DEPARTMENT OF ECOLOGY
State of Washington

# Quality Assurance Project Plan

## Pataha Creek Bacteria, Dissolved Oxygen, and pH Total Maximum Daily Load Study

November 2024

Publication 24-03-104

# Publication Information

Each study conducted by the Washington State Department of Ecology must have an approved Quality Assurance Project Plan (QAPP). The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, Ecology will post the study's final report to the Internet.

This QAPP was approved to begin work in July 2024. It was finalized and approved for publication in November 2024.

The final QAPP is available on Ecology's website at https://apps.ecology.wa.gov/publications/SummaryPages/2403104.html.

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This plan was prepared in part by a licensed hydrogeologist. A signed and stamped copy of the report is available upon request.

Data for this project are available in Ecology's EIM Database.[1] Search Study ID: tist0004

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**Federal Clean Water Act 1996 303(d) Listings Addressed in this Study.** See Section 3.3.

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**COVER PHOTO**: Pataha Creek near the mouth, looking downstream from Hwy 261 — photo BY Tighe Stuart.

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[1] https://www.ecology.wa.gov/Research-Data/Data-resources/Environmental-Information-Management-database

# Quality Assurance Project Plan

# Pataha Creek Bacteria, Dissolved Oxygen, and pH Total Maximum Daily Load Study

by Tighe Stuart, Joseph Zimbric, and Pam Marti, L. HG.

November 2024

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# 2.0 Abstract

Data collected from the Pataha Creek watershed show that multiple reaches of Pataha Creek do not meet Washington State water quality standards for bacteria, dissolved oxygen, and pH. This Quality Assurance Project Plan describes data collection, analysis, and computer modeling to confirm these water quality issues' geographic and temporal extent and to identify the pollution reductions needed to address them. This study will also investigate sediment and turbidity to assess whether turbidity listing is warranted.

Sources of pollution contributing to water quality impairments include nonpoint sources, which are diffuse and can result from residential and agricultural activities, and point sources, which are typically facilities that discharge at a particular location. Natural factors can contribute as well, including low flow conditions and a warm local climate. The modeling analysis outlined in this study is designed to differentiate between human versus natural impacts.

This work aims to restore and protect beneficial uses in the Pataha Creek watershed, particularly to improve conditions for aquatic life (salmonids and other species) and for people to recreate (e.g., swim, fish) in these streams. This study will develop bacteria, nutrient, and heat load limits for creeks in the watershed, as necessary, to protect these uses.

The Washington State Department of Ecology will collect bacteria, total suspended solids, turbidity, and flow data from October 2024 to September 2025. We will collect nutrient data and continuous dissolved oxygen, pH, temperature, and conductivity data during the summer of 2025, along with other supporting data types such as air temperature and dew point, effective shade, stream time of travel, and periphyton taxonomy and biomass. In addition, we may collect groundwater data in a reach of interest near Pomeroy during the summer low-flow period if appropriate sample sites can be located. We will use computer models along with statistical and mass-balance analyses to develop pollution limits needed for Pataha Creek and its tributaries to meet water quality standards.

# 3.0 Background

## 3.1 Introduction and problem statement

Data collected from the Pataha Creek watershed demonstrate that Pataha Creek is impaired (does not meet Washington State water quality standards) for bacteria, dissolved oxygen (DO), and pH (See sections 3.2.5 and 3.3). Based on those data, the Washington State Department of Ecology (Ecology) included 15 creek segments in the 2018 303(d) list of impaired waters, as well as in previous 303(d) lists. These impaired waters require a cleanup plan or total maximum daily load (TMDL). The *Tucannon River and Pataha Creek Temperature Total Maximum Daily Load* (Bilhimer et al. 2010) addressed temperature impairments in the Pataha Creek watershed.

This Quality Assurance Project Plan (QAPP), along with the *Programmatic QAPP for Water Quality Impairment Studies* (McCarthy and Mathieu 2017), details data collection, analysis, and modeling to provide the technical basis for determining the TMDLs of pollutants that cause all bacteria, DO, and pH impairments in the Pataha Creek watershed. The goal of this work is to restore and protect beneficial uses in the Pataha Creek watershed, particularly for aquatic life (salmonids and other species) and recreation (e.g., swimming and fishing).

## 3.2 Study area and surroundings

Pataha Creek is a tributary to the Tucannon River in WRIA 35, in southeastern Washington State. The Pataha Creek watershed (Figure 1) drains a 185 $mi^2$ area in Garfield and Columbia counties. Pataha Creek originates on the northern slope of the Blue Mountains in the Umatilla National Forest, flows approximately 53 miles, and enters the Tucannon River about 11 miles above the Tucannon's confluence with the Snake River. There are a number of small tributaries, including Dry Pataha Creek, Sweeney Gulch, Rickman Gulch, Bihmaier Gulch, Brown Gulch, Benjamin Gulch/Crystal Springs, and Tatman/Linville Gulch. Most of the watershed is semi-arid, hilly grassland except for the mountainous, forested headwaters.

Historically, the lower elevation areas were covered with canyon grasslands and shrub-steppe vegetation. Much of this land has now been converted to livestock and crop (mainly non-irrigated crops such as wheat) production. However, irrigated farmland (primarily pasture) can be found immediately bordering the stream. Coniferous forests still dominate the higher elevations of the Blue Mountains; much of this area is under state or federal ownership. Land use in the watershed is primarily rural, with few urban areas. The city of Pomeroy is the most populated area in the watershed, with a population of 1,397 in 2020.

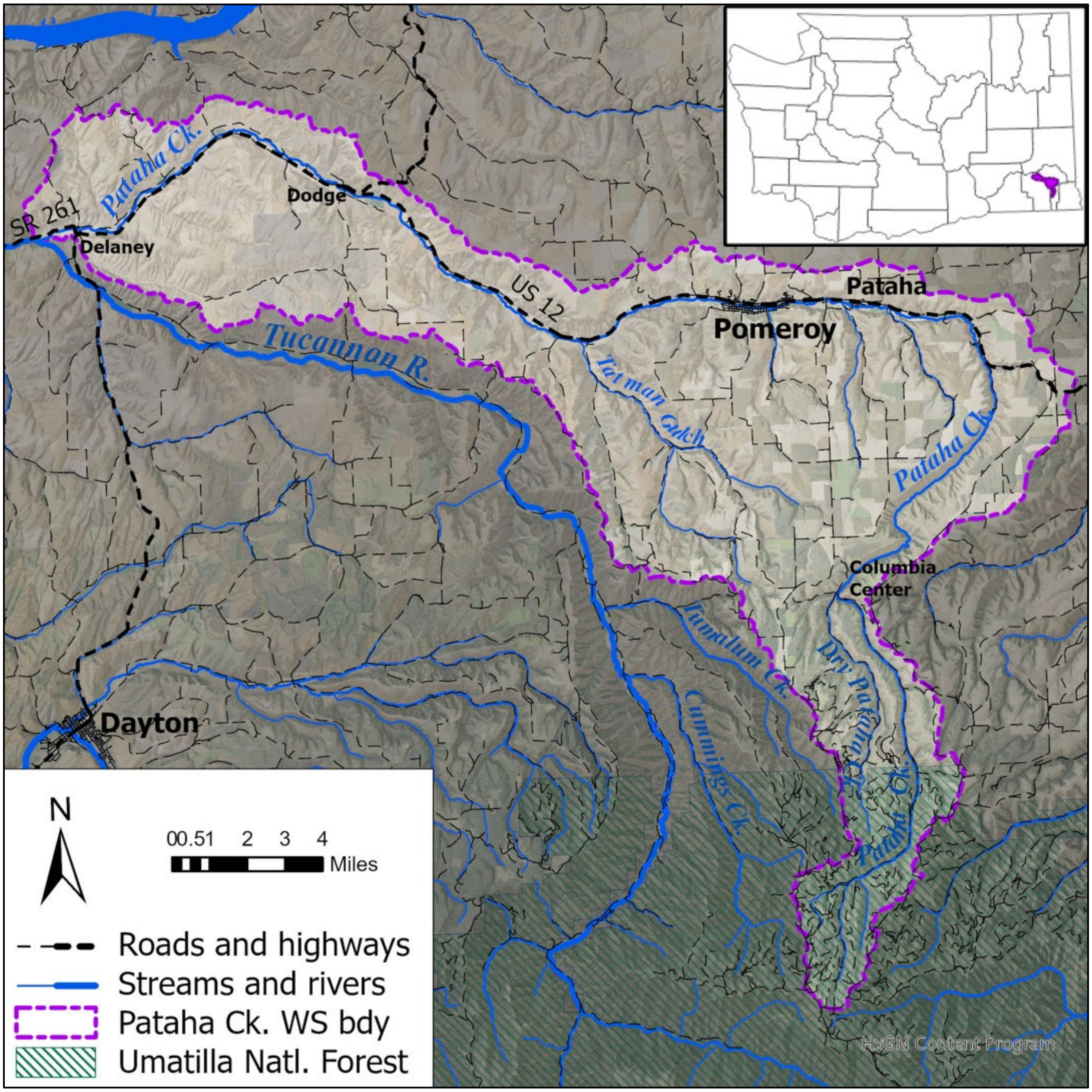


**Figure 1. Map of Pataha Creek watershed in SE Washington.**

### 3.2.1 History of study area

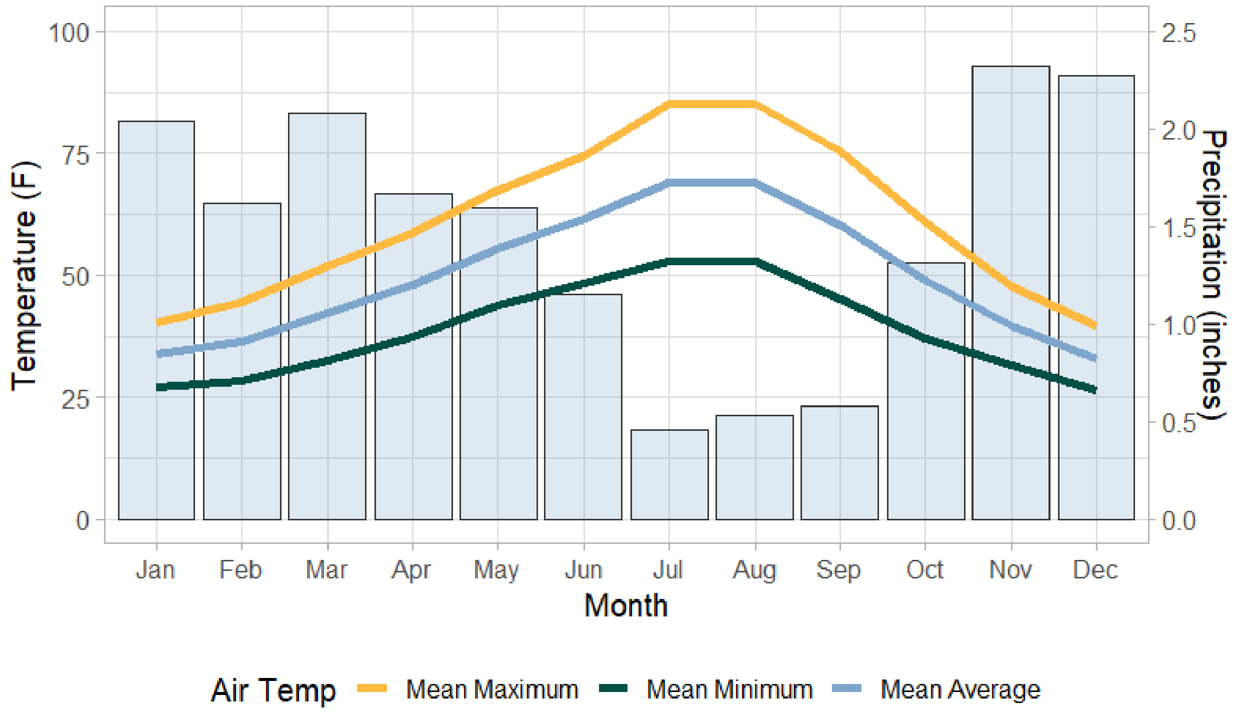
The Pataha Creek watershed sits near the historical boundary between areas inhabited by the Nez Perce, Cayuse, Walla Walla, and Umatilla peoples. The name “Pataha” comes from the Nez Perce word for “brush,” a reference to dense brush that grew along the creek. The indigenous peoples of this region lived a semi-nomadic lifestyle, which was notable for seasonal travels across the Rocky Mountains to hunt buffalo in the great plains. A trail roughly followed the route of present-day Hwy 12. This trail was a major regional thoroughfare used by tribes, including the Nez Perce, Umatilla, Cayuse, Walla Walla, Klickitat, and Yakama (Kuykendall 1955).

Historically, Beaver activity may have played an important role in Pataha Creek, with beavers still active in some areas (Bennett et al. 2015).

Euro-American exploration of the area included the Lewis and Clark expedition, which crossed Pataha Creek near the present-day location of Pomeroy during the 1806 return trip. Settlement began in earnest during the 1870s – 1880s, with the town of Pomeroy established in 1878. Early settlers mainly practiced cattle ranching or vegetable farming. Wheat farming became prominent in the following decades. During the 20th century, peas and grass seed became important crops alongside wheat. Today, agricultural production and storage continue to underpin the economy of the Pataha Creek watershed (Walsh 2022).

### 3.2.2 Climate and hydrology

The Pataha Creek watershed is mostly semi-arid, with most of the low-elevation western and central parts receiving between 14 and 18 inches of precipitation per year. The town of Pomeroy receives around 17 inches per year. The eastern and southern parts of the watershed are wetter, with some areas in the Blue Mountains headwaters receiving as much as 39 inches per year. Figure 2 presents typical monthly temperature and precipitation data for Pomeroy.

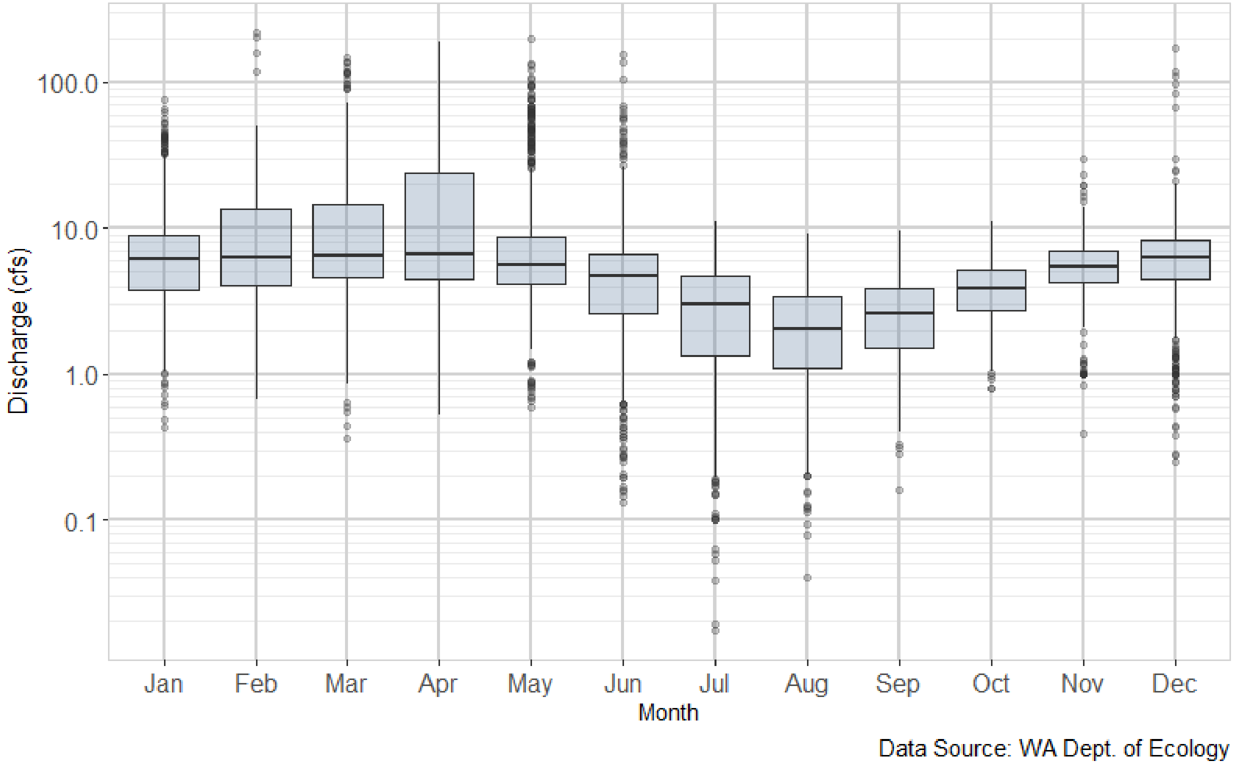


Data source: NOAA

**Figure 2. Mean monthly temperature and precipitation data for Pomeroy, WA, 1991 – 2020.**

The Department of Ecology has maintained a continuous stream gage near the mouth of Pataha Creek since 2003. Mean annual flow (MAF) in Pataha Creek is 8.7 cfs. However, the flow regime shows a distinct seasonal pattern that can be highly variable from year to year. Peak flows are typically observed during April and decrease to the annual low flow condition in

August (Figure 3). The watershed is prone to flashy events that produce short-lived high flows of more than 150 cfs.



Data Source: WA Dept. of Ecology

**Figure 3. Monthly flow statistics for Pataha Creek near the mouth (35F050), 2003 – 2024.**

### 3.2.3 Geology and hydrogeology

The Pataha Creek watershed, like most of the surrounding Columbia Basin and Blue Mountains regions, is underlain by the Miocene rock of the Columbia River Basalt Group. These basalt flows covered much of eastern Washington and northern Oregon during a series of events beginning about 17 million years ago and lasting until about 6 million years ago. The Blue Mountains began uplifting around 12 to 10 million years ago, during which time streams and rivers carved deep canyons through the basalt and, in some cases, into the older rocks beneath. The most recent basalt flows, which occurred after the Blue Mountains formed, did not cover the mountains but rather lapped along the edges of the new mountain range (DNR 2024).

Many upland areas of the Pataha Creek watershed are covered in a thick layer of wind-deposited loess soils of the Palouse Formation. Valley bottoms, including much of the Pataha Creek valley, are covered in a layer of alluvium. These Quaternary deposits are underlain by the Miocene Wanapum Basalt, including the Roza and Frenchman Springs Members (Hooper and Gillespie 1996).

A series of vertical faults that trend northeast to north-northeast cuts across the Pataha Valley in the vicinity of the towns of Pomeroy and Pataha. These include the northern end of the Hite Fault. Each of these faults represents a substantial offset in the corresponding basalt layers on either side.

Limited data regarding the hydrogeology of Pataha Creek are available. However, some area well logs indicate that the groundwater near the creek is shallow, approximately 5 to 13 feet below the ground surface. There are also some local springs (Bihmaier Springs and Butler Springs), which may be associated with the area faults. The shallow groundwater and area springs appear to contribute groundwater inflows to Pataha Creek in the Pataha-Pomeroy area.

Limited flow data collected by Ecology in 1991 and by Washington State University (WSU) in 2003 – 2006 (Figure 4) seem to indicate that low summertime baseflows (< 2 cfs) occur in the headwaters and canyon areas. Large flow gains from groundwater occur in the Pataha-Pomeroy area, as much as tripling the streamflows during summertime. The reach from Pomeroy to the confluence with the Tucannon River appears to be a losing reach, with the highest summertime flows occurring at the town of Pomeroy. There may also be seasonal effects on flow from irrigation pumping withdrawals (Ullman and Barber 2009).

