DEPARTMENT OF
ECOLOGY
State of Washington

Quality Assurance Project Plan

Washington Nitrate Prioritization Project

January 2014

Publication No. 14-10-005

Publication information

Each study conducted by the Washington State Department of Ecology (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 final report of the study to the Internet.

This Quality Assurance Project Plan is available on Ecology's website at https://fortress.wa.gov/ecy/publications/SummaryPages/1410995.html

Ecology's Activity Tracker Code for this study is 14-020.

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Quality Assurance Project Plan

Washington Nitrate Prioritization Project

December 2013

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Abstract

The Washington Nitrate Prioritization Project grew out of discussions held by agency directors in 2012 at the behest of then Governor Gregoire. The discussions centered on how agencies would move forward to address agricultural pollution of surface and ground water.

Public concern about nitrate contamination of drinking water has risen over the last few years as knowledge of these problems has grown. Many small water systems face difficulties and high costs to supply clean water when nitrates rise above the health limit of 10 mg/L.

Residential wells in many areas of the state have been sampled and found to exceed the health limit for nitrate in drinking water. There also may be numerous un-sampled residential wells in areas with known nitrate exceedances.

This project is being undertaken to:

- Identify areas statewide where nitrates in groundwater have exceeded or are at risk of exceeding drinking water standards.
- Based on the identified areas, draft provisional delineations of Nitrate Priority Areas to be ranked and prioritized based on such information as population and resources impacted by nitrate groundwater contamination.
- Develop and organize important hydrogeological information necessary to understand how the occurrence and movement of groundwater affects nitrate contamination occurrence for one or more Nitrate Priority Areas.
- Explore how the groundwater quality data for this project could be housed and publicly shared.
- Prepare and organize the data and GIS information collected during this project for a potential web application (to be proposed).

Information developed during this project can be used to help:

- Coordinate cross-agency nitrate management strategies and action plans.
- Target resources where they are most needed to protect public health.
- Prioritize the implementation of nitrate source loading reduction and controls.
- Plan monitoring strategies for current conditions and trends over time.
- Plan effectiveness monitoring strategies.
- Provide important information to well owners deciding whether to test their well water.
- Provide everyone, including those who control nitrate loading sources, information about what is known about nitrate contamination of groundwater in their area and how people and resources are impacted.

This information is also important when evaluating potential loading sources and for supporting future loading estimates.

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Introduction

Problem statement

Public concern about drinking water quality that has been compromised by high nitrates in groundwater has risen over the last several years. News articles have highlighted these concerns.

For example, the Yakima Herald-Republic published a series of articles titled "Hidden Wells, Dirty Water" in 2008. This series profiled high nitrates in groundwater in the Lower Yakima Valley. The result was a multi-agency task force (Ecology, 2010), a groundwater study (EPA, 2012) and subsequent enforcement by the Environmental Protection Agency (EPA, 2013), citizen suits and the formation of a Ground Water Management Area (GMA). There have been many follow-up articles by the Yakima Herald-Republic since.

Many small water systems face difficulties and high costs to supply clean water. Here are two examples:

– Outlook School, near Sunnyside in Yakima County, had to replace its drinking water well not once, but twice, as nitrate concentrations have risen. The original well was 90 feet deep, the first replacement well was 132 feet deep, and the second replacement well is 243 feet deep. Nitrates have been as high as 4.4 mg/L in the 243 foot deep well (WDOH, 2013).

  Leah Beth Ward reported the cost of Outlook School's well replacement in her article for the Yakima Herald-Republic, "Hidden Wells, Dirty Water" (10/12/2008): "Meanwhile, at the cost of $48,000 in taxpayer dollars, the Outlook school was able to drill a deeper well into cleaner water."

– Several public water systems in Northern Whatcom County are under Washington State Department of Health (WDOH) compliance orders because nitrates are over the limit, yet a new source proves hard to come by due to the limited nature of the aquifer and water rights issues (Cornerstone Management, Inc., 2010).

  Example costs are given in the report "North Whatcom County Nitrates Feasibility Study, Deliverable Number 2," (Reichhardt & Ebe Engineering, Inc., 2007). Table 4 of this report, which shows the costs over a 20-year period, is reproduced in Appendix A.

Appendix B shows other examples of costs to mitigate nitrate contamination issues for public water suppliers, often hundreds of thousands of dollars to into the millions.

Nitrate sampling of groundwater has identified many areas of the state where human activities have caused groundwater nitrate concentrations to rise (Figure 1). Many drinking water wells have had nitrate sample concentrations above the maximum contaminant limit of 10 mg/L. Many more have had nitrate sample concentrations above 5 mg/L.

The Washington State Department of Health requires more frequent sampling when public drinking water supply well samples are over 5 mg/L, and other actions are triggered. The Department of Health issues compliance orders to systems when samples are over 10 mg/L. The system must find a way to lower the nitrate concentration in water served. Options are limited,

costly, and include such actions as hooking up to a neighboring system, if available, drilling deeper wells, or reverse osmosis treatment.

Residents on single domestic wells are not regulated as public water supply systems, and so are not required to sample their well. Many do not know what the water quality of their drinking water supply is. When their source of drinking water is contaminated, options are limited and costly. Neither public water systems nor residents on single wells have regulatory authority to prevent or abate pollution from neighboring nitrate sources that may be causing the contamination.

The health effects of drinking high nitrates are well-documented and include blue baby syndrome, also known as methemoglobinemia. This is a condition where red blood cells are less able to carry oxygen. Less oxygen in the blood stream turns the skin an apparent blue. The EPA drinking water limit of 10 mg/L was set to prevent this condition (Washington State Dept. of Health, 2012). Other health effects, such as spontaneous abortions and cancer, have been the subject of studies; however, more research is needed (Dubrovsky, 2010).

Nitrogen sources that can end up contributing to nitrate concentrations in groundwater include manure, chemical fertilizers, on-site sewage systems and biosolids. Nitrogen sources, especially agricultural use of fertilizers, increased livestock densities and growth in human population, have increased for decades, leaving a legacy nitrate in groundwater.

The United States Geological Survey (USGS) has shown that nitrate recharge concentrations have increased as fertilizer use has increased since 1945. Since groundwater flow is slow, nitrate concentrations in groundwater can take a long time to abate, even when sources are controlled (Puckett, 2011). Locally, groundwater concentrations may respond in a shorter time period to reductions or increases in loading, especially when measured near the loading source.

Background

In 2012, the Governor instructed the directors of the departments of Ecology, Agriculture and the Conservation Commission to address pollution from agricultural sources. Other state and federal agencies joined the conversation. A copy of the Governor's Sept. 2012 letter to Agency Directors is in Appendix A.

The Water Quality Program of the Department of Ecology (Ecology) developed projects during this process, including an effort to inventory the data that various agencies have related to agriculture.

One of the data sets that Water Quality Program (WQP) staff compiled was statewide groundwater nitrate data from the Ecology Environmental Information Management System (EIM), the WDOH SENTRY data system, which houses public water supply system data, and the USGS National Water Information System (NWIS) (Morgan, 2012). This data was plotted on a map and shows the following ranges of the maximum value of the data set per well: >= 10 mg/L, 5 to 10 mg/L, 3 to 5 mg/L and < 3 mg/L (Figure 1).

Idaho has used statewide nitrate data to delineate and prioritize nitrate-impacted areas (Idaho Department of Environmental Quality, 2008). Ecology hosted a webinar in October, 2012, for Idaho to present their process to agency partners.

As a result of studying the Idaho Nitrate Prioritization project and statewide nitrate studies, Water Quality Program staff developed a proposal to carry work forward. This proposal resulted in the Washington Nitrate Prioritization Project.

Study area

The study area for this project is the state of Washington.

