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Relation Between Nitrate in Water Wells and Potential Sources in the Lower Yakima Valley, Washington

U.S. EPA Region 10
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ERRATA

Relation Between Nitrate in Water Wells and Potential Sources in the Lower Yakima Valley, Washington

In 2010, the U.S. Environmental Protection Agency (EPA) conducted a study to identify potential sources of nitrate contamination in groundwater and residential drinking water wells in the Lower Yakima Valley in central Washington State. EPA released a report on this study in September 2012, entitled "Relation Between Nitrate in Water Wells and Potential Sources in the Lower Yakima Valley, Washington" ("EPA 2012 Report"). The EPA 2012 Report was assigned document number EPA-910-12-003. Further review of the document identified errors in the report. Corrections to the EPA 2012 Report are summarized below and incorporated into this version of the document which has been assigned document number EPA-910-R-13-004. The page numbers below refer to the new document (EPA-910-R-13-004) and may vary slightly from the page number in the original version of the report (EPA-910-R-12-003).

ACKNOWLEDGEMENTS

Page xvi, third paragraph: During the public input period, David Tarkalson, PhD requested that his name and affiliation be removed from the final report. His name and affiliation were removed from the acknowledgements section.

Page xvi, third paragraph: Roger Burke, PhD of U.S. EPA's Office of Research and Development also provided an independent third party review of the EPA 2012 Report. His name has been added to the acknowledgements section.

EXECUTIVE SUMMARY

Page ES-3: The following was added to the end of the "Study Design" section.

> "A discussion of the quality assurance and quality control (QA/QC) procedures and a summary of the data validation process are presented in Appendix E. Uncertainties and limitations with analytical data were noted in Appendix E and described in detail in the data validation memoranda. Data usability is also indicated in the data summary tables by inclusion of data qualifiers."

Page ES-11, Table ES-1: Deleted "DVM" from the reference to the Sunny Dene Ranch.

SECTION I: INTRODUCTION

Page 1, 4th paragraph: The following revisions were made in response to comments made by the *Yakima Herald Republic* during the public input period and to correct the statement attributed to a letter from the *Yakima Herald Republic*:

> "According to the Herald, following the series, the reporter received a number of inquiries from citizens asking whether EPA could take action under the Safe Drinking Water Act (SDWA). These inquiries prompted the reporter to send a letter to EPA asking whether the agency would consider invoking emergency authority under Section 1431 of the SDWA to address the problem."

SECTION II: PURPOSE AND SCOPE

Page 2: The following sentence was added to the end of the second paragraph.

> "A data usability review and validation independent of the laboratories were conducted by EPA and are discussed in Appendix E."

SECTION VI: THREE STUDY PHASES

Page 15, Table 1: Deleted "DVM" from the reference to the Sunny Dene Ranch.

SECTION VII: PHASE 3: COMPOUNDS AND ANALYTICAL TECHNIQUES

Page 28: Inserted "δ" in several places.

SECTION VIII: QUALITY ASSURANCE AND QUALITY CONTROL

Page 29: In the fifth sentence, the word "is" was changed to "are".

SECTION IX: ANALYTICAL RESULTS AND DISCUSSION

Page 30: The following was added after the first full paragraph:

> "A data usability review and validation independent of the laboratories were conducted by EPA and are discussed in Appendix E. Data usability is indicated in the data summary tables by inclusion of data qualifiers. The data qualifiers are defined in the footnotes of the data summary tables and further explained in Appendix E. A discussion of data bias, where it could be determined, also is included in Appendix E."

Page 31: The following was added to the first paragraph:

> "A farm with 2500 dairy cattle is similar in waste load to a city of 411,000 people (EPA 2004). A difference lies in the fact that human waste is treated before discharge into the environment, but animal waste is either not treated at all or minimally treated before discharge into the environment (EPA 2004)."

Page 32: Replaced the first two full paragraphs with the following:

> "NRCS Washington recommends avoiding the use of "agricultural waste storage ponds" (lagoons), unless no reasonable alternative exists, at locations like the Haak Dairy where there is an aquifer that serves as a domestic water supply (NRCS Washington 2004). If no reasonable alternative exists, consideration should be given to the following: 1) a clay liner designed in accordance with procedures of Agricultural Waste Management Field Handbook Appendix 10D ("NRCS Appendix 10D") with a thickness and coefficient of permeability so that specific discharge is less than 1×10^{-6} cm/sec; 2) a flexible membrane liner over a clay liner; 3) a geosynthetic clay liner (GCL) flexible membrane liner; or 4) a concrete liner designed in accordance with slab on grade criteria for fabricated structures requiring water tightness."

> "EPA estimated the seepage from lagoons for the Haak Dairy using unit seepage rates from NRCS Appendix 10D and from a field study by Ham and DeSutter (Ham 2002). Lagoon design should consider unit seepage rates in addition to other factors such as state and local requirements and site-specific conditions (e.g., groundwater flow and depth to groundwater) (NRCS 2008). State regulations for specific discharge range from about 500 gallons per acre per day (1/56 inch or 0.45 mm per day) to about 6,800 gallons per acre per day (1/4 inch or 6.35 mm per day)

(NRCS 2008). Applying a unit seepage rate of 500 gallons per acre per day to the surface area of the Haak Dairy lagoons equates to an approximate seepage volume of 1,080,000 gallons per year, the equivalent of about 1.6 volumes of an Olympic-size swimming pool annually (Table 7)."

Page 32, Table 7: Corrected the title of the third column to read: "Estimated Lagoon System Leakage, Based on Unit Seepage Rate of 500 Gallons per Acre per Day (gallons per year)" and a footnote (formerly footnote number 24) was deleted.

Page 33: Replaced the second paragraph with the following:

> "The seepage rate of 0.45 mm per day falls within the Ham and DeSutter range of 0.2 to 2.4 mm per day. Leakage rates for the Haak Dairy lagoons would likely be greater than the above estimates if the lagoons are unlined. If the lagoons are lined with a plastic liner, the actual leakage rates could be lower, although plastic liners can be punctured during construction and lagoon maintenance, especially during periodic dredging activities."

Page 43, first paragraph: The second sentence was modified as follows: "Total coliform, but not *E. coli* or fecal coliform, was detected in WW-04."

Page 44: Table 16 has been corrected to reflect that atrazine was not detected in WW-03.

Page 48, Table 18: Corrected the title of the third column to read: "Estimated Lagoon System Leakage, Based on Unit Seepage Rate of 500 Gallons per Acre per Day (gallons per year)" and a footnote (formerly footnote number 30) was deleted.

Page 48: Replaced the second paragraph with the following:

> "As discussed previously, the NRCS Washington recommends avoiding the use of "agricultural waste storage ponds" (lagoons), unless no reasonable alternative exists, at locations like the Dairy Cluster where there is an aquifer that serves as a domestic water supply (NRCS Washington 2004). Assuming the same unit seepage rate as for the Haak Dairy (500 gallons per acre per day), seepage volume at the Dairy Cluster is approximately 7,391,000 gallons per year. This is the equivalent volume of about 11 Olympic-size swimming pools annually."

Page 51: The second sentence in the first paragraph was corrected as follows: "Figures 11 and 15 show the sample locations for the Dairy Cluster."

Page 58, Table 22: Deleted the reference to WW-18 which is not associated with the Dairy Cluster.

Page 65, Table 26: Deleted "DVM" from the reference to the Sunny Dene Ranch.

Page 67, Table 29: Added the units of measure to the bentazon result for SO-11 so that it reads "38 ug/kg".

SECTION X: STUDY LIMITATIONS AND UNCERTAINTIES

Page 79: The following was added to this section.

> "A discussion of the QA/QC procedures and a summary of the data validation process are presented in Appendix E. Uncertainties and limitations with analytical data were noted in Appendix E and described in detail in the data validation memoranda. Data usability is also indicated in the data summary tables by inclusion of data qualifiers."

SECTION XII: REFERENCES

Page 88: Reference EPA 2010b has been corrected to read "Yakima Basin Nitrate Study Phase 3 – Comprehensive Analytical Source Tracer Sampling April 2010 Sampling Event. Quality Assurance Project Plan. EPA Region 10. April 8, 2010."

APPENDICES

Appendix C

Table C11: Deleted the "h" from the end of the word "anti-inflammatory" after the word "naproxen".

Tables C11, C12 and C14: The sample type designations were corrected for samples SO-11 through SO-16.

Appendix E, pages E-8 and E-9, Section 1: The following paragraphs were added.

> Microbial Source Tracking
>
> Microbial Source Tracking (MST) analysis was performed on nine lagoon and four wastewater treatment plant samples using a polymerase chain reaction (PCR) technique. All quality control measures passed including laboratory QC, sterility controls, and blank analyses. Samples were assessed on a present (P) / absent (A) basis for *Bacteroides* species with possible source identification of general *Bacteroides* (GB), human (H), ruminant (R), or both human and ruminant (H/R).
>
> Bacteria
>
> Twenty-one well water, six lagoon, and three wastewater treatment plant samples were analyzed for total coliform by Standard Method (SM) 9222B, fecal coliform by SM 9221E, and/or *E. coli* by SM 9221F. All quality control measures passed including holding time requirements, laboratory QC, sterility controls, and blank analyses. All lagoon and wastewater treatment samples were qualified estimated ("J") for *E. coli* as the method, SM 9221F, has not been approved for use under the Clean Water Act (CWA).

Appendix E, page E-13, Section 6: The second sentence in the third paragraph was revised by replacing "changed" with "replaced".

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ACRONYMS/ABBREVIATIONS

Ada – U.S. Environmental Protection Agency's Robert S. Kerr Environmental Research Center in Ada, Oklahoma

AOAC – Association of Analytical Communities

CARE – Community Action for a Renewed Environment

CFC – chlorofluorocarbon

CHHP – Center for Hispanic Health Promotion

DEHP – bis-(2-ethylhexyl) phthalate

DOH – Washington State Department of Health

DQO – data quality objective

Ecology – Washington State Department of Ecology

EJ – environmental justice

EPA – U.S. Environmental Protection Agency

FDA – U.S. Food and Drug Administration

GIS – Geographic Information System

GPS – Global Positioning System

"J" data qualifier – Compound was positively identified, but the associated numerical value is an estimate.

LG – dairy lagoon

MCL – maximum contaminant level

MDL – method detection limit

MEL – U.S. Environmental Protection Agency Manchester Environmental Laboratory

mg/L – milligrams per liter

MST – microbial source tracking

NCEC – Northwest Communities Education Center

NRCS – Natural Resources Conservation Service

ng/g – nanograms per gram

ng/L – nanograms per liter

N_2 – nitrogen gas

^{14}N– nitrogen 14

^{15}N – nitrogen 15

NH_4 – ammonium

NO_2^- – nitrite

NO_3^- – nitrate

ND – not detected

NS – not sampled

NMP – nutrient management plan

NWQL – USGS National Water Quality Laboratory

ORD – U.S. Environmental Protection Agency Office of Research and Development

PCB – polychlorinated biphenyls

ppm – parts per million

QA/QC – quality assurance/quality control

QAPP – Quality Assurance Project Plan

QC – quality control

"R" data qualifier – The data are unusable for all purposes

RARE – Regional Applied Research Effort

REDOX – oxidation/reduction potential

SDWA – Safe Drinking Water Act

SF_6 – sulfur hexafluoride

SMOW – Standard Mean Ocean Water

SOP – standard operating procedure

TKN – total Kjeldahl nitrogen

"U" data qualifier – The analyte was not detected at or above the reported result.

μg/kg – micrograms per kilogram

μg/L – microgram per liter

UG – upgradient

"UJ" data qualifier – The analyte was not detected at or above the reported estimated result. The associated numerical value is an estimate of the quantitation limit of the analyte in the sample.

UNL – University of Nebraska – Lincoln Water Sciences Laboratory

U.S.C. – United States Code

USDA – U.S. Department of Agriculture

USGS – U.S. Geological Survey

VIRE – Valley Institute for Research and Education

WSDA – Washington State Department of Agriculture

WW – water well

WWTP – wastewater treatment plant

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ACKNOWLEDGEMENTS

This report was initiated as part of an U.S. Environmental Protection Agency (EPA) Regionally Applied Research Effort (RARE) project with additional support from EPA's regional and national Office of Compliance and Enforcement, including the Environmental Justice Showcase Community pilot program.

The report was prepared by EPA Region 10's Office of Environmental Assessment with assistance from Region 10's Offices of Water and Watersheds, Regional Counsel, Ecosystems, Tribal, and Public Affairs, Compliance and Enforcement and EPA's National Risk Management Research Laboratory at the Robert S. Kerr Environmental Research Center in Ada, Oklahoma.

We would like to acknowledge the following individuals who provided an independent third party review of the report: Megan Young, PhD, U.S. Geological Survey; Stephen Kraemer, PhD, U.S. EPA Office of Research and Development; Roger Burke, PhD, U.S. EPA Office of Research and Development; and Lorraine Edmond, U.S. EPA Region 10.

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EXECUTIVE SUMMARY

Several investigations relating to nitrate contamination in the Lower Yakima Valley in Washington State have been conducted over the last 30 years. These studies have repeatedly shown nitrate levels in drinking water above the U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) of 10 mg/L. Nitrate contamination in groundwater is primarily a health risk for rural populations who rely on private wells for drinking water.

From February through April 2010, EPA conducted sampling of drinking water wells and potential sources of nitrate contamination in the Lower Yakima Valley, which is in Yakima County in central Washington State. The Yakama Reservation composes a large percentage of the Lower Yakima Valley. EPA's effort entailed collecting over 331 samples from residential drinking water wells for nitrate and bacteria, and multi-parameter sampling on 29 water wells (26 residential drinking water wells and three dairy supply wells), 12 dairy lagoons (15 samples), 11 soil samples (five at dairy application fields and six at irrigated and fertilized crop fields[1]), five dairy manure pile samples, and three wastewater treatment plant (WWTP) influent samples. This report presents the results of these sampling efforts.

Purpose and Scope

The primary purpose of this study was to investigate the contribution from various land uses to the high nitrate levels in groundwater and residential drinking water wells, which is the predominant source of drinking water for many residents in the Lower Yakima Valley.

The study included sampling of residential drinking water wells, dairy supply water wells, and three sources of nitrate: dairies; irrigated cropland; and residential septic systems. In addition to nitrate and other forms of nitrogen, EPA analyzed samples for a variety of chemicals to evaluate whether chemicals other than nitrate can be used to identify likely sources of the nitrate contamination in the groundwater and drinking water wells.

EPA analyzed samples for chemicals that were expected to be associated with one or more of the sources. These included pharmaceuticals (both veterinary and human medications), personal care products, steroids and hormones, pesticides and herbicides, as well as other indicators of water quality such as total nitrogen and major ions such as chloride and calcium.

EPA also used microbial analysis to determine whether the water wells, lagoons and WWTP influent samples exhibited fecal contamination. If the samples were found to have fecal contamination, then microbial source tracking (MST) was performed to identify the source of the fecal contamination (in this case, human or ruminant). Isotopic analysis of water wells was conducted to identify the possible origin of the nitrate in water wells. Age dating analysis on the well samples was conducted to estimate the time since water infiltrated to the aquifer.

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[1] In this report, "application field" refers to fields owned or leased by the dairies and "crop field" or "irrigated cropland" refers to fields owned or leased by other farmers. Both application fields and crop fields could receive applications of manure and/or synthetic fertilizer.

The Yakima Basin is a watershed of great diversity in climate, vegetation, and land use. More than 30 percent of the Yakima Basin is forested, 30 percent is sage-steppe rangeland, and 28 percent is in agricultural production (USGS 2009). This investigation focused on a portion of the Yakima Basin referred to as the Lower Yakima Valley. This broad valley is bounded by basalt ridgelines to the north and south, the Cascade Mountains to the west, and encompasses two counties (Yakima and Benton) and the million-acre Confederated Tribes and Bands of the Yakama Nation Reservation (Yakama Reservation). The study area includes portions of the Toppenish Basin (western area) and the Benton Basin (eastern area) along the Yakima River. Together, both areas cover approximately 368,600 acres within Yakima County. The Lower Yakima Valley is home to about 75,000 people, of which about one-third (24,000) use private, unregulated residential wells (Ecology 2010).

Background

Nitrate is an inorganic compound and a naturally occurring form of nitrogen. On a national scale nitrate is typically found in shallow groundwater at concentrations up to 1.1 mg/L (Nolan and Hitt 2003). Higher nitrate concentrations than this usually indicates that human activities have contributed additional nitrate to the groundwater. Nitrate is highly soluble in water and mobile in soil, which makes it relatively easy for nitrogen from a variety of point and non-point sources to move through the soil and into the groundwater as nitrate.

EPA has established a MCL for nitrate in drinking water of 10 mg/L under the Safe Drinking Water Act (SDWA). EPA regulates nitrate in public drinking water systems because nitrate concentrations greater than the MCL may cause health problems. Exposure to excess nitrate can result in methemoglobinemia (blue-baby syndrome) in infants and susceptible individuals, which can lead to death in extreme cases (Ward 2005). Some studies have shown a positive association between long-term exposure to nitrate in drinking water and risk of cancer and certain reproductive outcomes, while other studies have shown no association (Ward 2005).

Study Design

EPA designed a three-phased study. The purpose of Phase 1 was to identify the major sources of nitrogen in the study area, based on historical records and available information. During Phase 1 EPA combined information on land use with some simple calculations to estimate the amount of potential nitrogen available from several sources. The estimates indicate that three sources — livestock (primarily dairy cattle), irrigated cropland, and septic and biosolids — account for as much as 98 percent of the nitrogen available for application to the land (EPA 2012b). Livestock (primarily dairy cattle) account for about 65 percent, irrigated cropland for about 30 percent and septic and biosolids about 3 percent of the available nitrogen. The estimates do not account for losses of nitrogen from various biological, physical, and chemical processes and do not account for crop utilization. Based on the estimates developed in Phase 1, EPA focused the Phase 2 and 3 sampling on the three predominant sources: dairies; irrigated cropland; and residential septic systems.

The objectives of Phase 2 were to: (1) evaluate nitrate contamination of groundwater at locations downgradient of the three types of sources identified in Phase 1; (2) assist in identifying sampling locations for Phase 3 sampling; and (3) provide residents with information on the nitrate levels in their drinking water wells. EPA conducted Phase 2 sampling between February 22 and March 6, 2010. EPA found that water from wells at 67 homes, about 20 percent of the wells sampled in Phase 2, exceeded the MCL of 10 mg/L for nitrate.

The results of Phases 1 and 2 were used in Phase 3 to identify residential drinking water wells with high nitrate concentrations and potential upgradient sources of nitrogen. Once these locations were identified, EPA collected and analyzed samples from the potential source areas and downgradient residential drinking water wells. EPA also collected and analyzed representative drinking water wells upgradient of the dairies (See Table ES-1). No drinking water wells upgradient of the crop fields or septic systems were sampled.

EPA analyzed samples for nearly 200 chemicals and used several analytical techniques to investigate the source of high levels of nitrate in water wells. The chemical analyses and analytical techniques were grouped as follows: general chemistry; microbial data; organic compounds; isotopic analysis; and age dating. The data for each of the analytical techniques were evaluated independently in an effort to identify the specific likely sources of the high nitrate concentrations found in residential drinking water wells (See Table ES-2). A discussion of the quality assurance and quality control (QA/QC) procedures and a summary of the data validation process are presented in Appendix E. Uncertainties and limitations with analytical data were noted in Appendix E and described in detail in the data validation memoranda. Data usability is also indicated in the data summary tables by inclusion of data qualifiers.

Phase 3 Study Limitations and Uncertainties

Several limitations in the study are important to note. First, water well samples were collected from existing wells. No new wells were installed for this study. Information on the depths and screened intervals of the water wells is known for about a third of the wells that were sampled. In this report, designations of upgradient and downgradient are based on regional groundwater flow data from the United States Geological Survey (USGS). Lack of complete well information limits our ability to verify if the wells upgradient and downgradient of the sources draw water from the same water bearing zone.

In addition, EPA lacks complete information regarding the dairies in this study. EPA requested information on specific aspects of the dairy operations and the physical setting; however, the dairies in this study did not provide this information. This information would have contributed to a more complete understanding of the dairy facilities, practices, and use of specific chemicals. It would have allowed EPA to provide actual values, or narrower ranges of estimates, for certain parameters in this report (for example, numbers of animals, quantities of nitrogen, estimates of lagoon leakage). EPA has, however, referenced general information regarding dairy operations, and specific information regarding the dairies in the Yakima Valley to the extent it was available.

Finally, EPA has limited information about the irrigated crop fields in this study. Verifiable, detailed crop production data, in terms of nutrients applied (the likely source of nitrate associated with irrigated crops), were not available and no irrigation data were available. EPA has included information about the crop fields to the extent it was available. In addition, the irrigated crop fields are surrounded by similar agricultural uses, and many are situated downgradient of dairies, making more difficult EPA's ability to discern the source of nitrate in drinking water wells downgradient of the irrigated crop fields.

Phase 3 Study Results

As stated previously, the primary purpose of the study was to investigate the contribution of various land uses to the high nitrate levels in groundwater and residential drinking water wells in the Lower Yakima Valley. The four main source areas sampled and the results of the sampling are discussed below.

<u>Haak Dairy</u>

The R&M Haak Dairy (Haak Dairy) is located in an agricultural area north of the Yakima River, about four miles north of the community of Sunnyside. EPA selected the Haak Dairy for this study because it generally met the criteria identified in the study plan for inclusion. Specifically, the dairy has a high concentration of animals per acre; Washington State Department of Agriculture (WSDA) inspectors noted in their reports for the Haak Dairy that elevated levels of nitrogen were detected in its application fields[2] in the past (WSDA 2012); it is located near the northern edge of cultivated land use and in a location with relatively few upgradient potential sources of nitrogen; and drinking water wells downgradient of the Haak Dairy showed levels of nitrate significantly above the MCL.

Several locations were sampled at the Haak Dairy during Phase 3: one dairy supply well; one dairy manure pile located on the dairy; two dairy lagoons; and one dairy application field. During Phase 3 EPA also resampled three of the residential drinking water wells downgradient of the Haak Dairy that exceeded the MCL during Phase 2, and one residential drinking water well upgradient of the Haak Dairy.

Based on data from the WSDA (WSDA 2010), EPA estimated that the Haak Dairy generates an estimated 84 to 210 tons of nitrogen per year after accounting for losses from volatilization and denitrification during storage.[3] Based on information from a field study by Ham and DeSutter (Ham 2002) and from the Natural Resources Conservation Service (NRCS) Agricultural Waste Management Field Handbook (NRCS 2008), EPA estimated that the Haak Dairy lagoons leak 482,000 to 5,873,000 gallons[4] of liquid waste per year into the underlying soils. The Dairy applies solid and liquid animal wastes to its application fields. WSDA inspectors documented that the Haak Dairy has also used inorganic fertilizer on its application fields (WSDA 2012).

Concentrations of total nitrogen increase in the direction of groundwater flow from the upgradient well to three residential drinking water wells downgradient of the Haak Dairy, with the highest concentrations detected in the dairy sources (lagoons, manure pile, and application field). The upgradient well was within the expected background concentration for nitrate.

The three residential drinking water wells downgradient of the Haak Dairy all have nitrate levels greater than EPA's MCL of 10 mg/L. Also, the concentration of six major ions (chloride, calcium, magnesium, potassium, sodium, and sulfate) show a pattern of increasing concentrations from the upgradient well to

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[2] See footnote 1.

[3] The Washington State Department of Agriculture can only provide information on the number of animals at each dairy in ranges. Because of this, the estimated amount of nitrogen generated at the Haak Dairy is presented as a range. See Section IX.A for a more detailed discussion.

[4] The EPA estimates are presented in a range because the Ham 2002 study provided a range of lagoon leakage rates. See Section IX.A for a more detailed discussion.

the three downgradient residential wells, with the highest concentrations in the dairy sources (with the exception of sulfate which was not detected in two lagoon samples). Alkalinity and the metals barium and zinc show a similar pattern. Information on the construction and depth of the upgradient and one downgradient well would be helpful to provide additional certainty regarding the likely sources. However, review of the data suggests that the Haak Dairy is a likely source of the nitrate and major ions in the three downgradient residential drinking water wells. Inorganic fertilizer used on the Haak Dairy's application fields also could be a source of the nitrate observed in the downgradient wells.

Two pharmaceuticals, tetracycline and monensin, were detected in all the dairy source samples collected at the Haak Dairy, indicating that these compounds are used by the dairy. Tetracycline was detected in two of the three downgradient residential drinking water wells but not in the upgradient well, indicating the Haak Dairy is a likely source. Monensin was detected in the upgradient well and in the three downgradient residential drinking water wells, although the upgradient residential drinking water well had a higher concentration than two of the downgradient water wells. It is possible that the Haak Dairy is a source of the monensin detected in the downgradient residential drinking water wells. Given the presence of monensin in the upgradient well, another source of monensin is likely. Additional information that supports that the dairy may be a source of monensin is that it was not detected in samples collected from the WWTP influents that were collected as surrogates for rural septic systems.

The isotopic data provide strong evidence that animal (human or non-human) waste is the likely dominant source of the nitrate contamination in at least one of the residential wells downgradient of the Haak Dairy. However, since isotopic analysis alone cannot differentiate between human and non-human waste, both could be sources of the nitrate in this downgradient well.

Several compounds that tend to be less mobile in groundwater than nitrate and some of the major ions were detected in Haak Dairy lagoon, manure pile, and application field samples, but not detected in the downgradient water wells (for example, trace organics and hormones). Fecal coliform was not detected in any of the wells downgradient of the Haak Dairy.

Dairy Cluster

The "Dairy Cluster" refers to a group of dairies, including George DeRuyter & Son Dairy, D and A Dairy, Cow Palace 1 and 2, Liberty Dairy, and Bosma Dairy, situated north of the Yakima River. The Dairy Cluster is located about 2 miles north of the town of Liberty, near the northern edge of the irrigated area in the Yakima Valley. The facilities generally consist of cow pens, milking parlors, animal waste lagoons, and animal waste application fields.[5] Irrigation ditches run through the dairy properties.

EPA selected these dairies for this study because they generally met the criteria identified in the study plan for inclusion. Specifically, the Dairy Cluster has; a high concentration of animals per acre; WSDA inspectors noted in their reports for the Dairy Cluster that elevated levels of nitrogen were detected in its application fields in the past (WSDA 2012); the dairies are located near the northern edge of cultivated

[5] See footnote 1.

land in the Lower Yakima Valley with relatively few upgradient potential sources of nitrogen; and drinking water wells downgradient of the dairies showed levels of nitrate significantly above the MCL.

Several locations were sampled in the Dairy Cluster during Phase 3: three dairy supply wells; four dairy manure piles; ten dairy lagoons; and four dairy application field samples. During Phase 3, EPA also sampled eight downgradient residential drinking water wells that were found to exceed the MCL for nitrate during Phase 2, and one upgradient residential drinking water well.[6]

Based on data from the Washington State Department of Agriculture (WSDA 2010), EPA estimated that the Dairy Cluster generates more than 2,055 tons of nitrogen per year after accounting for losses from volatilization and denitrification. Based on information from a field study by Ham and DeSutter (Ham 2002) and from the NRCS Agricultural Waste Management Field Handbook (NRCS 2008), EPA estimated that the Dairy Cluster lagoons leak between 3,330,000 and 39,600,000 gallons[7] of liquid lagoon waste per year into the underlying soils. All the dairies in the Dairy Cluster apply animal wastes as fertilizer onto application fields that they own or lease according to WSDA inspection reports (WSDA 2012). The dairies, (except for Cow Palace) also reported using synthetic fertilizer on some of their application fields.

Similar to the Haak Dairy, the results from the sampling indicate that the concentration of total nitrogen increases in the direction of groundwater flow from the upgradient well to the downgradient residential drinking water wells, with the highest concentrations detected in the dairy sources.[8] The nitrate concentrations in the residential drinking water wells downgradient of the Dairy Cluster, with the exception of one unusually deep residential drinking water well, have nitrate levels greater than the EPA MCL. The concentrations of five major ions, especially calcium and chloride, increase between the upgradient well and the downgradient residential drinking water well, with the highest concentrations in the dairy sources. Alkalinity and barium show a similar pattern. The relatively young water in the upgradient well that EPA sampled in Phase 3 suggests that it is a shallow well.

As with the Haak Dairy, information on the construction and depth of the upgradient well and five of the downgradient water wells sampled during Phase 3 would be helpful to clarify the contribution of sources to the increased concentrations measured in the downgradient wells. However, the information presented above indicates that the Dairy Cluster is a likely source of the nitrate, major ions, and other substances in the downgradient residential drinking water wells.

The pharmaceuticals tetracycline and monensin were detected in all but one of the dairy source samples, which indicate they are used by the dairies in the Dairy Cluster. Tetracycline was detected in two of the downgradient residential drinking water wells, two dairy supply wells, dairy lagoons, manure piles and application fields. The concentration of tetracycline found in the upgradient residential well was similar

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[6] The results for samples that EPA collected during Phase 2 from other wells located upgradient of the Dairy Cluster were also below the MCL for nitrate. Those data are included in this report in Table C1 in Appendix C (sample locations WW-22103 and WW-22085).

[7] The EPA estimates are presented in a range because the Ham 2002 study provided a range of lagoon leakage rates. See Section IX.B for a more detailed discussion.

[8] See footnote 6.

to the concentrations detected in two of the downgradient residential wells. The dairies are a possible source of the tetracycline in the downgradient wells. However, given the concentration in the upgradient well, another source of tetracycline likely exists.

Monensin was detected in two of the downgradient residential drinking water wells, two dairy supply wells, dairy lagoons, manure piles and application fields. The Dairy Cluster is a likely source of monensin because this antibiotic is used in dairy cows but not by people. Monensin was not detected in samples from the WWTP influents which were collected as surrogates for residential septic systems, further supporting that the dairies are the likely source.

The hormone testosterone was detected in downgradient residential drinking water wells and dairy sources. The concentration of testosterone found in the upgradient residential drinking water well is similar to the concentrations detected in the downgradient water wells. The dairies are a possible source of the testosterone in the downgradient wells; however, given the concentration in the upgradient well, another source of testosterone is likely.

The isotopic data provide strong evidence that animal (human or non-human) waste is the likely dominant source of the nitrate in at least two of the residential drinking water wells downgradient of the Dairy Cluster. Because isotopic analysis cannot differentiate between human and non-human waste, both could be sources of the nitrate in this downgradient well.

Several other compounds that are generally less mobile in groundwater than nitrate and some of the major ions, were detected in the Dairy Cluster sources, but not in the residential drinking water wells (for example, the trace organics). Fecal coliform was not detected in any of the residential drinking water wells.

<u>Irrigated Cropland</u>

Nitrogen-rich fertilizers, such as inorganic synthetic fertilizer and manure, are applied to irrigated cropland and are a possible source of nitrate in drinking water wells. In Phase 3, EPA sampled six irrigated crop fields[9] (two mint, two hops, and two corn) and six residential drinking water wells downgradient of these fields.

Irrigated crop field soil samples were analyzed for several forms of nitrogen, pesticides, pharmaceuticals, and hormones. They were not analyzed for major ions, trace inorganic elements, perchlorate, microbiology, trace organics, isotopic analysis, or age dating.

The six water wells downgradient from the irrigated crop fields and sampled by EPA during Phase 3 all had nitrate levels greater than the MCL. Several organic compounds were detected in the crop soil samples, but only bentazon and monensin were detected in a water well and its associated crop soil sample. Bentazon was detected in two water wells and the associated soil samples. These results indicate that bentazon was applied to the crop field and is likely migrating to groundwater and the water wells. Monensin was the only veterinary pharmaceutical detected in one well and also in an associated soil

[9] See footnote 1.

sample collected from a hop field. Possible manure application to the hop field could account for the monensin detected in the downgradient residential well. The isotopic analysis indicated that the dominant source of nitrate for one residential drinking water well was synthetic fertilizer.

Residential Septic Systems

Four residential wells located in Mabton, Harrah, and Sunnyside were selected for evaluation of impacts from septic systems. However, all the residential drinking water wells sampled as part of Phase 3 of this study were analyzed for the same suite of chemicals. EPA also collected influent samples from three WWTPs located in Zillah, Mabton, and Toppenish. These WWTP samples were collected to serve as a surrogate for septic system waste.[10] The WWTP influent had no actual or potential hydrogeological connection with the residential wells. This approach was used to determine whether the same compounds are detected in WWTP influent samples and in water wells with high nitrate concentrations in areas with a high density of septic systems or whether these wells are affected by other sources.

The majority of the trace organics (e.g., personal care products) and wastewater pharmaceuticals were detected in the WWTP influent samples but only two of these compounds were detected in the residential drinking water wells sampled by EPA in Phase 3. Specifically, bis-(2-ethylhexyl) phthalate (DEHP, a plasticizer) was detected in four residential drinking water wells and DEET (an insect repellant) was detected in one residential drinking water well. These results indicate that these compounds are being used and can be found in wastewater, but with a few exceptions are not reaching residential drinking water wells.

Four veterinary pharmaceutical compounds were detected in the WWTP influent samples, three of which were also detected in one or more of the residential drinking water wells in the study. Specifically, sulfamethazine (used for cattle, poultry and swine) was detected in two residential drinking water wells, sulfamethoxazole (used for people) in one residential drinking water well, and tetracycline (used for people, cattle, and several other animals) in six residential drinking water wells.

There were 10 additional veterinary pharmaceuticals detected in residential drinking water wells, but not detected in WWTP influent samples. Monensin (used for cattle and poultry) and virginiamycin (used in poultry and swine) were the most frequently detected veterinary pharmaceuticals: monensin was detected in nine residential drinking water wells and virginiamycin in four. Monensin and virginiamycin were not detected in the WWTP influent samples. Given the results, septic systems are a possible source of tetracycline and sulfamethoxazole in the residential drinking water wells.

Of the 20 hormones analyzed, 14 were detected in at least one WWTP influent sample. Of those 14 hormones, seven were detected in residential drinking water wells. Testosterone and androsterone were the most frequently detected hormones: testosterone was detected in nine wells and androsterone was detected in four wells. Given both testosterone and androsterone are natural sex hormones it is possible they came from septic systems in proximity to the residential drinking water wells.

[10] EPA recognizes that the WWTP influent may contain substances that are not found in residential septic systems (for example they may also receive commercial and industrial waste streams). The WWTPs sampled serve rural communities and are sufficiently similar to residential septic systems for the purpose of EPA's study.

Microbial source tracking was not performed because there were no detectable concentrations of fecal coliform in any of the residential drinking water wells. The isotopic data provide strong evidence that animal (human or non-human) waste is a likely dominant source of the nitrate contamination in at least six residential drinking water wells. Since isotopic analysis cannot differentiate between human and non-human waste, both could be sources of the nitrate in this downgradient well based on the isotopic analysis.

Conclusions

Nitrate levels above EPA's drinking water standard in residential drinking water wells in the Lower Yakima Valley are well documented. The objective of this study was to evaluate the effectiveness of certain chemicals, microbial parameters, or analytical techniques to identify specific sources of the high nitrate levels detected in residential drinking water wells.

Many of the chemicals and microbial parameters evaluated in this study were not detected in the residential drinking water wells. There were no detections of fecal coliform in the Phase 3 residential drinking water wells, although high concentrations were found in the dairy sources and WWTP influent. There were very few trace inorganic elements, trace organics, or wastewater pharmaceuticals detected in the residential drinking water wells or crop field soil samples, although many of these chemicals were detected in the dairy sources and WWTPs. The isotopic data provide some indication of the likely nitrate sources for seven of the 25 residential wells tested (six animal waste and one synthetic fertilizer). Although the isotopic analysis identified animal waste as the source of the nitrate in six wells, this analytical technique cannot differentiate between human and non-human waste.

There appears to be a correlation between the age dating data and the depths of the wells for which boring logs are available. The water in the dairy supply wells that are known to be screened in the deeper basaltic aquifer is older than in the downgradient residential wells which are commonly screened in the shallower alluvial aquifer. The age dating results were not useful to determine when the nitrate contamination was introduced into the well.

Given the historic and current volumes of wastes generated and stored by dairies, and the application of nitrogen-rich fertilizers including dairy waste in the Lower Yakima Valley, it is expected that dairies are a likely source of high nitrate levels in downgradient drinking water wells. The total nitrogen, major ions, alkalinity and barium data provide strong evidence that the dairies evaluated in this study are likely sources of the high nitrate levels in the drinking water wells downgradient of the dairies. Additional information that supports this conclusion includes: there are few potential sources of nitrogen located upgradient of the dairies; the dairy lagoons are likely leaking large quantities of nitrogen-rich liquid into the subsurface; and Washington State Department of Agriculture inspectors have reported elevated levels of nitrogen in application fields of the dairies in the study.

Given the historic and current application of nitrogen-rich fertilizers in the Lower Yakima Valley, it is expected that irrigated crop fields would be a likely source of high nitrate levels in downgradient drinking water wells. The data collected in this study provide some corroboration that irrigated crop fields are a likely a source of nitrate in groundwater. The data supporting this conclusion is not as strong for the crop fields as it is for the dairies. The reasons for this include: lack of upgradient well data; the irrigated crop fields sampled are situated amongst other agricultural uses, including upgradient dairy operations; fewer analytes detected in both the crop field samples and the corresponding downgradient wells; more limited information about crop field operations; and the crop fields' positions on the landscape relative to other potential sources.

While septic systems could be a source of nitrate in drinking water wells, there is insufficient information from this study to support this conclusion.

The high nitrate levels in residential drinking water wells in the Lower Yakima Valley are likely coming from several sources. This study attempted to identify those sources. In some cases it was possible to identify likely or possible sources of the nitrate contamination.

Evaluating actions to reduce nitrate concentrations in residential drinking water wells to safe levels is beyond the scope of this report. Although actions to reduce nitrate are needed, it may take many years to reduce the nitrate levels in residential drinking water wells to safe levels because of the extent of the nitrate contamination in the Lower Yakima Valley and the persistence of nitrate in the environment.

Table ES-1: Overview of the Study Design to Investigate Suspected Sources of Nitrate in Water Wells Near Dairies, Irrigated Cropland, and Septic Systems

Source Type	Sampling Area	Upgradient Well Sample	Supply Well Sample	Potential Sources of Nitrate	Downgradient Well Sample	Study Design [c,d]
Dairies	Haak Dairy	WW-01	WW-02	Lagoons (LG-01 to LG-03) Manure Piles (SO-01) Application Fields (SO-02)	WW-03 to WW-05	Compare chemicals and microbiology in upgradient wells with sources and downgradient wells. Conduct isotopic analyses for water wells and lagoons and age dating for water wells.
	Dairy Cluster	WW-06[a]	WW-07, WW-08, and WW-09	Lagoons (LG-04 to LG-15) Manure Piles (SO-03, SO-05, SO-07, and SO-09) Application Fields[b] (SO-04, SO-06, SO-08, and SO-10)	WW-10 to WW-17	
Irrigated Croplands	Schilperoort Farm	NA	NA	SO-11 (Mint)	WW-23	Compare chemicals in downgradient wells with soil samples from associated crop fields.
	Havilah Farm	NA	NA	SO-12 (Mint)	WW-24	
	Wheeler Farm	NA	NA	SO-13 (Corn)	WW-25	
	Sunny Dene Ranch	NA	NA	SO-14 (Corn)	WW-28	
	Golden Gate Hops	NA	NA	SO-15 (Hops)	WW-26	
	Golden Gate Hops	NA	NA	SO-16 (Hops)	WW-27	
Septic Systems	Mabton	NA	NA	Septic Systems	WW-21	Compare chemicals in water wells with influent from 3 wastewater treatment plants (Zillah, Mabton, and Toppenish).
	Harrah	NA	NA	Septic Systems	WW-19	
	Sunnyside	NA	NA	Septic Systems	WW-20 and WW-22	

[a]As noted above, in footnote 2 of the text, EPA collected samples from other wells located upgradient of the Dairy Cluster which were also below the MCL for nitrate during Phase 2. That data is included in this report in Table C1 in Appendix C (sample location WW-22103 and WW-22085).

[b]Thirty soil samples per application field or crop field were collected at a depth of 1 inch and composited to obtain a representative sample.

[c]Two additional residential wells, WW-18 and WW-30, were sampled during this study, but were not included in the original study design or listed in this table. The results for these two wells are documented in Section IX.E of this report.

[d]See Table C2 in Appendix C and Table ES-2 for a description of the analytes for each source.

NA – not applicable.

Table ES-2: Summary of the Chemical Groups and Media Included in Phase 3 of the Study

Compound or Analytical Technique (Number of Compounds Analyzed)	Water Wells	Dairy Lagoons	Dairy Manure Piles	Dairy Application Fields	WWTP Influent[c]	Crop Soils
General Chemistry						
Nitrate (1)	X		X	X		X
Other Nitrogen Forms[a]	X	X	X	X	X	X
Major Ions (9)	X	X			X	
Trace Elements (12)	X	X			X	
Perchlorate (1)	X					
Microbiology						
Bacteria (3)	X	X			X	
Microbial Source Tracking[b]	X	X			X	
Organic compounds						
Pesticides (50)	X	X[d]	X	X	X[d]	X
Trace Organics (69)	X	X			X	
Pharmaceuticals (31)	X	X	X	X	X	X
Hormones (20)	X	X	X	X	X	X
Analytical Techniques						
Isotopic Analysis (2)	X	X			X	
Age Dating (NA)	X					

[a]Other nitrogen forms for water wells and lagoons include ammonia, TKN, and nitrate plus nitrite. Other forms of nitrogen for manure piles, dairy application fields, and crop samples include extractable nitrate, extractable ammonia, and total nitrogen by combustion.

[b] Microbial source tracking was conducted only if there was an indication of fecal contamination detected in the sample.

[c]Majority of influent from households but contribution from businesses and industry also expected.

[d]Because of matrix interference, results for pesticide analysis for lagoon and wastewater treatment influent samples were not useable.

X – the compound or analytical technique was analyzed.

NA – not applicable

I. INTRODUCTION

This report presents the results for sampling conducted from February through April 2010 by the U.S. Environmental Protection Agency (EPA) in the Lower Yakima Valley in central Washington State. The primary purpose of this study was to investigate the contribution of various sources from nearby land uses to the high nitrate levels in groundwater and residential drinking water wells. The study looked at three likely sources of nitrate: dairies; irrigated cropland; and residential septic systems.

EPA used standard investigation and analytical methods as well as several research methods. The sampling was conducted as part of an EPA Regionally Applied Research Effort (RARE)[11] grant (EPA 2009). Funding was also provided by EPA's regional and national Offices of Compliance and Enforcement including the Environmental Justice (EJ) Showcase Community pilot program.[12] Yakima is one of ten communities in the nation to receive focused attention on disproportionate environmental health burdens.

EPA's sampling effort in the Lower Yakima Valley was partially in response to concerns raised by several agencies and community members who participated in the EPA Community Action for a Renewed Environment (CARE) cooperative agreement with the Northwest Communities Education Center (NCEC) in Yakima County, Washington. The objective of the cooperative agreement was to assist the Yakima Valley community to establish its priorities for environmental health concerns. Numerous meetings were held over a 2-year period from 2007 to 2009. One of the outcomes from the cooperative agreement was that community members identified their top three environmental health priorities as groundwater contamination, asthma, and children's exposure to pesticides.

In October 2008, the *Yakima Herald Republic* ran a series of articles titled "Hidden Wells, Dirty Water" that examined a long history of groundwater contamination affecting public and private drinking water wells, primarily in the Lower Yakima Valley. According to the Herald, following the series, the reporter received a number of inquiries from citizens asking whether EPA could take action under the Safe Drinking Water Act (SDWA). These inquiries prompted the reporter to send a letter to EPA asking whether the agency would consider invoking emergency authority under Section 1431 of the SDWA to address the problem. Section 1431 (42 U.S.C. § 300i) authorizes EPA to take action when, among other things, a contaminant is present or may enter a public water system or underground source of drinking water that may present an imminent and substantial endangerment to human health.

EPA facilitated the formation of a workgroup consisting of representatives from state and local agencies, EPA, and the community. The workgroup released a report in February 2010 entitled, "Lower Yakima Valley Groundwater Quality: Preliminary Assessment and Recommendations" (Ecology 2010) ("February 2010 Report"). One of the recommendations identified in the February 2010 Report was to conduct an investigation to gather information to try to link high nitrate levels in drinking water wells with specific sources.

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[11] The purpose of the RARE program is to provide EPA Regional Offices with support for near-term applied research projects and enhance interactions and connections between regional staff and EPA's Office of Research and Development.

[12] The EJ showcase projects focus on low income and minority communities experiencing disproportionate impacts from environmental health burdens.

The February 2010 Report documented that groundwater data collected in the Lower Yakima Valley from 1990 to 2008 indicated that as many as 12 percent of private wells had nitrate levels above EPA's drinking water standard for nitrate (10 mg/L) and about 20 percent of private wells demonstrated bacterial contamination (Ecology 2010).

II. PURPOSE AND SCOPE

As discussed above, the primary purpose of this study was to collect data to investigate the contribution of various sources from nearby land uses to the high nitrate levels in groundwater and residential drinking water wells. To accomplish this, EPA sampled and analyzed sources of nitrate (dairies, irrigated croplands, and residential septic systems) and private residential drinking water wells for a variety of chemicals to evaluate whether chemicals, including nitrate, could be used to link the nitrate contamination in groundwater and drinking water wells to the sources. The analysis included chemicals that are expected to be associated with one or more of the likely sources, such as pharmaceuticals (both veterinary and human medications), personal care products, steroids and hormones, pesticides and herbicides, as well as other indicators of water quality such as nitrogen and major ions such as chloride and calcium.

EPA also used microbial analysis to determine whether the water wells, lagoons and WWTP influent samples exhibited fecal contamination. If the samples were found to have fecal contamination, then microbial source tracking (MST) was performed to identify the source of the fecal contamination (in this case, human or ruminant). In addition, EPA performed isotopic analysis for the water wells to identify the possible origin of the nitrate in water wells. Finally, an age dating analysis was completed for the water wells to estimate the time since water infiltrated from the surface to the aquifer. A data usability review and validation independent of the laboratories were conducted by EPA and are discussed in Appendix E.

Figure 1 provides a conceptual site model for the project. The conceptual site model (in conjunction with Figure 2 – Nitrogen Cycle) provides a graphic description of how nitrate from various sources can reach groundwater and eventually drinking water wells. This study evaluated three likely sources of the nitrate contamination in drinking water wells (dairies, irrigated cropland, and residential septic systems). The main sources of nitrogen from the dairies include dairy waste lagoons; manure piles; and manure and synthetic fertilizers applied to application fields on land controlled by the dairies. For irrigated crop fields[13], the main source is the synthetic fertilizers and manure[14] applied to the land to promote plant growth. For septic systems, it is the human waste that can migrate from septic systems into nearby drinking water wells.

As described in Figure 2 (Nitrogen Cycle), nitrogen is applied to the land from different sources. The different forms of nitrogen typically migrate through the unsaturated silts, sands, and gravels and arrive at the water table via preferential pathways. The nitrogen is converted to nitrate through chemical and biological processes. Groundwater contaminated with nitrate can be pumped up in drinking water wells

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[13] In this report, "application field" refers to fields owned or leased by the dairies and "crop field" or "cropland" refers to fields owned or leased by other farmers. Both application fields and crop fields could receive applications of manure and/or synthetic fertilizer.

[14] Although initially EPA considered irrigated cropland to be a potential source of nitrate because of synthetic fertilizer application, through this study, it became clear that several of the irrigated crop fields sampled had also received manure applications.

where people consume the water. Groundwater contaminated with nitrate can also migrate to surface water such as the Yakima River.

The scope of this study consists of an area approximately 40 miles long and ranging between 10 and 25 miles wide. The study area includes parts of Yakima County and the Confederated Tribes and Bands of the Yakama Nation Reservation (Yakama Reservation). EPA identified areas with some of the highest nitrate concentrations to conduct additional sampling to evaluate whether other chemicals are traveling with the nitrate from the sources to the groundwater and drinking water wells. This report includes the results for the sampling of 331 wells for nitrate and bacteria, and multi-parameter analysis of 29 wells (25 residential wells and four dairy supply wells), 12 dairy lagoons (15 samples), 11 soil samples (five at dairy application fields and six at irrigated and fertilized crop fields), five dairy manure samples, and three wastewater treatment plant (WWTP) influent samples. The sampling was conducted from February through April 2010.

Several limitations in the study are important to note. First, water well samples were collected from existing wells. No new wells were installed for this study. Information on the depths and screened intervals of the water wells is known for about a third of the wells that were sampled. In this report, designations of upgradient and downgradient are based on regional groundwater flow data from the United States Geological Survey (USGS). Lack of complete well information limits our ability to verify if the wells upgradient and downgradient of the sources draw water from the same water bearing zone.

In addition, EPA lacks complete information regarding the dairies in this study. EPA requested information on specific aspects of the dairy operations and the physical setting; however, the dairies in this study did not provide this information. This information would have contributed to a more complete understanding of the dairy facilities, practices, and use of specific chemicals. It would have allowed EPA to provide actual values, or narrower ranges of estimates, for certain parameters in this report (for example, numbers of animals, quantities of nitrogen, estimates of lagoon leakage). EPA has, however, referenced general information regarding dairy operations, and specific information regarding the dairies in the Yakima Valley to the extent it was available and the ranges stated in the report are based on actual data.

Finally, EPA has limited information about the irrigated crop fields in this study. Verifiable, detailed crop production data, in terms of nutrients applied (the likely source of nitrate associated with irrigated crops), were not available and no irrigation data were available. EPA has included information about the crop fields to the extent it was available. In addition, the irrigated crop fields are surrounded by similar agricultural uses, and many are situated downgradient of dairies, making more difficult EPA's ability to discern the source of nitrate in drinking water wells downgradient of the irrigated crop fields.

III. BACKGROUND

Nitrate is an inorganic compound that is a naturally occurring form of nitrogen. On a national scale, nitrate is typically found in unimpacted shallow groundwaters at concentrations of up to 1.1 mg/L (Nolan and Hitt 2003). Nitrate concentrations higher than this range typically indicate that human activities have contributed nitrate to the groundwater. Nitrate is highly soluble in water and mobile in soil, which makes it relatively easy for nitrogen from a variety of point and non-point sources to move through the soil and into the groundwater as nitrate.

Nitrate is an acute contaminant, which means an immediate (within hours or days) health effect may result from exposure. EPA has established a maximum contaminant level (MCL) for nitrate in drinking water of 10 mg/L under the SDWA. EPA and state agencies regulate nitrate in public drinking water systems because nitrate concentrations greater than the MCL may cause a number of health problems. Exposure to excess nitrate can result in methemoglobinemia (blue-baby syndrome) in infants and susceptible individuals, which can lead to death in extreme cases (Ward 2005). Methemoglobinemia is caused by the reduction of nitrate to nitrite in the body. Nitrite binds to hemoglobin and lowers the body's ability to carry oxygen in the blood. Some studies have shown a positive association between long-term exposure to nitrate in drinking water and risk of cancer and certain reproductive outcomes, while other studies have shown no association (Ward 2005).

Numerous water quality investigations have been conducted regarding nitrate over the last 30 years in the Lower Yakima Valley, including a 2002 investigation by the Valley Institute for Research and Education (VIRE). All of these studies were summarized in the February 2010 Report prepared by the Washington State Departments of Agriculture, Ecology and Health; Yakima County Public Works Department; and EPA (Ecology 2010). The February 2010 Report found nitrate levels above the EPA MCL of 10 mg/L in about 12 percent of private wells. More than 2,000 people in the study area have private wells that exceed the MCL (Ecology 2010).

Nitrate contamination in groundwater is primarily a health risk for rural populations in the Lower Yakima Valley who rely on private unregulated wells for drinking water. Systems that meet the definition of "public water system" fall under state or federal drinking water regulations. Public water systems are required to test regularly for nitrate, and the data are reported to the Washington State Department of Health. EPA defines a "public water system" under Section 1401(4) of the SDWA, as amended in 1996, 42 U.S.C. § 300f, as:

> "…a system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such has at least fifteen service connections or regularly serves at least twenty-five people."

The State of Washington has established requirements for systems serving between three and fewer than 15 connections and fewer than 25 people. These water systems are called Group B (Chapter 246-291 of the Washington Administrative Code), and the state Department of Health (DOH) and local health jurisdictions share responsibility for administrating Group B requirements. The DOH does not regulate wells with just one or two connections that are residential systems, but some local jurisdictions regulate these systems. In 2009, the governor and state legislature set a new direction for regulating Group B systems, however, by eliminating all state funding for this program. Users of Group B systems therefore may be at risk.

Owners of drinking water wells that have fewer than three service connections (for example, a single, residential well) are not required to test their drinking water for contaminants. However, EPA and the Washington State Departments of Ecology and Health recommend that rural residents test their well water regularly. If residents choose to test and find contamination levels that exceed the MCL, they are not required to take action to address the situation.

IV. NITROGEN CYCLE

Nitrogen is an essential nutrient that is critical to plant growth. It aids in the formation and function of cellular tissue, proteins, and reproductive structures. Nitrogen can be supplied to plants through the organic decomposition of plants or animal waste products or by the application of synthetic fertilizers. It is present in many chemical forms in the environment, including organic nitrogen, ammonium (NH_4), nitrite (NO_2-), nitrate (NO_3-), and nitrogen gas (N_2). Nitrogen gas composes about 78 percent of the atmosphere. Atmospheric nitrogen must be processed, or fixed, to be used by plants. Some fixation is done by lightning strikes, but the majority of fixation occurs by bacteria. Additional small quantities of nitrate may wash out of the atmosphere from aerosol salt particles from the ocean or dusts from arid regions, or from fossil fuel combustion.

Figure 2 shows the nitrogen cycle (adapted from Pidwirny 2006). The processes of the nitrogen cycle transform nitrogen from one chemical form to another. Important processes in the nitrogen cycle include nitrogen fixation, mineralization, nitrification, and denitrification. The mobility of nitrogen is highly dependent on its form and the matrix it moves through.

In human-influenced systems, there are significant increases in the amount of nitrogen released to the soil, which frequently leaches into groundwater from various land uses, including application of synthetic fertilizers or animal waste. While many fertilizers may be composed of nitrate, urea or ammonia are often used. The urea and ammonia are ultimately converted to nitrate by soil bacteria. Animal wastes are another source of nitrogen frequently applied to the land or directly deposited by animals, and then often managed by people, for example, in lagoons or manure piles at dairies. Infiltrating rain or irrigation water can push excess nitrogen into groundwater from each of these sources, unless it is taken up by plants while still in the shallow subsurface.

Organic nitrogen is nearly immobile. Mineralization occurs when organic nitrogen in the soil is converted by bacteria into ammonium (NH_4). The ammonium is then converted to nitrite and then nitrate by bacteria through nitrification. The ammonium ion, while much less mobile than nitrate due to its positive charge, can be converted to nitrate as it moves through the vadose zone and oxygenated aquifer surfaces.

In soils, nitrate is the most mobile form of nitrogen in both the unsaturated zone and the saturated zone. In the saturated zone, it moves at nearly the speed of the migrating groundwater. The mobility of the nitrate ion is enhanced by the action of negatively charged soil particles, which repel the negatively charged nitrate (Frans 2000). The nitrate can then be converted back into nitrogen gas (N_2) by bacteria through denitrification. Denitrification, a process which can convert nitrate into nitrogen gas by bacteria, can occur in low oxygen environments. In the absence of denitrification, nitrate moves with the groundwater until the groundwater is discharged to surface water, or extracted from a well. For additional information on the nitrogen cycle, see Stumm and Morgan 1996.

V. STUDY AREA

The broad Yakima Basin is bounded by basalt ridgelines to the north and south, the Cascade Mountains to the west. The Yakima Basin is a watershed of great diversity in climate, vegetation, and land use. More than 30 percent of the Yakima Basin is forested, about 30 percent is shrub-steppe rangeland, and about 28 percent is in agricultural production (USGS 2009). The Yakima River flows from its headwaters near the Cascade Mountains crest to its mouth where it joins the Columbia River, 160 miles to the east. Precipitation diminishes to less than 9 inches annually in the rain shadow of the Cascades (Yakima County 2011), and irrigation plays a key role in the viability of agriculture. A series of high mountain reservoirs captures snowmelt, which is released through the Yakima River into a complex set of irrigation diversions and canals throughout the basin. Irrigation is supplied to fields during the March through October growing season in a variety of methods, including flood, furrow, sprinkler, and drip systems.

The study area included a portion of the Yakima Valley, referred to as the Lower Yakima Valley encompassing portions of the Toppenish Basin (western area) and the Benton Basin (eastern area) along the Yakima River (Figure 3). Together, both areas cover approximately 368,600 acres within Yakima County. The Lower Yakima Valley has about 75,000 people, of which about 24,000 use private, unregulated residential wells (Ecology 2010).

In Yakima County, more than 20 percent of the population is at or below the poverty level (less than $17,050 for a family of four in 2000) and a little more than 30 percent of adults have less than a high school diploma. Approximately 41 percent of the population is Hispanic/Latino, which is more than four times the state average of approximately 10 percent. American Indians and Alaskan Natives make up slightly more than 5 percent of the county's population, which is three times the state average of almost 2 percent. English is not the primary language (written or spoken) in many households in Yakima County (U.S. Census 2000). Economic viability depends on high-value agricultural production, irrigation, and a reliable supply of farm laborers. Yakima County leads the nation in production of milk per cow and is a top producer of apples, pears, sweet cherries, mint, and hops in the country (USDA 2007).

A. Western Study Area - The Toppenish Basin

Much of the Toppenish Basin is within the boundaries of the Yakama Indian Reservation. Land ownership in the major floodplain of the Toppenish Basin is a checkerboard of Indian trust, Indian fee, and deeded (privately held) parcels. Land use in this area is mixed, with open range and agriculture predominating. The basin is bordered on the north by the Ahtanum Ridge and on the south by the Toppenish Ridge.

B. Eastern Study Area – The Benton Basin

The Benton Basin includes some reservation lands and the non-reservation lands along the river and on the southeast side of the valley. Approximately 60 percent of the valley population resides in this area, which includes the Yakima County communities of Sunnyside, Granger, Grandview, and Mabton.

The Benton Basin lies in the southeastern part of the Lower Yakima Valley. The western boundary of the basin abuts the eastern boundary of the Toppenish Basin. The southern boundary is bordered by the Horse Heaven Hills, and the northeastern boundary generally follows the northern flank of the Cold Creek Syncline.

C. Geology, Hydrogeology, and Geochemistry of the Study Area

The information presented below, unless otherwise noted, is summarized from the U.S. Geological Survey (USGS) publication "Hydrogeologic Framework of the Yakima River Basin Aquifer System, Washington (USGS 2009).

The Toppenish and Benton Basins consists of fine- and coarse-grained sediments overlying a sequence of three major basalt flows. (See Figure 4 and Figure 5 for a general overview of the hydrogeology for the Toppenish and Benton Basins.) The structural setting for the study area is created by bounding ridges such as the Rattlesnake Mountains, Ahtanum Ridge, Toppenish Ridge, and Horse Heaven Hills. The uppermost basalts of the Saddle Mountain Unit of the Columbia River Basalt Group are typically exposed in these upland ridges. This unit averages more than 500 feet thick. The underlying Wanapum unit averages 600 feet thick. These units are separated by the Mabton Interbed, with an average thickness of 70 feet.

The valley is filled with a variety of sediments that pinch out along the flanks of the ridges. These sediments include Touchet Beds, loess and thick alluvial sands and gravels, and significant thickness of Ellensburg Formation. The thickness of these sedimentary units decreases from an average of more than 500 feet in the Toppenish Basin to less than 200 feet in the lower Benton Basin.

Water is found in fractures and interbeds formed of clinkers, permeable lava, lake deposits or paleo-soils and may occur at significant depths in the upland ridges, such as Horse Heaven Hills, and especially in the basalts. The water table is found at shallower depths as the valley is approached from these ridges. Near the Yakima River, it may be less than 10 feet to water, especially during the irrigation season.

There are two main aquifer types underlying the study area. They include a surficial unconfined to semi-confined alluvial aquifer and an extensive basalt aquifer of great thickness underlying the sedimentary deposits. The basalt aquifer is believed to be semi-isolated from the surficial aquifer and stream systems. Groundwater flow within the surficial aquifer generally follows topography, with natural recharge occurring within the headlands and on the sides of the valley and discharge occurring to the Yakima River. Flow within the uppermost portions of the underlying basaltic aquifer also generally follows this pattern.

However, since the basalts extend to great depths, those deeper basaltic layers may convey waters across local flow divides to more regionally significant discharge locations such as the Columbia River. This pattern produces a major flow direction from northwest to southeast as water moves down the valley parallel to the course of the Yakima River. Other, more localized directions of flow, typically at shallower depths in the uppermost sediments, tend to flow toward the Yakima River. Locally, the flow direction may be modified by geologic structures and by irrigation practices, drains, ditches, canals, and other hydrologic features.

The Lower Yakima Valley is filled with sediments shed by the ridges at the margins of the study area and those deposited in the valley bottom by the Yakima River. These sediments have an internal structure that strongly controls groundwater movement. As the water moves through these sediments, it tends to follow preferential flow paths composed of coarser sediments.

Very frequently, there are 10- to 100-fold differences in groundwater velocities among aquifer materials of such contrasting grain size (Freeze and Cherry 1979). These different preferential flow paths can have different water chemistry, depending on their location below a source of contamination. A well that is located along a preferential flow path may draw a substantial portion of its water from a particular source. A well located on an adjacent, but different, preferential flow path may have markedly different chemistry. For this reason, it is anticipated that upgradient sources of nitrate could produce different downgradient effects in groundwater (such as nitrate in water wells), even in wells from neighboring homes.

Shallower wells in the study area are more likely to be contaminated with nitrate than deeper wells because the sources of most of the nitrogen are anthropogenic activities on the land surface (for example, dairy lagoons and application of synthetic fertilizer). Well depths for about two thirds of the wells used in this study are not known, but the well depths that are known confirm that nitrate concentrations tend to be higher in shallower wells (See Appendix A2). The higher nitrate values in shallower wells were also documented in the February 2010 Report (Ecology 2010). Some of the wells sampled in the study may tap water from the deeper basalts. As water carries nitrogen from the surface through the soil column to the water table, oxygenated conditions in the vadose zone and the aquifer facilitate the formation of nitrate (See Figure 2).

The highest levels of nitrate generally occur in the shallow alluvial aquifer (Ecology 2010). Water-bearing zones in the upper basaltic layers that underlie the alluvial aquifer may be vulnerable to contamination from the shallow aquifer. Basaltic layers develop significant fracture permeability as they cool after volcanic eruption. They are often referred to as "fractured basalts."

Examination of available well logs in the vicinity of the dairies that EPA studied, Haak Dairy and the Dairy Cluster[15], indicates that residential wells are typically screened in the shallow alluvial aquifer or in the upper basalt layers (Appendix A2). Wells screened in these zones are vulnerable to anthropogenic contamination. The fractured condition of the shallow basalts often means the water-bearing layers between the shallow basaltic layers are likely to be in communication with the shallow aquifer. A well pump set in a shallow basaltic water-bearing zone could, depending on conditions, pull contaminated water down through the shallow upper layers.

A brief discussion of the subsurface soil types for the dairies and irrigated cropland is included in the results section. A more detailed soil discussion of soil types for the dairies and irrigated croplands is presented in Appendix B. A complete soil report for each dairy and irrigated crop field was compiled by EPA (EPA 2012a) from the Natural Resources Conservation Service (NRCS) soil data mart (NRCS 2012).

In addition to the variability caused by the physical characteristics of the aquifer, many compounds react with the silts, sands, and gravels of the aquifer in a way that slows their transport. Some compounds, such as nitrate and ions like chloride, tend to minimally adsorb and are transported nearly as fast as the water flows in the aquifer. Nitrate does not break down unless it encounters denitrifying bacteria and

[15] The "Dairy Cluster" refers to a group of dairies, including George DeRuyter & Son Dairy, D and A Dairy, Cow Palace 1 and 2, Liberty Dairy, and Bosma Dairy, situated north of the Yakima River. The Dairy Cluster is located about 2 miles north of the town of Liberty, near the northern edge of the irrigated area in the Yakima Valley.

organic carbon, resulting in a low oxygen or anoxic environment. Other compounds, such as iron or manganese, often participate in chemical reactions and can create relatively immobile minerals, which can change their concentrations as measured in water wells (Fetter 1980).

Organic compounds, which are any gaseous, liquid, or solid chemical compounds containing carbon, are typically less mobile in water than inorganic compounds. Organic compounds tend to adsorb to organic carbon in the aquifer and may be degraded by bacteria and either disappear entirely or may be greatly reduced in concentrations. Even if not broken down, most organic compounds will move much slower than nitrate because they tend to adsorb to other organic matter in the aquifer. As a result, in general, they are unlikely to be transported as far or as fast as the nitrate (Stumm and Morgan 1996).

VI. THREE STUDY PHASES

Several sampling efforts conducted to date in the Lower Yakima Valley by various agencies and groups have focused on nitrate. Although these studies have been useful to document the problem of high nitrate levels in groundwater and private wells, they did not evaluate the link between the various sources and the high nitrate levels. The objective of this study was to conduct sampling to evaluate whether chemicals other than nitrate that are associated with specific sources can be used to link the nitrate contamination in groundwater and drinking water wells to those sources. In addition, the study used several other analytical techniques (microbial source tracking, isotopic analysis, and age dating) to evaluate the contribution of various sources to high nitrate levels in drinking water wells.

To accomplish these objectives, EPA designed a three-phased study within two contiguous segments of the Yakima River Basin extending approximately 40 miles from the town of Union Gap to the Yakima County line near the town of Byron. The upper segment comprises the entire Toppenish Basin, and the lower segment comprises the northern portion of the Benton Basin. The width of the study area was defined by the width of the Toppenish and Benton Basins along the selected segment, which varies between approximately 10 and 25 miles (Figure 3).

The main focus of this report is the Phase 3 sampling. Phase 1 and Phase 2 of the study are summarized below to provide context for the Phase 3 sampling. The purpose of Phase 1 was to identify the major sources of nitrate in the study area, based on historical records. In Phase 2, the residential wells in closest proximity to the potential sources were identified, sampled, and the samples analyzed for nitrate using screening-level analytical protocols and confirmatory laboratory analysis.

Phase 3 involved using the results of Phases 1 and 2 to identify residential wells with high nitrate concentrations and locate potential upgradient nitrogen sources. Once these source areas were selected, Phase 3 involved the collection and analyses of numerous samples from the potential source areas, downgradient wells, and upgradient wells near the dairies. The following subsections provide details about each phase of the study.

A. Phase 1: Geographic Information System (GIS) Tool Development and Screening Analysis for Nitrogen Sources

The purpose of Phase 1 was to identify the major sources of nitrate in the study area based on historical records. Phase 1 included the development of a Geographic Information System (GIS) tool to organize a large amount of historical information and allow the examination of the landscape for spatial patterns in the data. EPA used the GIS tool to identify sites to be sampled in Phases 2 and 3 of the project. The tool incorporates information from the Lower Yakima Valley about known nitrate, bacteria, and general chemistry data. It also includes information on locations of wells, land ownership, parcels with septic systems, land elevation, depth to groundwater, crop type, estimated fertilizer application rates, dairy and animal feeding operation locations, roads, and an aerial photo layer.

Phase 1 included a screening analysis to identify the potential major sources of nitrogen in Yakima County. The estimates for the different sources were used as a relative value to compare with other source estimates to assist in the study design.

The screening analysis, described below, combined information on land use with some simple calculations to estimate the amount of potential nitrogen loading from several sources that can be applied to the land. The estimates indicate three sources — livestock with dairy cattle as the largest contributor, irrigated cropland, and septic and biosoilds — account for as much as 98 percent of the nitrogen available for application to the land and potentially delivered to the aquifer (EPA 2012b). Livestock are prevalent throughout the Yakima Valley study area and accounted for about 65% of the nitrogen. Of this, dairy cows accounted for 89% of the nitrogen produced by livestock, while beef cattle were estimated at 9% and all other livestock (sheep, goats) at less than 1% each (EPA 2012b). The estimates were used as guidelines for the screening and do not account for losses of nitrogen from various biological, physical, and chemical processes. Based on this screening, EPA focused the Phase 3 sampling on three sources: dairies, irrigated cropland, and residential septic systems. Although there are other sources of nitrogen in the Lower Yakima Valley, EPA focused on the three sources believed to contribute the largest quantities of nitrogen (See Figure 6).

EPA is working to further refine these estimates and further evaluate nitrogen fate and transport in a collaborative project between EPA and the USGS. A report is due in the winter of 2012. The project focuses on better characterizing the sources of nitrogen applied to the land and the relationship between changes in nitrogen loading on the land and levels of nitrate in drinking water wells.

1. DAIRIES

As a result of economies of scale, the total number of dairy operations in the United States has been declining over time[16] while the average number of cows per dairy operation has been increasing (EPA 1998 and USDA 2010). In Yakima County, the number of dairies has decreased from 71 dairies in 1998 to 67 dairies in 2010 (WSDA 2010).

For the Phase 1 analysis, EPA used the 2008 Washington State Department of Agriculture (WSDA) estimates of the number of dairies, number of animals per dairy, and total nitrogen produced. In 2008, there were 69 dairies in Yakima County (Figure 7) registered with the WSDA (WSDA 2009). These facilities had over 130,000 animals (WSDA 2009), an average of almost 2,000 milking animal units per dairy. Modern dairies generate large quantities of animal wastes, which must be managed appropriately to prevent pollution, including pollution of surface and groundwater. Greater concentrations of animals and competition for available land have made it increasingly challenging to effectively manage animal wastes to prevent adverse impacts to public resources (Harner and others 2007).

[16] http://www.ers.usda.gov/publications

In addition to generating large quantities of manure, dairies also generate large amounts of liquid waste from flushing waste from pens and parlors to collection sites. Liquid wastes are typically stored in a series of lagoons before they are sprayed on nearby fields as fertilizer.

Dairy wastes contain key components of fertilizer, including nitrogen, phosphorous, and potassium. When used as a fertilizer, dairy wastes are often supplemented with synthetic fertilizer to meet specific nutrient needs of the crop being grown. In the lower parts of the Yakima Valley, dairies are concentrated around the cities of Sunnyside, Grandview, Mabton and Granger, although some are in more sparsely populated areas of the valley and on the Yakama Indian Reservation.

The total annual nitrogen production associated with dairies in Yakima County in 2008, without accounting for estimated losses, is approximately 36 million pounds per year. This amount was calculated by multiplying the number of dairy cows by the estimated nitrogen production rate per cow provided by the WSDA (WSDA 2009).

In addition to the animal waste lagoons, manure piles, and application fields that EPA sampled for this study, there are other potential sources on a dairy that could contribute to groundwater nitrogen loading. Other potential nitrogen sources include, but are not limited to: silage leachate, cow pens, dry wells, and ditches and pipelines between lagoon solids separators.

Large dairies employ many workers – the Cow Palace has more than 85 employees, for example.[17] Presumably the dairies in the study have substantial human waste septic systems because the area is unsewered.

Ponded water on soils mixed with manure could result in infiltration of nitrogen into the soil column. WSDA inspection reports for some dairies indicate that roof runoff is generally not directed away from areas contaminated with manure (WSDA 2012), so roof runoff could flush nitrogen into the soil column during rain or snowmelt events.

Some of the dairies in the study may be a source of inorganic nitrogen from synthetic fertilizer. WSDA inspection reports indicate the George DeRuyter & Sons Dairy, D and A Dairy, and the Liberty and Bosma Dairies use synthetic fertilizer to supplement manure applications (WSDA 2012).

2. IRRIGATED CROPLAND

Yakima County is one of the world's most fertile growing regions, with more than 240,000 acres of cropland. Agriculture is the primary economic activity in Yakima County, accounting for approximately 70 to 80 percent of land use. Most of the cropland in the area is irrigated. The major irrigation districts include Roza, Sunnyside Valley, Wapato Irrigation Project, Grandview, and Zillah. Major commodities grown in the valley include apples, alfalfa, corn for silage and grain, grapes, hops, cherries, and mint (see Figure 8).

Inorganic fertilizers can contain high amounts of nitrogen. Nitrogen application is essential to crop growth and development. Application of nutrients or water at rates greater than plant demand can result in excess nitrogen infiltrating through the soil below the root zone into the groundwater. Also, nitrogen

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[17] Cow Palace website - http://cowpalacedairy.com/index.cfm?pid=inc_management

applied at appropriate rates but with high irrigation rates can move rapidly through the vadose zone, prior to full crop uptake. The amount, timing, frequency, and type of fertilizer, as well as the timing and amount of irrigation relative to the application of fertilizer and plant water demand affect the contribution to groundwater from fertilizer. Other factors such as denitrification in the soil by microorganisms, soil type, and volatilization to the atmosphere, also affect the amount of nitrate in groundwater.

EPA estimates that about 18.5 million pounds of nitrogen are applied to irrigated cropland each year in Yakima County. This estimate was derived by taking the total acreage for each crop in Yakima County in 2007 and multiplying the acreage by the Washington State University recommended average nitrogen application rate for each crop (EPA 2012b). With this methodology, EPA estimated that corn, mint and hops in Yakima County receive about 6.0, 2.1, and 1.6 million pounds of nitrogen per year respectively. Irrigated crop fields accounted for approximately 30% of the all nitrogen available for application to the land in Yakima County. These rates are general and the specific application rates and management practices by farmers could vary greatly.

3. Septic Systems and Wastewater

Septic systems and domestic wastewater account for about three percent of the total amount of nitrogen applied to the land in Yakima County. Domestic wastewater is managed by city wastewater treatment plants in Yakima County, but a large percentage of the rural population relies on septic systems (see Figure 9). As of 2009, there were about 22,000 septic systems registered with Yakima County (EPA 2012b). Septic systems in Yakima County are generally designed for an average number of occupants per home based on the square footage.

There are 16 permitted wastewater treatment facilities in Yakima County (EPA 2012b). As wastewater treatment facilities process and treat wastewater, they produce biosolids, which are nutrient-rich organic material. After the solids have been processed and treated, they are recycled as fertilizer and soil amendment. Biosolids land application requires a permit from Washington State Department of Ecology. About 200,000 pounds of nitrogen in biosolids are applied in Yakima County per year, which includes biosolids imported from metropolitan municipalities in Western Washington State (EPA 2012b).

An estimated 1.4 million pounds per year of potential nitrogen from human waste was calculated by multiplying the 2007 population in Yakima County (234,564) by the rate of 6 pounds of nitrogen per person per year (EPA 2012b). This approach provides an overall estimate of 1.6 million pounds per year of nitrogen from biosolids and septic systems combined.

4. Conclusion and Other Sources

This screening analysis showed that about 65 percent of the nitrogen generated in Yakima County comes from livestock predominantly as dairy cattle, about 30 percent from fertilizers applied to irrigated crops, about 3 percent from septic and wastewater systems, and the rest, less than two percent, from other relatively minor sources.

These minor sources include nitrogen deposited by precipitation and non-cropland application of fertilizer to lawns, public parks, and golf courses. Application of nitrogen fertilizers was not estimated for dryland wheat crops grown in the valley because they are not irrigated and the low natural precipitation for the area limits the leaching potential of nitrate.

B. Phase 2: Identification of Wells with High Nitrate Concentrations

The objective of Phase 2 was to sample wells that were downgradient of the potential nitrogen sources identified in Phase 1, to assist in identifying sampling locations for Phase 3 sampling, and to provide residents with information on the nitrate levels in their drinking water wells. The GIS tool developed in Phase 1 was used to help identify sampling locations for Phase 2. EPA conducted the Phase 2 sampling between February 22 and March 6, 2010. Figure 10 provides a map of the locations and nitrate concentrations for the Phase 2 sampling, Table C1 in Appendix C contains a summary of the results for the compounds evaluated in Phase 2.

EPA developed a Quality Assurance Project Plan (QAPP) for Phase 2 (EPA 2010a). It identifies the data quality objectives, sampling process design, sample collection procedures, sample handling and custody requirements, analytical methods, instrument calibration, data management, and standard operating procedures for instrument calibration, shipping container preparation, and chain-of-custody process. The Center for Hispanic Health Promotion (CHHP), a local bilingual, bicultural organization affiliated with the Fred Hutchinson Cancer Research Center, was contracted to assist in recruiting residences for sampling, scheduling, and Spanish interpretation assistance.

A series of public meetings, newspaper articles, and radio announcements notified the community of EPA's Phase 2 work. Samples were collected by two-person teams trained for the project. Sample teams verified consent for access from the homeowner, collected a global positioning system (GPS) location at the well, and completed a data collection form developed by EPA. Each sampling team maintained a field logbook to document sampling activities. Water quality parameters were measured in the field using a Horiba multi-parameter probe for each well.

The parameters measured included dissolved oxygen, oxidation/reduction potential, total dissolved solids, pH, and temperature. The sampling team also used nitrate colorimetric test strips (Hach® test strips) as a field screening tool to provide an indication of whether the water exceeded the MCL of 10 mg/L for nitrate. The Hach® test strips measure nitrate concentrations in increments of 0, 1, 2, 5, 10, 20, and 50 mg/L. If the Hach® test strip indicated the water may exceed the MCL (10 mg/L), samples were collected for analysis by EPA's Manchester Environmental Laboratory ("EPA's Manchester Laboratory").

Samples submitted to the laboratory were also analyzed for enumeration and quantification of total coliform using EPA's mobile microbiology laboratory. If total coliform bacteria were present, the samples were also analyzed for *Escherichia coli* (*E. coli*) and fecal coliform bacteria.

During the two weeks EPA was in the field, 331 homes were visited and all were screened for nitrate levels using the Hach® test strips. EPA's Manchester Laboratory received 189 samples for analysis. Of these 189 samples, 102 were analyzed for nitrate and chloride, two were analyzed for nitrate and nitrite, and 123 were analyzed for total Kjeldahl nitrogen (TKN). Samples for 67 of those homes, or about 20 percent, were found to exceed the MCL of 10 mg/L for nitrate (Figure 10).

The percentage of homes with nitrate levels in wells above the MCL in this study were higher than the 12 percent from earlier studies because the homes sampled in Phase 2 were selected based on their proximity to likely sources. This method of selection would be expected to bias the results compared with a study where the sampling locations were selected randomly. If potential upgradient sources such as dairy lagoons, dairy application fields, irrigated crop fields, or septic systems were likely sources of nitrate to the aquifer, this would help explain the higher percentage of residences with nitrate levels over the MCL. Another possible explanation for the higher percentages of water wells with nitrate levels above the MCL in this study is that the previous studies were completed several years ago and the areas with nitrate levels above the MCL may have increased in size.

Eight wells, or 2 percent, were found to have fecal coliform bacterial contamination or contamination with *E. coli*. This result is less than the 20 percent frequency found in past studies.

Residents were informed of the nitrate results from the Hach® test strips immediately. Residents of all of the homes with nitrate levels greater than 10 mg/L or with bacterial contamination were provided with written laboratory results.

The Phase 2 sampling was informative in several ways. The results confirmed that nitrate concentrations in many residential drinking water wells were above the EPA drinking water standard of 10 mg/L and provided information to the residents on the levels of nitrate in their wells. In addition, the Phase 2 results were used to identify the Phase 3 sampling locations.

C. Phase 3: Investigating Source Contributions to High Nitrate Concentrations in Drinking Water Wells

The objective of Phase 3 was to investigate the contribution of various sources from nearby land uses to high nitrate levels found in water wells using a wide array of sampling and analysis techniques. The water wells shown in Figure 10 with the highest nitrate concentrations were selected for more extensive Phase 3 sampling and analyses.

Drinking water samples were collected from existing wells. No new wells were installed for this study. Available information on well depths is summarized in Appendix A1.

EPA evaluated three types of sources (dairies, irrigated cropland, and residential septic system) (See Figure 11). The three source types and sampling areas are shown in Table 1. Table 1 also illustrates how the study design varied, depending on the waste source type (dairy, irrigated cropland, or septic systems). EPA also collected and analyzed representative residential drinking water wells upgradient of the dairies. No drinking water wells upgradient of the crop fields or septic systems were sampled.

In general:

- Investigation of each of the two dairy areas (Haak Dairy and the Dairy Cluster) included sampling a number of downgradient wells, dairy animal waste lagoons, dairy manure piles, and dairy application fields. In addition one upgradient well was sampled in each dairy area. The well and waste samples were analyzed for many different chemicals and microbes using several analytical techniques. The data for the downgradient wells were compared to the data for the upgradient wells and the various waste sources to show the relative nitrate contamination and to determine if any of the different compounds could be used to identify specific sources.[18]

[18] Note that during Phase 2, for both the Haak Dairy and the Dairy Cluster focus areas, nitrate data was collected from additional downgradient residential drinking water wells and, for the Dairy Cluster, nitrate data was collected from two additional upgradient drinking water wells (see Appendix C1 for results from sample locations WW-22103 and WW-22085).

Table 1: Overview of the Study Design to Investigate Potential Sources of Nitrate in Water Wells Near Dairies, Irrigated Cropland, and Septic Systems

Source Type	Sampling Area	Upgradient Well Sample	Supply Well Sample	Potential Sources of Nitrate	Downgradient Well Samples	Study Design[c,d]
Dairies	Haak Dairy	WW-01	WW-02	Lagoons (LG-01 to LG-03) Manure Piles (SO-01) Application Fields (SO-02)	WW-03 to WW-05	Compare chemicals and microbiology in upgradient wells and sources with downgradient wells. Conduct isotopic analyses for water wells and lagoons and age dating for water wells.
	Dairy Cluster	WW-06[a]	WW-07, WW-08, and WW-09	Lagoons (LG-04 to LG-15) Manure Piles (SO-03, SO-05, SO-07, and SO-09) Application Fields[b] (SO-04, SO-06, SO-08, and SO-10)	WW-10 to WW-17	
Irrigated Croplands	Schilperoort Farm	NA	NA	SO-11 (Mint)	WW-23	Compare chemicals in downgradient wells with soil samples from associated crop fields.
	Havilah Farm	NA	NA	SO-12 (Mint)	WW-24	
	Wheeler Farm	NA	NA	SO-13 (Corn)	WW-25	
	Sunny Dene Ranch	NA	NA	SO-14 (Corn)	WW-28	
	Golden Gate Hops	NA	NA	SO-15 (Hops)	WW-26	
	Golden Gate Hops	NA	NA	SO-16 (Hops)	WW-27	
Septic Systems	Mabton	NA	NA	Septic Systems	WW-21	Compare chemicals in water wells with influent from 3 wastewater treatment plants (Zillah, Mabton, and Toppenish).
	Harrah	NA	NA	Septic Systems	WW-19	
	Sunnyside	NA	NA	Septic Systems	WW-20 and WW-22	

[a]As noted above, in footnote 2 of the text, EPA collected samples from other wells located upgradient of the Dairy Cluster which were also below the MCL for nitrate during Phase 2. That data is included in this report in Table C1 in Appendix C (sample location WW-22103 and WW-22085).

