Idaho State Department of Agriculture
Division of Agricultural Resources

Ground Water Nitrate Monitoring In Cassia County, Idaho 2002 Isotope Data Update

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ISDA Technical Results Summary #17 August 2003

Introduction

The Idaho State Department of Agriculture (ISDA) developed the Regional Agricultural Ground Water Quality Monitoring Program to characterize degradation of ground water quality by contaminants leaching from agricultural sources. The ISDA currently is conducting follow-up monitoring at dairy wells with previous nitrate levels above 10 milligrams per liter (mg/L) in Idaho, including a project in Cassia County (Figure 1). The objectives of the monitoring are to: (1) characterize ground water quality, primarily related to nitrate-nitrogen (NO_3-N), (2) relate data to agricultural land use practices, and (3) provide data to support Best Management Practices (BMP) and/or regulatory decision making and evaluation processes.

The ISDA Cassia County dairy monitoring project began in 2000 as a result of previous monitoring by the ISDA Dairy Bureau. Nine of twelve and four of twelve dairy wells in the area exceeded the Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL) of 10 mg/L for nitrate in 2000 and 2002, respectively. To establish this project, ISDA selected adjacent domestic wells in the area for testing and re-tested the dairy wells.

Nutrients, common ions, and isotopes were evaluated during ISDA's testing. Laboratory results indicated that numerous wells located south of Burley have NO_3-N levels that suggest some type of land use influence on ground water quality. ISDA is currently working to advise residents and officials of the area on how to minimize further ground water contamination and possible health risks. Monitoring results and evaluations of nitrate sources will assist in recommendations for dairy and farm improvements for ground water protection.

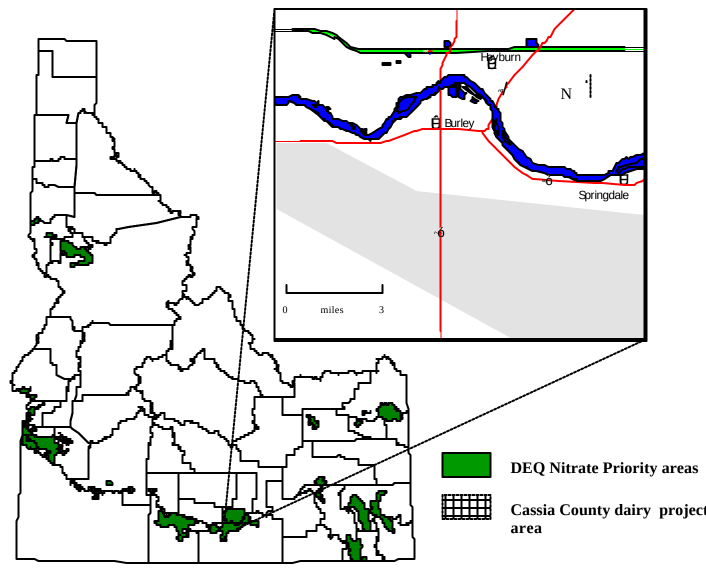


Figure 1. Location of Cassia County dairy monitoring project and other ISDA regional project areas.

Description of Project Area

The Cassia County dairy monitoring project encompasses an approximately 6 mile wide by 12 mile long area of livestock operations and irrigated agricultural land adjacent to the Snake River (Figure 1). The main sources of water for irrigation include diversions from the Snake River, local runoff, and deep wells (Maxwell, 1981). Sprinkler irrigation is the primary local irrigation method. Major crops in the area include alfalfa hay, sugar beets, potatoes, corn, wheat, barley, beans, and oats (Gerhardt, et. al., 2000). Eleven of the twelve dairies sampled in 2000 and 2002 reside in the sampling area of Figure 1. The eleven dairies within the sampling area hold less than 600 animal units each. The dairy not located in the sampling area is approximately twelve miles northeast of Springdale, across highway I-84.

