

Quality Assurance Project Plan

Using Isotopes to Trace Groundwater Movement and Mixing at Taneum MAR Site

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Using Isotopes to Trace Groundwater Movement and Mixing at Taneum MAR Site

WRYBIP-2527-CeWaUn-00079

By Carey Gazis and Lisa Ely

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2.0 Abstract

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 for use during seasonal dry periods or drought. A 60-acre parcel next to Taneum Creek, northwest of Thorp, WA, has been identified as a location where infrastructure to provide recharge water is present and soil and aquifer conditions are appropriate for aquifer recharge through surface infiltration. A pilot test was conducted in 2023 and the site is now being developed for MAR by Kittitas Reclamation District (KRD).

The goal of this project is to better understand the fate of the recharge mound at the Taneum MAR site. This will be accomplished by determining stable isotope composition of recharge water and groundwater collected before, during and after a recharge event. The isotope data will be used to trace recharge water movement and mixing with ambient groundwater. The geochemical data will be combined with water elevation data to estimate seepage rates and travel times to the Yakima River. In assessing this site, the project will also serve as a proof-of-concept for application of the stable isotope tracer method at other MAR sites.

3.0 Background

3.1 Introduction and problem statement

The Taneum Creek MAR site is a 60-acre parcel owned by the Bureau of Reclamation, located on the Taneum Creek floodplain at River Mile 2 (Figure 1). This site was highly ranked in a 2021 assessment of MAR potential in the Yakima Basin (EA Engineering et al., 2021) based on land access, suitable hydrogeology, and the proximity to infrastructure that can provide recharge water. Over the past five years, Kittitas Reclamation District (KRD) has prepared the site for MAR, including installation of four monitoring wells and a pilot test in 2023. However, the site is relatively close to both Taneum Creek and the Yakima River and one question that remains is how quickly artificially recharged water will move into one or both of these nearby surface water bodies.



Figure 1. Map of Taneum MAR site. Location of monitoring wells (MW), tream gage, and KRD infrastructure is shown. Modified from Gregory and Jacobs (2024).

The purpose of the project is to use stable isotopes to better understand the fate of the recharge water that is applied at this site. In particular, the project aims to determine the travel time of that water to the Yakima River and thus explore the overall benefit to streamflow of MAR at the Taneum site. This study will also serve as a proof-of-concept for the use of isotopes to estimate groundwater flow and travel times at other potential MAR sites.

Stable isotopes are useful for tracking movement of recharge water, particularly in cases where that water is isotopically distinct from the resident groundwater. Previous studies indicate that recharge water from the Yakima River is isotopically heavier and distinct from the ambient groundwater (Vaccaro, 2011; Hinkle and Ely, 2013; Taylor and Gazis, 2014; Vlasenko, 2023).

This difference in isotopic composition will allow for calculations of percent contribution of the two end members within a mixture. When recharge is added to an area in a single event, that recharged water will tend to flow downgradient in the aquifer, spreading both through diffusion and mechanical dispersion, as it moves downgradient.

The general method of this project is to combine isotope data with water elevation data to characterize the movement of groundwater after a recharge event at the Taneum MAR site. Isotope data tracks the movement of water molecules themselves, while elevation data tracks the pulse of pressure that is transmitted through the subsurface after the rapid head increase resulting from recharge. Ideally, we will observe both a natural recharge event during snowmelt and an artificial recharge using the KRD infrastructure and water derived from the Yakima River.

Based on previous isotopic studies near the Teanaway River (Petralia, 2023; Gazis and Ely, 2024), we expect that the two wells closest to Taneum Creek will be fed to a large degree by Taneum Creek and will vary seasonally along with the Taneum Creek water. The uphill wells likely have more influence from snowmelt and other hillslope inputs. The Yakima River is isotopically distinct from Taneum Creek waters. An artificial recharge event with Yakima River water should be discernible, especially in the well closest to the application area. The isotope data will be used to calculate proportions of recharge water versus ambient water at each location with time. For each well, the time between recharge and observation of that isotopic change in well water will be determined. Isotope data and analysis will be combined with an analysis of groundwater elevations to refine our conceptual model of groundwater flow at the site.

The project will be directed by Dr. Carey Gazis and Dr. Lisa Ely of the Department of Geological Sciences at Central Washington University (CWU), who will manage the project tasks and budget, prepare a QAPP, and submit the final report. A CWU graduate student, Adriana Pacheco Garcia, will participate in the data collection and analysis for a master's thesis. The project has been developed in collaboration with Kittitas Reclamation District (KRD), who will provide access to hydrological data, and water sample collection wells.

