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State of Washington

Quality Assurance Project Plan

East Fork Lewis

Fecal Coliform Bacteria and Temperature Source Assessment

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Quality Assurance Project Plan

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March 2017

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2.0 Abstract

Segments of the East Fork Lewis River are listed on the 303(d) list for temperature and bacteria impairments. Washington State Department of Ecology originally selected the East Fork Lewis River for a TMDL study in 2004, and field collection for bacteria and temperature measurements occurred in 2005-06. Due to constraints on resources, the East Fork Lewis River study was put on hold.

The goal of this project is to use the data from the 2005-06 field study to complete a source assessment for temperature and bacteria impairments in the East Fork Lewis River watershed. Additional fecal coliform sampling will be conducted in sites with historical fecal coliform impairments to assess potential changes in bacteria concentrations since the 2005-06 field study.

This Quality Assurance Project Plan (QAPP) describes the study design and procedures to meet the project goals and objectives. This QAPP describes the technical study that will evaluate pollutants in the impaired waterbodies and the field study design for additional fecal coliform sampling to build on the previous data collection efforts.

This project will be completed as a source assessment in lieu of a TMDL from the original project. The source assessment will be used to identify and prioritize sources of pollutants. The final report for this source assessment will describe the study results of the technical analysis for the 2005-06 field collection, bacteria concentration status from the additional fecal coliform sampling, and implementation efforts needed to attain Water Quality Standards.

3.0 Background

3.1 Introduction and Problem Statement

The East Fork Lewis River and its tributaries lie within Water Resource Inventory Area (WRIA) 27 in southwestern Washington. The study area includes waterbody segments impaired by fecal coliform and heat (measured as temperature degrees C), as listed in the Clean Water Act Section 303(d) lists. The impairments were identified based on sampling conducted by Clark County, Ecology, and other entities.

Ecology selected the East Fork Lewis River for a TMDL study in late 2004 that included 12 impaired waterbody segments for temperature and bacteria. A peer-reviewed Quality Assurance Project Plan (QAPP) was completed in May 2005. Field collection for temperature and bacteria data was completed from 2005-06. The purpose of the original study was to characterize temperature and bacteria impairments within the river and its associated tributaries.

Due to constraints on resources and schedules, the original TMDL study was put on hold. The purpose of this study is to utilize the 2005-06 data collection for a temperature and fecal coliform (FC) bacteria technical analysis and source assessment. The original FC sampling effort will be supplemented with additional sampling to confirm and narrow in on problem areas identified during the 2005-06 sample season.

3.2 Study area and surroundings

The original Quality Assurance Project Plan (QAPP) for East Fork Lewis River described the study area and surroundings (Bilhimer et al., 2005). This information is contained in the following sections, unless otherwise noted.

The East Fork Lewis River is one of the three major rivers located within WRIA 27, which also includes the North Fork Lewis and Kalama Rivers. The headwaters of the East Fork Lewis River, which originate from a small alpine lake, flow out of the western crest of the Cascade Mountain range. Elevation at the headwater of the East Fork is 4,442 feet above mean sea level. The river flows 42 miles to its confluence with the North Fork Lewis River at an elevation of 4 feet below mean sea level. The East Fork is influenced by the tidal bulge from the Columbia River from its mouth to a short distance below Daybreak Park Bridge at approximately river mile 10.2 (PGG, 2003).

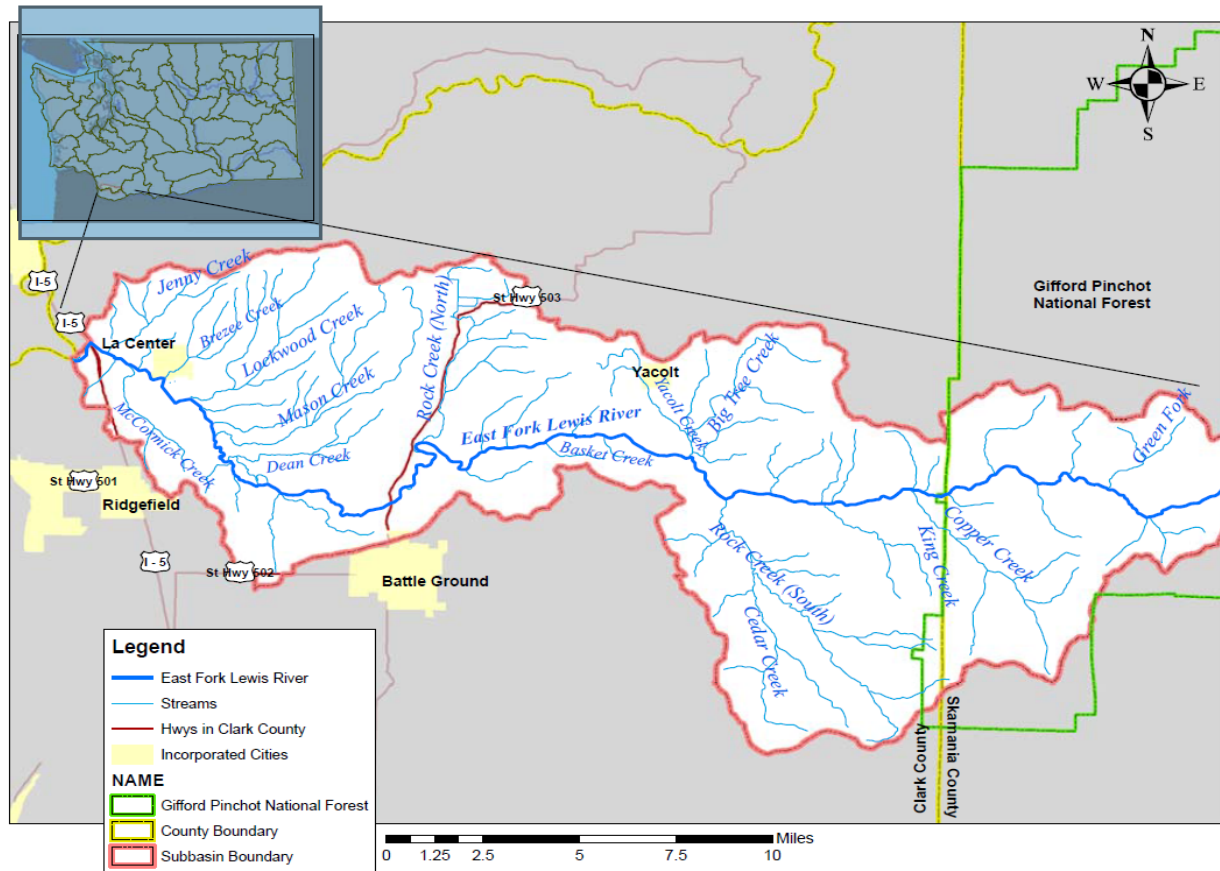


Figure 1 Overview of the East Fork Lewis River watershed (Bilhimer et al., 2005)

Fishing Resources

The original East Fork Lewis River study QAPP (Bilhimer et al., 2005) described the factors influencing fish resources within the watershed and are described below.

The Habitat Limiting Factors Analysis (Wade, 2000) describes WRIA 27 as having generally poor riparian conditions, loss of off-channel habitat, and large woody debris below habitat standards. The East Fork Lewis River subbasin has critical fall Chinook and chum spawning habitat in the lower 10 miles of the mainstem (from Daybreak Park to the mouth) and provides critical winter and summer steelhead spawning and rearing habitat above Sunset Falls and on Rock Creek (south) (Bilhimer et al., 2005).

The limiting factors analysis considers elevated water temperatures as “a major problem in many tributaries and especially within the lower East Fork.” Channel instability, diking, and development within the floodplain are also recognized as factors limiting the amount of rearing habitat during the summer for juvenile salmon and steelhead. According to the analysis, the mainstem migration (avulsion) into the abandoned Ridgefield pits have added to the channel instability and led to a significant loss in spawning habitat for fall chinook.

The only barriers to anadromous passage within the mainstem East Fork Lewis River are Lucia Falls (RM 21.5) and other natural falls upstream. Sunset Falls (Gifford Pinchot National Forest Boundary RM 32.7) was notched in 1982, opening up a significant amount of habitat in the upper watershed. Steelhead are the only species that consistently migrate past Lucia Falls. The following tributaries have known access problems for anadromous fish species: McCormick Creek, Brezee Creek, Lockwood Creek, Mason Creek, and Dean Creek. Details on the identified barriers are given in Wade (2000).

The Habitat Limiting Factors report (Wade, 2000) estimates that over 50% of the off-channel habitat and associated wetlands within the floodplains of the lower East Fork have been disconnected from the river. This conversion of the channel from braided to a mostly single channel morphology has substantially reduced the complexity of habitat and largely eliminated side channel and backwater habitats that were historic salmon and steelhead spawning and rearing grounds.

The lower six miles of the East Fork Lewis main stem has a naturally high rate of lateral migration and is very meandered. The following channel modifications, identified by Wade (2000), Delk and Dyrland (2005), and Johnston et al. (2005), have contributed to destabilizing the stream channel:

- An old right-angle dike at the Clark County Maintenance Facility (~RM 9) and subsequent erosion and bedload from the cliffs the river was forced into.
- Dikes on the north side of the river at LaCenter bottoms (RM 3.3-4.5).
- Dikes along the lower end of Lockwood Creek.
- A number of dikes that disconnect the river from the floodplain on county-owned properties along the south side of the river from RM 4.5 to RM 7. Drainage ditches drain wetlands and channels in this area that help replenish groundwater throughout the year and provide overwintering habitat for coho juveniles.
- Remnant/discontinuous dikes that run along the north side of the river across from the Ridgefield Pits near RM 8.
- Remnant dikes that run along the county's property (referred to as the Zimmerly property) just downstream of the Ridgefield Pits near RM 7, reducing the connection between the river and downstream wetland and floodplain habitat.
- Dikes that run along the north side of the river downstream of Dean Creek (near RM 7.2) to protect properties from flooding.
- Remnant dikes that are left in mid-channel around the old RM 9 gravel pit.
- Daybreak Dike, located on the south side of the river upstream from Daybreak Park near RM 12, disconnecting a large overflow channel with floodplain habitat from the river.

Bank stability is a major concern along certain reaches of the lower 14 miles of the river. In this area, soils and channel materials consist mainly of silts and sands, and lateral migration of the channel is common. Unstable banks are counterproductive to riparian revegetation projects and result in lost time and money spent on the plantings.

The avulsion of the East Fork Lewis River into the gravel pits near RM 9 and the

Ridgefield Pits (RM 8) in the mid-1990s caused significant changes in bank and channel stability in the area and in sediment supply both upstream and downstream of the avulsions (Wade, 2000). The avulsion of the East Fork into the Ridgefield pits is shown in Figure 2.



Figure 2 From 2005 QAPP, aerial photo of Ridgefield Pits on the East Fork Lewis River. Photo adapted from Wade (2000).

Hydrogeology and hydrology

The headwaters of the East Fork Lewis River originate on the western slope of the Cascades and receive most of their baseflow from groundwater (Figure 3). The upper part of the subbasin, from approximately river mile 20.3, consists of substrate comprised primarily of andesite and other older rocks of volcanic origin. There is limited unconsolidated material in the streambed and the bedrock is exposed in many places. The upper subbasin (as defined for this study approximately from river mile 20.3 to 32.5) consists of V-shaped valleys with steep banks that confine stream channels and restrict lateral movement.

The East Fork Lewis River downstream of Heisson Road cuts through the Lower Troutdale gravel aquifer which overlays the larger undifferentiated fine-grained sediments of Pliocene origin. These layers are topped by a layer of unconsolidated materials consisting of Pleistocene sediments that were washed down during catastrophic floods of the Columbia River and Holocene pyroclastic debris deposits. The unconsolidated layer is a highly productive aquifer (Swanson et al., 1993).

