Quality Assurance Project Plan

Lower Yakima Valley
Land Use Practices that Reduce Nitrate Loading to Groundwater

April 2026, Publication 26-03-103

DEPARTMENT OF ECOLOGY
State of Washington

Publication Information

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

This QAPP was approved to begin work in August 2024. It was finalized and approved for publication in April 2026.

The final QAPP is available on Ecology's website at https://apps.ecology.wa.gov/publications/SummaryPages/2603103.html.

Suggested Citation
Redding, M., Schukow, E 2026. Quality Assurance Project Plan: Land Use Practices that Reduce Nitrate Loading to Groundwater. 26-03-105. Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/2603103.html.

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

Data for this project are available in Ecology's EIM Database.[1] Search Study ID: ESCH0001.

The Activity Tracker Code for this study is 23-033.

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

COVER PHOTO: Agricultural field planted with grape plants. Photo by: Elijah Schukow.

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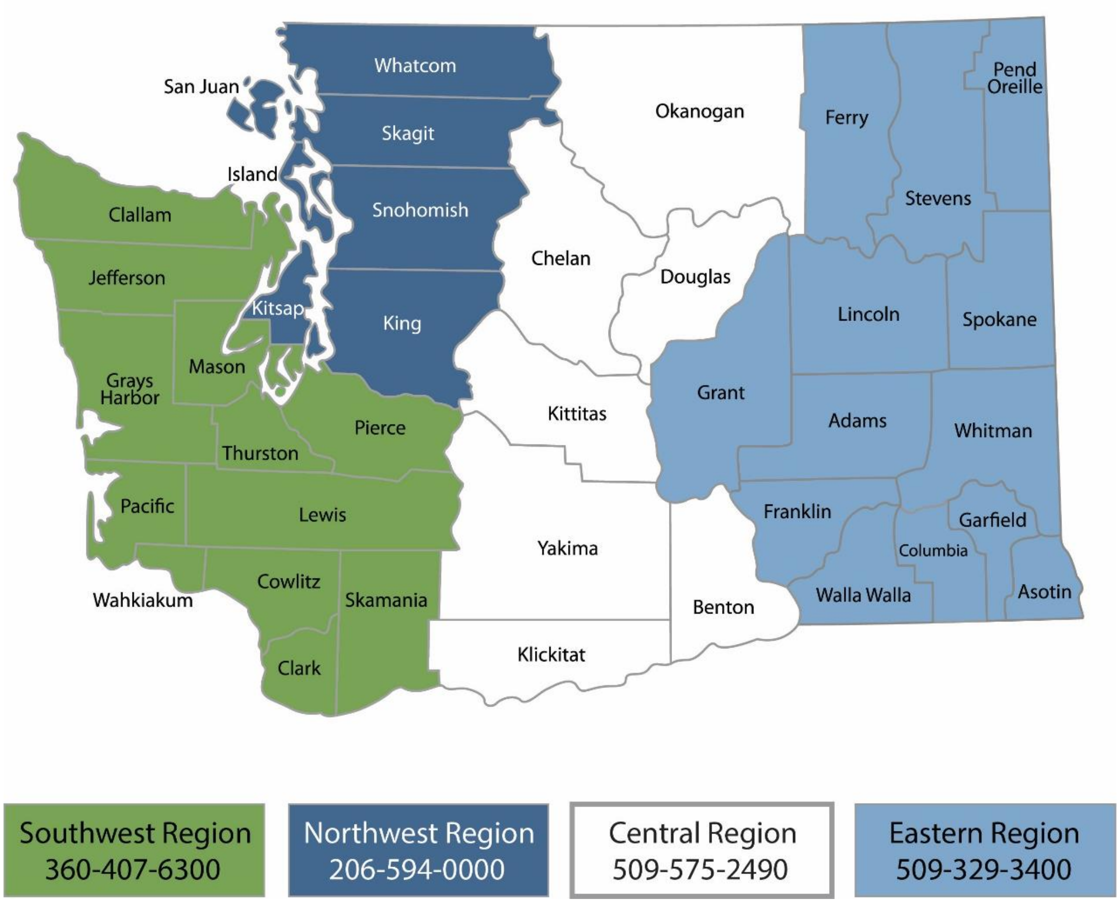
[1] https://www.ecology.wa.gov/Research-Data/Data-resources/Environmental-Information-Management-database

Department of Ecology's Regional Offices

Map of Counties Served



Region	Counties Served	Mailing Address	Phone
Southwest	Clallam, Clark, Cowlitz, Grays Harbor, Jefferson, Mason, Lewis, Pacific, Pierce, Skamania, Thurston, Wahkiakum	PO Box 47775 Olympia, WA 98504	360-407-6300
Northwest	Island, King, Kitsap, San Juan, Skagit, Snohomish, Whatcom	PO Box 330316 Shoreline, WA 98133	206-594-0000
Central	Benton, Chelan, Douglas, Kittitas, Klickitat, Okanogan, Yakima	1250 W Alder St Union Gap, WA 98903	509-575-2490
Eastern	Adams, Asotin, Columbia, Ferry, Franklin, Garfield, Grant, Lincoln, Pend Oreille, Spokane, Stevens, Walla Walla, Whitman	4601 N Monroe Spokane, WA 99205	509-329-3400
Headquarters	Across Washington	PO Box 47600 Olympia, WA 98504	360-407-6000

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Lower Yakima Valley
Land Use Practices that Reduce Nitrate Loading to Groundwater

By Melanie Redding and Elijah Schukow

April 2026

Approved by:

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Signature:	Date:
Damon Roberts, Client, Section Manager, WQP, CRO	
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Signature:	Date:
Rob Waldrop Laboratory Director, EAP, MEL	
Signature:	Date:
Christina Frans, Ecology Quality Assurance Officer	

All staff are from the Washington State Department of Ecology
CRO: Central Regional Office
EAP: Environmental Assessment Program
EOS: Eastern Operations Section
MEL: Manchester Environmental Laboratory
MTGU: Modeling, TMDL, & Groundwater Unit
WQP: Water Quality Program

Signatures are not available on the Internet version.

1.0 Table of Contents

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2.0 Abstract

The *Land Use Practices that Reduce Nitrate Loading to Groundwater* study supports the Lower Yakima Valley Groundwater Management Area (GWMA) efforts. The goal of this study is to assess land use practices and identify those that are successful in reducing nitrate loading to groundwater. By determining which practices are effective, we can work with our partners and inform the community, so they can make positive changes that will ultimately improve groundwater quality in the Lower Yakima Valley. This project implements or partially implements, four of the recommended actions in the GWMA plan, which was developed and approved by a locally led committee. These actions are:

- Design and implement pilot studies focusing on innovative farm techniques, which will reduce nitrogen loading to crops and monitor results (recommended action #10).
- Monitor changes occurring in agricultural operations. Evaluate whether these changes positively affect improvement in groundwater quality (recommended action #23).
- Establish a multi-year deep soil sampling program (recommended action #24).
- Develop an agricultural producer education and outreach campaign (recommended action #7).

This project, which is funded by the Washington State Legislature, is a cooperative effort between Washington State University (WSU), Washington State Department of Agriculture (WSDA), South Yakima Conservation District (SYCD), and Washington State Department of Ecology (Ecology). This assessment will generate data to determine the effectiveness of selected land use management practices using groundwater monitoring and deep soil sampling at multiple locations within the Lower Yakima Valley.

The results and conclusions from this study may be applied to other areas in Washington State, where groundwater is impacted by elevated nitrate concentrations.

3.0 Background

3.1 Introduction and problem statement

Groundwater in parts of the Lower Yakima Valley contains elevated nitrate concentrations, with approximately 21% of the wells exceeding the drinking water standard. Groundwater in the Lower Yakima Valley is the principal drinking water source for approximately 56,000 residents in the area. Results from two years of aquifer wide sampling indicate a correlation between elevated nitrate concentrations and well depth, where 90% of shallow wells in the study area exceeded the drinking water standard for nitrate (Redding et al. 2023).

Nitrate originates from many sources including animal waste, human waste, fertilizers, plant decomposition, and atmospheric deposition. Irrigated agriculture is the main land use in the Lower Yakima Valley, comprising 87% of the area in the Lower Yakima Valley Groundwater Management Area (GWMA). It is also considered to be one of the contributing factors to degraded groundwater in the Lower Yakima Valley (Washington State Department of Agriculture (WSDA) and Yakima County 2018). Agriculture in the Lower Yakima Valley produces a wide variety of commodities including dairy products, apples, grapes, cherries, pears, nectarines, corn, triticale, alfalfa, pasture, hops, wheat, mint, and asparagus (WSDA and Yakima County 2018). In addition to irrigation, these crops need nutrients such as nitrogen for proper growth and development.

The Lower Yakima Valley is an area with environmental justice issues. Figure 1 illustrates the environmental health disparities for Washington state. The Lower Yakima Valley is highlighted and indicates this area has a high risk. (UW and WDOH 2022).

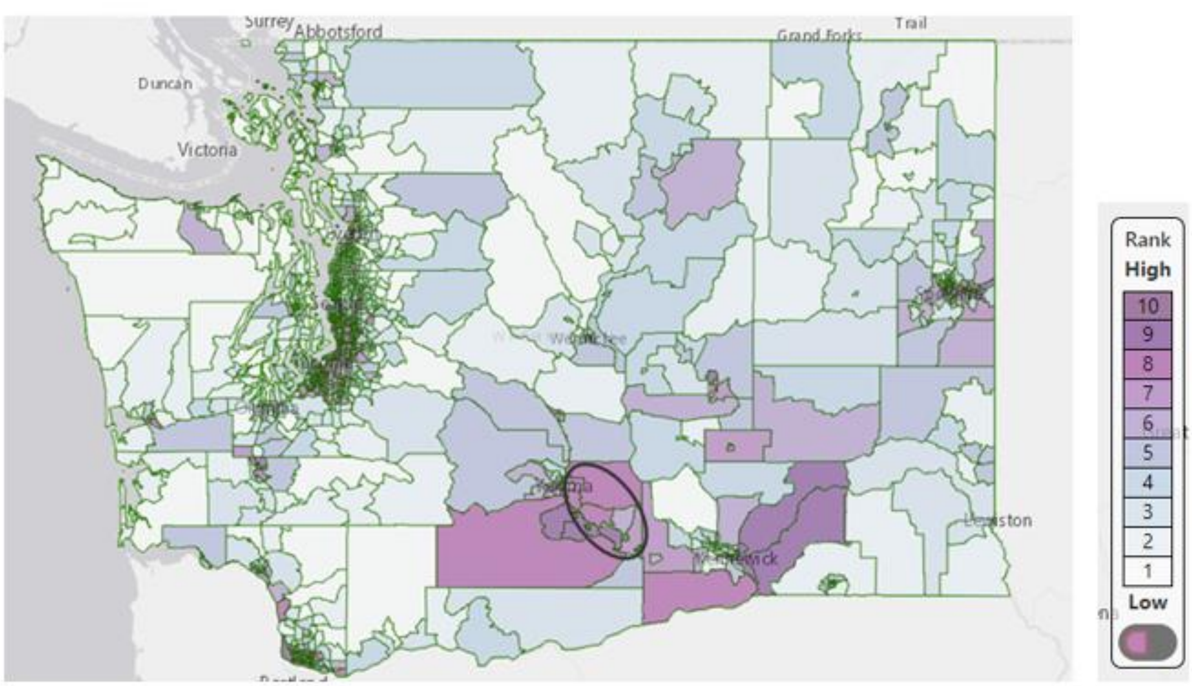

Figure 1. Washington State environmental health disparities map

In 2012 a GWMA was formed with the goal of reducing nitrate concentrations in groundwater. In support of the GWMA, a multi-disciplinary and multi-stakeholder groundwater advisory committee (GWAC) developed a comprehensive plan with 64 recommended actions for achieving their goal (GWAC 2019). Implementing agencies who were members of the GWAC are currently working to implement the recommended actions.