[b]Thirty soil samples per application field or crop field were collected at a depth of 1 inch and composited to obtain a representative sample.

[c]Two additional residential wells, WW-18 and WW-30, were sampled during this study, but were not included in the original study design or listed in this table. The results for these two wells are documented in Section IX.E of this report.

[d]See Table C2 in Appendix C and Table C ES-2 for a description of the analytes for each source.

NA – not applicable.

- The investigation of six irrigated crop fields (two hops, two mint, and two corn) included sampling six downgradient wells, one downgradient of each crop field. A soil sample was collected from each of the six irrigated crop fields. The chemicals detected in each downgradient well were compared with the chemicals detected in the corresponding soil sample from each of the six crop fields.
- The investigation of the three septic waste areas included sampling residential wells downgradient from septic systems. The chemicals detected in the downgradient wells were compared to samples collected from the influent to wastewater treatment plants (WWTPs) located in Toppenish, Mabton and Zillah. These WWTP influent samples were selected to be representative of the types of chemicals that could be released from residential septic systems, while recognizing that these WWTPs also may receive commercial and industrial waste streams.

The water well, dairy lagoon, dairy manure pile, dairy application field, crop field, and WWTP influent samples were evaluated for several general water chemistry parameters, microbiology parameters, and organic chemicals. Not all samples were evaluated for all of the general chemistry, microbiology parameters, or organic chemicals. The water well, dairy lagoons, and WWTP influent samples were evaluated using isotopic analysis and the water well samples were evaluated using age dating techniques (See Section VII).

1. PHASE 3 SAMPLING LOCATIONS

EPA used the Phase 1 GIS tool, Phase 2 sampling results, and a set of selection criteria to identify 63 sampling locations for Phase 3. (See Figure 11 for the location for each of the sampling sites). Table C2 in Appendix C provides the sample location, sample location type, description of the sample medium, and a summary of analytes at each location. For more information on the sampling locations and sampling procedures see the Quality Assurance Project Plan for the Yakima Basin Nitrate Study, Phase 3 – Comprehensive Analytical Source Tracer Sampling, April 2010 (EPA 2010b).

Criteria for Selection of Dairies and Associated Sampling Locations

EPA collected samples at several dairies. Dairies were selected based on data from Phases 1 and 2 of the project, considering the following criteria:

- High concentration of animals per acre.
- Indication of over-application of nutrients to fields associated with the dairies based on information contained in WSDA inspection reports. (WSDA 2012).
- Relatively consistent direction of groundwater flow from season to season.
- Minimal upgradient nitrate sources to the extent possible.
- Existence of private drinking water wells along the downgradient side, or sides, of the dairy.
- History of nitrate levels above the MCL in downgradient drinking water wells.

Samples were collected from dairy animal waste lagoons, dairy manure piles, dairy application fields, and supply wells associated with the dairies. In general, one sample was collected at the influent to the lagoon system, and two samples were collected at the outlet from the lagoon system. The dairy manure pile samples were collected on site at each dairy. The dairy application field samples were collected where lagoon waste had recently been applied. Residential drinking water wells upgradient and downgradient of the dairies were also sampled.

Selection of upgradient and downgradient wells for this study was based on groundwater flow direction and gradient data compiled by USGS. According to USGS, the generalized direction of groundwater flow in the study area in both the shallow sedimentary hydrogeologic unit and the deeper basalts is toward the Yakima River (USGS 2009). Flow directions can vary locally due to canal/lateral leakage, irrigation, drains, streams, pumpage, variations in recharge, spatially varying hydraulic characteristics, and topographic setting (USGS 2009). Groundwater flow directions were determined by USGS by measuring depth to water and reflecting these localized influences at the time it was measured. In this study, EPA sampled residential drinking water from a tap and depth to water was not measured.

<u>Criteria for Selection of Irrigated Cropland Areas and Associated Sampling Locations</u>

Soil samples were collected from two fields each of corn, hops, and mint.[19] These crops were selected because they require significant quantities of nitrogen to produce the large amounts of plant biomass for yield in contrast with other crops such as tree fruit. Thirty shallow soil samples per field were collected at a depth of 1 inch and composited to obtain a representative soil sample. One well situated downgradient of each crop field was selected for sampling. The criteria used for selection of the six crop fields were as follows:

- History of high fertilizer application rates, use of agricultural chemicals, and irrigation water applied for crop growth.
- Relatively consistent direction of groundwater flow from season to season.
- Minimal upgradient nitrate sources.
- History of nitrate levels above the MCL in downgradient drinking water wells.

<u>Criteria for Selection of Residential Septic System Areas and Associated Sampling Locations</u>

Samples were collected from four private drinking water wells that had high nitrate concentrations in Phase 2 and were located downgradient of areas with a high density of residential septic systems. Additionally, samples were collected from the influent to three small wastewater treatment plants in the Lower Yakima Valley (Zillah, Mabton, and Toppenish) to serve as a surrogate for septic system influent and to characterize compounds found in rural septic systems. The criteria used to select the water well sampling locations in the residential septic system areas included:

- High density of homes not served by sanitary sewers.
- Relatively consistent direction of groundwater flow from season to season.
- Minimal upgradient nitrate sources other than septic.

[19] The owners of the six crop fields sampled are indicated in Table 1.

VII. PHASE 3: COMPOUNDS AND ANALYTICAL TECHNIQUES

EPA analyzed for nearly 200 chemicals and used several analytical techniques to investigate the source of high levels of nitrate in water wells. The chemical analyses and analytical techniques were grouped as follows: general chemistry; microbial data; organic compounds; isotopic analysis; and age dating. The data for each of the analytical techniques are evaluated independently in an effort to identify the specific sources of the high nitrate concentrations found in residential drinking water wells. Table 2 summarizes the chemicals analyzed and the techniques used to analyze the samples collected from the water wells, dairy sources (dairy lagoons, dairy manure piles, and dairy application fields), wastewater treatment plants and irrigated crop fields.

This section describes the analyses that make up each of the five groups, the rationale for performing each of the analyses, and the issues or challenges associated with specific analyses and techniques. The analytical results are summarized in Appendix C and a discussion of the results is provided in Section IX.

A. General Chemistry

The study evaluated four areas of general chemistry: nitrate and other forms of nitrogen; major ions; minor and trace inorganic elements; and perchlorate. Each is discussed below.

1. NITRATE AND OTHER FORMS OF NITROGEN

Water well samples were analyzed for nitrate, nitrate plus nitrite, ammonia, and TKN. TKN is the total concentration of organic nitrogen and ammonia. TKN was analyzed to ensure all major forms of nitrogen were quantified. Samples from the dairy lagoons and WWTP influent were analyzed for nitrate plus nitrite, ammonia, and TKN. Nitrate alone was not analyzed in the lagoon and WWTP influent samples because nitrate would not be expected to be present in these media because of the anoxic (lack of oxygen) conditions.

In addition, the total nitrogen concentration for each sample was calculated by summing the concentrations of nitrate, nitrite, and TKN. These values were used to compare total nitrogen concentrations in upgradient and downgradient water wells with total nitrogen concentrations in sources, such as dairy lagoons, dairy manure piles, and dairy application fields, located between the up- and down-gradient wells, and to evaluate whether patterns exist. The results for the water wells, dairy lagoons, and WWTP influent samples are summarized in Table C3 in Appendix C.

Dairy manure piles, dairy application field, and crop field samples were analyzed for extractable nitrate (reported as Nitrate-N/Nitrite), extractable ammonia (reported as Ammonium-N), and total nitrogen by combustion (reported as Total Nitrogen/Solid). These analyses were conducted to provide an indication of the total nitrogen concentration in the dairy manure piles, dairy application field, and crop field samples. The results for the dairy manure piles, dairy application field samples, and crop field samples are included in Table C4 in Appendix C. Nitrate was analyzed at three different laboratories using different methods. Cascade Analytical Laboratory in Union Gap analyzed the water wells samples for nitrate using EPA Method 300.0 because this method is specified for evaluating nitrate concentrations in drinking water. Method 300.0 provides for measurement of nitrate alone. Method 300.0 requires the

Table 2: Summary of the Chemical Groups and Media Included in Phase 3 of the Study

Compound or Analytical Technique (Number of Compounds Analyzed)	Water Wells	Dairy Lagoons	Dairy Manure Piles	Dairy Application Fields	WWTP Influent[c]	Crop Soils
General Chemistry						
Nitrate (1)	X		X	X		X
Other Nitrogen Forms[a]	X	X	X	X	X	X
Major Ions (9)	X	X			X	
Trace Elements (12)	X	X			X	
Perchlorate (1)	X					
Microbiology						
Bacteria (3)	X	X			X	
Microbial Source Tracking[b]	X	X			X	
Organic compounds						
Pesticides (50)	X	X[d]	X	X	X[d]	X
Trace Organics (69)	X	X			X	
Pharmaceuticals (31)	X	X	X	X	X	X
Hormones (20)	X	X	X	X	X	X
Analytical Techniques						
Isotopic Analysis (2)	X	X			X	
Age Dating (NA)	X					

[a]Other nitrogen forms for water wells and lagoons include ammonia, TKN, and nitrate plus nitrite. Other forms of nitrogen for manure piles, dairy application fields, and crop samples include extractable nitrate, extractable ammonia, and total nitrogen by combustion.

[b] Microbial source tracking was conducted only if there was an indication of fecal contamination detected in the sample.

[c]Majority of influent from households but contribution from businesses and industry also expected.

[d]Because of matrix interference, results for pesticide analysis for lagoon and wastewater treatment influent samples were not useable.

X – the compound or analytical technique was analyzed.

NA – not applicable

sample to be analyzed within 48 hours after it is collected; therefore, samples were shipped to Cascade Analytical Laboratory because of its proximity to the study area.

EPA's Manchester Laboratory analyzed the water well samples for nitrate using Method 353.2. Method 353.2 measures nitrate plus nitrite. Finally, the University of Nebraska – Lincoln Water Sciences Laboratory ("UNL" or "UNL Laboratory"), also analyzed the water well samples for nitrate as part of the isotopic analysis. The UNL Laboratory used *Distillation and Determination of Ammonium and Nitrate Nitrogen in Water for Nitrogen Isotope Analysis* (SOP# Analyte-DISTN15-004) for their analysis.

Table C5 in Appendix C provides a summary of the nitrate concentrations reported by each of the three laboratories for the water wells sampled in Phase 3. The results for the nitrate analysis are similar among the three laboratories, with one exception: sample WW-18 where there was good agreement between two of the three results.

2. Major Ions

All water wells, dairy lagoons, and WWTP influent samples were analyzed for the major ions by EPA's Manchester Laboratory. The major ions were not analyzed in the soil and manure samples because, in general, the purpose for analyzing the major ions is to track the chemical evolution of migrating groundwater.

An ion is an electrically charged species consisting of a single atom or a group of atoms. It is formed when a neutral atom or group of atoms either gains or loses electrons. The major ions evaluated included calcium, chloride, fluoride, iron, magnesium, nitrate, potassium, sodium, and sulfate. The results for the major ions are included in Table C6 in Appendix C.

Different ions have different chemistries and transport mechanisms. For example, chloride does not generally sorb to particles or participate in reactions with the aquifer material. Other ions, such as potassium and sodium, are much more likely to react with minerals and sorb to aquifer materials.

For this study, the results for major ions in the various samples were compared to determine whether a spatial pattern was observed in the concentrations. If the concentrations of specific ions in the downgradient wells are higher than in the upgradient wells, and those same ions are abundant in a specific source then the source is a likely contributor to those higher levels. For example, if chloride is detected at high levels in a dairy lagoon and the concentrations of chloride in a water well downgradient of the dairy lagoon are higher than in a well upgradient of the dairy lagoon, it indicates the dairy lagoon is a likely source of chloride to the downgradient well.

3. Minor and Trace Inorganic Elements

EPA's Manchester Laboratory analyzed the samples from all water wells, dairy lagoons, and WWTP influents for minor and trace inorganic elements. Twelve minor and trace inorganic elements were evaluated: arsenic, barium, bromide, cadmium, chromium, copper, lead, manganese, mercury, selenium, silver, and zinc. Minor and trace inorganic elements were not analyzed in the samples from crop fields or manure piles. The results for the minor and trace inorganic elements are included in Table C6 in Appendix C.

The trace inorganic elements were included in this study to evaluate the potential influence of organic carbon sources. The mobility of certain metals is controlled by oxidation/reduction potential (how oxygen rich the waters are), which in turn is controlled by the amount of organic carbon consumed in microbial reactions. For example, if the metal concentrations in downgradient water wells are elevated compared with the upgradient wells, it may indicate the influence of an organic carbon source such as a dairy lagoon.

4. Perchlorate

All wells were tested for perchlorate and analyzed by the EPA's Robert S. Kerr Environmental Research Center in Ada, Oklahoma ("EPA's Ada Laboratory" or "Ada"). The results for perchlorate are in Table C7 in Appendix C. Perchlorate is the most highly oxidized form of chlorine and tends to accumulate in caliche-associated soils in arid regions such as Eastern Washington and Oregon (Rao and others 2007). In this study, it was used as an indicator for potential naturally occurring nitrate.

There is a very slight, but steady, deposition of nitrate and perchlorate from the atmosphere. Much of the deposition starts as aerosol salt particles released from combustion in transportation or power generation or carried off the oceans as aerosols or dust particles from deserts by winds (Prospero and Lamb 2003). In this region, the National Atmospheric Deposition Program (http://nadp.sws.uiuc.edu/) calculates aerial deposition of atmospherically derived nitrate at approximately 0.9 pound per acre per year. Perchlorate accumulates at much lower rates but has not been studied to the same extent, so data are lacking.

This accumulation of nitrate and perchlorate has been occurring since the end of the last glacial period, approximately 10,000 years ago. In areas of higher rainfall, both these compounds are sufficiently soluble to be carried into the subsurface and potentially into groundwater. However, these compounds can build up in the shallow subsurface with the calcium carbonate that forms the cement-like caliche layer in arid regions such as the Lower Yakima Valley. The same conditions that would wash the nitrate out of a caliche soil horizon (the first application of irrigation water to a new field converted from sage habitat) would flush out perchlorate as well.

B. Microbiology

All water wells, dairy lagoons, and WWTP influent samples were analyzed for either total coliform, fecal coliform, or *E. coli* as an indicator of fecal contamination. The results for microbiology are in Table C8 in Appendix C. EPA's mobile microbiology laboratory from its Manchester Laboratory or Cascade Analytical Laboratory in Union Gap conducted the analysis. MST was performed for nine of the dairy lagoons and all three of the WWTP influent samples because they tested positive for fecal contamination. Six of the lagoons were not tested for MST, even though they tested positive for fecal contamination, because of limited resources. MST was not conducted for the Phase 3 water well samples because fecal coliform was not detected.

MST is a means of identifying the source of the fecal contamination in a water sample. The method used in this study is genotypic and is used to detect the presence of host-specific Bacteroides species shed in the fecal material of humans or ruminants. This method allows a presence or absence reporting format for these two sources. A common way of referring to the host-specific genetic identifier for each of these species is a "biomarker."

Because the MST method used in this case is limited to presence or absence reporting only for human and ruminant sources, the data cannot be used to: (1) identify the quantity or proportional levels of contamination from either source; (2) identify specific sources other than human or ruminant; or (3) differentiate between the various kinds of ruminants — cattle, goats, sheep, deer, or elk.

However, the data can be used to: (1) identify the frequency of identification of either of the sources from a particular sampling site if more than one set of samples is collected from the same site; (2) identify human or ruminant source contamination; and (3) confirm that recent fecal contamination has occurred.

C. Organic Compounds

The study looked at four groups of organic compounds: pesticides; trace organics; pharmaceuticals; and hormones. Organic compounds are subject to a number of factors that affect their fate and transport properties and would cause them to travel differently from nitrate in groundwater. Organic molecules are much more likely to sorb to materials in the aquifer, which could retard their migration compared to nitrate. In addition, organic compounds are subject to microbial degradation, which would reduce their concentration in groundwater over time.

1. Pesticides

Fifty pesticides were analyzed in water wells, dairy lagoons, WWTP influents, dairy manure piles, dairy application field samples, and crop soil samples by EPA's Manchester Laboratory. The term "pesticide" refers to insecticides, herbicides, fungicides, and various other substances used to control pests. The pesticide analysis conducted as part of this investigation included insecticides and herbicides. The results for the pesticides are included in Table C9 in Appendix C.

The pesticides selected for analysis were those that USGS reported had been used in the Yakima Valley and are considered mobile in groundwater, persistent, or both (Nakagaki and Wolock 2005). Many of the pesticides are used on specific crops and during specific times of the year. This pattern of usage can be an advantage, as it can assist to identify the specific crop where the pesticide was applied. At the same time, it is possible that a particular pesticide, though used in the area, was not applied before the time of sample collection and may not have been detected in the soil samples collected by EPA.

EPA's Manchester Laboratory reported that the sample matrices provided significant interferences that made pesticide analysis difficult for dairy lagoons and WWTP influent samples. Because of this problem, the pesticide concentrations could not be quantified in the dairy lagoons or WWTP influent samples. The laboratory attempted to develop an extraction and cleanup procedure for the dairy lagoon and WWTP sample matrix; however, a procedure to resolve the matrix interference could not be developed within the maximum holding time specified for these samples. The maximum sample holding times would have been exceeded by the time the laboratory could have developed and tested an effective and reliable procedure. Therefore, the pesticide results for the dairy lagoon and WWTP samples are considered unusable for all purposes.

2. Trace Organics

Each water well, dairy lagoon, and WWTP influent sample was tested for 69 trace organic compounds by the USGS National Water Quality Laboratory in Denver ("USGS NWQ Laboratory"). The trace organics were not analyzed in soil or manure samples because the USGS NWQ Laboratory was not equipped for this type of analysis and the methods for extraction of such samples are complex. The results for the trace organics and a description of their main use are included in Table C10 in Appendix C.

The USGS developed a method for analyzing a large number of trace organics because USGS and other researchers had found them in domestic and industrial wastewater (Zaugg and others 2006) as well as groundwater and surface waters (Kolpin and others 2002, Barnes and others 2008). EPA believed the trace organics would help to differentiate water wells affected by septic systems (humans) from water wells influenced by other sources such as dairy lagoons or irrigated cropland. The compounds analyzed include many that can be associated with human usage, including caffeine, bisphenol A, cholesterol, menthol, phenol, various flame retardants, acetophenone (fragrance in detergent), benzophenone (fixative for perfumes), camphor (flavor, oxidant), isoborneol (fragrance in perfume), and many others.

3. Wastewater and Veterinary Pharmaceuticals

The sample from each water well, dairy lagoon, WWTP influent, dairy manure pile, dairy application field, and crop sample was analyzed for 14 wastewater pharmaceuticals (Table 3). UNL performed the analysis. The results are included in Table C11 in Appendix C.

Table 3: Wastewater Pharmaceuticals Analyzed and a Description of their Uses

Compound Name[a]	Description
Acetaminophen	Pain reliever (Tylenol)
Amphetamine	Psychostimulant (Dexedrine)
Azithromycin	Antibiotics (Zithromax)
Caffeine	Stimulant
Carbamazepine	Anticonvulsant
Cotinine	Metabolite of nicotine
DEET	Insect repellent
Diphenhydramine	Antihistamine
Ibuprofen	Pain reliever
Methamphetamine	Psychostimulant
Naproxen	Pain reliever (Aleve)
Paraxanthine	Stimulant (metabolite of caffeine)
Thiabendazole	Parasiticide (mintezol)
Triclosan	Antibacterial

[a]The University of Nebraska – Lincoln Water Sciences Laboratory (UNL) conducted the analyses for these compounds.

The group is identified as “wastewater pharmaceuticals” because they are generally used by people for therapeutic reasons and have been detected in municipal wastewater (Ternes and others 2004), surface waters (Kolpin and others 2002), groundwater (Barnes and others 2008), and drinking water (Benotti and others 2009). Many of the compounds are for over-the-counter use (for example, acetaminophen and ibuprofen) and are ingested, but a few are applied topically (DEET and triclosan). Two of the compounds may be used in other animals (thiabendazole and DEET).

People typically excrete 50 to 90 percent of the active ingredients in ingested drugs, either as unmetabolized pharmaceuticals or as metabolites (McGovern and McDonald 2003). These excreted compounds can enter a municipal WWTP or a septic system. Detection of these compounds in water wells may provide evidence that septic systems are a likely source of nitrate. If detected in the influent to the WWTPs, it can establish whether these compounds are being excreted by humans and ending up in municipal sewage waste. If the compounds are detected in the WWTP influent, they can be compared with detected compounds in water wells to evaluate whether septic systems may contribute to the presence of these compounds in well water.

In addition, the sample from each water well, dairy lagoon, WWTP influent, dairy manure pile, dairy application field, and crop sample was analyzed for 17 additional pharmaceuticals and classified as "veterinary pharmaceuticals" for this study. Table 4 lists the compounds and the current U.S. Food and Drug Administration (FDA) approved uses (FDA 2011a and FDA 2011b). Many of the pharmaceuticals shown in Table 4 do not require a veterinarian's prescription and are available for over-the-counter purchase (FDA 2011a and FDA 2011b).[20] The majority of the over-the-counter pharmaceuticals are included in animal feed. The UNL Laboratory also conducted these analyses. The results are included in Table C12 in Appendix C.

Detections of the compounds in Table 4 in water wells would provide evidence that dairy cattle or other animals are a likely source of those compounds. For example, if monensin is detected in water wells, then it is coming from a source other than people (monensin is not approved for use in humans). If the compounds are detected in dairy lagoons, dairy manure piles, or dairy application fields, it is a good indication that the dairy is using the compound.

The UNL Laboratory analyzed the compounds in Table 4 because they are used in livestock production at therapeutic doses to treat and prevent disease and at sub-therapeutic doses as prophylactics and growth promoters (Meyer 2004) and have been found at low levels in various environmental media: groundwater (Barnes and others 2008 and Kummerer 2009); surface water (Koplin and others 2002; Christina and others 2003; and Kummerer, 2009); and wastewater treatment facilities (Ternes and others 2004; and Lubliner and others 2010). More specifically, several of the compounds have been found in dairy lagoons (Watanabe and others 2008 and Watanabe and others 2010); soil and surface samples from dairies (Watanabe and others 2010); private wells nearby a beef cattle operation (Batt and others 2006); and in groundwater underlying swine and beef cattle facilities (Bartlet-Hunt and others 2011). Some of the compounds in Table 4 (such as tetracycline and erythromycin) are also used by people (Kummerer 2009).

The U.S. Department of Agriculture's (USDA's) National Animal Health Monitoring System conducted a survey to evaluate the use of antibiotics in dairy operations for disease prevention, disease treatment, and growth promotion in pre-weaned heifers, weaned heifers, and mature cows (USDA 2008). The survey represented 17 of the nation's major dairy states (Washington was included) and represented about 82 percent of the U.S. dairy cows. The results indicate that the majority of dairy operations use antibiotics to

[20] Compounds that can be obtained over-the-counter include chlortetracycline; erythromycin; lincomycin; monensin; ractopamine; sulfadimethoxine; sulfamethazine; sulfathiazole; tetracycline; tiamulin; trenbolone; tylosin; and virginiamycin.

treat for diarrhea, digestive problems, respiratory problems, mastitis, reproductive disorders, and lameness.

Table 4: Veterinary Pharmaceuticals Analyzed and their FDA Approved Uses

Compound Name[a]	Current FDA Approved Use[b]
Chlortetracycline (total)	Cattle (beef, dairy), poultry, swine, and sheep
Erythromycin	Cattle (beef, dairy) and humans
Lincomycin	Swine, poultry, and humans
Monensin	Cattle (beef, dairy), and poultry
Oxytetracycline	Cattle (beef, dairy), poultry, sheep, and humans
Ractopamine	Cattle (beef), swine, and poultry.
Sulfachloropyridazine	Cattle (beef), swine, and sheep
Sulfadimethoxine	Cattle (beef, dairy), and poultry
Sulfamerazine	Poultry
Sulfamethazine	Cattle (beef, dairy), poultry, and swine
Sulfamethizole	Dogs and cats
Sulfamethoxazole	Humans
Sulfathiazole	Swine
Tetracycline	Cattle (beef, dairy), poultry, sheep, swine, and humans
Tiamulin	Swine
Tylosin	Cattle (beef, dairy), poultry, and swine
Virginiamycin	Swine and poultry

[a]The University of Nebraska – Lincoln Water Sciences Laboratory (UNL) conducted the analyses for these compounds.

[b]Approved as of November 2011.

EPA requested information from the dairies on the use of pharmaceuticals in their operations to identify which of the pharmaceuticals might be used by the dairies in this study. The dairies declined to provide this information to EPA; therefore, there is no specific information from the dairies on their use of these compounds.

4. HORMONES

Each water well, lagoon, and WWTP influent sample was analyzed for five estrogen hormones (17-α-estradiol, 17-α-ethynyl-estradiol; 17-β-estradiol; estriol; and estrone) by EPA's Robert S. Kerr Environmental Research Center in Ada, Oklahoma. The results for these hormones are in Table C13 in Appendix C.

In addition, each water well, dairy lagoon, WWTP influent, dairy manure pile, dairy application field sample, and crop sample was tested for 20 estrogen, androgen, and progestin hormones by the UNL Laboratory, including the five estrogen hormones analyzed by EPA's Ada Laboratory. The results for these analytes are in Table C14 in Appendix C. Table 5 shows all the compounds evaluated and their natural source or general use. The table also provides information on the FDA approved uses for certain of the analytes as of November 1, 2011 (FDA 2011a and FDA 2011b).

Table 5: Hormonally Active Compounds Analyzed and Descriptions of their Origins and Current FDA Approved Uses

Compound Name[a]	Description (Current FDA Approved Use)
Analyzed at both EPA's Ada Laboratory and the UNL Laboratory	
17-β-Estradiol	Estrogen, natural female sex hormone - many animals
17-α-Estradiol	Estrogen, natural isomer of 17- β-estradiol - many animals
Estriol	Estrogen, natural female sex hormone - many animals
Estrone	Estrogen, natural female sex hormone - many animals
17-α-Ethynyl Estradiol	Estrogen, synthetic analogue of estradiol used for birth control (human)
Analyzed at the UNL Laboratory Only	
11-Keto Testosterone	Androgen, oxidized metabolite of natural testosterone - many animals
17-α-Hydroxyprogesterone	Inactive metabolite of natural progesterone - many animals
4-Androstenedione	Androgen, natural precursor in producing testosterone and estrogens - many animals
Androsterone	Androgen, natural metabolite of testosterone - many animals
Epitestosterone	Inactive isomer of natural testosterone - many animals
Progesterone	Progestin, natural female sex hormone - many animals; also used as a growth promoter (beef cattle)
Testosterone	Androgen, natural male sex hormone - many animals
17-α-trenbolone	Androgen, synthetic growth promoter (beef cattle)
17-β-trenbolone	Androgen, synthetic growth promoter (beef cattle)
Androstadienedione	Androgen, metabolite of natural progesterone and testosterone - many animals; also used as precursor for producing synthetic boldenone, a growth promoter (horse)
α-Zearalanol	Estrogen, naturally produced by plant fungi and found in pasture animals - many animals; also produced synthetically as a growth promoter (beef cattle and sheep)
α-Zearalenol	Estrogen, precursor of natural α-zearalanol- many animals
β-Zearalanol	Estrogen, isomer of α-zearalanol naturally produced by plant fungi and found in pasture animals - many animals
β-Zearalenol	Estrogen, precursor of natural β-zearalanol- many animals
Melengesterol Acetate	Progestin, synthetic growth promoter (beef cattle)

[a]EPA's Robert S. Kerr Environmental Research Center (EPA's Ada Laboratory) and the University of Nebraska – Lincoln Water Sciences Laboratory (UNL Laboratory) both conducted the analyses for these compounds.

Analytes were selected both as a result of laboratory method development showing success at analysis and because of the frequent detections in the environment. Most of these hormones are produced naturally by humans and other animals (Williams and Stancel, 1996; Wilson, 1996; Lange and others, 2002;

Johnson and others, 2006), and some are even produced by plants or fungi (Carson and others, 2008). Many of these hormones can be used as pharmaceuticals in human and veterinary clinical practices (Zheng and others 2008).

Many of the compounds have been detected at low levels in various environmental media or sources, including surface waters (Kolpin and others 2002); dairy lagoons (Kolodziej and others 2004; Arnon and others 2008; Hutchins and others 2007, and Zheng and others 2008); groundwater associated with dairies (Kolodziej and others 2004, Arnon and others 2008); and manure at dairy facilities (Raman and others 2004).

Some of the synthetic hormones analyzed could be indicative of specific animal sources. For example, 17-α-ethynyl-estradiol is a synthetic analogue of 17-α-estradiol and is used in hormonal contraception exclusively in humans. This compound would not be expected to be found in dairy lagoons, unless the lagoons also receive human waste, but could be found in WWTP influent and septic systems.

Another example includes the synthetic growth hormones trenbolone and melengesterol acetate, which are used to promote growth in beef cattle. These compounds are not approved for use in dairy cows, and would not be expected to be detected in dairy lagoons, dairy manure piles, or dairy application fields. If these compounds are detected in water wells, it is an indication that there is a source other than dairy cows or people.

In addition to these compounds, there are some hormones that might indicate a specific animal source, but are not necessarily conclusive. For example, 17-α-estradiol is predominantly produced by dairy cows and could be useful for source tracking (Hanselman and others, 2003), but it is also found in smaller amounts in other animals and in fact can be produced during biotransformation of other natural hormones (Czajka and Londry, 2006). Another example is α-zearalanol and its isomers and precursors; this is produced synthetically as a growth promoter for sheep and beef cattle, but is also produced naturally by plant fungi and can be found in pasture-grazed animals not subject to hormone treatment (Erasmuson and others, 1994).

D. Isotopic Analysis

Samples from all the water wells, dairy lagoons, and WWTPs were submitted to the UNL Laboratory for isotopic analysis. The results of the isotopic analyses are presented in Table C15 in Appendix C. A detailed discussion regarding the interpretation of the isotopic data can be found in Appendix D.

Stable isotopes of the various nitrogen species that make up dissolved inorganic nitrogen (nitrate, nitrite, and ammonium) in water can indicate the general source, or combination of sources, or dominant processes acting on nitrogen in groundwater (Kendall 1998; Kendall and Aravena 1999; Michener and Lajtha 2007). Stable isotopes of nitrate and ammonium can explain the possible origin and process that formed the dissolved inorganic nitrogen in water wells. The ability to attribute nitrate in water wells to specific sources using isotopic analysis maybe a useful supplement to other methods used to identify possible sources.

The interpretation of isotopic data is complex. Multiple studies have shown that different nitrate sources can have overlapping isotopic composition (Kendall and others 2007). In many cases, it is not possible to distinguish the different nitrate sources using isotopic analysis alone if the isotopic ranges overlap.

Extensive sampling within a specific study area is needed to allow different nitrate sources to be identified with more confidence.

Isotopes are forms of the same element that have a different number of neutrons and thus a different mass. As an example, the atomic weight of nitrogen is 14.0067 because the most common isotope of nitrogen is the form with seven neutrons and seven protons and a mass number of 14, written as ^{14}N. ^{14}N makes up 99.636 percent of the total nitrogen in the atmosphere and is referred to as the "light isotope" because it has a lower atomic weight than ^{15}N. Nitrogen 15 consists of seven protons and eight neutrons and, written as ^{15}N, makes up the rest of the total nitrogen in the atmosphere at 0.364 percent and is referred to as the "heavy" isotope."

Isotopic values are reported as the ratio of the heavy isotope (in this case, ^{15}N) to the light isotope (in this case, ^{14}N) in the sample compared with that ratio in a chosen standard. For nitrogen, the standard is the pool of nitrogen in the earth's atmosphere, referred to as the atmospheric standard. Nitrogen isotopic composition is expressed in terms of "delta ^{15}N," which is written as $\delta^{15}N$ and is expressed as parts per thousand differences from the atmospheric standard stated as, "per mil" or written as ‰.

$$\delta^{15}N\ (‰) = \frac{(^{15}N/^{14}N)_{sample} - (^{15}N/^{14}N)_{standard}}{(^{15}N/^{14}N)_{standard}} * 1000$$

$\delta^{15}N$ will be positive (for example, +6.1‰) and therefore heavier if there is more of the ^{15}N compared with the atmospheric standard in the sample. $\delta^{15}N$ will be negative (for example, -0.2‰), or lighter, if there is less of ^{15}N in the sample compared with the atmospheric standard. The $\delta^{15}N$ values are reported as either $\delta^{15}N\text{-}NO_3$ (for nitrate) or $\delta^{15}N\text{-}NH_4$ (for ammonium).

Isotopes of oxygen (^{18}O) have also been used to provide information on the source of nitrate in a sample. The standard for ^{18}O is "Standard Mean Ocean Water," or SMOW. The $\delta^{18}O$ of O_2 gas in the atmosphere is 23.5‰, which is heavier than the $\delta^{18}O\text{-}NO_3$ typically found in nitrate sources without atmospheric influence. Nitrate derived from atmospheric deposition has much heavier $\delta^{18}O\text{-}NO_3$ values in comparison to other nitrate sources of 60‰ to 95‰ (Kendall and others 2007). The ^{18}O values are reported as $\delta^{18}O\text{-}NO_3$ (for nitrate).

E. Age Dating

Several methods are available to measure the age of groundwater in a well, meaning the amount of time that has elapsed between the initial infiltration of the water into the ground and when it was sampled in the well. The measured age of the water may be useful in determining whether the nitrate in water wells is associated with either past or current practices. For this study, EPA used a method involving the analysis of sulfur hexafluoride (SF_6). SF_6 is used for age dating because it has been steadily increasing in the atmosphere as it is released by human activities. To determine the age of the water, the laboratory measures the concentration of SF_6 in the water sample and compares it to measured atmospheric concentrations of SF_6 over time.

SF_6 is a liquid at room temperature and can occur naturally in igneous formations. Industrial production began in the early 1950s. Significant production of SF_6 began in the 1960s for use in high-voltage electrical switches as a replacement for polychlorinated biphenyls (PCBs). SF_6 is extremely stable, with an estimated atmospheric lifetime of 800 years (Morris and others 1995) to 3,200 years (Ravishankara and others 1993). As more of it is produced, more of it is found in the atmosphere. SF_6 is very persistent in the atmosphere, so the concentration has been steadily increasing. The SF_6 age dating method used in this study can estimate the age of water up to about 40 years, since approximately 1970.

All water wells samples were analyzed for SF_6. The analysis was completed by the USGS laboratory in Reston, Virginia ("USGS Reston Laboratory"). The USGS Reston Laboratory was selected because this laboratory has developed a method that had been used successfully by USGS in Washington State. This analysis is not conducted by commercial laboratories.

In addition to the SF_6 analysis, five gas studies were conducted. These studies involved filling containers with water for the analysis of nitrogen and argon gas to measure the temperature and elevation of the recharge zone for the groundwater. These data are used to correct the SF_6 measurement for excess nitrogen, which can be dissolved when groundwater elevations fluctuate rapidly. It also provides a means to determine if nitrogen gas has been added to the sample from denitrifying bacteria breaking down nitrate in an anoxic setting. None of the EPA samples showed evidence of denitrification based on measured nitrogen to argon ratios. A summary of the results for the age dating is in Table C16 in Appendix C.

SF_6 values were not reported for WW-01, WW-11, WW-12, WW-23, WW-27, and WW-28 (Table C16 in Appendix C). Values were not reported for these samples because the concentration of SF_6 in the groundwater exceeded the highest expected concentration based on average atmospheric concentrations of SF_6. These samples may indicate areas where localized human-caused releases of SF_6 occurred. For example, there could have been an accidental release during servicing of high-voltage equipment or the intentional introduction of SF_6 into water for localized fate and transport studies or for tracing leaking pipes. Based on USGS SF_6 age dating research, the high values of SF_6 observed in certain samples are likely from anthropogenic sources and not related to background levels seen in some volcanic regions.

VIII. QUALITY ASSURANCE AND QUALITY CONTROL

As discussed previously, the project was implemented in three phases. In Phase 1, a GIS screening application was developed and used to identify potential sample locations and sites in the Lower Yakima Valley for Phase 2 sampling. Phase 1 also developed estimates of the nitrogen available for application to the land from different sources. Phase 2 and Phase 3 involved sampling and analysis as described in Sections V, VI, and VII. A discussion of the QA/QC procedures followed in Phase 2 and Phase 3 and a summary of the data validation process conducted by EPA QA chemists are presented in Appendix E. All of the chemical analyses conducted for the Phase 3 study met project data quality goals and criteria and are useable for all purposes, except as noted in Appendix E.

IX. ANALYTICAL RESULTS AND DISCUSSION

The following subsections present the analytical results for the Phase 3 sampling and are organized by the type and location of the source area. The three types of source areas include: dairies; irrigated cropland; and residential septic systems. In addition, one well was sampled that was not related to a specific dairy or crop field (WW-18) and one well was sampled that was not included in the QAPP (WW-30). The locations sampled are illustrated on Figure 11 and include the following:

- Haak Dairy.
- Dairy Cluster (composed of a group of dairies in close proximity).
- Irrigated and fertilized crop fields (three locations: Mabton [three separate crops], Harrah [one crop], and Sunnyside [two separate crops]).
- Septic Systems (four downgradient wells: one in Mabton; one in Harrah; and two in Sunnyside; plus influent from the WWTPs located in Zillah, Mabton, and Toppenish).
- Two residential drinking water wells (WW-18 and WW-30) not associated with a specific dairy or irrigated cropland.

The analytical data for each of the five locations listed above are presented according to the analytical groups described in Section VII: general chemistry; microbiology; organic chemicals; isotopic analyses, and age dating. Each section provides a summary of all of the results for each location.

A data usability review and validation independent of the laboratories were conducted by EPA and are discussed in Appendix E. Data usability is indicated in the data summary tables by inclusion of data qualifiers. The data qualifiers are defined in the footnotes of the data summary tables and further explained in Appendix E. A discussion of data bias, where it could be determined, also is included in Appendix E.

A. R&M Haak Dairy

The R&M Haak Dairy (Haak Dairy) is located in an agricultural area north of the Yakima River, about four miles north of the community of Sunnyside. It is in the Benton groundwater basin, which includes the communities of Sunnyside, Grandview, Satus, Kiona, Prosser, Mabton, and Richland. A ditch runs from north to south through the Haak Dairy. Cow pens, a milking parlor, and three animal waste lagoons lie west of the ditch. There are several large structures where cows are kept. East of the ditch, a center-pivot irrigation system is installed on a large application field that the dairy uses to apply animal waste.

EPA selected this dairy for this study because it generally met the criteria identified in the study plan (see Section VI.C.1). Specifically, the Haak Dairy has: a high concentration of animals per acre; WSDA inspectors noted in their reports for the Haak Dairy that elevated levels of nitrogen were detected in its application fields in the past (WSDA 2012); the Haak Dairy is located near the northern edge of cultivated land use and in a location with relatively few upgradient potential sources of nitrogen; and drinking water wells downgradient of the Haak Dairy showed nitrate levels above the MCL.

NUMBERS OF ANIMALS AND AMOUNT OF WASTE GENERATED

In the past 30 years, the average U.S. dairy herd has increased from 29 to 139 head per farm (USDA 2009). While this is a sizable increase, the dairies in this study are considerably larger. In general, the WSDA is prohibited by state law from providing information to the public identifying the number of animals; the volume of livestock nutrients generated; the number of acres covered by a Nutrient Management Plan (NMP) or used for land application of livestock nutrients; quantities of livestock nutrients transferred to other persons; and crop yields in plans, records, and reports obtained by the state and local agencies from dairies, Animal Feeding Operations (AFOs) or Concentrated Animal Feeding Operations (CAFOs). They can provide some of this information in ranges (WSDA 1996 and WSDA 2010). Table 6 provides information on the number of animals and the amount of dairy waste generated at the Haak Dairy before and after factoring in estimated losses during storage from volatilization or denitrification.

Table 6: Haak Dairy – Approximate Numbers of Dairy Cattle, Annual Manure Production, and Annual Nitrogen Production

Mature Dairy Cattle	Heifers/ Calves	Annual Manure Production[a] (tons)	Annual Nitrogen Production as Excreted[b] (tons)	Annual Nitrogen After 35% Losses Occur[c] (tons)
700 to 1,699	300 to 399	20,573 – 52,220	129 – 323	84 – 210

[a]Annual manure production is calculated using the following formula: [((# of milking cows)*1.4*108) + ((# of dry cows)*1.4*51) + ((# of heifers)*0.97*56) + ((# of calves *0.33*83)]*365/2000 (WSDA 2010)

[b]Nitrogen production is calculated using the following formula: [((# of milking cows)*1.4*.71) + ((# of dry cows)*1.4*.3) + ((# of heifers)*0.97*.27) + ((# of calves *0.33*.42)]*365/2000 (WSDA 2010)

[c]Losses due to volatilization or denitrification during storage are estimated at 35%. This does not include application losses.

A farm with 2500 dairy cattle is similar in waste load to a city of 411,000 people (EPA 2004). A difference lies in the fact that human waste is treated before discharge into the environment, but animal waste is either not treated at all or minimally treated before discharge into the environment (EPA 2004). Applying this estimate to the range of 700 to 1,699 mature dairy cattle, the Haak Dairy produces an amount of waste similar to a community of 115,000 to 278,000 people.[21] This estimate is based only upon the numbers of mature dairy cattle. It does not include the additional waste load of heifers and calves. For comparison, the human population of Yakima County in 2010 was 243,231.[22]

Sizable amounts of nitrogen, a component of manure, are generated by the Haak Dairy. Nitrogen production can be roughly estimated by applying the ranges of the numbers of animals to formulas used by the WSDA to estimate manure and nitrogen production. The WSDA estimates that during storage at a typical dairy, about 35 percent of the nitrogen in dairy waste is "lost" through the process of volatilization or denitrification (WSDA 2010). The formula does not assume any leakage into the subsoils from the lagoons or other structures or conveyances. If the remaining nitrogen is not taken up by crops or is transported off site to another location, it can migrate to groundwater after being mobilized by irrigation water or precipitation.

WASTE MANAGEMENT

The Haak Dairy uses a variety of animal waste storage methods, including a solids separator, a lagoon system, and dry stacking. The surface area of the Haak Dairy's lagoons is approximately 269,000 square feet, which is equivalent to about 5 football fields (assumes a football field is 57,600 square feet). EPA estimated the surface area of the lagoon system using aerial photographs. The storage capacity of the Haak Dairy's lagoon systems was derived from WSDA inspection reports (WSDA 2012). The Haak

[21] Calculations: 411,000 persons divided by 2500 dairy cows equals 164 persons per cow. 700 cows times 164 persons per cow equals 115,000 persons. 1.699 cows times 164 persons per cow equals 278,000 persons.

[22] U.S. Census Bureau: http://quickfacts.census.gov/qfd/states/53/53077.html

Dairy's lagoon system storage capacity is 9,400,000 gallons which is equivalent to the volume of about 14 Olympic-size swimming pools (assumes the capacity of an Olympic-size swimming pool is 660,000 gallons).

NRCS Washington recommends avoiding the use of "agricultural waste storage ponds" (lagoons), unless no reasonable alternative exists, at locations like the Haak Dairy where there is an aquifer that serves as a domestic water supply (NRCS Washington 2004). If no reasonable alternative exists, consideration should be given to the following: 1) a clay liner designed in accordance with procedures of Agricultural Waste Management Field Handbook Appendix 10D ("NRCS Appendix 10D") with a thickness and coefficient of permeability so that specific discharge is less than 1 x 10^{-6} cm/sec; 2) a flexible membrane liner over a clay liner; 3) a geosynthetic clay liner (GCL) flexible membrane liner; or 4) a concrete liner designed in accordance with slab on grade criteria for fabricated structures requiring water tightness."

EPA estimated the seepage from lagoons for the Haak Dairy using unit seepage rates from NRCS Appendix 10D and from a field study by Ham and DeSutter (Ham 2002). Lagoon design should consider unit seepage rates in addition to other factors such as state and local requirements and site-specific conditions (e.g., groundwater flow and depth to groundwater) (NRCS 2008). State regulations for specific discharge range from about 500 gallons per acre per day (1/56 inch or 0.45 mm per day) to about 6,800 gallons per acre per day (1/4 inch or 6.35 mm per day) (NRCS 2008). Applying a unit seepage rate of 500 gallons per acre per day to the surface area of the Haak Dairy lagoons equates to an approximate seepage volume of 1,080,000 gallons per year, the equivalent of about 1.6 volumes of an Olympic-size swimming pool annually (Table 7).

Table 7: Haak Dairy – Lagoon System Surface Area, Storage Capacity, and Estimated Leakage Rate

Approximate Lagoon System Liquid Surface Area (square feet)	Lagoon System Storage Capacity (gallons)[23]	Estimated Lagoon System Leakage, Based on Unit Seepage Rate of 500 Gallons per Acre per Day (gallons per year)	Estimated Range of Lagoon System Leakage, Based on Ham Seepage Rate Range (gallons per year)
269,000	9,400,000	1,080,000	482,000 to 5,873,000

Leakage rates of lagoon systems with compacted soil liners were estimated in the field by Ham and DeSutter (Ham 2002). The leakage rates they derived were based on field measurements of animal waste lagoons lined with compacted soil liners with an average hydraulic conductivity of 1.8 x 10^{-7} centimeters per second. Based on field observations, they concluded that lined dairy lagoons leak at a rate of 0.2 to 2.4 millimeters per day (Ham 2002). Applying the Ham and DeSutter rates to the surface area of the Haak Dairy lagoons, leakage rates can be estimated and are presented in Table 7.

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[23] Lagoon systems are generally designed to hold about one third of a dairy's annual liquid waste generation (the amount that would be generated over a four month time period).

Based on the liner infiltration rates developed by the Ham and DeSutter study (Ham 2002), a lined lagoon system of the size of the Haak Dairy's would release approximately 482,000 to 5,873,000 gallons per year into the underlying soils and could threaten groundwater. This amount is the equivalent of about 1 to 9 volumes of Olympic-size swimming pools annually.

The seepage rate of 0.45 mm per day falls within the Ham and DeSutter range of 0.2 to 2.4 mm per day. Leakage rates for the Haak Dairy lagoons would likely be greater than the above estimates if the lagoons are unlined. If the lagoons are lined with a plastic liner, the actual leakage rates could be lower, although plastic liners can be punctured during construction and lagoon maintenance, especially during periodic dredging activities.

EPA requested information from the Haak Dairy about how its lagoons were constructed, but the Dairy declined to provide this information. EPA has asked Yakima County, the WSDA, the Washington Department of Ecology, and the NRCS if any of the Haak lagoons have engineered liners, but none of the agencies could affirm that they do. Many states require lagoons to meet permeability requirements. However, EPA is unaware of any state or local requirements that would compel dairies in Yakima County to construct lagoons to any specific level of permeability.

Utilization rates of the lagoon systems (the percent of lagoon capacity occupied by liquid waste) at the time of the inspection are also provided in the inspection reports. Lagoon utilization rates tend to vary throughout the year. One purpose of the lagoons is to provide storage of liquid dairy waste during the winter months. Such storage is needed to avoid applying dairy wastes to fields during the winter, which can result in the contamination of groundwater if there are no plants growing to take up the nutrients in the waste. Dairy operators generally try to pump out their lagoons toward the end of the growing season so they have sufficient lagoon capacity to store waste through the winter months. Lagoon utilization rates noted in recent inspection reports for the Haak Dairy are summarized in Table 8. A dashed line indicates there was no entry in the report for that particular data element.

SURFACE SOILS

Surface soils in Yakima County have been characterized and mapped by the U.S. NRCS (NRCS 2012). A soil report has been developed for the Haak Dairy (EPA 2012a) and is summarized in Appendix B. All of the surface soils underlying the Haak Dairy have a "well drained" classification, which means water moves readily through the soil.

Most of the surface soils on which the Haak Dairy operates have a high saturated hydraulic conductivity. The percentage of surface soils with a "high" saturated hydraulic conductivity at the Haak Dairy is 82 percent while the percent of surface soils with a "low" saturated hydraulic conductivity is 18 percent. The permeability of the surface soils at the Haak Dairy is more fully described in Appendix B.

Table 8: Haak Dairy – Washington State Department of Agriculture Inspection Dates and Reported Values for Lagoon Capacity

Date of Inspection	Lagoon Capacity (gallons)	Number of Days of Lagoon Capacity[24]	Percent of Lagoon Capacity Utilized at Time of Inspection
3/25/2010	9,400,000	4 months plus	75%
12/18/2008	-----	-----	60%
7/7/2008	9,400,000	4 months plus	80%
9/5/2006	9,400,000	120 days	100%

Animal waste applied to crop fields can be a significant source of nitrogen loading to the soil, groundwater and surface water. Applying large quantities of animal wastes on highly permeable surface soil (i.e., soil with a high hydraulic conductivity) increases the risk of groundwater contamination because water from irrigation or precipitation can readily infiltrate the soil and carry nitrogen past the root zone before it can be taken up by plants (EPA 2004). "Agronomic" nitrogen application rates are typically based on soil types and crop yield goals. However, agronomic nitrogen application rates are not necessarily protective of drinking water. Even with agronomic application rates, mismanagement of irrigation water can move nitrogen through the vadose zone.

Application Fields

The Haak Dairy applies animal wastes as fertilizer onto between 121 and 300 acres of application fields that it owns or leases (WSDA 2010). The WSDA does not disclose exact acreages of the application fields to the public. Corn and triticale (a cross of wheat and rye) are grown in these fields. These crops have relatively high nitrogen needs and can be used as feed. At the time of inspection, WSDA inspectors documented in inspection reports that animal wastes were applied to six fields using a spreader "honey wagon", a sprinkler irrigation system, and a dry spreader (WSDA 2012). Because the Haak Dairy did not provide the information EPA requested about its operations, it is unknown how much manure or liquid dairy lagoon waste the Haak Dairy applies to its fields. However, WSDA inspectors documented that the Haak Dairy measured and recorded elevated levels of nitrogen on some of the its application fields (WSDA 2012). State records also indicate the Haak Dairy exported some of its animal waste to other landowners.

Figure 11 and Figure 12 show the Phase 3 sample locations associated with the Haak Dairy. The sampling locations include:

[24] "Number of Days of Lagoon Capacity" is an estimate of the maximum number of days a lagoon system could accept liquid dairy waste under normal operating conditions without having to be pumped out. It is intended to assess whether a lagoon system is sufficiently large enough to hold liquid waste generated by the dairy throughout the winter months, without having to be pumped out to the waste application fields when there are no crops growing that could take up the nutrients in the waste. It assumes the lagoon system was completely pumped out at the beginning of the time period.

- One residential drinking water well upgradient of the dairy (WW-01);
- One dairy supply well (WW-02);
- One dairy manure pile located on the dairy (SO-01);
- Two dairy lagoons from which three samples were collected (LG-01, LG-02, and LG-03). Lagoon samples LG-02 and LG-03 are from the same lagoon;
- One dairy application field sample (SO-02) and;
- Three downgradient residential drinking water wells (WW-03, WW-04, and WW-05).

1. HAAK DAIRY: GENERAL CHEMISTRY

The four types of general chemistry data collected at the Haak Dairy were: nitrate and other forms of nitrogen; major ions; minor ions and trace inorganic elements; and perchlorate. The results for each of these analyses are discussed below.

Haak Dairy: Nitrate and Other Forms of Nitrogen

Five water well samples, three dairy lagoon samples, one dairy manure pile sample, and one dairy application field sample were analyzed for several forms of nitrogen. The water wells and lagoons were analyzed for nitrate, nitrate plus nitrite, ammonia or ammonium (if in an aqueous solution), and TKN. The dairy manure pile and the dairy application field samples that were receiving dairy waste were analyzed for extractable nitrate-N (Nitrate-N Solid), extractable ammonia-N (Ammonia-N Solid), and total nitrogen by combustion (Total Nitrogen Solid).

In addition, the total nitrogen was calculated for each sample. Total nitrogen is the sum of nitrate, nitrite, and TKN. Using total nitrogen values allows a comparison between different locations. These calculated values are presented as "Calculated Total Nitrogen" in Table 9. The manure sample, SO-01, contained only 22 percent solids and was analyzed for TKN rather than total nitrogen by combustion. For SO-02, the total nitrogen equals the nitrate plus the TKN value. The total nitrogen for all other solid samples equals the nitrogen by combustion result.

Organic forms of nitrogen were not detected in the five water wells and therefore the total nitrogen values in Table 9 for the water wells are the sum of the nitrate plus nitrite concentrations. Nitrate and nitrite were not detected in the lagoon samples LG-01 or LG-03 and therefore the total nitrogen values in Table 9 for the two dairy lagoons are reflected by the TKN values. There is an increase in concentrations of total nitrogen between the upgradient well and the downgradient wells (Figure 12 and Table 9).

The dairy lagoons, dairy manure piles, and dairy application fields at the Haak Dairy are located between the upgradient and downgradient wells sampled and are a likely source of the increased nitrogen levels in the downgradient residential water wells. A WSDA inspection report indicates the Haak Dairy has used inorganic fertilizer on its application fields, in addition to animal wastes (WSDA 2012). In addition, the alkalinity concentrations are greater in the downgradient wells compared to the upgradient well, with the highest concentrations in the dairy lagoons.

Available information about the construction and depth of WW-03 and WW-04, the downgradient wells, suggest they are completed in the alluvial aquifer at depths of 95 feet and 88 feet. Information about the upgradient well, WW-01, is limited. Information on the construction of the dairy lagoons (if they are lined, and if so, with what material) would be useful to determine the extent to which they may be contributing to the increase in nitrogen concentrations. EPA formally requested this information from the Haak Dairy, but the information was not provided.

Table 9: Haak Dairy – Distribution of Total Nitrogen in Wells, Lagoons, a Manure Pile, and an Application Field.

Sample Location	Nitrate as N (ppm)	Nitrate + Nitrite as N (ppm)	Ammonia as N (ppm)	TKN as N (ppm)	Calculated Total Nitrogen (ppm)
Water Wells and Lagoons					
WW-01: Upgradient Well	0.38	0.39	ND	ND	0.39
WW-02: Dairy Supply Well	3.1	3.4	ND	ND	3.4
LG-01: Dairy Lagoon	NA	ND	1000 (J)	1200 (J)	1200
LG-02: Dairy Lagoon	NA	1.2 (J)	870 (J)	1400 (J)	1401
LG-03: Dairy Lagoon	NA	ND	870 (J)	1400 (J)	1400
WW-03: Downgradient Well	33.1	35.5	ND	ND	35.5
WW-04: Downgradient Well	51.9	55.0	ND	ND	55.0
WW-05: Downgradient Well	12.8	13.4	ND	ND	13.4

Dairy Manure Pile

Sample Location	Ammonia-N Solid (ppm)	Nitrate-N Solid (ppm)	Total Nitrogen Solid (ppm)	Total Nitrogen (ppm)
SO-01: Dairy Manure Pile	10,100	ND	29,700 (as TKN)	29,700

Dairy Application Field

Sample Location	Ammonium as N (ppm)	Nitrate + Nitrite as N (ppm)	Total Nitrogen Solid (ppm)	Total Nitrogen (ppm)
SO-02: Dairy Application Field	4.6	71.7	2760	2760

NA – Not analyzed.

ND – Not detected.

J – the analyte was positively identified, but the associated numerical value is an estimate.

Haak Dairy: Major Ions

Five wells and three dairy lagoon samples were analyzed for the major ions. Figure 13 shows the concentrations of six major ions (calcium, chloride, magnesium, potassium, sodium, and sulfate) in the upgradient well, the dairy lagoons, and the downgradient wells. The concentrations of these six ions all have higher concentrations in the downgradient wells and one or more of the lagoons than the upgradient well. Alkalinity shows a similar pattern.

The difference in concentrations from the upgradient well to downgradient wells ranges from up to a 3-fold increase for potassium; an 8–fold increase for magnesium; more than a 10-fold increase for calcium and sodium; more than a 30-fold increase for chloride and more than a 65-fold increase for sulfate.

Chloride is considered a conservatively transported ion (Freeze and Cherry 1979; Gooddy and others 2002), meaning that it typically flows with the groundwater unchanged and is unlikely to participate in reactions or be electrically attracted to minerals making up the aquifer matrix. Based on the observed concentrations, chloride and other ions are being introduced to the aquifer between the upgradient and downgradient wells at the Haak Dairy. One explanation for the observed increase in these major ions is that the dairy lagoons are introducing these ions to the groundwater. As with total nitrogen, this indicates that the Haak Dairy is a likely source of the major ions in the three downgradient residential drinking water wells at the Haak Dairy.

Haak Dairy: Minor and Trace Inorganic Elements

Five water well and three dairy lagoon samples were analyzed for minor and trace inorganic elements. Two metals, barium and zinc, which may be used at dairies, were detected in both the water wells and dairy lagoons (Table 10). There is an increase in the concentrations from the upgradient to the downgradient wells for both barium and zinc, with the highest concentrations in the lagoons. Other metals (chromium, copper, iron, and manganese) were detected in dairy lagoons, but were not found in the water wells. The dairy manure pile and dairy application field samples were not analyzed for minor or trace inorganic elements.

Table 10: Haak Dairy – Concentrations of Barium and Zinc in Wells and Lagoons

Location	Barium (µg/L)	Zinc (µg/L)
WW-01 – Upgradient Well	13.5	Not detected
WW-02 – Dairy Supply Well	32.7	5.4
LG-01 – Dairy lagoon	297	1790
LG-02 – Dairy lagoon	931	5410
LG-03 – Dairy lagoon	907	5260
WW-03 – Downgradient Well	135	21
WW-04 – Downgradient Well	178	12
WW-05 – Downgradient Well	164	15

Haak Dairy: Perchlorate

Perchlorate was analyzed only in the water well samples (Table C7 in Appendix C). The concentrations ranged from 0.14 micrograms per liter (µg/L) (WW-01) to 1.96 µg/L (WW-03). The results for the perchlorate analysis are evaluated together with the isotopic data because perchlorate was used as an indicator of potential accumulation of atmospherically derived nitrate associated with caliche soils (see Appendix D). Perchlorate was not evaluated in the dairy lagoon system because it is not expected to persist in the anoxic environment of a dairy lagoon.

2. HAAK DAIRY: MICROBIOLOGY

The water well samples were analyzed for total coliform and *E. coli* (Table C8 in Appendix C). Only one well (WW-04) had a detectable level of total coliform, but *E. coli* was not detected. MST was not completed for this well because *E. coli*, a form of fecal coliform, was not detected.

Samples from the three dairy lagoons were analyzed for fecal coliform. As would be expected, high concentrations of fecal coliform were found in the dairy lagoons. MST was performed on the samples from the three dairy lagoons. One of the samples (LG-01) indicated a ruminant source, while two of the samples (LG-02 and LG-03) indicated both human and ruminant sources. Lagoon samples LG-02 and LG-03 are collocated, so similar results for these samples are expected; however, it is unknown why the MST results for this dairy lagoon indicate human sources.

3. HAAK DAIRY: ORGANIC COMPOUNDS

The organic compounds evaluated included: pesticides; trace organics; pharmaceuticals; and hormones.

<u>Haak Dairy: Pesticides</u>

All the samples collected at the Haak Dairy were analyzed for pesticides; however, the laboratory was unable to quantify pesticide concentrations in the lagoon samples because of matrix interference (Table C9 in Appendix C).

Atrazine was the only pesticide detected in the water wells. Atrazine also was detected in one of the dairy application field samples. The concentrations of atrazine detected in the water wells and dairy application field sample at the Haak Dairy are summarized in Table 11. None of the water well samples exceeded the MCL for atrazine of 3.0 µg/L.

Table 11: Haak Dairy – Concentrations of Atrazine in Wells, a Manure Pile, and an Application Field

Location	Atrazine
WW-01 – Upgradient Well	0.015 (J) µg/L
WW-02 – Dairy Supply Well	0.041 (J) µg/L
WW-03 – Downgradient Well	Not Detected
WW-04 – Downgradient Well	0.015 (J) µg/L
WW-05 – Downgradient Well	0.11 (J) µg/L
SO-01 – Dairy Manure Pile	Not Detected
SO-02 – Dairy Application Field	1.1 (J) µg/kg

J – the analyte was positively identified, but the associated numerical value is an estimate.

Atrazine is an herbicide commonly used on corn fields and is frequently detected in groundwater beneath both urban and agricultural land uses (Barbash and others 1999). Both grain and silage corn is significant in dairy and other cattle livestock operations. The detection of atrazine at a higher concentration in one of the downgradient wells compared with the upgradient well indicates that there likely is a source from a crop field associated with the Haak Dairy; however, the presence of atrazine in the upgradient well indicates that the Haak Dairy is not the only source.

Three pesticides (Dicamba, Dacthal-DCPA, and 2,4-D) were found in the dairy manure pile sample from the Haak Dairy (SO-01). In addition to atrazine, five other compounds were detected in the dairy application field sample collected adjacent to the Haak Dairy (SO-02): 4-nitrophenol; pentachlorophenol; endosulfan sulfate; chlorpyrifos ethyl; and diuron. The dairy application field was historically planted with corn and triticale.

Haak Dairy: Trace Organics

Trace organic analysis was performed on the water well and lagoon samples, but not on the manure or soil samples collected at the Haak Dairy (Table C10 in Appendix C). One compound, bis-(2-ethylhexyl) phthalate, (DEHP) was detected in WW-01 (upgradient well) at a concentration of 2.66 µg/L and in WW-03 (downgradient well) at a concentration of 5.26 µg/L. The MCL for DEHP is 6.0 µg/L. Phthalates, such as DEHP, are compounds used in the manufacture of plastics to decrease the brittleness of containers and other objects. They are increasingly ubiquitous in the environment (EPA 2011).

Other trace organics were detected in the three Haak Dairy lagoons but not detected in any of the downgradient wells (Table C10 in Appendix C). Compounds found in all three dairy lagoons included fecal indicators (such as 3-beta-coprostanol and 3-methyl-1h-indole); plant sterols (for example, beta-sitosterol, beta-stigmastanol, and cholesterol); p-creosol; 4-nonylphenol-monoethoxylate; and phenol.

Haak Dairy: Pharmaceuticals

Analyses were conducted for two suites of pharmaceutical chemicals: wastewater pharmaceuticals and veterinary pharmaceuticals. The wastewater pharmaceuticals analyzed in this study are generally used by humans. Veterinary pharmaceuticals are used in veterinary practice and many can also be used to treat people.

There were no wastewater pharmaceuticals detected in the water well, dairy manure pile, or dairy application field samples. Thiabendzadole, which is used to treat worm infections in both livestock and humans and can be used as a pesticide (Mayo Clinic 2011), was detected in one dairy lagoon (LG-01) sample. DEET, an insect repellent, was detected in one dairy lagoon (LG-03) sample. A summary of the wastewater pharmaceutical data is provided in Table C11 in Appendix C.

Three veterinary pharmaceuticals (tetracycline, chlortetracycline, and monensin) were detected in one or more water wells, dairy lagoon, dairy application field or dairy manure pile sample. Detected concentrations for these three compounds are summarized in Table 12. Several additional veterinary compounds were detected in the dairy lagoons: LG-01 (eight compounds); LG-02 (nine compounds), and LG-03 (six compounds). Several compounds were also detected in the manure sample (SO-01: four compounds) and dairy application field sample (SO-02: five compounds). A summary of the veterinary pharmaceutical data is provided in Table C12 in Appendix C.

Tetracycline was detected in two of the downgradient wells (WW-03 and WW-04) and in the dairy lagoon, dairy manure pile, and dairy application field samples. The detections in all the dairy supply sources provides a good indication that tetracycline is used at the Haak Dairy. These data indicate that the Haak Dairy is a likely source of tetracycline in the two downgradient residential water wells.

Table 12: Haak Dairy – Concentrations of Pharmaceuticals in Wells, Lagoons, a Manure Pile, and an Application Field

Sample Location	Tetracycline	Chlortetracycline	Monensin
WW-01 – Upgradient Well	ND	ND	0.027 µg/L
WW-02 – Dairy Supply Well	ND	ND	ND
LG-01 – Dairy Lagoon	1.96 (J) µg/L	R	45.0 (J) µg/L
LG-02 – Dairy Lagoon	5.83 (J) µg/L	0.067 (J) µg/L	1086 (J) µg/L
LG-03 – Dairy Lagoon	2.88 (J) µg/L	R	420 (J) µg/L
SO-01 –Dairy Manure Pile	178 µg/kg	ND	441 µg/kg
SO-02 – Dairy Application Field	26.9 µg/kg	45.6 µg/kg	2.9 µg/kg
WW-03 – Downgradient Well	0.041 (J) µg/L	ND	0.028 µg/L
WW-04 – Downgradient Well	0.075 (J) µg/L	0.049 µg/L	0.023 µg/L
WW-05 – Downgradient Well	ND	ND	0.022 µg/L

J – the compound was positively identified, but the associated numerical value is an estimate.

ND – Not detected

R – the data is unusable for all purposes because of analytical problems with the sample.

Monensin was detected in the upgradient well (WW-01) and all three of the downgradient wells (WW-03, WW-04, and WW-05). Monensin was also detected in the Haak dairy lagoons, manure sample, and application field sample. The detection of monensin in the upgradient well indicates there is an upgradient source of this compound. The high concentrations of monensin seen in the Haak Dairy lagoon samples, manure pile, and application field sample indicate that it is used at the Haak Dairy. The data indicate that the Haak Dairy is a possible source of monensin in the three downgradient residential drinking water wells. Given the presence of monensin in the upgradient well, another source of monensin is likely.

Haak Dairy: Hormones

Hormone analysis was conducted by two laboratories. EPA's Ada Laboratory, analyzed water well and dairy lagoon samples for five hormones (Table C13 in Appendix C). Solid samples (soil and manure) were not analyzed by EPA's Ada Laboratory because the laboratory specializes in liquid samples and had not developed solid extraction techniques at the time of the study. Hormone analysis also was conducted by the UNL Laboratory. The UNL Laboratory analyzed both the liquid and solid samples, including the samples collected from water wells, dairy lagoons, dairy manure piles, and dairy application fields. The UNL's Laboratory hormone analysis includes 20 compounds (Table C14 in Appendix C), including the five hormones analyzed by EPA's Ada Laboratory.

EPA's Ada Laboratory did not detect hormones in any of the water well samples. EPA's Ada Laboratory detected 17-β-estradiol, 17-α-estradiol, and estrone in the three lagoons at the Haak Dairy, but did not detect 17-α-ethynyl-estradiol or estriol in the dairy lagoons.

The UNL Laboratory did not detect any of the five hormones analyzed by EPA's Ada Laboratory in water well samples. The UNL Laboratory detected testosterone in samples from all five wells and epitestosterone in one well (WW-04). Testosterone also was detected in LG-01 (See Table 13). Epistesterone was not detected in any of the dairy sources. Four hormones were detected in all three dairy lagoons (17-α-estradiol, α-zearalanol, and progesterone) and two hormones were detected in both the dairy manure pile and dairy application field samples (4-androstenedione, 17-α-estradiol) (Table C14 in Appendix C). The concentration of testosterone in the upgradient well (WW-01) was greater than in the downgradient wells (WW-03 to WW-05), although the highest concentrations were in LG-01.

Table 13: Haak Dairy – Concentrations of Testosterone in Wells, Lagoons, a Manure Pile, and an Application Field

Location	Testosterone
WW-01 – Upgradient Well	21 ng/L
WW-02 – Dairy Supply Well	16 ng/L
LG-01 – Dairy Lagoon	32 ng/L
LG-02 – Dairy Lagoon	Not Detected
LG-03 – Dairy Lagoon	Not Detected
SO-01 – Dairy Manure Sample	Not Detected
SO-02 – Dairy Application Field Sample	Not Detected
WW-03 – Downgradient Well	9 ng/L
WW-04 – Downgradient Well	12 ng/L
WW-05 – Downgradient Well	7 ng/L

ng/L – Nanograms per liter

4. Haak Dairy: Isotopic Analyses

As discussed in Section VII.D, isotopic analysis can indicate the general source, or combination of sources, or dominant processes acting on nitrogen in groundwater (Kendall 1998; Michener and Lajtha 2007). Stable isotopes of nitrate and ammonium can explain the possible origin and process that formed the nitrate in water wells. The ability to attribute nitrate in water wells to specific sources using isotopic analysis may be a useful supplement to other methods used to determine possible sources.

The three main sources of nitrate evaluated for their contribution to water wells using isotopic analysis were animal waste, synthetic fertilizer, and atmospheric deposition. Animal waste can include both human and non-human animal waste. Based on the isotopic results from this study, and the scientific literature, a $\delta^{15}N$-NO_3 value greater than 8.4‰ indicate that the likely dominant source of nitrate in water wells is animal waste. A $\delta^{15}N$-NO_3 value less than 2.0‰ indicate that the likely dominant source of nitrate in water wells is synthetic fertilizer. Values of $\delta^{15}N$-NO_3 between 2.0‰ and 8.4‰ indicate that the nitrate source is animal waste, synthetic fertilizer, or a combination of the two. $\delta^{18}O$-NO_3 values of 20‰ or higher were interpreted as evidence of some atmospheric contribution. The rationale for the selection of these values is in Appendix D. Table 14 below provides the specific results for the five water wells.

Table 14: Haak Dairy – Concentration of Nitrate in Wells, Isotopic Signatures, and the Interpreted Dominant Source of the Nitrate

Well Number	Nitrate-N (mg/L)[a]	$\delta^{15}N\text{-}NO_3$ (‰)	$\delta^{18}O\text{-}NO_3$ (‰)	Interpreted Dominant Source(s)[b]
WW-01	0.2	NM	NM	NM
WW-02	3.0	2.7	15	Indeterminate
WW-03	34	2.3	29	Fertilizer and/or Animal Waste[c] with Some Atmospheric Contribution
WW-04	49.9	3.5	-4.5	Fertilizer and/or Animal Waste
WW-05	12.8	9.7	7.1	Animal Waste

[a]The nitrate concentrations are from the UNL isotopic analysis.

[b]Interpretation of dominant sources is based on the following:

- $\delta^{15}N\text{-}NO_3$. Values less than 2.0 = dominated by synthetic fertilizer; values between 2.0 to 8.4 = undetermined mixture of synthetic fertilizer and/or animal waste; values greater than 8.4 = dominated by animal waste.
- $\delta^{18}O\text{-}NO_3$ values greater than 20.0‰ provide evidence for some atmospheric contribution. $\delta^{18}O\text{-}NO_3$ values below 20.0‰ could have an atmospheric contribution, but it becomes indistinguishable from other sources.

[c] Animal waste can be either human or non-human waste

NM – the sample was not measured because of the low nitrate concentrations.

The dominant source of nitrate for WW-05 is likely animal waste based on the interpretation of dominant sources indicated above for animal waste. The dominant sources for WW-02 are indeterminate given the low nitrate value. The dominant sources for WW-03 are likely synthetic fertilizer and/or animal waste with some atmospheric contribution, while the dominant sources for WW-04 are likely synthetic fertilizer and/or animal waste.

5. Haak Dairy: Age Dating

Age dating analysis was conducted on the water well samples to estimate the length of time since the water infiltrated from the surface to the aquifer, including transport time to the wells. The reported ages may not correspond to when the water became contaminated. Two SF_6 samples were collected from each well and the values were averaged (Table 15). The age of the water in the Haak Dairy supply well and the downgradient wells ranged from approximately 16 to 25 years.

Table 15: Haak Dairy – Results of Age Dating Analyses Performed for Wells Reported in Years Since the Water Infiltrated From the Surface to the Aquifer.

Sample Location	Sample Age (years)	Duplicate Age (years)	Average (years)
WW-01: Upgradient Well	Over Value[a]	Over Value	NA
WW-02: Supply Well	15.8	16.3	16.1
WW-03: Downgradient Well	24.8 (J)	25.8 (J)	25.3
WW-04: Downgradient Well	21.8 (J)	23.3 (J)	22.6
WW-05: Downgradient Well	18.3 (J)	20.8 (J)	19.6

[a] Over value means that the sample contained more SF_6 than can be explained by equilibrium with modern air.

J – the analyte was positively identified, but the associated numerical value is an estimate.

6. Haak Dairy: Summary of Results for Residential Water Wells

Table 16 summarizes the nitrate levels and compounds detected in the water wells upgradient and downgradient of the Haak Dairy and the compounds also detected in the source areas sampled on the dairy along with conclusions from the isotopic analysis. Total coliform, but not *E. coli* or fecal coliform, was detected in WW-04. The age of the water in the Haak Dairy supply well and the downgradient wells ranged from approximately 16 to 25 years.

All of the residential water wells except WW-01, the upgradient well, have nitrate levels that exceed the MCL of 10 mg/L. The concentration of total nitrogen, six major ions (chloride, calcium, magnesium, potassium, sodium, and sulfate), and two metals (barium and zinc) increased from the upgradient well to the downgradient wells at the Haak Dairy, with the highest concentrations detected in the dairy lagoon, dairy manure pile, and dairy application field samples. Alkalinity showed a similar pattern. Sample LG-01 was taken from liquid waste in a ditch just before entering the lagoon system and contained sulfate. Sulfate was not detected in co-located samples LG-02 and LG-03, likely because of anoxic conditions in the lagoon.

EPA evaluated four groups of organic compounds: pesticides; trace organics; pharmaceuticals; and hormones as part of this study. Atrazine was the only pesticide detected in the water well samples. Atrazine is widely used throughout the area, and the source is likely historical and current use of the pesticide, which may or may not be associated with dairy operations. EPA's Manchester Laboratory was unable to quantify the pesticide concentrations in the lagoon samples as a result of matrix interference. Atrazine was detected in the dairy field application sample. Several other pesticides were detected in the manure pile samples and application field samples but were not detected in the water wells.

The only trace organic detected in the water wells was bis-(2-ethylhexyl) phthalate (DEHP). DEHP was not detected in any of the dairy lagoons and was not analyzed for in the dairy manure pile or application field samples. Several trace organics were detected in all three dairy lagoons (for example, beta-sitosterol, beta-stigmastanol, and phenol) but not in the water wells.

Table 16: Haak Dairy – Comparisons of General Chemistry and Organic Compounds Detected in Wells and Dairy Operations and Assessment of Nitrate Sources in the Residential Wells Using Isotopic Analyses

Residential Well Number	Nitrate Concentration (mg/L)[a]	General Chemistry in Well	Organic Compounds Detected in Well	Organic Compounds also Detected in Dairy Sources	Dominant Source(s) of Nitrate Based on Isotopic Analyses
WW-01 Upgradient Well	0.38	No trends in total nitrogen or major ions as this is an upgradient well	Atrazine DEHP Testosterone Monensin	Not applicable. WW-01 is an upgradient well.	Not measured because lack of nitrate in sample
WW-03 Downgradient Well	34	Total nitrogen concentrations increased 90 –fold compared with the upgradient well. Three- to 65-fold increase in concentrations of six major ions compared with the upgradient well.	DEHP Tetracycline, Testosterone Monensin	Tetracycline (all dairy sources) Testosterone (LG-01) Monensin (all dairy sources)	Fertilizer and/or animal waste with some atmospheric contribution
WW-04 Downgradient Well	49.9	Total nitrogen concentrations increased over 100-fold compared with the upgradient well. Four- to 45-fold increase in concentrations of six major ions compared with the upgradient well.	Atrazine Tetracycline Chlortetracycline Testosterone Monensin	Atrazine (S0-02) Tetracycline (all dairy sources) Chlortetracycline (LG-02 and SO-02) Testosterone (LG-01) Monensin (all dairy sources)	Fertilizer and/or animal waste
WW-05 Downgradient Well	12.8	Total nitrogen concentrations increased more than 30-fold compared with the upgradient well. Four- to over 10-fold increase in concentrations of six major ions compared with the upgradient well.	Atrazine Testosterone Monensin	Atrazine (SO-02) Testosterone (LG-01) Monensin (all dairy sources)	Animal waste

[a] Nitrate results are from Cascade Analytical Laboratory

There were no wastewater pharmaceuticals detected in the water wells associated with the Haak Dairy. Thiabendzadole and DEET were each detected in one dairy lagoon while no compounds were detected in the manure pile or application field samples. For the veterinary pharmaceuticals, three compounds were detected in the water wells (chlortetracycline, tetracycline and monensin). Chlortetracycline was detected in one downgradient well and in one dairy lagoon and the application field sample. Tetracycline was detected in two of the three downgradient wells and in all three dairy lagoons, the dairy manure pile, and the dairy application field samples. Monensin was detected in the upgradient well and in the three downgradient wells. Monensin was detected in all the dairy lagoons and the dairy manure pile and dairy application field samples. Several additional compounds were detected in the dairy lagoons, dairy manure pile, and application field samples.

Two hormones were detected in water wells (testosterone and epitestosterone). Testosterone was detected in all five water wells with the highest concentration in the upgradient well, and in one lagoon but not in the manure pile or application field samples. Epitestosterone was detected in one downgradient well but not in any other source.

The isotopic data indicates that the source of nitrate in each of the wells varies. For WW-02, the source is indeterminate given the low nitrate value. The possible likely sources in WW-03 are fertilizer and/or animal waste with an atmospheric contribution. The dominant sources in WW-04 are likely fertilizer and/or animal waste. The likely dominant source in water well WW-05 is animal waste.

In conclusion, all of the residential water wells except WW-01 (the upgradient well as determined by general USGS flow direction) have nitrate levels above the MCL. The total nitrogen and major ions data indicate that the Haak Dairy is likely releasing nitrogen and six major ions to the groundwater and is a likely source of those higher levels in downgradient wells. The metals barium and zinc and alkalinity show a similar pattern. Information on the construction and depth of the upgradient well would be helpful to verify groundwater flow direction and clarify the contributions of sources to the higher concentrations seen from the upgradient well to the downgradient wells.

The Haak Dairy is a likely source of the tetracycline detected in the two downgradient residential water wells. The multiple detections of monensin in the Haak Dairy sources and in the downgradient wells indicates monensin is being used at the Haak Dairy and is a possible source in the downgradient wells. The isotopic data provide good evidence that animal waste (human or non-human) is a dominant contributor to the nitrate contamination for WW-05.

B. Dairy Cluster

The "Dairy Cluster" refers to a group of dairies north of the Yakima River. The Dairy Cluster is located about 2 miles north of the town of Liberty, near the northern edge of the irrigated area in the Yakima Valley. George DeRuyter & Son Dairy and the D and A Dairy are treated as two separate facilities, although they have some common ownership ("DeRuyter Dairy" and "D and A Dairy"- see Figure 14). Cow Palace 1 and 2 comprise a single facility ("Cow Palace" - see Figure

14). Liberty Dairy and Bosma Dairy are adjacent to one another and share some facilities and so are treated as a single facility ("Liberty and Bosma Dairies" - see Figure 14). The facilities generally consist of cow pens, milking parlors, animal waste lagoons, and animal waste application fields. Irrigation ditches run through the dairy properties.

EPA selected these dairies for this study because they met the criteria identified in the study plan (see Section VI.C.1). Specifically, the Dairy Cluster has: high concentration of animals per acre[25]; dairy inspection reports (WSDA 2012) indicate that elevated levels of nitrogen had been measured in dairy application fields in the past; the dairies are located near the northern edge of cultivated land in the Valley with relatively few upgradient potential sources of nitrogen; and drinking water wells downgradient of the dairies showed levels of nitrate significantly elevated above the MCL.

Numbers of Animals and Amount of Waste Generated

The WSDA provides the ranges for the number of animals at the Dairy Cluster facilities and the amount of waste generated including the estimated losses during storage of the waste (WSDA 2010) (See Table 17).

As a group, in 2009 the dairy cluster had more than 17,240 mature dairy cattle, and more than 7,000 heifers/calves. As discussed above, a farm with 2500 dairy cattle is similar in waste load to a city of 411,000 people (EPA 2004). A difference lies in the fact that human waste is treated before discharge into the environment, but animal waste is either not treated at all or minimally treated before discharge into the environment (EPA 2004). Applying this estimate to the Dairy Cluster range of 17,240 to 19,378 mature dairy cattle, the Dairy Cluster produces an amount of waste similar to a community of more than 2,827,000 people.[26] This estimate is based only upon the numbers of mature dairy cattle. It does not include the additional waste load of heifers and calves. For comparison, the human population of Yakima County in 2010 was 243,231.[27]

Sizable amounts of nitrogen, a component of manure, are generated by the dairies. Nitrogen production can be roughly estimated for each dairy by applying the ranges of the numbers of animals to formulas used by the WSDA to estimate manure and nitrogen production (WSDA 2010). As a whole, the Dairy Cluster generates more than 500,000 tons of manure each year equating to more than 3,100 tons of nitrogen.

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[25] Cow Palace had 23 cows per acre. The number of cows per acre at specific Yakima County dairies ranged from 1 to 34. Cow Palace had the second-highest ratio in the county (WSDA 2010). Cows per acre ratios are not static and have changed since EPA began this study.

[26] Calculations: "Mature dairy cattle estimate": 5,700 cows + 6,840 cows +4,700 cows = 17,240 cows (low end of range for each dairy). 411,000 persons divided by 2500 dairy cows equals 164 persons per cow. 17,240 cows times 164 persons per cow equals 2,827,360 persons. Rounded off to the nearest thousand equals 2,827,000 persons.

