Follow-up Sampling for Bacteria, Nitrates, Major Ions, Stable Isotopes, and Tritium 2009–2010:

Ashton-Drummond Nitrate Priority Area

Ground Water Quality Technical Report No. 43



State of Idaho
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Ground Water Quality Technical Report No. 43

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1. Introduction

Nitrate concentrations exceed the state and federal maximum contaminant level (MCL) of 10 milligrams per liter (mg/L) for the city of Ashton public water supply (PWS) wells and for a number of private wells within the area, based on regular monitoring. A public sampling event conducted in June 2008 confirmed the distribution of elevated nitrate levels and the public's concern regarding those levels. The Idaho Department of Environmental Quality (DEQ), Idaho State Department of Agriculture, Idaho Soil and Water Conservation Commission, Yellowstone Soil Conservation District, and Eastern Idaho Public Health District are working with the city of Ashton, and those parties relying on the public water system, to develop solutions that will address the elevated nitrate levels. The focus of this study is to follow up with private well owners whose wells exceed the MCL for nitrates and to aid them with potential solutions. Samples were collected in November–December, 2009, with selected sites resampled in June 2010.

The Ashton-Drummond Nitrate Priority Area (NPA) is located along the northeastern margin of the eastern Snake River Plain (ESRP) where tributary aquifers associated with the Henrys Fork of the Snake River and Fall and Teton Rivers transition to the ESRP aquifer. Previous investigations have confirmed that the primary sources of elevated nitrates in the Ashton-Drummond area are related to agricultural practices and a combination of unique hydrogeologic and climatic characteristics (DEQ 2001; Martin et al. 2003). Locally, there may be other sources, including failed or failing septic systems and confined animal feeding operations (CAFOs) or local hydrogeologic conditions contributing to the nitrate concentrations observed.

1.1 Ashton-Drummond Nitrate Priority Area

The extent of nitrate contamination the Ashton-Drummond region has been defined through the Nitrate Priority Area analysis process directed by DEQ.

The Ashton-Drummond NPA (Figure 1) was delineated using nitrate concentration data based on samples collected for the period 2001–2007 (DEQ 2008). Where results for multiple sampling events were available, the latest result was used in the analysis. Final monitoring results for this time period are summarized in Table 1. Results used to delineate the Ashton-Drummond area came from three primary sources: Idaho State Department of Agriculture (ISDA), Idaho Department of Water Resources (IDWR), and results for public drinking water systems' regulatory monitoring submitted to DEQ. The delineated area includes portions of southern Fremont and northern Teton Counties. The maximum, mean, and median nitrate concentrations did not change appreciably from the 2002 NPA delineation.

Table 1. Summary of nitrate concentrations: Ashton-Drummond NPA, 2001–2007.

Number of Sample Results Considered	Concentration (mg/L)			Percent of Samples		
	Maximum	Mean	Median	≥2 mg/L	≥5 mg/L	≥10 mg/L
179	48.0	7.03	6.00	89	69	16

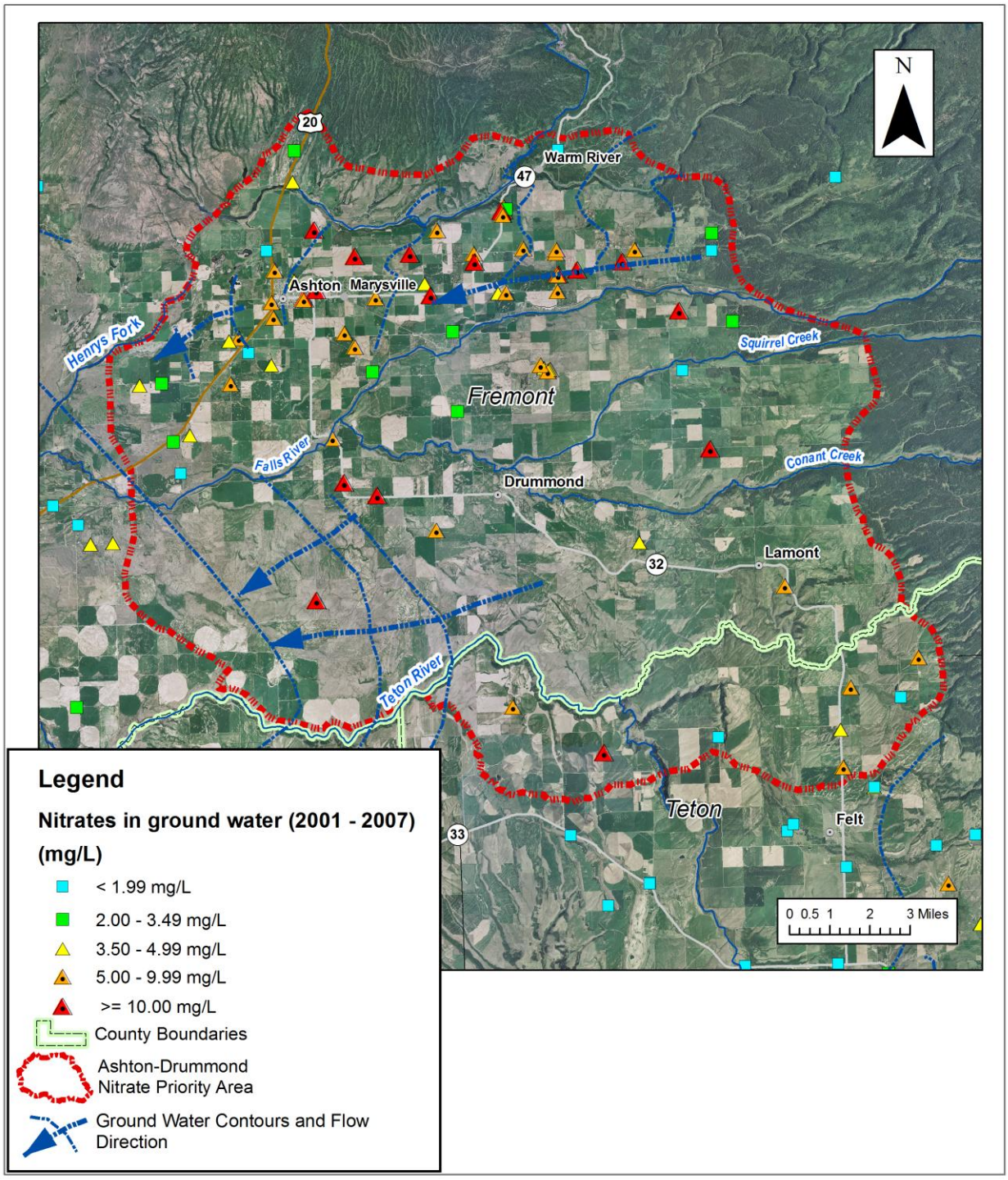


Figure 1. Ashton-Drummond Nitrate Priority Area.

1.2 Objectives

The objectives of this study were as follows:

- Resample sites with nitrate concentrations that approach or exceed 10 mg/L based on historic sampling or nitrate screening events.
- Identify potential sources for elevated nitrate levels (across the region or specific to individual wells).
- Identify hydrogeologic and climatic characteristics that may be significant factors in the observed nitrate levels.
- Provide feedback to the private well owners on addressing elevated nitrate concentrations in their wells.

2. Study Area

The Ashton-Drummond NPA covers approximately 162,500 acres or about 254 square miles and includes the communities of Ashton, Marysville, Drummond, Felt, and other small unincorporated areas. The largely rural, agricultural area was identified as an area of concern in the 2002 NPA analysis and ranked 13th in the 2008 NPA analysis (DEQ 2008).

The Ashton-Drummond NPA can be subdivided based on hydrogeology into a northern portion, associated with the Henrys Fork of the Snake and Fall Rivers, and a southern portion associated with the Teton River. However, due to the spatial coverage of data for nitrate levels in ground water and similarity of land uses (predominantly agriculture), the Ashton-Drummond advisory team (including DEQ, Idaho Soil and Water Conservation Commission, Yellowstone Soil Conservation District, and Eastern Idaho Public Health District) and planning team (including the city of Ashton and local citizens) have chosen to develop a management plan for the region as a whole.

2.1 Climate

The Ashton-Drummond NPA, located on the elevated eastern margin of the ESRP and at the foot of the Yellowstone Plateau and Teton Range of Wyoming, has unique climate conditions. The average annual precipitation is approximately 20 inches, with most of that precipitation occurring as snowfall during the winter months. The summers are relatively dry (WRCC 2010; Dallas et al. 2008). A few miles to the south along the ESRP (near St. Anthony, Idaho), precipitation is approximately 30% less, and to the north and east on the Yellowstone Plateau, precipitation is at least 50% greater. Snow cover exists from November through April in a typical year.

2.2 Hydrogeology

The Ashton-Drummond NPA is characterized by a volcanic and glacial-fluvial geology. Rhyolitic ash flows, which erupted from the 2-million-year-old Huckleberry Ridge tuff, underlie basaltic lava flows in the vicinity of Ashton. Overlying the basalts is a thin accumulation of Quaternary-age glacially derived gravel and recent stream alluvium (Martin et al. 2003). It is

assumed similar stratigraphy underlies the majority of the Ashton-Drummond NPA, with local variations depending on topography (within a drainage or on the broader plateaus) and elevation.

Shallow basalts of the Snake River Group and deeper silicic volcanic rocks of the Yellowstone Group are the host units for ground water sources in the Ashton-Drummond area. The shallow basalt aquifer produces adequate water for domestic wells, but larger yields suitable for municipal and irrigation wells depend on localized conditions including deeper fracture zones. South and east of the immediate vicinity of Ashton, the aquifers in the deeper Yellowstone Group rhyolites tend to be more productive (Martin et al. 2003; DEQ 2001).

Ground water flow direction tends to follow the topography and is influenced by topographic divides and various surface water drainages (Figure 1). In the vicinity of Ashton, ground water flow is generally east to west, in the direction of the Henrys Fork of the Snake River. Likewise, flow in the central and southern portions of the area is assumed to be generally west, in the direction of the Fall and Teton Rivers (Martin et al. 2003).

2.3 Previous Investigations

Elevated nitrate levels in ground water in the Ashton-Drummond region were first identified in the mid-1990s. A number of investigative efforts have been completed to understand and address this issue. These efforts include the following:

- *City of Ashton Water Supply System Nitrate Mitigation Study* (Jorgensen Engineering and Land Surveying, P.C. 2000). This effort, funded in part by IDWR, summarized previous work, reviewed local hydrogeologic conditions, and proposed alternatives to aid the city of Ashton with ensuring a quality supply of drinking water for residents. The study reported characteristic seasonal nitrate concentration fluctuations and an apparent lack in correlation between nitrate concentrations and well depth.

- G*round Water Quality Investigation and Wellhead Protection Study, City of Ashton, Idaho* (DEQ 2001). DEQ, ISDA, United States Geological Survey (USGS), and the city of Ashton conducted an investigation to characterize the extent of nitrate contamination in the area, identify potential contaminant sources, and propose best management practices (BMPs) to address this issue. Results from the sampling identified commercial fertilizer as the dominant source for nitrates, with negligible contributions from septic or animal waste sources. Nitrate levels tend to increase as the local aquifer flows toward Ashton.

- *City of Ashton Drinking Water Protection Plan PWS-7220004* (City of Ashton 2002). This effort by the city of Ashton reviewed potential contaminant sources and enlisted a local planning team to develop and implement drinking water protection strategies. The city of Ashton recertified this drinking water protection plan in 2006.

- *Hydrogeologic Analysis of the Water Supply for Ashton, Fremont County, Idaho–Draft* (Martin et al. 2003). An Idaho Water Resources Research Institute report focusing on the Ashton area states that fractured basalt is the regional aquifer immediately next to the city of Ashton wells. Correlations exist between the increase in nitrate levels and fall and

winter recharge, after the growing season. This study concluded that practices minimizing nitrate leaching from the soil column after the growing season may be beneficial in controlling nitrate leaching to ground water.

- *Ashton Groundwater Protection Project Final Report*. (Yellowstone Soil Conservation District 2008) The Yellowstone Soil Conservation District worked with local farmers to improve fertilizer application practices, resulting in a 19% reduction in nitrogen applied to fields, which then reduced the potential nitrate loading to ground water. During the 2007 growing season, nearly 60% of lands under cultivation were part of this study.

- *Ground Water Quality of Middle Henrys Fork Basin, Regional Monitoring Project, 2003-2007* (Dallas et al. 2008). ISDA began a regional ground water monitoring project for the Ashton-Drummond NPA to characterize ground water degradation from agricultural activities. This monitoring effort provided most of the nitrate and pesticide monitoring results for the NPA from 2003–2009. ISDA has provided recommendations to reduce agricultural impacts to ground water for the region.