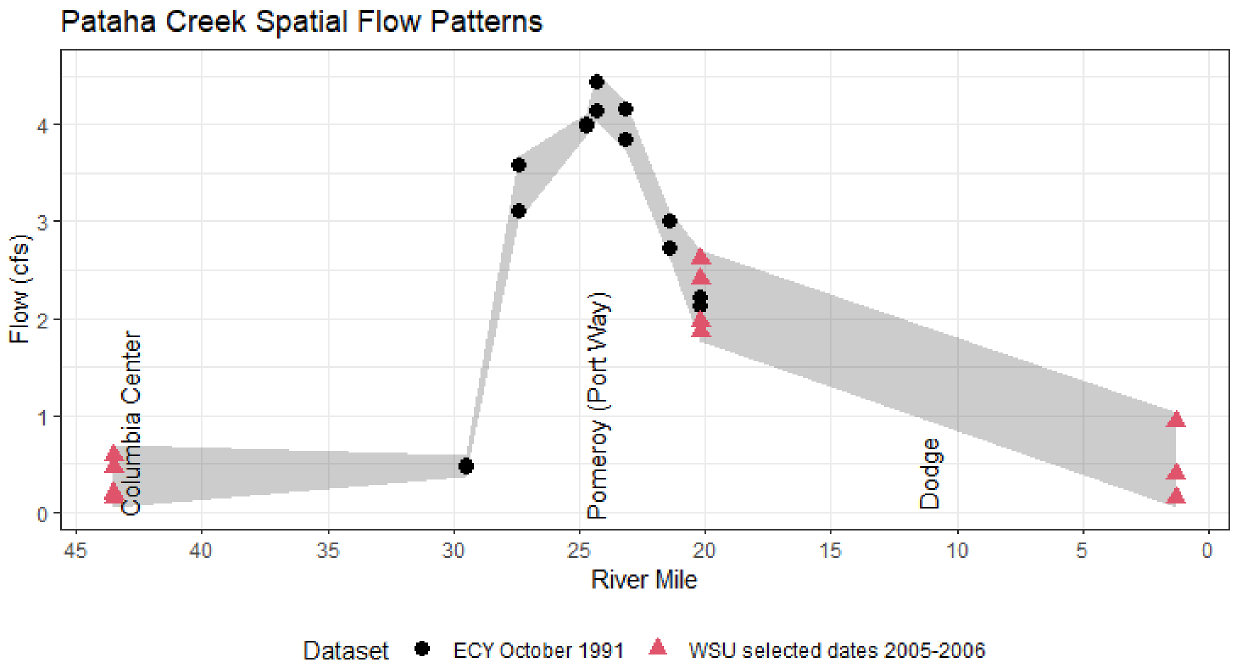


**Figure 4. Spatial flow patterns in Pataha Creek, based on Ecology 1991 and WSU 2003 – 2006 datasets.**

Selected dates 2005 – 2006 represent low flow condition.

### 3.2.4 Land use

Figure 5 shows land use patterns in the Pataha Creek watershed. Most of the lower and middle watershed is situated in the Dissected Loess Uplands ecoregion (Clarke and Bryce 1997). The dissected landscape and relatively shallow soils limit cultivated crop production's footprint, accounting for approximately 36% of the total watershed area. Grassland for livestock grazing is the dominant land use, accounting for 50% of the total area. The headwaters of the Pataha Creek watershed reside in the Mesic Forest Zone of the Blue Mountains (7%). The USFS manages them for multiple uses, including fish and wildlife habitat, livestock grazing, and timber production. Urban development occupies 1% of the watershed.

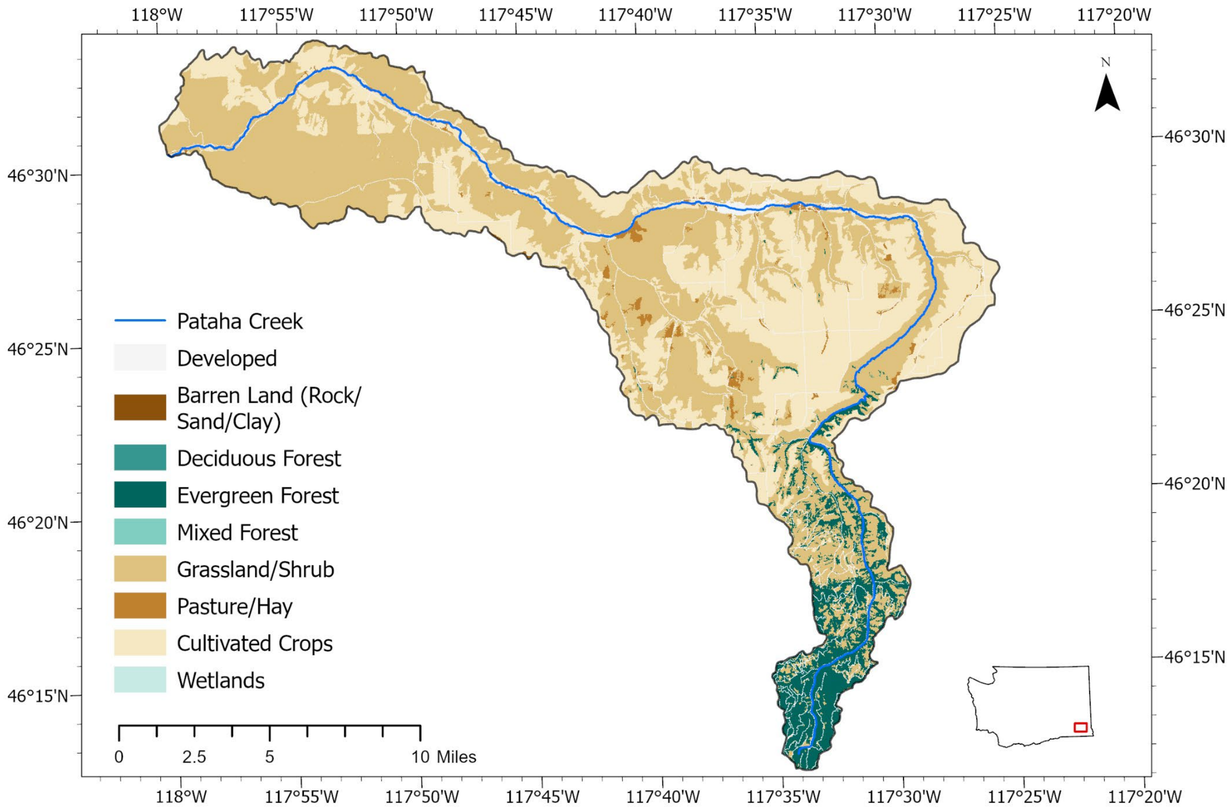


**Figure 5. 2021 National Land Cover Database, Pataha Creek Watershed.**

### 3.2.5 Summary of previous studies and existing data

Water quality in Pataha Creek has been sparsely studied compared to many areas in Washington State. Few data exist, and most of the existing data are at least 15 years old. One exception to this is stream flow and temperature at the mouth of Pataha Creek, which Ecology monitors continuously. The following sources of data exist, from newest to oldest. These data are available at Ecology's stream gaging webpage[2] or in EIM[3].

- **Ecology stream gage** — Ecology operates a stream gage near the mouth of Pataha Creek at Hwy 261. This gage has operated from 2003 to the present and records continuous streamflow and stage, as well as water and air temperature. (Gage ID 35F050)
- **Ecology ambient water quality monitoring** — Ecology's ambient monitoring program collected monthly water quality data near the mouth of Pataha Creek during Water Years (WY) 2009 and 2010. These data included nutrients, fecal coliform, total suspended solids, and other measurement parameters. (Search EIM Study ID AMS001; Location ID 35F050)
- **Ecology channel surveys** — Ecology collected channel geometry data at 17 locations on Pataha Creek during August 2008. (These data are not in EIM, as EIM does not support this data type.)

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[2] https://apps.ecology.wa.gov/continuousflowandwq/

[3] https://apps.ecology.wa.gov/eim/search/default.aspx

- **Garfield Co. riparian restoration study** — Washington State University (WSU), along with Pomeroy Conservation District (PCD), collected fecal coliform, total suspended solids, streamflow measurements, and other water quality data at three locations in Pataha Creek (as well as locations in other nearby watersheds) from February 2003 – January 2007. (Search EIM Study ID G0300114)
- **Effectiveness monitoring on Alpowa, Deadman, & Pataha creeks** — Ecology collected fecal coliform, nutrients, total suspended solids, and other water quality data at three locations in Pataha Creek (as well as locations in other nearby watersheds) during April – December 2002. (Search EIM Study ID KB0035EM)
- **Pataha Creek TMDL** — Ecology collected data at nine locations near Pomeroy WWTP during a single sampling event in 1991. Data included flow, fecal coliform, nutrients, total suspended solids, AM and PM dissolved oxygen, and other water quality data. (Search EIM Study ID BCUS0001)

Figure 6 presents Ecology ambient water quality monitoring data for the mouth of Pataha Creek (35F050), organized as seasonal boxplots for several key parameters.

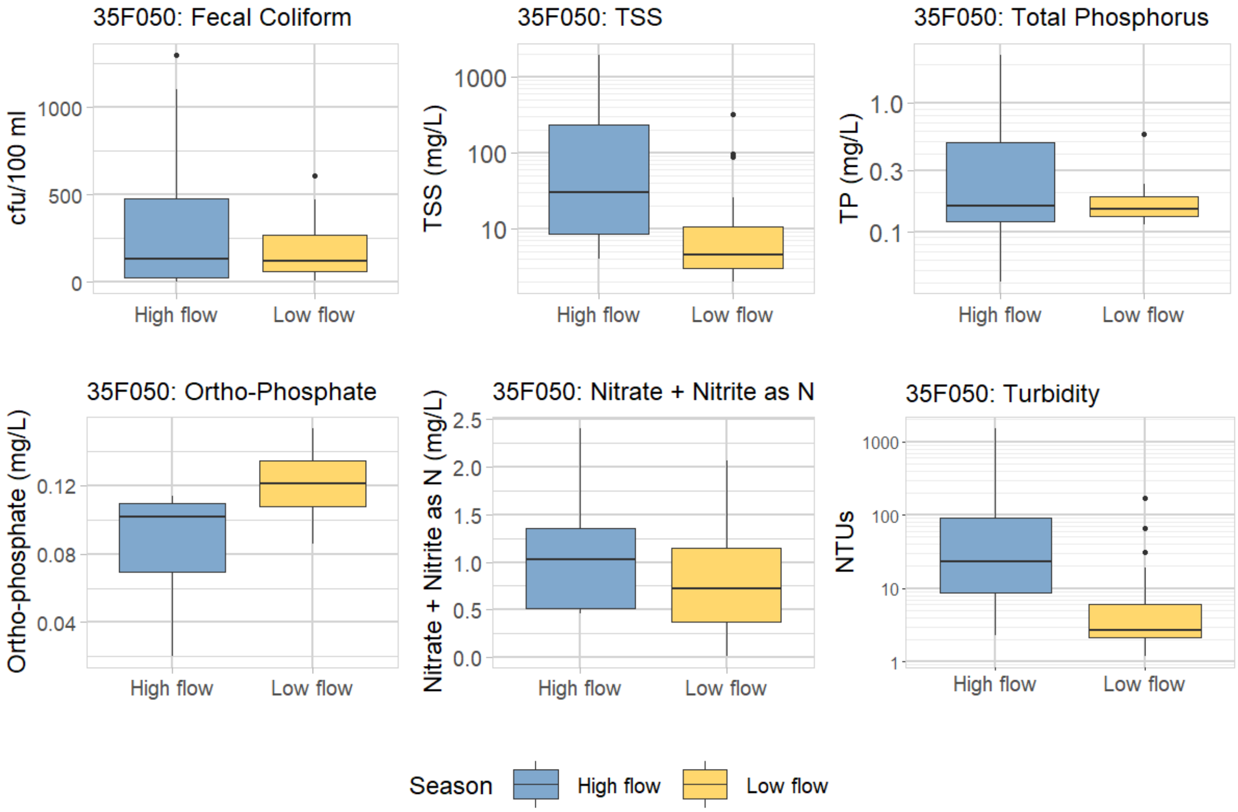

**Figure 6. Pataha Creek at mouth ambient monthly water quality data for WY 2009 – 2010.** High flow season: Feb – May; Low flow season: Jun – Jan; TSS: total suspended solids; TP: total phosphorus; NTU: nephelometric turbidity units.

### 3.2.6 Parameters of interest and potential sources

The primary parameters of interest in this study are E. coli bacteria, dissolved oxygen (DO), and pH. Additional parameters are of interest because they can drive impairments of E. coli, DO, and pH. These include temperature, nitrogen, phosphorus, and biochemical oxygen demand (BOD). Some of these parameters may serve as surrogates for the primary parameters in the final TMDL. The *Programmatic QAPP for Water Quality Impairment Studies* (McCarthy and Mathieu 2017) includes additional discussion of potential sources for these parameters.

Suspended sediment and turbidity are also parameters of interest. Currently, 303(d) listings for turbidity have not been established because listing for turbidity requires determining background levels. However, high TSS (6 of 24 results > 50 mg/L; max value 1960 mg/L) and high turbidity (9 of 27 results > 20 NTU; max value 1500 NTU) results (see Figure 6) indicate that sediment and turbidity are likely an issue in Pataha Creek. High sediment and turbidity occur during the high-flow season and are likely linked to precipitation and runoff events.

### Water temperature increases and potential sources

Although water temperature is not a directly regulated parameter for this TMDL study, temperature is a key determinant of DO levels. Temperature impairments in Pataha Creek were addressed by the *Tucannon River and Pataha Creek Temperature Total Maximum Daily Load* (Bilhimer et al. 2010). Potential sources of water temperature increases include the following:

- Loss of riparian shade resulting in more direct solar radiation reaching the stream surface. This loss can be due to land use changes in the riparian zone immediately adjacent to the stream channel, affecting vegetation species, height, abundance, and quality.
- Changes to channel morphology. Pataha Creek has undergone substantial degradation from the removal of riparian vegetation and channel modification, resulting in significant erosion and channel incision. This incision has disconnected the creek from its floodplain and resulted in reduced riparian function, which is less able to protect water quality from land uses in the surrounding areas. The bank tops outside the incision are now well removed from the water table and are less able to support riparian vegetation.
- Loss of baseflow due to water withdrawals and floodplain disconnection, which can reduce the amount of cool groundwater or upstream surface water, increasing the stream's bulk mixed temperature and making the stream shallower and more susceptible to warming from solar radiation.
- Loss of floodplain/hyporheic connectivity and channel complexity due to the development and modification of stream channels, including straightening, dredging, and bank armoring.
- Increased air temperatures due to climate changes or loss of riparian buffer microclimate effects.

### Dissolved oxygen decreases and potential sources

Depressed stream oxygen levels can harm aquatic life, particularly salmonids and aquatic insects. Potential mechanisms and sources of decreased DO include the following:

- Increases in stream temperature due to sources described above. Colder water can hold more dissolved oxygen than warmer water.
- Increases in dissolved instream nutrient concentrations (inorganic phosphorus, nitrate-nitrite, and ammonia), which fuels short-term, often direct, algae growth increases, resulting in increased oxygen consumption from biological respiration.

- Increases in particulate organic matter loading (which includes particulate organic carbon, nitrogen, and phosphorus) to the sediment bed, which is broken down by organisms in the sediment layer or hyporheic zone over a longer period, resulting in increased oxygen consumption from biological respiration (sediment oxygen demand).
- Increase in carbonaceous biochemical oxygen demand (CBOD) due to readily degradable organic carbon loading to the water column.
- Discharge of water with depressed oxygen levels (for example, groundwater or flushing of stagnant water).
- The sources and pathways of these nutrients and low DO water are complex and numerous but can include the following:
    - Application of chemical or organic fertilizers above plant requirements.
    - Pet, livestock, or other domestic animal waste.
    - Wildlife waste.
    - Decomposing organic matter on surfaces, in soils, or in stagnant water.
    - Stormwater infrastructure is a pathway that can potentially short-circuit normal transport and biochemical cycles and result in the discharge of any of the above sources.
    - Atmospheric deposition is another pathway that can result in the import of nutrients through either wet or dry deposition.
    - Wastewater discharge from sanitary sewer overflows or on-site septic systems.

### Bacteria

Escherichia coli (E. coli) and fecal coliform (FC) are both forms of coliform bacteria that indicate the presence of fecal contamination from a warm-blooded animal. These types of bacteria can cause sickness and disease in humans and pets. As of December 2020, Chapter 173-201A WAC designates E. coli as the primary indicator to protect water contact recreation due to the strong correlation with illness from waterborne diseases. Sources of bacteria can include the following:

- Pet waste from parks and residential areas.
- Wildlife waste, including mammals and waterfowl.
- Range and pastured livestock with access to stream or livestock manure applied to fields.
- Municipal and industrial wastewater and stormwater discharges.
- Failing on-site septic systems.

### Sediment/turbidity

Turbidity in the water column and sediment that has settled out on the river bottom can affect fish and other aquatic life. The effects of turbidity, sediment, and solids on fish and other aquatic life can be divided into four categories: (1) acting directly on the fish swimming in the water and either killing them or reducing their growth rate, resistance to disease, etc.; (2) preventing the successful development of fish eggs and larvae; (3) modifying behavior, natural movements, and migrations; and (4) reducing the abundance of available food (Joy et al. 2009). The effects of sediment on aquatic life tend to be a function of both concentration and duration (Newcombe and McDonald 1991). Sources of sediment and turbidity can include the following:

- Eroding stream banks. Bank erosion can be caused or exacerbated by several factors:
    - Loss of riparian vegetation, which stabilizes and protects stream banks.
    - Hydrograph modification, where degraded floodplain and wetland function result in more "flashy" high flow events. Significant erosion can occur during these events.
    - Stream banks being trampled and disturbed by livestock or wildlife.
- Tillage practices that leave fields bare during the winter and springtime runoff season, without plant roots or residue to stabilize the soil, leading to field erosion.
- Stormwater from urban areas and roads

### Permitted point sources

Table 1 identifies permitted point source discharges in the Pataha Creek watershed. Pomeroy Wastewater Treatment Plant (WWTP) discharges to Pataha Creek shortly downstream of the Port Way bridge at approximately RM 24. All other permitted sources are either stormwater or sand and gravel sources. There are no industrial stormwater sources, or active construction stormwater permits.

Pomeroy has a Municipal Separate Storm Sewer System (MS4) with at least 29 outfalls to Pataha Creek (Appendix C). As a small, rural town, Pomeroy is not included in the Phase II municipal stormwater permit. Stormwater discharges from Pomeroy's MS4 system are considered nonpoint pollution for regulatory purposes.

**Table 1. Permitted point source discharges.**

| WQ Permit No. | Facility Site Name | Permitted Receiving Water (Surface) | Facility/Permit Type |
|---|---|---|---|
| WA0021164 | Pomeroy WWTP | Pataha Creek | Municipal NPDES IP |
| WAG507173 | WSDOT QS-GA-68 Dixon Quarry | None | Sand & Gravel GP |
| WAR043000 | WSDOT Stormwater GP | Pataha Creek, Sweeney Gulch | Muni SW GP |

GP: General Permit
NPDES IP: National Pollutant Discharge Elimination System Individual Permit
WQ: Ecology's Water Quality Program
WWTP: Wastewater Treatment Plant
WSDOT: Washington State Department of Transportation

## 3.2.7 Regulatory criteria or standards

Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201A-200) establish beneficial uses of waters and incorporate specific numeric and narrative criteria. The criteria are intended to define the level of protection necessary to support the beneficial uses. WAC 173-201A-600 and WAC 173-201A-602 list the use designations for specific areas, while WAC 173-201A-200 lists the criteria for specific parameters.

The designated uses of the waters in the study area in the Pataha Creek watershed include the following:

- **Aquatic Life Uses:**
    - *Char spawning and rearing* (Pataha Creek, Dry Pataha Creek, and all tributaries upstream of Dry Pataha Creek confluence at Columbia Center) — The key identifying characteristics of this use are spawning or early juvenile rearing by native char (bull trout and Dolly Varden), or use by other aquatic species similarly dependent on such cold water. Other common characteristic aquatic life uses for waters in this category include summer foraging and migration of native char and spawning, rearing, and migration by other salmonid species.
    - *Salmonid spawning, rearing, and migration* (Pataha Creek and all tributaries downstream of Dry Pataha Creek confluence at Columbia Center) — The key identifying characteristic of this use is salmon or trout spawning and emergence that only occurs outside of the summer season (September 16 – June 14). Other common characteristic aquatic life uses for waters in this category include rearing and migration by salmonids.
- **Recreation Use:** *Primary contact recreation.*
- **Water Supply Uses:** *Domestic, Industrial, Agricultural, Stock.*
- **Miscellaneous Uses:** *Wildlife Habitat, Harvesting, Commerce and Navigation, Boating, Aesthetics.*

Table 2 outlines the criteria for protecting the aquatic life and primary contact uses.

