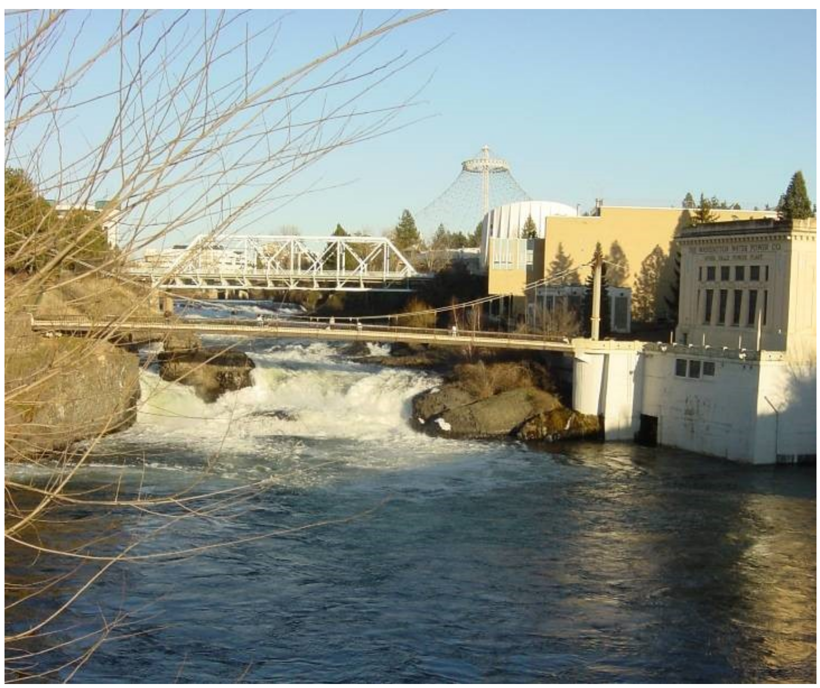
DEPARTMENT OF ECOLOGY
State of Washington

Quality Assurance Project Plan

Spokane River and Lake Spokane Dissolved Oxygen Total Maximum Daily Load, 10-Year Effectiveness Monitoring Study



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Contact Information

Environmental Assessment Program Publications Coordinator
Washington State Department of Ecology
P.O. Box 47600
Olympia, WA 98504-7600
Phone: 360 407-6764

Washington State Department of Ecology: https://ecology.wa.gov

- Headquarters, Olympia 360-407-6000
- Northwest Regional Office, Bellevue 425-649-7000
- Southwest Regional Office, Olympia 360-407-6300
- Central Regional Office, Union Gap 509-575-2490
- Eastern Regional Office, Spokane 509-329-3400

COVER PHOTO: Spokane River in downtown Spokane (Jani Gilbert)

Quality Assurance Project Plan

Spokane River and Lake Spokane Dissolved Oxygen Total Maximum Daily Load 10-Year Effectiveness Monitoring Study

by Tighe Stuart, Andy Albrecht, and Janna Stevens

August 2021

Approved by:

Signature:	Date:
Karl Rains, Client, WQP, ERO	
Signature:	Date:
Adriane Borgias, Client's Section Manager, WQP, ERO	
Signature:	Date:
Tighe Stuart, Author / Project Manager, EAP, ERO	
Signature:	Date:
Andrew Albrecht, Co-Author, Principal Investigator, EAP, ERO	
Signature:	Date:
Janna Stevens, Co-Author, EAP, ERO	
Signature:	Date:
Cathrene Glick, Author's Unit Supervisor, EAP, ERO	
Signature:	Date:
George Onwumere, Author's Section Manager, EAP	
Signature:	Date:
Alan Rue, Director, Manchester Environmental Laboratory	
Signature:	Date:
Arati Kaza, Ecology Quality Assurance Officer	

Signatures are not available on the Internet version.
EAP: Environmental Assessment Program
ERO: Eastern Regional Office
WQP: Water Quality Program

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2.0 Abstract

The Spokane River begins at the outlet of Lake Coeur d'Alene in Idaho and flows west through the city of Spokane, Washington. The river continues northwest through Lake Spokane, then west-northwest toward its confluence with the Columbia River. Lake Spokane (also referred to as Long Lake) is created by Avista Corporation's Long Lake Dam.

Low dissolved oxygen (DO) levels are common in the deeper parts of Lake Spokane, and algae blooms have plagued the lake for decades. Scientific studies on the lake dating back to the 1970s indicated the lake contained too much phosphorus. These studies prompted the City of Spokane to take steps to reduce phosphorus and other nutrients discharged from their wastewater treatment plant (WWTP). Despite water quality improvements resulting from those efforts, as of the early 2000s Lake Spokane still did not meet Washington State water quality standards for DO.

In 2010, the U.S. Environmental Protection Agency (EPA) approved the Washington State Department of Ecology's (Ecology's) *Spokane River and Lake Spokane Dissolved Oxygen Total Maximum Daily Load (TMDL) Water Quality Improvement Plan* (Moore and Ross, 2010). The TMDL report established pollutant load allocations and actions to meet DO standards in Lake Spokane.

This 10-Year Effectiveness Monitoring Assessment is intended to capture a snapshot of conditions about 10 years into the implementation of the 2010 TMDL in order to evaluate progress toward meeting the goals of the TMDL.

3.0 Background

3.1 Introduction and problem statement

Ecology adopted the *Spokane River and Lake Spokane Dissolved Oxygen Total Maximum Daily Load Water Quality Improvement Plan* (Moore and Ross, 2010; henceforth referred to as the *Spokane River and Lake Spokane DO TMDL,* or simply the *Spokane TMDL*) to address ongoing low DO levels, as well as harmful algal blooms, in Lake Spokane. The TMDL report established allocations for point and nonpoint total phosphorus (TP), carbonaceous biochemical oxygen demand (CBOD), and ammonia to meet DO standards in Lake Spokane. Since that time (1) point source dischargers have made upgrades to effluent treatment, likely resulting in significant reductions in pollutant loading, and (2) several organizations have worked to reduce nonpoint pollution.

The 2010 TMDL report stated that Ecology would conduct an assessment of conditions in the Spokane River and Lake Spokane about 10 years after the adoption of the TMDL in 2010. Changes made in the decade since the TMDL was adopted, particularly those relating to point source improvements to wastewater treatment, are likely to have resulted in improvements to DO in Lake Spokane. This 10-year Assessment will provide an updated picture of nutrient and DO conditions in the Spokane River and Lake Spokane. This will in turn allow Ecology to evaluate progress toward meeting the goals of the TMDL, namely meeting water quality standards.

3.2 Study area and surroundings

The Spokane River above Long Lake drains over 6,000 square miles of land in Washington and Idaho (Figure 1). Most of the people in the watershed live in the Spokane metropolitan area. The Spokane River flows west from Lake Coeur d'Alene in Idaho, across the state line to the City of Spokane in Washington. From Spokane, the river flows northwesterly to its confluence with the Columbia River at Lake Roosevelt.

The proposed study area for this project extends from the Stateline Bridge at about river mile (RM) 96 to Long Lake Dam at RM 33.9.

The Spokane River watershed is located in a transition area between the barren scablands of the Columbia basin to the west, coniferous forests and mountainous regions to the north and east, and prairie lands to the south (Hsieh et al., 2007).

Spokane receives an average of 16.5 inches of precipitation annually. It is affected by the rain shadow from the Cascade Mountains and thus receives roughly half of what Seattle gets annually (36.2 inches). Temperatures in Spokane also tend to be more extreme with warm summers and cold winters. Much of the winter precipitation can fall as snow, particularly at higher elevations. Detailed meteorological data for the Spokane area can be accessed at the National Oceanic and Atmospheric Administration (NOAA) website:
https://www.wrh.noaa.gov/map/?obs=true&wfo=mso

The Spokane River sits atop the western portion of the Spokane Valley-Rathdrum Prairie Aquifer (Figure 2) (Kahle et al., 2007). There is significant interchange between the river and the aquifer (Bartolino, 2007). Spring snowmelt and rainfall dominate flows in the Spokane River from April through June, whereas July through September baseflows mostly come from the aquifer.

There are five major dams along the Spokane River in Washington (Figure 3): Upriver Dam, Upper Falls Dam, Monroe Street Dam, Nine-Mile Dam, and Long Lake Dam. There is also a dam at Post Falls, Idaho that influences the hydrodynamics of the river. All of the Washington dams are run-of-the-river types except Long Lake Dam, which creates Long Lake (Lake Spokane), a 24-mile long reservoir.

Historically, anadromous salmonids were present in much of the study area. However, today a number of dams, including Grand Coulee Dam, eliminate fish passage and connectivity to the ocean.

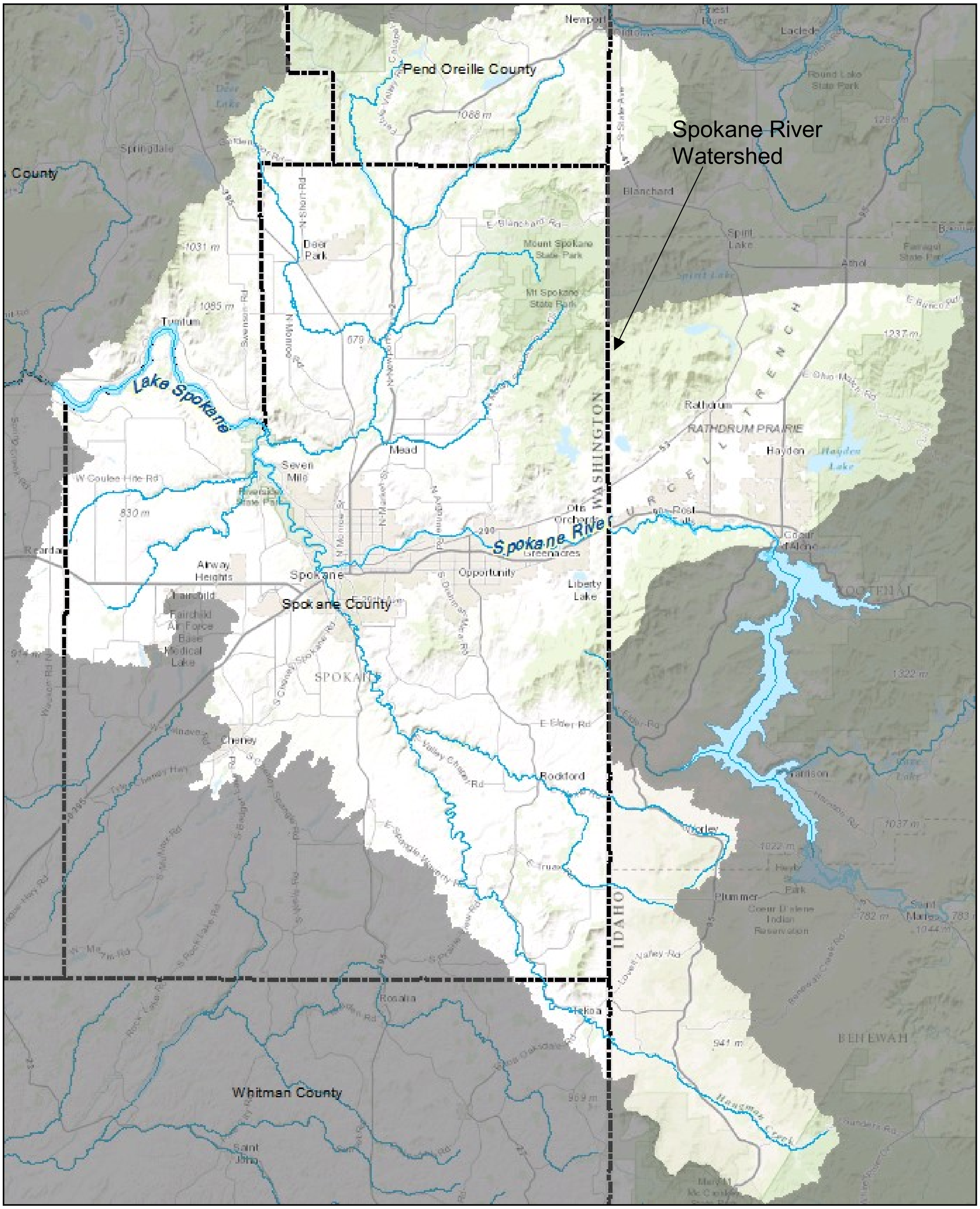

Figure 1. The Spokane River watershed covered by the dissolved oxygen (DO) TMDL.

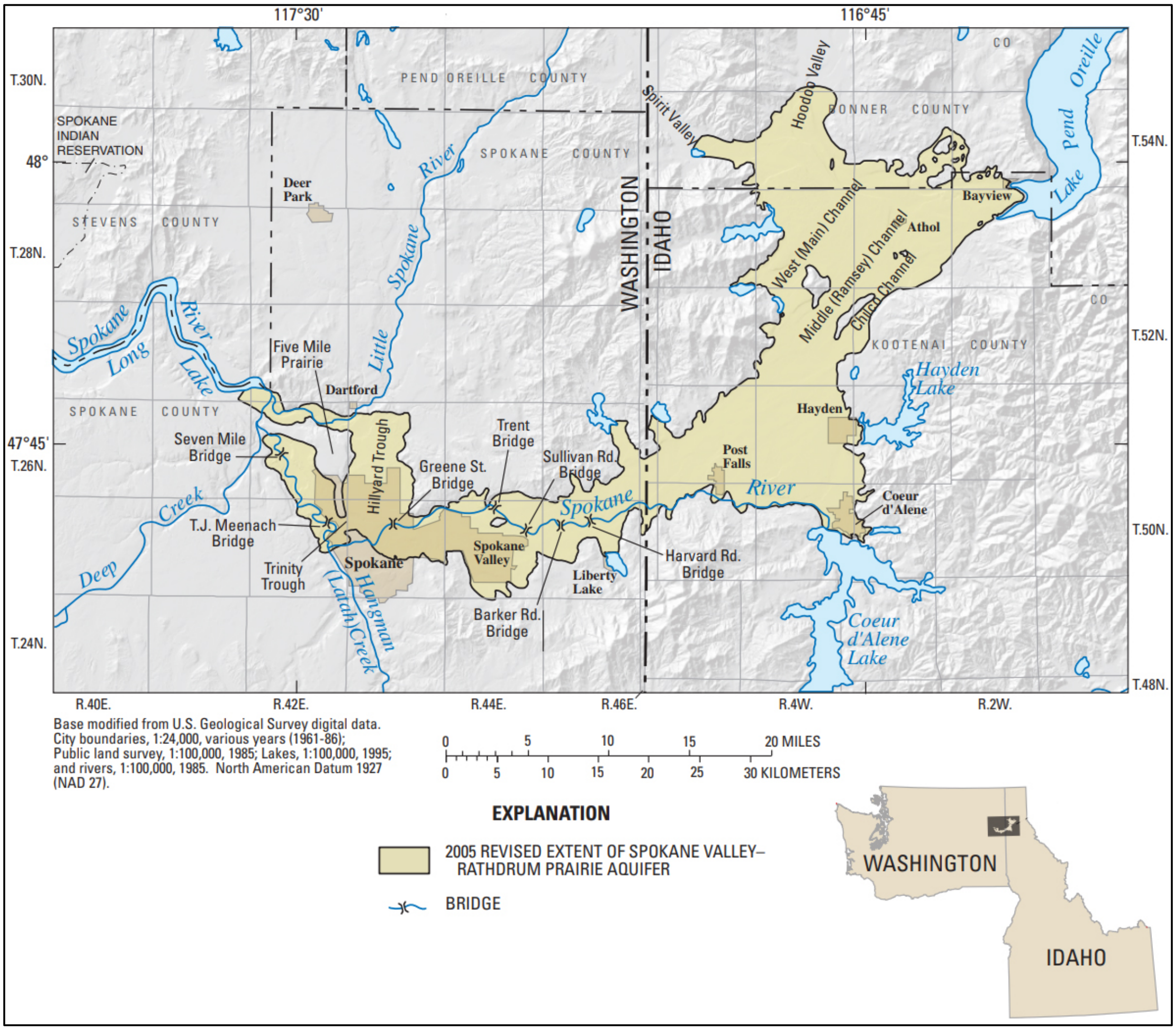

Figure 2. Map of Spokane Valley Rathdrum Prairie Aquifer (from Kahle et al., 2005)