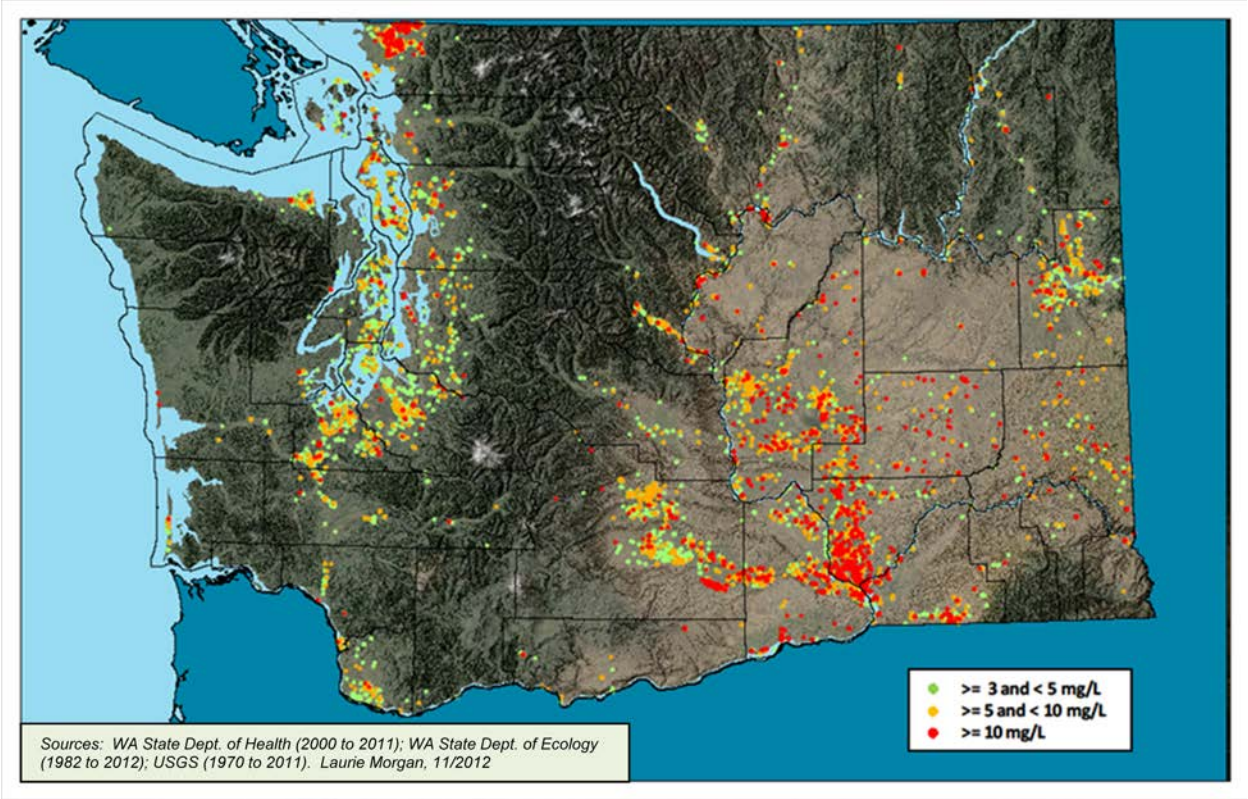


Figure 1: Maximum reported nitrate concentrations for sampled Washington wells with at least one sample greater than or equal to 3 mg/l (Morgan, 2012).

Nitrate at very low levels can be present naturally in groundwater. The USGS has researched the level above which indicates that nitrate loading from land activities has reached groundwater. Nitrate in groundwater above 3 mg/L has been cited as a general indication of this, and recent study by the USGS places this level as low as 1 mg/L (Nolan, 2003). For the purposes of this project, 3 mg/L is a useful threshold, since we are focusing on areas where elevated nitrate concentrations in groundwater are definitely a human-caused problem.

Previous studies

Several efforts at analyzing where nitrates tend to occur in Washington State and under what conditions due to loading at the land surface have been undertaken by the USGS and others.

The Columbia Basin Ground Water Management Area (GWMA) formation was preceded by an Interagency Ground Water Committee report on nitrate contamination of groundwater in the mid-Columbia basin (Cook, 1996). Several consultant and USGS studies have been undertaken in the GWMA, including nitrate sampling, analyses for trends, and groundwater modeling.

Ecology has published several studies related to groundwater nitrates in Whatcom County. These are summarized in the publication "Sumas-Blaine Aquifer Nitrate Contamination Summary" (Carey, 2011). Ecology completed several other groundwater nitrate studies. Here are examples:

- Sinclair, Kirk, 2003. Groundwater Quality in the Central Ahtanum Valley, Yakima County, March 2001 - December 2002. Washington State Dept. of Ecology Publication No. 03-03-017, 55 pp. Online at https://fortress.wa.gov/ecy/publications/summarypages/0303017.html.

- Sinclair, Kirk, 2003. Groundwater Quality in the Agnew and Carlsborg area, Clallam County, December 2000-September 2002. Washington State Dept. of Ecology Publication No. 03-03-017, 52 pp

- Garrigues, Robert, 1996. Ground Water Quality Characterization and Nitrate Investigation of the Glade Creek Watershed. Washington State Dept. of Ecology Publication No. 96-348, 62 pp. Online at https://fortress.wa.gov/ecy/publications/summarypages/96348.html.

Examples of USGS regional nitrate studies include:

- Frans, L.M., and Helsel, D.R., 2005, Evaluating regional trends in ground-water nitrate concentrations of the Columbia Basin Ground Water Management Area, Washington: U.S. Geological Survey Scientific Investigations Report 2005-5078, 7 p.

- Cox, S.E., and Kahle, S.C., 1999, Hydrogeology, ground - water quality, and sources of nitrate in lowland glacial aquifers of Whatcom County, Washington, and British Columbia, Canada: U.S. Geological Survey Water-Resources Investigations Report 98-4195, 251 p.

- Ebbert, J. C., Cox, S. E., Drost, B. W., and Schurr, K.M., 1995, Distribution and sources of nitrate, and presence of fluoride and pesticides, in parts of the Pasco Basin, Washington, 1986-88: U.S. Geological Survey Water-Resources Investigations Report 93-4197, 173 p.

The following USGS studies evaluated the entire state and are particularly helpful for the Washington Nitrate Prioritization Project:

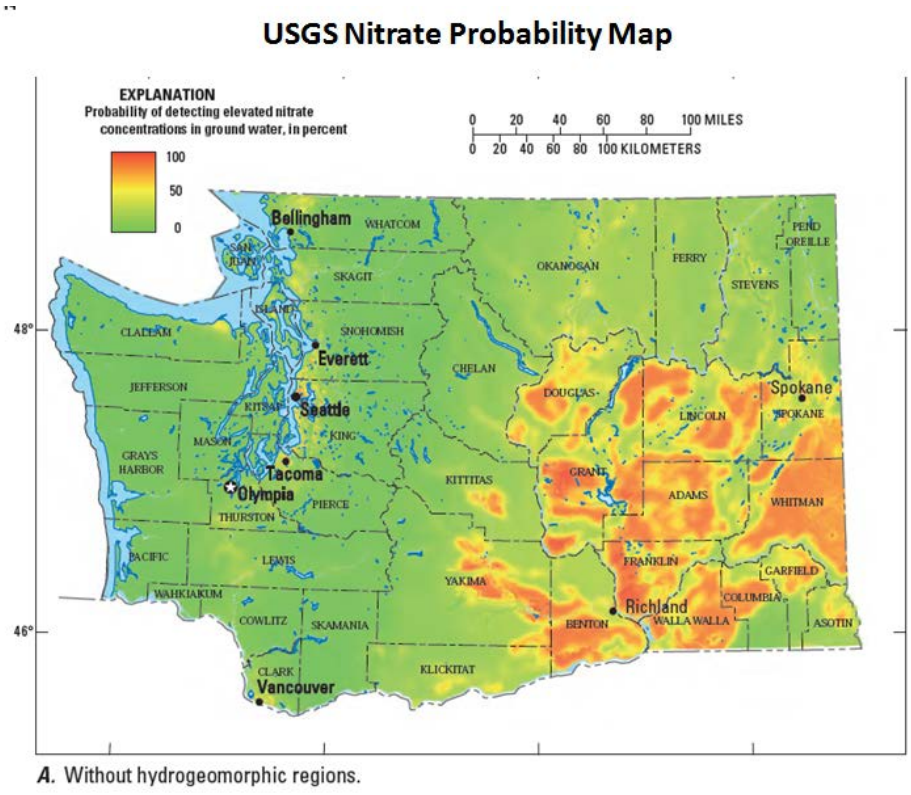
- Estimating the probability of elevated nitrate concentrations in ground water in Washington State, U.S. Geological Survey Scientific Investigations Report, Lonna Frans, 2008.