[27] U.S. Census Bureau: http://quickfacts.census.gov/qfd/states/53/53077.html

Table 17: Dairy Cluster – Approximate Numbers of Dairy Cattle, Annual Manure Production, and Annual Nitrogen Production

Mature Dairy Cattle	Heifers and Calves	Annual Manure Production (tons) [a]	Annual Nitrogen Production as Excreted [b] (tons)	Annual Nitrogen After 35% Losses Occur [c] (tons)
Liberty and Bosma Dairies				
5,700 to 6,839	1,000 to 1,999	155,040 to 193,950	984 to 1,220	640 to 793
Cow Palace				
More than 6,840	2,000 to 2,999	More than 188,570	More than 1,200	More than 780
DeRuyter and D and A Dairies				
4,700 to 5,699	More than 4,000	More than 161,460	More than 977	More than 635

[a]Annual manure production is calculated using the following formula: [((# of milking cows)*1.4*108) + ((# of dry cows)*1.4*51) + ((# of heifers)*0.97*56) + ((# of calves *0.33*83)]*365/2000 (WSDA 2010)

[b]Nitrogen production is calculated using the following formula: [((# of milking cows)*1.4*.71) + ((# of dry cows)*1.4*.3) + ((# of heifers)*0.97*.27) + ((# of calves *0.33*.42)]*365/2000 (WSDA 2010)

[c]Losses caused by volatilization or denitrification during storage are estimated at 35%. This estimate does not include application losses.

The WSDA estimates that during storage at a typical dairy, about 35 percent of the nitrogen in dairy waste is "lost" through the process of volatilization or denitrification (WSDA 2010). The formula does not assume any leakage into the subsoils from the lagoons or other structures or conveyances. If the remaining nitrogen is not taken up by crops grown on application fields or transported offsite to another location, it may end up in the groundwater. For the Dairy Cluster as a whole, more than 2,050 tons of nitrogen remain after losses.

WASTE MANAGEMENT

The dairies in the Dairy Cluster use a variety of animal waste storage methods, including lagoon systems, dry stacking, manure pits, composting, above ground tanks, and (at the DeRuyter Dairy) an anaerobic digester.

All the facilities in the Dairy Cluster use their own lagoon systems to store animal wastes. The nitrogen-rich liquids that leak through the bottom and sides of the lagoons can migrate downward through the soil column to the drinking water aquifer. EPA estimated the surface areas of the Dairy Cluster lagoon systems using aerial photographs. The lagoon systems' storage capacities were derived from WSDA inspection reports (Table 18).

Table 18: Dairy Cluster – Lagoon System Surface Area, Storage Capacity, and Approximate Leakage Rate

Dairy	Approximate Lagoon System Liquid Surface Area (square feet)	Lagoon System Storage Capacity (gallons)[28]	Estimated Lagoon System Leakage, Based on Unit Seepage Rate of 500 Gallons per Acre per Day (gallons per year)	Estimated Range of Lagoon System Leakage, Based on Ham Seepage Rate Range (gallons per year)
Liberty and Bosma Dairies	932,600	67,000,000	3,744,000	1,700,000 to 20,000,000
Cow Palace	400,000	40,800,000	1,606,000	720,000 to 8,600,000
DeRuyter and D and A Dairies	508,400	33,000,000	2,041,000	910,000 to 11,000,000

In combination, the Dairy Cluster lagoon systems have a surface area of approximately 1,841,000 square feet (equivalent to about 32 football fields – assumes a football field is 57,600 square feet). The lagoons have a combined maximum storage capacity of about 126,800,000 gallons, the equivalent volume of about 192 Olympic-size swimming pools (assumes the capacity of an Olympic-size swimming pool is 660,000 gallons).

As discussed previously, the NRCS Washington recommends avoiding the use of "agricultural waste storage ponds" (lagoons), unless no reasonable alternative exists, at locations like the Dairy Cluster where there is an aquifer that serves as a domestic water supply (NRCS Washington 2004). Assuming the same unit seepage rate as for the Haak Dairy (500 gallons per acre per day), seepage volume at the Dairy Cluster is approximately 7,391,000 gallons per year. This is the equivalent volume of about 11 Olympic-size swimming pools annually.

Based on the Ham and DeSutter study (Ham 2002), a lined lagoon system with a similar surface area would release approximately 3,330,000 to 39,600,000 gallons per year into the underlying soils, the equivalent of about five to 60 volumes of Olympic-size swimming pools annually.

Leakage rates for the Dairy Cluster lagoons would likely be greater than the above estimates if the lagoons are unlined, especially if they are constructed in well drained, highly permeable soils. If the lagoons are lined with a plastic liner, the actual leakage rates could be lower, although plastic liners are easily punctured during construction and lagoon maintenance and, therefore, also leak. The most effective liner system incorporates both plastic and clay layers.

[28] Lagoon systems are generally designed to hold about one third of a dairy's annual liquid waste generation (the amount that would be generated over a four month time period).

EPA requested information from the Dairy Cluster dairies about how their lagoons are constructed, but they declined to provide the information. EPA has asked Yakima County, the WSDA, the Washington Department of Ecology, and the NRCS if any of the Dairy Cluster lagoons have engineered liners, but none of the agencies could affirm that they do. EPA is unaware of any state or local requirements that would compel dairies in Yakima County to construct lagoons to any specific level of permeability.

Utilization rates of the lagoon systems vary and are indicated in the WSDA inspection reports (WSDA 2012). Table 19 provides a summary of the lagoon system information contained in the inspection reports. A dashed line indicates no information was provided in the reports for a particular data element.

Table 19: Dairy Cluster – Washington State Department of Agriculture Inspection Dates and Reported Values for Lagoon Capacity

Date of Inspection	Lagoon Capacity (gallons)	Number of Days of Lagoon Capacity[a]	Percent of Lagoon Capacity Utilized at Time of Inspection	Number of Lagoons
Liberty and Bosma Dairies				
3/2/1011	67,000,000	-----	-----	17
1/26/2010	67,000,000	120 days plus	60%	13
4/24/2008	67,000,000	120 days plus	60%	-----
7/18/2006	67,000,000	1 year plus	60%	-----
Cow Palace				
3/25/2010	9,400,000	4 months plus	75%	-----
12/18/2008	-----	-----	60%	-----
7/7/2008	9,400,000	4 months plus	80%	-----
9/5/2006	9,400,000	120 days	100%	-----
DeRuyter Dairy				
1/25/2011	25,000,000	-----	-----	4
12/4/2008	19,000,000	4 months plus	30%	-----
1/11/2007	-----	-----	70%	-----
D and A Dairy				
1/25/2011	8,000,000	-----	-----	5
12/4/2008	9,000,000	4 months plus	35%	-----
1/11/2007	-----	-----	60%	-----

[a]"Number of Days of Lagoon Capacity" is an estimate of the maximum number of days a lagoon system could accept liquid dairy waste under normal operating conditions without having to be pumped out. It is intended to assess whether a lagoon system is sufficiently large enough to hold liquid waste generated by the dairy throughout the winter months, without having to be pumped out to the waste application fields when there are no crops growing that could take up the nutrients in the waste. It assumes the lagoon system was completely pumped out at the beginning of the time period.

SURFACE SOILS

Surface soils in Yakima County have been characterized and mapped by the U.S. NRCS (NRCS 2012). A soil report has been developed for each of the dairies (EPA 2012a) and is summarized in Appendix B. Almost all the surface soils underlying the Dairy Cluster have a "well drained" classification, which means water moves readily through the soil.

More than 80 percent of the surface soils underlying the Dairy Cluster have a high saturated hydraulic conductivity. The percentage of surface soils with a "high" saturated hydraulic conductivity at the dairies is approximately: 88 percent at the Liberty and Bosma Dairies; 82 percent at the Cow Palace; and 93 percent at the DeRuyter and D and A Dairies. The permeability of the surface soils at the different dairies is more fully described in Appendix B.

Animal waste applied to crop fields can be a significant source of nitrogen loading to the soil, groundwater, and surface water. Applying large quantities of animal wastes on highly permeable surface soils (i.e., soil with a high hydraulic conductivity) increases the risk of groundwater contamination because water from irrigation or precipitation can readily infiltrate the soil surface and carry nitrogen past the root zone before it can be taken up by plants (EPA 2004). Agronomic nitrogen application rates are typically based on soil types and crop yield goals. However, agronomic nitrogen application rates are not necessarily protective of drinking water.

APPLICATION FIELDS

All the dairies in the Dairy Cluster apply animal wastes as fertilizer onto application fields that they own or lease according to WSDA inspection reports (WSDA 2012). Corn and triticale (a cross of wheat and rye) are typical crops grown by dairies because they have high nitrogen needs and can be used as feed. Animal waste application fields can be a significant source of nitrogen loading to the soil and potentially the groundwater and surface water.

n general, Washington law restricts WSDA ability to disclose to the public the exact size of application fields, but WSDA can release the information in ranges (WSDA 1996). The Liberty Dairy and Bosma Dairy own or lease between 1,800 and 2,500 acres of application fields; the Cow Palace owns or leases between 551 and 900 acres; and the DeRuyter Dairy and D and A Farms Dairy own or lease between 3,201 and 4,000 acres (WSDA 2010).

The dairies employ a variety of animal waste application methods, including spreaders ("honey wagons"), "big gun" sprinklers, sprinkler irrigation systems, dry spreaders, and custom applicators. If a dairy does not have enough land on which to apply the waste within agronomic rates, excess waste may be transferred offsite to another user.

WSDA inspectors noted in their reports for the Dairy Cluster that elevated levels of nitrogen were detected in some of its application fields in the past (WSDA 2012). Excessive amounts of nitrogen on highly permeable, irrigated surface soils pose a threat to groundwater. In addition, WSDA records indicate the dairies in the Dairy Cluster exported some of their animal wastes to other landowners.

For this study, the samples were collected from the following dairies: DeRuyter Dairy; D and A Dairy; Cow Palace; and Liberty and Bosma Dairies. Figures 11 and Figures 15 show the sample locations for the Dairy Cluster. The sampling locations include:

- One upgradient drinking water well (WW-06) located north (upgradient) of the other sample locations in the Dairy Cluster.
- Dairy supply wells located on the DeRuyter Dairy (WW-07); D and A Dairy (WW-08); and Cow Palace (WW-09). The supply well at the Liberty and Bosma Dairies was not sampled because it has a water treatment system.
- One dairy manure pile sample was collected from each of the following dairies: DeRuyter Dairy (SO-03), D and A Dairy (SO-05); Cow Palace (SO-07); and Liberty and Bosma Dairies (SO-09).
- Twelve dairy lagoon samples:
  - DeRuyter Dairy (LG-04, LG-05, and LG-06. These samples were collected from three separate lagoons);
  - D and A Dairy (LG-07, LG-08, and LG-09. LG-08 and LG-09 were collocated);
  - Cow Palace (LG-10, LG-11, and LG-12. LG-11 and LG-12 were collocated); and
  - Liberty Dairy (LG-13 and LG-14) and Bosma Dairy (LG-15). These samples were collected from three separate lagoons.
- Four dairy application field samples;
  - DeRuyter Dairy (SO-04);
  - D and A Dairy (SO-06);
  - Cow Palace (SO-08); and
  - Liberty and Bosma Dairies (SO-10).
- Eight downgradient residential drinking water wells (WW-10 to WW-17).

1. DAIRY CLUSTER: GENERAL CHEMISTRY

The four types of general chemistry data collected at the Dairy Cluster were: nitrate and other forms of nitrogen; major ions; minor ions and trace inorganic elements; and perchlorate. Each of these is discussed below.

<u>Dairy Cluster: Nitrate and Other Forms of Nitrogen</u>

Twelve water well and 12 dairy lagoon samples were analyzed for nitrate, nitrate plus nitrite, ammonia or ammonium, and TKN. The dairy manure pile and dairy application field samples were analyzed for extractable nitrate-N (Nitrate-N Solid), extractable ammonia-N (Ammonia-N Solid), and total nitrogen by combustion (Total Nitrogen Solid). Table 20 summarizes the nitrate and other forms of nitrogen data. In addition, total nitrogen from all forms was calculated for each sample and is presented as “Calculated Total Nitrogen” in Table 20.

Table 20: Dairy Cluster – Distribution of Total Nitrogen in Wells, Dairy Lagoons, Manure Piles, and Application Fields

Location	Nitrate as N (ppm)	Nitrate + Nitrite as N (ppm)	Ammonia as N (ppm)	TKN as N (ppm)	Calculated Total Nitrogen (ppm)
Water Wells and Lagoons					
WW-06: Upgradient Well	0.71	0.73	ND	ND	0.73
WW-07: Supply Well	1.02	1.19	ND	ND	1.19
WW-08: Supply Well	11.7	12.9	ND	ND	12.9
WW-09: Supply Well	ND	ND	ND	ND	ND
LG-04: Lagoon	NA	ND	920 (J)	1600 (J)	1600
LG-05: Lagoon	NA	ND	1200 (J)	1600 (J)	1600
LG-06: Lagoon	NA	ND	1200 (J)	1800 (J)	1800
LG-07: Lagoon	NA	3.1 (J)	950 (J)	1700 (J)	1703
LG-08: Lagoon	NA	ND	730 (J)	1200 (J)	1200
LG-09: Lagoon	NA	ND	760 (J)	1100 (J)	1100
LG-10: Lagoon	NA	ND	190 (J)	380 (J)	380
LG-11: Lagoon	NA	ND	240 (J)	500 (J)	500
LG-12: Lagoon	NA	ND	240 (J)	290 (J)	290
LG-13: Lagoon	NA	2.5 (J)	970 (J)	1700 (J)	1703
LG-14: Lagoon	NA	ND	860 (J)	1400 (J)	1400
LG-15: Lagoon	NA	ND	560 (J)	900 (J)	900
WW-10: Downgradient Well	ND	ND	ND	ND	ND
WW-11: Downgradient Well	22.3	23	ND	ND	23
WW-12: Downgradient Well	45	46.7	ND	ND	46.7
WW-13: Downgradient Well	41.4	44	ND	ND	44
WW-14: Downgradient Well	40.9	43.4	ND	ND	43.4
WW-15: Downgradient Well	29.4	30.2	ND	ND	30.2
WW-16: Downgradient Well	22.3	23.4	ND	ND	23.4
WW-17: Downgradient Well	21.7	22.7	ND	ND	22.7

Dairy Manure Piles

Location	Ammonia-N Solid (ppm)	Nitrate-N solid (ppm)	Total Nitrogen Solid (ppm)	Total Nitrogen (ppm)
SO-03: Manure	1470	32.8	9210	9210
SO-05: Manure	1060	43.1	13600	13600
SO-07: Manure	3600	18.9	16100	16100
SO-09: Manure	1700	5.69	13700	13700

Dairy Application Fields

Location	Ammonium as N (ppm)	Nitrate + Nitrite as N (ppm)	Total Nitrogen Solid (ppm)	Total Nitrogen (ppm)
SO-04: Application field	7.3	247	2110	2110
SO-06: Application field	6.8	45.6	960	960
SO-08: Application field	2.9	84.3	3040	3040
SO-10: Application field	7.1	139	3590	3590

J – the analyte was positively identified, but the associated numerical value is an estimate.

Figure 15 shows the concentration of total nitrogen for the samples collected at the Dairy Cluster. As with the Haak Dairy, the total nitrogen concentrations are higher in the downgradient wells compared with the upgradient well, with several significant sources of nitrogen in between (such as dairy lagoons, dairy manure piles, and dairy application fields). The concentration of nitrate in the upgradient well is within background range. Nitrate concentrations in some downgradient wells are more than four times the MCL. The data suggest that the Dairy Cluster is a likely source of the increased nitrogen levels in the downgradient wells.

Dairy Cluster: Major Ions

Figures 16a, 16b, and 16c shows the concentrations of several major ions in the upgradient water wells, the supply wells, the lagoons, and the downgradient wells. An average concentration for the three lagoon samples collected in each of the four areas was calculated (LG-04, LG-05, and LG-06; LG-07, LG-08, and LG-09; LG-10, LG-11, and LG-12; and LG-13, LG-14, and LG-15). The average concentrations were calculated for the four sets of lagoon samples to allow for easier comparison of the data.

The figures show a similar pattern to that observed at the Haak Dairy, with elevated concentrations in the downgradient wells (WW-10 to WW-17) compared with the upgradient wells (WW-06) and the supply wells (WW-07 to WW-09), with the highest concentrations in the lagoons. Alkalinity also showed a similar pattern. The increase in the concentrations ranges from up to: seven-fold for sodium; nine-fold for magnesium; 10-fold for calcium; and more than 30-fold for chloride. Potassium showed a slight increase. As with the Haak Dairy, sulfate showed the largest increase in concentration between the upgradient and downgradient wells. As with the Haak Dairy, the dairy sources are a likely source of major ions in the downgradient water wells.

Dairy Cluster: Minor Ions and Trace Inorganic Elements

All water well and dairy lagoon samples were analyzed for minor ions and trace elements, but the dairy manure pile and dairy application field samples were not analyzed (Table C6 in Appendix C). The trace inorganic elements found in both the water wells and the dairy lagoons included barium, iron, manganese, mercury, and zinc. Barium was detected in all 11 wells, iron was detected in five wells, manganese was detected in four wells, mercury was detected in one well, and zinc was detected in eight wells. Barium was the only trace inorganic element that increased between the upgradient well and the downgradient wells, with the highest concentrations in the lagoons.

Dairy Cluster: Perchlorate

Perchlorate analysis was performed on all of the water samples collected from wells near the dairies (Table C7 in Appendix C). The concentrations ranged from less than the detection limit (0.003 µg/L) to 3.08 µg/L (WW-17). Perchlorate analysis was conducted to augment the isotopic data as an indicator of potential accumulation of atmospherically derived nitrate associated with caliche soils. The dairy lagoon samples were not analyzed for perchlorate because this compound is rapidly degraded in anoxic environments, such as a dairy lagoon.

2. Dairy Cluster: Microbiology

There were no detections of total coliform, fecal coliform, or *E. coli* in the water well or supply well samples associated with the Dairy Cluster with the exception of water well WW-06 which had a detectable level of total coliform. *E. coli* was not detected in WW-06 and therefore MST was not completed for this well or for any of the wells because there was no indication of fecal contamination.

All the dairy lagoons in the Dairy Cluster were analyzed for fecal coliform. Samples LG-04 through LG-09 also were analyzed for *E. coli* and MST was performed. *E. coli* or MST analyses were not performed on the other lagoon samples (LG-10 to LG-15) because EPA's mobile microbiology laboratory was available to participate in the sampling effort for only a limited period of time (Table C8 in Appendix C).

All the dairy lagoons had high levels of fecal coliform. Of the six dairy lagoons evaluated using MST, five indicated a ruminant source (LG-04, LG-05, LG-06, LG-07, and LG-08) while one indicated both a ruminant and a human source (LG-09). It is unknown why human waste was detected in LG-09 at the D and A Dairy, given that this facility likely is on a septic system.

3. Dairy Cluster: Organic Compounds

Dairy Cluster: Pesticides

Four pesticides (atrazine, bentazon, alachlor, and ioxynil) were detected in the water wells associated with the Dairy Cluster. Atrazine, bentazon, and alachlor are pesticides commonly used in agricultural crop production. Ioxynil is not registered for use in the United States (PAN 2011).

- Atrazine: WW-06 (upgradient well) and downgradient wells WW-12, WW-13, WW-14, WW-15, WW-16, and WW-17
- Bentazon:WW-08 (dairy supply well)
- Alachlor:WW-13 and WW-17
- Ioxynil: WW-13

No results are reported for pesticides in the dairy lagoon samples because the laboratory experienced problems with interferences as a result of the complex nature of the sample media. The four pesticides detected in the water wells were not detected in the dairy manure pile or dairy application field samples.

The concentrations of atrazine found in the water wells ranged from 0.016 µg/L to 0.19 µg/L. None of the samples exceed the MCL for atrazine of 3 µg/L. Alachlor levels found in two water wells were 0.048 µg/L and 0.057 µg/L. None of the samples exceed the MCL for alachlor of 2 µg/L. The concentration of bentazon in water well WW-08 was 0.036 µg/L. The concentration of ioxynil in well sample WW-13 was 0.063µg/L. There are no MCLs established for bentazon or ioxynil.

The four pesticides are not anticipated to be used in animal operations at the dairies for pest control (Pike 2004), but atrazine, alachlor, and bentazon are commonly used in corn production.

Each of the dairies includes crop land where pesticides may have been applied. Given the historical use of these pesticides and the detection of these compounds in other studies, it is likely that these pesticides are from the current and historical use of pesticides for agriculture, which could include application by the dairies on the associated fields. See Table C9 in Appendix C for all the results.

Seven pesticides were detected in one or more of the dairy manure pile samples. These pesticides were not detected in the water well samples. Seven pesticides were also detected in one or more of the field application samples, but they were not detected in the water well samples.

Dairy Cluster: Trace Organics

Three compounds were detected in water well samples associated with the Dairy Cluster:

- Bis-(2-ethylhexyl) phthalate (DEHP) in WW-06 (upgradient well), WW-11, and WW-17
- Naphthalene in WW-07 (supply well)
- Tetrachloroethylene in WW-07 (supply well).

Of the three compounds found in water wells, only DEHP was found in one dairy lagoon sample (LG-10). DEHP is a common plasticizer and could come from a variety of sources. Naphthalene and tetrachloroethylene were not detected in any of the dairy lagoons.

All 12 dairy lagoons associated with the Dairy Cluster had one or more detection of trace organics (Table C10 in Appendix C). Eight compounds were detected in all 12 dairy lagoons associated with the Dairy Cluster. These compounds are generally the same as those detected at the Haak Dairy: 3-beta-coprostanol; 3-methyl-1h-indole (skatol); 4-nonyphenol monoethoxylate; beta-sitosterol; beta-stigmastanol; cholesterol; p-cresol; and phenol. Trace organics were not analyzed in manure or soil samples.

Dairy Cluster: Pharmaceuticals

Only one wastewater pharmaceutical, DEET, was detected in a single downgradient well (WW-10). There were no detections of any of the wastewater pharmaceuticals in the dairy manure pile or dairy field application samples. Three wastewater pharmaceutical compounds were detected in dairy lagoons associated with the Dairy Cluster: DEET (eight dairy lagoons); diphenhydramine (two dairy lagoons); and thiabendazole (three dairy lagoons). The source of the DEET could be its use as an insect repellent. The source of the diphenhydramine in the dairy lagoons is unknown. Diphenhydramine is a common antihistamine used by people and can be used on dogs and cats. Thiabendzadole is a parasiticide that is used to treat worm infections in both livestock and humans and can be used as a pesticide (Mayo Clinic 2011).

Table 21 indicates the veterinary pharmaceuticals that were detected in one or more water well samples and in the dairy lagoons, dairy manure piles, and dairy application field samples. Five veterinary pharmaceuticals were detected in the water wells (chlortetracycline, monensin, tetracycline, tylosin, and virginiamycin). Veterinary pharmaceuticals were not detected in water wells WW-12 and WW-16 and lagoon sample LG-04.

Table 21: Dairy Cluster – Concentrations of Five Veterinary Pharmaceuticals in Wells, Lagoons, Manure Piles, and Application Fields

Sample Location[a]	Chlortetracycline	Monensin	Tetracycline	Tylosin	Virginiamycin
Upgradient Water Well (reported as µg/L)					
WW-06	ND	ND	0.051 (J)	ND	ND
Dairy Supply Wells (reported as µg/L)					
WW-07	ND	0.109	0.041 (J)	ND	0.023 (J)
WW-08	ND	ND	5.17	ND	ND
WW-09	ND	0.023	ND	ND	ND
Dairy Lagoons (reported as µg/L)					
LG-05	0.075 (J)	430.2 (J)	4.48 (J)	1.7(J)	0.334 (J)
LG-06	ND	463.8 (J)	5.41 (J)	10.22(J)	R
LG-07	R	R	0.442 (J)	0.184 (J)	R
LG-08	R	449.6 (J)	6.07 (J)	R	R
LG-09	R	337.7 (J)	3.6 (J)	1.07 (J)	R
LG-10	0.079 (J)	2.24 (J)	6.55 (J)	R	0.816 (J)
LG-11	R	85 (J)	1.76 (J)	R	0.413 (J)
LG-12	R	135 (J)	1.91 (J)	R	0.314 (J)
LG-13	R	662 (J)	10.3 (J)	0.139 (J)	0.184 (J)
LG-14	R	498 (J)	8.6 (J)	R	R
LG-15	R	426 (J)	7.55 (J)	R	1.0 (J)
Dairy Manure Piles and Dairy Application Fields (reported as µg/kg)					
SO-03	0.7	109	954	14.8	ND
SO-04	0.6	5.1	27.4	2.1	ND
SO-05	17.7	1329	17.9	ND	ND
SO-06	3.0	5.1	16.5	ND	ND
SO-07	2303	283	2484	21.1	ND
SO-08	13.5	7.9	104	ND	ND
SO-09	ND	437	309	ND	ND
SO-10	ND	7	53	ND	ND
Downgradient Water Wells (reported as µg/L)					
WW-10	ND	0.499	ND	ND	ND
WW-11	ND	ND	0.038	0.029	ND
WW-13	ND	ND	ND	ND	0.041
WW-14	ND	0.033	ND	ND	0.024
WW-15	0.119	ND	ND	ND	ND
WW-17	ND	ND	0.049	ND	ND

[a]Water wells WW-12 and WW-16 had no detections and dairy lagoon sample LG-04 had no detections of these five compounds.

J – the compound was positively identified, but the associated numerical value is an estimate.

ND – not detected.

R – the data are unusable for all purposes because of analytical problems with the sample.

Monensin was not detected in the upgradient well. Monensin was detected in WW-10 and WW-14, and was also detected in all the dairy lagoons (exception of LG-07), dairy manure piles, and dairy application field samples. These detections indicate that monensin is likely used at the dairies in the Dairy Cluster. The dairies are a likely source of the monensin in WW-10 and WW-14. This conclusion is reinforced by the isotopic findings, which indicate that the source of nitrate for WW-14 is animal waste (although animal waste can be either human or non-human).

Tetracycline was detected in the upgradient well (WW-06) and in two downgradient wells, which had lower concentrations than the upgradient well (WW-11 and WW-17). Tetracycline was detected in all of the dairy lagoon samples, dairy manure pile samples, and dairy application field samples, indicating that tetracycline is used at the dairies. It is possible that the dairy sources are one of the sources of the tetracycline in the downgradient wells. However, given that the concentrations in the upgradient well are higher than the downgradient wells, another source for the tetracycline is likely.

Tylosin was detected in one downgradient well (WW-11) and five of the dairy lagoons, along with several dairy manure pile and dairy application field samples. Virginiamycin was detected in two downgradient wells (WW-13 and WW-14) and six dairy lagoons but not in any of the dairy manure piles or application field samples. Chlortetracycline was detected in dairy lagoons and manure and soil samples and in one downgradient well (WW-15). The data suggest the dairies are possible sources of these substances in the downgradient wells.

Several other veterinary pharmaceutical compounds (ractopamine, sulfachloropyridazine, sulfadimethoxine, sulfamethazine, and sulfathiazole) were detected in the majority of dairy lagoon, dairy manure pile, and dairy application field samples but were not detected in downgradient water wells. This finding would indicate they are being used by the dairies in the Dairy Cluster.

<u>Dairy Cluster: Hormones</u>

EPA's Ada Laboratory analyzed the liquids samples (water wells and dairy lagoons), but not the solids samples (dairy manure pile and dairy application fields) for five hormones. The laboratory did not detect any of the five hormones in water wells associated with the Dairy Cluster; however three of these five hormones (17-α-estradiol, 17-β-estradiol, and estrone) were detected in all 12 of the dairy lagoons. The hormones 17-α-ethyl-estradiol and estriol were not detected in any of the Dairy Cluster lagoon samples (Table C13 in Appendix C).

The UNL Laboratory analyzed the Dairy Cluster liquids and solids samples for 20 hormones, including the five hormones that the EPA's laboratory analyzed. The UNL Laboratory detected 17-α-estradiol in the upgradient well (WW-06) and in one supply well (WW-08) but not in any of the downgradient wells. The UNL Laboratory also detected 17-β-estradiol and estrone in one supply well (WW-09).

For all the 20 hormones analyzed by UNL, four were detected in an upgradient well or in a downgradient well (17-α-estradiol, androstadienedione, androsterone, and testosterone) (Table 22).

Table 22: Dairy Cluster – Concentrations of Four Hormones in Wells, Lagoons, Manure Piles, and Application Fields

Sample Location[a]	17-α-Estradiol[b]	Androstadienedione[b]	Androsterone[b]	Testosterone[b]
Upgradient Water Well (reported as µg/L)				
WW-06	0.003	ND	ND	0.005
Dairy Supply Wells (reported as µg/L)				
WW-08	0.003	0.002 (J)	ND	0.003
WW-09	ND	ND	0.005 (J)	0.008
Dairy Lagoons (reported as µg/L)				
LG-05	ND	3.50	ND	0.193
LG-06	ND	ND	ND	0.195
LG-07	ND	ND	ND	0.016
LG-08	0.383	ND	ND	0.090
LG-09	0.844	ND	ND	0.007
LG-10	0.459	ND	ND	0.028
LG-11	2.92	0.166	ND	ND
LG-12	3.27	0.20	ND	0.024
LG-13	ND	ND	ND	0.262
LG-14	ND	ND	ND	0.170
LG-15	ND	ND	ND	ND
Dairy Manure Piles and Dairy Application Fields (reported as µg/kg)				
SO-03	34.7	29.4	ND	2.95
SO-05	ND	15.4	ND	ND
SO-06	0.11	ND	ND	ND
SO-07	18.7	13.5	ND	ND
SO-09	16.9	19.3	ND	ND
Downgradient Water Wells (reported as µg/L)				
WW-11	ND	ND	ND	0.004
WW-12	ND	0.004 (J)	0.018 (J)	ND
WW-15	ND	ND	0.019 (J)	ND
WW-17	ND	ND	0.008 (J)	ND

[a]The four hormones were not detected in dairy supply well (WW-07), four downgradient water wells (WW-10, WW-13, WW-14, and WW-16), one dairy lagoon (LG-04) and three dairy application field samples (SO-04, SO-08, and SO-10).

[b] Analyses were conducted by the UNL Laboratory

J – the compound was positively identified, but the associated numerical value is an estimate.

ND – not detected.

The hormone 17-α-Estradiol was detected in the upgradient well and in several of the dairy lagoons and dairy manure pile samples but not in any of the downgradient wells. Androstadienedione was detected in one downgradient water well and several dairy lagoons and dairy manure pile samples. Androsterone was detected in three downgradient wells but not in any of the dairy sources. Testosterone was detected in the upgradient well and two downgradient wells and in the majority of the dairy lagoons. The concentration in the upgradient well was greater than the downgradient wells. It is possible that the dairies are a source of androstadienedione and testosterone in the downgradient wells; however, given the detection of testosterone in an upgradient well, other sources are likely.

4. Dairy Cluster: Isotopic Analysis

Isotopic analyses were completed for water wells WW-06 to WW-17 (Table 23) by the UNL Laboratory. There was insufficient nitrate in WW-06, WW-09, and WW-10 to complete the analysis. Additional details on the results of isotopic analyses conducted for this study are provided in Appendix D of this report.

Table 23: Dairy Cluster – Concentration of Nitrate in Water Wells, Isotopic Signatures, and the Interpreted Dominant Source of the Nitrate Based on the Observed Values

Location	Nitrate-N (mg/L)[a]	$\delta^{15}N\text{-}NO_3$ (‰)	$\delta^{18}O\text{-}NO_3$ (‰)	Interpreted Dominant Source(s)[b]
WW-06	0.6	NM	NM	NM
WW-07	1.1	-0.1	NM	Fertilizer
WW-08	11.7	5.3	23	Fertilizer and/or Animal Waste[c] with Some Atmospheric Contribution
WW-09	NM	NM	NM	NM
WW-10	NM	NM	NM	NM
WW-11	21.6	3.0	18	Fertilizer and/or Animal Waste
WW-12	43.6	6.2	-1.4	Fertilizer and/or Animal Waste
WW-13	42	11	16	Animal Waste
WW-14	40.7	10	8.5	Animal Waste
WW-15	27.4	5.2	30	Fertilizer and/or Animal Waste with Some Atmospheric Contribution
WW-16	23	5.9	5.8	Fertilizer and/or Animal Waste
WW-17	23.3	6.9	2.5	Fertilizer and/or Animal Waste

[a] The nitrate concentrations are from the UNL isotopic analysis.

[b] Interpretation of dominant sources is based on the following:

- $\delta^{15}N\text{-}NO_3$. Values less than 2.0 = dominated by synthetic fertilizer; values between 2.0 to 8.4 = undetermined mixture of synthetic fertilizer or animal waste; values greater than 8.4 = dominated by animal waste.
- $\delta^{18}O\text{-}NO_3$ values greater than 20.0‰ provide evidence for some atmospheric contribution. $\delta^{18}O\text{-}NO_3$ values below 20.0‰ could have an atmospheric contribution, but it becomes indistinguishable from other sources.

[c] Animal waste can include both human and non-human waste

NM – the sample was not measured because of the low nitrate concentrations.

The dominant source of nitrate for WW-13 and WW-14 is likely animal waste while the dominant source of nitrate for WW-07 is likely fertilizer. The dominant sources of nitrate for WW-11, WW-12, WW-16, and WW-17 is likely a combination of synthetic fertilizer and/or animal waste while the dominant sources for WW-08 and WW-15 is likely a combination of synthetic fertilizer and/or animal waste with some atmospheric contributions.

5. Dairy Cluster: Age Dating

Table 24 presents the age dating data and, similar to the Haak Dairy, two samples were collected for each water well.

Table 24: Dairy Cluster – Results of Age Dating Analyses Performed for Wells Reported in Years Since the Water Infiltrated From the Surface to the Aquifer

Location	Sample Age	Duplicate Age	Average of Samples	Average of Group
WW-06 – Upgradient	16.3 (J)	15.8 (J)	16.1	16.1
WW-07 – Supply Well	36.3 (J)	32.8 (J)	34.6	42.5
WW-08 – Supply Well	35.3 (J)	40.8 (J)	38.1	
WW-09 – Supply Well	58.3 (J)	51.3 (J)	54.8	
WW-10 – Downgradient Well	44.3 (J)	44.8 (J)	44.6	31.6
WW-11 – Downgradient Well	Over Value[a]	Over Value[a]	NA	
WW-12 – Downgradient Well	Over Value[a]	Over Value[a]	NA	
WW-13 – Downgradient Well	24.3 (J)	23.8 (J)	24.1	
WW-14- Downgradient Well	30.8	29.3	30.1	
WW-15 – Downgradient Well	27.8 (J)	28.3 (J)	28.1	
WW-16 – Downgradient Well	29.8 (J)	28.8 (J)	29.3	
WW-17 – Downgradient Well	33.3 (J)	33.8 (J)	33.6	

[a] "Over value" means that the sample contained more SF_6 than can be explained by equilibrium with modern air.

J – the compound was positively identified, but the associated numerical value is an estimate.

Averages were calculated for the upgradient well (WW-06), three supply wells (WW-07, WW-08, and WW-09), and the six downgradient wells with reported values (WW-10, WW-13, WW-14, WW-15, WW-16, and WW-17). The results indicate the youngest water was sampled in the upgradient well, with an average age of 16.1 years, which suggests that it is a relatively shallow well and is consistent with its upgradient location. The reported ages may not correspond to when the water became contaminated. The oldest waters were in supply wells associated with the Dairy Cluster, with an average age greater than 40 years. The average age of the waters in the downgradient wells was 31.6 years. These relative ages are generally consistent with available well log information indicating that the dairy supply wells are typically screened in the basaltic aquifer, and the downgradient residential wells are commonly screened in the shallower alluvial aquifer.

6. Dairy Cluster: Summary of Results for Residential Water Wells

Table 25 provides a summary of the groups of compounds (general chemistry and organic compounds) and analytical techniques (isotopic analyses) that provide information useful to address the question of the likely sources of the nitrate for the nine residential water wells associated with the Dairy Cluster. No microbial contamination was found in the downgradient wells. There appears to be a correlation between the age dating data and the well depths for those water wells that have well depth information (see Appendix A3).

As with the Haak Dairy, the nitrate levels in residential wells downgradient of the Dairy Cluster are greater than EPA's MCL for nitrate with the exception WW-10. Nitrate levels in the Dairy Cluster supply wells were generally low, with the exception of WW-08. This well serves the DeRuyter Dairy and D and A Dairy and was measured at 11.7 mg/L, which exceeds the MCL for nitrate. The well is located immediately downgradient of one of the DeRuyter Dairy's waste application fields.

The total nitrogen data show increasing concentrations from the upgradient well, past several sources of nitrogen, and to the downgradient wells. The downgradient wells contain substantially more nitrogen than is present in the upgradient well. The major ion concentrations, especially for calcium and chloride, increase between the dairy sources (dairy lagoons, dairy manure piles, and dairy application fields) and the downgradient wells with high nitrate. This pattern was also seen for barium and alkalinity.

For the organic compounds, four pesticides were detected in the water wells associated with the Dairy Cluster. However, none of these pesticides was detected in the dairy manure pile or dairy application field samples and as stated above the lagoon samples could not be quantified because of matrix interference problems.

Three trace organics were detected in water wells (DEHP, naphthalene, and tetrachloroethylene). Naphthalene and tetracycline were detected in a dairy supply well, while DEHP was detected in one downgradient well. Several of the trace organic compounds were found in all of the 12 dairy lagoons (for example, 3-beta-coprostanol; beta-sitosterol, and phenol).

For the wastewater pharmaceuticals, one water well had a detected level of DEET while there were three compounds detected in dairy lagoons (DEET; diphenhydramine; and thiabendazole). There were no detected levels in the dairy manure piles or application field samples.

Veterinary pharmaceuticals were detected in 10 water wells. Chlortetracycline was detected in one downgradient well, two dairy lagoons, and six manure pile or application field samples. Monensin was detected in two supply wells and two downgradient wells and in all but one of the dairy sources. Tetracycline was detected in the upgradient water well, two supply wells, and two downgradient wells and all of the dairy sources. Tylosin was detected in one downgradient well and several dairy sources while virginiamycin was detected in one supply well and two downgradient wells and several dairy lagoon samples.

Table 25: Dairy Cluster – Comparisons of Major Ions and Organic Compounds Detected in Samples from Wells and Dairy Operations and Assessment of Nitrate Sources in the Wells Using Isotopic Analyses

Residential Well Number	Nitrate Concentration (mg/L)[a]	General Chemistry in Well	Organic Compounds Detected in Well	Organic Compounds also Detected in Dairy Sources	Dominant Source(s) of Nitrate Based on Isotopic Analyses
WW-06 Upgradient Well	0.6	No trends in total nitrogen or major ions as this is an upgradient well	Atrazine, DEHP Tetracycline α-Estradiol testosterone	Not applicable. WW-06 is an upgradient well.	Not measured because lack of nitrate in sample
WW-10 Downgradient Well	Not Detected	No large trends in total nitrogen or major ions between WW-06 and WW-10	DEET Monensin	DEET (8 lagoons) Monensin (all the dairy sources except LG-07)	Not measured because lack of nitrate in sample
WW-11 Downgradient Well	21.6	Total nitrogen concentration increased 30-fold compared with the upgradient well Three to 25-fold increase in concentration of five major ions compared with the upgradient well.	DEHP Tetracycline Tylosin Testosterone	DEHP (LG-10) Tetracycline (all dairy sources) Tylosin (5 lagoons, 2 manure pile, and one application field sample) Testosterone (9 lagoons and one manure pile sample)	Fertilizer and/or animal waste
WW-12 Downgradient Well	43.6	Total nitrogen concentration increased more than 60-fold compared with the upgradient well Five to almost 20-fold increase in concentration of five major ions compared with the upgradient well.	Atrazine Androstadienedione Androsterone	Androstadienedione (three lagoons and 4 manure samples)	Fertilizer and/or animal waste

Residential Well Number	Nitrate Concentration (mg/L)[a]	General Chemistry in Well	Organic Compounds Detected in Well	Organic Compounds also Detected in Dairy Sources	Dominant Source(s) of Nitrate Based on Isotopic Analyses
WW-13 Downgradient Well	42.0	Total nitrogen concentration increased more than 60-fold compared with the upgradient well Six to more than 35-fold increase in concentration of five major ions compared with the upgradient well.	Alachlor Atrazine Ioxynil Virginiamycin	Virginiamycin (6 lagoons)	Animal waste
WW-14 Downgradient Well	40.7	Total nitrogen concentration increased almost 60-fold compared with the upgradient well. Two to almost 50-fold increase in concentration of six major ions compared with the upgradient well.	Atrazine Monensin	Monensin (All the dairy sources except LG-07)	Animal waste
WW-15 Downgradient Well	27.4	Total nitrogen concentration increased more than 40-fold between compared with the upgradient well. Two to more than 20-fold increase in concentration of six major ions compared with the upgradient well.	Atrazine Chlortetracycline Androsterone	Chlortetracycline (2 lagoons, all manure and application fields except SO-09 and SO-10)	Fertilizer and/or animal waste with some atmospheric contribution
WW-16 Downgradient Well	23.0	Total nitrogen concentration increased more than 30-fold compared with the upgradient well. Three to almost 30-fold increase in concentration of five major ions compared with the upgradient well.	Atrazine		Fertilizer and/or animal waste
WW-17 Downgradient Well	23.3	Total nitrogen concentration increased more than 30-fold compared with the upgradient well. Four to almost 30-fold increase in concentration of five major ions compared with the upgradient well.	Alachlor Atrazine DEHP Tetracycline Androsterone	DEHP (LG-10) Tetracycline (all dairy sources)	Fertilizer and/or animal waste

[a]Nitrate results are from Cascade Analytical Laboratory

ND – Not Detected

Four hormones were detected in either the upgradient well or downgradient water wells and in a dairy source. The hormone 17-α-Estradiol was detected in the upgradient well and in several of the dairy sources but not in the downgradient wells. Androstadienedione was detected in one supply well, one downgradient well, and several dairy sources. Androsterone was detected in one supply well and three downgradient wells but not in any dairy sources. The concentration of testosterone was higher in the upgradient well than in the one downgradient well where testosterone was detected. The majority of dairy lagoons had testosterone detections.

The isotopic analysis indicates that the dominant nitrogen source for two downgradient wells is animal waste (WW-13 and WW-14) while the dominant source for dairy supply well WW-07 is fertilizer. The other wells show a mixture of animal waste and fertilizer as a source. Wells WW-08 and WW-15 have some atmospheric nitrogen contribution in addition to animal waste and fertilizer.

In conclusion, all the downgradient residential water wells (with the exception of WW-10) associated with the Dairy Cluster have nitrate levels greater than the MCL. The data for total nitrogen and major ions indicate an increase in concentrations from the upgradient well to the downgradient wells, with the dairy lagoons, dairy manure piles, or dairy application fields likely sources. Barium and total alkalinity also show similar patterns.

Monensin and tetracycline were detected in the majority of dairy sources and in downgradient wells. Tetracycline was detected in two of the downgradient residential water wells and at a similar concentration in the upgradient well. It is possible that the dairies are sources of tetracycline, but given the concentration of tetracycline in the upgradient well was higher than the concentrations in the downgradient residential water wells, another source of tetracycline is likely. The dairy sources are a likely source of the monensin detected in the downgradient wells. These compounds were not detected in samples from the wastewater treatment plants influents, which suggests septic systems are not a likely source.

The hormone testosterone was detected in downgradient residential drinking water wells and dairy sources, although the concentration in the upgradient well is similar to the concentrations in the downgradient wells. It is possible that the dairies are a source of testosterone, but given the concentration of testosterone in the upgradient well, another source is likely.

C. Irrigated Cropland

Another likely source of nitrate in drinking water wells is nitrogen-rich fertilizers, such as inorganic synthetic fertilizer and manure applied to irrigated crops. As part of this study EPA looked at two fields each for three crops: mint, hops, and corn. EPA collected soil samples from six fields that were located upgradient from six residential drinking water wells which had been tested and found to exceed the MCL for nitrate. In each field, thirty soil subsamples at a depth of approximately one inch were collected and composited for analysis. Each downgradient water well and its associated soil sample is shown in Figure 11 and Table 26 along with the USDA NRCS soil type.

Table 26: Irrigated Cropland –Well Sample Locations and Associated Soil Samples, Crop Types and Soil Types

Water Well Sample	Associated Soil Sample	Crop Owner	Crop Type	USDA NRCS Soil Type
WW-23	SO-11	Schilperoort Farm	Mint	Warden Silty Loam
WW-24	SO-12	Havilah Farm	Mint	Warden Silty Loam
WW-25	SO-13	Wheeler Farm	Corn	Warden Silty Loam
WW-28	SO-14	Sunny Dene Ranch	Corn	Hezel Loamy Fine Sand & Cleman Very Fine Sandy Loam
WW-26	SO-15	Golden Gate Hops	Hops	Hezel Loamy Fine Sand
WW-27	SO-16	Golden Gate Hops	Hops	Warden Silty Loam

EPA contacted the cropland owners about crop history and fertilizer use. Information about the corn and mint fields is presented in Table 27; however, the hop field owners did not respond. All farmers stated that the application of fertilizer was determined by periodic crop or soil sampling. In addition, one of the corn field owners (SO-14) identified his field as an application field for waste from his dairy.

Table 27: Irrigated Cropland – Crop Field History and Fertilizer Use

Soil Sample ID	Current Crop	Crop Field History	Fertilizer History
SO-11	Mint	Planted with mint for past 23 years.	Synthetic fertilizer only.
SO-12	Mint	Planted with mint for past 4 years.	Mix of compost and synthetic fertilizer.
SO-13	Corn	Planted with corn for at least the past 5 years.	Synthetic fertilizer only.
SO-14	Corn	Planted with corn since 2010. Planted with alfalfa in 2008 and 2009. Planted with hops prior to 2008.	Manure in the fall and synthetic fertilizer during the growing season.
SO-15	Hops	No information was provided by the crop field owner.	No information was provided by the crop field owner.
SO-16	Hops	No information was provided by the crop field owner.	No information was provided by the crop field owner.

Soil types in the parcels selected for sampling in this study were from two USDA NRCS soil units. Warden soils are silt loams which are wind deposited silts, which lie on terraces of the Yakima River or on lake sediments deposited during the last glacial period. Warden soils are deep and well drained with little likelihood to retain nutrients which infiltrate beyond the root zone. Hezel soil is loamy fine sand. Hezel soils are formed in lacustrine sediment and have a mantel of eolian sand. Hezel soils are well drained with rapid permeability in the upper loamy fine sand part, dropping to moderately slow in the underlying stratified material. The rapid infiltration provides little opportunity for attenuation of any excess nutrients moving beyond the root zone. (See EPA 2012a for detailed soil reports for the six crops.)

The soil samples were analyzed for several forms of nitrogen, pesticides, pharmaceuticals, and hormones. They were not analyzed for major ions, trace inorganic elements, perchlorate, microbiology, trace organics, isotopic analysis, or age dating analysis.

1. IRRIGATED CROPLAND: GENERAL CHEMISTRY

Irrigated Cropland: Nitrate and Other Forms of Nitrogen

All of the water wells sampled downgradient of the irrigated cropland had nitrate levels greater than the MCL of 10 mg/L. Soil samples were analyzed for several forms of nitrogen, including extractable nitrate (nitrate-N), extractable ammonium (ammonia-N), and total nitrogen by combustion. Table 28 shows the measured values for these forms of nitrogen in these crop soils. If irrigation is applied above crop demand the levels of nitrate in the soils, if not reduced either by uptake by growing plants, volatilization, or denitrification, could ultimately move out of the root zone and become a source of groundwater contamination.

Table 28: Irrigated Cropland – Concentrations of Nitrogen in Soil Samples Collected From Mint, Corn, and Hop Fields Near Wells WW-23 to WW-28

Soil Sample/Crop	Nitrate-N (ppm)	Ammonium-N (ppm)	Total N by Combustion (ppm)
SO-11/Mint	245	210	3330
SO-12/Mint	191	8.2	2350
SO-13/Corn	24.3	7.5	1100
SO-14/Corn	6.3	12	1180
SO-15/Hops	83.5	21	2210
SO-16/Hops	26.5	7.7	3000

2. IRRIGATED CROPLAND: MICROBIOLOGY

There were no detections of total coliform, fecal coliform, or *E. coli* in the six water wells. The crop samples were not evaluated for microbiology.

3. IRRIGATED CROPLAND: ORGANIC COMPOUNDS

Irrigated Cropland: Pesticides

Atrazine and bentazon were the only pesticides detected in the water wells. Atrazine was detected in WW-24 and WW-26 and bentazon was detected in WW-23 and WW-24. Atrazine was not detected in any of the crop soil samples, while bentazon was detected in SO-11 (mint field) and SO-12 (mint field). Bentazon is used for selective control of weeds in beans, rice, corn, peanuts, and mint (ETN 1993). Bentazon was detected in two water wells and crop soil samples associated with each other (WW-23 and SO-11 and WW-24 and SO-12) (Table 29). This result indicates that the bentazon applied to the mint fields is likely migrating to groundwater and the water wells. Fifteen other pesticides were detected in crop soil samples, but not detected in the associated water wells (Table C9 in Appendix C).

Table 29: Irrigated Cropland – Concentrations of Atrazine and Bentazon in Wells WW-23 to WW- 28 and in Nearby Crop Soil Samples

Water Well and Soil Sample Location (Crop)	Concentration of Atrazine	Concentration of Bentazon
WW-23 SO-11 (Mint)	ND ND	0.028 (J) µg/L 38 µg/kg
WW-24 SO-12 (Mint)	0.017 (J) µg/L ND	0.033 (J) µg/L 2 (J) µg/kg
WW-25 SO-13 (Corn)	ND 1.6 (J) µg/kg	ND ND
WW-26 SO-15 (Hops)	0.025 (J) µg/L ND	ND ND
WW-27 SO-16 (Hops)	ND ND	ND ND
WW-28 SO-14 (Corn)	ND 0.7 (J) µg/kg	ND ND

J – the compound was positively identified, but the associated numerical value is an estimate.

Irrigated Cropland: Pharmaceuticals

There were no detections of wastewater pharmaceuticals in the water wells or the crop soil samples.

Nine veterinary pharmaceuticals were detected in one well (WW-26). Monensin was the only compound detected in a water well (WW-26 at 0.319 µg/L) and its associated soil sample (SO-15 at 4.5 µg/kg). The other compounds detected in water well WW-26 (erythromycin, lincomycin, ractopamine, sulfamethazine, sulfamethoxazole, sulfathiazole, tiamulin, and virginiamycin) were not detected in the associated crop soil sample. There were no detections of any veterinary pharmaceuticals in any of the other water wells.

Four veterinary pharmaceuticals were detected in the crop soil samples.

- SO-11: Oxytetracycline
- SO-12: Oxytetracycline
- SO-13: No detections
- SO-14: Oxytetracycline
- SO-15: Monensin, oxytetracycline, and tetracycline
- SO-16: Monensin, oxytetracycline, tylosin, and tetracycline.

Irrigated Cropland: Hormones

EPA's Ada Laboratory analyzed the six water well samples for five hormones (17-α-estradiol, 17-β-estradiol, estrone, 17-α-ethyl-estradiol and estriol). The laboratory did not detect any of the five hormones in the water wells.

The UNL Laboratory analyzed the water wells and associated soil samples for 20 hormones, including the five hormones that the EPA's Ada Laboratory analyzed. The UNL Laboratory detected six hormones in one well WW-27 (17-α-estradiol, androstadienedione, 17-β-trenbolone, androsterone, epitestosterone, and testosterone). These six compounds were not detected in the crop soil sample (SO-16) associated with WW-27. The UNL Laboratory did not detect any hormones in the other five water wells.

Five hormones were detected in crop soil samples (Table C14 in Appendix C).

- SO-11: Androstadienedione and progesterone
- SO-12: 4-androstenedione, 17-α-estradiol, and progesterone
- SO-13: Melengesterol acetate
- SO-14: No detections
- SO-15: 4-androstenedione, androstadienedione, and progesterone
- SO-16: 4-androstenedione and progesterone

4. Irrigated Cropland: Isotopic Analyses

An isotopic analysis was performed for six wells associated with the irrigated croplands. Table 30 provides the results for these six wells. Additional details on the results of isotopic analyses conducted for this study are provided in Appendix D of this report.

The dominant source for WW-24 is fertilizer, while the dominant source for WW-27 is animal waste. For the other water wells, the potential sources are likely to be a combination of fertilizer and animal waste for WW-23, WW-25, and WW-26 and a combination of fertilizer and animal waste with some atmospheric contribution for WW-28.

Table 30: Irrigated Cropland - Concentration of Nitrate in Wells, Isotopic Signatures, and the Interpreted Dominant Source(s) of the Nitrate Based on Observed Values

Location	Nitrate-N (mg/L)[a]	$\delta^{15}N-NO_3$ (‰)	$\delta^{18}O-NO_3$ (‰)	Interpreted Dominant Source(s)[b]
WW-23 (Mint)	17.3	2.2	18.0	Fertilizer and/or Animal Waste
WW-24 (Mint)	14	-0.3	12	Fertilizer
WW-25 (Corn)	32.9	2.4	15	Fertilizer and/or Animal Waste
WW-26 (Hops)	15.1	7.5	6.3	Fertilizer and/or Animal Waste
WW-27 (Hops)	19.9	8.8	17	Animal Waste
WW-28 (Corn)	69.6	5.5	44	Fertilizer and/or Animal Waste with Some Atmospheric Contribution

[a]The nitrate concentrations are from the UNL isotopic analysis.

[b]Interpretation of dominant sources is based on the following:

- ♦ $\delta^{15}N-NO_3$. Values less than 2.0 = dominated by synthetic fertilizer; values between 2.0 to 8.4 = undetermined mixture of synthetic fertilizer and/or animal waste; values greater than 8.4 = dominated by animal waste.
- ♦ $\delta^{18}O-NO_3$ values greater than 20.0‰ provide evidence for some atmospheric contribution. $\delta^{18}O-NO_3$ values below 20.0‰ could have an atmospheric contribution, but it becomes indistinguishable from other sources.

5. Irrigated Cropland: Age Dating

The age dating data for the six wells associated with the irrigated crops is presented in Table 31. The values for the water wells are younger than for any other group of samples in the study. The reported ages may not correspond to when the water became contaminated.

Table 31: Irrigated Cropland – Results of Age Dating Analyses Performed for Wells Reported in Years Since the Water Infiltrated From the Surface to the Aquifer

Location	Sample Age	Duplicate Age	Average
WW-23 (Mint)	Over Value[a]	Over Value	NA
WW-24 (Mint)	14.8 (J)	15.8 (J)	15.3
WW-25 (Corn)	10.3	9.8	10.1
WW-26 (Hops)	12.8 (J)	11.8 (J)	12.3
WW-27 (Hops)	Over Value	14.3 (J)	14.3
WW-28 (Corn)	Over Value	Over Value	NA

[a]"Over Value" means that the sample contained more SF_6 than can be explained by equilibrium with modern air.
J – the analyte was positively identified, but the associated numerical value is an estimate.

6. Irrigated Cropland: Summary of Results for Residential Wells

Table 32 summarizes information on the nitrate concentrations in the water wells along with any organic compounds detected in the water wells and the associated crop soil samples and the dominant source of nitrate based on the isotopic analysis. No microbial contamination was found in the downgradient wells.

Bentazon and atrazine were the only pesticides detected in the water wells associated with the six crop field soil samples. Bentazon was detected in the soil samples associated with water wells at two sites: SO-11/WW-23 and SO-12/WW-24. Atrazine was detected in two of the wells, but not in the associated soil samples.

Nine veterinary pharmaceuticals were detected in one well (WW-26). Monensin was the only veterinary pharmaceutical detected in the associated soil sample (SO-15) which was collected from a hop field. There were no detections of any veterinary pharmaceuticals in the other five water wells. Three hormones were detected in one well (WW-27) but were not detected in the associated soil sample (SO-16). Of these three hormones, 17- β-trenbolone is a synthetic growth hormone used exclusively in beef cattle (not dairy cows), while the other two hormones are natural compounds. The source of the 17- β-trenbolone is unknown. There were no detections in any hormones in the other five water wells.

The isotopic data indicate that fertilizer is a dominant source of nitrate in water well WW-24 which is downgradient of a mint field. The dominant source of nitrate in water well WW-27 which is downgradient of a hops field is animal waste (human or non-human).

Table 32: Irrigated Cropland – Comparisons of Organic Compounds Detected in Samples from Wells and Croplands and Assessment of Nitrate Sources in the Wells Using Isotopic Analyses

Water Well Location	Nitrate Concentration in Wells (mg/L)[a]	Summary of Organic Compounds Detected in Water Wells	Associated Crop Location	Summary of Organic Compounds Detected in Wells and Associated Crop Fields	Dominant Source(s) of Nitrate in Wells Based on Isotopic Analyses
WW-23	16.0	Bentazon	SO-11 (mint)	Bentazon	Fertilizer and/or Animal Waste
WW-24	13.8	Atrazine Bentazon	SO-12 (mint)	Bentazon	Fertilizer
WW-25	33.4	No detects	SO-13 (corn)	Nothing to compare	Fertilizer and/or Animal Waste
WW-26	15.3	Atrazine, erythromycin, lincomycin, monensin, ractopamine, sulfamethazine, sulfathiazole, tiamulin, and virginiamycin	SO-15 (hops)	Monensin only compound also detected in soil sample	Fertilizer and/or Animal Waste
WW-27	19.8	17-a-estradiol, androstadienedione 17- β-trenbolone, testosterone, androsterone, and epitestosterone	SO-16 (hops)	These compounds were not detected in soil samples	Animal Waste
WW-28	71.2	No detects	SO-14 (corn)	Nothing to compare	Fertilizer and/or Animal Waste with Atmospheric Contribution

[a]Nitrate results are from Cascade Analytical Laboratory.

In conclusion, the nitrate levels in all the water wells associated with the crop samples were above the nitrate MCL. Bentazon and monensin were the only compounds detected in water wells and the associated crop soil samples. This finding suggests that bentazon and monensin detected in the crop field soil are likely migrating to groundwater and nearby water wells. Possible manure application to the hop field could account for the monensin detected in the downgradient residential well.

Some of the cropland soils are well drained and highly permeable. High nitrogen crops planted on such soils and especially those that utilize rill irrigation may pose a threat to the aquifer (see Appendix G, Figure 1).

D. Residential Septic Systems

Four residential water wells (WW-19, WW-20, WW-21, and WW-22) were identified to evaluate whether high nitrate concentrations could be coming from septic systems (Figure 11). These wells were selected because they are in residential areas served by septic systems, but are not located near dairies or crop fields. To conduct this evaluation, samples were collected from the wastewater entering the treatment plants located in Zillah (SP-01), Mabton (SP-02), and Toppenish (SP-03 and SP-04). Sample SP-04 was collected because additional sample volume was requested for SP-03 by EPA's Manchester Laboratory. Sample SP-04 was collected on a different day and was assigned a different sample number. The laboratory did not need the extra volume to supplement sample SP-03 so sample SP-04 was analyzed for the same compounds as SP-03. Samples SP-03 and SP-04 are not duplicate samples because they were collected at different times.

The treatment plant influent samples were collected to serve as surrogates for septic systems by providing a characterization and quantification of compounds that are found in rural septage. EPA recognizes that these WWTPs may receive substances that are not found in residential septic systems (for example they may also receive commercial and industrial waste streams). The WWTPs sampled serve rural communities and are sufficiently similar to residential septic systems for the purposes of this study. This approach was used to determine whether the compounds detected in wells with high nitrate concentrations in areas with a high density of septic systems are similar to the compounds detected in WWTP influent or whether these wells are affected by other sources.

Samples collected from the WWTPs were analyzed for the same compounds as the water well samples, excluding the analysis for nitrate, pesticides, perchlorate, and age dating (Table C2). Nitrate was not analyzed in the WWTP influent samples as there would be very little formation of nitrate from the organic nitrogen in the waste because of the low oxygen environment of the sewer system. EPA's Manchester Laboratory attempted to analyze the pesticides in the WWTPs influent samples. However, the laboratory reported that because of significant interferences from the large number of organic compounds present in the waste, the pesticide concentrations could not be quantified. Perchlorate and age dating analyses were not conducted because the influent was composed of water co-mingled from many sources.

Although four wells were selected for this evaluation, all of the residential wells were compared with the WWTP data to determine whether septic systems are a likely source of the nitrate found in any Phase 3 well in the study.

1. Septic Systems: General Chemistry

The WWTP influent samples were collected to serve as surrogates for septic system influent and to characterize compounds found in rural septic systems. While the major ions and trace elements were measured for the WWTP and water wells, the results are not summarized here as there are no upgradient wells that can be used to compare the results.

Septic Systems: Nitrate and other Forms of Nitrogen

The nitrate levels in the four water wells were all greater than the MCL of 10 mg/L. The water wells also were evaluated for different forms of nitrogen. Ammonium and TKN were not detected in any of these wells indicating all detectable nitrogen was in the form of nitrate. No analysis similar to that conducted for the Haak Dairy and Dairy Cluster is possible because no upgradient wells were sampled for comparison.

2. Septic Systems: Microbiology

As found with other water wells in the study, neither total coliform, fecal coliform nor *E. coli* were detected in the four selected water wells. The WWTP influent samples were analyzed for fecal coliform and *E. coli*. (Table C8 in Appendix C). As expected, very high concentrations of both fecal coliform and *E. coli* were found in the influent to the WWTPs. Samples were also analyzed using MST to identify the source of the fecal contamination. Three of the samples indicated human sources, while one sample indicated both human and ruminant sources.

3. Septic Systems: Organic Compounds

Septic Systems: Pesticides

Atrazine and bentazon were detected in one well (WW-20). There were no pesticides detected in the other three water wells (WW-19, WW-21, and WW-22).

EPA's Manchester Laboratory attempted to analyze the pesticides in the WWTPs influent samples; however, the laboratory reported that the WWTP sample matrix was too difficult to analyze because of significant interferences from the large number of organic compounds present in the waste. Therefore, the pesticide concentrations could not be quantified from the WWTP influent samples.

Septic Systems: Trace Organics

The trace organics analysis includes compounds such as caffeine, fragrances, and disinfectants, which would be expected to be found in domestic wastewater. Trace organics were not detected in any of the four selected water wells. For the entire study, four residential wells had detectable levels of DEHP. Thirty-seven trace organics were detected in the WWTP influents (Table C10 in Appendix C). Nineteen of the trace organics were detected in all of the WWTP influent samples. This indicates that trace organics are being used and can be found in wastewater entering WWTP, but with a few exceptions these compounds were not detected in residential water wells.

Septic Systems: Pharmaceuticals

No wastewater pharmaceutical compounds were detected in the four selected water wells. For the entire study one wastewater pharmaceutical (DEET) was detected in one residential water well. Nine wastewater pharmaceuticals compounds were detected in at least one WWTP influent sample, with six of the compounds detected in all three WWTP influent samples (acetaminophen, cotinine, DEET, ibuprofen, naproxen, and triclosan) (Table C11 in Appendix C). As with the trace organics, the wastewater pharmaceuticals were detected in the WWTP influent, but not in the residential water wells.

Table 33 shows the veterinary pharmaceuticals detected in three water wells and the WWTP influent samples. Water well WW-22 contained no detected veterinary pharmaceuticals.

Table 33: Septic Systems – Concentrations of Veterinary Pharmaceutical Detected in Wells and WWTP Influents

Compound	Wells[a]			WWTP Influent[b]		
	Units: µg/L					
	WW-19	WW-20	WW-21	SP-01	SP-02	SP-03
Erythromycin	ND	ND	0.11	ND	R	ND
Lincomycin	ND	ND	0.371	ND	R	ND
Monensin	1.62	ND	0.194	ND	R	ND
Ractopamine	ND	ND	0.079	ND	R	ND
Sulfamethazine	ND	ND	0.053	ND	R	0.086
Sulfamethoxazole	ND	ND	0.04	ND	0.106 (J)	0.662
Sulfathiazole	ND	ND	0.051	ND	R	ND
Tetracycline	ND	0.04 (J)	ND	0.55 (J)	ND	ND
Tiamulin	ND	ND	0.05	ND	R	ND
Virginiamycin	ND	ND	0.162	ND	R	ND

[a]Water well WW-22 had no detected veterinary pharmaceuticals.

[b]Sample SP-04 was not analyzed for veterinary pharmaceuticals.

J – the compound was positively identified, but the associated numerical value is an estimate.

ND – not detected.

R – the sample was unusable.

Three compounds were detected in the water wells and in at least one WWTP influent sample (sulfamethazine, sulfamethoxazole, and tetracycline). Eight compounds were detected in the water wells, but not in the WWTPs. Nine compounds were detected in WW-21. Water well WW-21 is surrounded by possible septic sources; it is also downgradient from several hop yards and at a greater distance, downgradient from several large dairies. The residents raise poultry and beef cattle. Many of the compounds detected in WW-21 were not found in the WWTP influent samples. The data suggest that septic systems are not the source of many of the compounds detected in this well.

For the entire study, four veterinary pharmaceuticals were detected in the WWTP influent samples with three of those also detected in one or more residential water wells: sulfamethazine (two water wells); sulfamethoxazole (one water wells); and tetracycline (five water wells). Sulfamethoxazole and tetracycline are used by humans and it is possible that septic systems could be a source of these compounds in the residential wells.

Septic Systems: Hormones

EPA's Ada Laboratory analyzed the four water well samples and the WWTP influent samples for five hormones (17-α-estradiol, 17-β-estradiol, estrone, 17-α-ethyl-estradiol and estriol). The laboratory did not detect any of the five hormones in the water wells, but detected three of the hormones in all three of WWTP influent samples (17-β-estradiol, estriol, and estrone) (Table C13 in Appendix C).

The UNL Laboratory analyzed samples from the same four water wells and the WWTP influent samples for 20 hormones, including the same five hormones as the EPA's Ada Laboratory (Table C14 in Appendix C). The UNL Laboratory detected 17-α-estradiol, 17-β-estradiol, and estrone in water well WW-22 along with several other compounds. Androsterone was the only other hormone detected in any of the four water wells (WW-20).

Table 34 shows the concentrations of the compounds detected in water wells WW-20 and WW-22 and the corresponding concentrations in WWTP influent samples. No hormones were detected in water wells WW-19 and WW-21.

Table 34: Septic Systems – Hormone Concentrations in Wells and WWTP Influents

Compound	WW-20	WW-22	SP-01	SP-02	SP-03
	(Units: µg/L)				
17-β-estradiol	ND	0.006 (UNL)	0.021 (Ada)	0.035 (Ada)	0.034 (Ada)
Estrone	ND	0.004 (UNL)	0.077 (Ada)	0.096 (Ada)	0.073 (Ada)
Estriol	ND	ND	1.030 (Ada)	0.863 (Ada)	0.640 (Ada)
17-α-estradiol	ND	0.005 (UNL)	0.263 (UNL)	ND	ND
Androsterone	0.004(J) (UNL)	ND	5.049(J) (UNL)	2.137(J) (UNL)	3.187(J) (UNL)
Androstadienedione	ND	0.003 (UNL)	0.255(J) (UNL)	0.614(J) (UNL)	14.1 (J) (UNL)
β-Zearalanol	ND	0.003 (UNL)	ND	ND	ND
Testosterone	ND	0.01 (UNL)	0.053 (UNL)	0.059 (UNL)	0.045 (UNL)
11-Keto Testosterone	ND	0.005 (UNL)	0.1 (UNL)	0.043 (UNL)	ND
Epitestosterone	ND	0.004 (UNL)	ND	0.06 (UNL)	ND

J – the compound was positively identified, but the associated numerical value is an estimate.

ND – not detected.

Androsterone was detected in water well WW-20 and in the three WWTP influent samples. Eight compounds were detected in water well WW-22. It is possible that septic systems are a source of several of the compounds found in WW-22 and the androsterone in WW-20. Many of these compounds are naturally produced by humans (for example 17-β-estradiol, estrone, estriol, androsterone, and testosterone). All of these compounds were detected in the WWTP influent samples.

For the entire study, 14 hormones were detected in WWTP influent samples with seven of those detected in residential water wells. Testosterone and androsterone were the most frequently detected hormones: testosterone in nine water wells and androsterone in four water wells. Given that both of these compounds are natural sex hormones, the septic systems are a possible source of the hormones detected in the residential water wells.

4. Septic Systems: Isotopic Analysis

Isotopic analysis was performed for wells WW-19 to WW-22 by the UNL Laboratory. Table 35 provides the results for these four wells. Additional details on the results of isotopic analysis conducted for this study are provided in Appendix D of this report.

Table 35: Septic Systems – Concentration of Nitrate in Wells, Isotopic Signatures, and the Interpreted Dominant Source(s) of the Nitrate Based on Observed Values

Location	Nitrate-N (mg/L)[a]	$\delta^{15}N-NO_3$ (‰)	$\delta^{18}O-NO_3$ (‰)	Interpreted Dominant Source(s)[b]
WW-19	36.4	8.7	15.4	Animal Waste[c]
WW-20	15	6.3	52.9	Fertilizer and/or Animal Waste with Some Atmospheric Contribution
WW-21	36.5	7.7	12.2	Fertilizer and/or Animal Waste
WW-22	16.6	10	11.0	Animal Waste

[a]The nitrate concentrations are from the UNL isotopic analysis.

[b]Interpretation of dominant sources is based on the following:

- $\delta^{15}N-NO_3$. Values less than 2.0 = dominated by synthetic fertilizer; values between 2.0 to 8.4 = undetermined mixture of synthetic fertilizer and/or animal waste; values greater than 8.4 = dominated by animal waste.
- $\delta^{18}O-NO_3$ values greater than 20.0‰ provide evidence for some atmospheric contribution. $\delta^{18}O-NO_3$ values below 20.0‰ could have an atmospheric contribution, but it becomes indistinguishable from other sources.

[c] Animal waste can be either human or non-human waste

The dominant source of nitrate for WW-19 and WW-22 appears to be animal waste (human or non-human). For WW-20 the dominant sources are likely a combination of synthetic fertilizer and/or animal waste with some atmospheric contribution for WW-20. The likely source of nitrate in well WW-21 is a combination of synthetic fertilizer and/or animal waste. The probable sources of nitrate for these water wells match the variety of land uses surrounding these highly scattered water wells.

5. Septic Systems: Age Dating

Table 36 provides the age dating results for the four selected water wells. There is a wide scatter of ages in the water wells, with age measurements ranging from 14.3 years to 44.3 years. As previously discussed, the age dating indicates the number of years since the water infiltrated from the surface to the aquifer, not the time that has elapsed since the water became contaminated. The method used in this study can determine the age of water up to about 40 years, or approximately 1970. Beginning in the 1960s, SF_6 concentrations in the environment began increasing as a result of its use in electrical equipment as a replacement for PCBs. Prior to 1970, atmospheric concentrations of SF_6 were generally below the analytical method detection limit. Ages older than 40 years are considered approximations.

Table 36: Septic Systems – Results of Age Dating Analyses Performed for Wells Reported in Years Since the Water Infiltrated from the Surface to the Aquifer

Location	Sample Age	Duplicate Sample Age	Average
WW-19	44.3 (J)	34.3 (J)	39.3
WW-20	14.3 (J)	14.3 (J)	14.3
WW-21	31.3	28.8	30.1
WW-22	29.3 (J)	29.3 (J)	29.3

J – the analyte was positively identified, but the associated numerical value is an estimate.

6. Septic Systems: Summary of Results for Residential Water Wells

Table 37 summarizes the nitrate concentrations for the four water wells along with a summary of the organic compounds detected in both the four water wells and the WWTP influents. The dominant sources of nitrate based on the isotopic data are also included in Table 37. Although microbial contamination is often observed in situations where septic systems contaminate residential wells, no microbial contamination was found in the downgradient wells. There appears to be a correlation between the age dating data and the well depths for those water wells that have well depth information (see Appendix A3). Older water suggests a deeper well.

All four water wells had nitrate concentrations greater than the nitrate MCL. These four water wells were sampled in isolation – that is, without a pairing with an upgradient well with a specific source separating them. For this reason, no chemical or temporal evolution along a flow path can be demonstrated from these data.

The pesticides atrazine and bentazon were detected in WW-20; however, the WWTP influent samples could not be analyzed for pesticides because of matrix interference so there are no wastewater data with which to compare these results.

There were no detections of any trace organics for the water wells selected for the septic systems. WWTP influent had detections of multiple trace organics. Nineteen of the trace organics were detected in all of the WWTP influent samples.

Table 37: Septic Systems – Comparisons of Organic Compounds Detected in Wells and WWTP Influent, and an Assessment of Dominant Source(s) of Nitrate in the Wells Based on Isotopic Analyses

Sample Location	Nitrate Concentration in Water Wells (mg/L)[a]	Summary of Organic Compounds Detected in Well	Summary of Organic Compounds Detected in Well and WWTPs Influent	Dominant Source of Nitrate Based on Isotopic Analyses
WW-19	38.2	Monensin	None.	Fertilizer and/or Animal Waste
WW-20	15	Atrazine and bentazon Tetracycline Androsterone	(Atrazine and bentazon not analyzed) Tetracycline (SP-01) Androsterone (All WWTPs)	Animal Waste and/or Fertilizer with Some Atmospheric Contribution
WW-21	38	Sulfamethazine Sulfamethoxazole Erythromycin, lincomycin, monensin, ractopamine, sulfathiazole, tiamulin, and virginiamycin	Sulfamethazine (SP-03) Sulfamethoxazole (SP-02 and SP-03) Other organics detected in wells were not detected in WWTP influents	Fertilizer and/or Animal Waste
WW-22	16.4	11-keto testosterone 17-β-estradiol 17-α-estradiol Androstadienedione β-zearalanol Estrone Testosterone Epitestosterone	11-keto testosterone (SP-01and SP-02) 17-α-estradiol (SP-01) Androstadienedione (All WTPs) Testosterone (All WWTPs) Epitestosterone (SP-02)	Animal waste

[a]Nitrate results are from Cascade Analytical Laboratory

No wastewater pharmaceuticals were detected in the four water wells, while several of the wastewater pharmaceuticals were detected in the WWTP influent samples. Three water wells had veterinary pharmaceuticals detected. Water well WW-21 had nine detected compounds. Veterinary pharmaceuticals that were detected in the water wells and one or more WWTP influent samples were sulfamethazine (WW-21 and SP-03), sulfamethoxazole (WW-21 and SP-02 and SP-03), and tetracycline (WW-20 and SP-01).

Eight hormones were detected in water well WW-22 and each of those hormones was detected in one or more WWTP influent samples, except for β-Zearalanol. All of these hormones can be produced naturally by many different animals, and the detections in the water well could therefore arise from a variety of sources.

The isotopic data indicate that the dominant source of nitrate for WW-19 and WW-22 is animal waste (human or non-human) while the dominant sources for WW-20 is a combination of fertilizer, animal waste and/or atmospheric. The dominant source for WW-21 is fertilizer and/or animal waste.

In conclusion, the four water wells had nitrate levels greater than the MCL of 10 mg/L. Drinking water well WW-21 had nine pharmaceuticals detected, is surrounded by possible septic sources, and the family raises cattle and poultry on their parcel. Well WW-21 is also downgradient from several hop yards and at a greater distance downgradient from a dairy. Well WW-22 is not in close proximity to a current livestock operation. It is also possible that the detections for WW-22 are from a septic system.

E. Water Wells WW-18 and WW-30

Two other residential water wells were evaluated: WW-18 and WW-30. These water wells were not in the original study design. Water well WW-18 was sampled because the owner was aware of the study and volunteered his property for sampling. Water well WW-30 was sampled because it is located in an area not otherwise sampled, was high in nitrate, and the homeowner was willing to participate in the study.

Water well WW-18 was analyzed for all the compounds, including an isotopic and age dating analysis. Sample WW-30 was not evaluated for hormones, pharmaceuticals, isotopic, or age dating as the location was added later in the study. The summary results for the two wells are included in Table 38.

Table 38: WW-18 and WW-30 – Summary of Results Related to Nitrate Concentrations, Microbiology Evaluation, Detected Organic Compounds, Isotopic Analysis, and Age Dating Analysis

Compounds	WW-18	WW-30
Nitrate[a]	72.2 µg/L	23.4 µg/L
Microbiology	No detects	No detects
Organic Compounds	Atrazine, tetracycline, and testosterone	Atrazine, bentazon, and phenol
Isotopic Analysis	Fertilizer and/or Animal Waste with Some Atmospheric Contribution	Not conducted
Age Dating	28.1 years	Not conducted

[a]Nitrate results are from Cascade Analytical Laboratory

While the major ions and different nitrogen forms were measured for both of these samples, the results are not included here as there were no upgradient wells or potential sources sampled that could be used for comparison.

Neither fecal coliform nor *E. coli* was detected in the WW-18 or WW-30. Atrazine, tetracycline, and testosterone were detected in WW-18. Atrazine, bentazon, and phenol were detected in WW-30. Phenol was abundant in the dairy lagoons sampled and can also be found in household wastewater. Sample WW-30 is not located in the vicinity of a dairy. Sample WW-30 was not analyzed for wastewater pharmaceuticals because of its late addition at the end of the study.

X. STUDY LIMITATIONS AND UNCERTAINTIES

Several limitations in the study are important to note. First, water well samples were collected from existing wells. No new wells were installed for this study. Information on the depths and screened intervals of the water wells is known for about a third of the wells that were sampled. In this report, designations of upgradient and downgradient are based on regional groundwater flow data from the USGS. Lack of complete well information limits our ability to verify if the wells upgradient and downgradient of the sources draw water from the same water bearing zone.

A discussion of the QA/QC procedures and a summary of the data validation process are presented in Appendix E. Uncertainties and limitations with analytical data were noted in Appendix E and described in detail in the data validation memoranda. Data usability is also indicated in the data summary tables by inclusion of data qualifiers.

In addition, EPA lacks complete information regarding the dairies in this study. EPA requested information on specific aspects of the dairy operations and the physical setting; however, the dairies in this study did not provide this information. This information would have contributed to a more complete understanding of the dairy facilities, practices, and use of specific chemicals. It would have allowed EPA to provide actual values, or narrower ranges of estimates, for certain parameters in this report (for example, numbers of animals, quantities of nitrogen, estimates of lagoon leakage). EPA has, however, referenced general information regarding dairy operations, and specific information regarding the dairies in the study to the extent it was available.

Finally, EPA has limited information about the irrigated crop fields in this study. Verifiable, detailed crop production data, in terms of nutrients applied (the likely source of nitrate associated with irrigated crops), were not available and no irrigation data were available. EPA has included information about the crop fields to the extent it was available. In addition, the irrigated crop fields are surrounded by similar agricultural uses, and many are situated downgradient of dairies, making more difficult EPA's ability to discern the source of nitrate in drinking water wells downgradient of the irrigated crop fields.

XI. CONCLUSIONS

Nitrate levels above EPA's drinking water standard in residential drinking water wells in the Lower Yakima Valley are well documented. The objective of this study was to evaluate the effectiveness of certain chemicals, microbial parameters, or analytical techniques to identify specific sources of the high nitrate levels detected in residential drinking water wells.

Many of the chemicals and microbial parameters evaluated in this study were not detected in the residential drinking water wells. There were no detections of fecal coliform in the residential drinking water wells, although high concentrations were found in the dairy sources and WWTP influent. There were very few trace inorganic elements, trace organics, or wastewater pharmaceuticals detected in the residential drinking water wells or crop field soil samples, although many of these chemicals were detected in the dairy sources and WWTPs. The isotopic data provide some indication of the likely nitrate sources for seven of the 25 residential wells tested (six animal waste and one synthetic fertilizer). Although the isotopic analysis identified animal waste as the source of the nitrate in six wells, this analytical technique cannot differentiate between human and non-human waste.

There appears to be a correlation between the age dating data and the depths of the wells for which boring logs are available. The water in the dairy supply wells that are known to be screened in the deeper basaltic aquifer is older than in the downgradient residential wells which are commonly screened in the shallower alluvial aquifer. The age dating results were not useful to determine when the nitrate contamination was introduced into the well.

Haak Dairy

There are large quantities of nitrogen-rich materials on the Haak Dairy that could serve as sources of nitrate in groundwater and residential drinking water wells. The dairy lagoons are likely leaking nitrogen-rich wastewater into the underlying soils. Also, WSDA inspection reports show that the Haak Dairy has reported elevated nitrogen levels in some of their application fields. This poses a threat to groundwater because irrigation water or precipitation can carry excess nitrogen through the soil and into the aquifer. The prevalence of highly permeable surface soils at the Haak Dairy increases the risk of nitrogen migrating past the crop root zone to the aquifer resulting in groundwater contamination.

All three residential drinking water wells downgradient of the Haak Dairy that were sampled have nitrate levels greater than the MCL. Samples collected at the Haak Dairy show that the concentrations of total nitrogen and several of the major ions increase between the upgradient and downgradient wells, with the highest concentrations detected in the samples collected from the dairy lagoons, dairy manure pile, and dairy application fields. Barium, zinc and alkalinity show a similar pattern. These data indicate that the Haak Dairy is a likely source of the nitrate contamination in the three downgradient residential drinking water wells. Inorganic fertilizer used on the Haak Dairy's application fields also could be a source of nitrate observed in the downgradient wells.

Two pharmaceuticals, tetracycline and monensin, were detected in all of the dairy source samples collected at the Haak Dairy, indicating that these compounds are used by the dairy. Tetracycline was detected in two of the three downgradient residential water wells, but not in the upgradient well, indicating the Haak Dairy is a likely source.

Monensin was detected in the upgradient well and in the three downgradient residential water wells, although the upgradient residential drinking water well had a higher concentration than two of the downgradient wells. It is possible that the Haak Dairy is a possible source of the monensin detected in the downgradient residential drinking water wells. Given the presence of monensin in the upgradient well, another source of monensin is likely. Additional information that supports that the dairy source is a possible source of monensin is that it was not detected in samples collected from the WWTP influents that were collected as surrogates for rural septic systems.

The isotopic data provide strong evidence that animal waste (human or non-human) is the likely dominant source of the nitrate contamination in at least one of the residential water wells (WW-05) downgradient of the Haak Dairy. However, since isotopic analysis cannot differentiate between human and non-human waste, both could be sources of the nitrate in the downgradient well. Isotopic data for the other two residential drinking water wells downgradient of the Haak Dairy indicate that the source of the nitrate could be animal waste, fertilizer, derived from the atmosphere, or some combination of these sources.