3.2 Study area and surroundings

3.2.1 History of study area

The Taneum Creek MAR site (Figure 1) is located on the Taneum Creek floodplain at river mile 2, in the area where the Taneum Creek Valley opens into the Kittitas Basin. It is an ≈60-acre parcel of land that is owned by the Bureau of Reclamation (Reclamation) and was previously farmed. The site was the highest ranked in a 2021 assessment of MAR potential in the Yakima Basin by KRD (EA Engineering et al., 2021). This high ranking was based on land access, suitable hydrogeology, and the proximity to infrastructure that can provide recharge water. This infrastructure includes a flume which carries diverted Yakima River water downgradient, allowing for management of Yakima streamflow and distribution of irrigation water and the Taneum Creek (TC) Chute, which runs along the west side of the property and contains overflow water from the flume.

The parcel is a field immediately adjacent to Taneum Creek on the north side. The basic hydrogeology of the site is that of a floodplain with mixed sedimentary fill underlain by basalt bedrock. On the field, the sedimentary fill is believed to be braided channel deposits that fine upward and host an unconfined aquifer. Water can be supplied to the site either through the KRD canal system which runs across the area, or from two smaller irrigation entities, Taneum Canal Company or Mann Ditch, or potentially from Taneum Creek itself.

To aid in MAR assessment at the Taneum site, KRD emplaced four monitoring wells on the corners of the parcel (Figure 1) and have monitored water levels in those wells since 2021. Based on those well logs, the aquifer is 40 to > 60 ft thick and the depth to groundwater in the four wells ranges from 1-3 ft in the southeast corner to 8-12 ft in the northeast corner.

A pilot test was conducted at the site in September, 2023 by Gregory Geologic LLC (described in Gregory and Jacobs, 2024). Approximately 53 acre-ft of water was applied to the field over seven days, applied through three north/south ditches at the site, fed by the KRD infrastructure. Water levels in the four monitoring wells were observed along with patterns of inundation on the field. During this pilot test, head increases were observed in all four observation wells (Figure 2).

The peak in head moved downgradient within less than a week, but the water table remained above pre-test level for over three weeks in three of the four wells. Based on these observations, Gregory and Jacobs (2024) estimate that the recharge water is delayed by approximately 6 to 8 weeks before discharging to the Yakima River.