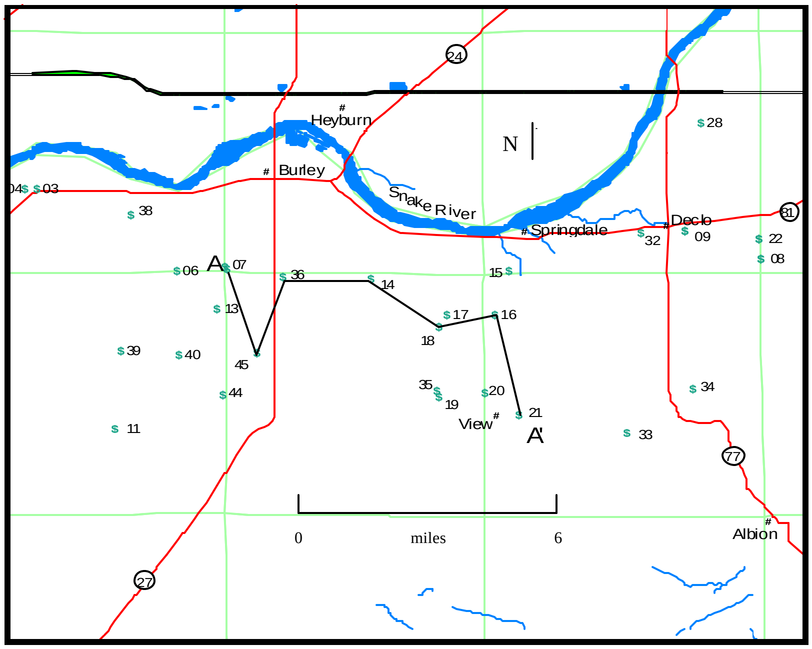


Figure 2. Location of wells sampled by ISDA and cross-section line from previous Cassia County regional study.