Other studies in progress included a ground water monitoring project by Brigham Young University-Idaho's (BYU-I) Department of Geology; hydrogeologic analyses by Idaho Water Resources Research Institute and Idaho State University; and a 3-year study of surface and ground water interactions and impacts caused by water conservation in the Henrys Fork watershed (Van Kirk 2010).

Additional background information was provided through the Ashton-Drummond public water fair/nitrate testing event held on June 7, 2008. Organized by the planning and advisory teams for the Ashton-Drummond NPA, the public was invited to bring water samples from their private wells to be screened for nitrate concentrations using nitrate test strips. Samples were screened at the event, and the results were explained to the person bringing in the sample. Residents were invited to put markers, coded to their nitrate results, on a regional map identifying their well locations. Representatives from ISDA, DEQ, Yellowstone Soil Conservation District, and a local well driller provided displays and answered questions. Samples from 143 wells were tested. A summary of all results is presented in Table 2. Results for the immediate vicinity of the Ashton-Drummond NPA are shown in Figure 2.

Table 2. Nitrate testing results for Ashton-Drummond water fair, June 7, 2008.

	Green <2 mg/L	Yellow 2–<5 mg/L	Orange 5–10 mg/L	Red ≥10 mg/L
Total for NPA	8	23	42	20
Fremont County not within the NPA	12	7	1	0
Teton County not within the NPA	22	5	3	0
Total	42	35	46	20

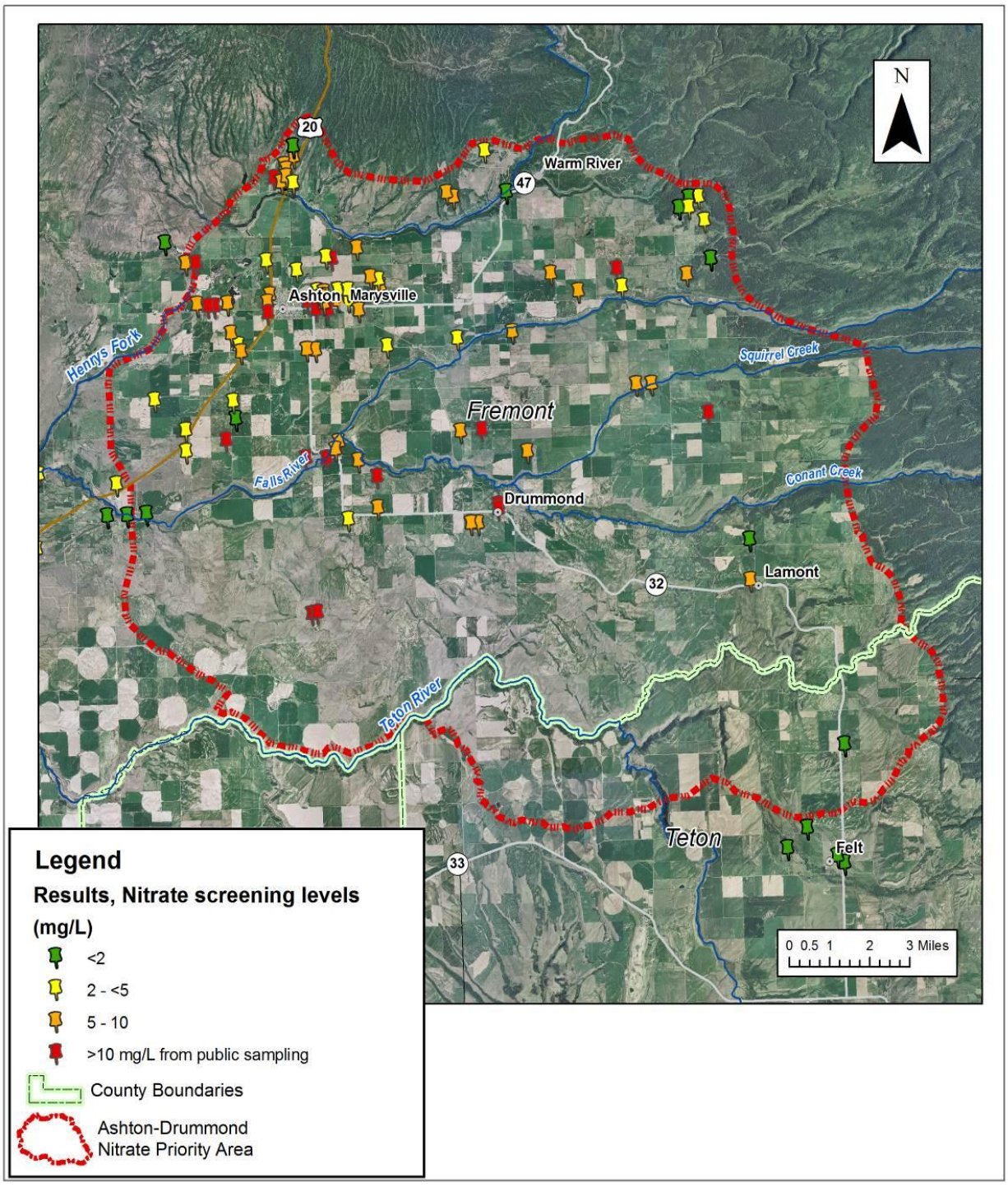


Figure 2. Results from Ashton-Drummond public water fair/nitrate testing event, June 2008.

Water monitoring results for the city of Ashton PWS are consistent with nitrate concentrations observed for domestic wells in the Ashton-Drummond region as a whole. Nitrate concentrations for city of Ashton PWS wells tend to increase in the spring, peaking in early June and declining in the fall and winter. Recent years of increased snowpack and recharge have resulted in an increase in the annual peak of nitrate levels. DEQ and the United States Environmental Protection Agency (EPA) have worked with the city of Ashton to provide grants and loans to develop a treatment system for the elevated nitrates in the city's PWS and improvements to their municipal wastewater treatment system.

3. Methods

The Ashton-Drummond NPA advisory and planning teams intend to respond to private well owners whose wells that have approached or exceeded the 10 mg/L MCL for nitrates. Sampling for analytes followed the model from other southern Idaho nitrate source investigations; Springdale in Cassia County (Schorzman and Baldwin 2009) and Pleasant Valley in Bingham County (Welhan and Poulson 2009), using major ion chemistry, stable isotope ratios, bacteria, and tritium to develop relationships that might shed light on potential sources contributing to the elevated nitrate levels for individual wells. Additionally, a basic site history including location of wells and septic systems, general maintenance habits, photographs of the wellhead, and well logs, if available, was collected to identify potential impacts to water quality at the wellhead. Objectives, methods, and quality assurance for this sampling event are included in the project's quality assurance project plan (DEQ 2009).

3.1 Site Selection

Previous sampling results, compiled as part of the NPA analysis from the BYU-I ground water monitoring project and the June 2008 Ashton-Drummond ground water quality management plan public water fair/nitrate testing event, identified nitrate results from 45 wells that approached or exceeded the 10 mg/L MCL (Figure 3). Private well owners were invited to participate in this sampling through a DEQ-issued press release and a Rexburg *Standard Journal* article reporting on elevated nitrates in the area. Additionally, residents in the elevated nitrate areas were contacted and were given the opportunity to participate in the sampling. Sites were selected from those who responded.

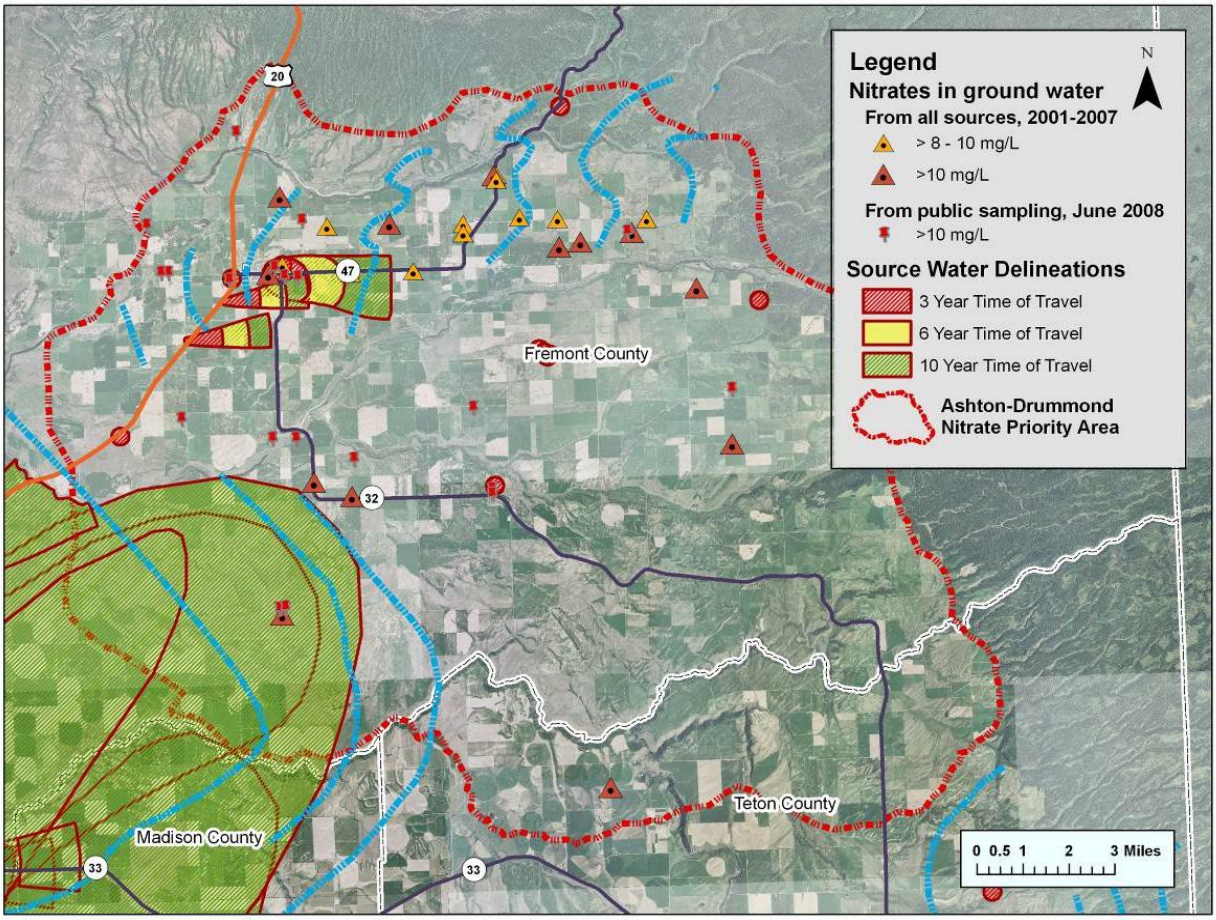


Figure 3. Sites with nitrate results between 8 and 10 mg/L or greater than 10 mg/L as tested during the Ashton-Drummond water fair and public nitrate screening event, June 2008.

3.2 Data and Sample Collection

Attempts were made to contact owners for 27 potential sample sites during October and November 2009. Contact was made, and permission to sample was obtained for 18 sites, including a city of Ashton PWS well and a well owned by the city of Drummond.

For each location (Figure 4), the sample team described the sampling objectives, offered to conduct a nitrate screening from an inside faucet using a nitrate test strip, and presented informational brochures about nitrates and bacteria in ground water to the well owners. With well owner concurrence, water sampling permission and site inventory forms were completed, and a sketch identifying the relative location of the home, well, septic system, and any pertinent structures was drawn. The well tag, if present, and wellhead conditions were noted. Results of the nitrate screening test were explained to the well owner by one of the sample team members while the inventory was compiled by another team member. When the screening test was less than 5 mg/L, the location was not sampled, unless other indicators (e.g., location, conditions at the wellhead) suggested that the site may present unique information. In November and December 2009, 16 of the 18 sites were sampled; 2 of these 16 sites were resampled in

June 2010. A set of blank samples prepared in the field was sent to the analyzing laboratories with the 2009 samples as an additional, quality assurance site.