- Vulnerability of Shallow Groundwater and Drinking-Water Wells to Nitrate in the United States, Bernard Nolan and others, 2006.

In addition, Geographic Information System (GIS) assets developed by the Washington State Department of Agriculture pesticide vulnerability project (Cook, 2010) are being considered as a valuable resource for this project (Appendix D).

Maps from the previously mentioned USGS studies (Figures 2 and 3 respectively) compare favorably with a map of the maximum nitrate concentrations from agency databases (Figure 1). Kriging trials of the compiled nitrate data have also been undertaken, using the same agency data sources previously noted (Figure 4). Collectively these maps show a similar distribution of vulnerability to nitrates in groundwater at the statewide scale. Hot spot cluster analysis could also improve our understanding of the distribution of nitrate problem areas.

Once nitrate impacted areas are delineated, they may be prioritized using ranking criteria such as population and public health, water quality data and trends, nitrogen sources, threats to public water supply systems and domestic wells, sole source aquifers and nutrient impacts on surface water.



A. Without hydrogeomorphic regions.

Figure 9. Probability of detecting nitrate concentrations greater than 2 milligrams per liter in ground water at a depth of 145 feet below land surface for the two logistic regression models with and without hydrogeomorphic regions, Washington.

Figure 2: USGS nitrate probability grid (Frans, 2008)

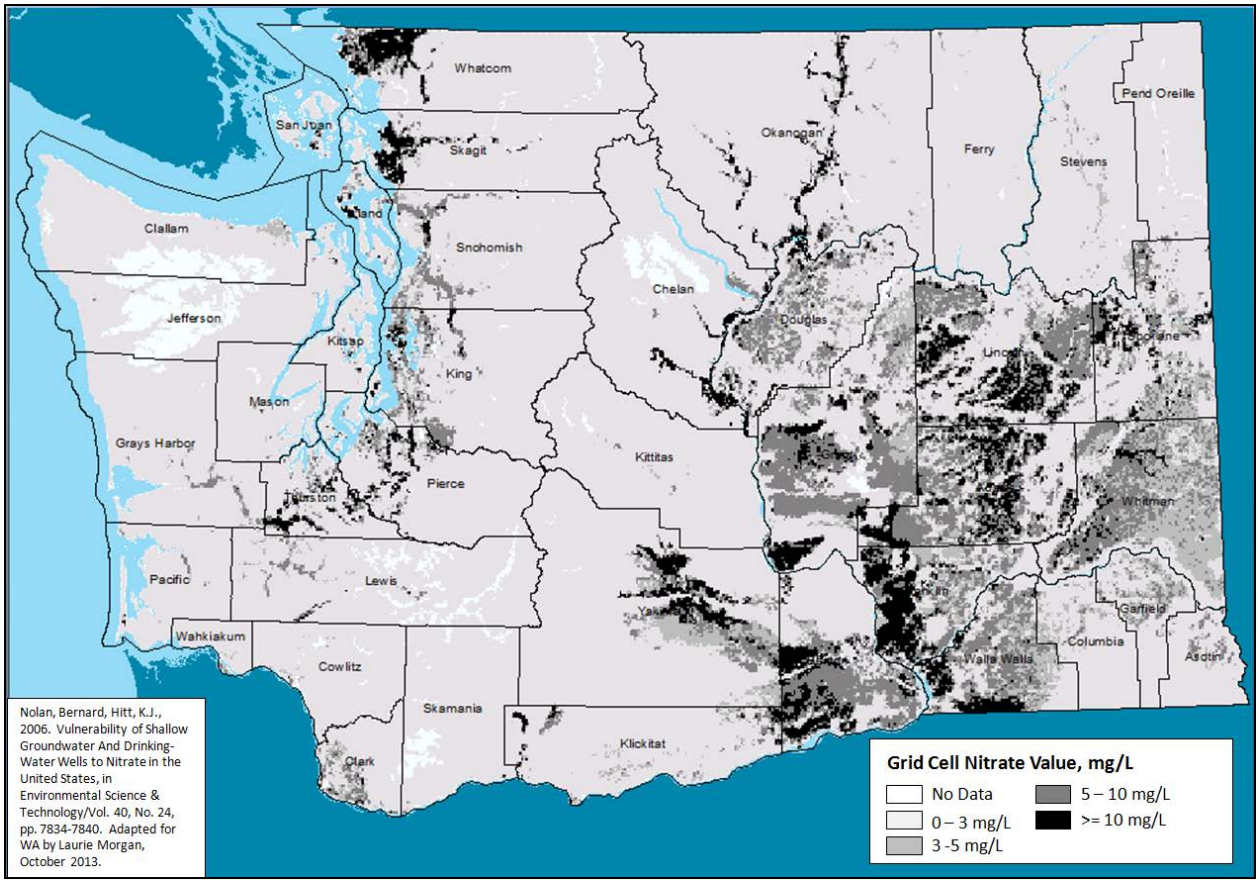


Figure 3: USGS national nitrate concentration prediction grid for shallow groundwater

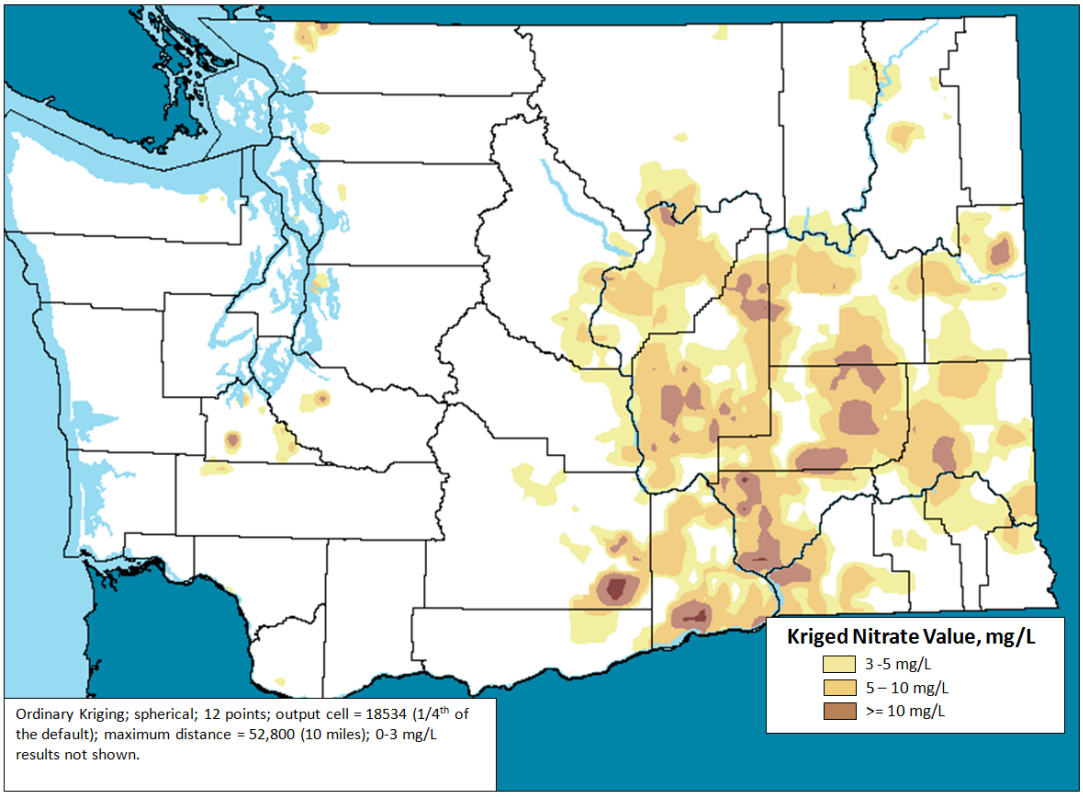


Figure 4: Kriging trial of maximum nitrate well sample results within a ten-mile analysis distance (Morgan, 2012)

Project Description

Goals

Multiple authorities and agencies are involved with management of nitrate sources. These authorities, including Ecology, need to know where nitrate sampling has occurred; what was found; the severity of the problem; and whether it has worsened.