Collaborative partnerships are important to reduce nitrate loading from all sources. By increasing our understanding of how land use practices affect the quality of groundwater we can better support the community by providing them with the ability to make informed choices through access to credible data and resources.

3.2 Study area and surroundings

This study will utilize multiple sites both within the GWMA, and just outside the GWMA boundaries at the Washington State University (WSU) Prosser Irrigated Agriculture Research and Extension Center (IAREC).

The Lower Yakima Valley GWMA covers 175,000 acres, with the Yakima River and the Yakama Nation bordering the GWMA to its south (GWAC 2019).

The WSU facility is located 6 miles east of the GWMA, and is situated over the same aquifer, with similar land use, and climate as the Lower Yakima Valley.

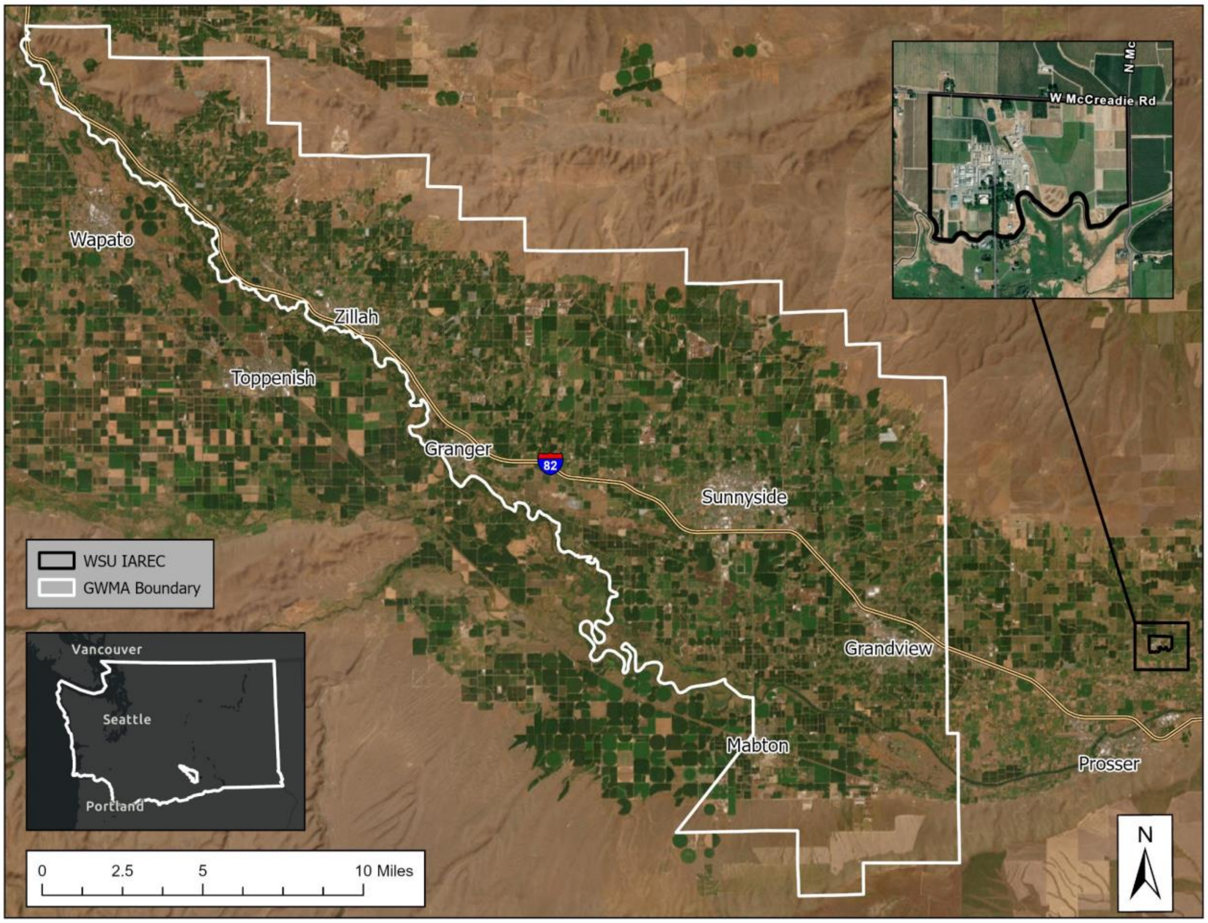

Figure 2. Lower Yakima Valley GWMA and WSU Prosser Irrigated Agriculture Research and Extension Center (IAREC) project study areas.

Groundwater and Hydrogeology

Groundwater

The Lower Yakima Valley aquifer is the primary drinking water source for area residents. Groundwater originates as precipitation, infiltration from streamflow, irrigation, stock water, canal water infiltration, and on-site sewage system effluent recharge. Annual precipitation ranges from 6 to 9 inches (PGG 2011) while groundwater recharge is estimated to range from 7 to 25 inches per year (Vaccaro and Olsen 2007). The higher recharge rates are the result of irrigated agriculture and leakage of canal water. Groundwater recharge is difficult to quantify since it varies based on precipitation, irrigation, canal leakage, and crop management.

Surficial groundwater generally flows towards surface water, with the Yakima River flowing southeast through the Lower Yakima Valley GWMA area. Depth to water varies depending upon the location. In the valley bottom near Granger, Sunnyside and Grandview, depth to water is shallow measuring from a few feet below land surface to approximately 15 feet deep.

The further away from the river, depth to groundwater is generally deeper, increasing to over 100 feet below land surface near the foothills.

The hydraulic gradient is also variable depending on location (7 to 400 feet per mile).

Hydrogeology

There are four major hydrogeologic units that were formed during significant geologic events.

Alluvium

Alluvium are sediments transported and deposited via streamflow. These sediments consist of well-rounded cobbles, gravel, sand, and silt. This unit is predominant near the Yakima River, and the thickness ranges from a few feet to approximately 30 feet thick (Vaccaro and Olsen 2007; Vaccaro et al. 2009).

Missoula Glacial Lake Deposits

During the Ice Age, approximately 12,000 years ago, glacial Lake Missoula was formed by a series of ice dams on the Clark Fork River in northeast Idaho, creating a body of water greater than 500 cubic miles. The ice dam was breached, which created a massive flood. It is estimated that the ice dam was formed and breached 80 to 100 times over a period of 2,500 years (Bretz 1930). This flooding caused many well-known features such as Dry Falls, the channeled scablands (giant ripple marks), erratics (giant boulders), and resulted in mammoth fossils in the area.

These catastrophic floods deposited fine grained sands, silts and gravel. Fine grained sediments were also deposited throughout the valley by wind. These deposits are common over much of the Lower Yakima Valley and most of the shallow wells are part of the basin fill deposits. This unit is recharged by precipitation, losses from streams, canal leakage, and irrigation water (Vaccaro and Olsen 2007; Vaccaro et al. 2009).

Ellensburg Formation

The Ellensburg Formation consists of over 1500 feet of volcanic sedimentary deposits, sandstone, shale, and conglomerates containing gravel and boulders of andesitic lavas.

The tectonic folding during the Pliocene age caused the uplift of the Cascade Range, which extends into Yakima. Compression from the north-south direction formed anticlines and synclines in the Yakima Fold Belt. The anticlines created the boundaries in the form of hills, and the synclines created valley bottoms where sediments were eroded and deposited, creating the Ellensburg Formation (Vaccaro and Olsen 2007; Vaccaro et al. 2009).

Wanapum Basalt

The Lower Yakima Valley is in the Columbia Basin Physiographic Province, which is an extensive basalt plain that formed from lava flows through fissures southeast of the valley approximately 15 million years ago during the Miocene age. The Wanapum basalt unit is part of the Columbia River Basalt Group, which includes extensive basalt flows within Washington, Idaho and Oregon.

The Wanapum Basalt is comprised of interbedded layers of basalt and sedimentary rocks formed from the continued weathering of volcanic andesite. The repeated process of lava flows and weathering create permeable aquifers (Vaccaro et al. 2009).

3.2.1 History of study area

Agriculture is the historic and current primary economic source of income within the Lower Yakima Valley (Ecology 2010; GWAC 2019). Irrigated agriculture contributes approximately 64% of the total nitrogen to the GWMA area. The top 15 crops comprise 87% of the irrigated acreage within the GWMA and include apples, silage corn, triticale, juice grapes, alfalfa, pasture, cherries, hops, wine grapes, pears, mint, wheat, grain corn, asparagus, and peach/nectarines (WSDA 2018).

Cattle and dairy farms have a strong historical presence in the Lower Yakima Valley. While the number of farms has historically decreased over time, the number of animals on farms has increased. Nitrogen produced from animal pens and lagoons is estimated to account for 31% of the total available in the GWMA (WSDA 2018).

This area is also a predominately rural area with extensive use of on-site sewage systems to manage household wastewater (WSDA 2018).

3.2.2 Summary of previous studies and existing data

Nitrate in the Lower Yakima Valley groundwater has been documented in past studies conducted by Sell and Knutson (2002), Redifer (2011), the US EPA (2012) and Huffman (2018).

In 2021 the Washington State Department of Ecology (Ecology) launched the Ambient Groundwater Monitoring Network to measure the health of the aquifer over time (GWAC 2019). The Ambient Groundwater Monitoring Network consists of 170 wells located across the Lower Yakima Valley (Figure 3). This study is ongoing, with quarterly sampling conducted for the first two years and continues annually.

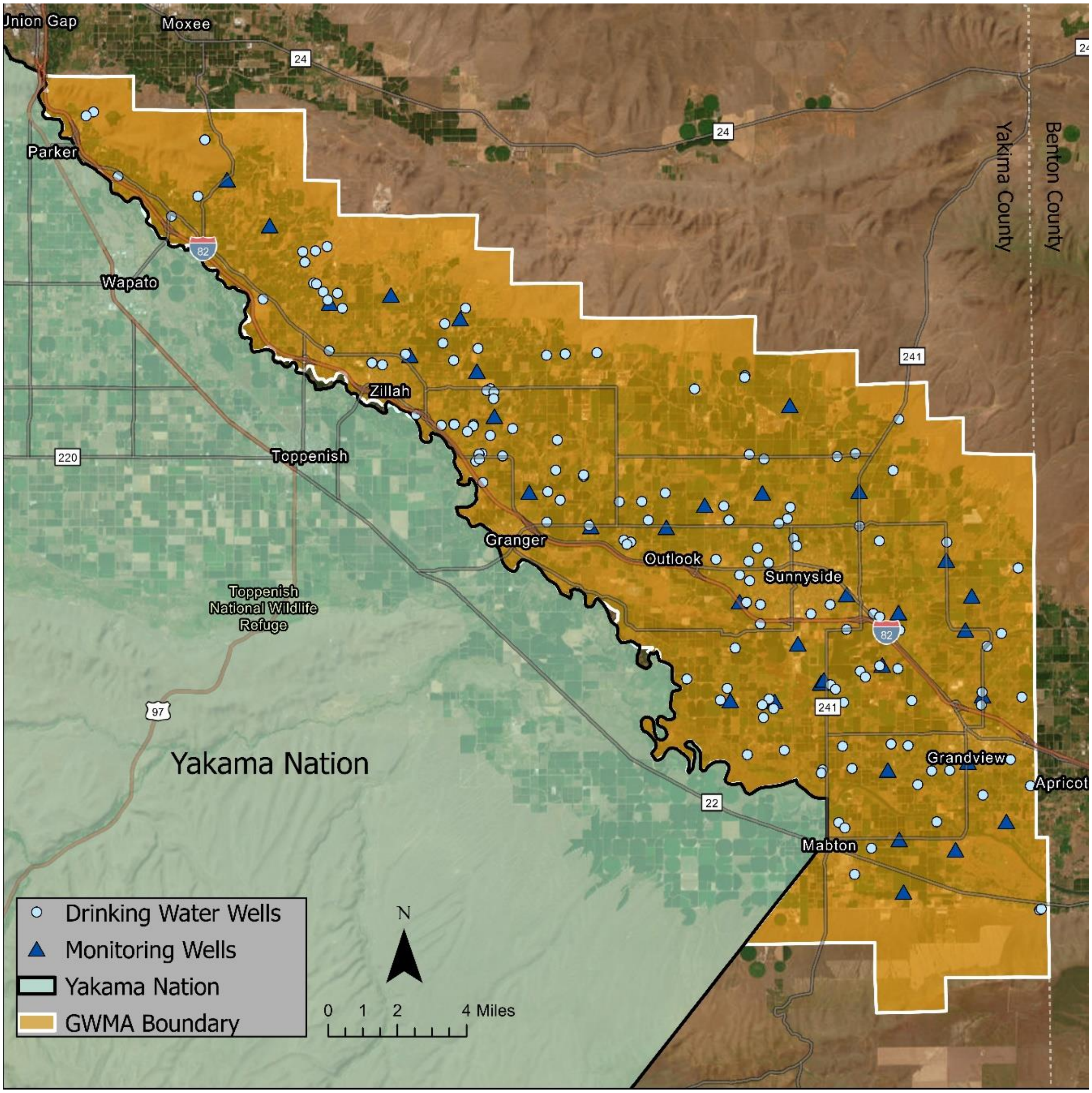

Figure 3. Ambient Groundwater Monitoring Network (AGWMN).

