



Quality Assurance Project Plan

Hydrochemical Assessment of Managed Aquifer Recharge on the Toppenish Alluvial Fan

July 2026

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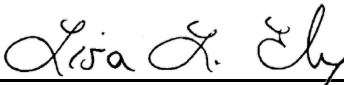
A Hydrochemical Assessment of Managed Aquifer Recharge on the Toppenish Alluvial Fan

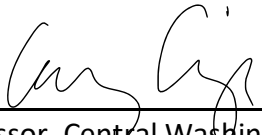
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2.0 Abstract

The goal of this project is to investigate aquifer characteristics, hydrogeology, and surface water–groundwater interactions in the Toppenish Creek alluvial fan using geochemical and stratigraphic techniques. The project will quantify the stratigraphy and hydrochemistry of the Toppenish Creek alluvial fan to assess the recharge and mixing of surface water with groundwater in the Yakama Nation Toppenish Fan Shallow Aquifer Recharge Project (TFSARP).

Specific questions that will be addressed include identifying the sources of recharge to the groundwater and springs; travel times and flow directions of water introduced from the TFSARP recharge canals; locations of mixing of surface water and groundwater; and the effects of physical characteristics of the Toppenish fan aquifers on the attributes listed above. The availability of water-level data from multiple monitoring wells in the TFSARP, together with the application of geochemical techniques, provides a unique opportunity to understand the effectiveness of shallow aquifer recharge in this area.

The results could be applied toward other areas of the Toppenish subbasin, such as identifying locations for Managed Aquifer Recharge (MAR) to store water for recovery during seasonal dry periods or drought, or how and where to effectively enhance instream flow through groundwater recharge.

3.0 Background

3.1 Introduction and problem statement

Securing the future water supply for agriculture, domestic use, instream flow and habitat in the Yakima Basin is the focus of coordinated efforts under the Yakima Basin Integrated Plan (YBIP). Managed Aquifer Recharge (MAR) is one sustainable and cost-effective approach to store water underground (Dillon et al., 2019). Previous projects for the YBIP Groundwater Storage Subcommittee have used groundwater modeling and field investigations to identify sites within the Yakima basin or sub-basins with promising potential for Shallow Aquifer Recharge (SAR) (Anderson et al., 2009; Gibson and Campana, 2018; Kittitas Reclamation District, 2020). The stored groundwater would naturally discharge and could be available for use during drier summer periods or to sustain instream flow or natural springs.

This project is a hydrochemical study of the existing Toppenish Fan Shallow Aquifer Recharge Project (TFSARP) on the Yakama Indian Reservation. The project will use stable isotope and geochemical analysis of surface water and groundwater to quantify groundwater sources, resident times, and mixing and thus assess the impact of the TSARP on aquifer recharge in this alluvial fan environment. The availability of water-level data from multiple monitoring wells in the TFSARP, together with the application of geochemical techniques, provides a unique opportunity to understand the effectiveness of SAR in this area and apply the results to the optimal siting of MAR on other alluvial fans within the Yakima Basin.

Specific questions that will be addressed include identifying the sources of recharge to the groundwater and springs; travel times and flow directions of water introduced from the TFSARP recharge canals; locations of mixing of surface water and groundwater; and the effects of physical characteristics of the Toppenish fan aquifers on the attributes listed above.

This project has been developed in collaboration with the Yakama Nation and the results will be used to help inform their management of on-reservation aquifer recharge projects. Yakama Nation personnel will supervise all field data collection and will collect some of the water samples and water-level data. The data will be collected on Yakama Nation land and thus will not be entered into Ecology's EIM database.

3.2 Study area and surroundings

The Toppenish alluvial fan is one of several large alluvial fans entering the subbasins of the Yakima River watershed (Figure 1) that have been identified as having good prospects for groundwater recharge and storage (Gibson and Campana, 2018).

The study area for this project will focus on the upper portion of the Toppenish alluvial fan, within and surrounding the location of the Toppenish Fan Shallow Aquifer Recharge Project (Figures 2 and 3). The project will incorporate well logs from a larger area of the fan to characterize the regional aquifer stratigraphy. Water samples from surface streams, recharge canals and groundwater wells will be collected within and adjacent to the TFSARP to analyze inputs and outflows from the area of aquifer recharge.

Multiple perennial and ephemeral streams enter the Toppenish Basin from the west. The Toppenish alluvial fan, which covers approximately 25% of the basin, is located where Toppenish Creek enters the southwestern corner of the Toppenish subbasin, west of the Yakima River (Figures 2 and 3, next page). The creek is fed by Toppenish and Simcoe Creeks, which join within the fan. Toppenish Creek continues to flow along the southern boundary of the basin to its confluence with the Yakima River.

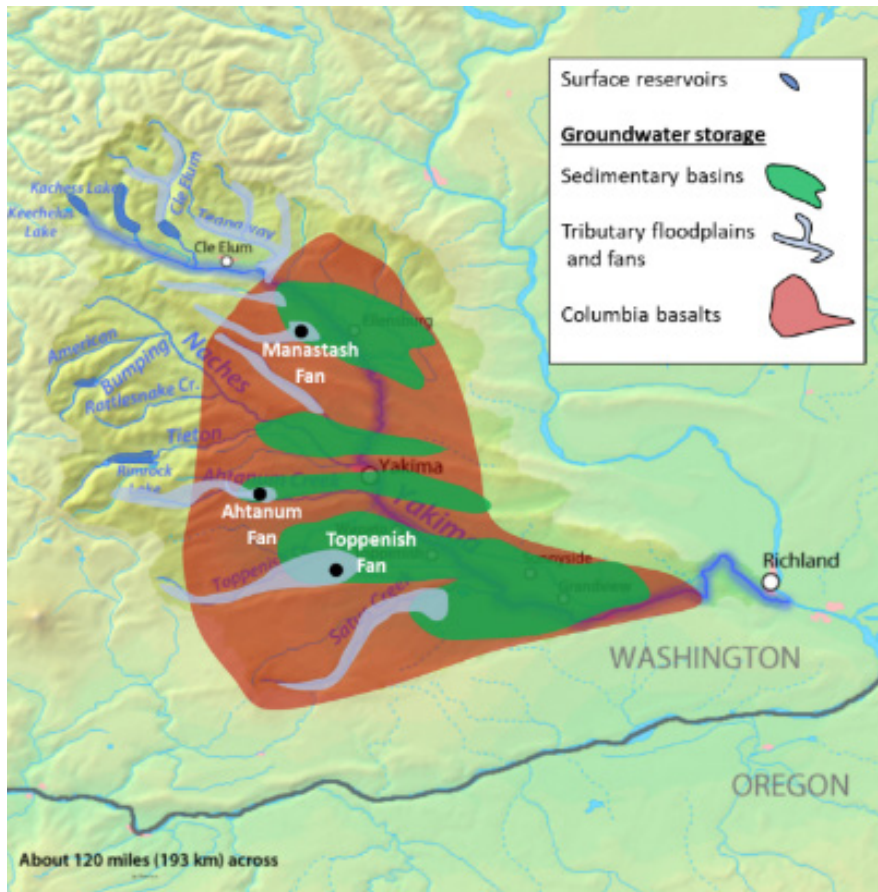


Figure 1. Map of natural groundwater storage sedimentary basins.

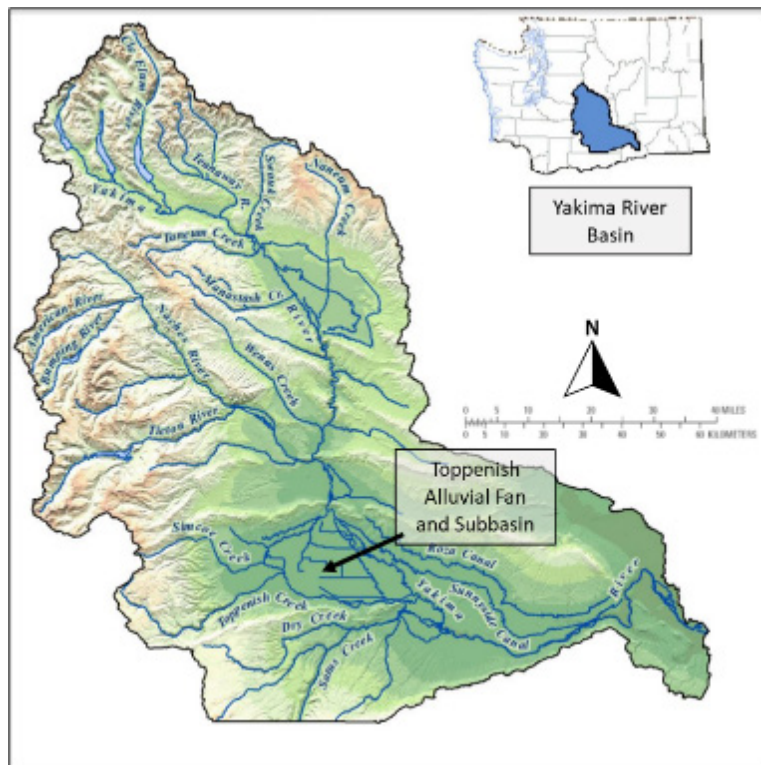


Figure 2. Toppenish Creek alluvial fan location map.



Figure 3. Toppenish Creek alluvial fan study area.

In addition to these natural hydrologic inputs, approximately 145,000 acres of the northern and central portions of the subbasin are irrigated with water that is largely diverted from the Yakima River through the Wapato Irrigation Project and spread throughout the subbasin in a series of canals (Figure 5).

The typical annual diversion of Yakima River water applied to the basin is ~500,000 acre-ft between April and October (Yakama Nation Dept. of Natural Resources, 2024). Groundwater in aquifers adjacent to the lower portion of Toppenish Creek could be influenced by infiltration from irrigation water, but the upper Toppenish alluvial fan is above the Wapato Irrigation Project canals.

Alluvial fans develop where rivers exit confined mountain canyons into wide basins. The sediment that is transported in the steeper, narrower mountain streams is deposited as the streams widen or diverge upon entering the basin. Alluvial fans incorporate features that are favorable to the implementation of effective MAR projects.

The tributary water supply is initially confined to a single source at the head of the fan, which can be diverted or contained in an infiltration basin for MAR. Alluvial fans tend to be composed of relatively permeable sand and gravel near the upstream head, transitioning to finer sediment at the distal end (Bull, 1977). The fan sediments are therefore conducive to infiltration and transmission of water in the shallow subsurface.

The fining distal sediments provide a means of slowing groundwater flow and loss from the storage volume. The stratigraphy of the alluvial fans and underlying sedimentary aquifer of the upper Ellensburg Formation can be heterogeneous, however, due to shifting channel positions, debris flows, volcanic layers and other factors. Investigations of the site-specific hydrogeology of a MAR project can help determine how groundwater moves through the subsurface.

3.2.1 History of study area

This study area for this project on the Toppenish alluvial fan is located within the Yakama Indian Reservation (Figure 3). Yakama Nation initiated the Toppenish Fan Shallow Aquifer Recharge Project in 2014 (Figure 4). The TFSARP diverts 5-20 cfs from Toppenish Creek during the non-irrigation season (November-April) to recharge shallow groundwater storage and increase baseflows in springs and creeks.

The water is diverted at the Toppenish Unit Headworks, also known as the Olney Diversion, into leaky unlined irrigation canals and historical paleochannels. Yakama Nation has installed piezometers in several wells to monitor groundwater levels within the study area, some of which will be utilized to collect water samples in the current YBIP study. Yakama Nation personnel regularly measure recharge flows and groundwater levels during the diversion period.