**Table 2. Designated beneficial uses and associated criteria.**

| Parameter | Beneficial Use | Criteria |
|---|---|---|
| Dissolved Oxygen | Aquatic Life — Char spawning and rearing | Water column 1-Day minimum greater than or equal to 10 mg/L or 90% saturation [a] |
| Dissolved Oxygen | Aquatic Life — Salmonid spawning, rearing, and migration | Water column 1-Day minimum greater than or equal to 10 mg/L or 90% saturation [a] |
| pH | Aquatic Life — Char spawning and rearing | Within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.2 units. |
| pH | Aquatic Life — Salmonid spawning, rearing, and migration | Within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.5 units. |
| Turbidity | Aquatic Life — Char spawning and rearing | Not to exceed:<br>5 NTU over background when the background is 50 NTU or less; or<br>• 10% increase when background is greater than 50 NTU |
| Turbidity | Aquatic Life — Salmonid spawning, rearing, and migration | Not to exceed:<br>• 10 NTU over background when the background is 50 NTU or less; or<br>• 20% increase when background is greater than 50 NTU |
| *E. coli* | Primary Contact Recreation | *E. coli* organism levels within a 3-month averaging period [b] must not exceed a geometric mean value of 100 CFU or MPN per 100 mL, with not more than 10% of all samples (or any single sample when less than 10 samples exist) obtained within the averaging period exceeding 320 CFU or MPN per 100 mL. |

[a] Intragravel dissolved oxygen (DO) criteria for these aquatic life use categories may be used for compliance. When intragravel DO is used for compliance, the intragravel DO (1-day minimum) concentration must be 8.0 mg/L or greater, and the DO water column (1-day minimum) concentration must be 9.0 mg/L or greater. Intragravel DO must be measured as a spatial median within the same habitat area.

[b] A minimum of three samples collected at well-distributed times within the averaging period is needed to calculate a geometric mean to compare to criteria. Averages should be calculated within the same season.

## 3.3 Water quality impairment studies

This study will be completed as a TMDL to address DO, pH, and bacteria impairments. The following section generally describes the elements of a TMDL.

### What is a Total Maximum Daily Load (TMDL)?

A TMDL is a numerical value representing the highest pollutant load a surface water body can receive and still meet Water Quality Standards. Any amount of pollution over the TMDL level needs to be reduced or eliminated to achieve clean water.

### Federal Clean Water Act Requirements

The Clean Water Act established a process to identify and clean up polluted waters. The Clean Water Act requires each state to have its own Water Quality Standards designed to protect, restore, and preserve water quality. Water quality standards consist of (1) a set of designated uses for all water bodies, such as salmon spawning, swimming, and fish and shellfish harvesting; (2) numeric and narrative criteria to achieve those uses; and (3) an antidegradation policy to protect high-quality waters that surpass these conditions.

### The Water Quality Assessment (WQA) and the 303(d) List

Every two years, states are required to prepare a list of water bodies that do not meet Water Quality Standards. This list is called the Clean Water Act Section 303(d) list. This list is part of the Water Quality Assessment (WQA) process in Washington State. To develop the WQA, the Washington State Department of Ecology (Ecology) compiles its own water quality data and data from local, state, and federal governments, tribes, industries, and citizen monitoring groups. All data in this WQA are reviewed to ensure that they were collected using appropriate scientific methods before they are used to develop the assessment. The list of waters that do not meet standards [the 303(d) list] is the Category 5 part of the larger assessment.

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

- **Category 1** — Waters that meet standards for the parameter(s) for which they have been tested.
- **Category 2** — Waters of concern.
- **Category 3** — Waters with no data or insufficient data available.
- **Category 4** — Polluted waters that do not require a TMDL because of the following:
  - 4a — Have an approved TMDL being implemented.
  - 4b — Have a pollution-control program in place that should solve the problem.
  - 4c — Are impaired by a non-pollutant such as low water flow, dams, and culverts.
- **Category 5** — Polluted waters that require a TMDL — the 303(d) list.

Further information is available at Ecology's Water Quality Assessment website.[4] The Clean Water Act requires that a TMDL be developed for each water body on Category 5 of the 303(d) list.

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[4] https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Assessment-of-state-waters-303d

### Listings to be addressed by this TMDL study

Table 3 lists the Category 5 [303 (d) listings] and Category 2 designations for bacteria, dissolved oxygen, and pH in the Pataha Creek watershed. The exact geographical locations of these listings were likely influenced heavily by the vagaries of past sampling efforts, such as where sample sites were located and what time of day sampling occurred. (Low DO is most likely to occur in the early morning, and high pH is most likely in the afternoon.) Furthermore, the data that led to these listings are typically at least 15 years old. Therefore, a key goal of the data collection will be to confirm and define the real-world geographic extent of the water quality impairments.

Bacteria impairments were defined in terms of fecal coliform. The current *E. coli* standard replaced the old fecal coliform standard in 2020. TMDLs for bacteria will be in terms of *E. coli.*

There are currently no turbidity listings in the Pataha Creek watershed. The turbidity criteria require defining a background level, meaning turbidity listings do not happen automatically during the WQA process and typically only occur when Ecology or a stakeholder group actively pursues this. Turbidity values over 1000 NTU and total suspended solids values over 1000 mg/L have been observed near the mouth of Pataha Creek (Location ID 35F050; see Figure 6), indicating that turbidity and sediment likely are a problem in this watershed. Data collected during this study will help Ecology determine whether and where to pursue listing Pataha Creek for turbidity.

**Table 3. Bacteria, DO, and pH impairments listed for the Pataha Creek watershed.**

| Listing # | Listing Category | Parameter | Water Body | NHD Reach Code |
|---|---|---|---|---|
| 10454 | 5 | Bacteria — Fecal coliform | PATAHA CREEK | 17060107000163 |
| 10459 | 5 | Bacteria — Fecal coliform | PATAHA CREEK | 17060107000167 |
| 16797 | 5 | Bacteria — Fecal coliform | PATAHA CREEK | 17060107000140 |
| 40548 | 5 | Bacteria — Fecal coliform | PATAHA CREEK | 17060107000133 |
| 40549 | 5 | Bacteria — Fecal coliform | PATAHA CREEK | 17060107000145 |
| 40550 | 5 | Bacteria — Fecal coliform | PATAHA CREEK | 17060107000152 |
| 40551 | 5 | Bacteria — Fecal coliform | PATAHA CREEK | 17060107000174 |
| 40552 | 5 | Bacteria — Fecal coliform | PATAHA CREEK | 17060107000180 |
| 47211 | 5 | Dissolved Oxygen | PATAHA CREEK | 17060107000174 |
| 47212 | 5 | Dissolved Oxygen | PATAHA CREEK | 17060107000180 |
| 11141 | 5 | pH | PATAHA CREEK | 17060107000140 |
| 42566 | 5 | pH | PATAHA CREEK | 17060107000133 |
| 42567 | 5 | pH | PATAHA CREEK | 17060107000163 |
| 42568 | 5 | pH | PATAHA CREEK | 17060107000174 |
| 50519 | 5 | pH | PATAHA CREEK | 17060107000180 |
| 8160 | 2 | Bacteria — Fecal coliform | PATAHA CREEK | 17060107000164 |
| 10458 | 2 | Bacteria — Fecal coliform | CRYSTAL SPRING | 17060107001174 |
| 10460 | 2 | Bacteria — Fecal coliform | PATAHA CREEK | 17060107000172 |
| 47209 | 2 | Dissolved Oxygen | PATAHA CREEK | 17060107000133 |
| 47210 | 2 | Dissolved Oxygen | PATAHA CREEK | 17060107000163 |

DO: dissolved oxygen.
NHD: National Hydrography Dataset

# 4.0 Project Description

The purpose of this TMDL study is to address water quality impairments in the Pataha Creek watershed for DO, pH, bacteria, and possibly turbidity. This work will align with the already-established *Tucannon River and Pataha Creek Temperature Total Maximum Daily Load* (Bilhimer et al. 2010), which addressed temperature impairments. All these efforts aim to restore Pataha Creek and its tributaries to meet Washington State water quality standards, thereby protecting the beneficial uses these waterways can provide to humans, fish, other aquatic life, and wildlife.

## 4.1 Project goals

The major goals of this project are to do the following:

- Verify and define the representative geographical and temporal extent of DO, pH, and bacteria impairments.
- Complete TMDL assessments to address all DO, pH, and bacteria impairments in the Pataha Creek watershed.
- Assess the extent of sediment and turbidity problems to help determine whether and where it is warranted to pursue 303(d) listing for turbidity. If applicable, complete TMDL assessments to address turbidity impairments.

## 4.2 Project objectives

The project goals will be met by achieving the following objectives:

- Collect one year of bacteria (E. coli and fecal coliform[5]), total suspended solids, turbidity, and streamflow data at locations throughout the Pataha Creek watershed.
- Collect one summer of DO, pH, nutrient, and other data needed to assess DO and pH impairments.
- Collect groundwater data in the gaining reach near Pataha-Pomeroy (if resource and logistical considerations allow).
- Assess bacteria (and, as applicable, sediment/turbidity) using a statistical rollback and mass balance approach.
- Assess DO and pH using a mechanistic modeling approach tailored to small streams. This will likely require defining a natural condition for DO, pH, and related parameters.
- Provide technical assistance to WQP, as needed, to establish wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources that, when fully implemented, will result in Pataha Creek and its tributaries meeting water quality standards.

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[5] The laboratory method for analyzing E. coli bacteria also produces fecal coliform results as an earlier step in the analysis (see Section 9.1). Therefore, submitting a water sample for E. coli analysis means receiving results for both E. coli and fecal coliform. The fecal coliform results are not central to this project but may be useful for comparison to past data.

## 4.3 Information needed and sources

### Information to be collected as part of the field study or other Ecology sources

- Year-round E. coli, total suspended solids, turbidity, and streamflow data
- Summertime nutrient, alkalinity, and carbonaceous biochemical oxygen demand (CBOD) data, including at reference location(s).
- Continuous water temperature data
- Continuous air temperature and dew point data at selected locations
- Continuous streamflow and turbidity data at three locations
- Continuous DO and pH data at two locations and short-term continuous (diel) summertime DO and pH data at the remaining locations
- Effective shade estimates (these were not obtained during the Temperature TMDL study)
- Stormwater characterization from the City of Pomeroy, including E. coli, fecal coliform, total suspended solids, and nutrients
- Summertime groundwater data, including nutrients, alkalinity, temperature, conductivity, pH, and DO, to characterize the large groundwater inflows in the Pataha-Pomeroy area. (~RM 24-30; see Figure 4)
- Summertime system time-of-travel data

### Information that can be obtained from existing sources

- Weather data other than local temperature and dew point — e.g., wind speed, cloud cover, and long-term temperature and dew point
- Stream channel geometry data (Ecology 2008 channel survey data)
- GIS Lidar DSM and DTM layers
- GIS Orthophoto layers
- As much information as possible about historical/natural conditions of Pataha Creek, including pre-agricultural channel morphology, riparian vegetation, etc. (In practice, this type of information is often limited.)

## 4.4 Tasks required

This section provides a high-level overview of the tasks required. Section 7 presents the study design in detail.

### Field and data management tasks

- Collect surface water samples (E. coli/Fecal Coliform, TSS), field water quality measurements (DO, pH, conductivity, temperature, turbidity), and flow measurements from 19 sites twice monthly from October 2024 to September 2025.
- Collect additional surface water samples for nutrients, alkalinity, and CBOD twice monthly, July – September 2025, including 1 – 2 reference locations.
- If resource and logistical considerations allow, collect shallow groundwater samples and measurements three times during the summer of 2025 in the strongly gaining reach near Pataha-Pomeroy (nutrients, alkalinity, DO, pH, conductivity, temperature). This can be

accomplished using any combination of surface springs, existing shallow wells, and either a PushPoint sampler or instream piezometers in identified groundwater discharge areas.

- As weather allows, collect stormwater samples (E. coli/Fecal Coliform, TSS, nutrients) from a subset of MS4 outfalls in the City of Pomeroy.
- Deploy multiprobe sondes at all mainstem Pataha Creek locations three times from July to September 2025 for ~72 hours per deployment. Also deploy sondes at tributary locations as time and instrument resources allow.
- Deploy temperature dataloggers at all sample locations from April to October 2025, except possibly for locations where the temperature is already being collected by another instrument (e.g., multiprobe sonde, pressure transducer).
- Log continuous stage at two locations using pressure transducers for the entire year duration of the project. Develop stage-discharge rating and estimate continuous streamflow. (The third location where continuous flow is needed is at an existing stream gage operated by Ecology.)
- Deploy turbidity dataloggers (stand-alone or station-attached) at the three continuous flow locations.
- Deploy multiprobe sondes at two locations for long-term continuous monitoring from April to October 2025.
- Collect near-stream air temperature and dew point data from at least 3 locations from April to October 2025. In addition, find at least one location with excellent riparian vegetation cover and deploy one air/dew point logger inside and one outside the riparian vegetation zone to estimate the effect of the vegetation on riparian microclimate.
- Collect and analyze hemispherical riparian canopy photos during leaf-on conditions in the summer of 2025 at all sampling locations and any additional sites where practical.
- Conduct at least one time-of-travel dye study during low-flow summertime conditions.
- Conduct a thorough QA/QC review of all data collected
- Load all data collected into EIM

### Analytical tasks

- Conduct GIS tasks to support analysis, including finding the boundaries of the contributing subbasins for each sampling location, and high-resolution delineation of the course of Pataha Creek.
- Analyze E. coli data using the statistical rollback method or mass balance approach.
- Analyze springtime turbidity/sediment data using the mass balance approach.
- Investigate the applicability of the existing shade model used for the *Tucannon River and Pataha Creek Temperature Total Maximum Daily Load*, to see if it can adequately provide current and potential shade estimates for the PointWQ modeling effort. If not, then build an improved shade model using Lidar, which was not available at the time of the 2010 temperature TMDL.
- Build and calibrate PointWQ models for sampling locations, as appropriate, to analyze DO, pH, nutrients, algal productivity, and BOD/SOD.
- Develop model scenarios to estimate pollutant loading capacity and explore pre-human development, climate change, and future growth.

- Write, obtain reviews, finalize, and publish a technical report detailing the findings of this study.
- If needed, provide technical assistance to the Water Quality Program (WQP) to develop performance-based natural conditions water quality criteria (Ecology 2024b), or site-specific criteria.
- Provide technical assistance to WQP, as needed, to develop load and wasteload allocations. Draft appendices D and E for the water quality improvement report developed for TMDL submittal. These tasks may occur outside the project timeline presented in Section 5.4 after the project report has been published.

## 4.5 Systematic planning process

This project was designed with input from Ecology's Water Quality and Environmental Assessment Programs during an extended scoping process during late 2023 – early 2024 (Weathered and Stuart 2024).

This QAPP, in combination with the *Programmatic QAPP for Water Quality Impairment Studies* (McCarthy and Mathieu 2017) and the extended scoping process, represents the systematic planning process for this study.

# 5.0 Organization and Schedule

## 5.1 Key individuals and their responsibilities

Table 4 shows the responsibilities of those involved in this project.

**Table 4. Organization of project staff and responsibilities.**

| Staff[1] | Title | Responsibilities |
|---|---|---|
| Jennie Weathered<br>Water Quality Program<br>Eastern Regional Office<br>Phone: 509-601-0898 | EAP Client | Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP. Coordinates with external stakeholders. Provides field support. Reviews the draft technical report. Co-develops draft allocations. Lead author for the water quality improvement report. |
| Tighe Stuart<br>ERO Unit<br>Eastern Operations Section<br>Phone: 509-638-3257 | Project Manager | Co-authors the QAPP. Assists with field study and leads non-routine aspects of field study. Co-conducts QA review of data. Conducts modeling, analyzes and interprets data. Lead author for technical report. Co-develops draft allocations. |
| Joseph Zimbric<br>ERO Unit<br>Eastern Operations Section<br>Phone: 509-530-8799 | Principal Investigator | Co-authors the QAPP. Oversees field sampling and transportation of samples to the laboratory. Serves as primary field lead. Co-conducts QA review of data and enters data into EIM. |
| Pam Marti<br>Groundwater Monitoring Unit<br>Statewide Coordination Section<br>Phone: 360-628-3852 | Groundwater Lead Licensed Hydrogeologist | Co-authors the QAPP. Oversees sampling and measurement activities associated with groundwater. Oversees installation of piezometers, if needed. |
| TBD<br>ERO Unit<br>Eastern Operations Section<br>Phone: TBD | Field Assistant | Helps collect samples and records field information. After initial training, serves as additional field crew lead. |
| Erik Hanson<br>ERO Unit<br>Eastern Operations Section<br>Phone: 509-406-5369 | Acting Unit Supervisor for the Project Manager | Provides internal review of the QAPP, approves the budget, and approves the final QAPP. |
| Stacy Polkowske<br>EAP Program Manager<br>Phone: 360-407-6699 | Acting Section Manager for the Project Manager and Study Area | Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP. |
| Rob Waldrop<br>MEL<br>Phone: 360-871-8801 | Manchester Lab Director | Reviews and approves the final QAPP. |
| Darren Lantzer<br>Tshimakain Creek Labs<br>Phone: 509-928-3577 | Contract Lab Manager | Reviews draft QAPP coordinates with Ecology project leadership and QA staff. |
| Britta Voss<br>Phone: 360-280-4305 | Ecology QA Officer (interim) | Reviews and approves the draft QAPP and the final QAPP. |

[1] Staff listed are from EAP, except as noted.

EAP: Environmental Assessment Program; ERO: Eastern Regional Office; EIM: Environmental Information Management database; MEL: Manchester Environmental Laboratory; QA: quality assurance; QAPP: Quality Assurance Project Plan; TBD: to be determined

## 5.2 Special training and certifications

All field staff involved with this project either already have relevant experience following SOPs or will be trained by senior staff who do. Field staff who lack the necessary skills and experience to work independently will be paired with staff mentors who will oversee and verify their work and provide the necessary training to enable them to work proficiently and independently. A licensed hydrogeologist will direct the groundwater sampling activities.

## 5.3 Organization chart

See Table 4, Section 5.1.

## 5.4 Proposed project schedule

Tables 5 – 6 list key activities, due dates, and lead staff for this project.

**Table 5. Schedule for completing field and laboratory work, data review/entry, and modeling/analysis.**

| Task | Due date | Lead staff |
|---|---|---|
| Fieldwork completed [1] | Sep 2025 | Joseph Zimbric |
| Laboratory analyses completed | Nov 2025 | MEL/TCL |
| Internal data QA/QC review | Feb 2026 | Joseph Zimbric |
| EIM data loaded* [2] | Apr 2026 | Joseph Zimbric |
| EIM QA [3] | May 2026 | TBD (Field Assistant) |
| EIM complete [4] | Jun 2026 | Joseph Zimbric |
| Bacteria/TSS analyses | Aug 2026 | Tighe Stuart |
| PointWQ model development/calibration [5] | Oct 2026 | Tighe Stuart |
| Natural conditions determination and Scenario modeling | Jan 2027 | Tighe Stuart |

*EIM Project ID: tist0004

EIM: Environmental Information Management database

[1] If 303(d) listed segments for bacteria are meeting standards, we may collect bacteria data for another year only at those locations (see Section 7.2). This will not impact the project schedule very much. We will load all data through September 2025 into EIM as planned and treat the bacteria data from the second year separately. TMDL analytical tasks will proceed according to this schedule, as these tasks do not depend on the bacteria data from the second year. Field time required to collect the bacteria data from the second year would be minimal.

[2] All data entered into EIM by the lead person for this task.

[3] Data entry is verified correct by a different person; any data entry issues are identified. Allow one month for this step.

[4] All data entry issues identified in the previous step are fixed (usually by the original entry person); EIM Data Entry Review Form is signed off and submitted to Melissa Peterson (who then enters the "EIM Completed" date into Activity Tracker). Allow one month for this step. Normally, the final EIM completion date is no later than the final report publication date.

[5] If it becomes necessary to use the QUAL2Kw modeling framework to assess the Pomeroy WWTP reach (see Section 7.3), then this timeline may extend by several months, as QUAL2Kw is a significantly more complex model to build and calibrate than PointWQ.

**Table 6. Schedule for final technical report.**

| Task | Due Date | Lead Staff |
|---|---|---|
| Draft to supervisor | Jul 2027 | Tighe Stuart |
| Draft to client/ peer reviewer | Aug 2027 | Tighe Stuart |
| Final draft to publications team | Oct 2027 | Tighe Stuart |
| Final report due on web | Dec 2027 | Tighe Stuart |

## 5.5 Budget and funding

Tables 7 – 11 outline the estimated laboratory costs for different monitoring elements of the project. E. coli/fecal coliform and total suspended solids samples will be analyzed by Tshimakain Creek Laboratories (TCL) in Spokane Valley, WA. Rhithron Associates, Inc. (Rhithron) in Missoula, MT, will analyze the periphyton taxonomy samples. Ecology's Manchester Environmental Laboratory (MEL) will analyze all other sample parameters. This project's estimated lab budget, including work by TCL, Rhithron, and MEL, is **$76,137.**

If a second year of bacteria data is required at five 303(d) listed sites (see Section 7.2), this could add up to 72 E. coli + fecal coliform samples for an additional cost of $3,024.