The USGS has maintained a streamflow gauge near Heisson Road with a historical record going back to 1929. Low summer baseflows typically occur during late July through August and peak flows occur during storm events in October through June.

The hydrogeology and hydrology for the East Fork Lewis River were further studied within a surface water/groundwater study Ecology completed using data from the original 2005-06 field collection (Carey and Bilhimer, 2009).

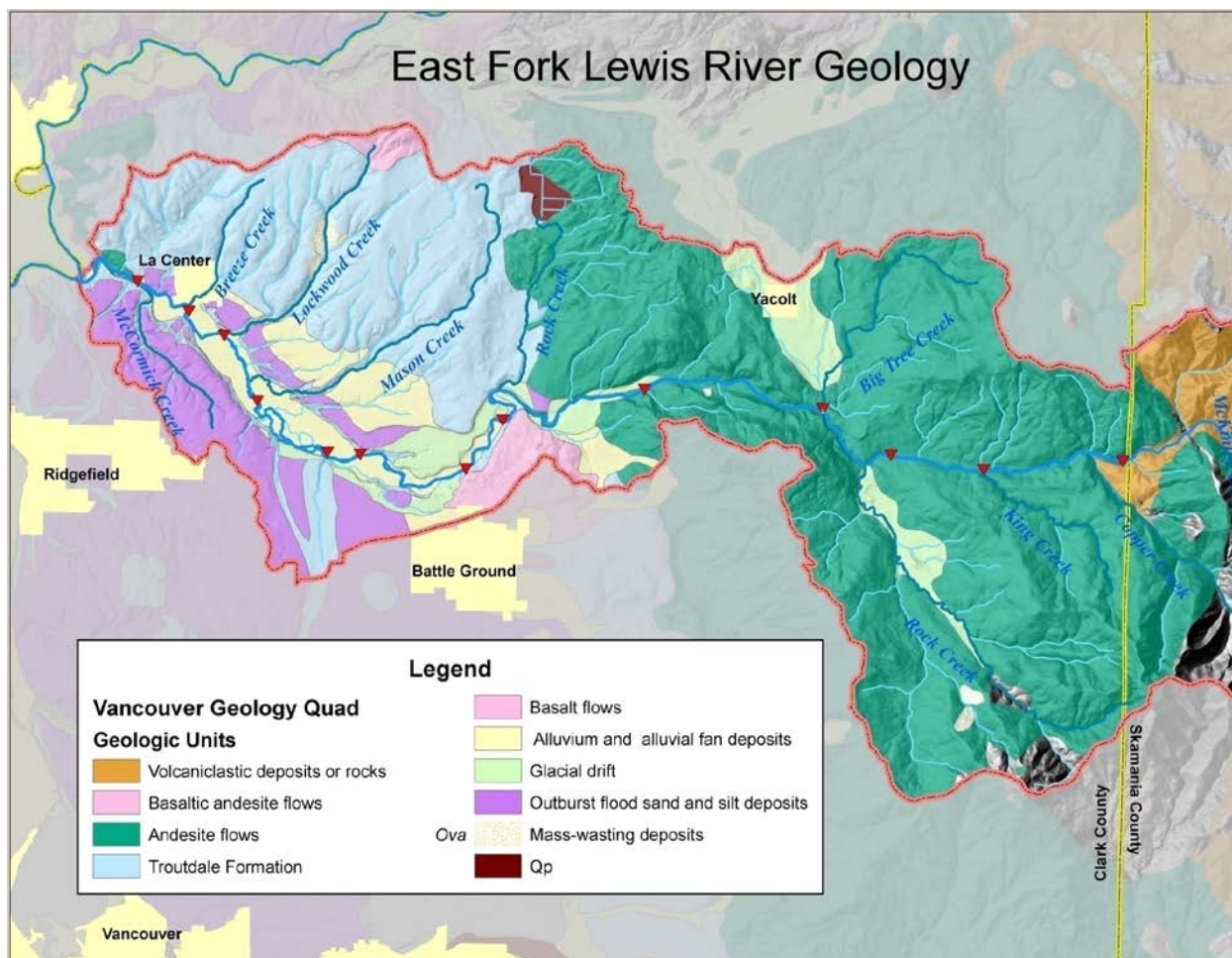


Figure 3 Surficial geology map of the East Fork Lewis River study area (Washington State Department of Natural Resources, 2005)

Climate

The 2005 QAPP presented the influence of climate on average precipitation within the East Fork Lewis River watershed in Figure 4 (Bilhimer et al., 2005). The climate of the East Fork Lewis River subbasin is moderated by its proximity to the Pacific Ocean to the west and the Cascade Mountains directly to the east. The headwaters of the East Fork receive between 100 to 120 inches of precipitation yearly. The lower valley near the mouth receives between 40 to 50 inches of precipitation per year, approximately half the precipitation received at the headwaters (Figure 3 4).

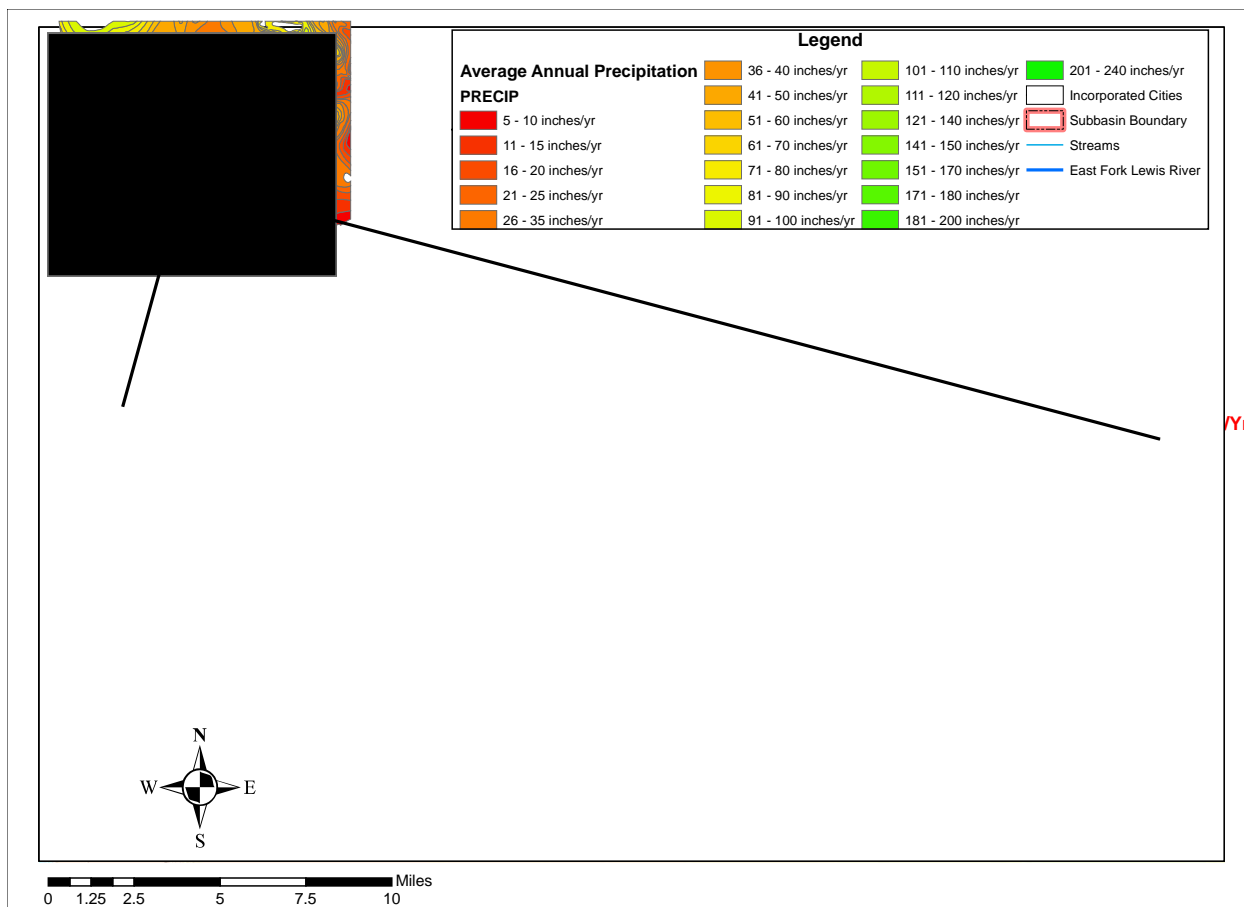


Figure 4 Average annual precipitation map for the East Fork Lewis River subbasin (Bilhimer et al., 2005)

Much of the precipitation that falls in the upper part of the subbasin occurs as snow during the winter and rain on snow during the late winter through spring. The consensus of climatologists in the Pacific Northwest will be increased average annual air temperatures and reduced snow pack levels at higher elevations. The result will be less water storage as snow in the winter, more precipitation contributing to streamflow during the winter, and lower baseflows in the summer (Storck, 2004; Miles, 2004; Hamlet, 2004). Gradual rises in average winter air temperatures contribute to the rise in snow elevation levels and temporal changes in the basin hydrograph. Increases in average summer air temperatures contribute to higher than average instream temperatures caused by conduction of heat at the air-water interface.

3.2.1 Summary of previous studies and existing data

- **NOTE:** This section does not include all of the studies and surveys conducted by Ecology or all implementation efforts completed by local jurisdictions to clean up pollution in the watershed.

3.2.2 Summary of 2005-06 field data collection

East Fork Lewis River was originally selected as a TMDL study in 2004. From May 2005 – November 2006, field collection for the study included climate, streamflow, ground water, in-

stream temperature, percent effective shade, and fecal coliform data. The purpose of the study was to evaluate pollutants in the impaired waterbodies and characterize temperature and bacteria problems.

The 303(d) listings addressed in the original study included East Fork Lewis River and its tributaries Brezee Creek, McCormick Creek, Rock Creek (North), Rock Creek (South), and Yacolt Creek (Table 1).

Table 1 303(d) listings addressed in original study

Waterbody	Listing ID	New ID	Old Water Body ID (WBID)	Parameter	Year Listed
BREEZE CREEK	21992	WG95PJ		Fecal Coliform	2004*
LEWIS RIVER, E.F.	7818	E160MF	WA-27-2030	Fecal Coliform	1998, 1996
LEWIS RIVER, E.F.	7815	E160MF	WA-27-2020	Fecal Coliform	1998, 1996
LEWIS RIVER, E.F.	166771	E160MF	WA-27-2020	Fecal Coliform	1996
LOCKWOOD CREEK	7819	YD45JI	WA-27-2024	Fecal Coliform	1998, 1996
MCCORMICK CREEK	7822	GF76XA	WA-27-2022	Fecal Coliform	1998, 1996
ROCK CREEK (NORTH)	7824	XD64JB	WA-27-2026	Fecal Coliform	1998, 1996
ROCK CREEK (NORTH)	21995	XD64JB	WA-27-2026	Fecal Coliform	1996, 2004*
ROCK CREEK (SOUTH)	7825	MI81KO	WA-27-2034	Fecal Coliform	1998, 1996
YACOLT CREEK	7826	KS71ST	WA-27-2032	Fecal Coliform	1998, 1996
LEWIS RIVER, E.F.	6588	E160MF	WA-27-2020	Temperature	1998, 1996, 2004*
LEWIS RIVER, E.F.	37824	E160MF	WA-27-2020	Temperature	2004*

Temperature

The 2005-06 East Fork Lewis River field data collection for temperature consisted of five different study components:

- Continuous temperature monitoring.
- Streamflow measurements.
- Groundwater monitoring using piezometers within the mainstem.
- Channel geometry surveys.
- Riparian habitat surveys.

