Quality Assurance Project Plan

Hangman Creek
Dissolved Oxygen, pH, and Nutrients
Pollutant Source Assessment

May 2017

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Cover photo: Hangman Creek looking downstream from the Keevy Road bridge, during low flow and high flow. Credit: Department of Ecology

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2.0 Abstract

Each study conducted by the Washington State Department of Ecology must have an approved Quality Assurance Project Plan (QAPP). This document, together with the *Programmatic QAPP for Water Quality Impairment Studies* (McCarthy and Mathieu, 2017), describes the objectives of the study and the procedures to be followed to achieve those objectives. After completion of the study, a final report describing the study results will be posted to the Internet.

The Hangman Creek watershed is located south of Spokane, Washington, and is a major tributary to the Spokane River. The watershed drains approximately 670 square miles of land spanning the Washington and Idaho border.

There are two main objectives of this proposed study:

- To assess the Hangman Creek watersheds contribution of pollutants affecting dissolved oxygen in the Spokane River.

  The *Spokane River and Lake Spokane Dissolved Oxygen Total Maximum Daily Load* (Moore and Ross, 2010) set allocations for the mouth of Hangman Creek for total phosphorus, carbonaceous biochemical oxygen demand (CBOD), and ammonia. A watershed springtime runoff study will determine where reductions need to occur within the watershed to achieve the desired results at the mouth of Hangman Creek during the spring runoff season. A surface water and groundwater study in the lower reaches of the basin will show where reductions are needed during the summer low-flow season.

- To determine the nutrient and CBOD loads from the Tekoa Wastewater Treatment Plant (WWTP) that will protect dissolved oxygen and pH in Hangman Creek.

  The treatment plant is aging, and needs to come into compliance with new temperature permit limits, so therefore needs to be upgraded. Findings from this study will help to guide the City of Tekoa as it plans improvements to this facility to ensure that the facility does not adversely impact Hangman Creek water quality.

3.0 Background

3.1 Introduction and problem statement

Hangman Creek is a major tributary to the Spokane River. Ecology developed a plan to address low oxygen and high nutrients (phosphorus) in the Spokane River and Lake Spokane (Long Lake; Moore and Ross, 2010). Hangman Creek is an important contributor of phosphorus to the Spokane River and is the single largest source of nonpoint phosphorus during the March-May season. Efforts to reduce nutrients, especially phosphorus, in the Hangman Creek watershed will be necessary to address water quality issues in the Spokane River and Lake Spokane.

The City of Tekoa, located in the upper part of the Hangman Creek watershed, owns and operates a wastewater treatment facility. The original facility consisting of a single stage trickling filter system was constructed in 1950 with major modifications occurring in 1974 to convert the plant to an activated sludge system with chlorine disinfection. Additional improvements to the WWTP were made in 1990, adding a new lift station, drying beds for biosolids storage, and installation of a dechlorination system. This aging facility is in need of significant upgrades. Studies of facilities in nearby streams, as well as preliminary data collected during 2009, suggest that nutrient reduction or elimination may be needed to meet water quality standards for dissolved oxygen (DO) and pH in Hangman Creek (Snouwaert and Stuart, 2015; Ross, 2011).

Without a wasteload allocation from a Total Maximum Daily Load study (TMDL), the municipal permit team has requested support from Ecology's Environmental Assessment Program (EAP) in collecting data that will (1) support the development of permit limits for nutrients that are protective of water quality and (2) allow the City of Tekoa to move forward with necessary facility planning efforts.

These problems will be addressed by four studies that are parts of the larger project. Each study/part of this project will fill critical data gaps to address these two concerns. The four studies of the project are:

- Tekoa receiving water study
- Watershed springtime runoff study
- Lower watershed ground water study
- Lower watershed low flow study

303(d) listed (impaired) waters exist for DO and pH throughout the Hangman Creek watershed. There is a need to assess the source of these impairments and eventually develop a TMDL for DO and pH on Hangman Creek. The data collected during this project are expected to support development of a future TMDL, however TMDL development is not a goal of this project.

3.2 Study area and surroundings

The Hangman Creek (also known as Latah Creek) watershed drains approximately 431,000 acres and spans across two states and four counties. More than 60 percent of the watershed resides in eastern Washington State (WRIA 56) while the remaining portion, including the headwaters, originates in the western foothills of the Rocky Mountains near Sanders, Idaho. The major tributaries to Hangman Creek are Marshall Creek, California Creek, Spangle Creek, Rock Creek, Rattler Run Creek, and the Little Hangman Creek. Hangman Creek is a tributary to the Spokane River.

The watershed contains remnant populations of redband trout and other native and introduced fish species.

Figure 1 shows the Hangman Creek watershed, along with the approximate boundaries of the component parts of this project. These boundaries are described in detail in section 7.1.

Geology

Bedrock in the lower watershed is mainly Miocene basalt flows with pockets of Tertiary biotite granite and granodiorite (WDNR, 1998). During the Miocene, the basalt flows would periodically dam rivers and form lakes. Material deposited in these lakes formed the siltstones and sandstones of the Latah Formation. Pleistocene glacial deposits produced large amounts of wind-blown silt, known as loess. This wind-blown silt accumulated up to 200 feet over most of the basalt flows and formed dune-shaped hills.

During the late Pleistocene period, lobes from ice sheets in northern Washington, Idaho, and Montana blocked several major drainages and produced extensive lakes. The largest lake produced was Glacial Lake Missoula, located near present day Missoula, Montana; at one time it covered over 3,000 square miles. Periodically the ice dams broke, and significant floods occurred in Washington, including in the lower Hangman Creek watershed. There were over 40 separate flood events from Glacial Lake Missoula (Waitt, 1980). The floods left major channels in the region, removed the loess deposits covering the basalt, and deposited much of the sand, gravel, cobble, and boulders found in the lower reaches of Hangman Creek.

Easily erodible material is found throughout the Hangman Creek watershed. The unconsolidated material consists of three major deposits:

- Glacial Lake Missoula flood deposits of sand, gravel, and cobbles.
- Reworked Missoula flood deposits.
- Loess deposits found in the upper watershed (Buchanan and Brown, 2003).

The Missoula Flood deposits extend from the Spokane River confluence to the Rock Creek confluence. Along with the unconsolidated sediments, the weakly lithified sedimentary rocks of the Latah Formation are also subject to stream erosion.

The Latah Formation consists of fine laminations of silts and clays with low permeability that tend to perch water above the formations. Bank slumping occurs as water erodes sediment from between the confining silt and clay layers. The silts and clays are resistant bands that tend to form vertical banks above them. Poorly consolidated sands and gravels within the Latah Formation tend to wash out, undercutting and exposing the silt and clay layers. This undercutting can result in block slumps and rapid bank loss.

Figure 1. Hangman Creek watershed study area.

The Lake Missoula flood deposits consist of sorted-to-unsorted silt sands, gravels, cobbles, and boulders. The unconsolidated material erodes easily along streams, producing steep, unstable slopes over 100 feet high. The major type of erosion is toe failure caused by the stream removing the material at the base of the streambank. Once the toe is removed, the bank is over-steepened. The over-steepened bank fails and deposits large amounts of material directly into the stream. The deposited material is available to be mobilized under most flow conditions.

Post-Missoula flood alluvium generally overlies all the other sediment layers. The post-Missoula flood material is reworked flood deposits and is unconsolidated and easily eroded. The deposits are generally terraces that originally formed as flood plains when Hangman Creek was downcutting through the flood alluvium. The erosional characteristics are similar to the Lake Missoula flood deposits discussed above, but are more cohesive because a significant amount of sand and gravel has been removed.

Soils within the Hangman Creek watershed have formed from a wide variety of materials. The main soils are deep soils that formed from the silty loess deposits. The soils are generally medium to fine-textured, with moderate to slow permeability. The soils have high to moderate water-holding capacity. Other parent materials for the soils include volcanic ash, glacial deposits, alluvium deposited by streams, and material weathered from basaltic, granite, and metamorphic bedrock.

Hydrogeologic setting

There are two distinct aquifers in the area: the shallow, unconfined alluvial aquifer and the lower, confined water-bearing zones in the deeper basalt. The Hangman Valley is underlain primarily by glacio-alluvial deposits. These deposits are up to 200 feet thick and overlay the Columbia River Basalt Group. In the shallow alluvial aquifer, depth to water is about 10 to 20 feet below land surface.

The Latah formation is comprised of weakly cemented lacustrine silt and clay mixed with some sand and gravel. This confining layer separates the upper glacio-alluvial deposits from the lower Columbia River Basalt Group. GeoEngineers (2000) determined that significant hydraulic continuity between the upper and lower aquifers is unlikely.

Locally, the Columbia River Basalt Group is comprised of the Wanapum and Grand Ronde members. Depth to basalt varies but is estimated to be approximately 200 feet below land surface. The basalt group is interspersed with the Latah formation which is interbedded between the basalt flows. It is comprised of weakly cemented lacustrine silt and clay with some sand and gravel. This group contains discontinuous confined water-bearing zones. Groundwater flow direction is estimated to be to the west-southwest. (GeoEngineers, 2000)

Hydrology

Figure 2 illustrates streamflow patterns at the mouth of Hangman Creek. The spring runoff period typically occurs between January and May. Flows drop quickly between April and July, with the baseflows occurring during August and September. A wide seasonal variation in flows exists in Hangman Creek, with typical spring runoff flows about 40 times higher than typical flows during the summer low flow period. Flows during the spring runoff period are very "flashy," exhibiting a quick response to precipitation and snowmelt events. Peak flows in excess of 10,000 cfs occasionally occur.

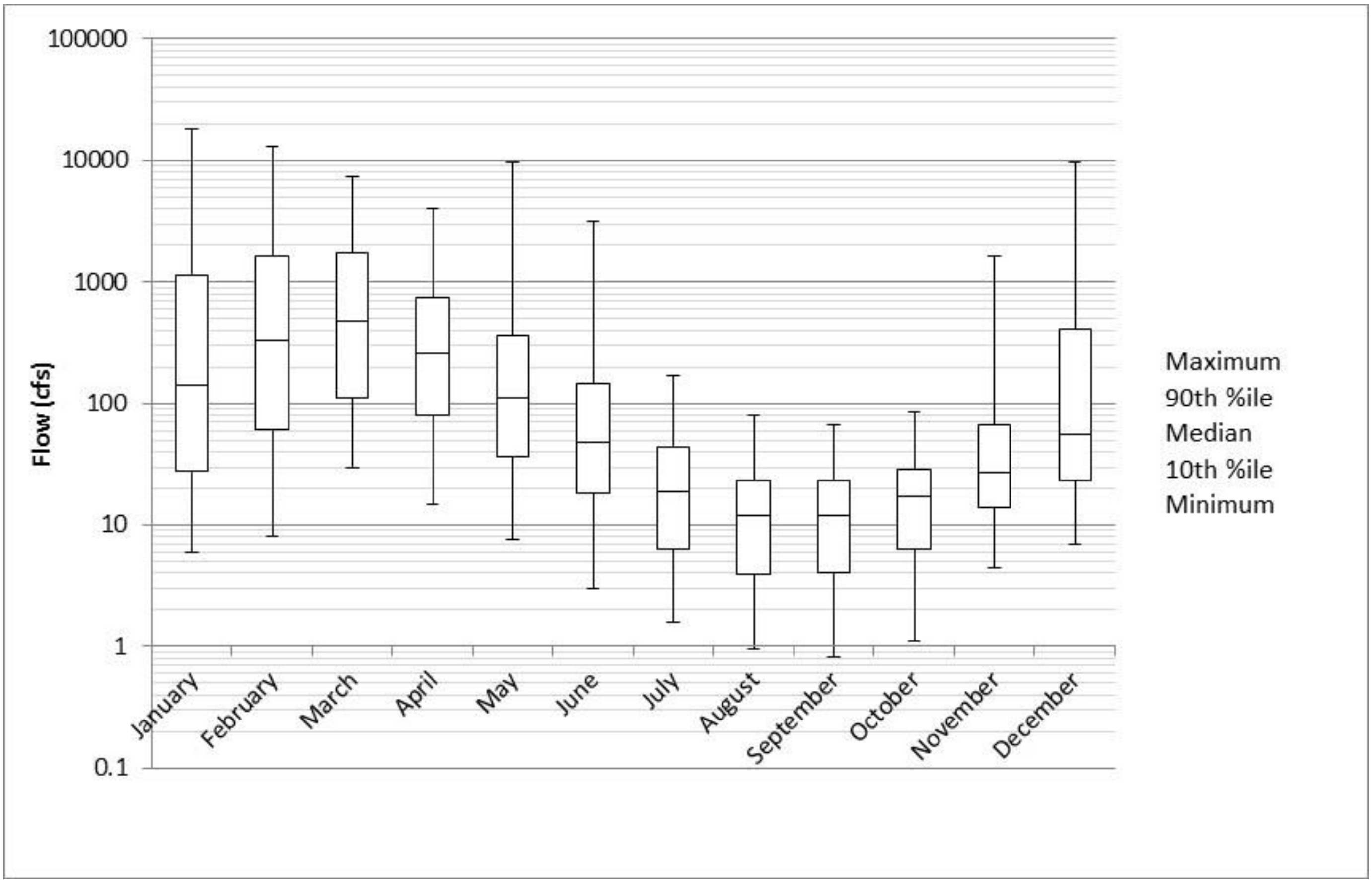

Figure 2. USGS stream-gage monthly flow statistics between 1948 and 2016 for Hangman Creek at the mouth.

Land use

Figure 3 shows land use in the Hangman Creek watershed. The watershed is dominated by dryland agriculture, particularly in the south and eastern areas where loess soils occur. Forested areas occur on buttes and low mountains in the eastern part of the watershed, in canyons along Hangman and Rock creeks, and in the channeled scablands that occur in the western part of the watershed. Urban development is concentrated in and around the city of Spokane, in the far northern part of the watershed.