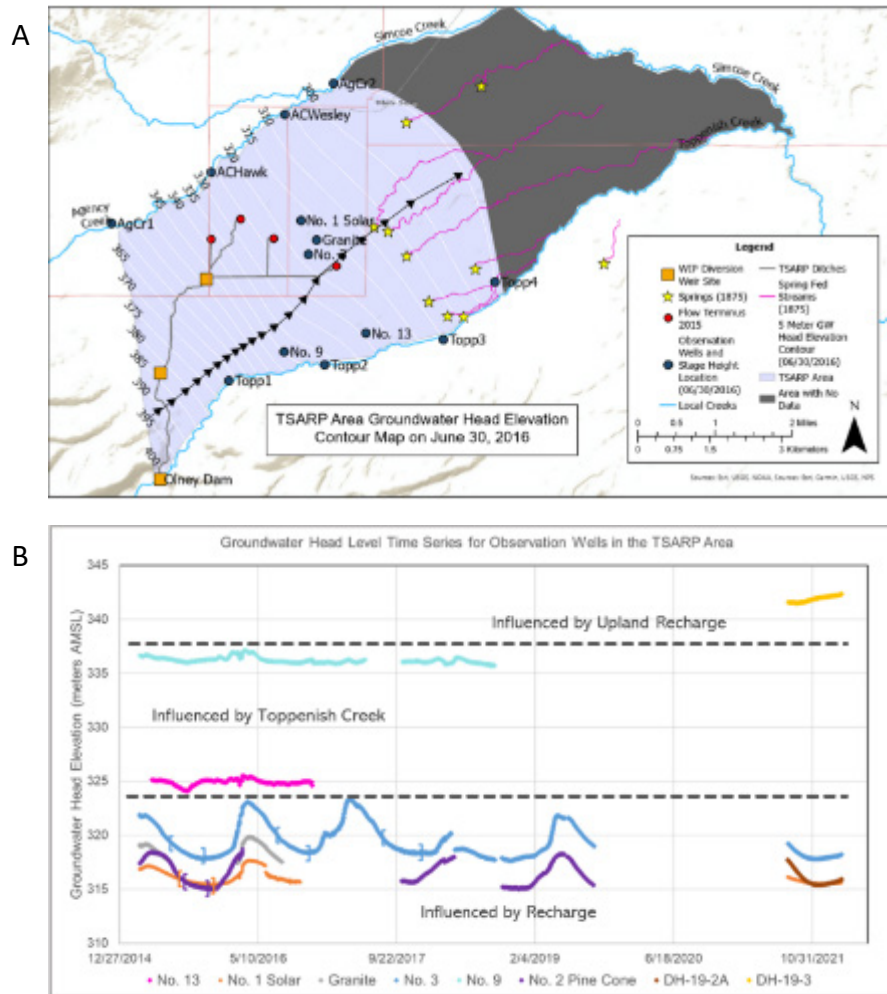


Figure 4. A. Toppenish Fan Shallow Aquifer Recharge Project Map. B. Groundwater level time series at observation wells shown the above map.

Figure 4 notes: Figures modified from Jimmie et al., 2023 and Yakama Nation Department of Natural Resources, 2024.

3.2.2 Summary of previous studies and existing data

This project will rely on previously collected groundwater-level data for existing piezometers within the study area through our collaborative arrangement with the Yakama Nation Water Resource Program (Figure 4). A master's thesis project by Jimmie (2023) assessed the timing and effects of the recharge through a series of piezometers downgradient from the recharge canals and in stage gages along Toppenish and Simcoe Creek (Figure 4). The TFSAR project increased groundwater elevation adjacent to the project area by 5-15 feet. Half of the applied water leaves the observation well area in 30-63 days with less than 2% annual carryover as groundwater storage (Jimmie, 2023; Yakama Nation Dept. of Natural Resources, 2024).

Using geochemical characteristics of the groundwater and surface water, the project proposed here will refine the model of the groundwater sources, flow paths, timing, and mixing with surface water during the recharge period. We will expand the study area to include upstream

and downstream portions of the Toppenish Fan to assess sources and areas of groundwater-surface water mixing throughout the year.

Previous studies of the hydrogeologic setting of the Toppenish basin indicate that, as for most of the major sedimentary basins in the Yakima River watershed, the Toppenish basin can be described as three aquifers that correlate with the three primary lithostratigraphic units: a) alluvial aquifer; b) Ellensburg aquifer; c) basalt aquifer. Based on a large set of well data, the upper two sedimentary units were further subdivided into five units in the Toppenish fan and basin by the USGS in their ten-year study (Jones et al., 2006): Unit 1 – fine-grained unconsolidated sediments; Unit 2 – coarse-grained unconsolidated sediment; Unit 3 – consolidated upper Ellensburg formation deposits; Unit 4 – Upper Rattlesnake Hills Formation; Unit 5 – Lower Rattlesnake Hills formation. The Rattlesnake Hills formation is a sub-unit of the Ellensburg formation. On the valley floor, most wells are completed within Unit 2, which is approximately 150-250 feet thick in the deeper parts of the basin. In the alluvial fan itself, units generally thin to the south and west (Hendry et al., 1992).

The methods to be used in this project on the Toppenish fan are modeled after a YBIP Groundwater Storage Subcommittee project funded to Central Washington University in the 2023-25 biennium, entitled “Hydrogeology and potential for groundwater recharge and storage on alluvial fans in the Yakima Basin” that supported two CWU master’s theses (Bauer, 2025; Myers, 2025). That project focused on the Ahtanum and Manastash alluvial fans in the Yakima and Kittitas sedimentary sub-basins, respectively. In both alluvial fans, the well-log stratigraphy, geochemical analyses, seepage velocity estimates, and soil infiltration maps were combined to identify promising locations for MAR projects. Application of a similar approach on the Toppenish fan will help us understand existing recharge patterns, movement, and mixing of surface water and groundwater.

On the Ahtanum alluvial fan, six hydrochemical groups exhibited various degrees of surface-water interaction with groundwater (Bauer, 2025). These groups aligned to a large extent with the aquifer stratigraphy, which was divided into three sedimentary units and the Columbia River Basalt Group. The results of the hydrochemistry, stratigraphy and soil infiltration characteristics highlighted optimal regions for SAR, including the active fan and shallow fractured basalt in the upstream portion of the fan, and mid-fan sedimentary aquifer units along the northern and southern slopes of the anticlinal ridges.

On the Manastash fan, three hydrochemical groups were identified in groundwater samples, one of which indicated surface water - groundwater interactions in select sedimentary and basalt wells. The results identified at least three sedimentary aquifer locations suitable for SAR (Myers, 2025).

The project on Manastash Creek built on previous work that included a portion of the Manastash alluvial fan in a much larger study area across the Kittitas Valley (Taylor and Gazis, 2014). In that research, groundwater samples were collected from 26 wells, analyzed geochemically, and compared to 24 surface water samples.

Based on this analysis, they identified seven hydrochemical groups that were interpreted to represent the following:

- A – interaction with basalts, no surface water influence.
- B and C – heavily influenced by Yakima River water or irrigation water.
- D and E – interaction with Ellensburg formation with some influence from surface water.
- F – interaction with Ellensburg formation, no surface water influence.

These groups are defined by major ion and stable isotope geochemistry and their seasonal variations. Groundwater from basalt wells is characterized by high Na concentration and light stable isotope signatures (low δD and $\delta^{18}O$). Waters that are heavily influenced by Yakima River water and irrigation water from the Yakima River have heavy stable isotope signatures (high δD and $\delta^{18}O$) and variable and often elevated concentrations of NO_3 , SO_4 and Cl. Ellensburg Formation groundwaters have intermediate isotopic signatures and are dominated by Ca, Mg, and HCO_3 .

3.2.3 Parameters of interest and potential sources

This project is not aimed at measuring environmental pollutants. The environmental parameters of interest in this study are:

- Groundwater levels and temperatures at select locations
- Alluvial fan aquifer stratigraphy in relation to groundwater levels, aquifer storage capacity, and groundwater flow
- Stable isotope and major ion geochemistry as a tracer of groundwater flow

3.2.4 Regulatory criteria or standards

Not applicable.

3.3 Water quality impairment studies

Not applicable.

3.4 Effectiveness monitoring studies

Not applicable.

4.0 Project Description

This project will investigate aquifer characteristics, hydrogeology, and surface water–groundwater interactions in the Toppenish alluvial fan using geochemical and stratigraphic techniques. The project will quantify the stratigraphy and hydrochemistry of the Toppenish alluvial fan to assess the recharge and mixing of surface water with groundwater in the Yakama Nation Toppenish Fan Shallow Aquifer Recharge Project (TFSARP).

Specific questions that will be addressed include identifying the sources of recharge to the groundwater and springs; travel times and flow directions of water introduced from the TFSARP recharge canals; locations of mixing of surface water and groundwater; and the effects of physical characteristics of the Toppenish fan aquifers on the attributes listed above.

The availability of water-level data from multiple monitoring wells in the TFSARP, together with the application of geochemical techniques, provides a unique opportunity to understand the effectiveness of shallow aquifer recharge in this area and apply the results to the optimal siting of MAR on other alluvial fans within the Yakima Basin. The results could be applied toward other areas of the Toppenish subbasin, such as identifying locations where MAR could store water for recovery during seasonal dry periods or drought, or how and where to effectively enhance instream flow through groundwater recharge.

The project will be conducted in collaboration with the Yakama Nation Water Resource Program. Yakama Nation personnel will supervise all field data collection and will collect some of the water samples and water-level data. The data will be collected on Yakama Nation land, and thus will not be entered into Ecology's EIM database.

4.1 Project goals

The primary goals of this project are to quantify the hydrochemistry, stratigraphy and hydrogeology of the Toppenish alluvial fan to assess the extent and locations of recharge and mixing of surface water with groundwater; groundwater travel times and flow directions; and physical characteristics of the Toppenish fan aquifers. The hydrochemistry and stratigraphy will be used to assess the sources of water that contribute to groundwater wells and springs on the Toppenish Fan and what proportion of that water is from the existing Toppenish Fan Shallow Aquifer Recharge Project.

The results will augment the existing information on seasonal groundwater fluctuations in monitoring wells from the TFSARP (Jimmie, 2023; Yakama Nation Water Resource Program, 2024). We will collaborate with representatives from the Yakama Nation during the project design to ensure that it fulfills our joint intent to support and enhance existing and planned projects on the Toppenish fan. During the project, we will share data with the Yakama Nation to maintain the design objectives and prevent unintended redundancy.

Specific project goals

- 1. Describe physical and hydrogeologic characteristics of the sedimentary aquifers** at the study site from analysis of existing well logs, geologic maps, previous reports and publications. These data will be supplemented with new field observations of the stratigraphy, sedimentology, soil characteristics and geomorphology of the tributary channels and alluvial fans.
- 2. Document the surface-water and groundwater hydrology.** We will collect manual measurements of water levels in combination with data from existing pressure transducers in wells to monitor the seasonal groundwater variations and compare water levels among wells across the study sites.
- 3. Use geochemistry to trace surface water recharge and mixing with groundwater.** Geochemical analysis will be used to decipher surface water/groundwater interactions and trace the spatial patterns in infiltration and mixing of surface water within the aquifer (e.g., Taylor and Gazis, 2014; Sleeper, 2020; Petralia, 2022). The resulting details of groundwater/surface water interactions and flow directions will aid in pinpointing the sources and flow paths of groundwater recharge during and after the TFSARP recharge period.

4.2 Project objectives

Specific project objectives

- Describe the physical stratigraphy and hydrogeological characteristics of the sedimentary aquifers of the Toppenish Fan based on analysis of existing well logs and previous studies (e.g. Jimmie, 2023; Jones et al., 2006).
- Map relevant surface characteristics of the fan from existing maps and field observations, including 1) surficial soils and geomorphic landforms; 2) springs, wetlands and streams; 3) human-made water infrastructure, e.g. canals, etc. These features will be used to assess infiltration capacity of surface water, groundwater upwelling, and sources or sinks of water in different locations on the alluvial fan.
- Document seasonal and spatial variations in groundwater levels during and outside of the TFSARP recharge period from Toppenish Creek using the Yakama Nation existing network of piezometers on the Toppenish alluvial fan. This will be done through measurements conducted by Yakama Nation personnel and analysis of preexisting water-level data for a subset of piezometers within the study area.
- Determine stable isotope composition and major ion concentrations for samples from surface waters, groundwater wells, and springs on the Toppenish fan. Use data to characterize hydrochemical groups and to identify mixing end members.
 - Collect water samples for stable isotope analysis every 2 weeks during the recharge project period from selected wells and springs downstream of the recharge canals, and every week from surface water streams within the recharge project area; collect samples every month after the recharge period.

- Collect water samples during and outside of the recharge project period for stable isotope analysis and major ion concentrations from the broader selection of wells, springs and surface waters within and surrounding the recharge project area.
- Compare the geochemical results with the seasonal recharge inflow and groundwater levels from the Toppenish Fan Shallow Aquifer Recharge Project.
- Compare the geochemical characteristics of the recharge-activated springs with those of the groundwater and surface-water.

4.3 Information needed and sources

Existing data:

- Well log data – well depths, log of sediments, and depth to water at time of drilling. These will be obtained from the Washington State well report viewer: <https://apps.wa.gov/ecology/wellconstruction/map/WCLWebMap/default.aspx>
 - Additional well log data will be obtained from the Yakama Nation Water Resource Program.
- Geologic data from Washington State Geological Survey Geology Portal: <https://www.dnr.wa.gov/geologyportal>
- Existing characterizations of hydrogeology based on geology, field observations, and well log data (e.g. Hendry, 1992; Jones et al., 2006; Vaccaro et al., 2009; Jimmie, 2023).
- Existing and ongoing measurements of groundwater levels from pressure transducers in piezometers within the TSARP study area will be obtained from the Yakama Nation Water Resource Program.
- Stream discharge data for Toppenish Creek will be obtained from the Yakama Nation Water Resource Program for streamflow gages listed in Section 7.2.