**Table 7. Laboratory budget — Tshimakain Creek Labs (October 2024 – September 2025).**

| Parameter | Non-QA samples per event (#) | QA Samples per event (#) | Sampling events (#) | Total Samples (#) | Cost Per Sample ($) | Lab Subtotal ($) |
|---|---|---|---|---|---|---|
| E. coli + fecal coliform | 19 | 4 | 24 | 552 | $45 | $24,840 |
| Total suspended solids | 19 | 2 | 24 | 504 | $20 | $10,080 |
| **Total TCL** | | | | | | **$34,920** |

**Table 8. Laboratory budget — Rhithron Associates, Inc. (Summer 2025).**

| Parameter | Non-QA Samples Per Event (#) | QA Samples Per Event (#) | Sampling Events (#) | Total Samples (#) | Cost Per Sample ($) | Lab Subtotal ($) |
|---|---|---|---|---|---|---|
| Periphyton taxonomy | 4 | 0 | 1 | 4 | $385 | $1,540 |
| **Total Rhithron** | | | | | | **$1,540** |

**Table 9. Laboratory budget — MEL (Surface water samples; July – September 2025).**

| Parameter | Non-QA Samples Per Event (#) | QA Samples Per Event (#) | Sampling Events (#) | Total Samples (#) | Cost Per Sample ($) | Lab Subtotal ($) |
|---|---|---|---|---|---|---|
| Alkalinity | 20 | 2 | 6 | 132 | $34.00 | $4,488 |
| TPN | 20 | 2 | 6 | 132 | $35.00 | $4,620 |
| NO2-3 | 20 | 2 | 6 | 132 | $35.00 | $4,620 |
| NH4 | 20 | 2 | 6 | 132 | $35.00 | $4,620 |
| TP | 20 | 2 | 6 | 132 | $36.00 | $4,752 |
| OP | 20 | 2 | 6 | 132 | $36.00 | $4,752 |
| CBOD5 -inhib [1] | 4 | 1 | 6 | 30 | $70.00 | $2,100 |
| Chl a (periphyton slurry) | 4 | 1 | 1 | 5 | $55.00 | $275 |
| **Total MEL Surface Water** | | | | | | **$30,227** |

[1] If Manchester Environmental Laboratory (MEL) needs to contract this parameter and the contract laboratory cannot provide a low detection limit, we may substitute dissolved organic carbon (DOC) instead for $50/sample.

**Table 10. Laboratory budget — MEL (Provisional groundwater samples; July – September 2025).**

| Parameter | Non-QA Samples Per Event (#) | QA Samples Per Event (#) | Sampling Events (#) | Total Samples (#) | Cost Per Sample ($) | Lab Subtotal ($) |
|---|---|---|---|---|---|---|
| Alkalinity | 6 | 1 | 3 | 21 | $34.00 | $714 |
| TPN | 6 | 1 | 3 | 21 | $35.00 | $735 |
| NO2-3 | 6 | 1 | 3 | 21 | $35.00 | $735 |
| NH4 | 6 | 1 | 3 | 21 | $35.00 | $735 |
| TP | 6 | 1 | 3 | 21 | $36.00 | $756 |
| OP | 6 | 1 | 3 | 21 | $36.00 | $756 |
| **Total MEL Groundwater** | | | | | | **$4,431** |

MEL: Manchester Environmental Laboratory.

**Table 11. Laboratory budget — MEL (Stormwater samples; November 2024 – June 2025).**

| Parameter | Non-QA Samples Per Event (#) | QA Samples Per Event (#) | Sampling Events (#) | Total Samples (#) | Cost Per Sample ($) | Lab Subtotal ($) |
|---|---|---|---|---|---|---|
| E. coli + fecal coliform | 6 | 1 | 3 | 21 | $42.00 | $882 |
| Total suspended solids | 6 | 1 | 3 | 21 | $20.00 | $420 |
| TPN | 6 | 1 | 3 | 21 | $35.00 | $735 |
| NO2-3 | 6 | 1 | 3 | 21 | $35.00 | $735 |
| NH4 | 6 | 1 | 3 | 21 | $35.00 | $735 |
| TP | 6 | 1 | 3 | 21 | $36.00 | $756 |
| OP | 6 | 1 | 3 | 21 | $36.00 | $756 |
| **Total MEL Groundwater** | | | | | | **$5,019** |

MEL: Manchester Environmental Laboratory.

# 6.0 Quality Objectives

Quality objectives are statements of the precision, bias, and lower reporting limits necessary to meet project objectives. Precision and bias together express data accuracy. Other considerations of quality objectives include representativeness and completeness. The standard and approved requirements for project quality objectives listed in the QAPP are referenced from *Programmatic QAPP for Water Quality Impairment Studies* (McCarthy and Mathieu 2017).

## 6.1 Data quality objectives [6]

Refer to *Programmatic QAPP for Water Quality Impairment Studies.*

This project's main data quality objective (DQO) is to collect water samples and measurements representative of the Pataha Creek watershed and analyze samples using standard methods to obtain water quality data that meet this project's measurement quality objectives (MQOs).

## 6.2 Measurement quality objectives

Water samples and measurements will follow the MQOs outlined in *Programmatic QAPP for Water Quality Impairment Studies*. These MQOs will apply to both surface and groundwater samples.

Turbidity field measurements taken with the stand-alone Hach meter will conform to the same MQOs as listed for FTS DTS-12 and multiprobe sonde turbidity probes in the Programmatic QAPP.

## 6.3 Acceptance criteria for quality of existing data

Any water quality data from outside this study used in the TMDL analysis must meet the agency's credible data policy requirements: Water Quality Policy 1-11 Chapter 2 — Ensuring Credible Data for Water Quality Management.[7] The final report will include an assessment of data quality for any outside data used for TMDL analysis and certification that the data meets an acceptable quality for TMDL development. The data quality assessment would include one or all the following elements:

- Reference to a peer-reviewed and published Quality Assurance (QA) Project Plan or equivalent plan.
- Demonstration that the data collected yielded results of comparable quality to the study (based on data quality objectives and requirements in this QA Project Plan).
- Documentation that the objectives of the QA Project Plan or equivalent quality assurance procedures were met and that the data are suitable for water quality-based actions. The

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[6] DQO can also refer to ***Decision*** Quality Objectives. The need to identify Decision Quality Objectives during the planning phase of a project is less common. For projects that do lead to important decisions, DQOs are often expressed as tolerable limits on the probability or chance (risk) of the collected data leading to an erroneous decision. And for projects that intend to estimate present or future conditions, DQOs are often expressed in terms of acceptable uncertainty (e.g., width of an uncertainty band or interval) associated with a point estimate at a desired level of statistical confidence.

[7] https://apps.ecology.wa.gov/publications/SummaryPages/2110032.html

assessment of the data must consider whether the data, in total, fairly characterize the quality of the water body at that location at the time of sampling.

- Documentation of the planning, implementation, and assessment strategies used to collect the information, including the following:
    - Documentation of the original intended use of the information gathered (e.g., chemical/physical data for TMDL analyses).
    - Description of the data's limitations (e.g., these measurements only represent storm-event conditions).
    - Datasets must be complete, that is, not censored to include only part of the data results from the project.

## 6.4 Model quality objectives

The *Programmatic QAPP for Water Quality Impairment Studies* (section 6.3) provides an excellent discussion of the considerations for model calibration decisions. Some modeling projects use quantitative criteria for model goodness-of-fit, while others use only qualitative criteria. Universally applied quantitative criteria for model performance do not exist. Quantitative criteria can be useful if thoughtfully set for individual projects and balanced with other considerations, such as accurately representing system processes. This project uses quantitative and qualitative model quality objectives to assess model performance.

The primary quality objective for the PointWQ models for temperature, DO, and pH is to visually demonstrate a good match to observed data by using mechanisms and parameter values well supported by the study data and scientific literature and theory.

Table 12 presents numerical goodness-of-fit targets that will be used to help evaluate PointWQ water quality calibration (Mathieu et al. 2023). These targets will guide a thoughtful, comprehensive evaluation of model quality within a larger domain. As such, poor goodness-of-fit in parts of the model outputs (in either space or time) compared to any of these targets does not necessarily indicate that the model's calibration is unacceptable. Conversely, a good or fair rating does not necessarily mean the model will be deemed acceptable for all study objectives.

Ecology will not determine the overall quality of the model predictions based on a single statistic alone or comparison to a single established criterion. Instead, we will assess overall quality based on the following:

- The model's ability to simulate key drivers and processes seen in observed data.
- Multiple statistical metrics that evaluate model bias, accuracy, and correlation.

The same goodness-of-fit targets and calibration principles will apply if we use the QUAL2Kw model to simulate the Pomeroy WWTP reach (see section 7.3 below).

**Table 12. PointWQ model calibration goodness-of-fit targets.**

| Parameter (unit) | Metric | Measure | Good | Fair | Poor |
|---|---|---|---|---|---|
| Temperature (°C) | Daily Max | RMSE | <0.8 | 0.8–1.6 | >1.6 |
| Temperature (°C) | Daily Max | Bias | <0.4 | 0.4–0.8 | >0.8 |
| DO (mg/L) | Daily Min | RMSE | <1.0 | 1.0–2.0 | >2.0 |
| DO (mg/L) | Daily Min | Bias | <0.5 | 0.5–1.0 | >1.0 |
| pH (S.U.) | Daily Min/Max | RMSE | <0.3 | 0.3–0.6 | >0.6 |
| pH (S.U.) | Daily Min/Max | Bias | <0.15 | 0.15–0.3 | >0.3 |

Bias: mean error
RMSE: root mean square error (see QC glossary in Appendix D)

# 7.0 Study Design

## 7.1 Study boundaries

The Pataha Creek watershed is in the Columbia Plateau in southeast Washington State, inside WRIA 35. The study encompasses the boundaries of the Pataha Creek watershed, which includes the mainstem of Pataha Creek and several small tributaries, including Linville Gulch, Tatman Gulch, Bihmaier Gulch, Rickman Gulch, Sweeny Gulch, and Dry Pataha Creek. Figure 7 and Table 13 present the study area and proposed monitoring locations.

**Figure 7. Map of proposed monitoring locations (see Table 13).**

**Table 13. Proposed monitoring site IDs and location information.**

| Map Code | Site ID | Site Description | Latitude | Longitude |
|---|---|---|---|---|
| 1 | 35PAT-01.3 | Pataha Ck. nr mouth at Hwy 261 | 46.51218 | -117.973 |
| 2 | 35PAT-06.8 | Pataha Ck. at Archer Rd. | 46.54552 | -117.892 |
| 3 | 35PAT-11.2 | Pataha Ck. at Owens Rd. at Dodge | 46.52387 | -117.822 |
| 4 | 35PAT-20.2 | Pataha Ck. at Tatman Mtn. Rd. | 46.46189 | -117.69 |
| 5 | 35TAT-01.4 | Tatman Gulch just US Linville at Linville Gulch Rd. | 46.44679 | -117.685 |
| 6 | 36LIN-00.6 | Linville Gulch US Tatman in DNR section | 46.43965 | -117.688 |
| 7 | 35POM-WWTP | Pomeroy WWTP effluent | 46.47473 | -117.615 |
| 8 | 35PAT-24.4 | Pataha Ck. at Port Way in Pomeroy | 46.47521 | -117.613 |
| 9 | 35CRY-00.1 | Crystal Springs at Arlington St. in Pomeroy | 46.47125 | -117.589 |
| 10 | 35PAT-27.4 | Pataha Ck. at Fairgrounds Rd. | 46.47502 | -117.556 |
| 11 | 35BRO-00.2 | Brown Gulch nr mouth at Fairgrounds entrance | 46.47129 | -117.553 |
| 12 | 35BIH-00.1 | Bihmaier Gulch at mouth at Garfield Co. Fairgrounds | 46.47271 | -117.548 |
| 13 | 35PAT-29.5 | Pataha Ck. at Rickman Gulch Rd. | 46.47053 | -117.521 |
| 14 | 35RIC-00.2 | Rickman Gulch nr Mouth (exactly location TBD) | 46.46835 | -117.521 |
| 15 | 35PAT-33.5 | Pataha Ck. at Pataha Canyon Ln. private driveway | 46.44703 | -117.469 |
| 16 | 35SWE-00.1 | Sweeney Gulch nr mouth at Pataha Canyon Ln. | 46.44729 | -117.468 |
| 17 | 35PAT-42.9 | Pataha Ck. just US Dry Pataha Ck. at Columbia Ctr. | 46.36094 | -117.556 |
| 18 | 35DRY-00.0 | Dry Pataha Ck. at mouth at Columbia Ctr. | 46.36115 | -117.556 |
| 19 | 35PAT-48.5 | Pataha Ck. 0.15 mi abv NF bdy at CG/Rd 020 jct | 46.29156 | -117.516 |
| 20 | 35TUM-01.3 | Tumalum Ck. at state wildlife area | 46.35981 | -117.671 |
| N/A | GW TBD | 1-6 Groundwater sampling locations TBD, near the Pataha-Pomerory area | TBD | TBD |
| N/A | SW TBD | ~6 Pomeroy MS4 outfalls (see Appendix C) | TBD | TBD |

## 7.2 Field data collection

Ecology will collect field data for one year, from October 2024 to September 2025. The monitoring locations (Figure 7 and Table 13) include the mainstem of Pataha Creek and the mouths of tributaries. Mainstem Pataha Creek sites are spaced approximately 5 river miles apart on average. However, this varies based on site access and the need to bracket certain features such as groundwater, tributaries, point source outfalls, etc. This spacing equates to an estimated low-flow travel time of roughly 12 hours. This distance is close enough that conditions at one site will somewhat correlate with conditions at the next site downstream due to advective forcing. This is an ideal segmentation distance for bacteria and sediment/turbidity mass balances, and it serves the project goal of confirming the spatial and temporal extent of water quality impairments.

The data collection plan includes the following elements:

- **Discrete monitoring**
    - **Primary monitoring network (Oct 2024 – Sep 2025):** Ecology will collect bacteria samples (E. coli and fecal coliform), total suspended solids samples, discrete water quality measurements (DO, temperature, pH, specific conductivity, and turbidity), and flow measurements twice monthly at a fixed network of sites during the duration of the study. The primary monitoring network includes every site in the study except for the reference site (35TUM-01.3) and groundwater locations. Continuous water temperature loggers (HOBO tidbits) will be deployed at each primary monitoring network location.
    - **Summer Nutrient Sampling (Jul – Sep 2025):** Alkalinity, nutrient, and CBOD samples will be collected at the primary monitoring network twice monthly from July through September. Data will also be collected at the reference site near the mouth of Tumalum Creek and the groundwater monitoring locations during this period.
    - **Year-round ambient monitoring (Oct 2024 – Sep 2025):** Staff from Ecology's ambient monitoring program will collect bacteria samples (E. coli and fecal coliform), total suspended solids and turbidity samples, nutrient samples, and discrete water quality measurements (DO, temperature, pH, specific conductivity) at two locations monthly throughout the study period.
    - **Hemispherical Canopy Photos (1x, summer 2025):** Ecology will characterize solar radiation load, canopy cover, and effective shade at ten or more locations using hemispherical digital photography.
    - **Time of Travel (1x, summer 2025):** We will conduct one time-of-travel dye study during summertime low flow conditions. The study will cover the length of Pataha Creek from the National Forest boundary (RM 48.5) to the mouth.
    - **Groundwater monitoring (Jul – Sept 2025):** Ecology may monitor groundwater at up to six locations if logistical and resource considerations allow. This will include collecting nutrient samples and discrete water quality information from inflowing groundwater in the major gaining reach near Pataha-Pomeroy. This can be accomplished using any combination of surface springs, existing shallow wells, and a PushPoint sampler or instream piezometers in the identified groundwater discharge area. If we cannot sample groundwater, we may use summertime results from the mouth of Bihmaier Gulch to approximate groundwater characteristics. Water at the mouth of Bihmaier Gulch

  appears to be dominated by recent groundwater inflows from the last half-mile or so of the stream.
  - **Stormwater monitoring (Nov 2024 – Jun 2025):** As weather allows, we will collect E. coli/fecal coliform, total suspended solids, and nutrient samples from approximately six MS4 outfalls in the City of Pomeroy on three occasions. Appendix C presents a list of known MS4 outfalls in Pomeroy.
  - **Periphyton sampling (1x, summer 2025):** We will collect periphyton samples to be analyzed for taxonomy and areal photosynthetic biomass (measured in terms of chlorophyll a) at four locations during warm summertime growing season conditions.
  - **Optional extra year of bacteria monitoring for de-listing (Oct 2025 – Sep 2026):** If we find that after one year of sampling, one or more of the five segments on the 303(d) list for bacteria is meeting standards for E. coli, we may elect to collect an additional year of bacteria samples (E. coli and fecal coliform) for just those locations. This would satisfy the requirements of Ecology's Water Quality Assessment listing methodology (Policy 1-11; Ecology 2018), which requires two years of data to de-list a segment (place a segment in Category 1). This monitoring would occur monthly and would not include any other sample or measurement parameters.
- **Continuous monitoring:**
  - **Streamflow (Oct 2024 – Sep 2025):** Ecology will monitor continuous streamflow at two or more locations on the mainstem of Pataha Creek in the upper and middle watershed to supplement the existing gage that Ecology currently operates in the lower watershed near the mouth. This will result in a continuous flow record from 1) the upper watershed, prior to the large groundwater gains; 2) the mid-watershed, after the large groundwater gains in the area of highest summertime flow; and 3) the lower watershed near the mouth, after the long losing reach. From these three records, we can estimate daily continuous flow at other monitoring locations. Also, the mid-watershed location (Pataha Creek at Port Way) is just upstream of Pomeroy WWTP, allowing for accurate assessment of effluent dilution. The tributaries are generally too small (<< 1cfs) for continuous flow monitoring.
  - **Temperature (Apr – Oct 2025):** We will deploy HOBO® TidbiT® or similar temperature dataloggers at all regular monitoring locations, except possibly for intermittent/ephemeral tributary streams.
  - **Water quality (Oct 2024 – Sep 2025 for turbidity; Apr – Oct 2025 for EXO):** We will deploy YSI EXO and/or Hydrolab multiparameter water quality sondes and FTS DTS-12 (or similar) turbidity sensors in at least two locations in the middle and lower watershed to collect continuous DO, pH, specific conductivity, temperature, and turbidity data.
  - **Short-term diel DO/pH surveys (Jul – Sep 2025):** Ecology will deploy YSI EXO and/or Hydrolab water quality sondes to measure DO, pH, specific conductivity, and temperature at select sites across the watershed to understand diurnal water quality patterns better. Three surveys will occur, one each during July, August, and September. Sondes will be deployed on a short-term basis, at least ~72 hours per survey. This will result in at least 6 full days of data at each site, not counting partial days when the sondes are deployed or retrieved. This is an ideal amount of data to assess whether each location is impaired for DO and pH, per the hypergeometric test employed by Ecology's Water Quality Assessment listing methodology (Policy 1-11; Ecology 2018).

  - **Air temperature (Apr – Oct 2025):** Ecology will also deploy continuous air temperature and dew point data loggers (HOBO® U23 Pro v2® or similar) in at least three locations. In addition, we will attempt to find at least one location with excellent riparian vegetation cover and deploy one air/dew point logger inside and one outside the riparian vegetation zone to estimate the effect of the vegetation on riparian microclimate.

### 7.2.1 Sampling locations and frequency

Table 14 outlines the monitoring elements and frequency of monitoring at each site. These sampling locations may be moved, and additional locations may be added during the study based on site conditions, resource availability, and site access. Sampling locations are strategically located to capture tributary inputs and major point source contributions to the mainstem of Pataha Creek.