Several other compounds that tend to be less mobile in groundwater were detected in the Haak Dairy lagoon, manure pile, and application field samples, but not detected in the downgradient water wells (for example trace organics and hormones). Fecal coliform was not detected in any of the wells downgradient of the Haak Dairy.

Dairy Cluster

Similar to the Haak Dairy, the Dairy Cluster has large quantities of nitrogen-rich materials that could serve as sources of the nitrate found in the groundwater and residential drinking water wells. The lagoons at the Dairy Cluster are likely leaking nitrogen-rich wastewater into the underlying soils. WSDA inspection reports show that the Dairy Cluster dairies have reported elevated nitrogen levels in some of their application fields. This poses a threat to groundwater because irrigation water or precipitation can carry excess nitrogen through the soil and to the aquifer.

Similar to the Haak Dairy, the results from the sampling indicate that the concentration of total nitrogen and several of the major ions increase between the upgradient and downgradient wells, with the highest concentrations detected in the samples collected from the dairy lagoons, dairy manure piles, and dairy application fields. Barium and alkalinity showed a similar pattern. These data indicate the Dairy Cluster is a likely source of the nitrate contamination in the downgradient residential drinking water wells.

The pharmaceuticals tetracycline and monensin were detected in all but one of the dairy sources samples, which indicates they are used by the dairies at the Dairy Cluster. Tetracycline was detected in two of the downgradient residential drinking water wells, two dairy supply wells, dairy lagoons, manure pile, and application fields. The concentration of tetracycline in the upgradient well was similar to the concentrations detected in the two downgradient residential wells. The dairies are a possible source of the tetracycline in the downgradient residential water wells. However, given the concentration in the upgradient well, another source of the tetracycline likely exists.

Monensin was detected in two of the downgradient residential water wells, two dairy supply wells, dairy lagoons, manure piles, and application fields. The Dairy Cluster is a likely source of monensin because this antibiotic is used in dairy cows but not people. Monensin was not detected in samples from the WWTP influent samples that were collected as surrogates for residential septic systems, providing further support that the dairies are a likely source.

The hormone testosterone was detected in downgradient residential drinking water wells and dairy sources. The concentration of testosterone detected in the upgradient residential water well is similar to the concentrations detected in the downgradient water wells. The dairies are a possible source of the testosterone in the downgradient wells; however, given the concentration in the upgradient well, another source for the testosterone is likely.

The isotopic data provide strong evidence that animal waste (human or non-human) is the likely dominant source of the nitrate in at least two of the residential water wells downgradient of the Dairy Cluster. Because isotopic analysis cannot differentiate between human and non-human waste, both could be sources of the nitrate in these downgradient wells. Isotopic data for the other residential drinking water wells downgradient of the Dairy Cluster indicate that the source of the nitrate could be animal waste, fertilizer, or derived from the atmosphere, or some combination of these sources.

Several other compounds that are generally less mobile in groundwater than nitrate and some of the major ions, were detected in the Dairy Cluster sources (for example, the trace organics), but not in the downgradient residential water wells. Fecal coliform was not detected in any of the residential water wells.

Given the historic and current volumes of wastes generated and stored by dairies, and the application of nitrogen-rich fertilizers including dairy waste in the Lower Yakima Valley, it is expected that dairies are a likely source of high nitrate levels in downgradient drinking water wells. The total nitrogen, major ions, alkalinity and barium data provide strong evidence that the dairies evaluated in this study are likely sources of the high nitrate levels in the drinking water wells downgradient of the dairies. Additional information that supports this conclusion includes: there are few potential sources of nitrogen located upgradient of the dairies; the dairy lagoons are likely leaking large quantities of nitrogen-rich liquid into the subsurface; and Washington State Department of Agriculture inspectors have reported elevated levels of nitrogen in application fields of the dairies in the study.

Irrigated Cropland

Nitrogen-rich fertilizers, such as inorganic synthetic fertilizer and manure, are applied to irrigated crop fields and are a possible source of nitrate in drinking water wells. In Phase 3, EPA sampled six irrigated crop fields (two mint, two hops, and two corn) and six residential water wells downgradient of these fields. The six water wells downgradient from the irrigated crop fields and sampled by EPA during Phase 3 all had nitrate levels greater than the MCL. Several organic compounds were detected in the crop soil samples but only bentazon and monensin were detected in a water well and its associated crop field soil sample. Bentazon was detected in two water wells and the associated mint field soil samples. These results indicate that bentazon was applied to the crop field and is likely migrating to the groundwater and water wells. Monensin was the only veterinary pharmaceutical detected in one well and also in an associated soil sample collected from a hop field. Possible manure application to the hop field could account for the monensin detected in the downgradient residential well.

The isotopic data provide strong evidence that synthetic fertilizer is a dominant source in one residential drinking water well downgradient of a mint field and that animal waste (human and non-human) is a dominant source of the nitrate in one well downgradient of a hops field. Isotopic analysis cannot differentiate between human and non-human waste. Isotopic data for the other residential drinking water wells downgradient of the crop fields indicate that the source of the nitrate could be animal waste or fertilizer, with some contribution from the atmosphere.

Given the historic and current application of nitrogen-rich fertilizers in the Lower Yakima Valley, it is expected that irrigated crop fields would be a likely source of high nitrate levels in downgradient drinking water wells. The data collected in this study provide some corroboration that irrigated crop fields are a likely a source of nitrate in groundwater. The data supporting this conclusion is not as strong for the crop fields as it is for the dairies. The reasons for this include: lack of upgradient well data; the irrigated crop fields sampled are situated amongst other agricultural uses, including upgradient dairy operations; fewer analytes detected in both the crop field samples and the corresponding downgradient wells; more limited information about crop field operations; and the crop fields' positions on the landscape relative to other potential sources.

Residential Septic Systems

Four residential water wells were identified for evaluation of impacts from septic systems. However, all of the residential drinking water wells sampled as part of Phase 3 of this study were analyzed for the same suite of chemicals. Although all the residential water wells were evaluated to determine if septic systems could be a likely source of the nitrate in water wells, the four wells identified to evaluate the potential contribution from septic systems were selected because they are in residential areas served by septic systems, but are not located near dairies or crop fields. EPA also collected influent samples from three WWTP located in Zillah, Mabton, and Toppenish.

The WWTP influent had no actual or potential hydrogeological connection with the residential wells. These treatment plant influent samples were collected to serve as surrogates for septic systems by providing a characterization and quantification of compounds that are found in rural septage, while recognizing that these WWTPs also may receive commercial or and industrial waste streams. The WWTP and residential drinking water well data were compared to determine whether the drinking water wells contained the same compounds as the WWTP influent samples which could indicate that the septic systems are a source of nitrate in the residential drinking water wells.

The majority of the trace organics (for example personal care products) and wastewater pharmaceuticals were detected in the WWTP influent samples, but only two of these compounds were detected in the residential drinking water wells sampled by EPA in Phase 3. Specifically, DEHP was detected in four residential drinking water wells and DEET was detected in one residential water well. This indicates the trace organics are being used and can be found in wastewater, but with a few exceptions are not reaching residential drinking water wells.

Four veterinary pharmaceutical compounds were detected in the WWTP influent samples, three of which were also detected in one or more residential water wells. Specifically, sulfamethazine (used for cattle, poultry, and swine) was detected in two residential water wells, sulfamethoxazole (used for people) in one residential drinking water well, and tetracycline (used for people, cattle, and several other animals) in six residential drinking water wells.

There were 10 additional veterinary pharmaceuticals detected in residential water wells, but not detected in WWTP influent samples. Monensin (used for cattle and poultry) and virginiamycin (used in poultry and swine) were the most frequently detected veterinary pharmaceuticals: monensin was detected in nine residential water wells and virginiamycin in four. Monensin and virginiamycin were not detected in the

WWTP influent samples. Given the results, septic systems are a possible source of tetracycline and sulfamethoxazole, both of which can be used by humans, in the residential drinking water wells.

Of the 20 hormones analyzed, 14 were detected in at least one WWTP influent sample. Of those 14 hormones, seven were detected in residential water wells. Testosterone and androsterone were the most frequently detected hormones: testosterone was detected in nine wells and androsterone was detected in four wells. Given both testosterone and androsterone are natural sex hormones it is possible they came from septic systems in proximity to the residential water wells, but these compounds were also detected in wells downgradient of the dairies.

While the septic systems could be a source of nitrate in drinking water wells, there is insufficient information from this study to support this conclusion.

The high nitrate levels in residential drinking water wells in the Lower Yakima Valley are likely coming from several sources. This study attempted to identify those sources. In some cases it was possible to identify likely or possible sources of the nitrate contamination.

Evaluating actions to reduce nitrate concentrations in residential drinking water wells to safe levels is beyond the scope of this report. Although actions to reduce nitrate are needed, it may take many years to reduce the nitrate levels in residential drinking water wells to safe levels because of the extent of the nitrate contamination in the Lower Yakima Valley and the persistence of nitrate in the environment.

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FIGURES

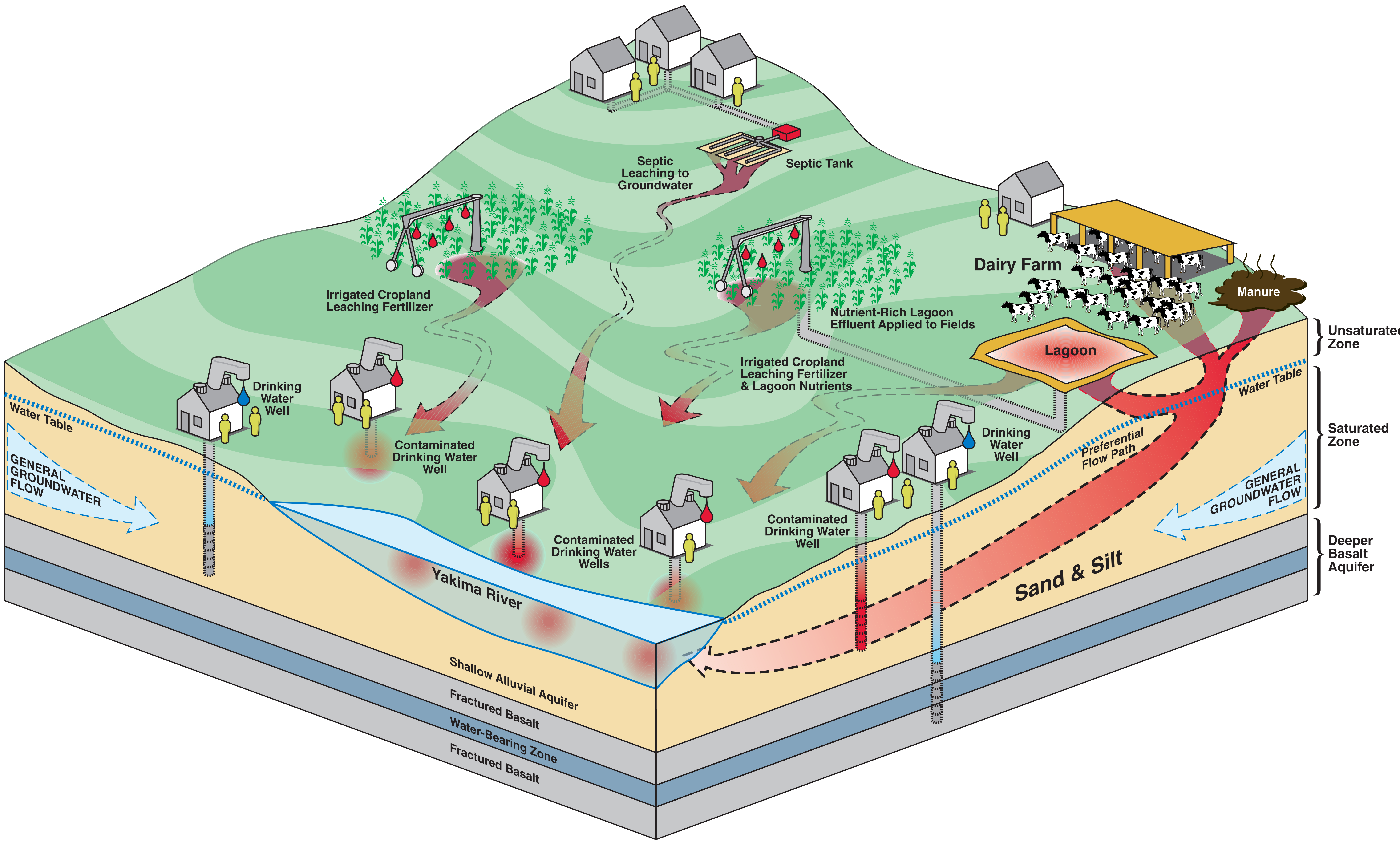


Figure 1: Conceptual Site Model for Lower Yakima Valley Project

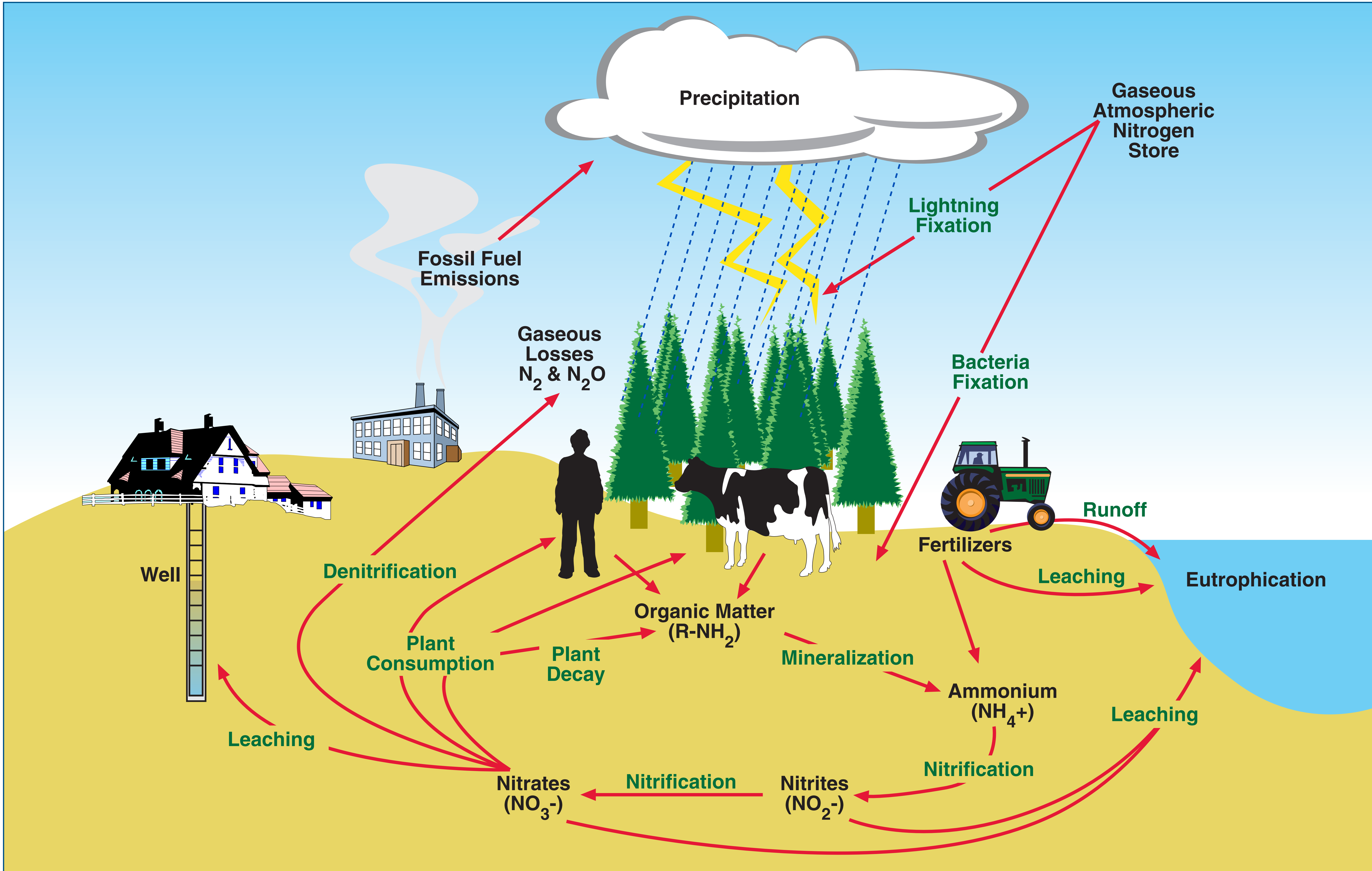


Figure 2: Nitrogen Cycle

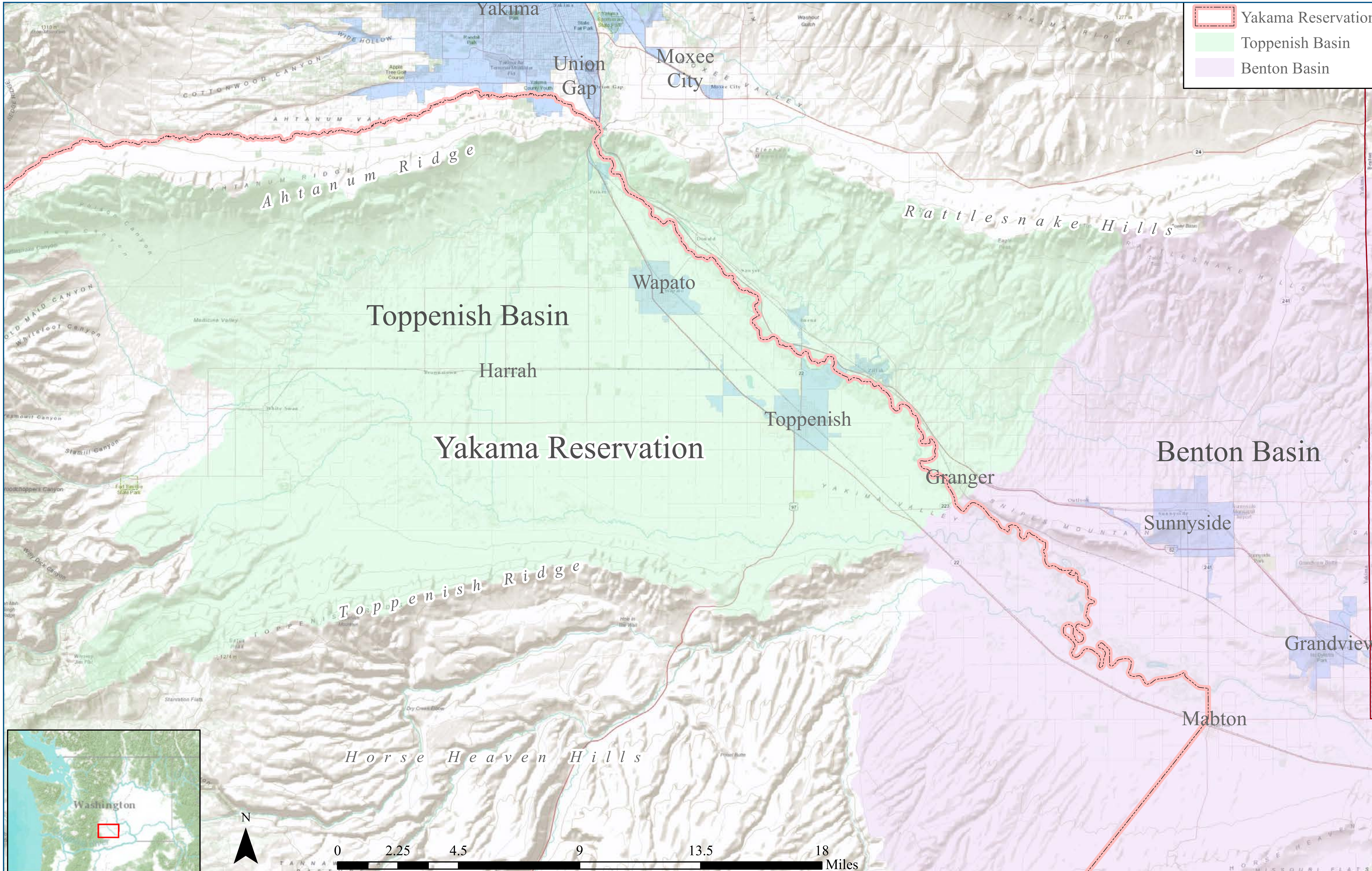


Figure 3: Study Area for EPA Lower Yakima Valley Project

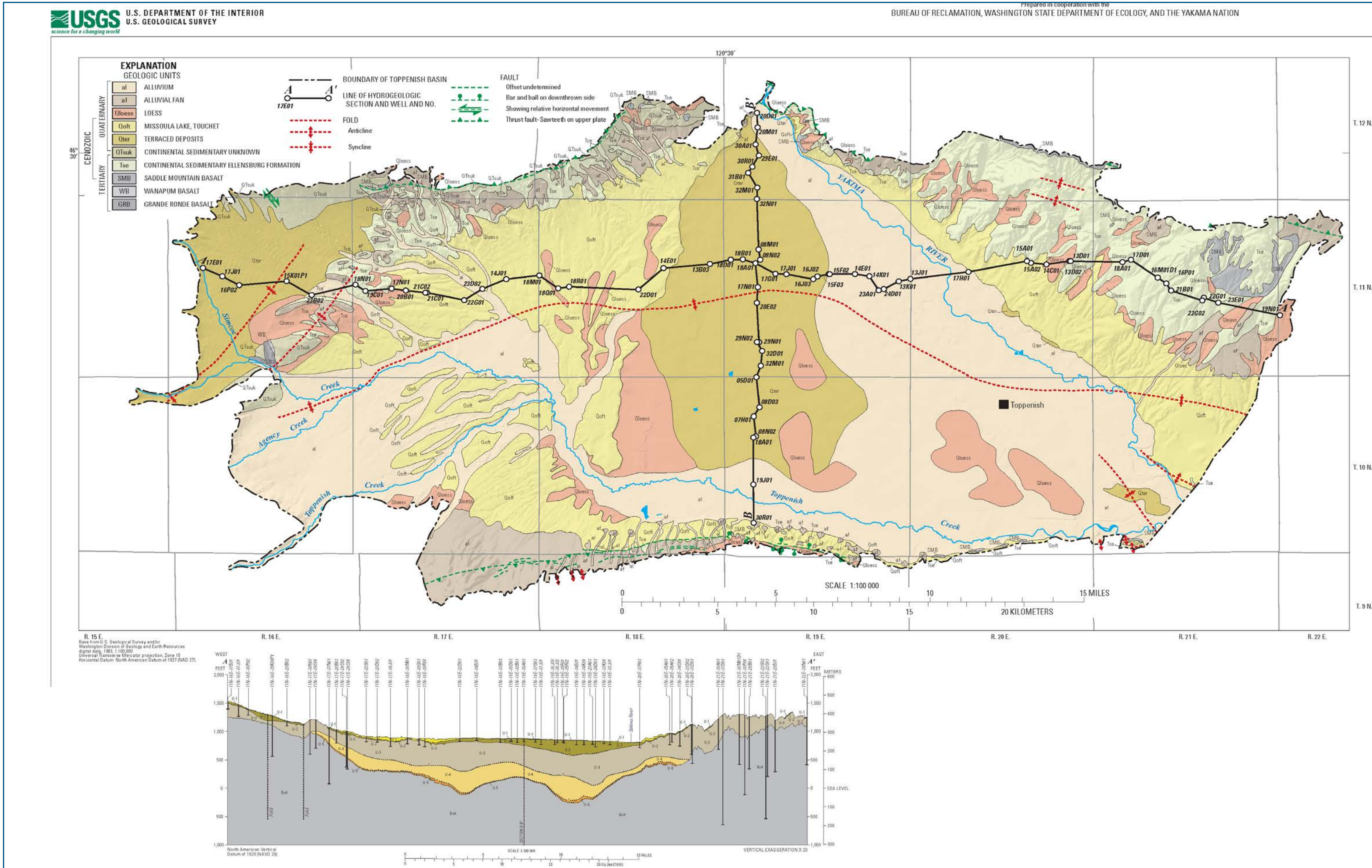
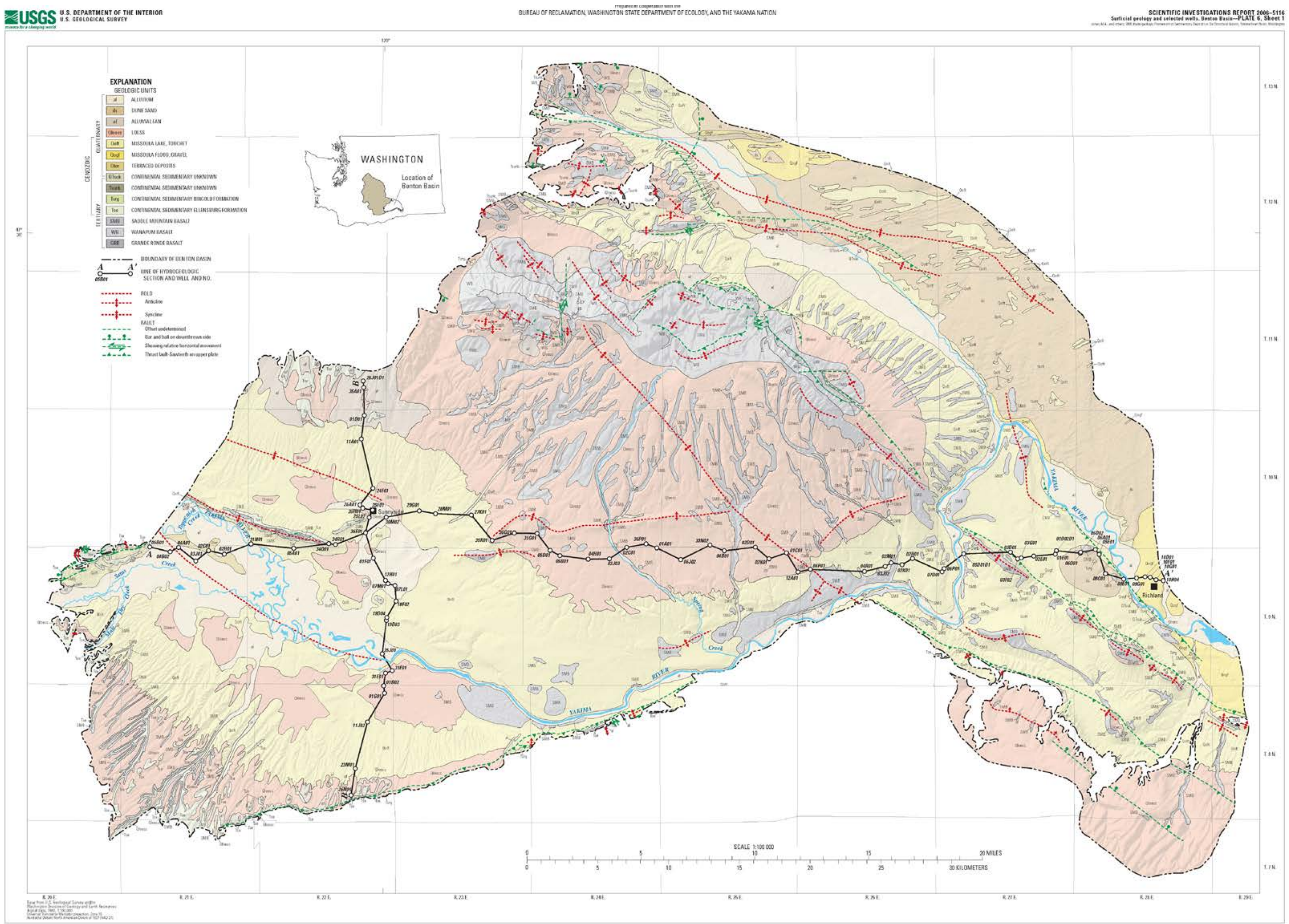


Figure 4: Hydrogeology of Toppenish Basin



Map Showing Surficial Geology and Locations of Selected Wells in the Benton Basin, Yakima River Basin, Washington

By

Myrtle A. Jones, John Vaccaro, and Anni M. Watkins

2006

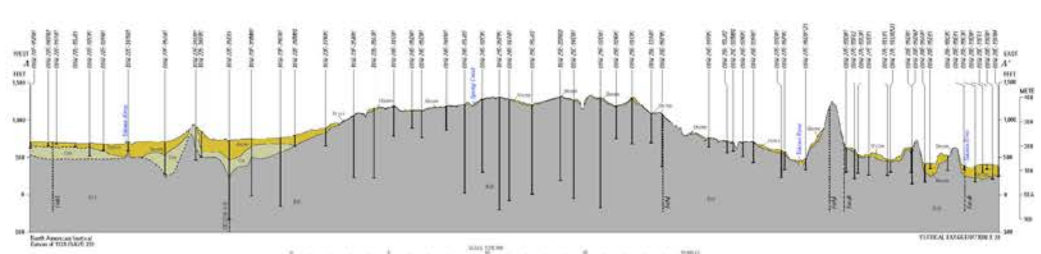


Figure 5: Hydrogeology of Benton Basin

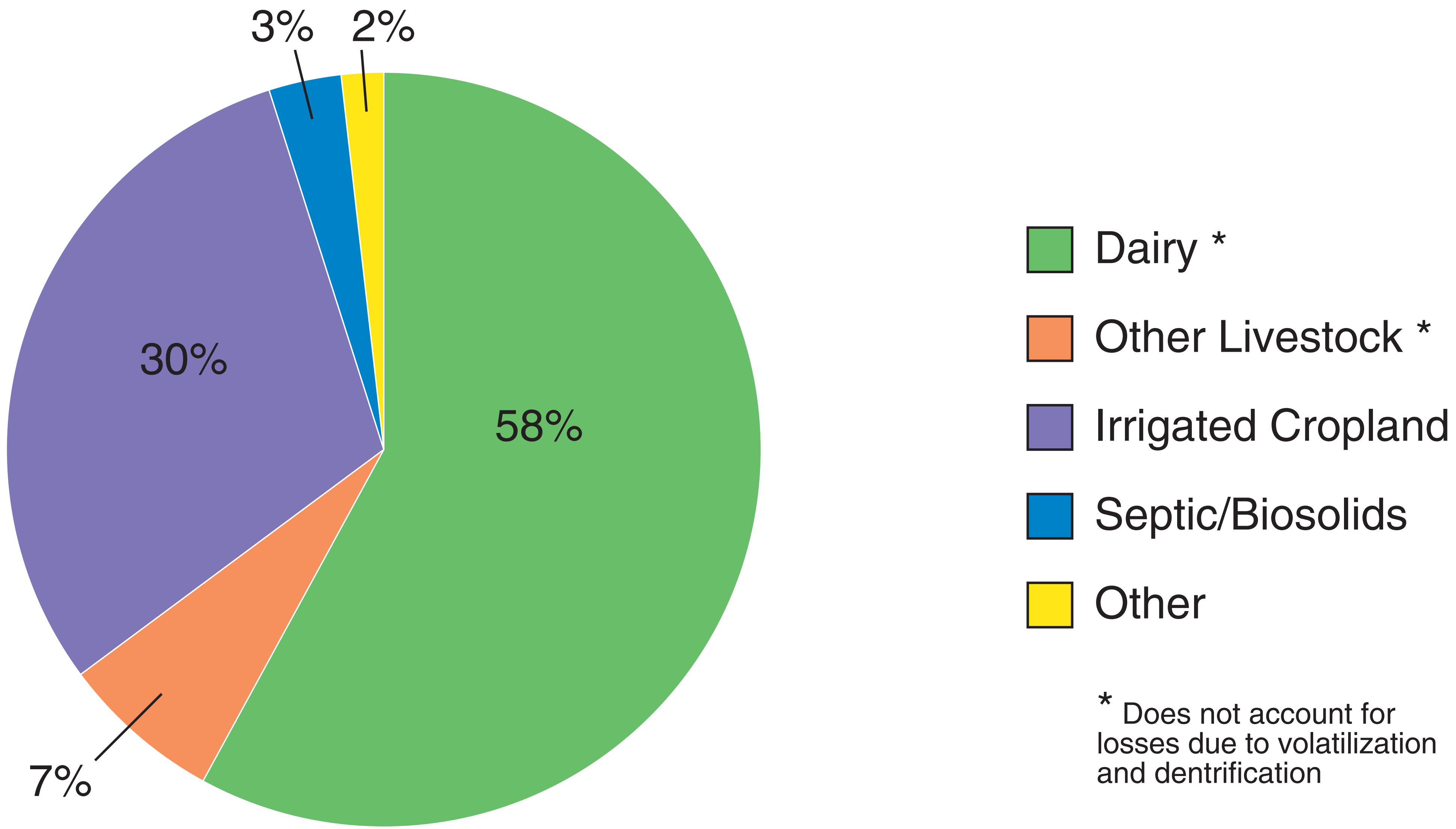


Figure 6: Nitrogen Generated by Major Sources in Yakima County

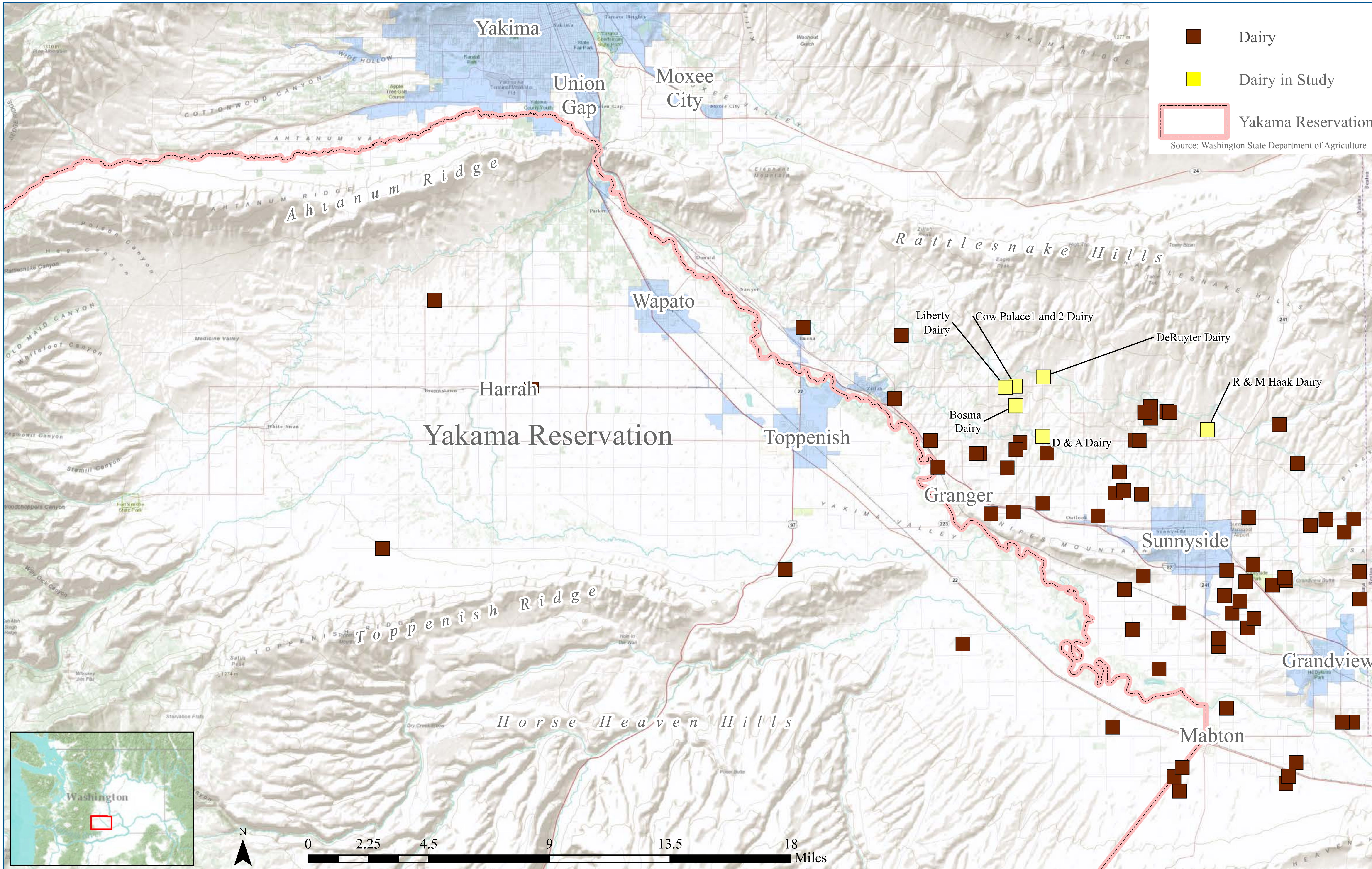


Figure 7: Lower Yakima Valley Dairy Locations

EPA

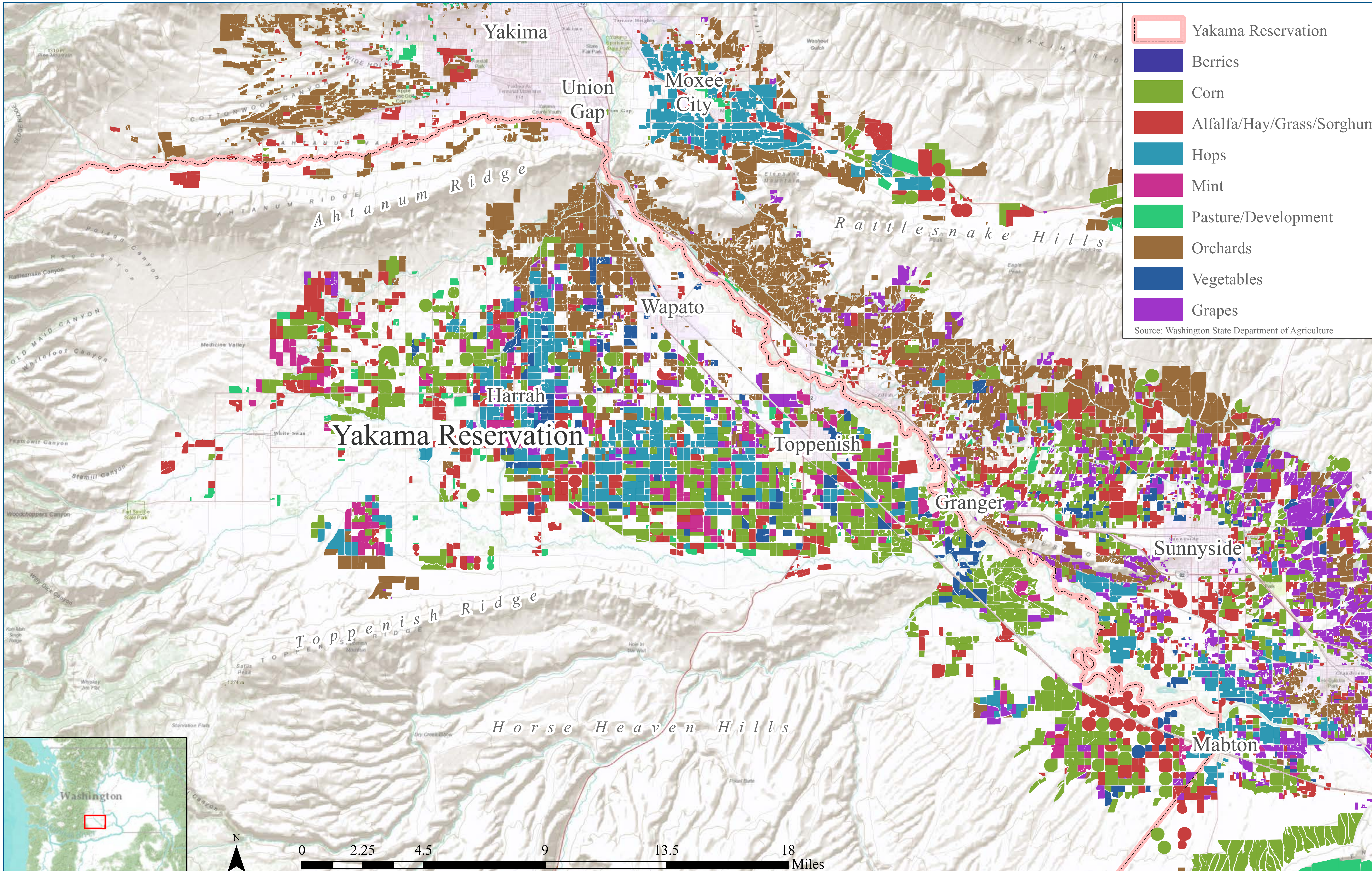


Figure 8: Lower Yakima Valley Crop Inventory

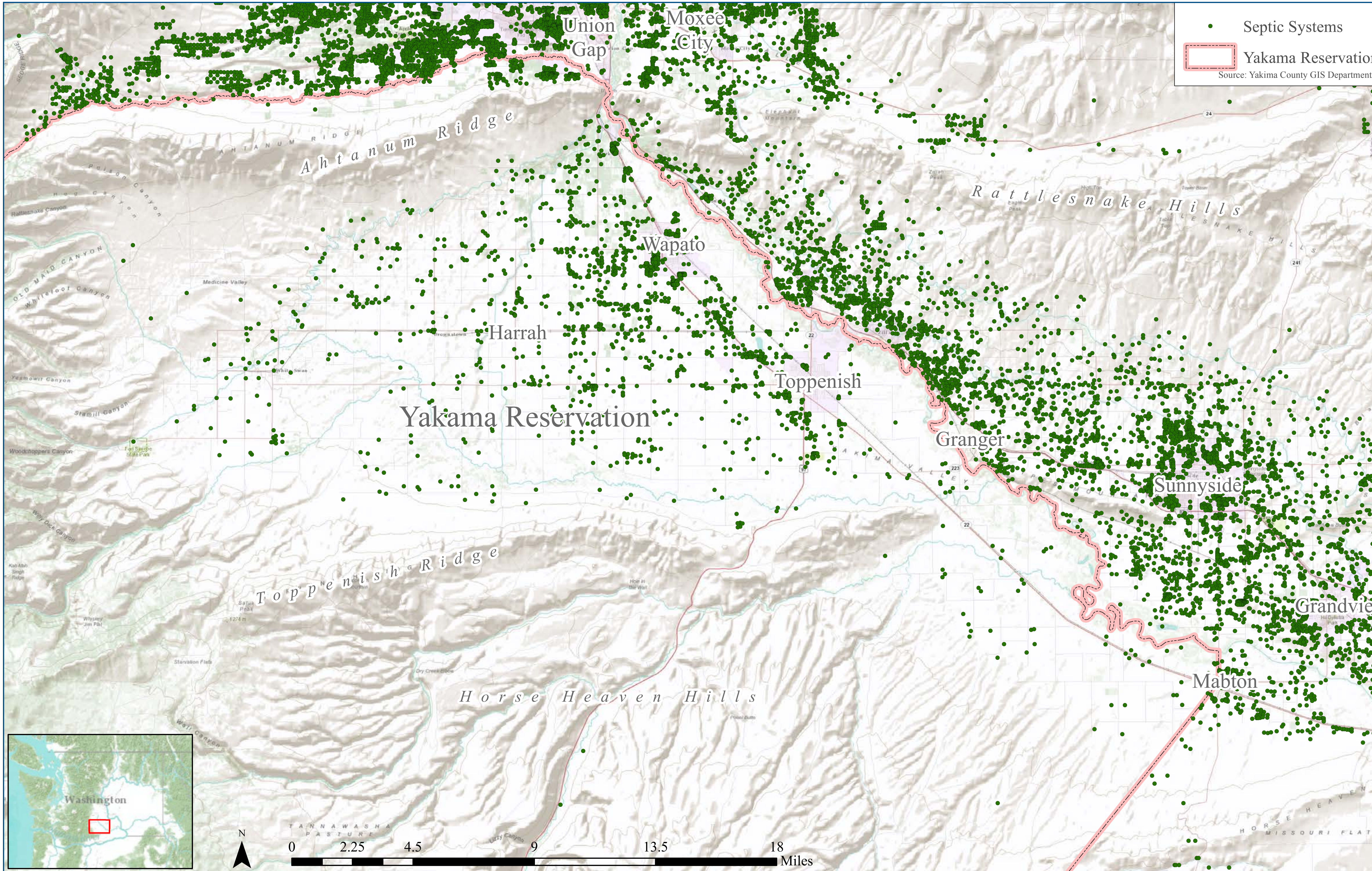


Figure 9: Lower Yakima Valley Septic System Distribution

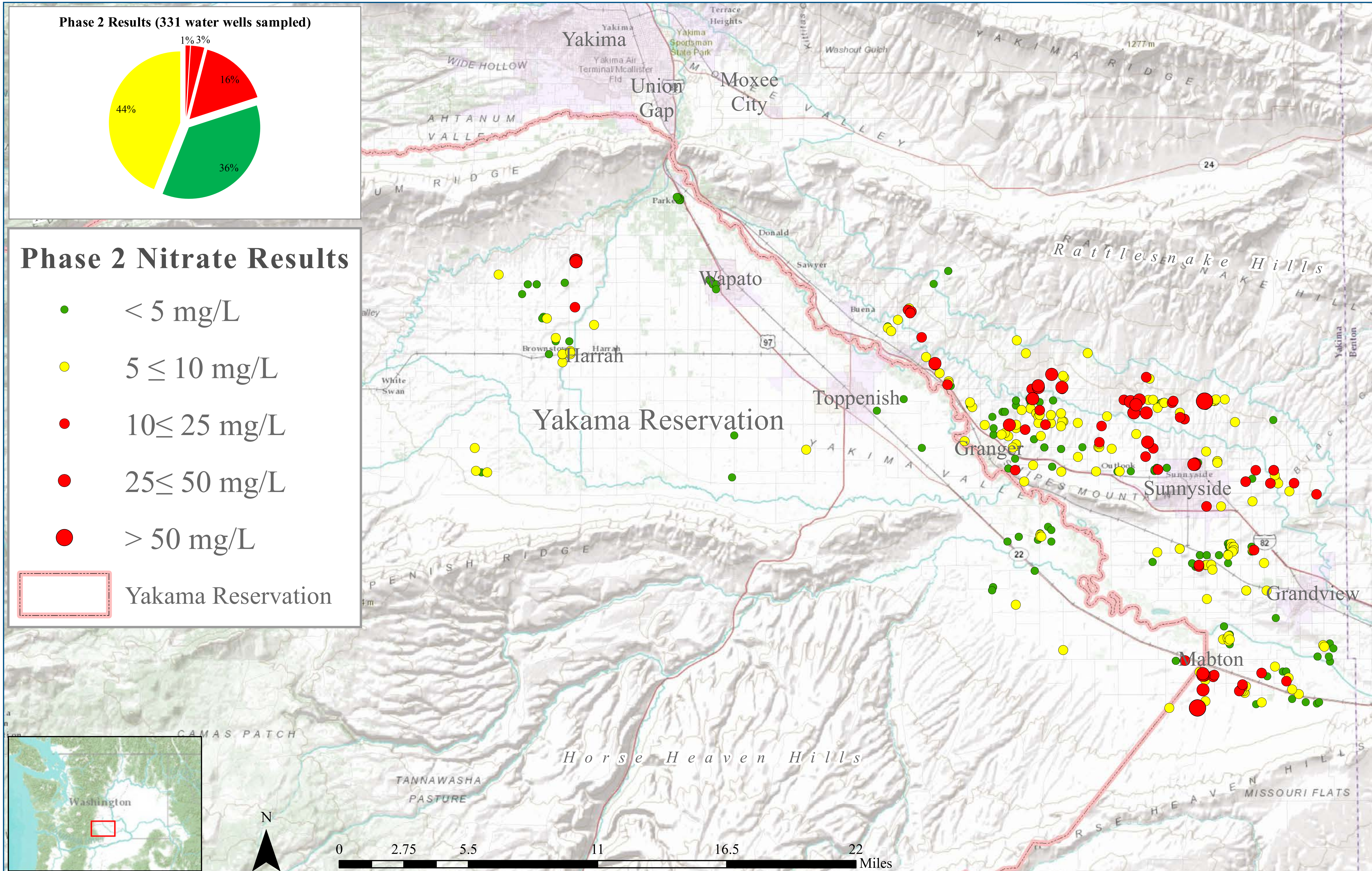


Figure 10: Lower Yakima Valley Phase 2 Nitrate Sampling Locations and Results

EPA

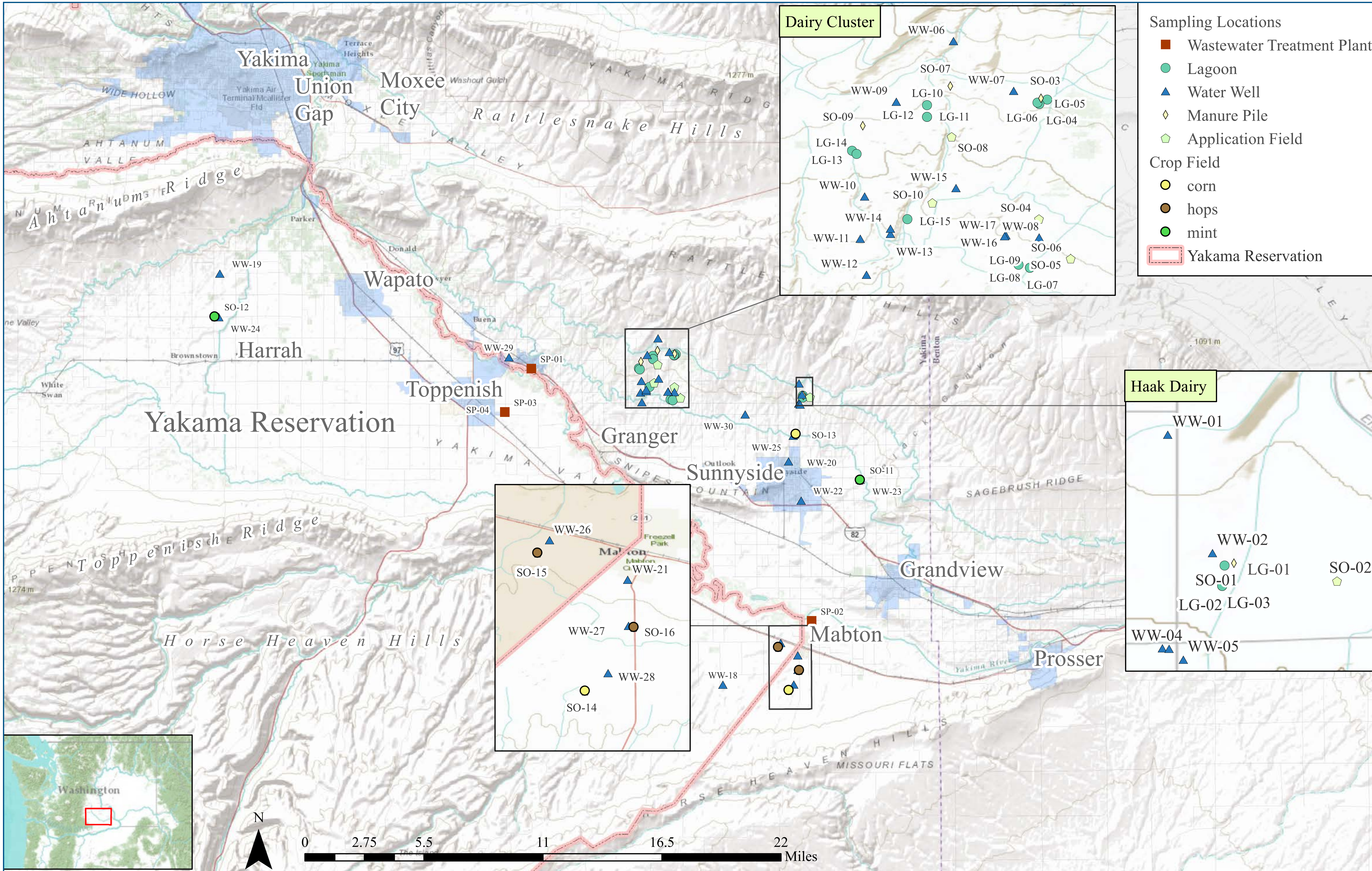


Figure 11: Lower Yakima Valley Phase 3 Sampling Locations

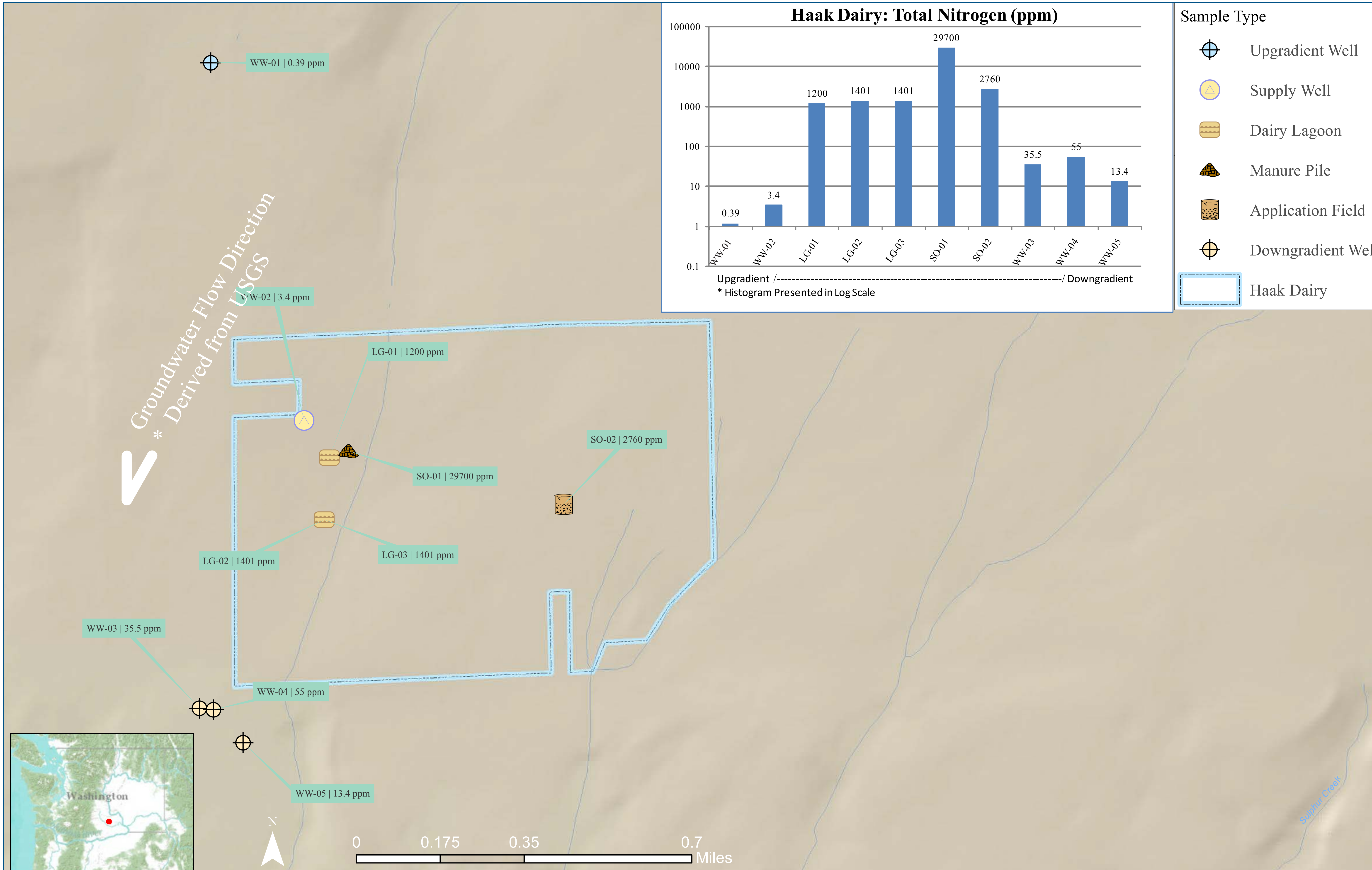


Figure 12: Haak Dairy: Total Nitrogen in Water Wells, Lagoons, Manure Piles, and Application Field Samples

EPA

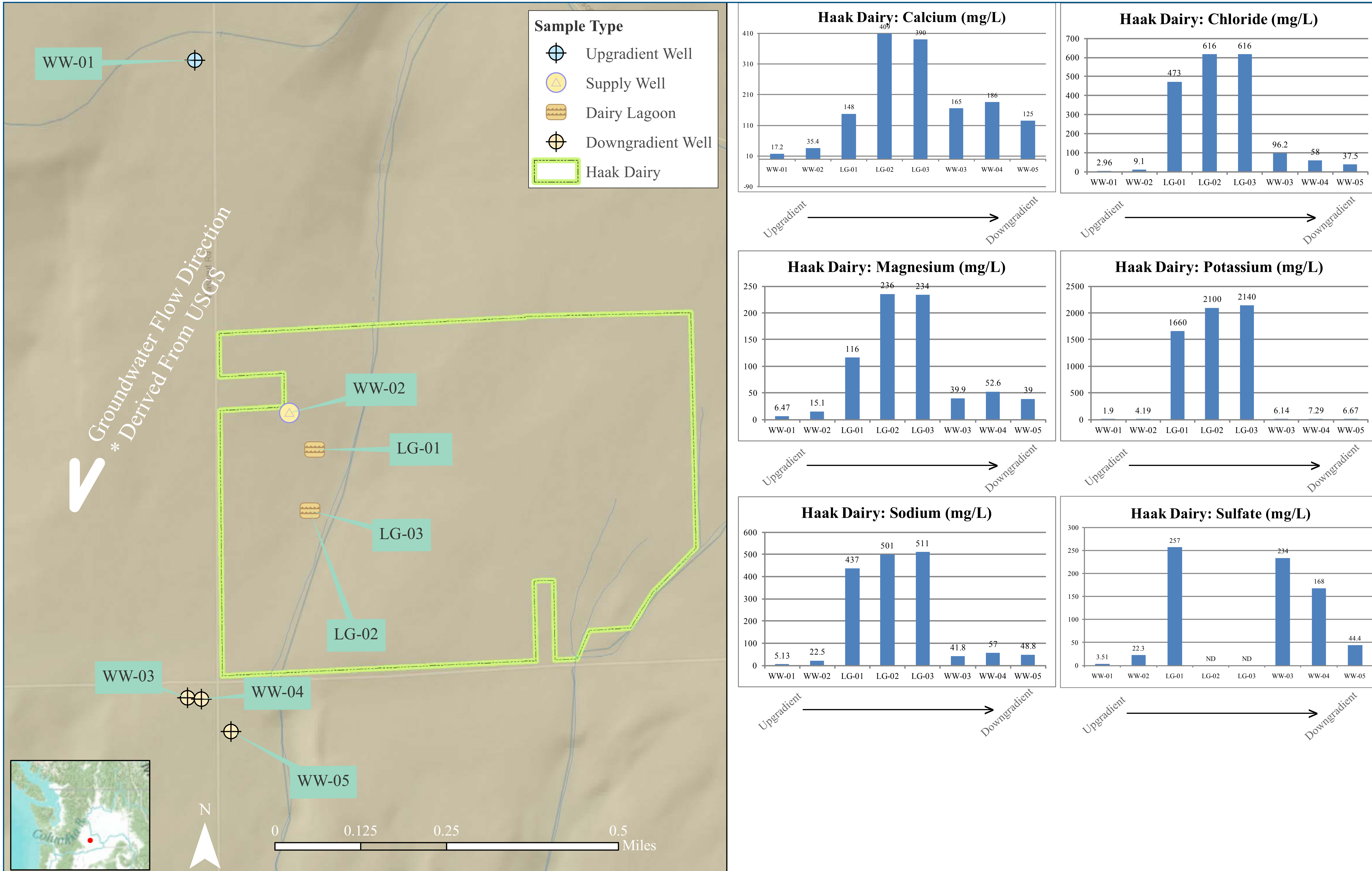


Figure 13: Haak Dairy: Concentration of Major Ions in Water Wells and Lagoons

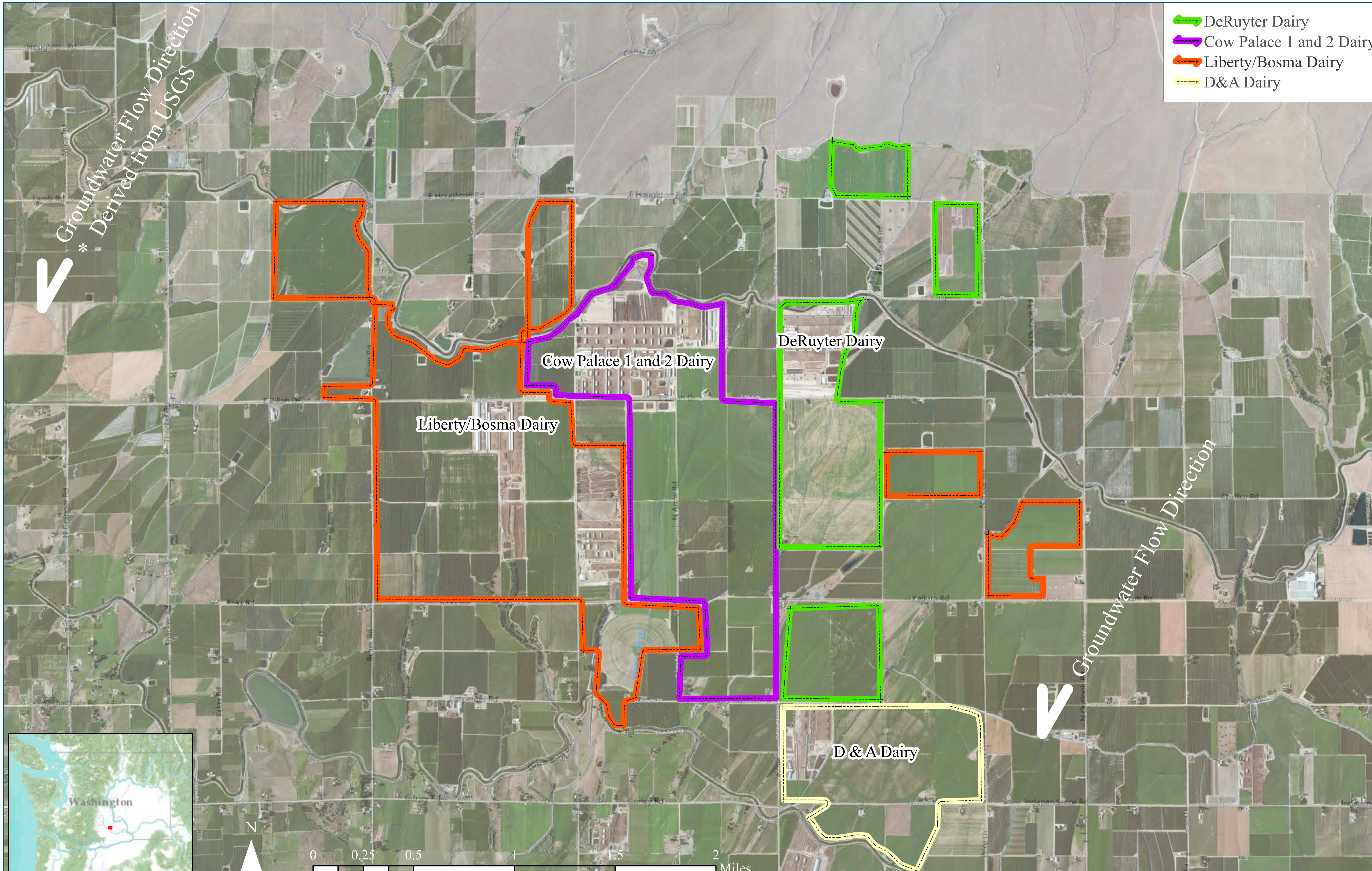


Figure 14: Dairy Cluster: Dairy Property Boundaries

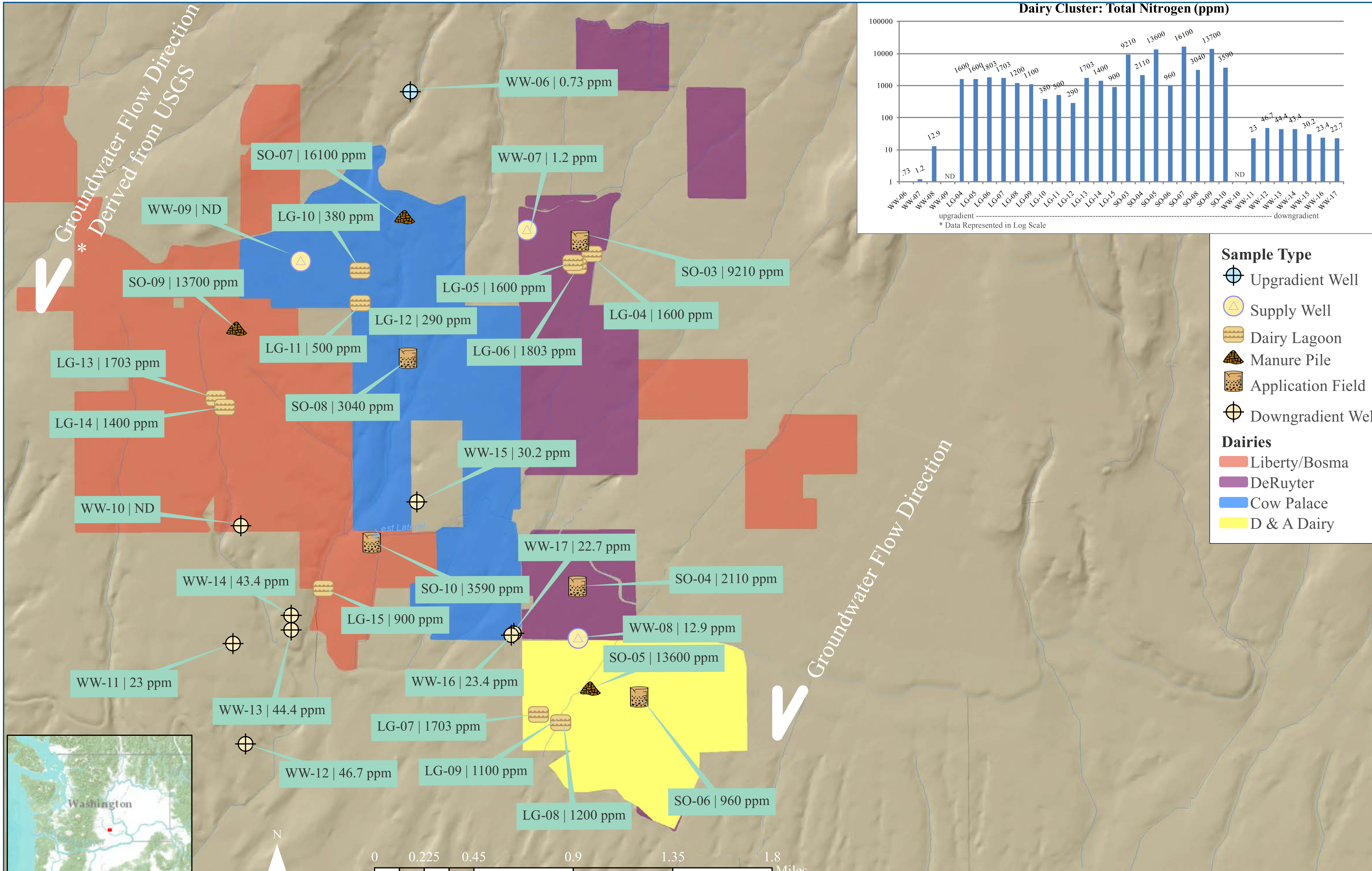


Figure 15: Dairy Cluster: Total Nitrogen Concentrations in Water Wells, Lagoons, Manure Piles, and Application Fields

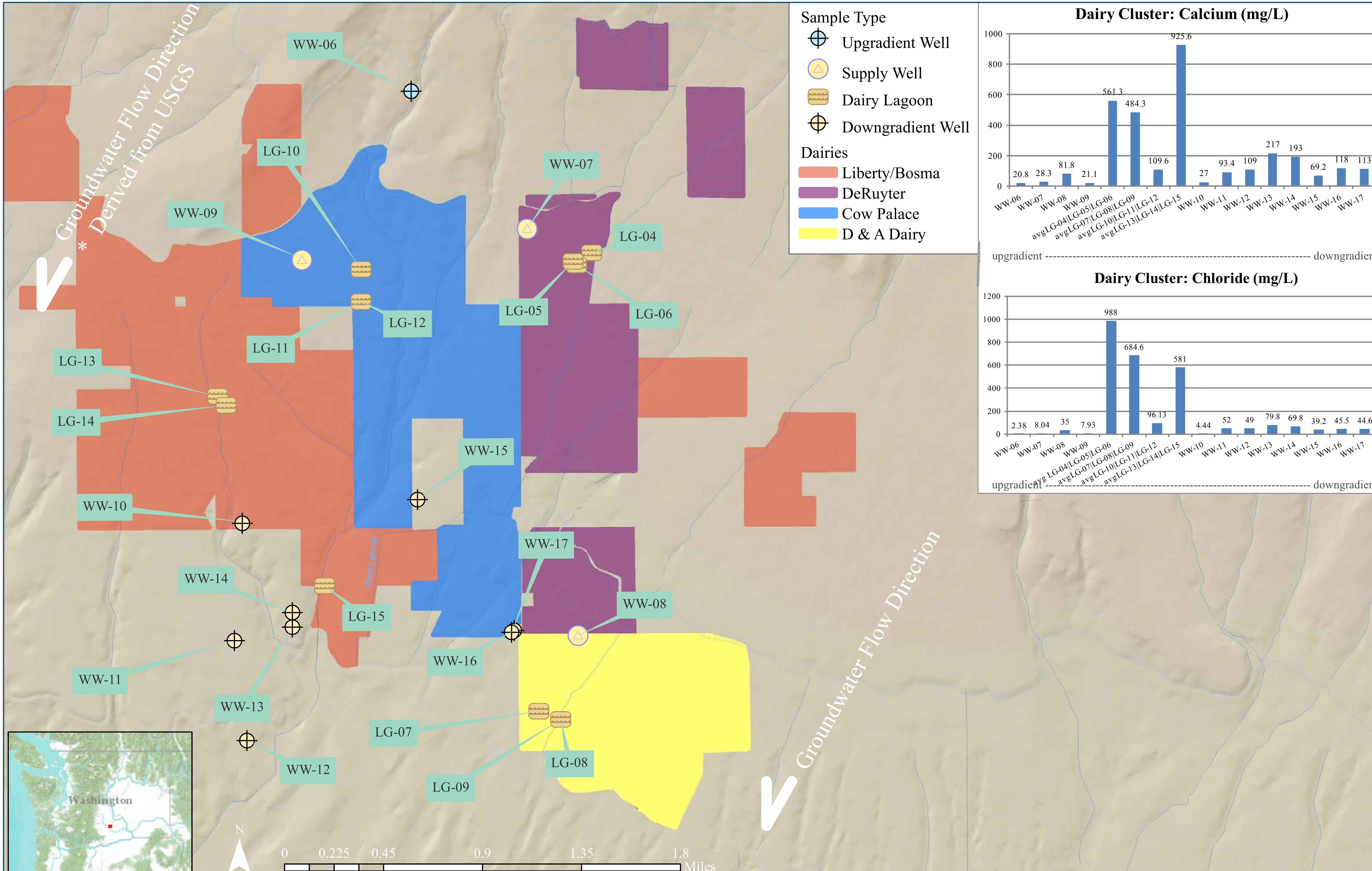


Figure 16a: Dairy Cluster: Calcium and Chloride Concentrations in Water Wells and Lagoons

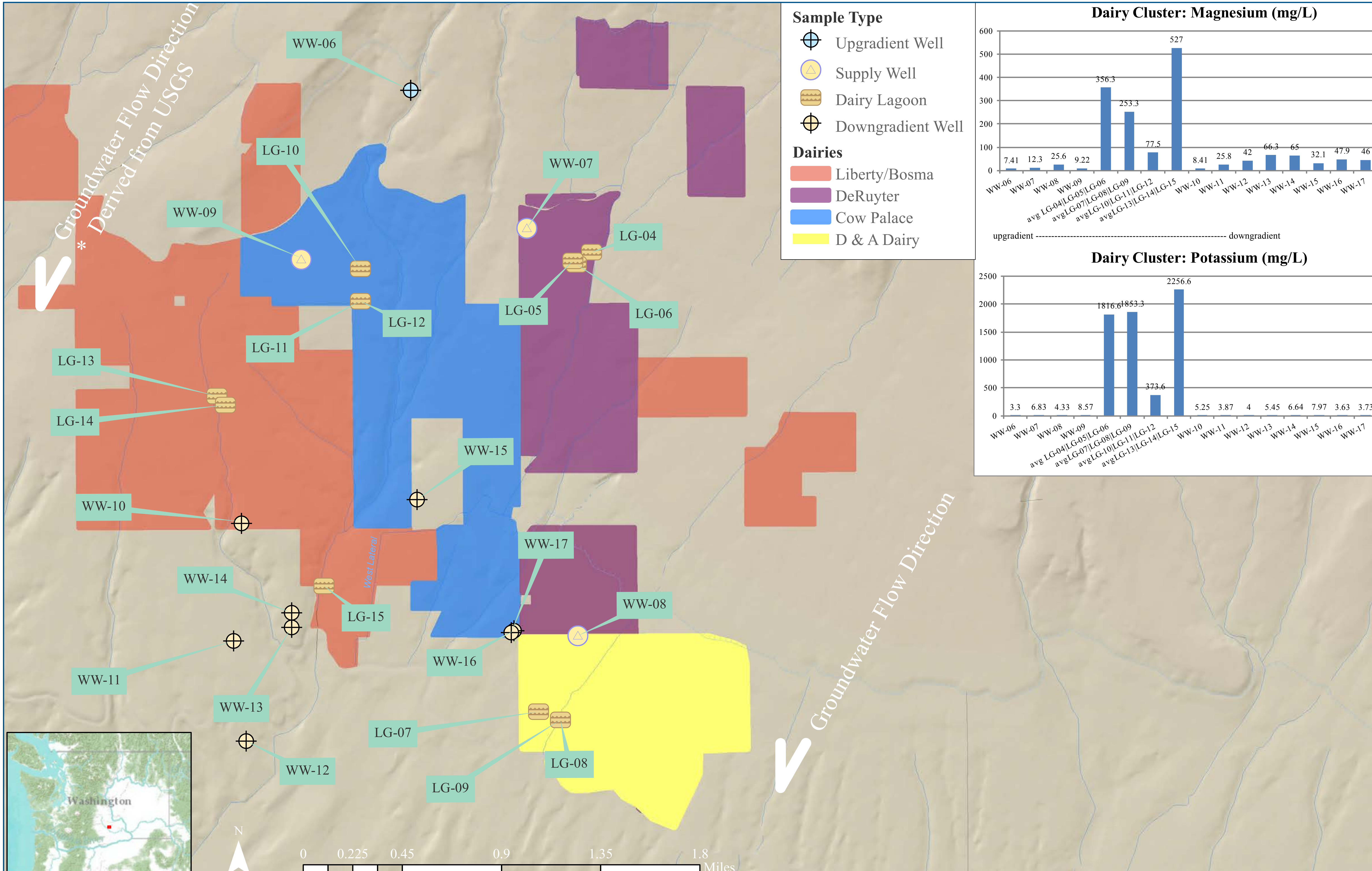


Figure 16b: Dairy Cluster: Magnesium and Potassium Concentrations in Water Wells and Lagoons.

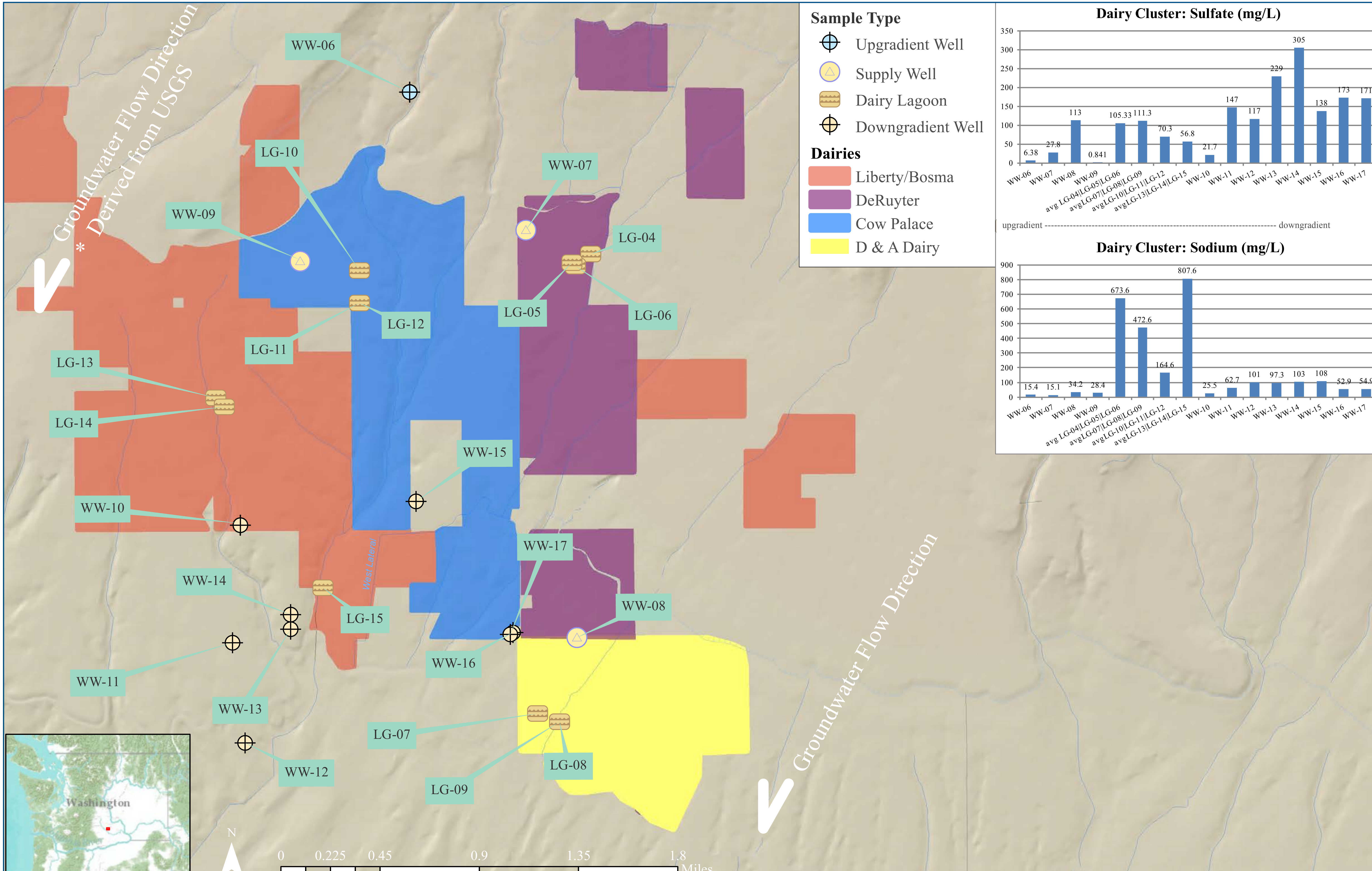


Figure 16c: Dairy Cluster: Sulfate and Sodium Concentrations in Water Wells and Lagoons

APPENDIX A

WATER WELL INFORMATION

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Table A1: Phase 3 - Water Well Information

Location ID	Sample ID	Sample Type	Nitrate Concentration[a] (units: mg/L)	Well depth (ft) from Phase 2 (reported by owners)	Well depth (ft) from Phase 3 (reported by owners)	Well depth (ft) from WSDA (reported by the dairy)	Well depth (ft) from WDOE well report (total depth/ static level)
WW-01	10154201	Upgradient well – Dairy	0.38				
WW-02	10154202	Supply well – Dairy	3.12			80	210 / 70
WW-03	10154203	Downgradient well – Dairy	33.1	330			95/25
WW-04	10154204	Downgradient well – Dairy	51.9				88/20
WW-05	10154205	Downgradient well – Dairy	12.8	220			
WW-06	10154206	Upgradient – Dairy	0.71				
WW-07	10154207	Supply well – Dairy	1.02			200	470 / 220
WW-08	10154208	Supply well – Dairy	11.7			200	220 / 73
WW-09	10164209	Supply well – Dairy	0.05			430	482 / 201
WW-10	10164210	Downgradient well – Dairy	0.05			300	345 / 185
WW-11	10154211	Downgradient well – Dairy	22.3				
WW-12	10154212	Downgradient well – Dairy	45	158			158 / 50
WW-13	10154213	Downgradient well – Dairy	41.4	120			
WW-14	10154214	Downgradient well – Dairy	40.9				
WW-15	10154215	Downgradient well – Dairy	29.4	230	126		
WW-16	10154216	Downgradient well – Dairy	22.3				
WW-17	10154217	Downgradient well – Dairy	21.7	96			105 / 64
WW-18	10154218	Residential well	72.2				
WW-19	10154219	Downgradient well – Septic	38.2				
WW-20	10154220	Downgradient well – Septic	15.0				
WW-21	10154221	Downgradient well – Septic	38				
WW-22	10164222	Downgradient well – Septic	16.4				
WW-23	10154223	Downgradient well – Mint	16	50			
WW-24	10154224	Downgradient well – Mint	13.8				
WW-25	10154225	Downgradient well – Corn	33.4				192 / 67
WW-26	10154226	Downgradient well – Hops	15.3	90			
WW-27	10154227	Downgradient well – Hops	19.8				
WW-28	10154228	Downgradient well – Corn	71.2				120 / ?
WW-30	10164230	Residential well	23.4				

[a]Phase 3 nitrate concentrations reported by Cascade Analytical Laboratory.