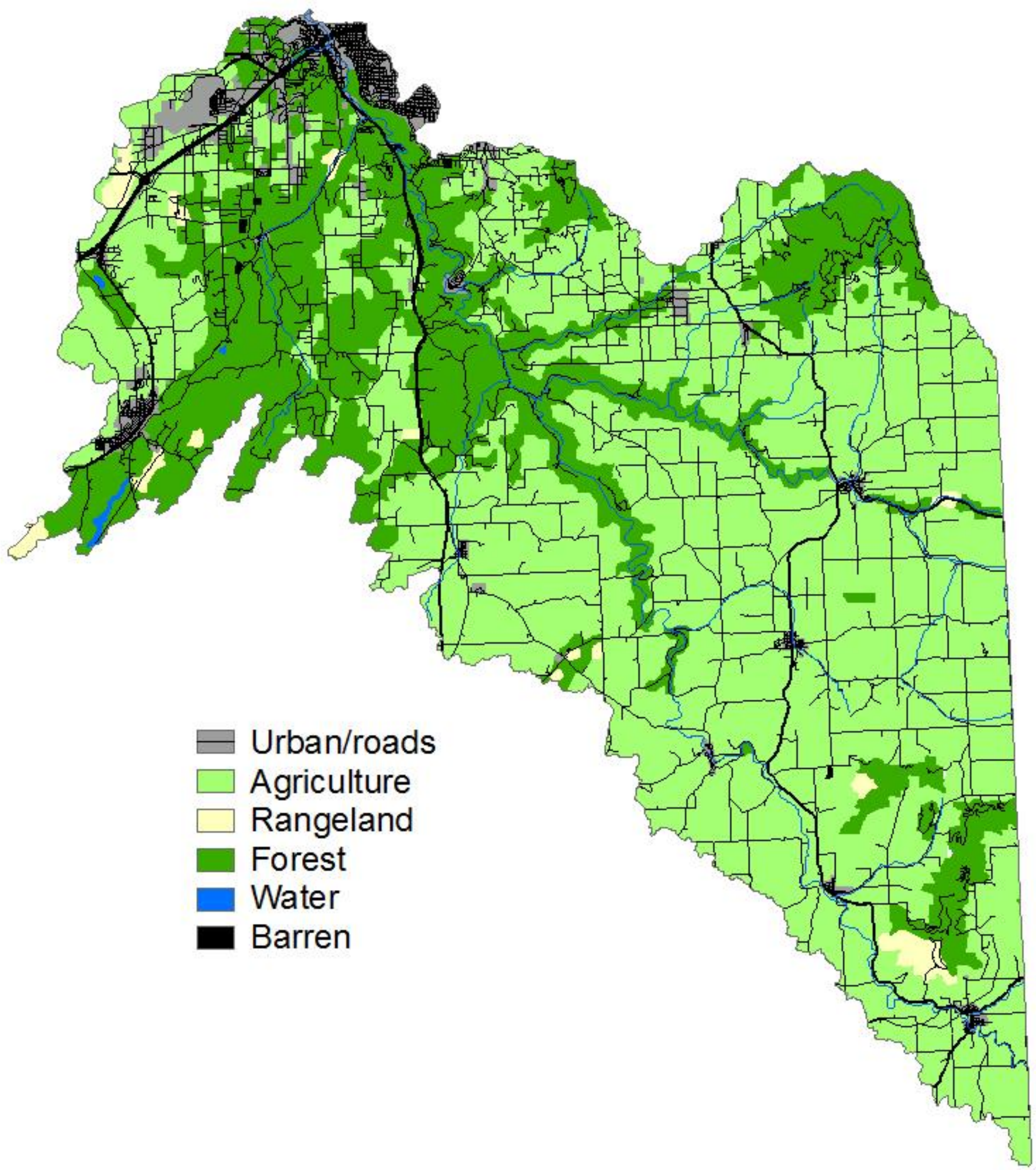

Figure 3. General land use map of the Washington portion of the Hangman Creek watershed.

Source: USGS Land Use/Land Cover (GIRAS).

3.2.1 History of study area

Agriculture has been the dominant land use in the Hangman Creek watershed since the early 1900s. By the 1920s, a significant portion of the farmable land had been cleared and cultivated. The watershed has some of the most productive farmland in the nation, shipping wheat, barley, lentils, and peas worldwide (Palouse Watershed Plan, 2007). Whitman County, which has similar land use as the rest of the watershed, consistently produces more wheat than any other county in the nation (yields of 100 bushels/acre are common in many parts of the county). Approximately 93% (1,948,350 acres) of the 2,095,000 acres in the Palouse River Watershed are classified as agricultural (Palouse Watershed Plan, 2007). A majority of waterways within the watershed have become a part of the agricultural landscape which has resulted in many waterways becoming highly channelized with limited riparian areas.

3.2.2 Summary of previous studies and existing data

Agencies including the U.S. Geological Survey (USGS), Spokane Conservation District (SCD), Idaho Department of Environmental Quality (IDEQ), the Coeur d'Alene Tribe, and Ecology have collected water quality and streamflow data in the Hangman Creek watershed. The following sections highlight key findings that are important to this project.

Summertime low-flow characteristics

Ecology conducted synoptic surveys in 2008 and 2009 during low flow conditions (Joy, 2008; Ross, 2011). Key findings from these surveys included:

- Algal productivity is generally nitrogen-limited.
- Dissolved oxygen (DO) and pH experience wide diel variations due to algal productivity and low reaeration.
- Dye study results show very slow travel times resulting from very low flows and wide, deep, long pools.
- Nutrients from sources in the upper watershed are taken up by algae and generally do not reach the lower watershed during low flow conditions.
- Most of the phosphorus load and nearly all of the nitrate load that reaches the mouth of Hangman Creek, enters in the downstream-most 9 miles of Hangman Creek. These nutrients likely enter the stream via groundwater inputs.

Phosphorus, sediment, and turbidity during spring runoff

Hangman Creek carries large amounts of suspended sediment as well as phosphorus during the springtime runoff period. Ambient monitoring data collected by Ecology at the mouth of Hangman Creek demonstrates that sediment (represented as total suspended solids/TSS) and phosphorus are linked (Figure 4). This conclusion is also supported by a study conducted by Spokane Conservation District (SCD, 2009), which found high soil phosphorus levels in the Hangman Creek watershed. Ambient monitoring data also demonstrates that both phosphorus and sediment are closely related to turbidity (Figure 5).

These findings are key to the design of the high flow study part of this project, which depends on the relationships between turbidity, sediment, and phosphorus. (See section 7.3.1).

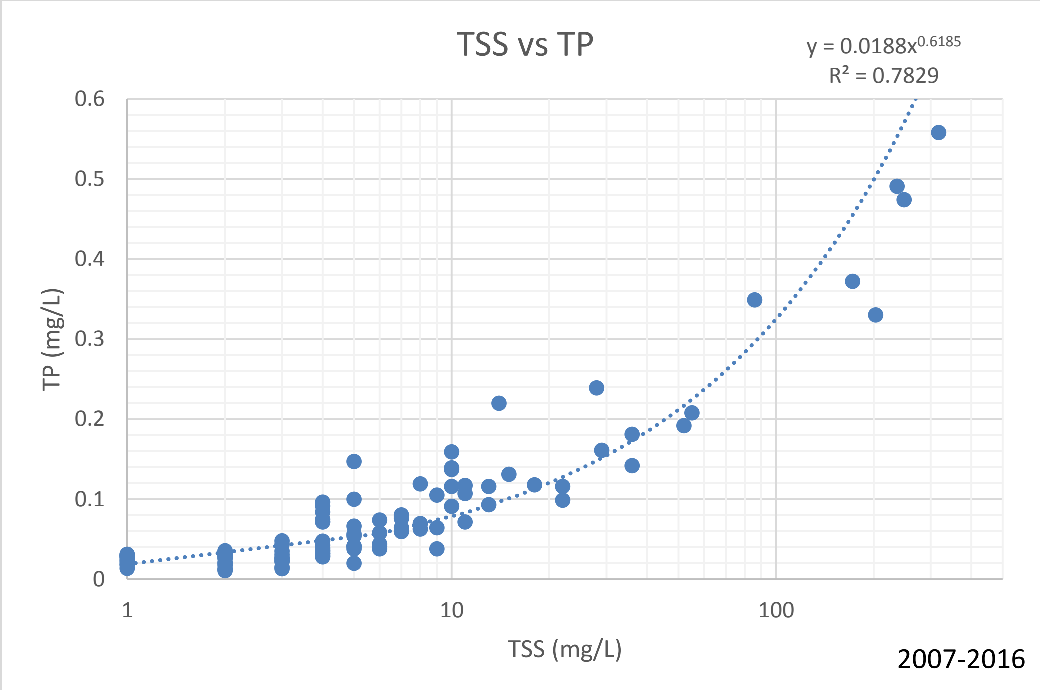

Figure 4. Plots of monthly total suspended solids (TSS) vs. total phosphorus (TP) data from the ambient station at the mouth of Hangman Creek (56A070).

TSS is shown on a log scale.

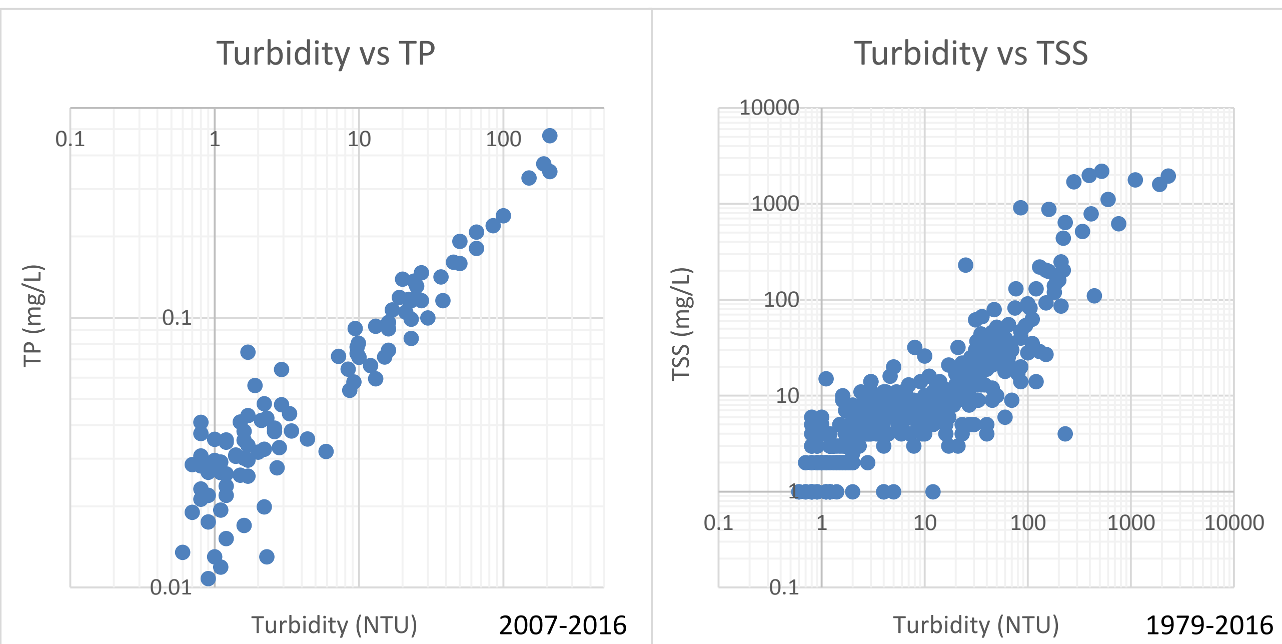

Figure 5. Plots of monthly turbidity vs TP and turbidity vs TSS data from the ambient station at the mouth of Hangman Creek (56A070).

Best-fit lines are not shown for these graphs because a single fit line does not apply do all parts of the regression. Graphs are shown on a log scale.

WWTP contribution to phosphorus loads during spring runoff

During springtime runoff conditions, algae are not expected to take up nutrients very actively due to the cold, turbid water. Furthermore, travel times are much quicker. Therefore, it is expected that, unlike during low-flow conditions, nutrients from point sources in the upper watershed will be transported through Hangman Creek to the Spokane River. Table 1 provides an analysis to estimate the total phosphorus (TP) load from wastewater treatment plants (WWTPs) during the spring runoff months.

Table 1. Analysis of wastewater treatment plant (WWTP) contribution to Hangman Creek total phosphorus (TP) load during spring runoff.

Month	Effluent TP load (lbs/day) during 2009 [1]						Historical mean TP load at mouth of Hangman Ck. (lbs/day) [2]	% of TP load that may originate from WWTPs
	Tekoa	Rockford	Fairfield	Spangle	Freeman School Dist.	Total of all WWTPs		
January	2.77	5.85	2.98	0.48	0	**12.08**	440	**2.7%**
February	1.14	4.44	2.29	0.54	0.080	**8.48**	857	**1.0%**
March	4.15	4.05	3.21	0.71	0.23	**12.35**	835	**1.5%**
April	3.48	2.50	3.36	0.57	0.36	**10.27**	205	**5.0%**
May	4.51	0	1.52	0.63	0	**6.66**	72	**9.3%**

[1] Calculated from TP data collected by Ecology during 2009, and average monthly flows during 2009 reported by the facilities in their discharge monitoring reports (DMRs).
[2] This calculation is a historical average, it is not specific to 2009. Calculated from Ecology ambient monitoring data collected at the mouth of Hangman Creek, and from mean monthly flows provided by USGS StreamStats.