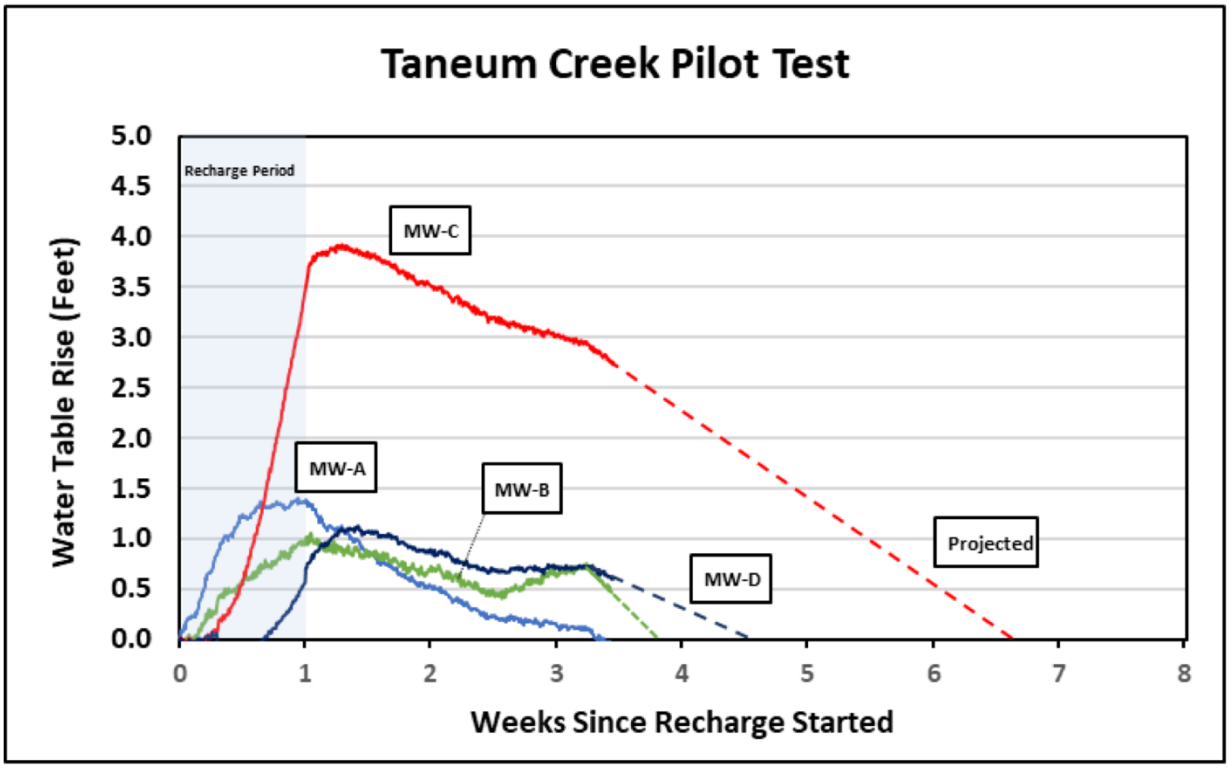


Figure 2. Groundwater levels after MAR pilot test. Duration of pilot test is shown by blue shading. Locations of MW wells is shown in Figure 1. Figure from Gregory and Jacobs (2024).

Although the results of this pilot test are promising, some questions remain regarding the fate of the recharge water. Given the site's proximity to Taneum Creek, it is possible that some recharge water is discharged more directly to Taneum Creek, decreasing its retention time. The hydraulic properties of the aquifer, particularly permeability and porosity, are not well constrained. In addition, it is possible that there are preferential flow paths such as paleochannels in this floodplain aquifer that increase transport times and dominate the overall transmissivity of the location.

The 2023 pilot test was conducted in September, at a time when the water table was at its lowest and soils were dry. Water availability and managed aquifer recharge is likely to occur in the spring, when the water table is higher and soils are wetter. For this reason, KRD is proposing to conduct a smaller scale pilot test in a spring month. We propose to coordinate with this small-scale pilot test to conduct our study.

3.2.2 Summary of previous studies and existing data

As described above, a pilot test was conducted at the site in September, 2023 by Gregory Geologic LLC (described briefly above and in Gregory and Jacobs, 2024). Approximately 53 acre-ft of water was applied to the field over seven days, applied through three north/south ditches at the site, fed by the KRD infrastructure. Water levels in the four monitoring wells were observed along with patterns of inundation on the field. During this pilot test, head increases

were observed in all four observation wells (Figure 2). The peak in head moved downgradient within less than a week, but the water table remained above pre-test level for over three weeks in three of the four wells. Based on these observations, Gregory and Jacobs (2024) estimate that the recharge water is delayed by approximately 6 to 8 weeks before discharging to the Yakima River.

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 – these are being measured by the Kittitas Reclamation District.
- Stable isotope 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

The project investigates the fate of recharge water at the Taneum Creek Managed Aquifer Recharge (MAR) site. It uses stable isotopes and groundwater elevations to determine the travel time of recharge water to the Yakima River and thus explore the overall benefit to streamflow of MAR. The technique and results can be applied to other potential MAR sites.

4.1 Project goals

The goal of this project is to better understand the fate of the recharge mound at the Taneum site when water is applied through MAR. This will be accomplished by determining stable isotope composition of recharge water and groundwater collected before, during and after a managed recharge event. The isotope data will be used to trace recharge water movement and mixing with ambient groundwater. The geochemical data will be combined with water elevation data and modelled to estimate seepage rates and travel times to the Yakima River. In assessing this site, the project will also serve as a proof-of-concept for application of the stable isotope tracer method at other MAR sites.

Use geochemistry to trace surface water recharge and mixing with groundwater. Stable isotope geochemistry 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 most effective locations for groundwater recharge and predicting the fate of a groundwater mound created by artificial recharge.

4.2 Project objectives

The specific project objectives are to:

- Describe the physical stratigraphy and hydrogeological characteristics of the Taneum MAR site based on analysis of existing well logs and previous studies (e.g., Gregory and Jacobs, 2024).
- Map relevant surface characteristics of the MAR site 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.
- Document seasonal and spatial variations in groundwater levels at Taneum MAR. This will be done using measurements collected by KRD at four monitoring well.
- Determine stable isotope composition for samples from surface waters and groundwater wells at the Taneum MAR site. Use data to characterize movement and mixing of recharge water.
    - Collect water samples from four monitoring wells and nearby surface water sites before, during, and after a recharge event.
    - Analyze samples for oxygen and hydrogen isotopic composition.