This project will establish provisional Nitrate Priority Areas based on existing nitrate sampling and nitrate risk evaluations. The prioritization data sources needed to apply the criteria will be developed with the WDOH Office of Drinking Water and applied to the delineated Nitrate Priority Areas. The criteria will be based on broad criteria that have been reviewed by several state and federal agency staff. We will solicit continued input and review.

The groundwater quality data for this project will be housed in a Microsoft® (MS) Access database. Ecology and others will review the database in preparation for a web application and to discuss how this data could be shared publically. Groundwater characteristics (such as direction of flow, depth to water and others that inform the physical setting for nitrate occurrence) are very important. An effort to obtain GIS resources for groundwater characterization should be pursued as resources allow.

Plotting nitrate sampling results on a map helps to show where nitrates are a problem in the state. The prioritizing of impacted areas helps target resources and actions to where they are most needed. The hydrogeological framework is necessary to understand how the occurrence and movement of groundwater affects nitrate contamination occurrence.

Information developed by this project can be used in the future to coordinate multiple agency strategies and action. It can also be used to aid in the development of strategies for monitoring conditions, trends and effectiveness of nitrate reduction actions. Monitoring can determine what nitrate levels are currently, and whether or not they are improving over time. Effectiveness monitoring can determine if changes in practices are resulting in lower nitrate levels in groundwater over time. This information is also important when evaluating potential loading sources and for supporting future loading estimates.

Objectives

This project seeks to accomplish the following objectives, as far as may be completed during the time allocated for this phase:

1) Identify areas where nitrates in groundwater have exceeded or are at risk of exceeding drinking water standards.
2) Draft provisional delineations of Nitrate Priority Areas based on hydrogeological/physical attributes of the landscape (such as soils, surficial geology, topography and hydrology) where nitrate in groundwater is a high concern.

3) Determine what data and information are available to identify population and resources impacted by contamination. Collect and prepare that data for the prioritization step.

4) Prioritize and rank the delineated areas of concern.

5) If time and resources allow, develop and organize important hydrogeologic information for one or more Nitrate Priority Areas. Hydrogeologic information is necessary to understand how the occurrence and movement of groundwater affects nitrate contamination occurrence. Depending on outcomes, this step may be started or continued in the next phase of this project.

6) Explore how the groundwater quality data for this project could be housed and publically shared.

7) Prepare and organize data and GIS information for a potential web application (to be proposed).

Information that is useful to meet these objectives include existing groundwater nitrate data from statewide sources, GIS covers from USGS nitrate risk studies, Natural Resources Conservation Service (NRCS) SSURGO soils data, GIS topographic layers, orthophotos, GIS Digital Elevation Model grid, WA Dept. of Natural Resources Surficial Geology GIS layer; Washington State Department of Agriculture (WSDA) layers used for the pesticide vulnerability study, and hydrogeologic studies by Ecology, the USGS and others.

Project deliverables

- Quality Assurance Project Plan
- Periodic updates on project progress
- Provisional delineations of areas where groundwater is known to be impacted by nitrates, with review and comment from agencies and interested parties. The report for this project will describe and discuss the delineation criteria and the results of the review process.
- Prioritization of nitrate impacted areas, with review and comment from agencies and interested parties. The report for this project will describe and discuss the prioritization criteria and the results of the review process.
- Groundwater Nitrate MS Access database with sample data from the following sources: Washington State Department of Health Public Water Supply data; Washington State Department of Ecology Environmental Information Management System; U.S. Geological Survey National Water Information System.
- Organization of this information to prepare for a proposed web application. This is a good way to ensure that the information developed for this project is available to everyone.
- Report on the methods and outcomes of this project, with review and comment from peer reviewers, agencies and interested parties.

Team roles

- Laurie Morgan, Hydrogeologist, Water Quality Program: Project Lead; Delineation and Prioritization (with agency reviewers); Groundwater quality data
- Ron Cummings, Senior Planner, Water Quality Program: Nonpoint Lead and project client/advisor

Agencies and other stakeholders

The following agencies have major roles with respect nitrates in groundwater issues:

- **Washington Department of Ecology**: Has regulatory authority with respect to nitrate pollution through RCW 90.48, the nonpoint program, confined animal feeding operation (CAFO) permit program and state waste discharge to ground permit program. Ecology has responsibilities with respect to dairies in conjunction with the Department of Agriculture.
- **Washington State Department of Health:** Oversees public water supply systems. When these systems are contaminated with nitrates, they face significant and often costly corrective actions.
- **Washington State Department of Agriculture:** Regulates dairies under the Nutrient Management Act.
- **NRCS**: Provides voluntary technical assistance and funding to potential sources of nonpoint pollution.
- **Conservation Districts**: Provides review and approval of nutrient management plans, as well as technical assistance to agricultural operators.
- **Conservation Commission**: Provides services and guidance to Conservation Districts. Oversees the voluntary approach to Critical Aquifer Recharge Areas in agricultural areas under the GMA.
- **USGS**: Produces major hydrogeological studies and vast amounts of useful information in electronic form that we can collect and use, including statewide statistical nitrate maps and a statewide nitrate prediction grid.
- **Environmental Protection Agency:** Provides both WDOH and Ecology with grants for groundwater protection, oversees state implementation of the Safe Drinking Water Act and is a major player in the Lower Yakima nitrate issue.
- **Local Jurisdictions:** Conduct land use planning under the Growth Management Act; produce critical aquifer recharge area plans and ordinances to protect the local drinking water supply.
- **Universities:** Washington State universities provide technical assistance and produce important studies and research related to nonpoint pollution and groundwater.

Other stakeholders: Citizens, agricultural entities, public officials, consultants, and non-profit groups will be able to use this information to protect and improve groundwater quality.

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Organization and Schedule

Table 1 lists the people involved in this project. All are employees of the Washington State Department of Ecology. Table 2 presents the proposed project schedule.

Table 1: Organization of project staff and responsibilities

Staff	Title	Responsibilities
Ron Cummings Watershed Planning Unit Watershed Management Section WQP Phone: (360) 407-6795	EAP Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Laurie Morgan Water Quality Management Unit Watershed Management Section WQP Phone: (360) 407-6483	Project Manager/ Principal Investigator	Writes the QAPP. Works with partner agencies with internal and external review, responsible for delineation and prioritization of nitrate priority areas. Works on the groundwater quality data collection. Coordinates review and comments. Writes the draft report and final report.
Susan Braley Water Quality Management Unit Watershed Management Section WQP Phone: (360) 407-6414	Unit Supervisor for the Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Melissa Gildersleeve Watershed Management Section WQP Phone: (360) 407-6461	Section Manager for the Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.

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

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Table 2: Proposed project schedule

Tasks	Staff	2013-14																	
		J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
QAPP/project planning																			
Draft QAPP	Laurie Morgan	•																	
Draft QAPP review and comment	Peer Reviewer	•	•	•															
Draft QAPP review and comment	QAPP Signatories				•	•													
Final QAPP	Laurie Morgan						•												
Quarterly Reports	Laurie Morgan									•			•			•			
Communication Plan																			
Draft	Sandy Howard/Ron Cummings							•											
Final	Sandy Howard/Ron Cummings								•										
Groundwater Quality Data																			
Final data QA/QC	Laurie Morgan						•												
Distribute existing database data dictionary for review and comment	Laurie Morgan									•									
Data dictionary review and comment	Agency Reviewers/ECY										•	•							
Finalize data dictionary	Laurie Morgan												•						
Report on alternatives for housing of source data and how the data could be updated	Laurie Morgan												•	•					
Nitrate Priority Areas Delineation																			
Develop draft delineation method	Laurie Morgan					•	•												
Preliminary draft delineations available for review and comment	Laurie Morgan							•											
Review and comment of draft areas	Agency Partners								•	•									
Finalize provisional Nitrate Priority Areas	Laurie Morgan										•	•							
Refine boundaries	Laurie Morgan/GIS (as available)												•	•					
Prioritization																			
Initiate process with WDOH	Laurie Morgan/WDOH						•												
Data sources identified and draft criteria developed	Laurie Morgan/WDOH							•	•	•	•								
Review and comment of draft criteria	Agency Reviewers											•	•						

Tasks	Staff	2013-14																	
		J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Prioritization data and scores produced	Laurie Morgan/WDOH														•	•			
Project Report																			
Draft report	Laurie Morgan														•				
Review and comment	QAPP Signatories/Agency Reviewers/Peer Review															•	•		
Final report	Laurie Morgan																	•	•

Analysis Methods

Delineation of nitrate priority areas

Delineations will be based on known groundwater nitrate exceedences and risk factors that contribute to the likelihood of nitrate contamination in topographically distinct areas.