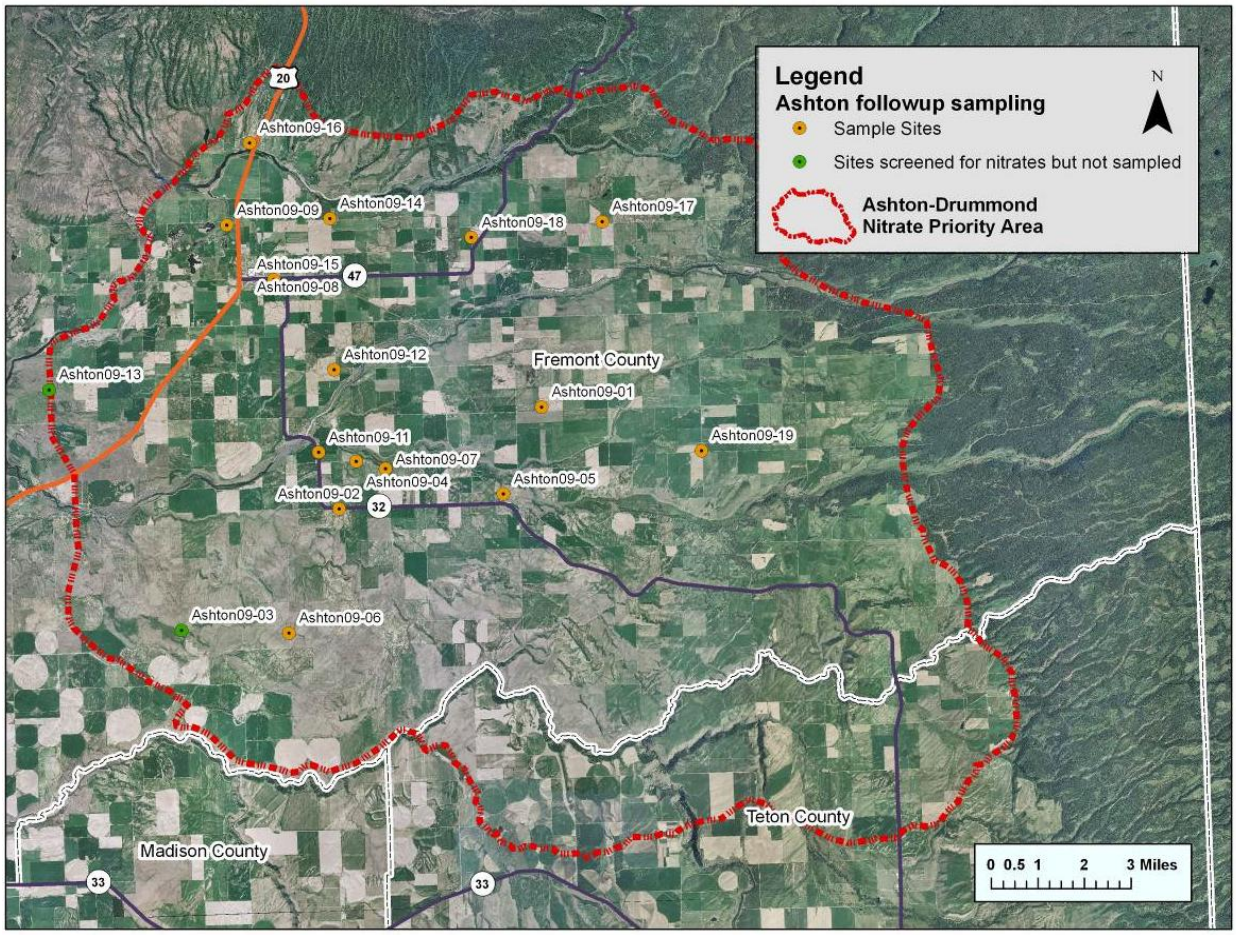


Figure 4. Ashton-Drummond sample locations, 2009–2010.

3.3 Analytes

Field parameters (water temperature, specific conductance, dissolved oxygen, and pH) were collected at each well before sample collection. Samples were collected from an outside faucet. Wells were purged prior to sample collection, with samples collected when field parameters were within 10% of the preceding measurement.

Samples were analyzed for major cations (calcium, magnesium, sodium, and potassium); major anions (alkalinity, total dissolved solids, chloride, fluoride, and sulfate); nutrients (total nitrate plus nitrite and total phosphorus); total coliform and *E. coli* bacteria; stable isotopes of oxygen (^{18}O), deuterium (^{2}H), nitrogen (^{15}N), and tritium. Table 3 lists samples, parameters, analytical methods, and collection, preservative, and holding time information. Major cation, anion, and nutrient analyses were completed by the Idaho Bureau of Laboratories in Boise; bacterial analyses were completed by IAS-Enviro Chem in Pocatello; stable isotope analysis was conducted by the University of Arizona in Tucson; and tritium analysis was conducted by the Idaho State University Environmental Monitoring Laboratory in Pocatello.

Samples were handled according to standard methods and as described in the *Ashton-Drummond Nitrate Follow-up Ground Water Sampling Quality Assurance Project Plan* (DEQ 2009).

Table 3. Samples, parameters, methods, containers, preservatives, and holding times.

Sample	Parameter[a]	Analytical Method	Sample Container[b]	Preservative[c]	Holding Time
Major cations	Ca, Mg, Na, K	EPA 200.7	1 L LDPE	HNO_3, 4(±2)°C	6 months
Major anions	Cl, F, SO_4,	EPA 300.0	1 L LDPE	4(±2)°C	28 days
	Alkalinity (as $CaCO_3$)	SM2320B		4(±2)°C	14 days
	Total dissolved solids	SM2540C		4(±2)°C	7 days
Nutrients	NO_2+NO_3-N	EPA 353.2	1 L LDPE	H_2SO_4, 4(±2)°C	28 days
	Total phosphorus	SM4500P-E		H_2SO_4, 4(±2)°C	28 days
Tritium	Environmental-level tritium	HASL 300	1 L HDPE	None	180 days
Bacteria	Total Coliform/ *E. coli* bacteria	SM9223B	150 mL HDPE	4(±2)°C	30 hours
Stable isotopes	$\delta^{15}N$	TP11	1 L LDPE	Freeze samples	Unlimited if frozen
	$\delta^{18}O$	TP13	250 mL HDPE	None	None
	$\delta^{2}H$	TP04		None	None

a. Ca–calcium; Mg–magnesium; Na–sodium; K–potassium; Cl–chloride; F–fluoride; SO_4–sulfate; $CaCO_3$–calcium carbonate; NO_2+NO_3–N - nitrite + nitrate as nitrogen; $\delta^{15}N$–ratio of nitrogen-15/nitrogen-14; $\delta^{18}O$–ratio of oxygen-18/oxygen-16; $\delta^{2}H$ (deuterium)–ratio of hydrogen-2/hydrogen-1
b. LDPE–low-density polyethylene; HDPE–high-density polyethylene
c. HNO_3–nitric acid; H_2SO_4–sulfuric acid

4. Results and Discussion

This section presents a summary of sampling results from November and December 2009 and resampling results from June 2010. Analysis results are included in Appendix A. As the sites sampled were selected primarily because of their elevated nitrate levels, medians and measurement ranges presented only reflect sites with elevated nitrates and do not reflect the distribution of nitrate concentrations across the NPA. Discussion of sample results focuses on interwell characteristics and comparisons that may help to identify the potential sources of the nitrate concentrations observed.

Site inventories conducted for sampling locations included identifying relationships between well locations and septic systems on the property and their maintenance history. All well owners were aware of the well and septic locations. All sites appeared to meet minimum separation distances between the wells and septic systems. At least three of the sites were old homesteads. Some owners had replaced the site's septic systems and wells, while others did not know the age or condition of their systems.

Well logs and water-level information were found for 10 of the sites sampled. Most of those wells with available logs also had water-level information from the time of drilling. As expected, older wells had little information concerning well seals, and those with information indicated the minimum seal depth. At several sites, wells had been recently deepened or old wells had been replaced with new wells. These wells had more complete information on well seals and tended to have deeper seals, 40 feet below land surface (ft bls) to as deep as 78 ft bls. Several of the wells were reported to be as much as 100 years old. None of the sample locations had wells situated within pastures or feed lots. While several wellheads were in poor condition, most were well maintained.

4.1 Field Measurements and Bacteria

Field Parameters

Water temperature at the time of collection ranged from 9.44 to 13.2°C, with a median of 10.71 °C; pH ranged from 7.09 to 8.26 with a median of 7.92. Specific conductance ranged from 256 to 900 microsiemens per centimeter (µS/cm), with a median of 526 µS/cm. Dissolved oxygen measurements were made the first two field days (November 2 and 9, 2009) for eight sites and during the resampling event (June 6, 2010) for two sites. Measurements ranged from 0.63 to 9.9 mg/L with a median of 7.52 mg/L. The dissolved oxygen sensor on the Hydrolab probe used for measurements would not calibrate for the sampling days November 17–18 and December 12, 2009. The meter was returned for factory service following the December 12, 2009, field day and was received after reconditioning for the resampling event in June 2010.

Measurements from two sites indicated low dissolved oxygen conditions (Ashton09-05 and 09). Specific conductance for Ashton09-05, 06, 08, 09, and 17 appeared greater at these sites than locations around them, suggesting a local source for the increased dissolved ions in the ground water. Other field parameters, including temperature and pH, did not indicate local influences.

Bacteria

Samples from four locations (Ashton09-02, 07, 09, and 14) indicated the presence of total coliform bacteria. All of these sites are older wells that needed maintenance, including an overgrown well pit area, poor wellhead seal, or open wellhead. Coliform bacteria occur naturally in soils and can be present within piping and on the outsides of faucets. While not generally harmful, they can indicate the presence of more harmful bacteria. Samples were also analyzed for *E. coli* bacteria with no detections identified. Detection of *E. coli* would indicate direct influence from human or animal wastes.

The bacteria detections, wellhead maintenance information, and instructions for disinfecting the wells were forwarded to the well owners. At least one well owner responded by conducting maintenance to the wellhead.

4.2 Nitrates and Major Ion Chemistry

Nitrate Screening

Nitrate test strips were used to screen for elevated nitrates at the 18 sites visited. A summary is presented in Table 4. For most locations, the nitrate screening result was consistent with the

laboratory nitrate results. For two locations sampled (Ashton09-01 and 06), the screening result differed significantly from the final nitrate laboratory result.

Table 4. Nitrate screening results for Ashton-Drummond follow-up sampling, 2009-2010.[a]

<2 mg/L	2-<5 mg/L	5-10 mg/L	≥10 mg/L
2	4	3	13

a. Includes two sites screened but not sampled and two resampled in June 2010.

The nitrate screening test proved to be a valuable tool and provided an incentive for well owners to participate in the process and the peace of mind that nitrate levels in their wells were not elevated. For one site (Ashton09-04), a nitrate test was conducted at the wellhead (>10 ml/L) and from a faucet after treatment (2-<5 mg/L) using a reverse osmosis treatment system, confirming the effectiveness of the on-site treatment system.

Nitrates

Nitrate (as nitrogen) concentrations ranged from 0.280 mg/L to 30 mg/L with a median of 8.9 mg/L. Samples from seven sites were greater than or equal to 10 mg/L (Figure 5). The highest concentrations were for Ashton09-05 and 06 at 30 mg/L and 29 mg/L, respectively. Ashton09-09 had the lowest reported concentration of 0.280 mg/L and anoxic conditions indicated by the low dissolved oxygen. If nitrogen is present at this site, it is likely in a chemically reduced form, such as ammonia.

For Ashton09-01 and 06, the initial nitrate screening result and the laboratory nitrate result did not agree. The screening result for Ashton09-01 suggested >10 mg/L nitrates, where the laboratory result indicated 8.2 mg/L. The screening result for Ashton09-06 indicated 10 mg/L, where the laboratory analysis yielded 29 mg/L. These sites were resampled in June 2010, with the laboratory analysis results, 7.9 mg/L for Ashton09-01 and 23 mg/L for Ashton09-06, consistent with the screening results. Based on the laboratory analysis, other sites exceeding 10 mg/L are Ashton09-19, 04, 15, and 17.

Site history for Ashton09-05 is significant because of historic chemical spills in the vicinity of the wellhead. Liquid fertilizer spills of 800 gallons ammonium phosphate and 600 gallons urea ammonium nitrate were reported in 1991–1992 at a bulk fertilizer storage facility and railroad depot within 500 feet and upgradient of the wellhead. The nitrate concentration from this well was 8.86 mg/L prior to the spills in 1990. Sample results following the spill showed that nitrate concentrations increased to 18–20 mg/L by the 1994 sampling. The spill was investigated with the cooperation of the Eastern Idaho Public Health District, IDWR, and USGS (Brown and Caldwell 1993, 1994). The rail line was abandoned, and the fertilizer depot site was relocated since the spill. The depth of the Drummond city well is 310 ft bls, and the wellhead is about 100 feet higher in elevation than the bulk storage/railroad depot spill site.