Data to be generated through this study:

NOTE: New data generated by this study on Yakama Nation land is the property of Yakima Nation, and will not be posted to Ecology’s EIM database.

- Descriptions and measurements of Toppenish alluvial fan stratigraphy.
- Manual measurements of groundwater levels in a selection of existing piezometers within and surrounding the TFSARP study area during and outside of the recharge period (See Section 7.2 for well locations).
- Stable isotopes of O and H for 300 surface-water and groundwater samples collected during and outside of the recharge period. Surface waters will be sampled weekly and groundwater every 2 weeks during the recharge period; both will be sampled monthly after the recharge period. See Section 7.2 for well locations.
- Major ion concentrations (Ca, Mg, Na, K, Cl, F, sulfate, nitrate, phosphate) of surface water and groundwater samples twice during times of the year outside of the recharge

period to establish the background water chemistry in the study area. See Section 7.2 for well locations.

4.4 Tasks required

- Construct topographic and stratigraphic cross sections along transects across the alluvial fan based on well logs, geologic maps and exposed stratigraphy in stream banks and unlined canals.
- Acquire streamflow data from Toppenish Creek gages run by the Yakama Nation as listed in Section 4.3 (page 11) of this QAPP.
- Acquire existing measurements of groundwater levels from piezometers within the TSARP study area from the Yakama Nation Water Resource Program as listed in Section 4.3 (page 11).
- Measure groundwater levels in wells identified in Section 7.2 (page 24)
- Collect 300 water samples from wells and Toppenish Creek during and outside of the recharge period. Surface waters will be sampled weekly and groundwater every 2 weeks during the recharge period; both will be sampled at least monthly after the recharge period through the end of the study. See Section 7.2 (page 24) for sample locations.
- Collect 35 water samples for major ion concentrations (Ca, Mg, Na, K, Cl, F, sulfate, nitrate, phosphate) of surface water and groundwater samples twice during times of the year outside of the recharge period. See Section 7.2 (page 24) for sample locations.
- Conduct laboratory measurements of stable isotopes and major ion concentrations.
- Compile and analyze new data including graphical and statistical analysis, assessment of spatial patterns in groundwater flow, and mixing with TFSARP recharge water.
- Prepare final report and present results.

4.5 Systematic planning process

The QAPP is the systematic planning process for this project.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

This QAPP was prepared by Lisa Ely and Carey Gazis for Central Washington University (CWU). Dr. Ely, a professor in the Department of Geological Sciences at CWU, is the Project Manager and Principal Investigator; Dr. Gazis, a professor in the Department of Geological Sciences at CWU, is the co-Principal Investigator. Much of the project work will be undertaken by Sam Dossa, an M.S. graduate student at CWU, as part of his thesis research. The Principal Investigators and graduate student at CWU will collaborate with Mary Weber, Danielle Squeochs, and other personnel from the Yakama Nation during the project, particularly for sample collection and water-level measurements in the field. We will communicate regularly with Jeff Dermond, grant project manager, at the Department of Ecology and other members of the Groundwater Storage Subcommittee of the Yakima Basin Integrated Plan.

Table 1 shows the responsibilities of those who will be involved in this project.

Table 1. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Lisa Ely Geological Sciences Dept. Central Washington Univ. Phone: 509-963-2177	Project Manager/ Principal Investigator	Write the QAPP. Oversee reporting and project budget. Collaborate on QA ² review of data. Oversee analysis and interpretation of stratigraphic, geologic and hydrogeologic data. Prepare final report in collaboration with Carey Gazis, with input from Sam Dossa.
Carey Gazis Geological Sciences Dept. Central Washington Univ. Phone: 509-963-2820	Co-Principal Investigator	Collaborate on writing the QAPP. Oversee field sampling and transportation of water samples to the laboratory. Collaborate on QA review of data. Oversee analysis and interpretation of geochemical and groundwater data. Collaborate on preparation of final report with Lisa Ely, with input from Sam Dossa.
Sam Dossa Geological Sciences Dept. Central Washington Univ.	Graduate Student Researcher	Conduct research on Toppenish alluvial fan. Compile existing data from well logs, maps and reports. Collect samples and record field information. Work with Dr. Ely and Dr. Gazis to interpret data and prepare Technical Memorandum.
Jeff Dermond Office of Columbia River WA Dept. of Ecology Phone: 509-268-1784	Grant Project Manager	Manage the project grant, provide oversight of project, and approve the budget. Provide internal review of the QAPP, approve the final QAPP.
McKenna Murray Office of Columbia River WA Dept. of Ecology Phone: 509-867-6534	OCR Quality Assurance Coordinator	Review and approve the draft and final QAPP

² QA -Quality Assurance

5.2 Special training and certifications

Graduate student Sam Dossa will receive training from Dr. Ely and Dr. Gazis in field measurement, field sampling and data processing protocols. Individuals performing project tasks will be trained in and experienced with the relevant SOPs for the required instrumentation.

Mr. Dossa will receive training in laboratory safety, sample preparation, and use of the Picarro water isotope analyzer and ion chromatograph. Training will be given by Dr. Gazis and a laboratory technician at Central Washington University.

5.3 Organization chart

Not applicable - See Table 1.

5.4 Proposed project schedule

Table 2– Four (4) list key activities, due dates, and lead staff for this project.

Table 2. Schedule for completing field and laboratory work

Task	Due date	Lead staff
Field work	December, 2026	Ely and Gazis
Laboratory analyses	May, 2027	Gazis
Contract lab data validation	NA	NA

Table 3. Schedule for data entry

Task	Due date	Lead staff
EIM data loaded	NA	Data are from Yakama Nation--not entered in EIM
EIM QA	NA	
EIM complete	NA	

EIM: Environmental Information Management; NA: Not Applicable

Table 4. Schedule for final report

Task	Due date	Lead staff
Draft to Ecology project manager	March 1, 2028	Ely and Gazis
Final report	March 31, 2028	Ely and Gazis

5.5 Budget and funding

This project is funded by the Department of Ecology Office of Columbia River Grant WRYBIP-2527-CeWaUn-00080, as recommended by the Groundwater Storage Subcommittee under the Yakima Basin Integrated Plan. Funding covers summer and academic-year salary, benefits, and tuition costs for the CWU graduate student, Sam Dossa; partial summer salary for principal investigators, Dr. Gazis and Dr. Ely; summer funding for student field assistants; travel for field measurements, observations and sample collection; field supplies; and geochemical analyses of 40 water samples. The remainder of Dr. Gazis' and Dr. Ely's effort toward this project is funded by Central Washington University. Tables 5 and 6 show project and laboratory budget details.

Table 5. Project budget and funding

Cost Category	Cost (\$)
Salary, benefits, and indirect/overhead	\$66,440
Equipment, incl. pressure transducers and supplies	\$3000
Travel and other	\$2100
Graduate student tuition	\$10,897
Laboratory (See Table 6 for details.)	\$6075

Table 6. Laboratory budget details

Parameter	Number of Samples	Number of QA Samples	Total Number of Samples	Cost Per Sample (\$)	Lab Subtotal (\$)
Stable Isotope Analyses	300		300	\$15	\$4500
Stable Isotope Analyses (QA)		12	12	NA	0
Major Ion Analyses	35		35	\$30	\$1575
Major Ion Analyses (QA)		12	12	NA	0

6.0 Quality Objectives

6.1 Data quality objectives

The main measurement data quality objectives (DQO) for this project are as follows:

- 1) Collect 335 water samples to analyze the geochemistry of the groundwater and surface water on the Toppenish alluvial fan during and outside of the TFSARP recharge period. The analyses will use standard methods to obtain major ion and stable isotope data that meet measurement quality objectives (MQOs) that are described below and are comparable to previous study results.
- 2) Collect discrete groundwater elevation measurements during and outside of the TFSARP recharge period from manual measurements at the sampling locations described in Section 7.2. These results will be compared with groundwater elevation data from pressure transducers previously installed and continually monitored by the Yakama Nation in the study area. The study will use standard methods to obtain groundwater elevations that meet the MQOs described below and are comparable to previous study results.

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

Pressure transducers to measure groundwater levels were installed by and are monitored by the Yakama Nation on some wells within and surrounding the study area of this project. We will compare those data with the geochemical data and manual measurements of water levels from this project. The pressure-transducer data collected by the Yakama Nation are considered existing data for the purposes of this project (see Section 4.3), and are thus not included in the Quality Objectives or Methods of this QAPP.

6.2 Measurement quality objectives

One measurement objective of this study is to collect representative geochemical and isotopic data for hydrogeologic characterization. Data quality objectives (DQOs) for this project are based on precision, bias, and sensitivity and are used to establish measurement quality objectives (MQOs) which will be used to assess data quality. Laboratory MQOs for the individual parameters are summarized in Table 7.

A second measurement objective is to take manual measurements of water levels in wells to determine the effects of the TFSARP recharge and seasonal variations. Specifications for the depth-to-water measuring tape are given in Table 8 and MQOs for the water level and measurements are given in Table 9.

6.2.1 Targets for precision, bias, and sensitivity

The MQOs for project results, expressed in terms of acceptable precision, bias, and sensitivity, are described in this section and summarized in the table below.

Table 7. Measurement quality objectives for laboratory analyses of water samples.

Parameter	Laboratory Duplicate (RPD)	Field Duplicate (RPD)	Matrix Spike Duplicate (RPD)	Lab Control Standard (%Recovery)	Matrix Spike (% Recovery)	Internal Standard Recovery (% Recovery)	Lowest Conc. of Interest (Detection Limit*)
Alkalinity	<8%	<10%	<10%	80-120%	75-125%	NA	10 mg/L
Chloride	<8%	<10%	<10%	80-120%	75-125%	NA	0.1 mg/L
Fluoride	<8%	<10%	<10%	80-120%	75-125%	NA	0.1 mg/L
Sulfate	<8%	<10%	<10%	80-120%	75-125%	NA	0.5 mg/L
Nitrate-N	<8%	<10%	<10%	80-120%	75-125%	NA	0.1 mg/L
Phosphate-P	<8%	<10%	<10%	80-120%	75-125%	NA	0.05 mg/L
Calcium	<8%	<10%	<10%	80-120%	75-125%	NA	0.05 mg/L
Magnesium	<8%	<10%	<10%	80-120%	75-125%	NA	0.05 mg/L
Potassium	<8%	<10%	<10%	80-120%	75-125%	NA	0.05 mg/L
Sodium	<8%	<10%	<10%	80-120%	75-125%	NA	0.05 mg/L
Oxygen-18	0.05 per mil	0.1 per mil	NA	NA	NA	NA	NA
Deuterium	0.6 per mil	1.0 per mil	NA	NA	NA	NA	NA

Table notes: NA Not Applicable; Although statistically derived, these values represent a realistic estimate of the detection limit rather than a statistical measure of instrument detection; Treatment of measurements below detection limits is discussed in section 14.2 (Treatment of Non-Detects).

Table 8. Specifications of water level manual measurements and surface elevations.

	Measurement	Range	Accuracy	Resolution	Response Time (90%)	Stability (Drift)
Solinst Water Level Meter (Model 101 and 102)	Water Level Depth (Manual)	0.5 to 300 ft	0.03 ft	0.01 ft	< 1 sec	
Garmin GPSMap 64st	Surface Elevation	1200 to 2500 ft	±10 ft	1 ft	n/a	
LiDAR Dataset Yakima Basin 2018	Surface Elevation		0.1 ft			

Table 9. Measurement quality objectives: water levels.

MQO	Precision		Bias	Sensitivity
Parameter	Duplicate Measurement or Sensor Resolution		Based on reported accuracies from user manuals and/or manual measurements (ft.)	Minimum Measurement (ft.)
	Relative Percent Difference (%RPD)	In feet (ft.)		
Groundwater Level(manual measurement)	n/a	0.02 ft	0.08 ft	0.02 ft

6.2.1.1 Precision

Precision will be determined based on duplicate field measurements and laboratory measurements of duplicate samples. For major ion concentrations, the MQOs require that duplicate samples are within 10% of each other. For stable isotope analyses, measurements are of ratios that are expressed in delta notation³* (per mil units). For these analyses, in addition to measuring duplicate samples, the laboratory method includes multiple injections and measurements of each sample (typically ten). The first three injections are discarded because of memory effects. The reproducibility of the remaining analyses provides another determination of the precision of the method. Both the duplicate sample measurements and the multiple analyses of the same sample should meet the MQOs for stable isotopes, 0.1 per mil for Oxygen-18 and 0.6 per mil for deuterium.

For manual water-level measurements using a water-level meter, estimated precision is based on duplicate measurements.