Figure A1: Phase 3 - Relationship Between Water Well Depth and Nitrate Concentrations

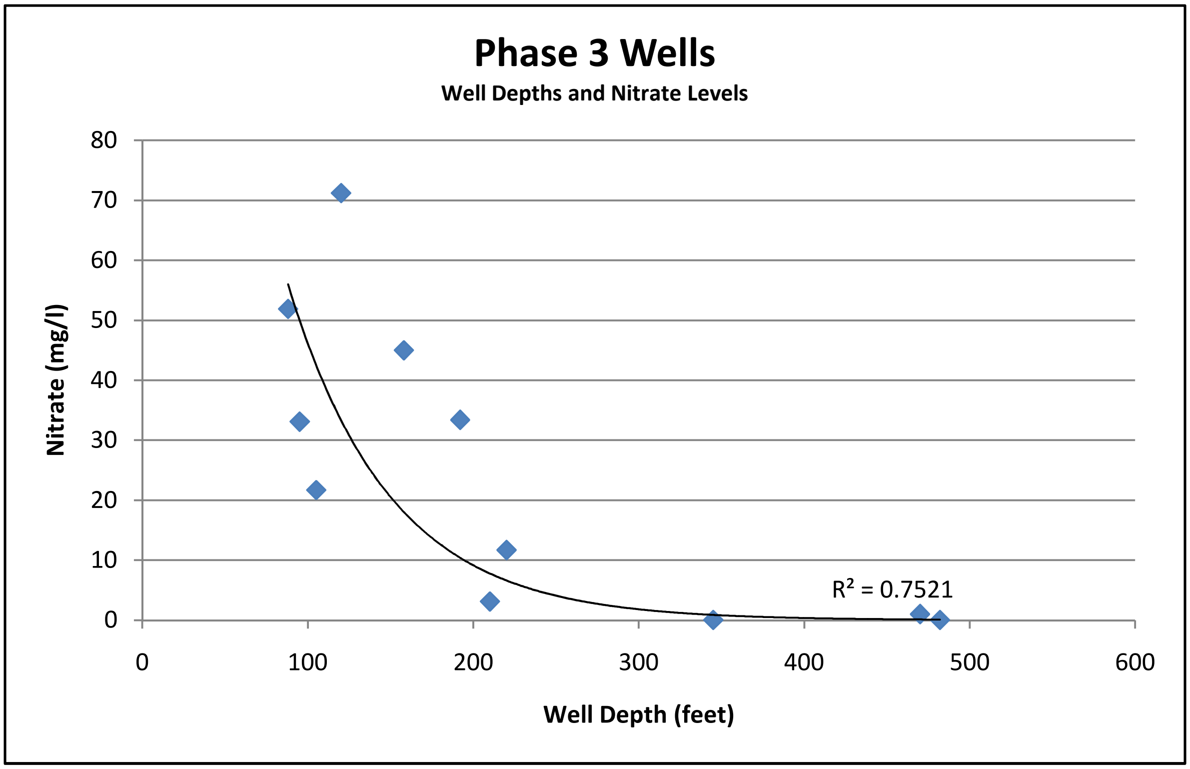

Figure A1 Supporting Data

EPA Phase 3 Well Number	Well Depth from WADOE Well Report (Total Depth)	Nitrate (mg/l)	Well Completed in Alluvial Aquifer or in Basalt	Well Type
WW-04	88	51.9	Alluvial	Domestic
WW-03	95	33.1	Alluvial	Domestic
WW-17	105	21.7	Alluvial	Domestic
WW-28	120	71.2	Unknown	Domestic
WW-12	158	45	Alluvial	Domestic
WW-25	192	33.4	Alluvial	Domestic
WW-02	210	3.12	Basalt	Dairy/Domestic
WW-08	220	11.7	Alluvial	Dairy
WW-10	345	0.05	Alluvial	Domestic
WW-07	470	1.02	Basalt	Dairy
WW-09	482	0.05	Basalt	Dairy

Notes:
Well logs are probable matches based on available information.
WW-28 information based on well owner interview.
The WW-02 well log may be for one of two wells that feed into the Haak dairy water supply.
"Well Type" is based on EPA's understanding of the current use of the well.
WADOE = Washington State Department of the Ecology

Figure A2: Phase 3 - Relationship Between Water Well Depth and Age Dating Data

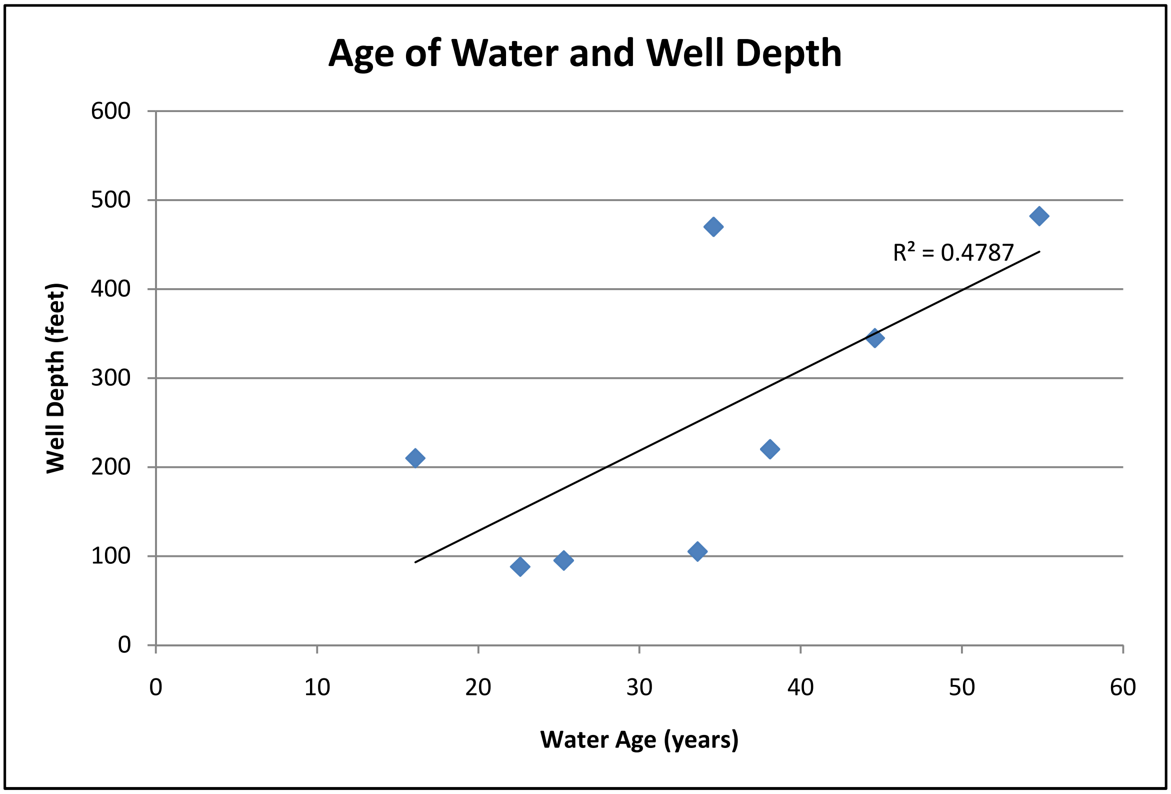

Figure A2 Supporting Data

Well No.	Water Age	Well Depth
WW-03	25.3	95
WW-04	22.6	88
WW-17	33.6	105
WW-02	16.1	210
WW-08	38.1	220
WW-10	44.6	345
WW-07	34.6	470
WW-09	54.8	482

Notes:

Water in wells WW-09 and WW-10 may be older than indicated.

APPENDIX B
SURFACE SOIL CHARACTERISTICS OF THE STUDY AREA

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Appendix B: Surface Soil Characteristics of the Study Area

Surface soils in Yakima County have been characterized and mapped by the Natural Resources Conservation Service (NRCS 2012). A soil report was generated from the NRCS database for each dairy and irrigated crop field in the study and EPA compiled the soil reports (EPA 2012). A summary of surface soil characterization for each of the dairies and irrigated crop field is presented below.

HAAK DAIRY

Within the Haak Dairy property boundary, five soil units have been mapped by the NRCS. All five soil units have a silt loam texture with a "well-drained" classification. Three of the soil units (Scooteney, Sinloc, and Warden) represent 82 percent of the surface area. They have a saturated hydraulic conductivity in the range of 1.1 to 4.0 feet per day, which is characterized as "moderately high to high" in their capacity to transmit water. Saturated hydraulic conductivity is a measure of soil permeability and describes how quickly water moves through soil under saturated conditions. Likewise the other two soil units (Burke and Scoon) have a moderately high to high capacity to transmit water to a depth of 2 to 3 feet below ground surface; however, a cemented layer is present below this depth with a saturated hydraulic conductivity in the "very low to moderately low" range of 0.0 to 0.10 feet per day. The Burke and Scoon units are located in the northwest portion of the Haak Dairy property and account for 18 percent of the surface area.

DAIRY CLUSTER

Almost all the surface soils underlying the Dairy Cluster have a "well drained" classification, which means water moves readily through the soil.

More than 80 percent of the surface soils underlying the Dairy Cluster are highly permeable. Highly permeable is defined here to mean having a high hydraulic conductivity. The prevalence of highly permeable surface soils is significant because it increases the risk of groundwater contamination due to water carrying nitrogen into the ground more readily than if the soils were of lower permeability.

Within the approximate boundary of the Liberty Dairy and Bosma Dairy, 10 soil units have been mapped by NRCS. Most all of them are characterized by a silt loam texture and are classified as "well drained", except for two (Outlook and Sinloc) which have a "somewhat poorly drained" classification. Six of the soil units (Outlook, Scooteney, Shano, Sinloc, Warden, and Esquatzel) represent approximately 87 percent of the surface area. The soil units have a saturated hydraulic conductivity in the range of 1.1 to 4.0 feet per day, which is characterized as "moderately high to high". Three of the soil units (Burke, Moxee, and Scoon) have a saturated hydraulic conductivity in the range of 0.0 to 0.10 feet per day, which is characterized as "very low to moderately low." One of the soil units (Finlay) has a saturated hydraulic conductivity of 1.98 to 5.95 feet per day, which is characterized as "high".

Within the approximate property boundary of the Cow Palace, six soil units have been mapped by the NRCS. All six soil units have a silt loam texture with a "well-drained" classification. Three of the soil units (Esquatzel, Shano, and Warden) represent approximately 81 percent of the surface area. These units have a saturated hydraulic conductivity in the range of 1.1 to 4.0 feet per day, which is characterized as "moderately high to high" in their capacity to transmit water. Two of the soil units (Burke and Scoon) represent approximately 19 percent of the surface area and have a saturated hydraulic conductivity in the range of 0.0 to 0.12 feet per day, which is characterized as "very low to moderately low." One of the soil units (Finlay) represents less than 1 percent of the surface area and has a saturated hydraulic conductivity of 4 to 11.9 feet per day, which is characterized as "high."

Within the approximate boundary of the DeRuyter Dairy and the D and A Dairy, five soil units have been mapped by the NRCS. All five soil units have a silt loam texture with a "well drained" classification. Three of the soil units (Scooteney, Esquatzel, and Warden) represent 92 percent of the surface area. They have a saturated hydraulic conductivity in the range of 1.1 to 4.0 feet per day, which is characterized as "moderately high to high" in their capacity to transmit water. One of the soil units (Scoon) represents approximately 7 percent of the surface area, and has a saturated hydraulic conductivity of 0.0 to 0.12 feet per day, which is described as "very low to moderately low." Another soil unit (Finley) represents just over 1 percent of the land surface area and has a saturated hydraulic conductivity in the range of 4.0 to 11.9 feet per day, which is described as "high."

Irrigated Crop Fields

There were six crop fields sampled in this study: two mint fields (soil samples SO-11 and SO-12); two corn fields (soil samples SO-13 and SO-14); and two hop fields (soil samples SO-15 and SO16). Soil samples SO-11, SO-12, and SO-13 were collected from the same type of soil unit – Warden - which is classified as being "well drained" with a saturated hydraulic conductivity in the range of 1.1 to 4.0 feet per day, which is characterized as "moderately high to high".

Soil sample SO-14 is composed of three soil units – Cleman, Hezel, and Warden. The Cleman unit is well drained and is characterized as having a saturated hydraulic conductivity of "moderately high to high." The Hezel is classified as being "somewhat excessively drained" with a "moderately high" saturated hydraulic conductivity. The Warden soil is also "somewhat excessively drained" with a "moderately high to high" saturated hydraulic conductivity.

Soil sample SO-15 is composed of three soil units – Esquatzel, Hezel, and Warden. The Esquatzel and Warden units are classified as well drained with a "moderately high to high" saturated hydraulic conductivity. The Hezel soil unit is classified as being "somewhat excessively drained" with a "moderately high" saturated hydraulic conductivity.

Soil sample SO-16 is composed of two soil units – Esquatzel and Warden. Both of these units are classified as well drained with a "moderately high to high" saturated hydraulic conductivity.

References Appendix B

Natural Resources Conservation Service (NRCS). 2012. Soil survey staff, U.S. Department of Agriculture, Soil Survey Geographic (SSURGO) Database for Yakima County. Available online at http://soildatamart.nrcs.usda.gov. Accessed January 2012.

U.S. Environmental Protection Agency (EPA). 2012. Soil reports for dairies and irrigated crop fields associated with Phase 3 sampling for EPA Lower Yakima Valley Study. February 2012.

APPENDIX C

DATA SUMMARY TABLES

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Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-11007	10086001f	Field Measurement	Nitrate as N	2	J	mg/L	
	10086001	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-11008	10086002f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086002	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	1		#/100ml	SM 9222-B
			Chloride	49.7		mg/L	300.0
			Total Kjeldahl Nitrogen	5	U	mg/L	351.2
			Nitrate as N	21.1		mg/L	300.0
WW-11009	10086003f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-11010	10086004f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086004	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-11011	10086005f	Field Measurement	Nitrate as N	1	J	mg/L	
WW-11012	10086006f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-11013	10086007f	Field Measurement	Nitrate as N	50	J	mg/L	
	10086007	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	112		mg/L	300.0
			Total Kjeldahl Nitrogen	50	U	mg/L	351.2
			Nitrate as N	53.5		mg/L	300.0
	10086008	Duplicate Sample (10086007)	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	114		mg/L	300.0
			Total Kjeldahl Nitrogen	5	U	mg/L	351.2
			Nitrate as N	54.6		mg/L	300.0
WW-11014	10086009f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086009	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-11015	10086010f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-11016	10086011f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-11017	10086012f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-11018	10086013f	Field Measurement	Nitrate as N	10	J	mg/L	
	10086013	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	5.1	U	mg/L	351.2
	10086015	Duplicate Sample (10086013)	Nitrate+Nitrite as N	13.1		mg/L	353.2
WW-11020	10086014f	Field Measurement	Nitrate as N	2	J	mg/L	

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-11022	10086016f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086016	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-11023	10086017f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-11024	10086018f	Field Measurement	Nitrate as N	0		mg/L	
	10086018	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.5	U	mg/L	351.2
WW-11025	10086020f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086020	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-11026	10086021f	Field Measurement	Nitrate as N	10	J	mg/L	
	10086021	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	9.47		mg/L	300.0
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
			Nitrate as N	6.84		mg/L	300.0
WW-11027	10086022f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-11028	10086023f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-11030	10086024f	Field Measurement	Nitrate as N	10	J	mg/L	
	10086024	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	13.9		mg/L	300.0
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
			Nitrate as N	8.52		mg/L	300.0
WW-11031	10086025f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086025	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-11032	10086026f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-11033	10086027f	Field Measurement	Nitrate as N	2	J	mg/L	
	10086027	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	23.6		mg/L	300.0
			Total Kjeldahl Nitrogen	0.5	U	mg/L	351.2
			Nitrate as N	3.02		mg/L	300.0

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-11034	10086028f	Field Measurement	Nitrate as N	10	J	mg/L	
	10086028	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	11.9		mg/L	300.0
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
			Nitrate as N	8.71		mg/L	300.0
WW-11035	10086029f	Field Measurement	Nitrate as N	10	J	mg/L	
	10086029	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	13.4		mg/L	300.0
			Nitrate as N	17.4		mg/L	300.0
WW-11036	10086030f	Field Measurement	Nitrate as N	0		mg/L	
	10086030	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-11037	10086031f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-11039	10086032f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086032	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.5	U	mg/L	351.2
WW-11040	10086033f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-11041	10086034f	Field Measurement	Nitrate as N	50	J	mg/L	
	10086034	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	32.7		mg/L	300.0
			Nitrate as N	20.8		mg/L	300.0
WW-11042	10086035f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-11043	10086036f	Field Measurement	Nitrate as N	10	J	mg/L	
	10086036	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	28.8		mg/L	300.0
			Nitrate as N	6.72		mg/L	300.0
WW-11044	10086037f	Field Measurement	Nitrate as N	0		mg/L	
	10086037	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
	10086038	Duplicate Sample (10086037)	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-11045	10086039f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086039	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	68.5		mg/L	300.0
			Nitrate as N	17.7		mg/L	300.0
	10086040	Duplicate Sample (10086039)	Chloride	68.6		mg/L	300.0
			Nitrate as N	17.4		mg/L	300.0
WW-11046	10086041f	Field Measurement	Nitrate as N	1	J	mg/L	
	10086041	Laboratory Sample	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-11047	10086043f	Field Measurement	Nitrate as N	1	J	mg/L	
	10086043	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-11048	10086042f	Field Measurement	Nitrate as N	2	J	mg/L	
	10086042	Laboratory Sample	Total Kjeldahl Nitrogen	0.5	U	mg/L	351.2
WW-11049	10086044f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086044	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	34.6		mg/L	300.0
			Nitrate as N	17.5		mg/L	300.0
	10086045	Duplicate Sample (10086044)	Chloride	35		mg/L	300.0
			Nitrate as N	17.4		mg/L	300.0
WW-11050	10086046f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-11051	10086047f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086047	Laboratory Sample	Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-11052	10086048f	Field Measurement	Nitrate as N	1	J	mg/L	
	10086048	Laboratory Sample	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-11053	10086049f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-11054	10086050f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086050	Laboratory Sample	Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-11055	10086051f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086051	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.5	U	mg/L	351.2
WW-11056	10086052f	Field Measurement	Nitrate as N	10	J	mg/L	
	10086052	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	14.5		mg/L	300.0
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
			Nitrate as N	8.93		mg/L	300.0
WW-11057	10086053f	Field Measurement	Nitrate as N	2	J	mg/L	
	10086053	Laboratory Sample	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-11058	10086054f	Field Measurement	Nitrate as N	1	J	mg/L	
	10086054	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.5	U	mg/L	351.2
WW-11059	10086055f	Field Measurement	Nitrate as N	1	J	mg/L	
	10086055	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-11060	10086056f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-11061	10086057f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086057	Laboratory Sample	Total Kjeldahl Nitrogen	0.5	U	mg/L	351.2
WW-11062	10086058f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-11063	10086059f	Field Measurement	Nitrate as N	1	J	mg/L	
	10086059	Laboratory Sample	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-11064	10086060f	Field Measurement	Nitrate as N	n/a		mg/L	
WW-11065	10086061f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-12066	10096301f	Field Measurement	Nitrate as N	1	J	mg/L	
	10096301	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.5	U	mg/L	351.2
WW-12068	10096302f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-12069	10096303f	Field Measurement	Nitrate as N	5	J	mg/L	
	10096303	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-12071	10096304f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-12072	10096305f	Field Measurement	Nitrate as N	2	J	mg/L	
	10096305	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-12074	10096306f	Field Measurement	Nitrate as N	2	J	mg/L	
	10096306	Laboratory Sample	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-12075	10096307f	Field Measurement	Nitrate as N	1	J	mg/L	
	10096307	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-12076	10096308f	Field Measurement	Nitrate as N	50	J	mg/L	
	10096308	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	60		mg/L	300.0
			Total Kjeldahl Nitrogen	5	U	mg/L	351.2
			Nitrate as N	52.6		mg/L	300.0
	10096309	Duplicate Sample (10096308)	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	59.4		mg/L	300.0
			Total Kjeldahl Nitrogen	5	U	mg/L	351.2
			Nitrate as N	52.1		mg/L	300.0
WW-12078	10096310f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-12079	10096311f	Field Measurement	Nitrate as N	1	J	mg/L	
	10096311	Laboratory Sample	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-12080	10096312f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-12081	10096314f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-12083	10096315f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-12084	10096316f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-12085	10096317f	Field Measurement	Nitrate as N	1	J	mg/L	
WW-12086	10096318f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-12087	10096319f	Field Measurement	Nitrate as N	1	J	mg/L	
	10096319	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-12089	10096320f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096320	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	12.5		mg/L	300.0
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
			Nitrate as N	9.75		mg/L	300.0
WW-12090	10096323f	Field Measurement	Nitrate as N	1	J	mg/L	
	10096323	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-12091	10096321f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096321	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	16.7		mg/L	300.0
			Nitrate as N	17.1		mg/L	300.0
WW-12092	10096322f	Field Measurement	Nitrate as N	5	J	mg/L	
	10096322	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-12094	10096324f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096324	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	19.2		mg/L	300.0
			Nitrate as N	9.71		mg/L	300.0
	10096325	Duplicate Sample (10096324)	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	19.1		mg/L	300.0
			Nitrate as N	9.66		mg/L	300.0
WW-12095	10096326f	Field Measurement	Nitrate as N	5	J	mg/L	
	10096326	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-12096	10096328f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-12097	10096329f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096329	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	13.2		mg/L	300.0
			Nitrate as N	11		mg/L	300.0
	10096330	Duplicate Sample (10096329)	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	13.2		mg/L	300.0
			Nitrate as N	11		mg/L	300.0
WW-12099	10096331f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096331	Laboratory Sample	Chloride	18.1		mg/L	300.0
			Nitrate as N	16.6		mg/L	300.0
WW-12100	10096332f	Field Measurement	Nitrate as N	5	J	mg/L	
	10096332	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-12101	10096333f	Field Measurement	Nitrate as N	5	J	mg/L	
	10096333	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-12102	10096334f	Field Measurement	Nitrate as N	5	J	mg/L	
	10096334[b]	Laboratory Sample	Escherichia coli	>120		#/100ml	SM 9221-F
			Fecal Coliform	>120		#/100ml	SM 9221-E
			Total Coliform	>200		#/100ml	SM 9222-B
WW-12109	10096336f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096336	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	5		#/100ml	SM 9222-B
			Chloride	9.81		mg/L	300.0
			Nitrate as N	11.1		mg/L	300.0
WW-12111	10096337f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-12114	10096338f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-12115	10096339f	Field Measurement	Nitrate as N	2	J	mg/L	

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-12116	10096340f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-12117	10096341f	Field Measurement	Nitrate as N	2	J	mg/L	
	10096341	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-12118	10096342f	Field Measurement	Nitrate as N	1	J	mg/L	
WW-12119	10096343f	Field Measurement	Nitrate as N	1	J	mg/L	
WW-12120	10096344f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-12121	10096345f	Field Measurement	Nitrate as N	2	J	mg/L	
	10096345	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-12122	10096346f	Field Measurement	Nitrate as N	2	J	mg/L	
	10096346	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-12127	10096347f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-12130	10096348f	Field Measurement	Nitrate as N	n/a		mg/L	
	10096348	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-12131	10096349f	Field Measurement	Nitrate as N	2	J	mg/L	
	10096349	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-12132	10096350f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-12133	10096351f	Field Measurement	Nitrate as N	1	J	mg/L	
WW-12134	10096352f	Field Measurement	Nitrate as N	n/a		mg/L	
	10096352	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-12135	10096353f	Field Measurement	Nitrate as N	2	J	mg/L	
	10096353	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-12136	10096354f	Field Measurement	Nitrate as N	1	J	mg/L	
	10096354	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	26.3		mg/L	300.0
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
			Nitrate as N	1.2	U	mg/L	300.0
WW-12137	10096355f	Field Measurement	Nitrate as N	1	J	mg/L	
WW-12138	10096356f	Field Measurement	Nitrate as N	0		mg/L	
	10096356	Laboratory Sample	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-12139	10096357f	Field Measurement	Nitrate as N	0		mg/L	
	10096357	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-12140	10096358f	Field Measurement	Nitrate as N	0		mg/L	
	10096358	Laboratory Sample	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-12141	10096359f	Field Measurement	Nitrate as N	1	J	mg/L	
	10096359	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-12142	10096360f	Field Measurement	Nitrate as N	2	J	mg/L	
	10096360	Laboratory Sample	Escherichia coli	12		#/100ml	SM 9221-F
			Fecal Coliform	12		#/100ml	SM 9221-E
			Total Coliform	12		#/100ml	SM 9222-B
WW-12143	10096361f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-12144	10096362f	Field Measurement	Nitrate as N	2	J	mg/L	
	10096362	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	5.02		mg/L	300.0
			Nitrate as N	2.79		mg/L	300.0
WW-12145	10096363f	Field Measurement	Nitrate as N	50	J	mg/L	
	10096363	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	14.8		mg/L	300.0
			Nitrate as N	19.9		mg/L	300.0
WW-12146	10096364f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096364	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	10.1		mg/L	300.0
			Nitrate as N	10.7		mg/L	300.0
WW-12147	10096366f	Field Measurement	Nitrate as N	2	J	mg/L	
	10096366	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-12148	10096367f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-12149	10096368f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096368	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	16.3		mg/L	300.0
			Nitrate as N	10.3		mg/L	300.0
WW-12150	10096369f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-12151	10096370f	Field Measurement	Nitrate as N	5	J	mg/L	

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-12153	10096371f	Field Measurement	Nitrate as N	2	J	mg/L	
	10096371	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-12281	10096313f	Field Measurement	Nitrate as N	5	J	mg/L	
	10096313	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-12296	10096327f	Field Measurement	Nitrate as N	5	J	mg/L	
	10096327	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-12354	10096372f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-21009	10086101f	Field Measurement	Nitrate as N	10	J	mg/L	
	10086101	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	7.82		mg/L	300.0
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
			Nitrate as N	11.4	J	mg/L	300.0
WW-21010	10086102f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086102	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-21013	10086103f	Field Measurement	Nitrate as N	10	J	mg/L	
	10086103	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-21014	10086104f	Field Measurement	Nitrate as N	2	J	mg/L	
	10086104	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-21015	2101501f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-21016	10086106f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086106	Laboratory Sample	Chloride	38.7		mg/L	300.0.0
			Nitrate as N	27.6		mg/L	300.0.0
WW-21017	2101702f	Field Measurement	Nitrate as N	10	J	mg/L	
WW-21018	2101803f	Field Measurement	Nitrate as N	10	J	mg/L	
WW-21019	10086108f	Field Measurement	Nitrate as N	0		mg/L	
	10086108	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-21020	2102004f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-21021	2102105f	Field Measurement	Nitrate as N	10	J	mg/L	
WW-21022	2102206f	Field Measurement	Nitrate as N	2	J	mg/L	

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-21023	10086112f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086107	Duplicate Sample (10086112)	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
	10086109	Duplicate Sample (10086112)	Total Kjeldahl Nitrogen	1	U	mg/L	351.2
	10086112	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-21024	10086113f	Field Measurement	Nitrate as N	10	J	mg/L	
	10086113	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	18.9		mg/L	300.0.0
			Total Kjeldahl Nitrogen	5	U	mg/L	351.2
			Nitrate as N	18.9		mg/L	300.0.0
WW-21025	10086114f	Field Measurement	Nitrate as N	2	J	mg/L	
	10086114	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	>60		#/100ml	SM 9222-B
WW-21026	10086115f	Field Measurement	Nitrate as N	2	J	mg/L	
	10086115	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-21027	2102707f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-21028	10086117f	Field Measurement	Nitrate as N	2	J	mg/L	
	10086117	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-21029	2102908f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-21030	2103009f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-21035	10086120f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086119	Duplicate Sample (10086120)	Chloride	35.2		mg/L	300.0.0
			Nitrate as N	11.9		mg/L	300.0.0
	10086120	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	10		#/100ml	SM 9222-B
			Chloride	36.1		mg/L	300.0.0
			Nitrate as N	12.1		mg/L	300.0.0
WW-21036	10086122f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086122	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	25.6		mg/L	300.0.0
			Nitrate as N	29.1		mg/L	300.0.0

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-21037	10086123f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086123	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-21038	2103810f	Field Measurement	Nitrate as N	10	J	mg/L	
WW-21039	10086124f	Field Measurement	Nitrate as N	1	J	mg/L	
	10086124	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-21040	2104011f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-21041	10086127f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086127	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	10.2		mg/L	300.0.0
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
			Nitrate as N	12.1		mg/L	300.0.0
WW-21042	10086129f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086129	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	26.4		mg/L	300.0.0
			Nitrate as N	12.1		mg/L	300.0.0
WW-21043	10086130f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086130	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-21044	10086131f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086131	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	21.6		mg/L	300.0.0
			Total Kjeldahl Nitrogen	5.1	U	mg/L	351.2
			Nitrate as N	16.6		mg/L	300.0.0
WW-21045	10086132f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086132	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	51.3		mg/L	300.0.0
			Nitrate as N	25.2		mg/L	300.0.0
WW-21046	2104612f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-21047	2104713f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-21048	2104814f	Field Measurement	Nitrate as N	5	J	mg/L	

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-21049	10086136f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086136	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	40		mg/L	300.0.0
			Nitrate as N	18.1		mg/L	300.0.0
WW-21050	10086138f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086138	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	17.6		mg/L	300.0.0
			Nitrate as N	6.06		mg/L	300.0.0
WW-21051	10086139f	Field Measurement	Nitrate as N	10	J	mg/L	
	10086139	Laboratory Sample	Chloride	21.6		mg/L	300.0.0
			Nitrate as N	14		mg/L	300.0.0
WW-21052	10086140f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086140	Laboratory Sample	Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-21053	10086141f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086141	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	57.3		mg/L	300.0.0
			Nitrate as N	27.6		mg/L	300.0.0
WW-21054	2105415f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-21055	10086143f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086143	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	20.2		mg/L	300.0.0
			Nitrate as N	12.8		mg/L	300.0.0
WW-21056	2105616f	Field Measurement	Nitrate as N	10	J	mg/L	
WW-21057	2105717f	Field Measurement	Nitrate as N	10	J	mg/L	
WW-21058	2105818f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-21059	10086147f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086147	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	13.3		mg/L	300.0.0
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
			Nitrate as N	10		mg/L	300.0.0
WW-21142	10086128f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086126	Duplicate Sample (10086128)	Total Kjeldahl Nitrogen	1	U	mg/L	351.2
	10086128	Laboratory Sample	Total Kjeldahl Nitrogen	1	U	mg/L	351.2

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-21150	10086137f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086135	Duplicate Sample (10086137)	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	17		mg/L	300.0.0
			Total Kjeldahl Nitrogen	5	U	mg/L	351.2
			Nitrate as N	18.2		mg/L	300.0.0
	10086137	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	16.8		mg/L	300.0.0
			Total Kjeldahl Nitrogen	5.1	U	mg/L	351.2
			Nitrate as N	18		mg/L	300.0.0
WW-22060	10096401f	Field Measurement	Nitrate as N	1	J	mg/L	
	10096401	Laboratory Sample	Total Kjeldahl Nitrogen	0.5	U	mg/L	351.2
WW-22061	2206119f	Field Measurement	Nitrate as N	1	J	mg/L	
WW-22062	2206220f	Field Measurement	Nitrate as N	0	J	mg/L	
WW-22063	10096404f	Field Measurement	Nitrate as N	20	J	mg/L	
	10096404	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	17.3		mg/L	300.0
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
			Nitrate as N	10.8		mg/L	300.0
WW-22064	10096405f	Field Measurement	Nitrate as N	20	J	mg/L	
	10090060	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
	10096405	Laboratory Sample	Chloride	45.8		mg/L	300.0
			Nitrate as N	21.1		mg/L	300.0
WW-22065	10096406f	Field Measurement	Nitrate as N	20	J	mg/L	
	10096406	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	44.5		mg/L	300.0
			Nitrate as N	20.3		mg/L	300.0
WW-22066	10096407f	Field Measurement	Nitrate as N	20	J	mg/L	
	10090061	Duplicate Sample (10096407)	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
	10096407	Laboratory Sample	Chloride	79.9		mg/L	300.0
			Total Kjeldahl Nitrogen	5.1	U	mg/L	351.2
			Nitrate as N	41.1		mg/L	300.0
WW-22067	10096408f	Field Measurement	Nitrate as N	50	J	mg/L	
	10090062	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
	10096408	Laboratory Sample	Chloride	70		mg/L	300.0
			Total Kjeldahl Nitrogen	5	U	mg/L	351.2
			Nitrate as N	39.8		mg/L	300.0
WW-22068	2206821f	Field Measurement	Nitrate as N	2	J	mg/L	

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-22069	2206922f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22070	10096411f	Field Measurement	Nitrate as N	20	J	mg/L	
	10096411	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	52.1		mg/L	300.0
			Nitrate as N	21.4		mg/L	300.0
WW-22071	2207123f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-22072	2207224f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22073	2207325f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-22074	2207426f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22075	2207527f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22076	10096412f	Field Measurement	Nitrate as N	2	J	mg/L	
	10096412	Laboratory Sample	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-22078	2207828f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22079	10096413f	Field Measurement	Nitrate as N	2	J	mg/L	
	10096413	Laboratory Sample	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-22080	2208029f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-22082	2208230f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22083	10096423f	Field Measurement	Nitrate as N	1	J	mg/L	
	10096423	Laboratory Sample	Total Kjeldahl Nitrogen	0.5	U	mg/L	351.2
WW-22084	2208431f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-22085	2208532f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22086	10096426f	Field Measurement	Nitrate as N	5	J	mg/L	
	10096426	Laboratory Sample	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
	10096427	Duplicate Sample (10096426)	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-22087	10096428f	Field Measurement	Nitrate as N	20	J	mg/L	
	10096428	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	45		mg/L	300.0
			Nitrate as N	14.3		mg/L	300.0
	10096429	Duplicate Sample (10096428)	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	44.8		mg/L	300.0
			Nitrate as N	14.9		mg/L	300.0
WW-22088	10096431f	Field Measurement	Nitrate as N	1	J	mg/L	
	10096431	Laboratory Sample	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-22089	2208933f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22090	10096433f	Field Measurement	Nitrate as N	20	J	mg/L	
	10096433	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	72		mg/L	300.0
			Nitrate as N	11.3		mg/L	300.0

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-22091	10096434f	Field Measurement	Nitrate as N	20	J	mg/L	
	10096434	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	37.9		mg/L	300.0
			Nitrate as N	12.2		mg/L	300.0
WW-22092	10096435f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096435	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	7.89		mg/L	300.0
			Nitrate as N	8.57		mg/L	300.0
WW-22093	10096436f	Field Measurement	Nitrate as N	1	J	mg/L	
	10096436	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-22094	2209434f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22096	2209635f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22098	10096439f	Field Measurement	Nitrate as N	5	J	mg/L	
	10096439	Laboratory Sample	Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-22099	2209936f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22100	2210037f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22101	2210138f	Field Measurement	Nitrate as N	1	J	mg/L	
WW-22102	2210239f	Field Measurement	Nitrate as N	1	J	mg/L	
WW-22103	2210340f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22104	10096445f	Field Measurement	Nitrate as N	5	J	mg/L	
	10096445	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-22105	2210541f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22106	10096446f	Field Measurement	Nitrate as N	0		mg/L	
	10096446	Laboratory Sample	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-22107	2210742f	Field Measurement	Nitrate as N	1	J	mg/L	
WW-22108	2210843f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-22109	10096450f	Field Measurement	Nitrate as N	50	J	mg/L	
	10096450	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	53.3		mg/L	300.0
			Nitrate as N	46.4		mg/L	300.0
	10096451	Duplicate Sample (10096450)	Chloride	51.3		mg/L	300.0
			Nitrate as N	44.6		mg/L	300.0
WW-22110	2211044f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22111	10096452f	Field Measurement	Nitrate as N	2	J	mg/L	
	10096452	Laboratory Sample	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-22112	10096453f	Field Measurement	Nitrate as N	2	J	mg/L	
	10096453	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-22113	2211345f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-22114	10096455f	Field Measurement	Nitrate as N	50	J	mg/L	
	10096455	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	30.7		mg/L	300.0
			Total Kjeldahl Nitrogen	5.1	U	mg/L	351.2
			Nitrate as N	22.8		mg/L	300.0
WW-22115	10096456f	Field Measurement	Nitrate as N	50	J	mg/L	
	10096456	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	34.8		mg/L	300.0
			Total Kjeldahl Nitrogen	5	U	mg/L	351.2
			Nitrate as N	23.8		mg/L	300.0
WW-22116	2211646f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22117	10096459f	Field Measurement	Nitrate as N	50	J	mg/L	
	10096459	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	50.8		mg/L	300.0
			Total Kjeldahl Nitrogen	5.1	U	mg/L	351.2
			Nitrate as N	37		mg/L	300.0
WW-22118	10096461f	Field Measurement	Nitrate as N	20	J	mg/L	
	10096461	Laboratory Sample	Chloride	13.3		mg/L	300.0
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
			Nitrate as N	12.5		mg/L	300.0
WW-22201	2220147f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22202	2220248f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22203	2220349f	Field Measurement	Nitrate as N	10	J	mg/L	
WW-22204	2220450f	Field Measurement	Nitrate as N	10	J	mg/L	
WW-22205	2220551f	Field Measurement	Nitrate as N	1	J	mg/L	
WW-22206	2220652f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-22207	2220753f	Field Measurement	Nitrate as N	10	J	mg/L	
WW-22208	10096465f	Field Measurement	Nitrate as N	50	J	mg/L	
	10096465	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	21.9		mg/L	300.0
			Total Kjeldahl Nitrogen	5	U	mg/L	351.2
			Nitrate as N	20.1		mg/L	300.0
WW-31011	3101154f	Field Measurement	Nitrate as N	1	J	mg/L	
WW-31012	10086201f	Field Measurement	Nitrate as N	1	J	mg/L	
	10086201	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-31013	3101355f	Field Measurement	Nitrate as N	5	J	mg/L	

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-31014	3101456f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-31016	3101657f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-31017	3101758f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-31018	3101859f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-31019	10086202f	Field Measurement	Nitrate as N	1	J	mg/L	
	10086202	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-31020	3102060f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-31022	10086203f	Field Measurement	Nitrate as N	1	J	mg/L	
	10086203	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-31024	10086204f	Field Measurement	Nitrate as N	50	J	mg/L	
	10086204	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	62.6		mg/L	300.0
			Nitrate as N	38.2		mg/L	300.0
	10086205	Duplicate Sample (10086204)	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	63.4		mg/L	300.0
			Nitrate as N	38.1		mg/L	300.0
	10097002	Laboratory Sample	Nitrate+Nitrite as N	40.6		mg/L	353.2
	10107004	Laboratory Sample	Nitrate+Nitrite as N	40.6		mg/L	353.2
	10117006	Laboratory Sample	Nitrate+Nitrite as N	40.3		mg/L	353.2
	10127008	Laboratory Sample	Nitrate+Nitrite as N	39.3		mg/L	353.2
	10137010	Laboratory Sample	Nitrate+Nitrite as N	41.1		mg/L	353.2
	10157014	Laboratory Sample	Nitrate+Nitrite as N	41	J	mg/L	353.2
	10167016	Laboratory Sample	Nitrate+Nitrite as N	41	J	mg/L	353.2
	10177018	Laboratory Sample	Nitrate+Nitrite as N	41	J	mg/L	353.2
WW-31025	10086206f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086206	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	41.5		mg/L	300.0
			Nitrate as N	18.4		mg/L	300.0
	10097001	Laboratory Sample	Nitrate+Nitrite as N	20.6		mg/L	353.2
	10107003	Laboratory Sample	Nitrate+Nitrite as N	20.6		mg/L	353.2
	10117005	Laboratory Sample	Nitrate+Nitrite as N	20.7		mg/L	353.2
	10127007	Laboratory Sample	Nitrate+Nitrite as N	20.4		mg/L	353.2
	10137009	Laboratory Sample	Nitrate+Nitrite as N	40.4		mg/L	353.2
	10147011	Laboratory Sample	Nitrate+Nitrite as N	40.8		mg/L	353.2
	10147012	Laboratory Sample	Nitrate+Nitrite as N	44		mg/L	353.2
	10157013	Laboratory Sample	Nitrate+Nitrite as N	24	J	mg/L	353.2
	10167015	Laboratory Sample	Nitrate+Nitrite as N	22	J	mg/L	353.2
	10177017	Laboratory Sample	Nitrate+Nitrite as N	22	J	mg/L	353.2
WW-31029	3102961f	Field Measurement	Nitrate as N	2	J	mg/L	

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-31030	10086207f	Field Measurement	Nitrate as N	1	J	mg/L	
	10086207	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-31031	10086208f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086208	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-31032	10086209f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086209	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-31034	3103462f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-31035	10086211f	Field Measurement	Nitrate as N	10	J	mg/L	
	10086211	Laboratory Sample	Chloride	10.5	J	mg/L	300.0
			Nitrate as N	12.9	J	mg/L	300.0
WW-31036	3103663f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-31038	10086212f	Field Measurement	Nitrate as N	2	J	mg/L	
	10086212	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-31039	10086213f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086213	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Total Coliform	<1		#/100ml	SM 9221-E
			Fecal Coliform	<1		#/100ml	SM 9222-B
			Chloride	24.2		mg/L	300.0
			Nitrate as N	15		mg/L	300.0
WW-31040	10086214f	Field Measurement	Nitrate as N	1	J	mg/L	
	10086214	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-31041	10086215f	Field Measurement	Nitrate as N	0		mg/L	
	10086215	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.5	U	mg/L	351.2
	10086216	Duplicate Sample (10086215)	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-31045	3104564f	Field Measurement	Nitrate as N	5	J	mg/L	

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-31046	10086217f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086217	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	18.2		mg/L	300.0
			Nitrate as N	14.8		mg/L	300.0
WW-31047	10086218f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086218	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	26.7		mg/L	300.0
			Nitrate as N	16.2		mg/L	300.0
WW-31048	3104865f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-31050	3105066f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-31051	10086219f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086219	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	8.03		mg/L	300.0
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
			Nitrate as N	12.1		mg/L	300.0
WW-31052	10086221f	Field Measurement	Nitrate as N	2	J	mg/L	
	10086221	Laboratory Sample	Total Kjeldahl Nitrogen	0.5	U	mg/L	351.2
WW-31054	10086222f	Field Measurement	Nitrate as N	20	J	mg/L	
	10086222	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	34.4		mg/L	300.0
			Nitrate as N	22		mg/L	300.0
WW-31056	10086223f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086223	Laboratory Sample	Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-31057	10086224f	Field Measurement	Nitrate as N	0		mg/L	
	10086224	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
	10086225	Duplicate Sample (10086224)	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-31058	3105867f	Field Measurement	Nitrate as N	1	J	mg/L	
WW-31059	10086226f	Field Measurement	Nitrate as N	5	J	mg/L	
	10086226	Laboratory Sample	Total Kjeldahl Nitrogen	1	U	mg/L	351.2
	10086227	Duplicate Sample (10086226)	Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-31060	3106068f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-31064	3106469f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-31355	10086220f	Field Measurement	Nitrate as N	0		mg/L	
	10086220	Laboratory Sample	Nitrate+Nitrite as N	0.05	U	mg/L	353.2
WW-31356	3135670f	Field Measurement	Nitrate as N	5	J	mg/L	

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-32068	10096501f	Field Measurement	Nitrate as N	50	J	mg/L	
	10096501	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	40.2		mg/L	300.0
			Nitrate as N	27.1		mg/L	300.0
WW-32069	10096502f	Field Measurement	Nitrate as N	0		mg/L	
	10096502	Laboratory Sample	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-32070	10096503f	Field Measurement	Nitrate as N	50	J	mg/L	
	10096503	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	104		mg/L	300.0
			Nitrate as N	31.4		mg/L	300.0
WW-32071	10096504f	Field Measurement	Nitrate as N	20	J	mg/L	
	10096504	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	37.2		mg/L	300.0
			Total Kjeldahl Nitrogen	5.1	U	mg/L	351.2
			Nitrate as N	12.7		mg/L	300.0
WW-32072	10096505f	Field Measurement	Nitrate as N	20	J	mg/L	
	10096505	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	26.8		mg/L	300.0
			Nitrate as N	12.4		mg/L	300.0
WW-32073	10096506f	Field Measurement	Nitrate as N	20	J	mg/L	
	10096506	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	28.5		mg/L	300.0
			Nitrate as N	16.1		mg/L	300.0
WW-32074	10096507f	Field Measurement	Nitrate as N	20	J	mg/L	
	10096507	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	47.8		mg/L	300.0
			Nitrate as N	10.5		mg/L	300.0
WW-32075	3207572f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-32076	3207673f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-32079	3207974f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-32080	10096508f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096508	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	15.8		mg/L	300.0
			Total Kjeldahl Nitrogen	1.15		mg/L	351.2
			Nitrate as N	8.65		mg/L	300.0

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-32081	10096509f	Field Measurement	Nitrate as N	2	J	mg/L	
	10096509	Laboratory Sample	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-32082	10096594f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096594	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	34.3		mg/L	300.0
			Nitrate as N	8.06		mg/L	300.0
	10096595	Duplicate Sample (10096594)	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	34.6		mg/L	300.0
			Nitrate as N	8.05		mg/L	300.0
WW-32083	10096596f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096596	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	21.1		mg/L	300.0
			Nitrate as N	6.53		mg/L	300.0
WW-32084	3208475f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-32085	3208576f	Field Measurement	Nitrate as N	10	J	mg/L	
WW-32086	3208677f	Field Measurement	Nitrate as N	10	J	mg/L	
WW-32087	3208778f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-32091	10096597f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096597	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	35.6		mg/L	300.0
			Nitrate as N	3.76		mg/L	300.0
WW-32092	3209279f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-32093	3209380f	Field Measurement	Nitrate as N	10	J	mg/L	
WW-32094	3209481f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-32095	3209582f	Field Measurement	Nitrate as N	2	J	mg/L	
WW-32096	3209683f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-32097	3209784f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-32098	3209885f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-32100	10096599f	Field Measurement	Nitrate as N	20	J	mg/L	
	10096599	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	13		mg/L	300.0
			Total Kjeldahl Nitrogen	5.1	U	mg/L	351.2
			Nitrate as N	15.8		mg/L	300.0
WW-32101	10096598f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096598	Laboratory Sample	Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-32102	10096510f	Field Measurement	Nitrate as N	5	J	mg/L	
	10096510	Laboratory Sample	Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-32103	3210386f	Field Measurement	Nitrate as N	5	J	mg/L	

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-32104	10096511f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096511	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.99	U	mg/L	351.2
WW-32105	10096512f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096512	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
WW-32106	10096513f	Field Measurement	Nitrate as N	20	J	mg/L	
	10096513	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	9.23		mg/L	300.0
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
			Nitrate as N	12		mg/L	300.0
WW-32107	10096514f	Field Measurement	Nitrate as N	20	J	mg/L	
	10096514	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	26.2		mg/L	300.0
			Nitrate as N	11.6		mg/L	300.0
WW-32108	10096515f	Field Measurement	Nitrate as N	20	J	mg/L	
	10096515	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	26.2		mg/L	300.0
			Nitrate as N	9.51		mg/L	300.0
WW-32109	10096516f	Field Measurement	Nitrate as N	1	J	mg/L	
	10096516	Laboratory Sample	Total Kjeldahl Nitrogen	0.5	U	mg/L	351.2
WW-32110	3211087f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-32111	10096517f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096517	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	9.9		mg/L	300.0
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
			Nitrate as N	9.29		mg/L	300.0
	10096518	Duplicate Sample (10096517)	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	9.87		mg/L	300.0
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
			Nitrate as N	9.29		mg/L	300.0
WW-32112	10096519f	Field Measurement	Nitrate as N	0		mg/L	
	10096519	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-32113	10096520f	Field Measurement	Nitrate as N	50	J	mg/L	
	10096520	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	45.9		mg/L	300.0
			Nitrate as N	21.3		mg/L	300.0
WW-32114	10096521f	Field Measurement	Nitrate as N	2	J	mg/L	
	10096521	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-32115	10096522f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096522	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	17.2		mg/L	300.0
			Nitrate as N	9.61		mg/L	300.0
WW-32116	10096523f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096523	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	14.1		mg/L	300.0
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
			Nitrate as N	9.01		mg/L	300.0
WW-32117	10096524f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096524	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	9.08		mg/L	300.0
			Nitrate as N	14.2		mg/L	300.0
WW-32118	10096525f	Field Measurement	Nitrate as N	2	J	mg/L	
	10096525	Laboratory Sample	Total Kjeldahl Nitrogen	0.51	U	mg/L	351.2
WW-32119	3211988f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-32120	10096526f	Field Measurement	Nitrate as N	5	J	mg/L	
	10096526	Laboratory Sample	Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-32122	10096527f	Field Measurement	Nitrate as N	10	J	mg/L	
	10096527	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	16.6		mg/L	300.0
			Total Kjeldahl Nitrogen	1	U	mg/L	351.2
			Nitrate as N	8.98		mg/L	300.0
WW-32123	3212389f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-32124	3212490f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-32125	3212591f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-32126	10096528f	Field Measurement	Nitrate as N	5	J	mg/L	
	10096528	Laboratory Sample	Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-32127	3212792f	Field Measurement	Nitrate as N	2	J	mg/L	

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method
WW-32128	10096529f	Field Measurement	Nitrate as N	20	J	mg/L	
	10096529	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	23.8		mg/L	300.0
			Nitrate as N	14.4		mg/L	300.0
	10096530	Duplicate Sample (10096529)	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	23.8		mg/L	300.0
			Nitrate as N	14		mg/L	300.0
WW-32129	10096531f	Field Measurement	Nitrate as N	20	J	mg/L	
	10096531	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	51.1		mg/L	300.0
			Total Kjeldahl Nitrogen	5.1	U	mg/L	351.2
			Nitrate as N	18.9		mg/L	300.0
	10096532	Duplicate Sample (10096531)	Total Kjeldahl Nitrogen	5	U	mg/L	351.2
WW-32130	10096533f	Field Measurement	Nitrate as N	20	J	mg/L	
	10096533	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	125		#/100ml	SM 9222-B
			Chloride	27.9		mg/L	300.0
			Nitrate as N	20.6		mg/L	300.0
WW-32131	10096534f	Field Measurement	Nitrate as N	50	J	mg/L	
	10096534	Laboratory Sample	Escherichia coli	<1		#/100ml	SM 9221-F
			Fecal Coliform	<1		#/100ml	SM 9221-E
			Total Coliform	<1		#/100ml	SM 9222-B
			Chloride	71.5		mg/L	300.0
			Total Kjeldahl Nitrogen	5	U	mg/L	351.2
			Nitrate as N	20.6		mg/L	300.0
WW-32132	3213293f	Field Measurement	Nitrate as N	5	J	mg/L	
WW-32133	10096535f	Field Measurement	Nitrate as N	5	J	mg/L	
	10096535	Laboratory Sample	Total Kjeldahl Nitrogen	1	U	mg/L	351.2
WW-32135	3213571f	Field Measurement	Nitrate as N	10	J	mg/L	

Units

mg/L = milligrams per liter

Data Qualifiers

J = The analyte was positively identified. The associated numerical value is an estimate.

U = The analyte was not detected at or above the reported value.

< = The level of the target organism present in the sample is less than the detection limit. The reported value is the detection limit.

> = The level of the target organism present in the sample exceeds the upper limit for microbial estimates. The reported value is the

Table C1: Phase 2 Field Measurements and Laboratory Analytical Results

Location ID	Sample ID	Sample Type[a]	Compound	Result	Qualifier	Units	Analytical Method

Notes:

[a]Samples submitted to the laboratory were analyzed by the EPA Manchester Environmental Laboratory.

[b]Sample No. 10096334 was submitted to the laboratory for microbial source tracking (MST) analysis. Results are presented below.

Biomarker	Result
BAC-32	Present
CF-128	Absent
CF-193	Absent
MST-	General Bacteriodes Present
HF-183	Absent
HF-134	Absent

BAC32: This is the screening Bacteroides biomarker. If it is present, further testing is done to determine the specific source. If the test is negative, nothing more is done.

CF128 and CF193: These are two separate biomarkers that identify the presence of ruminant fecal source. Between the two of them, they comprise most of the biomarkers that would be found in ruminants. There may be other biomarkers that could exist in very isolated populations of ruminants, but these two will identify the majority. A "P" would identify detection of the biomarker in the particular sample, an "A" indicates absence of that biomarker in the sample.

HF134 and HF183: These are two separate biomarkers that identify the presence of human fecal source. As above, between the two of these biomarkers, the majority of human source will be detected. Again, a very isolated community might develop a different biomarker. A "P" would identify detection of the biomarker in the particular sample, an "A" indicates absence of that biomarker in the sample.

MST- Microbial Source Tracking. MST contaminants: This identifies by two letter code the kind of fecal source was identified in the particular sample.GB indicates that although Bacteroides DNA was present, the source was neither human nor ruminant. An "A" indicates that no Bacteroides DNA was present in the sample. H indicates human source; R indicates ruminant; H/R indicates that both were found in that sample. To be noted, where there is a species identification, there may be fecal contamination from other species present as well, but due to method limitations is not identified.

Table C2: Phase 3 Summary of Sampling Locations and Laboratory Analyses

				Laboratory Analyses													
				Nitrate	Other forms of Nitrogen[1]	Major Ions and Alkalinity	Trace Inorganic Elements	Perchlorate	Pesticides[2]	Pathogens[3]	Hormones (EPA Laboratory)	Hormones (U. of Nebraska - Lincoln Laboratory)	Veterinary Pharmaceuticals	Wastewater Pharmaceuticals	Isotopic Analysis	Trace Organics	Age Dating and Gas Study
			Number of Analytes	1	4	9	12	1	50	Varies	5	20	17	14	NA	69	NA
Location ID	Sample ID	Sample Type	Sample Media														
WW-01	10154201	Upgradient Well – Haak Dairy	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-02	10154202	Supply Well – Haak Dairy	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-03	10154203	Downgradient Well – Haak Dairy	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-04	10154204	Downgradient Well – Haak Dairy	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-05	10154205	Downgradient Well – Haak Dairy	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-06	10154206	Upgradient – Dairy Cluster	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-07	10154207	Supply Well – DeRuyter Dairy	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-08	10154208	Supply Well – D and A Dairy	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-09	10164209	Supply Well – Cow Palace	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-10	10164210	Downgradient Well – Dairy Cluster	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-11	10154211	Downgradient Well – Dairy Cluster	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-12	10154212	Downgradient Well – Dairy Cluster	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-13	10154213	Downgradient Well – Dairy Cluster	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-14	10154214	Downgradient Well – Dairy Cluster	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-15	10154215	Downgradient Well – Dairy Cluster	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-16	10154216	Downgradient Well – Dairy Cluster	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-17	10154217	Downgradient Well – Dairy Cluster	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-18[4]	10154218	Residential Well	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-19	10154219	Downgradient Well – Septic	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-20	10154220	Downgradient Well – Septic	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-21	10154221	Downgradient Well – Septic	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-22	10164222	Downgradient Well – Septic	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-23	10154223	Downgradient Well – Mint	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-24	10154224	Downgradient Well – Mint	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-25	10154225	Downgradient Well – Corn	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-26	10154226	Downgradient Well – Hops	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-27	10154227	Downgradient Well – Hops	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-28	10154228	Downgradient Well – Corn	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-29	10154229	Field Blank	Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WW-30[5]	10164230	Residential well	Water	X	X	X	X	X	X	X	X					X	
LG-01	10154251	Dairy Lagoon - Haak Dairy	Dairy Lagoon		X	X	X			X	X	X	X	X		X	
LG-02	10154252	Dairy Lagoon - Haak Dairy[6]	Dairy Lagoon		X	X	X			X	X	X	X	X		X	
LG-03	10154253	Dairy Lagoon - Haak Dairy[6]	Dairy Lagoon		X	X	X			X	X	X	X	X		X	
LG-04	10154254	Dairy Lagoon - DeRuyter Dairy	Dairy Lagoon		X	X	X			X	X	X	X	X		X	
LG-05	10154255	Dairy Lagoon - DeRuyter Dairy	Dairy Lagoon		X	X	X			X	X	X	X	X		X	
LG-06	10154256	Dairy Lagoon - DeRuyter Dairy	Dairy Lagoon		X	X	X			X	X	X	X	X		X	
LG-07	10154257	Dairy Lagoon - D and A Dairy	Dairy Lagoon		X	X	X			X	X	X	X	X		X	
LG-08	10154258	Dairy Lagoon - D and A Dairy[6]	Dairy Lagoon		X	X	X			X	X	X	X	X		X	
LG-09	10154259	Dairy Lagoon - D and A Dairy[6]	Dairy Lagoon		X	X	X			X	X	X	X	X		X	
LG-10	10164260	Dairy Lagoon - Cow Palace	Dairy Lagoon		X	X	X			X	X	X	X	X		X	
LG-11	10164261	Dairy Lagoon - Cow Palace[6]	Dairy Lagoon		X	X	X			X	X	X	X	X		X	
LG-12	10164262	Dairy Lagoon - Cow Palace[6]	Dairy Lagoon		X	X	X			X	X	X	X	X		X	
LG-13	10164263	Dairy Lagoon - Bosma Dairy	Dairy Lagoon		X	X	X			X	X	X	X	X		X	
LG-14	10164264	Dairy Lagoon - Bosma Dairy	Dairy Lagoon		X	X	X			X	X	X	X	X		X	
LG-15	10164265	Dairy Lagoon - Bosma Dairy	Dairy Lagoon		X	X	X			X	X	X	X	X		X	

Table C2: Phase 3 Summary of Sampling Locations and Laboratory Analyses

				Laboratory Analyses													
				Nitrate	Other forms of Nitrogen[1]	Major Ions and Alkalinity	Trace Inorganic Elements	Perchlorate	Pesticides[2]	Pathogens[3]	Hormones (EPA Laboratory)	Hormones (U. of Nebraska - Lincoln Laboratory)	Veterinary Pharmaceuticals	Wastewater Pharmaceuticals	Isotopic Analysis	Trace Organics	Age Dating and Gas Study
			Number of Analytes	1	4	9	12	1	50	Varies	5	20	17	14	NA	69	NA
Location ID	**Sample ID**	**Sample Type**	**Sample Media**														
SO-01	10154231	Manure - Haak Dairy	Solid		X				X			X	X	X			
SO-02	10154232	Soil – Haak Dairy Application Field	Solid		X				X			X	X	X			
SO-03	10154233	Manure - DeRuyter Dairy	Solid		X				X			X	X	X			
SO-04	10154234	Soil – DeRuyter Dairy Application Field	Solid		X				X			X	X	X			
SO-05	10154235	Manure - D and A Dairy	Solid		X				X			X	X	X			
SO-06	10154236	Soil – D and A Dairy Application Field	Solid		X				X			X	X	X			
SO-07	10164237	Manure - Cow Palace	Solid		X				X			X	X	X			
SO-08	10164238	Soil – Cow Palace Application Field	Solid		X				X			X	X	X			
SO-09	10164239	Manure - Bosma Dairy	Solid		X				X			X	X	X			
SO-10	10164240	Soil – Bosma Dairy Application Field	Solid		X				X			X	X	X			
SO-11	10154241	Soil – Mint	Solid		X				X			X	X	X			
SO-12	10154242	Soil- Mint	Solid		X				X			X	X	X			
SO-13	10154243	Soil – Corn	Solid		X				X			X	X	X			
SO-14	10154244	Soil – Corn	Solid		X				X			X	X	X			
SO-15	10154245	Soil – Hops	Solid		X				X			X	X	X			
SO-16	10154246	Soil – Hops	Solid		X				X			X	X	X			
SP-01	10154271	Zillah Wastewater Treatment Plant Influent	Water		X	X	X			X	X	X	X	X		X	
SP-02	10154272	Mabton Wastewater Treatment Plant Influent	Water		X	X	X			X	X	X	X	X		X	
SP-03	10154273	Toppenish Wastewater Treatment Plant Influent[7]	Water		X	X	X			X	X	X	X	X		X	
SP-04	10154274	Toppenish Wastewater Treatment Plant Influent[7]	Water		X	X	X			X							

Abbreviations

NA- Not applicable

Notes

[1]The other nitrogen compounds evaluated included: total Kjeldahl Nitrogen (TKN); extractable nitrate, extractable ammonia and total nitrogen by combustion.

[2]Lagoon samples were evaluated but it was determined that because of matrix interferences it was not possible to reliably quantify the compounds..

[3]The specific analysis depended on which laboratory analyzed the sample. The analysis included either total coliform, fecal coliform, and/or E Coli. Microbial source tracking was performed for 9 lagoons and all wastewater treatment plant influent samples.

[4]Sample WW-18 collected at the owner's request.

[5]Sample WW-30 was collected because this residential well is located in an area not otherwise sampled and is high in nitrate. WW-30 was not evaluated for hormones, pharmaceuticals, isotopic, or age dating as the location was added later in the study.

[6]Co-located samples: LG-02 and LG-03; LG-08 and LG-09; and LG-11 and LG-12.

[7]Samples SP-03 and SP-04 were collected at the same wastewater treatment plant at different times. Sample SP-04 was submitted to EPA's Manchester Laboratory only and was analyzed for a subset of compounds as identified in the table.

Table C3: Phase 3 Analytical Results for Nitrogen Compounds in Wells, Lagoons and Wastewater Treatment Influents

Location ID	Sample ID	Sample Type	Sample Media	Compound	Result	Units	Analytical Laboratory	Analytical Method
WW-01	10154201	Upgradient Well – Dairy	Water	Ammonia (NH3+NH4) as N	0.3 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	0.39	mg/L	MEL	353.2
				Nitrate-N	0.38	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	0.5 U	mg/L	MEL	351.2
WW-02	10154202	Supply Well – Dairy	Water	Ammonia (NH3+NH4) as N	0.3 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	3.4	mg/L	MEL	353.2
				Nitrate-N	3.12	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	0.5 U	mg/L	MEL	351.2
WW-03	10154203	Downgradient Well – Dairy	Water	Ammonia (NH3+NH4) as N	0.3 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	35.5	mg/L	MEL	353.2
				Nitrate-N	33.1	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	5.1 U	mg/L	MEL	351.2
WW-04	10154204	Downgradient Well – Dairy	Water	Ammonia (NH3+NH4) as N	0.3 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	55	mg/L	MEL	353.2
				Nitrate-N	51.9	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	5.1 U	mg/L	MEL	351.2
WW-05	10154205	Downgradient Well – Dairy	Water	Ammonia (NH3+NH4) as N	0.3 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	13.4	mg/L	MEL	353.2
				Nitrate-N	12.8	mg/L	Cascade	300
				Total Kjeldahl Nitrogen	2.5 U	mg/L	MEL	351.2
WW-06	10154206	Upgradient – Dairy	Water	Ammonia (NH3+NH4) as N	0.3 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	0.73	mg/L	MEL	353.2
				Nitrate-N	0.71	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	0.5 U	mg/L	MEL	351.2
WW-07	10154207	Supply Well - Dairy	Water	Ammonia (NH3+NH4) as N	0.05 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	1.19	mg/L	MEL	353.2
				Nitrate-N	1.02	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	0.51 U	mg/L	MEL	351.2
WW-08	10154208	Supply Well - Dairy	Water	Ammonia (NH3+NH4) as N	0.05 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	12.9	mg/L	MEL	353.2
				Nitrate-N	11.7	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	2.5 U	mg/L	MEL	351.2
WW-09	10164209	Supply Well - Dairy	Water	Ammonia (NH3+NH4) as N	0.05 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	0.05 U	mg/L	MEL	353.2
				Nitrate-N	0.05 U	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	0.51 U	mg/L	MEL	351.2
WW-10	10164210	Downgradient Well – Dairy	Water	Ammonia (NH3+NH4) as N	0.05 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	0.05 U	mg/L	MEL	353.2
				Nitrate-N	0.05 U	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	0.5 U	mg/L	MEL	351.2

Table C3: Phase 3 Analytical Results for Nitrogen Compounds in Wells, Lagoons and Wastewater Treatment Influents

Location ID	Sample ID	Sample Type	Sample Media	Compound	Result	Units	Analytical Laboratory	Analytical Method
WW-11	10154211	Downgradient Well – Dairy	Water	Ammonia (NH3+NH4) as N	0.3 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	23	mg/L	MEL	353.2
				Nitrate-N	22.3	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	2.5 U	mg/L	MEL	351.2
WW-12	10154212	Downgradient Well – Dairy	Water	Ammonia (NH3+NH4) as N	0.3 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	46.7	mg/L	MEL	353.2
				Nitrate-N	45	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	5.1 U	mg/L	MEL	351.2
WW-13	10154213	Downgradient Well – Dairy	Water	Ammonia (NH3+NH4) as N	0.05 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	44	mg/L	MEL	353.2
				Nitrate-N	41.4	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	5.1 U	mg/L	MEL	351.2
WW-14	10154214	Downgradient Well – Dairy	Water	Ammonia (NH3+NH4) as N	0.05 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	43.4	mg/L	MEL	353.2
				Nitrate-N	40.9	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	5.1 U	mg/L	MEL	351.2
WW-15	10154215	Downgradient Well – Dairy	Water	Ammonia (NH3+NH4) as N	0.3 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	30.2	mg/L	MEL	353.2
				Nitrate-N	29.4	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	5.1 U	mg/L	MEL	351.2
WW-16	10154216	Downgradient Well – Dairy	Water	Ammonia (NH3+NH4) as N	0.3 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	23.4	mg/L	MEL	353.2
				Nitrate-N	22.3	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	2.5 U	mg/L	MEL	351.2
WW-17	10154217	Downgradient Well – Dairy	Water	Ammonia (NH3+NH4) as N	0.3 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	22.7	mg/L	MEL	353.2
				Nitrate-N	21.7	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	2.5 U	mg/L	MEL	351.2
WW-18	10154218	Residential Well	Water	Ammonia (NH3+NH4) as N	0.05 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	16.1	mg/L	MEL	353.2
				Nitrate-N	72.2	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	5.1 U	mg/L	MEL	351.2
WW-19	10154219	Downgradient Well – Septic	Water	Ammonia (NH3+NH4) as N	0.3 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	41.1	mg/L	MEL	353.2
				Nitrate-N	38.2	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	5.1 U	mg/L	MEL	351.2
WW-20	10154220	Downgradient Well – Septic	Water	Ammonia (NH3+NH4) as N	0.3 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	16	mg/L	MEL	353.2
				Nitrate-N	15	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	2.5 U	mg/L	MEL	351.2

Table C3: Phase 3 Analytical Results for Nitrogen Compounds in Wells, Lagoons and Wastewater Treatment Influents

Location ID	Sample ID	Sample Type	Sample Media	Compound	Result	Units	Analytical Laboratory	Analytical Method
WW-21	10154221	Downgradient Well – Septic	Water	Ammonia (NH3+NH4) as N	0.05 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	40.5	mg/L	MEL	353.2
				Nitrate-N	38	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	5.1 U	mg/L	MEL	351.2
WW-22	10164222	Downgradient Well – Septic	Water	Ammonia (NH3+NH4) as N	0.05 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	17.3	mg/L	MEL	353.2
				Nitrate-N	16.4	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	2.5 U	mg/L	MEL	351.2
WW-23	10154223	Downgradient Well – Mint	Water	Ammonia (NH3+NH4) as N	0.3 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	17.2	mg/L	MEL	353.2
				Nitrate-N	16	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	2.5 U	mg/L	MEL	351.2
WW-24	10154224	Downgradient Well – Mint	Water	Ammonia (NH3+NH4) as N	0.3 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	14.9	mg/L	MEL	353.2
				Nitrate-N	13.8	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	2.5 U	mg/L	MEL	351.2
WW-25	10154225	Downgradient Well – Hops	Water	Ammonia (NH3+NH4) as N	0.3 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	35.5	mg/L	MEL	353.2
				Nitrate-N	33.4	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	5.1 U	mg/L	MEL	351.2
WW-26	10154226	Downgradient Well – Hops	Water	Ammonia (NH3+NH4) as N	0.05 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	16.7	mg/L	MEL	353.2
				Nitrate-N	15.3	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	2.5 U	mg/L	MEL	351.2
WW-27	10154227	Downgradient Well – Corn	Water	Ammonia (NH3+NH4) as N	0.3 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	21.8	mg/L	MEL	353.2
				Nitrate-N	19.8	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	2.5 U	mg/L	MEL	351.2
WW-28	10154228	Downgradient Well – Corn	Water	Ammonia (NH3+NH4) as N	0.3 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	76	mg/L	MEL	353.2
				Nitrate-N	71.2	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	5.1 U	mg/L	MEL	351.2
WW-29	10154229	Field Blank	Water	Ammonia (NH3+NH4) as N	0.05 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	0.05 U	mg/L	MEL	353.2
				Nitrate-N	0.05 U	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	0.51 U	mg/L	MEL	351.2
WW-30	10164230	Residential Well	Water	Ammonia (NH3+NH4) as N	0.05 U	mg/L	MEL	350.1
				Nitrate+Nitrite as N	24.5	mg/L	MEL	353.2
				Nitrate-N	23.4	mg/L	Cascade	300.0
				Total Kjeldahl Nitrogen	2.5 U	mg/L	MEL	351.2

Table C3: Phase 3 Analytical Results for Nitrogen Compounds in Wells, Lagoons and Wastewater Treatment Influents

Location ID	Sample ID	Sample Type	Sample Media	Compound	Result	Units	Analytical Laboratory	Analytical Method
LG-01	10154251	Dairy Lagoon	Liquid	Ammonia (NH3+NH4) as N	1000 J	mg/L	MEL	350.1
				Total Kjeldahl Nitrogen	1200 J	mg/L	MEL	351.2
				Nitrate+Nitrite as N	1 UJ	mg/L	MEL	353.2
LG-02	10154252	Dairy Lagoon	Liquid	Ammonia (NH3+NH4) as N	870 J	mg/L	MEL	350.1
				Total Kjeldahl Nitrogen	1400 J	mg/L	MEL	351.2
				Nitrate+Nitrite as N	1.2 J	mg/L	MEL	353.2
LG-03	10154253	Dairy Lagoon	Liquid	Ammonia (NH3+NH4) as N	870 J	mg/L	MEL	350.1
				Total Kjeldahl Nitrogen	1400 J	mg/L	MEL	351.2
				Nitrate+Nitrite as N	1 UJ	mg/L	MEL	353.2
LG-04	10154254	Dairy Lagoon	Liquid	Ammonia (NH3+NH4) as N	920 J	mg/L	MEL	350.1
				Total Kjeldahl Nitrogen	1600 J	mg/L	MEL	351.2
				Nitrate+Nitrite as N	1 UJ	mg/L	MEL	353.2
LG-05	10154255	Dairy Lagoon	Liquid	Ammonia (NH3+NH4) as N	1200 J	mg/L	MEL	350.1
				Total Kjeldahl Nitrogen	1600 J	mg/L	MEL	351.2
				Nitrate+Nitrite as N	1 UJ	mg/L	MEL	353.2
LG-06	10154256	Dairy Lagoon	Liquid	Ammonia (NH3+NH4) as N	1200 J	mg/L	MEL	350.1
				Total Kjeldahl Nitrogen	1800 J	mg/L	MEL	351.2
				Nitrate+Nitrite as N	1 UJ	mg/L	MEL	353.2
LG-07	10154257	Dairy Lagoon	Liquid	Ammonia (NH3+NH4) as N	950 J	mg/L	MEL	350.1
				Total Kjeldahl Nitrogen	1700 J	mg/L	MEL	351.2
				Nitrate+Nitrite as N	3.1 J	mg/L	MEL	353.2
LG-08	10154258	Dairy Lagoon	Liquid	Ammonia (NH3+NH4) as N	730 J	mg/L	MEL	350.1
				Total Kjeldahl Nitrogen	1200 J	mg/L	MEL	351.2
				Nitrate+Nitrite as N	1 UJ	mg/L	MEL	353.2
LG-09	10154259	Dairy Lagoon	Liquid	Ammonia (NH3+NH4) as N	760 J	mg/L	MEL	350.1
				Total Kjeldahl Nitrogen	1100 J	mg/L	MEL	351.2
				Nitrate+Nitrite as N	1 UJ	mg/L	MEL	353.2
LG-10	10164260	Dairy Lagoon	Liquid	Ammonia (NH3+NH4) as N	190 J	mg/L	MEL	350.1
				Total Kjeldahl Nitrogen	380 J	mg/L	MEL	351.2
				Nitrate+Nitrite as N	1 UJ	mg/L	MEL	353.2
LG-11	10164261	Dairy Lagoon	Liquid	Ammonia (NH3+NH4) as N	240 J	mg/L	MEL	350.1
				Total Kjeldahl Nitrogen	500 J	mg/L	MEL	351.2
				Nitrate+Nitrite as N	1 UJ	mg/L	MEL	353.2
LG-12	10164262	Dairy Lagoon	Liquid	Ammonia (NH3+NH4) as N	240 J	mg/L	MEL	350.1
				Total Kjeldahl Nitrogen	290 J	mg/L	MEL	351.2
				Nitrate+Nitrite as N	1 UJ	mg/L	MEL	353.2
LG-13	10164263	Dairy Lagoon	Liquid	Ammonia (NH3+NH4) as N	970 J	mg/L	MEL	350.1
				Total Kjeldahl Nitrogen	1700 J	mg/L	MEL	351.2
				Nitrate+Nitrite as N	2.5 J	mg/L	MEL	353.2
LG-14	10164264	Dairy Lagoon	Liquid	Ammonia (NH3+NH4) as N	860 J	mg/L	MEL	350.1
				Total Kjeldahl Nitrogen	1400 J	mg/L	MEL	351.2
				Nitrate+Nitrite as N	1 UJ	mg/L	MEL	353.2

Table C3: Phase 3 Analytical Results for Nitrogen Compounds in Wells, Lagoons and Wastewater Treatment Influents

Location ID	Sample ID	Sample Type	Sample Media	Compound	Result	Units	Analytical Laboratory	Analytical Method
LG-15	10164265	Dairy Lagoon	Liquid	Ammonia (NH3+NH4) as N	560 J	mg/L	MEL	350.1
				Total Kjeldahl Nitrogen	900 J	mg/L	MEL	351.2
				Nitrate+Nitrite as N	1 UJ	mg/L	MEL	353.2
SP-01	10154271	WWTP	Liquid	Ammonia (NH3+NH4) as N	26.6	mg/L	MEL	350.1
				Nitrate+Nitrite as N	0.942	mg/L	MEL	353.2
				Total Kjeldahl Nitrogen	46.8	mg/L	MEL	351.2
SP-02	10154272	WWTP	Liquid	Ammonia (NH3+NH4) as N	25.2	mg/L	MEL	350.1
				Nitrate+Nitrite as N	0.05 U	mg/L	MEL	353.2
				Total Kjeldahl Nitrogen	46.7	mg/L	MEL	351.2
SP-03[1]	10154273	WWTP	Liquid	Ammonia (NH3+NH4) as N	38.4	mg/L	MEL	350.1
				Nitrate+Nitrite as N	0.05 U	mg/L	MEL	353.2
				Total Kjeldahl Nitrogen	53.8	mg/L	MEL	351.2
SP-04[1]	10154274	WWTP	Liquid	Ammonia (NH3+NH4) as N	35.1	mg/L	MEL	350.1
				Nitrate+Nitrite as N	0.1	mg/L	MEL	353.2
				Total Kjeldahl Nitrogen	57	mg/L	MEL	351.2

Abbreviations

LG - lagoon

MEL - EPA Manchester Environmental Laboratory

SP - wastewater treatment plant influent

WW - water well

WWTP - wastewater treatment plant

Units

mg/L = milligrams per liter

Data Qualifiers

J = The analyte was positively identified. The associated numerical value is an estimate.

R = The data are unusable for all purposes.

U = The analyte was not detected at or above the reported value.

UJ = The analyte was not detected at or above the reported estimated result. The associated numerical value is an estimate of the quantitation limit of the analyte in this sample.

Notes

[1]Samples SP-03 and SP-04 were collected at the same wastewater treatment plant at different times. Sample SP-04 was submitted to EPA's Manchester Laboratory only and was analyzed for a subset of compounds as identified in the table.

Table C4: Phase 3 Analytical Results for Nitrogen Compounds in Manure Piles, Application Fields, and Crop Soils

Location ID	Sample ID	Sample Type	Compound	Result	Units	Analytical Method
SO-01	10154231	Manure	Ammonia Solid	10100	mg/kg	4500-NH3
			Kjedahl Nitrogen/Solid	29700	mg/kg	4500N-ORG-C
			NO3N/Total Solid	0.32 U	mg/kg	4500
SO-02	10154232	Soil	Ammonium-N	4.6	mg/kg	4500-NH4 H
			Nitrate-N/Nitrite	71.7	mg/kg	4500-NO3 F
			Total Nitrogen/Solid	2760	mg/kg	993.13
SO-03	10154233	Manure	Ammonia Solid	1470	mg/kg	4500-NH3
			NO3N/Total Solid	32.8	mg/kg	4500-NO3 E
			Total Nitrogen/Solid	9210	mg/kg	993.13
SO-04	10154234	Soil – Dairy Application Field	Ammonium-N	7.3	mg/kg	4500-NH4 H
			Nitrate-N/Nitrite	247	mg/kg	4500-NO3 F
			Total Nitrogen/Solid	2110	mg/kg	993.13
SO-05	10154235	Manure	Ammonia Solid	1060	mg/kg	4500-NH3
			NO3N/Total Solid	43.1	mg/kg	4500-NO3 E
			Total Nitrogen/Solid	13600	mg/kg	993.13
SO-06	10154236	Soil – Dairy Application Field	Ammonium-N	6.8	mg/kg	4500-NH4 H
			Nitrate-N/Nitrite	45.6	mg/kg	4500-NO3 F
			Total Nitrogen/Solid	960	mg/kg	993.13
SO-07	10164237	Manure	Ammonia Solid	3600	mg/kg	4500-NH3
			NO3N/Total Solid	18.9	mg/kg	4500-NO3 E
			Total Nitrogen/Solid	16100	mg/kg	993.13
SO-08	10164238	Soil – Dairy Application Field	Ammonium-N	2.9	mg/kg	4500-NH4 H
			Nitrate-N/Nitrite	84.3	mg/kg	4500-NO3 F
			Total Nitrogen/Solid	3040	mg/kg	993.13
SO-09	10164239	Manure	Ammonia Solid	1700	mg/kg	4500-NH3
			NO3N/Total Solid	5.69	mg/kg	4500-NO3 E
			Total Nitrogen/Solid	13700	mg/kg	993.13
SO-10	10164240	Soil – Dairy Application Field	Ammonium-N	7.1	mg/kg	4500-NH4 H
			Nitrate-N/Nitrite	139	mg/kg	4500-NO3 F
			Total Nitrogen/Solid	3590	mg/kg	993.13
SO-11	10154241	Soil - Mint Field	Ammonium-N	210	mg/kg	4500-NH4 H
			Nitrate-N/Nitrite	245	mg/kg	4500-NO3 F
			Total Nitrogen/Solid	3330	mg/kg	993.13

Table C4: Phase 3 Analytical Results for Nitrogen Compounds in Manure Piles, Application Fields, and Crop Soils

Location ID	Sample ID	Sample Type	Compound	Result	Units	Analytical Method
SO-12	10154242	Soil - Mint Field	Ammonium-N	8.2	mg/kg	4500-NH4 H
			Nitrate-N/Nitrite	191	mg/kg	4500-NO3 F
			Total Nitrogen/Solid	2350	mg/kg	993.13
SO-13	10154243	Soil - Corn Field	Ammonium-N	7.5	mg/kg	4500-NH4 H
			Nitrate-N/Nitrite	24.3	mg/kg	4500-NO3 F
			Total Nitrogen/Solid	1100	mg/kg	993.13
SO-14	10154244	Soil - Corn Field	Ammonium-N	12	mg/kg	4500-NH4 H
			Nitrate-N/Nitrite	6.3	mg/kg	4500-NO3 F
			Total Nitrogen/Solid	1180	mg/kg	993.13
SO-15	10154245	Soil -Hops Field	Ammonium-N	21	mg/kg	4500-NH4 H
			Nitrate-N/Nitrite	83.5	mg/kg	4500-NO3 F
			Total Nitrogen/Solid	2210	mg/kg	993.13
SO-16	10154246	Soil -Hops Field	Ammonium-N	7.7	mg/kg	4500-NH4 H
			Nitrate-N/Nitrite	26.5	mg/kg	4500-NO3 F
			Total Nitrogen/Solid	3000	mg/kg	993.13

Samples were analyzed by Cascade Analytical Laboratory.

Abbreviations
SO - solid

Units
mg/kg = milligrams per kilogram

Data Qualifiers
J = The analyte was positively identified. The associated numerical value is an estimate.
R = The data are unusable for all purposes.
U = The analyte was not detected at or above the reported value.
UJ = The analyte was not detected at or above the reported estimated result. The associated numerical value is an estimate of the quantitation limit of the analyte in

Table C5: Comparison of Phase 3 Analytical Results for Nitrate Levels in Wells

Location ID	Sample ID	Sample Type	Cascade Analytical Laboratory[1]	Manchester Environmental Laboratory[2]	Univeristy of Nebraska Water Sciences Laboratory[3]
			Maximum Contaminant Level = 10 mg/L		
			Units: mg/L		
WW-01	10154201	Upgradient Well	0.38	0.391	0.2
WW-02	10154202	Dairy Supply Well	3.12	3.4	3
WW-03	10154203	Downgradient Well	33.1	35.5	34
WW-04	10154204	Downgradient Well	51.9	55	49.9
WW-05	10154205	Downgradient Well	12.8	13.4	12.8
WW-06	10154206	Upgradient Well	0.71	0.73	0.6
WW-07	10154207	Dairy Supply Well	1.02	1.19	1.1
WW-08	10154208	Dairy Supply Well	11.7	12.9	11.7
WW-09	10164209	Dairy Supply Well	<0.05U	0.05U	NM
WW-10	10164210	Downgradient Well	<0.05U	0.05U	NM
WW-11	10154211	Downgradient Well	22.3	23	21.6
WW-12	10154212	Downgradient Well	45	46.7	43.6
WW-13	10154213	Downgradient Well	41.4	44	42
WW-14	10154214	Downgradient Well	40.9	43.4	40.7
WW-15	10154215	Downgradient Well	29.4	30.2	27.4
WW-16	10154216	Downgradient Well	22.3	23.4	23
WW-17	10154217	Downgradient Well	21.7	22.7	23.3
WW-18	10154218	Residential Well	72.2	16.1	72.3
WW-19	10154219	Downgradient Well	38.2	41.1	36.4
WW-20	10154220	Downgradient Well	15	16	15
WW-21	10154221	Downgradient well	38	40.5	36.5
WW-22	10164222	Downgradient Well	16.4	17.3	16.6
WW-23	10154223	Downgradient Well	16	17.2	17.3
WW-24	10154224	Downgradient Well	13.8	14.9	14
WW-25	10154225	Downgradient Well	33.4	35.5	32.9

Table C5: Comparison of Phase 3 Analytical Results for Nitrate Levels in Wells

Location ID	Sample ID	Sample Type	Cascade Analytical Laboratory[1]	Manchester Environmental Laboratory[2]	Univeristy of Nebraska Water Sciences Laboratory[3]
			Maximum Contaminant Level = 10 mg/L		
WW-26	10154226	Downgradient Well	15.3	16.7	15.1
WW-27	10154227	Downgradient Well	19.8	21.8	19.9
WW-28	10154228	Downgradient Well	71.2	76	69.6
WW-29	10154229	Field Blank	<0.05U	0.05U	NM
WW-30	10164230	Residential Well	23.4	24.5	NA

Abbreviations

NM = Insufficient Nitrate to complete analysis.