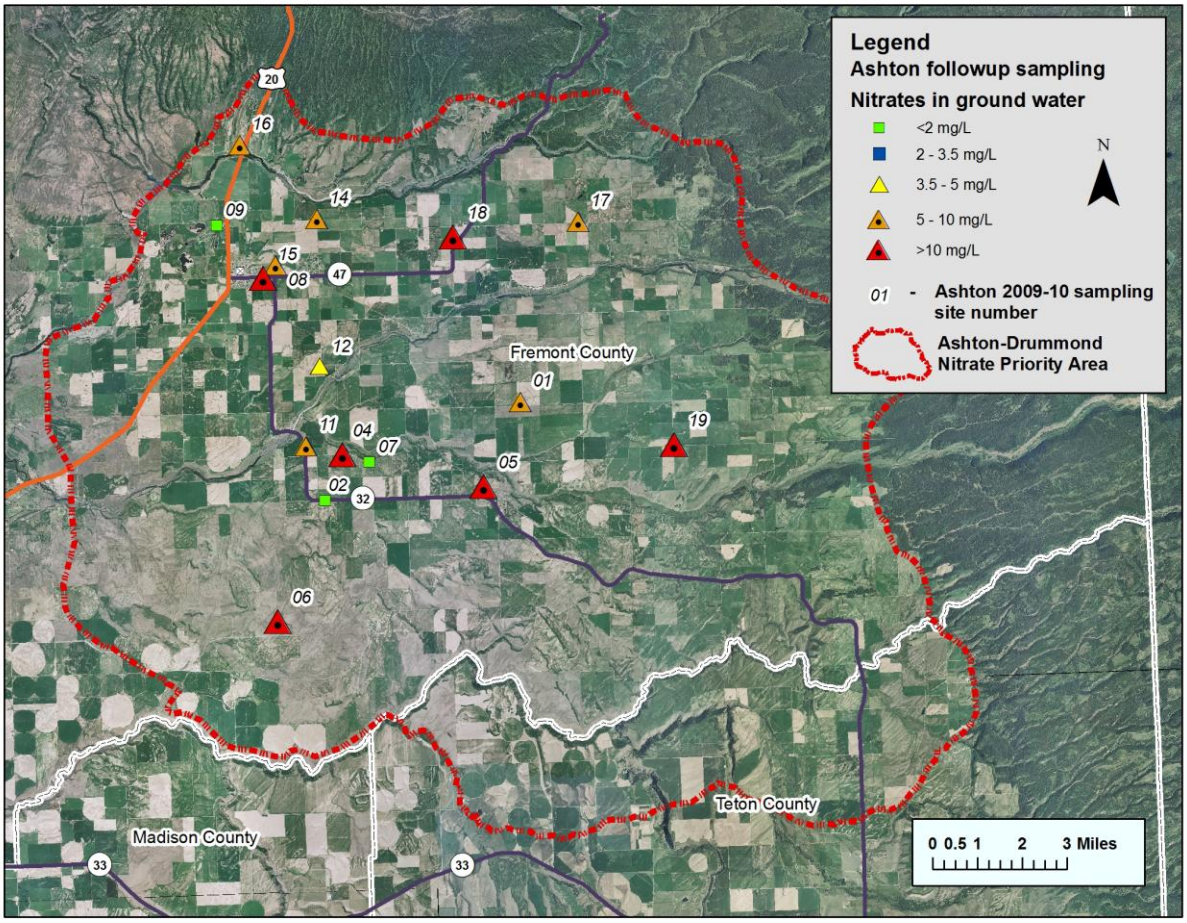


Figure 5. Nitrate concentrations: Ashton-Drummond sites, 2009-2010.

Major Ions

The dissolved ions of calcium, magnesium, sodium, and potassium, along with alkalinity assumed to be from carbonate sources, and sulfate and chloride tend to compose 90% or more of the dissolved and chemically reactive ions in ground water. Waters in the Ashton-Drummond area can be identified as primarily calcium-carbonate type water, typical for ESRP aquifer waters. The Piper diagram (Figure 6) shows some variation in anion chemistry and shows a clear chloride-to-sulfate relationship characteristic for the area. In Figure 6, the anion space shows a mixing trend similar to that observed for deep, less-evaporated ground water in the Pleasant Valley area (Welhan and Poulson 2009). Samples from locations Ashton09-02, 05, 08, 09, 17, and 19 are distinctive when the combination of major ions is considered.

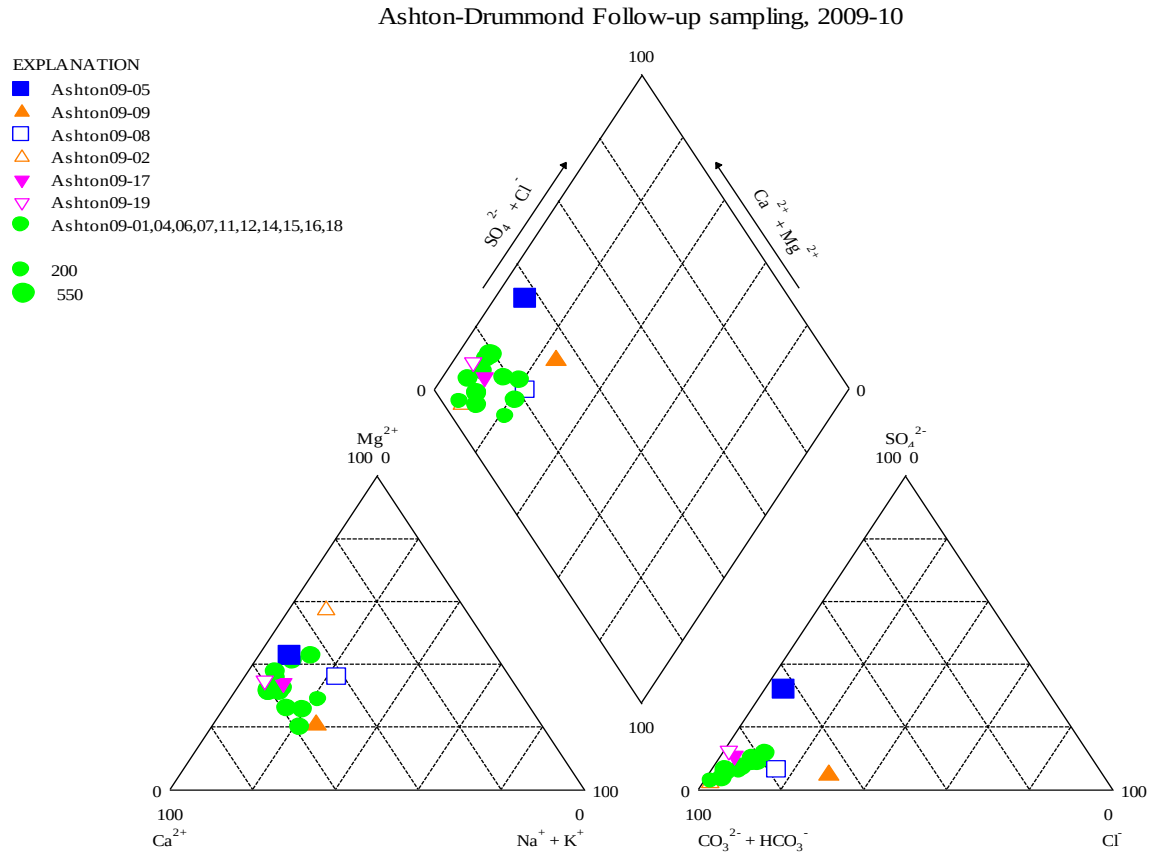


Figure 6. Piper diagram for Ashton-Drummond sites sampled.

A plot of chloride relative to sulfate chloride concentrations is presented in Figure 7. A characteristic chloride-to-sulfate relationship for natural ground waters was apparent. Additionally, results for Ashton09-05 and 09 stand out with greater sulfate relative to chloride and greater chloride relative to sulfate concentrations, respectively. Note that these distinctions are apparent in the anion portion of Figure 7. DEQ (2001), Welhan and Poulson (2009), Schorzman and Baldwin (2009), among other studies, offer waste-related or fertilizer-related sources for sulfate or chloride concentrations that depart from this "natural" relationship. Waste-related nitrate sources from septic systems or CAFOs would tend to have elevated chloride relative to sulfate. Likewise, for fertilizer sources, especially when the fertilizer is in ammonium sulfate form, sulfate would be elevated relative to chloride. Ashton09-17 and 19 exhibit higher relative sulfate than this "typical" relationship based on the results presented, suggesting synthetic-based fertilizer as a primary source of contamination. These sites also exceed 10 mg/L of nitrate as nitrogen and are surrounded by agricultural lands. Ashton09-08 plots with higher relative chloride. Sampling notes for this site indicate that the home uses a water softener. A home water softener uses a mixed bed of ion exchange resins to remove the dissolved calcium and magnesium from the water, increasing the sodium in the water and making it "softer." A water softener uses a salty brine to "recharge" the resins and the salty water goes down the drain. When the home has a septic tank, the salty water, elevated in sodium and chloride, is added to the ground water. In addition to home water conditioning, sodium chloride added to water during food preparation may also be a factor (Seiler 1996).

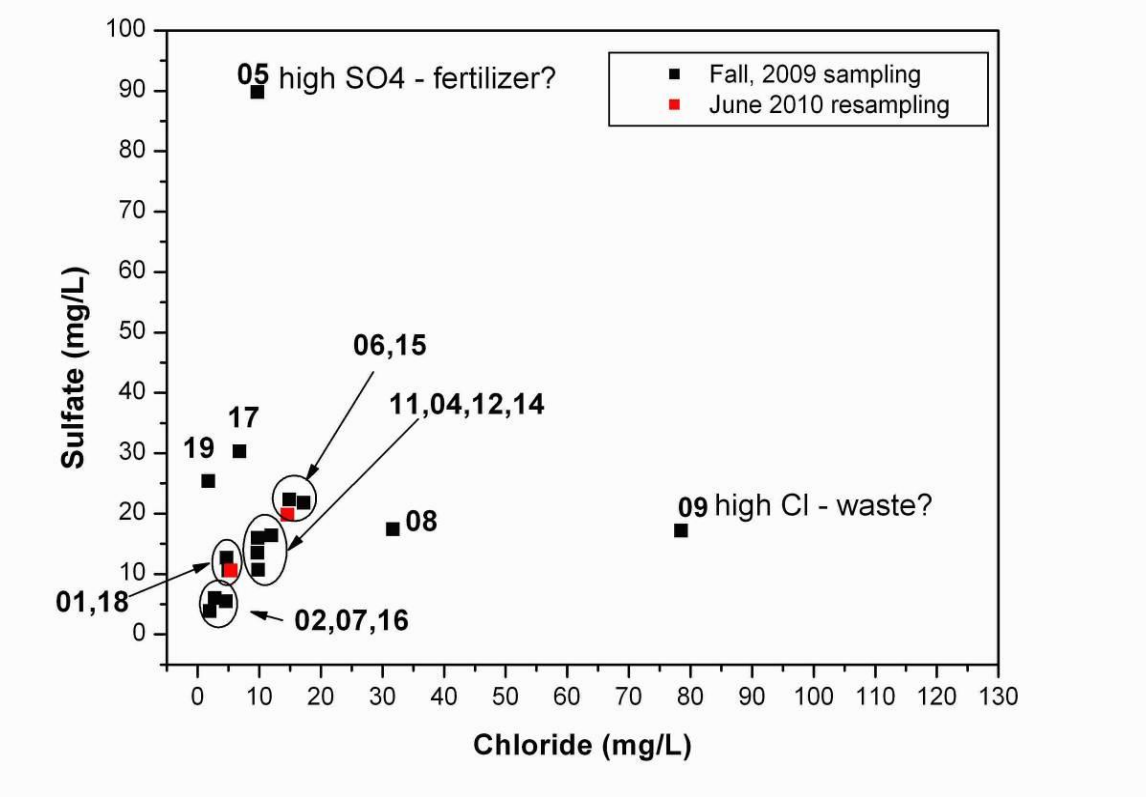


Figure 7. Chloride versus sulfate concentrations, Ashton-Drummond sampling.

As water evaporates, concentrations of chloride and sulfate increase in the resultant liquid at the same rate. Ground water impacted by a nitrate source that adds a disproportionate amount of either chloride, as a waste-related source, or sulfate, as a fertilizer-related source, reflects a differing chloride-to-sulfate ratio. Figure 8 shows two sites (Ashton09-08 and 09) already identified with disproportionately higher chloride concentrations. The figure also shows a grouping of sites with about the same ratio of sulfate to chloride but increased chloride (Ashton09-04, 11, 12, 14, 15, and 06). These sites illustrate a simple concentration of chloride and sulfate, perhaps due to evaporation or continued dissolution of chloride and sulfate from aquifer host units or soil materials. Ashton09-05, 17, and 19 were previously identified as elevated in sulfate relative to chloride. All three of these sites also exceed 10 mg/L of nitrate, pointing primarily to a fertilizer source for the elevated nitrates. The grouping of results for Ashton09-01, 02, 07, 16, and 18 exhibits about the same chloride concentrations but shows a range for the sulfate-to-chloride ratio, suggesting a proportionately greater sulfate source, consistent with sulfate-based fertilizer.