Temperature sampling included 25 continuous temperature monitoring stations for both instream and air temperature thermistors co-located to characterize the average instream temperature and air temperatures near the station. Table 2 provides a preliminary analysis of the data from the temperature stations from the 2005-06 field study. It presents the stations that violated water quality criteria based on the number of days 7DADMax above water quality criteria and the number of days on record, with the resulting percentage of water quality standards violated.

More details for temperature monitoring procedures are provided in the 2005 QAPP.

Table 2 Temperature sampling results from 2005-06 field study

Station ID	Description	Days 7DADM above WQ Criteria	Number of Days on Record	% WQ Standard Violated
16°C criteria				
27EFL29.0	EFLR abv King Cr	12	90	13%
27KNG00.0	King Cr near mouth	25	112	22%
27EFL26.9	EFLR at Dole Valley Rd	39	95	41%
27RCS03.9	Rock Cr S at Dole Valley Rd	34	112	30%
27EFL24.6	EFLR abv Moulton Falls	39	83	47%
27BIG00.0	Big Tree Cr at mouth	36	112	32%
27EFL20.3	EFLR at the USGS gage	58	113	51%
RCN050	Rock Cr North	80	131	61%
27RCN00.6	Rock Cr North	59	91	65%
27EFL14.7	EFLR at Shultz residence	62	75	83%
27EFL13.2	EFLR at Lewisville Park	60	90	67%
27D090	EF Lewis R nr Dollar Corner	43	49	88%
27EFL10.1	EFLR at Daybreak Park	92	120	77%
MAN010	Manley Cr	62	79	78%
27EFL08.1	EFLR abov Ridgefield pits	33	39	85%
27DEA00.8	Dean Cr at JA Moore Rd	91	114	80%
27DEA00.0	Dean Cr at mouth	22	28	79%
27EFL07.3	EFLR blw Dean Cr	49	73	67%
27MAS00.8	Mason Cr ds of Heitmann Cr	47	115	41%
17.5°C criteria				
27EFL04.6	EFLR abv Lockwood Cr	97	189	51%
27LOC00.0	Lockwood Creek at Mouth	32	65	49%
BRZ010	Breeze Cr	45	131	34%
27BRZ00.1	Breeze Cr near mouth	53	113	47%
27EFL01.8	EFLR at gage near mouth	100	127	79%
27JEN00.3	Jenny Creek at Pacific Hwy	50	112	45%

Fecal coliform

The 2005-06 bacteria field data collection consisted of characterizing annual and seasonal fecal coliform bacteria loads in the East Fork Lewis River. Sixteen months of fecal coliform and flow data were collected to calculate basic fecal coliform concentration and loading data in various reaches of the watershed.

The fecal coliform sampling design utilized a fixed network of sites sampled twice monthly. The fixed network emphasized water quality in the East Fork Lewis River by targeting tributaries as well as mainstem sites and by bracketing land uses (Bilhimer et al., 2005).

Fecal coliform data was collected bi-weekly from sampling runs from May 2005 through August 2006. An additional storm event sampling occurred during November 6-7, 2006. Flow measurements were collected from bi-monthly sampling runs from May 2005-August 2006.

Goals of the original FC data collection were to determine fecal coliform targets for the wet season (November-May) and dry season (June-October).

More details for the fecal coliform procedures are provided in the 2005 QAPP.

A preliminary data analysis for fecal coliform in the East Fork Lewis River and its surrounding tributaries was started following the 2005-06 field collection. The highlights of this preliminary FC data analysis are presented in Figures 5 and 6. McCormick Creek (MCC-3.4) had the largest water quality impairments for FC, having the highest geometric mean and 90th percentile, for both the wet and dry seasons. Additionally, Lockwood Creek and Brezee Creek both displayed high geometric means of FC in the dry season. Generally, the main areas of FC concern occur in the lower watershed. These results were used to help designate sampling sites for the 2017-18 field collection, by focusing sampling efforts on the lower watershed.

The LaCenter waste water treatment plant (WWTP) was noted as an area that failed to meet water quality criteria in the dry season. Discharge monitoring reports analyzed from 2006 to present show that the WWTP has since fixed this issue. The discharge now meets water quality criteria during all seasons.

Due to constraints on resources, the East Fork Lewis Project was put on hold until this time. This study will utilize the data from the 2005-06 field collection and complete the technical analyses for temperature and fecal coliform at the original sites. The original field work from 2005-06 was used to help designate sampling locations for supplemental sampling to confirm FC problem areas.

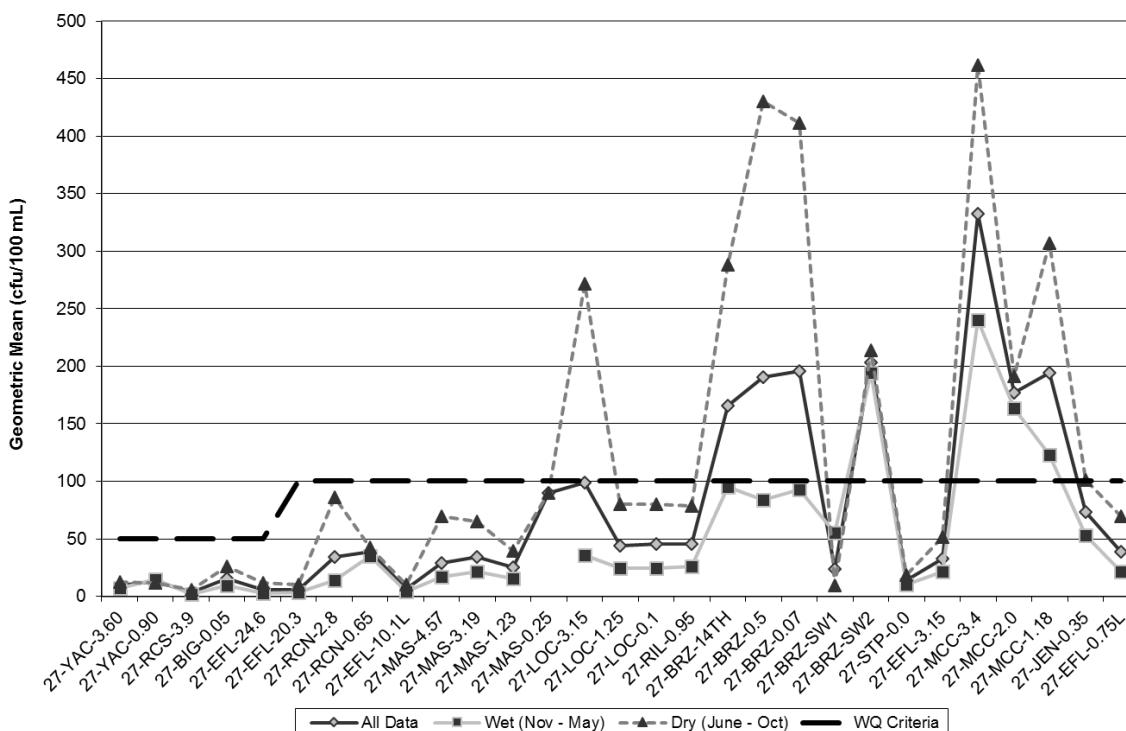


Figure 5 Preliminary analysis FC geometric mean data compared to WQ criteria (Brock, 2009)*

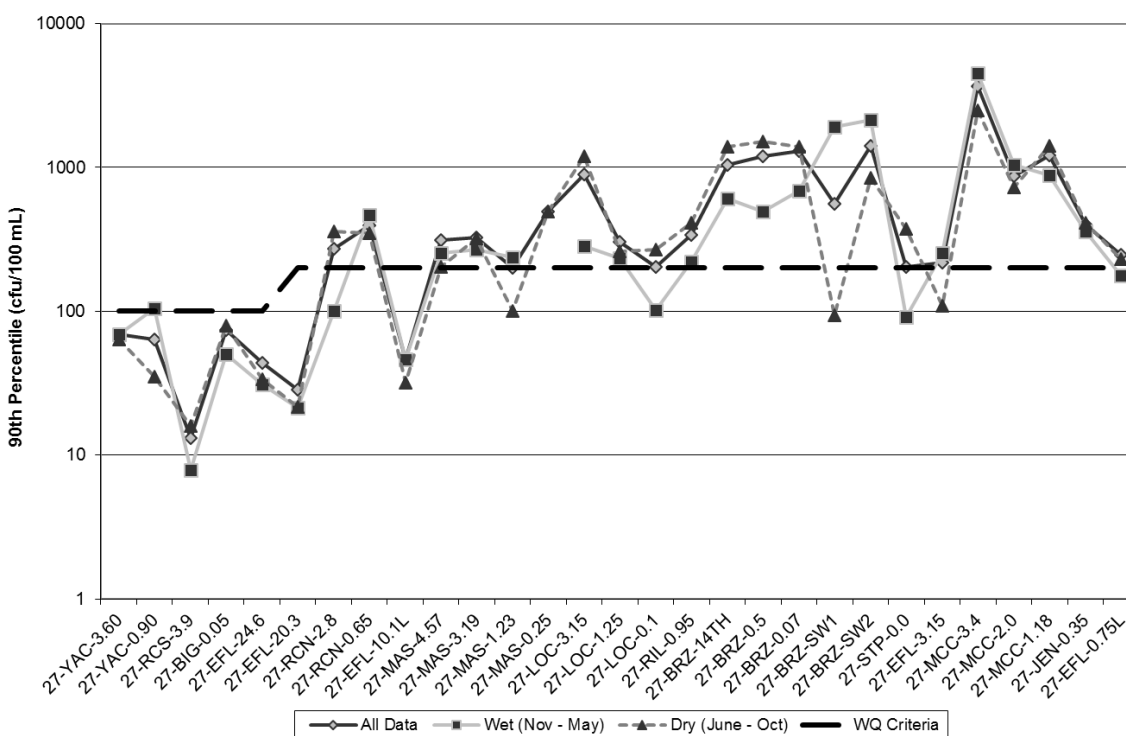


Figure 6 Preliminary analysis FC 90th percentile data compared to WQ criteria (Brock, 2009)*

*Statistical analysis not quality assured

Streamflow summary

Ecology conducted a streamflow assessment as part of the field collection effort from 2005-06 (Springer, 2009). Continuous stage height gages were installed at two sites, one upstream and one downstream, in the East Fork Lewis River that measured water surface elevation. The long-term monitoring station at Daybreak Park and a USGS station at Heisson (River Mile 20.3) were also used.

The gage installed at the downstream site collected tide-impacted stage height data, influenced by the Columbia River tidal bulge. This station was flooded during a large storm event in December 2005 and was not able to be used for the entire study duration. The gage installed at the upstream site collected discharge measurements at river mile 32.5. The gage recorded discharge data throughout the study duration and a load duration curve was developed.

Surface water/groundwater exchange study

A surface water/groundwater exchange study was completed for the East Fork Lewis River (Carey and Bilhimer, 2009). The purpose of the groundwater assessment was to gather and interpret evidence of groundwater inflow and outflow along the East Fork Lewis River and estimate the temperature of groundwater inputs into the river. The surface water/groundwater exchange study included seepage surveys, vertical hydraulic gradient measurements, and continuous streambed temperature measurements from instream piezometers during 2005.

Figure 7 depicts the results of the seepage survey, indicating gaining and losing reaches, and areas with no significant change. Streamflow gains indicate an inflow of groundwater into the stream system, and streamflow losses indicate an outflow of streamflow into groundwater. The total of streamflow gains from this seepage survey was 64 cfs and total streamflow losses was 18 cfs (Carey and Bilhimer, 2009). The largest percentage of streamflow gains occurred in the lower reaches.