Ecology will not re-sample the WWTPs during the watershed springtime runoff study part of this project. (We will sample Tekoa WWTP during the receiving water study.) Because the contribution of WWTPs to the TP load in Hangman Creek is fairly small, it is appropriate to estimate their contribution using 2009 data.

Previously collected data usability for this project

Table 2 summarizes previous monitoring studies conducted by Ecology during 2008-2009 (Joy, 2008; Ross, 2011) and 2010-2012 (Redding, in publication). The table also provides an assessment of the applicability of these data to this project.

3.2.3 Parameters of interest and potential sources

3.2.3.1 Parameters of interest

This study addresses pH and DO impacts. Existing data (see section 3.2.2) and studies of other regional waterbodies (Snouwaert and Stuart, 2015; Joy et al., 2007) indicate that these impacts generally result from excessive nutrients and organic matter, high water temperatures, poor channel conditions from erosion and sedimentation, and/or low streamflows. In addition to DO and pH, nitrogen, phosphorus, carbon, and biochemical oxygen demand are of the greatest interest to this project because of their influence on in-stream biological productivity and/or their inclusion in the Spokane TMDL.

Table 2. Applicability of previously collected Ecology data to this project.

Data type	When collected	Description	Applicable to this project?*
Border sites	2008-2009	5 sites were sampled where streams cross from Idaho into Washington. Monitoring was conducted year-round with twice-monthly trips during spring runoff.	Yes, usable to estimate border loads of nutrients and total suspended solids (TSS).
Reference sites	2008-2009	Sites were sampled to represent each of the 4 ecoregions in the Hangman watershed. Ideally, these sites would have minimal human impact. However, such sites were mostly not found. Results from the sites that were chosen unfortunately suggest they have little value as reference sites.	No
WWTP effluent characterization	2008-2009	Each of the wastewater treatment plants (WWTPs) with a surface discharge was sampled regularly. This included Tekoa, Rockford, Fairfield, Spangle, and Freeman School District. It did not include Latah Creek (Hangman Hills) WWTP which discharges to retention ponds.	Yes, these data are likely still valid as none of the facilities has altered its treatment process.
Summertime synoptics	2008-2009	Two synoptic nutrient surveys were conducted along Hangman and Rock Creeks, along with diel Hydrolab data, periphyton biomass data, and time-of-travel dye studies. These surveys suffered from issues with site spacing, weather conditions, and uncontrollable circumstances such as WWTP malfunction during survey.	Time-of-travel dye study data are still usable. Periphyton biomass data are still usable, because these data are used in a very general way and differences between years are acceptable. Other data are usable in an informative capacity but not for modeling.
Storm event	2009	Sites were sampled throughout the watershed during one February storm event.	Usable in an informative capacity but site-to-site comparisons cannot be made because conditions were changing too rapidly during sampling.
Latah Creek (Hangman Hills) WWTP groundwater study	2010-2012	Surface water and groundwater data in the vicinity of the Latah Creek (Hangman Hills) WWTP. Latah Creek WWTP discharges to retention ponds adjacent to Hangman Creek near the Hangman Valley Golf Course. These data indicate that nitrate loading via groundwater to Hangman Creek from Latah WWTP has been reduced following the installation of a denitrification system in 2011.	Yes, use to characterize groundwater nutrient concentrations in vicinity of Latah Creek WWTP.

The ratio of nitrogen to phosphorus from the 2009 data suggests that Hangman Creek in the vicinity of Tekoa is likely nitrogen-limited. Therefore, nitrogen is a key parameter of interest for studying the impact of the Tekoa WWTP and other potential sources of impairment in Hangman Creek.

Biochemical oxygen demand (BOD) from breakdown of carbon-based organic matter and nitrification of ammonia to nitrate (NBOD) is of interest to the Tekoa receiving water study because of the potential impact on Hangman Creek DO levels from these sources. Dissolved and total organic carbon are also of interest due to their close relationship with carbonaceous biochemical oxygen demand (CBOD).

The Spokane River/Lake Spokane system is generally considered to be phosphorus-limited (Moore and Ross, 2010). Phosphorus is a key parameter of interest for the aspects of the project which are aimed at meeting the allocations for the mouth of Hangman Creek set by the *Spokane*

River/Lake Spokane Dissolved Oxygen TMDL. Load allocations were also set for CBOD and ammonia. These parameters are of secondary interest.

Suspended sediment is also a parameter of interest during the watershed springtime runoff study portion of this project because of the demonstrated link between phosphorus and sediment in Hangman Creek during spring runoff conditions (See section 3.2.2).

3.2.3.2 Nonpoint sources

Nonpoint sources of pollutants contributing to pH and DO problems in the watershed may include diffuse sources of nutrients, BOD, eroded sediments, and areas with a lack of riparian shade. The watershed has extensive areas of farming. Some farming practices are potential sources of nutrients and eroded sediments rich in phosphorus. Riparian areas are also lacking riparian vegetation along many reaches throughout the watershed (Joy et al., 2009; SCD, 2003). Channel areas exposed to long periods of sunlight can become choked with periphyton, grasses, and aquatic plants when flows are low, water is clear, and nutrients are plentiful in the water column or in bed sediments.

Some livestock access areas have been observed in the previous TMDL surveys. Poor livestock management in riparian corridors can be sources of nutrients and oxygen-demanding manures.

Eroding banks may be enriched with nutrients or may have native nutrient concentrations high enough to stimulate algae growth in the stream channels. As mentioned earlier, soils and geologic factors in much of the watershed leave unprotected banks and uplands susceptible to erosion. Land uses and channelization have destabilized streambanks in the watershed (Joy et al., 2009).

Residential and urban areas supply nutrients through run-off and can have denuded riparian areas. Fertilizers, on-site septic systems, and pets can be sources of nutrients and BOD. Riparian areas with bank-side development may lack shade and be subject to streambank erosion.

3.2.3.3 Point sources

The Hangman Creek watershed contains ten permitted wastewater facilities in Washington. Six of these wastewater treatment plants (WWTPs) have National Pollutant Discharge Elimination System (NPDES) permits to discharge to surface water (Table 3).

Table 3. Wastewater facilities with permits to discharge to surface water.

Facility	City	Permit Number	Discharges to
Cheney WWTP	Cheney	WA0020842	Wetland drains to Minnie Creek
Fairfield WWTP	Fairfield	WA0045489	Rattler Run Creek
Freeman School District	Rockford	WA0045403	Little Cottonwood Creek
Rockford WWTP	Rockford	WA0044831	Rock Creek
Spangle WWTP	Spangle	WA0991010	Spangle Creek
Tekoa WWTP	Tekoa	WA0023141	Hangman Creek

Tekoa and Spangle WWTPs are currently the only NPDES permitted facilities that discharge continuously throughout the year. Rockford WWTP is limited to discharge to Rock Creek only during the months between December and May when the receiving water flow exceeds 2.38 cfs. Fairfield and Freeman School District lagoon systems have enough capacity to hold effluent during the late-summer and early-fall low streamflow season.

The NPDES permit for Cheney's WWTP prohibits direct surface discharge to the ditch (tributary to Minnie Creek) during the months of June, July, and August. The facility discharges to series of constructed treatment wetlands. During wet weather these wetlands could theoretically discharge to ditch that ultimately goes to Minnie Creek. A wetlands bypass exists that directs effluent directly to the ditch in event of extreme flows, however it has never been used (Peterschmidt, 2011).

An additional four facilities (Badger Lake Estates, Liberty School District, Latah Creek, and Upper Columbia Academy) have Washington State wastewater discharge permits to discharge to ground or wetlands. The Latah Creek (Hangman Hills) WWTP discharges to ponds located adjacent to of Hangman Creek. Data collected by Ecology indicates that this reach of Hangman Creek gains flow from groundwater, and that the WWTP discharge infiltrates to groundwater which then flows to Hangman Creek (Redding, in publication).

All of the permitted municipal WWTPs have effluent limits for BOD and suspended solids. Ammonia effluent limits have been established for Tekoa, Spangle, Cheney, and Fairfield. Only Cheney has a phosphorus effluent limit.

Hangman Creek and Rock Creek receive effluent from three additional wastewater facilities located across the Idaho border on the Coeur d'Alene Reservation. The Tensed WWTP, in the town of Tensed, is located on the mainstem Hangman Creek upstream of Tekoa. Worley and the Coeur d'Alene Casino have wastewater facilities that discharge to Rock Creek. Their nutrient loads will not be specifically evaluated, but are included in loads measured at the border.

Spokane County and the City of Spokane are both Phase II municipal separate stormwater sewer system (MS4) permit holders covered by the Municipal Stormwater Permit. This NPDES permit regulates pollutants carried to waterbodies by stormwater. The Washington Department of Transportation also has a stormwater permit which covers runoff from state highways and associated facilities. Stormwater permits do not have specific permit limits, but jurisdictions are required to create stormwater management plans that meet specific management requirements.

Other permit types, such as construction stormwater and sand and gravel, are not expected to be significant pollutant contributors. Construction stormwater permits regularly change with the initiation and completion of various construction projects. Therefore, some of the construction stormwater permits listed below may not exist by the end of this project, while other new permits may apply. Table 4 lists all permitted point sources in the Washington portion of the Hangman Creek watershed (WRIA 56).

Table 4. Permitted point sources in WRIA 56.

Facility Name	Permit Number	Permit Type	City	Water Body
Cheney WWTP	WA0020842	Municipal NPDES IP	Cheney	Constructed wetlands (year round)
Fairfield WWTP	WA0045489	Municipal NPDES IP	Fairfield	Rattler Run Creek
Freeman School District 358	WA0045403	Municipal NPDES IP	Rockford	Little Cottonwood Creek
Rockford WWTP	WA0044831	Municipal NPDES IP	Rockford	Rock Creek
Spangle WWTP	WA0991010	Municipal NPDES IP	Spangle	Spangle Creek
Tekoa WWTP	WA0023141	Municipal NPDES IP	Tekoa	Hangman Creek
Latah Creek WWTP	ST0008045	Municipal to ground SWDP IP	Spokane	To ground
Liberty School District 362	ST0005397	Municipal to ground SWDP IP	Spangle	To ground
Upper Columbia Academy	ST0008034	Municipal to ground SWDP IP	Spangle	To ground
Eastern Washington University	ST0008098	Industrial (IU) to POTW/ Private SWDP IP	Cheney	Unknown
Spokane International Airport-Deicing	ST0045499	Industrial to ground SWDP IP	Spokane	To ground
Spokane County Muni SW	WAR046506	Municipal SW GP	Spokane	Hangman Cr, Unknown
WSDOT SW GP	WAR043000	Municipal SW GP	Spokane	Various
City of Spokane SW	WAR046505	Municipal SW GP	Spokane	Hangman Cr, Unknown
Rockford Elevator & Agronomy	WAR302313	Industrial SW GP	Rockford	Rock Cr, Unknown
Ben Burr Road Development	WAR302628	Construction SW GP	Spokane	Unknown
Eagle Ridge 11th Addition	WAR303736	Construction SW GP	Spokane	Unknown
Eagle Ridge 12th Addition	WAR304933	Construction SW GP	Spokane	Unknown
EWU PUB	WAR304431	Construction SW GP	Cheney	Unknown
Harvest Bluff Phase 2	WAR303432	Construction SW GP	Cheney	Minnie Cr, Unknown
Moran View Estates	WAR304540	Construction SW GP	Spokane	Hangman Cr, Unknown
Park Road	WAR302970	Construction SW GP	Tekoa	Hangman Cr, Unknown
Spangle Creek	WAR302910	Construction SW GP	Spangle	Spangle Cr, Unknown
Acme Concrete Paving Inc.	WAG500033	Sand and Gravel GP	Spokane	Dewatering to Dry Cr and Irrigation Ditch; Storm and process water to ground
Camas Gravel Company	WAG500054	Sand and Gravel GP	Spokane	Unknown; facility currently inactive
Interstate Concrete & Asphalt Key Rock	WAG507201	Sand and Gravel GP	Cheney	Stormwater to ground
Mutual Materials POTTRATZ	WAG507044	Sand and Gravel GP	Waverly	Stormwater to both Hangman Cr and ground
Spokane County PWD Cutoff	WAG507024	Sand and Gravel GP	Fairfield	Stormwater to ground
WA DOT QS-C-171 Excelsior Quarry	WAG507174	Sand and Gravel GP	Spokane	Stormwater to ground

IP: Individual permit
SWDP: Stormwater discharge permit
SW: Stormwater
GP: General permit
PWD: Public Works Deparment

3.2.4 Regulatory criteria or standards

Dissolved oxygen (DO) and pH

This study addresses the protection of aquatic habitat and attainment of the aquatic life uses in the Hangman Creek watershed and the Spokane River. According to watershed assessments of current and historical fish populations (SCD, 2005):

> *Fish habitat and distribution throughout the watershed has radically changed over the last one hundred years. Hangman Creek once had viable populations of native redband trout and healthy runs of salmon and steelhead. The removal of riparian vegetation, channel alterations, and heavy sedimentation has significantly reduced the spawning and rearing habitat on Hangman Creek. The primary species now found in the stream are adapted to warmer, slower waters and considered undesirable as gamefish. Resident trout populations are severely depressed.*

California Creek, Rock Creek, and Marshall Creek support remnant populations of redband trout (Western Native Trout Initiative, 2007; Lee, 2005). However, there is no major effort to re-establish anadromous (sea-run) salmon or steelhead in the Hangman Creek watershed because downstream barriers in the Spokane River system prevent migration. Improving water quality conditions is a necessary step to enhance and protect the aquatic community, including cold water fisheries on which the water quality standards are based in this watershed. Proper levels of DO and pH are essential for healthy fish and macroinvertebrate populations.