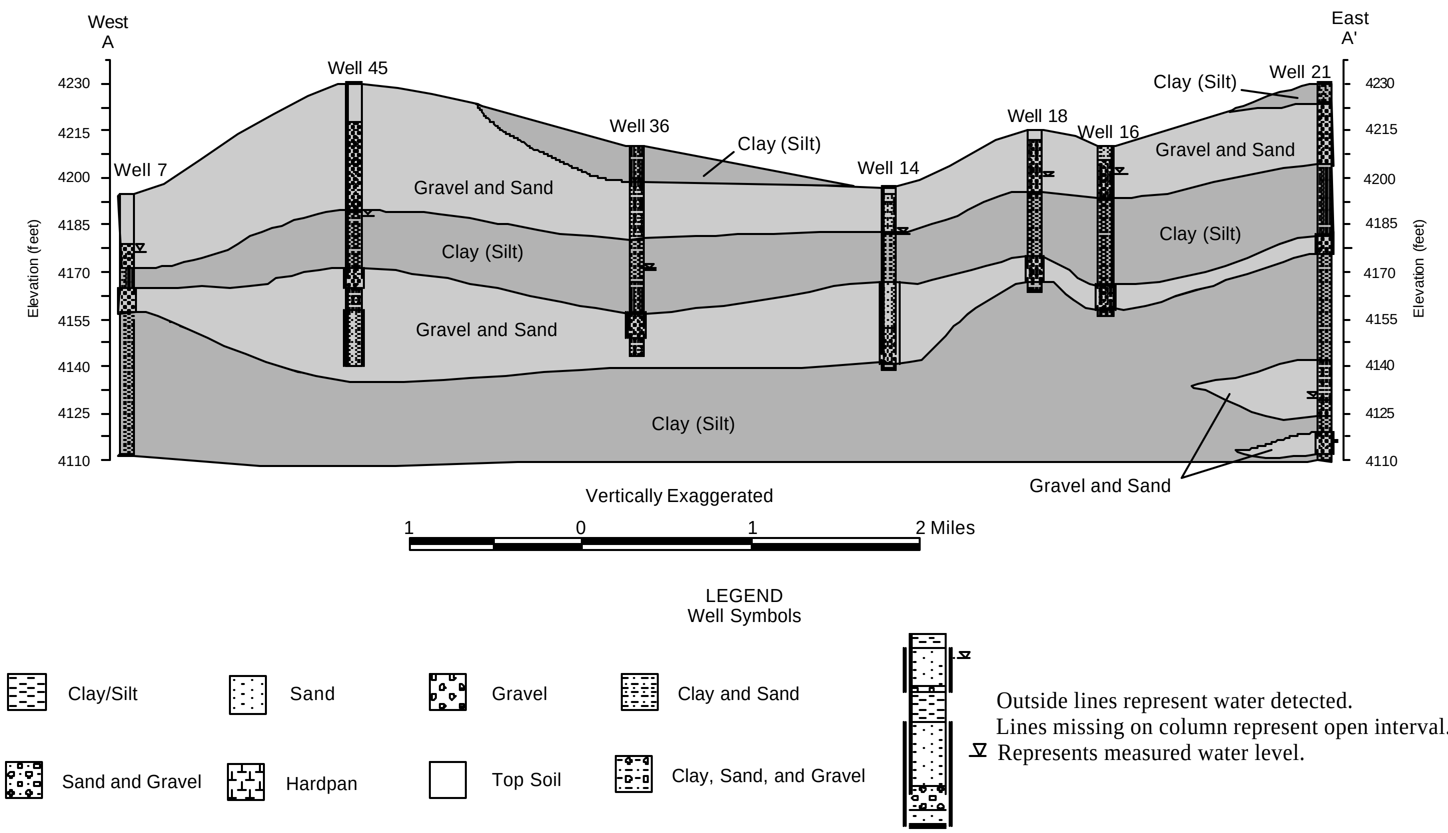


Figure 3. Cross section of shallow aquifer in Cassia County monitoring area. See Figure 2 for cross section location.

The hydrogeology of Cassia County consists of an upper aquifer composed of alluvial deposits (Figures 2 and 3) overlying a lower aquifer composed of fractured basalt. Based on well drillers' reports from domestic wells in the project area, typical depth to ground water is less than 50 feet below ground level in the upper aquifer and over 150 feet below ground level in the lower aquifer. The shallow aquifer is composed of alluvial deposits, mainly sand and gravel, with a few thin interbedded clay layers.

The shallow subsurface alluvial deposits are conducive to leaching of contaminants. Potential sources for nitrate leaching to the ground water in the area include applied nitrogen-based fertilizers, septic systems, cattle manure, legume crops, and wastewater lagoons. A potential source of recharge to this shallow system is applied irrigation waters. Ground water flow direction in the sampling area varies (Figure 4). The extent of interaction of the Goose Creek-Golden Valley and Marsh Valley aquifers with the Snake River is unreported. Ground water flow in the southern part of Minidoka County, near the Snake River, displays a "… complex pattern … because of recharge from the shallow, perched irrigation-induced alluvial aquifer in the Minidoka Irrigation District" (Minidoka Soil and Water Conservation District, 1996).

Results

Sampling results indicate NO_3-N impacts have occurred to the aquifer. Results are summarized and presented in the following sections.

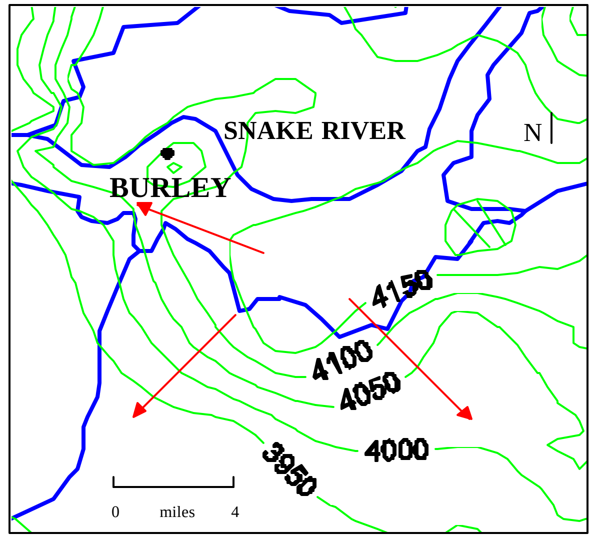


Figure 4. Ground water flow map of Cassia County showing direction of ground water flow (arrows) and equipotential lines (feet above sea level).

Nitrate

The ISDA conducted NO_3-N testing of 56 wells during 2000 and 2002 in Cassia County (Tables 1-3). Nitrate concentrations show a general decrease from 2000 to 2002 and are most elevated in the area southeast of Burley (Figure 5). Results of ground water sampling indicate a maximum concentration of 23.7 mg/L (Table 1). The number of wells over the MCL health standard of 10 mg/L was 26 in 2000 and 13 in 2002 (Table 1). The median nitrate value for all wells dropped from 9.5 mg/L in 2000 to 7.8 mg/L in 2002 (Table 1).