Instream piezometers measured continuous streambed temperatures. Temperatures from inflowing groundwater were found in the deepest streambed thermistors in gaining piezometers (located at RM 4.6, 7.3, and 10.1) and ranged from 10.6°C-12.5°C. Groundwater temperature measurements were unable to be obtained from the upper basin due to the geology of the area. Groundwater temperatures were lower than surface water temperatures except at the most downstream site (RM 1.8) due to the influence of the tidal bulge.

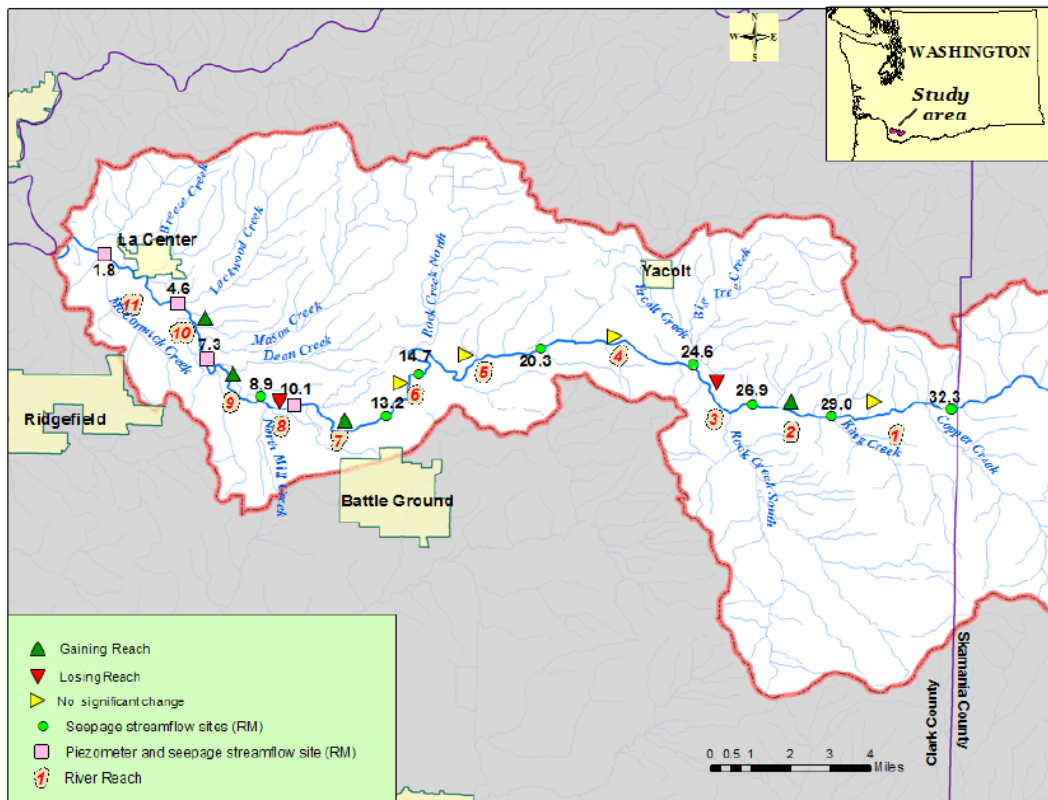


Figure 7 Results of seepage survey discharge gain and loss estimates on the East Fork Lewis River, August 9-10, 2005 (Carey and Bilhimer, 2009).

3.2.2.1 Summary of previous studies prior to 2005-06 field work

Prior to the 2005-06 field study, the East Fork Lewis River subbasin was extensively studied by many groups because of its importance for fish resources and its high potential for salmon recovery. Listed below are the studies conducted prior to 2005. Detailed information regarding these data sources are provided within the 2005 QAPP (Bilhimer et al., 2005):

- Clark County Public Utilities Water Quality Monitoring
- Clark County Water Quality Monitoring
- Channel Assessment by the Friends of the East Fork Lewis River
- USGS
- Lower Columbia Fish Recovery Board

Ecology Ambient Monitoring Station at Daybreak Park

Ecology's Environmental Assessment Program (EAP) maintains a water quality monitoring station on the mainstem East Fork Lewis River at the bridge crossing in Daybreak Park near Dollar Corner (River Mile 10.2, Location ID 27D090).

The ambient monitoring station has a record of monthly fecal coliform data from 1988 to present. A seasonal Kendal (SKWOC) trend analysis was performed using WQHydro Software

(Aroner, 1994) to determine the historic trend from 1988-2004, to assess fecal coliform trends before the 2005-06 field collection. Results of the trend analysis, provided in Figure 8, have a slope of 0.29 and significance of 99% (Bilhimer et al., 2005). These results indicate a statistically significant increase in bacteria levels over the 1988-2004 period. Additionally, a trend analysis performed on data collected during 1994-2004 had a slope of 0.69 and a significance of 99% which also indicates a rise in bacteria levels during this period (Bilhimer et al., 2005).

Continuous instream temperature monitoring was added at this station in June 2001 and continued through 2013. This continuous instream monitoring station recorded flow, water temperature, and air temperature.

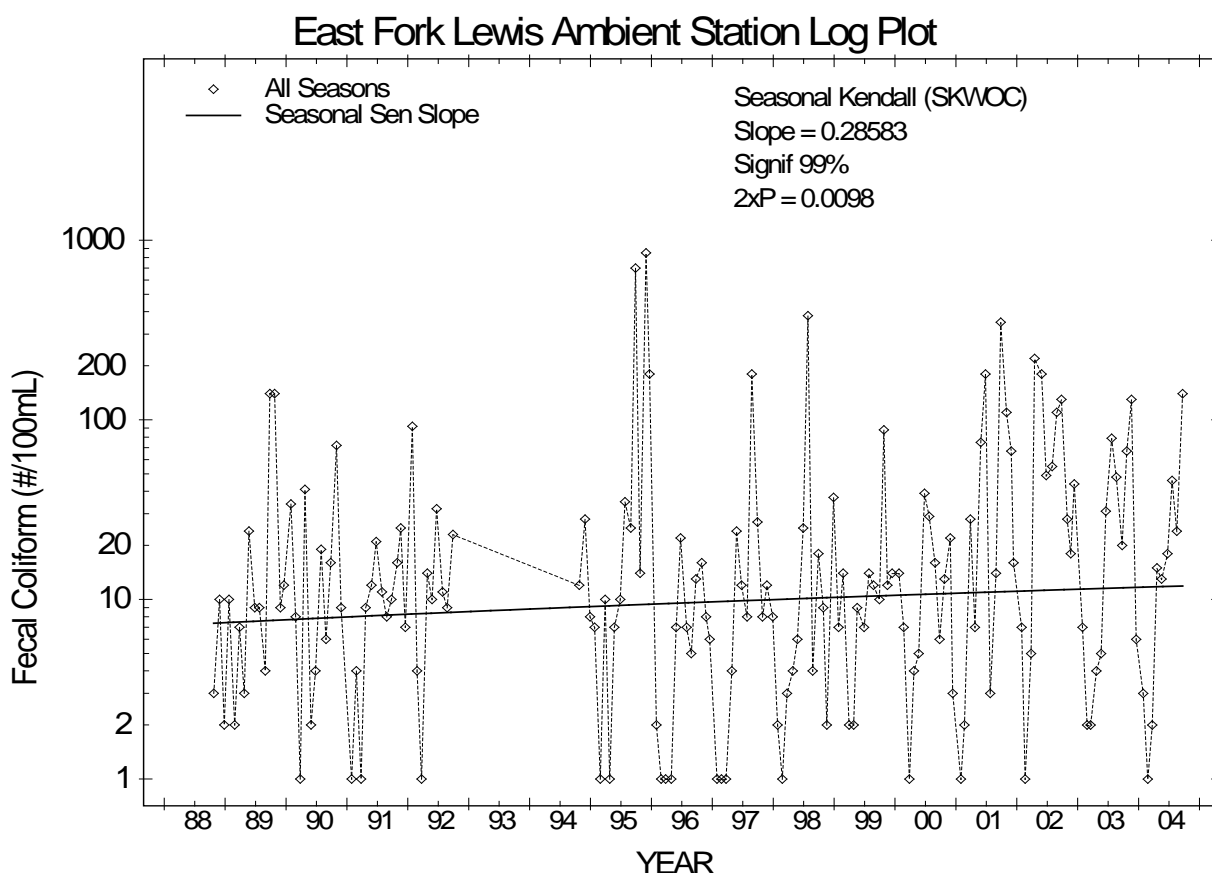


Figure 8 Fecal coliform trend analysis from Ecology's ambient monitoring station from 1988-2004 (Bilhimer et al., 2005).

USGS

The US Geological Service (USGS) has operated a continuous streamflow gage on the East Fork Lewis River near Heisson Rd (# 14222500) from 1929 to present. Its location is at the downstream end of the bedrock formations that dominate the streambed material in the upper East Fork Lewis River and at the head of the unconsolidated deposits. This streamflow gage was included in the 2005-06 streamflow monitoring network (Bilhimer et al., 2005).

For more background on previous studies and to view the original 2005 Quality Assurance Project Plan for the East Fork Lewis River Temperature and Fecal Coliform Bacteria Total Maximum Daily Load Study may be found at <https://fortress.wa.gov/ecy/publications/SummaryPages/0503110.html>.

3.2.3 Parameters of interest and potential sources

The parameters of interest for the East Fork Lewis River Source Assessment are temperature and fecal coliform (FC).

Temperature affects the physiology and behavior of fish and other aquatic life. It also affects the physical and biological properties of the water body which can increase the harmful effects of other pollutants and stream characteristics. Potential sources of increased temperature from heat loads are loss of riparian shade, point source discharges, loss of groundwater from water withdrawals, and loss of channel complexity.

The presence of fecal coliform (FC) bacteria is a concern because it poses a human health risk. In Washington, surface water quality standards use FC as an “indicator bacteria” for the state’s freshwaters (e.g. lakes and streams). The presence of FC indicates the presence of waste from humans or other warm-blooded animals. The water quality standards for bacteria are set to protect people who work and play in the water from waterborne illnesses, and to protect shellfish harvesting areas where present. Potential sources of FC are stormwater, pet waste, wildlife, leaking or failing septic systems, leaking sewer lines, and agricultural livestock wastes.

3.2.4 Regulatory criteria or standards

The Water Quality Standards (WQS) are the basis for protecting and regulating the quality of surface waters in Washington State. The standards implement portions of the federal Clean Water Act by specifying the designated and potential uses of water bodies in the state. They set water quality criteria to protect those uses and acknowledge limitations. The standards also contain policies to protect high quality waters (antidegradation) and in many cases specify how criteria will be implemented, such as permits.

The WQS are established to sustain public health and public enjoyment of the waters, and the propagation and protection of fish, shellfish, and wildlife. A three-part approach was designed to set limits on pollution in water systems in order to protect beneficial uses such as aquatic life, swimming, and fishing. The aquatic life uses contain six categories of aquatic communities and are described using key species (salmon versus warm-water species) and life-stage conditions (spawning versus rearing) (WAC 173-201A-200; 2003 edition). These criteria are used to support water quality impairment projects.

Regulatory criteria for the East Fork Lewis River watershed are presented in Table 3 (temperature) and Table 4 (fecal coliform bacteria).

Temperature

Washington's numeric water quality criteria are based on the temperature needs of the most sensitive species supported by the water body. Washington State uses the temperature criteria to ensure a water body's natural capability for providing full support for its designated aquatic life uses will be maintained.

