, the resulting data, and the implications for the existing bacteria TMDL for the Colville River.

Under the current designated use category of primary contact recreation, the creeks monitored in this study are required to meet water quality standards of 100 coliform forming units per 100 milliliters (geometric mean) with no more than 10 percent of the samples in the geometric mean data set exceeding 200 coliform forming units per 100 milliliters. This addendum shows which creeks failed to meet these standards, and prescribes the necessary load reductions for them to meet the appropriate water quality standards and the requirements of the Colville River bacteria TMDL. The implementation actions for the original TMDL will also apply to these listings, now effectively incorporated into the TMDL.

Acknowledgements

The author of this report thanks the following people for their contributions to this addendum:

- The Stevens County landowners for their interest and cooperation with accessing the sample sites.
- Lane Mountain Company for allowing access through their property.
- Stevens County Conservation District for historical data and site coordination.
- Washington State Department of Ecology staff:
    - Brian Gallagher for his work sampling, data entry, and data review.
    - Scott Tarbutton for his help sampling and guidance through the project and report.
    - Jim Ross for his supervision and guidance through the project and report.
    - Nancy Rosenbower and fellow staff at the Manchester Environmental Laboratory for providing laboratory analysis and coordination.
    - Eiko Urmos-Berry for peer review and Paul Pickett for consistency review.

Introduction

A total maximum daily load (TMDL) report is a plan to help attain state water quality standards by determining the allowable pollutant load a stream may receive. Section 303(d) of the federal Clean Water Act (CWA) requires the Washington State Department of Ecology (Ecology) to implement water-quality-based pollution controls on streams where technology-based controls are inadequate to achieve water quality standards. To meet the requirements of Section 303(d) on the Colville River, a TMDL must be established for pollutants violating water quality standards. The purpose of this addendum is to add tributary creeks not addressed in the original TMDL report.

The CWA establishes a process to identify and clean up polluted waters. Under the CWA, each state is required to have its own water quality standards designed to protect, restore, and preserve water quality.

Every two years, states are required to prepare a list of water bodies – lakes, rivers, streams, or marine waters – that do not meet water quality standards. This list of impaired water bodies is called the 303(d) list after the section in the CWA that mandated its creation. The CWA states that every water body on the 303(d) list must have a TMDL or other appropriate water quality improvement plan developed.

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

The Primary Contact Recreation use is intended for waters "where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and waterskiing." More to the point, however, the use is to be designated to any waters where human exposure is likely to include exposure of the eyes, ears, nose, throat, and urogenital system. Since children are the most sensitive group for many of the waterborne pathogens of concern, even shallow waters may warrant primary contact protection. To protect this use category: "Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200 colonies/100 mL" [WAC 173-201A-200(2)(b), 2003 edition].

Compliance is based on meeting both the geometric mean criterion and the 10 percent of samples (or single sample if less than ten total samples) limit. FC samples follow a log-normal distribution. Therefore, in Washington State FC TMDL studies the upper limit statistic (i.e., not more than 10 percent of the samples shall exceed) has been interpreted as a 90^{th} percentile value of the log-normalized values (Joy, 2000; Sargeant, 2002). These two measures used in combination − geometric mean and 90th percentile − ensure that bacterial pollution in a water body will be maintained at levels that will not cause a greater risk to human health than considered safe.

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

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

The Colville River and its tributaries are required to meet Primary Contact Recreation beneficial use standards (WAC 173-201A-602).

In 2002 a TMDL, which aimed to address FC bacteria 303(d) listings in the Colville River watershed, was completed (Coots, 2002). In support of this TMDL project, FC bacteria samples were collected from 10 mainstem Colville River sites and 15 tributary sites between March 2000 and March 2001 (Coots, 2002).

FC bacteria data collected by Stevens County Conservation District (SCCD, 1993) showed elevated concentrations in the Colville River watershed, and these data resulted in the 303(d) listings that were not addressed in the original TMDL. The reason why they were not included in the original TMDL is unknown. These additional listings are located within three tributaries to the Colville River (Paye Creek, Bulldog Creek, and Sheep Creek) (Table 1). The purpose of this addendum is to address listings previously not covered, and to amend the original TMDL.

Table 1. Colville River tributaries 303(d) listings

Listing ID	Creek Name	Parameter	2012 Category	Township	Range	Section
45569	Paye	Fecal Coliform	5	32N	40E	15
46161	Bulldog	Fecal Coliform	5	31N	40E	26
8525	Sheep	Fecal Coliform	4a	30N	40E	16
46534*	Sheep	Fecal Coliform	5	30N	40E	28
10085*	Sheep	Fecal Coliform	4a	30N	40E	21

*These listings merge with 8525 under the proposed adoption of the National Hydrography Dataset (NHD).

The goal of this TMDL addendum is to achieve compliance with Washington State FC bacteria criteria, which will return Paye Creek, Bulldog Creek, and Sheep Creek to a condition that provides low illness risk to people and animals using the streams.

A Quality Assurance Project Plan Addendum (Albrecht, 2012) was approved to gather the data for this study.
The objectives of this addendum are to:

- Develop percent reductions and load allocations to address the FC bacteria water quality listings.
- Recommend implementation efforts in the watershed.
- Determine if land management changes have altered bacteria levels in the watershed since the 1993 sampling.

Study Area

The study area for this project consists of the Paye Creek, Bulldog Creek, and Sheep Creek sub-watersheds. These sub-watersheds are within the Colville River watershed located in the northeast corner of Washington State (Figure 1). This watershed is known as the Water Resource Inventory Area (WRIA) 59.

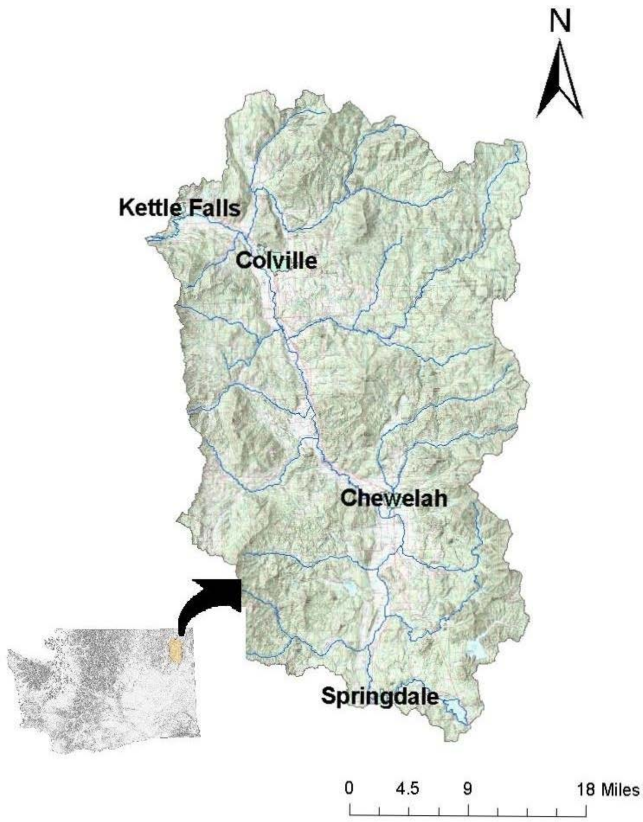


Figure 1. Map of the Colville River watershed - WRIA 59

FC bacteria and streamflow data were collected from 9 sites in the study area. Figures 2, 3, and 4 show all sampling locations. Tables 2, 3, and 4 list the corresponding location identification, latitude/longitude, and description of the sampling sites.

Figure 2. Map of the Paye Creek sample sites

Table 2. List of the Paye Creek sample locations

Creek Name	Location ID	Latitude	Longitude	Site Description
Paye	59PAY0.0	48.2727	-117.7407	Paye Creek at Mouth
Paye	59PAY1.8	48.2880	-117.7259	Paye Creek at Hwy 395 Crossing

Figure 3. Map of the Bulldog Creek sample sites

Table 3. List of the Bulldog Creek sample locations

Creek Name	Location ID	Latitude	Longitude	Site Description
Bulldog	59BUL0.0	48.1650	-117.7258	Bulldog Creek at Mouth
Bulldog	59BUL1.2	48.1565	-117.7155	Bulldog Creek at Bulldog Creek Road Crossing
Bulldog	59BUL1.6	48.1564	-117.7091	Bulldog Creek Near Springs

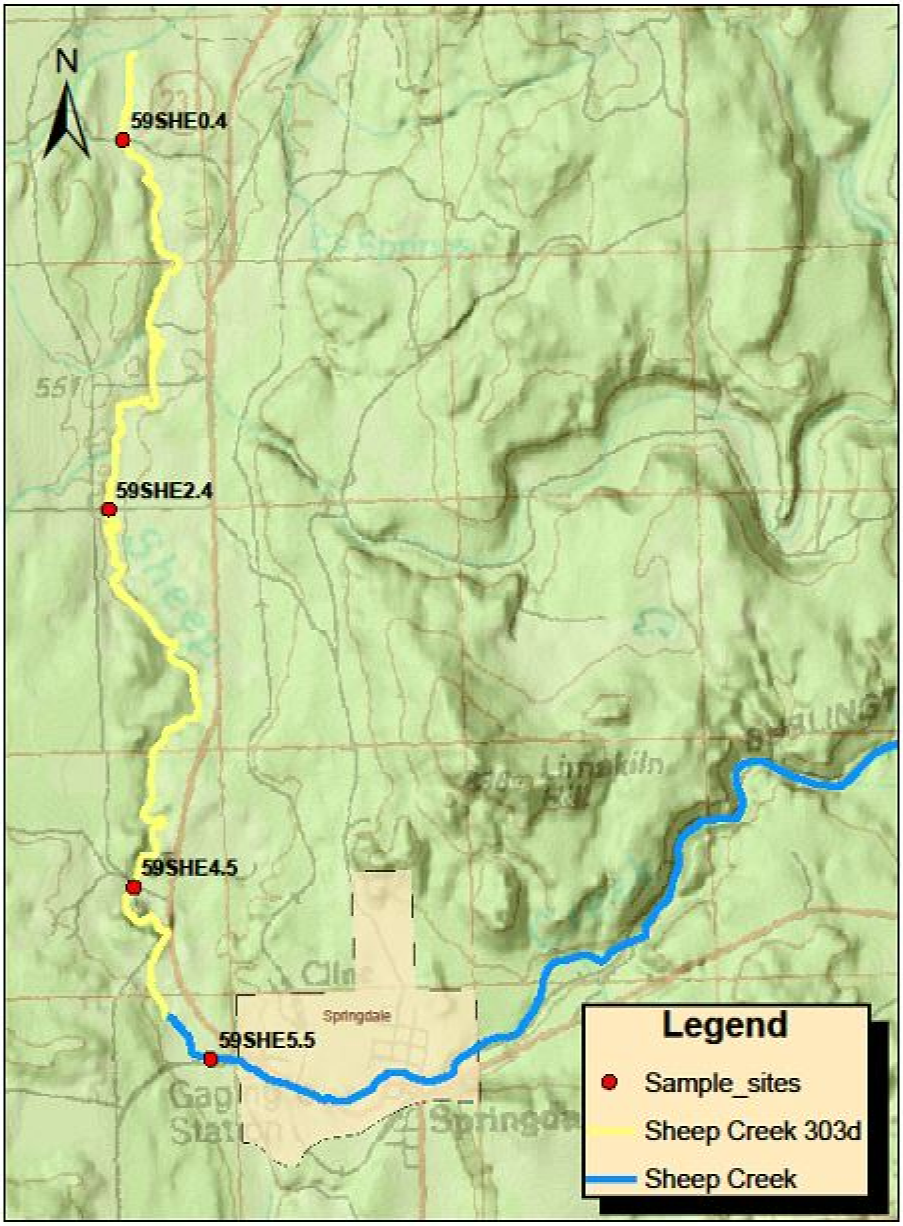


Figure 4. Map of the Sheep Creek sample sites

Table 4. List of the Sheep Creek sample locations

Creek Name	Location ID	Latitude	Longitude	Site Description
Sheep	59SHE0.4	48.1144	-117.7649	Sheep Creek at Deer Creek Road
Sheep	59SHE2.4	48.0922	-117.7674	Sheep Creek at Forest Center Road Crossing
Sheep	59SHE4.5	48.0699	-117.7664	Sheep Creek at Hesseltine Road Crossing
Sheep	59SHE5.5	48.0597	-117.7600	Sheep Creek Near Springdale Hunters Road Crossing

Climate and hydrologic characteristics

Seasonal variations in streamflow result from hydrologic and climatological patterns. In the Colville River watershed, seasonal high flows occur during the cooler period of late winter and early spring from snow melt and spring rain runoff, while seasonal low flows typically occur during the warmer summer and early fall dry periods.

The range of annual precipitation for the period from 1917 to 2000 was 8.22 inches to 29.02 inches (WRCC, 2002). Precipitation averages 17.2 inches per year at Colville. About two-thirds of the total annual precipitation in the basin falls between October and March. Average precipitation from June to September is approximately 3.89 inches or approximately 20 percent of the total annual precipitation.

All three water bodies have similar seasonal hydrologic characteristics. The majority of the flow during the study was present from October through May, peaking in March, when the watershed routed snowmelt runoff (Figure 5).