NA = Not analyzed.

Notes

[1]Cascade used Method 300.0 to analyze the samples.

[2]Manchester conducted the nitrate analysis as part of the general water chemistry using Method 353.2.

[3]UNL conducted the nitrate analysis as a part of their isotopic analysis.

Table C6: Phase 3 Analytical Results for Major Ions and Trace Inorganic Elements in Wells, Lagoons, and Wastewater Treatment Plant Influents

		Location ID	WW-01	WW-02	WW-03	WW-04	WW-05	WW-06	WW-07	WW-08	WW-09
		Sample ID	10154201	10154202	10154203	10154204	10154205	10154206	10154207	10154208	10164209
		Sample Type	Upgradient Well	Dairy Supply Well	Downgradient Well	Downgradient Well	Downgradient Well	Upgradient Well	Dairy Supply Well	Dairy Supply Well	Dairy Supply Well
		Sample Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water
Compound	**Method No.**	**Units**									
Alkalinity as $CaCO_3$	2320B	mg/L	78.4	165	181	394	454	119	129	178	155
Arsenic	200.7	ug/L	45 U	45 U	45 U	45 U	45 U	45 U	45 U	45 U	45 U
Barium	200.7	ug/L	13.5	32.7	135	178	164	11.2	10	30.7	15.1
Bromide	300.0	mg/L	0.2 U	0.2 U	0.873	0.39	0.2 U	0.2 U	0.2 U	0.336	0.2 U
Cadmium	200.7	ug/L	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U
Calcium	200.7	ug/L	17200	35400	165000	186000	125000	20800	28300	81800	21100
Chloride	300.0	mg/L	2.96	9.11	96.2	58	37.5	2.38	8.04	35	7.93
Chromium	200.7	ug/L	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Copper	200.7	ug/L	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Fluoride	300.0	mg/L	0.113	0.528	0.307	0.319	0.332	0.416	0.298	0.257	0.405
Iron	200.7	ug/L	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
Lead	200.7	ug/L	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
Magnesium	200.7	ug/L	6470	15100	39900	52600	39000	7410	12300	25600	9220
Manganese	200.7	ug/L	2 U	2 U	2 U	2 U	2 U	2 U	3.4	2 U	37.7
Mercury	245.1	ug/L	0.05 U	0.05 U	0.05 U	0.05 U	0.077	0.05 U	0.05 U	0.05 U	0.05 U
Phosphorus, total	365.1	mg/L	0.0292	0.0926	0.0327	0.0439	0.0606	0.0664	0.0299	0.0271	0.0304
Potassium	200.7	ug/L	1900	4190	6140	7290	6670	3300	6830	4330	8570
Selenium	200.7	ug/L	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Silver	200.7	ug/L	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Sodium	200.7	ug/L	5130	22500	41800	57000	48800	15400	15100	34200	28400
Sulfate	300.0	mg/L	3.51	22.3	234	168	44.4	6.38	27.8	113	0.841
Zinc	200.7	ug/L	5 U	5.4	21	12	15	471	5 U	12	5 U

See Table C6 notes on page 7 of 7.

Table C6: Phase 3 Analytical Results for Major Ions and Trace Inorganic Elements in Wells, Lagoons, and Wastewater Treatment Plant Influents

		Location ID	WW-10	WW-11	WW-12	WW-13	WW-14	WW-15	WW-16	WW-17	WW-18
		Sample ID	10164210	10154211	10154212	10154213	10154214	10154215	10154216	10154217	10154218
		Sample Type	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Residential Well
		Sample Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water
Compound	**Method No.**	**Units**									
Alkalinity as $CaCO_3$	2320B	mg/L	141	178	350	604	502	240	318	316	280
Arsenic	200.7	ug/L	45 U	45 U	45 U	45 U	45 U	45 U	45 U	45 U	45 U
Barium	200.7	ug/L	63.8	34	14.7	8.7	35.9	47.8	25.4	39.2	70.5
Bromide	300.0	mg/L	0.2 U	0.333	0.237	0.428	0.389	0.246	0.418	0.406	0.522
Cadmium	200.7	ug/L	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U
Calcium	200.7	ug/L	27000	93400	109000	217000	193000	69200	118000	113000	210000
Chloride	300.0	mg/L	4.44	52	49	79.8	69.8	39.2	45.5	44.6	39.7
Chromium	200.7	ug/L	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Copper	200.7	ug/L	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Fluoride	300.0	mg/L	0.328	0.282	0.285	0.132	0.106	0.363	0.205	0.205	0.439
Iron	200.7	ug/L	550	91	20 U	20 U	20 U	194	27	135	33
Lead	200.7	ug/L	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
Magnesium	200.7	ug/L	8410	25800	42000	66300	65000	32100	47900	46000	67100
Manganese	200.7	ug/L	89.9	2 U	2 U	2 U	2 U	2 U	2 U	2.1	2 U
Mercury	245.1	ug/L	0.05 U	0.05 U	0.05 U	0.106	0.05 U	0.05 U	0.05 U	0.05 U	0.084
Phosphorus, total	365.1	mg/L	0.0477	0.0204	0.0201	0.02 U	0.02 U	0.0272	0.0213	0.023	0.0443
Potassium	200.7	ug/L	5250	3870	4000	5450	6640	7970	3630	3730	5610
Selenium	200.7	ug/L	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Silver	200.7	ug/L	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Sodium	200.7	ug/L	25500	62700	101000	97300	103000	108000	52900	54900	48800
Sulfate	300.0	mg/L	21.7	147	117	229	305	138	173	171	361
Zinc	200.7	ug/L	8.3	66.9	5 U	9.7	17	53.8	5 U	8.5	5 U

See Table C6 notes on page 7 of 7.

Table C6: Phase 3 Analytical Results for Major Ions and Trace Inorganic Elements in Wells, Lagoons, and Wastewater Treatment Plant Influents

		Location ID	WW-19	WW-20	WW-21	WW-22	WW-23	WW-24	WW-25
		Sample ID	10154219	10154220	10154221	10164222	10154223	10154224	10154225
		Sample Type	Downgradient - Septic	Downgradient well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well
		Sample Matrix	Water	Water	Water	Water	Water	Water	Water
Compound	**Method No.**	**Units**							
Alkalinity as $CaCO_3$	2320B	mg/L	111	359	178	136	251	259	388
Arsenic	200.7	ug/L	45 U	45 U	45 U	45 U	45 U	45 U	45 U
Barium	200.7	ug/L	243	94.4	107	184	121	27.8	106
Bromide	300.0	mg/L	0.761	0.2 U	0.737	0.415	0.2 U	0.2 U	0.2 U
Cadmium	200.7	ug/L	3 U	3 U	3 U	3 U	3 U	3 U	3 U
Calcium	200.7	ug/L	79200	96500	111000	79300	92000	70600	95100
Chloride	300.0	mg/L	60	24.9	51.2	26.8	23.1	10.5	23.6
Chromium	200.7	ug/L	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Copper	200.7	ug/L	5 U	5 U	5 U	5 U	5 U	5 U	32.8
Fluoride	300.0	mg/L	0.216	0.352	0.462	0.239	0.251	0.385	0.364
Iron	200.7	ug/L	35	259	67	112	20 U	89	44
Lead	200.7	ug/L	25 U	25 U	25 U	25 U	25 U	25 U	25 U
Magnesium	200.7	ug/L	29800	29700	35700	19600	24600	22700	27200
Manganese	200.7	ug/L	2 U	22.4	3.1	4.8	2 U	2 U	2 U
Mercury	245.1	ug/L	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Phosphorus, total	365.1	mg/L	0.041	0.0745	0.101	0.0399	0.078	0.0961	0.0769
Potassium	200.7	ug/L	5280	5370	4590	4180	6160	6510	4680
Selenium	200.7	ug/L	50 U	50 U	55	50 U	50 U	50 U	50 U
Silver	200.7	ug/L	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Sodium	200.7	ug/L	37400	49700	55800	18000	23900	44000	112000
Sulfate	300.0	mg/L	63.4	63.6	164	69.8	51.9	29.8	45.6
Zinc	200.7	ug/L	51.2	10	5 U	5 U	9	53.4	55.4

See Table C6 notes on page 7 of 7.

Table C6: Phase 3 Analytical Results for Major Ions and Trace Inorganic Elements in Wells, Lagoons, and Wastewater Treatment Plant Influents

		Location ID	WW-26	WW-27	WW-28	WW-29	WW-30	LG-01	LG-02	LG-03	LG-04	LG-05
		Sample ID	10154226	10154227	10154228	10154229	10164230	10154251	10154252	10154253	10154254	10154255
		Sample Type	Downgradient Well	Downgradient Well	Downgradient Well	Field Blank	Residential Well	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon
		Sample Matrix	Water	Water	Water	Water	Water	Liquid	Liquid	Liquid	Liquid	Liquid
Compound	**Method No.**	**Units**										
Alkalinity as $CaCO_3$	2320B	mg/L	352	180	237	5 U	255	3820	6340	6320	6110	8920
Arsenic	200.7	ug/L	45 U	45 U	45 U	45 U	45 U	180 U	170 U	160 U	170 U	180 U
Barium	200.7	ug/L	102	56.6	89.6	1 U	57.5	297	931	907	2480	722
Bromide	300.0	mg/L	0.2 U	0.3	1.36	0.2 U	0.248	10 U	10 U	10 U	10 U	10 U
Cadmium	200.7	ug/L	3 U	3 U	3 U	3 U	3 U	12 U	11 U	11 U	12 U	12 U
Calcium	200.7	ug/L	83200	88600	238000	30 U	99300	148000	409000	390000	1010000	351000
Chloride	300.0	mg/L	12.7	22.4	130	0.06 U	33.1	473	616	616	684	1140
Chromium	200.7	ug/L	10 U	10 U	10 U	10 U	10 U	40 U	88	85	203	44
Copper	200.7	ug/L	5 U	5 U	5 U	5 U	5 U	575	1850	1810	3110	1030
Fluoride	300.0	mg/L	0.378	0.721	0.574	0.04 U	0.258	2 U	2 U	2 U	2 U	2 U
Iron	200.7	ug/L	115	20 U	20 U	20 U	100	9000	16700	15800	205000	15500
Lead	200.7	ug/L	25 U	25 U	25 U	25 U	25 U	100 U	95 U	89 U	97 U	99 U
Magnesium	200.7	ug/L	32100	28600	85000	50 U	24700	116000	236000	234000	514000	281000
Manganese	200.7	ug/L	2 U	2 U	2 U	2 U	2 U	1370	3970	3950	14800	4420
Mercury	245.1	ug/L	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.25 UJ	0.25 UJ	0.25 UJ	0.387 J	0.25 UJ
Phosphorus, total	365.1	mg/L	0.0855	0.0406	0.0367	0.02 U	0.0204	39.6	118	126	354	103
Potassium	200.7	ug/L	11700	3650	4790	700 U	2900	1660000	2100000	2140000	2160000	2590000
Selenium	200.7	ug/L	50 U	50 U	72	50 U	50 U	200 U	190 U	180 U	190 U	200 U
Silver	200.7	ug/L	10 U	10 U	10 U	10 U	10 U	40 U	38 U	35 U	39 U	40 U
Sodium	200.7	ug/L	58500	40400	53800	100 U	107000	437000	501000	511000	517000	751000
Sulfate	300.0	mg/L	64.9	124	386	0.3 U	176	257	15 U	15 U	286	15 U
Zinc	200.7	ug/L	9.3	47.6	26.3	5 U	22	1790	5410	5260	11000	3720

See Table C6 notes on page 7 of 7.

Table C6: Phase 3 Analytical Results for Major Ions and Trace Inorganic Elements in Wells, Lagoons, and Wastewater Treatment Plant Influents

		Location ID	LG-06	LG-07	LG-08	LG-09	LG-10	LG-11	LG-12	LG-13	LG-14	LG-15
		Sample ID	10154256	10154257	10154258	10154259	10164260	10164261	10164262	10164263	10164264	10164265
		Sample Type	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon
		Sample Matrix	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Compound	**Method No.**	**Units**										
Alkalinity as $CaCO_3$	2320B	mg/L	8700	6210	5280	5280	1170	2060	2060	11300	9490	5640
Arsenic	200.7	ug/L	160 U	190 U	190 U	160 U	160 U	170 U	160 U	180 U	150 U	160 U
Barium	200.7	ug/L	683	1080	720	720	220	259	240	3160	2350	803
Bromide	300.0	mg/L	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Cadmium	200.7	ug/L	10 U	13 U	13 U	11 U	11 U	11 U	11 U	22	10 U	11 U
Calcium	200.7	ug/L	323000	578000	433000	442000	103000	124000	102000	1210000	1180000	387000
Chloride	300.0	mg/L	1140	633	699	722	62.4	113	113	661	558	524
Chromium	200.7	ug/L	46	70	42 U	37	37 U	38 U	36 U	180	130	36 U
Copper	200.7	ug/L	989	1850	1290	1290	193	148	157	2870	2090	743
Fluoride	300.0	mg/L	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
Iron	200.7	ug/L	13900	53000	23600	23600	5960	1560 J	1470 J	208000	152000	20300
Lead	200.7	ug/L	86 U	100 U	100 U	90 U	91 U	94 U	90 U	100 U	84 U	91 U
Magnesium	200.7	ug/L	274000	358000	202000	200000	63100	84500	85000	707000	580000	294000
Manganese	200.7	ug/L	4070	7780	3990	4010	660	793	673	11100	9810	2410
Mercury	245.1	ug/L	0.25 UJ	0.25 UJ	0.25 UJ	0.25 UJ	0.065 J	0.05 UJ	0.05 UJ	0.707 J	0.495 J	0.25 UJ
Phosphorus, total	365.1	mg/L	111	221	90.8	89.8	57.1	82.9	58.5	297	239	74
Potassium	200.7	ug/L	3E+06	2E+06	1820000	1810000	327000	394000	400000	2650000	2290000	1830000
Selenium	200.7	ug/L	170 U	210 U	210 U	180 U	180 U	190 U	180 U	200 U	170 U	180 U
Silver	200.7	ug/L	34 U	42 U	42 U	36 U	37 U	38 U	36 U	41 U	34 U	36 U
Sodium	200.7	ug/L	753000	443000	488000	487000	142000	175000	177000	906000	830000	687000
Sulfate	300.0	mg/L	15 U	304	15 U	15 U	181	15 U	15 U	96	59.6	15 U
Zinc	200.7	ug/L	3470	6080	4160	4290	926	496	377	8470	8650	2920

See Table C6 notes on page 7 of 7.

Table C6: Phase 3 Analytical Results for Major Ions and Trace Inorganic Elements in Wells, Lagoons, and Wastewater Treatment Plant Influents

		Location ID	SP-01	SP-02	SP-03[1]	SP-04[1]
		Sample ID	10154271	10154272	10154273	10154274
		Sample Type	WWTP	WWTP	WWTP	WWTP
		Sample Matrix	Liquid	Liquid	Liquid	Liquid
Compound	**Method No.**	**Units**				
Alkalinity as $CaCO_3$	2320B	mg/L	444	307	257	255
Arsenic	200.7	ug/L	45 U	45 U	45 U	45 U
Barium	200.7	ug/L	107	65.3	64.1	30.7
Bromide	300.0	mg/L	0.213	0.2 U	0.2 U	0.2 U
Cadmium	200.7	ug/L	3 U	3 U	3 U	3 U
Calcium	200.7	ug/L	71000	36500	58900	24500
Chloride	300.0	mg/L	67.6	42.8	489	40.1
Chromium	200.7	ug/L	10 U	10 U	10 U	10 U
Copper	200.7	ug/L	34.1	51.5	63.1	81
Fluoride	300.0	mg/L	0.184	0.784	0.534	0.614
Iron	200.7	ug/L	268	1300	674	555
Lead	200.7	ug/L	25 U	25 U	25 U	25 U
Magnesium	200.7	ug/L	24600	11200	19400	10700
Manganese	200.7	ug/L	29.6	75.6	36.2	26.4
Mercury	245.1	ug/L	0.05 UJ	1.21 J	0.152 J	0.072 J
Phosphorus, total	365.1	mg/L	6.87	6.14	8.4	8.37
Potassium	200.7	ug/L	21800	20800	19100	15700
Selenium	200.7	ug/L	50 U	50 U	50 U	50 U
Silver	200.7	ug/L	10 U	10 U	10 U	10 U
Sodium	200.7	ug/L	114000	72300	230000	50300
Sulfate	300.0	mg/L	88.2	13.5	15.9	21
Zinc	200.7	ug/L	130	193	172	121

See Table C6 notes on page 7 of 7.

Table C6: Phase 3 Analytical Results for Major Ions and Trace Inorganic Elements in Wells, Lagoons, and Wastewater Treatment Plant Influents

Samples were analyzed by the EPA Manchester Environmental Laboratory

Abbreviations

LG - Dairy waste lagoon
SP - wastewater treatment plant influent
WW - water well
WWTP - wastewater treatment plant

Units

ug/L = micrograms per liter
mg/L = milligrams per liter

Data Qualifiers

< = less than
R = The data are unusable for all purposes.

UJ = The analyte was not detected at or above the reported estimated result. The associated numerical value is an estimate of the quantitation limit of the analyte in this sample.

Notes

[1]Samples SP-03 and SP-04 were collected at the same wastewater treatment plant at different times. Sample SP-04 was submitted to EPA's Manchester Laboratory only and was analyzed for a subset of compounds as identified in the table.

Table C7: Phase 3 Analytical Results for Perchlorate in Wells

Location ID	Sample ID	Sample Type	Result
WW-01	10154201	Upgradient Well	0.135
WW-02	10154202	Dairy Supply Well	0.493
WW-03	10154203	Downgradient Well	1.96
WW-04	10154204	Downgradient Well	1.38
WW-05	10154205	Downgradient Well	0.547
WW-06	10154206	Upgradient Well	0.06
WW-07	10154207	Dairy Supply Well	0.231
WW-08	10154208	Dairy Supply Well	1.4
WW-09	10164209	Dairy Supply Well	0.003 U
WW-10	10164210	Downgradient Well	0.003 U
WW-11	10154211	Downgradient Well	0.915
WW-12	10154212	Downgradient Well	1.68
WW-13	10154213	Downgradient Well	1.17
WW-14	10154214	Downgradient Well	1.84
WW-15	10154215	Downgradient Well	1.76
WW-16	10154216	Downgradient Well	3.08
WW-17	10154217	Downgradient Well	2.9
WW-18	10154218	Residential Well	2.3
WW-19	10154219	Downgradient Well	3.25
WW-20	10154220	Downgradient Well	1.31
WW-21	10154221	Downgradient well	0.978
WW-22	10164222	Downgradient Well	1.74
WW-23	10154223	Downgradient Well	1.36
WW-24	10154224	Downgradient Well	3.42
WW-25	10154225	Downgradient Well	1.98
WW-26	10154226	Downgradient Well	1.44
WW-27	10154227	Downgradient Well	0.556
WW-28	10154228	Downgradient Well	4.69
WW-29	10154229	Field Blank	0.003 U
WW-30	10164230	Residential Well	1.07

Robert S. Kerr Environmental Research Center.

Abbreviations

WW - water well

Units

ug/L = micrograms per liter

Data Qualifiers

U = The analyte was not detected at or above the reported value.

Analytical Method

SW846 Method 6850, "*Perchlorate in Soils, Water and Wastes Using High performance Liquid Chromatography/Electrospray/Ionization (ESI) Mass Spectroscopy (MS) or Tandem Mass Spectroscopy (MS/MS)* .

Table C8: Phase 3 Analytical Results for Total Coliform, E. Coli, Fecal Coliform, and Microbial Source Tracking in Wells, Lagoons, and Wastewater Treatment Plant Influents

Location ID	Sample ID	Sample Type	Sample Media	Total Coliform	Laboratory	Units	Fecal Coliform	Laboratory	Units	E.Coli	Laboratory	Units	BAC-32	CF-128	CF-193	MST-Contaminants	HF-183	HF-134
WW-01	10154201	Upgradient Well – Dairy	Water	<1	Cascade	#/100ml	NA	NA	NA	<1	Cascade	#/100ml	NA	NA	NA	NA	NA	NA
WW-02	10154202	Supply Well – Dairy	Water	<1	Cascade	#/100ml	NA	NA	NA	<1	Cascade	#/100ml	NA	NA	NA	NA	NA	NA
WW-03	10154203	Downgradient Well – Dairy	Water	<1	Cascade	#/100ml	NA	NA	NA	<1	Cascade	#/100ml	NA	NA	NA	NA	NA	NA
WW-04	10154204	Downgradient Well – Dairy	Water	23.8	Cascade	#/100ml	NA	NA	NA	<1	Cascade	#/100ml	NA	NA	NA	NA	NA	NA
WW-05	10154205	Downgradient Well – Dairy	Water	<1	Cascade	#/100ml	NA	NA	NA	<1	Cascade	#/100ml	NA	NA	NA	NA	NA	NA
WW-06	10154206	Upgradient – Dairy	Water	2	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-07	10154207	Supply Well – Dairy	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-08	10154208	Supply Well – Dairy	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-09	10164209	Supply Well – Dairy	Water	<1	Cascade	#/100ml	0	Cascade	CFU/100ml	<1	Cascade	#/100ml	NA	NA	NA	NA	NA	NA
WW-10	10164210	Downgradient Well – Dairy	Water	<1	Cascade	#/100ml	0	Cascade	CFU/100ml	<1	Cascade	#/100ml	NA	NA	NA	NA	NA	NA
WW-11	10154211	Downgradient Well – Dairy	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-12	10154212	Downgradient Well – Dairy	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-13	10154213	Downgradient Well – Dairy	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-14	10154214	Downgradient Well – Dairy	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-15	10154215	Downgradient Well – Dairy	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-16	10154216	Downgradient Well – Dairy	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-17	10154217	Downgradient Well – Dairy	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-18	10154218	Residential Well	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-19	10154219	Downgradient Well – Septic	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-20	10154220	Downgradient Well – Septic	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-21	10154221	Downgradient Well – Septic	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-22	10164222	Downgradient Well – Septic	Water	<1	Cascade	#/100ml	0	Cascade	CFU/100ml	<1	Cascade	#/100ml	NA	NA	NA	NA	NA	NA
WW-23	10154223	Downgradient Well – Mint	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-24	10154224	Downgradient Well – Mint	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-25	10154225	Downgradient Well – Corn	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-26	10154226	Downgradient Well – Hops	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-27	10154227	Downgradient Well – Hops	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-28	10154228	Downgradient Well – Corn	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-29	10154229	Field Blank	Water	<1	Manchester	#/100ml	<1	Manchester	#/100ml	<1	Manchester	#/100ml	NA	NA	NA	NA	NA	NA
WW-30	10164230	Residential Well	Water	<1	Cascade	#/100ml	NA	NA	NA	<1	Cascade	#/100ml	NA	NA	NA	NA	NA	NA
LG-01	10154251	Dairy Lagoon	Liquid	NA	NA	NA	TNTC	Cascade	CFU/100ml	NA	NA	NA	P	P	ND	R	P	A
LG-02	10154252	Dairy Lagoon	Liquid	NA	NA	NA	TNTC	Cascade	CFU/100ml	NA	NA	NA	P	P	ND	H/R	ND	P
LG-03	10154253	Dairy Lagoon	Liquid	NA	NA	NA	TNTC	Cascade	CFU/100ml	NA	NA	NA	P	P	ND	H/R	P	A
LG-04	10154254	Dairy Lagoon	Liquid	NA	NA	NA	> 16 million	Manchester	#/100ml	>16 million (J)	Manchester	#/100ml	P	P	ND	R	A	A
LG-05	10154255	Dairy Lagoon	Liquid	NA	NA	NA	2000	Manchester	#/100ml	2000 (J)	Manchester	#/100ml	P	P	ND	R	A	A
LG-06	10154256	Dairy Lagoon	Liquid	NA	NA	NA	1800	Manchester	#/100ml	1800 (J)	Manchester	#/100ml	P	P	ND	R	A	A
LG-07	10154257	Dairy Lagoon	Liquid	NA	NA	NA	5.4 million	Manchester	#/100ml	5.4 million (J)	Manchester	#/100ml	P	P	ND	R	A	A

Table C8: Phase 3 Analytical Results for Total Coliform, E. Coli, Fecal Coliform, and Microbial Source Tracking in Wells, Lagoons, and Wastewater Treatment Plant Influents

Location ID	Sample ID	Sample Type	Sample Media	Total Coliform	Laboratory	Units	Fecal Coliform	Laboratory	Units	E.Coli	Laboratory	Units	BAC-32	CF-128	CF-193	MST-Contaminants	HF-183	HF-134
LG-08	10154258	Dairy Lagoon	Liquid	NA	NA	NA	130,000	Manchester	#/100ml	130,000 (J)	Manchester	#/100ml	P	P	ND	R	A	A
LG-09	10154259	Dairy Lagoon	Liquid	NA	NA	NA	79,000	Manchester	#/100ml	79,000 (J)	Manchester	#/100ml	P	P	ND	H/R	ND	P
LG-10	10164260	Dairy Lagoon	Liquid	NA	NA	NA	1.1 billion	Cascade	CFU/100ml	NA	NA	NA	NA	NA	NA	NA	NA	NA
LG-11	10164261	Dairy Lagoon	Liquid	NA	NA	NA	5.4 million	Cascade	CFU/100ml	NA	NA	NA	NA	NA	NA	NA	NA	NA
LG-12	10164262	Dairy Lagoon	Liquid	NA	NA	NA	4.5 million	Cascade	CFU/100ml	NA	NA	NA	NA	NA	NA	NA	NA	NA
LG-13	10164263	Dairy Lagoon	Liquid	NA	NA	NA	3.3 billion (J)	Cascade	CFU/100ml	NA	NA	NA	NA	NA	NA	NA	NA	NA
LG-14	10164264	Dairy Lagoon	Liquid	NA	NA	NA	2.4 billion (J)	Cascade	CFU/100ml	NA	NA	NA	NA	NA	NA	NA	NA	NA
LG-15	10164265	Dairy Lagoon	Liquid	NA	NA	NA	5.4 million	Cascade	CFU/100ml	NA	NA	NA	NA	NA	NA	NA	NA	NA
SP-01	10154271	WWTP Influent	Liquid	NA	NA	NA	TNTC	Cascade	CFU/100ml	NA	NA	NA	P	A	A	H	ND	P
SP-02	10154272	WWTP Influent	Liquid	NA	NA	NA	9.2 million	Manchester	#/100ml	5.4 million (J)	Manchester	#/100ml	P	A	A	H	ND	P
SP-03[1]	10154273	WWTP Influent	Liquid	NA	NA	NA	>1.6 million	Manchester	#/100ml	>1.6 million (J)	Manchester	#/100ml	P	A	A	H	A	P
SP-04[1]	10154274	WWTP Influent	Liquid	NA	NA	NA	13 million	Manchester	#/100ml	13million (J)	Manchester	#/100ml	P	P	ND	H/R	P	A

Samples were analyzed by the EPA Manchester Environmental Laboratory.

Abbreviations

A = Absent

H = Human

MST - Microbial Source Tracking

NA = Not analyzed

ND = Not detected

P = Present

R = Ruminant

TNTC = Too numerous to count

WWTP - Wastewater Treatment Plant

BAC32: This is the screening Bacteroides biomarker. If it is present, further testing is done to determine the specific source. If the test is negative, nothing more is done.

CF128 and CF193: These are two separate biomarkers that identify the presence of ruminant fecal source. Between the two of them, they comprise most of the biomarkers that would be found in ruminants. There may be other biomarkers that could exist in very isolated populations of ruminants, but these two will identify the majority. A "P" would identify detection of the biomarker in the particular sample, an "A" indicates absence of that biomarker in the sample.

HF134 and HF183: These are two separate biomarkers that identify the presence of human fecal source. As above, between the two of these biomarkers, the majority of human source will be detected. Again, a very isolated community might develop a different biomarker. A "P" would identify detection of the biomarker in the particular sample, an "A" indicates absence of that biomarker in the sample.

MST- Microbial Source Tracking. MST contaminants: This identifies by two letter code the kind of fecal source was identified in the particular sample.GB indicates that although Bacteroides DNA was present, the source was neither human nor ruminant. An "A" indicates that no Bacteroides DNA was present in the sample. H indicates human source; R indicates ruminant; H/R indicates that both were found in that sample. To be noted, where there is a species identification, there may be fecal contamination from other species present as well, but due to method limitations is not identified.

Units

#/100ml - number per 100 millilters

<1 - less than one organism

Data Qualifiers

J = The analyte was positively identified. The associated numerical value is an estimate.

Notes

[1]Samples SP-03 and SP-04 were collected at the same wastewater treatment plant at different times. Sample SP-04 was submitted to EPA's Manchester Laboratory only and was analyzed for a subset of compounds as identified in the table.

Table C9: Phase 3 Analytical Results for Pesticides in Wells, Manure Piles, Application Fields, and Crop Soils

Location ID	WW-01	WW-02	WW-03	WW-04	WW-05	WW-06	WW-07
Sample ID	10154201	10154202	10154203	10154204	10154205	10154206	10154207
Sample Type	Upgradient Well	Dairy Supply Well	Downgradient Well	Downgradient Well	Downgradient Well	Upgradient Well	Dairy Supply Well
Sample Matrix	Water	Water	Water	Water	Water	Water	Water
Compound Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
2,3,4,5-Tetrachlorophenol	0.2 U	0.2 U	0.2 U	0.19 U	0.19 U	0.2 U	0.19 U
2,3,4,6-Tetrachlorophenol	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
2,4,5-T	0.5 U	0.49 U	0.49 U	0.49 U	0.48 U	0.5 U	0.48 U
2,4,5-Trichlorophenol	0.2 U	0.2 U	0.2 U	0.19 U	0.19 U	0.2 U	0.19 U
2,4,6-Trichlorophenol	0.5 UJ	0.49 UJ	0.49 UJ	0.49 UJ	0.48 UJ	0.5 UJ	0.48 UJ
2,4-D	0.5 UJ	0.49 UJ	0.49 UJ	0.49 UJ	0.48 UJ	0.5 UJ	0.48 UJ
2,4-DB	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
3,5-Dichlorobenzoic acid	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
4-Nitrophenol	0.5 UJ	0.49 UJ	0.49 UJ	0.49 UJ	0.48 UJ	0.5 UJ	0.48 UJ
Acifluorfen	0.5 U	0.49 U	0.49 U	0.49 U	0.48 U	0.5 U	0.48 U
Alachlor	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Atrazine	0.015 J	0.041 J	0.1 UJ	0.015 J	0.11 J	0.026 J	0.1 UJ
Azinphos-methyl	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Bentazon	0.1 U	0.1 U	0.098 U	0.1 U	0.1 U	0.1 U	0.012 NJ
Benzonitrile, 2,6-dichloro-	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Bromoxynil	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Chloramben	0.2 UJ	0.2 UJ	0.2 UJ	0.19 UJ	0.19 UJ	0.2 UJ	0.19 UJ
Chlorpyrifos, Ethyl	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Clopyralid	1 UJ	0.99 UJ	0.98 UJ	0.97 UJ	0.95 UJ	1 UJ	0.96 UJ
DACTHAL-DCPA	0.5 UJ	0.49 UJ	0.49 UJ	0.49 UJ	0.48 UJ	0.5 UJ	0.48 UJ
Diazinon	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Dicamba	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Dichlorprop	0.5 U	0.49 U	0.49 U	0.49 U	0.48 U	0.5 U	0.48 U
Diclofop, Methyl	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Dinoseb	0.5 U	0.49 U	0.49 U	0.49 U	0.48 U	0.5 U	0.48 U
Diuron	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Endosulfan I	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ

Table C9: Phase 3 Analytical Results for Pesticides in Wells, Manure Piles, Application Fields, and Crop Soils

Location ID	WW-01	WW-02	WW-03	WW-04	WW-05	WW-06	WW-07
Sample ID	10154201	10154202	10154203	10154204	10154205	10154206	10154207
Sample Type	Upgradient Well	Dairy Supply Well	Downgradient Well	Downgradient Well	Downgradient Well	Upgradient Well	Dairy Supply Well
Sample Matrix	Water	Water	Water	Water	Water	Water	Water
Compound Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Endosulfan II	0.1 UJ	0.1 UJ	0.098 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.096 UJ
Endosulfan Sulfate	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Fenhexamid	1 UJ	0.99 UJ	0.98 UJ	0.97 UJ	0.95 UJ	1 UJ	0.96 UJ
Fenpropathrin	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Imidan	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.19 UJ	0.2 UJ	0.19 UJ
Ioxynil	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Kresoxim-methyl	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
MCPA	0.2 U	0.2 U	0.2 U	0.19 U	0.19 U	0.2 U	0.19 U
MCPP	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Metribuzin	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Myclobutanil	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Oxyfluorfen	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Pendimethalin	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Pentachlorophenol	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Picloram	1 UJ	0.99 UJ	0.98 UJ	0.97 UJ	0.95 UJ	1 UJ	0.96 UJ
Propargite	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Silvex	0.2 U	0.2 U	0.2 U	0.19 U	0.19 U	0.2 U	0.19 U
Simazine	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
SURFLAN	2 UJ	1.97 UJ	2 UJ	2 UJ	1.9 UJ	2 UJ	1.9 UJ
Terbacil	2 UJ	2 UJ	2 UJ	2 UJ	1.9 UJ	2 UJ	1.9 UJ
Trichlorpyr	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Triflumizole	0.4 UJ	0.39 UJ	0.39 UJ	0.39 UJ	0.38 UJ	0.4 UJ	0.39 UJ
Trifluralin	0.1 UJ	0.1 UJ	0.1 UJ	0.098 UJ	0.1 UJ	0.1 UJ	0.1 UJ

See Table C9 notes on page 15 of 15.

Table C9: Phase 3 Analytical Results for Pesticides in Wells, Manure Piles, Application Fields, and Crop Soils

Location ID	WW-08	WW-09	WW-10	WW-11	WW-12	WW-13	WW-14
Sample ID	10154208	10164209	10164210	10154211	10154212	10154213	10154214
Sample Type	Dairy Supply Well	Dairy Supply Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well
Sample Matrix	Water	Water	Water	Water	Water	Water	Water
Compound Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
2,3,4,5-Tetrachlorophenol	0.19 U	0.19 U	0.19 U	0.2 U	0.19 U	0.19 U	0.19 U
2,3,4,6-Tetrachlorophenol	0.1 U	0.096 U	0.096 U	0.1 U	0.097 U	0.096 U	0.097 U
2,4,5-T	0.47 U	0.48 U	0.48 U	0.5 U	0.49 U	0.48 U	0.49 U
2,4,5-Trichlorophenol	0.19 U	0.19 U	0.19 U	0.2 U	0.19 UJ	0.19 U	0.19 U
2,4,6-Trichlorophenol	0.47 UJ	0.48 UJ	0.48 UJ	0.5 UJ	0.49 UJ	0.48 UJ	0.49 UJ
2,4-D	0.47 UJ	0.48 UJ	0.48 UJ	0.5 UJ	0.49 UJ	0.48 UJ	0.49 UJ
2,4-DB	0.1 U	0.096 U	0.096 U	0.1 U	0.097 U	0.096 U	0.097 U
3,5-Dichlorobenzoic acid	0.1 U	0.096 U	0.096 U	0.1 U	0.097 U	0.096 U	0.097 U
4-Nitrophenol	0.47 UJ	0.48 UJ	0.48 UJ	0.5 UJ	0.49 UJ	0.48 UJ	0.49 UJ
Acifluorfen	0.47 U	0.48 U	0.48 U	0.5 U	0.49 U	0.48 U	0.49 U
Alachlor	0.095 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.048 J	0.1 UJ
Atrazine	0.095 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.016 J	0.048 J	0.06 J
Azinphos-methyl	0.095 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Bentazon	0.036 J	0.096 U	0.096 U	0.1 U	0.097 U	0.096 U	0.097 U
Benzonitrile, 2,6-dichloro-	0.095 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Bromoxynil	0.1 U	0.096 U	0.096 U	0.1 U	0.097 U	0.096 U	0.097 U
Chloramben	0.19 UJ	0.19 UJ	0.19 UJ	0.2 UJ	0.19 UJ	0.19 UJ	0.19 UJ
Chlorpyrifos, Ethyl	0.095 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Clopyralid	0.95 UJ	0.96 UJ	0.96 UJ	1 UJ	0.97 UJ	0.96 UJ	0.97 UJ
DACTHAL-DCPA	0.47 UJ	0.48 UJ	0.48 UJ	0.5 UJ	0.49 UJ	0.48 UJ	0.49 UJ
Diazinon	0.095 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Dicamba	0.1 UJ	0.096 UJ	0.096 UJ	0.1 UJ	0.097 UJ	0.096 UJ	0.097 UJ
Dichlorprop	0.47 U	0.48 U	0.48 U	0.5 U	0.49 U	0.48 U	0.49 U
Diclofop, Methyl	0.1 U	0.096 U	0.096 U	0.1 U	0.097 U	0.096 U	0.097 U
Dinoseb	0.47 U	0.48 U	0.48 U	0.5 U	0.49 U	0.48 U	0.49 U
Diuron	0.095 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Endosulfan I	0.095 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ

Table C9: Phase 3 Analytical Results for Pesticides in Wells, Manure Piles, Application Fields, and Crop Soils

Location ID	WW-08	WW-09	WW-10	WW-11	WW-12	WW-13	WW-14
Sample ID	10154208	10164209	10164210	10154211	10154212	10154213	10154214
Sample Type	Dairy Supply Well	Dairy Supply Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well
Sample Matrix	Water	Water	Water	Water	Water	Water	Water
Compound Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Endosulfan II	0.095 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Endosulfan Sulfate	0.095 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Fenhexamid	0.95 UJ	0.96 UJ	0.96 UJ	1 UJ	0.97 UJ	0.96 UJ	0.97 UJ
Fenpropathrin	0.095 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Imidan	0.19 UJ	0.19 UJ	0.19 UJ	0.2 UJ	0.19 UJ	0.19 UJ	0.19 UJ
Ioxynil	0.1 U	0.096 U	0.096 U	0.1 U	0.097 U	0.0063 J	0.097 U
Kresoxim-methyl	0.095 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
MCPA	0.19 U	0.19 U	0.19 U	0.2 U	0.19 U	0.19 U	0.19 U
MCPP	0.1 U	0.096 U	0.096 U	0.1 U	0.097 U	0.096 U	0.097 U
Metribuzin	0.095 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Myclobutanil	0.095 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Oxyfluorfen	0.095 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Pendimethalin	0.095 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Pentachlorophenol	0.1 U	0.096 U	0.096 U	0.1 U	0.097 U	0.096 U	0.097 U
Picloram	0.95 UJ	0.96 UJ	0.96 UJ	1 UJ	0.97 UJ	0.96 UJ	0.97 UJ
Propargite	0.095 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Silvex	0.19 U	0.19 U	0.19 U	0.2 U	0.19 U	0.19 U	0.19 U
Simazine	0.09 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
SURFLAN	1.9 UJ	1.9 UJ	1.9 UJ	2 UJ	1.9 UJ	1.9 UJ	1.9 UJ
Terbacil	1.9 UJ	1.9 UJ	1.9 UJ	2 UJ	1.9 UJ	1.9 UJ	1.9 UJ
Trichlorpyr	0.1 U	0.096 U	0.096 U	0.1 U	0.097 U	0.096 U	0.097 U
Triflumizole	0.38 UJ	0.39 UJ	0.39 UJ	0.4 UJ	0.39 UJ	0.39 UJ	0.39 UJ
Trifluralin	0.095 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ

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Table C9: Phase 3 Analytical Results for Pesticides in Wells, Manure Piles, Application Fields, and Crop Soils

Location ID	WW-15	WW-16	WW-17	WW-18	WW-19	WW-20	WW-21
Sample ID	10154215	10154216	10154217	10154218	10154219	10154220	10154221
Sample Type	Downgradient Well	Downgradient Well	Downgradient Well	Residential Well	Downgradient Septic	Downgradient Septic	Downgradient Septic
Sample Matrix	Water	Water	Water	Water	Water	Water	Water
Compound Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
2,3,4,5-Tetrachlorophenol	0.19 U	0.19 U	0.19 U	0.19 U	0.19 U	0.19 U	0.19 U
2,3,4,6-Tetrachlorophenol	0.096 U	0.096 U	0.097 U	0.096 U	0.097 U	0.096 U	0.094 U
2,4,5-T	0.48 U	0.48 U	0.49 U	0.48 U	0.48 U	0.48 U	0.47 U
2,4,5-Trichlorophenol	0.19 U	0.19 U	0.19 U	0.19 U	0.19 U	0.19 U	0.19 U
2,4,6-Trichlorophenol	0.48 UJ	0.48 UJ	0.49 UJ	0.48 UJ	0.48 UJ	0.48 UJ	0.47 UJ
2,4-D	0.48 UJ	0.48 UJ	0.49 UJ	0.48 UJ	0.48 UJ	0.48 UJ	0.47 UJ
2,4-DB	0.096 U	0.096 U	0.097 U	0.096 U	0.097 U	0.096 U	0.094 U
3,5-Dichlorobenzoic acid	0.096 U	0.096 U	0.097 U	0.096 U	0.097 U	0.096 U	0.094 U
4-Nitrophenol	0.48 UJ	0.48 UJ	0.49 UJ	0.48 UJ	0.48 UJ	0.48 UJ	0.47 UJ
Acifluorfen	0.48 U	0.48 U	0.49 U	0.48 U	0.48 U	0.48 U	0.47 U
Alachlor	0.1 UJ	0.1 UJ	0.057 J	0.1 UJ	0.1 UJ	0.1 UJ	0.094 UJ
Atrazine	0.011 J	0.19 J	0.18 J	0.048 J	0.1 UJ	0.03 J	0.094 UJ
Azinphos-methyl	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.094 UJ
Bentazon	0.096 U	0.096 U	0.097 U	0.096 U	0.097 U	0.091 J	0.094 U
Benzonitrile, 2,6-dichloro-	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.094 UJ
Bromoxynil	0.096 U	0.096 U	0.097 U	0.096 U	0.097 U	0.096 U	0.094 U
Chloramben	0.19 UJ	0.19 UJ	0.19 UJ	0.19 UJ	0.19 UJ	0.19 UJ	0.19 UJ
Chlorpyrifos, Ethyl	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.094 UJ
Clopyralid	0.96 UJ	0.96 UJ	0.97 UJ	0.96 UJ	0.97 UJ	0.96 UJ	0.94 UJ
DACTHAL-DCPA	0.48 UJ	0.48 UJ	0.49 UJ	0.48 UJ	0.48 UJ	0.48 UJ	0.47 UJ
Diazinon	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.094 UJ
Dicamba	0.096 UJ	0.096 UJ	0.097 UJ	0.096 UJ	0.097 UJ	0.096 UJ	0.094 UJ
Dichlorprop	0.48 U	0.48 U	0.49 U	0.48 U	0.48 U	0.48 U	0.47 U
Diclofop, Methyl	0.096 U	0.096 U	0.097 U	0.096 U	0.097 U	0.096 U	0.094 U
Dinoseb	0.48 U	0.48 U	0.49 U	0.48 U	0.48 U	0.48 U	0.47 U
Diuron	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.094 UJ
Endosulfan I	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.094 UJ

Table C9: Phase 3 Analytical Results for Pesticides in Wells, Manure Piles, Application Fields, and Crop Soils

Location ID	WW-15	WW-16	WW-17	WW-18	WW-19	WW-20	WW-21
Sample ID	10154215	10154216	10154217	10154218	10154219	10154220	10154221
Sample Type	Downgradient Well	Downgradient Well	Downgradient Well	Residential Well	Downgradient Septic	Downgradient Septic	Downgradient Septic
Sample Matrix	Water	Water	Water	Water	Water	Water	Water
Compound Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Endosulfan II	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.094 UJ
Endosulfan Sulfate	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.094 UJ
Fenhexamid	0.96 UJ	0.96 UJ	0.97 UJ	0.96 UJ	0.97 UJ	0.96 UJ	0.94 UJ
Fenpropathrin	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.094 UJ
Imidan	0.19 UJ	0.19 UJ	0.19 UJ	0.19 UJ	0.19 UJ	0.19 UJ	0.19 UJ
Ioxynil	0.096 U	0.096 U	0.097 U	0.096 U	0.097 U	0.096 U	0.094 U
Kresoxim-methyl	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.094 UJ
MCPA	0.19 U	0.19 U	0.19 U	0.19 U	0.19 U	0.19 U	0.19 U
MCPP	0.096 U	0.096 U	0.097 U	0.096 U	0.097 U	0.096 U	0.094 U
Metribuzin	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.094 UJ
Myclobutanil	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.094 UJ
Oxyfluorfen	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.094 UJ
Pendimethalin	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.094 UJ
Pentachlorophenol	0.096 U	0.096 U	0.097 U	0.096 U	0.097 U	0.096 U	0.094 U
Picloram	0.96 UJ	0.96 UJ	0.97 UJ	0.96 UJ	0.97 UJ	0.96 UJ	0.94 UJ
Propargite	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.094 UJ
Silvex	0.19 U	0.19 U	0.19 U	0.19 U	0.19 U	0.19 U	0.19 U
Simazine	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.09 UJ
SURFLAN	1.9 UJ	1.9 UJ	1.9 UJ	1.9 UJ	1.9 UJ	1.9 UJ	1.9 UJ
Terbacil	1.9 UJ	1.9 UJ	1.9 UJ	1.9 UJ	1.9 UJ	1.9 UJ	1.9 UJ
Trichlorpyr	0.096 U	0.096 U	0.097 U	0.096 U	0.097 U	0.096 U	0.094 U
Triflumizole	0.39 UJ	0.38 UJ	0.39 UJ	0.39 UJ	0.39 UJ	0.38 UJ	0.38 UJ
Trifluralin	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.094 UJ

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Table C9: Phase 3 Analytical Results for Pesticides in Wells, Manure Piles, Application Fields, and Crop Soils

Location ID	WW-22	WW-23	WW-24	WW-25	WW-26	WW-27	WW-28
Sample ID	10164222	10154223	10154224	10154225	10154226	10154227	10154228
Sample Type	Downgradient Septic	Downgradient Mint	Downgradient Mint	Downgradient Corn	Downgradient Hops	Downgradient Hops	Downgradient Corn
Sample Matrix	Water	Water	Water	Water	Water	Water	Water
Compound Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
2,3,4,5-Tetrachlorophenol	0.19 U	0.19 U	0.2 U	0.19 U	0.19 U	0.19 U	0.19 U
2,3,4,6-Tetrachlorophenol	0.094 U	0.096 U	0.1 U	0.097 U	0.097 U	0.097 U	0.097 U
2,4,5-T	0.47 U	0.48 U	0.49 U	0.49 U	0.48 U	0.48 U	0.48 U
2,4,5-Trichlorophenol	0.19 U	0.19 U	0.2 U	0.19 U	0.19 U	0.19 U	0.19 U
2,4,6-Trichlorophenol	0.47 UJ	0.48 UJ	0.49 UJ	0.49 UJ	0.48 UJ	0.48 UJ	0.48 UJ
2,4-D	0.47 UJ	0.48 UJ	0.49 UJ	0.49 UJ	0.48 UJ	0.48 UJ	0.48 UJ
2,4-DB	0.094 U	0.096 U	0.1 U	0.097 U	0.097 U	0.097 U	0.097 U
3,5-Dichlorobenzoic acid	0.094 U	0.096 U	0.1 U	0.097 U	0.097 U	0.097 U	0.097 U
4-Nitrophenol	0.47 UJ	0.48 UJ	0.49 UJ	0.49 UJ	0.48 UJ	0.48 UJ	0.48 UJ
Acifluorfen	0.47 U	0.48 U	0.49 U	0.49 U	0.48 U	0.48 U	0.48 U
Alachlor	0.094 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Atrazine	0.094 UJ	0.1 UJ	0.017 J	0.1 UJ	0.025 J	0.1 UJ	0.1 UJ
Azinphos-methyl	0.094 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Bentazon	0.094 U	0.028 J	0.033 J	0.03 NJ	0.097 U	0.097 U	0.097 U
Benzonitrile, 2,6-dichloro-	0.094 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Bromoxynil	0.094 U	0.096 U	0.1 U	0.097 U	0.097 U	0.097 U	0.097 U
Chloramben	0.19 UJ	0.19 UJ	0.2 UJ	0.19 UJ	0.19 UJ	0.19 UJ	0.19 UJ
Chlorpyrifos, Ethyl	0.094 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Clopyralid	0.94 UJ	0.96 UJ	0.98 UJ	0.97 UJ	0.97 UJ	0.97 UJ	0.97 UJ
DACTHAL-DCPA	0.47 UJ	0.48 UJ	0.49 UJ	0.49 UJ	0.48 UJ	0.48 UJ	0.48 UJ
Diazinon	0.094 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Dicamba	0.094 UJ	0.096 UJ	0.1 UJ	0.097 UJ	0.097 UJ	0.097 UJ	0.097 UJ
Dichlorprop	0.47 U	0.48 U	0.49 U	0.49 U	0.48 U	0.48 U	0.48 U
Diclofop, Methyl	0.094 U	0.096 U	0.1 U	0.097 U	0.097 U	0.097 U	0.097 U
Dinoseb	0.47 U	0.48 U	0.49 U	0.49 U	0.48 U	0.48 U	0.48 U
Diuron	0.094 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Endosulfan I	0.094 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ

Table C9: Phase 3 Analytical Results for Pesticides in Wells, Manure Piles, Application Fields, and Crop Soils

Location ID	WW-22	WW-23	WW-24	WW-25	WW-26	WW-27	WW-28
Sample ID	10164222	10154223	10154224	10154225	10154226	10154227	10154228
Sample Type	Downgradient Septic	Downgradient Mint	Downgradient Mint	Downgradient Corn	Downgradient Hops	Downgradient Hops	Downgradient Corn
Sample Matrix	Water	Water	Water	Water	Water	Water	Water
Compound Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Endosulfan II	0.094 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Endosulfan Sulfate	0.094 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Fenhexamid	0.94 UJ	0.96 UJ	0.98 UJ	0.97 UJ	0.97 UJ	0.97 UJ	0.97 UJ
Fenpropathrin	0.094 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Imidan	0.19 UJ	0.19 UJ	0.2 UJ	0.2 UJ	0.19 UJ	0.19 UJ	0.19 UJ
Ioxynil	0.094 U	0.096 U	0.1 U	0.097 U	0.097 U	0.097 U	0.097 U
Kresoxim-methyl	0.094 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
MCPA	0.19 U	0.19 U	0.2 U	0.19 U	0.19 U	0.19 U	0.19 U
MCPP	0.094 U	0.096 U	0.1 U	0.097 U	0.097 U	0.097 U	0.097 U
Metribuzin	0.094 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Myclobutanil	0.094 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Oxyfluorfen	0.094 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Pendimethalin	0.094 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Pentachlorophenol	0.094 U	0.096 U	0.1 U	0.097 U	0.097 U	0.097 U	0.097 U
Picloram	0.94 UJ	0.96 UJ	0.98 UJ	0.97 UJ	0.97 UJ	0.97 UJ	0.97 UJ
Propargite	0.094 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
Silvex	0.19 U	0.19 U	0.2 U	0.19 U	0.19 U	0.19 U	0.19 U
Simazine	0.09 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ
SURFLAN	1.9 UJ	1.9 UJ	2 UJ	2 UJ	1.9 UJ	1.9 UJ	1.9 UJ
Terbacil	1.88 UJ	1.9 UJ	2 UJ	2 UJ	1.9 UJ	1.9 UJ	1.9 UJ
Trichlorpyr	0.094 U	0.096 U	0.1 U	0.097 U	0.097 U	0.097 U	0.097 U
Triflumizole	0.38 UJ	0.38 UJ	0.39 UJ	0.39 UJ	0.39 UJ	0.39 UJ	0.39 UJ
Trifluralin	0.094 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ	0.1 UJ

See Table C9 notes on page 15 of 15.

Table C9: Phase 3 Analytical Results for Pesticides in Wells, Manure Piles, Application Fields, and Crop Soils

Location ID	WW-29	WW-30	SO-01	SO-02	SO-03	SO-04	SO-05	SO-06
Sample ID	10154229	10164230	10154231	10154232	10154233	10154234	10154235	10154236
Sample Type	Field Blank	Residential Well	Manure	Soil – Dairy Application Field	Manure	Soil – Dairy Application Field	Manure	Soil – Dairy Application Field
Sample Matrix	Water	Water	Solid	Solid	Solid	Solid	Solid	Solid
Compound Units	ug/L	ug/L	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
2,3,4,5-Tetrachlorophenol	0.19 U	0.19 U	96 U	24 U	45 U	22 U	37 U	13 U
2,3,4,6-Tetrachlorophenol	0.097 U	0.096 U	96 U	24 U	45 U	22 U	37 U	13 U
2,4,5-T	0.49 U	0.48 U	96 U	24 U	45 U	22 U	37 U	13 U
2,4,5-Trichlorophenol	0.19 U	0.19 U	96 U	24 U	45 U	22 U	37 U	13 U
2,4,6-Trichlorophenol	0.49 UJ	0.48 UJ	96 UJ	24 UJ	45 UJ	22 UJ	37 UJ	13 UJ
2,4-D	0.49 UJ	0.48 UJ	37 J	24 U	45 U	22 U	37 U	13 U
2,4-DB	0.097 U	0.096 U	96 U	24 U	45 U	22 U	37 U	13 U
3,5-Dichlorobenzoic acid	0.097 U	0.096 U	96 U	24 U	45 U	22 U	37 U	13 U
4-Nitrophenol	0.49 UJ	0.48 UJ	97 U	1400 J	31 J	1800 J	37 UJ	1700 J
Acifluorfen	0.49 U	0.48 U	96 UJ	24 UJ	45 U	22 UJ	37 UJ	13 UJ
Alachlor	0.1 UJ	0.1 UJ	720 U	20 U	71 U	19 U	62 U	23 U
Atrazine	0.1 UJ	0.02 J	720 U	1.1 J	71 U	19 U	62 U	23 U
Azinphos-methyl	0.1 UJ	0.1 UJ	720 UJ	20 UJ	71 UJ	19 UJ	62 UJ	23 UJ
Bentazon	0.097 U	0.015 J	96 U	24 U	45 U	22 U	37 U	13 U
Benzonitrile, 2,6-dichloro-	0.1 UJ	0.1 UJ	720 U	20 U	71 U	19 U	62 U	23 U
Bromoxynil	0.097 U	0.096 U	96 U	24 U	45 U	22 U	37 U	13 U
Chloramben	0.19 UJ	0.19 UJ	96 UJ	24 UJ	45 UJ	22 UJ	37 UJ	13 UJ
Chlorpyrifos, Ethyl	0.1 UJ	0.1 UJ	720 U	1.3 J	11 J	1.7 J	8.6 J	5.9 J
Clopyralid	0.97 UJ	0.96 UJ	96 U	24 U	45 U	22 U	36 J	13 U
DACTHAL-DCPA	0.49 UJ	0.48 UJ	7 J	24 U	9 J	22 U	28 J	13 U
Diazinon	0.1 UJ	0.1 UJ	720 U	20 U	71 U	19 U	62 U	23 U
Dicamba	0.097 UJ	0.096 UJ	4.9 J	24 U	4.1 J	22 U	3.8 J	13 U
Dichlorprop	0.49 U	0.48 U	96 U	24 U	45 U	22 U	37 U	13 U
Diclofop, Methyl	0.097 U	0.096 U	96 U	24 U	45 UJ	22 U	37 U	13 U
Dinoseb	0.49 U	0.48 U	96 UJ	24 UJ	45 UJ	22 UJ	37 UJ	13 UJ
Diuron	0.1 UJ	0.1 UJ	720 UJ	3.2 J	71 UJ	2.1 J	8.3 J	23 UJ
Endosulfan I	0.1 UJ	0.1 UJ	720 U	20 U	71 U	19 U	62 U	23 U

Table C9: Phase 3 Analytical Results for Pesticides in Wells, Manure Piles, Application Fields, and Crop Soils

Location ID	WW-29	WW-30	SO-01	SO-02	SO-03	SO-04	SO-05	SO-06
Sample ID	10154229	10164230	10154231	10154232	10154233	10154234	10154235	10154236
Sample Type	Field Blank	Residential Well	Manure	Soil – Dairy Application Field	Manure	Soil – Dairy Application Field	Manure	Soil – Dairy Application Field
Sample Matrix	Water	Water	Solid	Solid	Solid	Solid	Solid	Solid
Compound Units	ug/L	ug/L	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Endosulfan II	0.1 UJ	0.1 UJ	720 U	20 U	71 U	19 U	62 U	23 U
Endosulfan Sulfate	0.1 UJ	0.1 UJ	720 U	1.3 J	71 U	1.1 J	62 U	23 U
Fenhexamid	0.97 UJ	0.96 UJ	720 UJ	20 UJ	71 UJ	19 UJ	62 UJ	23 UJ
Fenpropathrin	0.1 UJ	0.1 UJ	720 U	20 U	71 U	19 U	62 U	23 U
Imidan	0.2 UJ	0.19 UJ	720 UJ	20 UJ	71 UJ	19 UJ	62 UJ	23 UJ
Ioxynil	0.097 U	0.096 U	96 U	24 U	45 U	22 U	37 U	13 U
Kresoxim-methyl	0.1 UJ	0.1 UJ	720 U	20 U	71 U	19 U	62 U	23 U
MCPA	0.19 U	0.19 U	96 U	24 U	45 U	22 U	37 U	13 U
MCPP	0.097 U	0.096 U	96 U	24 U	45 U	22 U	37 U	13 U
Metribuzin	0.1 UJ	0.1 UJ	720 UJ	20 UJ	71 UJ	19 UJ	62 UJ	23 UJ
Myclobutanil	0.1 UJ	0.1 UJ	720 U	20 U	71 U	19 U	62 U	23 U
Oxyfluorfen	0.1 UJ	0.1 UJ	720 U	20 U	71 U	19 U	62 U	23 U
Pendimethalin	0.1 UJ	0.1 UJ	720 U	20 U	71 U	5.7 J	62 U	23 U
Pentachlorophenol	0.017 J	0.096 U	96 U	1 J	0.9 J	4.2 J	1.9 J	13 U
Picloram	0.97 UJ	0.96 UJ	96 U	24 U	45 U	22 U	37 U	13 U
Propargite	0.1 UJ	0.1 UJ	720 U	20 U	71 U	19 U	62 U	23 U
Silvex	0.19 U	0.19 U	96 U	24 U	45 U	22 U	37 U	13 U
Simazine	0.1 UJ	0.1 UJ	720 U	20 U	71 U	19 U	62 U	23 U
SURFLAN	2 UJ	1.9 UJ	1400 UJ	39 UJ	140 UJ	37 UJ	120 UJ	47 UJ
Terbacil	2 UJ	1.9 UJ	720 U	20 U	71 U	19 U	62 U	23 U
Trichlorpyr	0.097 U	0.096 U	96 U	24 U	45 U	22 U	37 U	13 U
Triflumizole	0.39 UJ	0.19 UJ	720 U	20 U	71 U	19 U	62 U	23 U
Trifluralin	0.1 UJ	0.1 UJ	720 U	20 U	71 U	19 U	62 U	23 U

See Table C9 notes on page 15 of 15.

Table C9: Phase 3 Analytical Results for Pesticides in Wells, Manure Piles, Application Fields, and Crop Soils

Location ID	SO-07	SO-08	SO-09	SO-10	SO-11	SO-12	SO-13	SO-14
Sample ID	10164237	10164238	10164239	10164240	10154241	10154242	10154243	10154244
Sample Type	Manure	Soil – Dairy Application Field	Manure	Soil – Dairy Application Field	Soil - Mint Field	Soil - Mint Field	Soil - Corn Field	Soil - Corn Field
Sample Matrix	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid
Compound **Units**	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
2,3,4,5-Tetrachlorophenol	62 U	11 U	49 U	13 U	13 U	14 U	12 U	12 U
2,3,4,6-Tetrachlorophenol	62 U	11 U	49 U	13 U	13 U	14 U	12 U	12 U
2,4,5-T	62 U	11 U	49 U	13 U	13 U	14 U	12 U	12 U
2,4,5-Trichlorophenol	62 U	11 U	49 U	13 U	13 U	14 U	12 U	12 U
2,4,6-Trichlorophenol	62 UJ	11 UJ	49 UJ	13 UJ	13 UJ	14 UJ	12 UJ	12 UJ
2,4-D	62 U	11 U	49 U	13 U	13 U	14 U	69	6.1 J
2,4-DB	62 U	11 U	49 U	13 U	13 U	14 U	12 U	12 U
3,5-Dichlorobenzoic acid	62 U	11 U	49 U	13 U	13 U	14 U	12 U	12 U
4-Nitrophenol	44 J	300 J	49 UJ	670 J	1100 J	410 J	590 J	190 J
Acifluorfen	62 UJ	11 UJ	49 UJ	13 UJ	13 UJ	14 UJ	12 UJ	12 UJ
Alachlor	87 U	23 U	79 U	19 U	26 U	26 U	22 U	25 U
Atrazine	87 U	23 U	79 U	19 U	26 U	26 U	1.6 J	0.7 J
Azinphos-methyl	87 UJ	23 UJ	79 UJ	19 UJ	26 UJ	26 UJ	22 UJ	25 UJ
Bentazon	62 U	11 U	49 U	13 U	38	2 J	12 U	12 U
Benzonitrile, 2,6-dichloro-	87 U	23 U	79 U	19 U	0.5 J	26 U	22 U	25 U
Bromoxynil	62 U	11 U	49 U	13 U	13 U	4.1 J	12 U	12 U
Chloramben	62 UJ	11 UJ	49 UJ	13 UJ	13 UJ	14 UJ	12 UJ	12 UJ
Chlorpyrifos, Ethyl	13 J	1.5 J	79 U	2.3 J	26 U	0.5 J	22 U	25 U
Clopyralid	62 U	11 U	49 U	13 U	13 U	14 U	12 U	12 U
DACTHAL-DCPA	10 J	11 U	11 J	1 J	13 U	14 U	12 U	12 U
Diazinon	87 U	23 U	79 U	19 U	26 U	26 U	22 U	25 U
Dicamba	4.4 J	11 U	4 J	13 U	13 U	14 U	12 U	12 U
Dichlorprop	62 U	11 U	49 U	13 U	13 U	14 U	12 U	12 U
Diclofop, Methyl	62 U	11 U	49 U	13 U	13 U	14 U	12 U	12 U
Dinoseb	62 UJ	11 UJ	49 UJ	13 UJ	13 UJ	14 UJ	12 UJ	12 UJ
Diuron	22 J	2.6 J	79 UJ	19 UJ	7.9 J	26 UJ	22 UJ	25 UJ
Endosulfan I	87 U	23 U	79 U	19 U	26 U	26 U	22 U	25 U

Table C9: Phase 3 Analytical Results for Pesticides in Wells, Manure Piles, Application Fields, and Crop Soils

Location ID	SO-07	SO-08	SO-09	SO-10	SO-11	SO-12	SO-13	SO-14
Sample ID	10164237	10164238	10164239	10164240	10154241	10154242	10154243	10154244
Sample Type	Manure	Soil – Dairy Application Field	Manure	Soil – Dairy Application Field	Soil - Mint Field	Soil - Mint Field	Soil - Corn Field	Soil - Corn Field
Sample Matrix	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid
Compound Units	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Endosulfan II	87 U	23 U	79 U	19 U	26 U	26 U	22 U	25 U
Endosulfan Sulfate	87 U	23 U	79 U	19 U	26 U	26 U	22 U	25 U
Fenhexamid	87 UJ	23 UJ	79 UJ	19 UJ	26 UJ	26 UJ	22 UJ	25 UJ
Fenpropathrin	87 U	23 U	79 U	19 U	26 U	26 U	22 U	25 U
Imidan	87 UJ	23 UJ	79 UJ	19 UJ	26 UJ	26 UJ	22 UJ	25 UJ
Ioxynil	62 U	11 U	49 U	13 U	13 U	14 U	12 U	12 U
Kresoxim-methyl	87 U	23 U	79 U	19 U	26 U	26 U	22 U	25 U
MCPA	62 U	11 U	49 U	13 U	13 U	14 U	12 U	12 U
MCPP	62 U	11 U	49 U	13 U	13 U	14 U	12 U	12 U
Metribuzin	87 UJ	23 UJ	79 UJ	19 UJ	26 UJ	26 UJ	22 UJ	25 UJ
Myclobutanil	87 U	23 U	79 U	19 U	2.7 J	26 U	22 U	25 U
Oxyfluorfen	87 U	23 U	79 U	19 U	470	26 U	22 U	25 U
Pendimethalin	87 U	23 U	79 U	19 U	2100	1100	22 U	25 U
Pentachlorophenol	3.2 J	11 U	49 U	1.7 J	0.7 J	13 J	12 U	0.5 J
Picloram	62 U	11 U	49 U	13 U	13 U	14 U	12 U	12 U
Propargite	87 U	23 U	79 U	19 U	26 U	26 U	22 U	25 U
Silvex	62 U	11 U	49 U	13 U	13 U	14 U	12 U	12 U
Simazine	87 U	23 U	79 U	19 U	1.6 J	26 U	22 U	25 U
SURFLAN	170 UJ	46 UJ	160 UJ	39 UJ	51 UJ	52 UJ	44 UJ	50 UJ
Terbacil	87 U	23 U	79 U	19 U	1700	7.8 J	22 U	25 U
Trichlorpyr	62 U	11 U	49 U	13 U	13 U	14 U	12 U	12 U
Triflumizole	87 U	23 U	79 U	19 U	26 U	26 U	22 U	25 U
Trifluralin	87 U	23 U	79 U	19 U	3.1 J	26 U	22 U	25 U

See Table C9 notes on page 15 of 15.

Table C9: Phase 3 Analytical Results for Pesticides in Wells, Manure Piles, Application Fields, and Crop Soils

Location ID	SO-15	SO-16
Sample ID	10154245	10154246
Sample Type	Soil - Hops Field	Soil - Hops Field
Sample Matrix	Solid	Solid
Compound **Units**	ug/Kg	ug/Kg
2,3,4,5-Tetrachlorophenol	13 U	10 U
2,3,4,6-Tetrachlorophenol	13 U	10 U
2,4,5-T	13 U	10 U
2,4,5-Trichlorophenol	13 U	10 U
2,4,6-Trichlorophenol	13 UJ	10 UJ
2,4-D	14	7 J
2,4-DB	13 U	10 U
3,5-Dichlorobenzoic acid	13 U	10 U
4-Nitrophenol	510 J	410 J
Acifluorfen	13 UJ	10 UJ
Alachlor	21 U	18 U
Atrazine	21 U	18 U
Azinphos-methyl	21 UJ	18 UJ
Bentazon	13 U	10 U
Benzonitrile, 2,6-dichloro-	21 U	18 U
Bromoxynil	13 U	10 U
Chloramben	13 UJ	10 UJ
Chlorpyrifos, Ethyl	21 U	18 U
Clopyralid	13 U	10 U
DACTHAL-DCPA	13 U	10 U
Diazinon	21 U	18 U
Dicamba	13 U	10 U
Dichlorprop	13 U	10 U
Diclofop, Methyl	13 U	10 U
Dinoseb	13 UJ	10 UJ
Diuron	21 UJ	3 J
Endosulfan I	21 U	18 U

Table C9: Phase 3 Analytical Results for Pesticides in Wells, Manure Piles, Application Fields, and Crop Soils

Location ID	SO-15	SO-16
Sample ID	10154245	10154246
Sample Type	Soil - Hops Field	Soil - Hops Field
Sample Matrix	Solid	Solid
Compound Units	ug/Kg	ug/Kg
Endosulfan II	21 U	18 U
Endosulfan Sulfate	21 U	18 U
Fenhexamid	21 UJ	18 UJ
Fenpropathrin	21 U	18 U
Imidan	21 UJ	18 UJ
Ioxynil	13 U	10 U
Kresoxim-methyl	21 U	18 U
MCPA	13 U	10 U
MCPP	13 U	10 U
Metribuzin	21 UJ	18 UJ
Myclobutanil	21 U	26
Oxyfluorfen	21 U	13 J
Pendimethalin	21 U	18 U
Pentachlorophenol	1.6 J	8.3 J
Picloram	13 U	10 U
Propargite	21 U	18 U
Silvex	13 U	10 U
Simazine	21 U	18 U
SURFLAN	42 UJ	36 UJ
Terbacil	21 U	18 U
Trichlorpyr	13 U	10 U
Triflumizole	21 U	18 U
Trifluralin	21 U	18 U

See Table C9 notes on page 15 of 15.

**Table C9: Phase 3 Analytical Results for Pesticides in Wells,
Manure Piles, Application Fields, and Crop Soils**

Samples analyzed by the EPA Manchester Environmental Laboratory

Abbreviations

SO - soil

WW - water well

NA - Not analyzed

Units

ug/L = micrograms per liter

mg/L = milligrams per liter

Analytical Method

US EPA Method 8270D

Data Qualifiers

< = less than

J = The analyte was positively identified. The associated numerical value is an estimate.

NJ = The analyte was detected at the reported level, the mass spectrum did not meet criteria. The reported value is an estimate.

R = The data are unusable for all purposes.

U = The analyte was not detected at or above the reported value.

UJ = The analyte was not detected at or above the reported estimated result. The associated numerical value is an estimate of the quantitation limit of the analyte in this sample.

Table C10: Phase 3 Analytical Results for Trace Organics in Wells, Lagoons, and Wastewater Treatment Plant Influents

Location ID	WW-01	WW-02	WW-03	WW-04	WW-05	WW-06	WW-07	WW-08	WW-09	WW-10
Sample ID	10154201	10154202	10154203	10154204	10154205	10154206	10154207	10154208	10164209	10164210
Sample Type	Upgradient Well	Dairy Supply Well	Downgradient Well	Downgradient Well	Downgradient Well	Upgradient Well	Dairy Supply Well	Dairy Supply Well	Dairy Supply Well	Downgradient Well
Sample Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Compound **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
1,4-dichlorobenzene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
1-methylnaphthalene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UJ	0.2 U
2,2',4,4'-tetrabromodiphenyl ether	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U
2,6-dimethylnaphthalene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UJ	0.2 U
2-methylnaphthalene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UJ	0.2 U
3,4-dichlorophenyl isocyanate	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U
3-beta-coprostanol	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U
3-methyl-1h-indole (skatol)	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
3-tert-butyl-4-hydroxyanisole (bha)	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
4-cumylphenol	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UJ	0.2 UJ	0.2 U
4-n-octylphenol	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UJ	0.2 UJ	0.2 U
4-nonylphenol monoethoxylate - total (np1eo)	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 UJ	1.6 UJ	1.6 U
4-octylphenol diethoxylate (op2eo)	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ
4-octylphenol monoethoxylate (op1eo)	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 UJ	1 U
4-tert-octylphenol	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 UJ	0.4 UJ	0.4 U
5-methyl-1h-benzotriazole	1.6 UJ	1.6 UJ	1.6 UJ	1.6 UJ	1.6 UJ	1.6 UJ	0.2 UJ	1.6 UJ	1.6 UJ	1.6 UJ
acetophenone	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 UJ	0.4 UJ	0.4 U
acetyl-hexamethyl-tetrahydro-naphthalene (ahtn)	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
anthracene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UJ	0.2 U
anthraquinone	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
atrazine	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
benz[a]pyrene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UJ	0.2 U
benzophenone	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UJ	0.2 U
beta-sitosterol	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	0.2 U	1.6 U	1.6 U	1.6 U
beta-stigmastanol	1.7 U	1.7 U	1.7 U	1.7 U	1.7 U	1.7 U	0.2 U	1.7 U	1.7 U	1.7 U
bis-(2-ethylhexyl) phthalate (dehp)	2.66	2 U	5.26	2 U	2 U	1.74 J	0.2 U	2 U	2 U	2 U
bisphenol a	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.2 UJ	0.4 UJ	0.4 UJ	0.4 U
bromacil	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.2 U	0.8 U	0.8 U	0.8 U
bromoform	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
caffeine	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UJ	0.2 R
camphor	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
carbaryl	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
carbazole	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
chlorpyrifos	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
cholesterol	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	0.2 U	1.6 U	1.6 U	1.6 U
cotinine	0.8 UJ	0.8 UJ	0.8 UJ	0.8 UJ	0.8 UJ	0.8 UJ	0.2 U	0.8 UJ	0.8 UJ	0.8 UJ
diazinon	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U

Table C10: Phase 3 Analytical Results for Trace Organics in Wells, Lagoons, and Wastewater Treatment Plant Influents

Location ID	WW-01	WW-02	WW-03	WW-04	WW-05	WW-06	WW-07	WW-08	WW-09	WW-10
Sample ID	10154201	10154202	10154203	10154204	10154205	10154206	10154207	10154208	10164209	10164210
Sample Type	Upgradient Well	Dairy Supply Well	Downgradient Well	Downgradient Well	Downgradient Well	Upgradient Well	Dairy Supply Well	Dairy Supply Well	Dairy Supply Well	Downgradient Well
Sample Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Compound **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
dichlorvos	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
diethoxynonylphenols- total (np2eo)	3.2 U	3.2 U	3.2 U	3.2 U	3.2 U	3.2 U	0.2 U	3.2 U	3.2 U	3.2 U
diethyl phthalate	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.585 U	0.2 U	0.2 U	0.2 U	0.2 U
d-limonene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
fluoranthene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UJ	0.2 U
hexahydrohexamethyl cyclopentabenzopyran (hhcb)	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
indole	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
isoborneol	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
isophorone	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
isopropylbenzene (cumene)	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
isoquinoline	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
menthol	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
metalaxyl	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
methyl salicylate	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
metolachlor	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
n,n-diethyl-meta-toluamide (deet)	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
naphthalene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.242	0.2 U	0.2 UJ	0.2 U
para-nonylphenol total	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	0.2 U	1.6 UJ	1.6 U	1.6 U
p-cresol	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
pentachlorophenol	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 UJ	1.6 UJ	1.6 U
phenanthrene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
phenol	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UJ	0.2 UJ	0.2 U
prometon	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
pyrene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UJ	0.2 U
tetrachloroethylene	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.175 J	0.4 U	0.4 U	0.4 U
tri(2-butoxyethyl) phosphate	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
tri(2-chloroethyl) phosphate	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
tri(dichloroisopropyl) phosphate	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
tributyl phosphate	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
triclosan	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
triethyl citrate (ethyl citrate)	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
triphenyl phosphate	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U

See Table C10 notes on page 13 of 13.

Table C10: Phase 3 Analytical Results for Trace Organics in Wells, Lagoons, and Wastewater Treatment Plant Influents

Location ID	WW-11	WW-12	WW-13	WW-14	WW-15	WW-16	WW-17	WW-18	WW-19
Sample ID	10154211	10154212	10154213	10154214	10154215	10154216	10154217	10154218	10154219
Sample Type	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Residential Well	Downgradient - Septic
Sample Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water
Compound / **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
1,4-dichlorobenzene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
1-methylnaphthalene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
2,2',4,4'-tetrabromodiphenyl ether	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U
2,6-dimethylnaphthalene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
2-methylnaphthalene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
3,4-dichlorophenyl isocyanate	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U
3-beta-coprostanol	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U
3-methyl-1h-indole (skatol)	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
3-tert-butyl-4-hydroxyanisole (bha)	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
4-cumylphenol	0.2 UJ	0.2 UJ	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 UJ	0.2 U
4-n-octylphenol	0.2 UJ	0.2 UJ	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 UJ	0.2 U
4-nonylphenol monoethoxylate - total (np1eo)	1.6 UJ	1.6 UJ	1.6 U	1.6 UJ	1.6 U	1.6 U	1.6 U	1.6 UJ	1.6 U
4-octylphenol diethoxylate (op2eo)	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ
4-octylphenol monoethoxylate (op1eo)	1 UJ	1 UJ	1 U	1 UJ	1 U	1 U	1 U	1 UJ	1 U
4-tert-octylphenol	0.4 UJ	0.4 UJ	0.4 U	0.4 UJ	0.4 U	0.4 U	0.4 U	0.4 UJ	0.4 U
5-methyl-1h-benzotriazole	1.6 UJ	1.6 UJ	1.6 UJ	1.6 UJ	1.6 UJ	1.6 UJ	1.6 UJ	1.6 UJ	1.6 UJ
acetophenone	0.4 UJ	0.4 UJ	0.4 U	0.4 UJ	0.4 U	0.4 U	0.4 U	0.4 UJ	0.4 U
acetyl-hexamethyl-tetrahydro-naphthalene (ahtn)	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
anthracene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
anthraquinone	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
atrazine	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
benz[a]pyrene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
benzophenone	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
beta-sitosterol	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U
beta-stigmastanol	1.7 U	1.7 U	1.7 U	1.7 U	1.7 U	1.7 U	1.7 U	1.7 U	1.7 U
bis-(2-ethylhexyl) phthalate (dehp)	2.77 J	2 U	2 U	2 U	2 U	2 U	1.03	2 U	2 U
bisphenol a	0.4 UJ	0.4 UJ	0.4 U	0.4 UJ	0.4 U	0.4 U	0.4 U	0.4 UJ	0.4 U
bromacil	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U
bromoform	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
caffeine	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
camphor	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
carbaryl	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
carbazole	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
chlorpyrifos	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
cholesterol	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U
cotinine	0.8 UJ	0.8 UJ	0.8 UJ	0.8 UJ	0.8 UJ	0.8 UJ	0.8 UJ	0.8 UJ	0.8 UJ
diazinon	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U

Table C10: Phase 3 Analytical Results for Trace Organics in Wells, Lagoons, and Wastewater Treatment Plant Influents

Location ID	WW-11	WW-12	WW-13	WW-14	WW-15	WW-16	WW-17	WW-18	WW-19
Sample ID	10154211	10154212	10154213	10154214	10154215	10154216	10154217	10154218	10154219
Sample Type	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Residential Well	Downgradient - Septic
Sample Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water
Compound / **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
dichlorvos	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
diethoxynonylphenols- total (np2eo)	3.2 U	3.2 U	3.2 U	3.2 U	3.2 U	3.2 U	3.2 U	3.2 U	3.2 U
diethyl phthalate	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
d-limonene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
fluoranthene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
hexahydrohexamethyl cyclopentabenzopyran (hhcb)	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
indole	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
isoborneol	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
isophorone	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
isopropylbenzene (cumene)	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
isoquinoline	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
menthol	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
metalaxyl	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
methyl salicylate	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
metolachlor	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
n,n-diethyl-meta-toluamide (deet)	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
naphthalene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
para-nonylphenol total	1.6 UJ	1.6 UJ	1.6 U	1.6 UJ	1.6 U	1.6 U	1.6 U	1.6 UJ	1.6 U
p-cresol	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
pentachlorophenol	1.6 UJ	1.6 UJ	1.6 U	1.6 UJ	1.6 U	1.6 U	1.6 U	1.6 UJ	1.6 U
phenanthrene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
phenol	0.2 UJ	0.2 UJ	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 UJ	0.2 U
prometon	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
pyrene	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
tetrachloroethylene	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
tri(2-butoxyethyl) phosphate	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
tri(2-chloroethyl) phosphate	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
tri(dichloroisopropyl) phosphate	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
tributyl phosphate	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
triclosan	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
triethyl citrate (ethyl citrate)	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
triphenyl phosphate	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U

See Table C10 notes on page 13 of 13.