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). Hangman Creek has not been designated for protection of any special population of fish. Therefore, the statewide baseline designated aquatic life uses of "Salmonid Spawning, Rearing, and Migration" are to be protected.

The water quality criteria associated with the aquatic life use of "Salmonid Spawning, Rearing, and Migration" are biologically based. They are set to ensure the conditions necessary to fully support the aquatic life uses designated for the water body. As these criteria are based on biological requirements rather than the specific waterbody conditions, they may not be achievable in all seasons. Hangman Creek is well known for its "flashy" and variable flow regime with extremely low and spatially stagnant flows in the summer. These conditions often preclude the attainment of the numeric criteria. While Hangman Creek has been altered by human activities, extreme low summer flows are likely a natural feature in this watershed. Unfortunately, the water quality standards do not take flow regime into consideration except through the natural conditions provision (WAC 173-201A-260) which applies to the ambient conditions that result in such flows conditions (such as, lower DO and higher temperatures).

Table 5 summarizes the DO and pH water quality criteria associated with the "Salmonid Spawning, Rearing and Migration" use and therefore applicable to Hangman Creek.

Further information on these parameters is provided in the *Programmatic QAPP for Water Quality Impairment Studies* (McCarthy and Mathieu, 2017).

Table 5. Applicable water quality criteria for Hangman Creek.

Parameter	Criteria
Dissolved Oxygen	DO concentration will not fall below 8.0 mg/L more than once every ten years on average. When a water body's DO is lower than 8.0 mg/L (or within 0.2 mg/L) and that condition is due to natural conditions, then human actions considered cumulatively may not cause the DO of that water body to decrease more than 0.2 mg/L.
pH	pH shall be within the range of 6.5 to 8.5 with a human-caused variation within above range of less than 0.5 units.

Phosphorus, ammonia, and CBOD

The *Spokane River Dissolved Oxygen TMDL* (Moore and Ross, 2010) identified load allocations for the mouth of Hangman Creek. Table 6 summarizes the relevant allocations as reported in the TMDL, while Table 7 summarizes the load reductions for total phosphorus.

Table 6. Spokane River TMDL load allocations for Hangman Creek.

Season	2001 Flow (cfs)	Total Phosphorus		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)
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 – October Average	9	0.030	1.4	0.009	0.4	2.3	107.9

Table 7. Spokane River TMDL total phosphorus load reductions for Hangman Creek.

Month	Loads (lbs/day)			Load Reduction (lbs/day)	% Reduction	
	Natural (lbs/day)	2001 (lbs/day)	TMDL (lbs/day)		of 2001 Load (%)	of Human Load (%)
Mar-May	62.2	157.9	140.2	19.5	12	20
June	3.9	9.9	7.5	2.4	24	40
Jul - Oct	1	1.8	1.4	0.4	22	50

Total suspended solids (TSS)

Although the primary emphasis of this project is on nutrients, extensive turbidity and sediment data will also be collected during this project. This is because much of the phosphorus in Hangman Creek during the springtime runoff season is associated with suspended sediment. The *Hangman Creek Watershed Fecal Coliform, Temperature, and Turbidity Total Maximum Daily Load* (Joy et al., 2009) established load and wasteload allocations for TSS to address turbidity violations. Data collected during this study will be compared to these allocations. Tables 8 and 9 show the load and wasteload allocations for TSS in the Hangman Creek watershed.

Table 8. Total suspended solids (TSS) load allocations for Hangman Creek watershed.
For geographic sub-basins and 303(d) listed stream segments.

	Sub-basin	303(d) listed segment	Estimated % reduction	
			Basin	303(d)
Hangman Creek	Upper Hangman Creek	Hangman Creek at Bradshaw Road (ID 40942)	26%	19%
	Hangman Creek from Tekoa to Bradshaw Rd		16%	
	Hangman Creek from Bradshaw Rd to Duncan		15%	n/a
	Lower Hangman Creek		11%	
Tributaries	Little Hangman Creek	Little Hangman Creek (ID 40940)	16%	15%
	Rattler Run Creek	Rattler Run Creek (ID 40941)	15%	15%
	Rock Creek	Rock Creek at Jackson Road (40943)	18%	17%
	Marshall Creek		8%	n/a

n/a – There are no 303(d) listed segments in this geographic area.

Table 9. Total suspended solids (TSS) wasteload allocations for the Hangman Creek watershed.

Source	Permit Requirements		WLA
	Average Monthly Limit	Average Weekly Limit	
Tekoa WWTP	30 mg/L, 34.5 lbs/day	45 mg/L, 51.7 lbs/day	same
Fairfield WWTP	15 mg/L, 29.0 lbs/day	23 mg/L, 44.5 lbs/day	same
Spangle WWTP	15 mg/L, 8.5 lbs/day	23 mg/L, 12.8 lbs/day	same
Rockford WWTP	30 mg/L	45 mg/L	same
Freeman School District #358	20 mg/L, 7.2 lbs/day	30 mg/L, 10.8 lbs/day	same
Cheney WWTP	15 mg/L, 338 lbs/day	23 mg/L, 507 lbs/day	same
Industrial Facility Stormwater[1]	27 mg/L	88 mg/L[2]	same
Spokane County Stormwater	All known and reasonable treatment		80% reduction[3]
City of Spokane Stormwater	All known and reasonable treatment		80% reduction[3]
Washington Dept. of Transportation Stormwater	All known and reasonable treatment		80% reduction[3]
Construction Site Stormwater[4]	All necessary best management practices Turbidity Benchmark: 25NTU Background and discharge sampling required Turbidity Limit: 5 NTU over background or when background is over 50 NTU less than a 10% increase over background		same

[1] No permitted industrial facilities currently exist in the watershed.
[2] Limit is a maximum daily (not average weekly).
[3] Best management practices estimate 80% removal of TSS from stormwater sources (Ecology, 2004)
[4] Construction stormwater NPDES permit regulates turbidity but does not regulate TSS.

3.3 Water quality impairment studies

This Quality Assurance Project Plan (QAPP) serves jointly with the *Programmatic QAPP for Water Quality Impairment Studies* (McCarthy and Mathieu, 2017) to describe this 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.

This project has been classified as a Pollutant Source Assessment study. EAP conducts Source Assessment studies when more information is needed about the extent of the impairment and the contributing sources, but resources or other obstacles prevent the development of a full TMDL. More information about source assessments and other types of water quality impairment studies can be found in the Programmatic QAPP.

Ecology previously conducted a data collection effort during 2008-2009, which focused on completing TMDLs for dissolved oxygen (DO) and pH in the Hangman Creek watershed. At that time it became apparent that the natural flow regime in the watershed would preclude the attainment of the numeric criteria during certain times of the year. The disparity between attainable conditions and the assigned numeric criteria are significant in terms of magnitude and duration. Due to this disparity Ecology decided that relying solely on the natural condition provision may be challenging. Changes to the water quality standards that take into consideration the natural flow variability would be necessary to complete TMDLs that set achievable load and wasteload allocations.

Since 2010, Ecology has been engaged in an effort to research policy pathways to address water quality standards challenges like those found in the Hangman Creek watershed. This effort is ongoing, and Ecology's Water Quality Program is exploring pathways but none have yet been advanced. Additionally, legal challenges to the natural conditions provisions of the water quality standards in both Oregon and Washington have added a new layer of challenge and complexity to efforts to complete TMDLs in the Hangman Creek watershed and other similar systems. Because of all these factors, a decision was made to defer the completion of DO and pH TMDLs until there is a clear and feasible policy path. However, understanding and addressing the significant nonpoint source pollutant loading to Hangman Creek and the downstream Spokane River is of greater importance necessitating the need for this study.

This pollutant source assessment study is focused on answering specific questions to provide actionable information to address concerns which cannot or should not be postponed until a full TMDL can be completed. Two such concerns were identified:

- Tekoa's aging wastewater treatment facility needs to be upgraded to come into compliance with current and future permit limits. The City of Tekoa needs to know what permit limits, specifically for nutrients, they will be required to meet. Because of the state of the current facility and the amount of time needed to plan, design, and construct the necessary improvements, this cannot be delayed.
- The *Spokane River and Lake Spokane DO TMDL* set load allocations for total phosphorus (along with CBOD and ammonia) at the mouth of Hangman Creek. Hangman Creek is the largest contributor of nonpoint phosphorus during high flow. Identifying where in the

Hangman Creek watershed that implementation of best management practices (BMPs) needs to be focused to meet these allocations, is key to fulfilling the reasonable assurance to Spokane dischargers, that nonpoint targets will also be met. The level of attention in recent years to the Spokane TMDL and to Hangman Creek make this a high priority.

If a policy path to TMDL completion does open up in the near future, the data and modeling analysis included in this project will also be usable for that purpose. This project would provide much, but not all, of the information that would be needed to compete a watershed-wide DO and pH TMDL. This project is designed to avoid a potential duplication of effort.

4.0 Project Description

This project will address two main concerns. First, it will assess the effects of nutrients from the Hangman Watershed on the Spokane River system, identify nutrient sources, and help focus implementation activities to meet the load allocations at the mouth of Hangman Creek. Second, it will assess the impacts of nutrients from Tekoa WWTP and other nearby sources on upper Hangman Creek, and identify the allowable nutrient loading that will inform future permit limits.

These goals will be attained through four studies that are parts of the larger project. Each study/part of this project will fill critical data gaps to address these two concerns. The four studies of the project are:

- Tekoa receiving water study
- Watershed springtime runoff study
- Lower watershed ground water study
- Lower watershed low flow study

The Tekoa receiving water study will gather data necessary to develop nutrient limits for Tekoa WWTP, and will occur during May-October 2017. The Tekoa study will also provide enough data to assess other sources of impairment in the upper watershed.

The other three studies will all address meeting the load allocations for the mouth of Hangman Creek, set in the *Spokane River and Lake Spokane DO TMDL* (Moore and Ross, 2010).

During the springtime, phosphorus loads come from throughout the watershed, and much of that phosphorus is associated with sediment. The watershed springtime runoff study will occur during January-May 2018. This study will determine location and magnitude of reductions needed to meet the load allocation for the mouth of Hangman Creek for the March-May TMDL season. Although the load allocations for the *Spokane River and Lake Spokane TMDL* do not apply until March, springtime runoff conditions in Hangman Creek actually start during the winter, as early as January (see section 3.2; Figure 2). This study will begin in January in order to fully characterize conditions throughout the high-flow period. Starting the study in January also allows sediment data from this study to be used for comparison to earlier datasets (e.g. Joy et al., 2009) to determine if conditions are improving.

During summer months, most of the nutrient load (because most of the flow in the creek) comes from the last 9 miles of Hangman Creek (see section 3.2.2), where tributaries, springs, diffuse groundwater, and potential human sources all contribute phosphorus and nitrogen. The lower watershed groundwater study and the lower watershed low-flow study will be conducted concurrently during May-October 2018. These two studies will help determine where these loads are coming from, and how to meet load allocations at the mouth of Hangman during medium and low flow conditions.

4.1 Project goals

- **Primary Goal #1***:* Quantify sources of phosphorus to Hangman Creek throughout the year, in order to identify reductions needed to meet load allocations at the mouth of Hangman Creek for the Spokane River and Lake Spokane TMDL.
- **Primary Goal #2:** Assess impact of Tekoa WWTP effluent on DO and pH in Hangman Creek, and set nutrient discharge limits.
- **Secondary Goal:** Develop low-flow dynamic water quality models, for both upper and lower watershed, capable of supporting management decisions beyond the Spokane TMDL and Tekoa WWTP analysis, including future development of a DO and pH TMDL for Hangman.

4.2 Project objectives

The project goals will be met by achieving the specific project objectives for each part of this study:

Tekoa receiving water study

- Assess impact of Tekoa WWTP effluent on DO and pH in Hangman Ck. Provide information that can be used to set permit limits for nutrients.
- Define seasonal window when Tekoa WWTP effluent has the potential so cause a significant impact to DO and pH in Hangman Creek.
- Provide assessment of 303(d) listed areas of Hangman Creek in/near Tekoa, upstream of WWTP.

Watershed springtime runoff study

- Determine relative contributions of various parts of the watershed to sediment and phosphorus load.
- Use to set load reductions necessary to meet LA at Hangman mouth for Spokane TMDL, for March-May season.
- Provide up-to-date total suspended solids (TSS)/suspended sediment concentration (SSC) dataset for comparison to older datasets collected by the Spokane Conservation District and USGS during the late 1990s and 2000s.

Lower watershed groundwater study

- Define the gaining reaches in the area of interest to determine where groundwater is flowing into Hangman Creek.
- In these gaining reaches, characterize nutrient concentrations of groundwater inputs to the last 9 miles of Hangman Creek.
- Locate and quantify nutrient loads from groundwater in this reach.
- Quantify what portion of low-flow TP load to Spokane River comes from lower watershed groundwater.

- Provide groundwater input data for QUAL2Kw assessment of lower watershed.

Lower watershed low-flow study

- Provide accounting of sources of nutrients reaching the Spokane River at low flow in order to set load reductions needed to meet the load allocation at Hangman mouth for the Spokane TMDL, for the June and July-October seasons.
- Provide more instream confirmation as to whether impacts from the Latah (Hangman Hills) WWTP have been eliminated as a result of facility upgrades in 2011.