**Table 14. Monitoring locations, monitoring elements, and frequency.**

| Site ID | FC/E. Coli | TSS | DO/pH/Cond/ Temp/Turb[a] | Discrete Flow | Nutrient/ Alkalinity/ CBOD | Short-term diel DO/pH | Water temp | Ambient monitoring | Air temp/ dew point | Stream flow | Turb/DO/pH | Hemispherical canopy photos | Groundwater | Stormwater | Periphyton Sampling | Extra year of bacteria monitoring[b] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 35PAT-01.3 | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | — | C, 1yr | 1x/mo | C, 7mo | C, 1yr | C, 7mo | 1x | — | — | — | 1x/mo |
| 35PAT-06.8 | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | C | C, 1yr | — | — | — | — | 1x | — | — | — | — |
| 35PAT-11.2 | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | C | C, 1yr | — | C, 7mo | — | — | 1x | — | — | — | 1x/mo |
| 35PAT-20.2 | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | C | C, 1yr | — | — | — | — | 1x | — | — | 1x | 1x/mo |
| 35TAT-01.4 | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | (C) | C, 1yr | — | — | — | — | — | — | — | — | — |
| 36LIN-00.6 | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | (C) | C, 1yr | — | — | — | — | — | — | — | — | — |
| 35POM-WWTP | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | C | C, 1yr | — | — | — | — | — | — | — | — | — |
| 35PAT-24.4 | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | — | C, 1yr | 1x/mo | C, 7mo | C, 1yr | C, 7mo | 1x | — | — | 1x | — |
| 35CRY-00.1 | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | (C) | C, 1yr | — | — | — | — | — | — | — | — | — |
| 35PAT-27.4 | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | C | C, 1yr | — | — | — | — | 1x | — | — | — | — |
| 35BRO-00.2 | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | (C) | C, 1yr | — | — | — | — | — | — | — | — | — |
| 35BIH-00.1 | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | (C) | C, 1yr | — | — | — | — | — | — | — | — | — |
| 35PAT-29.5 | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | C | C, 1yr | — | — | — | — | 1x | — | — | — | — |
| 35RIC-00.2 | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | (C) | C, 1yr | — | — | — | — | — | — | — | — | — |
| 35PAT-33.5 | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | C | C, 1yr | — | C, 7mo | C, 1yr | — | 1x | — | — | 1x | 1x/mo |
| 35SWE-00.1 | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | (C) | C, 1yr | — | — | — | — | — | — | — | — | — |
| 35PAT-42.9 | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | C | C, 1yr | — | — | — | — | 1x | — | — | — | 1x/mo |
| 35DRY-00.0 | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | (C) | C, 1yr | — | — | — | — | — | — | — | — | — |
| 35PAT-48.5 | 2x/mo | 2x/mo | 2x/mo | 2x/mo | 6x | C | C, 1yr | — | C, 7mo | — | — | 1x | — | — | 1x | — |
| 35TUM-01.3 | — | — | 6x | — | 6x | — | C, 1yr | — | — | — | — | — | — | — | — | — |
| GW TBD | — | — | — | — | — | — | — | — | — | — | — | — | 3x | — | — | — |
| SW TBD | — | — | — | — | — | — | — | — | — | — | — | — | — | 3x | — | — |

**#**x: number of monitoring events; C: continuous monitoring (including short-term/diel and medium/long-term continuous); mo: month; Temp: temperature; TSS: total suspended solids; Turb: turbidity; yr: year).[a] Discrete sampling.. [b] Optional.

### 7.2.2 Field parameters and laboratory analytes to be measured

Tables 15 and 16 list the parameters that will be collected for this study.

**Table 15. Laboratory parameters.**

| Parameter | Primary Monitoring Network | Summertime Nutrient Sampling | Year-round Ambient Sampling | Groundwater Monitoring | Stormwater Monitoring | Periphyton Sampling | Optional extra Year of Bacteria Monitoring |
|---|---|---|---|---|---|---|---|
| FC/E. coli | X | — | X | — | X | — | X |
| Total suspended solids | X | — | X | — | X | — | — |
| Turbidity (sample) | — | — | X | — | — | — | — |
| Alkalinity | — | X | — | X | — | — | — |
| Total persulfate nitrogen | — | X | X | X | X | — | — |
| Ammonia | — | X | X | X | X | — | — |
| Nitrate-nitrite nitrogen | — | X | X | X | X | — | — |
| Total phosphorus | — | X | X | X | X | — | — |
| Orthophosphate | — | X | X | X | X | — | — |
| CBOD | — | X | — | — | — | — | — |
| Periphyton taxonomy | — | — | — | — | — | X | — |
| Chlorophyll a (field filtered) | — | — | — | — | — | X | — |

**Table 16. Field parameters.**

| Parameter | Primary Monitoring Network | Year-round Ambient Sampling | Short-term Diel Surveys | Continuous Monitoring | Hemispherical Canopy Photos | Groundwater Monitoring |
|---|---|---|---|---|---|---|
| Specific conductivity | X | X | X | X[a] | — | X |
| pH | X | X | X | X[a] | — | X |
| Dissolved oxygen | X | X | X | X[a] | — | X |
| Oxidation Reduction Potential | — | — | — | — | — | X |
| Turbidity (measurement) | X | — | — | X[a] | — | X |
| Streamflow | X | — | — | X[b] | — | — |
| Water level/Stage | — | — | — | X[b] | — | — |
| Temperature, water | X | X | X | X[a,b] | — | X |
| Temperature, air | — | — | — | X[c] | — | — |
| Dew Point, air | — | — | — | X[c] | — | — |
| Hemispherical canopy photos | — | — | — | — | X | — |

[a] Continuous water quality.
[b] Continuous streamflow.
[c] Continuous air temperature

# 7.3 Modeling and analysis design

## 7.3.1 Analytical framework

The *Programmatic QAPP for Water Quality Impairment Studies* provides additional information about the following methods.

### Statistical roll-back method — E. coli bacteria

Ecology may use the statistical roll-back method to calculate necessary load reductions for E. coli bacteria. This approach is based on "rolling back" the entire statistical distribution of bacteria concentration results. The approach relates easily to the bacteria standard and has proven successful in past bacteria TMDL assessments (Cusimano 1997; Joy 2000; Sargeant 2002; Tarbutton et al. 2010). Because the E. coli standard uses a rolling 3-month averaging period, the roll-back approach must be applied to each rolling 3-month period throughout the water year (Oct – Dec, Nov – Jan, Dec – Feb, etc., through Aug – Oct). The most restrictive rollback (largest %reduction) will determine the overall reduction needed.

The statistical roll-back method can establish E. coli reduction targets at all sampling sites that have sufficient sampling size (>4 samplings). The roll-back method assumes that the distribution of E. coli concentrations follows a log-normal distribution. The cumulative probability plot of the observed data estimates the geometric mean and 90th percentile, which can then be compared to the E. coli concentration standards.

The steps for the roll-back procedure are as follows. Calculation tasks may be performed in R®, Excel®, or other appropriate calculation tools.

- Check to ensure that each dataset (i.e., each sampling location for each seasonal division or rolling 3-month period) fits a log-normal distribution.
- Calculate the geometric mean for each dataset.
- Estimate the 90th percentile of each dataset by using the following statistical equation. This equation allows for a more robust estimate of the 90th percentile, assuming log-normal distribution, even if the number of samples in the dataset is small.

  $$[90th\ \%ile] = 10^{(\mu_{log}+1.28\sigma_{log})}$$

  Where:

  $\mu_{log}$ = mean of the log-transformed data

  $\sigma_{log}$ = standard deviation of the log-transformed data

- Calculate the target percent reduction as the highest of the following (refer to the E. coli standard in Table 2):

$$[Target\ \%\ reduction] = \left(\frac{[90th\ \%ile] - 320}{[90th\ \%ile]}\right) \times 100$$

$$[Target\ \%\ reduction] = \left(\frac{[Geomean] - 100}{[Geomean]}\right) \times 100$$

In addition to or instead of the statistical roll-back method, we may also apply the watershed mass-balance approach to analyzing bacteria data, particularly if longitudinal data patterns seem to suggest significant advective transport of bacteria.

### Watershed mass-balance — Turbidity/sediment and E. coli bacteria

We will analyze springtime turbidity/sediment data using a watershed mass-balance approach. We may also use this method to analyze E. coli bacteria data. This approach approximately follows the following steps:

- Calculate the seasonal average load for each sampling location using one or more of the following methods:
    - Use continuous turbidity data to estimate continuous records for associated parameters (e.gi. TSS)
    - Beales ratio estimator. This method is described in detail in the Programmatic QAPP.
    - Multiple linear regression model (Cohn et al. 1989; Cohn et al. 1992).
- Calculate the load residuals between adjacent mainstem sampling locations while accounting for tributary or point source loads between the stations.
- Optionally, estimate area-normalized subbasin contributions (yields) by dividing the load residual by the contributing subbasin area between the two sampling locations. This would be appropriate for pollutants likely to accumulate from the entire subbasin area (e.g., field erosion).
- Optionally, estimate stream-distance normalized contributions by dividing the load residuals by the stream distance between sampling locations. This would be appropriate for pollutants likely to originate from the near-stream environment (e.g., bank erosion).

It is also possible to build in additional assumptions to a mass-balance approach. For example, if the stream travel times are known, one could estimate a loss rate (representing, e.g., sediment settling or bacteria die-off) and incorporate time-dependent losses into the mass balance.

The watershed mass-balance approach can also work in reverse to estimate seasonal loads and concentrations under natural conditions or management scenarios. This requires estimating an area-normalized subbasin contribution (yield) representing natural conditions or a particular management scenario. Then, it is possible to perform the mass-balance analysis in reverse to calculate the seasonal average loads and concentrations at each monitoring station that would occur under that scenario. For example, this reverse calculation method can find the yield that would comply with a water quality standard.

### PointWQ model — Dissolved oxygen and pH

PointWQ (Stuart 2024) is a simple water quality model that simulates temperature, dissolved oxygen, and pH at a single location based on continuous monitoring data. PointWQ combines and links the Response Temperature (rTemp; Pelletier 2012) and River Metabolism Analyzer (RMA; Pelletier 2013) modeling tools. PointWQ and its component models, rTemp and RMA, are available on Ecology's Models and Tools for Water Quality Improvement webpage.[8]

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[8] https://ecology.wa.gov/research-data/data-resources/models-spreadsheets/modeling-the-environment/models-tools-for-tmdls

An early version of rTemp was developed by J.E. Edinger and Associates, Inc. (Edinger et al. 1968; Edinger et al. 1974). This was commonly used to estimate tributary inflow temperatures for other water quality modeling frameworks such as GEMSS (Krallis et al. 2004) and CE-QUAL-W2 (Jain et al. 2000). Ecology extended the model to include heat fluxes from the streambed, groundwater inflow, and hyporheic exchange (Pelletier 2012; Whiley and Cleland 2003). RMA extended the equilibrium concept used by rTemp to simulate the effects of productivity, respiration, and reaeration on DO and pH.

rTemp and RMA have been used previously as part of TMDL and other water quality studies. The tools have been used separately and together. Appendix B summarizes the history of rTemp's and RMA's use.

PointWQ is intended for small streams where full-scale river water quality models like QUAL2Kw may not be necessary or practical. Unlike most mechanistic water quality models, PointWQ simulates water quality at a single point. That is, it contains only one spatial model cell. This is similar to a batch reactor (Chapra 1997), sometimes called a "bathtub" model concept. This single cell represents a stream reach and does not consider advective transport. This is an acceptable simplification for many small streams, where water quality characteristics at a particular location reflect the equilibrium influence of conditions over some distance upstream.

PointWQ's temperature model (rTemp, with a few small modifications) is a fully mechanistic heat budget model, similar to the temperature model in QUAL2Kw. The heat fluxes include solar shortwave radiation, atmospheric longwave radiation, longwave back radiation from the water, convection, evaporation, streambed conduction, heat flux due to hyporheic flow, and heat flux due to groundwater flow.

PointWQ's DO and pH model, based on the RMA's inverse and predictive modeling tools, is a mechanistically simplified eutrophication model. The model tracks two state variables, dissolved oxygen (DO) and total inorganic carbon (TIC), and uses three main rate processes: gross primary productivity (GPP), ecosystem respiration (ER), and reaeration (re). Figure 8 presents a simple schematic of the internal mechanism of the PointWQ DO and pH model.

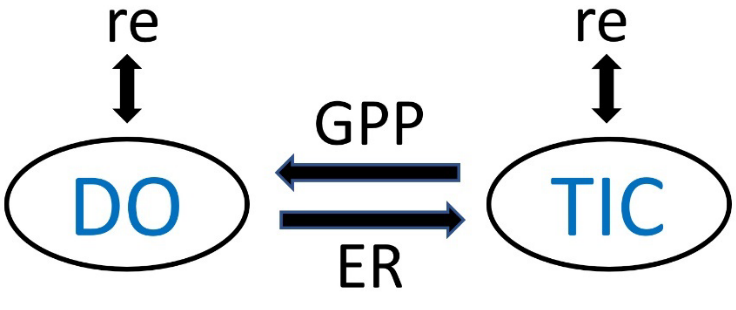

**Figure 8. Simplified schematic of PointWQ DO-pH model mechanism.**
DO: dissolved oxygen; ER: ecosystem respiration; GPP: gross primary productivity; re: reaeration; TIC: total inorganic carbon.

The most recent version of PointWQ also includes an additional heterotrophic respiration term, which can explicitly simulate the effects of biochemical oxygen demand (BOD) or sediment oxygen demand (SOD).

### QUAL2Kw model (optional) — Dissolved oxygen and pH

This project intends to use PointWQ to assess DO and pH dynamics in Pataha Creek and to evaluate loading capacity for pollutants that drive DO and pH impairments. If PointWQ cannot capture the relevant dynamics and processes for the reach downstream of Pomeroy WWTP, we may instead elect to use QUAL2Kw to evaluate impacts and management scenarios for Pomeroy WWTP. Section 7.5.3 provides more information about this contingency and the circumstances that would require using QUAL2Kw.

The QUAL2Kw model framework (Pelletier et al. 2006; Pelletier and Chapra 2008) and complete documentation are available on Ecology's Models and Tools for Water Quality Improvement webpage. Version 6.0 is currently available on the website; version 6.1 and documentation will be added soon. The programmatic QAPP describes the features of this framework in greater detail.

Unlike previous versions of QUAL2Kw, versions 6.0 and 6.1 can simulate a river continuously throughout a season or year. This is useful because it allows one model scenario to simulate conditions during different parts of the critical season and to be calibrated to multiple datasets collected at different times.

QUAL2Kw v6.1 is an appropriate choice for determining TMDL loading capacity for multiple reasons, including that the model is the following:

- Capable of simulating advanced bottom algae growth dynamics, including growth, respiration, scouring, nutrient/light/temperature limitation, and internal cell nutrient concentrations and quotas.
- Capable of simulating dynamic conditions for a full periphyton and macrophyte growth season, including flow, temperature, and solar radiation/shade. An hourly time series input may be used for each reach of the model.
- Capable of simulating three separate algal groups within a model reach.
- Well-documented and routinely used for nutrient-related DO and temperature TMDL development in EPA Region 10.
- Actively enhanced and maintained by Ecology.

### Additional modeling tools

In addition to the models and approaches listed above, we may use some or all of the following modeling tools.

- Gap Light Analyzer (GLA) — Imaging software to extract forest canopy structure and gap light transmission indices from true-color hemispherical (fisheye) photographs.
- Ttools — An Arc-GIS add-in used to process stream channel and riparian corridor spatial information for input into the shade model.
- Shade.xlsm model — An Excel spreadsheet interface model written in VBA for calculating effective riparian shade.
- rQUAL2Kw (optional; if using QUAL2Kw) — An R package developed by Ecology used to interface with Fortran executable for QUAL2Kw and pre and post-process model input and output files.

### 7.3.2 Model setup and data needs

#### PointWQ

We will construct a PointWQ model for each monitoring location along the mainstem of Pataha Creek and at tributary mouths as appropriate. PointWQ allows the time scale for the DO-pH model to be a shorter subset of the time scale for the temperature model (but not the other way). The time scale for each Pataha temperature model will be seasonal, representing the summertime low-flow period, such as July – August or July – September. The time scale for the DO-pH models will be just a few days, corresponding to the period of short-term continuous DO-pH data being used to calibrate. When multiple DO-pH deployment data periods are available at a monitoring location, we will select the period that represents "worst-case" conditions (e.g., lowest flow or highest temperature). Optionally, we may calibrate to multiple deployment periods.

PointWQ requires the following data types:

- Continuous meteorological data (air temperature, dewpoint temperature, wind speed, cloud cover, optional solar radiation)
- Continuous observed water temperature data
- (Short-term) continuous observed DO and pH data
- Surface water quality data, including conductivity, alkalinity, and limiting nutrient concentration. (See section 13.4.2 for discussion of nutrient limitation)
- Groundwater data including inflow rate, temperature, DO, and pH (See Figure 4 for an illustration of where large groundwater inflows occur in Pataha Creek)
- Water depth
- Effective shade
- Heterotrophic respiration, such as biochemical oxygen demand (BOD) and sediment oxygen demand (SOD), or a method of estimating. For this project, we may estimate as follows:
    - Assume an autotrophic GPP:ER ratio of 1.2 – 1.3 (Ge et al. 2017; Ecology unpublished data). If the overall GPP:ER ratio is greater than 1.2 – 1.3, then assume all respiration is heterotrophic.
    - Any respiration beyond the 1.2 – 1.3 ratio is assumed to be heterotrophic—that is, a mix of BOD and SOD.
    - Use observed sample data to quantify BOD.

      If estimated heterotrophic respiration is greater than observed BOD, assume the excess represents SOD.
- Various heat and temperature parameters (sediment characteristics, cloud adjustment of shortwave and longwave radiation, etc.)
- Various eutrophication-related parameters (light and nutrient limitation of algal growth, temperature adjustments of rates, etc.)

Figure 9 provides a conceptual diagram showing how the various data sources and modeling tools provide inputs and calibration guidance to the PointWQ model.

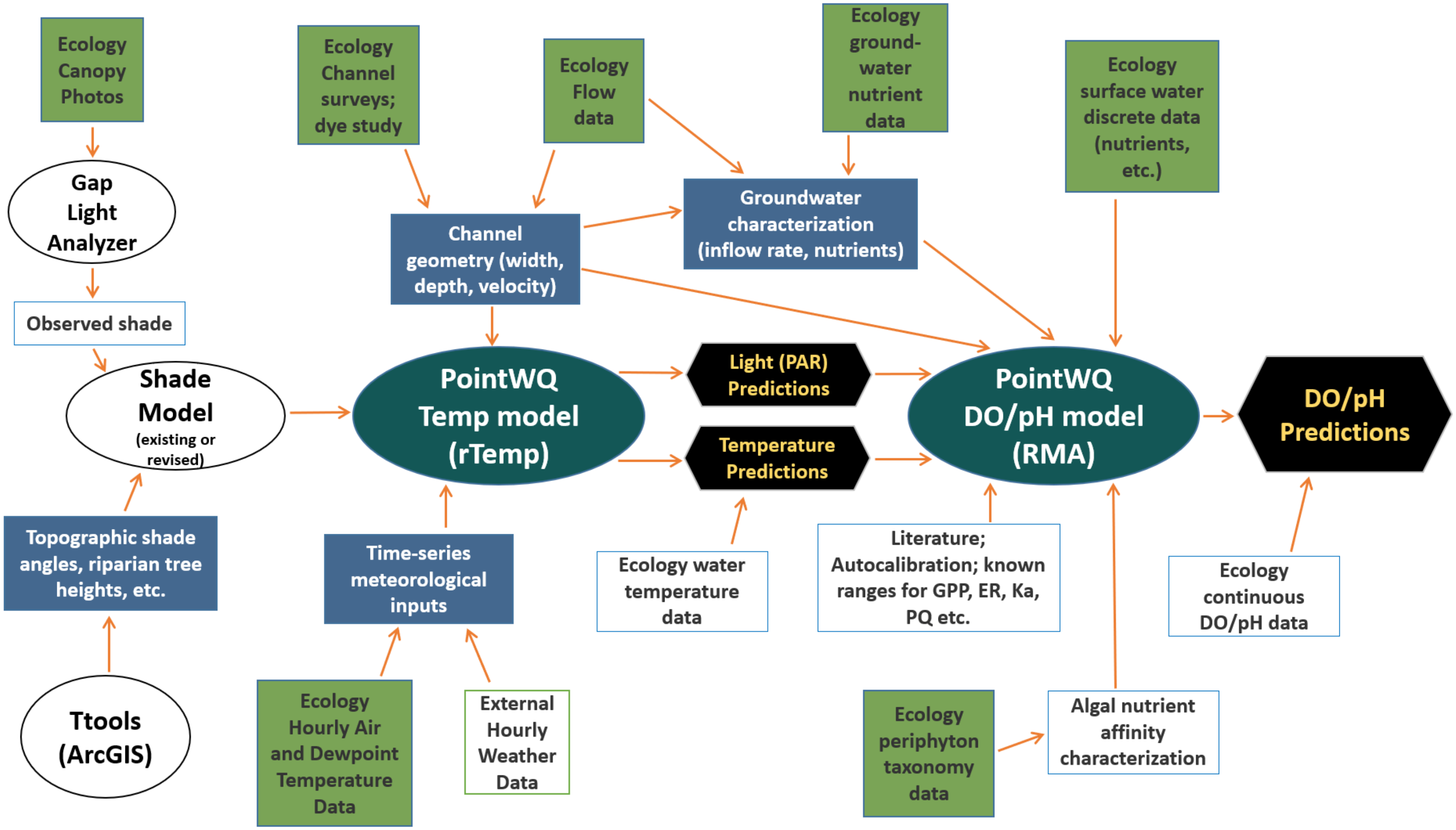

**Figure 9. Conceptual diagram of PointWQ model framework, including inputs and tools.**
Shaded squares (green) — raw data types that serve as model inputs.
Unshaded squares — non-Ecology raw data types.
Shaded rectangles (blue) — derived or calculated model inputs.
Unshaded rectangles — data that guide calibration; not direct model inputs.
Unshaded ovals — modeling tools.
Shaded ovals — PointWQ model.
Black hexagons — PointWQ model predictions.