Land use and management

Eighty-two percent of the land cover for the Colville River basin is within forest, shrubland, woody wetlands, and upland grasses. Most of the remainder is divided between agriculture and transitional/barren grounds. Less than 2 percent of the basin is covered by urban, residential, commercial/industrial, transportation, and recreational grasses. The urban/residential areas of the watershed are near the population centers of Chewelah, Colville, Kettle Falls, Springdale, and along portions of the highway corridors. The vast majority of the housing is single family residences. The sub-basins are rural/residential, with agriculture as the predominant land use along the valley bottoms and on some terraces higher up. The uplands are dominated by evergreen forest, accounting for about 75 percent of the basin (Coots, 2002). These were the original percentages of different land use in the original TMDL. The practices and land use have remained relatively unchanged and are mostly true still today.

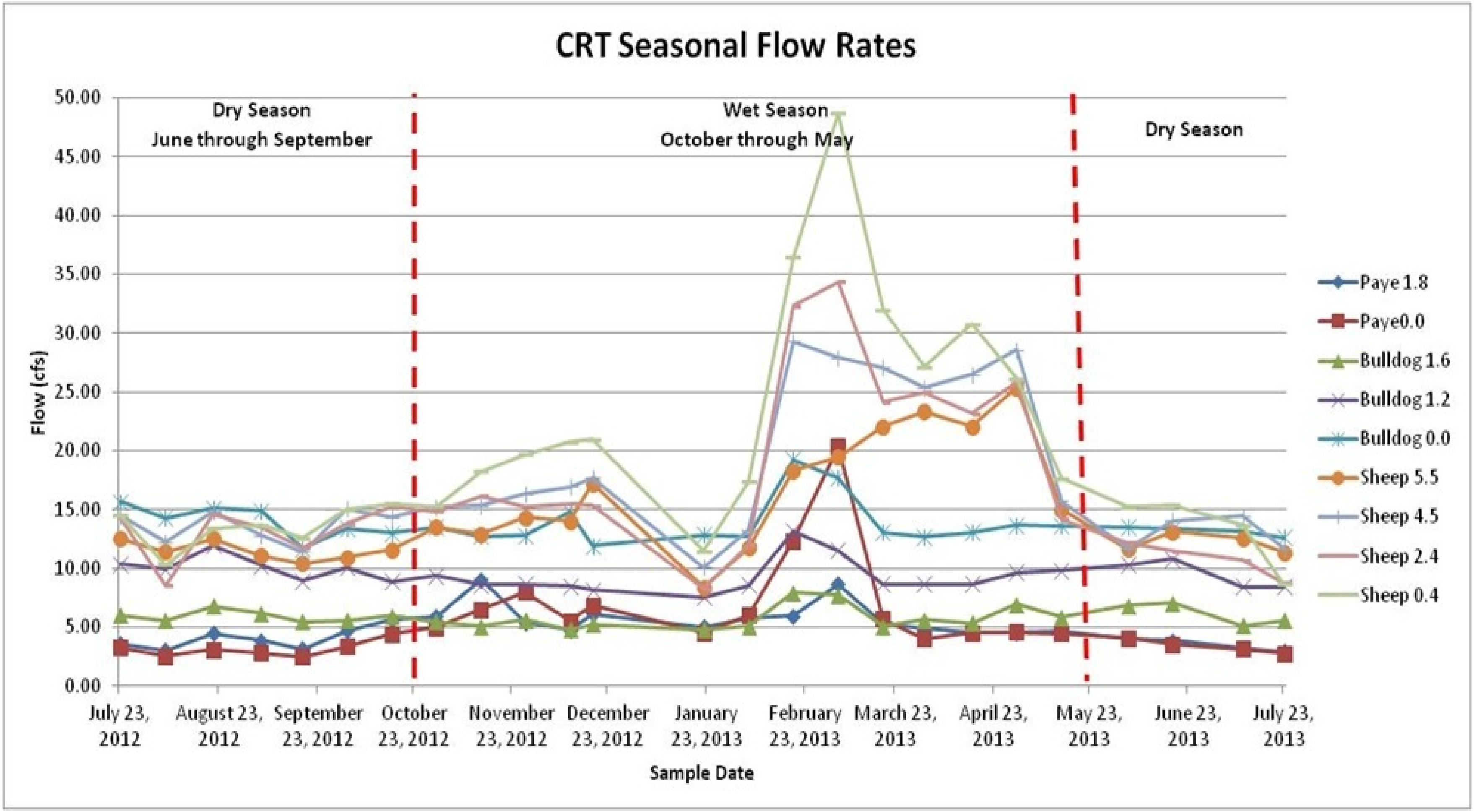


Figure 5. Colville River tributaries streamflow discharges during the 2012-13 study

Methods

Sampling and Measurement Procedures

Data collection and quality

Field data collection study methods were described in the *Addendum to Quality Assurance Project Plan: Colville River Fecal Coliform Total Maximum Daily Load Study* (Albrecht, 2012).

During the field surveys, streamflow was measured at selected stations, and/or staff gage readings were recorded. Estimation of instantaneous flow measurements followed the Environmental Assessment Program standard operating procedure (Ecology, 2009). Instream flow measurements were conducted during the project at the time of sampling.

Ecology's Manchester Environmental Laboratory (MEL) conducted all laboratory analyses. Laboratory analyses followed laboratory quality assurance/quality control (QA/QC) procedures (MEL, 2008; MEL, 2012). MEL prepared and submitted QA memos to Ecology's Environmental Assessment Program (EAP) for each sampling survey. Each memo summarized the QC procedures and results for sample transport and storage, sample holding times, and instrument calibration. The memo also included a QA summary of check standards, matrix spikes, method blanks (used to check for analytical bias), and lab-splits (used to check for analytical precision).

Measurement quality objectives (MQO) were updated to be consistent with the current EAP precision targets (Mathieu, 2006). Table 5 describes the analyses, methodologies, and measurement or data quality objectives used in the FC bacteria TMDL study.

Analytical laboratory precision was determined separately to account for its contribution to overall variability. Precision for chloride and total suspended solids (TSS) was determined by calculating an average relative standard deviation (%RSD) of lab-split results. About 15 percent of the TSS and chloride samples were analyzed as laboratory split samples. Precision for FC bacteria was determined by conducting a frequency analysis for %RSD values of lab-split pairs below 20 percent RSD and 50 percent RSD. For FC bacteria samples, about 10 percent were analyzed as split samples.

The RSD was first calculated by dividing the standard deviation by the mean of the replicate measurements and multiplied by 100 for the %RSD. A higher %RSD is expected for values that are close to their reporting limits. (For example, the %RSD for replicate samples with results of 1 and 2 is 47 percent, whereas the %RSD for replicate results of 100 and 101 is 0.7 percent, with each having a difference of 1.)

Higher %RSD is expected near the reporting limit, so two tiers were evaluated for chlorides and TSS: lab-split results less than five times the reporting limit were considered separately from lab-split results equal to or more than five times the reporting limit. For FC bacteria the two tiers evaluated were 50 percent of replicates ≤ 20 percent RSD and 90 percent of replicates ≤ 50 percent RSD.

Table 5. Study analysis methodologies with precision targets and reporting limits

Analysis	Method	Lab and Total Precision MQO	Lab Duplicate MQO	Reporting Limit
Field Measurements				
Velocity[1]	Marsh McBirney Flow-Mate® Flowmeter	0.1 ft/s	n/a	0.01 ft/s
Water Temperature[1]	Hydrolab MiniSonde®	+/- 0.1° C	n/a	0.01° C
Specific Conductivity[2]	Hydrolab MiniSonde®	+/- 10%	n/a	0.1 umhos/cm
pH[1]	Hydrolab MiniSonde®	0.1 SU	n/a	1 to 14 SU
Dissolved Oxygen[1]	Hydrolab MiniSonde®	10% RSD	n/a	0.1 - 15 mg/L
	Winkler Titration	+/- 0.1 mg/L	n/a	0.01 mg/L
Laboratory Analyses				
Fecal Coliform – MF	SM 9222D	20% and 50% RSD[3]	40% RPD	1 cfu/100 mL
Chloride	EPA 300.0	5% RSD[4]	20% RPD	0.1 mg/L
Total Suspended Solids	SM 2540D	15% RSD[4]	20% RPD	1 mg/L

[1] as units of measurement, not percentages.
[2] as percentage of reading, not relative standard deviation (RSD).
[3] two-tiered: 50% of replicates ≤ 20% RSD; 90% of replicates ≤ 50% RSD.
[4] replicate results with a mean of less than or equal to 5 times the reporting limit will be evaluated separately.
MQO = Measurement quality objective.
SU = Standard pH units.
MF = Membrane filter method.
SM = Standard Methods for the Examination of Water and Wastewater, 20th Edition (APHA et al., 2005).
EPA = U.S. Environmental Protection Agency method code.

Both tiers were compared to the target precision objectives for FC bacteria. The upper tier was compared to the target precision objective for chloride and TSS.

Field replicate samples (back-to-back duplicates) were collected for at least 10 percent of the total number of general chemistry samples and at least 10 percent of the total number of microbiology samples in order to assess total precision (i.e., total variation) for field samples. As was done for the lab precision evaluation, two tiers were also evaluated for total precision: field-replicate results less than five times the reporting limit and field-replicate results equal to or more than five times the reporting limit for chloride and TSS. For FC bacteria, the two tiers evaluated were 50 percent of replicates ≤ 20 percent RSD and 90 percent of replicates ≤ 50 percent RSD. %RSD was calculated for each parameter using field replicate results greater than reporting limits.

Analytical framework

Although TMDL studies normally express allocations as pollutant loads (pollutant concentration multiplied by streamflow), this approach does not work well for bacteria TMDL studies. An allocation of FC bacteria pollutant loads in terms of “numbers of bacteria per day” is awkward, challenging to understand, and not useful.

Statistical Roll-Back Method

Instead of managing FC pollution in terms of total load, Ecology has used the Statistical Roll-Back Method (Ott, 1995) to manage the distribution of FC counts. The approach relates the analysis to the FC concentration standard better and has proven successful in past bacteria TMDL assessments (Joy, 2000; Sargeant, 2002; Tarbutton et al., 2010).

The Statistical Roll-Back Method was used to establish FC reduction targets at all sampling sites that had sufficient sampling size (>4 samplings). The roll-back method assumes that the distribution of FC concentrations follows a log-normal distribution. The cumulative probability plot of the observed data gives an estimate of the geometric mean and 90th percentile which can then be compared to the FC concentration standards. If the geometric mean and/or the 90th percentile do not meet the criteria, the whole distribution needs to be “rolled-back” to match the more restrictive of the two criteria. The amount that a site’s distribution of FC counts needs to be “rolled-back” is expressed as the FC target percent reduction required to meet both parts of the FC water quality criteria.

The roll-back procedure used is as follows:

- A check was made to ensure the FC data collected in 2004-06 fit a log-normal distribution at each sampling location. WQHYDRO® (Aroner, 2003) was used to test the FC data for log-normal distribution fit.
- An Excel® (Microsoft, 2010) spreadsheet was used to calculate the geometric mean of the data.
- The 90th percentile of the data was estimated by using the following statistical equation. (The 90th percentile value of samples was used in this TMDL evaluation as an estimate for the “no more than 10 percent samples exceeding ….” criterion in the FC bacteria standard (WAC 173-201A.).

$$90^{th}\text{ percentile} = 10^{(\mu_{log} + 1.28 * \sigma_{log})}$$

Where: μ_{log} = mean of the log-transformed data.

σ_{log} = standard deviation of the log-transformed data.

- The target percent reduction required for the Colville River tributaries TMDL study was set as the highest of the following two resulting Primary Contact values:

$$\text{Target percent reduction} = \left[\frac{observed\ 90th\ percentile - 200\ cfu/100mL}{observed\ 90th\ percentile}\right]x100$$

$$\text{Target percent reduction} = \left[\frac{observed\ geometric\ mean - 100\ cfu/100mL}{observed\ geometric\ mean}\right]x100$$

The FC bacteria TMDL targets are developed to assist water quality managers in assessing the progress toward compliance with the FC water quality criteria. Compliance is measured as meeting water quality criteria. Any water body with FC bacteria TMDL targets is expected to meet both the applicable geometric mean and "not more than 10 percent of samples" criteria. It also is expected to support beneficial uses of the water body.

Simple loading analysis

Simple load analyses were performed using a spreadsheet to evaluate the mass balance of FC bacteria, TSS, and chloride for each reach. Loads were not used to determine the amount of FC reduction needed at sites - only measured concentration data were used to calculate the target percent reductions needed. A simple mass-balance analysis was performed to show the general pattern of loading and possible unidentified sources within the watershed. The patterns will help in directing implementation to the highest loading sources first. Cleaning up high loading sources will benefit downstream stations where the upstream loads are also causing exceedances.

Loads were calculated by multiplying the FC concentration by the flow at each site. FC bacteria are measured in colony forming units (cfu) per 100 mL, and flow is measured in cubic feet per second (cfs). The resulting product was converted to the daily load of FC bacteria, measured in billion cfu per day.

For each sampling survey, measured upstream and tributary loads entering a reach were subtracted from the measured downstream load of that reach to calculate a nonpoint load within that reach. If the downstream load was less than the sum of the upstream load and tributary loads, then there was no apparent nonpoint load to that reach.

The loading analysis treated FC bacteria, TSS, and chloride conservatively. Loss from settling, gain from re-suspension, and FC bacteria loss from die-off were not measured or approximated. Therefore, the residual term of the mass balance (i.e., the unexplained gain or loss in a reach) includes these unmeasured losses and gains, plus any errors in measuring the known loads.

The lack of steady-state flow for some sample dates increased the error of the reach-load analysis. Generally, the flow was steady during both the dry season and wet season.