Table 1. Statistical comparison of nitrate concentrations in 56 wells sampled in October 2000 and August 2002.

Nitrate Range (mg/L) and Statistics	2000	2002
	# of wells (% of total wells)	# of wells (% of total wells)
0.0 to 2.0	5 (8.9%)	4 (7.1%)
2.0 to 5.0	6 (10.7 %)	11 (19.6%)
5.0 to 10.0	19 (33.9%)	28 (50.0%)
> 10.0	26 (46.4%)	13 (23.2%)
Total	56 (100%)	56 (100%)
Mean Value (mg/L)	9.7	8.1
Median Value (mg/L)	9.5	7.8
Maximum Value (mg/L)	23.7	23.0

Table 2. Statistical comparison of nitrate concentrations at 12 dairies sampled in October 2000 and August 2002.

Nitrate Range (mg/L) and Statistics	2000	2002
	# of Wells (% of dairy wells)	# of Wells (% of dairy wells)
0.0 to 2.0	0 (0%)	0 (0%)
2.0 to 5.0	0 (0%)	1 (8.3%)
5.0 to 10.0	3 (25%)	7 (58.3%)
> 10.0	9 (75%)	4 (33.3%)
Total	12 (100%)	12 (100%)
Mean Value (mg/L)	12.4	10.2
Median Value (mg/L)	12.5	9.7
Maximum Value (mg/L)	17.4	16.0