### QUAL2Kw (optional)

If we use QUAL2Kw to model the Pomeroy WWTP reach, the model period will extend from April to October to capture the entire critical period along with shoulder seasons. The model domain will start just upstream of Pomeroy WWTP at Port Way (RM 24.4). Alternately, if capturing the Pataha-Pomeroy area's groundwater dynamics becomes important, we could start the model domain further upstream, such as Rickman Gulch Rd. (RM 29.5). The model domain will extend far enough downstream to fully capture the impacts from Pomeroy WWTP, at least one full day travel time at summertime flows. The downstream end of the model domain could be Dodge (RM 11.2), Archer (RM 6.8), or Hwy 261 near the mouth (RM 1.3).

The model segmentation will be chosen so that a single model segment typically represents 1 – 2 hours of travel time. The model time step will be chosen to minimize run time while maintaining numeric stability.

QUAL2Kw has all the same data requirements as PointWQ, as well as the following additional needs:

- Water balance, with continuous time-series estimates for inflows and abstractions for each model segment
- Channel geometry characterizes width, depth, and velocity as a function of flow
- Continuous time-series estimates of each simulated model variable for upstream boundary conditions, tributaries and point sources, and groundwater inflows

We will develop our water balance based on continuous flow data at the upstream boundary (Port Way or other location) and twice-monthly discrete flow measurements at downstream locations. We will interpret the diffuse inflow and abstraction quantities needed to approximately match downstream flow measurements as groundwater gains and losses unless there is evidence of large pumping withdrawals. We will assume that changes in groundwater inflows/abstractions tend to be smooth over time, and we will accept small phase shifts or quantitative mismatches to downstream observed flow data rather than invoking large or sudden groundwater changes to achieve an exact match.

We will develop channel geometry for each model segment as power functions relating width, depth, and velocity to flow:

$$W=aQ^b \qquad D=cQ^f \qquad V=kQ^m$$

Where:

| | | |
|---|---|---|
| $W$ = width (m) | $a$ = width coefficient | $b$ = width exponent |
| $D$ = depth (m) | $c$ = depth coefficient | $f$ = depth exponent |
| $V$ = velocity (m/s) | $k$ = velocity coefficient | $m$ = velocity exponent |
| $Q$ = flow (cms) | | |

These power functions are related by the continuity equation:

$$Q = WDV = (aQ^b)(cQ^f)(kQ^m)$$

Therefore:

$$\mathbf{b + f + m = 1} \qquad \text{and} \qquad \mathbf{ack = 1}$$

We plan to base the power functions for each model segment upon the following:

- Width — Ecology Pataha Creek channel survey data from 2008. We do not expect that significant changes to channel geometry have occurred since the time of these surveys. Ordinary stream dynamicism, such as bank cutting, point bar deposition, and downstream migration of pool-riffle sequences, are not a concern if overall reach-level geometric characteristics are similar. The large incisions appear to result from severe downcutting, which happened several decades ago but does not appear to be ongoing.
- Velocity — Ecology time-of-travel dye study to be collected for this project. For higher flow conditions, we may also reference the travel time of turbidity, conductivity, or other signals between continuous monitoring stations at Port Way and near the mouth of Pataha Creek.
- Depth — Given width and velocity from the above information, we will likely calculate depths from the above continuity equation. We will also reference other information, including the magnitude of diel temperature swings and channel survey data from 2008. (The 2008 channel survey data typically only includes one thalweg depth measurement, so it is not tremendously useful for determining average channel depths.)

We will develop boundary condition time-series inputs from continuous and discrete data, as available. This will include Ecology Ambient data from the Port Way location, which includes year-round nutrient data beyond the summertime samples from this project. Table 17 details how sample and measurement data are linked to water quality constituents in the QUAL2Kw model.

**Table 17. State variables/constituents in the QUAL2Kw model and methods for measuring or estimating.**

| Model Variable | Symbol | Units | Measured as |
|---|---|---|---|
| Conductivity | $s$ | μmhos | Specific Conductivity |
| Inorganic suspended solids | $m_i$ | mgD/L | TNVSS or estimate from known relationship with turbidity (Stuart 2022) |
| Dissolved oxygen | $o$ | mgO$_2$/L | DO |
| Slow-reacting CBOD | $c_s$ | mg O$_2$/L | $r_{oc}$ × DOC × SF or uBOD × SF |
| Fast-reacting CBOD | $c_{f,}$ | mg O$_2$/L | $r_{oc}$ × DOC × FF or uBOD × FF |
| Organic nitrogen | $n_o$ | μgN/L | TN - ($NO_3N$+$NO_2N$) - $NH_4N$ |
| Ammonia nitrogen | $n_a$ | μgN/L | $NH_4N$ |
| Nitrate nitrogen | $n_n$ | μgN/L | $NO_3N$+$NO_2N$ |
| Organic phosphorus | $p_o$ | μgP/L | TP - SRP |
| Inorganic phosphorus | $p_i$ | μgP/L | SRP (Orthophosphate) |
| General Algae<br>(as phytoplankton) | $a_p$ | μgA/L | Chlorophyll *a* or omit |
| Detritus | $m_o$ | mgD/L | $r_{dc}$ (TOC – DOC) |
| Alkalinity | $Alk$ | mgCaCO$_3$/L | ALK |
| Total inorganic carbon | $c_T$ | mole/L | Calculated from pH and alkalinity |
| Bottom algae biomass | $a_b$ | gD/m$^2$ | Periphyton biomass dry weight * LF$^{\#}$ |
| Bottom algae nitrogen | $IN_b$ | mgN/m$^2$ | Periphyton biomass N$^{\#}$ |
| Bottom algae phosphorus | $IP_b$ | mgP/m$^2$ | Periphyton biomass P$^{\#}$ |

Note: $r_{xx}$ refers to a stoichiometric ratio. The letters used in the subscripts are c (carbon), d (dry weight), and o (dissolved oxygen (DO)).

CBOD: carbonaceous biochemical oxygen demand; TNVSS: total non-volatile suspended solids; DO: dissolved oxygen; DOC: dissolved organic carbon; uBOD; ultimate biochemical oxygen demand; SF: slow-reacting fraction; FF: fast-reacting fraction; TN: total nitrogen; $NO_3N$+$NO_2N$: nitrate+nitrite nitrogen; $NH_4N$: ammonium nitrogen; TP: total phosphorus; SRP: soluble reactive phosphorus, also referred to as orthophosphate; ALK: alkalinity LF: live fraction (in many projects assumed to be 1, all volatile organic tissue assumed to come from living organism).

$^{\#}$ These simulated parameters are not field-measured in all projects. When measured, data tend to be highly variable and imprecise. Model fits to observed data are approximate.

### 7.3.3 Model scenarios

After calibrating the modeling framework, we will develop multiple management and future conditions scenarios. Currently planned scenarios include the following:

- **Existing conditions:** as described in section 7.3.2.
- **Load capacity under critical conditions:** Pollutant load reductions, where necessary, to meet water quality criteria under identified critical conditions (low flow, high air temperatures, etc.).

- **Load capacity under typical conditions (optional):** Pollutant load reductions, where necessary, to meet water quality criteria under identified typical conditions (median flow, median air temperatures, etc.).
- **Pre-human development under critical and typical conditions:** Given the low flows, hot weather, and semi-arid precipitation regime that occur in the Pataha Creek watershed, it is likely that natural DO levels may be below and natural pH above the biologically based numeric criteria. We will develop this scenario following current Ecology guidance (Ecology 2024b), in consultation with EPA Region 10, following Ecology's modeling natural conditions consideration checklist (see Appendix A for the planned application of each element).
- **Climate change impacts:** We may use dynamically downscaled Weather Research and Forecasting (WRF) model outputs from the UW Climate Impacts Group16 as meteorological inputs to the PointWQ and QUAL2Kw model frameworks.
    - The analysis will primarily focus on projected impacts on air temperature but will also include impacts on humidity, wind, and solar radiation. Predictions are available for a number of global climate models and emissions scenarios at an hourly temporal and 12 km spatial resolution.
    - The analysis will also consider the impact of changes to snowpack in the Blue Mountain headwater areas and overall basin-wide precipitation on streamflow, as data are available.
    - Alternately, if hydrology predictions are unavailable, we may use predicted changes to air temperature to inform meteorological model inputs.

## 7.4 Assumptions underlying design

The *Programmatic QAPP for Water Quality Impairment Studies* describes general data collection and modeling assumptions. In addition, this study makes the following assumptions:

- The statistical rollback method for bacteria is best suited to the assumption that bacteria concentrations are a function of nearby/local pollutant sources. If the downstream advective transport of bacteria appears significant, we may use a mass-balance approach instead.
- The PointWQ modeling framework assumes that temperature, DO, and pH at a monitoring location can be described as a function of equilibrium processes acting on the stream reach upstream of that location. If this assumption proves untrue for the Pomeroy WWTP reach, we may instead use QUAL2Kw to model that reach. See Section 7.5.3 below for more information.

## 7.5 Possible challenges and contingencies

### 7.5.1 Logistical problems

Refer to the *Programmatic QAPP for Water Quality Impairment Studies* for a list of common logistical problems.

A particular concern for this project is the potential denial of access to private property. If permission to access private property is denied, we will attempt to find a nearby alternate sampling location. If we cannot access many key monitoring locations, we will re-assess whether the project goals can still be obtained before beginning fieldwork.

Sample hold times and shipping logistics could be prohibitive for this project. To avoid this issue, we will use a local contract laboratory (Tshimakain Creek Labs) for short-hold parameters.

The timing of stormwater sampling in Pomeroy may be difficult. To accommodate bacteria samples, sampling must occur during the day on a Monday, Tuesday, or Wednesday. For municipal stormwater, the time lag between precipitation falling and pipe discharge is minimal, so sampling needs to occur while it is actively raining. The 2.5-hour drive time from ERO will make timing this sampling especially challenging.

An additional concern not mentioned in the Programmatic QAPP is weather challenges particular to Eastern Washington:

- Frozen streams, cold temperatures, and snow-covered or icy roads are common in the winter. During good weather, the Pataha Creek watershed is 2.5 hours away from ERO, with significant drive times between locations. Poor road conditions may make sampling safely within the allotted time difficult. We will assess weather conditions before sampling, and we may cancel or reschedule a sampling run if safety and time considerations dictate.
- Pataha Creek's low-elevation SE Washington location means it experiences high summertime temperatures, even by Eastern Washington standards. High temperatures over 100°F are common. Vehicle rest breaks using air conditioning may be necessary for crew safety to avoid heat-related illness. If extreme heat waves occur, we may cancel or reschedule sampling runs for safety.

### 7.5.2 Practical constraints

Refer to the *Programmatic QAPP for Water Quality Impairment Studies*.

### 7.5.3 Modeling challenges and contingencies

The PointWQ model framework's simplified approach has some limitations. The PointWQ Theory and User's Guide document (Stuart 2024) discusses these limitations in detail. The plan is, if possible, to use PointWQ as the primary analysis framework for assessing DO and pH impairments, including both point and nonpoint sources. However, conditions in the Pomeroy WWTP reach may be sufficiently complex or dynamic to violate the equilibrium assumption of the PointWQ framework. The following are examples of situations that, if sufficiently severe, could violate this assumption:

- Rapidly changing nutrient conditions such as overly "steep" or overly dynamic nutrient uptake curves downstream of a point source
- The "driving reach" upstream of the monitoring location contains multiple significant tributaries or sources
- The "driving reach" upstream of the monitoring location passes through multiple environments. For example, if the conditions at the monitoring location are being driven in part by areas upstream of the Pomeroy groundwater inflows, in part by areas within the groundwater inflows, and in part by areas downstream of the WWTP, this could be an excessively complex situation for PointWQ.

If we find conditions in the Pomeroy WWTP reach that violate PointWQ's equilibrium assumption, we will use QUAL2Kw to assess DO and pH impairments in that reach, as previously discussed.

### 7.5.4 Schedule limitations

Refer to the *Programmatic QAPP for Water Quality Impairment Studies*.

If we have to use QUAL2Kw to model the Pomeroy WWTP reach, this may add at least several months to the project timeline. Model setup and calibration are significantly more labor-intensive and time-consuming for QUAL2Kw than PointWQ.

# 8.0 Field Procedures

## 8.1 Invasive species evaluation

Refer to the *Programmatic QAPP for Water Quality Studies.* The Pataha Creek watershed is an area of moderate concern.

## 8.2 Measurement and sampling procedures

The *Programmatic QAPP for Water Quality Impairment Studies* lists standard operating procedures (SOPs) commonly used during TMDL and similar studies. Because some of the SOPs have been changed, combined, or updated since the Programmatic QAPP was published, we are listing the SOPs (Ecology 2024a) we will use in this study here.

- EAP011 — Instantaneous Measurements of Temperature in Water
- EAP015 — Manually Obtaining Surface Water Samples
- EAP023 — Collection and Analysis of Dissolved Oxygen (Winkler Method)
- EAP024 — Measuring Streamflow for Water Quality Studies
- EAP030 — Collection of Fecal Coliform Bacteria Samples in Surface Water
- EAP033 — Hydrolab® DataSonde®, MiniSonde®, and HL4 Multiprobes
- EAP037 — Time-of-Travel Studies in Freshwater Using a Dye Tracer
- EAP042 — Measuring Gage Height of Streams
- EAP044 — Collecting Data to Support a Temperature TMDL Study
- EAP045 — Hemispherical Digital Photography Field Surveys Conducted as Part of a Temperature Total Maximum Daily Load (TMDL) or Forests and Fish Unit Technical Study
- EAP046 — Computer Analysis of Hemispherical Digital Images Collected as Part of a TMDL or Forests and Fish Unit Technical Study
- EAP052 — Depth to Water Measurements
- EAP055 — Operation of the Teledyne RD Instruments RiverPro Acoustic Doppler Current Profiler
- EAP056 — Measuring and Calculating Stream Discharge
- EAP058 — Operation of the SonTek® FlowTracker® Handheld ADV®
- EAP061 — Installing, Monitoring, and Decommissioning Hand-driven In-water Piezometers (if piezometers are used)
- EAP070 — Minimize the Spread of Invasive Species
- EAP080 — Continuous Temperature Monitoring of Freshwater Rivers and Streams
- EAP096 — Collecting Groundwater Samples for General Chemistry Parameters from Water Supply Wells
- EAP099 — Collecting Groundwater Samples for General Chemistry Parameters from Monitoring Wells
- EAP111 — Periphyton Sampling, Processing and Identification in Streams and Rivers

- EAP129 — Short-term Continuous Data Collection with a Multiparameter Sonde, Part 1: Field Procedures
- EAP130 — Short-term Continuous Data Collection with a Multiparameter Sonde, Part 2: Data Processing

## 8.3 Containers, preservation methods, holding times

Refer to the *Programmatic QAPP for Water Quality Impairment Studies* for containers, preservations, and holding times for samples that MEL will process.

Table 18 presents the information for samples that TCL will process.

**Table 18. Sample containers, preservation, and holding times for samples to be processed by Tshimakain Creek Labs.**

| Parameter | Matrix | Minimum Quantity Required | Container | Preservative | Holding Time |
|---|---|---|---|---|---|
| E. Coli/Fecal Coliform | Surface Water | 500 mL | 500 mL w/m autoclavable poly bottle | Fill the bottle to the shoulder;<br>Cool to ≤10°C | 24 hours |
| Total Suspended Solids | Surface Water | 1000 mL | 1 L w/m poly bottle | Cool to ≤6°C | 7 days |

## 8.4 Equipment decontamination

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

Refer to specific listed groundwater SOPs in Section 8.2 for appropriate decontamination procedures.

## 8.5 Sample ID

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

Sample IDs for MEL follow the format YYMMWWW-SS, where YY is the two-digit year, MM is the two-digit month, WWW is the three-digit work order identifier, and SS is the sample ID number within the work order.

Sample IDs for TCL follow the format YYADDWW-SS, where YY is the two-digit year, A is an alphabetical month code (e.g., “A” for January or “D” for April), DD is the day of the month, WW is the two-digit work order identifier, and SS is the sample ID number within the work order.

The field lead will maintain a crosswalk spreadsheet to track MEL and TCL work order numbers for each sampling run. If possible, the -SS portion of the sample ID number will correspond to the same sample location for the two labs to avoid confusion and possible mistaken result assignments.

## 8.6 Chain of custody

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

The chain-of-custody (COC) forms for MEL and TCL contain the same basic information, although the format differs slightly. Field staff will fill out MEL COC forms upon arrival at the air cargo shipping facility. Field staff will fill out TCL COC forms upon arrival at TCL. TCL staff will be present at sample transfer (even for after-hours drop-off) and will sign to accept custody of samples at that time.

## 8.7 Field log requirements

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

## 8.8 Other activities

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

# 9.0 Laboratory Procedures

## 9.1 Lab procedures table

See Table 11 in the *Programmatic QAPP for Water Quality Impairment Studies* for lab methods for parameters sampled in this study. E. coli/fecal coliform will be analyzed using the membrane filtration option (SM 9222 D + G; APHA 2012).

Manchester Environmental Lab (MEL) will analyze samples for the following parameters (MEL 2016). We are requesting that MEL report results down to the method detection limit (MDL) for the parameters shown in **bold.** MDLs for these parameters are shown in parentheses.

- Alkalinity
- **Total persulfate nitrogen (0.051 mg/L)**
- **Nitrate-nitrite nitrogen (0.00289 mg/L)**
- **Ammonia nitrogen (0.0045 mg/L)**
- Total phosphorus
- Orthophosphate
- 5-day inhibited carbonaceous biochemical oxygen demand (CBOD5-inhib)
- Chlorophyll a (field filtered) — periphyton slurry

Tshimakain Creek Labs (TCL) in Spokane Valley, WA, will analyze samples for the following parameters:

- E. coli/fecal coliform
- Total suspended solids

Rhithron Associates, Inc. in Missoula, MT, will analyze periphyton taxonomy.

## 9.2 Sample preparation method(s)

Refer to *Programmatic QAPP for Water Quality Impairment Studies*. Periphyton taxonomy samples will be preserved with Lugol's iodine solution per SOP EAP111.

## 9.3 Special method requirements

Not applicable.

## 9.4 Laboratories accredited for methods

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

MEL is accredited for all methods used in this study. TCL is accredited for E. coli/fecal coliform according to SM 9222 D + G and total suspended solids according to SM 2540 D. Ecology does not accredit laboratories for periphyton taxonomy and enumeration. We will obtain a lab accreditation waiver to use Rhithron Associates, Inc.

# 10.0 Quality Control Procedures

Table 19 shows this study's quality control (QC) procedures. The *Programmatic QAPP for Water Quality Impairment Studies* explains these procedures in detail.

**Table 19. Quality control procedures.**

| QC Type | QC Procedures |
|---|---|
| Field Measurement QC | Meter/logger pre-calibration<br>Meter/logger calibration post-checks<br>Meter/logger field QC measurements<br>Fouling checks<br>Winkler DO samples |
| Field Sample QC | Field replicates<br>Field blanks |
| Laboratory Sample QC | Calibration/Verification blanks<br>Method blanks<br>Analytical duplicates<br>Matrix spikes<br>Lab control samples |

## 10.1 Table of field and laboratory quality control

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

## 10.2 Corrective action processes

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

# 11.0 Data Management Procedures

## 11.1 Data recording and reporting requirements

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

This project's Environmental Information System (EIM) Study ID is tist0004.

## 11.2 Laboratory data package requirements

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

See Sections 9.1 and 14.2 for information about requested reporting of non-detects.

TCL will provide electronic data deliverable (EDDs) at level 2B validation. For bacteria and TSS, this includes sample results and sample-level QC information.

## 11.3 Electronic transfer requirements

MEL will provide all data electronically to the project manager through the LIMS to EIM data feed. There is a protocol for how and what MEL transfers to EIM through LIMS.

TCL will provide EDDs to Ecology in Excel spreadsheet format. Spreadsheet format is not important as long as it stays consistent and contains all required data and metadata. EAP TMDL staff will re-format data from MEL and TCL as needed for upload to EIM.

## 11.4 EIM/STORET data upload procedures

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

## 11.5 Model information management

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

After modeling work is complete, we will store model files in a shared location, such as a network shared drive or SharePoint, to comply with Ecology's document retention schedules and practices.

# 12.0 Audits and Reports

## 12.1 Field, laboratory, and other audits

Refer to *Programmatic QAPP for Water Quality Impairment Studies*. No field audits are planned for this project; however, they could be added if requested by management or staff.