Table C10: Phase 3 Analytical Results for Trace Organics in Wells, Lagoons, and Wastewater Treatment Plant Influents

Location ID	WW-20	WW-21	WW-22	WW-23	WW-24	WW-25	WW-26	WW-27	WW-28
Sample ID	10154220	10154221	10164222	10154223	10154224	10154225	10154226	10154227	10154228
Sample Type	Downgradient - Septic	Downgradient - Septic	Downgradient - Septic	Downgradient - Mint	Downgradient - Mint	Downgradient - Corn	Downgradient - Hops	Downgradient - Hops	Downgradient - Corn
Sample Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water
Compound Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
1,4-dichlorobenzene	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
1-methylnaphthalene	0.2 U	0.2 R	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
2,2',4,4'-tetrabromodiphenyl ether	0.3 U	0.3 UJ	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U
2,6-dimethylnaphthalene	0.2 U	0.2 R	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
2-methylnaphthalene	0.2 U	0.2 R	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
3,4-dichlorophenyl isocyanate	1.6 U	1.6 UJ	1.6 U	1.6 UJ	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U
3-beta-coprostanol	1.6 U	1.6 UJ	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U
3-methyl-1h-indole (skatol)	0.2 U	0.2 UJ	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
3-tert-butyl-4-hydroxyanisole (bha)	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
4-cumylphenol	0.2 U	0.2 R	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UJ
4-n-octylphenol	0.2 U	0.2 R	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UJ
4-nonylphenol monoethoxylate - total (np1eo)	1.6 U	1.6 R	1.6 UJ	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 UJ
4-octylphenol diethoxylate (op2eo)	0.5 UJ	0.5 R	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ	0.5 UJ
4-octylphenol monoethoxylate (op1eo)	1 U	1 R	1 UJ	1 U	1 U	1 U	1 U	1 U	1 UJ
4-tert-octylphenol	0.4 U	0.4 R	0.4 UJ	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 UJ
5-methyl-1h-benzotriazole	1.6 UJ	1.6 UJ	1.6 UJ	1.6 U	1.6 UJ	1.6 UJ	1.6 UJ	1.6 UJ	1.6 UJ
acetophenone	0.4 U	0.4 R	0.4 UJ	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 UJ
acetyl-hexamethyl-tetrahydro-naphthalene (ahtn)	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
anthracene	0.2 U	0.2 R	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
anthraquinone	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
atrazine	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
benz[a]pyrene	0.2 U	0.2 R	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
benzophenone	0.2 U	0.2 R	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
beta-sitosterol	1.6 U	1.6 UJ	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U
beta-stigmastanol	1.7 U	1.7 UJ	1.7 U	1.7 U	1.7 U	1.7 U	1.7 U	1.7 U	1.7 U
bis-(2-ethylhexyl) phthalate (dehp)	2 U	2 UJ	2 U	2 U	2 U	2 U	2 U	1.25 J	2 U
bisphenol a	0.4 U	0.4 R	0.4 UJ	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 UJ
bromacil	0.8 U	0.8 UJ	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U
bromoform	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
caffeine	0.2 U	0.2 R	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UJ
camphor	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
carbaryl	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
carbazole	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
chlorpyrifos	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
cholesterol	1.6 U	1.6 UJ	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U
cotinine	0.8 UJ	0.8 UJ	0.8 UJ	0.8 UJ	0.8 UJ	0.8 UJ	0.8 UJ	0.8 UJ	0.8 UJ
diazinon	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U

Table C10: Phase 3 Analytical Results for Trace Organics in Wells, Lagoons, and Wastewater Treatment Plant Influents

Location ID	WW-20	WW-21	WW-22	WW-23	WW-24	WW-25	WW-26	WW-27	WW-28
Sample ID	10154220	10154221	10164222	10154223	10154224	10154225	10154226	10154227	10154228
Sample Type	Downgradient - Septic	Downgradient - Septic	Downgradient - Septic	Downgradient - Mint	Downgradient - Mint	Downgradient - Corn	Downgradient - Hops	Downgradient - Hops	Downgradient - Corn
Sample Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water
Compound Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
dichlorvos	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
diethoxynonylphenols- total (np2eo)	3.2 U	3.2 R	3.2 U	3.2 U	3.2 U	3.2 U	3.2 U	3.2 U	3.2 U
diethyl phthalate	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
d-limonene	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
fluoranthene	0.2 U	0.2 R	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
hexahydrohexamethyl cyclopentabenzopyran (hhcb)	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
indole	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
isoborneol	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
isophorone	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
isopropylbenzene (cumene)	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
isoquinoline	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
menthol	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
metalaxyl	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
methyl salicylate	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
metolachlor	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
n,n-diethyl-meta-toluamide (deet)	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
naphthalene	0.2 U	0.2 R	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
para-nonylphenol total	1.6 U	1.6 UJ	1.6 UJ	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 UJ
p-cresol	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
pentachlorophenol	1.6 U	0.8 R	1.6 UJ	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 UJ
phenanthrene	0.2 U	0.2 R	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
phenol	0.2 U	0.2 R	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 UJ
prometon	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
pyrene	0.2 U	0.2 R	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
tetrachloroethylene	0.4 U	0.4 UJ	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
tri(2-butoxyethyl) phosphate	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.713 U	0.2 U	0.2 U	0.2 U
tri(2-chloroethyl) phosphate	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
tri(dichloroisopropyl) phosphate	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
tributyl phosphate	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
triclosan	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
triethyl citrate (ethyl citrate)	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
triphenyl phosphate	0.2 U	0.2 UJ	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U

See Table C10 notes on page 13 of 13.

Table C10: Phase 3 Analytical Results for Trace Organics in Wells, Lagoons, and Wastewater Treatment Plant Influents

Location ID	WW-29	WW-30	LG-01	LG-02	LG-03	LG-04	LG-05	LG-06	LG-07	LG-08	LG-09	LG-10
Sample ID	10154229	10164230	10154251	10154252	10154253	10154254	10154255	10154256	10154257	10154258	10154259	10164260
Sample Type	Field Blank	Residential Well	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon
Sample Matrix	Water	Water	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Compound **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
1,4-dichlorobenzene	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 UJ	2 UJ	0.2 UJ
1-methylnaphthalene	0.2 U	0.2 U	2 UJ	2 R	2 R	2 R	2 R	2 R	2 R	30 UJ	2 R	0.2 R
2,2',4,4'-tetrabromodiphenyl ether	0.3 U	0.3 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.3 UJ
2,6-dimethylnaphthalene	0.2 U	0.2 U	2 UJ	2 UJ	2 UJ	2 R	2 R	2 R	2 R	30 UJ	2 R	0.2 R
2-methylnaphthalene	0.2 U	0.2 U	2 UJ	2 R	2 R	2 R	2 R	2 R	2 R	30 UJ	2 R	0.2 R
3,4-dichlorophenyl isocyanate	1.6 U	1.6 U	2 U	2 UJ	2 UJ	2 UJ	1.6 UJ	2 UJ	2 UJ	30 U	2 UJ	1.6 UJ
3-beta-coprostanol	1.6 U	1.6 U	95.6 J	48.2 J	62.9 J	23.1 J	4.22 J	16.7 J	14.9 J	200 J	37.6 J	12 J
3-methyl-1h-indole (skatol)	0.2 U	0.2 U	22.2 J	40.9 J	146 J	24.2 J	3.56 J	22.5 J	34.9 J	373 J	170 J	6.93 J
3-tert-butyl-4-hydroxyanisole (bha)	0.2 UJ	0.2 UJ	0.2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	0.2 UJ
4-cumylphenol	0.2 U	0.2 U	2 U	2 R	2 R	2 R	2 R	2 R	2 R	30 U	2 UJ	0.2 UJ
4-n-octylphenol	0.2 U	0.2 U	2 U	2 R	2 R	2 R	2 R	2 R	2 R	30 U	2 UJ	0.2 UJ
4-nonylphenol monoethoxylate - total (np1eo)	1.6 U	1.6 U	48 J	39.5 J	54.6 J	2.32 J	1.48 J	10.1 J	8.09 J	165 J	45.9 J	23.8 J
4-octylphenol diethoxylate (op2eo)	0.5 UJ	0.5 UJ	2 U	2 R	2 R	2 R	2 R	2 R	2 R	48.4	2 UJ	0.5 UJ
4-octylphenol monoethoxylate (op1eo)	1 U	1 U	2 U	2 R	2 R	0.697 J	2 R	2 R	2 J	30 U	2 UJ	1 UJ
4-tert-octylphenol	0.349 J	0.4 U	2 U	2 R	2 R	2 R	2 R	2 R	2 R	30 U	2 UJ	0.4 UJ
5-methyl-1h-benzotriazole	1.6 UJ	1.6 UJ	1.6 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	1.6 UJ
acetophenone	0.4 U	0.4 U	2 U	2 R	2 R	2 R	2 R	2 R	2 R	30 U	2 UJ	0.4 UJ
acetyl-hexamethyl-tetrahydro-naphthalene (ahtn)	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
anthracene	0.2 U	0.2 U	2 UJ	2 R	2 R	2 R	2 R	2 R	2 R	30 UJ	2 R	0.2 R
anthraquinone	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
atrazine	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
benz[a]pyrene	0.2 U	0.2 U	2 UJ	2 R	2 R	2 R	2 R	2 R	2 R	30 UJ	2 R	0.2 R
benzophenone	0.2 U	0.2 U	2 UJ	2 UJ	2 UJ	2 R	2 R	2 R	2 R	30 UJ	2 R	0.2 R
beta-sitosterol	1.6 U	1.6 U	104 J	77.6 J	82 J	43.5 J	7.07 J	15.2 J	23.7 J	219 J	56.6 J	14.6 J
beta-stigmastanol	1.7 U	1.7 U	135 J	77.5 J	91.3 J	34.1 J	4.38 J	15.6 J	19.3 J	292 J	52 J	12.5 J
bis-(2-ethylhexyl) phthalate (dehp)	2 U	2 U	2 U	2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	4.58 J
bisphenol a	0.4 U	0.4 U	2 U	2 R	2 R	2 R	2 R	2 R	2 R	30 U	0.4 UJ	0.4 UJ
bromacil	0.8 U	0.8 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	0.8 UJ	2 UJ	30 U	2 UJ	0.8 UJ
bromoform	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
caffeine	0.2 U	0.2 U	2 UJ	2 UJ	2 UJ	2 R	1.02 J	2 UJ	2 R	30 U	2 UJ	0.282 J
camphor	0.2 U	0.2 U	2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	34 J
carbaryl	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
carbazole	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
chlorpyrifos	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
cholesterol	1.6 U	1.6 U	243 J	81.4 J	121 J	59.6 J	12.3 J	25.9 J	37.3 J	377 J	78.3 J	76.4 J
cotinine	0.8 UJ	0.8 UJ	0.8 UJ	2 UJ	2 UJ	0.8 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	0.8 UJ
diazinon	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ

Table C10: Phase 3 Analytical Results for Trace Organics in Wells, Lagoons, and Wastewater Treatment Plant Influents

Location ID	WW-29	WW-30	LG-01	LG-02	LG-03	LG-04	LG-05	LG-06	LG-07	LG-08	LG-09	LG-10
Sample ID	10154229	10164230	10154251	10154252	10154253	10154254	10154255	10154256	10154257	10154258	10154259	10164260
Sample Type	Field Blank	Residential Well	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon
Sample Matrix	Water	Water	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Compound / **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
dichlorvos	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
diethoxynonylphenols- total (np2eo)	3.2 U	3.2 U	66 J	41.6 J	41.8 J	2.16 J	2 UJ	2 UJ	4.87 J	46.5 J	3.2 UJ	36.4 J
diethyl phthalate	1.69	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	15.1 J
d-limonene	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	12.2 J
fluoranthene	0.2 U	0.2 U	2 UJ	2 R	2 R	2 R	2 R	2 R	2 R	30 UJ	2 R	0.2 R
hexahydrohexamethyl cyclopentabenzopyran (hhcb)	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
indole	0.2 U	0.2 U	2 U	2 UJ	2 UJ	25.6 J	2 U	1.17 J	20.1 J	30 U	13 J	6.46
isoborneol	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	37.2 J
isophorone	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	1.06 J	2 UJ	5.33 J
isopropylbenzene (cumene)	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
isoquinoline	0.2 U	0.2 U	2 U	0.224 J	1.01 J	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
menthol	0.29	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
metalaxyl	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
methyl salicylate	0.2 U	0.2 U	2.24 J	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
metolachlor	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
n,n-diethyl-meta-toluamide (deet)	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
naphthalene	0.2 U	0.2 U	2 UJ	2 R	2 R	2 R	2 R	2 R	2 R	30 UJ	2 R	0.2 R
para-nonylphenol total	1.6 U	1.6 U	2 U	35.5 J	49.8 J	2 UJ	3.17 J	17.9 J	2 UJ	81.2 J	18.1 J	7.16 J
p-cresol	0.216	0.2 U	25600 J	5480 J	9010 J	1110 J	14.7 J	112 J	1880 J	9600 J	4690 J	787 J
pentachlorophenol	1.6 U	1.6 U	32 U	2 R	2 R	2 R	2 R	2 R	2 R	60 U	2 UJ	0.8 UJ
phenanthrene	0.2 U	0.2 U	2 UJ	2 R	2 R	2 R	2 R	2 R	2 R	30 UJ	2 R	0.2 R
phenol	0.2 U	1.42	1970 J	1100 J	1360 J	147 J	3.85 J	31.3 J	245 J	2930 J	1120 J	56.6 J
prometon	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
pyrene	0.2 U	0.2 U	2 UJ	2 R	2 R	2 R	2 R	2 R	2 UJ	30 UJ	2 R	0.2 R
tetrachloroethylene	0.4 U	0.4 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.4 UJ
tri(2-butoxyethyl) phosphate	0.178 J	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
tri(2-chloroethyl) phosphate	0.179 J	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
tri(dichloroisopropyl) phosphate	0.323	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
tributyl phosphate	0.202 J	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
triclosan	0.2 U	0.2 U	2 U	2 J	2 UJ	2 UJ	2 U	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
triethyl citrate (ethyl citrate)	0.2 U	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	0.2 UJ
triphenyl phosphate	0.285	0.2 U	2 U	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	2 UJ	30 U	2 UJ	1.47 J

See Table C10 notes on page 13 of 13.

Table C10: Phase 3 Analytical Results for Trace Organics in Wells, Lagoons, and Wastewater Treatment Plant Influents

Location ID	LG-11	LG-12	LG-13	LG-14	LG-15	SP-01	SP-02	SP-03	SP-04
Sample ID	10164261	10164262	10164263	10164264	10164265	10154271	10154272	10154273	10154274
Sample Type	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	WWTP	WTTP	WWTP	WWTP
Sample Matrix	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Compound Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
1,4-dichlorobenzene	0.2 UJ	0.2 UJ	30 U	30 UJ	2 UJ	2.42 J	2.18 J	1.42 J	NA
1-methylnaphthalene	0.2 R	0.2 R	30 UJ	30 UJ	2 R	2 UJ	0.2 UJ	0.2 UJ	NA
2,2',4,4'-tetrabromodiphenyl ether	0.3 UJ	0.3 UJ	30 U	30 U	2 UJ	2 U	0.3 U	0.3 U	NA
2,6-dimethylnaphthalene	0.2 R	0.2 R	3.41 J	2.01 J	2 R	2 UJ	0.2 UJ	0.2 UJ	NA
2-methylnaphthalene	0.2 R	0.2 R	30 UJ	30 UJ	2 R	2 UJ	0.2 UJ	0.2 UJ	NA
3,4-dichlorophenyl isocyanate	1.6 UJ	1.6 UJ	30 U	30 U	2 UJ	2 U	1.6 U	1.6 U	NA
3-beta-coprostanol	2.82 J	2.6 J	591 J	356 J	46.8 J	227 J	75.9 J	166 J	NA
3-methyl-1h-indole (skatol)	45.4 J	48.3 J	1360 J	1170 J	330 J	3.89 J	2.97 J	4.06 J	NA
3-tert-butyl-4-hydroxyanisole (bha)	0.2 UJ	0.2 UJ	2 UJ	2 UJ	2 UJ	3.75 J	0.2 UJ	0.2 U	NA
4-cumylphenol	0.2 UJ	0.2 R	30 U	30 U	2 UJ	2 U	0.2 R	0.2 R	NA
4-n-octylphenol	0.2 UJ	0.2 R	30 U	30 U	2 UJ	2 U	0.489 R	0.2 R	NA
4-nonylphenol monoethoxylate - total (np1eo)	3.14 J	3.06 J	745 J	559 J	166 J	2.66 J	2.86 R	1.6 R	NA
4-octylphenol diethoxylate (op2eo)	0.5 UJ	0.5 R	30 U	30 U	2 UJ	2 UJ	7.9 U	4.45	NA
4-octylphenol monoethoxylate (op1eo)	1 UJ	1 R	30 U	30 U	2 UJ	1.77 J	1 R	0.733 J	NA
4-tert-octylphenol	0.4 UJ	0.4 R	30 U	30 U	2 UJ	1.02 J	0.335 J	0.4 R	NA
5-methyl-1h-benzotriazole	1.6 UJ	1.6 UJ	1.6 UJ	2 UJ	2 UJ	2 UJ	1.6 UJ	1.6 UJ	NA
acetophenone	0.4 UJ	0.4 R	30 U	30 U	2 UJ	0.743 J	0.239 J	0.4 R	NA
acetyl-hexamethyl-tetrahydro-naphthalene (ahtn)	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	0.406 J	5.25 U	0.283 J	NA
anthracene	0.2 R	0.2 R	30 UJ	30 UJ	2 R	2 UJ	0.2 UJ	0.2 UJ	NA
anthraquinone	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	2 U	9.98 U	0.2 U	NA
atrazine	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	2 U	0.2 U	0.2 U	NA
benz[a]pyrene	0.2 R	0.2 R	30 UJ	30 UJ	2 R	2 UJ	0.2 UJ	0.2 UJ	NA
benzophenone	0.2 R	0.2 R	30 UJ	30 UJ	2 R	1.03 J	0.408 J	0.486 J	NA
beta-sitosterol	2.41 J	2.22 J	613 J	312 J	77.6 J	19.3 J	19 J	24.3 U	NA
beta-stigmastanol	2.73 J	2.64 J	535 J	260 J	45.3 J	7.94 J	19.9 J	8.04 J	NA
bis-(2-ethylhexyl) phthalate (dehp)	2 U	2 UJ	30 U	30 U	2 UJ	4.35 J	3.95 J	2.42 J	NA
bisphenol a	0.4 UJ	0.4 R	30 U	30 U	2 UJ	2 J	0.4 R	0.4 R	NA
bromacil	0.8 UJ	0.8 UJ	30 U	30 U	2 UJ	2 U	2.34 U	0.8 U	NA
bromoform	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	2 U	0.2 U	0.2 U	NA
caffeine	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	81.3	8.59	18.1	NA
camphor	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	1.79 J	0.398 J	1.07 J	NA
carbaryl	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	2 U	0.2 U	0.2 U	NA
carbazole	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	2 U	0.2 U	0.2 U	NA
chlorpyrifos	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	2 U	0.2 U	0.2 U	NA
cholesterol	3.83 J	3.71 J	808 J	406 J	114 J	77.5 J	118 J	181.6 J	NA
cotinine	0.8 UJ	0.8 UJ	0.8 UJ	2 UJ	2 UJ	0.8 UJ	0.8 UJ	0.8 U	NA
diazinon	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	2 U	0.2 U	0.2 U	NA

Table C10: Phase 3 Analytical Results for Trace Organics in Wells, Lagoons, and Wastewater Treatment Plant Influents

Location ID	LG-11	LG-12	LG-13	LG-14	LG-15	SP-01	SP-02	SP-03	SP-04
Sample ID	10164261	10164262	10164263	10164264	10164265	10154271	10154272	10154273	10154274
Sample Type	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	WWTP	WTTP	WWTP	WWTP
Sample Matrix	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Compound **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
dichlorvos	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	2 U	0.2 U	0.2 U	NA
diethoxynonylphenols- total (np2eo)	2.24 J	2.02 J	293 J	247 J	55.3 J	8.84 J	11.2 J	15.6 J	NA
diethyl phthalate	0.2 UJ	0.2 U	30 U	30 U	2 UJ	8.03 J	4.03 J	1.83 J	NA
d-limonene	0.2 UJ	0.2 UJ	30 U	0.892 J	2 UJ	4.92	2.3 J	7.74 J	NA
fluoranthene	0.2 R	0.2 R	30 UJ	30 UJ	2 R	2 UJ	0.2 UJ	0.393 J	NA
hexahydrohexamethyl cyclopentabenzopyran (hhcb)	0.2 U	0.2 UJ	30 U	30 U	2 UJ	3.5	5.95 J	3.2 J	NA
indole	4.04 J	4.57 J	30 U	30 U	6.68 J	3.4 J	18.1 J	1.81 J	NA
isoborneol	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	2 J	0.395 J	1.02 J	NA
isophorone	0.2 U	0.2 U	2.36 J	2.12 J	1.26 J	2 U	0.2 U	0.2 U	NA
isopropylbenzene (cumene)	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	2 U	0.2 U	0.2 U	NA
isoquinoline	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	2 U	3.9 U	0.2 U	NA
menthol	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	24.5 J	8.6 J	15.3 J	NA
metalaxyl	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	2 U	0.2 U	0.2 U	NA
methyl salicylate	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	1.06	0.306 J	1.28 J	NA
metolachlor	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	2 U	0.374 U	0.2 U	NA
n,n-diethyl-meta-toluamide (deet)	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	0.986 J	0.476 U	0.2 U	NA
naphthalene	0.2 R	0.2 R	30 UJ	30 UJ	2 R	2 UJ	0.2 UJ	0.2 UJ	NA
para-nonylphenol total	37.4 J	32.1 J	328 J	233 J	129 J	3.9 J	2.79 U	1.74 J	NA
p-cresol	889 J	1350 J	10800 J	8970 J	935 J	69.4 J	11.4 J	27.8 J	NA
pentachlorophenol	0.8 UJ	0.8 R	1.6 U	30 U	2 UJ	2 U	1.6 R	0.8 R	NA
phenanthrene	0.2 R	0.2 R	30 UJ	30 UJ	2 R	2 UJ	0.2 UJ	0.2 UJ	NA
phenol	66.6 J	125 J	4600 J	2760 J	1780 J	16.4 J	6.84 R	12.8 J	NA
prometon	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	2 U	0.2 U	0.2 U	NA
pyrene	0.2 R	0.2 R	30 UJ	30 UJ	2 R	2 UJ	0.2 UJ	0.242 J	NA
tetrachloroethylene	0.4 UJ	0.4 UJ	30 U	30 U	2 UJ	2 U	0.4 U	0.4 U	NA
tri(2-butoxyethyl) phosphate	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	1.86	0.2 U	2.06 J	NA
tri(2-chloroethyl) phosphate	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	0.413 J	0.2 U	0.2 U	NA
tri(dichloroisopropyl) phosphate	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	39.5 J	0.2 U	0.2 U	NA
tributyl phosphate	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	0.2 U	0.2 U	0.2 U	NA
triclosan	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	6.19	1.62 J	3.53 J	NA
triethyl citrate (ethyl citrate)	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	1.56 J	0.351 J	0.724 J	NA
triphenyl phosphate	0.2 UJ	0.2 UJ	30 U	30 U	2 UJ	2 U	0.2 U	0.2 U	NA

See Table C10 notes on page 13 of 13.

Table C10: Phase 3 Analytical Results for Trace Organics in Wells, Lagoons, and Wastewater Treatment Plant Influents

Samples were analyzed by the United States Geological Survey National Water Quality Laboratory.

Abbreviations

WWTP - Wastewater Treatment Plant Influent

NA - Not Analyzed

Units

ug/L = micrograms per liter

Analytical Method

United States Geological Survey (USGS) Standard Operating Procedure (SOP) for the "*Analysis of Waste Water Samples by Gas Chromatography/Mass Spectroscopy*" – USGS SOPs 1433 and 4433.

Data Qualifiers

J = The analyte was positively identified. The associated numerical value is an estimate.

R = The data are unusable for all purposes.

U = The analyte was not detected at or above the reported value.

UJ = The analyte was not detected at or above the reported estimated result. The associated numerical value is an estimate of the quantitation limit of the analyte in this sample.

Table C11: Phase 3 Analytical Results for Wastewater Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	WW-01	WW-02	WW-03	WW-04	WW-05	WW-06	WW-07
Sample ID	10154201	10154202	10154203	10154204	10154205	10154206	10154207
Sample Type	Upgradient Well	Dairy Supply Well	Downgradient Well	Downgradient Well	Downgradient Well	Upgradient Well	Dairy Supply Well
Sample Matrix	Water	Water	Water	Water	Water	Water	Water
Compound and Description — **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Acetaminophen - pain reliever	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Amphetamine - psychostimulant	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Azithromycin - antibiotics	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Caffeine - stimulant	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Carbamazepine - anticonvulsant	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Cotinine - metabolite of nicotine	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
DEET - insect repellent	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Diphenhydramine - antihistimine	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Ibuprofen - pain reliever	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 U
Methamphetamine - psychostimulant	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Naproxen - anti-inflamatory	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R
Paraxanthine - stimulant (metabolite of caffeine)	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Thiabendazole - parasiticide (mintezol)	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Triclosan - antibacterial	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R

See Table C11 notes on page 11 of 11.

Table C11: Phase 3 Analytical Results for Wastewater Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	WW-08	WW-09	WW-10	WW-11	WW-12	WW-13	WW-14
Sample ID	10154208	10164209	10164210	10154211	10154212	10154213	10154214
Sample Type	Dairy Supply Well	Dairy Supply Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well
Sample Matrix	Water	Water	Water	Water	Water	Water	Water
Compound and Description **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Acetaminophen - pain reliever	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Amphetamine - psychostimulant	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Azithromycin - antibiotics	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Caffeine - stimulant	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Carbamazepine - anticonvulsant	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Cotinine - metabolite of nicotine	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
DEET - insect repellent	0.2 U	0.2 U	0.67	0.2 U	0.2 U	0.2 U	0.2 U
Diphenhydramine - antihistimine	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Ibuprofen - pain reliever	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Methamphetamine - psychostimulant	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Naproxen - anti-inflamatory	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R
Paraxanthine - stimulant (metabolite of caffeine)	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Thiabendazole - parasiticide (mintezol)	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Triclosan - antibacterial	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R

See Table C11 notes on page 11 of 11.

Table C11: Phase 3 Analytical Results for Wastewater Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	WW-15	WW-16	WW-17	WW-18	WW-19	WW-20
Sample ID	10154215	10154216	10154217	10154218	10154219	10154220
Sample Type	Downgradient Well	Downgradient Well	Downgradient Well	Residential Well	Downgradient - Septic	Downgradient - Septic
Sample Matrix	Water	Water	Water	Water	Water	Water
Compound and Description **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Acetaminophen - pain reliever	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Amphetamine - psychostimulant	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Azithromycin - antibiotics	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Caffeine - stimulant	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Carbamazepine - anticonvulsant	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Cotinine - metabolite of nicotine	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
DEET - insect repellent	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Diphenhydramine - antihistimine	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Ibuprofen - pain reliever	0.2 U	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Methamphetamine - psychostimulant	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Naproxen - anti-inflamatory	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R
Paraxanthine - stimulant (metabolite of caffeine)	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Thiabendazole - parasiticide (mintezol)	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Triclosan - antibacterial	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R

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Table C11: Phase 3 Analytical Results for Wastewater Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	WW-21	WW-22	WW-23	WW-24	WW-25
Sample ID	10154221	10164222	10154223	10154224	10154225
Sample Type	Downgradient - Septic	Downgradient - Septic	Downgradient - Mint	Downgradient - Mint	Downgradient - Corn
Sample Matrix	Water	Water	Water	Water	Water
Compound and Description **Units**	ug/L	ug/L	ug/L	ug/L	ug/L
Acetaminophen - pain reliever	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Amphetamine - psychostimulant	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Azithromycin - antibiotics	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Caffeine - stimulant	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Carbamazepine - anticonvulsant	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Cotinine - metabolite of nicotine	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
DEET - insect repellent	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Diphenhydramine - antihistimine	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Ibuprofen - pain reliever	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Methamphetamine - psychostimulant	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Naproxen - anti-inflamatory	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R
Paraxanthine - stimulant (metabolite of caffeine)	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Thiabendazole - parasiticide (mintezol)	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Triclosan - antibacterial	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R

See Table C11 notes on page 11 of 11.

Table C11: Phase 3 Analytical Results for Wastewater Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	WW-26	WW-27	WW-28	WW-29	WW-30	LG-01
Sample ID	10154226	10154227	10154228	10154229	10164230	10154251
Sample Type	Downgradient - Hops	Downgradient - Hops	Downgradient - Corn	Field Blank	Residential Well	Dairy Lagoon
Sample Matrix	Water	Water	Water	Water	Water	Liquid
Compound and Description / **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Acetaminophen - pain reliever	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	NA	0.2 U
Amphetamine - psychostimulant	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	NA	0.2 R
Azithromycin - antibiotics	0.2 U	0.2 U	0.2 U	0.2 U	NA	0.2 U
Caffeine - stimulant	0.2 U	0.2 U	0.2 U	0.2 U	NA	0.2 U
Carbamazepine - anticonvulsant	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	NA	0.2 UJ
Cotinine - metabolite of nicotine	0.2 U	0.2 U	0.2 U	0.2 U	NA	0.2 U
DEET - insect repellent	0.2 U	0.2 U	0.2 U	0.2 U	NA	0.2 U
Diphenhydramine - antihistimine	0.2 U	0.2 U	0.2 U	0.2 U	NA	0.2 U
Ibuprofen - pain reliever	0.2 UJ	0.2 UJ	0.2 UJ	0.2 U	NA	0.2 U
Methamphetamine - psychostimulant	0.2 U	0.2 U	0.2 U	0.2 U	NA	0.2 R
Naproxen - anti-inflamatory	0.2 R	0.2 R	0.2 R	0.2 R	NA	0.2 U
Paraxanthine - stimulant (metabolite of caffeine)	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	NA	0.2 U
Thiabendazole - parasiticide (mintezol)	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	NA	4.7 J
Triclosan - antibacterial	0.2 R	0.2 R	0.2 R	0.2 R	NA	0.2 U

See Table C11 notes on page 11 of 11.

Table C11: Phase 3 Analytical Results for Wastewater Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	LG-02	LG-03	LG-04	LG-05	LG-06	LG-07	LG-08	LG-09
Sample ID	10154252	10154253	10154254	10154255	10154256	10154257	10154258	10154259
Sample Type	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon
Sample Matrix	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Compound and Description **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Acetaminophen - pain reliever	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Amphetamine - psychostimulant	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R
Azithromycin - antibiotics	0.2 U	0.2 U	0.2 U	0.2 U	0.2 R	0.2 U	0.2 U	0.2 U
Caffeine - stimulant	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Carbamazepine - anticonvulsant	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ
Cotinine - metabolite of nicotine	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
DEET - insect repellent	0.2 U	0.42 J	0.36 J	0.2 U	0.2 U	0.2 U	0.2 U	0.4 J
Diphenhydramine - antihistimine	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	1.3	2.3	0.2 U
Ibuprofen - pain reliever	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Methamphetamine - psychostimulant	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R
Naproxen - anti-inflamatory	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Paraxanthine - stimulant (metabolite of caffeine)	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Thiabendazole - parasiticide (mintezol)	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	1.9 J	0.2 UJ
Triclosan - antibacterial	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U

See Table C11 notes on page 11 of 11.

Table C11: Phase 3 Analytical Results for Wastewater Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	LG-10	LG-11	LG-12	LG-13	LG-14	LG-15	SP-01	SP-02
Sample ID	10164260	10164261	10164262	10164263	10164264	10164265	10154271	10154272
Sample Type	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	WWTP	WWTP
Sample Matrix	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Compound and Description / **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Acetaminophen - pain reliever	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	32	17
Amphetamine - psychostimulant	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 U	0.2 U
Azithromycin - antibiotics	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Caffeine - stimulant	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	42 J
Carbamazepine - anticonvulsant	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 UJ	0.2 U	0.2 U
Cotinine - metabolite of nicotine	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	1.5	0.59
DEET - insect repellent	0.48 J	0.61 J	0.58 J	0.67 J	0.78 J	0.45 J	1.6	1.6
Diphenhydramine - antihistimine	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.5	0.2 U
Ibuprofen - pain reliever	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	22 J	110 J
Methamphetamine - psychostimulant	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 R	0.2 U	0.2 U
Naproxen - anti-inflamatory	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	11	13
Paraxanthine - stimulant (metabolite of caffeine)	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Thiabendazole - parasiticide (mintezol)	0.2 UJ	1.3 J	0.2 UJ	0.2 UJ	1.8 J	0.2 UJ	0.57 J	0.2 UJ
Triclosan - antibacterial	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	1 J	1.5 J

See Table C11 notes on page 11 of 11.

Table C11: Phase 3 Analytical Results for Wastewater Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	SP-03	SP-04	SO-01	SO-02	SO-03	SO-04	SO-05
Sample ID	10154273	10154274	10154231	10154232	10154233	10154234	10154235
Sample Type	WWTP	WWTP	Manure	Soil – Dairy Application Field	Manure	Soil – Dairy Application Field	Manure
Sample Matrix	Liquid	Liquid	Solid	Solid	Solid	Solid	Solid
Compound and Description / **Units**	ug/L	ug/L	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Acetaminophen - pain reliever	83	NA	100 U	100 U	100 U	100 U	100 U
Amphetamine - psychostimulant	0.2 U	NA	50 U	50 U	50 U	50 U	50 U
Azithromycin - antibiotics	0.2 U	NA	NA	NA	NA	NA	NA
Caffeine - stimulant	46 J	NA	50 U	50 U	50 U	50 U	50 U
Carbamazepine - anticonvulsant	0.2 U	NA	50 U	50 U	50 U	50 U	50 U
Cotinine - metabolite of nicotine	2.2	NA	50 U	50 U	50 U	50 U	50 U
DEET - insect repellent	0.88	NA	50 U	50 U	50 U	50 U	50 U
Diphenhydramine - antihistimine	0.9	NA	50 U	50 U	50 U	50 U	50 U
Ibuprofen - pain reliever	91 J	NA	50 U	50 U	50 U	50 U	50 U
Methamphetamine - psychostimulant	0.2 U	NA	50 U	50 U	50 U	50 U	50 U
Naproxen - anti-inflamatory	59	NA	50 U	50 U	50 U	50 U	50 U
Paraxanthine - stimulant (metabolite of caffeine)	0.2 U	NA	50 U	50 U	50 U	50 U	50 U
Thiabendazole - parasiticide (mintezol)	0.2 UJ	NA	50 U	50 U	50 U	50 U	50 U
Triclosan - antibacterial	2.5 J	NA	50 U	50 U	50 U	50 U	50 U

See Table C11 notes on page 11 of 11.

Table C11: Phase 3 Analytical Results for Wastewater Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	SO-06	SO-07	SO-08	SO-09	SO-10	SO-11	SO-12
Sample ID	10154236	10164237	10164238	10164239	10164240	10154241	10154242
Sample Type	Soil – Dairy Application Field	Manure	Soil – Dairy Application Field	Manure	Soil – Dairy Application Field	Soil – Mint Field	Soil – Mint Field
Sample Matrix	Solid	Solid	Solid	Solid	Solid	Solid	Solid
Compound and Description / **Units**	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Acetaminophen - pain reliever	100 U	100 U	100 U	100 U	100 U	100 U	100 U
Amphetamine - psychostimulant	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Azithromycin - antibiotics	NA	NA	NA	NA	NA	NA	NA
Caffeine - stimulant	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Carbamazepine - anticonvulsant	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Cotinine - metabolite of nicotine	50 U	50 U	50 U	50 U	50 U	50 U	50 U
DEET - insect repellent	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Diphenhydramine - antihistimine	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Ibuprofen - pain reliever	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Methamphetamine - psychostimulant	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Naproxen - anti-inflamatory	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Paraxanthine - stimulant (metabolite of caffeine)	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Thiabendazole - parasiticide (mintezol)	50 U	50 U	50 U	50 U	50 U	50 U	50 U
Triclosan - antibacterial	50 U	50 U	50 U	50 U	50 U	50 U	50 U

See Table C11 notes on page 11 of 11.

Table C11: Phase 3 Analytical Results for Wastewater Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	SO-13	SO-14	SO-15	SO-16
Sample ID	10154243	10154244	10154245	10154246
Sample Type	Soil – Corn Field	Soil – Corn Field	Soil – Hops Field	Soil – Hops Field
Sample Matrix	Solid	Solid	Solid	Solid
Compound and Description **Units**	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Acetaminophen - pain reliever	100 U	100 U	100 U	100 U
Amphetamine - psychostimulant	50 U	50 U	50 U	50 U
Azithromycin - antibiotics	NA	NA	NA	NA
Caffeine - stimulant	50 U	50 U	50 U	50 U
Carbamazepine - anticonvulsant	50 U	50 U	50 U	50 U
Cotinine - metabolite of nicotine	50 U	50 U	50 U	50 U
DEET - insect repellent	50 U	50 U	50 U	50 U
Diphenhydramine - antihistimine	50 U	50 U	50 U	50 U
Ibuprofen - pain reliever	50 U	50 U	50 U	50 U
Methamphetamine - psychostimulant	50 U	50 U	50 U	50 U
Naproxen - anti-inflamatory	50 U	50 U	50 U	50 U
Paraxanthine - stimulant (metabolite of caffeine)	50 U	50 U	50 U	50 U
Thiabendazole - parasiticide (mintezol)	50 U	50 U	50 U	50 U
Triclosan - antibacterial	50 U	50 U	50 U	50 U

See Table C11 notes on page 11 of 11.

Table C11: Phase 3 Analytical Results for Wastewater Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Wastewater pharmaceutical analyses were conducted by the University of Nebraska Water Sciences Laboratory in Lincoln, Nebraska.

Abbreviations

LG - Dairy waste lagoon

NA - Not analyzed

SOP- Standard Operating Procedure

SP - wastewater treatment plant influent

WW - water well

WWTP - wastewater treatment plant

Units

ug/L = micrograms per liter

ug/Kg = micrograms per kilogram

Analytical Methods

Liquids: UNL LC/MS SOP- LCQ-Wastewater-001*"Determination of antibiotics in water and wastewater using off- line solid phase extraction liquid chromatography (LC) - atmospheric pressure electro spray ionization ion trap mass spectrometry (MS) "*.

Solids: UNL SOP-LCQ-Wastesolid-001 "*Determination of antibiotics in solid samples by microwave-assisted solvent extraction (MASE), solid –phase extraction (SPE) and isotope dilution liquid chromatography (LC)- atmospheric pressure electro spray ionization ion trap mass spectrometry (MS)*".

Data Qualifiers

J = The analyte was positively identified. The associated numerical value is an estimate.

R = The data are unusable for all purposes.

U = The analyte was not detected at or above the reported value.

UJ = The analyte was not detected at or above the reported estimated result. The associated numerical value is an estimate of the quantitation limit of the analyte in this sample.

Table C12: Phase 3 Analytical Results for Veterinary Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	WW-01	WW-02	WW-03	WW-04	WW-05	WW-06	WW-07
Sample ID	10154201	10154202	10154203	10154204	10154205	10154206	10154207
Sample Type	Upgradient Well	Dairy Supply Well	Downgradient Well	Downgradient Well	Downgradient Well	Upgradient Well	Dairy Supply Well
Sample Matrix	Water	Water	Water	Water	Water	Water	Water
Compound **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Chlortetracycline(total)	0.02 U	0.02 U	0.02 U	0.049	0.02 U	0.02 U	0.02 U
Erythromycin	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Lincomycin	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.04 U
Monensin	0.027	0.02 U	0.028	0.023	0.022	0.02 U	0.109
Oxytetracycline	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Ractopamine	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfachloropyridazine	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfadimethoxine	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfamerazine	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfamethazine	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfamethazole	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfamethoxazole	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfathiazole	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Tetracyline	0.02 U	0.02 U	0.041 J	0.075 J	0.02 U	0.051 J	0.041 J
Tiamulin	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Tylosin	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Virginiamycin	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.023 J

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Table C12: Phase 3 Analytical Results for Veterinary Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	WW-08	WW-09	WW-10	WW-11	WW-12	WW-13	WW-14
Sample ID	10154208	10164209	10164210	10154211	10154212	10154213	10154214
Sample Type	Dairy Supply Well	Dairy Supply Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well
Sample Matrix	Water	Water	Water	Water	Water	Water	Water
Compound **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Chlortetracycline(total)	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Erythromycin	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Lincomycin	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.085 U	0.073 U
Monensin	0.02 U	0.023	0.499	0.02 U	0.02 U	0.02 U	0.033
Oxytetracycline	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Ractopamine	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfachloropyridazine	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfadimethoxine	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfamerazine	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfamethazine	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfamethazole	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfamethoxazole	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfathiazole	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Tetracyline	5.17	0.02 U	0.02 U	0.038	0.02 U	0.02 U	0.02 U
Tiamulin	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Tylosin	0.02 U	0.02 U	0.02 U	0.029	0.02 U	0.02 U	0.02 U
Virginiamycin	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.041	0.024

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Table C12: Phase 3 Analytical Results for Veterinary Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	WW-15	WW-16	WW-17	WW-18	WW-19	WW-20	WW-21
Sample ID	10154215	10154216	10154217	10154218	10154219	10154220	10154221
Sample Type	Downgradient Well	Downgradient Well	Downgradient Well	Residential Well	Downgradient - Septic	Downgradient - Septic	Downgradient - Septic
Sample Matrix	Water	Water	Water	Water	Water	Water	Water
Compound **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Chlortetracycline(total)	0.119	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Erythromycin	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.11
Lincomycin	0.02 U	0.02 U	0.02 U	0.03 U	0.02 U	0.02 U	0.371
Monensin	0.393 U	0.02 U	0.02 U	0.02 U	1.62	0.02 U	0.194
Oxytetracycline	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Ractopamine	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.079
Sulfachloropyridazine	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfadimethoxine	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfamerazine	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfamethazine	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.053
Sulfamethazole	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfamethoxazole	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.04
Sulfathiazole	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.051
Tetracyline	0.02 U	0.02 U	0.049	0.02 U	0.02 U	0.04 J	0.02 U
Tiamulin	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.05
Tylosin	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Virginiamycin	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.162

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Table C12: Phase 3 Analytical Results for Veterinary Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	WW-22	WW-23	WW-24	WW-25	WW-26	WW-27
Sample ID	10164222	10154223	10154224	10154225	10154226	10154227
Sample Type	Downgradient - Septic	Downgradient - Mint	Downgradient - Mint	Downgradient - Corn	Downgradient - Hops	Downgradient - Hops
Sample Matrix	Water	Water	Water	Water	Water	Water
Compound Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Chlortetracycline(total)	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Erythromycin	0.02 U	0.02 U	0.02 U	0.02 U	0.185	0.02 U
Lincomycin	0.038 U	0.02 U	0.02 U	0.02 U	0.376	0.02 U
Monensin	0.02 U	0.02 U	0.02 U	0.023 U	0.319	0.02 U
Oxytetracycline	0.02 U	0.02 U	0.02 U	0.02 U	0.2	0.02 U
Ractopamine	0.02 U	0.02 U	0.02 U	0.02 U	0.061	0.02 U
Sulfachloropyridazine	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfadimethoxine	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfamerazine	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfamethazine	0.02 U	0.02 U	0.02 U	0.02 U	0.055	0.02 U
Sulfamethazole	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Sulfamethoxazole	0.02 U	0.02 U	0.02 U	0.02 U	0.041 U	0.02 U
Sulfathiazole	0.02 U	0.02 U	0.02 U	0.02 U	0.037	0.02 U
Tetracyline	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Tiamulin	0.02 U	0.02 U	0.02 U	0.02 U	0.029	0.02 U
Tylosin	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Virginiamycin	0.02 U	0.02 U	0.02 U	0.02 U	0.084	0.02 U

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Table C12: Phase 3 Analytical Results for Veterinary Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	WW-28	WW-29	WW-30	LG-01	LG-02	LG-03	LG-04	LG-05
Sample ID	10154228	10154229	10164230	10154251	10154252	10154253	10154254	10154255
Sample Type	Downgradient - Corn	Field Blank	Residential Well	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon
Sample Matrix	Water	Water		Liquid	Liquid	Liquid	Liquid	Liquid
Compound **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Chlortetracycline(total)	0.02 U	0.02 U	NA	0.02 R	0.067 J	0.02 R	0.02 UJ	0.075 J
Erythromycin	0.02 U	0.02 U	NA	0.02 UJ	0.02 UJ	0.02 UJ	0.02 UJ	0.916 J
Lincomycin	0.02 U	0.059	NA	0.02 UJ	0.02 UJ	0.02 UJ	0.02 UJ	3.55 J
Monensin	0.02 U	0.02 U	NA	44.97 J	1086 J	420 J	0.02 UJ	430.2 J
Oxytetracycline	0.02 U	0.02 U	NA	0.02 R	0.02 R	0.02 R	0.02 UJ	1.24 J
Ractopamine	0.02 U	0.02 U	NA	0.081 J	0.085 J	0.078 J	0.02 UJ	0.04 J
Sulfachloropyridazine	0.02 U	0.02 U	NA	0.02 UJ	0.02 UJ	0.02 UJ	0.02 UJ	1.21 J
Sulfadimethoxine	0.02 U	0.02 U	NA	0.38 J	4.68 J	2.18 J	0.02 UJ	0.322 J
Sulfamerazine	0.02 U	0.02 U	NA	0.02 UJ	0.117 J	0.02 UJ	0.02 UJ	0.068 J
Sulfamethazine	0.02 U	0.02 U	NA	0.071 J	0.109 J	0.02 UJ	0.02 UJ	1.5 J
Sulfamethazole	0.02 U	0.02 U	NA	0.06 J	0.02 UJ	0.02 UJ	0.02 UJ	0.02 R
Sulfamethoxazole	0.02 U	0.02 U	NA	0.02 UJ	0.02 UJ	0.02 UJ	0.02 UJ	0.02 R
Sulfathiazole	0.02 U	0.02 U	NA	0.305 J	0.312 J	0.216 J	0.02 UJ	0.137 J
Tetracyline	0.02 U	0.02 U	NA	1.96 J	5.83 J	2.88 J	0.02 UJ	4.48 J
Tiamulin	0.02 U	0.02 U	NA	0.02 UJ	0.02 UJ	0.02 UJ	0.02 UJ	0.02 R
Tylosin	0.02 U	0.02 U	NA	0.381 J	1.85 J	1.12 J	0.02 UJ	1.7 J
Virginiamycin	0.02 U	0.02 U	NA	0.02 UJ	0.02 UJ	0.02 UJ	0.02 UJ	0.334 J

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Table C12: Phase 3 Analytical Results for Veterinary Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	LG-06	LG-07	LG-08	LG-09	LG-10	LG-11	LG-12	LG-13	LG-14
Sample ID	10154256	10154257	10154258	10154259	10164260	10164261	10164262	10164263	10164264
Sample Type	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon
Sample Matrix	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Compound **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Chlortetracycline(total)	0.02 UJ	0.02 R	0.02 R	0.02 R	0.079 J	0.02 R	0.02 R	0.02 R	0.02 R
Erythromycin	0.02 UJ	0.02 R	0.02 R	1.87 J	0.02 R	2 J	1.11 J	1.3 J	0.02 R
Lincomycin	8.5 J	0.02 R	0.02 R	0.02 R	1.7 J	2.64 J	1.54 J	3.37 J	2.04 J
Monensin	463.8 J	0.02 R	449.6 J	337.7 J	2.24 J	85 J	135 J	662 J	498 J
Oxytetracycline	4.49 J	0.02 R	0.929 J	0.02 R	0.02 R	0.02 R	0.02 R	0.02 R	0.02 R
Ractopamine	0.02 R	0.02 R	0.02 R	0.02 R	0.048 J	0.066 J	0.046 J	0.081 J	0.056 J
Sulfachloropyridazine	0.157 J	0.095 J	0.254 J	0.02 R	0.043 J	0.156 J	0.172 J	0.32 J	0.16 J
Sulfadimethoxine	0.02 R	0.02 R	0.02 R	0.02 R	0.065 J	0.841 J	0.875 J	4.13 J	3.65 J
Sulfamerazine	0.02 R	0.02 R	0.02 R	0.02 R	0.02 R	0.02 R	0.02 R	0.02 R	0.02 R
Sulfamethazine	0.17 J	0.02 R	0.39 J	2.07 J	0.077 J	0.064 J	0.07 J	0.108 J	0.139 J
Sulfamethazole	0.02 R	0.02 R	0.02 R	0.02 R	0.114 J	0.02 R	0.02 R	0.148 J	0.02 R
Sulfamethoxazole	0.02 R	0.02 R	0.02 R	0.02 R	0.133 J	0.269 J	0.264 J	0.02 R	0.031 J
Sulfathiazole	0.829 J	0.02 R	0.872 J	0.02 R	0.038 J	0.089 J	0.065 J	0.24 J	0.061 J
Tetracyline	5.41 J	0.442 J	6.07 J	3.6 J	6.55 J	1.76 J	1.91 J	10.3 J	8.6 J
Tiamulin	0.02 R	0.02 R	0.02 R	0.02 R	0.02 R	0.02 R	0.02 R	0.079 J	0.02 R
Tylosin	10.22 J	0.184 J	0.02 R	1.07 J	0.02 R	0.02 R	0.02 R	0.139 J	0.02 R
Virginiamycin	0.02 R	0.02 R	0.02 R	0.02 R	0.816 J	0.413 J	0.314 J	0.184 J	0.02 R

See Table C12 notes on
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Table C12: Phase 3 Analytical Results for Veterinary Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	LG-15	SP-01	SP-02	SP-03	SP-04	SO-01	SO-02	SO-03
Sample ID	10164265	10154271	10154272	1E+07	10154274	10154231	10154232	10154233
Sample Type	Dairy Lagoon	WWTP	WTTP	WWTP	WWTP	Manure	Soil – Dairy Application Field	Manure
Sample Matrix	Liquid	Liquid	Liquid	Liquid	Liquid	Solid	Solid	Solid
Compound **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/Kg	ug/Kg	ug/Kg
Chlortetracycline(total)	0.02 R	0.02 R	0.02 UJ	0.02 U	NA	0.5 U	45.6	0.7
Erythromycin	4.35 J	0.02 UJ	0.02 R	0.02 U	NA	0.5 U	0.5 U	2.1
Lincomycin	1.71 J	0.02 UJ	0.02 R	0.02 U	NA	17.1	0.5 U	1.5
Monensin	426 J	0.02 UJ	0.02 R	0.02 U	NA	441	2.9	109
Oxytetracycline	0.02 R	0.02 R	0.02 UJ	0.02 U	NA	4.5	2.4	251
Ractopamine	0.06 J	0.02 UJ	0.02 R	0.02 U	NA	0.5 U	0.5 U	0.5 U
Sulfachloropyridazine	0.658 J	0.02 UJ	0.02 R	0.02 U	NA	0.5 U	0.5 U	0.5 U
Sulfadimethoxine	2.98 J	0.021 J	0.02 R	0.02 U	NA	0.5 U	1	0.5 U
Sulfamerazine	0.028 J	0.02 UJ	0.02 R	0.02 U	NA	0.5 U	0.5 U	0.5 U
Sulfamethazine	0.601 J	0.02 UJ	0.02 R	0.086	NA	0.5 U	0.5 U	0.5 U
Sulfamethazole	1.27 J	0.02 UJ	0.02 R	0.02 U	NA	0.5 U	0.5 U	0.5 U
Sulfamethoxazole	0.037 J	0.02 UJ	0.106 J	0.662	NA	0.5 U	0.5 U	0.5 U
Sulfathiazole	0.135 J	0.02 UJ	0.02 R	0.02 U	NA	0.5 U	0.5 U	0.5 U
Tetracyline	7.55 J	0.55 J	0.02 UJ	0.02 U	NA	178	26.9	954
Tiamulin	0.132 J	0.02 UJ	0.02 R	0.02 U	NA	0.5 U	0.5 U	0.5 U
Tylosin	0.02 R	0.02 UJ	0.02 R	0.02 U	NA	0.5 U	0.5 U	14.8
Virginiamycin	1 J	0.02 UJ	0.02 R	0.02 U	NA	0.5 U	0.5 U	0.5 U

See Table C12 notes on page 10 of 10.

Table C12: Phase 3 Analytical Results for Veterinary Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	SO-04	SO-05	SO-06	SO-07	SO-08	SO-09	SO-10
Sample ID	10154234	10154235	10154236	10164237	10164238	10164239	10164240
Sample Type	Soil – Dairy Application Field	Manure	Soil – Dairy Application Field	Manure	Soil – Dairy Application Field	Manure	Soil – Dairy Application Field
Sample Matrix	Solid	Solid	Solid	Solid	Solid	Solid	Solid
Compound Units	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Chlortetracycline(total)	0.6	17.7	3	2303	13.5	0.5 U	0.5 U
Erythromycin	0.5 U	3.1	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Lincomycin	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	6.9	0.5 U
Monensin	5.1	1329	5.1	283	7.9	437	7
Oxytetracycline	3.2	0.5 U	3.3	134	2.4	2.1	2.4
Ractopamine	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Sulfachloropyridazine	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Sulfadimethoxine	0.5 U	0.5 U	0.5 U	6.8	0.5 U	0.5 U	0.6
Sulfamerazine	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.7
Sulfamethazine	0.9	7.7	0.5 U	2	0.5 U	0.5 U	0.5 U
Sulfamethazole	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Sulfamethoxazole	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Sulfathiazole	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Tetracyline	27.4	17.9	16.5	2484	104	309	53
Tiamulin	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Tylosin	2.1	0.5 U	0.5 U	21.1	0.5 U	0.5 U	0.5 U
Virginiamycin	0.5 U	0.5 U	0.5 U	0.5	0.5 U	0.5 U	0.5 U

See Table C12 notes on page 10 of 10.

Table C12: Phase 3 Analytical Results for Veterinary Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	SO-11	SO-12	SO-13	SO-14	SO-15	SO-16
Sample ID	10154241	10154242	10154243	10154244	10154245	10154246
Sample Type	Soil – Mint Field	Soil – Mint Field	Soil – Corn Field	Soil – Corn Field	Soil – Hops Field	Soil – Hops Field
Sample Matrix	Solid	Solid	Solid	Solid	Solid	Solid
Compound Units	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Chlortetracycline(total)	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Erythromycin	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Lincomycin	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Monensin	0.5 U	4.3	0.5 U	0.5 U	4.5	0.7
Oxytetracycline	1.3	1.4	0.5 U	1.3	10.5	5.3
Ractopamine	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Sulfachloropyridazine	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Sulfadimethoxine	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Sulfamerazine	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Sulfamethazine	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Sulfamethazole	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Sulfamethoxazole	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Sulfathiazole	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Tetracyline	0.5 U	0.5 U	0.5 U	0.5 U	20.7	10.5
Tiamulin	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Tylosin	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5
Virginiamycin	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U

See Table C12 notes on page 10 of 10.

Table C12: Phase 3 Analytical Results for Veterinary Pharmaceuticals in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Veterinary pharmaceutical analyses were conducted by the University of Nebraska Water Sciences Laboratory in Lincoln, Nebraska (UNL).

Abbreviations

LG - dairy waste lagoon

NA - not analyzed

SO - solid

SOP- Standard Operating Procedure

SP - wastewater treatment plant influent

WW - water well

WWTP - wastewater treatment plant

Units

ug/L = micrograms per liter

ug/Kg = micrograms per kilogram

Analytical Method

Liquids: UNL SOP "*Analysis of veterinary pharmaceuticals in water samples using a Spark Holland symbiosis on-line C18 cartridge solid phase extraction (SPE) and high pressure liquid chromatography/tandem mass spectrometry (HPLC/MS/MS)"; Document File number: LCMS_VET_PHARM_WATER_001".*

Solids: UNL SOP "*Analysis of Steroids in solid samples (i.e. soils, manure, etc) by microwave-assisted solvent extraction (MASE) and liquid chromatography-tandem mass spectrometry (LC/MS/MS)" (SOP-VetPharmSED-001)"* .

Data Qualifiers

J = The analyte was positively identified. The associated numerical value is an estimate.

R = The data are unusable for all purposes.

U = The analyte was not detected at or above the reported value.

UJ = The analyte was not detected at or above the reported estimated result. The associated numerical value is an estimate of the quantitation limit of the analyte in this sample.

Table C13: Phase 3 Analytical Results for Hormones in Well, Lagoons, Manure Piles, Application Field, Wastewater Treatment Influents, and Crop Soils

Location ID	WW-01	WW-02	WW-03	WW-04	WW-05	WW-06
Sample ID	10154201	10154202	10154203	10154204	10154205	10154206
Sample Type	Upgradient Well	Dairy Supply Well	Downgradient Well	Downgradient Well	Downgradient Well	Upgradient Well
Sample Matrix	Water	Water	Water	Water	Water	Water
Compound / **Units**	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
17-α-estradiol	0.21 U	0.21 U	0.21 U	0.21 U	0.21 U	0.21 U
17-α-ethynyl-estradiol	0.16 U	0.16 U	0.16 U	0.16 U	0.16 U	0.16 U
17-β-estradiol	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U
Estriol	0.22 U	0.22 U	0.22 U	0.22 U	0.22 U	0.22 U
Estrone	0.21 U	0.21 U	0.21 U	0.21 U	0.21 U	0.21 U

Samples were analyzed by the EPA Robert S. Kerr Environmental Research Center.

Abbreviations

LG - Dairy waste Dairy Lagoon
SOP- Standard Operating Procedure
SP - wastewater treatment plant influent
WW - water well
WWTP - wastewater treatment plant

Units

ug/L = micrograms per liter

Analytical Method

EPA SOP “*Quantitation of Estrogens in Groundwater and Animal Waste Lagoon Water Using Solid Phase Extraction, Pentafluorobenzyl and Trimethylsilyl Derivatization and Gas Chromatography Negative Ion Chemical Ionization/Mass Spectrometry/Mass Spectrometry, RSKSOP-253, Revision 2, October 2010"* .

Data Qualifiers

J = The analyte was positively identified. The associated numerical value is an estimate.
U = The analyte was not detected at or above the reported value.

Table C13: Phase 3 Analytical Results for Hormones in Well, Lagoons, Manure Piles, Application Field, Wastewater Treatment Influents, and Crop Soils

Location ID	WW-07	WW-08	WW-09	WW-10	WW-11	WW-12
Sample ID	10154207	10154208	10164209	10164210	10154211	10154212
Sample Type	Dairy Supply Well	Dairy Supply Well	Dairy Supply Well	Downgradient Well	Downgradient Well	Downgradient Well
Sample Matrix	Water	Water	Water	Water	Water	Water
Compound / Units	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
17-α-estradiol	0.21 U	0.21 U	0.21 U	0.21 U	0.21 U	0.21 U
17-α-ethynyl-estradiol	0.16 U	0.16 U	0.16 U	0.16 U	0.16 U	0.16 U
17-β-estradiol	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U
Estriol	0.22 U	0.22 U	0.22 U	0.22 U	0.22 U	0.22 U
Estrone	0.21 U	0.21 U	0.21 U	0.21 U	0.21 U	0.21 U

Samples were analyzed by the EPA Robert S. Kerr Environmental Research Center.

Abbreviations

LG - Dairy waste Dairy Lagoon
SOP- Standard Operating Procedure
SP - wastewater treatment plant influent
WW - water well
WWTP - wastewater treatment plant

Units

ug/L = micrograms per liter

Analytical Method

EPA SOP "*Quantitation of Estrogens in Groundwater and Animal Waste Lagoon Water Using Solid Phase Extraction, Pentafluorobenzyl and Trimethylsilyl Derivatization and Gas Chromatography Negative Ion Chemical Ionization/Mass Spectrometry/Mass Spectrometry, RSKSOP-253, Revision 2, October 2010*" .

Data Qualifiers

J = The analyte was positively identified. The associated numerical value is an estimate.
U = The analyte was not detected at or above the reported value.

Table C13: Phase 3 Analytical Results for Hormones in Well, Lagoons, Manure Piles, Application Field, Wastewater Treatment Influents, and Crop Soils

	Location ID	WW-13	WW-14	WW-15	WW-16	WW-17	WW-18
	Sample ID	10154213	10154214	10154215	10154216	10154217	10154218
	Sample Type	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Residential Well
	Sample Matrix	Water	Water	Water	Water	Water	Water
Compound	**Units**	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
17-α-estradiol		0.21 U	0.21 U	0.21 U	0.21 U	0.21 U	0.21 U
17-α-ethynyl-estradiol		0.16 U	0.16 U	0.16 U	0.16 U	0.16 U	0.16 U
17-β-estradiol		0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U
Estriol		0.22 U	0.22 U	0.22 U	0.22 U	0.22 U	0.22 U
Estrone		0.21 U	0.21 U	0.21 U	0.21 U	0.21 U	0.21 U

Samples were analyzed by the EPA Robert S. Kerr Environmental Research Center.

Abbreviations

LG - Dairy waste Dairy Lagoon
SOP- Standard Operating Procedure
SP - wastewater treatment plant influent
WW - water well
WWTP - wastewater treatment plant

Units

ug/L = micrograms per liter

Analytical Method

EPA SOP "*Quantitation of Estrogens in Groundwater and Animal Waste Lagoon Water Using Solid Phase Extraction, Pentafluorobenzyl and Trimethylsilyl Derivatization and Gas Chromatography Negative Ion Chemical Ionization/Mass Spectrometry/Mass Spectrometry, RSKSOP-253, Revision 2, October 2010*" .

Data Qualifiers

J = The analyte was positively identified. The associated numerical value is an estimate.
U = The analyte was not detected at or above the reported value.

Table C13: Phase 3 Analytical Results for Hormones in Well, Lagoons, Manure Piles, Application Field, Wastewater Treatment Influents, and Crop Soils

	Location ID	WW-19	WW-20	WW-21	WW-22	WW-23
	Sample ID	10154219	10154220	10154221	10164222	10154223
	Sample Type	Downgradient - Septic	Downgradient - Septic	Downgradient - Septic	Downgradient - Septic	Downgradient - Mint
	Sample Matrix	Water	Water	Water	Water	Water
Compound	**Units**	ng/L	ng/L	ng/L	ng/L	ng/L
17-α-estradiol		0.21 U	0.21 U	0.21 U	0.21 U	0.21 U
17-α-ethynyl-estradiol		0.16 U	0.16 U	0.16 U	0.16 U	0.16 U
17-β-estradiol		0.14 U	0.14 U	0.14 U	0.14 U	0.14 U
Estriol		0.22 U	0.22 U	0.22 U	0.22 U	0.22 U
Estrone		0.21 U	0.21 U	0.21 U	0.21 U	0.21 U

Samples were analyzed by the EPA Robert S. Kerr Environmental Research Center.

Abbreviations

LG - Dairy waste Dairy Lagoon
SOP- Standard Operating Procedure
SP - wastewater treatment plant influent
WW - water well
WWTP - wastewater treatment plant

Units

ug/L = micrograms per liter

Analytical Method

EPA SOP "*Quantitation of Estrogens in Groundwater and Animal Waste Lagoon Water Using Solid Phase Extraction, Pentafluorobenzyl and Trimethylsilyl Derivatization and Gas Chromatography Negative Ion Chemical Ionization/Mass Spectrometry/Mass Spectrometry, RSKSOP-253, Revision 2, October 2010*" .

Data Qualifiers

J = The analyte was positively identified. The associated numerical value is an estimate.
U = The analyte was not detected at or above the reported value.

Table C13: Phase 3 Analytical Results for Hormones in Well, Lagoons, Manure Piles, Application Field, Wastewater Treatment Influents, and Crop Soils

	Location ID	WW-24	WW-25	WW-26	WW-27	WW-28
	Sample ID	10154224	10154225	10154226	10154227	10154228
	Sample Type	Downgradient - Mint	Downgradient - Corn	Downgradient - Hops	Downgradient - Hops	Downgradient - Corn
	Sample Matrix	Water	Water	Water	Water	Water
Compound	**Units**	ng/L	ng/L	ng/L	ng/L	ng/L
17-α-estradiol		0.21 U	0.21 U	0.21 U	0.21 U	0.21 U
17-α-ethynyl-estradiol		0.16 U	0.16 U	0.16 U	0.16 U	0.16 U
17-β-estradiol		0.14 U	0.14 U	0.14 U	0.14 U	0.14 U
Estriol		0.22 U	0.22 U	0.22 U	0.22 U	0.22 U
Estrone		0.21 U	0.21 U	0.21 U	0.21 U	0.21 U

Samples were analyzed by the EPA Robert S. Kerr Environmental Research Center.

Abbreviations

LG - Dairy waste Dairy Lagoon
SOP- Standard Operating Procedure
SP - wastewater treatment plant influent
WW - water well
WWTP - wastewater treatment plant

Units

ug/L = micrograms per liter

Analytical Method

EPA SOP "*Quantitation of Estrogens in Groundwater and Animal Waste Lagoon Water Using Solid Phase Extraction, Pentafluorobenzyl and Trimethylsilyl Derivatization and Gas Chromatography Negative Ion Chemical Ionization/Mass Spectrometry/Mass Spectrometry, RSKSOP-253, Revision 2, October 2010"* .

Data Qualifiers

J = The analyte was positively identified. The associated numerical value is an estimate.
U = The analyte was not detected at or above the reported value.

Table C13: Phase 3 Analytical Results for Hormones in Well, Lagoons, Manure Piles, Application Field, Wastewater Treatment Influents, and Crop Soils

	Location ID	WW-29	WW-30	LG-01	LG-02	LG-03	LG-04	LG-05
	Sample ID	10154229	10164230	10154251	10154252	10154253	10154254	10154255
	Sample Type	Field Blank	Residential Well	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon
	Sample Matrix	Water	Water	Liquid	Liquid	Liquid	Liquid	Liquid
Compound	**Units**	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
17-α-estradiol		0.21 U	0.21 U	10320	1610	1590	3430	1100
17-α-ethynyl-estradiol		0.16 U	0.16 U	38.3 U	20 U	20 U	20 U	20 U
17-β-estradiol		0.14 U	0.14 U	86.8	18 J	21.3	555	44
Estriol		0.22 U	0.22 U	8.8 U	8.8 U	8.8 U	8.8 U	8.8 U
Estrone		0.21 U	0.21 U	2660	1920	1950	1100	3180

Samples were analyzed by the EPA Robert S. Kerr Environmental Research Center.

Abbreviations

LG - Dairy waste Dairy Lagoon
SOP- Standard Operating Procedure
SP - wastewater treatment plant influent
WW - water well
WWTP - wastewater treatment plant

Units

ug/L = micrograms per liter

Analytical Method

EPA SOP "*Quantitation of Estrogens in Groundwater and Animal Waste Lagoon Water Using Solid Phase Extraction, Pentafluorobenzyl and Trimethylsilyl Derivatization and Gas Chromatography Negative Ion Chemical Ionization/Mass Spectrometry/Mass Spectrometry, RSKSOP-253, Revision 2, October 2010*" .

Data Qualifiers

J = The analyte was positively identified. The associated numerical value is an estimate.
U = The analyte was not detected at or above the reported value.

Table C13: Phase 3 Analytical Results for Hormones in Well, Lagoons, Manure Piles, Application Field, Wastewater Treatment Influents, and Crop Soils

	Location ID	LG-06	LG-07	LG-08	LG-09	LG-10	LG-11	LG-12
	Sample ID	10154256	10154257	10154258	10154259	10164260	10164261	10164262
	Sample Type	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon
	Sample Matrix	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Compound	**Units**	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
17-α-estradiol		1190	1730	1200	1270	292	570	559
17-α-ethynyl-estradiol		20 U	20 U	20 U	20 U	20 U	20 U	20 U
17-β-estradiol		38.5	38.2	25.4	22.3	16 J	12 J	11 J
Estriol		8.8 U	8.8 U	8.8 U	8.8 U	8.8 U	8.8 U	8.8 U
Estrone		3300	592	1020	1050	73	453	451

Samples were analyzed by the EPA Robert S. Kerr Environmental Research Center.

Abbreviations

LG - Dairy waste Dairy Lagoon
SOP- Standard Operating Procedure
SP - wastewater treatment plant influent
WW - water well
WWTP - wastewater treatment plant

Units

ug/L = micrograms per liter

Analytical Method

EPA SOP “*Quantitation of Estrogens in Groundwater and Animal Waste Lagoon Water Using Solid Phase Extraction, Pentafluorobenzyl and Trimethylsilyl Derivatization and Gas Chromatography Negative Ion Chemical Ionization/Mass Spectrometry/Mass Spectrometry, RSKSOP-253, Revision 2, October 2010"* .

Data Qualifiers

J = The analyte was positively identified. The associated numerical value is an estimate.
U = The analyte was not detected at or above the reported value.

Table C13: Phase 3 Analytical Results for Hormones in Well, Lagoons, Manure Piles, Application Field, Wastewater Treatment Influents, and Crop Soils

Location ID	LG-13	LG-14	LG-15	SP-01	SP-02	SP-03	SP-04
Sample ID	10164263	10164264	10164265	10154271	10154272	10154273	10154274
Sample Type	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	WWTP	WTTP	WWTP	WWTP
Sample Matrix	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Compound / **Units**	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
17-α-estradiol	1220	1050	792	7.6 U	7.6 U	7.6 U	NA
17-α-ethynyl-estradiol	20 U	20 U	20 U	6.4 U	6.4 U	6.4 U	NA
17-β-estradiol	179	41	25.3	21.1	35.4	34.1	NA
Estriol	8.8 U	8.8 U	8.8 U	1030	863	640	NA
Estrone	390	419	830	77.1	96.4	72.7	NA

Samples were analyzed by the EPA Robert S. Kerr Environmental Research Center.

Abbreviations

LG - Dairy waste Dairy Lagoon
SOP- Standard Operating Procedure
SP - wastewater treatment plant influent
WW - water well
WWTP - wastewater treatment plant

Units

ug/L = micrograms per liter

Analytical Method

EPA SOP "*Quantitation of Estrogens in Groundwater and Animal Waste Lagoon Water Using Solid Phase Extraction, Pentafluorobenzyl and Trimethylsilyl Derivatization and Gas Chromatography Negative Ion Chemical Ionization/Mass Spectrometry/Mass Spectrometry, RSKSOP-253, Revision 2, October 2010*" .

Data Qualifiers

J = The analyte was positively identified. The associated numerical value is an estimate.
U = The analyte was not detected at or above the reported value.

Table C14: Phase 3 Analytical Results for Hormones in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	WW-01	WW-02	WW-03	WW-04	WW-05	WW-06	WW-07	WW-08
Sample ID	10154201	10154202	10154203	10154204	10154205	10154206	10154207	10154208
Sample Type	Upgradient Well	Dairy Supply Well	Downgradient Well	Downgradient Well	Downgradient Well	Upgradient Well	Dairy Supply Well	Dairy Supply Well
Sample Matrix	Water	Water	Water	Water	Water	Water	Water	Water
Compound / Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
11-Keto Testosterone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
17-α-Hydroxyprogesterone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.005 U
17-α-trenbolone	0.003 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.004 U
17-β-estradiol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
17-β-trenbolone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.003
4-Androstenedione	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.003 U	0.002 U	0.004 U
17-α-estradiol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.003	0.002 U	0.003
Androstadienedione	0.002 UJ	0.002 UJ	0.002 UJ	0.003 U	0.002 UJ	0.002 UJ	0.002 UJ	0.002 J
Androsterone	0.006 U	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ
α-Zearalanol	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.005 J	0.009 J
α-Zearalenol	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 J
β-Zearalanol	0.002 U	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ
β-Zearalenol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Epitestosterone	0.002 U	0.002 U	0.002 U	0.003	0.002 U	0.002 U	0.002	0.003
Estriol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Estrone	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ
17-α-ethynyl-estradiol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Melengesterol Acetate	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.004 U
Progesterone	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.004 U	0.004 U	0.007 U
Testosterone	0.021	0.016	0.009	0.012	0.007	0.005	0.002 U	0.003

See Table C14 notes on page 10 of 10.

Table C14: Phase 3 Analytical Results for Hormones in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	WW-09	WW-10	WW-11	WW-12	WW-13	WW-14	WW-15	WW-16
Sample ID	10164209	10164210	10154211	10154212	10154213	10154214	10154215	10154216
Sample Type	Dairy Supply Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well
Sample Matrix	Water	Water	Water	Water	Water	Water	Water	Water
Compound / Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
11-Keto Testosterone	0.003	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
17-α-Hydroxyprogesterone	0.003 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
17-α-trenbolone	0.003 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
17-β-estradiol	0.006	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
17-β-trenbolone	0.004	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
4-Androstenedione	0.003 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
17-α-estradiol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Androstadienedione	0.002 UJ	0.002 UJ	0.002 UJ	0.004 J	0.002 U	0.002 U	0.002 UJ	0.002 UJ
Androsterone	0.005 J	0.002 UJ	0.002 UJ	0.018 J	0.002 U	0.002 U	0.019 J	0.004 UJ
α-Zearalanol	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 U	0.002 U	0.002 UJ	0.002 UJ
α-Zearalenol	0.002 UJ	0.002 UJ	0.002 UJ	0.002 UJ	0.002 U	0.002 U	0.002 UJ	0.002 UJ
β-Zearalanol	0.002 J	0.002 UJ	0.002 UJ	0.002 UJ	0.002 U	0.002 U	0.002 UJ	0.002 UJ
β-Zearalenol	0.003	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Epitestosterone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Estriol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Estrone	0.002 J	0.002 UJ	0.002 UJ	0.002 UJ	0.002 U	0.002 U	0.002 UJ	0.002 UJ
17-α-ethynyl-estradiol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Melengesterol Acetate	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Progesterone	0.005 U	0.002 UJ	0.002 U	0.002 UJ	0.002 U	0.002 U	0.002 UJ	0.002 UJ
Testosterone	0.008	0.002 U	0.004	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U

See Table C14 notes on page 10 of 10.

Table C14: Phase 3 Analytical Results for Hormones in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	WW-17	WW-18	WW-19	WW-20	WW-21	WW-22	WW-23
Sample ID	10154217	10154218	10154219	10154220	10154221	10164222	10154223
Sample Type	Downgradient Well	Residential Well	Downgradient - Septic	Downgradient - Septic	Downgradient - Septic	Downgradient - Septic	Downgradient - Mint
Sample Matrix	Water	Water	Water	Water	Water	Water	Water
Compound **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
11-Keto Testosterone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.005	0.002 U
17-α-Hydroxyprogesterone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.006 U	0.002 U
17-α-trenbolone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.007 U	0.002 U
17-β-estradiol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.006	0.002 U
17-β-trenbolone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
4-Androstenedione	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.006 U	0.002 U
17-α-estradiol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.005	0.002 U
Androstadienedione	0.002 UJ	0.002 U	0.002 UJ	0.002 UJ	0.002 U	0.003	0.002 UJ
Androsterone	0.008 J	0.002 U	0.002 UJ	0.004 J	0.002 U	0.002 U	0.002 UJ
α-Zearalanol	0.002 UJ	0.002 U	0.002 UJ	0.002 UJ	0.002 U	0.002 U	0.002 UJ
α-Zearalenol	0.002 UJ	0.002 U	0.002 UJ	0.002 UJ	0.002 U	0.002 U	0.002 UJ
β-Zearalanol	0.002 UJ	0.002 U	0.002 UJ	0.002 UJ	0.002 U	0.003	0.002 UJ
β-Zearalenol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Epitestosterone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.004	0.002 U
Estriol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Estrone	0.002 UJ	0.002 U	0.002 UJ	0.002 UJ	0.002 U	0.004	0.002 UJ
17-α-ethynyl-estradiol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Melengesterol Acetate	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.005 U	0.002 U
Progesterone	0.002 UJ	0.003 U	0.002 UJ	0.002 UJ	0.002 U	0.008 U	0.002 UJ
Testosterone	0.002 U	0.003	0.002 U	0.002 U	0.002 U	0.01	0.002 U

See Table C14 notes on page 10 of 10.

Table C14: Phase 3 Analytical Results for Hormones in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	WW-24	WW-25	WW-26	WW-27	WW-28	WW-29	WW-30
Sample ID	10154224	10154225	10154226	10154227	10154228	10154229	10164230
Sample Type	Downgradient - Mint	Downgradient - Corn	Downgradient - Hops	Downgradient - Hops	Downgradient - Corn	Field Blank	Residential Well
Sample Matrix	Water	Water	Water	Water	Water	Water	
Compound Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
11-Keto Testosterone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002	NA
17-α-Hydroxyprogesterone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.003	NA
17-α-trenbolone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002	NA
17-β-estradiol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	NA
17-β-trenbolone	0.002 U	0.002 U	0.002 U	0.005	0.002 U	0.002 U	NA
4-Androstenedione	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.003	NA
17-α-estradiol	0.002 U	0.002 U	0.002 U	0.002	0.002 U	0.002 U	NA
Androstadienedione	0.002 UJ	0.002 UJ	0.002 U	0.003 J	0.002 U	0.002 U	NA
Androsterone	0.002 UJ	0.002 UJ	0.002 U	0.022 J	0.002 U	0.002 U	NA
α-Zearalanol	0.002 UJ	0.002 UJ	0.002 U	0.002 UJ	0.002 U	0.002 U	NA
α-Zearalenol	0.002 UJ	0.002 UJ	0.002 U	0.002 UJ	0.002 U	0.002 U	NA
β-Zearalanol	0.002 UJ	0.002 UJ	0.002 U	0.002 UJ	0.002 U	0.004 J	NA
β-Zearalenol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	NA
Epitestosterone	0.002 U	0.002 U	0.002 U	0.005	0.002 U	0.002 U	NA
Estriol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	NA
Estrone	0.002 UJ	0.002 UJ	0.002 U	0.002 UJ	0.002 U	0.002 U	NA
17-α-ethynyl-estradiol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	NA
Melengesterol Acetate	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.003	NA
Progesterone	0.002 UJ	0.002 UJ	0.003 U	0.002 UJ	0.002 U	0.005	NA
Testosterone	0.002 U	0.002 U	0.002 U	0.004	0.002 U	0.002 U	NA

See Table C14 notes on page 10 of 10.

Table C14: Phase 3 Analytical Results for Hormones in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	LG-01	LG-02	LG-03	LG-04	LG-05	LG-06	LG-07	LG-08	LG-09
Sample ID	10154251	10154252	10154253	10154254	10154255	10154256	10154257	10154258	10154259
Sample Type	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon
Sample Matrix	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Compound Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
11-Keto Testosterone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.857	0.765	0.549	0.444
17-α-Hydroxyprogesterone	0.002 U	0.002 U	0.002 U	0.002 U	0.131	0.038	0.002 U	0.002 U	0.002 U
17-α-trenbolone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
17-β-estradiol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
17-β-trenbolone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
4-Androstenedione	0.196	0.35	0.171	0.002 U	0.5	0.101	0.107	0.16	0.204
17-α-estradiol	7.401	0.374	1.043	0.002 U	0.002 U	0.002 U	0.002 U	0.383	0.844
Androstadienedione	0.002 UJ	0.074 J	0.002 UJ	0.002 U	3.504	0.002 U	0.002 U	0.002 U	0.002 U
Androsterone	1.48 J	0.002 UJ	0.002 UJ	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
α-Zearalanol	1.643 J	1.181 J	2.889 J	13.9	11.9	12.6	11.3	4.819	6.969
α-Zearalenol	0.002 UJ	0.002 UJ	0.002 UJ	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
β-Zearalanol	0.002 UJ	0.002 UJ	0.002 UJ	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
β-Zearalenol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Epitestosterone	0.002 U	0.002 U	0.002 U	0.181	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Estriol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Estrone	0.994 J	0.002 UJ	0.002 UJ	0.002 U	1.945	1.666	0.002 U	0.002 U	0.002 U
17-α-ethynyl-estradiol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Melengesterol Acetate	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Progesterone	0.806 J	0.532 J	0.333 J	0.002 U	0.912	0.185	0.757	0.184	0.328
Testosterone	0.032	0.002 U	0.002 U	0.002 U	0.193	0.195	0.016	0.09	0.007

See Table C14 notes on page 10 of 10.

Table C14: Phase 3 Analytical Results for Hormones in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	LG-10	LG-11	LG-12	LG-13	LG-14	LG-15	SP-01	SP-02
Sample ID	10164260	10164261	10164262	10164263	10164264	10164265	10154271	10154272
Sample Type	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	WWTP	WTTP
Sample Matrix	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Compound **Units**	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
11-Keto Testosterone	0.002 U	0.002 U	0.002 U	0.758	0.002 U	0.002 U	0.1	0.043
17-α-Hydroxyprogesterone	0.002 U	0.085	0.107	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
17-α-trenbolone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	1.562	1.014
17-β-estradiol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
17-β-trenbolone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	1.059
4-Androstenedione	0.033	0.411	0.23	0.314	0.31	0.002 U	0.28	0.269
17-α-estradiol	0.459	2.92	3.268	0.002 U	0.002 U	0.002 U	0.263	0.002 U
Androstadienedione	0.002 U	0.166	0.2	0.002 U	0.002 U	0.002 U	0.255 J	0.614 J
Androsterone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	5.049 J	2.137 J
α-Zearalanol	1.434	1.664	2.576	9.851	8.83	4.977	0.176 J	0.22 J
α-Zearalenol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 UJ	0.002 UJ
β-Zearalanol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 UJ	0.002 UJ
β-Zearalenol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Epitestosterone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.06
Estriol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.632	0.002 U
Estrone	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 UJ	0.002 UJ
17-α-ethynyl-estradiol	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U	0.002 U
Melengesterol Acetate	0.002 U	0.043	0.002 U	0.002 U	0.039	0.002 U	0.002 U	0.002 U
Progesterone	0.002 U	0.251	0.248	0.926	0.682	0.002 U	0.002 UJ	0.002 UJ
Testosterone	0.028	0.002 U	0.024	0.262	0.17	0.002 U	0.053	0.059

See Table C14 notes on page 10 of 10.

Table C14: Phase 3 Analytical Results for Hormones in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	SP-03	SP-04	SO-01	SO-02	SO-03	SO-04	SO-05	SO-06
Sample ID	10154273	10154274	10154231	10154232	10154233	10154234	10154235	10154236
Sample Type	WWTP	WWTP	Manure	Soil – Dairy Application Field	Manure	Soil – Dairy Application Field	Manure	Soil – Dairy Application Field
Sample Matrix	Liquid	Liquid	Solid	Solid	Solid	Solid	Solid	Solid
Compound **Units**	ug/L	ug/L	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
11-Keto Testosterone	0.002 U	NA	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
17-α-Hydroxyprogesterone	0.002 U	NA	0.1 U	0.1 U	1.94	0.1 U	0.1 U	0.1 U
17-α-trenbolone	1.521	NA	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
17-β-estradiol	0.002 U	NA	0.1 U	0.1 U	12.4	0.1 U	1.48	0.1 U
17-β-trenbolone	0.439	NA	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
4-Androstenedione	1.352	NA	2.08	0.16	33.2	0.1 U	5.63	0.12
17-α-estradiol	0.002 U	NA	2.39	0.24	34.7	0.1 U	0.1 U	0.11
Androstadienedione	14.1 J	NA	0.1 U	0.1 U	29.4	0.1 U	15.4	0.1 U
Androsterone	3.187 J	NA	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
α-Zearalanol	0.011 J	NA	17.4	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
α-Zearalenol	0.002 UJ	NA	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
β-Zearalanol	0.002 UJ	NA	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
β-Zearalenol	8.015	NA	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Epitestosterone	0.002 U	NA	0.1 U	0.1 U	8.47	0.1 U	0.1 U	0.1 U
Estriol	0.55	NA	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Estrone	0.002 UJ	NA	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
17-α-ethynyl-estradiol	0.002 U	NA	6.3	0.1 U	4.22	0.1 U	10.5	0.1 U
Melengesterol Acetate	0.002 U	NA	0.44	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Progesterone	0.002 UJ	NA	2.83	0.1 U	70.4	0.25	33.1	0.17
Testosterone	0.045	NA	0.1 U	0.1 U	2.95	0.1 U	0.1 U	0.1 U

See Table C14 notes on page 10 of 10.