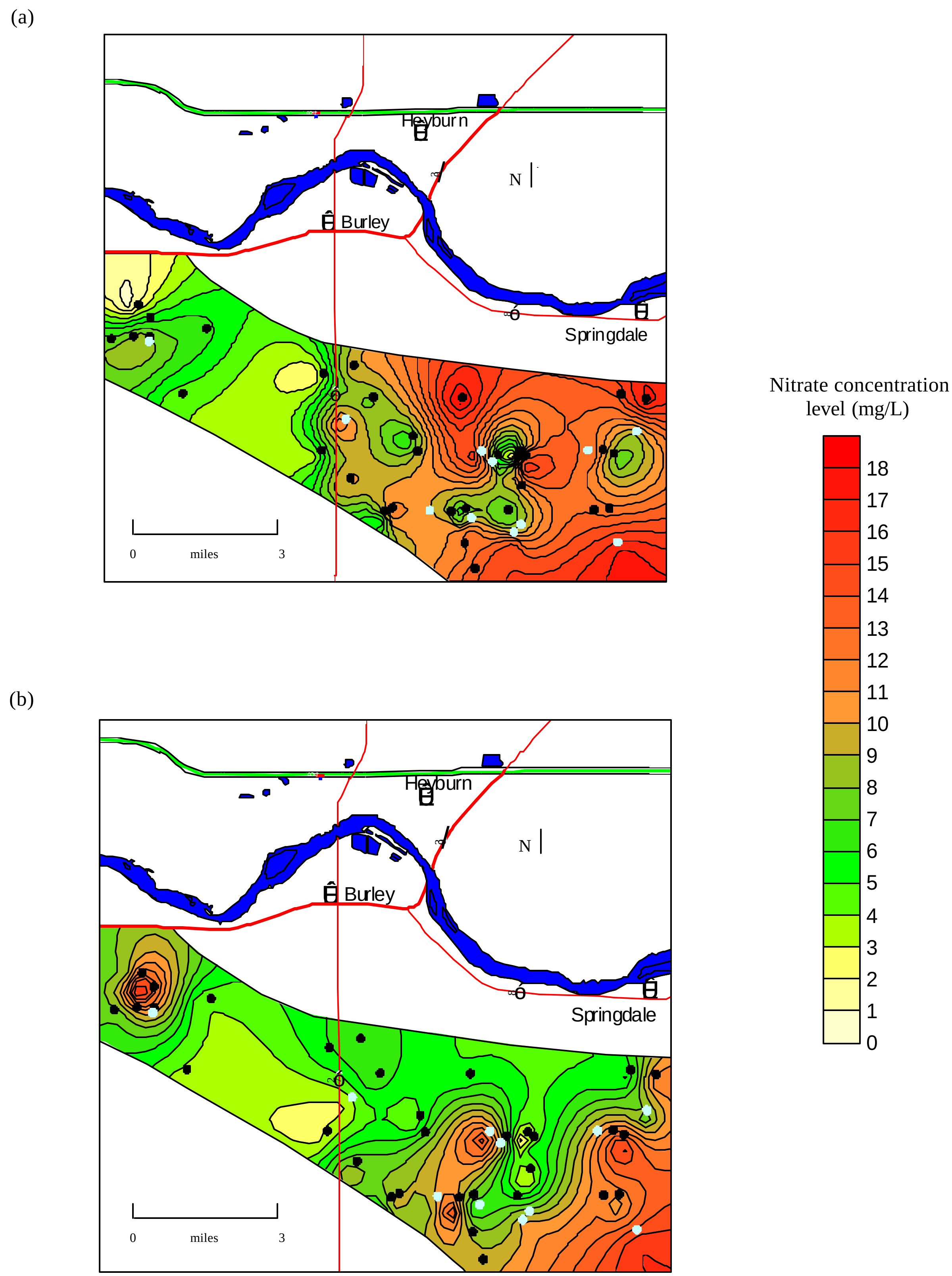


Figure 5. Kriged contour map of ground water nitrate concentration south of Burley for (a) 2000 and (b) 2002. Black dots indicate domestic wells and blue dots indicate dairy wells.

Table 3. Statistical comparison of nitrate concentrations at 44 domestic wells sampled in October 2000 and August 2002.

Nitrate Range (mg/L) and Statistics	2000	2002
	# of Domestic Wells (% of total domestic wells)	# of Domestic Wells (% of total domestic wells)
0.0 to 2.0	5 (11.4%)	4 (9.1%)
2.0 to 5.0	6 (13.6%)	10 (22.7%)
5.0 to 10.0	16 (36.4%)	21 (47.7%)
> 10.0	17 (38.6%)	9 (20.5%)
Total	44 (100%)	44 (100%)
Mean Value (mg/L)	8.9	7.6
Median Value (mg/L)	8.5	7.5
Maximum Value (mg/L)	23.7	23

Samples obtained only from dairy wells (Table 2) show a drop in median nitrate value from 12.5 mg/L in 2000 to 9.7 mg/L in 2002. Samples obtained only from domestic wells show a drop in median nitrate value from 8.5 mg/L in 2000 to 7.5 mg/L in 2002 (Table 3). Additionally, there appears to be no correlation between nitrate values and casing depth (Figure 6) for both 2000 and 2002.

Nitrogen Isotopes

The ratio of the common nitrogen isotope ^{14}N to its less abundant counterpart ^{15}N relative to a known standard (denoted $d^{15}N$) can be useful in determining sources of NO_3-N. Common sources of NO_3-N in ground water are applied commercial fertilizers, animal or human waste, precipitation, and organic nitrogen within the soil. Each of these NO_3-N source categories has a potentially distinguishable nitrogen isotopic signature (Table 4). The typical $d^{15}N$ range for fertilizer is –5 $^0/_{00}$ to +5 $^0/_{00}$, while typical values for waste sources are greater than 10 $^0/_{00}$. $d^{15}N$ values between 5 $^0/_{00}$ and 10 $^0/_{00}$ can indicate an organic or mixed source (Kendall and McDonnel1, 1998).

Use of nitrogen isotopes as the sole means to determine NO_3-N sources should be done with great care. $d^{15}N$ values in ground water can be complicated by several reactions (e.g., ammonia volatilization, nitrification, denitrification, plant uptake, etc.) that can modify the $d^{15}N$ values (Kendall and McDonnel1, 1998). Furthermore, mixing of sources along shallow flowpaths makes determination of sources and extent of denitrification very difficult (Kendall and McDonnel1, 1998).

ISDA conducted $d^{15}N$ testing of 49 of the 56 wells in 2000 and 46 wells in 2002 to determine potential sources of NO_3-N in the ground water (Figure 7). Wells chosen for $d^{15}N$ testing had elevated NO_3-N concentrations. Water samples collected in 2000 were sent to the University of Illinois Laboratory, at Urbana-Champaign, for $d^{15}N$ analysis. Water samples collected in 2002 were sent to the North Carolina State University Stable Isotope Laboratory in Raleigh, North Carolina because of the laboratory's ability to test for $d^{18}O_{NO3}$ in addition to $d^{15}N$.