6.2.1.2 Bias

Bias will be determined based on measurement of quality control (QC) standards of known ion concentration or isotopic composition. These QC samples are independent from the calibration standards for each measurement. For major ions, the recovery limits for these QC standards should be 90-110%. For stable isotope analyses, these QC standards should measure within 0.1 per mil (oxygen-18) and 0.6 per mil (deuterium) from their known value.

Equipment/filter field blanks will be collected to determine if sampling equipment or filters are introducing bias into the sampling results. Blanks will be used to determine whether the syringe, filters, sample containers, or transport methods represent a source of bias. If bias is recognized in blank samples early in the project, additional steps will be taken to isolate the source of error, and field procedures or equipment will be modified to eliminate the problem.

³ $\delta = \left(\frac{R_{sam} - R_{std}}{R_{std}} \right) * 1000$, where R_{sam} and R_{std} are the isotope ratios $\left(\frac{^{18}O}{^{16}O} \right)$ for $\delta^{18}O$, $\frac{D}{H}$ for δD) of the sample and the standard, respectively.

For manual depth-to-water measurements, bias is introduced by any curvature in the measuring tape. The measuring tape will be examined periodically to assure that there are no kinks or bends.

6.2.1.3 Sensitivity

Sensitivity is a measure of signal strength compared to the concentration that creates that signal. It is one measure of the capability of a method to detect a substance. Sensitivity differs from the detection limit in that it does not depend on the signal stability. Detection limits are based on both signal strength (sensitivity) and signal stability. Sensitivity is usually not an issue for major ions in water because they are present in concentrations well above the detection limit and therefore have strong signals and high signal-to-noise ratios. Stable isotope analyses are measurements of ratios, not concentrations, and therefore sensitivity is not a valid measure for these analyses. Instrumental detection limits for the major ion analyses are given as the lowest concentration of interest in Table 7.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

Comparability is the degree to which data can be compared directly to similar studies. The use of standardized sampling procedures, analytical methods with comparable sensitivity, and units of reporting, and quality control procedures and standards ensure comparability of data. For comparability with existing data, particularly for stable isotope analyses, standards of known concentration will be analyzed and those analyses will either serve as the basis for the measurement calibration or as a check (quality control) standard for the calibration.

Standardized sampling procedures will be used as described in this document and informed by the SOPs listed in Section 8.2.

6.2.2.2 Representativeness

Representativeness is the degree to which sample data from the project accurately represent a particular characteristic of the environmental matrix which is being sampled.

Representativeness of the samples collected is ensured by adherence to the field sampling protocols and standard laboratory protocols. Sampling locations are selected to represent the groundwater geochemistry in the vicinity of each well.

Groundwater levels can be relatively slow to change compared with surface water.

Groundwater fluctuations are expected to occur seasonally in some wells either due to the TFSARP recharge, input from spring snowmelt or irrigation, or withdrawals through pumping in the region. Wells were chosen to represent shallow aquifers that are likely to be influenced by these seasonal effects. All of the wells selected for this project (Section 7.2) are not being used for pumping so that they are more representative of the regional water level.

The existing streamflow gages on Toppenish Creek maintained by the Yakama Nation will provide continual flow measurements that are representative of the surface water fluctuations at the study site.

6.2.2.3 Completeness

To ensure data completeness, only properly calibrated and maintained equipment will be used. Problems occasionally arise during sample collection or water-level measurements that cannot be controlled; thus, a completeness of 95% is acceptable. Example problems are flooding, site access problems, non-linear measurement drift, or equipment failure. For the laboratory analyses, a complete or valid result will include sample documentation and a laboratory analysis report. Greater than 95% completeness is expected for samples collected as part of this project.

6.3 Acceptance criteria for quality of existing data

Existing geochemical data will be used as a comparison to data collected in this project. Existing data will not be used as part of this study unless it has met the same measurement quality outcomes outlined in this QAPP. Existing water-level data measured from pressure transducers in groundwater wells on the Toppenish alluvial fan was collected by the Yakama Nation following the protocols of the Yakama Nation Water Resource Program (Appendix A) and is documented in previous reports (Jimmie, 2023; Yakama Nation, 2024). The pressure transducer data will be verified against manual measurements from the same or nearby wells (Table 10) taken during this study or by Yakama Nation personnel. We will work closely with the Yakama Nation personnel on this project to review and assess data acquired from the Yakama Nation.

6.4 Model quality objectives

Not applicable.

7.0 Study Design

7.1 Study boundaries

General location maps of the Toppenish alluvial fan and study area are in Figures 1 and 2. The study area boundary is outlined in Figure 3. Figures 5 and 6 show the locations of wells and surface-water sites within the Toppenish fan study area that will be sampled in this study.

7.2 Field data collection

Water samples and water-level measurements will be collected every two weeks from the wells shown in Figure 5 during the TFSARP recharge period, and surface water samples every week during the same period. An additional set of water samples and level measurements will be collected twice from the broader set of wells and surface water sites shown in Figure 6 during seasons when the TFSARP recharge is not occurring. The sampling strategies and field measurement methods are described below.

Geologic and stratigraphic information will mainly rely on existing data from well logs, geologic maps and soil maps. Some of the surface soils and shallow stratigraphic units will be verified in the field at naturally occurring exposures in streambanks or unlined canals.

7.2.1 Sampling locations and frequency

The aquifer stratigraphy will be examined from multiple well logs within and surrounding the study area to represent, as much as possible, a range of typical stratigraphic characteristics that could affect the infiltration, storage and mixing of surface water with groundwater.

Locations of wells and surface-water sites within the Toppenish fan study area that will be sampled in this study are shown in Figures 5 and 6 (next page). Locations shown in Figure 5 will be sampled twice during seasons outside of the TFSARP recharge period for major ion geochemistry and stable isotopes. Locations shown in Figure 6 will be sampled twice during seasons outside of the TFSARP recharge period for major ion geochemistry and stable isotopes. Locations for both figures are listed in Table 10.

The wells for sampling were selected from existing monitoring wells that were drilled and maintained by the Yakama Nation within and surrounding the TFSARP area.

The subset of wells for more frequent sampling during the TFSARP recharge period (Figure 5) were chosen to represent the variety of hydrogeological and geomorphic settings downgradient from the unlined canals and paleochannels used for the TFSARP recharge (Figures 4 and 5), plus natural springs and Toppenish Creek surface water sites in the same area.

The broader selection of wells for less frequent sampling outside of the TFSARP recharge period were chosen to capture a more widespread representation of groundwater characteristics within and surrounding the TFSARP area, including upgradient from the recharge area. Wells represent different depths within the alluvial aquifer.

Approximately 300 water samples will be collected for stable isotope analysis during the project. This sample number was chosen partly based on time constraints and budget and partly because it is our experience that this is an adequate number of samples to characterize changes in the hydrogeochemistry of a site of this size during the recharge and non-recharge periods, and to track the spatial distribution of surface-water and groundwater mixing (Bauer, 2025; Myers, 2025).

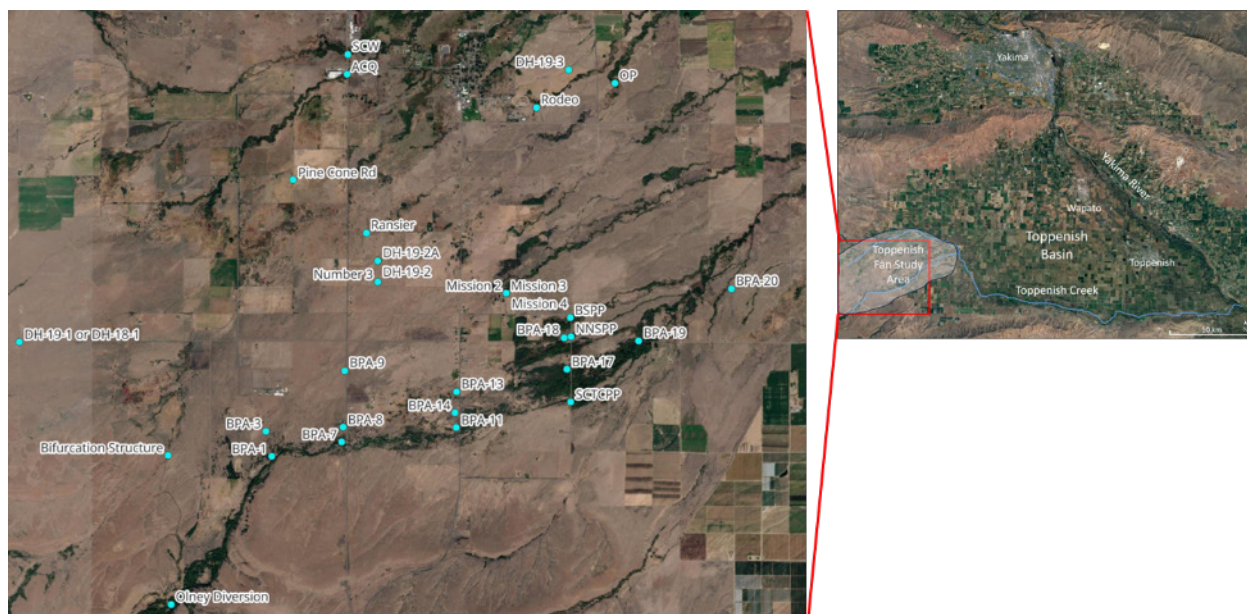


Figure 6. Locations of the expanded selection of sampling sites in the study area.

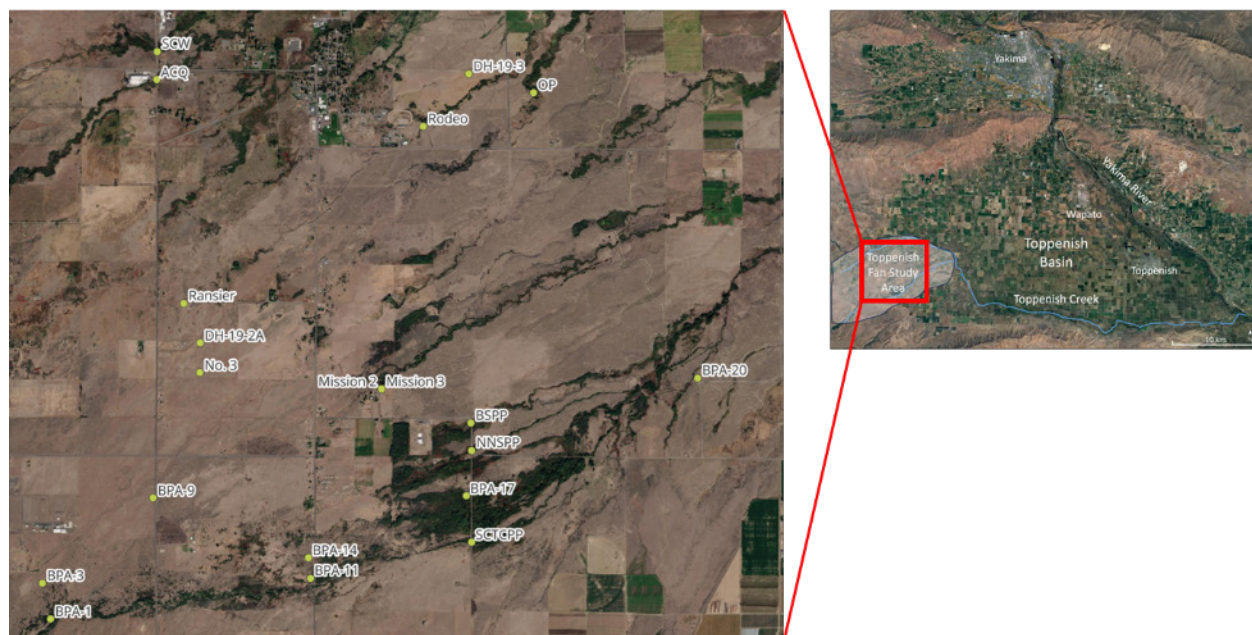


Figure 6. Locations of sampling sites within the TFSARP recharge area.

Groundwater samples will be collected every two weeks during the 2026 TFSARP recharge period and monthly thereafter until after the irrigation season ends in fall 2026. Surface water will be collected from multiple sites along Toppenish, Simcoe, and Agency Creeks (Figures 5 and 6; Table 10). Sampling locations were chosen to reflect representative surface water geochemistry and accessibility.

When water samples are collected for geochemical analysis, manual depth-to-water measurement will be collected from the same wells. The ground elevation of each well in which water level is measured will be obtained from the Yakama Nation data on the wells. These data will be supplemented by hand-held GPS location and elevation measurements taken in the field and refined as needed by deriving the elevation for the latitude/longitude location of the well from lidar imagery (Washington Lidar Portal, 2026; Table 8). The distance from the ground surface to the top of the casing (TOC) will be measured manually with a measuring tape. These two values (elevation and ground surface to TOC) allow for the conversion of depth from TOC to groundwater measurements to groundwater elevations.