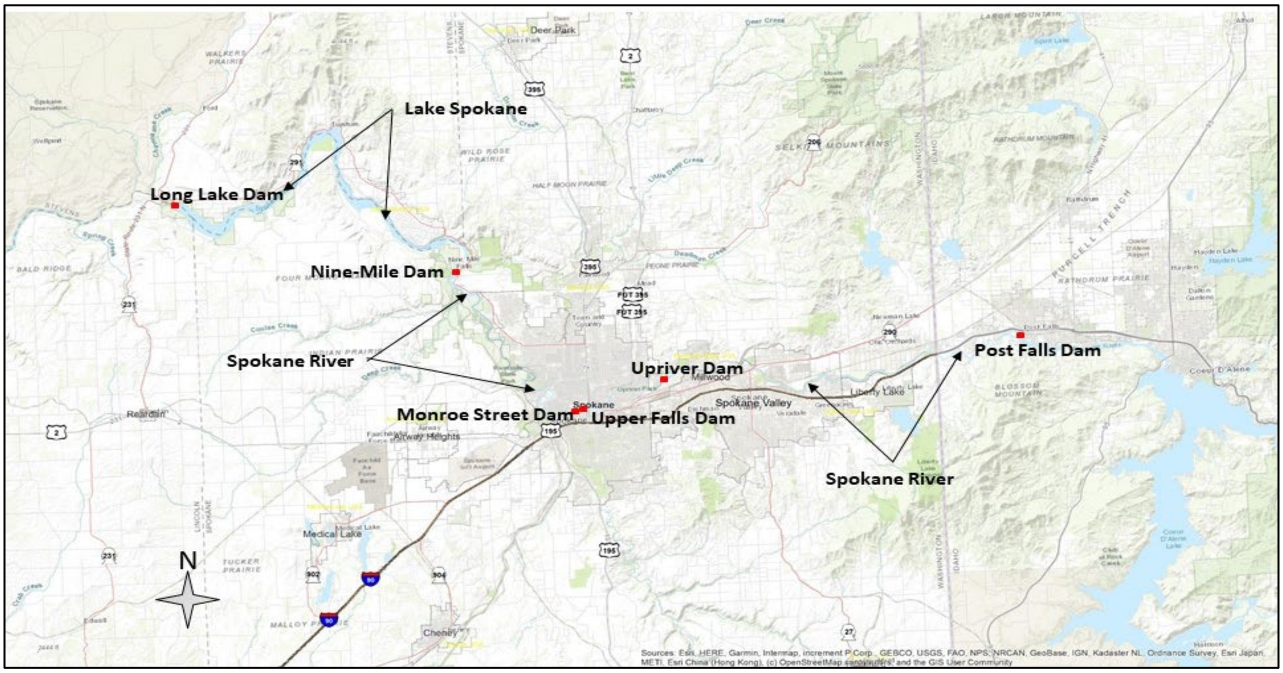

Figure 3. Dams on the Spokane River in Washington and Idaho.

3.2.1 History of study area

Algae blooms and low DO levels in the lower depths of Lake Spokane (Long Lake) have existed for decades. Patmont et al. (1987) described water quality problems that occurred in the lake during the 1930s, 1960s, and beyond. During the 1970s, Eastern Washington University and others completed multiple studies on the lake. These studies indicated that removing total phosphorus (TP), particularly from the City of Spokane's WWTP, would help improve the lake's water quality (Patmont et al., 1987). In December 1977, the City of Spokane completed an upgrade to their WWTP to remove 85% of the TP coming into the plant (Patmont et al., 1987). As a result, the lake's minimum DO concentrations in the summer of 1978 showed significant improvement (Cusimano, 2004).

Despite the improvement, algae blooms continued to occur and more point source dischargers began operating. This prompted a group of Lake Spokane homeowners to file a lawsuit. The lawsuit launched decades of study, modeling, phosphorus management planning (*1989 Spokane River Phosphorus Management Plan*; *1992 Total Phosphorus TMDL*; *2010 Spokane River and Lake Spokane Dissolved Oxygen TMDL*), and improvement actions.

The goal of the TMDL is to achieve the DO water quality standard in Lake Spokane. The TMDL includes requirements for the following nutrient sources within Washington State:

- Point sources such as municipal WWTPs or industrial facilities that discharge treated water into the river. There are five point source dischargers in Washington on the Spokane River.
- Nonpoint source pollution that enters our waters from everyday activities such as over-application of fertilizer, poor management of livestock and pet waste, bare stream banks that erode, and failing septic systems. Most of the nonpoint source pollution comes from the tributaries (Hangman Creek, Coulee Creek, and the Little Spokane River) and the area around Lake Spokane.
- Avista received a portion of the responsibility because Long Lake Dam created the conditions that led to the DO problem.

Idaho point sources to the Spokane River are included in the TMDL because federal law requires upstream states to comply with water quality standards of downstream states. Modeling for the TMDL showed that nutrients from the three Idaho dischargers affect DO levels in Lake Spokane. Ecology does not have authority to require reductions in Idaho, but we worked with EPA which was responsible for issuing National Pollutant Discharge Elimination System (NPDES) wastewater discharge permits in Idaho at that time (EPA, 2013). (The Idaho Department of Environmental Quality is now the permitting agency.) The permits contain conditions that ensure compliance with Washington water quality standards.

Since 2010, Ecology and its partners have been implementing the TMDL through point and nonpoint source reductions. Point source dischargers in Washington have largely implemented tertiary treatment technology, with the last major point source, the City of Spokane, scheduled to bring tertiary treatment online and optimize during 2021. Idaho point sources are at varying points in this process, with improvements either online or under construction.

Many organizations have been working to reduce nonpoint pollution through riparian restoration, implementation of best management practices (BMPs) for agricultural, residential, and forest land, outreach and education, and a variety of other actions. These groups include the Spokane, Pend Oreille, and Whitman Conservation Districts; the Spokane and Coeur d'Alene Tribes; Avista; Spokane Riverkeeper; The Lands Council; and many others.

To date, these groups have completed hundreds of projects to reduce nonpoint source pollution. Many of these projects are located in the Hangman Creek and Little Spokane watersheds. The types of projects completed include connecting homes historically on septic systems to a municipal sewer system; improving forest roads to reduce erosion; installing livestock BMPs such as fencing off waterways and offsite watering; improving tillage practices such as converting to direct seeding or minimum till; planting riparian (stream bank) areas with trees and shrubs; and using various methods to protect stream banks from eroding.

The cities of Spokane and Spokane Valley, along with Spokane County, are working to redirect stormwater runoff so it can infiltrate into the ground instead of flowing directly into the Spokane River. In addition, the City of Spokane has installed large underground vaults that can store some stormwater until it can be treated at the WWTP. The Washington State Department of Transportation is also an active partner in reducing stormwater from the highways by performing maintenance and working with adjacent landowners to eliminate pollution sources entering the ditches and drains.

3.2.2 Summary of previous studies and existing data

Multiple groups have been collecting monitoring data from Lake Coeur d'Alene to Long Lake Dam since the *Spokane River and Lake Spokane DO TMDL* was adopted in 2010. This section provides a brief overview of some of the most applicable findings.

3.2.2.1 Ecology ambient monitoring data

Ecology's ambient monitoring program collects a variety of water quality data monthly at streams around Washington state. Since around 2007, this has included varying locations in the Spokane TMDL study area (Figure 4), including:

- Spokane River at state line (57A150)
- Spokane River at Sullivan Rd. (57A146)
- Spokane River at Plante's Ferry/Centennial Trail Bridge (57A140)
- Spokane River at Greene St. (57A133)

- Spokane River at Sandifur Bridge (57A123)
- Hangman Creek at mouth (56A070)
- Spokane River 57 at TJ Meenach Dr. (54A130)
- Spokane River at Riverside State Park (54A120)
- Spokane River below Ninemile Dam (54A090)
- Little Spokane River at mouth (55B070)

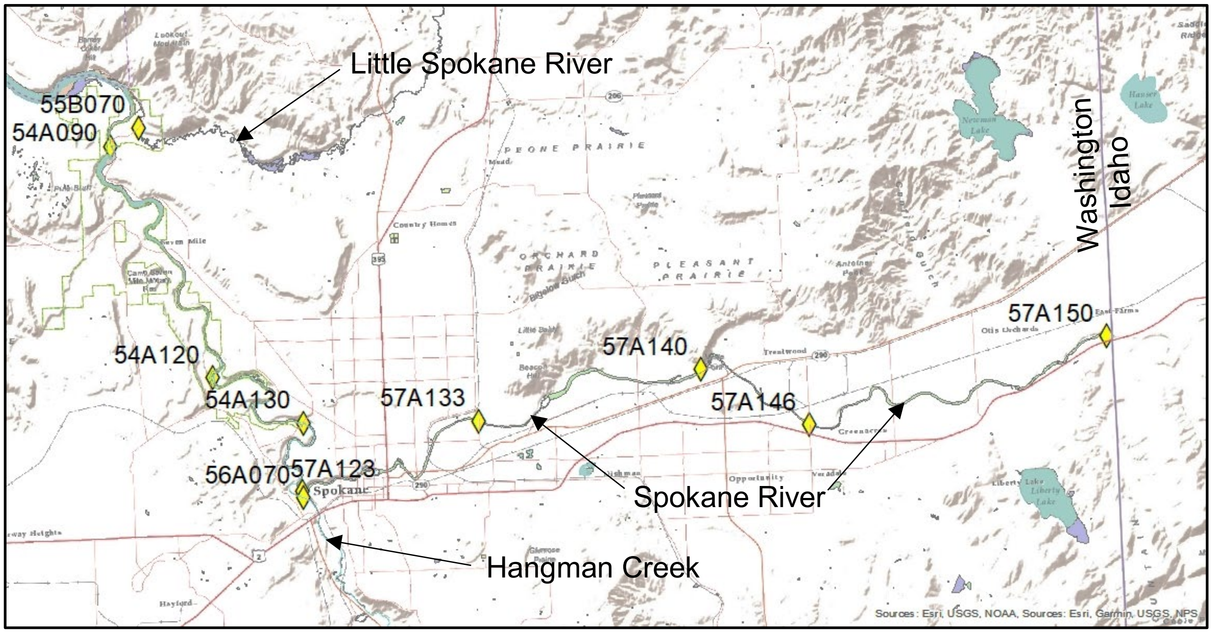

Figure 4. Ambient water quality stations in Spokane TMDL study area

Figure 5 presents total phosphorus (TP) results from surface water sampling events at these monitoring stations. Data from the Ninemile Dam and Riverside State Park monitoring sites, which represent the lower part of the system downstream of all the major point sources, indicate a declining trend in TP concentrations from 2007 through 2020. There is also an apparent downward trend for Hangman Creek. The upper Spokane River (for example, at state line) and the Little Spokane River do not display any clear trends for TP.

In early 2018, EPA instituted a change in TP analytical test reporting limit methodology which raised the reporting limit from 0.005 milligrams per liter (mg/L) to 0.01 mg/L. This reporting limit increase impacted the data for Stateline and Greene Street Bridge ambient monitoring stations through mid-2020 when Ecology's Manchester Environmental Laboratory (MEL) developed a testing and reporting protocol which was able to lower the testing reporting limit back to 0.005 mg/L concentrations.