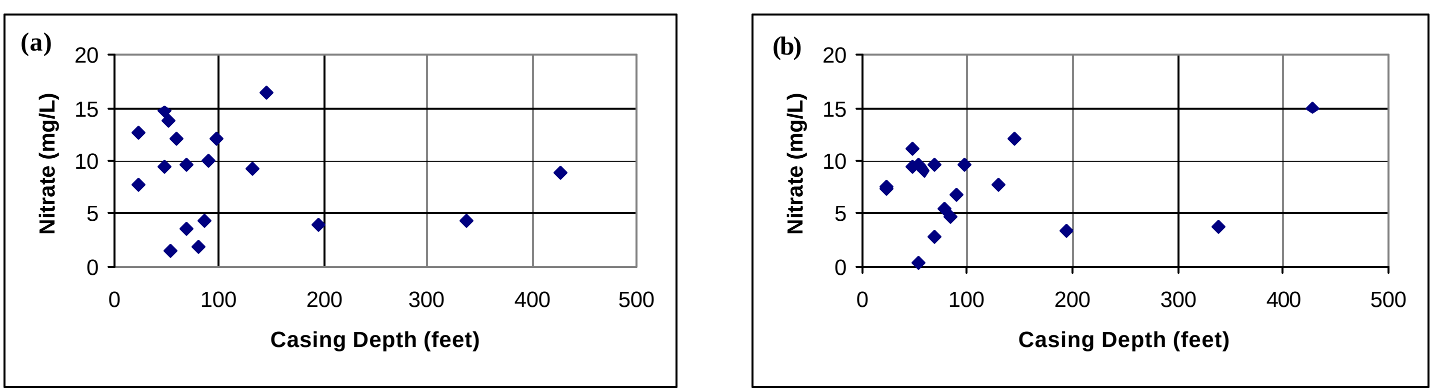
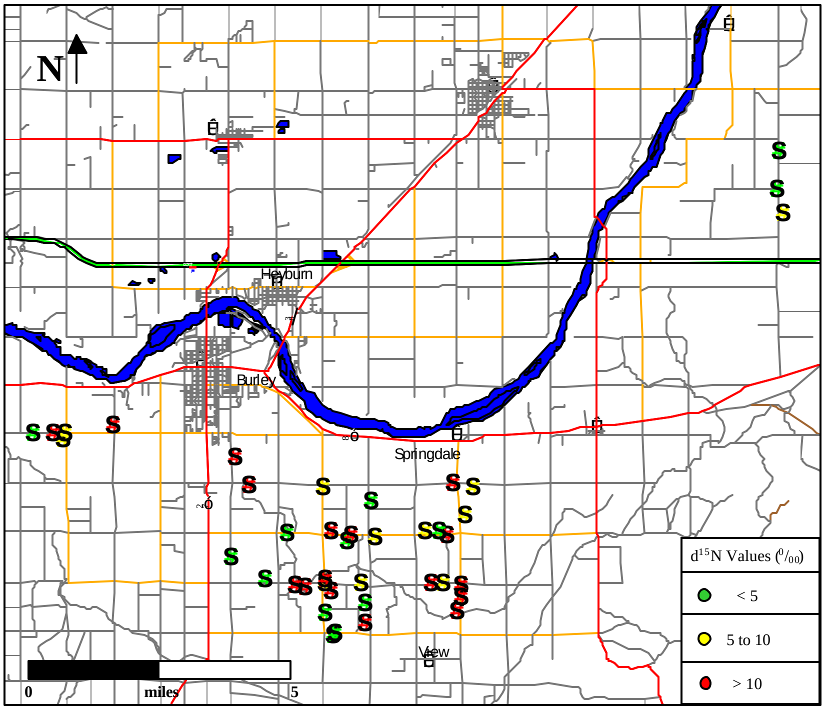


Figure 6. Plots of nitrate values versus casing depth for the same 18 wells sampled in (a) 2000 and (b) 2002.