Table 10. Locations of sampling sites and frequency of sampling

Site Type	Site Name	Abbreviated Site Name	Latitude (decimal degrees)	Longitude (decimal degrees)	Sampling Frequency
Well	BPA-1	BPA-1	46.3309591	-120.7686805	Biweekly during recharge; monthly after
Well	BPA-11	BPA-11	46.3348484	-120.7334019	Biweekly during recharge; monthly after
Well	BPA-14	BPA-14	46.3367928	-120.7336797	Biweekly during recharge; monthly after
Well	BPA-17	BPA-17	46.34262627	-120.7122902	Biweekly during recharge; monthly after
Well	BPA-20	BPA-20	46.3537375	-120.6809005	Biweekly during recharge; monthly after
Well	BPA-3	BPA-3	46.3342924	-120.7697917	Biweekly during recharge; monthly after
Well	BPA-9	BPA-9	46.34234817	-120.7547915	Biweekly during recharge; monthly after
Well	*DH-19-2A	DH-19-2A	46.35690416	-120.7484962	Biweekly during recharge; monthly after
Well	*DH-19-3	DH-19-3	46.3822652	-120.7120987	Biweekly during recharge; monthly after
Well	*Number 3	No. 3	46.3541243	-120.7484857	Biweekly during recharge; monthly after
Well	*Ransier Road	Ransier	46.36060677	-120.7506887	Biweekly during recharge; monthly after
Well	WSQAL-2	Mission 2	46.35265077	-120.7238908	Biweekly during recharge; monthly after

Site Type	Site Name	Abbreviated Site Name	Latitude (decimal degrees)	Longitude (decimal degrees)	Sampling Frequency
Well	WSQAL-3	Mission 3	46.35265035	-120.7238331	Biweekly during recharge; monthly after
Spring	Beaver Spring on Pom Pom Road	BSPP	46.3494515	-120.711668	Biweekly during recharge; monthly after
Spring	Numb Nuts Spring on Pom Pom Road	NNSPP	46.346904	-120.711537	Biweekly during recharge; monthly after
Spring	Oliver Pimm's Spring	OP	46.380483	-120.703256	Biweekly during recharge; monthly after
Spring	Rodeo Grounds Spring	Rodeo	46.377286	-120.718224	Biweekly during recharge; monthly after
Creek	Agency Creek on Wesley Road	ACQ	46.3816063	-120.7544766	Weekly during recharge; biweekly after
Creek	Simcoe Creek on Wesley Road	SCW	46.3842548	-120.7544197	Weekly during recharge; biweekly after
Creek	Toppenish Creek South, Pom Pom Rd	SCTCPP	46.3382919	-120.7115367	Weekly during recharge; biweekly after
Well	DH-19-1 or DH-18-1	DH-19-1 or DH-18-1	46.34598333	-120.817	Twice during non-recharge
Recharge Canal	Bifurcation Structure	Bifurcation Structure	46.33104437	-120.7885075	Twice during non-recharge
Creek	Olney Diversion	Olney Diversion	46.31127807	-120.7877876	Twice during non-recharge
Well	BPA-7	BPA-7	46.33290379	-120.755347	Twice during non-recharge
Well	BPA-8	BPA-8	46.3348482	-120.7550692	Twice during non-recharge
Well	Pine Cone Rd*	Pine Cone Rd	46.36758151	-120.764746	Twice during non-recharge
Well	BPA-13*	BPA-13	46.3395706	-120.733402	Twice during non-recharge
Well	WSQAL-4	Mission 4	46.3526547	-120.7238271	Twice during non-recharge
Well	BPA-18	BPA-18	46.3467929	-120.7128458	Twice during non-recharge
Well	BPA-19	BPA-19	46.3464121	-120.6985615	Twice during non-recharge

*Well with existing pressure transducer and data logger for water-level measurements, installed and monitored by Yakama Nation.

Yakama Nation personnel manually measure groundwater levels in wells in the TFSARP area on a weekly or biweekly basis. They have agreed to collect water samples for this project at the locations in Figure 5 during their regular measuring rounds and share all relevant groundwater data and samples with CWU. CWU graduate student Sam Dossa will participate in the

measuring/sampling during this project, but must be accompanied by a Yakama Nation staff person at all times, as the study site is in a restricted area of the Yakama Nation land. The data sheet used by the Yakama Nation for water-level measurements is in Appendix A. A Chain of Custody form (also in Appendix A) will be submitted to the Principal Investigators of this project with each set of water samples that are transferred from the Yakama Nation to CWU for the geochemical laboratory analysis.

7.2.2 Field parameters and laboratory analytes to be measured

Every two weeks during the TFSARP recharge period and monthly thereafter, the following manual measurements will be made:

- Depth-to-groundwater in all wells in Figure 5.

Additional environmental parameters to be measured in the field:

- Stratigraphy in exposures along stream banks and unlined canals

In the laboratory at CWU, collected water samples will be analyzed for:

- Oxygen isotope ratio (oxygen-18/oxygen-16)
- Hydrogen isotope ratio (deuterium/hydrogen)
- Major element geochemistry (Table 7)

7.3 Modeling and analysis design

Not applicable.

7.3.1 Analytical framework

Not applicable.

7.3.2 Model setup and data needs

Not applicable.

7.4 Assumptions of study design

The study is based on the following assumptions:

- There is connection between the groundwater and surface water in the alluvial fan.
- The sediment and rock units recorded in the well logs accurately represent the stratigraphy of the alluvial fan and its aquifers.
- The water level in the wells represents the static water level in the portion of the aquifer where the well is screened or perforated. Most of the wells in this study were drilled specifically for the purpose of groundwater monitoring and none of them are currently pumped for use as a water source, so this assumption is reasonable.
- The water that is sampled from the groundwater wells is geochemically representative of the water from the aquifer(s) in which the wells are screened or perforated. This

includes an assumption that any mixtures of end member waters that are observed occurred in aquifers and not in well casings. This assumption is not met when wells have inadequate seals and there is leakage from the surface. In interpreting our data, we will remain open to the possibility that waters have been geochemically altered between the aquifer and the sampling point.

7.5 Possible challenges and contingencies

Contingency plans for potential sampling shortfalls are described below. There are no known environmental hazards in the study areas.

7.5.1 Logistical problems

Regular access to wells is a possible challenge. CWU personnel must be accompanied by a staff member of the Yakama Nation to access the study site, which is in a closed area of the Yakama Nation, and we are dependent on their schedule. They regularly measure water levels of wells within and near the TFSARP study area. We have been closely collaborating with the Yakama Nation Water Resource Program in the development of this project, and they have agreed to assist in the field measurements and sampling. The contingency plan if CWU personnel are not able to coordinate schedules is for the Yakama Nation personnel to collect the samples using the protocols described in this QAPP and in Appendix A.

7.5.2 Practical constraints

There is always the possibility of instrument failure, either in the field or in the laboratory. For field measurements, we have extra water-level tapes that can be substituted. In the laboratory, we also have alternative instruments that can be used. There is a Metrohm Ion Chromatograph in the Chemistry Department at CWU that can be used for major ion analyses. An Agilent Inductively Coupled Optical Emission Spectrometer (ICP-OES) can be used for analyses of calcium, magnesium, potassium, sodium, iron, copper, and lead. Finally, there are two operational isotope ratio mass spectrometers that can be used for stable isotope analyses of water if the Picarro water isotope analyzer breaks down.

7.5.3 Schedule limitations

The main person at CWU involved in accomplishing the tasks of this study is Sam Dossa, graduate student at CWU. Inasmuch as this research constitutes his thesis project, it will be his top priority. The research stipend funded in this project will allow him to devote his time to this research. Mary Weber of the Yakama Nation regularly measures water levels in the TFSARP study area and will coordinate with CWU to collect water samples. If her schedule is interrupted, it could affect the sample collection or measurements. The Yakama Nation has been regularly monitoring the TFSARP wells for several years, and the results of this current project are of significant interest to them, so we are confident that it will remain a priority through the course of this study.

8.0 Field Procedures

8.1 Invasive species evaluation

SOP EAP070, Version 2.2 (Parsons et al 2018) will be followed to minimize any chance of spreading of invasive species.

8.2 Measurement and sampling procedures

Collection of samples and associated field QC samples will follow accepted procedures. The principal investigator will ensure that field sampling personnel will be appropriately trained and thoroughly familiar with these procedures.

Sampling and measurement procedures will be based on the following SOPs:

- ASTM Standard Practices for Description and Identification of Soils (Visual-Manual Procedures). International Standard, Designation D2488-17e1 (2017).
- Collecting Groundwater Samples: Purging and Sampling Monitoring Wells for General Chemistry Parameters, Standard Operating Procedure EAP099 (Washington Department of Ecology, 2023a)
- Collecting Groundwater Samples for Metal Analysis from Water Supply Wells, Standard Operating Procedure EAP098 (Washington Department of Ecology, 2019a)
- Collection, Processing, and Analysis of Stream Samples, Standard Operating Procedure EAP034 (Washington Department of Ecology, 2017b)
- Groundwater Manual Depth to Water Measurements, Standard Operating Procedure EAP052 (Washington Department of Ecology, 2023b)

The following methods will be used for major ion analyses:

- U.S. EPA. 1997. Method 300.1: Determination of Inorganic Anions in Drinking Water by Ion Chromatography, Revision 1.0.
- http://quimica.udea.edu.co/~carlopez/cromatoion/ionchro_envir_anal.pdf
- Jackson P.E., 2006 Ion Chromatography in Environmental Analysis. Encyclopedia of Analytical Chemistry: Applications, Theory and Instrumentation.
http://quimica.udea.edu.co/~carlopez/cromatoion/ionchro_envir_anal.pdf

Sampling for stable isotope analysis will be done in accordance with protocols developed by the CWU laboratories that have been conducting these analyses. These procedures are documented in internal laboratory SOPs. The general method is documented in Lis et al. (2008).

The procedures for water sampling described here are in general agreement with Standard Operating Procedure EAP098 (Washington Department of Ecology, 2019a). The SOP provides greater detail on many of the steps in sampling.

This study will utilize monitoring wells that are not pumped or used as water sources. Water samples will be collected using a plastic well bailer that is smaller in diameter than the well pipe. The bailer is attached to a string and lowered into the well until it reaches the standing water within the well. The bailer is designed to allow inflow when it reaches the water, but automatically closes when it is raised, trapping the water sample inside. An outflow tube is inserted into the end of the bailer when it is retrieved at the surface, and the water is released into a clean, dry 15 ml sample bottle. The bottle is filled almost to the top, tightly sealed to avoid evaporation, and labeled as described in Section 8.5.

The person collecting samples will record the location of the sampling point relative to any treatment units or other in-line hydraulic components such as surge/pressure tanks or cisterns. Upon collection, samples will be labeled and stored as specified in Table 11 until delivery to the laboratory. When necessary, field equipment will be decontaminated using a Liquinox solution and rinsed with deionized water. If a piece of sampling equipment cannot be cleaned, it will be dedicated to the specific well.

Samples from small streams will be collected from the thalweg. For larger streams, samples will be collected from the side of the stream in a location where the water appears to be flowing and in continuity with the thalweg. When needed, an extendable sampling device or a Wildco horizontal alpha sampler will be used.

The near-surface stratigraphy will be described at exposures along stream banks and unlined canals to assess the range of typical surface sediment characteristics that could affect the shallow groundwater infiltration capacity within the general study area. Stratigraphic depth from the surface will be measured with a vertically placed measuring tape. Boundaries between major stratigraphic units, if any, will be noted. The average and range of grain sizes, macro organic content, roots, color, and cementation will be described for each major stratigraphic unit or soil horizon following the SOP in ASTM (2017). The location and ground elevation of each stratigraphic site will be obtained from hand-held GPS location and elevation measurements taken in the field, which will be refined as needed by deriving the elevation for the latitude/longitude location of the site from lidar imagery (Washington Lidar Portal, 2026).

8.3 Containers, preservation methods, holding times

Table 11 presents containers, preservation techniques, and holding times for all laboratory geochemical analyses. The container sizes will provide enough sample that it is possible to make at least five separate measurements of each parameter if needed.

Table 11. Sample containers, preservation, and holding times.

Parameter	Container	Sample Handling and Preservative	Holding Time
Alkalinity	250 mL high density polyethylene (HDPE) bottle	No headspace, store at 4°C	3 days
Major Ion: Chloride, Fluoride, Sulfate, Nitrate, Phosphate, Calcium, Magnesium, Potassium, Sodium, Ammonium	60 mL HDPE bottle	Filtered (0.45 micron), store at 4°C	28 days
Stable Isotopes (O and H)	15 mL HDPE bottle with screw cap	Tightly sealed to prevent evaporation	NA

8.4 Equipment decontamination

It is unlikely that any sample will contain high levels of contaminants or organic materials. In the event that one does, the following SOP will be used to decontaminate equipment: SOP EAP090, Decontamination of Sampling Equipment for Use in Collecting Toxic Chemical Samples (Washington Department of Ecology, 2021).