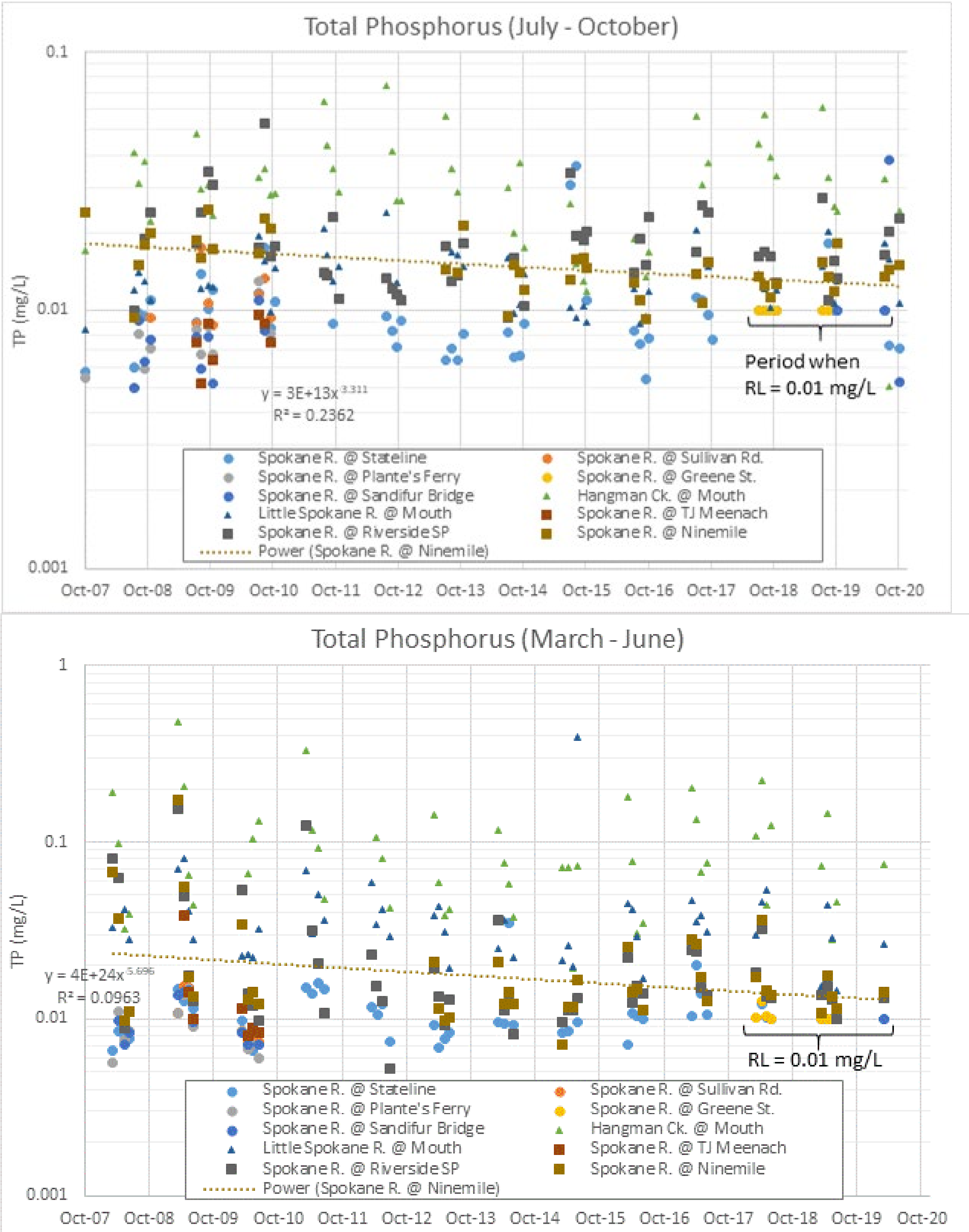

Figure 5. Ambient total phosphorus (TP) data for the Spokane River and tributaries, for the 2008-2020 water years.

3.2.2.2 Avista/Tetra Tech Lake Spokane monitoring

In response to the Spokane River TMDL, and as part of their Washington 401 Certification and Federal Energy Regulatory Commission (FERC) relicensing, Avista developed a *Lake Spokane Dissolved Oxygen Water Quality Attainment Plan* and have been preparing annual summary reports to document their monitoring program (Avista and Golder, 2012; Avista, 2014; and Avista, 2015).

From 2010-2018, Avista contracted with Tetra Tech to conduct monitoring in Lake Spokane (Avista and Tetra Tech, 2020). This included nutrient sampling as well as vertical profile measurements of temperature, DO, conductivity, and pH, using the same six monitoring locations that were used in the original TMDL data collection (Cusimano, 2003) and that we will use in this 10-year assessment. This monitoring showed that hypolimnetic DO conditions in Lake Spokane during 2010-2018 were significantly better than during earlier studies from the 1970s and 1980s. The comparison of these recent and historical data also revealed a strong inverse relationship between mean inflow TP concentration and hypolimnetic DO levels.

Figure 6 shows typical summertime DO conditions in Lake Spokane during this 2010-2018 monitoring.

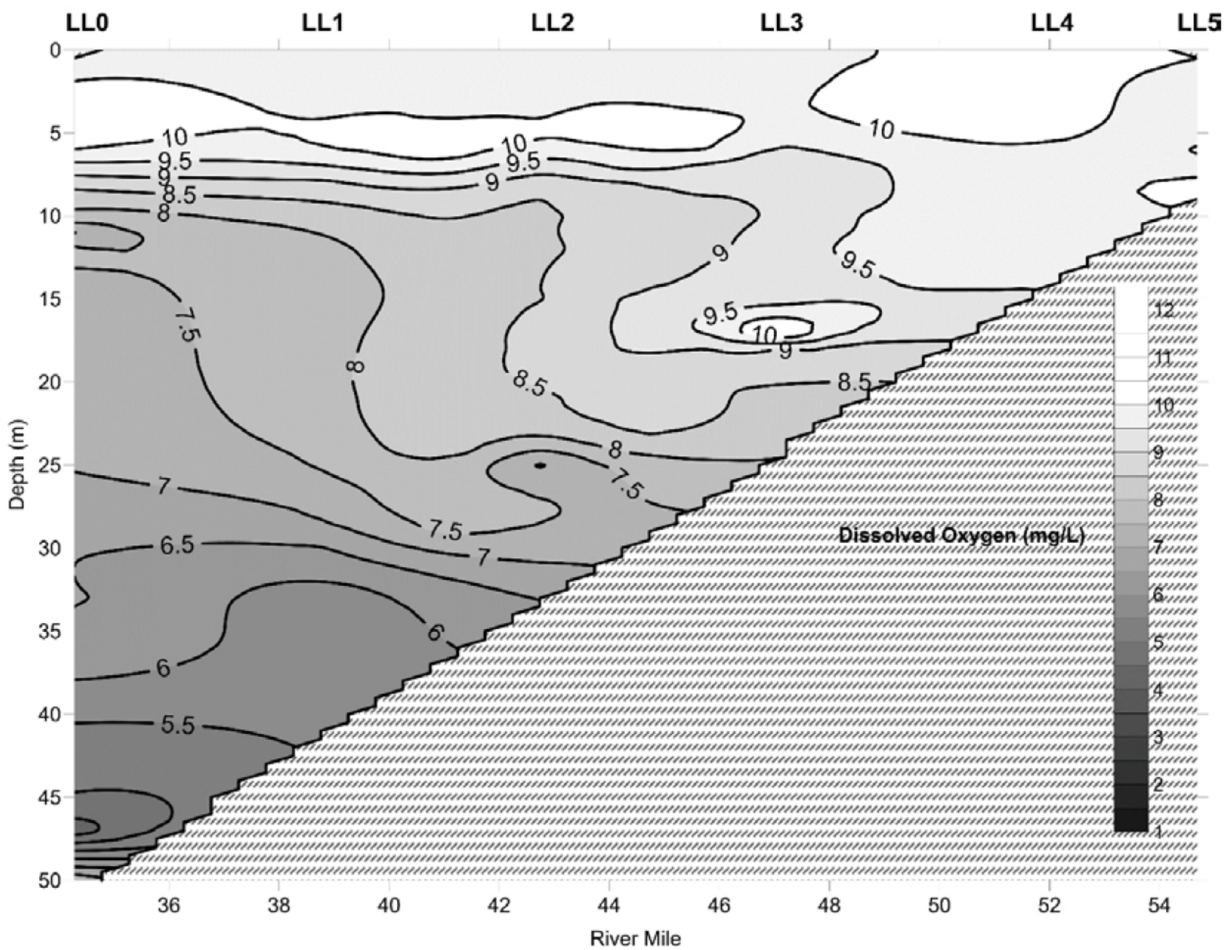

Figure 6. Average June-October dissolved oxygen (DO) contours in Lake Spokane, 2010-2018 (from Avista and Tetra Tech, 2020)

In 2017 Ecology conducted a literature review to identify and evaluate alternative methods or analyses that could be used to measure improvements in water quality, reservoir health, and support for aquatic life in Lake Spokane (Pickett, 2018). Recommendations from the literature review included implementing continuous DO/pH/Temp monitoring of mid-epilimnion in the lake.

In 2020 Avista, in conjunction with Ecology, conducted a diurnal monitoring study consisting of continuous measurements of temperature and DO within the epilimnetic waters at three locations within Lake Spokane:

- DAILY-A located downstream from the Lake Spokane Campground in the vicinity of LL1 in water no deeper than 9 m (30 feet).
- DAILY-B located near northshore of TumTum Bay in the vicinity of LL2a in water no deeper than 9 m (30 feet).
- DAILY-C located near Suncrest in the vicinity of LL4 in water no deeper than 8 m (26 feet).

The purpose of monitoring temperature and DO continuously within the epilimnion is to provide a better understanding of the diurnal fluctuations that may be present during the summer critical season.

Avista measured continuous temperature and DO during the summer months (June through September 2020) using Onset HOBO data loggers secured to a chain and buoy system at specified depths. Avista also measured secchi disk transparency monthly at each of the three diurnal monitoring locations as well as at the nearby baseline water quality stations.

Avista is currently evaluating the data from this study. We anticipate a report from them during 2021.

3.2.2.3 U.S. Geological Survey (USGS) groundwater monitoring

USGS performed an evaluation of the concentrations of total phosphorus (TP) and nitrogen in shallow groundwater discharging along the northern shoreline of Lake Spokane in 2014-2015 (Gendaszek et al., 2016). This was to determine if there is a difference between nutrient concentrations in groundwater discharging to the lake (1) downgradient of residential development with on-site septic systems and (2) downgradient of undeveloped land without on-site septic systems. USGS collected near-surface groundwater from shallow piezometers installed at 30 locations in Lake Spokane in the lakebed within 20 ft of the shoreline. This included 19 piezometers installed and sampled during March 24-26, 2015, and 11 piezometers installed and sampled during April 29-30, 2015.

USGS performed two additional groundwater seepage studies to address nonpoint source input of nitrogen and TP to Lake Spokane:

- Sampling from October 2016 to October 2017 to investigate seepage along the northern shoreline of Lake Spokane.
- Sampling in the summer and fall of 2019 to investigate seepage along the southern shoreline of Lake Spokane.

These studies included measuring the concentration of nitrogen and TP in groundwater and estimating groundwater discharge rates. The findings of the studies will provide resource managers with the information to support a decision on whether installation of a new sewer collection and treatment system is warranted in order to protect human health and improve habitat for biota in Lake Spokane. The USGS report from these studies is in progress.

3.2.2.4 Discharger monitoring data

Point source dischargers to the Spokane River routinely monitor their effluent for a variety of parameters, as part of the requirements of their National Pollutant Discharge Elimination System (NPDES) permits. These dischargers report the results of this monitoring to Ecology in monthly Discharge Monitoring Reports (DMRs). All of the Spokane dischargers monitor TP, ammonia, and CBOD (or BOD), the parameters for which the 2010 Spokane TMDL report set wasteload allocations. Most of the dischargers also collect other nutrient parameters, such as total reactive phosphorus (TRP), nitrate-nitrite (NO2-3), and total Kjeldahl nitrogen (TKN). In addition, many of the dischargers collect parameters relevant to this study, such as total suspended solids (TSS) and alkalinity. These DMR effluent data will be a key part of this Spokane 10-year assessment.

3.2.2.5 Water quality improvement studies in Hangman (Latah) Creek

In September 2009, EPA approved the *Hangman (Latah) Creek Watershed Fecal Coliform, Temperature, and Turbidity Total Maximum Daily Load* (Joy et al., 2009). An implementation plan (Snouwaert and Noll, 2011) followed in May 2011. Multiple implementation projects by the Spokane Conservation District, The Lands Council, the City of Spokane, the Coeur d'Alene Tribe, and the Washington Department of Transportation to reduce pollution from nonpoint sources have been completed or are underway. Many of these projects will also reduce nutrients that contribute to DO and pH impairments.

Ecology's intention was to complete another TMDL to comprehensively address DO and pH impairments in the Hangman watershed. This effort faced significant policy challenges relating to the application of the Washington State water quality standards to the low-flow and intermittent conditions that occur in the Hangman Creek watershed. Until 2016, Ecology's approach focused on finding a policy solution to issues related to stagnant and intermittent flow conditions, which are in part a natural phenomenon in the watershed. The goal of the policy work was to better align the water quality standards with the modeled natural conditions in order to reflect conditions present prior to human influence in the watershed. This effort was further complicated by litigation filed in 2014 that successfully challenged EPA's approval of provisions to incorporate natural conditions in the application of water quality criteria.

In 2016, Ecology adopted a different approach: targeted source assessment studies to provide information relating to specific water quality issues that we could address. During 2017-2018, we collected field data for these studies (Albrecht et al., 2017). In May 2020, we completed the *Tekoa Wastewater Treatment Plant Dissolved Oxygen, pH, and Nutrients Receiving Water Study* (Stuart, 2020). Work on the *Hangman Creek Watershed Dissolved Oxygen, pH, Nutrients, and Sediment Pollutant Source Assessment* is ongoing. This study will address sources of nutrients, particularly TP, in the Hangman Creek watershed, with an emphasis on those sources that contribute to pollutant loads entering the Spokane River.

3.2.2.6 Water quality improvement studies in the Little Spokane River

In April 2012, EPA approved the *Little Spokane River Watershed Fecal Coliform Bacteria, Temperature, and Turbidity Total Maximum Daily Load* (Joy and Jones, 2012). Implementation partners, such as the Spokane and Pend Oreille County conservation districts, continue to implement BMPs for agriculture and septic systems in the watershed. The Lands Council is also working on riparian restoration projects. These implementation activities also address DO and pH impairments in the watershed.

In January 2021, EPA approved the *Little Spokane River Dissolved oxygen, pH, and Total Phosphorus Total Maximum Daily Load* (Johnson et al., 2020). This TMDL (1) reinforces the need to restore riparian vegetation throughout the Little Spokane watershed, and (2) establishes nutrient reductions needed to meet DO and pH standards as well as requirements of the Spokane TMDL. The implementation plan included in this TMDL report is intended to address the needs of both this (2020) TMDL as well as the earlier 2012 TMDL, since there is significant overlap in the BMPs needed to address both sets of impairments.

3.2.3 Parameters of interest and potential sources

The Spokane River/Lake Spokane system is generally considered to be TP-limited (Moore and Ross, 2010). The TMDL report included a *Managed Implementation Plan* to reduce nutrients in the Spokane River and Lake Spokane in order to prevent low DO, excessive algae blooms, and degradation of downstream water quality. DO levels in this system are affected by natural variability and human activities that alter the physical, chemical, and biological characteristics of the lake. The TMDL report established limits for the three pollutants affecting DO in the lake: ammonia (NH_3-N), total phosphorus (TP), and carbonaceous biochemical oxygen demand (CBOD).

These pollutants can come from natural and human sources.

Natural sources can include geologic sources such as dissolution of minerals in groundwater and biological sources such as wildlife.

Human sources include point and nonpoint sources:

- Point sources are typically associated with facilities such as municipal and industrial wastewater treatment plants (WWTPs) or infrastructure such as stormwater. Point sources are regulated by National Pollutant Discharge Elimination System (NPDES) permits administered by agencies such as Washington State Department of Ecology (Ecology) and the Idaho Department of Environmental Quality. The majority of point source pollution in the Spokane River watershed enters the Spokane River mainstem rather than the tributaries, although some smaller point sources also discharge to the tributaries.
- Nonpoint sources are diffuse sources often associated with land-use practices. These can include residential and urban sources such as runoff from lawns and streets, pet waste, and septic systems. They can also include agricultural sources such as field erosion due to tillage, fertilizer, livestock waste, and bank erosion resulting from removal of riparian vegetation and altered stream hydraulics. Forest practices such as logging and road building can also contribute nonpoint pollution. Nonpoint pollution can enter the stream directly, such as bank erosion, via overland runoff, or through groundwater. The majority of nonpoint pollution in the Spokane River watershed enters through the tributaries, chiefly Hangman Creek and the Little Spokane River.