3.2.3 Parameters of interest and potential sources

The focus of the Lower Yakima Valley GWMA is to reduce nitrate concentrations in groundwater to below the drinking water standards. The primary parameters of interest in both groundwater and soil samples are nitrate and ammonia. Nitrate originates from many sources including animal waste, human waste, fertilizers, plant decomposition and atmospheric deposition. Additional parameters of interest were selected to characterize the groundwater geochemistry and soil chemistry (Table 1).

Table 1. Groundwater and Soil parameters.

Groundwater Parameters	Soil Parameters
Nitrate	Nitrate
Ammonium	Ammonium
Chloride	Total Carbon
Bromide	—
Potassium	—
Sulfate	—
Bicarbonate	—
Sodium	—
Calcium	—
Magnesium	—

3.2.4 Regulatory criteria or standards

Washington State adopted groundwater quality standards to protect the resource (Chapter 173-200 WAC). The standards protect existing background water quality, and the criterion indicates when groundwater has been degraded. The drinking water standards (Chapter 246-290 WAC), protect the point of use, and are the maximum contaminant level (MCL) that can be present in drinking water. Table 2 lists the standards for water quality parameters monitored in this study.

Table 2. Water Quality Standards.

Parameter	Groundwater Quality Standard	Drinking Water Standard
Nitrate	10 mg N/L	10 mg N/L
Chloride	250 mg/L	250 mg/L
Sulfate	250 mg/L	250 mg/L

3.3 Water quality impairment studies

NA

3.4 Effectiveness monitoring studies

NA

4.0 Project Description

Groundwater in some parts of the Lower Yakima Valley aquifer contain elevated nitrate concentrations. This project is focused on identifying land use practices that reduce nitrate loading to groundwater. This project will utilize existing farms and farming practices. The location and specific land use practices are dependent upon farmer permission and access to private property. The assessment will generate data to determine the effectiveness of selected land use management practices using groundwater monitoring and deep soil sampling at multiple locations within the Lower Yakima Valley

This is a cooperative effort between Ecology, Washington State University (WSU), Washington State Department of Agriculture (WSDA), and the South Yakima Conservation District (SYCD).

4.1 Project goals

- Identify land use practices which reduce nitrate loading to groundwater, and
- Provide outreach to agricultural community members on our findings to promote positive changes.

4.2 Project objectives

- Design and launch pilot studies focusing on management practices which reduce nitrogen loading to groundwater.
- Establish a multi-year deep soil sampling program and groundwater monitoring network.
- Monitor changes occurring in agricultural operations. Evaluate whether these changes positively affect improvement to groundwater quality.
- Develop an agricultural producer education outreach campaign.

4.3 Information needed and sources

- Analyze existing groundwater and deep soil sampling data, and associated management practices.
  - Groundwater and soil data have been collected in the dairy cluster area of the GWMA by Environmental Protection Agency (EPA) contractors for over 10 years. This data has recently become accessible and will be reviewed to determine if there are practices which indicate they are beneficial in reducing nitrate loading to the land surface.
  - The GWMA plan also contains recommended best management practices for irrigated agriculture. In consultation with our partners, we can use these to identify which practices are best suited for this research and which have the potential to reduce nitrate loading.
- Work with local and state experts to identify which agricultural land use treatments and practices are protective of groundwater quality.

4.4 Tasks required

The main tasks for this study include:

- Establish collaborative partnerships with local and state experts, and with local landowners.
- Analyze data from existing datasets.
- Identify potentially effective land use practices which are protective of groundwater quality.
- Establish test plots which will compare different land use practices.
- Where monitoring wells are available, collect groundwater quality samples for nitrate, ammonium, chloride and other major cations and anions.
- Collect water quality field parameters (pH, temperature, electrical conductivity, dissolved oxygen, oxidation/reduction potential) from monitoring wells.
- Measure monthly static water levels in the monitoring wells
- Make sure a cultural resource assessment has been completed prior to deep soil sampling.
- Collect deep soil samples in the spring and fall from the same locations each year, and analyze for nitrate (N), ammonium (N), and total carbon.
- Evaluate results for quality assurance (QA) using standard Environmental Assessment Program (EAP) QA procedures.
- Evaluate data to determine if there are variances with the land use test plots.
- Enter data into Environmental Information Management (EIM) database.
- Prepare a report describing the study along with results and conclusions.
- Develop outreach materials for distribution to relevant community members.

4.5 Systematic planning process

This QAPP serves as the planning document for the project.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 3. Organization of project staff and responsibilities.

Staff[1]	Title	Responsibilities
David Bowen Regional Director CRO Phone: (509)-480-1753	Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Damon Roberts Section Manager, Water Quality Program CRO Phone (509) 823-9626	Client	Reviews the QAPP and assists with defining the scope of the project.
Elijah Schukow LHg Hydrogeologist CRO/ Eastern Operations Section Phone: (509)-406-6474	Project Manager	Writes the QAPP. Designs test plots with assistance from agricultural partners. Conducts QA review of data, analyzes and interprets data, Writes the report.
Elijah Schukow LHg Hydrogeologist CRO/ Eastern Operations Section Phone: (509)-406-6474	Principal Investigator	Assists with writing the QAPP and the report. Oversees and conducts field sampling and transportation of samples to the laboratory.
Teo Fisher CRO Eastern Operations Section Phone: (509) 406-5944	Field Assistant	Collect samples and records field information. Enters data into EIM.
Travis Bartholomew MTGU Eastern Operations Section Phone: (509)-724-7319	MTGU Unit Supervisor	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Scott Tarbutton EAP EOS Section Manager Phone: (509)-867-6534	EOS Section Manager	Reviews the project scope and budget, tracks progress, reviews and approves the final QAPP.

Staff[1]	Title	Responsibilities
Rob Waldrop Manchester Environmental Laboratory Phone: (564)-669-4869	Laboratory Director	Reviews and approves the final QAPP.
Christina Frans Phone: (360)-519-2067	Ecology Quality Assurance Officer	Reviews and approves the final QAPP.

[1]All staff except the clients are from EAP.
CRO: central Regional Office;
EAP: Environmental Assessment Program;
EIM: Environmental Information Management database;
QAPP: Quality Assurance Project Plan

5.2 Special training and certifications

It is required that a licensed hydrogeologist oversee or conduct hydrogeologic studies (Chapter 18.220; Chapter 308-15 WAC; and Chapter 18.235 RCW). The project manager is a licensed geologist and hydrogeologist.

All lead field staff must have training to ensure consistent field methods are utilized. All field staff must be familiar with this QAPP and relevant SOPs. Relevant SOP's are listed in section 8.2.

5.3 Organization

Table 4. External partners.

Staff	Title	Responsibilities
Dr. Elizabeth Gillispie Soil Health Vineyard Manager Washington State University Phone: 703-973-3964	Soil Scientist	Maintains vineyard and WSU field study site.
Rodney Heit Manager South Yakima Conservation District 509-829-9025	Manager	Assists with identifying land use practices and locations for deep soil sampling. Operates the deep soil sampling rig.
Savannah Crnick, Resources Conservation Planner South Yakima Conservation District 509-829-9025	Resource Conservation Panner	Assists with operating the deep soil sampling rig. and collecting soil samples.
Kyrre Flege Program Manager Washinton State Department of Agriculture Dairy Nutrient Management Program 360-746-1249	Program Manager	Assists with identifying land use practices and locations for deep soil sampling. Assists with data interpretation.
Dani Gelardi Washinton State Department of Agriculture Dairy Nutrient Management Program	Senior Soil Scientist	Assists with identifying land use practices and locations for deep soil sampling. Assists with data interpretation.
Adam Peterson Washinton State Department of Agriculture Dairy Nutrient Management Program	Agronomist	Assists with identifying land use practices and locations for deep soil sampling. Assists with data interpretation.

5.4 Proposed project schedule

Tables 5 – 7 list key activities, due dates, and lead staff for this project.

Table 5. Schedule for completing field and laboratory work.

Task	Due date	Lead staff
Field work	October 2024 – 2029	Project Staff
Laboratory analyses	6 weeks after samples received	MEL
Contract lab data validation	3 months after lab analyses completed	MEL

MEL: Manchester Environmental Laboratory

Table 6. Schedule for data entry.

Year	Task	Due date	Lead staff
Year 1	EIM data loaded*	January 2025	Field Assistant
	EIM QA	April 2025	Principal Investigator
	EIM complete	July 2025	Project Manager
Year 2	EIM data loaded*	January 2026	Field Assistant
	EIM QA	April 2026	Principal Investigator
	EIM complete	July 2026	Project Manager
Year 3	EIM data loaded*	January 2027	Field Assistant
	EIM QA	April 2027	Principal Investigator
	EIM complete	July 2027	Project Manager
Year 4	EIM data loaded*	January 2028	Field Assistant
	EIM QA	April 2028	Principal Investigator
	EIM complete	July 2028	Project Manager
Year 5	EIM data loaded*	January 2029	Field Assistant
	EIM QA	April 2029	Principal Investigator
	EIM complete	July 2029	Project Manager

*EIM Project ID: ESCH0001
EIM: Environmental Information Management database

Table 7. Schedule for final report.

Task	Due date	Lead staff
Draft to supervisor	December 2029	Project Manager
Draft to client/ peer reviewer	January 2030	Project Manager
Draft to external reviewers	February 2030	Project Manager
Final draft to publications team	April 2030	Project Manager
Final report due on web	June 2030	Project Manager

5.5 Budget and funding

Funding for this project comes from the Washington State Legislature 2021 – 2023 supplemental budget request. Tables 8 and 9 list the itemized costs for the project. The budget reflects the annual cost of running this project.

Table 8. Project budget and funding.

Item	FY 2023 Cost ($)	FY 2024 Cost ($)	FY 2025 Cost ($)	FY 2026 Cost ($)	FY 2027 Cost ($)
Salary, benefits, and indirect/overhead	237,032	237,032	237,032	237,032	237,032
Equipment	10,643	2,643	2,643	2,643	2,643
Travel and other	4,800	4,800	4,800	4,800	4,800
Contracts	78,000	4,500	4,500	4,500	4,500
Laboratory (See Table 10 for details.)	—	13,500	13,500	13,500	13,500

—: no data

Table 9. Annual Laboratory budget.

