DEPARTMENT OF ECOLOGY
State of Washington

Quality Assurance Project Plan

Lower Yakima Valley Groundwater Management Area (GWMA), Ambient Groundwater Monitoring Network

June 2021

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Quality Assurance Project Plan

Lower Yakima Valley Groundwater Management Area (GWMA), Ambient Groundwater Monitoring Network

by Melanie Redding

Published June 2021

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Signatures are not available on the Internet version.
CRO: Central Regional Office
EAP: Environmental Assessment Program

1.0 Table of Contents

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2.0 Abstract

The *Lower Yakima Valley Groundwater Management Area (GWMA) Ambient Groundwater Monitoring Network* is designed to assess the condition of the aquifer over time. The Department of Ecology will collect nitrate samples from 170 wells, spatially distributed across the GWMA. To characterize seasonal variability, samples will be collected quarterly for two years (July 2021-April 2023) and collected annually thereafter. This assessment will provide the data to statistically determine trends in nitrate concentrations across the aquifer over time.

This project was funded by the Washington State Legislature to continue the work of the GWMA and implement the top recommendation: establish an ambient groundwater monitoring network and collect data.

3.0 Background

3.1 Introduction and problem statement

Nitrate is the most prevalent groundwater contaminant in the world (Nolan and Stoner, 2000; Rosenstock et al., 2014). Nitrogen is a natural element that is concentrated through many sources and activities, including animal and human wastes, plants, fertilizers, and precipitation. Nitrate is very soluble in water and highly mobile. Leaching of nitrate to groundwater occurs when precipitation or other water sources transport it through the subsurface beyond the root zone. Nitrate is a negatively charged ion and is not attenuated by negatively charged soil particles (Killpack and Buchholz, 1993; O'Leary et al., 2002).

Groundwater in the Lower Yakima Valley contains elevated nitrate concentrations. In 2008, the Yakima Herald Republic printed a series of articles entitled "Hidden Wells, Dirty Water" by Leah Beth Ward. The articles described nitrate issues documented in private wells that are used for drinking water. The articles also highlighted the lack of coordination between local, state, and federal government agencies, and prompted community meetings to address the issue.

In November 2009, the U.S. Environmental Protection Agency (EPA) designated the Lower Yakima Valley as an Environmental Justice Showcase Community. In January 2010, the EPA issued a finding in support of section 1431 of the Safe Drinking Water Act to address groundwater contamination. Additionally, EPA determined that the groundwater in the Yakima Valley is an underground source of drinking water.

A Preliminary Assessment (Ecology, 2010) determined that 34% of residents get their drinking water from private wells, with an estimated 2,000 people in the area exposed to water above (not meeting) the drinking water standard. This water was determined to be contaminated and may present an imminent and substantial endangerment to human health (PGG, 2011).

The historic nature and pervasiveness of this problem led to community involvement. A preliminary assessment and recommendations document (Ecology, 2010) was developed, which summarized the groundwater issues and offered regulatory options to address the problems. The Yakima County Commissioners chose to establish a Groundwater Management Area (GWMA) to manage this issue and signed an interagency agreement with the Washington State Department of Ecology (Ecology).

In 2012, a Groundwater Advisory Committee was formed with about 30 members representing the diverse interests in groundwater protection.

Groundwater Management Area (GWMA)

The Lower Yakima Valley GWMA was formed with the goal of reducing nitrate concentrations in groundwater. A large and diverse committee was formed with representatives from identified groups interested in water quality: local, state, and federal government agencies, local citizens, farmers, dairy producers, agronomists, irrigation districts, conservation districts, environmental groups, and other vested parties. A comprehensive program was developed and approved, which includes decisions, recommendations, and accomplishments made by the committee. This program is the foundation for implementing actions that will improve groundwater quality (GWAC, 2019).

The GWMA committee identified over 250 potential alternative management strategies that could reduce nitrate concentrations in groundwater. Consensus was reached on 64 recommended actions, and these were prioritized. The development and approval of the GWMA program concludes the planning stage, and implementation of the recommended actions is now underway.

- The first recommended action was to install ambient groundwater monitoring wells. This work was completed by Pacific Groundwater Group in 2019 (PGG, 2019).
- The second prioritized recommended action was to establish an ambient groundwater monitoring network that addresses seasonal variability and long-term trends to determine the status of the aquifer over time. The actions described in this Quality Assurance Project Plan (QAPP) will implement this second recommendation.

3.2 Study area and surroundings

The Lower Yakima Valley GWMA (Figure 1) is located south of Union Gap, north and east of the Yakima River (which is coincident with the southwestern border of the GWMA), and west of the Yakima-Benton County line. The Yakama Nation is to the south; the northern boundary generally lies along the southern slopes of the Rattlesnake Hills. The total area is 175,161 acres (GWAC, 2019).

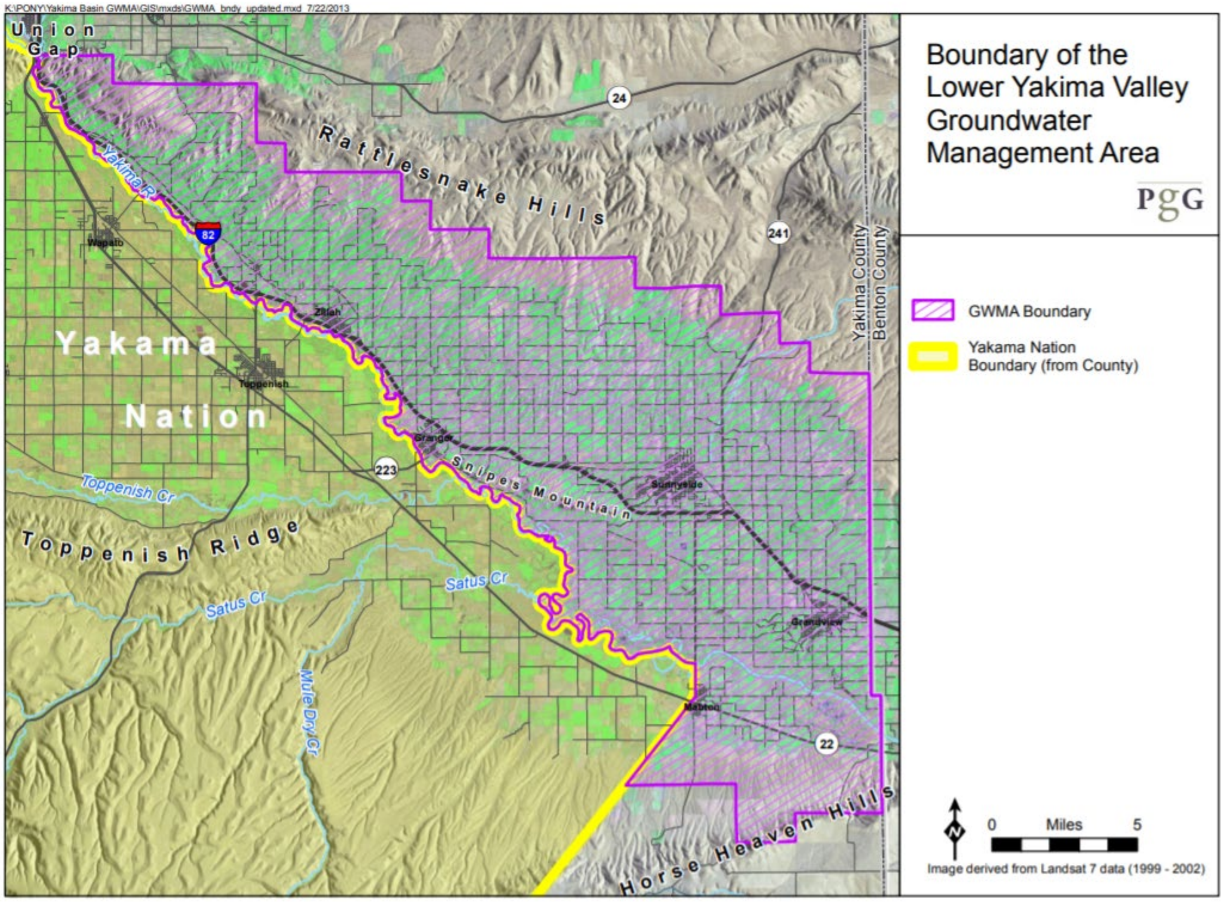

Figure 1. Map of study area. (PGG, 2013b)

Groundwater and Hydrogeology

Groundwater

The Lower Yakima Valley aquifer is the principal drinking water source for over 56,000 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, while groundwater recharge is estimated to range from 7 to 25 inches per year (PGG, 2011). The higher recharge rates, estimated by Vaccaro and Olsen (2007), are the result of irrigated agriculture and leakage of irrigation water.