3.2.4 Regulatory criteria or standards

3.2.4.1 Water quality standards

In the Washington State water quality standards, freshwater aquatic life use categories are described using key species (salmonid versus warm-water species) and life-stage conditions (spawning versus rearing). Minimum DO concentrations are used as criteria to protect different categories of aquatic communities [WAC 173-201A-200; 2006 edition]. The state treats lakes differently from rivers for protecting DO conditions. Therefore, there are two DO standards for the TMDL, one for the mainstem of the Spokane River from the state line to Nine Mile Dam, and one for Lake Spokane from Nine Mile Dam to Long Lake Dam (Table 1).

For all lakes, and for reservoirs with a mean annual retention time of greater than 15 days, human actions considered cumulatively may not measurably decrease the one-day minimum DO concentration below estimated natural conditions. Ecology and EPA have consistently used the value of 0.2 mg/L to define “measurable.” Taking the two definitions together, DO cannot be reduced by more than 0.2 mg/L below estimated natural conditions.

The criteria described in Table 1 are used to ensure that where a water body is naturally capable of providing full support for its designated aquatic life uses, that condition will be maintained. However, when a water body is naturally lower in DO than the criteria, the state provides an additional allowance for further depression of DO conditions due to human activities.

Table 1. Designated aquatic life uses and criteria protected by this TMDL as defined in the 2006 water quality standards.

Portion of Study Area	Aquatic Life Uses	Dissolved Oxygen (DO) Criterion
Spokane River (from Nine Mile Bridge to the Idaho border)	Migration/Rearing/ Spawning	DO shall exceed 8.0 mg/L. If *natural conditions*[a] are less than the criteria, the natural conditions shall constitute the water quality criteria.
Lake Spokane (from Long Lake Dam to Nine Mile Bridge)	Core Summer Habitat	No measurable (0.2 mg/L) decrease from natural conditions.
Spokane Arm of Lake Roosevelt (from confluence of Columbia R. and Spokane R. to Little Falls Dam – outside of TMDL compliance point)	N/A	DO shall not be less than 8.0 mg/L.[b]

[a] Washington water quality standards (WAC 173-201A-020) define "Natural conditions" or "natural background levels" as "surface water quality that was present before any human-caused pollution. When estimating natural conditions in the headwaters of a disturbed watershed, it may be necessary to use the less disturbed conditions of a neighboring or similar watershed as a reference condition." See the Natural and Background Conditions section for more details on how natural conditions were determined for this TMDL.

[b] Spokane Tribe of Indians Surface Water Quality Standards (Resolution 2003-259).

3.2.4.2 Spokane TMDL allocations

The *Spokane River and Lake Spokane DO TMDL* report (Moore and Ross, 2010) established wasteload allocations for point source dischargers, as well as load allocations for nonpoint sources. The TMDL report also assigned a DO responsibility to Avista. Avista does not discharge pollutants to the Spokane River/Lake Spokane system, but Avista owns and operates Long Lake Dam, which creates Lake Spokane. The goal of the TMDL is to achieve the DO water quality standard in Lake Spokane. Achieving the allocations established in the TMDL report for point and nonpoint sources, Avista's responsibility and the assumptions for Idaho should result in the lake attaining the water quality standard.

Table 2 shows the wasteload allocations for Washington State point sources. These are based on meeting a monthly average TP concentration of 50 ug/L. The seasonal average concentrations reflected in the table are less than 50 ug/L because effluent concentrations are not constant over time.

Idaho point sources to the Spokane River are included in the 2010 TMDL report because federal law requires upstream states to comply with water quality standards of downstream states. Modeling for the TMDL showed that nutrients from the three Idaho dischargers (City of Coeur d'Alene, Hayden Area Regional Sewer Board, and City of Post Falls) affect DO levels in Lake Spokane. Ecology does not have authority to require reductions in Idaho, but we worked with EPA who is responsible for issuing permits in Idaho. The permits would contain conditions that ensure compliance with Washington water quality standards. So, the TMDL report assumed that Idaho WWTPs and stormwater combined would achieve the following nutrient reductions:

- 7.2 lbs/day total phosphorus (TP)
- 497 lbs/day CBOD
- 94.4 lbs/day ammonia

Table 2. Wasteload allocations for Washington State point sources (Moore and Ross, 2010)

Point Source Discharge	2027 Projected Flow Rates (MGD) [1]	NH3-N		TP		$CBOD_5$ [2]	
		mg/L	lbs/day (WLA)	mg/L	lbs/day (WLA)	mg/L	lbs/day (WLA)
Liberty Lake	1.5	variable[3]	variable[3]	0.036	0.45	3.6	45.1
Kaiser[4]	15.4	0.07	9.0	0.025	3.21	3.6	462.7
Inland Empire Paper Company	4.1	0.71	24.29	0.036	1.23	3.6	123.2
City of Spokane	50.8	variable[3]	variable[3]	0.042	17.81	4.2	1780.6
Spokane County (new plant)	8	variable[3]	variable[3]	0.042	2.80	4.2	280.4
Stormwater[5]	2.36	0.05	0.98	0.310	6.1	3.0	59.1
CSO	0.12	1.0	1.0	0.95	0.95	30.0	30.0

1- Actual, not projected flows, will determine compliance with wasteload allocations (WLAs) in NPDES permits.

2- NPDES permit limits will use $CBOD_5$ (as shown) rather than $CBOD_{ult}$ (as modeled).

3- Ammonia WLAs vary depending on the season based on the following effluent concentrations (loading limits use these concentrations and the design flow):

Liberty Lake:
March-May, October: 0.71 mg/L
June-September: 0.18 mg/L
City of Spokane and Spokane County:
March-May, October: 0.83 mg/L
June-September: 0.21 mg/L

4- WLAs for Kaiser are lower than other dischargers due to non-contact groundwater, which is low in nutrients and comprises a significant portion of the facility's discharge.

5- Stormwater WLAs are for Washington sources only and are based on average existing flows, not 2027 projected flows.

The TMDL report assigned load allocations to nonpoint sources of pollution (Table 3). The three tributaries (Hangman Creek, Coulee Creek, and the Little Spokane River) and the area surrounding Lake Spokane are the primary sources of nonpoint pollution to the river and lake. As with the point sources, the nonpoint allocations apply from March through October. In Hangman and Coulee Creeks, the allocations vary by season and translate to the following reductions:

- 20%: March – May
- 40%: June
- 50%: July – October

In the Little Spokane River, the allocation represents a 36% decrease in TP during the entire March through October critical season.

Table 3. Tributary and groundwater load allocations (Moore and Ross 2010)

Water Body and Season	2001 Flow (cfs)	Total Phosphorus (TP)		Ammonia (NH3-N)		CBOD	
		Allocation Concentration (mg/L) [1]	2001 Load Allocation (lbs/day)	Allocation Concentration (mg/L)	2001 Load Allocation (lbs/day)	Allocation Concentration (mg/L)	2001 Load Allocation (lbs/day)
Hangman Creek							
March– May Average	229	0.113	140.2	0.034	42.1	3.3	4102.1
June	31	0.044	7.5	0.012	2.1	2.8	479.0
July – Oct Average	9	0.030	1.4	0.009	0.4	2.3	107.9
Coulee Creek							
March– May Average	30	0.113	18.2	0.034	5.5	3.3	533.7
June	8	0.044	1.8	0.012	0.5	2.8	116.5
July – Oct Average	2	0.030	0.4	0.009	0.1	2.3	28.6
Little Spokane River							
March – May Average	565	0.034	102.5	0.035	106.2	2.1	6409.3
June	426	0.023	53.9	0.005	11.5	2.1	4828.2
July – Oct Average	364	0.016	32.2	0.006	11.0	1.5	2867.8
Groundwater – Upstream of Lake Spokane							
March – May Average	1946	0.0081	87	N/A	N/A	N/A	N/A
June	1583	0.0078	66	N/A	N/A	N/A	N/A
July – Oct Average	1165	0.0076	48	N/A	N/A	N/A	N/A
Groundwater / Surface Water Runoff – Lake Spokane watershed							
March – May Average	588[2]	0.025	79	N/A	N/A	N/A	N/A
June	225[2]	0.025	30	N/A	N/A	N/A	N/A
July – Oct Average	180[2]	0.025	24	N/A	N/A	N/A	N/A

1- Allocation concentrations are based on critical low-flow conditions.

2- Reservoir correction flows in the water quality model. Flows are both positive and negative. The listed value is the average of positive inflows to the reservoir.

In the 2010 TMDL report, Avista received a “responsibility” because they are not responsible for discharging nutrients, but their Long Lake Dam created the lake and conditions that contribute to the reservoir’s impairment. Avista’s task is to increase DO in the deeper parts of Lake Spokane from July 1 through October 31. The level of DO improvement required depends on the location and depth of the lake, as well as time of the year, but the required increase ranges from 0.1 to 1.0 mg/L.

3.3 Effectiveness monitoring studies

TMDL effectiveness monitoring is a fundamental component of any TMDL implementation activity. It is an essential part of the TMDL adaptive management process. Effectiveness monitoring measures to what extent management activities have resulted in progress toward meeting state water quality standards. Effectiveness monitoring takes a holistic look at TMDL implementation, watershed management plan implementation, and other watershed-based cleanup efforts. Rather than monitoring the effectiveness of any particular implementation action, effectiveness monitoring studies generally measure the cumulative effect of all activities in the watershed. Success may be measured against TMDL load allocations or targets, correlated with baseline conditions or desired future conditions.

The TMDL effectiveness monitoring evaluation provides:

- A measure of progress toward implementation of recommendations, namely how much watershed restoration has been achieved and how much more effort is required.
- More efficient allocation of funding and optimization in planning and decision-making.
- Identification of restoration activities that worked and those that were most successful for the money spent.
- Technical feedback to refine the initial TMDL model, BMPs, nonpoint source plans, and permits.

This 10-year effectiveness monitoring study is intended to provide an interim check on conditions in the Spokane River and Lake Spokane in order to assess progress toward compliance with water quality standards reflecting the first decade of implementation since adoption of the *Spokane River and Lake Spokane DO TMDL* (Moore and Ross, 2010). The TMDL report established needs and requirements for this 10-year study. We discuss these below in sections 4.0-4.1.

3.3.1 Impairments addressed by the TMDL

The Spokane River and Lake Spokane have a long history of water quality problems. Algae blooms, including toxic blue-green algae blooms in the 1970s, have been a recurring problem in Lake Spokane. These blooms impair the recreational use and aesthetics of Lake Spokane. Recurring impairments of the beneficial uses and violations of water quality standards resulted in some waterbody segments of the Spokane River and Lake Spokane being included on one or more of Ecology's 303(d) lists of impaired water bodies since 1996. Table 4 lists these impairments. These impairments are all currently listed on the 305(b) list, in category 4A. The DO impairments are listed in category 4A because of the *Spokane River and Lake Spokane DO TMDL*.

Table 4. Water bodies currently on the 305(b) list

Waterbody Segment	Parameter	Medium	2012 305(b) Listing ID	NHD Reach Code
Lake Spokane (Long Lake)	Dissolved oxygen	Water	40939	17010307000078
Spokane River	Dissolved oxygen	Water	15188	17010307000142
Spokane River	Dissolved oxygen	Water	17523	17010305000009
Spokane River	Dissolved oxygen	Water	15187	17010305000009
Spokane River	Dissolved oxygen	Water	11400	17010305000012
Spokane River	Total Phosphorus	Water	6373	17010307000774
Lake Spokane (Long Lake)	Total Phosphorus	Water	9016	17010307000075

The Spokane River downstream of Long Lake Dam also violates the Spokane Tribe of Indian's DO water quality standard of 8 mg/L (per. comm. Butler, 2004 and 2007). Continuous monitoring of the river below Long Lake Dam by the Spokane Tribe of Indians shows depressed DO levels, with recurring minimums below 3.0 mg/L near the mouth of the Spokane River attributed to decomposition of summer algal biomass (Lee et al., 2003).

4.0 Project Description

The *Spokane River and Lake Spokane DO TMDL* report (Moore and Ross 2010) defined a 20-year timeline for achieving water quality improvement goals. The concept of a Spokane River/Lake Spokane 10-year assessment emerged while working with the TMDL advisory group. However, the TMDL report did not set specific 10-year water quality objectives. Rather, the purpose of this 10-year effectiveness monitoring assessment is to provide a midway check to determine whether substantial progress is being made toward meeting the 20-year goals.

The TMDL report characterizes the 10-year assessment as a data-based, objective review conducted on the data summaries collected to date, monitoring information, and the CE-QUAL-W2 model. The 10-year assessment will consider factors such as how long the treatment technology has been in operation, and whether sufficient data are available to determine river conditions and DO response.

The 10-year assessment concept included using the CE-QUAL-W2 model but did not specify how the model would be used for determining progress towards the 20-year water quality objectives. We discuss potential uses of the model in section 7.3.

Ecology has determined that the goals of the 10-year assessment will be best served by using existing data collected by Avista, the Spokane River point source dischargers, USGS, and Ecology, along with additional data collected specifically to support this analysis.

This quality assurance project plan (QAPP) serves jointly with the *Programmatic QAPP for Water Quality Impairment Studies* (McCarthy and Mathieu, 2017) to describe this effectiveness monitoring project and the procedures that will be followed to achieve project goals and objectives. The Programmatic QAPP addresses elements that apply to all water quality impairment projects, while this QAPP mainly addresses elements specific to this project.

4.1 Project goals

The Spokane TMDL report (Moore and Ross, 2010) established goals for the 10-year assessment. We have not established any new goals, objectives, or approach since the TMDL was implemented. This 10-year effectiveness monitoring assessment will not attempt to evaluate whether any specific entity has achieved or met TMDL compliance. The 10-year assessment will be a data-based, objective review undertaken with the goal of determining:

- The amount of total phosphorus (TP) removed from the Spokane River compared to TP reduction requirements.
- The Spokane River and Lake Spokane's response to the reductions and associated changes in DO.
- The likelihood of further TP reductions occurring in the second 10 years (2020-2030) if the actions already taken are continued.
- A set of actions that could be initiated in the second 10 years that would likely result in further TP reductions.
- The reasonableness of pursuing other strategies if the DO standard has not been met and continuing existing or implementing additional TP removal strategies will likely achieve the DO standard.
- The progress on implementing Avista's DO responsibility.