- An example of a topographically distinct area is a valley floor bounded by bedrock hills.
- Groundwater exceedences may be defined in terms of values from 5 mg/L (half the Maximum Contaminant Level) to 10 mg/L (the Maximum Contaminant Level), and values above 10 mg/L.
- Risk factors that contribute to the likelihood of nitrate contamination have been studied by the USGS. USGS GIS rasters for nitrate analyses (Frans, 2008 and Nolan, 2006) can be used to guide delineation of initial Nitrate Priority Areas.

  These independent USGS projects have produced significantly similar results for the state of Washington (Figures 2 & 3). These studies and the associated GIS layers will be used in conjunction with nitrate sampling results to produce an initial draft GIS layer of Nitrate Priority Areas for review.

During this project, the following actions are planned in order to arrive at final provisional delineations of Nitrate Priority Areas that can be used for prioritization and ranking.

- Define preliminary Nitrate Priority Areas based on ground water nitrate data, USGS grids, WSDA aquifer vulnerability information, hot spot analysis, and visual inspection of topographic divisions. Examples of factors to define Nitrate Priority Areas that are under consideration include:
  - Percentages of wells with nitrate samples above 10 mg/L combined with percentage wells with nitrate samples above 5 mg/L. Idaho uses “25% probability of exceeding 5 mg/L for nitrate” (Idaho Department of Environmental Quality, 2008).
  - Using the USGS Frans Nitrate Probability Grid, 70% or greater probability of exceeding 3 mg/L at a depth of 145 feet for Eastern Washington and 50% probability for the same in Western Washington.
  - Using the USGS Nolan Nitrate Prediction Grid, areas that are predicted to equal or exceed 5 mg/L nitrate in shallow groundwater.

  These factors will be applied in draft and will be subjected to review and comment with adjustments as warranted.
- For wells with more than one nitrate sample, we propose to use the maximum recorded nitrate concentration. Other alternatives will be examined, such as using the most recent or another statistical value other than the maximum (such as an average).

- Work with people who have local knowledge related to nitrate contamination of groundwater and the physical setting where available, such as local health department staff and Ground Water Management Area personnel.
- Send out for review and comment and make changes in response.
- Replace the rough outlines defined during preliminary delineations with final outlines based on physical topography.
  - Use GIS layers for aquifer boundaries where available.
  - For areas that do not have a GIS outline for the surficial aquifer: Base surficial aquifer delineation on physical attributes of the landscapes (soils, surficial geology, topography, hydrology – see Nooksack Surficial Aquifer report).
- Provisional delineations will be peer reviewed and adjusted, where warranted, prior to finalization.

Prioritization criteria

Idaho developed a score sheet to rank Idaho's Nitrate Priority Areas (Appendix E). They use population data and the severity of the nitrate contamination to develop scores for their ranking.

Idaho's prioritization criteria can be viewed both in a presentation (page 13, 14): www.deq.idaho.gov/media/709576-npa-presentation-mitchell-042511.pdf and in their report "2008 Nitrate Priority Area Delineation and Ranking Process": www.deq.idaho.gov/media/471611-ranking_2008.pdf.

We will develop prioritization criteria for Washington in consultation with agencies. Prioritization criteria and the application of the criteria will be made available for review and comment by agencies and interested parties. The report for this project will describe and discuss the prioritization criteria and the results of the review process.

In December 2012, staff from Ecology, WSDA, WDOH, USGS, EPA, NRCS and the Washington State Conservation Commission reviewed a proposed list of potential analysis and ranking criteria and came up with the following:

- Population within priority area, water quality data (number of wells exceeding 5 and 10 mg/L nitrate), and water quality trends (nitrate levels are improving, staying the same, or worsening over time).
- Consideration of current and future nitrogen sources.
- Areas with public water supply systems that are in jeopardy or are spending money on treatment and other coping strategies.
- Areas where there are clusters of residents who rely on domestic wells, or a substantial portion of the population relies on domestic wells.
- Areas with very limited alternative water sources, such as sole source aquifers (officially designated or otherwise).

- Areas where groundwater nutrients are potentially causing low dissolved oxygen (DO) problems in surface water.
- Review of current work and resources under way to assess and mitigate groundwater pollution via major studies (such as work going on in Yakima and Whatcom counties).

We will work with the Washington State Department of Health Drinking Water Program to identify specific data sources. We will also use GIS resources, such as population census data and land use.

Hydrogeology information development

Groundwater occurrence and movement characteristics are very important for understanding and managing nitrate contamination of groundwater. The depth to the water table, general groundwater flow directions, how fast groundwater flows, where recharge and discharge occurs, and how thick the aquifer is tell us where contamination could be coming from, where it could go, how fast it travels, and the vertical and horizontal extent of the aquifer.

This information is typically developed during hydrogeologic studies. The Nooksack Surficial Aquifer study (Tooley, 1996), which included the Sumas-Blaine aquifer, specifically developed this information in GIS-useable form for Whatcom County.

Ecology, the USGS, universities, local government, consultants and the Columbia Basin GWMA all have used GIS for hydrogeological studies.

In order to make use of existing hydrogeologic information, the following activities are recommended when resources are available:

- Choose one or more high-priority areas to compile hydrogeologic information from various sources, including Ecology and USGS GIS assets where they exist.
- Explore extracting hydrogeology data from modflow models and USGS supporting databases.
- Organize GIS hydrogeology data, including metadata, in the agency catalog so that it is available for general use and in preparation for web application.
- Report findings and recommendations.

This procedure sets the stage for future acquisitions. It also provides data to use for demonstration purposes while planning for the future (to be proposed) web application.

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Data Management Procedures

Groundwater quality data

Groundwater nitrate data will be compiled into an M.S. Access database and used to map nitrate occurrence and create graphs. This data is also useful for kriging trials and may be used for hot spot cluster analysis (GIS). Data fields will include site identification, latitude and longitude, county, and well depth (as available).

Data sources include public water supply nitrate data from WDOH, USGS data from the National Water Information System, and Ecology data from EIM. The period of record retained in the database will depend on agency-specific factors, such as sampling considerations and database record availability. Data analysis will include an examination of samples by date ranges.

A data dictionary will document the data fields name, data type, size and definition. This data dictionary will be shared with other agencies. The final report will include recommendations on how agency data can be accessed more readily, such as with a front-end web application or through a data clearinghouse.

Data acceptance criteria

Ecology's QAPP guidance discusses a data quality objective process called "Performance and Acceptance Criteria Process". This process applies to projects like risk assessment studies, surveys, exploratory investigations and modeling. This process includes specifying information quality.

The following procedures, which are derived from Carey, 2011, will be followed:

- No new data will be collected for this project and specific quality objectives are not specified for existing data. However, the following acceptance criteria will be applied for data included in the report.

- Data reasonableness—Quality of existing data will be evaluated where available. Testing will be used to identify erroneous or outlier data (U.S. EPA, 2009), and these values will be removed from the data set.

- Data will be evaluated for representativeness.

- Data comparability—Procedures for sample collection, handling, preserving, and analysis evolve over time. Best professional judgment will be used to decide if data sets can be compared. The final report will explain any caveats or assumptions made if data are used that derive from differing sampling or analysis methods.

- The following general data screening procedures will be used (Carey, 2011):

  – Water quality results will be converted to common units, e.g., mg/L for nitrate-N.

- Results qualified as estimates will be included without change.
- Data from water supply wells and monitoring wells will be used.
- Data for filtered and unfiltered samples will be combined. If both are available, then the filtered result will be used.
- Duplicates and replicates will be removed.
- Non-detects will be treated at 0.5 x the reporting limit (U.S. EPA, 2009)

- Because USGS and Ecology data are pre-screened for quality, most data should be usable (Carey, 2011).