4.3 Information needed and sources

Tekoa receiving water study

- Nutrient, solids, alkalinity, chloride, and organic carbon sample data; both from stream locations and from Tekoa WWTP effluent – *to be collected by Ecology during this project.*
- Continuous (DO, pH, conductivity, and temperature) data; both at boundary locations upstream of Tekoa WWTP and of Tekoa WWTP effluent; and diel data for these parameters at other locations – *to be collected by Ecology during this project.*
- Continuous flow data at boundary condition locations and at Tekoa WWTP, and instantaneous flow data at other locations – *to be collected by Ecology during this project; one USGS gaging station (Hangman Creek at State Line) will also be used. Facility reported effluent flows from Tekoa WWTP will be used.*
- Continuous turbidity data at boundary condition locations – *to be collected by Ecology during this project.*
- Channel geometry data – *depths collected by Ecology during 2016; widths to be obtained using ArcGIS; some time of travel data collected during 2009, additional time of travel data to be collected during this project.*
- Meteorology data – *air temperature and dew point to be collected during this study; cloud cover, wind speed, and solar radiation will be obtained from National Weather Service stations at Spokane and/or Pullman airports.*
- Shade data – *will be adapted from Temperature TMDL if possible, or remodeled from ArcGIS data if necessary.*
- Periphyton biomass data – *collected by Ecology during 2009.*

Watershed springtime runoff study

- Nutrient and solids/sediment sample data – *to be collected by Ecology during this project.*
- Continuous stream flow data at 8-10 locations throughout watershed, and instantaneous flow data at other locations – *to be collected by Ecology at 6-8 locations during this project; 2 USGS gaging stations (Hangman Creek at State Line; Hangman Creek at Mouth) will also be used.*

- Additional sample and flow data from Hangman Creek and tributary locations where they cross the WA/ID state line – *collected by Ecology during 2009.*
- Continuous turbidity data at gage station locations – *to be collected by Ecology during this project.*
- WWTP effluent flow and nutrient concentration data – *Effluent nutrient data collected by Ecology during 2009. Effluent flow data reported by facilities in their Discharge Monitoring Reports (DMRs).*

Lower watershed groundwater study

- Synoptic seepage flow data to locate groundwater sources – *to be collected by Ecology during this project.*
- Piezometer groundwater sample data for nutrient, solids, alkalinity, chloride, bromide, boron and organic carbon – *to be collected by Ecology during this project.*

Lower watershed low-flow study

- Nutrient, solids, alkalinity, chloride, and organic carbon sample data – *to be collected by Ecology during this project.*
- Continuous DO, pH, conductivity, and temperature data at boundary locations, and diel data for these parameters at other locations – *to be collected by Ecology during this project.*
- Continuous stream flow data at boundary condition locations, and instantaneous flow data at other locations – *to be collected by Ecology during this project; one USGS gaging station (Hangman Creek at Mouth) will also be used.*
- Continuous turbidity data at one boundary condition location – *to be collected by Ecology during this project.*
- Channel geometry data – *depths collected by Ecology during 2016; widths to be obtained using ArcGIS; some time of travel data collected during 2009, additional time of travel data to be collected during this project.*
- Meteorology data – *air temperature and dew point to be collected during this study; cloud cover, wind speed, and solar radiation will be obtained from National Weather Service stations at the Spokane airport.*
- Shade data – *will be adapted from Temperature TMDL if possible, or remodeled from ArcGIS data if necessary.*
- Periphyton biomass data – *collected by Ecology during 2009.*

4.4 Tasks required

A general overview of the tasks required to meet the project goals for this effort are discussed below and in Section 4.2. Additional details on the technical approach and field and lab tasks are described in Section 7.

Tekoa receiving water study

- Collect surface water samples and flow measurements from 11 stream sites and from Tekoa WWTP effluent monthly during May – October 2017; for total suspended solids/total non-volatile suspended solids (TSS/TNVSS), nutrients, alkalinity, chloride, and total organic carbon/dissolved organic carbon (TOC/DOC).
- Collect samples from 4 of these sites twice monthly during this time period.
- Collect continuous streamflow, turbidity, DO, pH, conductivity, and temperature data at 2 sites upstream of Tekoa WWTP; and continuous DO, pH, conductivity, and temperature data of Tekoa WWTP effluent.
- Collect Diel DO, pH, conductivity, and temperature data at remaining sites during each sample event.
- Conduct one time-of-travel dye study at low flow in a short reach near Tekoa.
- Collect continuous air temperature and dew point data at 1 location.
- Collect hemispherical shade photographs at 10 sites on Hangman Creek.
- Use continuous QUAL2Kw model to assess impacts of Tekoa WWTP and other nutrient sources on DO and pH in Hangman Creek.

Watershed springtime runoff study

- Collect surface water samples and flow measurements from 20 sites twice monthly January – May 2018, for TSS, SSC, turbidity, and nutrients.
- Collect surface water samples and flow measurements during two storm events.
- Collect continuous streamflow data at 6-8 locations.
- Collect continuous turbidity data at 7-9 locations.
- If time and resources allow, use 3 flow-triggered ISCO® carousel samplers to collect TSS, SSC, and TP during up to 4 storm events.
- Calculate seasonal TP and sediment loads for contributing subwatersheds.

Lower watershed groundwater study

- Collect synoptic seepage streamflow data during 2 sample events summer 2017.
- Install piezometers at 10-20 locations during fall 2017.
- Sample piezometers monthly during May-October 2018, approximately concurrent with Lower watershed low-flow study sampling events. Sample nutrients, alkalinity, chloride, bromide, boron, TOC/DOC, and TDS.

Lower watershed low-flow study

- Collect surface water samples and flow measurements from 16 sites monthly during May – October 2018, for TSS/TNVSS, nutrients, alkalinity, chloride, and TOC/DOC.
- Collect samples from 2 of these sites twice monthly during this time period.

- Collect continuous streamflow, turbidity, DO, pH, conductivity, and temperature data at 2 boundary condition sites.
- Collect Diel DO, pH, conductivity, and temperature data at remaining sites during each sample event.
- Conduct one time-of-travel dye study at low flow near Spokane.
- Collect continuous air temperature and dew point data at 1 location.
- Collect hemispherical shade photographs at 12 sites on Hangman Creek.
- Use continuous QUAL2Kw model to account for loads from the Hangman Creek watershed to the Spokane River while accounting for instream nutrient cycling, and to assess impacts of nutrient loads to DO and pH in Hangman Creek.

4.5 Systematic planning process used

This QAPP, in combination with the *Programmatic QAPP for Water Quality Impairment Studies,* represent the systematic planning process.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 10. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Elaine Snouwaert Water Quality Program Eastern Regional Office Phone: (509) 329-3503	EAP Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Tighe Stuart Eastern Operations Section EAP Phone: (509) 329-3476	Project Manager	Co-writes the QAPP. Oversees field study. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. QUAL2Kw modeling, Writes the draft report and final report.
Andrew Albrecht Eastern Operations Section EAP Phone: (509) 329-3417	QAPP author	Co-writes the QAPP.
Melanie Redding Eastern Operations Section EAP Phone: (360) 407-6524	Groundwater lead Licensed Hydrogeologist	Co-writes the QAPP. Oversees installation of piezometers, as well as sampling and measurement activities associated with piezometers/groundwater.
Eiko Urmos-Berry Eastern Operations Section EAP Phone: (509) 575-2397	Principal Investigator	Directs field activities. Leads field sampling and transportation of samples to the laboratory. Performs maintenance and calibration of deployed field equipment.
James Ross Eastern Operations Section EAP Phone: (509) 329-3425	Unit Supervisor for the Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
George Onwumere Eastern Operations Section EAP Phone: (360) 407-6730	Section Manager for the Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Joel Bird Manchester Environmental Laboratory, EAP Phone: 360-871-8801	Director	Reviews and approves the final QAPP.
William R. Kammin Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAPP.

EAP: Environmental Assessment Program
EIM: Environmental Information Management database
QAPP: Quality Assurance Project Plan

5.2 Special training and certifications

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

See Section 8.1 for a list of the standard procedures and practices that will be followed during this project.

5.3 Organization chart

See Table 10, Section 5.1.

5.4 Proposed project schedule

Field work will be performed during the following time periods:

- Tekoa receiving water study – May through October 2017.
- Watershed springtime runoff study – January through May 2018.
- Lower watershed ground water study & low flow study – May through October 2018.

Table 11 provides a summary of the proposed project schedule as well as its specific tasks to be performed and the staff responsible.

Table 11. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

Field and laboratory work	**Due date**	**Lead staff**
Field work completed	Oct 2018	Eiko Urmos-Berry
Laboratory analyses completed	Dec 2018	
Environmental Information System (EIM) database		
EIM Study ID	tist0002	
Product	Due date	Lead staff
EIM data loaded [1]	Feb 2019	Tighe Stuart
EIM data entry review [2]	Mar 2019	Eiko Urmos-Berry
EIM complete [3]	Apr 2019	Tighe Stuart
Final report		
Author lead / Support staff	Tighe Stuart / Eiko Urmos-Berry	
Schedule		
Draft due to supervisor	Jan 2020	
Draft due to client/peer reviewer	Feb 2020	
Draft due to external reviewer(s)	NA	
Final (all reviews done) due to publications coordinator	Apr 2020	
Final report due on web	May 2020	

[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 entry person); EIM Data Entry Review Form signed off and submitted to Melissa McCall (who then enters the "EIM Completed" date into Activity Tracker). Allow one month for this step. Normally the final EIM completion date is no later than the final report publication date.

5.5 Budget and funding

Budgets and funding have been prepared to estimate the costs of this project both annually and for the life of the project. Costs of processing all samples collected through Ecology's Manchester Environmental Laboratory (MEL) have been included. The laboratory budget for this project is represented in Table 12 below.

Table 12. Laboratory budget and funding.

Description	Sites	Sample events	Site visits	Repli-cates	Blanks	Total sample sets	Parameters	Cost/ sample set	Total cost
Tekoa receiving water study									
FY17									
Monthly sampling runs	13	2	26	4	1	31	TSS/TNVSS, nutrients, alkalinity, chloride, TOC/DOC	$216	$6,696
Additional samples for twice-monthly sites	4	2	8	0	0	8	TSS/TNVSS, nutrients alkalinity, chloride, TOC/DOC	$216	$1,728
BOD sampling at Tekoa WWTP	1	1	1	0	0	1	BOD5 (filtered, inhibited)	$75	$75
								Total:	**$8,499**
FY18									
Monthly sampling runs	13	4	52	8	1	61	TSS/TNVSS, nutrients, alkalinity, chloride, TOC/DOC	$216	$13,176
Additional samples for twice-monthly sites	4	4	16	0	0	16	TSS/TNVSS, nutrients, alkalinity, chloride, TOC/DOC	$216	$3,456
BOD sampling at Tekoa WWTP	1	1	1	0	0	1	BOD5 (filtered, inhibited)	$75	$75
								Total:	**$16,707**
Watershed springtime runoff study									
FY18									
Twice-monthly sampling runs and storm events	20	12	240	96*	5	341	TSS, SSC, nutrients, turbidity	$125	$42,625
(ISCO event samples) **	3	48	144	0	0	144	TSS, SSC, TP	$50	$7,200
								Total:	**$49,825**
Lower watershed low-flow study									
FY18									
Monthly sampling runs	16	2	32	4	1	37	TSS/TNVSS, nutrients, alkalinity, chloride, TOC/DOC	$216	$7,992
Additional samples for twice-monthly sites	2	2	4	0	0	4	TSS/TNVSS, nutrients, alkalinity, chloride, TOC/DOC	$216	$864
								Total:	**$8,856**

FY19									
Monthly sampling runs	16	4	64	8	1	73	TSS/TNVSS, nutrients, alkalinity, chloride, TOC/DOC	$216	$15,768
Additional samples for twice-monthly sites	2	4	8	0	0	8	TSS/TNVSS, nutrients alkalinity, chloride, TOC/DOC	$216	$1,728
								Total:	**$17,496**
Lower watershed groundwater study*									
FY18									
Monthly piezometer sampling	20	2	40	4	2	46	Nutrients, alkalinity, chloride, bromide, boron, DOC	$210	$9,660
								Total:	**$9,660**
FY19									
Monthly piezometer sampling	20	4	80	8	4	92	Nutrients, alkalinity, chloride, bromide, boron, DOC	$210	$19,320
								Total:	**$19,320**
								Year	**Total:**
								FY17	$8,499
								FY18	$85,048
								FY19	$36,816
								Study total:	**$130,363**

* Replicates for the springtime runoff study are in triplicate, hence the large number. See Section 10.

** The ISCO event samples will be collected only if time and resources allow. If they are not collected, then the actual total lab budget may be up to $7,200 less than shown.

*** Lab estimates for lower watershed groundwater study are based on 20 piezometers. Actual number may be between 10-20. Actual budget could be lower.

FY: fiscal year.

6.0 Quality Objectives

6.1 Data quality objectives [1]

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

The main data quality objective (DQO) for this project is to collect over 750 water sample sets representative of the Hangman Creek watershed and have them analyzed, using standard methods, to obtain water quality data that meet the measurement quality objectives (MQOs) for this project.

6.2 Measurement quality objectives

6.2.1 MQOs for surface water

Surface water samples and measurements will follow the MQOs outlined in *Programmatic QAPP for Water Quality Impairment Studies*.

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.

6.2.2 MQOs for groundwater

MQOs for groundwater samples are shown in Table 13. Quality objectives are statements of the precision, bias, and lower reporting limits necessary to meet project objectives. Precision and bias together express data accuracy. Other considerations of quality objectives include representativeness, completeness, and comparability. Quality objectives apply equally to laboratory and field data collected.

Field sampling procedures and laboratory analyses inherently have a level of error associated with them. MQOs are the allowable error level determined acceptable for a project. Precision and bias are data quality criteria used to indicate agreement with MQOs. (Lombard and Kirchmer, 2004).

Field sampling precision and bias will be addressed by submitting replicate samples, which will be collected at a rate of 10%. MEL will assess precision and bias in the laboratory using duplicates, blanks and matrix spikes.

[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. 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.

Table 13. Measurement quality objectives for groundwater.