    - Analyze isotope results using mixing models to determine proportions of recharge water in monitoring wells with time.
- Compare isotope analysis results to water level measurements in wells with time and simple calculations of seepage velocity based on estimated aquifer properties.

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://appswr.ecology.wa.gov/wellconstruction/map/WCLSWebMap/default.aspx
- 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).
- Existing and ongoing measurements of groundwater levels from pressure transducers in piezometers within the Taneum MAR site will be obtained from KRD.
- Stream discharge data for Taneum Creek will be obtained from a nearby gage at Brain Ranch station on Taneum Creek (Ecology Freshwater DataStream, 2026): https://apps.ecology.wa.gov/continuousflowandwq/StationDetails?sta=39P080&tab=_DSG

Validation for existing data will depend on its source and use. Some of the existing data, most notably the well logs, is known to be inaccurate at times and inconsistent between well loggers. This data will be assessed based on comparisons with nearby well logs and known geological stratigraphy and structures. Pressure transducer groundwater elevations will be assessed based on comparisons with our manual measurements.

Prior to incorporation into project analyses, existing datasets will be evaluated for completeness, comparability, documentation, analytical methods, quality assurance procedures, and consistency with project data quality objectives. Only datasets determined to be of sufficient quality and appropriate for project objectives will be used in the interpretation of project results.

Data to be generated through this study:

- Stable isotopes of O and H for 200 surface-water and groundwater samples collected during and outside of the recharge period.
- Surface waters will be sampled daily to weekly during the recharge period; both will be sampled biweekly after the recharge period. See Section 7.2 for well locations.

4.4 Tasks required

- Construct topographic and stratigraphic cross sections of study area based on the well logs, geologic maps and exposed stratigraphy in stream banks and unlined canals.
- Acquire streamflow data from the Brain Ranch station on Taneum Creek (Ecology Freshwater DataStream, 2026) as listed in section 4.3 of this QAPP.
- Acquire existing measurements of groundwater levels in four piezometers at Taneum MAR site from KRD as listed in Section 4.3.
- Collect 200 water samples from surface water locations and wells at Taneum MAR site during and outside of the recharge period. Surface waters will be sampled weekly and groundwater daily to biweekly 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 for sample locations.
- Conduct laboratory measurements of stable isotope ratios.
- Compile and analyze new data including graphical and statistical analysis, assessment of spatial patterns in groundwater flow, and mixing between recharge water and ambient groundwater.
- 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 Carey Gazis and Lisa Ely for Central Washington University (CWU). Dr. Gazis, a professor in the Department of Geological Sciences at CWU, is the Project Manager and Principal Investigator; Dr Ely, a professor in the Department of Geological Sciences at CWU is the co-Principal Investigator. Much of the project work will be undertaken by Adriana Pacheco-Garcia, a M.S. graduate student at CWU, as part of her thesis research. The Principal Investigators and graduate student at CWU 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
Carey Gazis 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 review of data. Oversee analysis and interpretation of geochemical and groundwater data. Prepare final report in collaboration with Lisa Ely, with input from Adriana Pacheco-Garcia.
Lis Ely Geological Sciences Dept. Central Washington Univ. Phone: 509-963-2820	Co-Principal Investigator	Collaborate on writing the QAPP. Collaborate on QA review and data analysis. Collaborate on preparation of final report with Carey Gazis, with input from Adriana Pacheco-Garcia.
Adriana Pacheco-Garcia Geological Sciences Dept. Central Washington Univ.	Graduate Student Researcher	Conduct research on Taneum MAR site. Compile existing data. Collect samples and record field information. Enter data into EIM database. Work with Dr. Gazis and Dr. Ely 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: 509-823-0996	OCR Quality Assurance Coordinator	Review and approve the draft and final QAPP

QAPP: Quality Assurance Project Plan
NEP: National Estuary Program
WQX: Water Quality Exchange

5.2 Special training and certifications

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

Ms. Pacheco Garcia will receive training in laboratory safety, sample preparation, and use of the Picarro water isotope analyzer and ion chromatograph. These trainings 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

Tables 2 – 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	Gazis and Ely
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	March, 2028	Gazis
EIM QA	NA	NA
EIM complete	NA	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	Gazis and Ely
Final report	March 31, 2028	Gazis and Ely

5.5 Budget and funding

This project is funded by the Department of Ecology Office of Columbia River Grant WRYBIP-2527-CeWaUn-00079, 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, Adriana Pacheco Garcia; 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 200 water samples. The remainder of Dr. Gazis's 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 and supplies, software and training	$6700
Travel and other	$700
Graduate student tuition	$10,897
Laboratory (See Table 6 for details.)	$3000