- Whether the hypolimnion has met the DO standard with technology improvements and target pursuit actions or Avista's DO responsibility, or if modified water quality standards for this layer are appropriate.
- Whether the wasteload allocations, load allocations, and DO responsibility are being met and whether they should be lowered or raised (or redistributed) while still being protective of water quality.

4.2 Project objectives

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

Monitoring objectives

- Augment monthly Ecology ambient water quality monitoring with additional locations and sample parameters (See Section 7.2).
- Collect one season (April-October) of sample and measurement data from Lake Spokane.
- Collect continuous field measurement data including turbidity, DO, and other parameters at selected locations in the Spokane River and at tributary mouths.
- Refine groundwater nutrient data by sampling using temporary drive-points in gaining reaches of the Spokane and lower Little Spokane Rivers.
- Find location of specific unknown TP load source to the lower Little Spokane River through targeted source tracking surveys.

Analysis objectives

- Assess input loads, nutrient conditions in the Spokane River, and DO response in Lake Spokane measured during 2021-2022 to determine progress toward meeting the TMDL requirements, and specifically to provide answers to the questions listed above under "Project Goals."
- Assess data collected during the years between TMDL adoption in 2010 and the beginning of this study in 2021, particularly by Avista, the dischargers, and Ecology's ambient monitoring program, to determine trends and progress over the last decade.
- Consider developing a 2021-2023 scenario using the existing CE-QUAL-W2 Spokane model based on hydrologic conditions and data collected during the 2021-2022 study. This scenario could contribute to the understanding of the overall progress towards achieving the TMDL 20-year goals.

4.3 Information needed and sources

This section provides a brief overview of information needed for this 10-year assessment. Section 7.3 provides more detailed information of the data needs for the CE-QUAL-W2 model.

Information from existing sources (Ecology or otherwise), outside of this project:

- Streamflow data – USGS gages
- Reservoir pool elevations – Avista
- Meteorological data – National Weather Service (NWS) and Remote Automated Weather Stations (RAWS)
- Groundwater data – Spokane County well monitoring, USGS Lake Spokane piezometer studies
- River nutrient data – Ecology's ambient monitoring program
- Point source discharge data – Facility reported / Discharge monitoring reports (DMRs)

Information that we will collect as part of this effectiveness monitoring study:

- Additional river nutrient data – for locations and parameters not included in the ambient monitoring program.
- Lake water quality data – laboratory samples and field measurements.
- Continuous field measurement monitoring – turbidity (to provide a means to estimate continuous TP), DO, and other parameters.
- Additional groundwater data – drive-point groundwater samples in the Spokane and Little Spokane Rivers.
- Little Spokane River (LSR) data – to find unknown TP source in the lower LSR. See section 7.2 for more information.

4.4 Tasks required

This section provides a brief overview of the tasks required to complete this effectiveness monitoring study. Section 7 provides the details of the study design. The tasks required include the following:

- Collect stream/river water quality data for locations and parameters not covered by the ambient monitoring program.
- Collect laboratory samples and field measurement vertical profiles in Lake Spokane.
- Deploy and maintain instruments to continuously monitor turbidity, DO, and other parameters at selected locations.
- Sample groundwater nutrients entering surface water in gaining reaches of the Spokane and Little Spokane Rivers using temporary drive-point piezometers.
- Collect sample and flow data from the lower Little Spokane River to find the source of unknown TP load.
- Compile data from this study and from all other sources.
- Conduct thorough quality assurance/quality control (QA/QC) review on data.
- Conduct preliminary data analysis and evaluate need for additional CE-QUAL-W2 model scenario.
- If deemed necessary, pursue contract with Portland State University (PSU) to develop model scenario.
- Finalize analysis.
- Write, obtain reviews, finalize, and publish a report detailing the findings of this study.

4.5 Systematic planning process

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

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 5 shows the responsibilities of those who will be involved in this project.

Table 5. Organization of project staff and responsibilities.

Staff[1]	Title	Responsibilities
Adriane Borgias WQP, ERO Unit Phone: 509-329-3515	EAP Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Tighe Stuart EAP, ERO Unit, EOS Phone: 509-435-596	Project Manager	Writes the QAPP. Oversees field study. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the draft report and final report.
Andrew Albrecht EAP, ERO Unit, EOS Phone: 509-954-4950	Principal Investigator	Co-writes the QAPP. Performs the Ambient Water Quality Monitoring component of study. Oversees field sampling and transportation of samples to laboratory.
Janna Stevens EAP, ERO Unit, EOS Phone: 509-934-6725	Field Assistant	Co-writes the QAPP. Supports the Ambient Water Quality Monitoring component of study. Helps collect samples and records field information.
Brian Gallagher EAP, ERO Unit, EOS Phone: 509-638-6683	Field Assistant	Helps collect groundwater samples and records field information.
Cathrene Glick EAP, ERO Unit, EOS Phone: 509-209-7444	Unit Supervisor for the Project Manager	Co-writes the QAPP. Approves the budget, and approves the final QAPP. Directs groundwater sampling.
George Onwumere EAP, EOS Phone: 509-571-7036	Section Manager for the Project Manager and for the Study Area	Reviews the project scope and budget, tracks progress, provides internal review of the QAPP, and approves the final QAPP.
Alan Rue Manchester Environmental Laboratory Phone: 360-871-8801	Manchester Lab Director	Reviews and approves the final QAPP.
Portland State University Scott Wells & Chris Berger	Water Quality Modeler	CE-QUAL-W2 Model
Arati Kaza Phone: 360-407-6964	Ecology Quality Assurance Officer	Provides internal review of the draft QAPP and approves the final QAPP.

[1]All staff except the client are from EAP.
EAP: Environmental Assessment Program
EIM: Environmental Information Management database
EOS: Eastern Operations Section
ERO: Eastern Regional Office
QAPP: Quality Assurance Project Plan
WQP: Water Quality Program

5.2 Special training and certifications

All field staff involved with this project will have relevant experience following SOPs or will be trained by senior staff who do. Groundwater sampling will be directed by Cathrene Glick or another licensed hydrogeologist.

5.3 Organization chart

Table 5 shows the responsibilities of those who will be involved in this project.

5.4 Proposed project schedule

Tables 6 – 8 list key activities, due dates, and lead staff for this project. If flow conditions during the 2022 water year (Oct 1, 2021 – Sept 30, 2022) are not representative of TMDL critical conditions, Ecology may continue data collection during the 2023 water year. If this occurs, all task due dates will be extended by one year.

Table 6. Schedule for completing field and laboratory work

Task	Due date	Lead staff
Field work	10/2022	Andrew Albrecht
Laboratory analyses	11/2022	Alan Rue

Table 7. Schedule for data entry

Task	Due date	Lead staff
EIM data loaded* [1]	2/2023	Andrew Albrecht, Janna Stevens, or Tighe Stuart
EIM QA [2]	4/2023	Andrew Albrecht, Janna Stevens, or Tighe Stuart
EIM complete [3]	5/2023	Tighe Stuart

*EIM Project ID: tist0003.

EIM: Environmental Information Management database.

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

[2] Data verified to be entered correctly by a different person; any data entry issues identified. Allow one month.

[3] All data entry issues identified in the previous step are fixed (usually by the original data entry person); EIM Data Entry Review Form signed off and submitted to EAP's Activity Tracker Coordinator (who 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.

Table 8. Schedule for final report

Task	Due date	Lead staff
Draft to supervisor	4/2024	Tighe Stuart
Draft to client/ peer reviewer	5/2024	Tighe Stuart
Draft to external reviewers	6/2024	Tighe Stuart
Final draft to publications team	10/2024	Tighe Stuart
Final report due on web	1/2025	Tighe Stuart

5.5 Budget and funding

The cost for this project is $130,078. This includes (1) lab testing through Ecology's Manchester Environmental Laboratory (MEL) and (2) CE-QUAL-W2 modeling work through Portland State University (PSU), if needed.

Table 9 shows the budget breakdown for the project.

Table 10 details the laboratory budget.

Table 9. Project budget and funding

Item	Cost ($)
PSU CE-QUAL-W2 Salary, Benefits, and Indirect/Overhead	50,633
PSU Contract Service Fees/Supplies	2,000
PSU Travel and Other	2,000
CE-QUAL-W2 Modeling total	54,633
Laboratory (see Table 10)	75,445
TOTAL	130,078

Table 10. Laboratory budget details

Parameters [a]	Cost/ sample set	Total # sample sets	Total cost
Ambient river monitoring (Oct 2021 – Oct 2022)			
Regular ambient monitoring network locations where we are sampling additional parameters			
TNVSS[b], TOC, DOC, Alk	$130	87	$11,310
Regular ambient monitoring locations where we are adding TDS and Chl a			
TDS, Chl a	$75	59	$4,425
Additional sites to be sampled by TMDL staff (not part or regular ambient monitoring network)			
TSS, TNVSS[c], TPN, NO2-3, NH4, TP, OP, TOC, DOC, Alk	$240	44	$10,560
Lake monitoring (April – Oct 2022)			
TSS, TNVSS[c], TDS, TPN, NO2-3, NH4, TP, OP, TOC, DOC, Alk, Chl a	$330 [d]	112	$36,960
Continuous turbidity monitoring (Oct 2021 – Oct 2022)			
TSS, TP	$55	75	$4,125
Groundwater monitoring (August 2022)			
TDS, TPN, NO2-3, NH4, TDP, OP, DOC, Alk, Bromide, Boron	$265 [d]	16	$4,240
Little Spokane River source tracking (March – May 2022)			
TSS, TP, OP	$75	51	$3,825
Summary			
		Ambient river monitoring	$26,295
		Lake monitoring	$36,960
		Continuous turbidity monitoring	$4,125
		Groundwater monitoring	$4,240
		Little Spokane River source tracking	$3,825
		Total laboratory budget	**$75,445**

[a] See section 7.2.2 for explanation of parameter abbreviations

[b] The $30 cost of total non-volatile suspended solids (TNVSS) normally includes total suspended solids (TSS) as well. For these locations, the ambient monitoring program monitors TSS but not TNVSS. Because the TNVSS samples will be part of a separate project/work order, and presumably in a separate bottle, we are assuming we will have to pay the full $30 price for each TNVSS sample.

[c] For these sites, TNVSS and TSS are sampled together, and the combined cost for the two parameters is $30.

[d] Includes $5 surcharge for reporting down to the MDL for NO2-3, NH4, and OP.

6.0 Quality Objectives

6.1 Data quality objectives [1]

Refer to *Programmatic QAPP for Water Quality Impairment Studies* (McCarthy and Mathieu, 2017).

The main data quality objective (DQO) for this project is to (1) collect over 450 water sample sets representative of Lake Spokane, the Spokane River, its tributaries, and associated groundwater, over the course of 13 months, and (2) have the samples analyzed, using standard methods, to obtain water quality data that meet the measurement quality objectives (MQOs) for this project.

6.2 Measurement quality objectives

Surface water and groundwater samples and measurements will follow the MQOs outlined in the *Programmatic QAPP for Water Quality Impairment Studies*. Table 11 presents the MQOs for three laboratory parameters not included in the Programmatic QAPP.

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

Table 11. MQOs for laboratory parameters not included in the Programmatic QAPP.

Analysis	Method Lower Reporting and (Detection) Limit [a]	Method Blank Limit	Calibration Standards/ Blanks	Lab Control Samples (% recovery limits)	Matrix Spikes or SRMs (% recovery limits)	Precision – Lab Duplicates (RPD)	Precision – Field replicates (median RSD) [b]
Total Dissolved Solids	10 mg/L	<½ RL[c]	n/a	80-120%	n/a	20%	15%
Boron	1 ug/L (0.167 ug/L)	<MDL[c]	ICV/CCV 90-110% ICB/CCB <RL	85-115%	75-125%	20%	15%
Bromide	0.025 mg/L (0.006 mg/L)	<MDL[c]	ICV/CCV 90-110% ICB/CCB <MDL[c]	90-110%	75-125%	20%	5%

RL: reporting limit; MDL: method detection limit; CCV: Continuing Calibration Verification CCB: Continuing Calibration Blank; ICV: Initial Calibration Verification; ICB: Initial Calibration Blank; SRM: Standard Reference Material; RPD: Relative Percent Difference; RSD: Relative Standard Deviation.

[a] Reporting limit may vary depending on dilutions; detection limit in parentheses, no parentheses means MDL = lowest possible RL.

[b] Field duplicate results with a mean of less than or equal to 5x the reporting limit will be evaluated separately.

[c] Or less than 10% of the lowest sample concentration for all samples in the batch.

[1] 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.

6.3 Acceptance criteria for quality of existing data

Refer to section 14.1.2 and Appendix A in the *Programmatic QAPP for Water Quality Impairment Studies*. Most of the external data sources we will be using are discussed in the Programmatic QAPP. Additional data sources include Spokane County groundwater monitoring well data, which are collected following stringent quality assurance/quality control (QA/QC) protocols outlined in a QAPP (Spokane County, 2007); and point source discharger data included in Discharge Monitoring Reports (DMRs). We will evaluate all external data based on whatever QA/QC information is available, and we will ensure that our use of any dataset is commensurate with our ability to be confident in the quality of that dataset.

6.4 Model quality objectives

This effectiveness monitoring project will follow the model quality objectives outlined in the *Programmatic QAPP for Water Quality Impairment Studies*. This project does not involve any new model development, but includes the possibility of a new scenario using the existing Spokane CE-QUAL-W2 model. Berger et al. (2003) details the model calibration and provides extensive comparison between model predictions and observed data.

7.0 Study Design

7.1 Study boundaries

The study area for this project includes the Spokane River from the Washington/Idaho state line through Lake Spokane to Long Lake Dam. It also includes the lower reaches of the two major tributaries in the study reach: Hangman Creek and the Little Spokane River (Figure 7).