Surficial groundwater generally flows towards surface water, with the Yakima River flowing southeast through the Lower Yakima Valley GWMA. Depth to water varies depending on location. In the valley bottom near Granger, Sunnyside, and Grandview, depth to water is shallow measuring from a few feet below land surface (bls) to about 15 feet deep. The further away from the river, depth to groundwater is generally deeper, increasing to over 100 feet bls 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:

Wanapum Basalt

The Lower Yakima Valley is located in the Columbia Basin Physiographic Province, which is an extensive basalt plain that formed from lava flows through fissures southeast of the valley about 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).

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 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 et al., 2009; Vaccaro, 2011).

Missoula Glacial Lake Deposits

During the Ice Age 12,000 years ago, glacial Lake Missoula was formed by an ice dam 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 et al., 2009; Vaccaro, 2011).

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 about 30 feet thick (Vaccaro et al., 2009; Vaccaro, 2011).

3.2.1 History of study area

Agriculture is the historic and current land-use activity in the Lower Yakima Valley, and agriculture is the primary economic source of income within the GWMA, with 70% to 80% of the land utilized for agriculture (Ecology, 2010; GWAC, 2019). Most cropland is irrigated to grow apples, pears, cherries, peaches, vegetables, hay, mint, and hops. Concentrated animal feeding operations (CAFOs) have increased in the Lower Yakima Valley, with 37% of the cattle population in Washington State in 2008 (GWAC, 2019).

3.2.2 Summary of previous studies and existing data

A Preliminary Assessment (Ecology, 2010) was completed by a variety of government agencies to characterize the extent of the problem. This report found:

- About one-third of residents (24,000) rely on private domestic wells for their drinking water.
- Typically, private wells draw water from the surficial aquifer, which is often shallow.
- Over 2,000 people are exposed to elevated nitrate levels higher than (not meeting) the drinking water standard of 10 mg as nitrogen per liter (N/L), with about 12% of the wells sampled not meeting the drinking water standard.
- There is a correlation between nitrate concentration and well depth, with nitrate concentrations decreasing with increasing well depth.
- Naturally occurring nitrate is generally less than 1 mg N/L. Concentrations higher than 1 mg N/L typically indicate impacts from human activity (Dubrovsky et al., 2010).
- No clear trends in nitrate concentrations across the valley were apparent.

Nitrate in groundwater has been documented in several historic studies in the Lower Yakima Valley (GWAC, 2019). Two recent studies conducted by the GWMA planning committee provide a more comprehensive and current assessment with groundwater quality sampling:

1. *Concentrations of Nitrate in Drinking Water in the Lower Yakima River Basin, Groundwater Management Area, Yakima County, Washington, 2017* documents a drinking water quality survey of 156 private domestic wells (USGS; 2018).
2. *Lower Yakima Valley Groundwater Management Area, Ambient Groundwater Monitoring Well Installation Report* documents the installation and one-time sampling of 30 groundwater monitoring wells (PGG, 2019).

Drinking Water Survey

The U.S. Geological Survey (USGS; 2018) conducted an intensive sampling study focusing on private domestic drinking water sources. These researchers sampled 156 residential drinking water wells in the Lower Yakima Valley GWMA about every six weeks from April through December, 2017. All samples were collected before any filtration or treatment. Samples were collected directly from a spigot after purging the wells until field parameter measurements had stabilized. Figure 2 shows the locations of the residential wells sampled in this study and the relative nitrate concentrations.

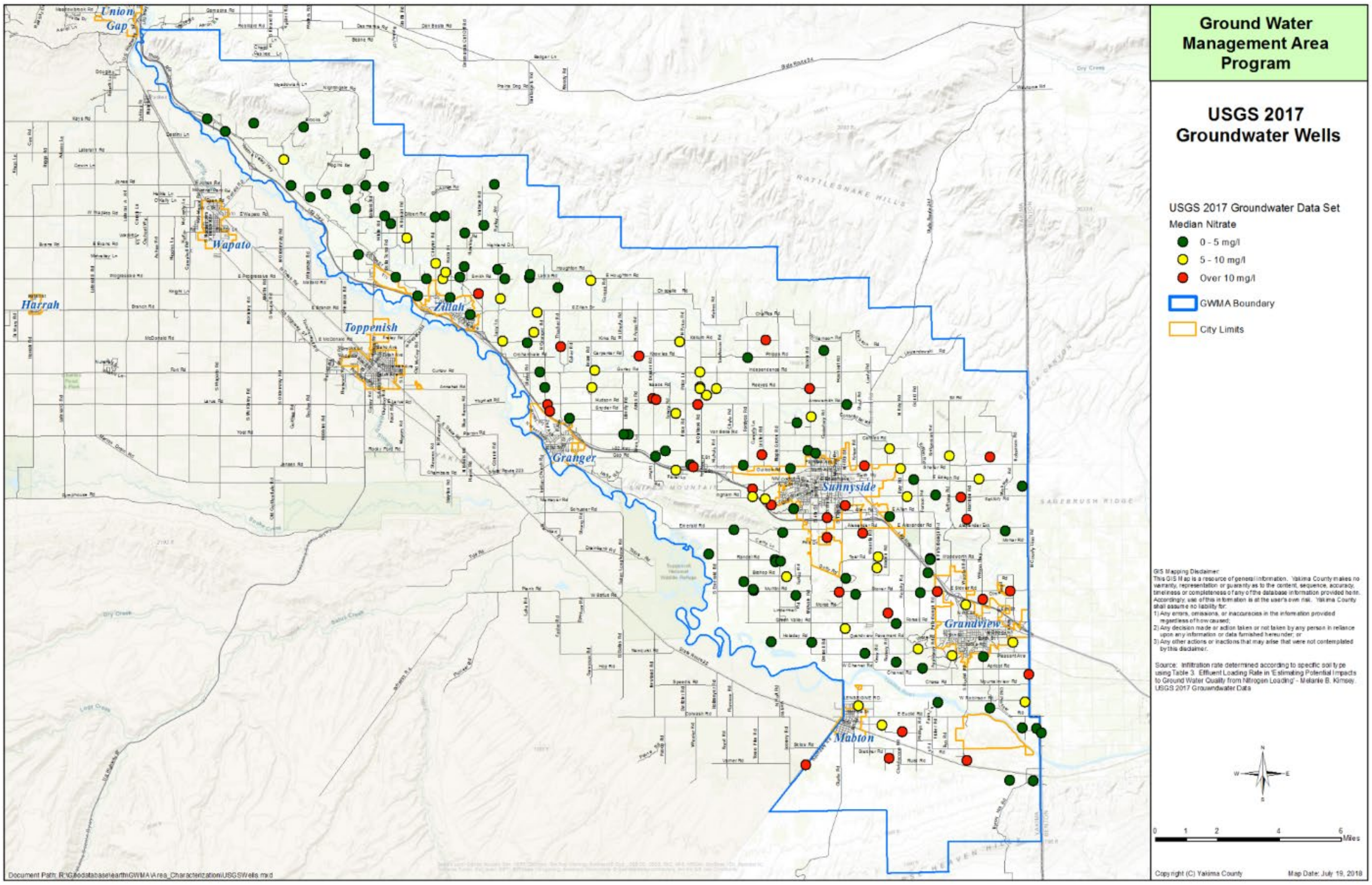

Figure 2. Private domestic drinking water sampling locations and results (GWAC, 2019)

This study found that nitrate concentrations in groundwater ranged from 0.04 to 45.2 mg N/L, with a mean concentration of 6.1 mg N/L. More than 20% of the samples had nitrate concentrations not meeting the drinking water standard of 10 mg N/L.

Monitoring Well Installation and Sampling

Pacific Groundwater Group (PGG, 2019) installed 30 monitoring wells to establish baseline groundwater nitrate concentrations near the water table (top of the aquifer). The wells were screened across the water table because there are few data from the water table and because concentration changes associated with land use changes will occur here first (PGG, 2016). Funding from the GWMA budget allowed for 30 monitoring wells to be installed, developed, conduct an aquifer test, and sampled once. The locations and nitrate concentrations of these 30 wells are shown in Figure 3.

Forty-five percent of the 30 randomly placed monitoring wells exceeded (did not meet) the safe drinking water standard for nitrate during the initial well sampling in the fall of 2018. Since the monitoring wells are screened across the water table, they intercept water impacted by surface activities as it first reaches groundwater. This upper zone is a good indicator of impacts from surface activities.

These results indicate that the elevated nitrate levels in the Lower Yakima Valley GWMA aquifer is a pervasive problem, and that residents in the Lower Yakima Valley may be drinking water that may pose a health risk.