These cool temperature requirements are expressed as the highest allowable 7-day average of the daily maximum temperatures (7-DADMax) in a water body – or in some specified water bodies, the allowable daily maximum temperature. The change from a daily maximum to a 7-DADMax metric for the majority of the state's streams was determined by scientists involved in the development of EPA's Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards (2003) to include an adequate magnitude and duration (averaging period) to protect salmonids.

The 7-DADMax temperatures represent conditions in the thalweg or main stream channel; therefore it is assumed that aquatic species have access to cold water refugia where they can reside in water that is cooler than the 7-DADMax temperatures. The 7-DADMax temperature criterion also assumes that colder temperatures are available to protect fish at night.

In the State Water Quality Standards, aquatic life use categories are described using key species (salmon versus warm-water species) and life-stage conditions (spawning versus rearing) [WAC 173-201A-200; 2003 edition].

- To protect the designated aquatic life uses of "Core Summer Salmonid Habitat," the highest 7-DADMax temperature must not exceed 16°C (60.8°F) more than once every ten years on average.
- To protect the designated aquatic life uses of "Salmonid Spawning, Rearing, and Migration, and Salmonid Rearing and Migration Only" the highest 7-DADMax temperature must not exceed 17.5°C (63.5°F) more than once every ten years on average.

Washington State uses these criteria to ensure full protection for its designated aquatic life uses. The standards recognize, however, that waters display thermal heterogeneity – some are naturally cooler, and some are naturally warmer. When a water body is naturally warmer than the above-described numeric criteria, the state limits the allowance for additional warming due to human activities. The combined effects of all human activities must not cause more than a 0.3 °C (0.54 °F) increase above the naturally warmer temperature condition.

While the criteria apply throughout a water body, there may be site-specific features, including shallow, stagnant, eddy pools where natural features unrelated to human influences are the cause of not meeting the criteria. For this reason, the standards direct that measurements are taken from well-mixed portions of rivers and streams. For similar reasons, samples are not to be taken from anomalously cold areas, such as at discrete points, where cold groundwater flow into the water body.

Table 3 Regulatory criteria for temperature

Waterbody Reach	Aquatic Life Uses	Temperature Standard Highest 7 DADMax
EFLR from mouth to Mason Creek (RM 5.9)	Salmonid Spawning, Rearing, and Migration	17.5°C (63.5°F)
EFLR from Mason Creek (RM 5.9) to headwaters	Core Summer Habitat	16°C (60.8°F)

Bacteria

Bacteria criteria are set to protect people who work and play in and on the water from waterborne illnesses. In Washington State, Ecology’s Water Quality Standards use fecal coliform as an indicator bacteria for the state’s freshwaters (e.g., lakes and streams). Fecal coliform in water indicates the presence of waste from humans and 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 fecal coliform criteria are set at levels that are shown to maintain low rates of serious intestinal illness (gastroenteritis) in people.

The fresh water contact recreation bacteria criteria are:

- The *Extraordinary Primary Contact* use is intended for waters capable of “providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas.” To protect this use category: Fecal coliform organism levels must not exceed a geometric mean value of 50 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 100/colonies mL” [WAC 173-201A-200(2)(b), 2003 edition].
- The *Primary Contact* use is intended for waters “where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and waterskiing.” More to the point, however, the use is designated to any waters where human exposure is likely to include exposure of the eyes, ears, nose, throat, and urogenital system. Since children are also the most sensitive group for many of the waterborne pathogens of concern, even shallow waters may warrant primary contact protection. To protect this use category: “Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200/colonies mL” [WAC 173-201A-200(2)(b), 2003 edition].

Compliance is based on meeting both the geometric mean criterion and criterion for 10% of samples (or a single sample if less than ten total samples) limit (this is calculated as the 90th

percentile). The 90th percentile is a measure of statistical distribution that determines the value for which 90% of the data points are smaller and 10% are higher. These two measures used in combination ensure that bacterial pollution in a water body will be maintained at levels that will not cause a greater risk to human health than intended. While some discretion exists for selecting sample averaging periods, compliance will be evaluated for both monthly (if five or more samples exist) and seasonal (dry season versus wet season) data sets.

The criteria used in the state standards are designed to allow seven or fewer illnesses out of every 1,000 people engaged in primary contact activities. Once the concentration of FC in the water reaches the numeric criterion, human activities that would increase the concentration above the criteria are not allowed. If the criterion is exceeded, the state will require that all known and reasonable technologies and targeted best management practices (BMPs) be implemented to reduce human impacts and bring FC concentrations into compliance with the standard.

If natural levels of fecal coliform (from wildlife) cause criteria to be exceeded, no allowance exists for human sources to measurably increase bacterial pollution, due to the natural conditions of the water body (WAC 173-201A-260). While the specific level of illness rates caused by animal versus human sources are not quantitatively known, warm-blooded animals (particularly those that are managed by humans and thus exposed to human-derived pathogens as well as those of animal origin) are a common source of serious waterborne illness for humans.

Table 4 Regulatory criteria for FC bacteria

Waterbody Reach	Recreation Uses	Bacteria Criteria
EFLR from mouth to Mason Creek (RM 5.9)	Primary Contact	geomean: 100 cfu/100mL
		10% not to exceed: 200 cfu/100mL
EFLR from Mason Creek (RM 5.9) to Moulton Falls (RM 24.6), including tributaries	Primary Contact	geomean: 100 cfu/100mL
		10% not to exceed: 200 cfu/100mL
EFLR from Moulton Falls (RM 24.6) to headwaters	Extraordinary Primary Contact	geomean: 50 cfu/100mL
		10% not to exceed: 100 cfu/100mL

3.3 Water quality impairment studies

East Fork Lewis River project will be completed as a source assessment in lieu of a TMDL from the original project. The source assessment will be used to identify and prioritize sources of pollutants.

4.0 Project Description

The East Fork Lewis River water quality impairment study will be completed as a source assessment study that will use the original 2005-06 field collection efforts. This project will complete the technical analysis for temperature and bacteria using the 2005-06 field collection data. Additional FC sampling will supplement the 2005-06 data collection to assess current bacteria concentrations.

4.1 Project goals

The goals of this project include:

- Confirm and identify sources of FC to the East Fork Lewis watershed.
- Assess existing shade and identify areas with the largest shade deficits in the East Fork Lewis River to help prioritize implementation strategies.

This project will provide information on key areas to focus implementation efforts.

4.2 Project objectives

The project goals will be accomplished through the following objectives.

For fecal coliform,

- Collect additional FC samples every two weeks at a fixed-network of stream locations (Feb 2017- Jan 2018). Investigate potential sources for elevated FC concentrations identified at these locations.
- Compare the FC data from the 2005-06 field collection with supplemental 2017-2018 FC samples to confirm areas with FC impairments.
- Compare the FC results to the Primary Contact Recreation criteria to determine whether waters are meeting standards.
- Determine FC concentration targets from statistical rollback analysis using the 2005-06 data collection.
- Compare monthly FC data from 2005-06 to present using data from Ecology's ambient station at Daybreak Park (27D090).

For temperature,

- Summarize temperature results of 2005-06 field collection.
- Characterize stream temperatures of the East Fork Lewis River through spatial analysis using GIS to show areas with temperature impairment issues.
- Develop shade analysis of river system to determine effective shade and system potential shade for the mainstem of the East Fork Lewis River using Shade model. Determine areas with shade deficits to help guide implementation efforts.
- Compare temperature data from 2005-06 to present using data from Ecology's ambient monitoring station at Daybreak Park (27D090).

This project will also provide high quality data to guide implementation efforts.

4.3 Information needed and sources

Information will be needed to assess options for closing in on potential bacteria sources, e.g. maps of roads, storm and sewer system. Discussions with local jurisdictions for assistance in identifying key areas of concern will continue throughout the field study.

The technical analysis component of this project will rely on data collected from previous studies, particularly the 2005-06 field collection effort of the original East Fork Lewis River TMDL project. This data will be used to assess temperature and fecal coliform within the watershed using statistical and spatial analyses. Monthly ambient monitoring data for East Fork Lewis River in Day Break Park (27D090) will be used to compare the results of the 2005-06 study with both historic and current trends.

The modeling setup and data needs are discussed in more detail in Section 7.3.2.

4.4 Tasks required

The tasks required to meet project goals are discussed in Section 4.2.

4.5 Systematic planning process

This QAPP represents the systematic planning process.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 5 Organization of project staff and responsibilities

Staff	Title	Responsibilities
Brett Raunig Water Cleanup and Technical Assistance Unit. WQP-SWRO-VFO Phone: 360-690-4660	Lower Columbia Water Quality Management Area TMDL Coordinator/ Client/ Project Manager & Field Lead	Clarifies scope of the project. Reviews and helps Co-author the draft Quality Assurance Project Plan (QAPP) and approves the final QAPP. Project Manager for supplemental Fecal Coliform field sampling and enters data into EIM. Reviews and approves the technical report.
Sheelagh McCarthy EAP - Modeling & TMDL Unit, Western Operations Section Unit Phone 360-407-7395	EAP Technical Lead Project Manager Source Assessment Technical report	Co-author of the QAPP. Assists with field sampling, conducts quality assurance review of the data, analyzes and interprets data. Writes the draft and final technical report. Enters data into EIM.
Andrew Kolosseus WQP-SWRO- Phone: 360-407-7453	Unit Supervisor for the TMDL coordinator	Reviews the project scope and budget, and tracks project progress. Provides review of the draft QAPP and approves the final QAPP. Reviews and approves the technical report.
Rich Doenges WQP-SWRO Phone: 360-407-6271	Section Manager for the TMDL coordinator	Approves the budget. Reviews and approves the final QAPP. Reviews and approves the technical report.
Joel Bird MEL Phone: 360-871-8801	Director	Reviews and approves the final QAPP.
Randall Marshall Phone: 360-407-6434	WQP Quality Assurance Officer	Reviews and comments on the draft QAPP.

EAP: Environmental Assessment Program

WQP: Water Quality Program

SWRO: Southwest Regional Office

VFO: Vancouver Field Office

EIM: Environmental Information Management database

5.2 Special training and certifications

All field staff involved in water quality studies must have either the relevant experience in the required Standard Operating Procedures (SOPs) or be trained by more senior field staff or the project manager who have the required experience. Any staff helping in the field who lack sufficient experience will always be paired with someone who does have the necessary training

and experience. The more experienced staff will then lead the field data collection and oversee/mentor less experienced staff.

Any maintenance needed for field equipment will be performed by trained field staff, following the associated Ecology SOP or the equipment manufacturer's guidance.

The field lead has experience collecting bacteria samples and analyzing the data. All field staff working on the project will be aware of the SOPs, (see Section 8.1) and will follow them.

5.3 Organization chart

See Section 5.1 Table 5.

5.4 Project schedule

Table 6 Proposed project schedule

Field and laboratory work	Due date	Lead staff
Field work completed	January 2018	Brett Raunig
Laboratory analyses completed	January 2018	Manchester Laboratory staff
Environmental Information System (EIM) database		
EIM Study ID: EFLewisSA		
Product – 2017-18 FC Data	Due date	Lead staff
EIM data loaded	April 2018	Brett Raunig/Sheelagh McCarthy
EIM data entry review	May 2018	Brett Raunig/Sheelagh McCarthy
EIM complete	June 2018	Brett Raunig/Sheelagh McCarthy
Final report – Source Assessment		
Author lead	Sheelagh McCarthy	
Schedule		
Draft due to supervisor	February 2018	
Draft due to client/peer reviewer	March 2018	
Draft due to external reviewer(s)	April 2018	
Final (all reviews done) due to publications coordinator	June 2018	
Final report due on web	July 2018	

5.5 Budget and funding

Table 7 summarizes the expected laboratory and shipping costs for the East Fork Lewis Fecal Coliform Bacteria and Temperature Source Assessment. Manchester Environmental Laboratory (MEL) will perform all analyses using the membrane filtration (MF) method. The funding source for this project will be from the State Toxics account.