Individual reach loads were averaged over a dry season and wet season, and then compared to other reach loads to develop an overall loading pattern. Averaging the loads lessened the impact of any one individual survey load, which helped smooth out the inherent variability of the loads.

Again, the goal of the simple mass-balance analysis was to show the general pattern of loading within the watershed to help in direct implementation efforts.

Ecology Study Results and Discussion

Sample Dates – 2012-13 Surveys

Sampling began on July 23, 2012, and continued until July 23, 2013. Table 6 lists the 25 sampling surveys. The surveys were partitioned into either a wet season or dry season group based on the streamflow in the study area.

Table 6. Sampling dates for Colville River Tributaries, 2012 - 2013

Wet Season	Dry Season
October 2, 2012	July 23, 2012
October 16, 2012	August 6, 2012
October 30, 2012	August 21, 2012
November 13, 2012	September 5, 2012
November 27, 2012	September 18, 2012
December 11, 2012	June 4, 2013
December 18, 2012	June 18, 2013
January 22, 2013	July 10, 2013
February 5, 2013	July 23, 2013
February 19, 2013	
March 5, 2013	
March 19, 2013	
April 1, 2013	
April 16, 2013	
April 30, 2013	
May 14, 2013	

Seasonal Source Assessment

Separate bacteria source assessment (or screening) was analyzed for either a low-flow “dry” or high-flow “wet” season. The determination of low-flow and high-flow seasons was based on the associated streamflows. Figure 5 is an example of the seasonal hydrologic characteristics in the study area of the targeted tributaries. FC bacteria data collected from the Colville River watershed show a definite pattern of seasonal variation with summertime excursions of the bacteria standards. The flow measurements taken during this study were compared with the estimates of the original TMDL and found to be accurate for the current dry and wet seasons broken out in this study.

Typically, months that receive less precipitation yield lower runoff events; however, with the seasonal land use practices and drainage, runoff pollution during these months is still a potential source. The large volume of dilution water during the wet season may also potentially mask some FC sources.

Dry season (June through September) sources can include:

- Indirect discharge from leaking sanitary sewer and septic systems.
- Direct discharge from failing septic systems.
- Direct deposition of feces into surface waters by animals.
- Contaminated runoff from dry weather outdoor water use, such as agriculture and landscape irrigation and vehicle washing.
- Direct discharge of contaminated non-stormwater discharges. During non-runoff periods, water from springs and other sources may be discharged to streams. It is possible for this water to be contaminated with bacteria at the source or within the conveyance system.

Wet season (October through May) sources include all of the previously-listed sources listed. But in addition, pollutant loading likely includes a high proportion of urban, rural, and agricultural runoff from precipitation, snowmelt, and stormwater flow.

Quality Assurance Results

Data collected for the Colville River tributaries study met the credible data requirements in Washington State law (RCW 90.48.585; Ecology, 2012) and the Ecology Water Quality Program Policy 1-11 (Ecology, 2006). The collection of the data followed standard data quality assurance (QA) procedures. The data were also evaluated to determine whether data QA/quality control (QC) objectives for the project were met. As a result, the data are credible and representative, and appropriate for use in TMDL development. Water quality data QA/QC objectives for precision are described in Table 5.

QA/QC for samples

Laboratory

The majority of the samples were received in good condition and were properly preserved, as necessary. The temperature of the shipping coolers was between proper ranges of 0°C to 6°C for the majority of sample shipments. Throughout the entirety of the project a total of 13 samples were received at too low a temperature when they arrived at MEL. Three samples arrived at MEL above acceptable temperatures. These samples were qualified as estimates using a “J” qualifier.

Although all samples were shipped the same day they were collected, holding times were violated one time because of delayed in-transport problems or because the samples were held too long at MEL before analysis. MEL qualified all samples that were analyzed beyond holding time as an estimate, using a “J” qualifier.

For the most part, data quality for this project met all laboratory QA/QC criteria as determined by MEL. Individual exceptions that caused the results to be qualified as an estimate were qualified with a “J” qualifier in the data tables. All qualifications will be taken into consideration for the purpose of data analysis. Table 7 lists the samples that were qualified as estimates due to temperature or holding time.

Table 7. Sample results affected by temperature or hold times

Date	Notes	Number of Samples Affected	Sample IDs	Sample Parameters	Holding Time Violation
8/6/2012	Ice (0 deg)	2	128076-08	FC	
8/6/2012	Ice (0 deg)		128076-09		
10/3/2012	Ice (0 deg)	3	1210043-02	TSS	
10/3/2012	Ice (0 deg)		1210043-04	TSS	
10/3/2012	Ice (0 deg)		1210043-05	Chloride	
12/18/2012	Hold Time	1	1212017-01	FC	1
12/18/2012	Ice (0 deg)	3	1212017-02	FC	
12/18/2012	Ice (0 deg)		1212017-03		
12/18/2012	Ice (0 deg)		1212017-10		
2/5/2013	Ice (0 deg)	2	1302007-08	FC	
2/5/2013	Ice (0 deg)		1302007-09		
2/5/2013	Warm (7 deg)	3	1302007-06	All except FC	
2/5/2013	Warm (7 deg)		1302007-08		
2/5/2013	Warm (7 deg)		1302007-09		
3/19/2013	Ice (0 deg)	1	1303008-06	FC	
7/23/2013	Ice (0 deg)	2	1307008-06	FC	
7/23/2013	Ice (0 deg)		1307008-10		

Precision

Analytical precision

The analytical precision results are listed in Table 8.

Table 8. Lab precision results for the Colville River Tributaries FC study

Parameter	Reporting Limit	Target Precision	% of replicates ≤ 20% RSD or Average %RSD for replicates < 5X reporting limit	% of replicates ≤ 50% RSD or Average %RSD for replicates ≥ 5X reporting limit
Fecal Coliform[1]	1 cfu/100 mL	> 50% and > 90%	66.7%	95.8%
Chloride[2]	0.1 mg/L	< 5% RSD	4.7%	0.9%
Total Suspended Solids[2]	1 mg/L	< 15% RSD	1.5%	2.5%

[1]Two-tiered: 50% of replicates ≤ 20% RSD; 90% of replicates ≤ 50% RSD
[2]Replicates divided into two categories; < 5 times and ≥ 5 times the reporting limit

All of the parameters had analytical precision values that met the target precision objectives.

Total precision

The total precision results are listed in Table 9.

Table 9. Total precision for the Colville River Tributaries FC study

Parameter	Reporting Limit	Target Precision	% of replicates ≤ 20% RSD or Average %RSD for replicates < 5X reporting limit	% of replicates ≤ 50% RSD or Average %RSD for replicates ≥ 5X reporting limit
Fecal Coliform[1]	1 cfu/ 100 mL	> 50% and > 90%	44.0%	68.0%
Chloride[2]	0.1 mg/L	< 5% RSD	all samples ≥ 5X	0.80%
Total Suspended Solids[2]	1 mg/L	< 15% RSD	7.0%	13.0%

[1]Two-tiered: 50% of replicates ≤ 20% RSD; 90% of replicates ≤ 50% RSD

[2]Replicates divided into two categories; < 5 times and ≥ 5 times the reporting limit

As expected, %RSD for field replicates was higher than that for lab splits because the %RSD is a measurement of total variability, including both field and analytical variability. The majority of total precision values met the target precision objectives.

While FC bacteria did not meet the two-tiered total precision objectives, it did meet Ecology's historic standard of an average %RSD less than 40 percent. Manchester Lab considers results less than 20 total counts or 20 counts per dilution as not statistically sufficient to make a valid evaluation on precision. If that criteria is used, and the too numerous to count (TNTC) result from November 2012 is omitted, we have an average %RSD of 24 percent. Also 70 percent of the duplicate pairs had a %RSD ≤ 20 percent and 80 percent had a %RSD of < 50 percent, which meets the two-tiered precision objectives. We therefore deem the duplicate precision for FC bacteria as acceptable for this study.

Conclusion

While there was a higher variability in FC data than is preferred, given the behavior of the bacteria colonies and their ability to be found clumped together, it's not unheard of to catch a clumped concentration in one sample and not another. Samples taken in these conditions could lead to a higher variability between duplicate samples. When variability between duplicate samples is compared between all parameters it is apparent that the FC samples were the only samples with high duplicate variability. Based on the QA and QC review, the Ecology data are of good quality, properly qualified, and acceptable for use in a TMDL analysis.

Study Results and Discussion

Paye Creek

Paye Creek was monitored from the Hwy 395 crossing (site 59PAY1.8) to just upstream of the confluence with the Colville River (site 59PAY0.0). Ecology sampled these two sites during 25 visits, 9 times during the dry season and 16 times during the wet season.

59PAY1.8 was sampled approximately 1.5 miles downstream of the creek's apparent headwaters. The majority of the creek's water source appears to originate from springs in a swampy area north of Hwy 395. Samples were collected on the downstream side of Hwy 395 where the creek flows through two culverts under the highway. Above RM 1.8, Paye Creek meanders through rural pastures and a few farmed fields.

59PAY0.0 is located very close to the mouth of the creek where it joins the Colville River. The reach between the upstream and downstream site is mostly residential properties, but also includes two farm fields near the creek.

FC Bacteria

A seasonal pattern is apparent in Paye Creek during the 2012-13 monitoring period. Combining all the FC bacteria data collected from both sites provides a visual example. Figure 6 shows the monthly geometric means and 90^{th} percentiles for Paye Creek during the 2012-13 study. Geometric means and 90^{th} percentiles statistics both exceeded the Primary Contact Recreation criteria for the months of July, August, and October. The 90^{th} percentiles of May, June, September, and November exceeded the criteria as well.

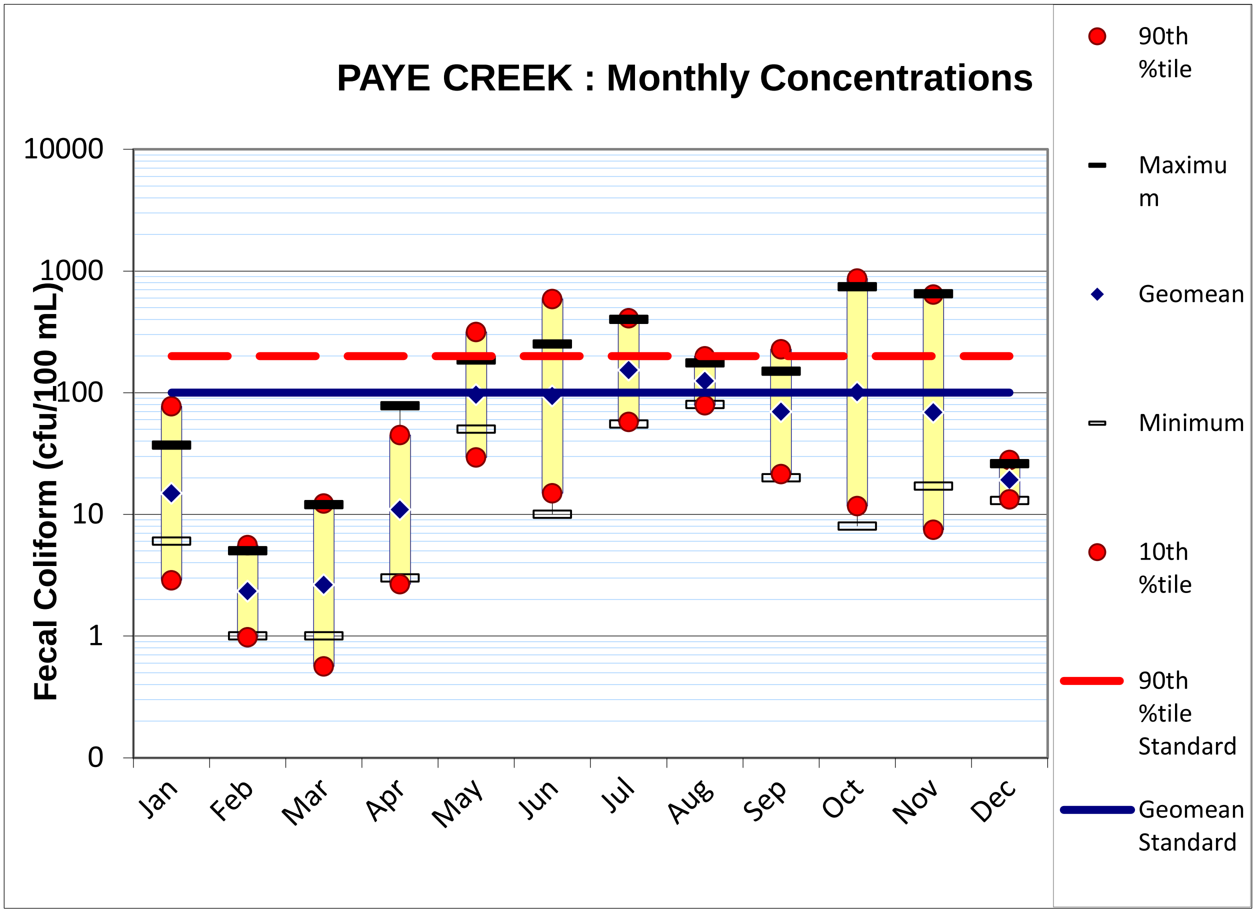


Figure 6. Monthly geometric means and 90th percentiles for FC data collected at Paye Creek, 2012 - 2013

Table 10 and Figure 7 present the dry season and wet season summary statistics of FC counts. Table 10 also presents the target reductions necessary to meet the water quality standards in Paye Creek.