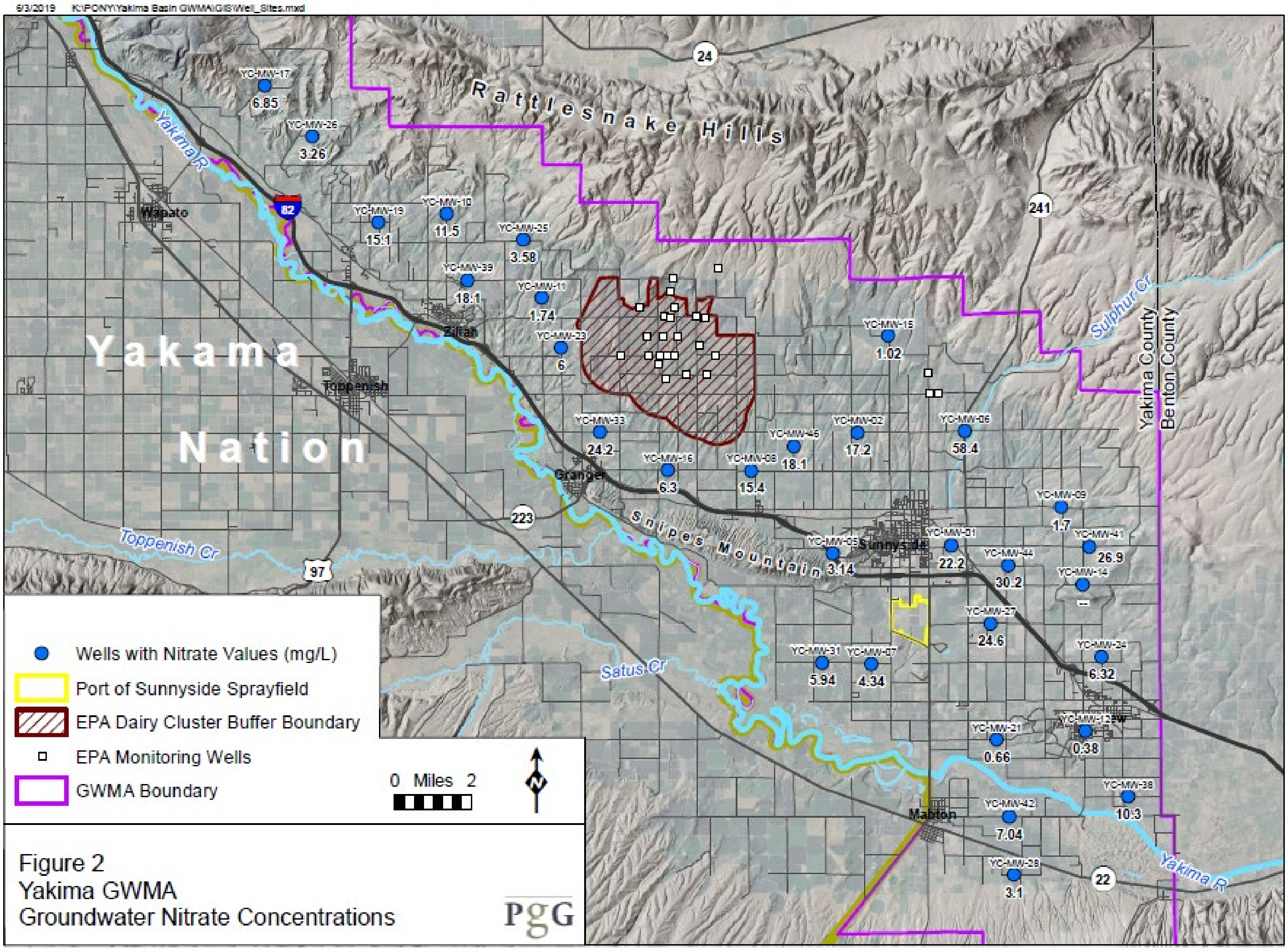

Figure 3. Locations of the monitoring wells installed by the GWMA and the respective nitrate concentrations (PGG, 2019).

3.2.3 Parameters of interest and potential sources

This study will focus on nitrate-nitrogen. Ammonia-nitrogen may also be sampled and analyzed if there is an indication that anaerobic conditions exist. This will give an accurate account of all nitrogen species that may be present in groundwater.

The focus of the Lower Yakima Valley GWMA is to reduce nitrate concentrations in groundwater to below (meeting) drinking water standards. This study is an ambient groundwater monitoring network that will indicate the quality of the aquifer over time. This study is not intended to identify specific sources of nitrate. Instead, this study is intended to provide long-term information on the state of the aquifer across the entire GWMA.

Nitrogen Availability Assessment

The Washington State Department of Agriculture (WSDA) conducted a detailed assessment in the Lower Yakima Valley GWMA of nitrogen available for transport to groundwater (WSDA, 2018). This study estimated the amount of nitrogen that is available for transport to groundwater, but the study does not calculate the amount of nitrogen actually transported through the vadose zone or loading to groundwater.

These estimates were made using as much local information as possible; scientific estimates were used to fill data gaps. The data were compiled in spreadsheets and incorporated into a GIS database. Since these were estimates, three different scenarios were presented: low, medium, and high. This provides a range and average of nitrogen loading estimates (Figure 4).

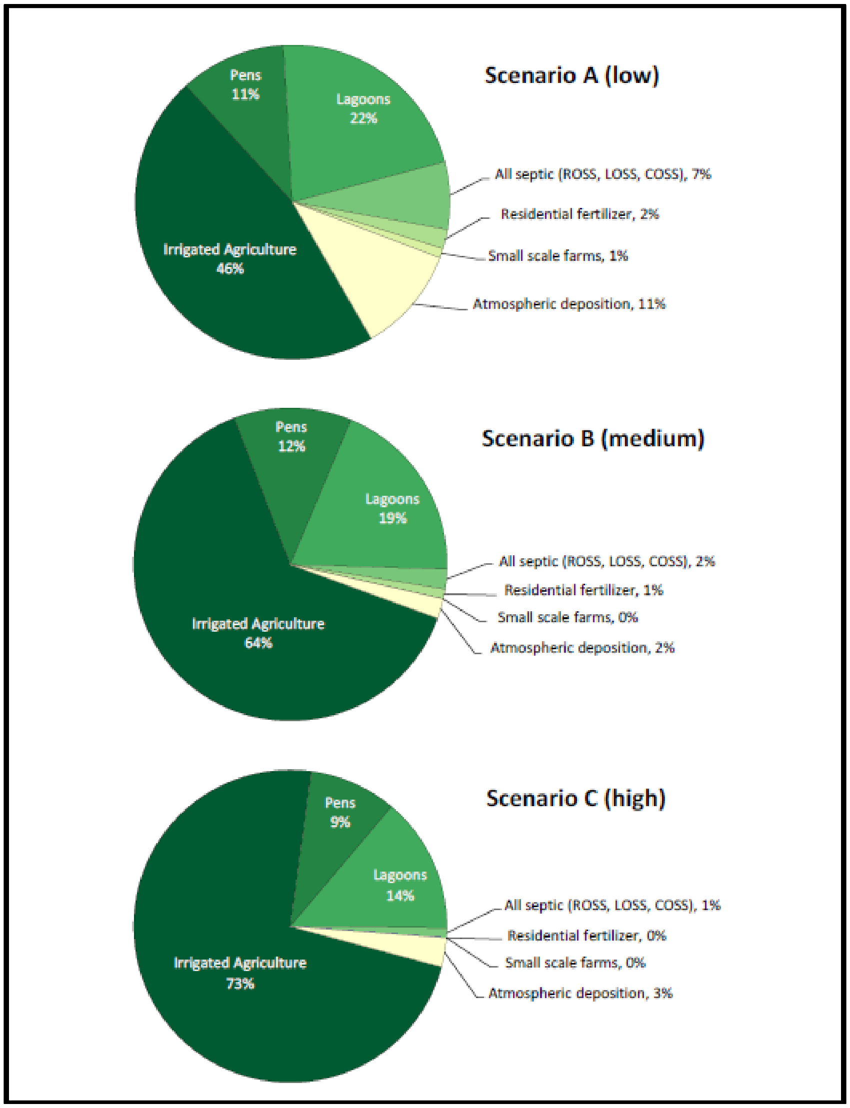

Figure 4. Low, medium, and high nitrogen estimates from all sources throughout the GWMA (WSDA, 2018).

Table 1 presents estimates of the amount of nitrogen available to migrate to groundwater per acre for each significant source (WSDA, 2018).

Table 1. Estimated nitrogen available per acre for all sources (WSDA, 2018).