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	200		200	$15	$3000
Stable Isotope Analyses (QA)		12	12	NA	0

6.0 Quality Objectives

6.1 Data quality objectives [2]

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

1) Collect 200 water samples to analyze the geochemisty of the groundwater and surface water at the Taneum MAR site during and outside of a recharge period. The analyses will use standard methods to obtain stable isotope data that meet measurement quality objectives (MQOs) that are described below and are comparable to previous study results.
2) Obtain discrete groundwater elevation measurements during and outside of the recharge period from manual measurements at the sampling locations described in Section 7.2. Goundwater level measurements by transducer will be made by KRD with periodic water level measurements when transducers are downloaded. When water samples are collected for isotope analyses, we will use standard manual measurement methods to obtain the groundwater elevations. These methods meet measurement quality objectives (MQOs) that are described below and are comparable to previous study results.

NOTE: Pressure transducers to measure groundwater levels were installed by and are monitored by Kittitas Reclamation District (KRD). We will compare those data with manual measurements and the isotope data from this project. The pressure-transducer data collected by the KRD 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 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 isotope parameters are summarized in Table 7.

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.

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[2] 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.

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*)
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

NA Not Applicable

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

Instrument	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	NA	
LiDAR Dataset Yakima Basin 2018	Surface Elevation		0.1 ft			

Table 9. Measurement quality objectives: water levels.

MQO (Parameter)	Precision (Duplicate Measurement or Sensor Resolution)		Bias*	Sensitivity (Minimum Measurement)
	Relative Percent Difference (%RPD)	In measurement units	In measurement units	In measurement units
Groundwater Level (manual measurement)	NA	0.02 ft	0.08 ft	0.02 ft

* Based on reported accuracies from user manuals and/or manual measurements

6.2.1.1 Precision

Precision will be determined based on duplicate laboratory measurements of duplicate samples. For stable isotope analyses, measurements are of ratios that are expressed in delta notation (per mil units):

$$\delta = \left(\frac{R_{sam} - R_{std}}{R_{std}}\right) * 1000$$

Where R_{sam} and R_{std} are the isotope rations $\left(\frac{^{18}O}{^{16}O}\ for\ \delta^{18}O, \frac{D}{H}\ for\ \delta D\right)$ of the sample and the standard, respectively.

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 isotopic composition. These QC samples are independent from the calibration standards for each measurement. 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.

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. Stable isotope analyses are measurements of ratios, not concentrations, and in this case are measurements of oxygen and hydrogen, the elements that make up the water molecule. Therefore sensitivity is not a valid measure for these analyses.

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. In addition,

we send our internal laboratory standards out to external isotope labs periodically (every 2-5 years) to ensure comparability between our data and data from external laboratories.

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 due to the recharge from spring snowmelt or irrigation, or managed recharge. The monitoring wells were constructed 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 gage on Taneum Creek at Brain Ranch 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 Taneum MAR site was collected by KRD and is documented in previous reports (Gregory and Jacobs, 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 KRD personnel.

6.4 Model quality objectives

Not applicable.

7.0 Study Design

7.1 Study boundaries

A general location map of the Taneum MAR site, with the site boundaries outlined in yellow is given in Figure 1.

7.2 Field data collection

Water samples and water-level measurements will be collected.

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

Samples will be collected from seven locations at the Taneum MAR site, the four monitoring wells and three surface water locations (Figure 3). The four wells range in depth from 35 to 60 feet. All but one (MW A) penetrate only the alluvial aquifer. MWA is drilled through the alluvial aquifer and 5 feet into the basalt bedrock.