Table 10. Dry and wet season's summary statistics of FC counts and target percent reductions for Paye Creek, 2012 - 2013

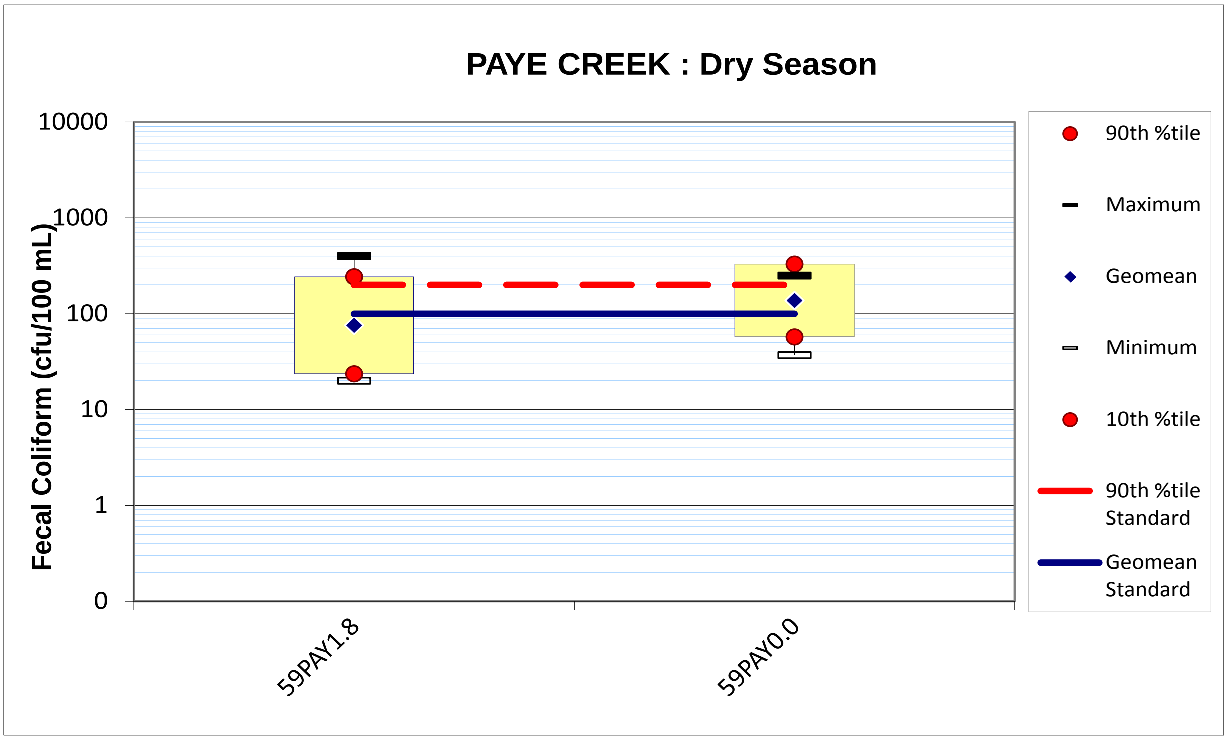
Station ID	Total # of Samples	Min	10th %tile	Geomean > 100 cfu/ 100 mL*	90th %tile	Max	Target % Reduction**
DRY SEASON							
59PAY1.8	9	20	24	76	243	400	18%
59PAY0.0	9	37	57	137	329	250	39%
WET SEASON							
59PAY1.8	16	1	2	18	171	650	0%
59PAY0.0	16	1	2	18	212	740	6%

*Cells shaded in these columns are values that do not meet (exceed) Washington State numeric standards.

**Cells shaded in this column are values based on less than 5 samples collected at that station.

NOTE: These station ID's pertain to listing ID 455569

The percent reduction values in Tables 10-12 indicate the relative degree the water body is currently out of compliance with the cited water quality criteria (i.e., how far it is over its capacity to receive FC loads and still provide Primary Contact recreation). Sites representing reaches or tributaries that are meeting their loading capacity have a zero percent reduction value. Sites that require aggressive reductions in FC sources have high target percent reductions, while sites with minor problems have lower target percent reductions.



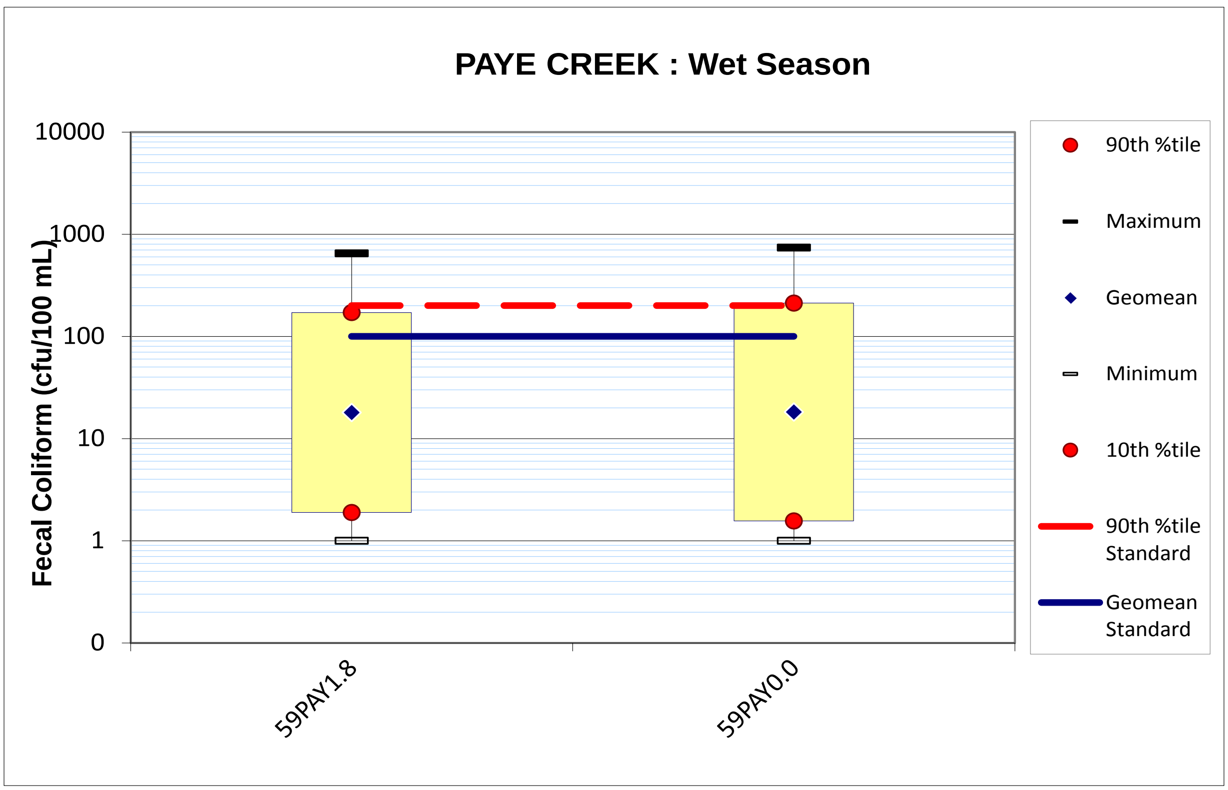
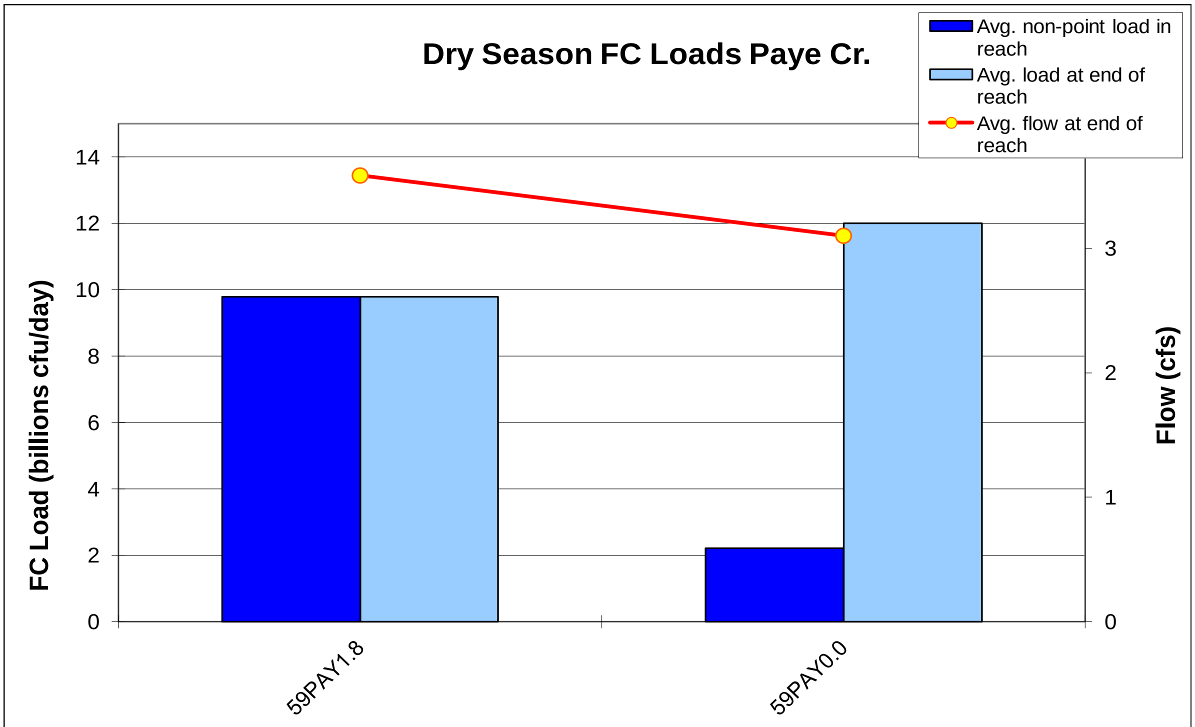


Figure 7. Dry and wet season summary statistics of FC counts for Paye Creek, 2012 - 2013

The upstream site (59PAY1.8) at Hwy 395 did not meet the Primary Contact Recreation 90th percentile criteria during the dry season. This site met both parts of the criteria; geomean and 90th percentile, for Primary Contact Recreation during the wet season.

The downstream site (59PAY 0.0) did not meet either part of the criteria, geomean or 90th percentile, during the dry season. This site also did not meet the 90th percentile criteria during the wet season.

Average seasonal FC loads were calculated for the two reaches, using the concentration and streamflow data collected at both sites. Streamflows during the wet season were much greater than during the dry season. Figure 8 presents the average dry season and wet season FC loads for each reach and tributary. Table 11 summarizes the average loads as their percentages of the total load to Paye Creek if FC die-off or settling is not considered.



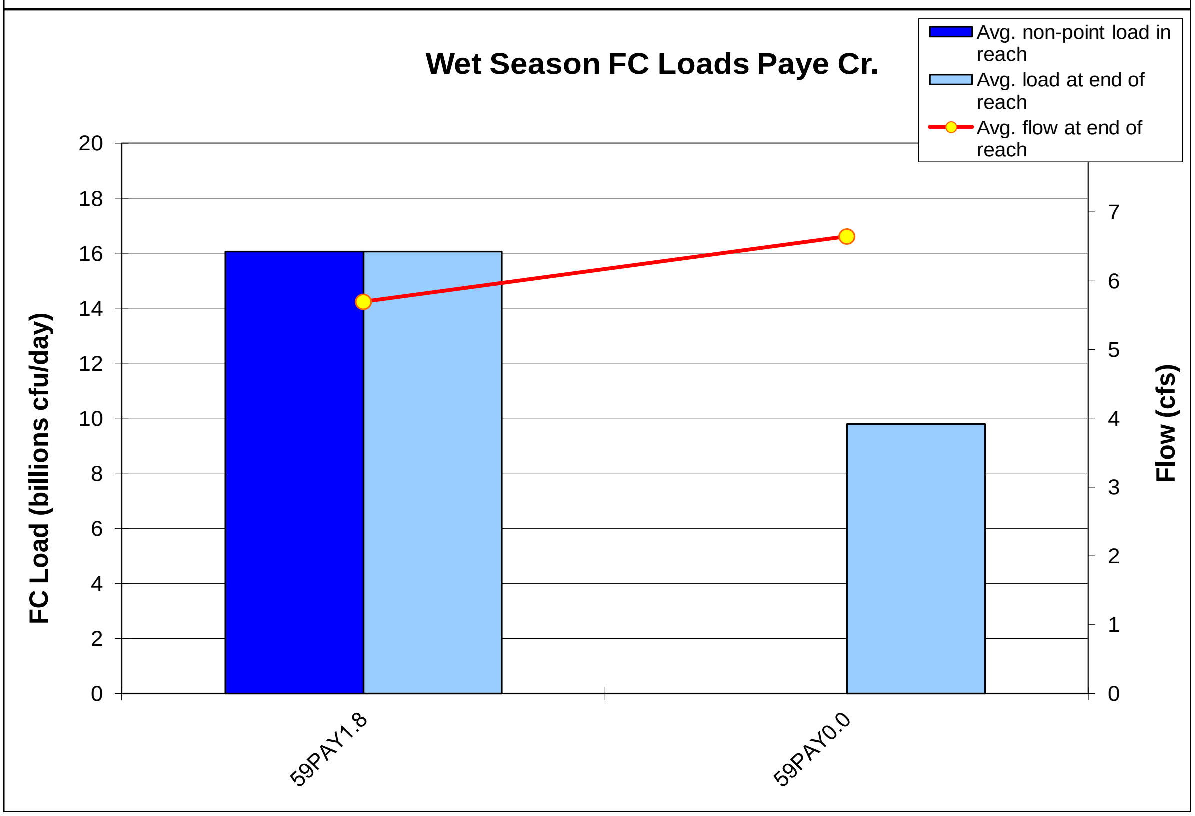


Figure 8. Dry and wet season average FC loads for Paye Creek, 2012 - 2013

Table 11. FC loading percentages for dry and wet seasons of Paye Creek, 2012 - 2013

Reach (Paye RM)	Site (End of Reach)	Dry Season	Wet Season
Above RM 1.8	59PAY1.8	82.0%	100.0%
RM 1.8 to 0.0	59PAY0.0	18.0%	0.0%

These reaches pertain to listing ID 455569

Tables 10 and 11 and Figures 6, 7, and 8 present the dry season and wet season summary statistics of FC counts. Table 10 also presents the target reductions necessary to meet the water quality standards in Paye Creek. Table 12 represents the percentage of TSS, and CL observed in Paye Creek during dry and wet seasons.