Source	Area (acres)	Scenario A (low) (lbs/acre/yr)	Scenario B (medium) (lbs/acre/yr)	Scenario C (high) (lbs/acre/yr)
Irrigated Agriculture	85,775	0-58	0-148	0-284
Animal (CAFO) Pens	2,096	67	480	892
Animal (CAFO) Lagoons	210	1,354	7,448	13,542
Residential On-Site Sewage Systems	398	223	403	662
Large On-Site Sewage Systems	3	195	209	225
Commercial On-Site Sewage Systems	30	163	173	183
Residential Fertilizer	4,381	4.70	11.70	18.60
Small Scale Farms	2,096	4.30	10.70	17.10
Atmospheric Deposition	87,082	1.53	2.05	6.15

CAFO = Concentrated Animal Feeding Operation

3.2.4 Regulatory criteria or standards

The Safe Drinking Water Act maximum contaminant level and the Washington State drinking water standard (Chapter 246-294 WAC) for nitrate is 10 mg N/L. The groundwater quality criterion defined in Chapter 173-200 WAC is also 10 mg N/L. These nitrate standards are measured as nitrogen (N) rather than nitrate (NO_3), as designated by mg N/L.

3.3 Water quality impairment studies

N/A

3.4 Effectiveness monitoring studies

N/A

4.0 Project Description

Groundwater in the Lower Yakima Valley GWMA aquifer contains elevated nitrate concentrations, indicating that water has been impacted by human activities. The proposed sampling design provides a statistically sound evaluation of groundwater quality by providing uniform coverage of the GWMA and characterizing the seasonal variability that naturally occurs in groundwater.

This long-term groundwater monitoring effort will establish baseline nitrate concentrations by sampling 170 wells four times a year during the first two years. After two years, sampling will be reduced to once per year. Seasonal variability will be established during the first two years, and will assist with determining the optimal time of year to sample in later years. The sampling design is consistent with Pacific Groundwater Group's recommendation that will provide the best representation of groundwater across the GWMA, which consists of over 175,000 acres (PGG, 2013a).

This network includes the 30 recently installed monitoring wells by PGG, which were randomly located and uniformly distributed. Three additional existing monitoring wells associated with the Port of Sunnyside sprayfield (Figure 3) will also be monitored, and data collected from select wells in the EPA dairy cluster, which are representative of aquifer conditions, will also be included in this study.

The remaining 137 wells in the monitoring network will be comprised of private domestic drinking water wells. These wells will be uniformly distributed across the GWMA, similar to the previously installed monitoring wells, and adequately represent the entire aquifer in order to characterize the groundwater nitrate concentrations over time.

Quality assurance measures will be in place to assure credible data are generated. Sampling methods will be evaluated using equipment blanks, travel blanks, and duplicate samples. Additionally, the laboratory will conduct internal quality control (QC) measures using duplicates, matrix spikes, blanks and surrogates.

4.1 Project goals

The goal of this project is to establish the Lower Yakima Valley GWMA ambient groundwater monitoring network to systematically characterize nitrate concentrations in the surficial aquifer.

4.2 Project objectives

The characterization of the aquifer will give us the information to:

- Assess long-term nitrate trends in the aquifer,
- Determine seasonality with nitrate concentrations in groundwater,
- Assess nitrate trends in individual wells, and
- Assist with evaluating the effectiveness of alternative management strategies implemented in the GWMA.

4.3 Information needed and sources

Nitrate samples will be collected from monitoring wells and private domestic drinking water wells to establish baseline conditions to determine the state of the aquifer over time. A groundwater monitoring network is essential to determine long-term trends in the aquifer and with the individual wells sampled. This trend information will assist with the effectiveness evaluation of alternative management practices which are designed to reduce nitrate loading to groundwater.

4.4 Tasks required

The main tasks for this study include:

- Evaluate the historic nitrate concentrations.
- Identify candidate wells to include in the network and conduct reconnaissance of candidate wells.
- Use criteria to select wells for the network (section 7.2.1).
- Receive permission from homeowners to participate in this study.
- Develop a Quality Assurance Project Plan (QAPP).
- Develop a communication plan for community outreach. Communicate with participants, the community, and the GWMA Implementation group.
- Collect water quality samples for nitrate+nitrite analysis from a total of 170 well quarterly for the first two years.
- Measure field parameters (pH, temperature, electrical conductivity, dissolved oxygen, and oxidation/reduction potential).
- Measure static water level in monitoring wells.
- Continue collecting groundwater samples from the same network of wells annually after the first two years.
- Evaluate results for quality assurance (QA) using standard Environmental Assessment Program (EAP) QA procedures.
- Report results to individual homeowners.
- Compare current data to historical data.
- Compare results to the drinking water standard.
- Determine if there are statistically significant trends in the individual wells and in the aquifer as a whole once sufficient data has been collected.
- Enter data into Ecology's Environmental Information Management System (EIM) database.
- Prepare a report after the first two years of sampling are completed.
- Prepare annual updates after the annual sampling is completed.

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

Table 2. Organization of project staff and responsibilities.

Staff[1]	Title	Responsibilities
Sage Park Regional Director CRO Phone: 509-457-7120	EAP Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Damon Roberts Water Quality Section Manager, CRO Phone: 509-457-7107	EAP Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Melanie Redding Hydrogeologist/ HQ Eastern Operations Section Phone: 360-407-6524	Project Manager	Writes the QAPP. Coordinates sampling and trains sampling staff. Conducts QA review of data, analyzes and interprets data. Writes the draft report and final report.
Eiko Urmos-Berry CRO Eastern Operations Section	Principal Investigator	Oversees and conducts field sampling and transportation of samples to the laboratory. Enters data into EIM.
Nevan Baus CRO Eastern Operations Section	Field Assistant	Helps collect samples and records field information. Assists with data management and ordering equipment
George Onwumere Eastern Operations Section Phone: (509) 454-4244	Section Manager for the Project Manager	Reviews the project scope, reviews and approves the budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Alan Rue Manchester Environmental Laboratory Phone: 360-871-8801	Manchester Lab Director	Reviews and approves the final QAPP.
Arati Kaza Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews and approves the draft QAPP and 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 assure consistent field methods are utilized. All field staff must be familiar with this QAPP and relevant SOPs.

The initial sampling event will involve multiple teams of two people each. One member of each team will be experienced in sampling water from monitoring wells and private domestic wells according to the listed SOPs in section 8.2.

5.3 Organization chart

See Table 2.

5.4 Proposed project schedule

Tables 3 – 5 list key activities, due dates, and lead staff for this project.

Table 3. Schedule for completing field and laboratory work

Task	Due date	Lead staff
Field work	July 2021	TBD
	October 2021	TBD
	January 2022	TBD
	April 2022	TBD
	July 2022	TBD
	October 2022	TBD
	January 2023	TBD
	April 2023	TBD
Laboratory analyses	6 weeks after samples received	MEL

TBD: To be determined
MEL: Manchester Environmental Laboratory

Table 4. Schedule for data entry

Task	Due date	Lead staff
Year 1		
EIM data loaded*	June 2022	TBD
EIM QA	September 2022	TBD
EIM complete	December 2022	TBD
Year 2		
EIM data loaded*	June 2023	TBD
EIM QA	September 2023	TBD
EIM complete	December 2023	TBD

*EIM Project ID: MRED0005
EIM: Environmental Information Management database

Table 5. Schedule for final report

Task	Due date	Lead staff
Draft to supervisor	September 2023	Melanie Redding
Draft to client/ peer reviewer	October 2023	Melanie Redding
Draft to external reviewers	December 2023	Melanie Redding
Final draft to publications team	February 2024	Melanie Redding
Final report due on web	April 2024	Melanie Redding

5.5 Budget and funding

Funding for this project comes from the Washington State Legislature 2020 Supplemental Budget. Table 6 shows the annual budget totals for this project, with higher costs the first two years while quarterly sampling is conducted, and lower costs starting the third year when sampling decreases to once per year.

Table 7 focuses on the laboratory costs for nitrate+nitrite nitrogen from 170 wells and the associated 10% quality assurance (QA) samples. Costs are described for both the quarterly sampling and the subsequent annual sampling.

Table 6. Project budget and funding.

Item	FY 2021 Cost ($)	FY-2022 Cost ($)	FY 2023 Cost ($)
Salary, benefits, and indirect/overhead	269,500	269,500	120,200
Equipment	9,825	3,825	1,583
Travel and other	10,000	10,000	3,500
Laboratory (See Table 7 for details.)	12,000	12,000	3,000
Total Operating Budget	378,000	372,000	163,000
FTEs	2.9	2.9	1.2

Table 7. Laboratory budget details.