As necessary, all non-dedicated, non-disposable field equipment coming into contact with sample water will be cleaned between uses at subsequent sampling locations as needed to prevent cross-contamination of samples. The e-tape used for water-level measurements will also be cleaned after sampling.

8.5 Sample ID

Sample identification will be based on a format that includes the overall project and year, the site, the type of water, and a sample number. The format will be as follows: YRB26-TF-type-site-#, where YRB26 is this project designation and year, TF designates the Toppenish Fan project site, the type is either G (groundwater) or S (surface water), site abbreviation (Table 10) and the sample number (#). For each sampling location/date, the following information will be recorded in a field log:

- Sample number
- Sample location
- Well Tag ID
- Sampling date and time
- Sampler's name and names of other field personnel present
- Well purging information, if relevant (flow rate, duration, total volume purged)
- Field parameter readings during purging, if relevant
- Final (stabilized) field parameter readings, if relevant
- Analytes sampled for and number of bottles collected for each analysis
- QA samples collected

- Any other relevant information (field conditions, details of how sample was collected).

Sample bottles will be labeled using self-adhesive labels, which will be completed in indelible ink and include:

- Sample identification number
- Analysis type (cation, anion, isotope)
- Sample date and time
- Whether acid preservative is added, if relevant
- Whether field filtered, if relevant

Following completion of each sampling trip, the principal investigator will review the field logs recorded by the samplers for completeness, accuracy, and clarity. The principal investigator will retain a copy of all documentation.

8.6 Chain of custody

Samples collected by Yakama Nation personnel will remain in the custody of Mary Weber at the Yakama Nation until transferred to CWU personnel. Each transfer of samples will be accompanied by a Chain of Custody Form (Appendix A). Samples at CWU will remain within the custody of Carey Gazis or Sam Dossa at CWU throughout the project. They will be stored on project-designated shelves in a refrigerator in the Stable Isotope Laboratory in the CWU Geological Sciences Department.

8.7 Field log requirements

Field data will be recorded by field personnel at the time of measurement, sampling or observations in a field notebook (log). Data to be entered into field notebooks includes:

- names of field personnel
- date and location at top of each page in field notebook
- site or data logger identification and description
- well tag ID
- environmental conditions
- sequence of events
- dates and times of measurement, sampling or other activity
- appropriate field measurement values and units of measure
- any observations or unusual circumstances that might affect interpretation of results. This should include observations of surface water use and hydrology (water in tributaries, irrigation on neighboring properties, etc.)
- GPS locations of any stratigraphic descriptions or other field observations
- locations and subjects of photographs
- detailed notes on any deviations from prescribed procedures
- recommended field log practices include:
 - Use bound, waterproof notebooks with pre-numbered pages.

- Use pencil or permanent, waterproof ink for all entries.

8.8 Other activities

In addition to the standardized procedures described previously in Section 8, the following additional steps will be taken to ensure an adequate level of quality control during sampling:

- Field instruments will be calibrated and/or checked in accordance with the manufacturer's instructions on a daily basis at the beginning of each sampling day, and as needed during the day.
- All non-dedicated, non-disposable field equipment coming into contact with sample water will be cleaned between uses at subsequent sampling locations to prevent cross-contamination of samples. Prior to collection of samples, a rinsing with deionized water followed by rinsing with sample water shall be considered sufficient. The e-tape used for water-level measurements will be sanitized with bleach overnight after sampling. Between well sampling measurements, the tip of the e-tape that comes into contact with the water will be sanitized with bleach prior to rinsing with deionized water and sample water.
- Sources of extraneous contamination (generator fumes, gasoline, sunscreen, wearing of luminescent watches, etc.) will be minimized during sampling. Sampling personnel will employ a "clean hands/dirty hands" approach to sample collection.
- Equipment/filter field blanks will be collected during each sampling round to determine if sampling equipment or filters are introducing bias into the sampling results. Blanks will be used to determine whether the sample tubing, filters, sample containers, preservatives, or transport methods represent a source of bias. If bias is recognized in blank samples early in the project, additional steps will be taken to isolate the source of error, and field procedures or equipment will be modified to eliminate the problem.

Samples will be stored in a CWU refrigerator at 4 degrees C until analysis.

9.0 Laboratory Procedures

9.1 Lab procedures table

The standard laboratory quality control procedures in place at CWU are adequate to estimate laboratory precision and accuracy, as described in Appendix B. Laboratory quality control samples will include blanks, duplicates, matrix spikes, and check standards (QC standards). Blanks, laboratory control standards, matrix spikes will be used to estimate overall bias due to the combination of the analytical procedure and matrix interferences. Duplicates, laboratory control standard duplicates, and matrix spike duplicates will be analyzed to quantify analytical precision. Check standards will be used to verify analytical precision, to test for instrument drift, and to provide an estimate of bias due to calibration. Laboratory method blanks will be used to ensure that there is no contamination in the laboratory procedures.

Tables 12 presents a summary of the laboratory measurement methods, and Table 13 summarizes the types and minimum frequency of field and laboratory quality control samples for this project. If QC results regularly fall outside of the acceptable limits defined in Table 7, the investigators will review the sampling and/or analytical methods to determine an appropriate course of action to obtain the desired data quality and rerun samples as needed. Any changes in procedure will be submitted for approval to Ecology. If these changes are significant, a QAPP addendum will be submitted.

Table 12. Measurement methods (laboratory).

Analyte	Sample Matrix	Samples (Number/ Arrival Date)	Expected Range of Results*	Detection Limit	Sample Prep Method	Analytical (Instrumental) Method
Alkalinity	water	60/Dec 2020	30 - 500 mg/L	10 mg/L		titration
Chloride	water	60/Dec 2020	0 - 50 mg/L	0.1 mg/L	filtered	IC, EPA 300.1
Fluoride	water	60/Dec 2020	0 - 10 mg/L	0.1 mg/L	filtered	IC, EPA 300.1
Sulfate	water	60/Dec 2020	0 - 50 mg/L	0.5 mg/L	filtered	IC, EPA 300.1
Nitrate-N	water	60/Dec 2020	0 - 20 mg/L	0.1 mg/L	filtered	IC, EPA 300.1
Phosphate-P	water	60/Dec 2020	0 - 5 mg/L	0.05 mg/L	filtered	IC, EPA 300.1
Calcium	water	60/Dec 2020	0 - 100 mg/L	0.05 mg/L	filtered	IC, EPA 300.1
Magnesium	water	60/Dec 2020	0 - 50 mg/L	0.05 mg/L	filtered	IC, EPA 300.1
Potassium	water	60/Dec 2020	0 - 50 mg/L	0.05 mg/L	filtered	IC, EPA 300.1
Sodium	water	60/Dec 2020	0 - 100 mg/L	0.05 mg/L	filtered	IC, EPA 300.1
Oxygen-18	water	60/Dec 2020	-5 to -25‰	NA	filtered	CRS
Deuterium	water	60/Dec 2020	-30 to -170‰	NA	filtered	CRS

* Treatment of measurements below detection limits is discussed in section 14.2 (Treatment of Non-Detects)

The equipment and instrumentation that will be used in these analyses are:

- Ion chromatograph – Thermo Scientific Dionex ICS-5000+ IC
- Cavity ring down spectroscope – Picarro L2130-I Isotopic H₂O Analyser

In most cases, there is alternative instrumentation to perform each type of analyses in cases where equipment or instrumentation are malfunctioning.

9.2 Sample preparation method(s)

For major ion analyses, two samples are collected, one for cations and one for anions. Both samples are filtered in the field using a clean 60-ml polypropylene syringe connected to a 0.45 micron polypropylene filter. The cation sample is placed in a 60 ml acid-washed high-density polyethylene (HDPE) bottle. Upon return to the laboratory, cation samples are acidified with 2% ultrapure nitric acid. The anion sample is placed in a clean 60 ml HDPE bottle that has not been acid washed.

For stable isotope analysis, water samples are collected directly into clean, dry 15 mL HDPE bottles, filled almost to the top, and capped tightly. The main objective is to protect the sample from evaporation and exchange with atmospheric water vapor. Samples need not be filtered unless they contain abundant particulate matter.

All samples are stored in a refrigerator at 4 degrees C in the Stable Isotope Laboratory at CWU.

9.3 Special method requirements

Not applicable.

9.4 Laboratories accredited for methods

The Central Washington University Environmental Testing Laboratory is certified for the following analytes: Ca, Mg, K, Na, Cl, NO₃, SO₄, alkalinity, pH, and conductivity. The most recent certificate and the title page and table of contents of the QA/QC Manual are given in Appendix B.

Stable isotope analyses is a specialized type of geochemical analysis that does not have EPA accreditation criteria. Dr. Gazis's laboratory in the Geological Sciences Department at Central Washington University has been performing this type of analyses for over twenty years, including over 350 analyses for an Ecology-funded project in the Columbia Basin Groundwater Management Area (Vlassopoulos, 2009) and six previous YBIP projects funded by Ecology (Sleeper, 2020; Gazis, 2023; Gazis and Ely, 2023; Ely et al., 2024; Ely et al., 2026; Gazis et al., 2026). We regularly (at least annually) calibrate our instruments and internal isotope standards using international reference materials. We also perform periodic cross-laboratory measurements of internal standards with other isotope laboratories.

10.0 Quality Control Procedures

The quality control procedures for field and laboratory measurements are outlined in Sections 8 and 9. Field notebooks and field data will be reviewed after each sampling trip. Laboratory results will be reviewed immediately to ensure that quality control standards are within accepted range and that there are no problems with the blanks, duplicates, or matrix spikes. One of the co-principal investigators, Carey Gazis or Lisa Ely, will meet weekly with the graduate student researcher to review quality control results and discuss any problems that have arisen and will accompany them regularly to the field site. We will be in frequent contact with Mary Weber at the Yakama Nation about our collaboration on field data acquisition.

Most stratigraphy will be determined from existing well logs. The quality control for this information will be to assess the detail provided in the well log; those with minimal detail will not be used. The stratigraphy from others will be compared among logs across a transect for reasonable correlations in elevations of major stratigraphic units as well as compared with published geologic maps. The quality control procedure for documenting the locations of near-surface stratigraphy measured in the field will be to compare the relative elevations and locations with landmarks and benchmarks from aerial photographs and satellite imagery.

10.1 Table of field and laboratory quality control

Table 13 shows a plan for frequency and types of quality control samples.

Table 13. Quality control samples, types, and frequency.

Parameter	Field Blanks	Field Duplicates	Laboratory Check Standards	Laboratory Method Blanks	Analytical Duplicates	Laboratory Matrix Spikes
Alkalinity	NA	1/10	1/12	NA	1/6	NA
Chloride	1/20	1/10	1/6	1/12	1/6	1/20
Fluoride	1/20	1/10	1/6	1/12	1/6	1/20
Sulfate	1/20	1/10	1/6	1/12	1/6	1/20
Nitrate-N	1/20	1/10	1/6	1/12	1/6	1/20
Phosphate-P	1/20	1/10	1/6	1/12	1/6	1/20
Calcium	1/20	1/10	1/6	1/12	1/6	1/20
Magnesium	1/20	1/10	1/6	1/12	1/6	1/20
Potassium	1/20	1/10	1/6	1/12	1/6	1/20
Sodium	1/20	1/10	1/6	1/12	1/6	1/20
Oxygen-18	NA	1/10	1/6	NA	1/6	NA
Deuterium	NA	1/10	1/6	NA	1/6	NA

Each type of QC sample listed has MQOs associated with it (Section 6.2) that will be used to evaluate the quality and usability of the results.

10.2 Corrective action processes

If there is a problem with a single sample or a set of samples, a series of steps will be taken to correct any faulty data:

- A series of standards will be run through the instrument to ensure that it is accurate.
- If there is a problem with the instrument, the instrument technicians at CWU will help with any trouble-shooting to solve the problem.
- Once the instrument is running properly, the samples will be rerun and checked again for quality of analysis.
- If necessary, samples will be recollected using the method described in this QAPP.