Table 11 shows that the nonpoint loads above the upstream site (59PAY1.8) had a significantly larger percentage of FC load contribution throughout both seasons. The reach above RM 1.8 contributed most of the dry season FC load (82 percent) and all (100 percent) of the FC loading during the wet season.

Total suspended solids and chloride

Table 12 presents the dry season and wet season TSS and Chloride load contribution percentages in Paye Creek.

Table 12. Dry and wet season TSS and Chloride loading percentages for Paye Creek, 2012 - 2013

Reach (Paye RM)	Site (End of Reach)	TSS		Chloride	
		Dry Season	**Wet Season**	**Dry Season**	**Wet Season**
Above RM 1.8	59PAY1.8	48.0%	76.5%	100.0%	78.7%
RM 1.8 to 0.0	59PAY0.0	52.0%	23.5%	0.0%	21.3%

During the wet season site (59PAY1.8) contributed the greatest amount of TSS input with a total of 76.5 percent. During the dry season site (59PAY0.0) contributed the larger percentage of TSS load with 52 percent, but nearly half of the TSS load during the dry season appears to also be from the above RM 1.8 (48 percent).

There is no apparent correlation between the dry season TSS loading percentages and FC loading percentages in Paye Creek.

The wet season TSS loading percentage and FC loading percentage were both high above RM 1.8. The data suggests that conditions that elevate TSS, such as high flows or runoff processes (causing soil erosion), could also elevate FC concentrations in this reach.

The reach above RM 1.8 (59PAY1.8) contributed 100 percent in wet season and 78.7 percent of the Chloride load during the dry season. This site measured well above site (59PAY0.0) with its largest Chloride load of 21.3 percent.

Chloride loading percentages and FC loading percentages were high above RM 1.8 during both seasons. This suggests that conditions and nonpoint sources that elevate chloride, such as new water or waste sources (manure or failing septic tanks), could be elevating FC concentrations. These unidentified sources should be considered for FC contamination in this reach.

Bulldog Creek

Bulldog Creek was monitored from near the headwaters just below the pond that is fed by springs on Bulldog Creek Rd. (59BUL1.6) to just downstream of where the creek flows under Bulldog Creek Rd (59BUL1.2). The lowest downstream site sampled on Bulldog Creek was on the Lane Mountain Company Silica quarry property near the creek's confluence with the Colville River (59BUL0.0). Ecology sampled these three sites during 25 visits: 9 times during the dry season and 16 times during the wet season.

FC Bacteria

Due to Bulldog Creek's heavy influence of groundwater, it does not follow the typical loading patterns of most creeks. The conditions of having a quite small catch basin to collect runoff and having a steady groundwater input creates a more uniform loading pattern between the seasons. Levels of recorded FC range from 12 percent to 60 percent during the dry season and 25 percent to 41 percent during the wet season. The recorded values had steady gains from upstream to downstream, as one might expect from concentration of these parameters throughout the system.

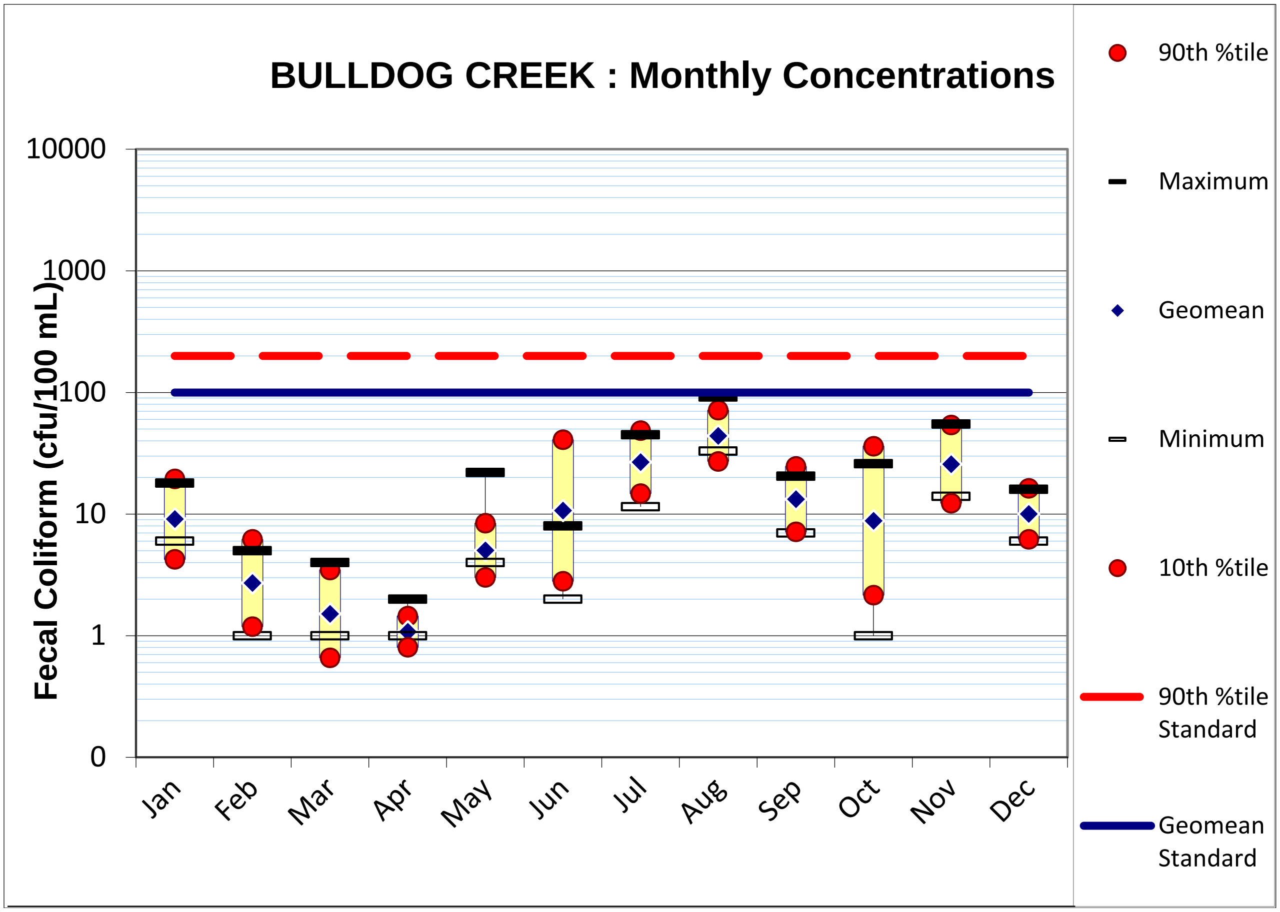


Figure 9. Monthly geometric means and 90th percentiles for FC data collected at Bulldog Creek, 2012 - 2013

Table 13. Dry and wet season's summary statistics of FC counts and target percent reductions for Bulldog Creek, 2012 - 2013

Station ID	Total # of Samples	Min	10th %tile	Geomean > 100 cfu/ 100 mL*	90th %tile	Max	% Samples > 200 cfu/ 100 mL*	Target % Reduction
DRY SEASON								
59BUL1.6	9	2	5	15	51	41	0%	0%
59BUL1.2	9	6	8	22	62	67	0%	0%
59BUL0.0	9	10	14	35	88	92	0%	0%
WET SEASON								
59BUL1.6	16	1	1	4	17	27	0%	0%
59BUL1.2	16	1	1	5	25	47	0%	0%
59BUL0.0	16	1	1	5	29	55	0%	0%

These station ID's pertain to listing ID 46161

Table 14. FC percentages for dry and wet seasons of Bulldog Creek, 2012 - 2013

Reach (Bulldog RM)	Site (End of Reach)	Dry Season	Wet Season
Above RM 1.6	59BUL1.6	12.0%	25.8%
RM 1.8 to 1.6	59BUL1.2	28.0%	33.1%
RM 1.6 to 0.0	59BUL0.0	60.0%	41.1%

These station ID's pertain to listing ID 46161

Tables 13 and 14, and Figures 9, 10, and 11 present the dry season and wet season summary statistics of FC counts. Table 13 also presents the target reductions necessary to meet the water quality standards in Bulldog Creek. Table 15 represents the percentage of TSS and CL observed in Bulldog Creek during dry and wet seasons.

The most upstream site on Bulldog Creek (59BUL1.6) had FC counts of 2 to 41 during the dry season and 1 to 27 during the wet season. The middle site (59BUL1.2) had FC counts of 6 to 67 during the dry season and 1 to 47 during the wet season. The furthest downstream site near the mouth of the creek (59BUL0.0) had FC counts of 10 to 92 during the dry season and 1 to 55 during the wet season.

All three sampling sites on Bulldog Creek met the criteria for Primary Contact Recreation for both the wet and dry season. Neither the geomean nor the 90th percentile criteria were exceeded at any of the sampling sites on this creek during our study.

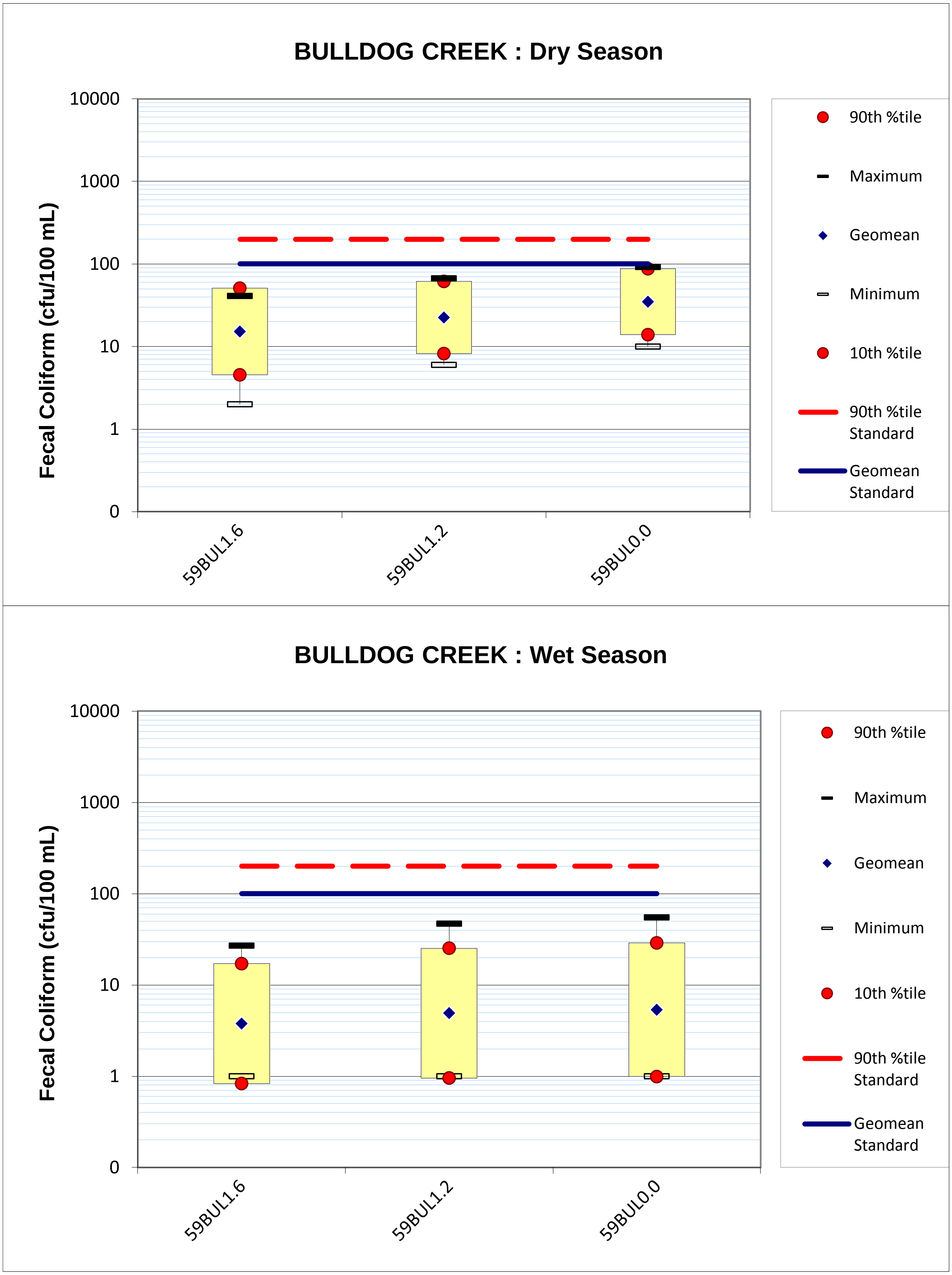


Figure 10. Dry and wet season summary statistics of FC counts for Bulldog Creek, 2012 - 2013