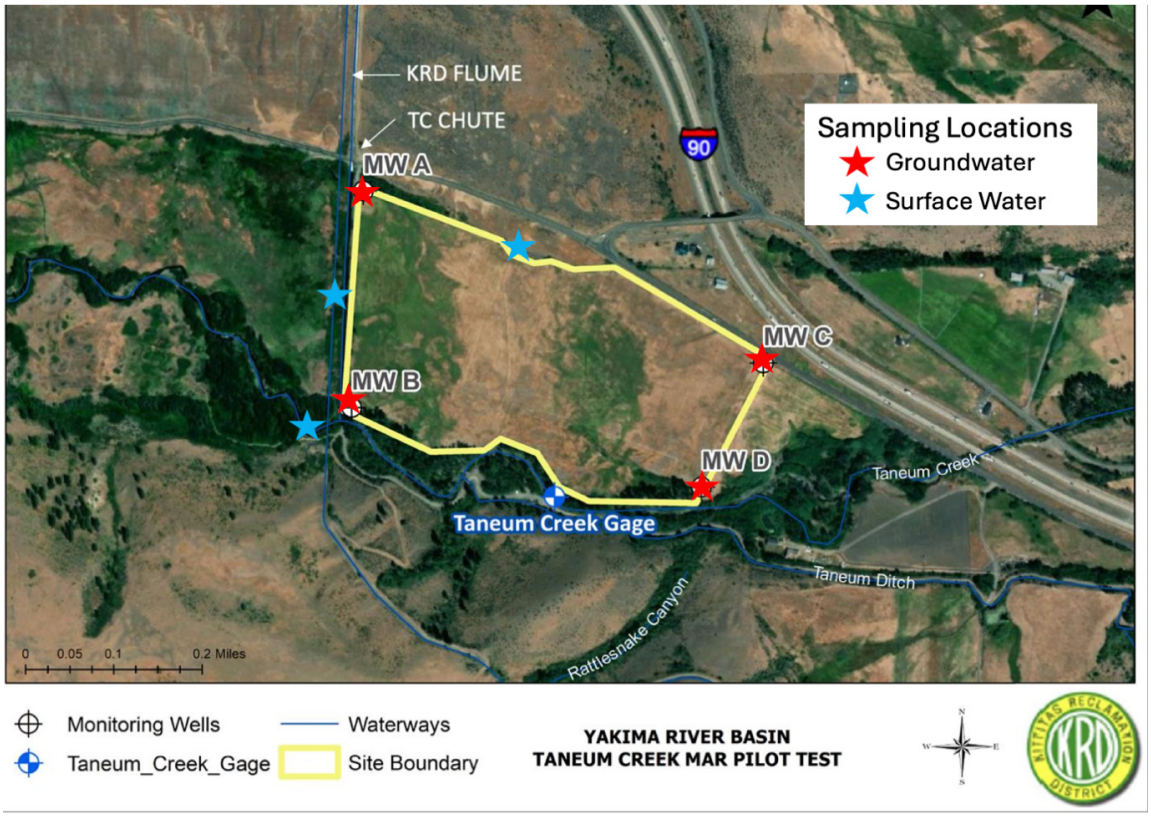


Figure 3. Sampling locations at Taneum MAR site. Figure modified from Gregory and Jacobs (2024).

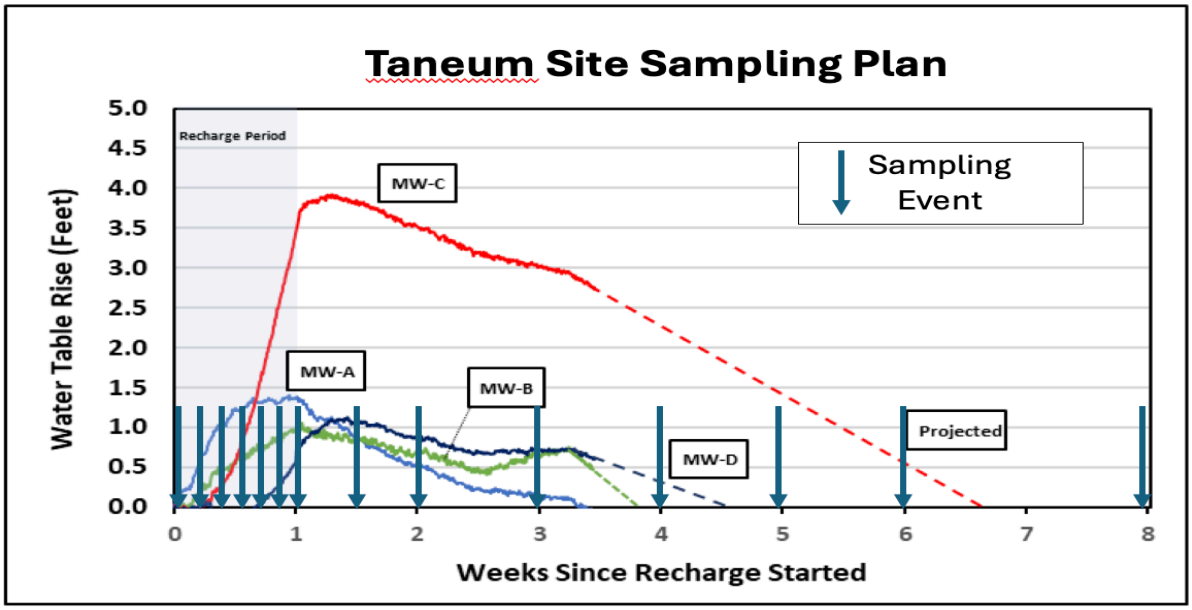


Figure 4. Example of sampling plan after pilot test. Arrows represent sampling events which become less frequent with time.