Table C14: Phase 3 Analytical Results for Hormones in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	SO-07	SO-08	SO-09	SO-10	SO-11	SO-12	SO-13	SO-14
Sample ID	10164237	10164238	10164239	10164240	10154241	10154242	10154243	10154244
Sample Type	Manure	Soil – Dairy Application Field	Manure	Soil – Dairy Application Field	Soil – Mint Field	Soil – Mint Field	Soil – Corn Field	Soil – Corn Field
Sample Matrix	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid
Compound **Units**	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
11-Keto Testosterone	8.8	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
17-α-Hydroxyprogesterone	3.64	0.1 U	3.42	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
17-α-trenbolone	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
17-β-estradiol	8.35	0.1 U	4.37	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
17-β-trenbolone	0.1 U	0.29	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
4-Androstenedione	10.2	0.1 U	12.4	0.12	0.1 U	0.12	0.1 U	0.1 U
17-α-estradiol	18.7	0.1 U	16.9	0.1 U	0.1 U	0.11	0.1 U	0.1 U
Androstadienedione	13.5	0.1 U	19.3	0.1 U	0.18	0.1 U	0.1 U	0.1 U
Androsterone	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
α-Zearalanol	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
α-Zearalenol	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
β-Zearalanol	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
β-Zearalenol	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Epitestosterone	2.78	0.1 U	4.43	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Estriol	0.1 U	0.48	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Estrone	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
17-α-ethynyl-estradiol	8.52	0.1 U	4.06	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Melengesterol Acetate	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.13	0.1 U
Progesterone	39	0.1 U	48	0.23	0.14	0.17	0.1 U	0.1 U
Testosterone	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U

See Table C14 notes on page 10 of 10.

Table C14: Phase 3 Analytical Results for Hormones in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Location ID	SO-15	SO-16
Sample ID	10154245	10154246
Sample Type	Soil – Hops Field	Soil – Hops Field
Sample Matrix	Solid	Solid
Compound / **Units**	ug/Kg	ug/Kg
11-Keto Testosterone	0.1 U	0.1 U
17-α-Hydroxyprogesterone	0.1 U	0.1 U
17-α-trenbolone	0.1 U	0.1 U
17-β-estradiol	0.1 U	0.1 U
17-β-trenbolone	0.1 U	0.1 U
4-Androstenedione	0.16	0.13
17-α-estradiol	0.1 U	0.1 U
Androstadienedione	0.15	0.1 U
Androsterone	0.1 U	0.1 U
α-Zearalanol	0.1 U	0.1 U
α-Zearalenol	0.1 U	0.1 U
β-Zearalanol	0.1 U	0.1 U
β-Zearalenol	0.1 U	0.1 U
Epitestosterone	0.1 U	0.1 U
Estriol	0.1 U	0.1 U
Estrone	0.1 U	0.1 U
17-α-ethynyl-estradiol	0.1 U	0.1 U
Melengesterol Acetate	0.1 U	0.1 U
Progesterone	0.13	0.1
Testosterone	0.1 U	0.1 U

See Table C14 notes on page 10 of 10.

Table C14: Phase 3 Analytical Results for Hormones in Wells, Lagoons, Manure Piles, Application Fields, Wastewater Treatment Plant Influents, and Crop Soils

Samples were analyzed by the U. of Nebraska Water Sciences Laboratory

Abbreviations

LG - dairy waste lagoon

NA - not analyzed

SO - solid

SOP - Standard Operating Procedure

SP - wastewater treatment plant influent

WW - water well

WWTP - wastewater treatment plant

Units

ug/L = micrograms per liter

ug/Kg = micrograms per kilogram

Analytical Methods

Liquids: UNL SOP LCMS-APPI-STEROIDS- WATER-001 *"Analysis of steroids in water samples using a Spark Holland symbiosis on-line C18 cartridge solid phase extraction (SPE) and high pressure liquid chromatography/tandem mass spectrometry (HPLC/MS/MS)"* .

Solids: UNL SOP Analyte-Steroids-Solids-001 *"Analysis of Steroids in solid samples (i.e. soils, manure, etc) by microwave-assisted solvent extraction (MASE) and liquid chromatography-tandem mass spectrometry (LC/MS/MS)"* .

Data Qualifiers

J = The analyte was positively identified. The associated numerical value is an estimate.

R = The data are unusable for all purposes.

U = The analyte was not detected at or above the reported value.

UJ = The analyte was not detected at or above the reported estimated result. The associated numerical value is an estimate of the quantitation limit of the analyte in this sample.

Table C15: Phase 3 Analytical Results for Isotopic Analyses in Wells, Lagoons, and Wastewater Treatment Plant Influents

	Location ID	WW-01	WW-02	WW-03	WW-04	WW-05	WW-06	WW-07
	Sample ID	10154201	10154202	10154203	10154204	10154205	10154206	10154207
	Sample Type	Upgradient Well	Dairy Supply Well	Downgradient Well	Downgradient Well	Downgradient Well	Upgradient Well	Dairy Supply Well
	Sample Matrix	Water	Water	Water	Water	Water	Water	Water
Compound	**Units**							
Nitrate	mg/L	0.2	3	34	49.9	12.8	0.6	1.1
δ15N-NO3	‰	NM	2.73	2.3	3.53	9.66	NM	-0.09
Ammonia	mg/L	<0.1	<0.1	0.3	0.8	0.3	0.1	<0.1
δ15N-NH4	‰	NM	NM	NM	NM	NM	NM	NM
δ18O-NO3	‰ SMOW	NM	15.1	29	-4.5	7.1	NM	NM

See Table C15 notes on page 9 of 9.

Table C15: Phase 3 Analytical Results for Isotopic Analyses in Wells, Lagoons, and Wastewater Treatment Plant Influents

	Location ID	WW-08	WW-09	WW-10	WW-11	WW-12	WW-13	WW-14
	Sample ID	10154208	10164209	10164210	10154211	10154212	10154213	10154214
	Sample Type	Dairy Supply Well	Dairy Supply Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well	Downgradient Well
	Sample Matrix	Water	Water	Water	Water	Water	Water	Water
Compound	**Units**							
Nitrate	mg/L	11.7	NM	NM	21.6	43.6	42	40.7
δ15N-NO3	‰	5.3	NM	NM	3.03	6.21	11.17	10.39
Ammonia	mg/L	0.2	0.1	<0.1	<0.1	<0.1	0.1	0.1
δ15N-NH4	‰	NM	NM	NM	NM	NM	NM	NM
δ18O-NO3	‰ SMOW	22.6	NM	NM	18.22	-1.4	15.9	8.5

See Table C15 notes on page 9 of 9.

Table C15: Phase 3 Analytical Results for Isotopic Analyses in Wells, Lagoons, and Wastewater Treatment Plant Influents

	Location ID	WW-15	WW-16	WW-17	WW-18	WW-19	WW-20
	Sample ID	10154215	10154216	10154217	10154218	10154219	10154220
	Sample Type	Downgradient Well	Downgradient Well	Downgradient Well	Residential Well	Downgradient - Septic	Downgradient - Septic
	Sample Matrix	Water	Water	Water	Water	Water	Water
Compound	**Units**						
Nitrate	mg/L	27.4	23	23.3	72.3	36.4	15
δ15N-NO3	‰	5.23	5.87	6.85	6.88	8.74	6.28
Ammonia	mg/L	1.1	<0.1	0.1	0.2	0.5	0.1
δ15N-NH4	‰	NM	NM	NM	NM	NM	NM
δ18O-NO3	‰ SMOW	30.27	5.83	2.45	8.8	15.43	52.86

See Table C15 notes on page 9 of 9.

Table C15: Phase 3 Analytical Results for Isotopic Analyses in Wells, Lagoons, and Wastewater Treatment Plant Influents

	Location ID	WW-21	WW-22	WW-23	WW-24	WW-25	WW-26
	Sample ID	10154221	10164222	10154223	10154224	10154225	10154226
	Sample Type	Downgradient - Septic	Downgradient - Septic	Downgradient - Mint	Downgradient - Mint	Downgradient - Corn	Downgradient - Hops
	Sample Matrix	Water	Water	Water	Water	Water	Water
Compound	**Units**						
Nitrate	mg/L	36.5	16.6	17.3	14	32.9	15.1
δ15N-NO3	‰	7.65	10.22	2.17	-0.3	2.43	7.54
Ammonia	mg/L	<0.1	0.1	0.5	<0.1	1.1	<0.1
δ15N-NH4	‰	NM	NM	NM	NM	NM	NM
δ18O-NO3	‰ SMOW	12.2	11	18.04	12.11	15.04	6.3

See Table C15 notes on page 9 of 9.

Table C15: Phase 3 Analytical Results for Isotopic Analyses in Wells, Lagoons, and Wastewater Treatment Plant Influents

	Location ID	WW-27	WW-28	WW-29	WW-30	LG-01	LG-02	LG-03
	Sample ID	10154227	10154228	10154229	10164230	10154251	10154252	10154253
	Sample Type	Downgradient - Hops	Downgradient - Corn	Field Blank	Residential Well	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon
	Sample Matrix	Water	Water	Water	Water	Liquid	Liquid	Liquid
Compound	**Units**							
Nitrate	mg/L	19.9	69.6	NM	NA	<0.1	<0.1	<0.1
δ15N-NO3	‰	8.83	5.36	NM	NA	NM	NM	NM
Ammonia	mg/L	0.2	0.4	NM	NA	907	923	896
δ15N-NH4	‰	NM	NM	NM	NA	3.37	10.07	9.88
δ18O-NO3	‰ SMOW	16.82	44.41	NM	NA	NM	NM	NM

See Table C15 notes on page 9 of 9.

Table C15: Phase 3 Analytical Results for Isotopic Analyses in Wells, Lagoons, and Wastewater Treatment Plant Influents

	Location ID	LG-04	LG-05	LG-06	LG-07	LG-08	LG-09	LG-10
	Sample ID	10154254	10154255	10154256	10154257	10154258	10154259	10164260
	Sample Type	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon
	Sample Matrix	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Compound	**Units**							
Nitrate	mg/L	NM	NM	NM	NM	NM	NM	NM
δ15N-NO3	‰	NM	NM	NM	NM	NM	NM	NM
Ammonia	mg/L	899	1151	1293	869	696	658	NM
δ15N-NH4	‰	6.69	10.63	10.25	5.36	10.27	10.13	NM
δ18O-NO3	‰ SMOW	NM	NM	NM	NM	NM	NM	NM

See Table C15 notes on page 9 of 9.

Table C15: Phase 3 Analytical Results for Isotopic Analyses in Wells, Lagoons, and Wastewater Treatment Plant Influents

	Location ID	LG-11	LG-12	LG-13	LG-14	LG-15	SP-01	SP-02
	Sample ID	10164261	10164262	10164263	10164264	10164265	10154271	10154272
	Sample Type	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	Dairy Lagoon	WWTP	WTTP
	Sample Matrix	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Compound	**Units**							
Nitrate	mg/L	NM	NM	NM	NM	NM	<0.1	<0.1
δ15N-NO3	‰	NM	NM	NM	NM	NM	NM	NM
Ammonia	mg/L	274	222	469	600	658	30.1	31.5
δ15N-NH4	‰	3.13	2.01	4.4	3.26	13.85	3.72	7.43
δ18O-NO3	‰ SMOW	NM	NM	NM	NM	NM	NM	NM

See Table C15 notes on page 9 of 9.

Table C15: Phase 3 Analytical Results for Isotopic Analyses in Wells, Lagoons, and Wastewater Treatment Plant Influents

	Location ID	SP-03	SP-04
	Sample ID	10154273	10154274
	Sample Type	WWTP	WWTP
	Sample Matrix	Liquid	Liquid
Compound	**Units**		
Nitrate	mg/L	<0.1	NA
δ15N-NO3	‰	NM	NA
Ammonia	mg/L	49.3	NA
δ15N-NH4	‰	2.7	NA
δ18O-NO3	‰ SMOW	NM	NA

See Table C15 notes on page 9 of 9.

Table C15: Phase 3 Analytical Results for Isotopic Analyses in Wells, Lagoons, and Wastewater Treatment Plant Influents

Samples were analyzed by the University of Nebraska Water Sciences Laboratory.

Abbreviations

NM = Insufficient Nitrate to complete analysis

NA = Not analyzed

‰ = parts per thousand difference from the atmospheric standard

SMOW = standard mean of ocean water

WWTP - wastewater treatment plant influent

δ15N-NO3 = Nitrogen isotopes of nitrate. Ratio of the nitrogen isotopes 15N and 14N in a specific sample using nitrate compared to a standard of known composition of 15N and 14N. This expressed as the parts per thousand (‰).

δ15N-HN4 = Nitrogen isotopes of ammonia. Ratio of the nitrogen isotopes 15N and 14N in a specific sample using ammonia compared to a standard of known composition of 15N and 14N. This expressed as the parts per thousand (‰).

δ180-NO3 = Oxygen isotopes of nitrate. Ratio of the oxygen isotopes 180 and 160 in a specific sample using nitrate compared to a standard of known composition of 180 and 160. This expressed as the parts per thousand (‰) standard mean of ocean water.

Units

mg/L - milligrams per liter

$$\delta^{15}N\ (‰.) = \frac{(^{15}N/^{14}N)_{sample} - (^{15}N/^{14}N)_{standard}}{(^{15}N/^{14}N)_{standard}} * 1000$$

Analytical Methods

UNL SOP: N15 Analysis Dual Inlet IRMS

UNL SOP: Inst-Isoprime EA-18O-001

Table C16: Phase 3 Analytical Results for Sulfur Hexafluoride Age Dating in Wells

Sample Location	Sample Type	Sample Media	Sample ID	SF_6 Age Range (Years)	Qualifier
WW-01	Upgradient Well – Dairy	Water	10154201	Over Value	
WW-02	Supply Well – Dairy	Water	10154202	15.8	
				16.3	
WW-03	Downgradient Well – Dairy	Water	10154203	24.8	J
				25.8	J
WW-04	Downgradient Well – Dairy	Water	10154204	21.8	J
				23.3	J
WW-05	Downgradient Well – Dairy	Water	10154205	18.3	J
				20.8	J
WW-06	Upgradient – Dairy	Water	10154206	16.3	J
				15.8	J
WW-07	Supply Well – Dairy	Water	10154207	36.3	J
				32.8	J
WW-08	Supply Well – Dairy	Water	10154208	35.3	J
				40.8	J
WW-09	Supply Well – Dairy	Water	10154209	58.3	J
				51.3	J
WW-10	Downgradient Well – Dairy	Water	10154210	44.3	J
				44.8	J
WW-11	Downgradient Well – Dairy	Water	10154211	Over Value	
WW-12	Downgradient Well – Dairy	Water	10154212	Over Value	
WW-13	Downgradient Well – Dairy	Water	10154213	24.3	J
				23.8	J
WW-14	Downgradient Well – Dairy	Water	10154214	30.8	
				29.3	
WW-15	Downgradient Well – Dairy	Water	10154215	27.8	J
				28.3	J
WW-16	Downgradient Well – Dairy	Water	10154216	29.8	J
				28.8	J
WW-17	Downgradient Well – Dairy	Water	10154217	33.3	J
				33.8	J
WW-18	Residential Well	Water	10154218	27.8	J
				28.3	J
WW-19	Downgradient Well – Septic	Water	10154219	44.3	J
				34.3	J
WW-20	Downgradient Well – Septic	Water	10154220	14.3	J
				14.3	J
WW-21	Downgradient Well – Septic	Water	10154221	31.3	
				28.8	

Table C16: Phase 3 Analytical Results for
Sulfur Hexafluoride Age Dating in Wells

Sample Location	Sample Type	Sample Media	Sample ID	SF_6 Age Range (Years)	Qualifier
WW-22	Downgradient Well – Septic	Water	10154222	29.3	J
				29.3	J
WW-23	Downgradient Well – Mint	Water	10154223	Over Value	
WW-24	Downgradient Well – Mint	Water	10154224	14.8	J
				15.8	J
WW-25	Downgradient Well – Corn	Water	10154225	10.3	
				9.8	
WW-26	Downgradient Well – Hops	Water	10154226	12.8	J
				11.8	J
WW-27	Downgradient Well – Hops	Water	10154227	Over Value	
				14.3	J
WW-28	Downgradient Well - Corn	Water	10154228	Over Value	
WW-29	Field Blank	Water	10154229	NA	
WW-30	Residential Well	Water	10164230	NA	

Samples were analyzed by the United States Geological Survey Chlorofluorocarbon Laboratory.

Analaytical Method

(http://water.usgs.gov/lab/) as well as the research publication *Dating Young Ground Water with Sulfur Hexafluoride: Natural and Anthropogenic Sources of Sulfur Hexafluoride* (E. Busenberg & L. Plummer, 2000).

Data Qualifiers

J = The analyte was positively identified. The associated numerical value is an estimate.

Notes

Over Value: These samples contained more SF6 than can be explained by equilibrium with modern air. Aquifer materials in volcanic areas such as the basalts under the Yakima Valley are known to host naturally-occurring SF6. No anthropogenic source of SF6 is known in the area of the Dairy Cluster.

SF_6 - Sulfur hexaflouride.

The SF6 recharge dating limit is around 1970. Any sample that has a model recharge date before about 1970 is older than the dating range of SF_6. The SF6 method is useful in dating very young waters.

APPENDIX D

DETAILS ON THE ISOTOPIC ANALYTICAL RESULTS

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Appendix D: Details on the Isotopic Analytical Results for the Study

The U.S. Environmental Protection Agency ("EPA") submitted all the water well, dairy lagoon, and wastewater treatment plant (WWTP) influent samples to the University of Nebraska – Lincoln Water Sciences Laboratory ("UNL Laboratory") for isotopic analysis. The results of the isotopic analyses are presented in Table C15 in Appendix C. Summary results for the dairy lagoons are presented below in Table D1. In addition, summary results for water wells are presented in Table D2 below and in Tables 14, 23, 30, and 35 within the main report. Summary results for the WWTP influent are included below as Table D3.

The dual isotopic composition of nitrate ($\delta^{15}N\text{-}NO_3$ and $\delta^{18}O\text{-}NO_3$) measured in any given water sample is determined by a combination of mixing between different nitrate sources, and in-situ biogeochemical processes. In groundwater, the main biogeochemical process which will significantly alter the isotopic composition of nitrate is denitrification, which requires anoxic conditions. Denitrification will result in a coupled linear increase of both $\delta^{15}N\text{-}NO_3$ and $\delta^{18}O\text{-}NO_3$ values as the nitrate concentrations exponentially decrease. This combined isotope and concentration pattern was not observed in the water wells, which indicates that the nitrate isotope compositions measured in the water wells are primarily controlled by mixing of one or more nitrate sources. These potential sources are referred to as "end-members" when doing either quantitative or qualitative mixing estimates.

Different end-members tend to have distinct nitrate isotope ranges, either in $\delta^{15}N\text{-}NO_3$ or $\delta^{18}O\text{-}NO_3$. For example, nitrate derived from fertilizer tends to have much lower $\delta^{15}N\text{-}NO_3$ values than nitrate derived from animal waste, but the $\delta^{18}O\text{-}NO_3$ values of these two end-members overlap. Nitrate derived from atmospheric sources has much higher $\delta^{18}O\text{-}NO_3$ values than all other major nitrate sources due to complex reactions in the atmosphere, but overlapping $\delta^{15}N\text{-}NO_3$ values. By measuring both the $\delta^{15}N\text{-}NO_3$ and $\delta^{18}O\text{-}NO_3$ for all water samples, more information about the possible end-member contributions to any given well can be obtained. If the $\delta^{15}N\text{-}NO_3$ and $\delta^{18}O\text{-}NO_3$ values of a given water sample fall within the ranges where the isotope values of the potential end-members overlap, then nitrate isotope composition cannot be used to identify the dominant end-member(s).

The isotopic ranges for major nitrate sources are well-established in the literature, however, local end-members specific to a particular study region often have a smaller isotopic range in comparison to world-wide reported values, and therefore measuring the isotopic compositions of local end-members can sometimes help better constrain and interpret nitrate isotope values within a specific data set. In this study, the EPA was able to measure samples representing local animal and human waste end-members.

EPA followed a two-step process to associate a specific source of nitrogen to each water well, dairy lagoon, and WWTP influent sample. First, the concentration of nitrate in each well was compared with nitrate values reported in the literature for unimpacted groundwater. Nitrate concentrations in unimpacted groundwater can be up to 1.1 milligrams per liter (mg/L) (Nolan and Hitt 2003). The second step was to evaluate which of the potential sources or combination of sources (animal waste, synthetic fertilizer, or atmospheric) were likely sources of the nitrate in the water wells. To evaluate whether animal waste was a potential source of the nitrates in the water wells, EPA used the dairy lagoon data presented in Table D1.

Based on the isotopic values observed in this study for nitrogen and oxygen in nitrate and for nitrogen in ammonia, the sources identified include: (1) nitrate formed locally in soil derived from the breakdown of plant material; (2) animal waste; (3) synthetic fertilizers; and (4) accumulation from atmospheric deposition from precipitation and dry deposition. It is important to note that the animal waste category does not differentiate between human and non-human wastes.

Concentrations of nitrate in the two upgradient wells (WW-01 and WW-06), two dairy supply wells (WW-07 and WW-09) and one downgradient well (WW-10) were below 1.1 mg/L (Table C5 in Appendix C). The concentration of nitrate in the majority of downgradient wells was higher. This indicates that animal waste, synthetic fertilizer, atmospheric contributions, or a combination of these sources, are the likely source of the nitrate in the water wells.

Three dairy lagoon samples were collected from each dairy in order to better characterize the local animal waste (includes both human and non-human) end-member. One sample was collected at the influent to each dairy lagoon system (LG-01, LG-04, LG-07, LG-10 and LG-13), and the other lagoon samples were collected at the "discharge" end of the system just before the manure wastes were pumped onto the dairy application fields. Lagoon samples LG-02 and LG-03 were collected from the same lagoon, as were lagoon samples, LG-08 and LG-09, and LG-11 and LG-12. Lagoon samples LG-05 and LG-06 and LG-14 and LG-15 were collected from different lagoons.

The concentration of ammonium was measured in each dairy lagoon sample. The $\delta^{15}N\text{-}NH_4$ values were then quantified for each sample. The $\delta^{15}N\text{-}NH_4$ value is the nitrogen isotopic composition reported for ammonium. It is the ratio of the nitrogen isotopes ^{15}N and ^{14}N in a specific sample compared to a standard of known composition of ^{15}N and ^{14}N. This is expressed as the parts per thousand or parts per mil (‰).

It is expected that the $\delta^{15}N\text{-}NH_4$ values would increase as the waste goes from the lagoon influent to the discharge point. In this process, the lighter ^{14}N isotope volatilizes resulting in a higher proportion of the heavier ^{15}N isotope in the remaining pool of NH_4. These data are summarized in Table D1. The samples collected from the lagoon influent generally have a lower $\delta^{15}N\text{-}NH_4$ ratio than the discharge samples, with the exception of samples LG-10, LG-11and LG-12.

The co-located samples (LG-02 and LG-03; LG-08 and LG-09; and LG-11 and LG-12) all show similar $\delta^{15}N\text{-}NH_4$ values. The average $\delta^{15}N\text{-}NH_4$ value for the five lagoon influent samples (LG-01, LG-04, LG-07, LG-10, and LG-13) is 5.0‰. The average $\delta^{15}N\text{-}NH_4$ value for the 10 dairy lagoons that are located immediately prior to land application (LG-02, LG-03, LG-05, LG-06, LG-08, LG-09, LG-11, LG-12, LG-14, and LG-15) is 8.4‰.

The $\delta^{15}N\text{-}NH_4$ ratios from the dairy lagoon samples provide a better understanding of the local animal waste end-member that could potentially contribute to groundwater nitrate. When NH_4 is converted to NO_3 in oxic groundwater (called "nitrification"), typically there is almost complete conversion of NH_4 to NO_3, and therefore the $\delta^{15}N\text{-}NO_3$ of the newly formed nitrate pool is very similar or equal to the ^{15}N of the NH_4. Therefore, the $\delta^{15}N\text{-}NH_4$ measurements in the lagoons represent minimum ^{15}N end-member values for animal waste derived nitrate, because it is quite likely that there is some additional increase in the $\delta^{15}N\text{-}NH_4$ from the waste ponds (due to continuing NH_3 loss) before it enters the groundwater.

Table D1: Phase 3 – Concentrations of Ammonium, and Isotopic Signatures in Dairy Lagoons

Location	Position in System	Ammonium (mg/L)	$\delta^{15}N\text{-}NH_4$ (‰)
LG-01: Haak	Influent	907	3.4
LG-02:Haak	Discharge	923	10.1
LG-03: Haak	Discharge	896	9.9
LG-04: DeRuyter	Influent	899	6.7
LG-05:DeRuyter	Discharge	1151	10.6
LG-06: DeRuyter	Discharge	1293	10.3
LG-07:D and A	Influent	869	5.4
LG-08: D and A	Discharge	696	10.3
LG-09: D and A	Discharge	658	10.1
LG-10: Cow Palace	Influent	NM	NM
LG-11:Cow Palace	Discharge	274	3.1
LG-12: Cow Palace	Discharge	222	2.0
LG-13:Liberty/Bosma	Influent	469	4.4
LG-14:Liberty/Bosma	Discharge	600	3.3
LG-15:Liberty/Bosma	Discharge	658	13.9

$\delta^{15}N\text{-}NO_3$ ratios measured in water wells that have elevated $\delta^{15}N\text{-}NO_3$ values similar to the $\delta^{15}N\text{-}NH_4$ measured in the waste lagoons would indicate that animal waste is a dominant source of the nitrate in water wells. $\delta^{15}N\text{-}NO_3$ is the nitrogen isotopic composition reported for nitrogen. It is the ratio of the nitrogen isotopes ^{15}N and ^{14}N in a specific sample compared to a standard of known composition of ^{15}N and ^{14}N. This is expressed as the parts per thousand or parts per mil (‰).

Literature values for animal waste indicate a range of $\delta^{15}N\text{-}NO_3$ ratios between 10‰ and 20‰ (Kreitler 1975; Komor and Anderson 1993; and Kendall and Aravena 1999), but with some values lower or higher than this range (Becker and others 2001 and Kendall 1998). For this study, a $\delta^{15}N\text{-}NO_3$ ratio above 8.4‰ was used to indicate that the likely dominant source of the nitrate in the water wells was animal waste (see Table D2 for a summary of the findings for water wells). As discussed above, the average $\delta^{15}N\text{-}NH_4$ ratio at the discharge end of the lagoons was 8.4‰ and this ratio forms the lower end of the expected range for the weights of nitrogen that, after microbial conversion to nitrate, would be transported in groundwater to drinking water wells. The process of isotopic fractionation could be expected to continue after the lagoon liquids escape or are applied as fertilizer. The tendency for the $\delta^{15}N\text{-}NH_4$ value to continue to increase is why 8.4‰ is considered a lower bound for identifying animal waste as a source of nitrate in the water wells. Values of $\delta^{15}N\text{-}NO_3$ below 8.4‰ do not rule out animal waste as a source.

Synthetic fertilizers are another potential source of nitrate in water wells. This study did not directly evaluate the isotopic values for fertilizer used in the study area, but $\delta^{15}N\text{-}NO_3$ ratios for synthetic fertilizers are often within a range of -4.0 to +4.0‰ (Komor and Anderson 1993; Kendall, C.1998; and Kendall and Aravena 1999). In addition, the lowest δ^{15}N-NH_4 value from the dairy lagoons was 2.0‰. This result suggests synthetic fertilizers are the likely dominant source of nitrate in water wells when the δ^{15}N-NO_3 values are below 2.0‰. As with the animal waste, this value does not mean synthetic fertilizer cannot be a likely source of the nitrate in water wells if δ^{15}N-NO_3 values are above 2.0‰.

For δ^{15}N-NO_3 values between 2.0‰ and 8.4‰, the source of nitrate in the water wells cannot be confidently attributed to a single source. The source could be animal waste or synthetic fertilizer, or a mixture of the two. In addition, for water wells that suggest an atmospheric contribution, other sources could be solely animal waste, solely synthetic fertilizer, or a mixture of all three with an atmospheric contribution.

Another possible source of nitrate in water wells is atmospheric deposition, although nitrogen contribution from this source is estimated to be less than 2% of the total amount of nitrogen in the Valley (EPA 2012). Because of the very low rainfall in the Lower Yakima Valley, atmospherically deposited nitrate may accumulate in shallow soils in the caliche layer. A caliche layer is a characteristic of desert regions that forms when carbonate minerals accumulate in the shallow subsurface because insufficient rainfall occurs to wash them into the deeper groundwater. Other minerals may accumulate along with the carbonates in areas of very low rainfall. These minerals include gypsum and, if the area is sufficiently dry, nitrates and perchlorate.

As mentioned above, nitrate derived from atmospheric sources has significantly higher δ^{18}O-NO_3 values in comparison to other major nitrate sources. δ^{18}O-NO_3 values for pure atmospheric deposition (the atmospheric end-member) typically range from 60‰ to 95‰ (Kendall and others 2007). If the nitrate in any given water sample has a significant component of atmospheric nitrate, then the δ^{18}O-NO_3 value will be higher than the δ^{18}O-NO_3 values reported for other sources such as fertilizers and animal waste. Since the major nitrate sources have ranges of δ^{18}O-NO_3 values, the exact contribution of each end-member cannot be determined, but a qualitative evaluation can be made.

The δ^{18}O-NO_3 results were used to evaluate the degree to which an atmospheric signature or contribution was dominant in the sample. Ratios above 20.0‰ for δ^{18}O-NO_3 were considered to have some contribution from atmospherically derived nitrate. This ratio was selected because the literature based on multiple studies of various nitrate sources suggests that δ^{18}O-NO_3 ratios from synthetic fertilizer, soil cycling, and animal wastes are typically below 15.0‰ (Kendall and others 2007) and the desire to use a value higher than 15.0‰ for δ^{18}O-NO_3 to ensure that the atmospheric contribution is dominate in the sample. Values of δ^{18}O-NO_3 below 20.0‰ could have an atmospheric contribution, but it becomes indistinguishable from other sources.

Table D2: Phase 3 – Nitrate Concentrations, Isotopic Signatures, and Interpreted Dominant Source(s) of Nitrate in Wells

Location	Nitrate-N (mg/L)[a]	$\delta^{15}N-NO_3$ (‰)	$^{18}O-NO_3$ (‰)	Interpreted Dominant Source
WW-01	0.2	NM	NM	NM
WW-02	3.0	2.7	15	Indeterminate
WW-03	34	2.3	29	Fertilizer and/or animal waste with some atmospheric contribution
WW-04	49.9	3.5	-4.5	Fertilizer and/or animal waste
WW-05	12.8	9.7	7.1	Animal waste
WW-06	0.6	NM	NM	NM
WW-07	1.1	-0.1	NM	Fertilizer
WW-08	11.7	5.3	23	Fertilizer and/or animal waste with some atmospheric contribution
WW-09	NM	NM	NM	NM
WW-10	NM	NM	NM	NM
WW-11	21.6	3.0	18	Fertilizer and/or animal waste
WW-12	43.6	6.2	-1.4	Fertilizer and/or animal waste
WW-13	42	11	16	Animal waste
WW-14	40.7	10	8.5	Animal waste
WW-15	27.4	5.2	30	Fertilizer and/or animal waste with some atmospheric contribution
WW-16	23	5.9	5.8	Fertilizer and/or animal waste
WW-17	23.3	6.9	2.5	Fertilizer and/or animal waste
WW-18	69.6	5.4	44.4	Fertilizer and/or animal waste with Some Atmospheric Contribution
WW-19	36.4	8.7	15.4	Animal waste
WW-20	15	6.3	52.9	Fertilizer and/or animal waste with some atmospheric contribution
WW-21	36.5	7.7	12.2	Fertilizer and/or animal waste
WW-22	16.6	10	11.0	Animal waste
WW-23	17.3	2.2	18	Fertilizer and/or animal waste
WW-24	14	-0.3	12	Fertilizer
WW-25	32.9	2.4	15	Fertilizer and/or animal waste
WW-26	15.1	7.5	6.3	Fertilizer and/or animal waste
WW-27	19.9	8.8	17	Animal waste
WW-28	69.6	5.5	44	Fertilizer and/or animal waste with some atmospheric contribution

[a]The nitrate concentrations are from the UNL isotopic analysis.

Isotopic results were obtained from the ammonium sampled from the inlet to three sewer treatment plants in the Lower Yakima Valley. The plants were located in Zillah, Mabton and Toppenish, and correspond to SP-01 through SP-03. The results for the analysis of $\delta^{15}N-NH_4$ from the ammonium in the influent are presented below.

Table D3: Phase 3 – Isotopic Signatures, and Nitrogen Enrichment in Wastewater Treatment Plants

Location	$\delta^{15}N-NH_4$ (‰)	Nitrogen Enrichment
SP-01: Zillah	3.72	Slightly Enriched
SP-02: Mabton	7.43	Ammonia Volatilization has occurred
SP-03: Toppenish	2.70	Slightly Enriched

References Appendix D

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APPENDIX E

QUALITY ASSURANCE AND QUALITY CONTROL

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Appendix E: Quality Assurance and Quality Control

This project was implemented in three phases. In Phase 1, a geographic information system (GIS) screening application was developed and used to identify potential sample locations and sites in the Lower Yakima Valley for Phase 2 sampling and screening. Phase 1 also developed estimates of the relative nitrogen available for application to the land from different sources. Phase 2 and Phase 3 involved extensive sampling and analysis. A discussion of the quality assurance and quality control (QA/QC) procedures followed in Phase 2 and Phase 3 is presented below.

Phase 2 was implemented following the specifications of the U.S. Environmental Protection Agency (EPA)-approved "*QA Project Plan for Yakima Nitrate Study, Phase 2 – Initial Nitrate/Coliform Screening of Domestic Wells, February 2010"* (EPA 2010a). Deviations from the quality assurance project plan (QAPP) included changes in sample locations and modifications to the analytical method used, sampling method techniques, and additional number of samples collected. The rationale for these deviations was documented in the project team-approved Sample Alteration Form or Corrective Action Form.

In Phase 2 a multi-parameter water quality instrument was used in the field for measuring dissolved oxygen, oxidation/reduction (redox) potential, pH, specific conductance, and temperature. All field instruments were calibrated before use. For quality control, duplicate sample readings and calibration checks were performed. All field testing QC samples met the frequency of analysis, precision, and accuracy checks. The data generated are acceptable and can be used for screening purposes.

In Phase 2, EPA's Manchester Environmental Laboratory ("EPA Manchester Laboratory") received 189 samples for analysis. Of these 189 samples, 102 were analyzed for nitrate and chloride, two were analyzed for nitrate and nitrite, and 123 were analyzed for total Kjeldahl nitrogen (TKN). Two percent of the total nitrate data points were qualified as follows: one sample (10086211) did not meet the holding time requirement and the result was qualified estimated; the nitrate concentration reported for this sample may be biased low. One sample (10086101) exceeded the highest level of the calibration curve and was qualified estimated. Data users are advised to consider the nitrate reported for this sample as biased low. All nitrate data, as reported and qualified, are acceptable for use for all purposes. All of the chloride and TKN analyses met the method required QC criteria. The data as reported are usable for all purposes.

A separate QAPP was developed for Phase 3 sampling (EPA 2010b). Phase 3 samples were collected and shipped to the following laboratories for chemical analysis: EPA's Manchester Laboratory, Cascade Analytical Laboratory, University of Nebraska – Lincoln, Water Sciences Laboratory ("UNL Laboratory"), U.S. Geological Survey National Water Quality Laboratory ("USGS NWQ Laboratory"), USGS Laboratory in Reston ("USGS Reston Laboratory") and EPA's Robert S. Kerr Environmental Research Center in Ada, Oklahoma ("EPA's Ada Laboratory"). The field sampling team and analytical laboratories followed the protocols described in the QAPP with the exception of the deviations identified in Table E1. The quality assurance review summaries for each lab are included below.

Table E1: Deviations from the Phase 3 Quality Assurance Project Plan (QAPP)

Location in QAPP	QAPP Description	Deviation or Action or Modification
Page 11, Table 2, First Column. Surface Soil	"Surficial soil from waste application fields (large area multi-increment sample of at least 30 subsamples…)"	The surface soil sampling method in the QAPP was misidentified as multi-increment sampling. It should have been identified as composite sampling. EPA collected composite surface soil samples comprised of at least 30 subsamples from a depth of 1 inch below the surface.
Page 13, Table 5	Schedule of Tasks	The actual schedule for laboratory analysis, data validation, and report preparation deviated from the schedule in the QAPP.
Page 15, Section 3.1, second full paragraph	"The laboratories performing the sample analysis of drinking water analytes …are SDWA certified and/or accredited."	EPA's Manchester Laboratory and Cascade Analytical Laboratory are Safe Drinking Water Act (SDWA) certified for nitrate analysis in drinking water. EPA's Manchester Laboratory used other standard methods for the analysis of metals and pesticides. The UNL Laboratory, USGS Laboratories and Ada Laboratory are not SDWA certified. A complete list of analytical methods used in Phase 3 is included in Appendix C, Table C-2.
Page 21, Section 4.0, third paragraph	"Water Wells ….Locations are identified as WW01 to WW29"	Water well locations were identified as WW-01 through WW-30 because one additional sample, a field blank (WW-29), was collected.
Page 21, Section 4.0, third paragraph	"Locations are identified as LG01 to LG15 and SP01 to SP03"	An additional wastewater treatment plan influent sample was collected at the Toppenish wastewater treatment plant (SP04) because the laboratory requested additional sample volume.
Page 28, Section 4.2, Shipping Location and Requirements	Samples to be shipped to the UNL Laboratory were to be frozen at -20C.	The on-site freezer trailer could not continuously maintain a temperature of -20C. Samples were transferred to a freezer at WSU. Samples were reported to have arrived frozen at the UNL Laboratory.
Page 33, Section 4.13, second bullet	"Coolers or boxes containing cleaned bottles will be sealed with a custody tape seal during transport to the field or while in storage before use."	After custody seals had been removed from coolers or boxes containing cleaned sample bottles, custody seals were not reapplied if coolers or boxes remained in the custody of EPA at all times.
Page 35, Section 5.0, first paragraph	"The required precision and accuracy for this project is 20% relative percent difference (RPD) …"	For herbicide, pesticide and age dating analyses, the laboratory established duplicate analysis control limits were used instead of the customary 20% RPD.

Location in QAPP	QAPP Description	Deviation or Action or Modification
Page 35, Section 5.0, first full paragraph	"Transfer blanks will be incorporated into the sample schedule at a rate of approximately 5% or once per sample location type."	Transfer blanks were collected for bacterial analysis only.
Page 39, Section 7.2, fourth sentence	"Data validation will be performed by the laboratory for all the analyses prior to the release of data in accordance with each laboratory's quality assurance plan."	The QAPP should have stated "Data **verification** will be performed by the laboratory for all the analyses prior to the release of data in accordance with each laboratory's quality assurance plan." EPA chemists conducted an independent validation of all Phase 3 data.
Page 40, Table 7	Bias of 80-120% was specified for Alkalinity, ammonia, mercury, metals, nitrate+nitrite, TKN and total phosphorus	The laboratory established control limits of 75%-125% were used.
Page 40, Table 7 General Chemistry and Inorganics	Plus 1 duplicate sample for QA out of each 10 drinking water wells. Plus 1 triple sample for QA out of each 20 lagoon samples.	Due to an oversight, no field duplicate or triplicate samples were collected from the water wells or the lagoons.
Page 40, Table 7	Chloride and bromide analysis of lagoon samples.	After analysis at EPA's Manchester Environmental Laboratory, excess volumes of thirteen of the fifteen lagoon samples were shipped to EPA's Laboratory in Ada, OK for analysis of bromide to see if lower detection limits could be achieved. Chloride also was reanalyzed by the Ada Laboratory to determine the Cl:Br ratio for the lagoon samples. The bromide results from the Ada Laboratory also were non-detects, therefore no Cl:Br ratios were determined.
Page 41, Table 8	Varian Plexa SPE cartridge was specified in the sample prep methods column.	The Varian Plexa adsorbent cartridge did not meet the laboratory recovery control limits of 70% to 130% specified in the QAPP. Water samples were extracted using Method 551.1.
Page 41, Table 8	Dichlobenil	Reported as IUPAC 2,6-dichlor-benzonitrile
Page 41, Table 8	Phosmet	Reported as Imidan
Page 41, Table 8	Oryzalin	Reported as Surflan
Page 41, Table 8	N/A	Acid Herbicides were added.
Page 48, Table 12	N/A	Laboratory also analyzed for ^{18}O. No blanks were analyzed for ^{18}O.

Location in QAPP	QAPP Description	Deviation or Action or Modification
Page 50, Table 14	N/A	The USGS laboratory's standard list of trace organic compounds included analytes in addition to those listed in the QAPP. These compounds were analyzed and the data are presented in the report.
Page 58, Table 18	N/A	Table 18 in the QAPP is incomplete. Cascade Analytical Laboratory also analyzed for ammonia solid by Standard Method 4500-NH_3, Nitrate-N/Total Solid by Standard Method 4500-NO_3 E, Ammonium-N by Standard Method 4500-NH_4 H, Nitrate-N/Nitrite by Standard Method 4500-NO_3 F and TKN by 4500N-ORG-C.
Page 58, Table 18	Matrix spike (bias) limits 85-115%.	Matrix spike (bias) limits were 80-120%.

1. EPA's Manchester Environmental Laboratory, Port Orchard, Washington

A Stage 4 data validation was performed by the EPA Region 10 Quality Assurance (QA) team for all the data generated by EPA's Manchester Laboratory (Appendix Table E2).

Table E2: Phase 3 – Chemical Analyses Conducted and Analytical Methods Used by the EPA's Manchester Laboratory

Sample Type	Number of Samples	Parameter or Compound	Analytical Method (Prep)	Analytical Method (Analysis)
Water Wells, Dairy Lagoons, and WWTP Influent	49	TKN	EPA Method 351.2	
	49	NH3	EPA Method 350.1	
	49	Nitrate-Nitrites	EPA Method 353.2	
	49	Total Metals	EPA Method 200.2 (water) SW846 Method 3010A (lagoons)	EPA Method 200.7
	49	Mercury	EPA Method 245.1	
	49	Alkalinity	Standard Method 2320B	
	32	Coliforms	Standard Methods 9221F/9221E/9222B	
	13	Microbial Source Tracking	DNA PCR Techniques	
	49	Bromide, Chloride, Fluoride, and Sulfate	EPA Method 300.0	
	49	Total Phosphorous	EPA Method 365.1	
	30	Pesticides (only water wells)	EPA Method 551.1	SW846 – Method 8270D-SIM
	30	Herbicides (only water wells)	EPA Method 551.1	SW846-Method 8270D-SIM
Soils and Manure	16	Pesticides	SW846- Method 3570	SW846 – Method 8270D-SIM
	16	Herbicides	SW846-Method 8151A	SW846-Method 8270D-SIM

All of the chemical and microbial analyses conducted at EPA's Manchester Laboratory met the project data quality goals and criteria for accuracy, precision, comparability, completion, representativeness, and sensitivity, and are useable for all purposes with the following exceptions:

Nitrate and Nitrogen Compounds

Nitrogen compounds included ammonia, TKN, and nitrate-nitrites. Samples 10154251, 10154252, 10154253, 10154254, 10154255, 10154256, 10154257, 10154258, 10154259, 10164260, 10164261, 10164262, 10164263, 10164264 and 10164265 did not meet the required preservation when they were received at the laboratory. Nitrate/nitrites, TKN, and ammonia results for these samples were qualified estimated with a possible low bias. Thirty-one (31 percent) of the data points (147) were qualified estimated.

Mercury and Alkalinity

Thirty-nine percent (39 percent) of the total mercury data points were qualified estimated based on out of control sample spike and blank spike recoveries. Alkalinity results met all the QC criteria. The mercury and alkalinity data, as reported and qualified, are acceptable for use for all purposes.

Metals

Two dairy lagoon samples, 10164261 and 10164262 (4 percent of the total metals data points), were qualified estimated based on blank contamination. The metals data, as reported and qualified, are acceptable for use for all purposes.

Pesticides and Herbicides

The project data quality goals for precision and accuracy for numerous target analytes were not met for dairy lagoons and WWTPs. As stated above, all of the pesticides and herbicide results for the dairy lagoons and WWTPs could not be quantified and are considered unusable because of (1) the complexity of the sample matrices, (2) holding times that were exceeded, (3) recurring QC failures, and (4) the limitations of modified Method 8270D for detecting pesticides and herbicides at the project reporting levels. However, the pesticides for water and soil, as qualified, are usable for all purposes.

Anions

Anions included chloride, fluoride, bromide, and sulfates. As a result of matrix interferences, the dairy lagoon and WWTP biosolids samples collected were analyzed at 50x dilutions for bromide, fluoride, and sulfate. The reporting limits for these bromide, fluoride, and sulfate were elevated and did not meet the project goals. As qualified and reported, the analytical results for water and soil are acceptable for use for all purposes.

Microbial Source Tracking

Microbial Source Tracking (MST) analysis was performed on nine lagoon and four wastewater treatment plant samples using a polymerase chain reaction (PCR) technique. All quality control measures passed including laboratory QC, sterility controls, and blank analyses. Samples were assessed on a present (P) / absent (A) basis for *Bacteroides* species with possible source identification of general *Bacteroides* (GB), human (H), ruminant (R), or both human and ruminant (H/R).

Bacteria

Twenty-one well water, six lagoon, and three wastewater treatment plant samples were analyzed for total coliform by Standard Method (SM) 9222B, fecal coliform by SM 9221E, and/or *E. coli* by SM 9221F. All quality control measures passed including holding time requirements, laboratory QC, sterility controls, and blank analyses. All lagoon and wastewater treatment samples were qualified estimated ("J") for *E. coli* as the method, SM 9221F, has not been approved for use under the Clean Water Act (CWA).

2. Cascade Analytical Laboratory, Wenatchee, Washington

Nitrate and Other Forms of Nitrogen

Cascade Analytical Laboratory is a certified by the State of Washington to conducted drinking water analysis including analysis for nitrate. It is located in Union Gap and Wenatchee Washington, and analyzed nitrate for this study. Because of the short holding times for certain nitrate analytical methods, Cascade Analytical Laboratory was sub-contracted by Region 10 to analyze the water well, soil, and manure samples for nitrate and nitrogen compounds for Phase 3. A total of 30 water wells, 11 soil, and five manure samples were submitted.

The analytical method used for the determination of nitrate in water samples was Method 300.0. Five samples were analyzed for Total Nitrogen/Solid by AOAC Method 993.13, Ammonia Solid by SM 4500-NH3, and Nitrate-N/Total Solid by SM 4500-NO_3 E. Ten samples were analyzed for Total Nitrogen/Solid by AOAC Method 993.13, Ammonium-N by SM 4500-NH_4 H, and Nitrate-N/Nitrite by SM 4500-NO_3 F. In addition, several samples were analyzed for TKN by 4500-Norg C. A Stage 4 data validation was performed by EPA Region 10 QA team for all data generated by Cascade Analytical Laboratory.

All of the QC samples and sample analysis met the technical acceptance criteria set forth by the methods. The data, as reported, are acceptable for use for all purposes.

Thirty split water samples were collected, shipped to Cascade Analytical Laboratory and EPA's Manchester Laboratory, and analyzed for nitrate using the EPA Method 300.0 (Cascade Analytical Laboratory) and EPA Method 353.2 (EPA's Manchester Laboratory). Both sets of data met all the method-specified QC criteria and are acceptable for use for all purposes. The nitrate concentrations reported by both laboratories are comparable within 10 percent. The following is a list of water samples that were collected, split, and sent to these two labs:10154201 10154202 10154203 10154204

10154206	10154207	10154208	10154211	10154212
10154213	10154214	10154215	10154216	10154217
10154218	10154219	10154220	10154221	10154223
10154224	10154225	10154226	10154227	10154228
10154229	10164209	10164210	10164222	10164230

Bacteria

Cascade Analytical Laboratory analyzed nine well water samples for Escherichia Coli and Total Coliform using a Quanti-Tray method (Standard Method 9223 B). Three of the well water samples along with nine dairy lagoon samples and one wastewater treatment plant influent sample were analyzed for fecal coliform in accordance with Standard Method 9222 D.

For bacterial analyses, a holding time of 30 hours must be met for drinking water samples and a holding time of 6 hours must be met for wastewater samples. All samples met these requirements, except for the following dairy lagoon and wastewater treatment plant samples: 10154251, 10154252, 10154253, 10154271, 10164263 and 10164264. The fecal coliform results for these samples were qualified estimated based on holding time exceeded. In addition, all sample results that exceeded the upper limit for microbial estimates were reported as "TNTC" or "too numerous to count." The data, as reported and qualified, are acceptable for use for all purposes.

3. EPA National Risk Management Research Laboratory, Robert S. Kerr Environmental Research Center, Ada,

Hormone and Perchlorate Analyses

Fifteen dairy lagoon, three WWTP, and 30 water samples were analyzed for estrogens (17-α-estradiol; 17-β-estradiol;17-α-ethynyl estradiol; estriol; and estrone) by EPA's Ada Laboratory following the in-house standard operating procedure (SOP) "*Quantitation of Estrogens in Groundwater and Animal waste Dairy lagoon Water Using Solid Phase Extraction, Pentafluorobenzyl and Trimethylsilyl Derivatization and Gas Chromatography Negative Ion Chemical Ionization/Mass Spectrometry/Mass Spectrometry, RSKSOP-253, Revision 2, October 2010.*"

The same 30 water samples were also analyzed for perchlorate following the modified *USEPA SW846 Method 6850, "Perchlorate in Soils, Water and Wastes Using High performance Liquid Chromatography/Electrospray/Ionization (ESI) Mass Spectroscopy (MS) or Tandem Mass Spectroscopy (MS/MS).* All sample analyses were evaluated following the EPA's Stage 2B Manual Data Validation Process. The summaries of sample and QC analyses were evaluated and laboratory qualifiers were mapped to Region 10 EPA validation qualifiers following the technical acceptance criteria and method quality control specifications. All of the technical acceptance criteria for QC were met by both analyses. Target compounds detected above the method detection limit (MDL) but below reporting limits were qualified estimated, "J." Data detected below the MDL were qualified non-detects, "U," and reported at the MDL level. The data, as qualified, are usable for all purposes.

4. USGS National Water Quality Laboratory, Denver, Colorado

Trace Organics

USGS NWQ Laboratory analyzed fifteen dairy lagoons, three WWTP plant influent, and 30 water samples for trace organic chemicals following the SOP for the "*Analysis of Waste Water Samples by Gas Chromatography/Mass Spectroscopy*" – USGS SOPs 1433 and 4433. All sample analyses were evaluated following EPA's Stage 2B Manual Data Validation Process (S2VM). The summaries of sample and QC analyses were evaluated and laboratory qualifiers were mapped to Region 10 EPA validation qualifiers following the technical acceptance criteria and method quality control specifications.

Data users are advised to consider the values reported as a screen. For full usability, data need further confirmation for the following reasons: (1) data were not thoroughly verified by the validator because of the absence of the instrument raw data output at the time of review, and (2) the laboratory followed their in-house SOP and the recurrence of results out of SOP QC control limits indicates that the data may not be reproducible by a third party. The data reported can only be used for information purposes and a good starting point in determining sample locations for confirmatory analyses.

Samples were analyzed following the technical specifications of the analytical method. Approximately 6 percent of the total data points were qualified unusable based on extremely low surrogate recoveries. Approximately 32 percent of the total data points were qualified estimated due to chromatographic interference and QC results that did not meet the specified criteria.

Trace levels of 4-tert-octylphenol, diethyl phthalate, menthol, p-cresol, tri(2-butoxyethyl)phosphate, tri(2-chloroethyl) phosphate, tri (dichloroisopropyl) phosphate, tributyl phosphate, and triphenyl phosphate were detected in the field blank (WW29). Only the diethyl phthalate in associated sample WW06 detected at a concentration less than 5x the value in the blank was qualified as non-detect, "U," based on blank contamination.

5. University of Nebraska – Lincoln Water Science Laboratory (UNL)

The University of Nebraska – Lincoln Water Science Laboratory (UNL Laboratory) analyzed several different types of compounds. Table E3 provides a summary of the compounds evaluated, number of samples, matrix, and analytical method.
A Stage 2A data validation review was conducted by the EPA QA team on all the data. The validation included the limited evaluation of calibration, QA, and sample analytical summary results. All samples were analyzed following the technical specifications of UNL's in-house SOPs.

<u>General QA Observations for UNL Analyses</u>

UNL data sets may not meet the third-party reproducibility criterion set forth by EPA's Information Quality Guidelines (EPA /260R-02-008 October 2002) for the following reasons: (1) there is no established or standard analytical method for the analysis of the target compounds, and the analytical methods used are for research purposes only, (2) the recurrence of out-of-control QC results; (3)variability in duplicate runs; and (4) compound identification and calculations were not verified at the time of review because the instruments' raw data output was not available.

Twenty-nine water, 15 dairy lagoons, three WWTP, and 16 soil or manure samples were collected and analyzed for wastewater pharmaceuticals, veterinary pharmaceuticals, hormones and steroids, and isotopic nitrogen and isotopic oxygen. The following is a summary of the data validations for UNL:

Table E3: Phase 3 – Chemical Analyses Conducted and Analytical Methods Used by the University of Nebraska – Lincoln Water Science Laboratory

Sample Type	Compound Class	No. of Samples	Analytical Method (Prep)	Analytical Method (Analysis)
Water Wells, Dairy Lagoons, and WWTP Influent	Hormones	47	On-line SPE with C18 clean-up	SOP#LCMS_APPI_Steroids_Water-001
	Wastewater Pharmaceuticals	47	Off-line SPE-Modified Method 3535	LC/MS SOP-LCQ-Wastewater-001
	Veterinary Pharmaceuticals	47	On-line SPE extraction with citrate buffer	SOP#LC/MS_Vet_Pharm_water-002
	Isotopic Nitrogen	47	Analyte Prep 15-002	N15 Analysis Dual Inlet IRMS
	Isotopic Oxygen	47	SOP#Analyte-O18 in Nitrate/$AgNO_3$	SOP# Inst-Isoprime EA-18O-001
	Ammonia	47	Analyte-DISTN15-004	Titrimetric
	Nitrate	47	Analyte Prep 15-002	Titrimetric
Soil and Manure	Hormones	16	Microwave-Assisted solvent extraction (MASE) and SPE	SOP# Analyte-Steroids_Solids-001
	Wastewater Pharmaceuticals	16	Microwave-Assisted solvent extraction (MASE) and SPE	SOP#-Analyte-LCQ-Wastesolid-001
	Veterinary Pharmaceuticals	16	On-line SPE extraction with citrate buffer	SOP#-Analyte-VetPharmSED-001

Wastewater Pharmaceuticals: Samples were analyzed following the technical specifications of UNL's in-house SOP. Data users are advised to consider the values reported as a screen. For full usability, data needs further confirmation for the following reasons: (1) data were not thoroughly verified by the validator because of the absence of the instrument raw data output at the time of review, and (2) there is no established standard analytical method for the analysis of the target compounds and the recurrence of out of control QC results and big variability in the duplicate runs indicated that the data may not be reproducible by a third party. The data reported can only be used for informational purposes only and a good starting point in determining sample locations for confirmatory analyses.

Approximately 10 percent of the wastewater pharmaceutical data points were qualified unusable because of extremely low spike and surrogate recoveries (less than 10 percent). An additional 55% of the total data points were qualified estimated due to out of control recoveries in the associated QC runs. The rest of the data as qualified are usable for all purposes.

Veterinary Pharmaceuticals: No significant problems were encountered with the analysis of soil/solid samples for veterinary pharmaceuticals. Most of the liquid samples (dairy lagoons, well water, and WWTP) underwent multiple analyses because of concentrations of some of the target compounds in the field blank and also because of matrix interferences. Approximately 9 percent of the total data points were qualified unusable and an additional 18 percent were qualified estimated concentrations with a high bias because of out of control internal standards or calibration. Five lincomycin and three monensin results in the water samples were detected above the reporting limits but were flagged non-detects based on contamination in the associated field blank, WW29. The concentrations reported were calculated using internal standard techniques. Most of the internal standards did not meet minimum area requirements when compared with the daily calibration standards. Therefore, the associated results may be biased high.

Steroids/Hormones: Because of the calibration results, the detected results or reporting limits for androstadienedione, androsterone, progesterone, estrone, α-zearalanol, α-zearalenol, β-zearalanol for samples associated with the calibration run on January 18, 2011, were qualified estimated, "J/UJ." Approximately 15 percent of the total data points were flagged estimated because of calibrations. In addition, some target compounds were qualified non-detects based on contamination in the associated blank.

Isotopic Nitrogen/Isotopic Oxygen Analyses/Ammonium and Nitrate Nitrogen Analyses: Isotopic nitrogen and oxygen were determined using the amounts of ammonium and nitrate-nitrogen in water. No problems were encountered with the isotopic nitrogen, isotopic oxygen, and intermediate ammonia and nitrate nitrogen results. For QC, laboratory reagent blanks, duplicates, and laboratory-fortified blanks were analyzed at the required frequency. All of the results were comparable to each other. Data were not qualified and are usable for all purposes.

6. USGS Laboratory, Reston Virginia

Recharge Age Dating

The USGS Laboratory located in Reston, Virginia (USGS Reston Laboratory) analyzed the recharge age of the water well samples following the SF_6 procedure.

Limitations of the Method: The recharge dating procedure is a statistical calculation derived from the SF_6 gas evolved in the sample and other existing data. It is applicable to young groundwater systems aged 1970 to present. This procedure is not applicable to areas with high anthropogenic and natural SF_6 background values such as indicated by samples WW-01, WW-11, WW-12, WW-13, WW-23, and WW-28. As a result, age could not be measured in those samples because of the high values of SF_6 as dissolved gases. These samples may indicate areas where localized anthropogenic sources of SF_6 exist. Alternatively, volcanic rocks can contain more SF_6 than the average atmospheric concentrations of SF_6 and the volcanic terrain and mineralogy of the sediments in the local aquifer may be the source of the SF_6.

The USGS Reston Laboratory flagged these six water wells samples with a "C" qualifier, meaning contaminated. For clarity, the validator replaced the "C" qualifier with "NM," not measured. In addition, there were also some samples with recharge calculated dates before 1970. The dating technique used provides only a range, and data users should be warned that the reported recharge ages are estimates.

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APPENDIX F

DAIRIES AND NITROGEN

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Appendix F - Dairies and Nitrogen

Animal feeding operations (AFOs) such as dairies generate large volumes of waste of the following types: animal manure and urine, hair and corpses, bedding and spilled feed, wash-flush water, and other processing wastes. If properly stored and used, manure from animal feeding operations can be an environmentally sound approach to fertilizing fields. However, if not managed correctly, the waste produced by AFOs can pollute the environment, including groundwater (NRCS 2008 and EPA 2004).

Animal wastes applied to the land can contaminate groundwater and surface water. This problem has received increasing attention as livestock operations have become more concentrated, with a trend toward more animals on fewer farms and less land (EPA 2001). In 1998, there were 71 dairies in Yakima County that generated 20,162,500 pounds of waste nitrogen. In 2010, the number of dairies contracted to 67 but the amount of nitrogen they generated increased by more than 50 percent to 33,278,300 pounds (WSDA 2010). Over this time period the amount of waste generated by the average Yakima Valley dairy increased substantially.

Concentrated animal feeding operations produce large amounts of waste in small areas (EPA 2004). Rapid growth in the amount of nitrogen per dairy poses waste disposal challenges. It can become increasingly difficult to effectively store and manage the waste onsite, and to find enough land on which it can be safely applied without causing pollution of groundwater and surface water.

A dairy cow produces considerable amounts of nitrogenous organic waste, typically in the range of 110 to 120 pounds of manure per day (EPA 2009). A lactating dairy cow excretes about 328 to 405 pounds of nitrogen over the same time period (USDA 2009). In a typical dairy, liquid waste from the cow pens is flushed with water into a ditch and then may go to a solids separator, which removes most of the solids. Then the liquid waste may drain into a lagoon, or into a sequence of lagoons. This allows time for additional solids to settle out to the bottom of the lagoon(s). Periodically, dairy lagoons fill with solids and must be dredged. After the liquid has passed through the lagoon system it is typically applied with irrigation water to wastewater application fields. Solids, either from the cow pens, aprons, the solids separator, or from the dredged lagoons, are also usually distributed onto the application fields as fertilizer for crops.

Agricultural ditches or creeks can receive nitrogen from overland runoff, discharges from agricultural return flows, or discharges from application fields. These surface waters can infiltrate into the underlying soils and carry nitrogen down to the aquifer. Contaminated surface water in creeks and ditches can carry nitrogen away from the dairy footprint and transport it into the soil column and groundwater at off-site locations.

As they age, underground pipes transporting dairy waste can deteriorate and develop cracks and holes resulting in leakage of liquid over time. Pipes can crack when the soils around them settle or shift, and they can be damaged by heavy equipment. Typically, it is difficult to determine if underground pipes are leaking once they have been installed unless a leak detection system was incorporated into the design or other integrity testing, such as pressure testing, is performed.

Intact concrete slabs are relatively impermeable, but liquid can move through cracks that occur from ground settlement, through unsealed joints between slabs, or from animal waste spillage off the slab onto the ground.

The rate of leakage, or seepage, from manure lagoons can be significantly reduced by the presence of an engineered liner. However, several studies have concluded that clay liners do not completely prevent leakage. A study in southwest Kansas reported seepage rates from swine and cattle waste lagoons lined with compacted soil liners ranging from 0.2 to 2.4 millimeters per day based on measurements of evaporation and changes in water depth in response to the addition or removal of waste (Ham 2002). Harter and others (2002) inferred manure lagoon leaching rates on the order of 2 millimeters per day at a site in California's Central Valley. Leakage from manure lagoons with clay liners has also been reported by Ritter and Chirnside (1987) and by McCurdy and McSweeney (1993).

Studies have shown that manure solids do not completely "self-seal" unlined lagoons. For example, when researchers analyzed samples from the vadose zone (the unsaturated zone above the water table) downgradient of unlined waste lagoons at five Texas dairies, they found that three of the five sites exhibited nitrate levels in excess of the maximum contaminant level (MCL) (Frarey and others 1994).[29] The term "sealing," as it is sometimes used with regard to dairy lagoon solids, is misleading because it suggests complete containment of the wastewater. The term refers to only a reduction in the seepage rate. Ham and DeSutter found that in new lagoons constructed without clay liners, permeability decreased on average by a factor of five after addition of waste to the lagoons, indicating some permeability reduction over time from organic sludge buildup.

Irrigation with manure lagoon water is a common animal waste disposal practice as it can be used as fertilizer while reducing the volume of liquid waste stored in the lagoons. Nitrogen is an essential nutrient for plant growth. However, if too much nitrogen or water is applied to a field, nitrogen can migrate downward and contaminate groundwater. The potential for nitrogen migration is increased if surface soils are highly permeable.

Nutrient Management in Washington

Because dairies generate large quantities of animal waste that can pollute surface water and groundwater, the State of Washington requires all newly licensed Grade A milk[30] producers to have an approved Nutrient Management Plan (NMP) on site within 6 months of licensing, and a certified NMP on site within two years of licensing. "Approved" means the local conservation district has determined that the facility's plan to manage nutrients meets all the elements identified on a checklist established by the Washington Conservation Commission. Certified means the local conservation district has determined all plan elements are in place and implemented as described in the plan. To be certified, both the dairy operator and an authorized representative of the local conservation district must sign the plan.

The checklist contains 20 elements that the dairy must meet in order to receive a license. Most dairies keep their NMPs and associated sampling data on location and they are not available for public review. At the end of the growing season, operators are required to collect soil samples from their fields to which they apply manure or dairy waste water and test for nitrogen. Soil nitrogen concentrations are not to

[29] Environmental Impacts of Animal Feeding Operations, U.S. Environmental Protection Agency, Office of Water Standards and Applied Sciences Division, December 31, 1998. Page 14.

[30] In the United States, Grade A milk refers to milk that is produced under sufficiently sanitary conditions to qualify for fluid (beverage) consumption.

exceed 45 parts per million (ppm) at the end of the growing season. Adherence to this guideline reduces, but does not eliminate the potential for nitrogen to move below the plant root zone and potentially contaminate groundwater.

Consequences of Waste Mismanagement

Improperly stored or used, animal waste can pollute rivers and groundwater, including underground drinking water supplies. Inadequately sized, unlined, or poorly lined lagoons or other storage structures allow manure to escape into the surrounding environment. Poorly maintained and unlined corrals can allow contaminated wastewater to seep into groundwater. Many AFOs also lack necessary stormwater runoff controls that divert rainwater and snowmelt from the animal confinement area. Stored manure can be washed into nearby streams or infiltrate into the soil column. Applying too much AFO wastewater to fields too quickly or by inadequate methods can also cause the pollutants in animal waste to pollute streams or groundwater before they can be completely absorbed by the land and crops. In some cases, an AFO's location - for example, on hillsides, along streams, and atop sensitive groundwater areas - complicates sound animal waste management practices. Animal waste has the potential to contribute contaminants such as nutrients (nitrogen or phosphorus), organic matter, sediments, pathogens (*E. coli*, giardia, or cryptosporidium), heavy metals, hormones, and antibiotics to groundwater and surface water (EPA 2011 and EPA 1999).

Nitrate Transport

Water wells can facilitate the downward migration of nitrogen. Water can flow downward outside a well casing. If a casing is cracked or deteriorated, water can migrate down the well shaft. Negative pressure created by the well pump can pull water from more shallow, contaminated parts of the aquifer downward more quickly that it would otherwise migrate. Improperly abandoned wells (that were not sealed to prevent the downward migration of shallow groundwater) can serve as conduits for downward water migration. A comparison of historical aerial photographs shows that a number of houses that used to exist on Dairy Cluster property have been demolished or removed. Some of these houses were situated where dairy animal waste application fields now exist. EPA has asked the dairies for documentation that any wells abandoned on their property were properly sealed on closure to prevent contaminant migration, but they have declined to provide this information.

Relatively high-production dairy supply wells are often located on the facility they serve, in areas where the shallow aquifer could become contaminated with nitrate from dairy operations. Dairy supply wells may be screened in the upper basalt layers below the shallow, alluvial aquifer. If the well casings are placed down to the top of the first basalt layer but not sealed to it, contaminated water from the shallow aquifer may migrate down the outside of the well casing into the water-bearing zones between the upper basalt layers. During the cooling process following a volcanic eruption, basaltic flows, like those in the Yakima Valley, develop significant fracture permeability. These fractures can serve as preferential pathways for the migration of contaminated groundwater. Dairy production wells and irrigation wells are generally high production wells with large pumps.

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APPENDIX G
IRRIGATED CROPS IN THE YAKIMA COUNTY

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Appendix G: Irrigated Crops in the Yakima County

The Yakima County is one of the world's most fertile growing regions with more than 240,000 acres of cropland in the county (USDA 2007a). Agriculture is the largest economic sector in Yakima County and it accounts for approximately 70% to 80% of land use. The top seven crops account for about 90% of the agricultural acreage in Yakima County (USDA 2007b):

- Orchards (about 95,000 acres)
- Corn for silage and grain (about 42,000 acres)
- Alfalfa hay (about 37,000 acres)
- Hops (about 19,000 acres)
- Mint (about 12,000 acres)
- Winter wheat (about 9,000 acres)
- Haylage (about 8,000 acres)

Nitrogen is essential to crop growth and development. This nutrient can be supplied in the form of fertilizer as synthetic compounds or through organic-based amendments including manure, plant residues, and for legume plants like alfalfa, by atmospheric nitrogen-fixing Rhizobium bacteria. Nitrate is the principal form of nitrogen used by plants, and numerous biological and chemical processes result in the conversion of nitrogen-containing compounds to nitrate.

The amount, timing, frequency, and form of nitrogen fertilizer affect the amount of nitrogen (in the form of nitrate) available for uptake. Many synthetic nitrogen fertilizers are readily available for assimilation into the plant. Organic forms of nitrogen fertilizer, such as manure or crop residue, require degradation and transformation over time and release nitrate at a slower rate than synthetic fertilizers. Other factors such as denitrification in the soil by microorganisms, soil type, and volatilization to the atmosphere, also affect the amount of nitrogen available for plant uptake. Regardless of the form of nitrogen, application of nutrients or water at rates greater than plant demand can result in excess nitrate infiltrating through the soil below the root zone into the groundwater.

Nitrogen Application to Irrigated Crops

It is likely that both historic and current use of nitrogen-based fertilizers and irrigation methods in Yakima County contribute to groundwater nitrate levels (Ecology 2010). Crop management has advanced substantially over the past 20 years with more precise nutrient and water management for many crops grown in the Yakima County including hops, grapes, and tree fruit. Based on recommended rates, EPA estimated the amount of nitrogen that is being applied to irrigated crop fields (EPA 2012) by determining the amount of irrigated crop acreage for individual crops (USDA 2007a) and multiplying that by the WSU fertilizer application guidelines (WSU 2009). When the 2007 census did not provide adequate information, crop data from the 2002 Census of Agriculture was used (USDA 2002).

Nitrogen application rates may be based on yield goals, soil type, and existing residual nitrate levels as determined by soil or plant tissue tests. The development of recommended agronomic nitrogen application rates does not take into account protection of groundwater. Since published application rates specific to Yakima County could not be found, the recommended average nitrogen application rates for each crop was obtained from the Washington State University fertilizer guidelines (WSU 2009). For each type of crop, WSU recommends a range of nitrogen application bounded by a high and low application rate. The annual nitrogen application rate for each crop was estimated by averaging the high and low rates. These are estimated rates and actual application rates by farmers vary.

Below is a list of the crops that EPA estimates have potentially the highest nitrogen demand for fertilizers, either synthetic, organic, or both based on the WSDA crop data (WSDA 2008) and WSU fertilizer guidelines (WSU 2009):

- Corn for silage and grain – 32%
- Orchard Land – 21%
- Hops – 9%
- Mint for oil, both peppermint & spearmint – 8%
- Alfalfa Hay – 7%
- Winter wheat for grain – 6%

These six crops account for nearly 83% of the total potential nitrogen loading from crop fertilization in Yakima County. Corn, when either grown for silage or grain, accounts for the greatest potential nitrogen loading due to its high nitrogen demand and high biomass yield potential. Silage corn is now a common crop associated with dairy operations in Yakima County. Washington State University Fertilizer Guides estimate total nitrogen requirements for a 30 ton yield of corn silage to be approximately 220 pounds per acre per year.

Orchard land has a relatively low recommended nitrogen application rate of approximately 50 pounds per acre per year, but because the total acreage of orchard land is large it accounts for high nitrogen loading in Yakima County for irrigated crops. The crop management practices for orchard land are generally closely monitored because of the need to ensure a high quality product for consumers (Peck and others 2006).

The form of fertilizer applied may also be constrained by crop physiology. Application of manure solids on mint and alfalfa is limited as these perennial crops cannot withstand tillage or incorporation of manure but could accept a liquid form of dairy waste (Mitchell and others, 1992). Application of manure to hop fields may be limited to amendment of soil prior to planting because hop production trellises limit manure incorporation between rows. Food safety concerns for directly consumed crops, such as apples, limit the application window for manure. The National Organic Program, Washington State Organic Standard, and USDA Good Agricultural Practices (GAP) prohibit the application of raw manure on any directly consumed crop 90 days prior to harvest and require incorporation of the waste into the soil (WSDA 2009).

Irrigation Practices

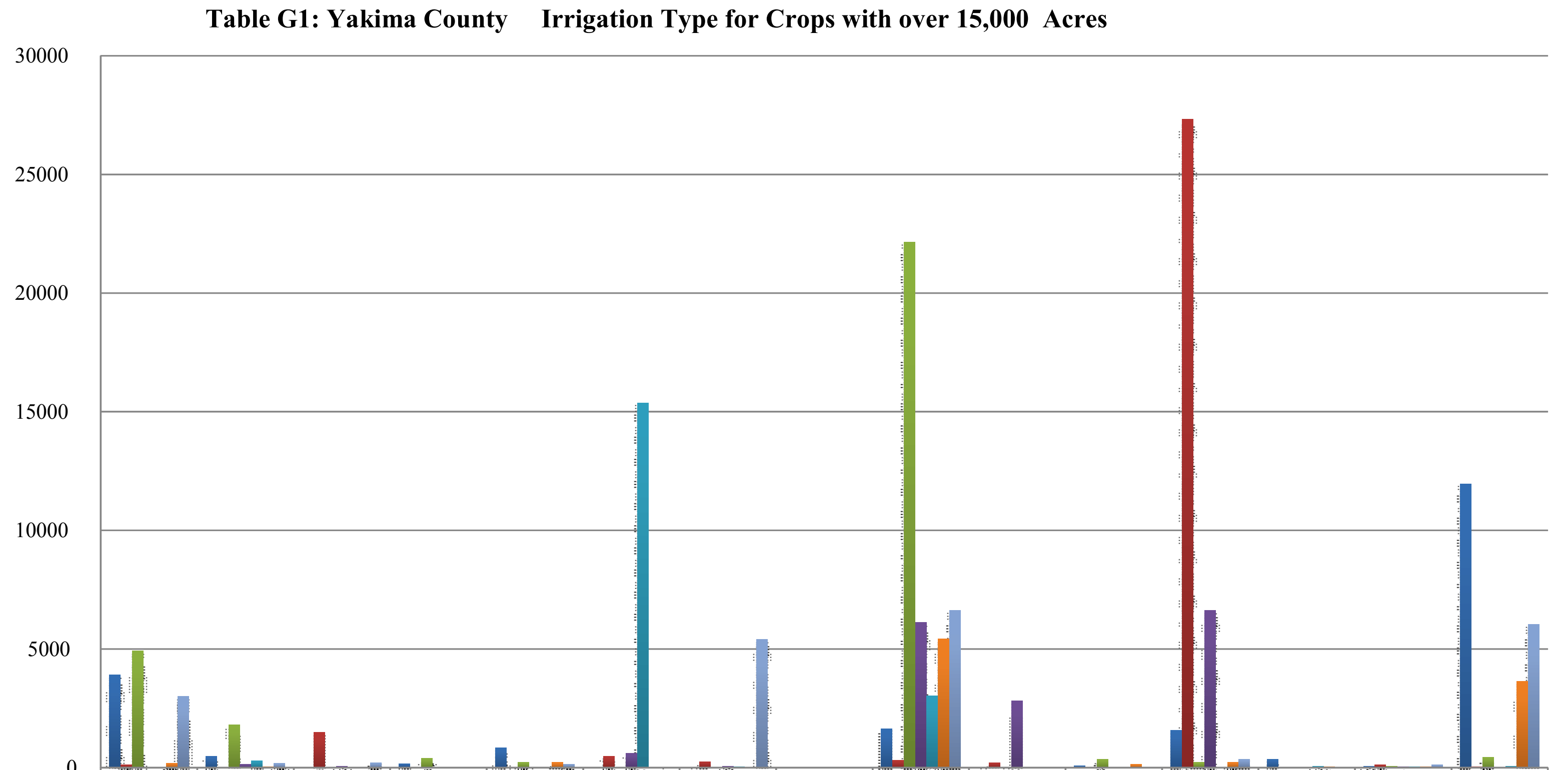
In addition to fertilizer, irrigation is a significant component of the Yakima County crop production. Water quality violations of total suspended sediment in the Yakima River led to enactment of Total Maximum Daily Load (TMDL) limits in the late 1990s. Since then, significant progress has been made in reducing soil erosion from agricultural fields through cost share incentive programs for growers to convert from highly erodible irrigation systems (rill and flood) to less erosive sprinkler-based or drip irrigation systems (NACD 2008). However, nitrate leaching may occur under any irrigation system, including sprinkler based, if irrigation water is applied beyond crop plant water demand.

Estimates of predominant irrigation methods for the top seven crops in Yakima County, based on acreage, are shown in Figure G1 (WSDA 2008). The irrigation method was estimated by quarter section and resulted in combinations of irrigation system types as shown by the example center pivot/rill. Rill irrigation is the practice of applying water to row crops via small ditches or channels between the rows made by tillage implements. Apples on sprinkler had the greatest acreage at 27,388 acres, followed closely by corn on rill irrigation at 22,145 acres.

Detailed irrigation water management studies conducted by universities, industry and agencies in the past have documented that rill (surface) irrigation results in significantly more deep percolation of irrigation water than sprinkler irrigation (USDA 1997). Drip irrigation has the lowest deep percolation rate. Figure G1 shows that there are approximately 22,145 acres of rill or surface irrigated cropland in Yakima County and of that, corn and wheat which are both annually seeded crops make up 38% of the total irrigated acres.

No published data are available for irrigation scheduling or management for Yakima County crops. USDA National Agriculture Statistics Service (NASS) conducted a survey in 2007 on the methods used by crop producers on when to irrigate (USDA 2007b). For Washington State, nearly 70% of irrigated farms surveyed use qualitative factors to determine water demand such as calendar scheduling, delivery by the irrigation provider, or crop appearance. It was estimated that less than 30% of Washington irrigated farms use quantitative methods such as crop evapotranspiration (ET), crop models, or soil or plant sensors to determine irrigation water quantity and application timing.

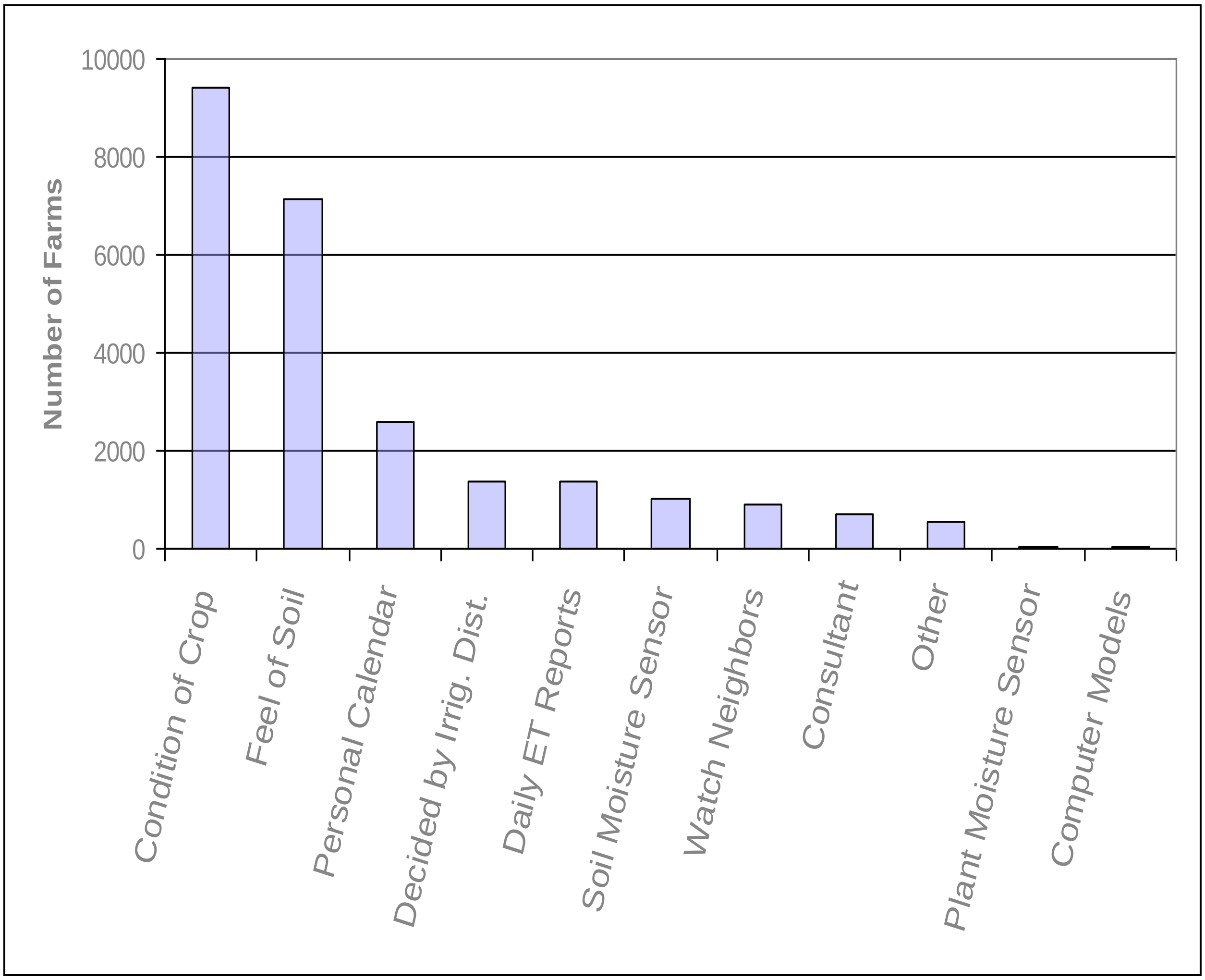
Figure G1: Irrigation System for the Seven Crops with the Highest Total Acreage in the Yakima County[1]



	Central Pivot	Central Pivot Rill	CRSP	Central Pivot Sprinkler	Central Pivot Wheel Line	Drip	None	No Sprinkler Wheel	Rill	Rill Sprinkler	Rill Wheel Line	Sprinkler	Sprinkler Wheel Line	Undefined	Wheel Line
Alfalfa, Hay	3932	496		173	838		21		1641	19	82	1588	368	57	11975
Apple	125		1502			497	267		313	211		27338		129	37
Corn, Field	4936	1826		401	232				22145	20	354	220		74	449
Grape, Concord		142	59			620	70		6133	2830		6647		41	
Hops		293				15388	33		3044				62	37	73
Mint	181	32			222		6		5436		142	228	46	47	3653
Wheat	3025	181	207		159	20	5424		6640			368		118	6031

[1]Irrigation system survey was conducted on a quarter section basis which results in combinations of irrigation system types (USDA 2007b).

Figure G2: USDA Survey of Methods Used to Determine When to Irrigate Crop Fields (USDA 2007b)



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