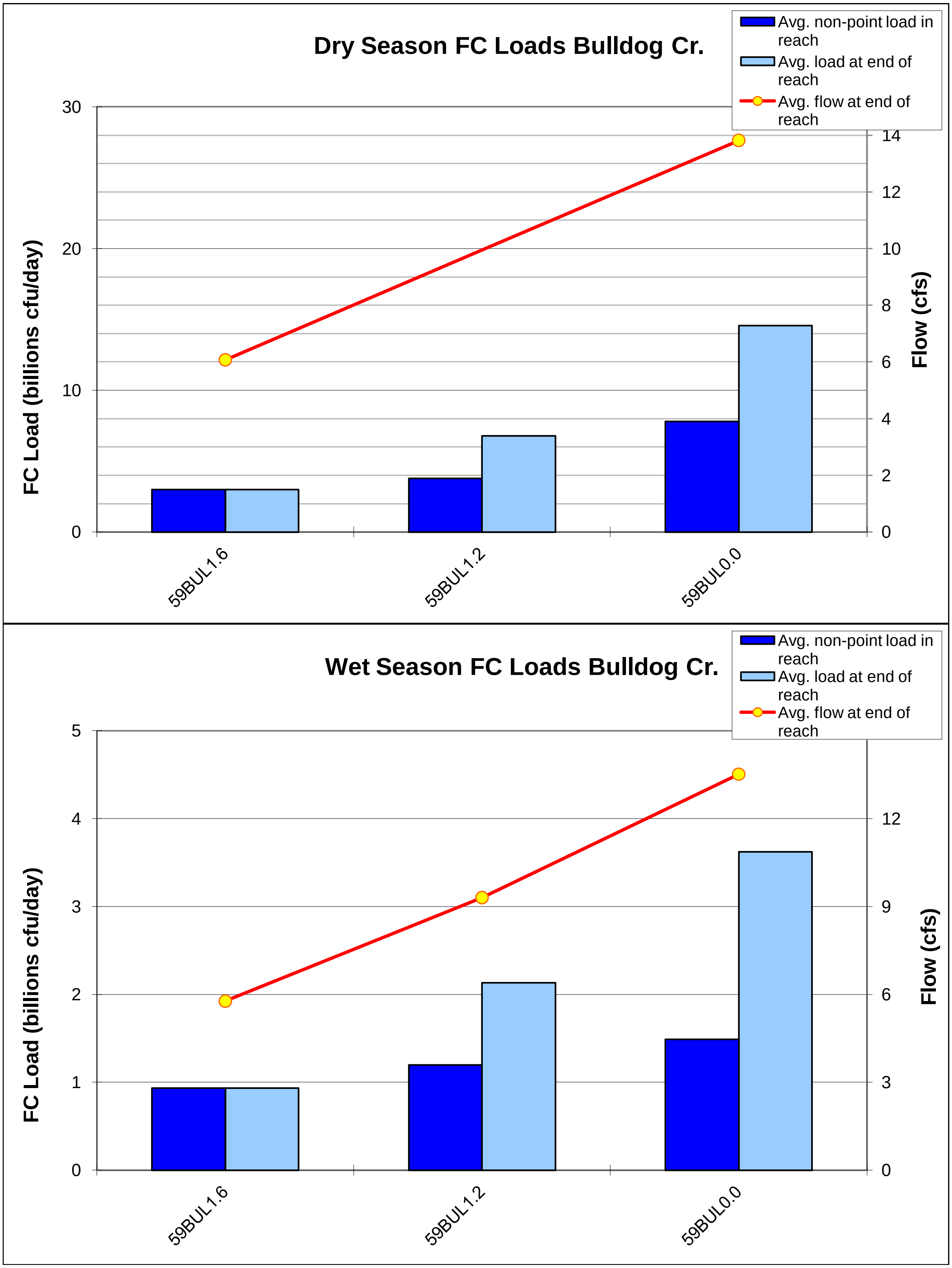


Figure 11. Dry and wet season average FC loads for Bulldog Creek, 2012 - 2013

Table 15. Dry and wet season TSS and Chloride loading percentages for Bulldog Creek, 2012 - 2013

Reach (Bulldog RM)	Site (End of Reach)	TSS		Chloride	
		Dry Season	Wet Season	Dry Season	Wet Season
Above RM 1.6	59BUL1.6	9.3%	12.2%	58.8%	55.9%
RM 1.8 to 1.6	59BUL1.2	34.5%	29.1%	17.6%	15.0%
RM 1.6 to 0.0	59BUL0.0	56.2%	58.7%	23.6%	29.1%

Total Suspended Solids

During our sampling of Bulldog Creek, TSS levels followed the same pattern as FC, with a gradual gain in parameter percentage as we sampled downstream. The dry season TSS percentage measured from 9 percent to 56 percent during the dry season and 12 percent to 58 percent during the wet season.

Chloride

Chloride was the one parameter that did not follow the pattern of instream gain as the other studied parameters did. However, the percentage of chloride did follow a similar pattern between the two seasons. A pattern of higher chloride percentage at the most upstream site and diminishing percentage downstream could possibly be caused by absorption into the sediment. But it is, again, likely due to the groundwater source for the majority of this creek's water source near the headwaters.

Sheep Creek

Sheep Creek was monitored from near the town of Springdale, just below the Springdale-Hunters road crossing (SHE5.5) downstream to just before the Hesseltine Rd crossing (59SHE4.5). The next sample site was downstream just before the Forest Center Rd crossing (59SHE2.4). The final sample site was located just downstream of the Deer Creek Rd crossing (59SHE0.4) approximately 2000 ft before the confluence with the Colville River. Ecology sampled these four sites during 25 visits: 9 times during the dry season and 16 times during the wet season.

FC Bacteria

During the dry season, the most upstream site near Springdale (59SHE5.5) failed to meet the criteria for geomean and 90th percentile with FC counts of 4 to 680 cfu/100 mL. During the wet season however, this site met the criteria for Primary Contact recreation. The next site downstream (59SHE4.5) failed to meet both criteria with FC counts of 25 to 703 cfu/100 mL for the dry season. This site met the geomean criteria in the wet season, but failed to meet the criteria for 90th percentile with FC counts of 3 to 377 cfu/100 mL. The third downstream site (59SHE2.4) failed to meet the geomean and 90th percentile criteria with FC counts of 41 to 630 in the dry season. In the wet season, this site met both the geomean and 90th percentile criteria. The last site, near the mouth of the creek (59SHE0.4), failed to meet geomean and 90th percentile criteria during the dry season with FC counts of 79 to 760. It also failed to meet the 90th percentile criteria during the wet season with FC counts of 2 to 770.

Along Sheep Creek, livestock graze in numerous areas along the whole system. The furthest downstream site (59SHE0.4) appeared to be the most heavily affected by this, as there was active streamside grazing in that area during the summer. There was also evidence of streamside grazing downstream of site (59SHE2.4) and part time grazing at site (59SHE4.5). The streamside grazing practices in the area could be a possible source of the elevated FC counts through these areas as there appears to be no exclusion fencing being used. The furthest upstream site (59SHE5.5) did not appear to have an obvious source for its elevated FC counts. There was evidence of some grazing but livestock were never witnessed having open access to the creek.

Two other sites upstream were sampled, in an attempt to isolate the source for the elevated FC counts. The samples taken upstream of town did not have elevated FC concentrations. The source was not found by the time the peak FC counts dropped off. Site (59SHE5.5) was very near to the town of Springdale. The source of the elevated counts appeared to be coming from the vicinity of the town of Springdale, possibly from a septic source in or near the town. However this was never confirmed.

Table 16. Dry and wet season's summary statistics of FC counts and target percent reductions for Sheep Creek, 2012 - 2013

Station ID	Total # of Samples	Min	10th %tile	Geomean > 50 cfu/ 100 mL*	90th %tile	Max	Target % Reduction
DRY SEASON							
59SHE5.5	9	4	19	132	912	680	78%
59SHE4.5	9	25	44	176	703	1300	0%
59SHE2.4	9	41	88	233	614	630	67%
59SHE0.4	9	79	112	259	600	760	67%
WET SEASON							
59SHE5.5	16	2	2	18	192	2031	0%
59SHE4.5	16	3	4	40	377	2000	47%
59SHE2.4	16	4	5	29	177	250	0%
59SHE0.4	16	2	5	39	280	770	29%

*Cells shaded in these columns are values that do not meet (exceed) Washington State numeric standards.

These station ID's pertain to listing ID 8525 under the proposed NHD classification.

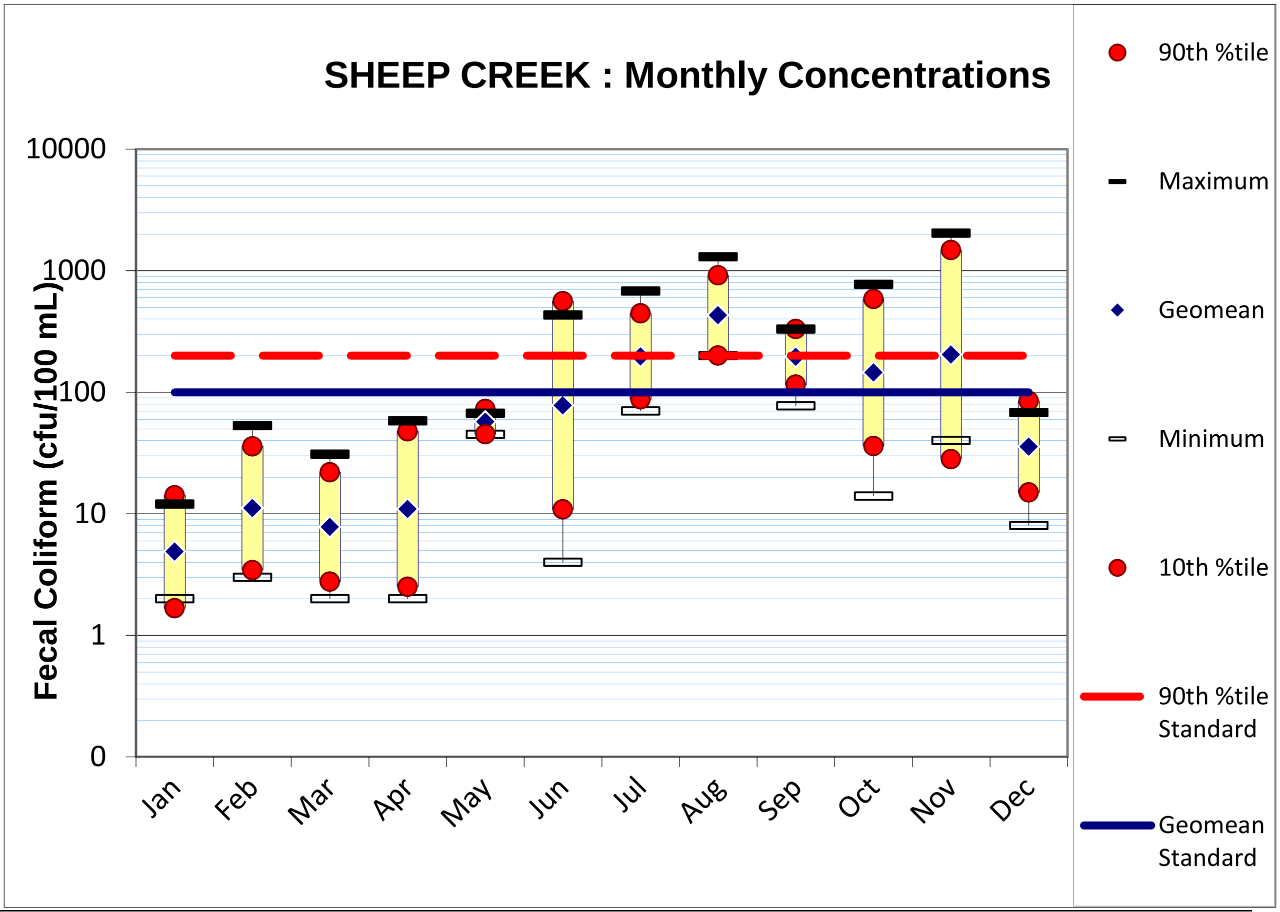


Figure 12. Monthly geometric means and 90th percentiles for FC data collected at Sheep Creek, 2012 - 2013

Table 17. FC percentages for dry and wet seasons of Sheep Creek, 2012 - 2013

Reach (Sheep RM)	Site (End of Reach)	Dry Season	Wet Season
Above RM 5.5	59SHE5.5	58.0%	51.4%
RM 5.5 to 4.5	59SHE4.5	25.0%	27.5%
RM 4.5 to 2.4	59SHE2.4	0.0%	0.0%
RM 2.4 to 0.4	59SHE0.4	17.0%	21.1%

These reaches pertain to listing ID 8525 under the proposed NHD classification.

Table 16 and 17, and Figures 12, 13, and 14 present the dry season and wet season summary statistics of FC counts. Table 16 also presents the target reductions necessary to meet the water quality standards in Sheep Creek.