For water depth measurements, the following corrective actions will be taken:

- Repeat manual measurement of depth-to-water.
- For field data collection with handheld GPS, the following steps will be taken to correct any faulty data:
- If there is a problem with the instrument or software, the instrument technicians at CWU will help with any trouble-shooting to solve the problem, which could include replacing the instrument.
- Once the instrument is running properly, the affected portion of the survey will be recalculated or resurveyed as appropriate using the method described in this QAPP.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

All field data will be recorded in a field notebook and on sample data sheets. Field notebooks will be checked for missing or improbable measurements before leaving each site. Field-generated sampling and measurement data will be entered into Excel spreadsheets or other instrument-specific formats as soon as practical after returning from the field or acquiring samples. Data entry will be checked by the field staff against the field notebook data for errors and omissions. Missing or unusual data will be brought to the attention of the project manager for consultation.

Laboratory-generated data will be managed by the Laboratory Information Management Systems (LIMS) at CWU and backed up to a dedicated data archive on the CWU Department of Geological Sciences server. In addition to sample results, the laboratory data package will include all relevant calibration standards and QC results needed for data validation.

Following evaluation of the analytical data against the project data quality objectives, the investigators will incorporate the results into a master Excel spreadsheet database. For each sample, the spreadsheet database will record station identification, coordinates, sampling date, and associated field and laboratory analytical data.

The documentation for each sampling location will include the completed field notebook (log) entry, a copy of the analytical results, as well as analytical results for associated field and laboratory QC samples. Full documentation for all samples will be compiled and stored on the CWU Geological Sciences data archive and at the Principal Investigator's office at CWU.

Results of quality control checks and calibrations will be recorded on electronic forms to allow for quality assurance review. Quality assurance records will be saved on CWU computers until Ecology's final approval of the project report so they may be accessed for post-project analysis and audits.

Samples and measurements collected in this study on the Yakama Nation land will not be uploaded to Ecology's EIM database. All data will be archived on the CWU Department of Geological Science server. Access to those data will be available upon request with prior permission obtained through the Yakama Nation Water Resource Program.

11.2 Laboratory data package requirements

The laboratory data will initially be transferred into an Excel workbook and sorted into the following worksheets:

1. Raw data
2. Results for calibration standards and calibrations
3. Results for QC standards with graph of results with time and comparison to quality control thresholds
4. Results of duplicates and any other QC samples and comparison with expected values
5. Results for unknown samples

11.3 Electronic transfer requirements

Data will not be transferred to Ecology's EIM system because the study site is on Yakama Nation land.

11.4 Data upload procedures

Data will not be transferred to Ecology's EIM system because the study site is on Yakama Nation land.

11.5 Model information management

Not applicable.

12.0 Audits and Reports

12.1 Audits

Not applicable.

12.2 Responsible personnel

See Table 1 in Section 5.1.

12.3 Frequency and distribution of reports

The data collected under this project will be summarized in a formal peer-reviewed report that includes results, methods, and data quality assessment. This final report will be submitted in March 2028.

12.4 Responsibility for reports

Lisa Ely, Carey Gazis, and Sam Dossa will co-author the final report.

13.0 Data Verification

All data collected are subject to review by the principal investigators to determine if the data meet QAPP objectives. Decisions to reject or qualify data are made by the principal investigators in conjunction with the other investigators. Data may be rejected because of inadequate or deficient documentation or because the QC sample results fail to meet the MQOs identified in Section 4.

13.1 Field data verification, requirements, and responsibilities

Field personnel will review data recorded in field notebooks for correctness, clarity and completeness at the end of each sampling day. Field notebooks will be scanned, reviewed by one of the principal investigators, and archived in the project database on the CWU Department of Geological Sciences server. Samples listed on the Chain of Custody forms (Appendix A) will be reviewed and verified against the individual sample bottle labels upon transfer to CWU.

13.2 Laboratory data verification

All laboratory data will undergo an initial quality assurance review by Sam Dossa to verify that laboratory quality control samples met acceptance criteria as specified in the laboratory's standard operating procedure for that method. The co-principal investigator, Carey Gazis, will provide a follow-up quality assurance review. Appropriate qualifiers will be attached to results that do not meet requirements. An explanation for the data qualification will be attached with the data package.

13.3 Validation requirements, if necessary

Not applicable.

13.4 Model quality assessment

Not applicable.

13.4.1 Calibration and validation

Not applicable.

13.4.1.1 Precision

Not applicable.

13.4.1.2 Bias

Not applicable.

13.4.1.3 Representativeness

Not applicable.

13.4.1.4 Qualitative assessment

Not applicable.

13.4.2 Analysis of sensitivity and uncertainty

Not applicable.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

After all field data are verified, the field lead or project manager will thoroughly examine the data to determine if MQOs have been met. The project manager will examine the data to determine if all the criteria for MQOs, completeness, representativeness, and comparability have been met. If the criteria have not been met, the project manager will decide if affected data should be qualified or rejected. The project manager will decide how any qualified data will be used in the technical analysis.

Upon receipt of the verified laboratory data, the co-principal investigator, Carey Gazis, will determine if the results meet the MQOs for bias, precision, and accuracy for that sampling episode. These values provide an indication of the degree of random variability introduced by sampling and analytical procedures. Analytical bias is assumed to be within acceptable limits if laboratory quality control limits are met for quality control and check standards. Sampling bias will be checked by verifying that the correct sampling and handling procedures were used.

To ensure that we are on track to meet the project objectives (Section 4.2), the PIs and graduate students will meet at least biweekly during the data collection and analysis phase to review the progress toward these objectives. All of the objectives can be measured with a number (e.g. number of samples collected) or the percentage completion can be estimated.

For each objective, we will review the percent completion and discuss any challenges that have been encountered in the field or laboratory. This will include a discussion of the sample location choices and the usefulness of the data for answering the research questions. In this way, we will track our progress to ensure that the project objectives are met. It will also allow us to adjust our sample or data collection as needed.

14.2 Treatment of non-detects

When a major ion is not detected, it will be entered as “nd” on the data table. This value will be converted to half of the detection limit for purposes of graphing and statistical analyses when necessary.

14.3 Data analysis and presentation methods

Stratigraphic data will be correlated and plotted in geologic cross sections. Locations will be presented in tabular form, plotted on geologic cross sections, and mapped.

Groundwater elevations derived from pressure transducer data (acquired from Yakama Nation) and manual depth-to-water measurements over the time period of the study will be graphically displayed. Once these have been plotted, comparisons can be made between wells, TFSARP recharge inflow canals, and nearby streams to estimate how hydraulic pressure is transmitted through time and space.

Geochemical data will be analyzed by a variety of means. To obtain a first-order view of geochemical variations, major ion data will be plotted on Piper diagrams and Stiff plots; stable isotope data will be displayed on a plot of $\delta^{18}\text{O}$ versus δD . Initially, a matrix scatter plot will be examined to find first order correlations between variables.

Based on that result, simple x-y plots of data pairs will be examined to quantify correlations between variables and any clustering among samples. Changes in the stable isotope values through time and space will be analyzed to assess the travel and mixing of TFSARP recharge with groundwater.

Two main multivariate analysis methods, hierarchical cluster analysis and principal component analysis, will be applied to the entire data set and subsets of the data to determine the defining characteristics of distinct groundwater chemistries at the study site. Multivariate analyses will be performed using JMP or R software. If necessary, this process will be repeated with subsets of samples to determine the robustness of the results.

14.4 Sampling design evaluation

The sampling design is based on existing information, and the actual conditions at the site may be more complex than indicated. The spatial distribution of the sampling locations is partially pre-determined by the locations of the existing wells at the study sites. If we identify deficiencies in our sampling design, we will evaluate the potential consequences on the project. We may recommend adding or changing the locations of sampling sites, or changing the frequency of sampling campaigns to resolve such problems.

The geochemical sampling design targets 20 sites for frequent sampling for stable isotopes within the TFSARP area, for a total of 300 samples over the course of the study. Most of the interpretations of spatial patterns and temporal changes across the study will be based on the stable isotope results, for which we will produce ample data.

An additional 10 sites will be sampled less frequently for major ion geochemistry, with a target of 35 sample analyses. For multivariate methods such as principal component analysis, a greater number of samples is always preferable, especially if one intends to document multivariate normality in principal component analysis.

However, this is not our intent. In our experience, 35 samples should be sufficient for exploratory purposes to determine end member and mixed groundwater chemistries. Even if interpretation of the multivariate analysis proves to be difficult, it is likely that the combination of graphical and statistical analyses of the geochemical data will provide important insight into the hydrogeology of the study area.

14.5 Documentation of assessment

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

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16.0 Appendices

Appendix A. Sampling and Measurement Data Sheets

Data sheets that will be used for measurements and sample transfer in Toppenish alluvial fan study area.

Data Sheet A-1. Yakama Nation Monitoring Well Water Depth Measurement Data Sheet.

Yakama Nation Water Resource Program

Monitoring Well Record

Well ID _____ Historic Well ID _____ T/R/S ID _____

GPS Location [dec. deg.] _____ N _____ W

GPS Source _____ GPS Datum _____ Well Casing Size [in] _____

Well Elevation _____ Well Elev. Source _____ Well Depth _____

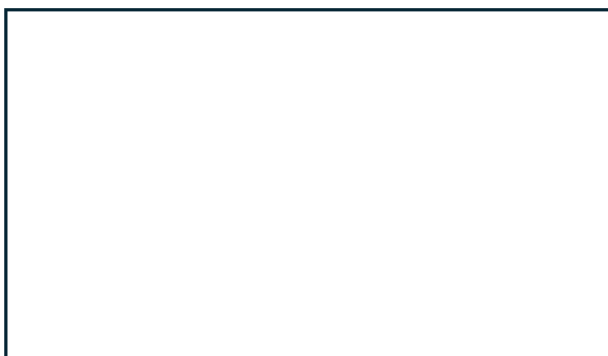
Owner Name and Phone #: _____

Address: _____

Well Location in Section

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Diagram of Well and Access



Describe Access to Well

Comments:

MP Number	MP Height from LS [ft]	MP Description

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Note: E-Tape measurement is listed from the MP; SS is Site Status (see below) and MM is Method of Measurement (see below)

Method of Measurement					
Airline	A	Calibrated Pressure Gage	H	Steel Tape	S
Analog	B	Geophysical Logs	L	Electric Tape	T
Calibrated Airline	C	Manometer	M	Calibrated Electric Tape	V
Estimated	E	Non-Recording Gage	N	Other	Z
Pressure Gage	G	Reported	R		

Data Sheet A-2.Yakama Nation Transducer Deployment Record Data Sheet.

Yakama Nation Water Resource Program

Transducer Deployment Record

Date: _____

Well Identification Number: _____

Historic Well Name: _____

Well Location (Township/Range/Section): _____

Well Owner's Contact Information (Name, Phone Number): _____

Well Depth [ft]: _____

Well Casing Size at Surface [in]: _____

Land Surface Elevation [ft]: _____

Land Surface Elev. Source: _____

Latitude (Dec. Degree): _____

Longitude (Dec. Degree): _____

Datum: _____

Time transducer deployed: _____

Transducer name: _____

mp [ft]: _____

eb [ft]: _____

Total Line Length [ft]: _____

E-tape Measurement [ft]: _____

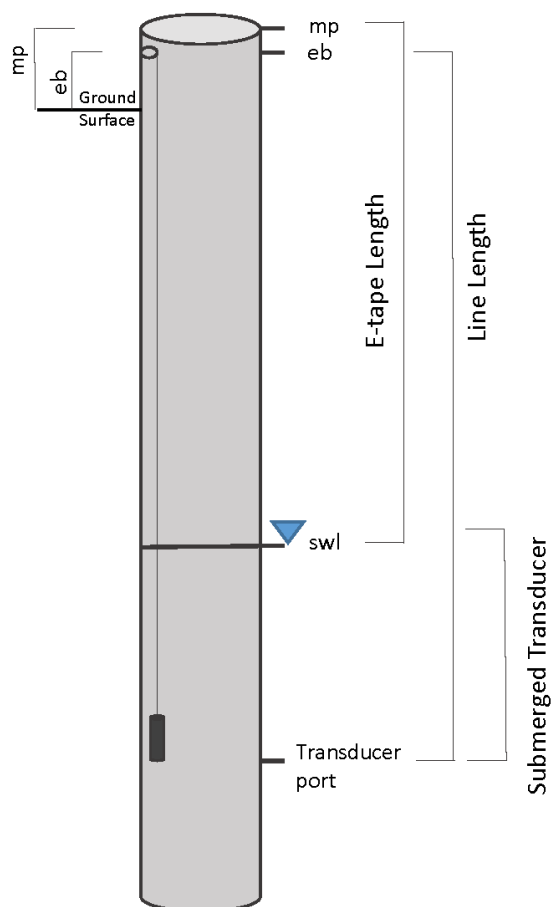
Other Notes:

Definitions

mp - elevation of monitoring point above or below land surface
(example: top of the well casing)

eb – eye bolt or elevation above or below land surface where a
transducer is tied off

swl – static water level



Data Sheet A-2 (continued).