Parameter	Number of Samples	Number of QA Samples	Total Number of Samples	Cost Per Sample ($)	Lab Subtotal ($)
Quarterly sampling per year (FY 2021 / FY 2022)					
Nitrate + Nitrite	680	80	760	15	11,400
Annual sampling per year (FY 2023)					
Nitrate + Nitrite	170	20	190	15	2,850

6.0 Quality Objectives

6.1 Data quality objectives [1]

The data quality objective for this project is to obtain data of sufficient quantity and quality to evaluate changes in groundwater nitrate concentrations in the Lower Yakima Valley GWMA over time. This objective will be achieved through attention to sampling design, sample collection and processing, laboratory measurement of nitrate + nitrite nitrogen, 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 8. The MQOs for calibration verification, ongoing precision and recovery, and labeled compound 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 8. 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	uS/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)

Dissolved oxygen, pH, electrical conductivity, temperature, and ORP will be measured in the field with a Hydrolab MS-5 multi-probe. Static water level in the monitoring wells will be measured with an electrical tape.

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 9 for each analytical method. These MQOs are then briefly discussed. 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). For most analytes, the designated method's achievable limit of quantitation (LOQ) will be adequate for this project.

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

Table 9. MQOs for laboratory analyses of water samples.

Parameter	Precision			Bias			Sensitivity
	Field Duplicate (RPD)	Laboratory Duplicate (RPD)	Matrix Spike Duplicate (RPD)	Lab Control Standard (%Recovery)	Matrix Spike (% Recovery)	Internal Standard Recovery (% Recovery)	MDL or Lowest Concentrations of Interest
Nitrate + Nitrite	≤ 20%	≤ 20%	≤ 20%	+/- 20%	+/- 25%	N/A	0.01 mg/L

MDL = method detection limit.
RPD = relative percent difference

6.2.1.1 Precision

Precision is a measure of the variability between results of duplicate measurements that is 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). Duplicate 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 in selecting the duplicate sampling locations. Precision for field and laboratory duplicate samples will be expressed as relative percent difference (RPD) as shown in Table 9. 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.

Sampling precision will be estimated using results from true field duplicates and expressed as the relative standard deviation (RSD). This project has no acceptance limits for estimates of sampling precision. The information helps to characterize the variability of the sampled population and inform evaluation and analyses of results.

6.2.1.2 Bias

Bias is defined as the difference between the sample value and 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 9). 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.

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. In a regulatory setting, the method detection limit (MDL) is often used to describe sensitivity. Targets for lab measurement sensitivity required for the project are listed in Table 9.

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.

6.2.2.2 Representativeness

Representativeness expresses the degree to which data accurately and precisely represent the actual site conditions. Groundwater samples will be collected from 170 wells uniformly distributed across the Lower Yakima Valley. The large number of wells in this ambient monitoring network assures that nitrate concentrations will be representative of the extent of the aquifer. The same wells will be sampled quarterly for two years. This frequency of sampling will provide a statistical basis for adequately characterizing each well. The number of wells and frequency of sampling will assure long term statistical evaluations of the data will be valid and representative.

6.2.2.3 Completeness

Completeness establishes whether a sufficient amount of valid measurements were obtained to meet project objectives. The number of samples and results expected 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, or sustained site access to the private domestic drinking water wells. 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 taken 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

Existing groundwater nitrate data was consolidated by Yakima County as one of the initiatives of the Lower Yakima Valley GWMA program. These data were accessed to determine (1) historic groundwater conditions, (2) wells which have been sampled numerous times, and (3) which of these wells might be candidate wells to include in this ambient groundwater monitoring network.

This database includes 3,369 data points from 795 wells in the GWMA sampled from 1978 through 2017. These data were evaluated using summary statistics with focus on (1) evaluation of the data by year, (2) nitrate concentration, and (3) well depth.

While examining the historic data is useful for planning for future sampling, it is important to recognize the limitations of this data set. This dataset contains data from numerous studies over 40 years. These data were not generated from one comprehensive study with the same quality assurance standards. Additionally, data were collected at many different times of the year and from different depths within the aquifer. Sampled wells include monitoring wells, private domestic wells, and public drinking water systems. Since seasonality with nitrate concentrations and a correlation with depth has been documented, it is challenging to use this data to determine trends over time.

This project will address the limitations of the existing dataset by monitoring the same 170 wells (including monitoring wells and private domestic wells) (1) quarterly for two years to address the effects of seasonality on groundwater nitrate concentrations, and (2) annually thereafter to determine long-term trends in the aquifer.

6.4 Model quality objectives

N/A

7.0 Study Design

7.1 Study boundaries

Groundwater in the Lower Yakima Valley GWMA is the focus of this study. Study boundaries and historic nitrate concentrations are shown in Figure 5.

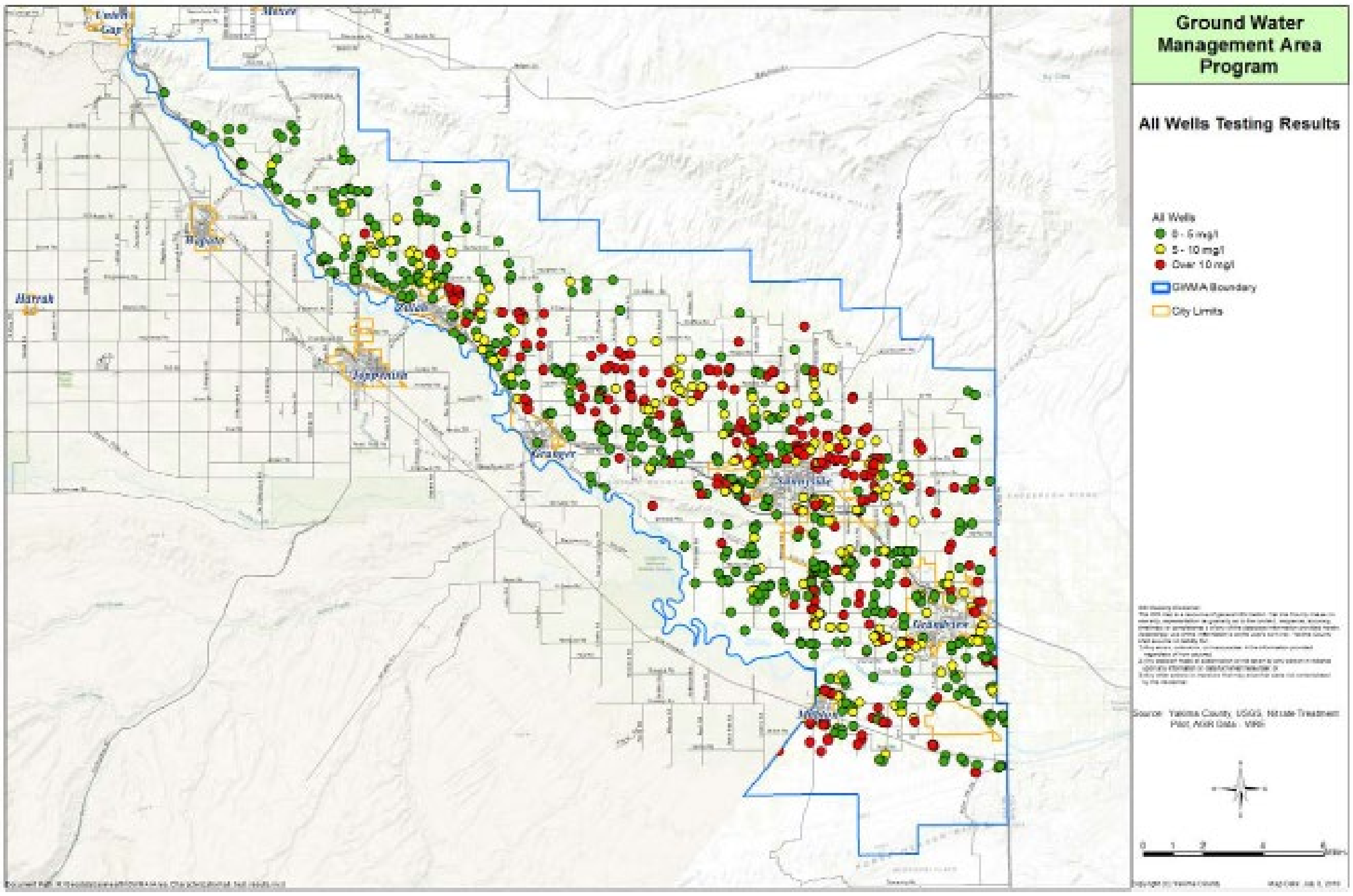

Figure 5. Map showing boundary of project study area with nitrate concentrations (GWAC, 2019).