(a)



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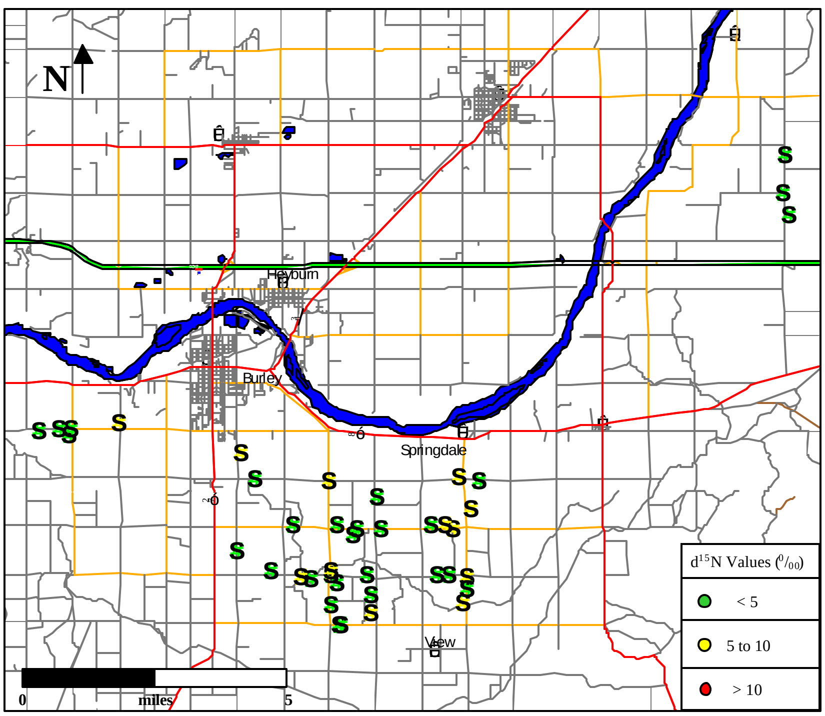

Figure 7. Ground water d^{15}N map south of Burley for the same 41 wells sampled in (a) 2000 and (b) 2002.

Table 4. d^{15}N results for the same 41 wells sampled in both 2000 and 2002.

d^{15}N Values ($^0/_{00}$)	Potential Contaminant Source	2000	2002
		# wells (% of wells)	# wells (% of wells)
< 5	Commercial Fertilizer	13 (32%)	29 (71%)
5 to 10	Organic or Mixed Source	11 (27%)	12 (29%)
> 10	Animal or Human Waste	17 (41%)	0 (0%)

d^{15}N values from 41 wells sampled in both October 2000 and August 2002 (Table 4 and Figure 7) show 17 occurrences of animal or human waste d^{15}N signatures in 2000 and zero in 2002. Five of the 17 wells in 2000 with d^{15}N values that suggested an animal or human waste source are dairy wells. The number of wells with d^{15}N values that suggested a fertilizer source was 13 in 2000 and 29 in 2002. An organic or mixed source signature was found at 11 wells in 2000 and 12 wells in 2002.

Oxygen Isotopes

Denitrification is the removal of nitrogen from compounds, by bacteria in the soil, which results in the escape of nitrogen into the air. Analysis of both d^{18}O and d^{15}N of nitrate allows denitrification effects to be distinguished from mixing of sources. Amberger and Schmidt (1987) reported that denitrification results in enrichment in both ^{18}O and ^{15}N of the residual nitrate. This dual isotope approach takes advantage of the observation that the ratio of the enrichment in ^{15}N to the enrichment in ^{18}O in residual nitrate during denitrification appears to be about 2:1 (Amberger and Schmidt, 1987).

Wells in the project area that were tested for d^{15}N in 2002 were also tested for d$^{18}O_{NO3}$. A linear trendline matched to data from a plot of d^{15}N versus d$^{18}O_{NO3}$ (Figure 8) shows a ratio much less than 2:1. This suggests that the d^{15}N values ranging from 5 $^0/_{00}$ to 10 $^0/_{00}$ represent organic or mixed sources and are not fertilizer signatures elevated by denitrification processes.

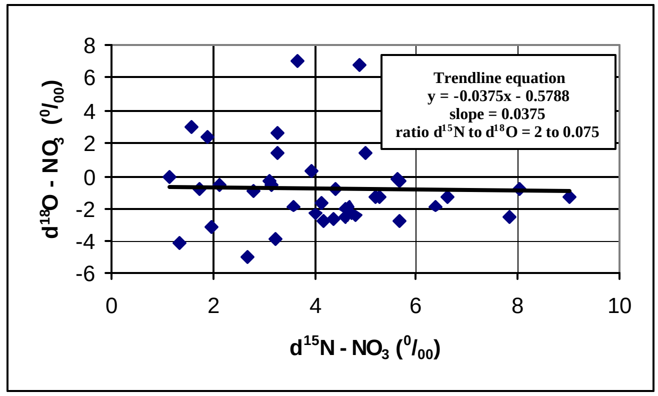

Figure 8. Plot of d$^{18}O_{NO3}$ versus d^{15}N for 41 wells in the Cassia County dairy monitoring area, 2002.