Table 7. Lab budget for the 2017-18 study.

Parameter	Number of Samples/month	Number of QA (20%) Samples/month	Total Number of Samples/month	Cost Per Sample	MEL Subtotal/ 12 months
Fecal Coliform (MF) at Fixed Sites	28 (14x2)	6 (3x2)	34	25.00	10,200.00
FC-MF Source Investigation	10	2	12	25.00	3,600
Est Shipping Costs to ship one cooler to MEL per sampling event				20.00	480.00
Total					14,280.00

6.0 Quality Objectives

6.1 Data Quality Objectives (DQOs)

Sampling will follow established standardized operating procedures (SOPs) that meet the following measurement quality objectives (MQOs). Data quality objectives (DQOs) are not needed for this study.

6.2 Measurement Quality Objectives

Field sampling procedures and laboratory analyses inherently have associated uncertainty which results in data variability. Measurement quality objectives (MQOs) state the acceptable data variability for a project. *Precision* and *bias* are data quality criteria used to indicate conformance with MQOs. The term *accuracy* refers to the combined effects of precision and bias (Lombard and Kirchmer, 2004).

Field sampling precision and bias will be measured by submitting replicate samples. MEL will assess precision and bias in the laboratory through the use of duplicates and blanks.

Table 8 outlines analytical methods, expected precision of sample duplicates, and method reporting limits. The targets for precision of field replicates are based on historical performance by MEL for environmental samples taken around the state by Ecology's Environmental Assessment Program (Mathieu, 2006). The reporting limits of the methods listed in the table are appropriate for the expected range of results and the required level of sensitivity to meet project objectives. The laboratory's MQOs and QC procedures are documented in the MEL *Lab User's Manual* (MEL, 2016).

Table 8 Measurement quality objectives.

Parameter	Method	Precision Field Replicates	Lab Duplicate MQO	Reporting Limits
Fecal Coliform	SM 9222 D MF	50% of replicate pairs < 20% RSD 90% of replicate pairs < 50 % RSD	40% RPD	1 cfu/100 mL

6.2.1 Targets for Precision, Bias, and Sensitivity

6.2.1.1 Precision

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

6.2.1.2 Bias

Bias is defined as the difference between the sample value and true value of the parameter being measured. Bias affecting measurement procedures can be inferred from the results of QC procedures. Bias in field measurements and samples will be minimized by strictly following Ecology's measurement, sampling, and handling protocols. Field sampling precision bias will be addressed by submitting replicates. MEL will assess bias in the laboratory through the use of duplicates and blanks.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance. It is commonly described as detection limit. In a regulatory sense, the method detection limit (MDL) is usually used to describe sensitivity.

6.2.2 Targets for Comparability, Representativeness, and Completeness

6.2.2.1 Comparability

Comparability to previously collected data will be established by strictly following EAP protocols and adhering to data quality criteria. Previous studies in the watershed have analyzed water quality samples for FC bacteria using the MF method (Bilhimer et al., 2005). This project will have MEL analyze bacteria samples using the MF method to ensure comparable results.

6.2.2.2 Representativeness

The study is designed to have enough sampling sites at sufficient sampling frequency to meet study objectives. Bacteria values are known to be highly variable over time and space. Sampling variability can be somewhat controlled by strictly following standard procedures and collecting QC samples, but natural spatial and temporal variability can contribute greatly to the overall variability in the bacteria value. Resources limit the number of samples that can be taken at one site spatially or over various intervals of time.

6.2.2.3 Completeness

EPA has defined completeness as a measure of the amount of valid data needed to be obtained from a measurement system (Lombard and Kirchmer, 2004). The goal for the East Fork Lewis River study is to correctly collect and analyze 100% of the samples for each of the sites. However, problems occasionally arise during sample collection that cannot be controlled; thus a completeness of 95% is acceptable. Example problems are flooding, site access problems, sample container shortages, or lack of water. If a completeness of less than expected occurs there will be a review the causes for the short fall and determine the implications. The information will be included in the final report by the project manager.

6.3 Model quality objectives

Model quality results should be comparable to other models used in similar water quality impairment modeling studies to meet the project goals and objectives. A summary of results for comparison is available in *A Synopsis of Model Quality from the Department of Ecology's Total Maximum Daily Load Technical Studies*

(<https://fortress.wa.gov/ecy/publications/SummaryPages/1403042.html> Sanderson and Pickett, 2014).

7.0 Study Design

The study design for the East Fork Lewis River study will involve a technical analysis of the 2005-06 field collection of temperature and FC measurements.

In 2017-18, Ecology will collect addition FC samples at fixed-network sites shown in Figure 9. Data will be used to confirm problem areas identified in the 2005-06 field study. The new data will narrow target areas and help guide implementation efforts.

7.1 Study Boundaries

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

WRIA: 27 - Lewis

7.2 Field data collection

The study objectives will be met through characterizing annual and seasonal FC bacteria concentrations and by increasing the intensity of sampling when high bacteria concentrations are identified. Additional samples will be taken upstream/downstream and in additional tributaries to narrow in on and identify possible sources.

FC concentrations will be monitored at multiple fixed locations within the study area from February 2017 through January 2018. The seasonal determination will be based on previous water quality impairment projects, effectiveness monitoring, and 2017-18 seasonal conditions to define the wet and dry seasons.

There will be a fixed network of sites sampled twice monthly throughout the sampling period. Additional investigative sampling and land-use research will occur when high FC concentrations are found. Investigative sampling will use a targeted or above/below sampling approach.

Data from the fixed network will provide an estimate of the annual and seasonal geometric mean and 90th percentile statistics. The schedule should provide at least 24 samples per fixed site to develop the annual statistics, including 12 samples per site during the dry season and 12 samples per site during the wet season.

The proposed locations of the fixed-network water sites are listed in Table 9 and shown in Figure 9. Sites were selected based on historical site locations and associated high FC concentrations, desire to find sources, as well as access capability. Sites may be added or removed from the sampling plan, depending on access and new information provided during the QAPP review, field observations, and preliminary data analysis.

7.2.1 Sampling location and frequency

The fixed-network monitoring stations are shown in Figure 9 and described in Table 9 for this project. The locations were chosen using the original QAPP for East Fork Lewis River (Bilheimer et. al, 2005). The data collected in 2005-06 confirmed these locations as violating water quality standards. The data collected in 2017-18 will be used to confirm listings and investigate sources.

The fixed-network sites will be sampled twice a month (Table 9). Professional judgment will be used when determining the source investigation site locations. Theses added sites will be used to narrow in on sources when concentrations are high and to investigate areas where Fecal Coliform presence is suspected.

The number of samples collected each event may vary depending on the number added for source identification. Field staff will contact Manchester Environmental Laboratory's (MEL's)

microbiologist's Nancy Rosenbower (360-871-8827) *and* Edlin Limmer (360-871-8810) at the end of each event with the actual number of samples that will arrive at MEL the following day.

Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community

Table 9 Name and location of field sampling sites for 2017-18 field work.

Map ID#	EIM Location ID	Location name	Description (more detailed)	Latitude	Longitude
1	27-YAC-0.90	Yacolt CK @ Railroad Ave	Yacolt Creek at Railroad Ave	45.842767	-122.391816
2	27-RCN-2.07	ROCK CK N @ NE Rock Creek Rd	Rock Creek at NE Rock Creek Rd	45.856153	-122.519507
3	27-MAS-3.19	MASON CK @ JR ANDERSON RD	Mason Creek at JR Anderson Rd	45.842059	-122.590721
4	27-MAS-1.11	MASON CREEK @ NE 290 th ST	Mason Creek at NE 290 th ST	45.832492	-122.628202
5	27-LOC-3.55	LOCKWOOD CK @ NE Taylor Valley Rd	NE Taylor Valley Rd	45.877430	-122.608207
6	27-RIL-0.95	RILEY CK @ JOHNSON RD	Riley Creek off Johnson Rd	45.866667	-122.635282
7	27-BRZ-14TH	TRIB TO BREEZE CK @ 14TH	Tributary to Breeze Creek at 14th	45.868151	-122.656512
8	27-BRZ-SW1	SW CULVERT CEDAR & 4TH	Stormwater culvert at Cedar & 4th	45.862642	-122.669213
9	27-BRZ-SW2	STRMWTR DITCH TO BREEZE CK NR MOUTH	Stormwater ditch near mouth Breeze Creek	45.860393	-122.669668
10	27-BRZ-0.07	BREEZE CK @ MOUTH	Breeze Creek near mouth	45.860115	-122.66954
11	27-EFL-3.35	EF LEWIS @ LACENTER RD	EF Lewis at LaCenter Rd	45.856971	-122.672006
12	27-JEN-1.03	JENNY CK @ NW 14 th Ave	Jenny Creek at NW 14th Ave	45.876595	-122.685656
13	27-MCC-1.18	MCCORMICK CK @ LACENTER RD	McCormick Creek at LaCenter Rd	45.851922	-122.691969
14	27-EFL-0.75L	EF LEWIS @ I-5 BRIDGE-L BANK	EF Lewis at I-5 bridge Left Bank	45.872951	-122.710607

The field sampling schedule is provided below in Table 10. These dates have been pre-arranged with MEL, and this allows for the lab to plan for the arrival of the samples. Some dates may change due to unforeseen circumstances, however, any change will have to be approved by MEL and occur only on a Sunday through Wednesday based on MEL's analytical schedule. The lab will be notified immediately if there are any deviations from the scheduled date of sampling. The field lead will also coordinate with the Courier for timely sample container delivery.

Table 10 Sampling event dates.

2017		
Month	Date	
Feb	7	21
Mar	7	21
April	4	18
May	2	16
June	6	20
July	5	18
Aug	1	15
Sept	5	19
Oct	3	17
Nov	7	20
Dec	5	19
2018		
Jan	2	16

7.2.2 Field parameters and laboratory analytes to be measured

Fecal coliform bacteria will be the parameter measured in the field and laboratory – See Table 8.

7.3 Modeling and analysis design

The modeling design for East Fork Lewis River involves a shade analysis to determine effective shade, potential shade, and shade deficits along the mainstem of the East Fork Lewis River, based on the data collection from 2005-06. The models used for this study include Ecology's TTools and Shade model.

7.3.1 Analytical framework

7.3.1.2 TTools

TTools will be used to estimate effective shade inputs for use in temperature modeling programs. TTools is an ArcView extension developed by the Oregon Department of Environmental Quality (ODEQ) and adapted by Ecology. It is used to develop GIS-based data from acquired polygon and grids coverages. It specifically uses these coverages to develop vegetation and topography data perpendicular to the stream channel and longitudinal stream channel characteristics, such as the near-stream disturbance zone and elevation. Typical inputs into TTools are LiDAR data, digital elevation models (DEMs) and aerial imagery (digital orthophoto quadrangles and rectified

aerial photos). Stream width, aspect, topographic shade angles, elevation, and riparian vegetation are sampled with TTools for incorporation into the Shade model. The riparian vegetation coverage will contain four specific attributes: vegetation height, general species type or combinations of species, percent vegetation overhang, and average canopy density of the riparian vegetation.