In addition to the above procedures as described by Carey, 2011, the following will also be added:

- EIM nitrate data at facilities (such as cleanup sites and landfills) will be considered separately.
- Washington Department of Health nitrate data will be evaluated working closely with the Washington Department of Health for the following considerations:
    - Location of sample
    - Whether the sample is from a single well or after blending from more than one well
    - Whether the sample was taken before or after treatment.
    - Sampling protocol
    - The sensitivity of nitrate samples to the above and other factors
- Table 3 lists the parameters the USGS has used for nitrate evaluation for retrospective datasets. These are the parameters that will be used for this project from the USGS NWIS database.

Table 3: Description of USGS NWIS database nitrate parameters

Code	Parameter	Group	Units
00618	Nitrate, water, filtered, as nitrogen, milligrams per liter.	Nitrates	mg/L
00620	Nitrate, water, unfiltered, as nitrogen, milligrams per liter.	Nitrates	mg/L
00630	Nitrite plus nitrate, water, unfiltered, as nitrogen, milligrams per liter.	Nitrates	mg/L
00631	Nitrite plus nitrate, water, filtered, as nitrogen, milligrams per liter.	Nitrates	mg/L
71850	Nitrate nitrogen, total, as nitrate, milligrams per liter.	Nitrates	mg/L
71851	Nitrogen, nitrate, dissolved, as nitrate, milligrams per liter.	Nitrates	mg/L

We will explore ways of dealing with the possibility of the same well having been sampled by more than one agency and impacts on analysis. Since the scale of this project is statewide and regional, we expect the impact on analysis to be manageable.

Sample results from wells that draw water from deeper in aquifers typically may be lower in nitrate concentration because nitrates are higher in concentration at the top of the aquifer compared to deeper in the aquifer (Nolan, 2006). Nitrate results from these wells can indicate contamination is present when the values are high, but do not necessarily rule out contamination in shallow aquifers when they are low. Well depth will be collected where available.

GIS assets

We will organize and prepare GIS layers and rasters collected during this project so that they may be included in the Ecology GIS catalog. This will include obtaining or providing appropriate metadata and projection to the agency standard.

The final report will include a discussion of data sources, strengths and limitations, data reliability, and spatial uncertainty.

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Appendices

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Appendix A: Governor Christine Gregoire letter

Written to directors of the Washington State Departments of Agriculture, Health, Ecology, Conservation Commission, and the Puget Sound Partnership on Agricultural Pollution Issues, on September 28, 2012.

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CHRISTINE O. GREGOIRE
Governor

STATE OF WASHINGTON
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September 28, 2012

Dan Newhouse, Director
Department of Agriculture
P.O. Box 42560
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Mary Selecky, Secretary
Department of Health
P.O. Box 47890
Olympia, WA 98504-7890

Ted Sturdevant, Director
Department of Ecology
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Mark Clark, Executive Director
Conservation Commission
P.O. Box 47721
Olympia, 98504-7721

Anthony Wright, Executive Director
Puget Sound Partnership
326 East D Street
Tacoma, WA 98421

Dear Dan, Mary, Ted, Mark, and Anthony:

As you know, ensuring clean water for current and future generations of Washingtonians has long been an important priority of mine. It concerns me that there is a statewide problem of pollution from various activities including agriculture affecting our surface and ground waters. Clean drinking water for people, and clean water for fish, shellfish, swimming, and other uses, are essential to Washington's quality of life.

We have made great progress in cleaning up and protecting our waters, but challenges clearly remain. I see too many shellfish beds closed due to bacterial contamination, unacceptable levels of nitrate contamination in key aquifers around the state, and polluted surface waters that threaten human and aquatic health.

Addressing this challenge is not something the state can or should do alone. This takes everybody working together: landowners, the agricultural sector, the environmental community, tribal governments and local, state and federal agencies. While we still have work to do in the Samish River basin, our collaborative effort in that basin has brought considerable progress. Because agriculture is only one of many sources of pollution, we must continue to bring everyone to the table in order to find solutions. I ask you to encourage and support collaborative processes as we step up to water quality challenges in other areas, such as in Whatcom County and the Yakima River valley.

Let me address up front the issues related to agriculture practices. Agriculture is central to Washington's economic success and cultural identity. Protecting Washingtonians' quality of life demands that we ensure clean water *and* a thriving agricultural sector. Too often, past practices have led to these values being mutually exclusive, and in many areas water quality has suffered due to inadequate agricultural practices. Accepting that one of these interests must suffer for the other to thrive is old thinking, and I reject it. Our challenge and responsibility is to lead the transition to a Washington that enjoys clean water all across the state as well as a robust agricultural way of life.

I know that you are all working hard to address this challenge, both in targeted areas of the state and statewide. You have launched several efforts to improve water quality over the past few years, and made progress on several fronts. However, there is clearly more work to do. The public needs

assurance that the nutrient management programs we have in place are adequate to prevent surface and ground water contamination. For that reason, I ask that you focus and accelerate your agency efforts on the following:

1. Finish the job to eliminate pollution that threatens Samish Bay and its rich shellfish resources. Much progress has been made through recent efforts, but we have more work to do in order to upgrade Samish Bay shellfish beds and protect them from pollution-related closures. (PSP, WSDA, ECY, WSCC, DOH)

2. Initiate on-the-ground efforts in Whatcom County to eliminate pollution from livestock, on-site septic, polluted runoff and other sources that threaten Drayton Harbor and Portage Bay shellfish beds. As part of the Washington Shellfish Initiative, I have high expectations that this collaborative effort will lead to protecting and reopening valuable shellfish beds. (PSP, WSDA, ECY, WSCC, DOH)

3. By December 31, 2012, finalize the policy and budget recommendations from the Yakima Valley Ground Water Management Area program to address nitrate pollution in the valley ground waters from agricultural practices and other sources (WSDA, ECY, WSCC, DOH).

4. Develop clear guidance for, and implement, Pollution Identification and Correction (PIC) programs in partnership with counties around Puget Sound. As part of the Washington Shellfish Initiative, clear guidance is needed by January 1, 2013 to expand this promising model, which has been shown to provide an effective, ongoing approach to finding and correcting sources of nonpoint pollution to Puget Sound. Your work on this guidance should be consistent with the work you complete in the Three Directors' Talks. (DOH, ECY)

5. Significantly increase the implementation, and ensure the effectiveness, of agricultural practices that protect both surface and ground water quality from nutrient pollution through successful completion of the work of you directors. Please report to me by December 15, 2012 on your improvements to current regulatory and voluntary tools and approaches, and how those improvements will lead to improved water quality across the state. (WSDA, WSCC, ECY)

6. Work with each other, industry, other stakeholders, and legislators to develop legislation for the 2013 legislative session that addresses the gaps in the state's regulation of nutrient management to ensure the state has adequate statutory authority. Such legislation should ensure that all livestock waste is managed responsibly, that surface and ground water is protected, and that adequate monitoring is in place to ensure clean water. (WSDA, ECY, WSCC)

Though your agencies each have different statutory missions, those missions are aligned when it comes to improving our regulatory and voluntary approaches to protecting water quality while supporting a healthy agricultural sector. I look forward to your report on the above actions.

Sincerely,

Chris

Christine O. Gregoire
Governor

Appendix B: Example costs from North Whatcom County nitrates feasibility study deliverable number 2.

Table 4 contains a 20-year life cycle cost analysis presented in present worth. The values are the sum of the O&M costs adjusted with 3.5% inflation, debt service on a loan of 1.5% interest over 20 years, and a 1.0% loan fee during the first year.

TABLE 4
20-Year Cost Analysis

Water System Name	Alternate 1 *Lynden Water Full Flow*	Alternate 2 *Lynden Water Blended Flow*	Alternate 3 *Water System Treatment Full Flow*	Alternate 4 *Water System Treatment Blended Flow*
Delta Grocery	$63,900	N/A	$622,000	N/A
Century	$497,800	$407,400	$1,370,000	$1,050,000
Kontree Apts.	$261,500	N/A	$730,000	N/A
Rathbone Park	$864,900	N/A	$1,550,000	N/A
Lynden Valley View	$202,500	N/A	$630,000	N/A
Northwood Park (1)	$298,500	N/A	$720,000	N/A
Delta Water Assoc.	$10,426,100	$8,494,800	$7,260,000	$6,123,000
Covenant Christian (1)	$214,700	N/A	$625,000	N/A
Northwood Water Assoc. (1)	$526,400	N/A	$802,000	N/A

(1) Costs for pipeline are shared by multiple users. Cost estimates for these systems have been prepared in a manner which each system would pay their share of the line to their property and nothing more (Figure 2). In a situation where one or more of these water systems are not interested in participating, additional costs will be allocated to the remaining participating systems

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Appendix C: Example costs incurred by public water supply systems due to nitrate contamination of groundwater issues

This spreadsheet was sent from the Washington Department of Health to the Washington Department of Ecology via email in December, 2012. It shows several projects funded by the Drinking Water Source Revolving Fund where the issue was nitrate contamination.