7.2 Field data collection

A total of 170 groundwater wells will be sampled including monitoring wells and private domestic drinking water wells.

7.2.1 Sampling locations and frequency

Monitoring Wells

The locations of the 30 monitoring wells installed previously (PGG, 2019) are shown in Figure 6. These wells are randomly located and uniformly distributed across the GWMA. The monitoring wells establish a baseline of groundwater nitrate concentrations near the water table. Typically, changes to groundwater quality associated with land use will occur near the water table before it occurs in deeper aquifers. (PGG, 2019).

The GWMA committee requested that the groundwater monitoring network of wells be randomly located and uniformly distributed. Geographical Information System program ArcMap was used to randomly distribute 1000 points across the GWMA, which created a pool of potential well sites from which the monitoring well locations were selected. The site selection process found the point that was the furthest from the GWMA boundary (essentially the center of the GWMA). The next site was selected by the point furthest from the combination of the boundary and the location of well #1. The process was repeated to add each subsequent monitoring location to the monitoring network. (PGG, 2016). Based on the prioritized locations, preliminary drilling sites also considered that wells should be located in public right of ways, land use that may cause anomalies should be avoided, and existing monitoring wells should be considered in lieu of drilling new wells. (PGG, 2016)

In total 30 locations were selected for the installation of new wells. All wells were installed in accordance with Chapter 173-160 WAC. All wells are constructed with 2-inch diameter PVC with standard flush mount vaults. Each well is fitted with a locking well cap. Historic water levels indicate that seasonal water level fluctuates about 10 feet between fall and spring. Wells screen lengths ranged between 10 to 20 feet (with one well screened only 5 feet) depending on the stratigraphy. The median monitoring well depth is 52 feet below land surface (bls), with the range between 22 and 275 feet bls. Well logs, field notes, pumping test results, sample results, well construction, well locations and photographs are all contained in a well installation report (PGG, 2019).

The selection process excluded two areas in the GWMA; the dairy cluster area and the Port of Sunnyside sprayfield (identified in Figure 6). Both areas have existing monitoring wells. The intent is to utilize existing sample stations and data in lieu of drilling new wells. (PGG, 2016). To provide uniform sample distribution, additional monitoring wells will be sampled from the existing Port of Sunnyside monitoring well network, and existing and on-going data collected in the EPA dairy cluster area will augment the dataset for this study. These wells will be chosen based on the study goals to assess aquifer conditions over time. By adding monitoring wells to our network of wells from these areas, the spatial coverage of the aquifer will be expanded without the redundancy and expense of installing new wells in areas where some already exist.

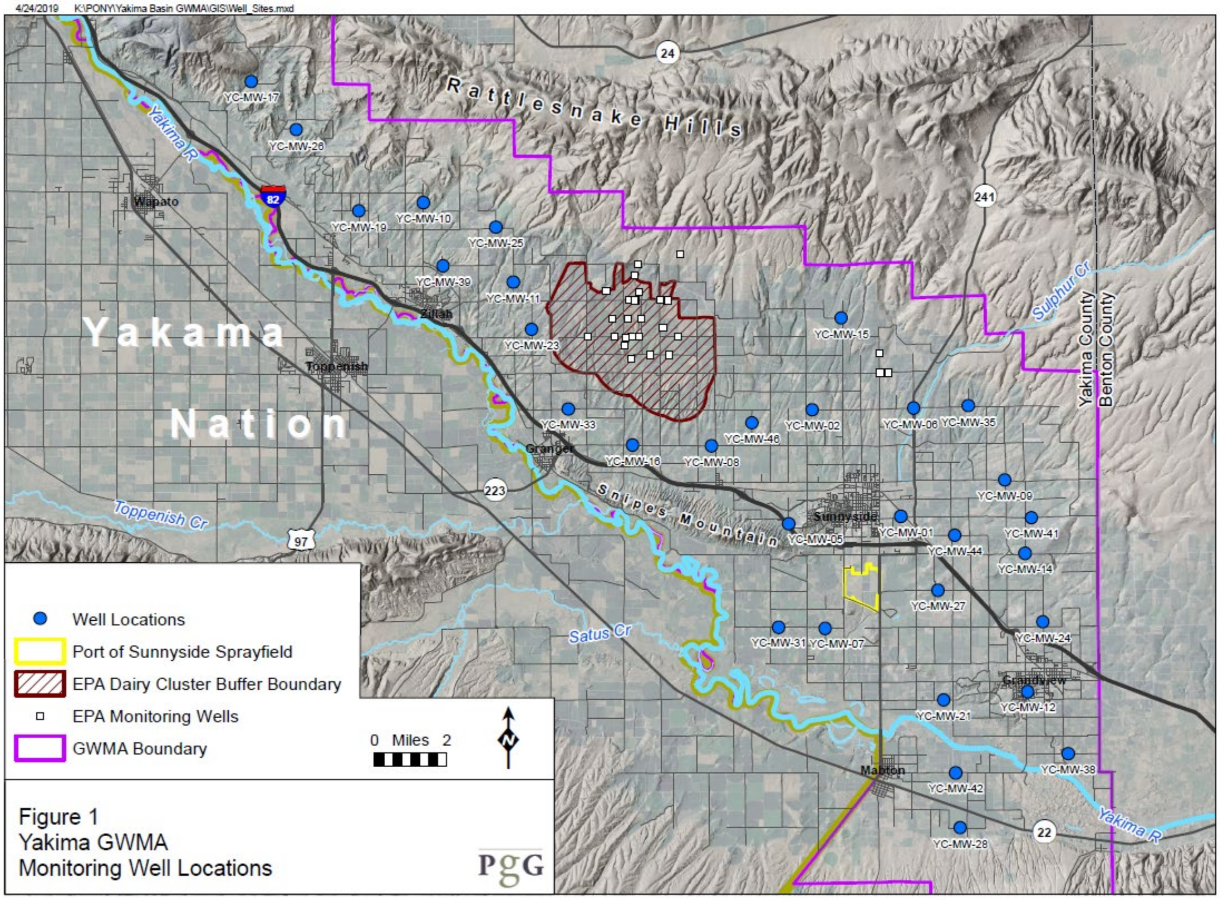

Figure 6. Locations of the monitoring wells installed by the GWMA (PGG, 2019).

Private Domestic Wells

The additional 137 wells that will be included in the monitoring network will be private domestic wells or public drinking water supply wells. The goals with selection of these wells will attempt to ensure uniform distribution across the GWMA. The GWMA database will be used to identify candidate wells.

The criteria used to select private domestic wells include:

- Owner permission to access the well.
- Available drillers well log.
- Well construction meets the well construction standards specified in Chapter 173-160 WAC.
- The well has an adequate surface seal.
- Distance of at least 0.25 miles from unlined irrigation canals (PGG, 2019; Papadopulos & Associates, 2008).
- Water must be untreated prior to the sampling point (collect sample before treatment or storage tank, as close to the well head as possible).
- Well water provides sample representative of the aquifer. The majority of wells should be completed in the uppermost surficial aquifer.
- The well must be accessible to sample.

7.2.2 Field parameters and laboratory analytes to be measured

Groundwater quality samples will be collected and analyzed for nitrate + nitrite nitrogen by MEL.

Before sampling, field measurements will be made at each well for pH, electrical conductivity, dissolved oxygen, temperature, and oxidation/reduction potential. Static water level will be measured at each monitoring well.

7.3 Modeling and analysis design

N/A

7.3.1 Analytical framework

N/A

7.3.2 Model setup and data needs

N/A

7.4 Assumptions underlying design

The design of this project assumes that the wells will produce groundwater nitrate concentrations which are representative of the uppermost surficial aquifer conditions. The design also assumes that the distribution and number of wells will provide adequate coverage across the GWMA.

This project is designed with many considerations that will help meet the stated goals and objectives. Specifically, elements in the Interim Final Groundwater Monitoring Plan (PGG, 2014), and the Potential Groundwater Monitoring Stations Report (PGG, 2013) will be followed and enhanced.

7.5 Possible challenges and contingencies

The main possible challenge for this study is related to accessing private property.

7.5.1 Logistical problems

About 80% of the wells that will be sampled in this study will be private domestic wells. Extensive reconnaissance will occur prior to sampling to ensure that the wells meet the criteria described in section 7.2.1. Since this is a long-term monitoring effort the homeowners must be willing to grant us extended access to their well. Based on the public education and outreach conducted in the Lower Yakima Valley by GWMA committee members, there is a general awareness about elevated nitrates in groundwater and the potential health effects. The awareness and concern by the community gives us confidence that residents will be interested in participating in this study.

Miscommunication with property owners is the main potential logistical problem. We will ensure that property owners 1) have given verbal permission for us to sample their wells, 2) have agreed to the date and time that we will be there to sample, and 3) will be notified if our schedule changes during the sampling event.