Sample Type	Parameter	Number of Samples	Number of QA Samples	Total Number of Samples	Cost Per Sample ($)	Lab Subtotal ($)
Groundwater	Nitrate + Nitrite	12	12	24	$33	**$792**
	Chloride	12	12	24	$17	**$408**
	Ammonia-NH3	12	12	24	$17	**$408**
	Bromide	3	3	6	$17	$102
	Sulfate	3	3	6	$17	$102
	Bicarbonate (Alkalinity)	3	3	6	$22	$132
	Sodium	3	3	6	$118	$708
	Calcium	3	3	6	—	—
	Magnesium	3	3	6	—	—
	Potassium	3	3	6	—	—
Soil	Nitrate Nitrogen	72	8	80	$75	$6,000
	Ammonium Nitrogen	72	8	80	$50	$4,000
	Total Carbon	24	3	27	$25	$675
Total						**$13,327**

6.0 Quality Objectives

6.1 Data quality objectives

The data quality objective for this project is to obtain data of sufficient quantity and quality to evaluate the effectiveness of land use practices in reducing nitrate loading to groundwater. This objective will be achieved through attention to sampling design, sample collection and processing, laboratory measurements in groundwater samples of nitrogen, and other ions, laboratory measurements in soil samples of nitrogen, and other soil health indicators, data management, and quality control (QC) procedures described or referenced in this plan.

6.2 Measurement quality objectives

Measurement quality objectives (MQOs) for field parameters are shown in Table 10. The MQOs for calibration verification, ongoing precision and recovery, correspond to the QC acceptance limits of the analytical methods. Results not meeting these MQOs will be evaluated for possible corrective action or use with qualification.

Table 10. MQOs for multi-parameter sondes and other field measurements.

Parameter	Unit	Accept	Qualify	Reject
Dissolved Oxygen	mg/L	≤ ± 0.3	> ± 0.3 and ≤ ± 1.0	> ± 1.0
pH	S.U.	≤ ± 0.3	> ± 0.3 and ≤ ± 1.0	> ± 1.0
Electrical Conductivity	µS/cm	≤ ± 10%	> ± 10% and ≤ ± 20%	> ± 20%
Water Temperature	°C	≤ ± 0.2	> ± 0.2 and ≤ ± 1.0	> ± 1.0
Oxidation/Reduction Potential (ORP)	mV	≤ ± 5%	> ± 5% and ≤ ± 10%	> ± 10%

(Anderson, 2020)

6.2.1 Targets for precision, bias, and sensitivity

The MQOs for laboratory analyses are expressed in terms of acceptable precision, bias, and sensitivity. These MQOs are summarized in Table 11 and 12 for each analytical method. These MQOs are then briefly described. Laboratory case narratives will discuss the outcomes of QC practices and address these MQOs for each batch of sample analyses. Most of these MQOs correspond to the acceptance limits specified in the analytical method. The lowest concentrations of interest shown in the table should be attainable and are expected to be met by Manchester Environmental Laboratory (MEL) and Analytical Resource, LLC (ARI). For most analytes, the designated method’s achievable limit of quantitation (LOQ) will be adequate for this project.

Table 11. Groundwater Measurement quality objectives.

Parameter	Field Duplicate[a] (RPD)	Laboratory Duplicate[a] (RPD)	Matrix Spike Duplicate[a]	Lab Control Standard[b]	Matrix Spike[b]	Lowest Concentrations of Interest[c]
Nitrate + Nitrite	≤ 20%	≤ 20%	≤ 20%	+/- 20%	+/- 25%	0.01 mg/L
Chloride	≤ 20%	≤ 20%	≤ 20%	+/- 20%	+/- 25%	0.1 mg/L
Bromide	≤ 20%	≤ 20%	≤ 20%	+/- 20%	+/- 25%	0.025 mg/L
Ammonia	≤ 20%	≤ 20%	≤ 20%	+/- 20%	+/- 25%	0.01 mg/L
Bicarbonate	≤ 20%	≤ 20%	≤ 20%	+/- 20%	+/- 25%	5 mg/L
Sulfate	≤ 20%	≤ 20%	≤ 20%	+/- 20%	+/- 25%	0.3 mg/L
Sodium	≤ 20%	≤ 20%	≤ 20%	+/- 20%	+/- 25%	0.025 mg/L
Calcium	≤ 20%	≤ 20%	≤ 20%	+/- 20%	+/- 25%	0.025 mg/L
Potassium	≤ 20%	≤ 20%	≤ 20%	+/- 20%	+/- 25%	0..25 mg/L
Magnesium	≤ 20%	≤ 20%	≤ 20%	+/- 20%	+/- 25%	0.025 mg/L

RPD: relative percent difference
[a] Measurement of precision
[b] Measurement of bias
[c] Measurement of sensitivity

Table 12.Soil Measurement quality objectives.

Parameter	Field Duplicate[a] (RPD)	Laboratory Duplicate[a] (RPD)	Matrix Spike Duplicate[a]	Lab Control Standard[b]	Matrix Spike[b]	Lowest Concentrations of Interest[c]
Nitrate + Nitrite (ARI)	< 20%	20 %	+/- 20%	+/- 20%	+/- 20%	0.100 mg/kg
Ammonia (ARI)	< 20%	20 %	+/- 20%	+/- 20%	+/- 20%	0.400 mg/kg
Total Carbon (MEL)	< 20%	20 %	+/- 20%	+/- 20%	+/- 20%	0.1%

RPD: relative percent difference
ARI: Analytical Resources, LLC
MEL: Manchester Environmental Lab
[a] Measurement of precision
[b] Measurement of bias
[c] Measurement of sensitivity

6.2.1.1 Precision

Precision is a measure of the variability between results of duplicate measurements due to random error. It is usually assessed using duplicate field measurements or laboratory analysis of duplicate samples. Random error is imparted by the variation in concentrations of samples from the environment as well as other introduced sources of variation (e.g., field and laboratory procedures). To address the amount of random error across different study sites the same sampling methods, equipment and procedures will be used at each study site. Additionally, the sites selected will reflect the natural variability of the parameters of interest across the region. To address the amount of random error within each sampling site, duplicate groundwater samples will be collected in the field by filling two sets of bottles at the same time from a pre-selected well. Professional judgement will be used to select the duplicate sampling locations. Duplicate soil samples will be collected at one of the selected land treatments in the study area. The soil core will be divided into one-foot sections, mixed and homogenized in a metal bowl, and filled into lab prepared sampling containers. Precision for field and laboratory duplicate samples will be expressed as relative percent difference (RPD) as shown in Table 11 and 12. The smaller the RPD, the more precise the measurement process. Good precision is indicative of relative consistency and comparability between different samples.

The targets for precision are based on past performance characteristics of measurements performed by MEL and ARI.

6.2.1.2 Bias

Bias is defined as the difference between the sample value and the true value of the parameter being measured. Bias is usually addressed by calibrating field and laboratory instruments, and by analyzing lab control samples, matrix spikes, and standard reference materials (see Table 11 and 12). Bias in field measurements and samples will be minimized by strictly following Ecology's measurement, sampling, and handling protocols. Laboratory control samples contain known amounts of analyte and indicate bias due to sample preparation and/or calibration. Matrix spikes are used to indicate bias due to matrix effects. Matrix spike duplicates provide an estimate of the precision of this bias. Bias in sampling design will be minimized by having study sites located in the area with similar climate, and soil type and environmental conditions.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance. It is commonly described as a detection limit. Targets for lab measurement sensitivity required for the project are listed in Table 11 and 12. Sensitivity for this study will also be how likely it is for us to detect differences between the specific treatment types. The degree of difference to which each treatment type effects how nitrates migrate through the soil column and into groundwater will be captured in this study. At this time, we cannot determine the magnitude of differences we expect to see between each of the treatments tested.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

Comparability expresses the confidence with which one set of data can be compared to another. Comparability will be ensured to the extent possible by implementing standardized procedures for sampling and analysis. Standard operating procedures (SOPs) to be used during this project are described in section 8.2. Data collected in this study will be comparable to other groundwater and soil data collected in the region that follow similar sampling protocols.

6.2.2.2 Representativeness

Representativeness expresses the degree to which data accurately and precisely represents the actual site conditions.

Representative groundwater samples will be collected for this project from upgradient and downgradient monitoring wells if available. The placement of these groundwater wells should capture representative data of the study site.

Multiple soil cores will be collected at each study site. The location and depth of each core should be representative of the area. Quality assurance samples collected during each sampling event will help to ensure that the data collected is representative of the sampling location. Representative data will be collected from each study site location by working in locations with similar climate and soil type and environmental conditions. This will allow data to be collected that is representative of the environmental conditions in the Lower Yakima Valley. Data collected in this study will be representative of the crop type and land treatments utilized in the study.

6.2.2.3 Completeness

Completeness establishes whether enough valid measurements were obtained to meet project objectives. The number of samples and results expected to establish the comparative basis for completeness.

The completeness goal for this project is to collect and analyze 100% of the measurements and samples. However, problems occasionally arise during sample collection that cannot be controlled; thus, a completeness of 90% is acceptable. Examples of potential problems that may be encountered are low yielding wells, equipment failure, analysis of data outside of hold times, and access to private property. The loss of any analytical or field data may decrease the ability of this project to achieve its objectives. If needed, additional efforts will be made to achieve 90% completeness of field and laboratory data. For example, additional sampling or analyses, or iterative reviews and corrections of laboratory data, may be requested until a data set is complete and accurate.

6.3 Acceptance criteria for quality of existing data

NA

6.4 Model quality objectives

NA

7.0 Study Design

7.1 Study boundaries

This study will be conducted in the Lower Yakima Valley. The plan is to assess a variety of land use management practices. This research will utilize existing farms and farming practices. The location and specific land use practices are dependent upon farmer permission and access to private property.

Additionally, Ecology is partnering with WSU to assess land use management practices on a plot of land at their Irrigated Agricultural Research and Extension Center (IAREC) in Prosser, WA. Figure 4 illustrates the location of the WSU research center with the study area highlighted in yellow. This site is located in WRIA 37. Specifically, the WSU irrigated agricultural research and extension center is located at address 24106 North Bunn Road, Prosser WA, 99350. The latitude and longitude of the field is 46.25474339° North, –119.7284636 ° West.

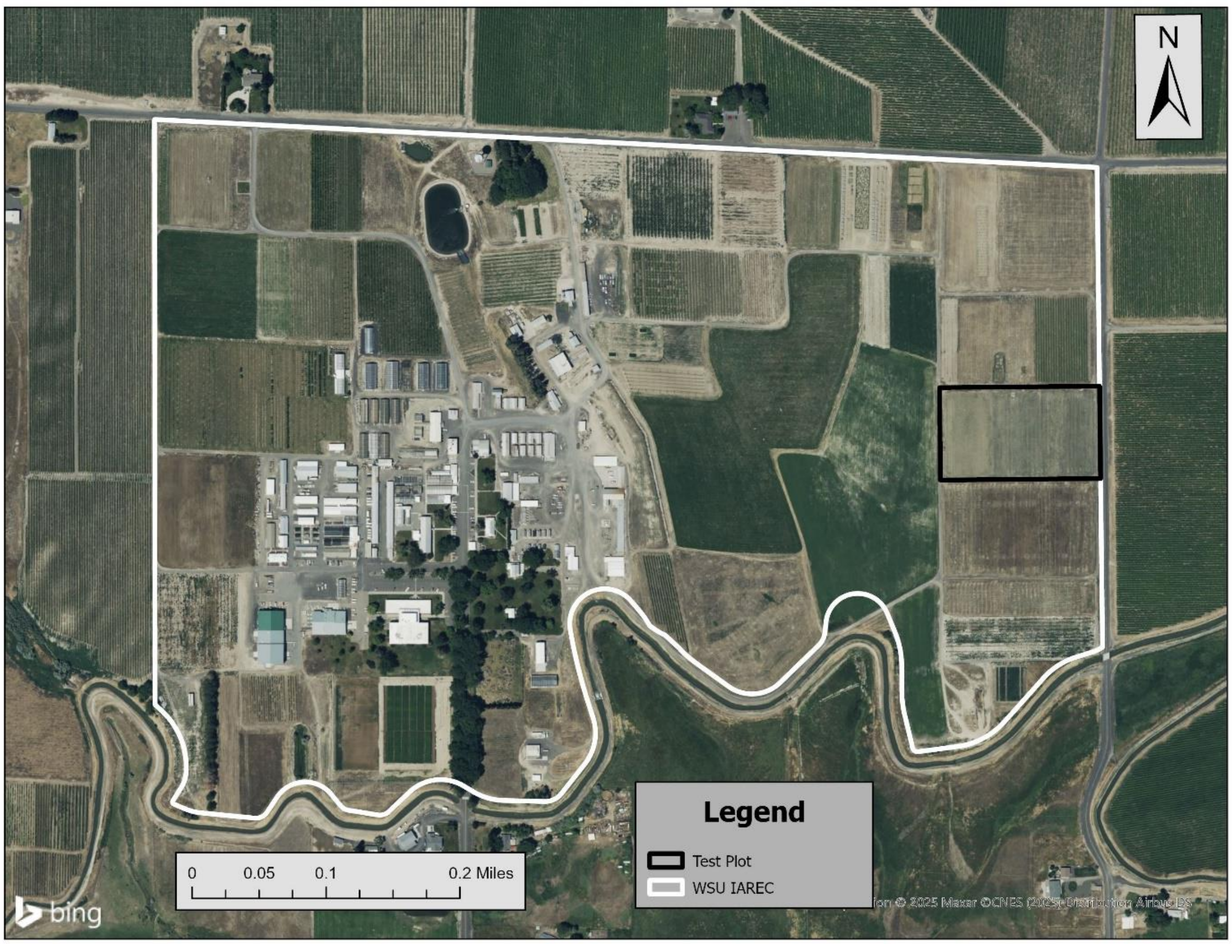

Figure 4. Study site at WSU irrigated agricultural research and extension center.