Documentation for Ecology's TTools: www.ecy.wa.gov/programs/eap/models.html

7.3.1.3 Shade Model

Ecology's Shade model is a tool for estimating shade from riparian vegetation and will be used to evaluate solar radiation and effective shade along the East Fork Lewis River. Shade was developed as a Microsoft Excel sheet and was adapted from a program that ODEQ developed as part of Version 6 of its HeatSource model. Shade.xls calculates effective shade using one of two methods. The first is Chen's method, based on the Fortran program, HSPF SHADE that Y.D. Chen developed for his 1996 Ph.D. dissertation at the University of Georgia (Chen, 1996), and it is further documented in the Journal of Environmental Engineering (Chen 1998a, 1998b). The second method is the original method by ODEQ from the HeatSource model version 6. The Shade model quantifies the potential daily solar load and generates the percent effective shade. Effective shade is the fraction of shortwave solar radiation that does not reach the stream surface because vegetative cover and topography intercept it. Effective shade is influenced by latitude/longitude, time of year, stream geometry, topography, and vegetative buffer characteristics, such as height, width, overhang, and density.

The Shade model requires physical and vegetation parameters such as stream width, aspect, topographic shade angles, elevation, and riparian vegetation that will be determined using the TTools GIS extension. Most data inputs for the Shade Model are easily available through aerial imagery and digital elevation models. Additional field data will be collected to characterize riparian shade (to compare observed shade to model-predicted shade) and vegetation. TTools output will be used as input for the Shade model to generate longitudinal effective shade profiles. Riparian vegetation, stream aspect, topographic shade angles, and latitude/longitude will be used to estimate effective shade.

Documentation of ODEQ HeatSource model: www.deq.state.or.us/wq/TMDLs/TMDLs.htm

7.3.2 Model setup and data needs

The data needs to run the Shade model are listed in Table 11. Data will be provided from field collection from Ecology, GIS, or another credible source. The final report will provide full documentation of the data used during the modeling effort.

Table 11 Data needs for Shade model.

	Shade Model Requirements	Data Source		
	Parameter	Ecology	TTools/GIS	Other
General	Calendar start date	x		
	Duration of simulation	x		
	Time Zone	x		
	Latitude/Longitude		x	
Physical	Longitudinal Distance		x	
	Elevation		x	
	Aspect		x	
	Wetted Width		x	
	NSDZ Width		x	
	Riparian zone ground elevations		x	
	Topographic Shade (West, South, East)		x	
Vegetation	Canopy-shading coefficient/veg density			x
	Vegetation height		x	
	Vegetation/riparian zone width		x	

All input data for the Shade model will be longitudinally referenced, allowing spatial and/or continuous inputs to apply to certain zones or specific river segments.

Riparian habitat field data collected during 2005 was compiled as part of the East Fork Lewis River Basin Habitat Assessment (Johnston et al., 2005). This included a GIS map of riparian vegetation in a 100-foot buffer around the East Fork Lewis River and several tributaries. The map includes data on vegetation type, general height class, and vegetation density. This information will be used during the GIS spatial and Shade analysis.

Image analysis of digital hemispherical pictures and field measurements were taken at the center of the stream during the 2005 field collection. These hemispherical photographs were analyzed to calculate effective shade at sampling points along the East Fork Lewis River. This analysis provides an estimate of the total effective shade at the stream surface during the critical period. This data will be used in this study to provide validation for the site factor assumptions and effective shade predictions generated from the Shade model.

7.4 Assumptions in relation to objectives and study area

The assumption underlying this study design is that sources of fecal coliform bacteria can be located by conducting bracketed sampling between two fixed sites. We are assuming that the elevated concentrations will be consistent enough to be traceable and not so variable that sources cannot be found.

7.5 Possible challenges and contingencies

7.5.1 Logistical Problems

Logistical problems can occur during field work and interfere with sampling. The majority of the fixed-network sites are located in the public access corridor. Permission will be obtained from

private land owners as needed. If permission is not granted this may hinder our ability to narrow down on possible source areas.

Numerous logistical issues can arise when transporting/shipping samples and attempting to meet holding times including:

- Samples will be shipped to MEL via FedEx.
- FedEx guarantees delivery to MEL by 12pm the following day.
- Inclement weather can cancel or delay flights or commercial shipping vehicles. Attempts should be made to reschedule sampling events during inclement weather.
- Overnight shipping drop-off times for commercial shipping is 4:30 pm. Delays in sampling or driving can result in missing the drop-off deadline.

Additional problems may include seasonal considerations, sample bottle delivery errors, vehicle and equipment problems, site access issues, road safety, and/or limited availability of personnel or equipment.

Any circumstance that interferes with data collection, holding times, and quality will be noted and discussed in the final report.

7.5.2 Practical Constraints

Practical constraints that can interfere within a project following lab and field work may include scheduling conflicts with personnel or availability of adequate resources, both human and budgetary, from EAP and WQP.

Any practical constraints that would affect the project schedule will be discussed with the appropriate supervisor as needed and discussed in the final report.

7.5.3 Schedule Limitations

Changes in project prioritization and workload for both EAP and WQP could affect the project schedule. Factors that can cause delays to the proposed project schedule include:

- Time required for QAPP review and approval.
- The need for additional sampling or technical analysis work.
- Addressing comments from reviewers that may lead to additional work
- Changes to schedule based on current needs and available resources from EAP and WQP.

Any unforeseen limitations that would affect the project schedule will be discussed with the appropriate supervisor as needed and discussed in the final report.

8.0 Sampling Procedures

8.1 Invasive species evaluation

Field staff will follow EAP's SOP EAP070 on minimizing the spread of invasive species (Parsons et al., 2012). At the end of each field visit, field staff will clean field gear in accordance with the SOP for minimizing the spread of invasive species for areas of moderate concern. Areas

of concern have or may have invasive species, such as New Zealand mud snails that are particularly hard to clean off equipment and are especially disruptive to native ecological communities (www.ecy.wa.gov/programs/eap/InvasiveSpecies/AIS-PublicVersion.html.)

8.2 Measurement and sampling procedures

Freshwater samples will be collected using Ecology SOPs EAP030 for bacteria (Ward and Mathieu, 2011) and EAP015 grab sampling (Joy, 2006). These SOPs can be found at [Ecology's QA Website](#) (Ecology, 2016)

Twenty percent of FC samples will be replicated in the field in a sequential manner to assess field and laboratory variability. Samples will be collected in a well-mixed flowing portion of the waterbody. A sampling pole will be used as possible to prevent sediment disturbance which will occur when entering the creek. A fecal coliform bridge-sampler will be used to sample from the bridges.

8.3 Containers, preservation methods, holding times

Table 12 shows the sample containers, preservation and holding times required to meet the goals and objectives of this project.

Table 12 Sample container, preservation and holding time.

Parameter	Matrix	Minimum Quantity Required	Container	Preservation	Holding Time
Fecal Coliform - MF	Water	250 mL	250 mL poly autoclaved	Fill the bottle to the shoulder; Cool to $\leq 10^{\circ}\text{C}$	24 hours

8.4 Equipment decontamination

A sampling pole and bridge sampler will be used when possible to eliminate entry into the water. No felt soled boots will be used. Rubber boots and sampling equipment will be cleaned with 3% hydrogen peroxide after the field day is complete.

After conducting field work, field staff will:

- Inspect and clean all equipment by removing any visible soil, vegetation, vertebrates, invertebrates, plants, algae or sediment. If necessary, a scrub brush will be used and then rinsed with clean water either from the site or brought for that purpose. The process will be continued until all equipment is clean.
- Drain all water in samplers or other equipment that may harbor water from the site. This step will take place before leaving the sampling site or at an interim site. If cleaning after

leaving the sampling site, no debris will leave the equipment and potentially spread invasive species during transit or cleaning.

Established Ecology procedures will be followed if an unexpected contamination incident occurs.

8.5 Sample ID

Ecology's Manchester Environmental Laboratory (MEL) will provide the field lead with work order numbers for all scheduled sampling dates. The work order number will be combined with a field ID number that is given by the field lead. This combination of work order number and field ID number constitute the sample ID. Sample ID numbers will follow the standard convention established by MEL, YYMMWW-SS, where YY is the two digit year, MM is the two digit month, WWW is the three digit work order identifier assigned by MEL, and SS is the sample ID number within the work order. All sample IDs will be recorded in field logs and in an electronic spreadsheet for tracking purposes.

8.6 Chain-of-custody, if required

Water quality samples will be stored on ice in coolers in the sampling vehicle. The vehicle will be locked when field personnel are not in the vehicle. Red sealing tape will be applied over the cooler opening and shipped to MEL using FedEx. MEL will inspect samples and chain of custody when received.

If FedEx is not used, samples will be transported to the Chain-of-Custody room at Ecology's Headquarters building, the chain-of-custody portion of the Laboratory Analysis Required sheet will be filled out; red sealing tape will be applied over the cooler opening; and the secured coolers will be placed in the walk-in cooler. The door to the Chain of Custody room is always locked and only approved personnel have access with an electronic identification entry card. The MEL courier will pick up the samples the following morning and deliver them to MEL while retaining chain of custody.

8.7 Field log requirements

A field log will be maintained by the field lead during each sampling event. The following information will be recorded during each visit to each site:

- Name of Project
- Field staff for that day
- Environmental conditions
- Location site name
- Date, Time, Sample ID, identity of QC samples
- Pertinent observations and/or any problems with sampling

8.8 Other activities

There are no other activities for this study that are not already described in this QAPP.

9.0 Measurement Methods

9.1 Lab procedures table.

The lab procedures and measurement methods for this study are presented in Table 13.

Table 13 Measurement methods (laboratory).

Analyte	Sample Matrix	Expected # of Samples	Expected Range of Results	Method	Method Detection Limit
Fecal Coliform - MF	Water	528	1-30,000 cfu/100 mL	SM 9222 D	1 cfu/100 mL

9.2 Sample preparation method(s)

There are no additional sample preparation methods that have not already been described.

9.3 Special method requirements

There are no special method requirements for this study.

9.4 Lab(s) accredited for method(s)

All chemical analysis will be performed at MEL, which is accredited for the FC-MF method to be used.

10.0 Quality Control (QC) Procedures

10.1 Table of field and lab QC required

Table 14 presents the quality control information for both the field and laboratory for this study.

Table 14 Quality control information for field and laboratory.

Parameter	Field		Laboratory			
	Blanks	Replicates	Check Standards	Method Blanks	Analytical Duplicates	Matrix Spikes
Fecal Coliform - MF	N/A	20%	N/A	1/batch	1/20 samples	N/A

10.2 Corrective action processes

QC results may indicate problems with data during the course of the project. Corrective action processes will be used if activities are found to be inconsistent with the QAPP, if analysis or modeling results do not meet MQOs or performance expectations, or if some other unforeseen problem arises.

The lab will follow prescribed procedures to resolve the problems. Options for corrective actions may include:

- Modifying the analytical procedures.
- Qualifying results.
- Retrieving missing information.
- Re-analyzing samples within holding time requirements.
- Requesting collection of additional samples or taking of additional field measurements.

Corrective actions in the field may include:

- Increased staff training.
- Modification/correction of field procedures.
- Specific comments provided to MEL staff regarding field conditions.

11.0 Data Management Procedures

11.1 Data recording/reporting requirements

All field data will be recorded in a field notebook. Field notebooks will be checked for missing or improbable information before leaving each site. Missing or unusual data will be brought to the attention of the project manager.

Lab results will be checked for missing and/or improbable data. Data received from MEL through Ecology's Laboratory Information Management System (LIMS) will be checked for omissions against the "Request for Analysis" forms by the project manager/field lead. Data requiring additional qualifiers will be determined by the project manager/field lead.

Summary statistics for all data will be generated using MS Excel® and SYSTAT. Data will be used to determine whether the data quality objectives and water quality criteria were met.