Download and Redeployment Data Sheet

[illegible]

We will not be collecting pressure transduction data of water levels in wells as part of this study, but will acquire existing pressure transducer data from wells in the study area collected by the Yakama Nation Water Resource Program. This data sheet is included here as an example of the quality control protocols in place for those data.

Data Sheet A-3. Chain of Custody Form for Toppenish Fan Samples.

This form will be used to document the transfer of samples collected on the Toppenish alluvial fan study site from the Yakama Nation Water Resource Program to Central Washington University.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Contact Information											
2	Name:											
3												
4	e-mail:											
5												
6	phone:											
7												
8	Project Name: CWU Toppenish Fan Study											
9												
10										Analyses Requested		
		Sample ID	Date sampled	Time sampled	Latitude	Longitude	Matrix (soil, water)	Other comments	# of containers	Trace elements*	Major elements**	Stable Isotope ***
11												
12		1			known	known	water					
13		2			""	""	water					
14		3			""	""	water					
15		4			""	""	water					
16		5			""	""	water					
17		6			""	""	water					
18		7			""	""	water					
19		8			""	""	water					
20		9			""	""	water					
21		10			""	""	water					
22		11			""	""	water					
23		12			""	""	water					
24		13			""	""	water					
25		14			""	""	water					
26		15			""	""	water					
27		16			""	""	water					
28		17			""	""	water					
29		18			""	""	water					
30		19			""	""	water					
31		20			""	""	water					
32		21			""	""	water					
33		22			""	""	water					
34		23			""	""	water					
35		24			""	""	water					
36		25			""	""	water					
37	*standard trace element analysis includes Al, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Mo, Ba, Pb, U											
38	**standard major element analysis includes Ca, Na, K, Mg, Si											
39	***stable isotope analysis available are δD and $\delta^{18}O$ in water and δN and $\delta^{18}O$ in nitrate											
40	Collected/Relinquished by:			Received by:								
41	Name			Name								
42												
43	Signature			Signature								
44												
45	Date			Date								
46												
47	Relinquished by:			Received by:								
48	Name			Name								
49												
50	Signature			Signature								
51												
52	Date			Date								
53												
54	Relinquished by:			Received by:								
55	Name			Name								
56												
57	Signature			Signature								
58												
59	Date			Date								

Appendix B. Laboratory Quality Assurance/Control Manual

The following pages contain the accreditation certificate for the Environmental Testing Laboratory at Central Washington University and the title page and table of contents from the laboratory's Quality Assurance/Quality Control Manual.

The State of
Department

Washington
of Ecology

CWU Environmental Testing Laboratory

Ellensburg, WA

has complied with provisions set forth in Chapter 173-50 WAC and is hereby recognized by the Department of Ecology as an ACCREDITED LABORATORY for the analytical parameters listed on the accompanying Scope of Accreditation.

This certificate is effective 4/25/2026 and shall expire 4/24/2027.

Witnessed under my hand on 4/24/2026.



Rebecca Wood
Lab Accreditation Unit Supervisor

Laboratory ID
A541

WASHINGTON STATE DEPARTMENT OF ECOLOGY

ENVIRONMENTAL LABORATORY ACCREDITATION PROGRAM

SCOPE OF ACCREDITATION

CWU Environmental Testing Laboratory

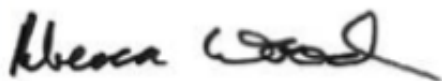
Ellensburg, WA

is accredited for the analytes listed below using the methods indicated. Full accreditation is granted unless stated otherwise in a note. EPA is the U.S. Environmental Protection Agency. SM is "Standard Methods for the Examination of Water and Wastewater." SM refers to EPA approved method versions. ASTM is the American Society for Testing and Materials. USGS is the U.S. Geological Survey. AOAC is the Association of Official Analytical Chemists. Other references are described in notes.

Matrix/ Analyte	Method	Note
Non-Potable Water		
Specific Conductance	EPA 120.1 1982	
Chloride	EPA 300.0 2.1 1993	
Nitrate	EPA 300.0 2.1 1993	
Sulfate	EPA 300.0 2.1 1993	
Calcium	EPA 300.7	1
Magnesium	EPA 300.7	1
Potassium	EPA 300.7	1
Sodium	EPA 300.7	1
Alkalinity	SM 2320 B-2011	
pH	SM 4500-H+ B-2011	

Accredited Parameter Note Detail

(1) Method not approved for NPDES testing.



Authentication Signature
Rebecca Wood, Lab Accreditation Unit Supervisor

04/24/2026

Date

Washington State Department of Ecology

Effective Date: 4/25/2026

Scope of Accreditation Report for CWU Environmental Testing Laboratory

Certificate Number: A541-26

Laboratory Accreditation Unit

Page 1 of 1

Scope Expires: 4/24/2027

QUALITY ASSURANCE/QUALITY CONTROL MANUAL
CENTRAL WASHINGTON UNIVERSITY
ENVIRONMENTAL TESTING LABORATORY



CWU Environmental Testing Lab – USEPA ID WA00210

Updated March 2025

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Appendix C. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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

Anthropogenic: Human-caused.

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

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

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

Chronic critical effluent concentration: The maximum concentration of effluent during critical conditions at the boundary of the mixing zone assigned in accordance with WAC [173-201A-100](#). The boundary may be based on distance or a percentage of flow. Where no mixing zone is allowed, the chronic critical effluent concentration shall be 100% effluent.

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

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

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

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

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

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

Dilution factor: The relative proportion of effluent to stream (receiving water) flows occurring at the edge of a mixing zone during critical discharge conditions as authorized in accordance with the state's mixing zone regulations at WAC 173-201A-100.

<http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-020>

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

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

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

Enterococci: A subgroup of the fecal streptococci that includes *S. faecalis*, *S. faecium*, *S. gallinarum*, and *S. avium*. The enterococci are differentiated from other streptococci by their ability to grow in 6.5% sodium chloride, at pH 9.6, and at 10 degrees C and 45 degrees C.

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

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

Extraordinary primary contact: Waters providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas.

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

Fish Tissue Equivalent Concentration (FTEC): The FTEC is a tissue contaminant concentration used by Ecology to determine whether the designated uses of fishing and drinking from surface waters are being met. The FTEC is an interpretation of Washington's water quality criterion for a specific chemical for the protection of human health: the National Toxics Rule (40 CFR 131.36). Fish tissue sample concentrations that are lower than the FTEC suggest that the uses of fishing and drinking from surface waters are being met for that specific contaminant. Where an FTEC is not met (i.e., concentration of a chemical in fish tissue is greater than the FTEC), that water body is then placed into Category 5 during Washington's periodic Water Quality Assessment ([WQA and 303d List](http://www.ecy.wa.gov/programs/Wq/303d/index.html)<http://www.ecy.wa.gov/programs/Wq/303d/index.html>).

Category 5 listings become part of Washington's 303(d) list during the assessment process. The FTEC is calculated by multiplying the contaminant-specific Bio-Concentration Factor (BCF) times the contaminant-specific Water Quality Criterion found in the National Toxics Rule.

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

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

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

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

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

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

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

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

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

pollution that does not meet the legal definition of “point source” in section 502(14) of the Clean Water Act.

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

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

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

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

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

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

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

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

Reach: A specific portion or segment of a stream.

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

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

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

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

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

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

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

System potential: The design condition used for TMDL analysis.

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

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

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

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

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

Total Maximum Daily Load (TMDL): A distribution of a substance in a water body designed to protect it from not meeting (exceeding) water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a margin of safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

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

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

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

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

1-DMax or 1-day maximum temperature: The highest water temperature reached on any given day. This measure can be obtained using calibrated maximum/minimum thermometers or continuous monitoring probes having sampling intervals of thirty minutes or less.

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.

7-DADMax or 7-day average of the daily maximum temperatures: The arithmetic average of seven consecutive measures of daily maximum temperatures. The 7-DADMax for any individual day is calculated by averaging that day's daily maximum temperature with the daily maximum temperatures of the three days before and the three days after that date.

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

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

90th percentile: An estimated portion of a sample population based on a statistical determination of distribution characteristics. The 90th percentile value is a statistically derived estimate of the division between 90% of samples, which should be less than the value, and 10% of samples, which are expected to exceed the value.

Acronyms and Abbreviations

BMP Best management practice

DO Dissolved oxygen

DOC Dissolved organic carbon

e.g. For example

Ecology Washington State Department of Ecology

EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
FC	Fecal coliform
GIS	Geographic Information System software
GPS	Global Positioning System
i.e.	In other words
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
NAF	New Approximation Flow
NPDES	National Pollutant Discharge Elimination System
NSDZ	Near-stream disturbance zones
NTR	National Toxics Rule
PBDE	Polybrominated diphenyl ethers
PBT	Persistent, bioaccumulative, and toxic substance
PCB	Polychlorinated biphenyls
QA	Quality assurance
QC	Quality control
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
SRM	Standard reference materials
TIR	Thermal infrared radiation

TMDL Total Maximum Daily Load

TOC Total organic carbon

TSS Total suspended solids

USFS United States Forest Service

USGS United States Geological Survey

WAC Washington Administrative Code

WDFW Washington Department of Fish and Wildlife

WQA Water Quality Assessment

WRIA Water Resource Inventory Area

WSTMP Washington State Toxics Monitoring Program

WWTP Wastewater treatment plant

Units of Measurement

°C degrees centigrade

cfs cubic feet per second

cfu colony forming units

cms cubic meters per second, a unit of flow

dw dry weight

ft feet

g gram, a unit of mass

kcfs 1000 cubic feet per second

kg kilograms, a unit of mass equal to 1,000 grams

kg/d kilograms per day

km kilometer, a unit of length equal to 1,000 meters

L/s liters per second (0.03531 cubic foot per second)

m meter

mm millimeter

mg milligram

mgd million gallons per day

mg/d milligrams per day

mg/kg milligrams per kilogram (parts per million)

mg/L milligrams per liter (parts per million)

mg/L/hr milligrams per liter per hour

mL milliliter

mmol millimole or one-thousandth of a mole

mole an International System of Units (IS) unit of matter

ng/g nanograms per gram (parts per billion)

ng/kg nanograms per kilogram (parts per trillion)

ng/L nanograms per liter (parts per trillion)

NTU nephelometric turbidity units

pg/g picograms per gram (parts per trillion)

pg/L picograms per liter (parts per quadrillion)

psu practical salinity units

s.u. standard units

µg/g micrograms per gram (parts per million)

µg/kg micrograms per kilogram (parts per billion)

µg/L micrograms per liter (parts per billion)

µm micrometer

µM micromolar (a chemistry unit)

µmhos/cm micromhos per centimeter

μS/cm microsiemens per centimeter, a unit of conductivity

ww wet weight

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 (Kammin, 2010). For Ecology, it is defined according to WAC 173-50-040: "Formal recognition by [Ecology] that an environmental laboratory is capable of producing accurate and defensible analytical data."

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* (USEPA, 2014).

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: Discrepancy between the expected value of an estimator and the population parameter being estimated (Gilbert, 1987; USEPA, 2014).

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, 2014; USEPA, 2020).

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, 2014; USEPA 2020).

Continuing Calibration Verification Standard (CCV): A quality control (QC) sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a

midpoint calibration standard that is re-run at an established frequency during the course of an analytical run (Kammin, 2010).

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

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

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

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

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

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

Data validation: The process of determining that the data satisfy the requirements as defined by the data user (USEPA, 2020). There are various levels of data validation (USEPA, 2009).

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 all 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, 2014).

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)/LCS duplicate: 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. Monitors a lab's performance for bias and precision (USEPA, 2014).

Matrix spike/Matrix spike duplicate: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias and precision errors 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 (USEPA, 2001).

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): The minimum measured concentration of a substance that can be reported with 99% confidence that the measured concentration is distinguishable from method blank results (USEPA, 2016). MDL is a measure of the capability of an analytical method of distinguished samples that do not contain a specific analyte from a sample that contains a low concentration of the analyte (USEPA, 2020).

Minimum level: Either the sample concentration equivalent to the lowest calibration point in a method or a multiple of the method detection limit (MDL), whichever is higher. For the purposes of NPDES compliance monitoring, EPA considers the following terms to be synonymous: "quantitation limit," "reporting limit," and "minimum level" (40 CFR 136).

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:

$$RPD = [Abs(a-b)/((a + b)/2)] * 100\%$$

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).

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).

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).

Reporting level: Unless specified otherwise by a regulatory authority or in a discharge permit, results for analytes that meet the identification criteria (i.e., rules for determining qualitative presence/absence of an analyte) are reported down to the concentration of the minimum level established by the laboratory through calibration of the instrument. EPA considers the terms “reporting limit,” “quantitation limit,” and “minimum level” to be synonymous (40 CFR 136).

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, 1992).

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, 2014).

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, 2014).

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).

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