APPL	B_NAME	Project	Description	DWSRF_LOAN	PROJECT_COST	COUNTY	RES_POP
2002-067	Pasadena Park Irrigation District No. 17	WATER SYSTEM CONSOLIDATION	Extend 3,200 ft of 12" water main to connect Pleasant Prairie to Pasadena Park (Pleasant Prairie has nitrate problems).	228,874.00	228,874.00	SPOKANE	4312
2003-064	Uniontown, Town of	NEW SOURCE WELL (WELL NO. 6)	Drill new municipal drinking water well. Current well's nitrate levels exceeds state standards. Drill new well abandon existing well.	247,794.00	247,794.00	WHITMAN	345
2005-005	Beneficial Water	NEW SOURCE FOR NITRATE MITIGATION	Construct new well into aquifer with nitrates below MCL, including pump, controls, meters.	167,214.00	167,214.00	FRANKLIN	84
2006-014	Chelan County PUD #1	EXTEND WATER SERVICE TO THE COMMUNITY OF MONITOR	Extend PUD water service to the community of Monitor, whose existing water services contain coliform bacteria and nitrate that exceed the maximum contaminant level.	2,569,642.00	6,044,200.00	CHELAN	10757
2006-060	Uniontown, Town of	WELL #6 COMPLETION	Complete municipal well to include pump, well house, and connection to address nitrate exceedance.	161,065.00	237,811.00	WHITMAN	324
2007-015	Columbia View Water Services	DISTRIBUTION LINE INCREASE IN SUPPORT OF NEW SOURCE CONSTRUCTION FOR NITRATE REMOVAL	Need additional engineering, design, construction permits & activities to address need to increase size of distribution system due to constructing new 1600' nitrate well (DWSRF 2006-018)	107,541.00	107,541.00	WALLA WALLA	350
2007-023	Desert Canyon Utility Company	NITRATE REDUCTION	Phase I - Construction of new nitrate facility; drill new well(s); Phase II - installation 6000 irrigation line; 5000 LF transmission line from nitrate facility; service meters.	423,695.00	423,695.00	DOUGLAS	43

APPL	B_NAME	Project	Description	DWSRF_LOAN	PROJECT_COST	COUNTY	RES_POP
2007-051	Rathbone Park Water Association	NORTH WHATCOM COUNTY NITRATES FEASIBILITY STUDY	Mitigation for nitrates levels in exceedance of the MCL; install nitrates treatment system or install connection to the City Lynden source	540,350.00	540,350.00	WHATCOM	240
2007-052	Royal City, City of	ROYAL CITY WELL NO. 2	Remove existing well due to high level of nitrate levels; install new well and generator	1,447,330.00	1,447,330.00	GRANT	1800
2011-025	Greater Bar Water District	GREATER BAR WATER DISTRICT COMPLIANCE AND CONSOLIDATION PROJECT	Install service meters, source meters, new reservoir, distribution piping and security features (nitrate issues)		2,722,800.00	DOUGLAS	153

Appendix D: Washington Department of Agriculture Aquifer Pesticide Susceptibility and Aquifer Pesticide Vulnerability Maps

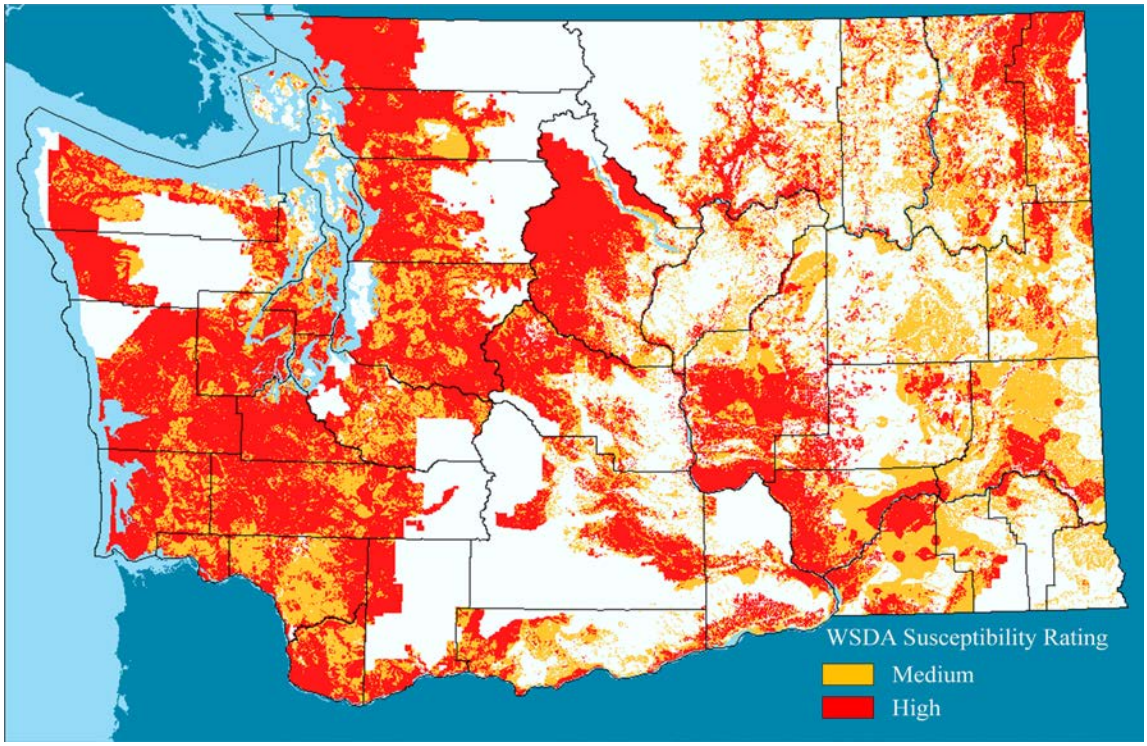

Figure 5: Washington State Dept. of Agriculture Pesticide Susceptibility Grid.

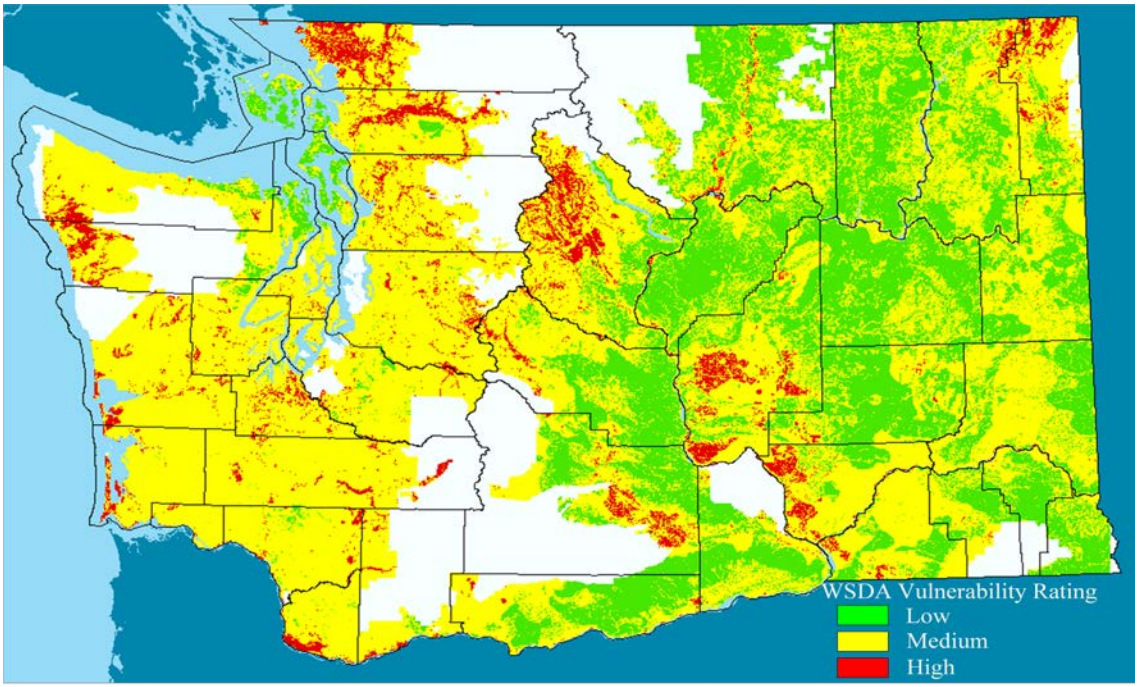

Figure 6: Washington State Dept. of Agriculture pesticide vulnerability grid

Susceptibility refers to how easily contamination can reach aquifers through soils and the ground beneath the soils. Vulnerability is susceptibility with loading from contaminant sources