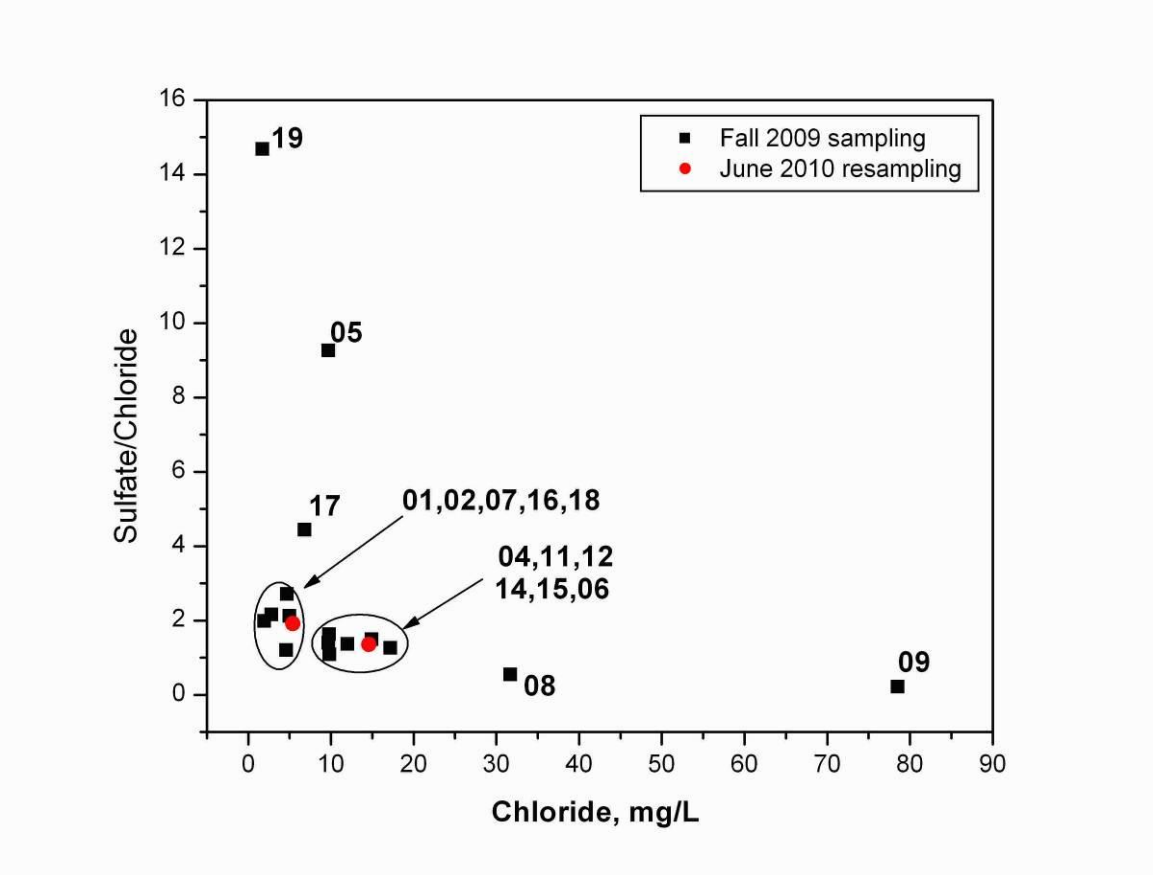


Figure 8. Chloride versus ratio of sulfate to chloride, Ashton-Drummond area sampling.

As sites with the greatest nitrate concentrations also tend to have greater sulfate relative to chloride, the relationship of sulfate to nitrate was plotted (Figure 9**)**. A linear regression computed for this relationship returned a correlation coefficient (r) strong enough (r = 0.72, probability value of 0.001 associated with the regression) to suggest that a sulfate-based fertilizer source may account for a significant proportion of the nitrates observed for the sites sampled. While the correlation is strong, Figure 9 suggests this is not a simple relationship, that other factors are likely involved. More information than nitrate, sulfate, and chloride concentrations should be evaluated to determine probable sources for individual sites; multiple sources or processes may be contributing nitrates to some sites.

4.3 Stable Isotopes and Tritium

Stable isotopes of hydrogen, oxygen, and nitrogen can be used to trace the history and source of both water and nitrogen sources in the environment. Stable isotopes of elements such as hydrogen, oxygen, and nitrogen act the same chemically, but the proportions of these isotopes in the environment can change (fractionate) in response to chemical reactions or kinetic processes. Stable isotope results are reported as a ratio of the lighter isotope to the heavier isotope (e.g., hydrogen-1/hydrogen-2; nitrogen-14/nitrogen-15; or oxygen-16/oxygen-18) compared to a standard and denoted as delta (δ)^{2}H, ^{15}N, or ^{18}O per mil (‰). Generally, chemical bonds between the lighter isotopes require less energy to break than for heaver isotopes.

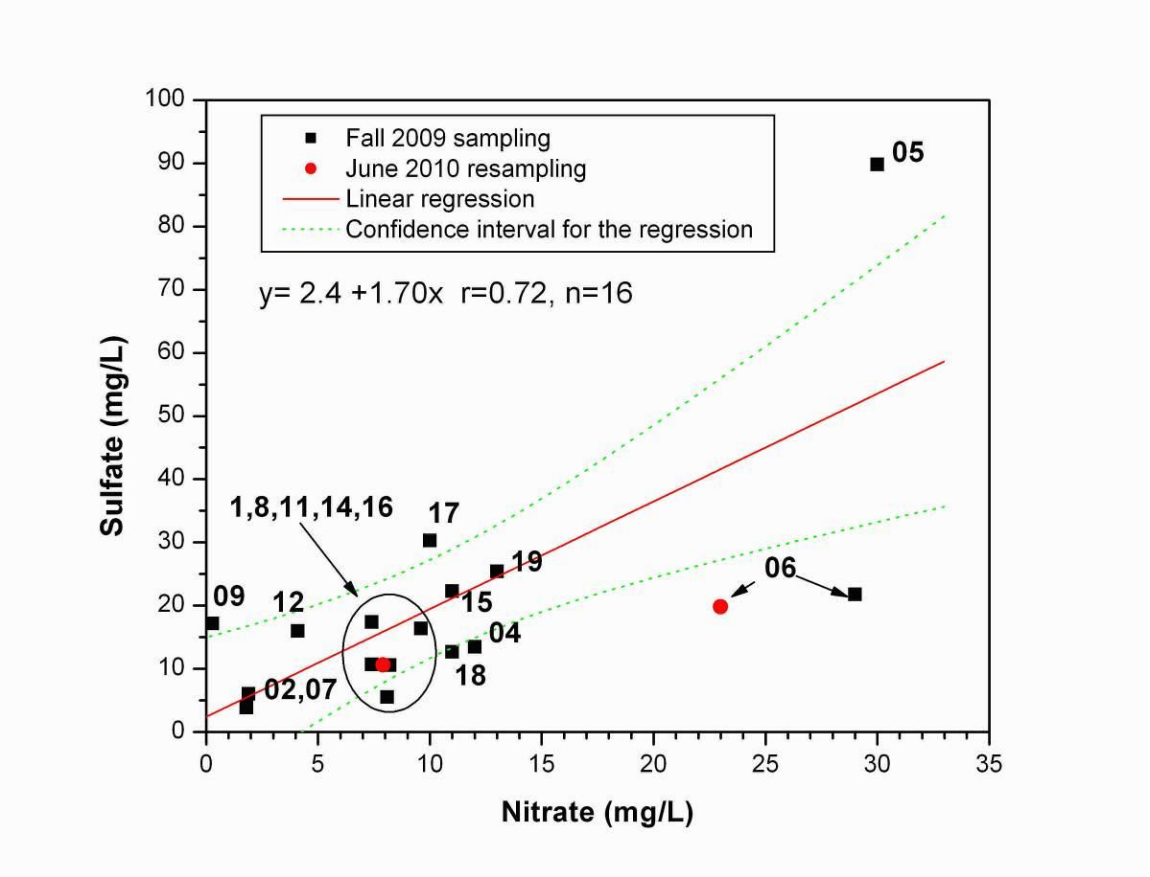


Figure 9. Nitrate versus sulfate, Ashton-Drummond sampling.

Likewise, molecules with lighter isotopes require less energy to effect a phase change and are typically favored by biological systems and physical processes. With this known, stable isotopes can provide insight but must be interpreted in the greater context of ground water chemistry and hydrogeology (Kendall and McDonnell 1998).

Hydrogen and Oxygen Isotopes

A combination of climatic and geographic factors result in a relationship of δ^2H and $\delta^{18}O$ measured relative to Vienna Standard Mean Ocean Water (VSMOW) for precipitation for a region, characterized by the local meteoric water line (LMWL). This characteristic LMWL was determined using a combination of factors that include mean annual temperature, elevation, typical storm tracts, and humidity, both in the area where the precipitation originally evaporated and where the precipitation fell as snow or rain (Clark and Fritz 1997). Evaporation can modify the δ^2H–$\delta^{18}O$ relationship, resulting in the evaporated water being depleted in the lighter isotopes and becoming enriched (less negative) in the heavier isotopes. This evaporation signature in recharge can be observed for ground water of the ESRP aquifer, defining the southeastern Idaho meteoric water line (MWL) with a lesser slope than the LMWL. Figure 10 includes regional winter and summer precipitation used to calculate the southeastern Idaho LMWL (Benjamin et al. 2004); ESRP ground water samples from Wood and Low (1988); and the samples collected in this study.

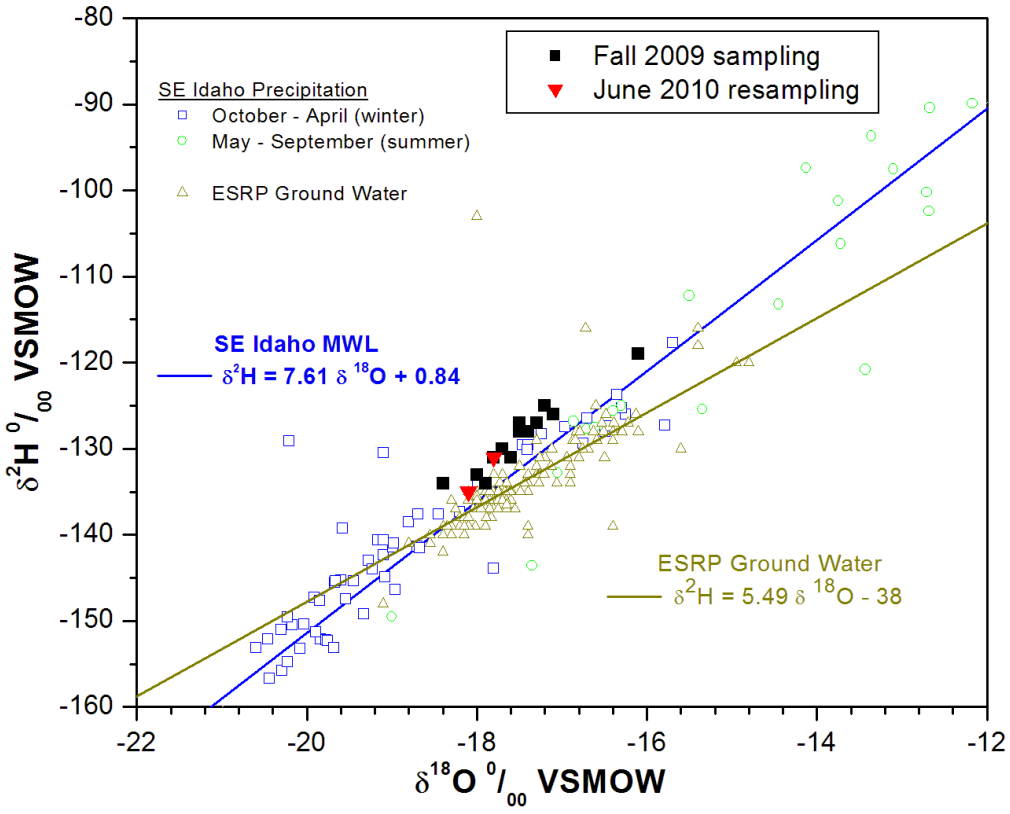


Figure 10. Stable oxygen and hydrogen composition for ground water, Ashton-Drummond sampling compared with local, seasonal precipitation and ESRP ground water.

Isotopic signatures of δ^2H and $\delta^{18}O$ for ground water samples from the Ashton-Drummond area ranged from -134 to -136‰ and -18.4 to -17.1‰, respectively. Results for δ^2H and $\delta^{18}O$ tended to plot more like southeastern Idaho winter precipitation than either the summer precipitation or ESRP ground water, suggesting that most ground water recharge for the Ashton-Drummond region likely occurs during times when evaporation is minimal. The recharge source is likely from spring snowmelt, or spring precipitation, prior to significant evapotranspiration (Benjamin et al. 2004; Cecil et al. 2005). Due to mixing of hydrogen and oxygen isotopes and vapor exchange within the melting snowpack, snowmelt recharge is slightly enriched from the original snowpack and represents more of an average isotopic signature for the recharge (Clark and Fritz 1997). This snowmelt signature is significant in that recharge is likely minimal during the irrigation season.