7.2 Field data collection

Groundwater and deep soil samples will be collected to assess variances in water and soil quality between land use management practices. Groundwater samples will measure impacts of land use on groundwater quality. It is often many years before changes in groundwater quality are detected due to a lag between what happens on the land surface, how nitrogen is used or retained in the soils, and how nitrate migrates through the soil profile to groundwater. Deep soil samples characterize the soil profile down to 6 feet. These soil samples will allow us to evaluate how contaminants move through the soil profile from one growing season to the next. This provides timely feedback to understand the link between what is happening on the land surface and how contaminants are removed, retained or migrated down below the root zone.

This combination of groundwater and deep soil sampling will allow a better understanding of specific agricultural conservation practices.

7.2.1 Sampling locations and frequency

This study involves multiple sampling locations to characterize multiple land use practices.

WSU Study Site:

Ecology is utilizing an existing study being conducted by Dr. Elizabeth Gillispie at the WSU Irrigated Agricultural Research Center. This study is a multiscale approach to evaluate and identify the influence of vineyard management practices on soil health in arid regions. The work being conducted by Dr. Gillispie aligns with the goals of this study and will be mutually beneficial.

Dr. Gillispie's study provides a well-controlled environment with precision irrigation and nutrient management. Ecology's study provides groundwater monitoring and deep soil sampling to provide a more comprehensive analysis of three treatment scenarios.

The vineyard is planted on five acres and divided into twenty test plots, which consist of four replicates of five different treatments (figure 5). This study focuses on 1) nutrient management, 2) cover crops, and 3) agronomic application. We will collect deep soil samples from test plots: T1, T4, and T5. Table 13 describes the different treatments for the test plots at the WSU study site and the planned sample sites. Two deep soils samples will be collected from each of the designated treatment types to assess variability.

Table 13. Treatment descriptions for WSU test plots.

Assigned study label	Treatment description	Under vine mowing	Fertilizer	Herbicide	Cover Crop
T1	WA 2021 Industry Standard (control)	no	Liquid fertilizer injection	yes	no
T2	Management Resident Vegetation	yes	Liquid fertilizer injection	no	no
T3	Under-vine Cover Crop	yes	Liquid fertilizer injection	no	under vine legume
T4	Organic Matter Additions	yes	composted dairy manure	no	no
T5	Integrated Management	yes	composted dairy manure	no	under vine legume, alleyway wheatgrass

Within each plot two types of wine grapes are growing: Cabernet Sauvignon and Chardonnay. For this project, our samples will be confined to the Cabernet Sauvignon side, which is the west side of each plot.

Deep soil sampling will be conducted twice each year, in the spring and the fall. Two soil cores will be collected from land treatments T1, T4, and T5 listed in table 13. In total six soil cores will be drilled. Six soil samples will be collected from each borehole, one at every foot. Samples will be collected adjacent to the vine root to capture targeted nitrogen applications. Locations of soil bores will be marked with a semi-permanent marker to consistently sample from the same proximate locations without sampling from previously disturbed boreholes.

Monitoring wells will be used to collect groundwater quality samples. The location of the monitoring wells in the area is shown in figure 5. Static water level measurements will assist with determining groundwater flow direction and any seasonal variations.

All wells were installed in accordance with Chapter 173-160 WAC and are constructed with 2-inch diameter PVC casing, with standard flush mount vaults. Each well is fitted with a locking J-plug, a keyed lock to keep the well secure, and a steel monument to protect the well. The shallow wells are approximately 15 to 24 feet below land surface, while the deep wells are approximately 50 feet below land surface.

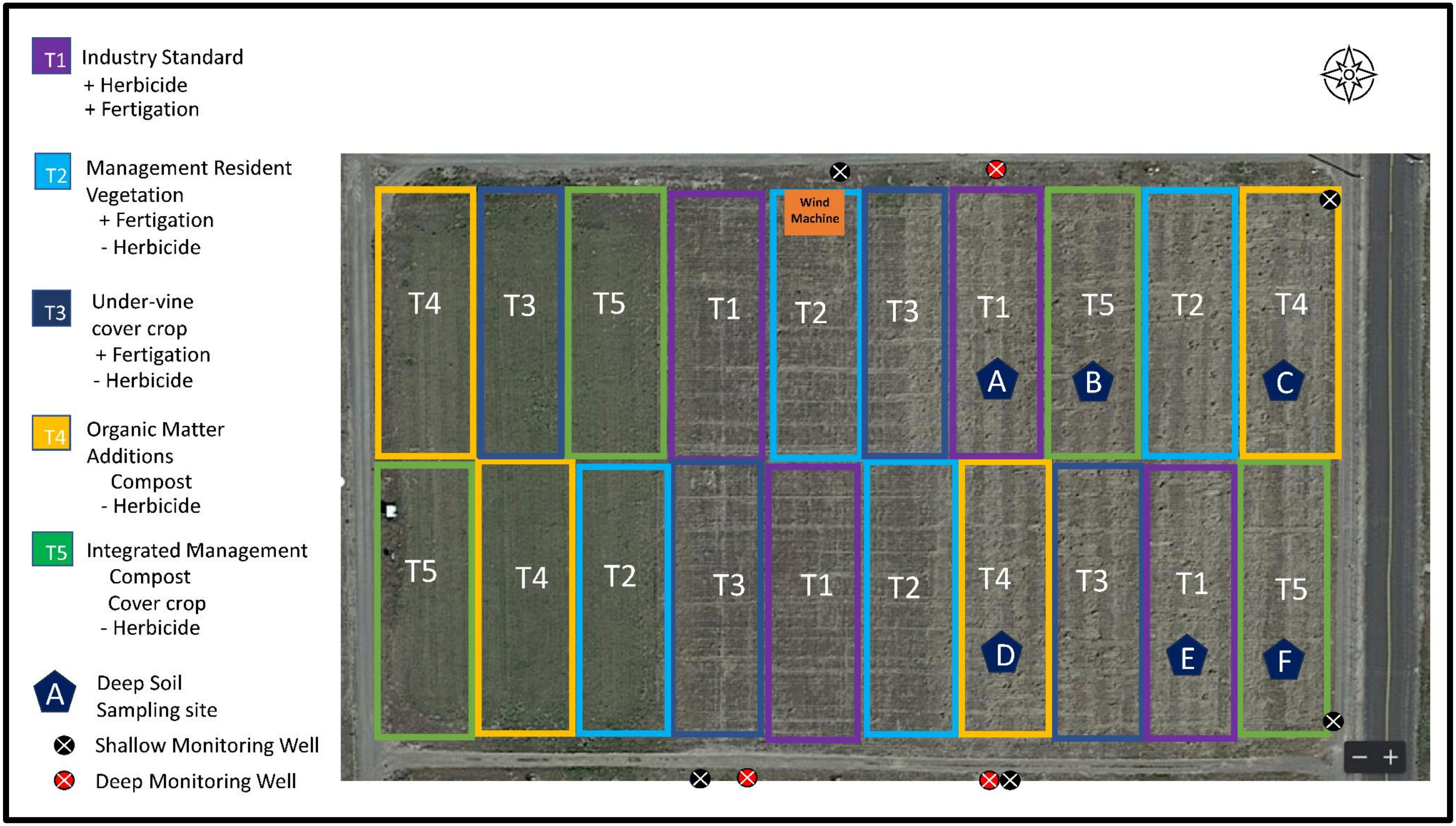

Figure 5. WSU Test Plot Treatments.

Additional Study Sites:

Ecology is working cooperatively with WSDA, SYCD and area soil consultants, to identify additional study sites. The intent with these sites is to work with farmers to compare typical practices with practices recommended to reduce nitrate loading.

Deep soil sampling will be conducted at these sites to track nitrate concentrations through the soil profile. Information will be taken from the farmer to understand the recent history of the field and management practices including:

- Irrigation schedule
- Fertilizer applications
- Type of fertilizer (liquid manure, solid manure, commercial, compost, etc.)
- Crop planted
- Crop yield
- Soil type
- Moisture content
- Root zone depth
- and geologic conditions.

Deep soil samples will be collected each year in the spring before nitrogen fertilizer is applied, and in the fall after harvest. Groundwater monitoring will occur if suitable existing wells are located near these study sites. Suitable wells would require the following conditions: wells be properly constructed, an adequate surface seal, completed in the surficial aquifer, an available driller well log, accessible to sample, ability to sample prior to any treatment, representative of aquifer conditions, and owner permission. Wells need to be able to indicate upgradient and downgradient conditions of the fields of interest.

7.2.2 Field parameters and laboratory analytes to be measured

Field parameters will be measured during the purging of the monitoring wells for pH, electrical conductivity, dissolved oxygen, temperature, oxidation/reduction potential, nitrate, and chloride. Static water level will be measured at each monitoring well.

Groundwater quality samples will be analyzed for nitrate (N), ammonia (N), chloride, bromide, sulfate, bicarbonate, sodium, potassium, magnesium and calcium.

Soil samples will be analyzed for nitrate (N), ammonium (N), and total carbon.

7.3 Modeling and analysis design

NA

7.3.1 Analytical framework

NA

7.3.2 Model setup and data needs

NA

7.4 Assumptions underlying design

The WSU site is outside the GWMA boundaries, although it is over the same aquifer. The WSU Irrigated Agriculture Research and Extension Center (IAREC) is the largest irrigated agricultural research center in the world. Findings from the work at WSU are often used to inform agricultural practices around the world.

Explanation of possible limitations is important for this study to acknowledge so that practices can be best applied to farms within the GWMA and in other areas of Washington State. The researchers are assuming that the soil type and climate at our study locations are the same or similar to those conditions in the GWMA. The researchers are also assuming that what is learned from the research may be applied to other farming practices within Washington State. Another assumption is that what we learn about one land treatment on a specific crop type may also be applied to other crop types.

7.5 Possible challenges and contingencies

The biggest challenge with this study is forming productive partnerships with farmers that will allow us to establish test plots on their property and follow protocols which allow us to identify practices that reduce nitrogen loading.

Anonymity will be offered to encourage participation.

7.5.1 Logistical problems

This project relies on the collaborative efforts between WSU, SYCD WSDA, farmers and Department of Ecology. Good communication will be crucial for a successful project.