Parameter		Field Replicates	Laboratory Control Standard (LCS)	Matrix Duplicate Samples	Matrix Spikes	Lowest Concentration of Interest
		% RPD	% Recovery Limits	% RPD	% Recovery Limits	mg/L
Nitrate+Nitrite-N	dissolved	20	80 – 120	20	75 – 125	0.01
Ammonia-N	dissolved	20	80 – 120	20	75 – 125	0.01
Total persulfate nitrogen-N	dissolved	20	80 – 120	20	75 – 125	0.025
Total dissolved phosphorus	dissolved	20	80 – 120	20	75 – 125	0.001
Orthophosphate-P	dissolved	20	80 – 120	20	75 – 125	0.003
Dissolved organic carbon	dissolved	20	80 – 120	20	75 – 125	1.0
Total dissolved solids	dissolved	20	80 – 120	20	75 – 125	1.0
Chloride	dissolved	20	90 – 110	20	75 – 125	0.1
Bromide	dissolved	20	90 – 110	20	75 – 125	0.05 [1]
Boron	dissolved	20	85 – 115	20	75 – 125	0.05
Alkalinity	total	20	80 – 120	20	75 – 125	5.0

[1] low level bromide is necessary for quantification
RPD: relative percent difference.

6.3 Model quality objectives

This project will follow the model quality objectives outlined in *Programmatic QAPP for Water Quality Impairment Studies*.

7.0 Study Design

7.1 Study boundaries

As described previously, the two goals of this project will be achieved by breaking it into four studies:

- Tekoa receiving water study
- Watershed springtime runoff study
- Lower watershed ground water study
- Lower watershed low flow study

Figure 6 through 8 below represent sample location maps for each part of this study. Site IDs are described in Tables 14 through 17. The Tekoa receiving water study area is located in the upper, or southeastern, part of the watershed, and extends from the WA/ID state line downstream as far as the town of Latah, with most of the sites focused around Tekoa. The watershed springtime runoff study area encompasses the entire Washington portion of the Hangman watershed (WRIA 56). The lower watershed low flow study extends from about the mouth of Stevens Creek downstream to the mouth of Hangman Creek. The lower watershed groundwater study overlaps with approximately two-thirds of the lower watershed low flow study, extending from the Yellowstone pipeline crossing (56HAN-08.9) to the mouth of Hangman Creek.

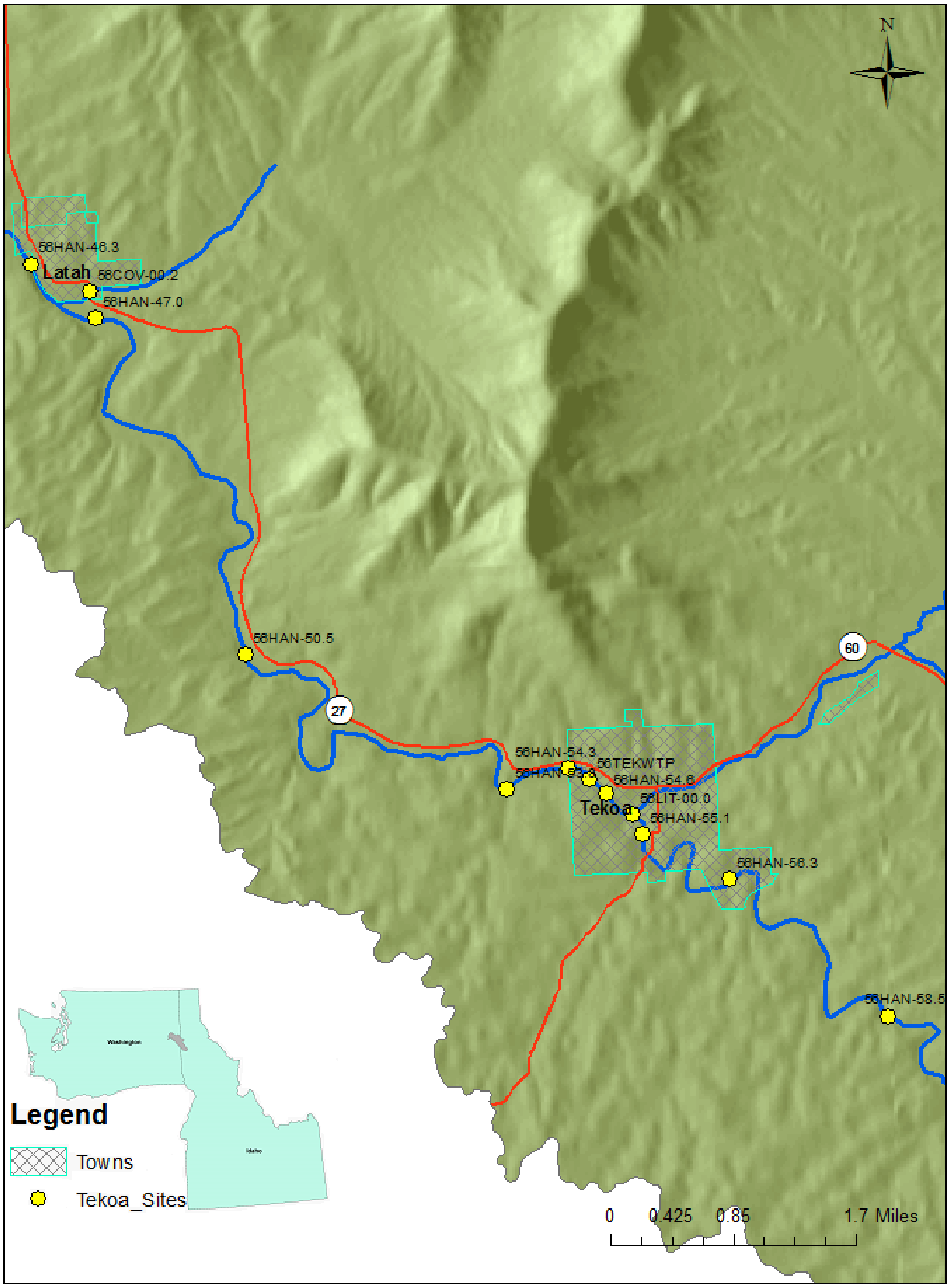

Figure 6. Tekoa receiving water sample sites.

Figure 7. Watershed springtime runoff study sample sites.

Figure 8. Lower watershed low-flow study sampling sites and groundwater study sampling area.

7.2 Field data collection

7.2.1 Sampling locations and frequency

Sampling locations are described in Tables 14 through 17 and Figures 6 through 8. Ecology will begin field work starting in the spring of 2017.

- Environmental Assessment Program (EAP) TMDL staff will perform sampling and field measurement tasks.
- EAP stream gaging staff will install and maintain gaging stations.
- Hydrolab equipment installed in gage stations to record continuous DO, pH, conductivity, and temperature data will be calibrated and maintained by TMDL staff.
- Piezometer installation and sampling will be conducted jointly by EAP groundwater staff and TMDL staff.
- Additional continuous flow data will be collected throughout this project by deploying stand-alone Hobo unvented water level loggers, and by recording stage measurements whenever flow is measured. This work will mostly be performed by TMDL staff, but stream gaging staff may assist with the development of stage-discharge rating curves for these locations if their time and resources allow.

Tekoa receiving water study

The project will start with the Tekoa receiving water study, which will be conducted during May-October 2017. At the beginning of this study, two gaging stations will be installed, which will record continuous flow, turbidity, DO, pH, conductivity, and temperature. Additional diel DO, pH, conductivity, and temperature data will be collected during monthly sampling events by deploying Hydrolab sondes the day prior to sampling, and retrieving them the day after sampling. We will sample at twelve sites: eight to be sampled monthly, and four to be sampled twice-monthly.

Watershed springtime runoff study

The watershed springtime runoff study will be the second study in this project, to be conducted during January-May 2018. At the beginning of this study, during the fall of 2017 we will install 4-6 more gages, which will record continuous flow and turbidity. The two gages from the Tekoa study will also be used, for a total of 6-8 gaging stations. If time and resources allow, up to 3 of these stations may be equipped with ISCO carousel samplers, which will automatically collect TSS, SSC, and TP samples during high-flow events in order to better resolve the relationship between turbidity and these parameters.

There will be a total 20 sampling sites to be sampled twice-monthly. The same 20 sites will be sampled an additional 1-2 times during storm events. Storm events will be timed to capture peak flow during large runoff events. These will be defined as events in which the flow increases to at least five times the flow prior to the event. Storm events will be planned by consulting the NOAA stream forecast for Hangman Creek at the mouth:
http://water.weather.gov/ahps2/hydrograph.php?wfo=otx&gage=hagw1

Because of rapidly changing conditions in Hangman Creek during high-flow conditions, it is not generally intended that results from different sampling sites during the same sampling event should be compared to one another in a “synoptic” fashion. Rather, the data collected throughout the study at each location will be used to calculate seasonal loads at that location. See section 7.3.1 for more details.

During times of high flow, streamflow measurements will be taken using Acoustic Doppler Current Profiler (ADCP) or bridgeboard meter. Because of the analytical design of the watershed springtime runoff study (see Section 7.3.1), it is appropriate for one crew to collect samples and a different crew to take flow measurements.

Lower watershed low flow study

The lower watershed low flow study will be conducted during May-October 2018. At the beginning of this study, we will install one more gage, which will record continuous flow, turbidity, DO, pH, conductivity, and temperature. We will collect continuous DO, pH, conductivity, and temperature at one additional location. Additional diel DO, pH, conductivity, and temperature data will be collected during monthly sampling events by deploying Hydrolab sondes the day prior to sampling, and retrieving them the day after sampling. We sample at 16 sites: 14 to be sampled monthly, and two to be sampled twice-monthly.

Lower watershed groundwater study

The lower watershed groundwater study will mostly be conducted concurrently with the lower watershed low-flow study. During steady low flow conditions in July-September 2017 we will conduct two synoptic seepage flow surveys to pinpoint groundwater inputs, in order to finalize the piezometer locations. In fall of 2017 we will install 10-20 piezometers in the lower 9 miles of Hangman Creek. Piezometers will be sampled monthly during May-October 2018, at approximately the same time as lower watershed surface-water sites.

Table 14. Sampling locations for Tekoa receiving water study.

Location ID	Laboratory samples	Diel DO, pH, cond, temp	Routine WQ sampling (1X or 2X monthly)	Air & Dew Point Temp	Continuous Turbidity	Continuous DO, pH, cond, temp	ECY Cont. Unvented Flow	Ecology Continuous Flow	USGS Continuous Flow	Description	NAD83 Latitude	NAD83 Longitude
Tekoa receiving water study												
56HAN-58.5	X		2X			X			X	Hangman Ck. at State Line	47.202846	-117.040620
56HAN-56.3	X	X	1X							Hangman Ck. near Tekoa Golf Course	47.217183	-117.062991
56HAN-55.1	X		2X		X	X		X		Hangman Ck. above Little Hangman Ck.	47.222044	-117.075470
56LIT-00.0	X		2X		X	X		X		Little Hangman Ck. at mouth	47.224066	-117.076691
56HAN-54.6	X	X	1X				X			Hangman Ck. at old RR bridge	47.226288	-117.080529
56TEKWTP	X		1X			X				Tekoa WWTP	47.227728	-117.082947
56HAN-54.3	X	X	1X	X			X			Hangman Ck. below Tekoa	47.228992	-117.085901
56HAN-53.8	X		1X			X				Hangman Ck. far below Tekoa	47.227133	-117.095027
56HAN-50.5	X	X	1X							Hangman Ck. at Fairbanks Rd.	47.241732	-117.132577
56HAN-47.0	X	X	1X				X			Hangman Ck. at Marsh Rd.	47.275962	-117.152527
56COV-00.2	X		2X			X	X			Cove Ck. at mouth	47.278705	-117.153181
56HAN-46.3	X	X	1X							Hangman Ck. at Spring Valley Rd.	47.281668	-117.161601

Table 15. Sampling locations for watershed springtime runoff study.

Station ID	Laboratory samples	Routine WQ sampling (1X or 2X monthly)	Continuous Turbidity	ECY Cont. Unvented Flow	Ecology Continuous Flow	USGS Continuous Flow	Description	NAD83 Latitude	NAD83 Longitude
Watershed springtime runoff study									
56HAN-58.5	X	2X				X	Hangman Ck. at State Line	47.202846	-117.04062
56HAN-55.1	X	2X	X		X		Hangman Ck. above Little Hangman Ck.	47.222044	-117.075470
56LIT-00.0	X	2X	X		X		Little Hangman Ck. at mouth	47.224066	-117.076691
56HAN-47.0	X	2X		X			Hangman Ck. at Marsh Rd.	47.275962	-117.152527
56COV-00.2	X	2X		X			Cove Ck. at mouth	47.278705	-117.153181
56HAN-32.8	X	2X	X		X		Hangman Ck. at Bradshaw Rd.	47.392807	-117.248068
56RAT-00.1	X	2X		X			Rattler Run Ck. at mouth	47.393768	-117.248298
56ROS-00.4	X	2X		X			Rose Ck. at mouth	47.41685	-117.066657
56ROC-17.1	X	2X	X?		X?		Rock Ck. above NF Rock Ck.	47.420669	-117.089238
56NFR-00.5	X	2X		X			NF Rock Ck. at mouth	47.438439	-117.093471
56ROC-13.0	X	2X	X		X		Rock Ck. at Hwy 27 in Rockford	47.453216	-117.14217
56MIC-00.2	X	2X		X			Mica Ck. at mouth	47.454005	-117.132756
56ROC-00.5	X	2X	X		X		Rock Ck. at mouth	47.495549	-117.322821
56SPA-00.0	X	2X		X			Spangle Ck. at mouth	47.501117	-117.343490
56HAN-19.1	X	2X	X		X		Hangman Ck. at Duncan	47.506417	-117.345235
56CAL-00.1	X	2X		X			California Ck. at mouth	47.512702	-117.346919
56HAN-04.6	X	2X		X			Hangman Ck. below Qualchan GC	47.614668	-117.420020
56MIN-00.5	X	2X		X			Minnie Ck. at mouth	47.55443	-117.499915
56MAR-00.0	X	2X		X?	X?		Marshall Ck. at mouth	47.614138	-117.425300
56HAN-00.7	X	2X	X			X	Hangman Ck. at mouth	47.654898	-117.455397

Table 16. Sampling locations for lower watershed low-flow study.