Nitrogen Isotopes

Nitrogen in the environment is an essential nutrient for common biological systems and comes from a variety of sources. Analysis of dissolved nitrogen species, considered in the context of other geochemical information, can provide clues to the primary sources of nitrogen to ground water. Chemical, kinetic, and biological processes (which can be a combination of chemical and

kinetic) occurring in the nitrogen cycle can work together to change the chemical form and the isotopic signature of nitrogen in ground water. The processes include mineralization where nitrogen from living sources (organic nitrogen) is converted to ammonia; nitrification where ammonia is converted to nitrate; and denitrification where the nitrate is converted to nitrogen gas. Ammonia can also volatilize and be lost to the atmosphere as a gas. All of these processes can modify both the nitrate concentration and the ranges of $\delta^{15}N$ observed for ground water (Kendall and McDonnell 1998).

The major sources of nitrogen for the Ashton-Drummond area include commercial fertilizer, leaching of organic nitrogen from soils, and waste sources from septic systems and CAFOs. Heaton (1986) presents ranges in isotopic signatures for nitrogen sources (Figure 11). The ranges themselves need to be interpreted in light of the available hydrochemical information, including the availability and isotopic signature of the accompanying oxygen, as well as other characteristic chemical components (Seiler 1996). Nitrogen isotope values ($\delta^{15}N$) from potential sources such as precipitation can have a broad range but are more typically from -3‰; inorganic, commercial fertilizer, -4 to +4 or +5‰; organic sources in soil, +4 or +5 to +9‰; and animal or human waste, greater than +9‰. Values for $\delta^{15}N$ for this project ranged from 4.8‰ to 12.5‰ with a median of 6.6‰. A histogram of the isotopic values is presented in Figure 12, and isotopic values are related to nitrate concentrations as shown in Figure 13. Results from three sites fell within the range more typical for waste sources (Ashton09-05, 06, and 09) and four fell within the range typical for an inorganic fertilizer source (Ashton09-01, 12, 14, and18). The remaining 10 sites were within the mixed/organic range. For the two sites resampled, Ashton09-06 was 9.1‰ for the initial sample and 8.8‰ for the resample. Ashton09-01 was 6.6‰ for the initial sample and 5.0‰ for the follow-up sample.

Field parameter results of three sampling locations, Ashton09-09, 05, and 08, indicated anoxic conditions in the ground water. Ashton09-09 at 12.5‰ $\delta^{15}N$, 0.63 mg/L dissolved oxygen, and a low nitrate concentration (0.28 mg/L) might be influenced by the denitrification process. Ashton09-05 had elevated nitrate concentrations (30 mg/L), 9.5‰ $\delta^{15}N$, and low dissolved oxygen. Additional factors potentially impacting this well are known liquid fertilizer spills nearby; high sulfate relative to chloride; and high nitrate concentrations. The geochemistry at this site suggests the ground water may be undergoing denitrification to explain the "waste-like" nitrogen isotopic signature.

The third location, Ashton09-08, has a mixed nitrogen source signature based on nitrogen isotope values but a high chloride-to-sulfate ratio indicative of a waste-related influence. More definitive confirmation that the shift in $\delta^{15}N$ values is related to denitrification can be gained by analyzing the $\delta^{18}O$ of the nitrate/nitrite/ammonium from the sample (Kendall et al. 1998, Clark and Fritz 1997). The $\delta^{18}O$ results reported here represent the $\delta^{18}O$ from the water molecule in ground water and not the oxygen of the nitrate molecule in the ground water.

Ashton09-06 yielded a waste signature based on $\delta^{15}N$ (9.1‰ and 8.8‰) and high nitrates (29 mg/L and 23 mg/L). This site did not have the same clear waste signature based on the chloride-to-sulfate ratio like Ashton09-08 and 09, but chloride was elevated relative to the sulfate-to-chloride ratio (Figure 8). A mixed source, waste and fertilizer, may provide an explanation for nitrate concentrations at this site.

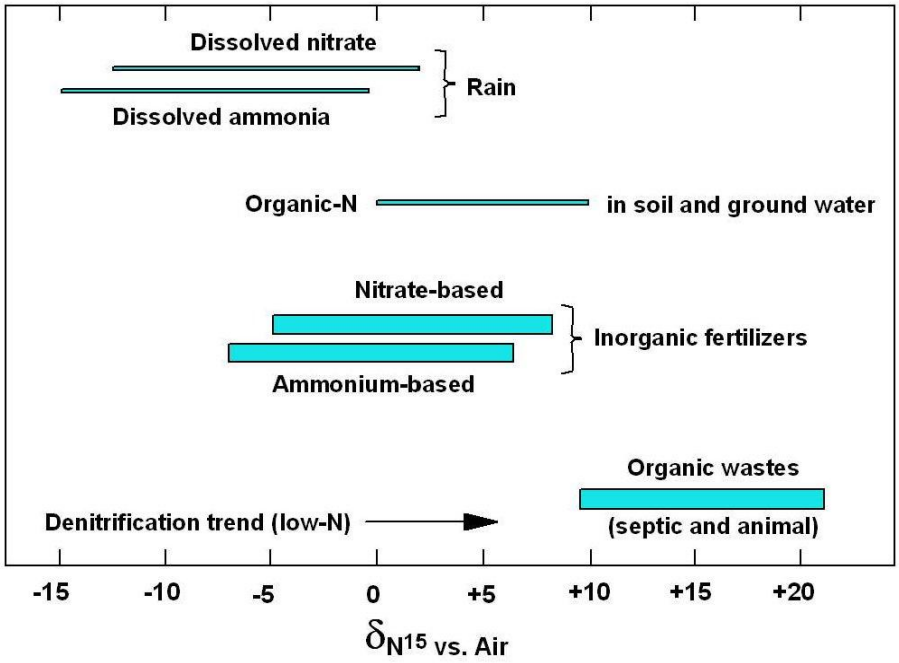


Figure 11. Range of nitrogen isotopic ratios characteristic of common nitrate sources (Heaton 1986), as presented by the Welhan and Poulson (2009). Bar thickness indicates the relative nitrate concentration typical of these sources.

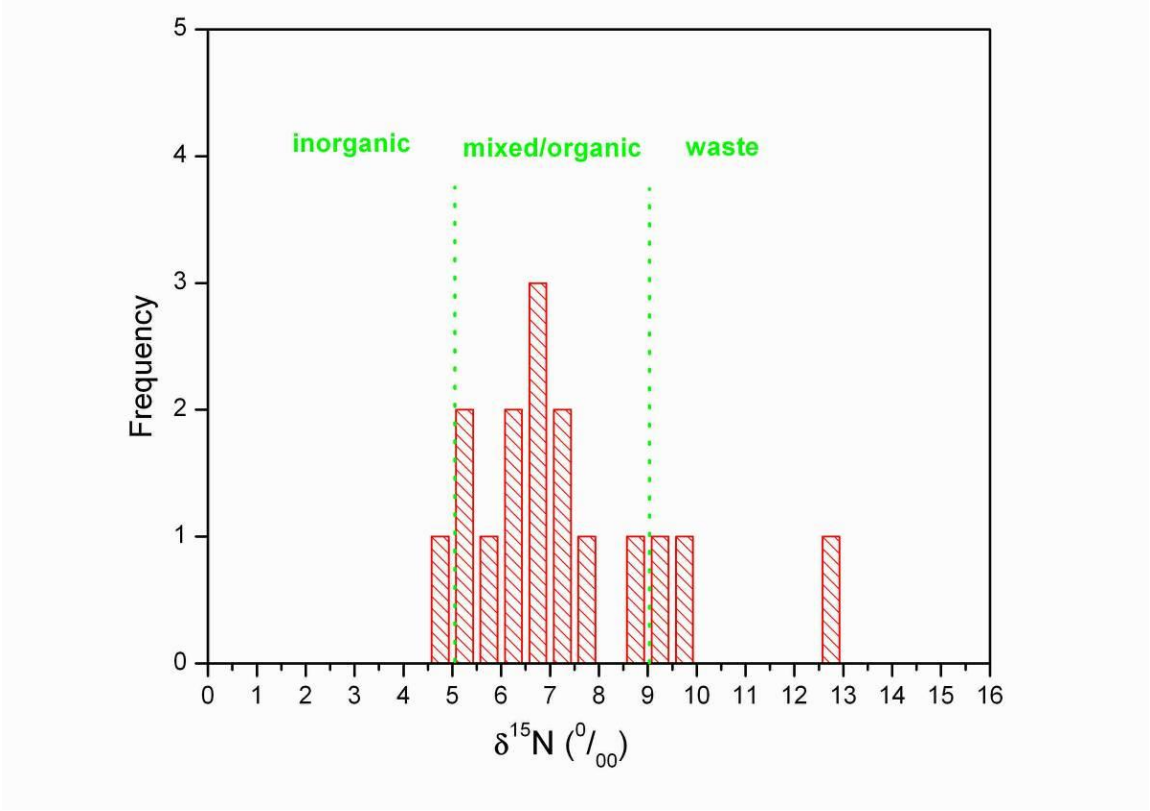


Figure 12. Histogram of stable nitrogen isotope values for samples collected.

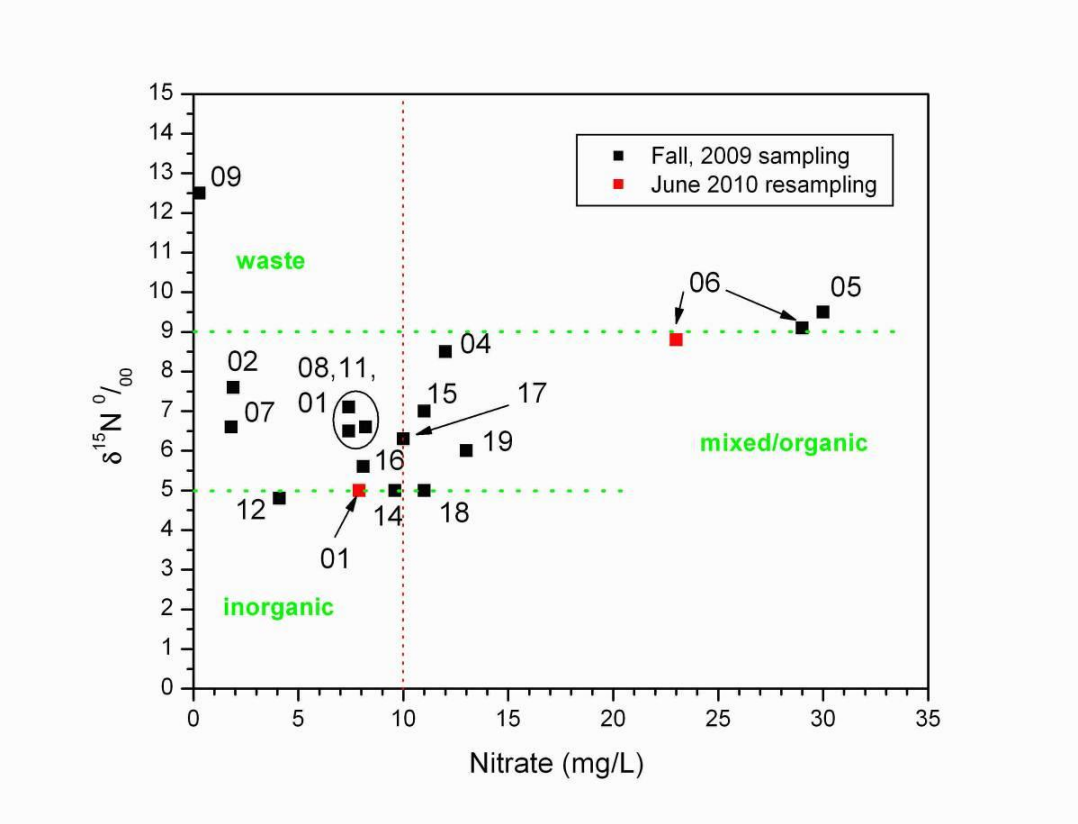


Figure 13. Stable nitrogen isotope values relative to nitrate concentrations. The 10 mg/L MCL is indicated on the graph by the red line.

Tritium

Tritium is a relatively short-lived radionuclide (12.43 year half-life) that occurs naturally and from human-made sources. This radionuclide can be used to provide a relative age for the ground water. Natural production of tritium is due primarily to cosmic ray interactions in the upper atmosphere. The tritium formed becomes part of a water molecule and falls as snow, rain, or atmospheric moisture. The predominant anthropogenic source of tritium is the "bomb-pulse" that resulted from atmospheric testing of thermonuclear weapons in the 1950s and 1960s. Most of this anthropogenic source has decayed away, with atmospheric levels approaching natural production rates. Current anthropogenic sources include nuclear reactors and illumination sources. Tritium concentration in precipitation has been shown to vary from season to season and with latitude due to atmospheric mechanisms. Tritium levels for modern precipitation should range from about 15 to 45 picocuries per liter (pCi/L) (Clark and Fritz 1997). Tritium results are presented with an error term representing two times the sample counting uncertainty, usually referred to as "2s uncertainty." This 2s error term represents a 95% confidence interval for the result.