The ability to evaluate land use practices and determine their success to reduce nitrate loading to groundwater, depends upon the willingness of our partners in the agricultural community to engage in scientific studies and cooperate with study design constraints. Threats to their livelihood could limit involvement.

Other logistical problems for this project include influences from inclement weather effecting sample schedules and issues with sample shipping.

7.5.2 Practical constraints

The success of the project involves collaboration and coordination with our partners and community members. Maintaining these relationships and staying focused on the long-term goals will help us stay connected. Damage to these relationships could risk the success of this project. We rely on our partner’s expertise, as well as their connections within the agricultural community.

The land use study at WSU is utilizing an existing project that was previously funded and designed. Ecology does not have the ability to alter the design of this project.

Other practical constraints include scheduling conflicts where multiple entities involved in the project need to be present and available at scheduled sampling events. Additionally staffing issues could affect the project (e.g., limitations in resources available, changes in funding, illness).

7.5.3 Schedule limitations

Field staff are working on multiple projects. Prioritization and planning are important to complete sampling for all projects.

Unforeseen field or laboratory complications (e.g., inability to collect samples from selected wells, problems with laboratory analytical equipment).

8.0 Field Procedures

8.1 Invasive species evaluation

NA

8.2 Measurement and sampling procedures

Groundwater

Groundwater sampling procedures for the study will follow Ecology SOP's and other relevant QAPPs:

- EAP052 version 1.4 for measuring depth to water (Marti 2023).
- EAP099 version 1.2 for purging and sampling monitoring wells for general chemistry (Carey 2023).
- Deep Soil Sampling for Lower Yakima Valley Nutrient Assessment and Planning Program QAPP (SYCD 2024)

Field measurements will be made at all sampling sites and recorded on waterproof field sheets and in the field notebook. The field notes recorded at each sampling site will include the information listed in section 8.7.

Monitoring Wells

Static water level will be measured using a clean electrical tape, before purging and sampling the monitoring wells. The water level measuring point will be permanently marked at the top of the PVC casing for each well. Measurements should be made to the nearest 0.01 foot. The electrical tape must be decontaminated after each use (Marti 2023).

A bladder pump will be used to purge and sample water from the monitoring wells. Clean disposable gloves will be worn. The pump will be lowered until the intake is below the water surface and within the zone of the well screen. The pump will be secured at the wellhead to prevent the pump from slipping during sampling. The depth of the pump water intake will be recorded in the field notes. Standard low-flow sampling techniques will be used to purge and sample the wells. The pump rate will be set at 0.5 liters per minute or less (Redding 2021).

Purge water will be routed into an airtight flow-through cell to measure field parameters using the calibrated EXO sonde. This allows measurements to be made before being exposed to the atmosphere. Measurements for temperature, pH, electrical conductivity, oxidation/reduction potential (ORP), and dissolved oxygen (DO) will be collected and recorded in the field notes. Purging will continue until the field parameters meet the stabilization criteria in Table 15. Stabilization is met once there are three consecutive readings within the criteria indicated for each specific parameter. Once the field parameters have stabilized, then samples will be collected through a 0.45 micron in-line cartridge filter, directly into clean laboratory-supplied containers from MEL. At least 500 ml of water will be rinsed through the filter before a sample is collected (Redding 2021).

Dedicated tubing for each monitoring well will be maintained in a clean, labeled, and sealed plastic bag. The bladder pump will be decontaminated between sampling each well.

Field Measurements

The water quality field sonde will be used to collect field measurements. The YSI EXO 3 will be calibrated before the beginning of each week. Calibration post checks will also take place at the end of each day of sampling to evaluate the accuracy of field measurements recorded each day. The water quality field sonde will be re-calibrated if needed. The calibration post check measurements will be recorded in the field notes. The YSI EXO 3 will be calibrated and maintained according to the manufacturer's directions.

Field measurement methods are listed in Table 14.

Table 14. Field measurement information.

Analyte	Sample Matrix	Expected Range of Results	Accuracy	Instrument
Temperature	Water	8-12 ˚C	± 0.01 ˚C	YSI EXO 3
pH	Water	4-8 S.U	± 0.01pH S.U	YSI EXO 3
Conductivity	Water	50-1000 µS/cm	± 1%	YSI EXO 3
Dissolved Oxygen	Water	0.0 -10 mg/L	± 1%	YSI EXO 3
Oxidation Reduction Potential	Water	-300 to 350 mV	± 20 mV	YSI EXO 3
Nitrate	Water	0.0–100 mg/L	± 2 mg/L	YSI EXO 3
Chloride	Water	0.0 – 250 mg/L	± 5 mg/L	YSI EXO 3
Static Water Level	Water	10-60 ft	± 0.01 ft	Electrical Tape

The goal of reaching field parameter stabilization criteria is to collect samples representative of in-situ conditions at the study site. Stabilization is met once three consecutive parameter readings have been taken that are within the stabilization criteria listed in table 15. When the stabilization criteria have been met for each of the parameters, then samples will be collected.

Table 15. Field Parameter stabilization criteria.

Field Parameter	Criteria
Temperature	±0.2 ˚C
pH	±0.2 SU
Specific Conductance	±10 µS/cm
Dissolved Oxygen	±0.3 mg/L
Oxidation/reduction potential	±20 mV

Soil

The sampling procedures for deep soil sampling in this study will generally follow the QAPP from the South Yakima Conservation District (SYCD 2024).

- Replicate soil samples will be collected from similar treatment plots.
- Two test plots per targeted treatment will be sampled.
- Soil samples will be collected at every foot down to 6 feet below land surface (or refusal) with a 2 inch or 1.25 inch diameter core.
- If taking multiple soil samples from one location, samples from each correlating depth will be composited.
    - Soil samples will be placed in clean plastic buckets (one for each depth interval) in preparation for composite mixing. Care will be taken to avoid mixing soils from different depths. Soil in the buckets will be mixed thoroughly to form a composite sample from the single foot depth. After compositing, a portion of soil in each bucket will be transferred to a lab-prepared sample container.
    - Soil samples will be characterized in terms of consistency, moisture content, color, grain size, as well as other observations.
- Soil core locations will be documented with a Global Positioning System (GPS).
- All equipment which contacts the soil samples will be cleaned between samples to prevent cross contamination. This includes any parts of the sampling rig, the plastic buckets, mixing and soil transfer tools. Clean gloves will be worn at each sample site.
- Boreholes will be backfilled with native soil to prevent creation of a vertical conduit (SYCD 2024).

South Yakima Conservation District staff will operate the mechanized sampling rig. Hard hats, protective eyewear and protective footwear will be required for everyone within 20 feet of the borehole rig.

A cultural resource survey and a utilities survey will be conducted prior to deep soil sampling.

8.3 Containers, preservation methods, holding times

Groundwater and soil will be analyzed by an accredited laboratory for the parameters shown in table 16. Sample containers will be provided by the laboratory.

Table 16. Sample containers, preservation, and holding times.

Sample Type	Parameter	Matrix	Minimum Quantity Required	Container	Preservative	Holding Time
Groundwater	Nitrate + Nitrite	Water	125 mL	Nalgene, HDPE / poly, clear	Sulfuric acid to pH <2, cool to < 6˚C	28 Days
	Ammonia	Water	125 mL	Nalgene, HDPE / poly, clear	Sulfuric acid to pH <2, cool to < 6˚C	28 Days
	Chloride	Water	500 mL	Nalgene, HDPE / poly, clear	Cool to < 6˚C	28 Days
	Bromide	Water	500 mL	Nalgene, HDPE / poly, clear	500 mL minimum Cool to < 6˚C	14 Days
	Sulfate	Water	500 mL	Nalgene, HDPE / poly, clear	Cool to < 6˚C	28 Days
	Bicarbonate	Water	500 mL	Nalgene, HDPE / poly, clear	Cool to < 6˚C	28 Days
	Sodium	Water	500 mL	Nalgene, HDPE / poly, clear	Nitric acid to pH ≤2, cool to ≤6°C	6 months
	Calcium	Water	500 mL	Nalgene, HDPE / poly, clear	Nitric acid to pH ≤2, cool to ≤6°C	6 months
	Potassium	Water	500 mL	Nalgene, HDPE / poly, clear	Nitric acid to pH ≤2, cool to ≤6°C	6 months
	Magnesium	Water	500 mL	Nalgene, HDPE / poly, clear	Nitric acid to pH ≤2, cool to ≤6°C	6 months
Soil	Nitrate + Nitrite	Soil	10 g	4-oz glass jar w/Teflon lid	Cool to ≤6˚ C	7 days
	Ammonia	Soil	10 g	4-oz glass jar w/Teflon lid	Cool to ≤6˚ C	7 days
Soil	Total Carbon	Soil	100 g	4-oz glass jar w/Teflon lid	Cool to ≤6˚ C	14 days

8.4 Equipment decontamination

<u>Groundwater</u>

All equipment that is not dedicated or new, will be decontaminated appropriately before sampling each site. Dedicated equipment is only used for one specific monitoring well and is not transferred between wells (e.g., pump tubing).

The electrical tape will be washed in a laboratory grade detergent followed by a deionized water rinse after use at each sampling location. The bladder pump will be disassembled, washed and scrubbed with a soft bristle brush in a laboratory grade detergent, followed by a rinse with deionized water. Pump tubing will be dedicated to each well and will not need to be decontaminated. All excess water left in the pump tubing will be blown out using an air compressor between sampling events.

Equipment blanks evaluate our decontamination procedures and will be collected and analyzed for every sampling event.

<u>Soil Sampling</u>

Any equipment that comes into contact with soil will be wiped clean after each field sampling site using clean cloths, water, and a solution containing 70% ethanol (or equivalent).

Samplers will wear clean gloves at each sampling site. Care will be taken to avoid touching the soil samples during sampling and compositing. All tools used in this process will be decontaminated prior to use.

Additional information on deep soil sampling decontamination procedures is available from SYCD, (2024).

8.5 Sample ID

MEL will provide the field lead with work order numbers for all scheduled sampling dates. The work order number will be combined with the field ID number that is established by the field lead. This combination of the work order number and field ID number constitutes the sample ID. All sample ID's will be recorded in field notebooks, field sheets, and within the electronic spreadsheet for tracking purposes.

In addition, each soil core collected at the designated location will be segmented into the appropriate depth interval designating the specific depth.

8.6 Chain of custody

Chain-of-custody procedures will be followed according to MEL protocol (MEL 2016).

Samples will be properly labeled and stored in ice-filled coolers and placed inside a secure vehicle. If the vehicle is left unattended, it will be locked to maintain chain-of-custody.

All samples will be stored at temperatures < 6˚C in the dedicated fridge in the locked laboratory at Ecology's CRO building until samples can be shipped to MEL or the contract laboratory. Samples will be shipped after each sampling event. Sample coolers will be secured with either metal clips or an adhesive seal. ID numbers for the metal clips or seals will be recorded on the Laboratory Analyses Required (LAR) form that will be placed in a plastic bag inside the cooler.

8.7 Field log requirements

A field log will be maintained by the field lead and used during each sampling event. The following information will be recorded:

- Name of the sampling location
- Field staff
- Environmental conditions
- ID's or serial number of sondes used
- Pump intake depth (Groundwater only)
- Field measurements (Groundwater only)
- Purge time (Groundwater only)
- Date, time, sample ID, and description of samples collected
- Soil sample depth interval (Soil only)
- Identity of QC sample, if appropriate
- Pertinent observations and any problems with sampling, including deviations from QAPP
- Unusual circumstances that might affect interpretation of results.

Field logs will consist of waterproof (rite in the rain) 8 x 11-inch field sheets preprinted for ease of recording and kept in an enclosed clipboard. Permanent waterproof ink will be used for all entries. Corrections will be made with a single-line strikethrough, initialed and dated.

8.8 Other activities

- Any field staff participating in this study will be trained by senior field staff or the project manager. Field sampling will follow the processes in this QAPP, and relevant Ecology SOPs listed in section 8.2.
- The principal investigator will notify the laboratory of any changes in scheduling.
- The principal investigator will work with the laboratory courier to develop a schedule for delivery of sampling containers.