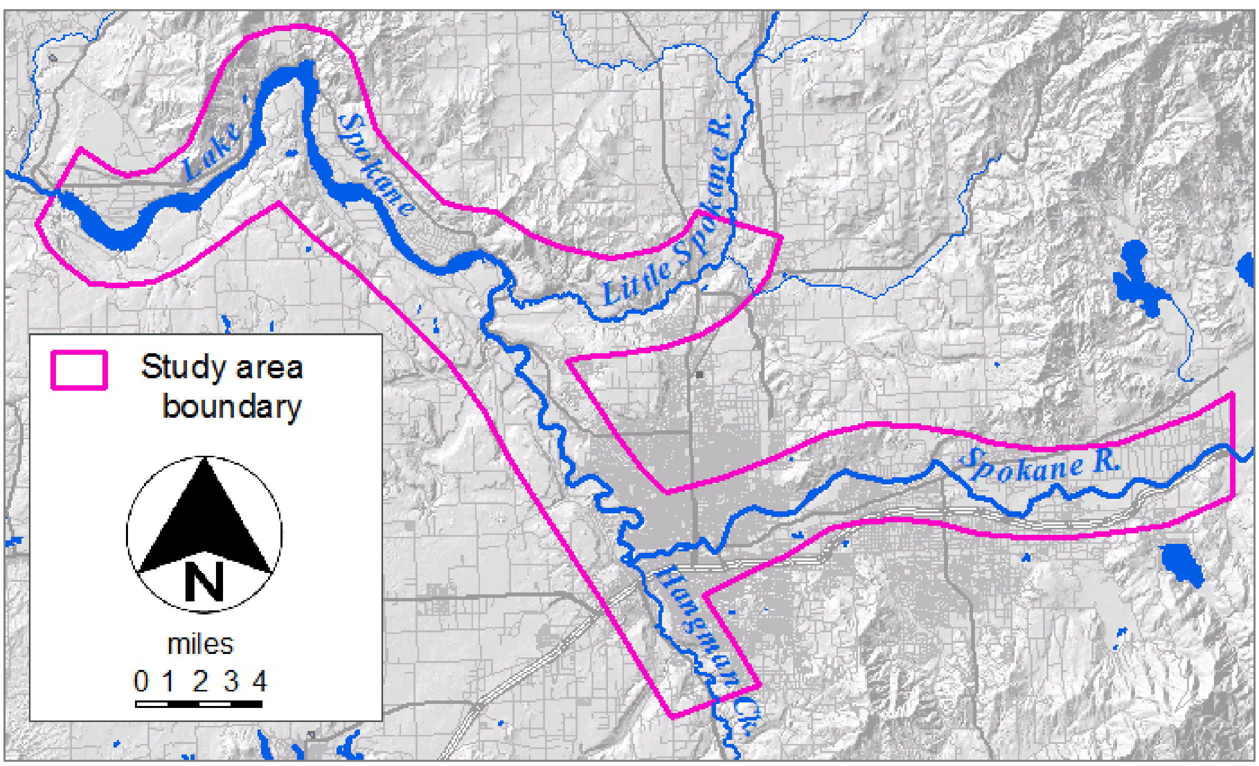

Figure 7. Map showing boundary of project study area

7.2 Field data collection

Field data will be collected during a 13-month period including the 2022 water year plus one month (Oct 1, 2021 – Oct 31, 2022) to capture the entire 2022 water year as well as the March-October Spokane TMDL allocation season. If flow conditions during the 2022 water year are not representative of TMDL critical conditions, Ecology may continue data collection during the 2023 water year. The field study will include the following elements:

- **Ambient river monitoring** – Ecology will collect water samples and measurements monthly at selected locations along the Spokane River and the mouths of the large tributaries. Most of this monitoring is part of EAP's ambient monitoring program, and is covered by that program's Quality Assurance Monitoring Plan (QAMP; Hallock and Ehinger, 2003). However, the pertinent monitoring locations are also described in this QAPP, as these data are a key part of this study effort.
    - We will collect data at a few additional locations not included in the ambient monitoring network, and we will collect a few additional parameters not included in the normal ambient parameter list. All additional sites and parameters beyond those the ambient program normally samples will be considered part of this project and covered by this QAPP.
    - One of these additional locations will address Indian Canyon Creek, which drains about 15 mi^2, mostly on the west plains, and enters Hangman Creek about 500m upstream of the confluence with the Spokane River. This is downstream of Riverside Ave., which is the ambient monitoring station (Location ID 56A070) and the downstream-most location for directed studies this far on Hangman Creek (Joy, 2008; Albrecht et al., 2017). This means that Indian Canyon Creek has never been included in loading totals for Hangman Creek. Ecology will conduct routine sampling and continuous flow monitoring at the mouth of Indian Canyon Creek in order to calculate load estimates.
- **Lake monitoring** – Ecology will collect water samples and measurements at six locations in Lake Spokane. This monitoring will occur monthly from April through October 2022.
- **Continuous turbidity monitoring** – Ecology will collect continuous turbidity data at four locations, one on the Spokane River, two on lower Hangman Creek, and one on the Little Spokane River. Turbidity is strongly linked to TP (Albrecht et al., 2017), and continuous records of turbidity will allow us to significantly improve our estimates of TP entering Lake Spokane, especially during runoff events.
- **Continuous DO, pH, conductivity, and temperature monitoring** – Ecology will collect continuous DO, pH, conductivity, and temperature at four locations: two on the Spokane River and one each on Hangman Creek and the Little Spokane River.
- **Groundwater monitoring** – Estimates of groundwater nutrient concentrations have been based on Spokane County's sampling of monitoring wells in the Spokane Valley-Rathdrum Prairie Aquifer (SVRPA; Spokane County, 2007). To verify that these estimates fully reflect the concentrations actually entering rivers, Ecology will collect samples and measurements from the hyporheic zone of gaining reaches of the Spokane and Little Spokane Rivers using temporary drive points.
- **Little Spokane River source tracking** – Monitoring for the Little Spokane River DO-pH TMDL (Johnson et al., 2020) found a large TP and sediment load of unknown origin entering the river somewhere in the lower 13 miles. This load occurred consistently during the high-flow springtime period but not during other seasons. To narrow down the source of this load, Ecology will conduct up to three synoptic surveys on the lower Little Spokane River during

the springtime (March – May) of 2022. We will target steady, high-flow conditions. After reviewing the data from these surveys, we may add additional, more focused surveys to further refine the location of the source.

7.2.1 Sampling locations and frequency

Sampling locations are described in Table 12 and Figure 8. Table 13 details the sample frequency and timing, as well as field staff roles. Ecology will begin field work in October 2021.

Table 12. Sampling locations for the Spokane River 10-year effectiveness monitoring assessment.

Location ID	Location Description	Approx. Frequency	Stream samples	Lake samples	Groundwater samples (temporary drive point)	Field measurements (Hydrolab or other meters)	Continuous turbidity	Instantaneous flow	Continuous flow (PT)
Ambient river monitoring (Oct 2021 – Oct 2022)									
57A150	Spokane R. @ State Line	1x/month	X			X			
57A140 [a]	Spokane R. @ Centennial Trail bridge	1x/month	X			X			
57A133 [a]	Spokane R. @ Greene St.	1x/month	X			X			
57A123	Spokane R. @ Sandifur Bridge	1x/month	X			X			
56IND-00.0 [a]	Indian Canyon Ck. @ Mouth	1x/month	X			X		X	X
56A070	Hangman Ck. @ Mouth	1x/month	X			X			
54A120	Spokane R. @ Riverside St. Pk.	1x/month	X			X			
54A090	Spokane R. @ Ninemile Bridge	1x/month	X			X			
55B070	Little Spokane R. @ Mouth	1x/month	X			X			
Lake monitoring (Apr – October 2022)									
LL5	Lk. Spokane nr. Ninemile campground	1x/month		X		X			
LL4	Lk. Spokane nr. Suncrest Park	1x/month		X		X			
LL3	Lk. Spokane upstream of Willow Bay	1x/month		X		X			
LL2	Lk. Spokane downstream of TumTum	1x/month		X		X			
LL1	Lk. Spokane nr. Lk. Spok. campground	1x/month		X		X			
LL0	Lk. Spokane nr. Long Lake Dam	1x/month		X		X			
Continuous turbidity monitoring (Oct 2021 – Oct 2022)									
56HAN-06.2	Hangman Ck. @ Meadowlane Rd.	Continuous	X				X		
56HAN-01.5	Hangman Ck. @ 11th Ave	Continuous	X				X		
55B070	Little Spokane R. @ Mouth	Continuous	X				X		
54SPK-57.2	Spokane R. @ Spokane House	Continuous	X				X		
Continuous DO, pH, conductivity, and temperature monitoring (March – Oct 2022)									
57A150	Spokane R. @ State Line	Continuous				X			
56A070	Hangman Ck. @ Mouth	Continuous				X			

Location ID	Location Description	Approx. Frequency	Stream samples	Lake samples	Groundwater samples (temporary drive point)	Field measurements (Hydrolab or other meters)	Continuous turbidity	Instantaneous flow	Continuous flow (PT)
54SPK-57.2	Spokane R. @ Spokane House	Continuous				X			
55B070	Little Spokane R. @ Mouth	Continuous				X			
Groundwater monitoring (August 2022)									
(TBD)	~5 drive points in Sullivan Rd. – Plantes Ferry gaining reach	Once			X	X			
(TBD)	~3 drive points in Upriver Dam – Greene St. gaining reach	Once			X	X			
(TBD)	~5 drive points in lwr. Little Spokane R. gaining reach	Once			X	X			
Little Spokane River source tracking (March – May 2022)									
55LSR-13.5	Little Spokane R. @ N. LSR Dr.	3x total	X			X		X	
55LDP-00.1	Little Deep Ck. at Shady Slope Rd.	3x total	X			X		X	
55DEA-00.2	Deadman Ck. blw Little Deep Ck.	3x total	X			X		X	
55LSR-11.7	Little Spokane R. @ Pine River Pk.	3x total	X			X		X	
55LSR-10.3	Little Spokane R. @ N. Dartford Dr.	3x total	X			X		X	
55DAR-00.2	Dartford Ck. @ Mouth	3x total	X			X		X	
55WAK-00.0	Waikiki Springs @ Mouth	3x total	X			X		X	
55LSR-09.4	Little Spokane R. blw Waikiki Springs	3x total	X			X		X	
55KCC-00.0	Kalispel Country Club springs @ Mouth	3x total	X			X		X	
55LSR-07.5	LSR @ W. Waikiki Rd.	3x total	X			X		X	
55GRI-00.0	Griffith Springs @ Mouth	3x total	X			X		X	
55STG-00.2	St. George's School spring abv slough	3x total	X			X		X	
55LSR-05.5	Little Spokane R. blw St. George's Schl.	3x total	X			X		X	
55LSR-03.9	Little Spokane R. @ Painted Rocks	3x total	X			X		X	
55B070	Little Spokane R. @ Mouth	3x total	X			X		X	

[a] These locations are not included in the regular Environmental Assessment Program (EAP) ambient monitoring network and will be sampled by EAP's TMDL staff.

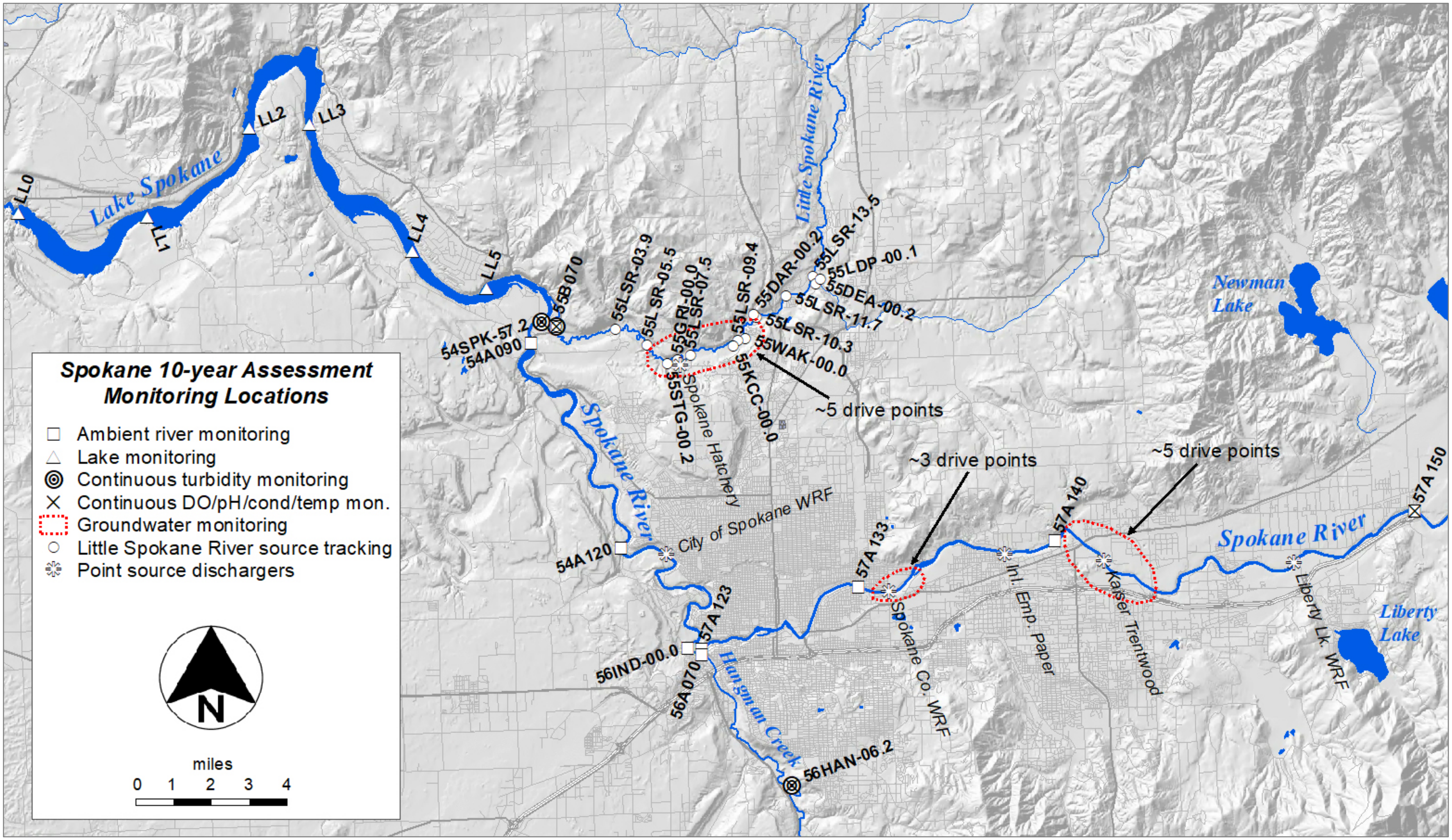

Figure 8. Map of sampling locations for the Spokane River 10-year effectiveness monitoring study.

Table 13. Sample frequency and timing, and staff roles, for each effectiveness monitoring element.