## 12.2 Responsible personnel

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

## 12.3 Frequency and distribution of reports

Refer to *Programmatic QAPP for Water Quality Impairment Studies*. A final technical report will be prepared detailing the findings of this study and is preliminarily scheduled to be completed in 2027. EAP will also complete the technical appendices of the TMDL submittal report. However, that timing will depend on WQP and EPA, so it is not part of this project timeline.

## 12.4 Responsibility for reports

Refer to *Programmatic QAPP for Water Quality Impairment Studies*. The project manager will be responsible for producing the final report for this project. The principal investigator will co-author the report.

# 13.0 Data Verification

## 13.1 Field data verification, requirements, and responsibilities

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

## 13.2 Laboratory data verification

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

## 13.3 Validation requirements, if necessary

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

## 13.4 Model quality assessment

The *Programmatic QAPP for Water Quality Impairment Studies* provides detailed information on principles of calibration, validation, and sensitivity/uncertainty analysis. This includes a detailed discussion of precision, bias, representativeness, and qualitative assessment. We will evaluate PointWQ (or QUAL2Kw) models based on the following:

- Whether the model can realistically reproduce real-world mechanisms and processes, using rate kinetics consistent with literature, research, and past modeling practice.
- Model prediction goodness-of-fit to observed data. We will use Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Bias (Mean Error) statistics as our primary evaluation of model fit. We may also use additional statistics such as Coefficient of Determination ($R^2$), centered RMSE or MAE, and others as appropriate.

The following sections provide additional information specific to PointWQ and its application for this project, as well as QUAL2Kw in case it is needed.

### 13.4.1 Calibration and evaluation

#### PointWQ — Temperature

Temperature model calibration in PointWQ is a manual process. This involves repeatedly running the temperature model while adjusting model settings until a good fit between observed and predicted data is achieved using realistic settings. Temperature is a function of well-understood physical processes with relatively few important rate parameters. Therefore, manual calibration is typically straightforward. Table 20 summarizes the most important rate settings and their effect.

We will use field data to guide the most important parameters: water depth, shade, groundwater inflow, and groundwater temperature. This will help to constrain these parameters to avoid "curve-fitting," i.e., achieving an apparent good model fit to data by invoking the wrong mechanistic explanations.

**Table 20. Key model settings for PointWQ manual temperature model calibration.**

| Setting | Effect | Other Settings that can Mimic the Same Effect | Setting Priority |
|---|---|---|---|
| Water depth | Size of diel variation.<br>Deeper = less diel range; shallower = more diel range | Hyporheic exchange | Primary [a] |
| Effective shade | Directional bias.<br>Less shade = warmer; more shade = cooler | Bras atmospheric turbidity factor (if using); Ryan-Stolzenbach ATC (if using); wind speed | Primary [a] |
| Groundwater inflow and temperature | Creates a bias tendency toward the groundwater temperature, reduces diel range | Groundwater could be mistaken for deeper channel and more shade if looking only at the hottest summer conditions; the difference will usually be more obvious if including cool, low-flow autumn conditions | Primary [a] |
| Effective windspeed coefficient | Directional bias | Shade, solar settings. However, wind varies by time of day and by weather pattern. The effective windspeed coefficient will have disproportionate effects on moments when wind is strong. | Secondary [b] |
| Bras atmospheric turbidity factor (if using);<br>Ryan-Stolzenbach ATC (if using) | Directional bias | Effective shade | Secondary [b] |
| Hyporheic exchange | Size of diel variation | Water depth | Secondary [b] |
| Cloud adjustment parameters (KCL1-4) | Temperature on cloudy days only | — | Secondary [b] |

[a] Primary settings are those that we will adjust first during temperature calibration.

[b] Secondary settings are those that we will adjust next, after adjusting primary settings, or if there is evidence that one of these is important. For example, if field crews notice visible hyporheic flow through cobble bars, we might increase the hyporheic exchange rate.

## PointWQ — DO/pH

PointWQ provides a genetic algorithm, PIKAIA (Charbonneau and Knapp 1995), to optimize the DO/pH model rate parameter values. The algorithm includes three primary parameters: maximum potential unlimited gross primary productivity (GPP) at 20°C, Ecosystem respiration (ER) at 20°C, and the DO reaeration coefficient at 20°C (Ka). The user may optionally select up to four additional values to optimize. For example, it is common to add the photosynthetic quotient (PQ) to the genetic algorithm. Table 21 summarizes key rate parameters and their effect. Table 22 lists the typical range of values for each parameter.

We will use the PIKAIA auto-calibration to optimize rate parameters within reasonable constraints. We may also manually calibrate some or all parameters as needed. For example, sometimes the best results are achieved by manually calibrating reaeration to the phase timing of the diel DO cycle and then using PIKAIA to find GPP and ER.

**Table 21. Key rate parameters for PointWQ DO/pH model calibration.**

| Rate Parameter | Effect |
|---|---|
| Maximum potential unlimited gross primary productivity (GPP) at 20°C | Increases DO and pH during daylight hours |
| Ecosystem respiration (ER) at 20°C | Decreases DO and pH during all hours |
| DO reaeration coefficient at 20°C (Ka) | Changes phase timing of DO and pH diel cycle. Higher Ka means peak DO occurs earlier in the day; lower Ka means peak DO occurs later in the day. Also affects magnitude of diel DO and pH swings; higher Ka means smaller diel swings; lower Ka means larger diel swings. |
| Photosynthetic quotient (PQ) (optional) | Affects pH. Does not affect DO. Lower PQ means higher pH and larger pH diel swings. Higher PQ means lower pH and smaller pH diel swings. |

DO: dissolved oxygen.

**Table 22. Typical range of values for PointWQ DO/pH model parameters.**

| Rate Parameter (abbreviation) | Typical range of values | Notes |
|---|---|---|
| GPP | 0–80 ($gO_2/m^2/day$) | 14 nutrient-replete estimates Palouse River[a]<br>22 low-reaeration estimates Little Spokane River watershed[b] |
| ER | 0–30 ($gO_2/m^2/day$) | 14 nutrient-replete estimates Palouse River[a]<br>22 low-reaeration estimates Little Spokane River watershed[b] |
| Ka | 0–200 (/day) | At high levels of reaeration, DO and pH become less sensitive to GPP and ER |
| PQ | 1.0–1.8 (mol $O_2$ / mol $CO_2$) | Typical value 1.0 for assimilation of $NH_4$[c]<br>Typical value 1.3 for assimilation of $NO_3$ (default assumption)<br>1.2–1.8 if protein and lipid major products of photosynthesis[d] |

DO: dissolved oxygen; GPP: gross primary productivity; ER: Ecosystem respiration; Ka: reaeration coefficient; PQ: Photosynthetic quotient.

[a] Snowaert and Stuart 2015

[b] Johnson et al. 2020

[c] Stumm and Morgan 1996

[d] Laws 1991

### QUAL2Kw (if using) — Temperature, flow balance, and hydrodynamics

Temperature calibration in dynamic/continuous applications of QUAL2Kw occurs concurrently with the refinement of channel geometry and flow balance. This is an iterative process which typically begins with the following:

- Approximate channel geometry based on a preliminary analysis of observed widths, depths, and time of travel, using steady-state flow balances

- A “bare” flow balance assuming only upstream boundary and tributary inflows, with no distributed groundwater inflows or abstractions.
- Common default settings for shortwave solar radiation, longwave radiation, cloud effects, wind sheltering, etc.

After running the model once, the next step is to apply distributed groundwater inflows and abstractions to achieve an approximate match between predicted and observed streamflows. Then, iterative adjustments are made as follows:

- Compare predicted vs. observed temperatures. Adjust channel geometry slightly if necessary. (Shallower depths result in larger diel temperature swings.) Adjust solar shortwave, longwave, cloud, and wind sheltering as appropriate.
- Compare predicted vs. observed width, depth, and time of travel. Make sure any adjustments to improve temperature fit stay true to observed geometry data.
- Make slight adjustments to distributed inflows and abstractions, as changes in geometry will somewhat affect the flow balance.
- Repeat.

This process continues until a good temperature calibration and flow balance have been achieved throughout the model period and spatial domain while using channel geometry and heat settings consistent with the literature, past modeling practice, and observed data.

### QUAL2Kw (if using) — Reaeration

QUAL2Kw contains several pre-defined reaeration models, as well as the option for a user-defined model that specifies reaeration as a function of depth and velocity. The best results in the past have been obtained using a user-defined model. This is done as follows:

- Begin with a water quality rate parameter set, such as a rate set from a previous model application, that produces clear DO and pH diel swings from productivity and respiration. A good calibration with observed DO and pH data is not needed at this stage; this happens after calibrating reaeration.
- Use the PIKAIA genetic algorithm to auto-calibrate the three model parameters. This is done using a fitness function based only on the phase timing of the DO and pH curves (typically the time of daily max DO and pH).

This approach works because the phase timing of the diel DO and pH swings is a function of reaeration only. This is also the principle behind the delta method for estimating reaeration (Chapra and DiToro 1991; Chapra 1997; McBride and Chapra 2005).

### QUAL2Kw (if using) — DO, pH, algae, nutrients, and other water quality variables

Calibration of the remaining water quality processes in QUAL2Kw is a complex process that involves optimizing many interdependent rate processes and model variables. Best results have typically been achieved using a combination of auto-calibration and manual adjustment, often as follows:

- Manual calibration of suspended solid parameters (settling rates).
- Automatic calibration process for remaining water quality parameters.

- Manual adjustment to water quality parameters, as necessary, within the recommended ranges of the literature and previous QUAL2Kw applications (see Mathieu and Khan 2020; Appendix F; Tables F-10 and F-11).
- Manual adjustments, only if deemed critical, to water quality parameters outside the pre-established ranges. Each adjustment that falls outside these ranges will have thorough documentation of a scientifically defensible explanation in the model report.

We do not plan to reserve a random set of observations or seek out an independent data set to validate/corroborate the QUAL2Kw models. While this type of traditional model validation can be very valuable in evaluating model performance, it comes at the cost of reduced information used to understand the system and calibrate the model. Resource constraints on data collection for this application make it preferable to use all available data to set up and calibrate the model.

## 13.4.2 Analysis of sensitivity and uncertainty

### Monte Carlo analysis

PointWQ and QUAL2Kw can use the YASAIw Excel add-in for Monte Carlo simulation (Pelletier 2009). We may use YASAIw to perform sensitivity and uncertainty analysis. For sensitivity analysis, we will replace model rate parameters such as GPP, ER, Ka, PQ, and other model input values with a distribution of values centered around the selected value. YASAIw will then perform many model runs and analyze the sensitivity of key model outputs (such as daily minimum DO and daily maximum pH) to each input parameter.

We may also assess the uncertainty in model scenarios, such as natural conditions or particular management scenarios (Johnson et al. 2020). In this case, we will estimate the uncertainty in scenario inputs (such as system potential shade or natural channel depth) and use YASAIw to track how uncertainty in multiple input types propagates to uncertainty in scenario predictions. This also allows us to assess which inputs contribute the most to scenario prediction uncertainty.

The key outputs from YASAIw include the following:

- Prediction output mean
- Prediction output standard deviation
- Prediction output distribution details (0%, 1%, 5%, 10%, 25%, 50%, 75%, 90%, 95%, 99%, 100%)
- Spearman's Rho (indicates the direction and strength of relationship between each input and each output)
- Percent contribution to variance of each input to each output

### Assessment of algal nutrient sensitivity

A model's sensitivity to nutrients refers to the relationship between the model's predictions of nutrient concentrations and algal productivity. This determines how the model predictions of DO and pH will respond under scenario conditions where nutrients are reduced relative to current conditions.

In PointWQ, the nutrient sensitivity is specified as a model setting, namely the limiting nutrient half-saturation concentration. In QUAL2Kw, there is no single rate parameter that controls the nutrient sensitivity. Instead, it is controlled by several rate parameters working together, including the N and P external half-sat constants, subsistence quotas, and internal half-sat ratios.

The sensitivity of algae to the presence of a limiting nutrient can be conceptualized as a relationship between primary productivity and the concentration of the limiting nutrient, using algorithms such as the Monod equation (Figure 10). This relationship is not linear. Instead, at low concentrations of the limiting nutrient, a small increase in limiting nutrient concentration will greatly impact productivity. At higher concentrations, additional increases in concentration will have a smaller impact on productivity.

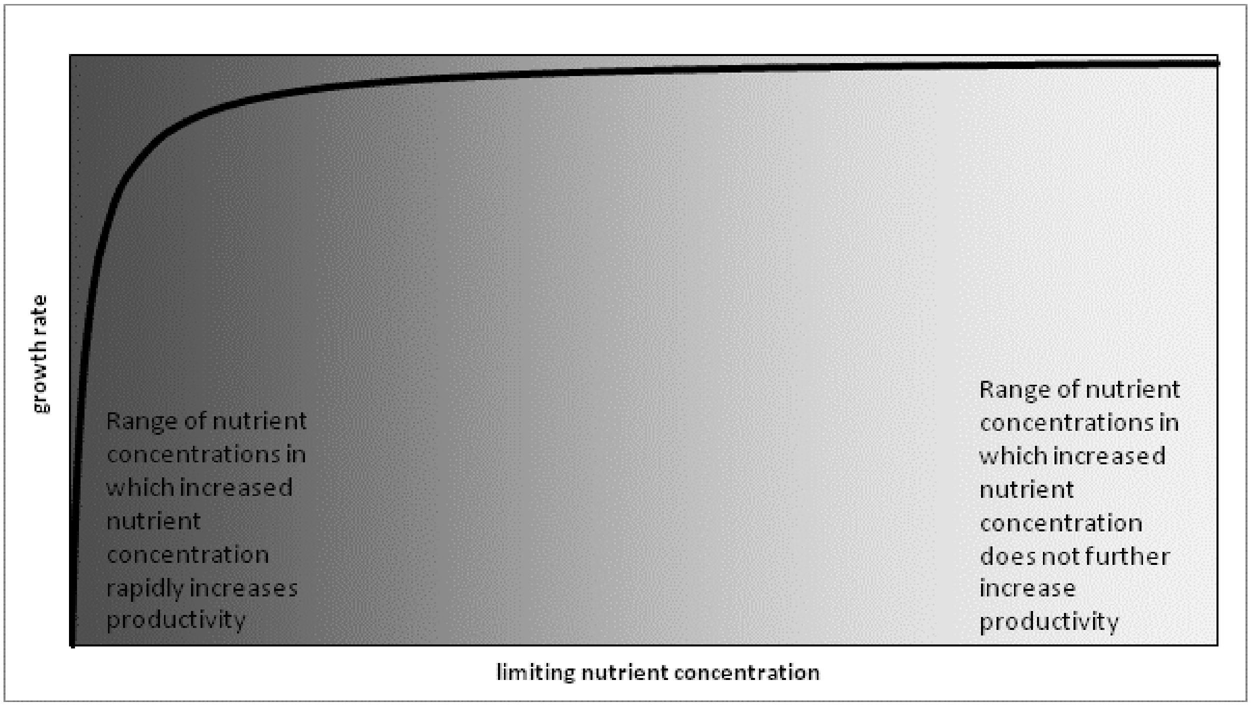

**Figure 10. Conceptual diagram of the relationship between limiting nutrient concentration and algal growth rate, using Monod equation (Monod 1950; see Borchardt 1996).**

The limited data available indicate that neither nitrogen nor phosphorus concentrations in Pataha Creek are low enough to significantly limit algal productivity. Therefore, the data we collect in Pataha Creek will likely not help inform the stream's real-world nutrient sensitivity.

Research literature, along with previous TMDL studies, provides a guide to algal sensitivity to nutrients. All studies on this topic have concluded that extraordinarily low concentrations of nutrients saturate the growth rate of periphyton communities dominated by diatom algae. This is likely because these organisms have evolved to be extremely efficient at extracting nutrients from very dilute water.

Bothwell (1985) observed approximately half-saturated growth at soluble reactive phosphorus (SRP) concentrations of 1.1 µg/L and about 90% saturated growth at SRP concentrations of 3 – 4 ug/L. Rier and Stevenson (2006) found 90% saturated growth at 16 µg/L SRP, which is higher than the Bothwell value but still relatively low. Data collected by Ecology from the Palouse River, a nitrogen-limited system, suggest about 90% saturated growth at dissolved inorganic nitrogen (DIN) concentrations of about 16 µg/L (Snouwaert and Stuart 2015; Ecology unpublished data). Rier and Stevenson (2006) found 90% saturated growth at 86 µg/L DIN.

Periphyton taxonomic data can provide an important clue regarding what part of the literature range to favor. Some algal taxa require higher nutrient levels to saturate their growth rates, while other taxa require lower levels. Potapova and Charles (2007) provide an extensive list of diatom taxa classified as high-nutrient, low-nutrient, or non-indicator. We may assess periphyton taxonomy data collected during this study using the methodology described in Appendix K of Johnson et al. (2020) or use another index of periphyton nutrient affinity.

Our taxonomic assessment will inform our selection of nutrient half-saturation concentration value. If low-nutrient diatoms predominate, we may select a value near the low end of the literature range (e.g., 1 – 2 µg/L for P; 7 – 15 µg/L for N). If high-nutrient diatoms predominate, we may select a value near the high end of the literature range (e.g., 3 – 4 µg/L for P; 21 – 28 µg/L for N). If green algae taxa are significant, we may select higher values than these. Because anthropogenic nutrient enrichment may change the taxonomic makeup of periphyton communities (Stelzer and Lamberti 2001), we will pay particular attention to the periphyton taxonomy at less-impacted locations such as the forested headwaters portion of Pataha Creek.

For PointWQ, this value is entered directly as the limiting nutrient half-saturation concentration. For QUAL2Kw, it is necessary to run a sensitivity analysis. If using QUAL2Kw, we will perform the sensitivity analysis by reducing nutrient inputs to the model. We will then compare model-predicted instream concentrations of inorganic P and N to the “botalg growth limitation by P” and “botalg growth limitation by N” predictions. If the QUAL2Kw simulated nutrient sensitivity curves do not agree with the sensitivity indicated by literature and periphyton analysis, we will adjust the model calibration accordingly.

# 14.0 Data Quality (Usability) Assessment

## 14.1 Process for determining project objectives were met

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

## 14.2 Treatment of non-detects

Refer to *Programmatic QAPP for Water Quality Impairment Studies.*

For this project, Manchester Environmental Laboratory (MEL) is requested to report results down to the method detection limit (MDL) for the following parameters:

- Ammonia
- Nitrate-Nitrite
- Total Persulfate Nitrogen

For these parameters, result values less than the MDL will be reported as a non-detect (U qualifier) at the MDL. Result values higher than the MDL but lower than the normal reporting limit (RL) will be qualified as estimates (J qualifier).

## 14.3 Data analysis and presentation methods

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

## 14.4 Sampling design evaluation

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

## 14.5 Documentation of assessment

Refer to *Programmatic QAPP for Water Quality Impairment Studies*.

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# 16.0 Appendices

# Appendix A. Considerations for natural conditions modeling checklist

| Element | Current planned application for PointWQ and QUAL2Kw (if using) |
|---|---|
| **Boundary conditions** | PointWQ: Because of the single-cell equilibrium approach used by PointWQ, the concept of boundary conditions does not apply.<br>QUAL2Kw: Use the natural conditions PointWQ model for the upstream boundary (Pataha Ck. at Port Way) and tributary temperature, DO, and pH time-series inputs. Also see “natural nutrient concentrations” below. |
| **Channel morphology changes** | We will explore potential changes to channel geometry (width, depth), slope, sinuosity, and hyporheic/floodplain connection and flow through historical research, particularly GLO plat survey maps/field notes, any relevant journal entries by Lewis and Clark, who crossed Pataha Creek on May 3rd, 1806, and any available Nez Perce or Umatilla tribal knowledge. We will pay particular attention to 1) the possible historical presence and effect of beaver activity and 2) the channel conditions that may have existed before the large incised banks that exist today. Changes will be implemented in the PointWQ and QUAL2Kw models where sufficient evidence exists. |
| **Flow reductions or increases** | We will add restored flow from estimated groundwater and surface water use back into the models where appropriate. Water use estimates can come from 1) water rights records (although these tend to produce gross overestimates) and 2) patterns in gaged flow records that suggest significant surface pumping.<br>PointWQ: Flow changes can be reflected in three ways in PointWQ: 1) increase groundwater inflow velocity; 2) increase depth; 3) apply a known relationship between model calibration bias and streamflow.<br>QUAL2Kw: Add restored flow directly to the model flow balance. |
| **Invasive species** | The edges of Pataha Creek are lined with large amounts of reed canary grass. We will assess the shade effect of reed canary grass using the shade model. However, we will also consider that while reed canary grass can produce a modest amount of shade, it also can suppress the establishment of woody riparian vegetation that might produce more shade. Furthermore, we may remove the reed canary grass in the natural conditions scenario if it is considered a nuisance species under the natural conditions rule. |
| **Microclimate** | We plan to deploy pairs of air temperature/dew point data loggers, with one logger near the stream in dense riparian vegetation and the other near the stream in a nearby unvegetated location. This data will show the real-world microclimate effect in the Pataha basin. If this approach fails, we will select values based on literature and previous TMDL work while considering the semi-arid and generally treeless landscape. |

| Element | Current planned application for PointWQ and QUAL2Kw (if using) |
|---|---|
| **Natural nutrient concentrations** | We will use nutrient data from reference locations, such as 1) Tumalum Creek, 2) Cummings Creek (existing ambient data), or 3) upper Pataha Creek. |
| **Nonpoint sources** | See natural nutrient concentrations for DO/pH.<br>See system potential shade for temperature. |
| **Point source effluent** | Remove Pomeroy WWTP and any other point source discharges from models.<br>PointWQ: Perform loading calculation to estimate instream calculation without Pomeroy WWTP (or use natural estimate at Port Way upstream site).<br>QUAL2Kw: Remove Pomeroy WWTP from model inputs. |
| **System potential shade** | Composite system potential tree heights and density are estimated based on a combination of information, including soil site index percentages within the riparian zone, GLO survey notes, and vegetation characteristics at undisturbed reference locations. We will apply LIDAR characterization of reference locations to non-reference reaches if available. We will also consider and evaluate the system potential vegetation characterization from the *Tucannon River and Pataha Creek Temperature Total Maximum Daily Load* (Bilhimer et al. 2010). |

# Appendix B. Use history of rTemp and RMA modeling tools

PointWQ (Stuart 2024) uses Response Temperature (rTemp) as its temperature model and the inverse and predictive modeling tools in River Metabolism Analyzer (RMA) as its DO/pH model. These tools have been used previously in TMDL and other water quality studies.