9.0 Laboratory Procedures

9.1 Laboratory procedures table

Table 17 lists the detection limits, analytical method, and range of expected results for each analyte.

Table 17. Measurement methods (laboratory).

Sample Type	Analyte	Sample Matrix	Samples (Number/ Sampling Event)	Expected Range of Results	Detection Limit	Analytical (Instrumental) Method
Groundwater	Nitrate + Nitrite-N	Filtered Water	6	0.1 – 60 mg/L	0.01 mg/L	SM4500 NO3 I
	Ammonia-N	Filtered Water	6	0.1 – 60 mg/L	0.01 mg/L	SM 4500 NH3 H
	Chloride	Filtered Water	6	0.1 – 250 mg/L	0.1 mg/L	EPA 300.0
	Bromide	Filtered Water	6	6 mg/kg	0.025 mg/L	EPA 300.0
	Sulfate	Filtered Water	6	0.2 – 96	0.3 mg/L	EPA 300.0
	Bicarbonate (Alkalinity)	Filtered Water	6	42 – 339 mg/L	5 mg/L	SM2320B
	Sodium	Filtered Water	6	4 – 90 mg/L	0.025 mg/L	EPA 6010D
	Calcium	Filtered Water	6	1 – 88 mg/L	0.025 mg/L	EPA 6010D
	Potassium	Filtered Water	6	1 – 13 mg/L	0.25 mg/L	EPA 6010D
	Magnesium	Filtered Water	6	0.1 – 33	0.025 mg/L	EPA 6010D
Soil	Nitrate + Nitrite	Soil	42	0 – 30 mg/kg	0.100 mg/kg	EPA 353.2
	Ammonia	Soil	42	0 – 3 mg/kg	0.400 mg/kg	SM 4500-NH3 H11
	Total Carbon	Soil	14	—	0.100 %	EPA 440.0

9.2 Sample preparation method(s)

The laboratory will follow standard sample preparation procedures for each method listed in table 17. Groundwater samples will be filtered in the field using a clean disposable 0.45 µm filter and collected in pre-acidified bottles supplied by MEL.

9.3 Special method requirements

NA

9.4 Laboratories accredited for methods

Groundwater

This study will use Ecology's Manchester Environmental Laboratory (MEL), which is accredited for all laboratory methods specified for the water samples listed in table 17.

Soils

ARI will be used to analyze soil samples. ARI is an accredited laboratory for methods to analytes nitrate + nitrite, and ammonia. MEL will analyze the soil samples for total carbon.

10.0 Quality Control Procedures

Quality control (QC) procedures provide the information needed to assess the quality of data that are collected and analyzed. They can also help identify problems or issues associated with data collection and analysis while the project is underway. Variability for field sampling and laboratory analysis will be assessed by collecting QC samples and conducting QC analysis.

Field

QC procedures for field work will follow Ecology's Environmental Assessment Program standard operating procedures related to groundwater sampling. Field measurements made when collecting samples (temperature, pH, specific conductance, dissolved oxygen, and oxidation/reduction potential) will follow groundwater sampling SOPs listed in section 8.2.

Field meters will be calibrated in accordance with the manufacturer's instructions at the start of each sampling week. A calibration check will also be conducted at the end of each sampling day to verify the accuracy of the readings. Table 10, in section 6.2, specifies how field measurements will be managed if there is a discrepancy between pre-calibration and post calibration measurements.

Any equipment that is not dedicated to a specific well will be decontaminated prior to use. Field staff will wear clean gloves at each site while collecting samples to prevent contamination.

Field duplicates will be collected for at least 10% of the samples to determine the overall precision of the sample collection.

Equipment blanks will be used to help characterize potential contamination from different steps of the sampling process. Equipment blanks will consist of running DI water through decontaminated equipment into a sample container for analysis. This process helps to determine if our decontamination procedures are adequate.

Travel blanks consist of a sampling container filled with blank water supplied by the laboratory. This container will travel with other sample bottles from the laboratory to the field and back to the laboratory to assess contamination from travel.

Laboratory

Routine laboratory QC procedures will be adequate to estimate laboratory QC for this project. Laboratory QC samples consist of blanks, duplicates, matrix spikes, and check standards (MEL 2016). Precision will be estimated using results from duplicate analyses and be expressed as the Relative Percent Difference (RPD). Check standards serve as an independent check on the calibration of the analytical system and can be used to evaluate bias. Matrix spikes are used to check for matrix interference with detection of the analyte and can be used to evaluate bias as it relates to matrix effects. Blanks are used to check for sample contamination in the laboratory process.

10.1 Table of field and laboratory quality control

Laboratory and field QC procedures are presented in tables 18 and 19.

Table 18. Groundwater Quality control samples, types, and frequency.

Parameter	Field Equipment Blank / Sampling Event	Field Trip Blanks / Sampling Event	Field Replicates (%)	Laboratory Check Standards	Laboratory Method Blanks	Analytical Duplicates	Laboratory Matrix Spikes
Nitrate + Nitrite-N	1	1	10	1/batch	1/batch	1/batch	1/batch
Ammonia-N	1	1	10	1/batch	1/batch	1/batch	1/batch
Chloride	1	1	10	1/batch	1/batch	1/batch	1/batch
Bromide	1	1	10	1/batch	1/batch	1/batch	1/batch
Sulfate	1	1	10	1/batch	1/batch	1/batch	1/batch
Bicarbonate	1	1	10	1/batch	1/batch	1/batch	1/batch
Sodium	1	1	10	1/batch	1/batch	1/batch	1/batch
Calcium	1	1	10	1/batch	1/batch	1/batch	1/batch
Potassium	1	1	10	1/batch	1/batch	1/batch	1/batch
Magnesium	1	1	10	1/batch	1/batch	1/batch	1/batch

Table 19.Soil Quality control samples, types, and frequency.

Parameter	Field Equipment Blank / Sampling Event	Field Replicates / Sampling Event	Laboratory Check Standards	Laboratory Method Blanks	Analytical Duplicates
Nitrate + Nitrite	1	1	1/batch	1/batch	1/batch
Ammonia	1	1	1/batch	1/batch	1/batch
Total Carbon	1	1	1/batch	1/batch	1/batch

Each type of QC sample listed above will have 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

Corrective actions will be taken if activities are found to be inconsistent with the QAPP, field procedures, laboratory analyses, data review processes, MQOs, performance expectations, or other unforeseen problems. Options for corrective actions may include:

- Re-calibrating the measurement system.
- Collecting new samples using the method described in the approved QAPP.
- Accepting and qualifying laboratory results that do not meet all QC criteria.
- Reanalyzing laboratory samples that do not meet QC criteria.
- Convening project personnel and technical experts to decide on the next steps that need to be taken to improve performance of project components.

11.0 Data Management Procedures

As field and laboratory data are completed, data will be organized using various tabular and graphical formats for additional review, calculations, characterization, and reporting.

11.1 Data recording and reporting requirements

Analytical data received from MEL will be stored in an electronic format in the MEL Laboratory Information System (LIMS) and downloaded directly for review and entry by project staff. After the data are verified, MEL will summarize the data in case narratives and provide them to the project manager. Laboratory data will be checked for missing data and the case narratives from MEL will be reviewed for any issues encountered during analysis by the project manager and lead investigator. The data received from MEL will be entered into Ecology Environmental Management (EIM) system under the Study ID ESCH0001.

Data generated in the field will be transferred from field sheets into Microsoft Excel spreadsheets. Data spreadsheets will be verified for accuracy and uploaded into the EIM study.

Data analysis conducted by contract laboratories will be validated by MEL staff to ensure that the provided data deliverables are meeting the project goals and requirements.

Physical data and data not entered into EIM will be retained in a file system managed by the lead investigator.

11.2 Laboratory data package requirements

Laboratory generated data produced by MEL will be sent to the project manager in electronic format (from LIMS) and be accompanied by a case narrative. The reported case narratives will follow procedures outlined in the MEL Lab User's Manual (MEL 2016) and address the various data verification checks described in section 13 of this document.

The contract laboratory conducting the analysis will send analytical results in an electronic data deliverable (EDD) and summarize findings in a case narrative to MEL. The information delivered to Ecology will also include copies of all raw data necessary to perform an independent evaluation of the results, calibration and verification standards, EIM, EDD, sample and QC bench sheets.

11.3 Electronic transfer requirements

Laboratory generated data produced by MEL will be entered into the Laboratory Information System (LIMS) by MEL staff. MEL will follow the established protocol for transferring data to the EIM system through LIMS. Project staff will be notified when data is made available and can access the LIMS data and prepare it for review and upload into EIM.

Results provided by a contract laboratory will be in an Excel-compatible format (e.g., .csv) for ease of review, editing, and transfer into EIM. The typical EDD format is shown in table 20. Other deliverables may be included as needed to help us understand the data packages.

Table 20. Required fields for electronic data deliverables (EDDs) from contract laboratory (table modified from Redding et al. 2020).

Ref #	Field Name	*Example* Value
1	Study ID (Project Name provided to contract laboratory)	XXXX 2018
2	Field Station Identification (Ecology Field ID provided to contract lab)	STA5-CCC
3	Contract Laboratory Sample ID	L180327-5
4	MEL Work Order Sample ID (Ecology Sample ID provided to contract lab)	1803015-01
5	Field Collection Date (listed in COC)	10/25/2018
6	Date of Receipt at Contract Laboratory	3/15/2019
7	Sample Matrix (provided to contract laboratory)	Tissue
8	Sample Preparation Method	1668C
9	Analysis Method	1668C
10	Parameter Name (the 7-character format for PCBs is required)	PCB-001
11	CAS Number	2051-60-7
12	Sample Extraction Date	3/30/2018
13	Analysis Date	4/10/2018
14	Analysis Time	12:22
15	Laboratory Batch ID (to associate results with QC samples)	L80882
16	Contract Laboratory Name	MegaMSLab
17	Result Value	0.743
18	Result Value Units	ng/g
19	Result Reporting Limit	4.33
20	Result Reporting Limit Type (e.g., LOQ/MRL)	LOQ
21	Result Detection Limit	0.743
22	Result Detection Limit Type (e.g., EDL/MDL)	EDL
23	Result Value Qualifier	UJ
24	Result Basis (Wet/Dry)	Wet
25	Laboratory Duplicate (Yes/No)	Y/N
26	Laboratory Reanalysis (Yes/No)	Y/N

11.4 EIM data upload procedures

Data will be loaded into Ecology's EIM database following the EIM user's manual and EIM guidance. Data from the field and MEL will be entered using an EIM upload template.

After field and laboratory data are entered into EIM, the EIM Data Review Procedure requires checks for about 10% of the data to ensure that the data were entered correctly. If significant entry errors are discovered, a more intensive review will be undertaken.

11.5 Model information management

NA

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

MEL participates in performance and system audits of their routine procedures. Reported results of these audits are available upon request. Ecology's Lab Accreditation Program establishes whether the laboratory has the capability to provide accurate and defensible data. To demonstrate the laboratory's ability to provide accurate and defensible data, the accreditation process involves an evaluation of the laboratory's quality system, staff, facilities, equipment, test methods, records and reports.

Field audits are appropriate for a project involving either field measurements or sampling. It's important to maintain field consistency by reviewing the field procedures for groundwater and soil sampling. The aim of such reviews is to improve consistency of fieldwork, improve adherence to SOPs, assure safety, provide a forum for sharing innovations, and strengthen our data quality assurance program. This field audit will be conducted by a licensed hydrogeologist.

12.2 Responsible personnel

See Section 12.1

12.3 Frequency and distribution of reports

A technical report will be prepared documenting the study procedures, findings, conclusions and recommendations. The report will include a quality assurance evaluation describing data acceptability and qualification. The final report will undergo technical peer review by staff with appropriate expertise who are not directly connected to the project. The final report will be published according to the project schedule shown in Section 5.4.