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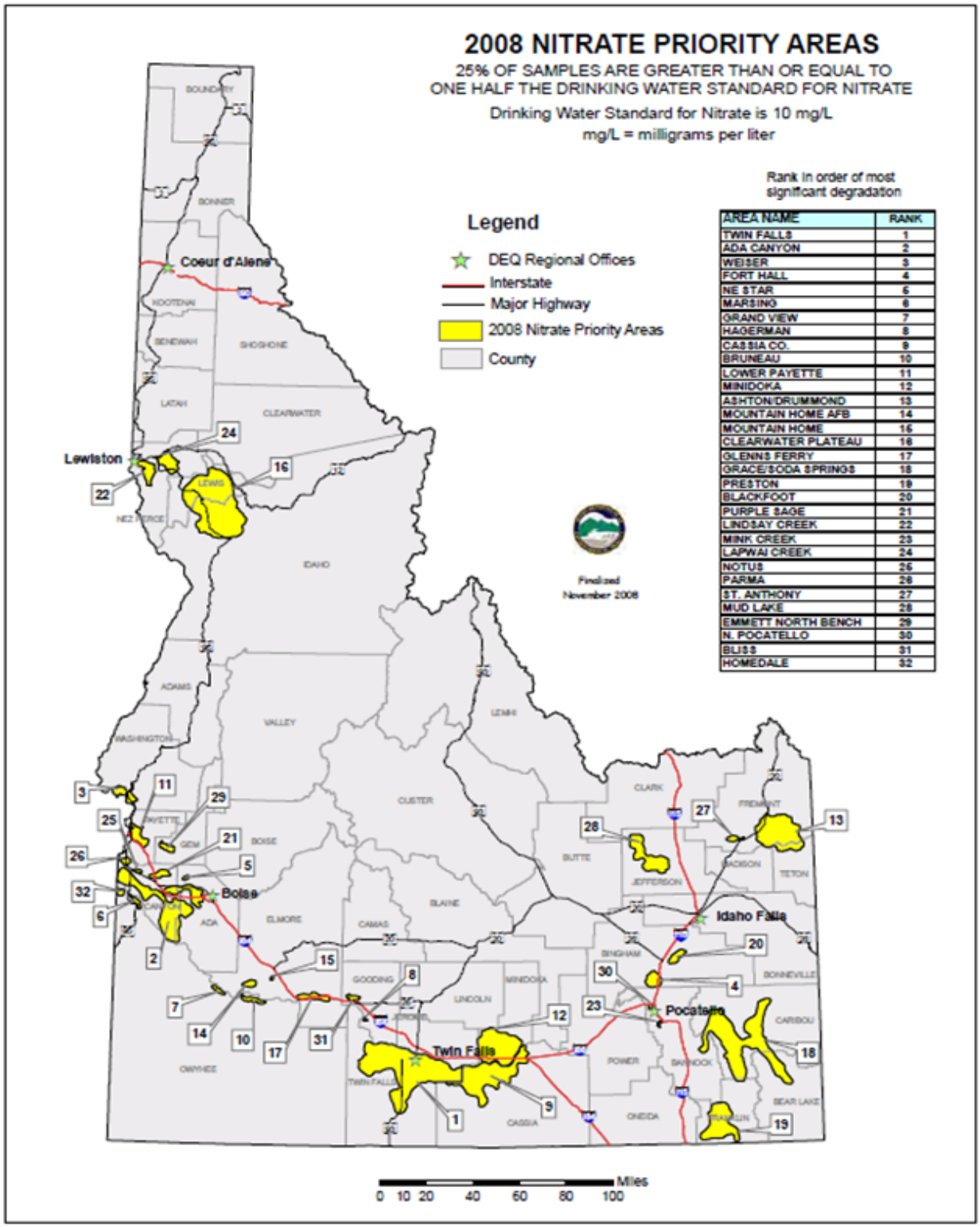
Appendix E: State of Idaho 2008 nitrate priority areas



AREA NAME	RANK
TWIN FALLS	1
ADA CANYON	2
WEISER	3
FORT HALL	4
NE STAR	5
MARSING	6
GRAND VIEW	7
HAGERMAN	8
CASSIA CO.	9
BRUNEAU	10
LOWER PAYETTE	11
MINIDOKA	12
ASHTON/DRUMMOND	13
MOUNTAIN HOME AFB	14
MOUNTAIN HOME	15
CLEARWATER PLATEAU	16
GLENNS FERRY	17
GRACE/SODA SPRINGS	18
PRESTON	19
BLACKFOOT	20
PURPLE SAGE	21
LINDSAY CREEK	22
MINK CREEK	23
LAPWAI CREEK	24
NOTUS	25
PARMA	26
ST. ANTHONY	27
MUD LAKE	28
EMMETT NORTH BENCH	29
N. POCATELLO	30
BLISS	31
HOMEDALE	32

Figure 7: State of Idaho 2008 nitrate priority areas map with ranked list

Table 5: State of Idaho 2008 nitrate priority area scoring sheet for ranking

Priority Area Number: 16		Priority Area Name: Clearwater Plateau		
Ranking Criteria			**Score**	**Comments**
1) POPULATION				
	Points	**Select One**		
a) Within Degraded Area				
<5000 1		x	1	4236
5000 to 50,000	2			
>50,000 3				
		Subtotal	**1**	
b) Source Water Protection Areas or Public Water System wells in Priority Area				
0 0				
1 to 20	1			
21 to 40	2	x	2	22
>40 3				
		Subtotal	**2**	
c) Number of Wells with NO_3 > 10 mg/l				
0 0				
1 to 5	1			
6 to 20	2			
21 to 40	3	x	3	39
>40 4				
		Subtotal	**3**	
		Population Score	**6**	
		Max Possible Score = 10		
2) WATER QUALITY				
	% wells	**Nitrate Concentration Criteria**		
Percent of wells with NO_3>2 mg/l	65%	2	1.30	
Percent of wells with NO_3>5 mg/l	37%	5	1.85	
Percent of wells with $NO_3 \geq$ 10 mg/l	21%	10	2.10	
		Water Quality Total	**5.25**	
3) WATER QUALITY TRENDS				
		Select One		
Increasing	10			
No Discernable Trend	5	x	5	
Decreasing trend	0			
		Trend Score	**5**	
		Max Possible Score = 10		
4) OTHER BENEFICIAL USES				
Other beneficial uses are impaired	1	Yes=1 No = 0	0	
		Beneficial use score	**0**	
		Max Possible Score = 1		
		Total Score	**16.25**	

Appendix F: Glossary, acronyms, and abbreviations

Glossary

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities. This includes, but is 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.

Point source: Sources of pollution that discharge 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 that clear more than 5 acres of land.

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.

Retrospective: A retrospective study uses historical data for analysis.

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.

Acronyms and abbreviations

BMP	Best management practices
e.g.	For example
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
GIS	Geographic Information System software
i.e.	In other words
MQO	Measurement quality objective
QA	Quality assurance
USGS	U.S. Geological Survey

WAC	Washington Administrative Code
WDOH	Washington State Department of Health
WSDA	Washington State Department of Agriculture

Units of Measurement

mg/L	milligrams per liter (parts per million)