Tritium was detectable in all samples. Results ranged from 15 ± 6 to 41 ± 6 pCi/L with a median of 22 ± 6 pCi/L. The tritium results indicate that the ground water for all sites has undergone recent recharge, within the last 5–10 years. Based on the relative ground water age and date, recharge for Ashton09-19, 15, 18, and 05, in that order, are likely the youngest at probably just a few years old. Recharge for Ashton09-09 is likely the oldest at more than 10 years (about

1 tritium half-life). Tritium concentrations relative to nitrates are presented in Figure 14. Tritium concentrations for most sites are indistinguishable (at the 95% confidence interval). Age of recharge does not appear to correlate with nitrate concentrations or distinct nitrate sources.

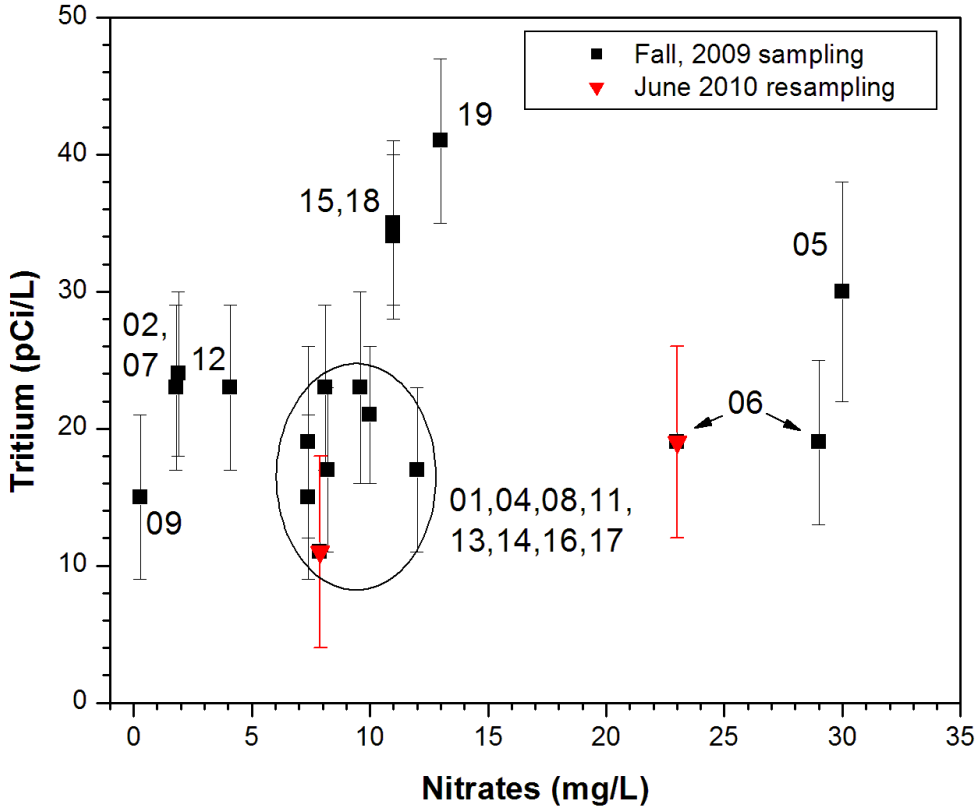


Figure 14. Tritium versus nitrate concentrations for Ashton-Drummond sites. Tritium error bars are ± 2 times the sample counting uncertainty.

5. Conclusions

The intent of this sampling was to provide information to private well owners with elevated nitrates in the Ashton-Drummond NPA. Specific areas were identified to draw sample locations from, but sites were not screened for availability of well construction information prior to sampling. As a result, water level, well construction, and hydrogeology were not available for all locations. Site selection was "biased" by availability and interest of the home owner. Site selection was also biased to sites where nitrate concentrations were known or suspected to be at or above 10 mg/L. While the resulting distribution of sites sampled did provide areal coverage of the NPA, statistical conclusions based on the results should not be considered valid for estimating the distribution of water quality across the region.

The observations that can be drawn from the sites sampled are valid in that they can be considered to represent a range of conditions "typical" for impacted sites. These observations are thus appropriate for guiding responses to individual well owners and general education efforts in the area.

Observations

1. Wellhead conditions were not an indicator of nitrate concentrations; however, there is a relationship between bacteria detections and wellheads in need of maintenance. Not all wells located within pits returned bacteria detections, and likewise, not all "older" wells or well houses that included other materials (e.g., hoses, buckets) stored at the wellhead returned bacteria detections. Wells that appeared to be properly maintained did not have these bacteria detections.

   Implication: proper wellhead maintenance can help reduce the potential for bacterial contamination for private domestic wells.

2. The nitrate screening test was a reasonable predictor of actual nitrate concentrations for a sampled site. There is some subjectivity in interpreting the colorimetric change of the test strip, and there could possibly be some interferences; however, no site indicated as <10 mg/L based on the test strip returned nitrate results >10 mg/L.

   Implication: nitrate test strips are an adequate screening tool, and in general, a qualitative estimate of nitrate concentration is a good predictor of actual nitrate concentrations.

3. Sites with nitrates >10 mg/L are not clearly associated with well construction, depth to ground water, aquifer material, or subregion within the NPA. Wells with elevated nitrate concentrations can be found near sites with relatively low nitrate concentrations.

   a. Implication: elevated nitrate impacts may be both regional, across the NPA, as well as associated with sources more local to the well.
   b. Implication: local variations in hydrogeology can be a factor in the nitrate concentrations observed.

4. Stable oxygen and hydrogen results do not have a significant evaporative signature. Tritium results suggest that ground water is relatively young, recharged within the last 5 to 10 years.

   a. Implication: recharge occurs primarily during times of minimal evaporation in the spring with snowmelt or in the fall after the growing season.

   b. Implication: recharge is relatively local to the wells sampled.

   c. Implication: ground water ages are relatively young and flow paths short based on the tritium signatures.

5. The ratio of sulfate to chloride and the relative concentrations of sulfate and chloride can aid in distinguishing possible nitrate sources (i.e., elevated sulfate related to fertilizer sources and elevated chloride related to waste sources).

   a. Implication: sites with the highest sulfate concentrations tended to have the highest nitrate concentrations.
   b. Implication: the ratio of sulfate to chloride relative to the chloride concentration allows for a distinction between sites and potential nitrate sources. Elevated sulfate indicates primarily a fertilizer source, and chloride indicates a potentially waste-related source.

6. Nitrogen isotope signatures suggest a mixed organic source for most sites, with a few primarily inorganic and a few possibly waste-related sources. Combining stable isotope

signatures with field parameter measurements and sulfate and chloride concentrations indicates that secondary processes could potentially modify the observed signatures. Figure 15 presents a summary of the primary nitrate source for the sites sampled, given the combination of data available. Three sites, Ashton09-06, 08, and 09, show a primarily waste signature; Ashton09-01, 05, 17,18, and 19 show a primarily inorganic fertilizer source; and the remaining sites show a mixed or organic source.

a. Implication: the primary source of nitrates for the NPA is likely related to over application of inorganic fertilizer.
b. Implication: secondary processes resulting in elevated nitrates in ground water; such as demineralization of organic nitrates by growing crops, with remaining nitrates flushed past the root zone after the growing season due to infiltrating winter precipitation or spring snow melt.
c. Implication: some sites may have mixed organic and waste sources; denitrification may be a factor in observed nitrogen-isotopic signature.

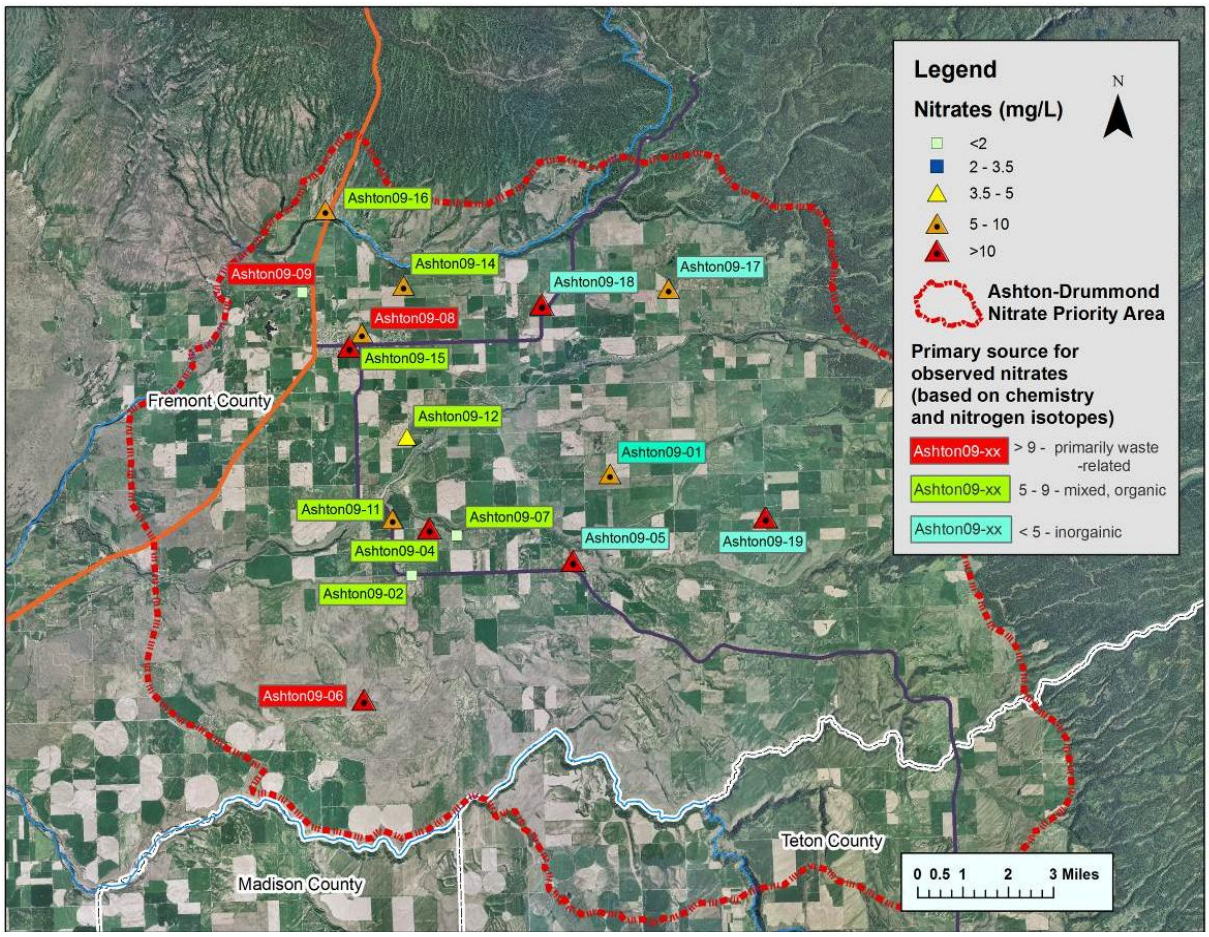


Figure 15. Primary source for nitrates based on nitrogen-isotopic signature, water chemistry, and site history.

6. Recommendations

Monitoring to identify trends in nitrates in response to changes in agricultural practices and to climate variations is needed and should be continued. This monitoring must be followed up with nitrate education for rural residents to understand the risks resulting from the high nitrate levels and to encourage them to reduce the risks by changing their agricultural practices and properly maintaining private wellheads and septic systems.

Fremont County and the Yellowstone Soil Conservation District should be encouraged to partner with the city of Ashton and local residents and groups interested in local water quality, such as the Henry's Fork Foundation and Friends of the Teton River, to further these education efforts.

Residents within the Ashton-Drummond NPA are aware of elevated nitrates in the region and are receptive to learning ways to reduce the impacts to ground water quality. The biggest impact could be made by encouraging local partnership/ownership of education in at least three areas: wellhead and septic system maintenance, climate and soil condition based nutrient management, and land use planning. Further recommendations are described below:

- Continue or reestablish regular monitoring for nitrates and common ions beyond just the few sites monitored by the IDWR statewide monitoring network.
- Provide education for wellhead and septic system maintenance and nutrient management, with suggestions for reducing potential nitrate leaching following the irrigation season.
- Encourage education and awareness in the schools.
- Encourage Fremont County to develop or include wellhead protection in its land use planning.
- Encourage interested parties to participate in the ground water quality management plan process, raising an active local planning team to implement BMPs in the Ashton-Drummond NPA.