11.2 Laboratory data package requirements

Laboratory-generated data reduction, review, and reporting will follow the procedures outlined in the *MEL User's Manual* (2016). Variability in lab duplicates will be quantified using lab procedures (MEL, 2016). Any estimated results will be qualified and their use restricted as appropriate. A standard case narrative of laboratory QA/QC results will be sent to the project manager/field lead for each set of samples.

11.3 Electronic transfer requirements

MEL has a protocol in place to provide all data electronically to the project manager through the LIMS to EIM data feed system.

11.4 EIM/STORET data upload procedures

All FC data will be entered into EIM following all existing Ecology business rules and the EIM User's Manual for loading, data quality checks, and editing.

11.5 Model information management

Data management for modeling work for this study will mainly include Excel spreadsheets.

Modeling information, including inputs, outputs, GIS files, will be archived. Modeling results will be included within the final report.

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

There is not a need for a formal audit for this study. However, field staff will monitor each other to maintain consistency with SOPs.

12.2 Responsible personnel

No formal audits will be performed.

12.3 Frequency and distribution of report

The project manager will inform the Lower Columbia Water Quality Management Area TMDL Coordinator of samples over 100 cfu/100mL upon receiving the data from MEL. The TMDL Coordinator will determine the appropriate local jurisdiction/s to notify.

12.4 Responsibility for reports

Sheelagh McCarthy will be responsible for the final report.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

Field notebooks and electronic information storage will be checked for missing or improbable measurements; and initial data will be verified before leaving each site. This process involves checking the data sheet (written or electronic) for omissions or outliers. If measurement data are missing or a measurement is determined to be an outlier, the measurement will be flagged in the data sheet and repeated if possible. The project workbook file containing raw field data will be labeled “Draft” until data verification and validation is complete. Validated data will be moved to a separate file labeled “Final”.

Before entering any data into EIM or using it for analysis or modeling, there will be a quality analysis of all field data to evaluate compliance with MQOs. Results of the data quality analysis will be summarized in final documentation and used for decisions on usability

13.2 Laboratory data verification

MEL staff will perform the laboratory verification following standard laboratory practices. After the laboratory verification, a secondary verification of *each data* package will be performed by the project manager. This secondary verification will entail a detailed review of all parts of the laboratory data package with special attention being paid to laboratory QC results. If any issues are discovered the project manager will take steps toward clarification/ resolution with appropriate MEL staff.

13.3 Validation requirements, if necessary

All laboratory data that have been verified by MEL staff will be validated by the project manager. After data entry and data validation tasks are completed, all data will be entered into the EIM system.

13.4 Model quality assessment

Model performance will be assessed both quantitatively and qualitatively to evaluate the quality of model calibration and model results. Because of uncertainty and lack of available literature on model performance criteria, inherent error in input and observed data, and the approximate nature of model formulations, absolute criteria for model acceptance or rejection are usually not appropriate.

Graphical assessment and spatial assessments with GIS will be used to provide a qualitative assessment of the goodness-of-fit.

The quality of quantitative model performance will be evaluated using statistical tests. Model performance statistics are used, not as absolute criteria for acceptance of the model, but rather, as guidelines to supplement the visual inspection of model-data plots.

For the Shade modeling analysis, a comparison of predicted and observed effective shade will be achieved through the use of plots and statistical analyses, such as including linear regressions. Shade along the East Fork Lewis River will be analyzed through comparing the shade model results with canopy measurements. If determined to be necessary and appropriate, additional tests of model fit may also be applied.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining whether project objectives have been met

14.1.1 Study data usability

After all laboratory and field data are verified, the project manager will thoroughly examine the data package using statistical techniques and professional judgment to determine if MQOs for completeness, representativeness, and comparability have been met. If the criteria have not been met (e.g., if the %RSD for sample duplicates exceeds the MQO), the project manager will decide if affected data should be qualified or whether it should be rejected. The project manager will decide how any qualified data will be used in the technical analysis, and will document this in the final technical report.

Ecology's 2005-06 field study resulted in data that are quality assured and usable for this study. The temperature and bacteria data collected from the 2005-06 were entered and quality assured in EIM. The continuous temperature statistics, stream survey measurements and flow data from the 2005-06 field study were entered and quality assured into EIM.

The final report will assess all data and analysis results and provide a final determination regarding usability in regards to the project goals and objectives.

14.1.2 External data usability

Any external data used for this study will meet the requirements of Ecology's credible data policy (www.ecy.wa.gov/programs/wq/qa/wqp01-11-ch2_final090506.pdf). Note that this requirement does not apply to non-quality data such as flow or meteorological data.

The usability of data from external sources that do not have readily available information on whether the data were peer reviewed or followed QA/QC procedures or SOPs will also be assessed by exploratory data analysis, plotting and visually assessing quality, and comparison/correlation to other data sources collected at nearby locations.

14.2 Treatment of non-detects

Non-detects will be included in data analysis. The non-detect will be reported at the reporting limit and qualified as "U" in EIM.

14.3 Data analysis and presentation methods

Data analysis will include evaluation of data distribution characteristics and, if necessary, appropriate distribution of transformations. Estimation of univariate statistical parameters and graphical presentation of the data (box plots, time series, regressions) will be made using SYSTAT and/or Microsoft Excel® software.

Bacteria concentration targets for East Fork Lewis River will be based on an analysis of FC data using the following methods described.

14.3.1 Statistical Rollback Method

The statistical rollback will be used to estimate FC reductions for stream segments in the East Fork Lewis River watershed. The Statistical Theory of Rollback from Ott (1995) will be applied to the estimated distributions of bacteria to establish distribution statistics that meet the water quality criteria (i.e. geometric mean and 90th percentile). It will be used to establish FC reduction targets for stream segments, both annual and seasonal.

The rollback method simply compares monitoring data to standards, and the difference is the percentage change needed to meet the standards.

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 water quality standards.

14.3.2 Simple loading analysis

A simple loading analysis will be performed using a spreadsheet to compare measured loading sources relative to each other and, in some cases, evaluate the mass balance of FC bacteria for a reach. Loading patterns will help in directing implementation to the highest loading sources. Cleaning up high loading sources will benefit downstream stations where the upstream loads are contributing to exceedances of water quality standards.

14.3.3 Kendall Seasonal Trend Test

FC data will be analyzed using a Seasonal Kendall trend test using long-term monitoring data from Ecology’s Daybreak Park ambient monitoring station. The purpose of the Seasonal Kendall trend test is to determine monotonic (increasing or decreasing) trends in data over a period of time (Hirsch et al., 1982; Gilbert, 1987; Helsel and Hirsch, 1995). Any significant trends will be presented in a chart showing the direction of the trend and the associated data. A summary will be written, discussing the test statistics, significance, confidence intervals, and any assumptions.

14.4 Sampling design evaluation

If the project manager determines that the data package meets the MQOs, criteria for completeness, representativeness, and comparability then the sampling design will be considered effective.

14.4.1 Modeling and analysis design evaluation

The combination of data collected from the 2005-06 original study and existing data is expected to be sufficient for the selected modeling tools. It is expected that these modeling tools, used with the existing data, will be satisfactory to meet project goals and objectives. The success of the data collection design used by modeling will be assessed as part of the quality assessment for the model.

Written documentation will be prepared addressing the model's ability to meet the project goals and objectives and will be included in the final report

14.5 Documentation of assessment

The project manager will include a section in the technical report summarizing the findings of the data quality assessment.

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16.0 Appendix A. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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

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

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.

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.

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.

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.

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

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

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

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

Total Maximum Daily Load (TMDL): 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.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

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, requiring 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: An estimated portion of a sample population based on a statistical determination of distribution characteristics. The 90th percentile value is a statistically derived

estimate of the division between 90% of samples, which should be less than the value, and 10% of samples, which are expected to exceed the value.

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

BMP	Best management practice
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
MEL	Manchester Environmental Laboratory
QA	Quality assurance
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
TMDL	(See Glossary above)
WAC	Washington Administrative Code
WRIA	Water Resource Inventory Area

Units of Measurement

cfu	colony forming units
mL	milliliter

Quality Assurance Glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data. For Ecology, it is "Formal recognition by (Ecology)...that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin, 2010)

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms precision and bias be used to convey the information associated with the term accuracy. (USGS, 1998)

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella. (Kammin, 2010)

Bias: The difference between the population mean and the true value. Bias usually describes a systematic difference reproducible over time, and is characteristic of both the measurement system, and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI). (Kammin, 2010; Ecology, 2004)

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process. (USGS, 1998)

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured. (Ecology, 2004)

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards, but should be referred to by their actual designator, e.g., CRM, LCS. (Kammin, 2010; Ecology, 2004)

Comparability: The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator. (USEPA, 1997)

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator. (USEPA, 1997)

Continuing Calibration Verification Standard (CCV): A QC sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run. (Kammin, 2010)

Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system. (Kammin, 2010; Ecology 2004)

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at ± 2 standard deviations from the mean, action limits at ± 3 standard deviations from the mean. (Kammin, 2010)

Data Integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading. (Kammin, 2010)

Data Quality Indicators (DQI): Data Quality Indicators (DQIs) are commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity. (USEPA, 2006)

Data Quality Objectives (DQO): Data Quality Objectives are qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions. (USEPA, 2006)

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010)

Data validation: An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment, and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability and integrity, as these criteria relate to the usability of the data set. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

- Use of raw or instrument data for evaluation.
- Use of third-party assessors.
- Data set is complex.
- Use of EPA Functional Guidelines or equivalent for review.

Examples of data types commonly validated would be:

- Gas Chromatography (GC).
- Gas Chromatography-Mass Spectrometry (GC-MS).
- Inductively Coupled Plasma (ICP).

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

- No qualifier, data is usable for intended purposes.
- J (or a J variant), data is estimated, may be usable, may be biased high or low.
- REJ, data is rejected, cannot be used for intended purposes (Kammin, 2010; Ecology, 2004).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set. (Ecology, 2004)

Detection limit (limit of detection): The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero. (Ecology, 2004)

Duplicate samples: Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis. (USEPA, 1997)

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport. (Ecology, 2004)

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples. (Kammin, 2010)

Laboratory Control Sample (LCS): A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples. (USEPA, 1997)

Matrix spike: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects. (Ecology, 2004)

Measurement Quality Objectives (MQOs): Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness. (USEPA, 2006)

Measurement result: A value obtained by performing the procedure described in a method. (Ecology, 2004)

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed. (EPA, 1997)

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples. (Ecology, 2004; Kammin, 2010)

Method Detection Limit (MDL): This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero. (Federal Register, October 26, 1984)

Percent Relative Standard Deviation (%RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

$$\%RSD = (100 * s)/x$$

where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin, 2010)

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all “parameters.” (Kammin, 2010; Ecology, 2004)

Population: The hypothetical set of all possible observations of the type being investigated. (Ecology, 2004)

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator. (USGS, 1998)

Quality Assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data. (Kammin, 2010)

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives. (Kammin, 2010; Ecology, 2004)

Quality Control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data. (Ecology, 2004)

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

$$[Abs(a-b)/((a + b)/2)] * 100$$

where “Abs()” is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled. (USGS, 1998)

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator. (USGS, 1998)

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population. (USGS, 1998)

Sample (statistical): A finite part or subset of a statistical population. (USEPA, 1997)

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit. (Ecology, 2004)

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method. (USEPA, 1997)

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency. (USEPA, 1997)

Split Sample: The term split sample denotes when a discrete sample is further subdivided into portions, usually duplicates. (Kammin, 2010)

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity. (Kammin, 2010)

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis. (Kammin, 2010)

Systematic planning: A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning. (USEPA, 2006)

References for QA Glossary

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