The three surface water sampling locations are: 1) the Taneum Creek chute, an overflow channel that carries water from the KRD flume to Taneum Creek; 2) Taneum Creek upstream of the chute outflow; 3) a ditch running along on the north side of the site. A fourth surface water sample will be collected weekly from the Yakima River at a site ≈2.5 miles northwest of the Taneum MAR site. This site is called Dudley Bridge, a public access area where Thorp Highway crosses the Yakima River.

A total of 200 water samples (including field duplicates) will be collected for stable isotope analysis during the project. This sample number was chosen partly based on time and budget constraints 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.

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 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	Abbreviate Site Name	Latitude (decimal degrees)	Longitude (decimal degrees)	Elevation (ft)	Sample Number, Sampling Frequency
Well*	Monitoring Well A	TAN MAR A	47.086135	-120.749983	1907	25, Biweekly; daily to weekly during recharge
Well*	Monitoring Well B	TAN MAR B	47.082624	-120.750131	1905	25, Biweekly; daily to weekly during recharge
Well*	Monitoring Well C	TAN MAR C	47.083304	-120.740367	1869	25, Biweekly; daily to weekly during recharge
Well*	Monitoring Well D	TAN MAR D	47.081223	-120.741954	1873	25, Biweekly; daily to weekly during recharge
Ditch	Taneum Creek chute	TAN MAR KRD	47.084596	-120.750228	1911	25, Biweekly; biweekly to weekly during recharge
River	Taneum Creek	TAN MAR TC	47.082260	-120.750902	1905	25, Biweekly; biweekly to weekly during recharge
Ditch	Ditch on north side of site	TAN MAR DIT	47.085343	-120.746431	1900	25, Biweekly; biweekly to weekly during recharge
River	Yakima River at Dudley Bridge	YR-DB	47.101086	-120.701955	1677	25, Weekly

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

7.2.2 Field parameters and laboratory analytes to be measured

Every one to three days during the recharge period and biweekly thereafter, the following manual measurements will be made during sample collection:

- 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)

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 at the Taneum MAR site.
- The sediment and rock units recorded in the well logs accurately represent the stratigraphy of the floodplain and its aquifers.
- The water level in the wells represents the equilibrium water level in the floodplain aquifer. 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 perforated. This includes an assumption that any mixtures of end member waters that are observed has 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 get permission from KRD prior to sampling. This is unlikely to be a problem. In addition, the site is accessible year-round via a paved county road. Another possible logistical problem is that a managed aquifer recharge event will not happen over the time period of our funding. As stated elsewhere, if this is the case, we will monitor changes after a natural recharge event (such as a winter thawing and/or flooding event) and/or after performing a slug test at the study site.

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 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 Adriana Pacheco Garcia, graduate student at CWU. Inasmuch as this research constitutes her thesis project, it will be her top priority. The research stipend funded in this project will allow her to devote her time to this research. KRD has been regularly monitoring the wells at the Taneum MAR site for several years, and the results of this current project are of significant interest to them, so we are confident that the well monitoring will remain a priority through the course of this study.

8.0 Field Procedures

8.1 Invasive species evaluation

As needed, Washington Department of Ecology SOP EAP070, Version 2.4 (WA Ecology, 2024) 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)
- 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)
- 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. 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.

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
Stable Isotopes (O and H)	15 mL (or 30 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).

For isotope analysis, the main way a sample can be contaminated is through introduction of a substantial amount of isotopically distinct water. All non-dedicated, non-disposable field equipment coming into contact with previous sample water will be rinsed with the new sample as needed to prevent cross-contamination of samples. The e-tape used for water-level measurements will be cleaned between wells.

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-TAN-type-site-#, where YRB26 is this project designation and year, TAN designates the Taneum MAR 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 ID
- Sampling date and time
- Sampler's name and names of other field personnel present
- 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 (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 will mostly be collected by Adriana Pacheco Garcia and remain in her custody. If any samples are collected by another individual, transfer of samples will be accompanied by a Chain of Custody Form (Appendix A). Samples at CWU will remain within the custody of Adriana Pacheco Garcia or Carey Gazis 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
- Well identification
- Environmental conditions
- Sequence of events
- Dates and times of measurement, sampling or other activity
- 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:

- 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 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.
- Field replicates will be collected every 15 samples to test for reproducibility, potential contamination, and to ensure that water within wells or streams is well mixed and homogeneous.