Conclusions

Ground water within the shallow alluvial aquifer of the project area is being impacted from nitrates. Nitrate concentrations exceed the EPA MCL of 10 mg/L in 46% of the 56 wells sampled in 2000 and 23% in 2002. The areas that had the highest NO_3-N concentrations were southeast of Burley. The majority of wells sampled were less than 250 feet deep.

Agricultural practices likely contribute to the NO_3-N detections in the ground water of this project area. Testing results indicate NO_3-N impacts to the shallow ground water of the project area are widespread. Leaching of fertilizers and animal waste is a potential cause of NO_3-N entering the ground water. Leaching of nitrate from legume crops and septic systems are other potential sources. The number of wells over the MCL health standard of 10 mg/L was 26 in 2000 and 13 in 2002.

Potential factors influencing change in nitrate values between the 2000 and 2002 sampling events include: (1) implementation of nutrient management plans by July 1, 2001, (2) seasonal and management variations during sampling events (August 2000 versus October 2002), (3) change in crops and irrigation practices and (4) continued regulation resulting in improvements at farms and dairies.

Potential factors influencing change in $d^{15}N$ values between the 2000 and 2002 sampling events include: (1) change in the contributing nitrate sources listed above and (2) a changeover to a new laboratory for isotope analysis. Sampling in 2003 will be conducted in August and isotopes will be analyzed by the same lab as those in 2002.

Recommendations

To determine if current farming practices are contributing to ground water degradation and to locate other potential contaminant sources, the ISDA recommends continued monitoring in the project area and evaluation of farming and dairy practices.

Testing may include, but not be limited to:

- Continued ground water monitoring for nutrients and common ions.
- Continued nitrogen isotope testing to determine possible nitrate sources and relative ages of ground water.
- Oxygen isotope testing to determine effects of nitrification and denitrification.
- Soil sampling and soil pore water sampling.
- Antibiotic and hormone testing of groundwater to determine potential human and animal waste sources.

ISDA further recommends that measures to reduce nitrate impacts on ground water be addressed and implemented. ISDA recommends that:

- Growers and agrichemical professionals conduct nutrient and irrigation water management evaluations.
- Producers follow the Natural Resources Conservation Service Nutrient Management Standard.
- Homeowners assess lawn and garden practices, especially near wellheads.
- Local residents assess animal waste management practices.
- State and local agencies assess impacts from private septic systems.
- Home and garden retail stores establish outreach programs to illustrate proper application and management of nutrients.
- Dairy facilities and records be further evaluated for pollution prevention.

ISDA recommends that the West Cassia Soil Conservation District lead a response process to create a plan of action to address these ground water contamination issues. The soil and water conservation district, SCC, and ISDA should work with local agrichemical professionals, landowners, and agencies to implement this process and seek funding to support these efforts. ISDA will support these local partners in seeking funding and implementing a comprehensive program. ISDA will be working with the DEQ led Cassia Nitrate Committee in creating a plan for nitrate response.

References

Amberger, A., and Schmidt, H.-L., 1987. Naturliche Isotopengehalte von Nitrat als Indikatoren fur dessen Herkunft. Geoch. Cosmo. Acta, 51:2699-2705.

Gerhardt, D.G., and Kurtz, T.E., 2000. Idaho Agricultural Statistics. Idaho Agricultural Statistics Service, p. 65.

Kendall, C., and McDonnell, J.J., 1998. Isotope Tracers in Catchment Hydrology. Elsevier Science B.V., Amsterdam, pp. 519-576.

Maxwell, H. B., 1981. Soil Survey of Cassia County, Idaho, Western Part. United States Department of Agriculture Soil Conservation Service, 150 p.

Minidoka Soil and Water Conservation District. 1996. Minindoka Land and Water Management Project; Initial Assessment.