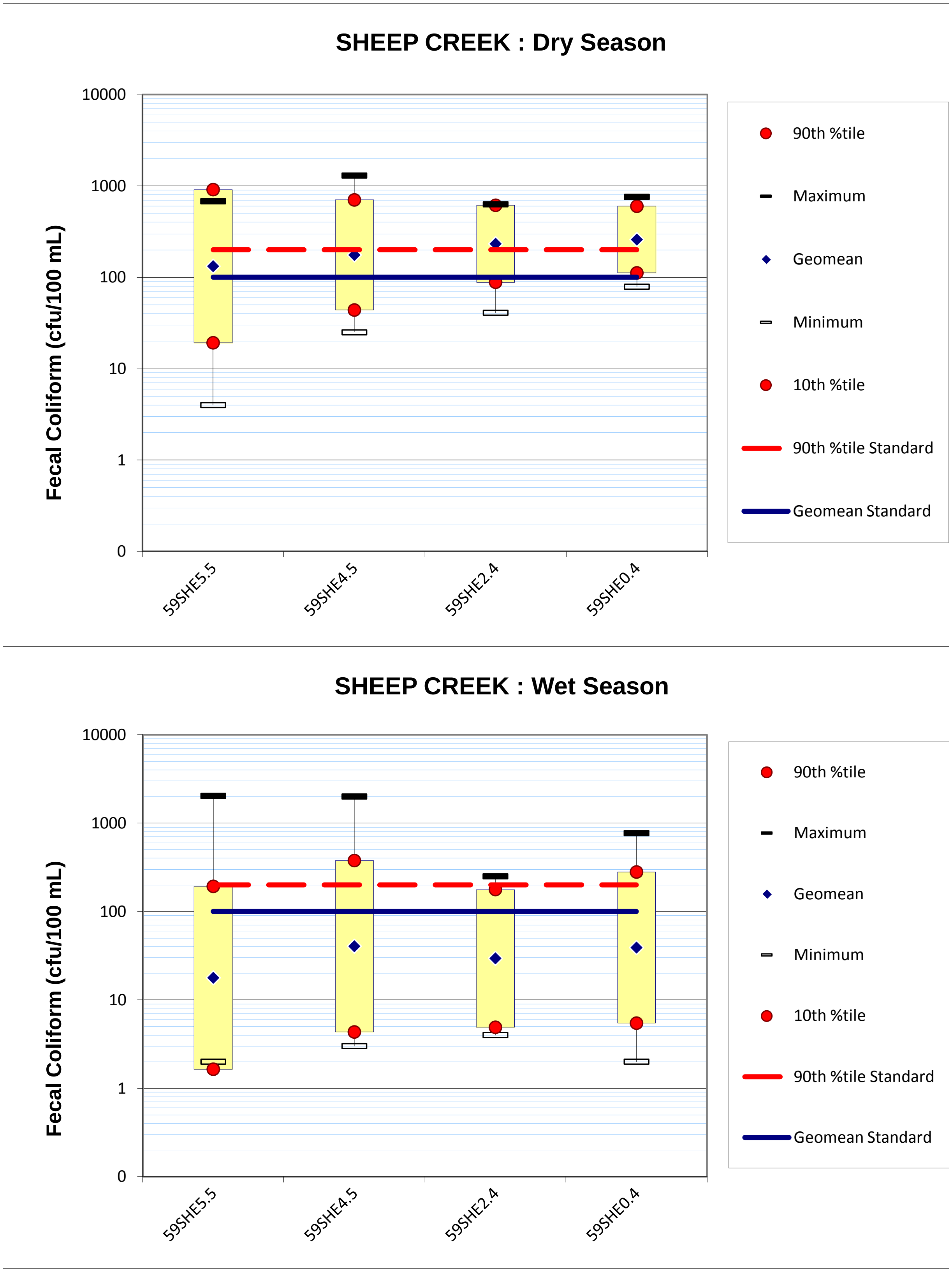


Figure 13. Wet and dry season summary statistics of FC counts for Sheep Creek, 2012 - 2013

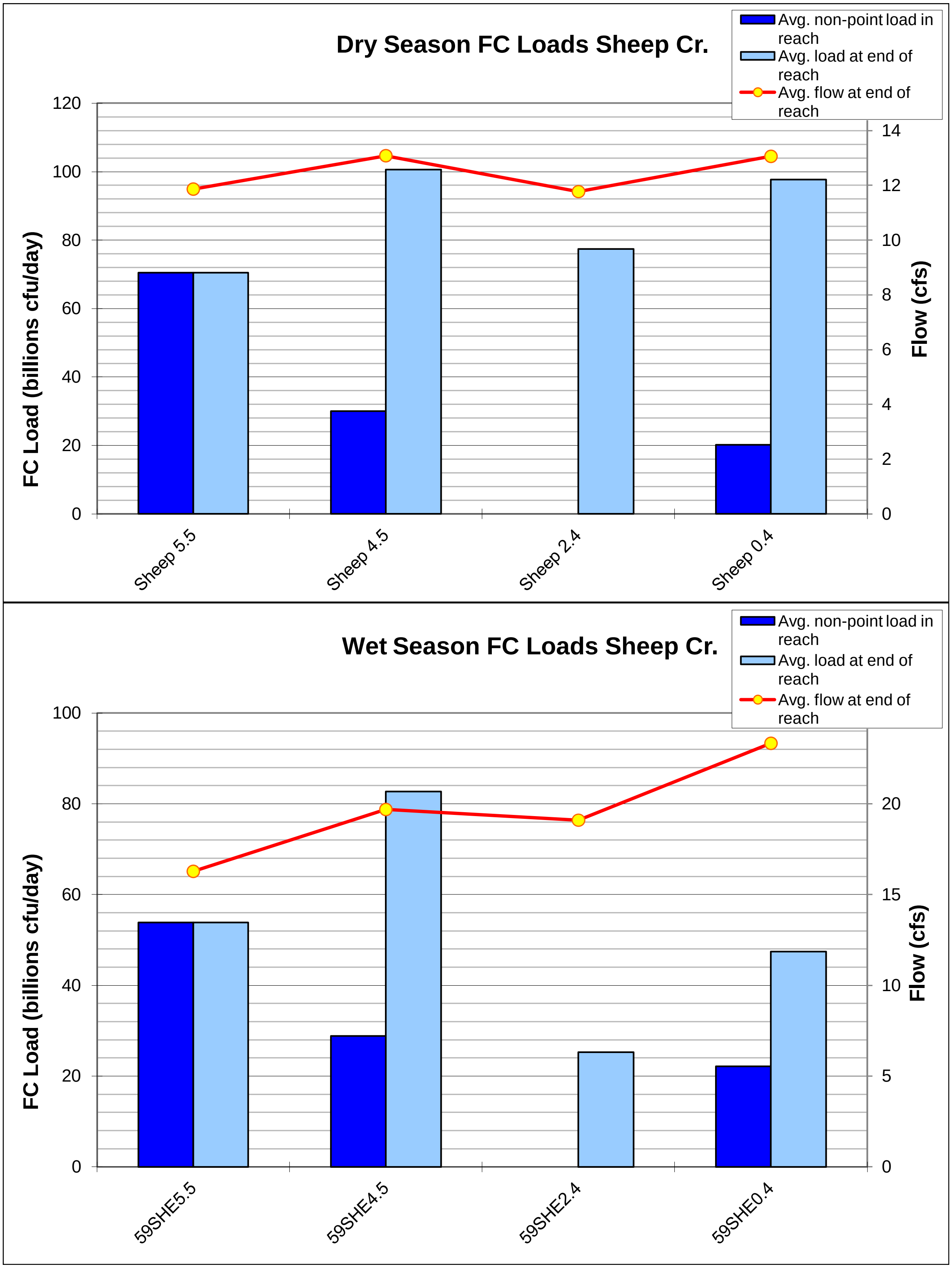


Figure 14. Wet and dry season average FC loads for Sheep Creek, 2012 - 2013

Table 18 presents the dry season and wet season FC load contribution percentages for Sheep Creek. A higher level of FC was recorded during the wet season for Sheep Creek, overall. With more snow and rain runoff transporting these nutrients into the creek during this time, this pattern is not uncommon. (SHE5.5) was the only site that did not fit this pattern. This site recorded higher numbers during the dry season. This is likely due to the high spike in FC that we recorded and attributed to a failed septic system upstream. Although it appears this site had limited grazing impacts, an upstream septic failure was a likely contributor to the unexpected seasonal pattern of nutrient loading.

Table 18. Dry and wet season TSS and Chloride loading percentages for Sheep Creek, 2012 - 2013

Reach (Sheep RM)	Site (End of Reach)	TSS		Chloride	
		Dry Season	Wet Season	Dry Season	Wet Season
Above RM 5.5	59SHE5.5	12.0%	29.4%	84.2%	69.9%
RM 5.5 to 4.5	59SHE4.5	19.2%	8.9%	6.3%	12.4%
RM 4.5 to 2.4	59SHE2.4	28.1%	15.2%	0.0%	0.0%
RM 2.4 to 0.4	59SHE0.4	40.6%	46.5%	9.4%	17.7%

Total suspended solids

During our study of Sheep Creek, TSS levels did not follow the expected pattern of fluctuating with runoff and elevated streamflow. The levels of TSS were only higher during the wet season for half of the sites. Sites (59SHE4.5) and (59SHE2.4) produced larger levels during the dry season. Site (59SHE0.4) was only slightly higher in the dry season. The sites having higher TSS levels in the dry season could possibly be impacted by streambank erosion, as two of the sample sites had active cattle grazing nearby in the dry season. The substrate of the creek also changes from cobbles to mostly sand and mud in the lower section of the creek. The middle sections of the creek at sites (59SHE4.5) and (59SHE2.4) had lower levels of TSS during the wet season, also not following an expected pattern. This middle section, however, had the least amount of grazing and farming activity and was the most densely vegetated. These factors may help why these sections do not seem to be as affected by the wet season runoff and higher contributions of FC and TSS typically seen during that season. Overall, this creek did not have a large swing in recorded measurements between wet and dry seasons. During the dry season, this creek was largely impacted by streamside grazing practices and farming. The wet season had much less streamside activity, even though the runoff is typically larger then. This could be the reason for this creek not having a larger variance between the seasons.

Chloride

Chloride levels throughout this creek were typically higher in the wet season and lower in the dry season, which is typical with higher runoff. The site (59SHE5.5) however, did not follow that pattern and had a 14.3 percent increase in chloride during the dry season. This could also be attributed to the event that raised the FC and chloride percentages at this site during the dry season.

TMDL Analysis

Fecal Coliform Bacteria

Loading capacity means the maximum amount of FC bacteria pollution a water body can assimilate and still meet the Washington State water quality standard. In this report, the goal is for the individual tributaries and various segments (reaches) of Paye Creek, Bulldog Creek, and Sheep Creek to meet the water quality standard. If they do, each creek as a whole would then be likely to meet the standard prior to its confluence with the Colville River.

Because the applicable FC bacteria water quality standard is based on statistical targets, and because FC bacteria loading is not relevant to meeting standards or implementation, this FC bacteria study uses statistical targets as surrogate measures to define loading capacities. The applicable statistics from the two-part FC criteria for the study are:

- A geometric mean less than 100 cfu/100 mL for Paye Creek, Bulldog Creek, and Sheep Creek.
- No more than 10 percent of the samples to exceed 200 cfu/100 mL for Paye Creek, Bulldog Creek, and Sheep Creek (The 90^{th} percentile of the sample distribution is less than 200).

Dry season and wet season statistics were developed for each site, using current data collected from the 2012 - 2013 study. The statistics were compared to the water quality criteria, and the percent reduction required to meet the water quality criteria was calculated. The statistic that needed the greatest percent reduction was chosen for each site as the basis for compliance.

The percent reduction values in Table 19 indicate the relative degree to which the water body is currently out of compliance with the cited water quality criteria (i.e., how far it is over its capacity to receive FC loads and still provide Primary Contact Recreation). Sites representing reaches or tributaries that are meeting their loading capacity have a zero percent reduction value. Sites that require aggressive reductions in FC sources have high target percent reductions, and sites with minor problems have lower target percent reductions.

In addition, to meet EPA reporting requirements, Table 20 displays the estimated seasonal FC load capacity at each evaluated site in number of FC bacteria per day. The loading calculations are based on the estimated average seasonal streamflow. Since the loading capacity is flow dependent, it changes as the flow changes. The reported load capacities are specific to the average seasonal flow measured at each station. Higher flow at a station results in a higher load capacity, while a lower flow results in a lower load capacity. Compliance with the water quality standard and this TMDL addendum should compare monitoring results to the concentration-based standard and not the average seasonal loading capacity indicated in Table 20, since it is unlikely the flow conditions will be the same.