Monitoring Element	Timing	Frequency	Staff performing task
Ambient river monitoring	Oct 2021 – Oct 2022	1x/month For Indian Canyon Creek: Continuous flow monitoring. Temporary removal of pressure transducer during Dec-Jan to avoid freezing conditions.	Regular ambient monitoring network sites: EAP ambient monitoring staff. Additional sites: EAP Eastern Operations Section, ERO staff
Lake monitoring	April – Oct 2022	1x/month samples and field measurements 1x/month additional visit, field measurements (profiles) only.	EAP ambient monitoring and ERO staff
Continuous turbidity monitoring	Equipment installation summer 2021. Monitoring Oct 2021 – Oct 2022	Continuous monitoring. Temporary removal of turbidity instrumentation during Dec-Jan to avoid freezing conditions. Spot turbidity QC checks and comparison lab samples 1x/month, except for 2x/month during Nov-May, with at least 2 targeted to high-flow events.	Equipment installation: EAP ERO staff. Equipment maintenance, QC, and comparison sampling: EAP ERO staff
Continuous DO, pH, conductivity and temperature monitoring	March – Oct 2022	Continuous. Maintenance/calibration 1/x week	EAP TMDL staff
Groundwater monitoring	August 2022	One drive-point groundwater sampling survey	EAP groundwater and TMDL ERO staff
Little Spokane River source tracking	March – May 2022	3x total	EAP ERO staff

EAP: Environmental Assessment Program
ERO: Eastern Regional Office
QC: Quality control

7.2.2 Field parameters and laboratory analytes to be measured

Table 14 lists the laboratory and field parameters that we will include in this study.

Table 14. Laboratory and field parameters for each effectiveness monitoring element.

Parameter	Unit of Meas.	Ambient river monitoring	Lake monitoring	Continuous turbidity monitoring	Continuous DO, pH, cond, temp monitoring	Groundwater monitoring	Little Spokane River source tracking
Laboratory parameters							
Total suspended solids (TSS)	mg/L	X	X	X			X
Total non-volatile susp. solids (TNVSS)	mg/L	X [n]	X				
Total dissolved solids (TDS)	mg/L	X [n b]	X			X	
Turbidity (lab) (Turb)	NTU	X [a]					
Total persulfate nitrogen (TPN)	mg/L	X	X			X	X
Nitrate-Nitrite (NO2-3)	mg/L	X	X			X	X
Ammonium (NH4)	mg/L	X	X			X	X
Total phosphorus (TP/TPLL)	mg/L	X	X	X			X
Total dissolved phosphorus (TDP)	mg/L					X	
Orthophosphate (soluble reactive phosphorus) (OP or SRP)	mg/L	X	X			X	X
Total organic carbon (TOC)	mg/L	X [n]	X				X
Dissolved organic carbon (DOC)	mg/L	X [n]	X			X	X
Alkalinity (Alk)	mg/L	X [n]	X			X	
Bromide (Br)	mg/L					X	
Boron (B) (dissolved)	ug/L					X	
Chlorophyll a (Chl a)	ug/L	X [n b]	X				
E. coli	cfu/100mL	X [a]					
Field parameters							
Temperature (Temp)	°C	D+C	P		C	D	
Conductivity (Cond)	uS/cm	D	P		C	D	
pH	S.U.	D	P		C	D	
Dissolved oxygen (DO)	mg/L	D	P		C	D	
Turbidity (field) (Turb)	NTU	D		D+C			D
Streamflow	cfs	D+C [i]					D
Secchi depth	m		D				
Light	W/cm^2		P				

[n] These sample parameters are not normally part of the ambient monitoring suite. We will add them to these sites for this study.

[a] These sample parameters are not needed for this study but will be collected as part of the normal ambient monitoring suite.

[b] We will collect/measure these parameters during regular stream sampling at four sites: 57A150 (Spokane R. @ State Line), 56A070 (Hangman Ck. @ mouth), 54A090 (Spokane R. @ Ninemile Bridge), and 55B070 (Little Spokane R. @ mouth).

[i] We will monitor streamflow at 56IND-00.0 (Indian Canyon Creek) but not the other river monitoring sites.

D = discrete measurements
C = continuous measurements
P = vertical profile measurements

7.3 Modeling and analysis design

The 10-year effectiveness monitoring assessment concept from the 2010 TMDL report included use of the CE-QUAL-W2 model but did not specify how the model would be used to evaluate progress towards meeting the 20-year water quality objectives. Progress towards meeting the 20-year TMDL objectives could be evaluated using analytical methods such as spatial mass balances, yearly and/or seasonal loading comparisons, trends analysis, and the comparison of inflow total phosphorus (TP) concentrations with volume-weighted hypolimnion DO concentrations. These evaluation methods would not require running the CE-QUAL-W2 model to document improvements in water quality since the TMDL was approved in 2010.

Ecology is, however, designing this data collection to support the option of running a 2021-2023 scenario using the existing CE-QUAL-W2 model of Spokane River and Lake Spokane (Berger et al., 2003). This model was previously developed and calibrated by Portland State University (PSU) and was used by Ecology to evaluate the *Spokane River and Lake Spokane DO TMDL* (Moore and Ross, 2010).

Including the a CE-QUAL-W2 model scenario in the 10-year assessment would allow us to:

- Normalize for varying hydrologic conditions between years. The TMDL was based on conditions during 2001, a low-flow year. If higher-flow conditions occur during 2022, the model will allow us, to some degree, to separate the hydrologic effects from the effects of reduced TP discharges.
- Evaluate whether DO response in Lake Spokane to TP reductions during 2010-2021 is consistent with projections made in 2010, the year of the TMDL approval.

We will decide whether to use the CE-QUAL-W2 model after completing data acquisition and initial analysis to determine if clear trends emerge showing progress towards achieving the 20-year water quality goals. If the data indicate substantial improvements in water quality in Lake Spokane, Spokane River, and tributaries to the Spokane River, then running a model scenario may not be necessary. However, if the data do not indicate clear progress, then a model scenario may be warranted to assist in developing adaptive management strategies for the next 10 years (2020-2030) of the TMDL timeline.

7.3.1 Analytical framework

7.3.1.1 CE-QUAL-W2

CE-QUAL-W2 is a two-dimensional (longitudinal-vertical), laterally averaged, hydrodynamic and water quality mechanistic model that was developed by the U.S. Army Corps of Engineers (Wells and Cole, 2000) and is now maintained by Portland State University. CE-QUAL-W2 simulates water movement and mixing, as well as a variety of conservative and non-conservative water quality parameters. CE-QUAL-W2 is commonly used to model reservoirs and other long, narrow waterbodies that exhibit vertical water quality gradients (Wells, 2020).

7.3.1.2 Other analytical methods

Refer to sections 7.3.1 and 14.3 in the *Programmatic QAPP for Water Quality Impairment Studies* (McCarthy and Mathieu, 2017) for common analytical methods we may use for this effectiveness monitoring study.

We will compare point and nonpoint loads to wasteload and load allocations. For point sources, we will use facility-reported discharge sample and flow data provided in DMRs. For nonpoint tributary sources and for the riverine compliance point (the flow-weighted average of Spokane River below Ninemile Dam and the Little Spokane River), we will use monitoring data along with continuous flow data obtained from USGS gages.

For total phosphorus (TP), we will use continuous turbidity data and a regression between observed turbidity and TP to estimate continuous TP loads that accurately account for storm-event loading.

For other parameters and where continuous turbidity is not available, we may use methods such as Cohn multiple-regression modeling (Cohn et al., 1989; Cohn et al., 1992) or the Beales ratio estimator (Thomann and Mueller, 1987).

Tributaries such as Hangman Creek and the Little Spokane River exhibit large year-to-year variations in loads due to hydrologic differences. Therefore, we are not interested solely in whether a tributary met its load allocation during the monitoring year. Rather, we want to know if the tributary meets load allocations during a variety of hydrologic conditions. To assess this, we will use ambient monitoring data and USGS continuous flow data from many years to build Cohn multiple-regression models of the tributaries. We will use these models to evaluate tributary load allocation compliance over multiple years representing a variety of conditions.

We will assess DO in Lake Spokane by using a volume-weighted average of DO measured throughout the water column, excluding the upper 8 meters, as specified in the 2010 TMDL report. However, we will consider all data and all layers of the lake, and may assess DO in other ways as well.

7.3.2 Model setup and data needs

Running a 2021-2023 validation scenario using the existing CE-QUAL-W2 model is a less data-intensive endeavor than developing and calibrating a new model. Because there is already a calibrated CE-QUAL-W2 model for the Spokane River and Lake Spokane, we will not need all of the data that would be required were we starting “from scratch.” Table 15 presents the data types that will be needed to run a new validation scenario, along with the source for each data type. Table 15 is based on Table 3 in the CE-QUAL-W2 user’s manual (Wells, 2020) as well as specific guidance we received from Portland State University water quality modeling staff (Berger, pers. comm., 2020).

The model domain includes the Spokane River from the WA/ID state line to the inlet of Lake Spokane, as well as Lake Spokane itself. We expect that the new scenario will cover a period of time approximately corresponding to the 2022 water year.

Table 15. Data requirements and sources for a new CE-QUAL-W2 model scenario

Category	Model requirement	Data parameters	Data source
Hydrodynamics	Boundary flows	Streamflow	USGS gages: Spokane R. nr Post Falls (12419000), Hangman Ck. at Spokane (12424000), Spokane R. blw Ninemile Dam (12426000) [a], Little Spokane R nr Dartford (12431500), Spokane R. at Long Lk. (12433000). [b]
Hydrodynamics	Groundwater gains/losses	Flow in/out	Flow residuals between adjacent USGS gages including bdy conditions gages as well as Spokane R. blw Greene St. (12422000) and Spokane R. at Spokane (12422500).
Hydrodynamics	Reservoir pool elevations	Elevation/Stage	Avista (Upriver, Upper Falls/Monroe St, Ninemile, Lake Spokane)
Meteorology	Air Temperature	Air Temperature	National Weather Service (NWS) Spokane Airport (KGEG)
Meteorology	Dew Point	Dew Point	
Meteorology	Wind Speed	Wind Speed	
Meteorology	Wind Direction	Wind Direction	
Meteorology	Cloud Cover	Cloud Cover	
Meteorology	Solar Radiation	Solar Radiation	RAWS Turnbull (TWRW1)
Boundary WQ	Temperature	Temperature	Surface water (Spokane R. at State Line, Spokane R. blw Ninemile Dam [a], tributary mouths): Ecology stream monitoring (this study) Point source dischargers: Discharge monitoring reports (DMR) submitted by dischargers
Boundary WQ	DO, pH	DO, pH, Alk	
Boundary WQ	Tracers	Cond	
Boundary WQ	Solids	TSS, TNVSS, TDS	
Boundary WQ	Nutrients	TPN, NO2-3, NH4, TP, SRP	
Boundary WQ	Carbon, organic material	TOC, DOC, Chl a	
Groundwater WQ	Temperature	Temperature	Ecology drive-point groundwater monitoring (this study), Spokane County monitoring well data.
Groundwater WQ	DO, pH	DO, pH, Alk	
Groundwater WQ	Tracers	Cond, Br, Bo	
Groundwater WQ	Solids	TDS	
Groundwater WQ	Nutrients	TPN, NO2-3, NH4, TDP, SRP	
Groundwater WQ	Carbon, organic material	DOC	
Reservoir WQ	Temperature	Temperature	Ecology lake monitoring (this study)
Reservoir WQ	DO, pH	DO, pH, Alk	
Reservoir WQ	Tracers	Cond	
Reservoir WQ	Solids	TSS, TNVSS, TDS	
Reservoir WQ	Nutrients	TPN, NO2-3, NH4, TP, SRP	
Reservoir WQ	Carbon, organic material	TOC, DOC, Chl a	
Reservoir WQ	Light penetration	Secchi, Light	

[a] Spokane R. blw Ninemile Dam is not a true boundary location; water does not enter the model domain at this site. However, it represents the inlet to Lake Spokane; therefore, a full set of data parameters commensurate to what we would collect at a boundary location is useful at this site.

[b] We may also estimate flows at locations where USGS gages have been discontinued, such as at Spokane R. abv Liberty Bridge (12419500) and at Spokane R. at Greenacres (12420500) by regression between these stations and nearby currently operating stations.

7.4 Assumptions underlying design

Assumptions are described in the *Programmatic QAPP for Water Quality Impairment Studies*.

7.5 Possible challenges and contingencies

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

The *Spokane River and Lake Spokane DO TMDL* (Moore and Ross, 2010) was developed based on 2001 hydrological conditions, which represent a critical low-flow year. The most ideal situation from a comparison standpoint would be to evaluate TMDL progress under a similar set of conditions. However, it is not likely that 2022 will be very similar to 2001. The CE-QUAL-W2 model provides a possible way to normalize between different hydrological conditions. There may be other mathematical tools available to aid in this comparison as well. Nevertheless, if 2022 is extremely different than 2001 (for example, if it is an unusually high-flow year), then a meaningful comparison could be difficult. If a high-flow year occurs in 2022, Ecology may decide to extend the field study for another year, through the 2023 water year.

8.0 Field Procedures

8.1 Invasive species evaluation

Refer to *Programmatic QAPP for Water Quality Impairment Studies* (McCarthy and Mathieu, 2017). The project area is located in an area of moderate concern.

8.2 Measurement and sampling procedures

Refer to *Programmatic QAPP for Water Quality Impairment Studies* for a comprehensive list of standard operating procedures (SOPs) that will be used during this project. The following sections provide additional detail, beyond the Programmatic QAPP, for each monitoring element of this project. We also identify any SOPs not listed in the Programmatic QAPP.

8.2.1 Ambient river monitoring

For sites not included in the regular ambient monitoring network, we will collect water samples in much the same way as the ambient monitoring program. This will usually involve using a "bucket" sampler, to hold clean sampling containers, lowered from a bridge. For smaller streams or where a bridge does not exist, we may use a pole sampler or collect grab samples while wading. We will collect field measurements using a Hydrolab® or YSI® multiparameter sonde and a Hach® portable turbidimeter.

8.2.2 Lake monitoring

Monitoring in Lake Spokane will follow the same procedures used by Ecology and Avista during the past decade (Sherratt and Stuart, 2010). Using a Kemmerer sampler, we will collect composite samples from the three vertical zones: euphotic, interflow, and hypolimnion.

The *euphotic zone* is defined by light penetration; the bottom of the euphotic zone is defined as the depth at which 1% of the light intensity measured at the surface remains.

The *interflow zone* is an area of more quickly traveling, newer water being drawn at mid-depth through the lake toward the penstocks of Long Lake Dam. Mid-depth is at a depth of 10-13 meters. The euphotic zone and the interflow zone often have considerable overlap. The upper boundary of the interflow zone is considered to be at a depth of 10 meters near Long Lake Dam, but is shallower in the upper portion of the reservoir (above about RM 48). The lower boundary of the interflow zone is considered to be a depth of 20 meters.

The *hypolimnion* in Lake Spokane is defined as the portion of the lake below the interflow zone (i.e., below a depth of 20 meters).

Table 16 defines the depths where we will collect samples to be composited for each layer.

We will determine the depth of the euphotic zone at each site by measuring light attenuation down through the water column using a light meter to measure light intensity. The depth where light intensity falls to 1% of the light intensity at the surface will be set as the total depth of the euphotic zone.