References

Benjamin, L., L. L. Knobel, L. F. Hall, L. D. Cecil, and J. R. Green. 2004. *Development of a Local Meteoric Water Line for Southeastern Idaho, Western Wyoming, and South-central Montana*. US Geological Survey Scientific Investigations Report 2004-5126.

Brown and Caldwell. 1993. *City of Drummond Groundwater Quality Information Review*.

Brown and Caldwell. 1994. *J.R. Simplot Company Soilbuilders Facility, Drummond, Idaho*. Brown and Caldwell, unpublished report on file in the Boise office of the US Geological Survey.

Cecil, L. D., L. F. Hall, L. Benjamin, L. L. Knobel, and J. R. Green. 2005. "Comparison of Local Meteoric Water Lines for Southeastern Idaho, Western Wyoming, and South-Central Montana." *Journal of the Idaho Academy of Science* 41(2):13-28.

City of Ashton, 2002, *City of Ashton Drinking Water Protection Plan, PWS–7220004,* May 2002.

Clark, I. D., and P. Fritz. 1997. *Environmental Isotopes in Hydrogeology*. New York: Lewis Publishers.

Dallas, K., R. Carlson and J. Atlakson. 2008. *Ground Water Quality of Middle Henrys Fork Basin, Regional Monitoring Project, 2003-2007*. Boise, ID: Idaho State Department of Agriculture, Division of Agricultural Resources. ISDA Technical Results Summary #39.

DEQ (Idaho Department of Environmental Quality). 2001. *Groundwater Quality Investigation and Wellhead Protection Study, City of Ashton, Idaho*. Idaho Department of Environmental Quality Ground Water Quality Technical Report Series No. 15.

DEQ (Idaho Department of Environmental Quality). 2008. *Nitrate Priority Area Delineation and Ranking Process.* Boise, ID: DEQ.

DEQ (Idaho Department of Environmental Quality). 2009. *Ashton-Drummond Nitrate Follow-up Ground Water Sampling Quality Assurance Project Plan*. Boise, ID: DEQ.

Harmon, C. 1961. "Isotopic Variations in Meteoric Waters." *Science* 133(3465):1,702–1,703.

Heaton, T. H. E. 1986. "Isotopic Studies of Nitrogen Pollution in the Hydrosphere and Atmosphere: A Review." *Chemical Geology* (Isotope Geosciences Section) 59: 87–102.

Jorgensen Engineering and Land Surveying P.C. 2000. *City of Ashton: Water Supply System Nitrate Mitigation Study.* Unpublished report. Jackson, WY.

Kendall, C., and J. J. McDonnell, eds. 1998. *Isotope Tracers in Catchment Hydrology*. Amsterdam: Elsevier Science Publishers.

Martin, M. J., A. H. Whylie, and B. R. Otto. 2003. *Hydrogeologic Analysis of the Water Supply for Ashton, Fremont County, Idaho-Draft.* Boise, ID: Idaho Water Resources Research Institute.

Schorzman, K., and J. Baldwin. 2009. *Nitrate and Emerging Contaminants Evaluation of Springdale, Idaho: Cassia County Nitrate Priority Area, Idaho*. Boise, ID: Idaho Department of Environmental Quality. Ground Water Quality Technical Report Series No. 38.

Seiler, R. L. 1996. *Methods for Identifying Sources of Nitrogen Contamination of Ground Water in Valleys in Washoe County, Nevada*. Carson City, NV: US Geological Survey. Open File Report 96-461.

Van Kirk, R. W. 2010. *Conservation of Surface and Ground Water in a Western Watershed Experiencing Rapid Loss of Irrigated Agricultural Land to Development*. A Proposal to the Integrated Research, Education, and Extension Competitive Grants Program—National Integrated Water Quality Program (NIWQP). US Department of Agriculture, Cooperative State Research, Education, and Extension Service. Department of Mathematics and Environmental Systems Graduate Program. Arcata, CA: Humboldt State University.

Welhan, J. A., and N. Poulson. 2009. *Sources of Nitrate Contamination in Ground Water of Pleasant Valley, Power County, Idaho, Final Report*. Moscow, ID: University of Idaho, Idaho Geological Survey, Department of Geosciences. Idaho Department of Environmental Quality Contract #C654.

Whitehead, R. L. 1978. *Water Resources of the Upper Henrys Fork Basin in Eastern Idaho.* Idaho Department of Water Resources. Water Information Bulletin No. 46.

Whitehead, R. L. 1992. *Geohydrologic Framework of the Snake River Plain Regional Aquifer System, Idaho and Eastern Oregon*. US Geological Survey Professional Paper 1408-B.

Wood, W. W., and W. H. Low. 1988. *Solute Geochemistry of the Snake River Plain Regional Aquifer System, Idaho and Eastern Oregon.* US Geological Survey Professional Paper 1408-D. 79.

WRCC (Western Regional Climate Center). 2010. *Western U.S. Historical Summary for Ashton, Idaho. (100470).* Record period February 2, 1897–December 31, 2009. Available at http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?id0470.

Yellowstone Soil Conservation District. 2008. *Ashton Groundwater Protection Project–Final Report.* St Anthony, Idaho. January.

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Appendix A—Follow-up Sampling for Bacteria, Nitrates, Major Ions, Stable Isotopes, and Tritium 2009–2010: Ashton-Drummond Nitrate Priority Area

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Table A-1. Major ions: Ashton-Drummond nitrate follow-up sampling, 2009-2010.

Well Name	Sample Date	Major Ion Concentration (mg/L)								
		Calcium Total	Magnesium Total	Sodium Total	Potassium Total	Chloride Total	Sulfate (as SO_4) Total	Fluoride Total	Alkalinity (as $CaCO_3$) Total	Total Dissolved Solids
Ashton09-01	11/2/2009	58	20	12	2.1	5.00	10.6	0.691	211	290
Ashton09-01	6/15/2010	61	20	12	2.2	5.47	10.5	0.583	210	310
Ashton09-02	11/2/2009	43	44	12	1.2	2.79	6.02	0.843	302	310
Ashton09-04	11/2/2009	52	26	10	1.3	9.68	13.5	0.578	199	320
Ashton09-05	11/9/2009	87	45	13	3.2	9.69	89.8	0.457	228	550
Ashton09-06	11/9/2009	94	30	13	3.2	17.2	21.8	0.377	241	470
Ashton09-06	6/15/2010	90	28	12	3.0	14.6	19.8	0.228	239	460
Ashton09-07	11/9/2009	42	16	6.1	1.7	1.94	3.86	0.470	176	200
Ashton09-08	11/9/2009	61	32	36	2.4	31.7	17.4	0.774	272	410
Ashton09-09	11/9/2009	90	21	44	5.9	78.5	17.2	1.51	306	540
Ashton09-11	11/17/2009	71	41	22	2.4	9.84	10.7	0.815	364	350
Ashton09-12	11/17/2009	48	10	19	1.9	9.79	16	1.27	169	300
Ashton09-14	11/17/2009	56	15	16	1.4	12.0	16.4	0.440	177	350
Ashton09-15	11/17/2009	61	17	22	3.8	14.9	22.3	1.02	194	380
Ashton09-16	11/17/2009	27	9.5	12	2.5	4.58	5.5	0.577	100	230
Ashton09-17	11/17/2009	87	32	17	2.4	6.82	30.3	0.304	307	460
Ashton09-18	11/18/2009	64	26	8	1.5	4.69	12.7	0.280	222	360
Ashton09-19	12/1/2009	72	25	6.4	1.4	1.73	25.4	0.360	228	360

Table A-2. Nitrates, total phosphorus, bacteria, and stable isotopes: Ashton-Drummond follow-up sampling, 2009-2010.

Well Name	Sample Date	Nutrient Concentration (mg/L)			Bacteria Concentration (colonies/mL)		Isotopic Ratio (‰)		
		Nitrate Screening	Total NO_2 + NO_3 as N	Total Phosphorus as P	Coliform Total	*E. coli*	$\delta^{15}N$	$\delta^{18}O$	$\delta^{2}H$
Ashton09-01	11/2/2009	>10	8.2	0.071	ND	ND	6.6	-18.4	-134
Ashton09-01	6/15/2010	5–10	7.9	0.070	—	—	5	-18.1	-135
Ashton09-02	11/2/2009	<2	1.9	0.064	13.4	ND	7.6	-17.1	-126
Ashton09-04	11/2/2009	10	12	0.052	ND	ND	8.5	-17.8	-131
Ashton09-05	11/9/2009	>10	30	0.063	ND	ND	9.5	-17.8	-131
Ashton09-06	11/9/2009	10	29	0.069	ND	ND	9.1	-17.9	-134
Ashton09-06	6/15/2010	>10	23	0.068	—	—	8.8	-17.8	-131
Ashton09-07	11/9/2009	2–5	1.8	0.110	11	ND	6.6	-17.7	-130
Ashton09-08	11/9/2009	10	7.4	0.066	ND	ND	7.1	-17.2	-125
Ashton09-09	11/9/2009	<2	0.28	0.020	3.1	ND	12.5	-17.5	-128
Ashton09-11	11/17/2009	5–10	7.4	0.056	ND	ND	6.5	-17.3	-127
Ashton09-12	11/17/2009	5–10	4.1	0.140	ND	ND	5	-17.4	-128
Ashton09-14	11/17/2009	10	9.6	0.072	2	ND	4.8	-17.4	-128
Ashton09-15	11/17/2009	10	11	0.057	ND	ND	7	-17.5	-128
Ashton09-16	11/17/2009	5–10	8.1	0.072	ND	ND	5.6	-17.6	-131
Ashton09-17	11/17/2009	10	10	0.100	ND	ND	6.3	-17.5	-127
Ashton09-18	11/18/2009	10	11	0.074	ND	ND	5	-17.7	-130
Ashton09-19	12/1/2009	>10	13	0.082	ND	ND	6	-18	-133

Note: ND indicates analyte not detected. A dash (—) indicates no data available.

Table A-3. Environmental -level tritium: Ashton-Drummond follow-up sampling, 2009-2010.

Well_Name	Sample Date	Tritium	
		pCi/L	± 2s
Ashton09-01	11/2/2009	17	6
Ashton09-01	6/15/2010	20	10
Ashton09-02	11/2/2009	24	6
Ashton09-04	11/2/2009	17	6
Ashton09-05	11/9/2009	30	8
Ashton09-06	11/9/2009	19	6
Ashton09-06	6/15/2010	28	9
Ashton09-07	11/9/2009	23	6
Ashton09-08	11/9/2009	15	6
Ashton09-09	11/9/2009	15	6
Ashton09-11	11/17/2009	19	7
Ashton09-12	11/17/2009	23	6
Ashton09-14	11/17/2009	23	7
Ashton09-15	11/17/2009	34	6
Ashton09-16	11/17/2009	23	6
Ashton09-17	11/17/2009	21	5
Ashton09-18	11/18/2009	35	6
Ashton09-19	12/1/2009	41	6

Table A-4. Field parameters: Ashton-Drummond follow-up-sampling, 2009-2010.

Well Name	Sample Date	Water Temperature (°C)	Specific Conductance (µS/cm)	pH	Dissolved Oxygen (mg/L)	Air Temperature (°C)	Water Level (ft bls)[a]
Ashton09-01	11/02/09	10.19	522	8.26	7.17	10.2	179
Ashton09-01	06/15/10	9.51	475	7.70	6.61	—	—
Ashton09-02	11/02/09	9.58	624	8.25	7.87	—	—
Ashton09-04	11/02/09	10.82	540	8.21	9.90	—	83
Ashton09-05	11/09/09	10.69	900	7.95	3.58	—	—
Ashton09-06	11/09/09	9.53	805	8.03	9.82	—	—
Ashton09-06	06/15/10	10.71	698	7.14	8.24	—	—
Ashton09-07	11/09/09	11.12	381	8.14	9.04	—	—
Ashton09-08	11/09/09	10.42	742	8.09	5.32	—	25
Ashton09-09	11/09/09	9.44	860	8.14	0.63	—	5
Ashton09-11	11/17/09	12.00	—	7.09	—	—	—
Ashton09-12	11/17/09	12.50	384	7.56	—	—	56
Ashton09-13	11/17/09	13.10	354	7.81	—	—	—
Ashton09-14	11/17/09	12.80	438	7.92	—	—	—
Ashton09-15	11/17/09	13.20	501	7.39	—	—	—
Ashton09-16	11/17/09	12.80	265	7.10	—	—	110
Ashton09-17	11/17/09	10.10	703	7.58	—	—	—
Ashton09-18	11/18/09	11.40	472	8.06	—	—	—
Ashton09-19	12/01/09	10.60	529	7.81	—	—	70

Note: Dash (—) indicates no data available.
a. Feet below land surface