12.4 Responsibility for reports

The EAP project manager will be the primary lead and the principal investigator will assist on the final report. The work will be conducted or overseen by a licensed hydrogeologist.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

Data verification is a review process that assesses the quality and completeness of analytical datasets. This section describes the data verification and validation process for this project.

MEL (2012) defines data verification as "The process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or contractual requirements." Data validation is defined as "the analyte-specific and sample specific process that extends the evaluation of data beyond method, procedural, or contractual requirements (i.e., data verification) to determine the analytical quality of a specific data set."

Field Data Verification

Field notebooks and electronic information storage will be checked for missing or improbable measurements, and initial data will be verified before leaving each site. This process involves checking the data sheet (written or electronic) for omissions or outliers. If measurement data are missing or a measurement is determined to be an outlier, the measurement will be flagged in the data sheet and repeated if possible. The field lead is responsible for in-field data verification (McCarthy et al. 2017).

Post-Field Work Data Verification

Upon returning from the field, data are either manually entered (data recorded on paper) or downloaded from instruments and then uploaded into the appropriate database or project folder (see Data Management Section). Manually entered data will be verified/checked by a staff member who did not enter the data. Downloaded electronic data files will also be checked for completeness and appropriate metadata (e.g., filename, time code, associated location ID) (McCarthy et al. 2017).

Sonde Data Verification

Following data entry verification, raw field measurement data will undergo a quality analysis verification process to evaluate the performance of the sensors. Field measurement data will be compared to post check data for the same sampling day. Data that falls out of the MQO will be flagged following the standards described in table 10 in section 6.2 of this document.

If Ecology staff adjust any data, it will be noted in the final report. Data adjustment must be performed or reviewed by a project manager or principal investigator with the appropriate training and experience in processing raw sensor data (McCarthy et al. 2017).

13.2 Laboratory data verification

All laboratory data generated for this project will undergo verification and validation analysis. The results produced by MEL are verified and validated using MEL SOPs and an extensive data review and verification process. MEL staff will review all laboratory analysis for the project to verify that the methods and protocols specified in the QAPP were followed; that all instrument calibrations, QC checks, and intermediate calculations were performed appropriately; and that the final reported data are consistent, correct and complete with no omissions or errors (Lombard and Kirchmer 2016). Evaluation criteria will include the acceptability of instrument calibrations, procedural blanks, spike sample analysis, precision data, laboratory control sample analysis and the appropriateness of assigned data qualifiers. MEL staff will prepare a written case narrative describing the results of their data review.

Data qualifiers are typically assigned to results as part of the analysis and data review process. Qualifiers may also be assigned or changed during the data validation process or by the project manager during the broader data quality assessment. Table 21 shows the most common data qualifiers used with results for this project's target analytes.

Table 21. Common laboratory data qualifiers.

Qualifier	Definition
U	The analyte was analyzed but was not detected at the reported quantitation limit.
J	The analyte was positively identified, and the associated numerical value is the approximate concentration of the analyte in the sample.
UJ	The analyte was not detected at or above the reported quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.
REJ	The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet the quality control criteria. The presence or absence of the analyte cannot be verified.
E	Reported result is an estimate because it exceeds the calibration range.
NAF [1]	Not analyzed for.
NC [1]	Not calculated.

[1] These are not EIM valid values (since there would be no reported data, these would not be present in EIM).

13.3 Validation requirements, if necessary

NA

13.4 Model quality assessment

NA

13.4.1 Calibration and validation

NA

13.4.1.1 Precision

NA

13.4.1.2 Bias

NA

13.4.1.3 Representativeness

NA

13.4.1.4 Qualitative assessment

NA

13.4.2 Analysis of sensitivity and uncertainty

NA

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

Once all laboratory and field data are verified, a detailed examination of the data package using statistics and professional judgment will be performed. The project manager will examine the entire data package to determine if the criteria for MQOs for accuracy, precision, and bias are met. Data completeness, representativeness, and comparability criteria will be evaluated. If the criteria have not been met, the project manager will decide if affected data should be qualified or rejected based upon the decision criteria from the QAPP. The project manager will decide how any qualified data will be used in the technical analysis.

14.2 Treatment of non-detects

Non-detect values will usually be handled using one to three of the following substitution methods, depending on the purpose of the analysis:

- Substitute the reporting limit. Typically used for general characterization of the data to provide a high-level view of the results and where substituting the reporting limit does not compromise decisions related to regulatory actions. This substitution method assumes that all target analytes were detected and yields the highest contaminant concentration values. This method can provide a worst-case scenario for risk assessment.
- Substitute one-half of the reporting limit. Also used for general characterization of the data. This assumes that all target analytes were detected, but at a level between the detection limit and zero. This method provides another scenario for risk assessment.
- Substitute the value of zero. This method assumes a best-case scenario for risk assessment.

The project manager will determine how non-detects will be treated. This will be evaluated based on the entire data set.

14.3 Data analysis and presentation methods

All acceptable and appropriate laboratory and field results will be compiled in Excel tables from which further data reduction will occur. Individual tables are used for compiling data that originates from different sources. These source tables are then used for data reduction tasks performed in different spreadsheets. The most common data sets will be:

- Field measurements.
- Laboratory results from MEL and Contract Laboratory: sample results and QC results.

A final data set is compiled from, and includes results from, other data reduction efforts. The final data set for further analysis and reporting purposes will be a single Excel table that includes:

- Sample ID, location, collection date and time. Anonymity will be preserved for samples collected from private property.
- Results and related parameter, method, and laboratory results for all target analytes.

Data will be presented in tabular and graphic forms.

Statistical methods will be used to determine if differences exist between the test plots. This will help with assessing the benefits of different land use practices.

14.4 Sampling design evaluation

The sampling design for this project is expected to be adequate to meet the project goals and objectives. However, smaller sample numbers and higher variability than expected may render the sampling design to be less effective than desired in some cases. The quality and quantity of results will be noted in the final report as well as any potential impacts on attaining the overall project objectives.

14.5 Documentation of assessment

Documents used for the data usability assessment will include a variety of notes and reports described above, such as:

- Field notes and laboratory case narratives.
- Verification and validation reports from vendors, laboratories, and project staff.
- Worksheets and tables comparing results from field and QC samples to MQOs and other data quality indicators

A data quality review worksheet may be created to record the overall decision about how to use laboratory results for each group of analytes for each sampling event. Further documentation of the data usability assessment will occur in the final report *Methods* section. The final report for the project will discuss data quality, usability and limitations (Redding 2021).

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16.0 Appendices

Appendix A. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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

Ammonia: is an inorganic chemical compound of nitrogen and hydrogen with the formula NH_3

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.

Cover crops: are plants grown to manage weeds, reduce erosion, improve soil quality, retain water, and prevent pests and diseases; they may help prevent nutrient leaching (WSDA 2018).

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

Electronic Data Deliverable (EDD): An Electronic Data Deliverable, or EDD for short is a flat file format, such as text, Excel, or other tabular file that follows a consistent design meant to organize information in a useful format. EDD files us a row of headers (typically one or two rows) that describe what information should be completed in each column the header precedes, and in what format that data should be entered (EPA 2010).

Groundwater: is water that exists underground in the saturated zones beneath the land surface. The upper surface of the saturated zone is called the water table (USGS 2025).

Maximum Contaminant Level (MCL): A standard that is set by the U.S. Environmental Protection Agency (EPA) for drinking water quality. An MCL is a legal threshold limit on the amount of a substance that is allowed in public water systems under the Safe Drinking Water Act.

Nitrate + nitrite-N: The sum concentration of nitrate and nitrite referring to the amount of nitrogen ion present.

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.

ORP: Oxidation / reduction potential also known as Redox is the chemical reaction in which an atom or molecule loses electrons to another atom or molecule. Oxidation is the loss of electrons; reduction is the gain of electrons. The more positive the potential, the greater the species affinity for electrons and tendency to be reduced (Driscoll 1986, EPA 2024).

Parameter: Water or soil quality constituent measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

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.

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

Acronyms and Abbreviations

ARI	Analytical Resource, LLC
BMP	Best management practice
COC	Chain of Custody
CRO	Central Regional Office
DO	Dissolved oxygen
DI	Deionized
EAP	Environmental Assessment Program
EDD	Electronic Data Deliverable
EDL	Estimated Detection Limit
e.g.	For example
etc.	Etcetera
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EOS	Eastern Operations Section
EPA	U.S. Environmental Protection Agency
et al.	And others
GPS	Global Positioning System
GWAC	Groundwater Advisory Committee
GWMA	Groundwater Management Area
HDPE	High-density Polyethylene
IAREC	Irrigated Agriculture Research and Extension Center
ID	Identification
i.e.	In other words
LAR	Laboratory Analyses Require
LIMS	Laboratory Information Systems
LOQ	Limit of Quantitation
MDL	Method Detection Limit
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
MTGU	Modeling, TMDL, & Groundwater Unit
NA	Not Applicable
ORP	Oxidation Reduction Potential
QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
RCW	Revised Code of Washington
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
SYCD	South Yakima Conservation District
USGS	United States Geological Survey
WA	Washington

WAC	Washington Administrative Code
WQP	Water Quality Program
WRIA	Water Resource Inventory Area
WSDA	Washington State Department of Agriculture
WSU	Washington State University

Units of Measurement

°C	degrees centigrade
ft	feet
g	gram, a unit of mass
kg	kilograms, a unit of mass equal to 1,000 grams
mg	milligram
mg/kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mL	milliliter
mV	millivolts
N	nitrogen
N/L	nitrogen per liter
OZ	ounce
S.U.	standard units
µm	micrometer (micron)
µmhos/cm	micromhos per centimeter
µS/cm	microsiemens per centimeter, a unit of conductivity
%	percent

Quality Assurance Glossary

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Data validation: An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability, and integrity, as these criteria relate to the usability of the data set. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

- Use of raw or instrument data for evaluation.
- Use of third-party assessors.
- Data set is complex.
- Use of EPA Functional Guidelines or equivalent for review.

Examples of data types commonly validated would be:

- Gas Chromatography (GC).
- Gas Chromatography-Mass Spectrometry (GC-MS).
- Inductively Coupled Plasma (ICP).

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

- No qualifier – data are usable for intended purposes.
- J (or a J variant) – data are estimated, may be usable, may be biased high or low.
- REJ – data are rejected, cannot be used for intended purposes.
  (Kammin 2010; Ecology 2004).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set (Ecology 2004).

Detection limit (limit of detection)**:** The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero (Ecology 2004).

Duplicate samples: Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis (USEPA 1997).

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport (Ecology 2004).

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples (Kammin 2010).

Laboratory Control Sample (LCS): A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples (USEPA 1997).

Matrix spike: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects (Ecology 2004).

Measurement Quality Objectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness (USEPA 2006).

Measurement result: A value obtained by performing the procedure described in a method (Ecology 2004).

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed (EPA 1997).

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples (Ecology 2004; Kammin 2010).

Method Detection Limit (MDL): This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero (Federal Register 2025).

Percent Relative Standard Deviation (%RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner: **%RSD = (100 * s)/x**

where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin 2010).

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all parameters (Kammin 2010; Ecology 2004).

Population: The hypothetical set of all possible observations of the type being investigated (Ecology 2004).

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator (USGS 1998).

Quality assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data (Kammin 2010).

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives (Kammin 2010; Ecology 2004).

Quality control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data (Ecology 2004).

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used: **[Abs(a-b)/((a + b)/2)] * 100**

where "Abs()" is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology 2004).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled (USGS 1998).

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator (USGS 1998).

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population (USGS 1998).

Sample (statistical): A finite part or subset of a statistical population (USEPA 1997).

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit (Ecology 2004).

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method (USEPA 1997).

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency (USEPA 1997).

Split sample: A discrete sample subdivided into portions, usually duplicates (Kammin 2010).

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity (Kammin 2010).

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis (Kammin 2010).

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

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