Table 16. Sample collection depths to be used for composites at each lake site.

Site	Euphotic Zone	Interflow Zone	Hypolimnion
LL0	1m, 3m, 6m, 9m*	12m, 15m, 18m	21m, 27m, 33m, 39m, 45m
LL1	1m, 3m, 6m, 9m*	12m, 15m, 18m	21m, 27m, 33m
LL2	1m, 3m, 6m*	12m, 15m, 18m	21m, 27m
LL3	1m, 3m, 6m*	12m, 15m, 18m	
LL4	1m, 3m, 6m*	9m	
LL5	1m, 3m*	Possibly near bottom**	

* The lower euphotic zone boundary will be determined before collecting samples; the euphotic zone composite will not include depths that are below that boundary.

** If the euphotic zone at LL5 extends all the way to the bottom, the interflow composite will be omitted. Note that there can be overlap between the euphotic zone and the interflow zone.

We will collect lake samples using a Kemmerer sampler with a graduated rope to ensure that samples are taken from the correct depth. We will triple-clean the Kemmerer sampler with deionized water between each station. The process of lowering the open sampler to depth will also provide a local-water rinse prior to sample collection. We will collect the discrete samples with the Kemmerer sampler and then empty them into a pre-cleaned carboy to form the composite sample. After collecting all the discrete samples to form each composite, we will mix the carboy well and fill individual sample containers from it.

We will profile temperature, DO, conductivity, and pH using a Hydrolab® or YSI® multiparameter sonde. The profile will consist of discrete measurements taken at 0.5m, 1m, 2m, 3m, 4m, 5m, 6m, 7m, 8m, 9m, 10m, 12m, 15m, 18m, and so on, continuing at 3m intervals to the bottom of the lake. The last measurement will be taken one meter from the bottom.

We will profile light using a submersible light meter to make euphotic zone determinations. We will profile light intensity through the euphotic zone by taking measurements at the following depth intervals:

- The surface (0 meters).
- One-meter intervals until the point at which <10% of the surface light is observed.

- Half-meter intervals until the point at which <1% of the surface light is observed.

We will record Secchi disk depths at each site as a measure of lake clarity.

8.2.3 Continuous turbidity monitoring

We will deploy FTS®, Hydrolab®, or YSI® turbidity sensors to record turbidity at 15-minute intervals. During past projects, we have observed that turbidity probes at different locations exhibit location-specific bias, either due to site characteristics or instrument calibration issues. To insure comparability between different locations, we will take spot turbidity measurements using a Hach® portable turbidimeter twice per month during the wet season (November – May) and once per month during the rest of the project. We will also collect lab samples for selected parameters whenever we take spot turbidity measurements, to determine the relationship between turbidity vs. sediment/phosphorus.

8.2.4 Continuous DO, pH, conductivity, and temperature monitoring

We will deploy Hydrolab® or YSI® multiparameter sondes to record DO, pH, conductivity, and temperature at 15-minute intervals. Our goal is to monitor these parameters continuously from the beginning of reliably ice-free conditions in spring 2022 until the end of the project. However, because of security concerns at certain locations (notably Hangman Creek), we may opt for monthly short-term (48-hour) deployments at those locations. We will visit continuously deployed sonde locations weekly to take quality control (QC) measurements and to perform cleaning, maintenance, and calibration checks on the deployed sondes.

We may also deploy TidbiT® or similar dataloggers to record continuous temperature, in case of data gaps in the multiparameter sonde datasets. Ecology's ambient monitoring program also deploys temperature dataloggers at sites in their monitoring network.

We will perform continuous DO, pH, conductivity, and temperature monitoring according to the following SOPs:

- SOP EAP129 Short-term Continuous Data Collection with a Multiparameter Sonde, Part 1: Field Procedures (Mathieu and Stuart, 2019).
- SOP EAP130 Short-term Continuous Data Collection with a Multiparameter Sonde, Part 2: Data Processing (Mathieu, 2019).

8.2.5 Groundwater monitoring

We will collect groundwater samples and measurements using a temporary drive-point sampling apparatus (e.g. a small-diameter steel piezometer) or a PushPoint sampling device. A drive-point sampling apparatus or a PushPoint sampling device allows for efficient sampling of the hyporheic zone. The drive-point is installed, developed, purged, sampled, and removed all during the same day. We will sample the hyporheic zone about two feet below the streambed, and will only sample in gaining reaches.

We will perform groundwater measurements and sampling according to the following SOPs:

- SOP EAP052 Depth to Water Measurements (Marti, 2018).
- SOP EAP099 Purging and Sampling Monitoring Wells for General Chemistry Parameters (Carey, 2018).

- SOP EAP033 Hydrolab® DataSonde®, MiniSonde®, and HL4 Multiprobes (Anderson, 2020).
- SOP EAP061 Installing, Monitoring and Decommissioning hand-driving in-water piezometers (Sinclair and Pitz, 2018).

Sediment pore water will be collected from manually installed temporary drive-point piezometers and/or 6-foot PushPoint samplers. Once the sampler has been inserted into the sediment, we will try to measure the depth of saturated conditions and collect water quality samples. All equipment will be decontaminated before sampling. The Hydrolab will be calibrated at the start and end of each day. These measurements will be recorded.

We will purge and collect groundwater samples with a peristaltic pump using low-flow sampling procedures (e.g., <0.5 L/min). We will use a flow-through cell to measure temperature, pH, electrical conductivity, DO, and ORP the water is exposed to the atmosphere. We will purge the temporary drive-point well, taking measurements at five-minute intervals, until the measurements have stabilized.

Table 17 lists stability criteria for purge completion. We will consider purging to be complete when three consecutive sets of parameter readings show changes less than the criteria. Once the field parameters have stabilized, we will collect samples through a 0.45 micron in-line, high-capacity cartridge filter, directly into clean laboratory-supplied containers from Manchester Environmental Laboratory (MEL). We will use a syringe filter to collect dissolved organic carbon (DOC) and orthophosphate samples.

Table 17. Stability criteria for sampling groundwater.

Field Parameter	Criteria
Temperature	0.1ºC
pH	0.1 SU
Conductivity	10 µs/cm for values <1000 µs/cm 20 µs/cm for values >1000 µs/cm
Dissolved Oxygen	0.05 mg/L for values < 1 mg/L 0.2 mg/L for values > 1 mg/L
ORP	10 mV

To minimize potential surface water leakage around the annular space of the temporary sample device, we may pack fine surface sediment around any obvious open spaces. To assess potential leakage, we will compare groundwater field parameters measured during purging to surface water values.

8.2.6 Little Spokane River source tracking

We will conduct up to three Little Spokane River source tracking surveys during relatively stable, high-flow conditions during Spring 2022. To facilitate load comparisons between sites, we will attempt to sample all sites during one day, probably by using multiple sample teams. At each site, teams will collect lab samples, discrete turbidity measurements using a Hach® portable turbidimeter, and streamflow measurements. We will typically measure streamflow using (1) Acoustic Doppler Current Profiling (ADCP) for mainstem and larger tributary sites, and (2) wading for small tributary sites.

8.3 Containers, preservation methods, holding times

Refer to *Programmatic QAPP for Water Quality Impairment Studies*. Table 18 lists containers, preservation methods, and holding times for additional sample parameters not included in the Programmatic QAPP.

Table 18. Sample containers, preservation, and holding times.

Parameter	Container	Preservative	Holding Time
Total Dissolved Solids	500 mL, wide mouth polyethylene	Cool to ≤6ºC	7 days
Bromide	500 mL, wide mouth polyethylene	Filter, cool to ≤6ºC	28 days
Boron (dissolved)	500 mL, wide mouth HDPE	Filter, nitric acid, cool to ≤6ºC	6 months

8.4 Equipment decontamination

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

We will use new clean dedicated sample tubing and filters to collect and prepare groundwater samples. Before collecting samples at each site, and between samples, we will decontaminate silastic tubing connecting to the peristaltic pump. We will rinse the tubing with deionized water, and then purge with sample water. When using an E-tape to measure water levels in the piezometers, we will rinse it with deionized water between wells. The PushPoint sampler will be cleaned and triple rinsed by running laboratory-grade, de-ionized water through the system.

We will clean any secondary sampling containers (e.g., 1-L poly containers used for sampling from bridges, Kemmerer samplers used for lake sampling, carboys used for compositing lake samples) by triple rinsing with deionized water between sites.

8.5 Sample ID

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

8.6 Chain of custody

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

8.7 Field log requirements

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

8.8 Other activities

Not applicable. Necessary activities are detailed in other sections of this QAPP.

9.0 Laboratory Procedures

9.1 Lab procedures table

Refer to *Programmatic QAPP for Water Quality Impairment Studies* (McCarthy and Mathieu, 2017). Table 19 lists laboratory methods for parameters not included in the Programmatic QAPP.

Table 19. Laboratory methods for parameters not included in the Programmatic QAPP.

Analyte	Sample Matrix	Method	Expected Range of Results	Method Detection Limit *
Total Dissolved Solids	Water	SM 2540 C	1-10,000 mg/L	1 mg/L
Boron (dissolved)	Water	EPA 200.8	0.3 – 20 mg/L	0.167 mg/L
Bromide	Water	EPA 300.0	0.006 – 0.1 mg/L	0.006 mg/L

*Method Detection Limit can vary based on sample dilutions.
EPA: Approved U.S. Environmental Protection Agency (EPA) analytical method;
SM: Standard Methods (APHA, 2012); ASTM: American Society for Testing and Material; RL: Reporting limit;

For the *Lake Monitoring* and *Groundwater Monitoring* portions of this field study, we are asking Manchester Environmental Laboratory (MEL) to report results down to the method detection limit (MDL) for the following parameters (MDLs are shown in parenthesis):

- Ammonia (0.005 mg/L)
- Nitrate-Nitrite (0.004 mg/L)
- Orthophosphate (0.0013 mg/L)

9.2 Sample preparation method(s)

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

9.3 Special method requirements

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

9.4 Laboratories accredited for methods

Refer to *Programmatic QAPP for Water Quality Impairment Studies*. MEL will analyze all samples collected during this study.

10.0 Quality Control Procedures

This study will include the following quality control (QC) procedures, as appropriate. The *Programmatic QAPP for Water Quality Impairment Studies* (McCarthy and Mathieu, 2017) describes these procedures in detail.

Laboratory sample QC

- Field replicates
- Field blanks
- Laboratory QC performed by MEL (e.g., calibration/verification blanks, method blanks, analytical duplicates, matrix spikes, lab control samples)

Field measurement QC

- Meter/logger pre-calibration
- Meter/logger post-checks
- Meter/logger field QC spot checks
- Fouling checks
- Winkler DO 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* (McCarthy and Mathieu, 2017).

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.

11.3 Electronic transfer requirements

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

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*. One difference from the Programmatic QAPP is that Portland State University (PSU), rather than Ecology, may maintain the model files for this project.

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

Refer to *Programmatic QAPP for Water Quality Impairment Studies* (McCarthy and Mathieu, 2017). We are not planning any field audits for this project; however, we could add one or more audits if requested by management or field 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*. We will prepare a final report detailing the findings of this study. This report is scheduled for completion in 2025; see section 5.4.

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.

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

Refer to *Programmatic QAPP for Water Quality Impairment Studies*. This project will not result in the development of a new model, but it might make use of the existing calibrated CE-QUAL-W2 model for the Spokane River and Lake Spokane (Berger et al., 2003).

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

Refer to *Programmatic QAPP for Water Quality Impairment Studies* (McCarthy and Mathieu, 2017).

14.2 Treatment of non-detects

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

For the *Lake Monitoring* and *Groundwater Monitoring* portions of this field study, we are asking MEL to report results down to the method detection limit (MDL) for the following parameters:

- Ammonia
- Nitrate-Nitrite
- Orthophosphate

For these parameters, we are asking MEL to report non-detects as estimated non-detects (UJ qualifier) at the MDL. We are asking that values higher than the MDL, but lower than the normal reporting limit (RL), be qualified as estimates (J qualifier).

14.3 Data analysis and presentation methods

Refer to *Programmatic QAPP for Water Quality Impairment Studies*. See section 7.3 for a description of our proposed analytical methods.

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 Appendix: Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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

Anthropogenic: Human-caused.

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

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).

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.

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

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.

Near-stream disturbance zone (NSDZ): The active channel area without riparian vegetation that includes features such as gravel bars.

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.

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 10 times more basic than one with a pH of 7.

Phase I stormwater permit: The first phase of stormwater regulation required under the federal Clean Water Act. The permit is issued to medium and large municipal separate storm sewer systems (MS4s) and construction sites of five or more acres.

Phase II stormwater permit: The second phase of stormwater regulation required under the federal Clean Water Act. The permit is issued to smaller municipal separate storm sewer systems (MS4s) and construction sites over one acre.

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.

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.

Synoptic survey: Data collected simultaneously or over a short period of time.

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 10 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

ADCP	Acoustic doppler current profiler
BMP	Best management practice
CBOD	Carbonaceous biochemical oxygen demand
DO	Dissolved oxygen (see Glossary above)
DOC	Dissolved organic carbon
DMR	Discharge monitoring report
DQO	Data quality objective
e.g.	For example
Ecology	Washington State Department of Ecology
EAP	Ecology's Environmental Assessment Program
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
ERO	Ecology's Eastern Regional Office
et al.	And others
i.e.	In other words
LSR	Little Spokane River
MDL	Method detection limit
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System (See Glossary above)
NWS	National Weather Service
PSU	Portland State University
QA	Quality assurance
QAPP	Quality assurance project plan
QC	Quality control
RAWS	Remote automated weather station
RL	Reporting limit
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
SRM	Standard reference materials
TNVSS	Total non-volatile suspended solids

TMDL	Total maximum daily load (see Glossary above)
TOC	Total organic carbon
TP	Total phosphorus
TSS	Total suspended solids
USGS	United States Geological Survey
WAC	Washington Administrative Code
WLA	Wasteload allocation
WWTP	Wastewater treatment plant
WY	Water year

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cfu	colony forming units
cm	centimeter
L	liter
lbs/day	pounds per day
m	meter
mgd	million gallons per day
mg/L	milligrams per liter (parts per million)
mL	milliliter
NTU	nephelometric turbidity units
s.u.	standard units
µg/L	micrograms per liter (parts per billion)
µS/cm	microsiemens per centimeter, a unit of conductivity
W/cm^2	Watts per square 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/or spiked blanks. These are all check standards but should be referred to by their actual designator, e.g., CRM, LCS (Kammin, 2010; Ecology, 2004).

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

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

Continuing Calibration Verification Standard (CCV): A 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/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis (Kammin, 2010).

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

References for QA Glossary

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