Station ID	Laboratory samples	Diel DO, pH, cond, temp	Routine WQ sampling (1X or 2X monthly)	Air & Dew Point Temp	Continuous Turbidity	Continuous DO, pH, cond, temp	ECY Cont. Unvented Flow	Ecology Continuous Flow	USGS Continuous Flow	Description	NAD83 Latitude	NAD83 Longitude
Lower watershed low flow study												
56HAN-14.5	X		2X		X	X		X		Hangman Ck. above Hangman Valley GC	47.540334	-117.371833
56HAN-13.2	X		1X							Hangman Ck. above Latah WWTP	47.547987	-117.375461
56HAN-12.6	X		1X							Hangman Ck. below Latah WWTP	47.553913	-117.369731
56HAN-11.7	X		1X							Hangman Ck. 1 mi below Latah WWTP	47.558254	-117.3829
56HAN-08.9	X		1X				X			Hangman Ck. at Yellowstone Pipeline	47.581170	-117.395947
56Unk(MUL)-00.0	X		1X							Unnamed drainage off Mullen Hill area	47.581985	-117.401355
56HAN-07.9	X		1X							Hangman Ck. at Campion Park	47.590496	-117.400195
56HAN-06.2	X		1X	X			X			Hangman Ck. at Meadowlane Rd.	47.602950	-117.405755
56HAN-04.6	X		1X							Hangman Ck. below Qualchan GC	47.614668	-117.420020
56MAR-00.0	X		2X			X				Marshall Ck. at mouth	47.614138	-117.425300
56HAN-03.3	X		1X				X			Hangman Ck. at railroad bridge	47.625272	-117.436419
56Spr(VinUS)-00.0	X		1X							Vinegar flats US surface spring at mouth	47.629436	-117.43615
56Spr(VinDS)-00.1	X		1X							Vinegar flats DS surface spring at end of Cherry St.	47.63479	-117.437978
56HAN-01.9	X		1X				X			Hangman Ck. at Chestnut St.	47.640923	-117.444267
56GAR-00.0	X		1X							Garden Springs at mouth	47.645619	-117.447651
56HAN-00.7	X		1X						X	Hangman Ck. at mouth	47.654898	-117.455397

Table 17. Sampling locations for lower watershed groundwater study.

Station ID	Synoptic flow measurements	Description	NAD83 Latitude	NAD83 Longitude
Lower watershed groundwater study – synoptic seepage flow sites				
56HAN-08.9	X	Hangman Ck. at Yellowstone Pipeline	47.581170	-117.395947
56Unk(MUL)-00.0	X	Unnamed drainage off Mullen Hill area	47.581985	-117.401355
56HAN-08.2	X	Hangman Ck. just US Hatch Rd	47.586189	-117.402449
56HAN-07.9	X	Hangman Ck. at Campion Park	47.590496	-117.400195
56HAN-06.2	X	Hangman Ck. at Meadowlane Rd.	47.602950	-117.405755
56HAN-04.6	X	Hangman Ck. below Qualchan GC	47.614668	-117.420020
56MAR-00.0	X	Marshall Ck. at mouth	47.614138	-117.425300
56HAN-04.3	X	Hangman Ck. just DS Marshall Ck.	47.616260	-117.425885
56HAN-03.3	X	Hangman Ck. at railroad bridge	47.625272	-117.436419
56Spr(VinUS)-00.0	X	Vinegar flats US surface spring at mouth	47.629436	-117.43615
56HAN-02.8	X	Hangman Ck. between Vin Flats springs at end of 26th Ave	47.631051	-117.436271
56Spr(VinDS)-00.1	X	Vinegar flats DS surface spring at end of Cherry St.	47.63479	-117.437978
56HAN-01.9	X	Hangman Ck. at Chestnut St.	47.640923	-117.444267
56GAR-00.0	X	Garden Springs at mouth	47.645619	-117.447651
56HAN-01.4	X	Hangman Ck. just US I-90 bridge	47.647725	-117.446332
56HAN-00.7	X	Hangman Ck. at mouth	47.654898	-117.455397
Lower watershed groundwater study – piezometer sites				
10-20 sites, locations TBD based on summer 2017 seepage survey				

7.2.2 Field parameters and laboratory analytes to be measured

Table 18 lists the parameters will be collected in the field and laboratory for this study:

Table 18. Field and laboratory parameters.

Parameter	Tekoa receiving water study	Watershed springtime runoff study		Lower watershed low-flow study	Lower watershed groundwater study	
		Sampling events/ monitoring	ISCO* carousel samplers		synoptic seepage flows	piezo-meters
Laboratory sample parameters						
Ammonia-N	X	X		X		X
Nitrate-Nitrite-N	X	X		X		X
Total persulfate nitrogen	X	X		X		X
Orthophosphate	X	X		X		X
Total phosphorus	X	X	X	X		
Total dissolved phosphorus						X
Dissolved organic carbon	X			X		X
Total organic carbon	X			X		
Suspended sediment concentration		X	X			
Total suspended solids	X	X	X	X		
Total non-volatile suspended solids	X			X		
Turbidity (as laboratory sample)		X				
Biochemical oxygen demand, 5-day, filtered, inhibited**	X					
Alkalinity	X			X		X
Chloride	X			X		X
Bromide						X
Boron						X
Field measurement parameters (discrete)						
Temperature	X	X***		X		X
Conductivity	X	X***		X		X
pH	X	X***		X		X
Dissolved oxygen	X	X***		X		X
Dissolved oxygen – Winkler (as QC)	X	X***		X		
Turbidity (stand-alone Hach meter)	X	X		X		
Streamflow	X	X		X	X	
Field measurement parameters (continuous/diel)						
Temperature	X			X		X
Conductivity	X			X		
pH	X			X		
Dissolved oxygen	X			X		
Turbidity	X	X		X		
Streamflow	X	X		X		
Air temperature	X			X		
Dew point temperature	X			X		

* As stated previously, the ISCO carousel samples will only be taken if time and resources allow.

**Filtered, inhibited BOD5 allows for an approximation of CBOD. This will be collected only at Tekoa WWTP.

***Hydrolab discrete measurements will not be taken during extreme cold or extreme high flows during the watershed springtime runoff study, as the instruments do not function well under these conditions, and these data from such conditions are not necessary or useful anyway. Measurements may be taken during the later portion of this study, as flows begin to drop and temperatures begin to warm.

7.3 Modeling and analysis design

7.3.1 Analytical framework

QUAL2Kw (Tekoa Receiving Water Study and Lower Watershed Low-flow Study)

The QUAL2Kw modeling framework (Pelletier et al., 2006; Pelletier and Chapra, 2008) will be used both for the Tekoa receiving water study and for the lower watershed low-flow study. The QUAL2Kw modeling framework is described in detail in the *Programmatic QAPP for Water Quality Impairment Studies*.

For the Tekoa receiving water study, the QUAL2Kw model will be used to predict the impact of nutrients and flows from Tekoa WWTP and other sources on DO and pH in Hangman Creek. The model will be used to test a variety of management scenarios, which can include various wastewater treatment options, effluent removal, or nonpoint improvements such as nutrient reductions or the addition of shade.

For the lower watershed low-flow study, the QUAL2Kw model will be used to simulate the transport of nutrients through the lower reaches of Hangman Creek. The model will keep account of successive nutrient sources, while simulating nutrient uptake and/or attenuation along the stream course. The model will then be used to make predictions about how nutrient reductions at various locations along Hangman Creek will translate into nutrient reductions at the Spokane River confluence. Although assessing the impact of nutrients on DO and pH in Hangman Creek itself is not the primary purpose for the lower watershed QUAL2Kw model, the model will be calibrated so that this can be performed, because:

- A good DO and pH calibration is necessary to ensure that the model provides a good simulation of nutrient cycling processes.
- This functionality will be needed for any future DO and pH TMDL for Hangman Creek.

Lower Watershed Groundwater Study

The lower watershed groundwater study will provide groundwater nutrient load estimates, which will feed the QUAL2Kw model for the lower watershed low-flow study. Groundwater inflows will be estimated primarily as flow residuals (the difference in flow between adjacent sites, accounting for all tributaries) from synoptic seepage flow runs during 2017 and from flow measurements taken during 2018 low-flow sampling. Groundwater nutrient concentrations will be obtained from piezometer sampling (See section 7.2). Chloride, bromide, and boron are also being collected as indicator parameters in an attempt to identify sources of nutrients.

Watershed Springtime Runoff Study

Flow and sediment conditions in Hangman Creek during spring runoff are extremely dynamic. It is not uncommon for flows to change by an order of magnitude or more during a matter of hours. Furthermore, sediment and phosphorus concentrations likely do not change in perfect synchronization with flows; it is common in many river systems for storm event sediment loads to peak sooner than flows (Morisawa, 1968). Previous experience on Hangman Creek has shown that this system's unusually "spiky" flow patterns during high-flow conditions mean that routine synoptic sampling surveys alone are of limited usefulness for comparing results from one location to another.

To avoid this problem, the watershed springtime runoff study will assess the relative contribution of sediment and phosphorus from various parts of the watershed by relying on continuous monitoring as much as possible. Continuous flow and turbidity data will be collected at locations dividing the study area up into catchments with an average size of ~75 mi^2. Turbidity will be correlated with total phosphorus (TP), suspended sediment concentration (SSC), and total suspended solids (TSS).

Additionally, discrete load data will be collected at locations further dividing the gaged subbasins into approximately HUC12-sized catchments, with an average area of ~35 mi^2. Continuous flow data will be collected at each of these sampling locations using stand-alone unvented pressure sensors.

Seasonal average loads of TP, SSC, and TSS will be calculated for each sampling location. This will be performed using one or more of the following methods:

- Use continuous turbidity data to estimate continuous record of TP, SSC, and TSS (see section 3.2.2, Figure 5). Use this estimated continuous record along with continuous flow data to calculate seasonal loads.
- Use data from sites without continuous turbidity to assign seasonal average loads from sites with turbidity to the smaller ungaged subbasins. This will be done judiciously in a synoptic fashion while referring to continuous flow data from each location to make sure that synoptic comparisons are valid.
- Beales ratio estimator. This method is described in detail in the Programmatic QAPP.
- Cohn multiple-regression model (Cohn et al., 1989; Cohn et al., 1992).

Uncertainty analysis will be performed on each of these methods by evaluating the strength of the correlations/regressions upon which they are based. In the case of synoptic comparisons, we will evaluate the potential change in load which may have occurred during the time between when samples were collected at the sites being compared.

Finally, a mass balance will be calculated based on seasonal average loads to evaluate the load contribution of each HUC12-sized subbasin. Subbasin load contributions will be normalized by catchment area and/or stream length to determine areas most in need of best management practices (BMPs).

7.3.2 Model setup and data needs

QUAL2Kw models

The QUAL2Kw model for the Tekoa receiving water study will begin at either the WA/ID state line or from just upstream of the Little Hangman Creek confluence in Tekoa. Data will be collected to allow either option to be chosen. The model domain will extend downstream to the Spring Valley Road crossing in Latah. The time scale will extend from May-October, 2017.

The QUAL2Kw model for the lower watershed low-flow study will begin at the upstream end of the Hangman Valley Golf Course, and extend downstream to the mouth of Hangman Creek. The time scale will extend from May-October, 2018.

The segmentations for both models will be chosen so that a single model segment typically represents 1-2 hours travel time. Because of the magnitude of velocity changes that occur between May and October, it may be necessary to use two different segmentations, one for the earlier medium flow portion of the season, with longer segments, and one for the later low flow portion of the season, with shorter segments. The outputs from the early-season model could be linked to the inputs for the late-season model using xQUAL2Kw, which is a version of QUAL2Kw that allows for multiple model runs in the same Excel spreadsheet. The model time step will be chosen to minimize run time while maintaining numeric stability.

Table 19 lists the state variables that are simulated by QUAL2Kw, along with the sample and measurement parameters that correspond to these state variables. The study is designed to provide all necessary data at an appropriate spatial and temporal scale.

Table 19: QUAL2Kw state variables and corresponding field parameters.

Variable	Symbol	Units	Measured as
Conductivity	s	μmhos	COND
Inorganic suspended solids	m_i	mgD/L	TNVSS
Dissolved oxygen	o	mgO$_2$/L	DO
Slow-reacting CBOD	c_s	mg O$_2$/L	r_{oc} * DOC
Fast-reacting CBOD	$c_{f,}$	mg O$_2$/L	r_{oc} * DOC
Organic nitrogen	n_o	μgN/L	TN – NO$_3$N NO$_2$N– NH$_4$N
Ammonia nitrogen	n_a	μgN/L	NH$_4$N
Nitrate nitrogen	n_n	μgN/L	NO$_3$N+NO$_2$N
Organic phosphorus	p_o	μgP/L	TP - Orthophosphate
Inorganic phosphorus	p_i	μgP/L	Orthophosphate
Phytoplankton	a_p	μgA/L	Chlorophyll *a*
Detritus	m_o	mgD/L	r_{dc} (TOC – DOC)
Alkalinity	*Alk*	mgCaCO$_3$/L	ALK
Total inorganic carbon	c_T	mole/L	Calculation from pH and alkalinity
Bottom algae biomass	a_b	gD/m^2	Periphyton biomass dry weight
Bottom algae nitrogen	IN_b	mgN/m^2	Periphyton biomass N*
Bottom algae phosphorus	IP_b	mgP/m^2	Periphyton biomass P*

Note: r_{xx} refers to a stoichiometric ratio. The letters used in the subscripts are: c = carbon; d = dry weight; o = dissolved oxygen.
*These simulated parameters are not field measured in this and many other projects.