Additionally, a list of backup wells will be assembled if a well is no longer able to be sampled.

Individual results will be shared with the respective homeowners, along with an explanation, and an attempt to address any issues or questions they may have.

7.5.2 Practical constraints

The success of the project requires each well to be sampled quarterly for the first two years. This requires two dedicated full time staff to conduct this project.

7.5.3 Schedule limitations

The identified challenges and contingencies are currently being addressed to avoid any delays or impacts to this study. The proposed schedule may be impacted due to public health threats, such as Covid-19.

8.0 Field Procedures

8.1 Invasive species evaluation

N/A

8.2 Measurement and sampling procedures

Groundwater sampling procedures for the study will follow Ecology SOPs:

- EAP052 for measuring depth to water (Marti, 2018)
- EAP033 for measurements using a Hydrolab MiniSonde® (Anderson, 2020)
- EAP096 for sampling water supply wells for general chemistry (Marti, 2019)
- EAP099 for purging and sampling monitoring wells for general chemistry (Carey, 2018)

Field notes will be recorded at each site with information listed in section 8.7.

Private domestic wells

Homeowners will be contacted by phone about a week before sampling to let them know the date and time the Ecology field team will arrive at their residence. Every effort will be made to ensure good communication with the homeowner and accommodate their schedules.

Water samples from private domestic wells should be collected as close to the wellhead as possible. It is essential that the faucet used to collect samples is located before the water passes through any storage tanks, pressure tanks, or physical/chemical treatment system that may alter the quality of the groundwater sample. Clean disposable gloves will be worn during purging and sampling.

Water supply wells will be purged using a Y-fitting on a faucet as close to the wellhead as possible (Figure 7). One discharge from the Y-fitting will be connected to a garden hose and set at a high discharge rate. The other outlet from the Y-fitting will be connected to an airtight flow through cell set at a low flow rate (~ 300 mL/minute). The Hydrolab is contained in the flow-through cell and allows field measurement to be recorded prior to water being exposed to the atmosphere.

If the closest faucet is located after a water tank, field staff will have to make sure the pump is running as field measurements are recorded and when the sample is collected.

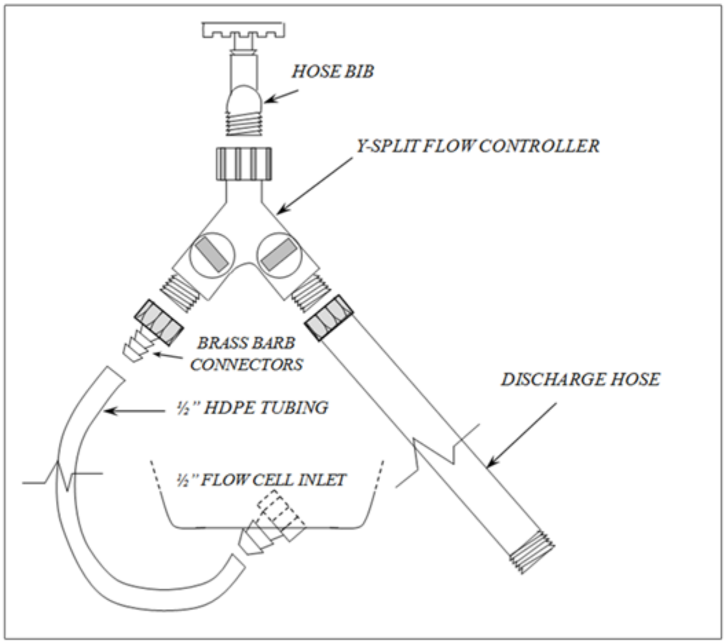

Figure 7. Schematic of Y-fitting.

Monitoring wells

Static water level will be measured before purging or sampling of 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 well sounder must be decontaminated after each use (Marti, 2018).

A bladder pump will be used to purge and sample the 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. Pump tubing will be connected to an airtight flow through cell for measurement of field parameters.

Dedicated tubing for each monitoring well will be maintained in clean labeled and sealed plastic bags. The bladder pump will be decontaminated between well locations.

Field measurements

The Hydrolab MiniSonde® will be calibrated before the beginning of each week of sampling and a calibration check at the end of each day of sampling. These measurements will be recorded in the field notes.

Field measurement methods are listed in Table 10.

Table 10. Field measurement methods.

Analyte	Sample Matrix	Expected Range of Results	Detection or Reporting Limit	Instrumental Method
Temperature	Water	8-12°C	0.2°C	Hydrolab MS-5
pH	Water	4-8 S.U.	NA	Hydrolab MS-5
Electrical conductivity	Water	50-1000 uS/cm	5 uS/cm	Hydrolab MS-5
Dissolved oxygen	Water	0.0-10 mg/L	0.1 mg/L	Hydrolab MS-5
Oxidation/reduction potential	Water	-300 to 350 mv	NA	Hydrolab MS-5
Static Water Level	Water	10-275 ft bls	0.01 ft	Electric well sounder

Purge water will be routed into a flow-through cell to measure field parameters using the calibrated Hydrolab. 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 11. 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 high 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.

Table 11. Field parameter stabilization criteria.

Field Parameter	Criteria	Typical Change
Temperature	0.2 ° C	2%
pH	0.2 SU	3%
Electrical conductivity	10 umhos/cm	7%
Dissolved oxygen	0.3 mg/L	10%
Oxidation/reduction potential	20 mV	20%

8.3 Containers, preservation methods, holding times

Groundwater will be analyzed in the laboratory for the parameters shown in Table 12.

Table 12. Sample containers, preservation, and holding times.

Parameter	Matrix	Minimum Quantity Required	Container	Preservative	Holding Time
Nitrate + Nitrite	Water	125 mL	Nalgene, HDPE, wide-mouth	Sulfuric acid to pH <2, Cool to < 6°	28 days
Ammonia[1]	Water	125 mL	Nalgene, HDPE, wide-mouth	Sulfuric acid to pH <2, Cool to < 6° C	28 days

[1] Ammonia will only be analyzed if anaerobic conditions exist.

8.4 Equipment decontamination

All equipment which is not dedicated will be decontaminated appropriately before sampling each site.

The electric well sounder will be washed in laboratory grade detergent, followed by a tap water rinse and then a deionized water rinse after use at each monitoring well.

Each day a pre-cleaned Y-fitting, as shown in Figure 7, will be used. The Y-fitting will be decontaminated after each use. The Y-fitting sample tubing used at the domestic wells will be either new or decontaminated between sites by pre-sample purging of the well.

The bladder pump, which will be used to sample the monitoring wells, will be disassembled and washed in laboratory grade detergent, followed by a tap water rinse and then a deionized water rinse. Pump tubing will be dedicated to each well and not reused.

A new pre-packaged in-line filter will be used for each sample.

Decontamination blanks will be collected and analyzed for 10% of the monitoring wells.

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 a field ID number that is established by the field lead. This combination of work order number and field ID number constitute the sample ID. All sample IDs will be recorded in field notebooks and in an electronic spreadsheet for tracking purposes.

All wells which do not have an Ecology well tag will be designated with a unique well ID tag that will be affixed to the wellhead. The well tag numbers will be recorded in the field notes.

8.6 Chain of custody

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

Once collected, samples will be properly labeled and stored in ice-filled coolers inside the sampling vehicle. If the sampling vehicle is left unattended, it will be locked to maintain chain-of-custody.

All samples will be stored in coolers on ice, in the locked chain of custody room at CRO. Samples will be shipped to MEL weekly. Sample coolers will be secured with either metal clips or seal. ID numbers for the metal clips or seals will be recorded on the 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.
- IDs or serial numbers of sonde used
- Field measurement results.
- Date, time, sample ID, and description of samples collected.
- Purge time.
- Identity of QC samples, if appropriate.
- Pertinent observations and/or any problems with sampling, including deviations from the QAPP.
- Unusual circumstances that might affect interpretation of results.

Field logs will consist of bound, waterproof notebooks. Permanent, waterproof ink or pencil will be used for all entries. Corrections will be made with single-line strikethroughs, initialed, and dated.

8.8 Other activities

Additional activities include:

- Any field staff new to the type of sampling being conducted for this study will be trained by senior field staff or the project manager, following relevant Ecology SOPs.
- The Hydrolab MS-5 MiniSonde® will be calibrated at the beginning of the week and checked at the end of each sampling day for stability of calibration. If needed, MiniSondes® will be re-calibrated to meet MQOs (Table 8).
- The principle investigator will notify the lab of any changes in scheduling.
- The principle investigator will work with MEL's courier to develop a schedule for delivery of sampling containers in order to ensure that the appropriate number and type of required sampling containers are available.