The concept of response temperature, that is, of modeling the equilibrium effect of meteorological and other drivers on water quality without considering advection, dates back at least to the work of J. E. Edinger and Associates, Inc. (JEEAI) in the 1960s. Edinger et al. (1968) and Edinger et al. (1974) provide the theoretical framework and governing equations for the response temperature model. During the 1990s – 2000s (and possibly later), JEEAI maintained a version of the model called “Response Temperature,” (not abbreviated rTemp) which they used to estimate tributary inflow temperatures for other model frameworks, including CE-QUAL-W2 (Jain et al. 2000) and GEMSS (Krallis et al. 2004).

Greg Pelletier created the Excel/VBA version of Response Temperature (rTemp) for use by Ecology and other agencies. He also developed RMA, extending the same equilibrium concept to productivity, respiration, and reaeration effects on DO and pH.

Table B-1 summarizes known previous applications of rTemp and RMA. This table focuses mainly on applications in Washington State. Other applications may exist as well. Note that another model framework was used for many of these projects. For example, the Pend Oreille River Temperature TMDL used CE-QUAL-W2 as its primary framework, and several of these river TMDL studies used QUAL2Kw. Table B-1 only describes the role rTemp and RMA played within the project.

**Table B-1. Previous applications of rTemp and RMA.**

| Project | Framework(s) used | Application description | Reference |
|---|---|---|---|
| Sammamish River CE-QUAL-W2 model | RT (JEEAI version) | Estimated tributary temperatures under both calibration and full-shade management scenario | Jain et al. 2000 |
| Wenatchee National Forest Temperature TMDL | rTemp (ECY version) | Estimated current and system potential stream temperatures and evaluated heat loading capacity | Whiley and Cleland 2003 |
| Hyco Reservoir (North Carolina) GEMSS model | RT (JEEAI version) | Estimated tributary temperatures | Krallis et al. 2004 |
| Colville National Forest Multiparameter TMDL | rTemp (ECY version) | Estimated current and system potential stream temperatures and evaluated heat loading capacity | Whiley et al. 2005 |
| Hangman Creek Multiparameter TMDL | rTemp (ECY version) | Used to set temperature WLA for Tekoa WWTP | Joy et al. 2009 |
| Pend Oreille River Temperature TMDL | rTemp (ECY version) | Estimated current and natural tributary temperatures | Baldwin et al. 2011 |
| Upper Mainstem Stillaguamish River DO Study | RMA | Estimated primary productivity and ecosystem respiration | Von Prause 2012 |
| Palouse River Temperature TMDL | rTemp (ECY version) | Used to set temperature WLA for Palouse WWTP | Snouwaert and Stuart 2013 |
| Little Klickitat | rTemp (ECY version) | Bloodgood Ck. 30-year long-term simulation | Newell 2024, pers. comm.; Sanderson and Pickett 2014. |
| NF Palouse River DO/pH TMDL | RMA | Estimated GPP at various locations to evaluate the relationship between N and GPP | Snouwaert and Stuart 2015 |
| Red Cedar (Wisconsin) CE-QUAL-W2 model | rTemp (ECY version) | Estimated inflow temperatures | Noren 2019 |
| Wide Hollow Creek Temperature/DO/pH Study | RMA | Estimated primary productivity, ecosystem respiration, and reaeration to compare to QUAL2Kw estimates | Carroll and Newell 2020; Carroll 2024 pers. comm.[1] |
| Little Spokane River DO/pH/TP TMDL | rTemp and RMA | Used RMA to simulate DO and pH in tributaries under current and natural conditions, and to evaluate load capacity. Used rTemp to estimate temperature and PAR change under natural conditions. Applied these changes to NC RMA models. (Indirect linkage) | Johnson et al. 2020 |
| Pilchuck River Temperature and DO TMDL | RMA | Estimated primary productivity, ecosystem respiration, reaeration, and sediment oxygen demand | Mathieu and Khan 2020 |

| Project | Framework(s) used | Application description | Reference |
|---|---|---|---|
| Tekoa Receiving Water Study | rTemp and RMA | Used rTemp and RMA to simulate temperature, DO, and pH under current and natural conditions and to evaluate load capacity for nutrients. Direct (manual) linkage between rTemp and RMA, roughly equivalent to PointWQ. | Stuart 2020 |

[1] Carroll, J., 2024. Personal communication. Email April 23, 2024. Washington State Department of Ecology Environmental Assessment Program.

RT: Response Temperature; JEEAI: J.E. Edinger and Associates, Inc.; ECY: Washington Department of Ecology; WLA: wasteload allocation; WWTP: wastewater treatment plant; RMA: River Metabolism Analyzer; GPP: gross primary productivity; DO: dissolved oxygen; N: nitrogen; TP: total phosphorus; TMDL: total maximum daily load; PAR: photosynthetically active radiation; NC: natural conditions.

# Appendix C. Pomeroy possible stormwater sampling locations

Table C-1 lists stormwater outfalls in the City of Pomeroy, identified and cataloged by Ecology staff. Figure C-1 provides a map showing these outfalls, as well as the likely locations of other outfalls, given the observed pattern of Pomeroy's MS4 layout, which generally follows north-south streets downhill to Pataha Creek from both sides. We could not access these other likely locations during reconnaissance due to vertical retaining walls or private property preventing access to the creek.

We will sample a representative subset of approximately six of these outfalls during this project. We will attempt to emphasize outfalls that drain larger areas with more impervious surface, such as those draining the historic downtown area (approximately 5th St to 10th St., north side/right bank of the creek).

**Table C-1. Known stormwater outfalls in the City of Pomeroy.**

| Street | Bank | Location | Description | LatDD | LongDD |
|---|---|---|---|---|---|
| 1st St. | L | Aligned w/ end of St. | Concrete box outfall (no bridge) | 46.4748 | -117.6103 |
| 2nd St. | L | Aligned w/ end of St. | 8" white plastic pipe (no bridge) | 46.4747 | -117.6089 |
| 3rd St. | L | US 10' | 10" pipe flush exiting wingwall at water level, hidden behind ivy | 46.4743 | -117.6073 |
| 3rd St. | R | DS 20' | 10" blue plastic pipe at corner of wingwall | 46.4744 | -117.6076 |
| 5th St. | L | US | 2' wide box channel outfall | 46.4735 | -117.6046 |
| 6th St. | L | US | 2-3' diameter pipe with grating cover | 46.4732 | -117.6031 |
| 6th St. | R | Directly under bridge | 2' corrugated culvert outfall | 46.4733 | -117.6032 |
| 7th St. | L | US | 12" blue plastic pipe sticking out of wingwall | 46.4730 | -117.6017 |
| 7th St. | R | US | 12" pipe flush exiting wingwall | 46.4731 | -117.6017 |
| 7th St. | L | DS | 8" metal pipe, drains small area above | 46.4731 | -117.6019 |
| 8th St. | L | DS | 8" metal pipe flush exiting retaining wall | 46.4726 | -117.6004 |
| 8th St. | R | US | 12" metal pipe exiting at base of retaining wall | 46.4727 | -117.6003 |
| 9th St. | L | US | 8" blue plastic pipe exiting ~7' up from base of retaining wall | 46.4725 | -117.5989 |
| 9th St. | R | DS | 10" pipe exiting high on wing wall, buried in vegetation | 46.4726 | -117.5990 |
| 10th St. | L | DS, but under bridge | 12" metal pipe flush exiting retaining wall | 46.4723 | -117.5975 |
| 10th St. | R | DS | 2' corrugated culvert outfall | 46.4724 | -117.5976 |
| 10th St. | L | US, but under bridge | 8" blue plastic pipe, flush exiting retaining wall | 46.4723 | -117.5974 |
| 10th St. | R | US ~100' | 8" blue plastic pipe | 46.4724 | -117.5969 |
| 12th St. | L | DS | 10" blue plastic pipe exiting wingwall 3' from water surface | 46.4724 | -117.5946 |
| 12th St. | R | US 15' | 2' corrugated culvert outfall | 46.4727 | -117.5944 |
| 15th St. | L | DS 5' | 2 pipes, 8" & 1.5', exiting wooden retaining wall | 46.4724 | -117.5902 |
| 15th St. | R | DS, footing | 10" concrete pipe flush exiting base of bridge footing | 46.4725 | -117.5902 |
| Arlington St. | R | DS 40' (60'?) | 6" white plastic pipe, flowing water | 46.4715 | -117.5888 |
| Arlington St. | R | DS 80' | 6" blue plastic pipe | 46.4715 | -117.5887 |
| 18th St. | L | DS 40' | 2 pipes exiting concrete structure | 46.4721 | -117.5860 |
| 18th St. | R | DS 20' | 2' corrugated culvert flush exiting rockwork at ground level | 46.4722 | -117.5859 |
| 18th St. | R | US 5' | 4" steel pipe exiting just above bridge footing | 46.4721 | -117.5856 |

| Street | Bank | Location | Description | LatDD | LongDD |
|---|---|---|---|---|---|
| 20th St. | L | US 10' | 6" black flex tubing draining out of wing wall base | 46.4725 | -117.5827 |
| 20th St. | L | DS 5' | 2 corrugated 8" pipes | 46.4726 | -117.5828 |

L: left
R: right
US: upstream
DS: downstream

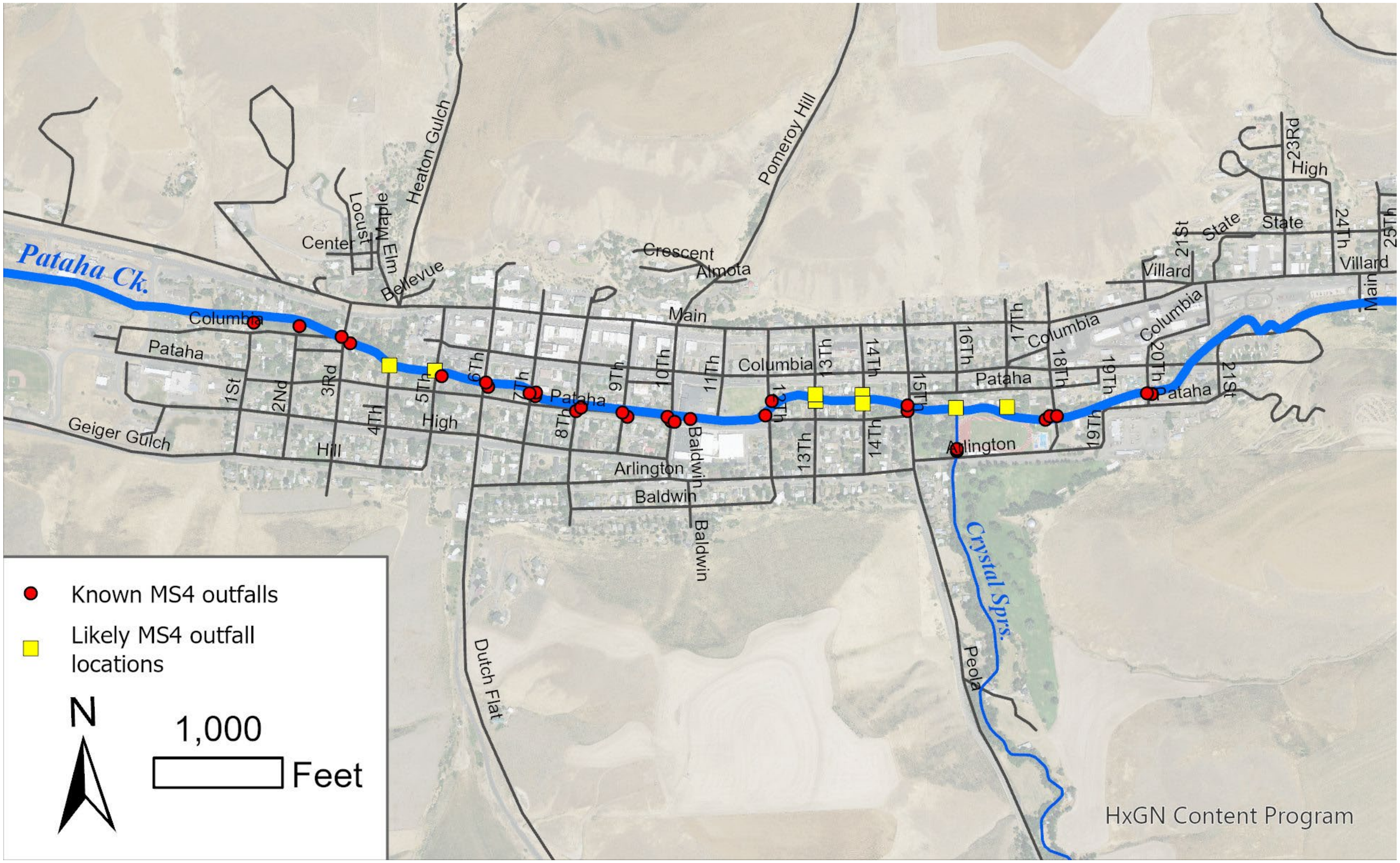

Figure C-1. Known and likely stormwater outfall locations in the City of Pomeroy

# Appendix D. Glossaries, Acronyms, and Abbreviations

## Glossary of General Terms

**Ambient**: Background or away from point sources of contamination. Surrounding environmental condition.

**Anthropogenic**: Human-caused.

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

**Baseflow:** The component of total streamflow that originates from direct groundwater discharges to a stream.

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

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

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

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

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

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

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

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

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

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

**Eutrophic:** Nutrient rich and high in productivity resulting from human activities such as fertilizer runoff and leaky septic systems.

**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.

**Hyporheic:** The area beneath and adjacent to a stream where surface water and groundwater intermix.

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

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

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

**Municipal separate storm sewer systems (MS4):** A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains): (1) owned or operated by a state, city, town, borough, county, parish, district, association, or other public body having jurisdiction over disposal of wastes, stormwater, or other wastes and (2) designed or used for collecting or conveying stormwater; (3) which is not a combined sewer; and (4) which is not part of a Publicly Owned Treatment Works (POTW) as defined in the Code of Federal Regulations at 40 CFR 122.2.

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

**Nonpoint source:** Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface-water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the 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.

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

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

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

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

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

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

**Reach:** A specific portion or segment of a stream.

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

**Salmonid:** Fish that belong to the family *Salmonidae*. 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.

**Streamflow:** Discharge of water in a surface stream (river or creek).

**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.

**System potential:** The design condition used for TMDL analysis.

**System-potential channel morphology:** The more stable configuration that would occur with less human disturbance.

**System-potential mature riparian vegetation:** Vegetation which can grow and reproduce on a site, given climate, elevation, soil properties, plant biology, and hydrologic processes.

**System-potential riparian microclimate:** The best estimate of air temperature reductions that are expected under mature riparian vegetation. System-potential riparian microclimate can also include expected changes to wind speed and relative humidity.

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

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

**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.

**Total suspended solids (TSS):** Portion of solids retained by a filter.

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

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

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

**303(d) list:** Section 303(d) of the federal Clean Water Act, 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.

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

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

**90th percentile:** 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

| | |
|---|---|
| BOD | Biochemical oxygen demand |
| CBOD | Carbonaceous biochemical oxygen demand |
| COC | Chain of custody |
| DIN | Dissolved inorganic nitrogen |
| DO | Dissolved oxygen (see Glossary above) |
| DOC | Dissolved organic carbon |
| DNR | Washington State Department of Natural Resources |
| DQO | Data quality objective |
| DSM | Digital surface model |
| DTM | Digital terrain model |
| EAP | Ecology's Environmental Assessment Program |
| EDD | Electronic data deliverable |
| e.g. | For example |
| Ecology | Washington State Department of Ecology |
| ECY | Washington State Department of Ecology |
| EIM | Environmental Information Management database |
| EPA | U.S. Environmental Protection Agency |
| ER | Ecosystem respiration |
| ERO | Ecology's Eastern Regional Office |
| et al. | And others |
| FC | Fecal coliform (see Glossary above) |
| GIS | Geographic Information System software |
| GLO | U.S. General Land Office |
| GP | General permit |
| GPP | Gross primary productivity |
| i.e. | In other words |
| IP | Individual permit |
| JEEAI | J.E. Edinger and Associates, Inc. |
| LA | Load allocation |
| LIDAR | Light detection and ranging |
| LIMS | Laboratory information management system |
| MAE | Mean absolute error |
| MAF | Mean annual flow |
| MDL | Method detection limit |

| | |
|---|---|
| MEL | Manchester Environmental Laboratory |
| MQO | Measurement quality objective |
| NPDES | National Pollutant Discharge Elimination System (See Glossary above) |
| PQ | Photosynthetic quotient |
| QA | Quality assurance |
| QAPP | Quality assurance project plan |
| QC | Quality control |
| RL | Reporting limit |
| RM | River mile |
| RMA | River Metabolism Analyzer |
| RMSE | Root mean square error |
| SOD | Sediment oxygen demand |
| SOP | Standard operating procedures |
| SRP | Soluble reactive phosphorus |
| TCL | Tshimakain Creek Laboratories |
| TIC | Total inorganic carbon |
| TMDL | Total maximum daily load (see Glossary above) |
| TOC | Total organic carbon |
| TP | Total phosphorus |
| TSS | Total suspended solids (see Glossary above) |
| UNF | Umatilla National Forest |
| US | Upstream |
| USFS | United States Forest Service |
| USGS | United States Geological Survey |
| UW | University of Washington |
| VBA | Microsoft Visual Basic for Applications |
| WAC | Washington Administrative Code |
| WLA | Wasteload allocation |
| WQA | Water Quality Assessment |
| WQP | Ecology’s Water Quality Program |
| WRIA | Water Resource Inventory Area |
| WRF | Weather Research and Forecasting |
| WSDOT | Washington State Department of Transportation |
| WSU | Washington State University |
| WWTP | Wastewater treatment plant |
| WY | Water year |

## Units of Measurement

| | |
|---|---|
| °C | degrees centigrade |
| cfs | cubic feet per second |
| cfu | colony forming units |
| /day | per day, a unit of first-order processes such as reaeration |
| °F | degrees Fahrenheit |
| $g/m^2$ | grams per square meter, a unit of areal biomass |
| $g/m^2/day$ | grams per square meter per day, a unit of areal productivity and respiration |
| L | liter |
| $mi^2$ | square mile |
| mg/L | milligrams per liter (parts per million) |

| | |
|---|---|
| mg/m$^2$ | milligrams per square meter, a unit of areal biomass |
| mL | milliliter |
| /100 mL | per 100 milliliters |
| mole | an International System of Units (IS) unit of matter |
| mole/L | moles per liter |
| MPN | most probable number |
| NTU | nephelometric turbidity units |
| s.u. | standard units |
| µg/L | micrograms per liter (parts per billion) |
| µmhos/cm | micromhos per centimeter |

## 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 sample 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 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 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 quality control (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):** 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):** 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 are usable for intended purposes.
- J (or a J variant) — data are estimated, may be usable, may be biased high or low.
- REJ — data are 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:** A discrete sample 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 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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