Watershed analysis (watershed springtime runoff study)

The watershed analysis will encompass the entire Washington portion of the Hangman Creek watershed (WRIA 56) and extend from January-May, 2018. This season will include the March-May season defined in the Spokane River and Lake Spokane DO TMDL. It also includes January and February because these are months when peak spring runoff often occurs. This study is designed to resolve the sources of phosphorus and sediment down to HUC12-sized subbasins, which are typically ~35 mi^2. Data will be collected to meet the needs of this analysis, as described in detail in sections 7.2 and 7.3.1.

7.4 Assumptions in relation to objectives and study area

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

One additional assumption that applies to the watershed springtime runoff study analysis is that during the spring runoff period, phosphorus and sediment that enter streams are delivered downstream without loss or "sinks". In other words, it is assumed that uptake and settling are minimal, and can be ignored. This assumption will be critically evaluated throughout the analysis, and a loss term could be added to the mass balance if necessary.

7.5 Possible challenges and contingencies

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

The springtime watershed study depends on reasonably high flows to assess runoff conditions. Any reasonably normal or above-normal flow year will work. However, if meteorological conditions as of January 2018 indicate the likelihood of an extremely dry year such as was experienced in 2015, that portion of the study would need to be postponed until a more appropriate year.

During some years, Hangman Creek freezes during January. In such years, the ice usually breaks up at the time of the first high-flow event. The beginning of the springtime runoff study will be delayed if low-flow, frozen conditions are present during January 2018. Due to safety concerns, we will not sample during an ice break-up event.

8.0 Field Procedures

8.1 Invasive species evaluation

Refer to *Programmatic QAPP for Water Quality Impairment Studies*. The project area is located in an area of moderate concern.

8.2 Measurement and sampling procedures

8.2.1 Measurement and sampling procedures for surface water

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

8.2.2 Measurement and sampling procedures for groundwater

Groundwater measurements and sampling will be performed according to the following SOPs:

- SOP EAP 052 Depth to Water Measurements (Marti, 2009).
- SOP EAP078 Purging and Sampling Monitoring Wells (Marti, 2011).
- SOP EAP061 Installing, Monitoring and Decommissioning hand-driving in-water piezometers (Sinclair and Pitz, 2013).

Groundwater samples will be collected with a peristaltic pump using low-flow sampling procedures. A flow-through cell will be used to measure temperature, pH, electrical conductivity, and DO prior to the water being exposed to the atmosphere. Purging will continue until parameters have stabilized with measurements taken at five minute intervals. Stability criteria are listed in Table 20. Purging will be considered complete when two consecutive sets of parameter readings show changes less than the criteria.

Table 20. Stability criteria for sampling groundwater.

Field Parameter	Criteria	Typical Change
Temperature	0.2ºC	2%
pH	0.2 SU	3%
Electrical Conductivity	10 µmhos/cm	7%
Dissolved Oxygen	0.3 mg/L	10%

All samples which require field filtration will use an inline 0.45 micron filter, except for dissolved organic carbon (DOC) and orthophosphate, where a syringe filter will be used. Staff will place samples in bottles obtained from Manchester Environmental Laboratory (MEL) and samples will be collected using the parameter specific criteria listed either in the programmatic QAPP or in Table 21.

Staff will place samples in coolers with ice while in transit. At the completion of the sampling event, the coolers will be transported to the Ecology Operations Center walk-in cooler, where a

MEL courier will pick up the coolers and transport the samples to MEL in Manchester, Washington.

8.3 Containers, preservation methods, holding times

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

Table 21 lists collection and preservation requirements for additional sample parameters not included in the programmatic QAPP.

Table 21. Sample containers, preservation methods, and holding times for sample parameters not included in the programmatic QAPP.

Parameter	Container	Preservative	Holding Time
Total Dissolved Phosphorus	125 ml, wide-mouth polyethylene	Filter, HCl to pH<2, cool to 4ºC	28 days
Bromide	500 ml, wide mouth polyethylene	Filter, cool to 4ºC	28 days
Boron	500 ml, wide mouth polyethylene	Filter, nitric acid, cool to 4ºC	28 days

8.4 Equipment decontamination

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

New clean dedicated sample tubing and filters will be used to gather and prepare groundwater samples. Silastic tubing connecting to the peristaltic pump will be decontaminated between samples by rinsing with deionized water followed by purging with sample water at each sit prior to collecting samples for laboratory analysis.

A field blank will be collected during each sampling event to assess the effectiveness of decontamination procedures.

The E-tape used to measure water levels in the piezometers will be rinsed with deionized water between wells.

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

N/A.

9.0 Laboratory Procedures

9.1 Lab procedures table

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

For this project, MEL is requested to report results down to the method detection limit (MDL) for the following parameters. MDLs are shown in parentheses.

- Ammonia (0.002 mg/L)
- Nitrate-Nitrite (0.005 mg/L)
- Total Persulfate Nitrogen (0.013 mg/L)
- Orthophosphate (0.0013 mg/L)
- Total Phosphorus (0.0024 mg/L)
- Dissolved Organic Carbon (0.05 mg/L)
- Total Organic Carbon (0.11 mg/L)
- Bromide (0.05 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 Stu*dies.

10.0 Quality Control Procedures

This project will follow quality control (QC) procedures described in the *Programmatic QAPP for Water Quality Impairment Studies*, with a few additional procedures:

Depth integrated vs grab samples

During the watershed springtime runoff study, field replicates will be collected in triplicate. That is, one primary sample set and two replicate sets. The primary sample set and the first replicate set will be grab samples. The second replicate set will be collected using equal width increment (EWI), depth-integrated sampling method (USGS, 2006). These samples will be collected using bridge or hand-operated depth-integrating samplers, and processed into subsamples using a churn splitter.

During a preliminary methods study (Stuart, 2016), Ecology determined that for TSS and TP, grab sampling and equal width increment, depth integrated sampling methods produce indistinguishable results across a wide variety of conditions on Hangman Creek (Figure 10). It is likely that the conclusions reached by Hallock (2005), which showed significant bias between USGS and Ecology results collected using the two different sampling methods, were largely the result of the different lab methods used, suspended sediment concentration (SSC) and total suspended solids (TSS). This would be consistent with Gray et al. (2000) and Galloway et al. (2005), who found similar bias between paired SSC and TSS samples.

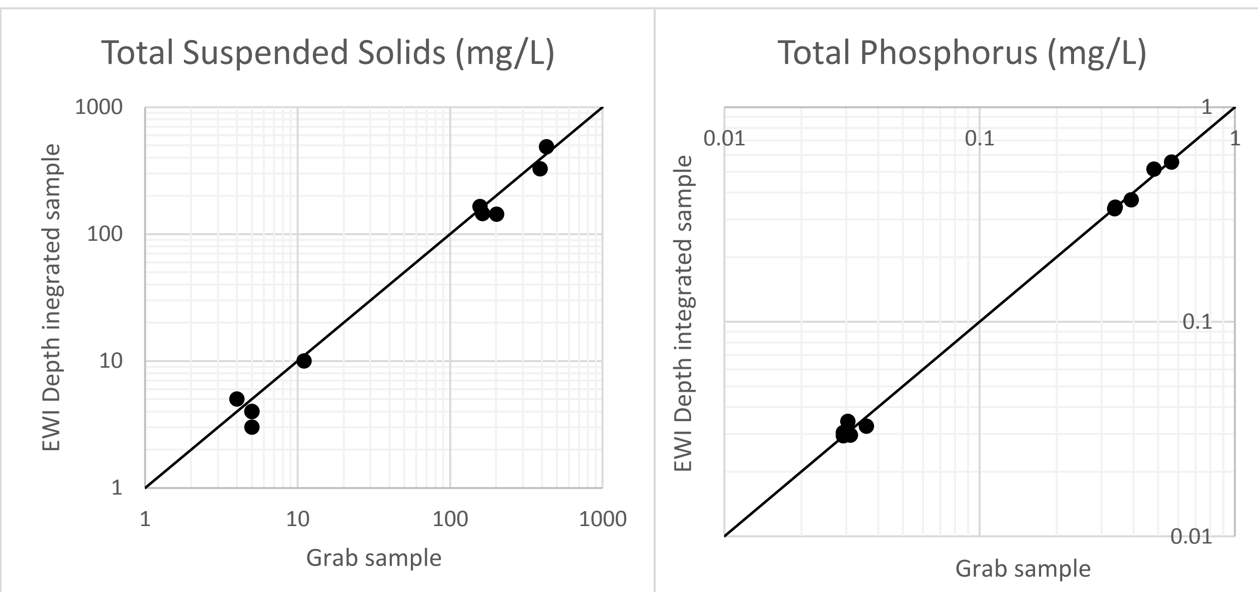

Figure 9. Paired grab and EWI Depth-integrated sample results from Hangman Creek during Spring 2016.

The diagonal black line represents a 1-to-1 relationship. Dots falling on that line indicate exact agreement between the two sampling methods.

These results from 2016 provide enough confidence to use grab sampling as a primary sampling method. However, by continuing to compare sampling methods during this study, it will be possible to either confirm that the methods produce comparable results, or else to provide a correction factor for grab samples should this turn out not to be the case. Additionally, by collecting paired TSS and SSC samples throughout the watershed high-flow study, it will be possible to assess bias between the two laboratory methods separately from bias between the two field methods.

Turbidity QC methods

Continuous turbidity data are one of the cornerstones of the watershed springtime runoff study. To ensure the quality of these data, two types of check data will be collected. First, samples will be analyzed on-site using a portable turbidity meter, which will be calibrated with stabilized formazin standards. Second, samples will be collected and sent to Manchester Environmental Laboratory to be analyzed for turbidity. This will allow for a three-way comparison between the continuous turbidity probes, the portable turbidity meter, and the laboratory samples.

Groundwater QC methods

Groundwater replicate samples will be collected for 10% of the sites sampled and will be submitted to the laboratory as a blind sample.

Field meters will be calibrated before and after sampling, in accordance with the manufacturer's instructions.

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 Management Procedures

11.1 Data recording and reporting requirements

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

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*.

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

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

12.2 Responsible personnel

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

12.3 Frequency and distribution of reports

Refer to *Programmatic QAPP for Water Quality Impairment Studies*. A final report will be prepared detailing the findings of this study and is preliminary scheduled to be completed in 2020.

12.4 Responsibility for reports

Refer to *Programmatic QAPP for Water Quality Impairment Studies*. For this project, 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*.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

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

14.2 Treatment of non-detects

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

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

- Ammonia
- Nitrate-Nitrite
- Total Persulfate Nitrogen
- Orthophosphate
- Total Phosphorus
- Dissolved Organic Carbon
- Total Organic Carbon
- Bromide

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

14.3 Data analysis and presentation methods

Refer to *Programmatic QAPP for Water Quality Impairment Studies*. The Beales Loading Estimate may be used for estimating seasonal loads during the watershed springtime runoff study.

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

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.

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

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

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

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

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

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.

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

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

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

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

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

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*. Any species of salmon, trout, or char.

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

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

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

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

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 waste load 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 waste load 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.

Waste load allocation: The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. Waste load 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.

Acronyms and Abbreviations

ADCP	Acoustic Doppler current profiler
BOD	Biochemical oxygen demand
BOD5	5-day biochemical oxygen demand
BMP	Best management practice
CBOD	Carbonaceous biochemical oxygen demand
DMR	Discharge Monitoring Report
DO	(see Glossary above)
DOC	Dissolved organic carbon
DQO	Data quality objectives
DS	Downstream
e.g.	For example
EAP	Ecology's Environmental Assessment Program
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
et al.	And others
EWI	Equal width increment

FY	Fiscal Year
GIS	Geographic Information System software
GIRAS	Geographical Information Retrieval and Analysis System
GP	General Permit
IDEQ	Idaho Department of Environmental Quality
i.e.	In other words
IP	Individual Permit
MDL	Method detection limit
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
MS4	Municipal separate stormwater sewer system
NBOD	Nitrogenous Biochemical Oxygen Demand
NH3-N	Ammonia Nitrogen
NOAA	National Oceanic and Atmospheric Administration
NPDES	(See Glossary above)
PWD	Public Works Department
QAPP	Quality Assurance Project Plan
QC	Quality control
RL	Reporting limit
RPD	Relative percent difference
SCD	Spokane Conservation District
SOP	Standard operating procedures
SSC	Suspended sediment concentration
SW	Stormwater
SWDP	Stormwater Discharge Permit
TDS	Total Dissolved Solids
TMDL	(See Glossary above)
TOC	Total organic carbon
TNVSS	Total non-volatile suspended solids
TP	Total phosphorus
TSS	(See Glossary above)
US	Upstream
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WAC	Washington Administrative Code
WDNR	Washington Department of Natural Resources
WRIA	Water Resource Inventory Area
WWTP	Wastewater treatment plant

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
lbs/day	pounds per day, a unit of loading
mi^2	square miles
mg/L	milligrams per liter (parts per million)
mole	an International System of Units (IS) unit of matter

NTU	nephelometric turbidity units
s.u.	standard units
ug/L	micrograms per liter (parts per billion)
umhos/cm	micromhos per centimeter, a unit of conductivity

Quality Assurance Glossary

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

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

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

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

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

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

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

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

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

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

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

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

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

Data Quality Indicators (DQI): 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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