9.0 Laboratory Procedures

9.1 Lab procedures table

Analytes for this project, along with the reporting limit, analytical method, and expected range of results, are listed in Table 13. The focus of this study is on assessing the state of the nitrate concentrations in the aquifer rather than determining the quality of residents' drinking water.

Table 13. Measurement methods (laboratory).

Analyte	Sample Matrix	Expected Range of Results	Detection or Reporting Limit	Analytical (Instrumental) Method
Nitrate + Nitrite	Filtered water	0.1 – 60 mg/L	0.01 mg/L	SM4500 NO3 I[2]
Ammonia[1]	Filtered water	0.1 – 60 mg/L	0.01 mg/L	SM4500 NH3 H

[1]Ammonia will only be analyzed if anaerobic conditions exist.

[2]Standard Methods for the Examination of Water and Wastewater, 23rd Edition (Rice et al., 2017).

9.2 Sample preparation method(s)

Well water will be filtered in the field using clean disposable 0.45 um filters and collected in pre-acidified bottles supplied by MEL. MEL will follow standard sample preparation procedures for the measurement of methods listed in Table 13.

9.3 Special method requirements

N/A

9.4 Laboratories accredited for methods

This study will use Manchester Environmental Laboratory (MEL), which is accredited for all laboratory methods specified in Table 13.

10.0 Quality Control Procedures

Quality control (QC) procedures provide the information needed to assess the quality of the 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 (EAP) standard operating procedures (SOPs) related to groundwater sampling. Field measurements made when collecting samples (temperature, pH, electrical conductivity, 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 readings. Table 8, in section 6.2, specifies how field measurements will be managed if there is a discrepancy between pre-calibration and post-calibration measurements.

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 rinsing any equipment used for sampling with blank water and directing the rinsate into a sample container. Decontamination blanks will consist of running blank water through equipment after it has been decontaminated, to determine if decontamination procedures are adequate. Travel blanks consist of a container filled with blank water by the lab and is never opened; this container travels with other sample bottles from the lab to the field and back to the lab.

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 Table 14.

Table 14. Laboratory quality control samples, types, and frequency.

Parameter	Field		Laboratory			
	Blanks	Duplicates	Check Standards	Method Blanks	Analytical Duplicates	Matrix Spikes
Nitrate+Nitrite	1/week	10%	1/batch	1/batch	1/batch	1/batch
Ammonia [1]	1/week	10%	1/batch	1/batch	1/batch	1/batch

[1] Ammonia samples will only be collected if there are indications of denitrification occurring.

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, or performance expectations, or if some other unforeseen problem arises. 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 lab results that do not meet all QC criteria.
- Reanalyzing lab 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 lab 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 from MEL will be stored in an electronic format in the MEL Laboratory Information System (LIMS). After the data are verified, MEL will summarize the data in case narratives and provide them to the project manager.

Field measurement data and observations will be entered into a field book. Sampling stations will be identified by a unique ID number and recorded on containers and field notes.

Field and laboratory data for the project will be entered into Ecology's Environmental Information System (EIM) system. The EIM Study ID for this project is MRED0005. Laboratory data will be downloaded directly into EIM from the LIMS database. Data entry into EIM is conducted using established data entry business rules. The EIM data will be reviewed by the project manager, staff entering the data and an independent reviewer.

Printed and electronic data not entered into EIM will be retained in a file system maintained by the project manager.

11.2 Laboratory data package requirements

Laboratory results from MEL analyses will be sent to the project manager in electronic format (from LIMS) and be accompanied by a case narrative. The case narrative will address various data verification checks described in section 13 of this document.

11.3 Electronic transfer requirements

Laboratory data generated by MEL will be entered into the Laboratory Information System (LIMS) by MEL staff. When notified of the availability of data, project staff can then access LIMS data and receive the data in an Excel file formatted similar to the EIM loading template.

11.4 EIM/STORET data upload procedures

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

After 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.

11.5 Model information management

N/A

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 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 of sampling procedures will be conducted routinely by the licensed hydrogeologist project manager.

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 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. A final technical report will be published according to the project schedule shown in Section 5.4.

Results will be communicated to respective well owners along with the study findings.

12.4 Responsibility for reports

The EAP Project Manager will be the primary lead on the final report and annual status reports. The work will be conducted or overseen by a licensed hydrogeologist.

13.0 Data Verification

Data verification is a review process to assess the quality and completeness of analytical datasets. This section describes data verification and validation which are typically sequential steps. 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.”

Results generated by MEL are verified and validated using MEL SOPs for data review. Data generated by EAP field staff are verified by the field lead or project manager, usually before leaving the sampling site.

13.1 Field data verification, requirements, and responsibilities

Field-collected data will be verified by examining field notes, sketches or diagrams of the sampling point, maps, and other notes for legibility, completeness, and errors. Where omissions or errors in the data are found, the generator of the data will be consulted to determine the correct value or form of the data in question. Corrections or qualifications will be made where possible. Where corrections cannot be made, additional information will be noted to explain the error. The data in question may also be qualified or rejected for further use.

Field QC procedures include reviewing field notes for completeness, errors, and consistency. Duplicate measurements and documentation of conditions in field notes will support verification of analytical measurement and field measurements.

After field data are entered into EIM, the EIM Data Review Procedure checks about 10% of the data to ensure that the data were entered correctly.

13.2 Laboratory data verification

All data will undergo a verification and validation analysis. 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, 2004). 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 15 shows the most common data qualifiers used with results for this project’s target analytes.

Table 15. Data qualifiers and definitions

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	Not analyzed for.
NC	Not calculated.

13.3 Validation requirements, if necessary

N/A

13.4 Model quality assessment

N/A

13.4.1 Calibration and validation

N/A

13.4.1.1 Precision

N/A

13.4.1.2 Bias

N/A

13.4.1.3 Representativeness

N/A

13.4.1.4 Qualitative assessment

N/A

13.4.2 Analysis of sensitivity and uncertainty

N/A

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 provides the best case scenario for risk assessment.

Determination of how non-detects will be treated will be evaluated based on the entire data set.

14.3 Data analysis and presentation methods

All acceptable and appropriate lab and field results will be compiled in Excel tables from which further data reduction will occur. Individual tables are used for compiling data that originate 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: sample and some 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.
- Results and related parameter, method, and lab results for all target analytes.

Data will be presented in tabular and graphic forms.

The Mann-Kendall test for trends with a 95% confidence level will be used to determine trends with nitrate concentrations. Historic data indicates that seasonality effects some wells in the GWMA. Where natural seasonal fluctuations exist, adjustments for seasonality will be made before conducting the test for trends. (EPA, 1989; Fisher and Potter, 1989; Kimsey, 1996).

14.4 Sampling design evaluation

Pacific Groundwater Group (PGG, 2013) used a simple random approach to calculate the number of samples and wells needed to calculate a basin-wide average. This number provides a level of confidence that supports use of the data to compare (1) currant average concentrations to past and future average concentrations, and (2) the basin-wide average to the drinking water standard of 10 mg N/L. PGG determined that 170 to 250 groundwater sampling sites would need to be sampled quarterly or six times per year.

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, as well as any potential impacts on attaining the overall project objectives, will be noted in the final report.

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 decisions about how to use laboratory results for each group of analytes for each sampling event. Further documentation of the data usability assessment will be presented in the final report *Methods* section. The final report for the project will also discuss data quality, usability, and limitations.

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16.0 Appendix. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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

Anthropogenic: Human-caused.

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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Acronyms and Abbreviations

bls	below land surface
BMP	Best management practice
DO	(see Glossary above)
e.g.	For example
EAP	Environmental Assessment Program
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
GIS	Geographic Information System software
GPS	Global Positioning System
GWMA	Groundwater Management Area
i.e.	In other words
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective

ORP	Oxidation/reduction potential
QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
USGS	United States Geological Survey
WAC	Washington Administrative Code
WRIA	Water Resource Inventory Area

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
km	kilometer, a unit of length equal to 1,000 meters
l/s	liters per second (0.03531 cubic foot per second)
m	meter
mm	millimeter
mg	milligram
mg/kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mg N/L	milligrams nitrate as nitrogen per liter
mL	milliliter
s.u.	standard units
µg/L	micrograms per liter (parts per billion)
µm	micrometer
µmhos/cm	micromhos per centimeter
µS/cm	microsiemens per centimeter, a unit of conductivity

Quality Assurance Glossary

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Examples of data types commonly validated would be:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\%RSD = (100 * s)/x$$

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

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

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

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

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

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

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

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

$$[\mathrm{Abs}(a-b)/((a + b)/2)] * 100$$

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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