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. Laboratory quality control samples will include duplicates and check standards (QC standards). Check standards are used to verify analytical precision, to test for instrument drift, and to provide an estimate of bias due to calibration. Blanks and matrix spikes are not appropriate as quality control measures for isotopic analysis because they are measured as ratios, not concentrations.

Table 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**
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)

** Cavity ring down spectroscope – Picarro L2130-I Isotopic H2O Analyser

There is alternative instrumentation to perform isotope analyses in cases where the instrument is malfunctioning.

9.2 Sample preparation method(s)

For stable isotope analysis water sample is collected directly into a clean, dry 15 mL or 30 mL HDPE bottle, filling it almost to the top, and capping it tightly. The main objective is to protect the sample from evaporation and exchange with atmospheric water vapor. To protect the isotope analyzer, samples are filtered through a 0.45-micron polypropylene filter using a polypropylene syringe. Syringe and filters are rinsed with sample prior to placement in analysis vials.

All samples are stored at 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 five previous YBIP projects funded by Ecology (Sleeper, 2020; Gazis, 2023; Gazis and Ely, 2023; Ely et al., 2024; Ely and Gazis 2024-2026, final report in prep.). 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 duplicates. 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 KRD and their consultant about site access and 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. 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
Oxygen-18	NA	1/15	1/6	NA	1/6	NA
Deuterium	NA	1/15	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.

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.

New isotope data will be uploaded to Ecology's EIM database. All data will also be archived on the CWU Department of Geological Science server.

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 be transferred to Ecology's EIM system using Study ID CWUTAN_001 according to the timeline approved for this project per online submittal guidelines. Only applicable project data, verified through the project QA process, will be uploaded into EIM.

11.4 Data upload procedures

Data will be transferred to Ecology's EIM system using Study ID CWUTAN_001 according to the timeline approved for this project per online submittal guidelines. Only applicable project data, verified through the project QA process, will be uploaded into EIM. The EIM data coordinator will be consulted if data submittal problems arise. The graduate student researchers will complete EIM training offered by Ecology and follow all existing Ecology business rules and the EIM User's Manual for loading, data quality checks, and editing.

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

Carey Gazis, Lisa Ely, and Adriana Pacheco Garcia 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 Adriana Pacheco Garcia 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 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 weekly during the data collection and analysis phase to review the progress toward these objectives. 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 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

Because stable isotope measurements are measurements of ratios of elements that are fundamental to the water molecule, there is no such thing as a non-detect for this type of data.

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 KRD) 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 and nearby streams to estimate how hydraulic pressure is transmitted through time and space.

Stable isotope data will be displayed on a plot of $\delta^{18}O$ versus δD. Changes in the stable isotope values through time and space will be analyzed to assess the travel and mixing of recharge with ambient groundwater.

14.4 Sampling design evaluation

The sampling design is based on existing information and well availability. The actual conditions at the site may be more complex than indicated. The spatial distribution of the sampling locations is 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 changing the frequency of sampling if this will resolve such problems.

The geochemical sampling design targets 4 monitoring wells and 3 surface water location at the Taneum MAR site as well as one Yakima River location for frequent sampling for stable isotopes, for a total of 200 samples over the course of the study. 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. Groundwater elevation data for the four monitoring wells provided by KRD will supplement the isotope data, providing addition insight into groundwater flow directions.

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. Chain of Custody Form

	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		
11		Sample ID	Date sampled	Time sampled	Latitude	Longitude	Matrix (soil, water)	Other comments	# of containers	Trace elements*	Major elements**	Stable Isotope ***
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 δ18O in water and δN and δ18O 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 Washington
Department 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 | **Laboratory Accreditation Unit**
Effective Date: 4/25/2026 | Page 1 of 1
Scope of Accreditation Report for CWU Environmental Testing Laboratory | Scope Expires: 4/24/2027
Certificate Number: A541-26

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 http://apps.leg.wa.gov/WAC/default.aspx?cite=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.

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. 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 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
KRD	Kittitas Reclamation District
MAR	Managed Aquifer Recharge
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 and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis (USEPA, 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).a

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:

$$RPD = \left[\frac{Abs(a-b)}{(a+b)/2}\right] * 100\%$$

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:

$$RSD = \frac{(100\% * s)}{x}$$

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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