Table 19. Seasonal FC loading capacities at sites in Paye Creek, Bulldog Creek, and Sheep Creek expressed as percentage reduction and statistical target values

Station ID	Station Description	Wet Season Target % Reduction	Wet Season FC Target Capacity (cfu/100 mL)		Dry Season Target % Reduction	Dry Season FC Target Capacity (cfu/100 mL)	
			Geomean	90th percentile		Geomean	90th percentile
Paye Creek							
59PAY1.8	Paye Cr. At Hwy 395 crossing	0%	0	0	18%	63	200
59PAY0.0	Paye Cr. At Mouth	6%	17	200	39%	84	200
Bulldog Creek							
59BUL1.6	Bulldog Cr. Near Springs	0%	0	0	0%	0	0
59BUL1.2	Bulldog Cr. At Bulldog Cr. Rd. crossing	0%	0	0	0%	0	0
59BUL0.0	Bulldog Cr. At Mouth	0%	0	0	0%	0	0
Sheep Creek							
59SHE5.5	Sheep Cr. Near Springdale Hunters Rd. crossing	0%	0	0	78%	30	200
59SHE4.5	Sheep Cr. At Hesseltine Rd. crossing	47%	22	200	72%	41	200
59SHE2.4	Sheep Cr. At Forest Center Rd. crossing	0%	0	0	67%	77	200
59SHE0.4	Sheep Cr. At Deer Cr. Rd.	29%	28	200	67%	86	200

Table 20. Estimated seasonal FC loading capacities for sites evaluated in Paye Creek, Bulldog Creek, and Sheep Creek

Station ID	Station Description	Dry Season Target % Reduction	Wet Season Target % Reduction	Average Daily FC Loading Capacity (billions cfu/day) based on average seasonal flow	
				Dry Season	Wet Season
Paye Creek					
Paye 1.8	Paye Cr. At Mouth	18%	0%	8.77	13.93
Paye 0.0	Paye Cr. At Hwy 395 crossing	39%	6%	7.59	16.25
Bulldog Creek					
Bull 1.6	Bulldog Cr. At Mouth	0%	0%	14.86	14.11
Bull 1.2	Bulldog Cr. At Bulldog Cr. Rd. crossing	0%	0%	24.35	22.76
Bull 0.0	Bulldog Cr. Near springs	0%	0%	33.80	33.06
Sheep Creek					
Sheep 5.5	Sheep Cr. At Deer Cr. Rd.	78%	0%	29.02	39.82
Sheep 4.5	Sheep Cr. At Forest Center Rd. crossing	0%	47%	32.01	48.16
Sheep 2.4	Sheep Cr. At Hesseltine Rd. crossing	67%	0%	28.80	46.70
Sheep 0.4	Sheep Cr. Near Springdale Hunters Rd. crossing	67%	29%	31.95	57.07

Margin of Safety

A margin of safety to account for scientific uncertainty must be considered in all TMDLs to ensure that the targets will protect water quality. The margin of safety for this FC bacteria TMDL analysis is implicit through the use of conservative assumptions in project design and analysis.

Target reductions generally were based on the 90th percentile of FC concentrations. The roll-back method assumes that the variance of the post-management data set will be equivalent to the variance of the pre-management data set. As pollution sources are managed, the frequency of high FC values is likely to decrease, which should reduce the variance and 90th percentile of the post-management condition.

Conclusions and Recommendations

Conclusions

Paye Creek

- The sites on Paye Creek (59PAY1.8 and 59PAY0.0) did not meet the water quality criteria during the dry season.

- The site (59PAY0.0) did not meet water quality criteria during the wet season.
- Wet season TSS loading percentages were also high at site (59PAY1.8). This suggests that conditions that elevate TSS, such as direct manure sources, or high flows or runoff processes that cause soil erosion, could also be elevating FC concentrations in these reaches.
- Wet season chloride loading percentages were also high at site (59PAY1.8). This suggests that conditions and nonpoint sources that elevate chloride, such as failing septic tanks, could be elevating FC concentrations. These sources should be considered for FC bacteria contamination in these reaches.
- The site (59PAY1.8) contributed 100 percent of the FC load during the wet season.
- The site (59PAY1.8) contributed 100 percent of the CL load during the dry season.

Bulldog Creek

- All three sites on Bulldog Creek (59BUL1.6, 59BUL1.2, 59BUL0.0) met the water quality criteria for both wet and dry seasons.

Sheep Creek

- No sites on Sheep Creek (59SHE5.5, 59SHE4.5, 59SHE2.4, 59SHE0.4) met the water quality criteria during the dry season.
- The site (59SHE5.5) was the only site on Sheep Creek that met the water quality criteria during the wet season.
- In the dry season, every site on Sheep Creek failed the 90^{th} percentile water quality criteria.
- In the wet season, sites (59SHE4.5 and 59SHE2.4) failed the 90^{th} percentile water quality criteria.
- During the dry season, site (59SHE5.5) recorded the highest target percentage reduction at 78 percent.
- During the wet season, site (59SHE4.5) recorded the highest target percentage reduction at 47 percent.
- Site (59SHE5.5) recorded the highest percentage of FC and Chloride during both wet and dry seasons of all the sites on Sheep Creek.
- Site (59SHE0.4) recorded the highest percentage of TSS during both wet and dry seasons of all the sites on Sheep Creek.
- Site (59SHE2.4) recorded 0 percent for FC and Chloride during both wet and dry seasons.

Recommendations

As a result of this study, the following recommendations are made.

Implementation of TMDL targets

The goal of this TMDL project is to reduce fecal coliform (FC) bacteria at all sampling sites that are assigned target percent FC reductions so that all sites within the Paye Creek, Bulldog Creek, and Sheep Creek basins comply with Washington State water quality standards. Some sites did not require a reduction in order to maintain water quality and continue meeting water quality standards. To remain in compliance, these sites in compliance during the study cannot receive additional inputs of FC bacteria.

The following FC loads are prioritized (based on size of load and concentration) for implementation actions to reduce FC loads and concentrations during the wet season and dry season. Implementation may include further assessment, if necessary.

Paye Creek

Unexplained FC loads to Paye Creek during the wet season (November through May)

- From (59PAY1.8) Paye Creek
  - Above RM 1.8 of Paye Creek
- From (59PAY1.8 to 59PAY0.0) Paye Creek
  - Between RM 1.8 and 0.0 of Paye Creek

Unexplained FC loads to Paye Creek during the dry season (June through September)

- From (59PAY1.8) Paye Creek
  - Above RM 1.8 of Paye Creek
- From (59PAY1.8 to 59PAY0.0) Paye Creek
  - Between RM 1.8 and 0.0 of Paye Creek

Bulldog Creek

- All three sites on Bulldog Creek (59BUL1.6, 59BUL1.2, 59BUL0.0) met the water quality criteria for both wet and dry seasons.

Sheep Creek

Unexplained FC loads to Sheep Creek during the wet season (November through May)

- From (59SHE5.5) Sheep Creek
  - Above RM 5.5 of Sheep Creek
- From (59SHE5.5 to 59SHE4.5) Sheep Creek

- Between RM 5.5 and 4.5 of Sheep Creek

- From (59SHE2.4 to 59SHE0.4) Sheep Creek
  - Between RM 2.4 and 0.4 of Sheep Creek
- From (59SHE4.5 to 59SHE2.4) Sheep Creek
  - Between RM 4.5 and 2.4 of Sheep Creek

Unexplained FC loads to Sheep Creek during the dry season (June through September)

- From (59SHE4.5) Sheep Creek
  - Above RM 4.5 of Sheep Creek
- From (59SHE2.4 to 59SHE0.4) Sheep Creek
  - Between RM 2.4 and 0.4 of Sheep Creek
- From (59SHE4.5 to 59SHE2.4) Sheep Creek
  - Between RM 4.5 and 2.4 of Sheep Creek
- From (59SHE5.5) Sheep Creek
  - Above RM 5.5 of Sheep Creek

Total suspended solids (TSS)

Correlations between TSS and FC load concentrations suggest that conditions that elevate TSS, such as high streamflow and runoff processes (causing soil erosion), could also be elevating FC concentrations. Further investigation in Paye Creek and Sheep Creek is warranted to determine whether soil-erosion controls could also reduce FC levels, or if waste sources are elevating both TSS and FC levels.

Chloride

Correlations between chloride and FC loads suggest that conditions that elevate chloride, such as new water or waste inputs, could also be elevating FC concentrations. Further investigation in Paye Creek and Sheep Creek is warranted to determine what sources could be elevating both chloride and FC levels.

Future monitoring for FC bacteria

Compliance with the FC bacteria water quality criteria and the target reduction goals should be monitored by sampling at the sites where data were used to generate those goals. Streamflow measurements should also be taken when samples are collected in order to estimate FC loads.

The following should be considered for further monitoring, to isolate or better define possible FC sources to Paye Creek, Bulldog Creek, and Sheep Creek:

Paye Creek

- The elevated levels of FC concentrations and loading from Paye Creek should be investigated to reveal pollution sources. Investigation should include an assessment of:

- Elevated FC sources above RM 1.8 and RM 0.0 of Paye Creek. Particular attention should be given to waste sources that elevate chloride in this reach.
- Large jumps in FC sources above RM 1.8 and RM 0.0 of Paye Creek during dry and wet seasons.
- Monitoring for land use changes along Paye Creek that have the potential to impact the water quality of the creek.

Bulldog Creek

- Continued monitoring of Bulldog Creek above RM 0.0, RM 1.2, and RM 1.6 to confirm that levels remain within compliance. Monitoring for land use changes along Bulldog Creek that have the potential to impact the water quality of the creek.

Sheep Creek

- The consistently high FC concentrations and loading from Sheep Creek should be investigated to reveal pollution sources. Investigation should include an assessment of:
  - Elevated levels of FC sources above RM 5.5 of Sheep Creek.
  - Elevated levels of FC sources above RM 4.5 of Sheep Creek.
  - Elevated levels of FC sources above RM 2.4 of Sheep Creek.
  - Elevated levels of FC sources above RM 0.4 of Sheep Creek.
  - Large jumps in FC sources above RM 5.5, RM 4.5, RM 2.4, and RM 0.0 of Sheep Creek during dry and wet seasons.
  - Establish BMPs and riparian buffers for farming and ranching operations along Sheep Creek.
  - Monitoring for land use changes along Sheep Creek that could impact the water quality of the creek.

References

Albrecht, Andrew, 2012. Addendum to Quality Assurance Project Plan: Colville River Fecal Coliform Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. Publication No. 12-03-116. https://fortress.wa.gov/ecy/publications/SummaryPages/1203116.html

APHA, AWWA, and WEF, 2005. Standard Methods for the Examination of Water and Wastewater 20th Edition. American Public Health Association, Washington, D.C.

Coots, Randy, 2000. Quality Assurance Project Plan: Colville River Fecal Coliform Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. Publication No. 00-03-082. https://fortress.wa.gov/ecy/publications/SummaryPages/0003082.html

Coots, Randy, 2002. Colville River Fecal Coliform Total Maximum Daily Load Study Washington State Department of Ecology, Olympia, WA. Publication No. 02-03-036. https://fortress.wa.gov/ecy/publications/SummaryPages/0203036.html

Ecology, 2009. Standard Operating Procedures (SOPs) for sampling, auditing, and field methodology. Washington State Department of Ecology, Olympia, WA. www.ecy.wa.gov/programs/eap/quality.html

Joy, J., 2000. Lower Nooksack River Basin Bacteria Total Daily Maximum Load Evaluation. Washington State Department of Ecology, Olympia, WA. Publication No. 00-03-006. https://fortress.wa.gov/ecy/publications/SummaryPages/0003006.html.

Mathieu, N., 2006. Replicate Precision for Twelve 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. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA.

MEL, 2012. Manchester Environmental Laboratory. Manchester Environmental Laboratory Users Manual. Tenth Edition. Washington Department of Ecology, Manchester, WA.

Microsoft, 2010. Microsoft Office XP Professional, Microsoft Corporation.

Ott, W.R., 1995. Environmental Statistics and Data Analysis. CRC Press LLC. Boca Raton, FL. 313 pages.

Sargeant, D., 2002. Dungeness River and Matriotti Creek Fecal Coliform Bacteria Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. Publication No. 02-03-014. 46 pages. https://fortress.wa.gov/ecy/publications/SummaryPages/0203014.html

SCCD, 1993. Water Quality Summary for Colville River Watershed Ranking and Planning. Stevens County Conservation District, Colville, WA.

Tarbutton, S., J. Carroll, and E. Snouwaert, 2010. Palouse River Fecal Coliform Bacteria Total Maximum Daily Load: Water Quality Improvement Report and Implementation Plan. Washington State Department of Ecology, Olympia, WA. Publication No. 10-10-067. https://fortress.wa.gov/ecy/publications/SummaryPages/1010067.html

Washington State Department of Ecology, 2003. Washington Administrative Code (WAC). Surface Water Criteria - Freshwater, in WAC 173-201A-200. Washington State Department of Ecology.

Washington State Department of Ecology, 2006. Water Quality Policy 1-11. Washington State Department of Ecology, Olympia, WA. http://www.ecy.wa.gov/programs/wq/303d/policy1-11Rev.html.

Washington State Department of Ecology, 2011. Washington Administrative Code (WAC). Use designations by WRIA - Freshwater, in WAC 173-201A-602. Washington State Department of Ecology.

Washington State Department of Ecology, 2012. Laws and Rules: Index of Laws. http://www.ecy.wa.gov/laws-rules/ecyrcw.html.

WRCC, 2002. Western Regional Climate Center. Period of Record General Climate Summary, Precipitation for Colville, Washington. http://www.wrcc.dri.edu/cgi-bin/cliGCStP.pl?wacolv

Appendix. Glossary, Acronyms, and Abbreviations

Glossary

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

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

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.

Exceeded criteria: Did not meet criteria.

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

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

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

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

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

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

Parameter: Water quality constituent being measured (analyte). 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.

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

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

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

Reach: A specific portion or segment of a stream.

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

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

Total Maximum Daily Load (TMDL): Water cleanup plan. A distribution of a substance in a waterbody 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.

Total suspended solids (TSS): The suspended particulate matter in a water sample as retained by a filter.

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

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

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 percent of the data exists and below which 90 percent of the data exists.

Acronyms and Abbreviations

BMP	Best management practices
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System software
MEL	Manchester Environmental Laboratory
TMDL	total maximum daily load (water cleanup plan)
WAC	Washington Administrative Code
WRIA	Water Resource Inventory Area

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cfu	colony forming unit
ft	feet
mg/L	milligrams per liter (parts per million)
mg/L/hr	milligrams per liter per hour
mL	milliliters
RPD	relative percent different
RSD	relative standard deviation