



Ground Water Quality Evaluation Craigmont, Idaho

February 2001

ABSTRACT

Ground water in the Craigmont, Idaho, area was sampled in August and November 1998 to evaluate potential sources of nitrogen contributing to elevated nitrate levels in the ground water that supplies the city's drinking water. The City of Craigmont was one of five communities in Idaho to receive technical assistance from the Idaho Department of Environmental Quality (DEQ) and financial assistance from a U.S. Environmental Protection Agency § 319 grant to investigate the causes of elevated nitrates in its drinking water. The community can use the information from the study to implement a ground water protection program.

Water quality monitoring of the Craigmont public water system has shown nitrate levels near the drinking water standard, also called the maximum contaminant level (MCL), of 10 milligrams per liter (mg/l) in the drinking water. Potential sources of nitrate in the area include domestic septic systems, chemical fertilizer application on agricultural lands, and legume crops (e.g., alfalfa, peas, and lentils).

The ground water quality evaluation consisted of reviewing previous water quality data, and collecting and analyzing water samples from two city wells and three domestic wells. Numerous laboratory analyses were performed to assess the potential sources of elevated nitrate. Water samples were analyzed for major ions, nitrate, ammonia, pesticides, and nitrogen isotope ratios. DEQ and the Idaho State Department of Agriculture have recently begun using the nitrogen isotope analyses.

Nitrate was detected in water samples collected from the three domestic wells, but not in samples from the two city wells. Nitrate was the only chemical detected in concentrations greater than the drinking water MCL. The shallow alluvial aquifer underlying the area appears to contain the highest concentrations of nitrate. The nitrogen isotope results indicate the predominant source of nitrate is inorganic chemical fertilizer. No pesticides were detected in any water samples. Based on the investigation results, regional

ground water protection efforts should focus on managing the use of inorganic commercial fertilizer. Other nitrogen sources may impact ground water quality on a localized scale and should be managed on a case-by-case basis.

INTRODUCTION

During May 1998, the Idaho Division (now Department) of Environmental Quality (DEQ) selected numerous communities within the state to be included in the Wellhead Protection Viability Demonstration Project. The project was designed to assist community water systems (CWSs) serving populations less than 10,000 impacted by nonpoint source contaminants such as nitrate. CWSs with detections of nitrate within 25 percent of the drinking water maximum contaminant level (MCL) were selected for the project. Craigmont was one of the communities selected because of elevated nitrate concentrations in its municipal well and because of its commitment to protecting and managing ground water.

Excessive levels of nitrate can cause serious illness and sometimes death in infants less than six months old. The primary hazard from consuming water high in nitrate is methemoglobinemia (sometimes referred to as "blue-baby syndrome"). The condition occurs because nitrite, which is transformed from nitrate in the digestive system, causes the iron in the hemoglobin to oxidize, creating methemoglobin. This methemoglobin lacks the oxygen-carrying capacity of hemoglobin. In most cases health deteriorates over a period of days, with symptoms including shortness of breath and blueness of skin.

Ground water quality data, including common ions, nutrients, bacteria, pesticides, and nitrogen isotopes, were collected and interpreted to determine the source of nitrate found in the ground water. All the analyses, except for the nitrogen isotope ratio analysis, are common tests that can be conducted by most analytical laboratories. The nitrogen isotope ratio analysis is an analytical procedure that is performed primarily at universities and research laboratories. Nitrogen isotope

information is extremely valuable in evaluating sources contributing to elevated levels of nitrate in ground water. Numerous scientific articles have documented the benefit of employing nitrogen isotope analyses in environmental studies (Gormly and Spalding, 1979; Aravena et.al., 1993; Exner and Spalding, 1994; Gellenbeck, 1994; Seiler, 1996; and Howarth, 1999).

DEQ activities during this study included:

- 1) meeting with city officials from Craigmont to explain the project and enlist them as project participants;
- 2) sampling wells;
- 3) conducting an inventory of potential contaminant sources (this activity was used to develop Craigmont's source water assessment);
- 4) delineating wellhead protection areas for Craigmont;
- 5) sending all ground water quality results to the respective well owners; and
- 6) preparing this summary report.

Purpose and Objectives

The purposes of this project are to collect ground water quality and hydrogeologic information to evaluate elevated nitrate concentrations near Craigmont, and to assist local residents in protecting their ground water resources. The project was originally intended to identify sources of nitrate impacting the drinking water supply of the city and surrounding domestic wells. However, Craigmont rehabilitated Well #2-East and Well #3-South in 1998, effectively eliminating nitrate from those wells. Specific objectives of this project include:

- 1) Collect and analyze ground water quality data and locate potential sources of ground water contamination in the vicinity of Craigmont.
- 2) Assess potential sources of nitrate contamination in the vicinity of Craigmont and use nitrogen isotope and hydrochemical data to identify, where possible, the source or sources of nitrate contamination in the ground water. potential contaminant sources within the different wellhead protection areas, determined by the different methods.
- 3) Estimate the wellhead protection area for Craigmont using two different methods (Basic Method and Refined Analytical Method); compare the sizes of the areas and the number of potential contaminant sources within the different wellhead

protection areas, determined by the different methods.

Due to the improved water quality in the Craigmont wells, objectives 1 and 2 were limited to evaluating nitrate contamination in shallow domestic wells outside Craigmont. Objective 3 was not achieved because insufficient hydrogeologic information was available on the deep aquifer to perform a refined delineation.

Historic Water Quality Data

Available historic water quality data for nitrate, bacteria, and organic compounds including pesticides and herbicides were reviewed and summarized for any evidence of trends. Data from the DEQ public water system monitoring database were included in the review.

Nitrate results for 1993-1999 for the public wells were reviewed and are shown in Table 1. The results indicate that nitrate concentrations (measured as total nitrogen) have fluctuated between less than the detection limit (0.005 milligrams per liter [mg/l]) and 8.03 mg/l over this time period. The federal and state drinking water standard, or MCL, for nitrate is 10 mg/l. Since September 1998, nitrate has not been detected in any water samples.

Laboratory tests conducted between 1990 and 1999 indicate water samples from the Craigmont public water system did not contain volatile organic compounds or synthetic organic compounds. No inorganic compounds were detected above MCLs. Coliform bacteria have not been detected in the drinking water system since November 1998.

Table 1. Nitrate Results for Craigmont Wells (1993-1999)

Sample Date	Nitrate Concentration (mg/l)	
	Well #2-West	Well #3-South
12/20/93	6.61	0.82
06/13/94	6.29	<0.005
10/25/95	6.10	0.40
01/14/97	8.03	1.96
09/29/98	<0.005	<0.005
11/04/98	<0.005	<0.005
11/17/99	<0.005	<0.005

Study Area

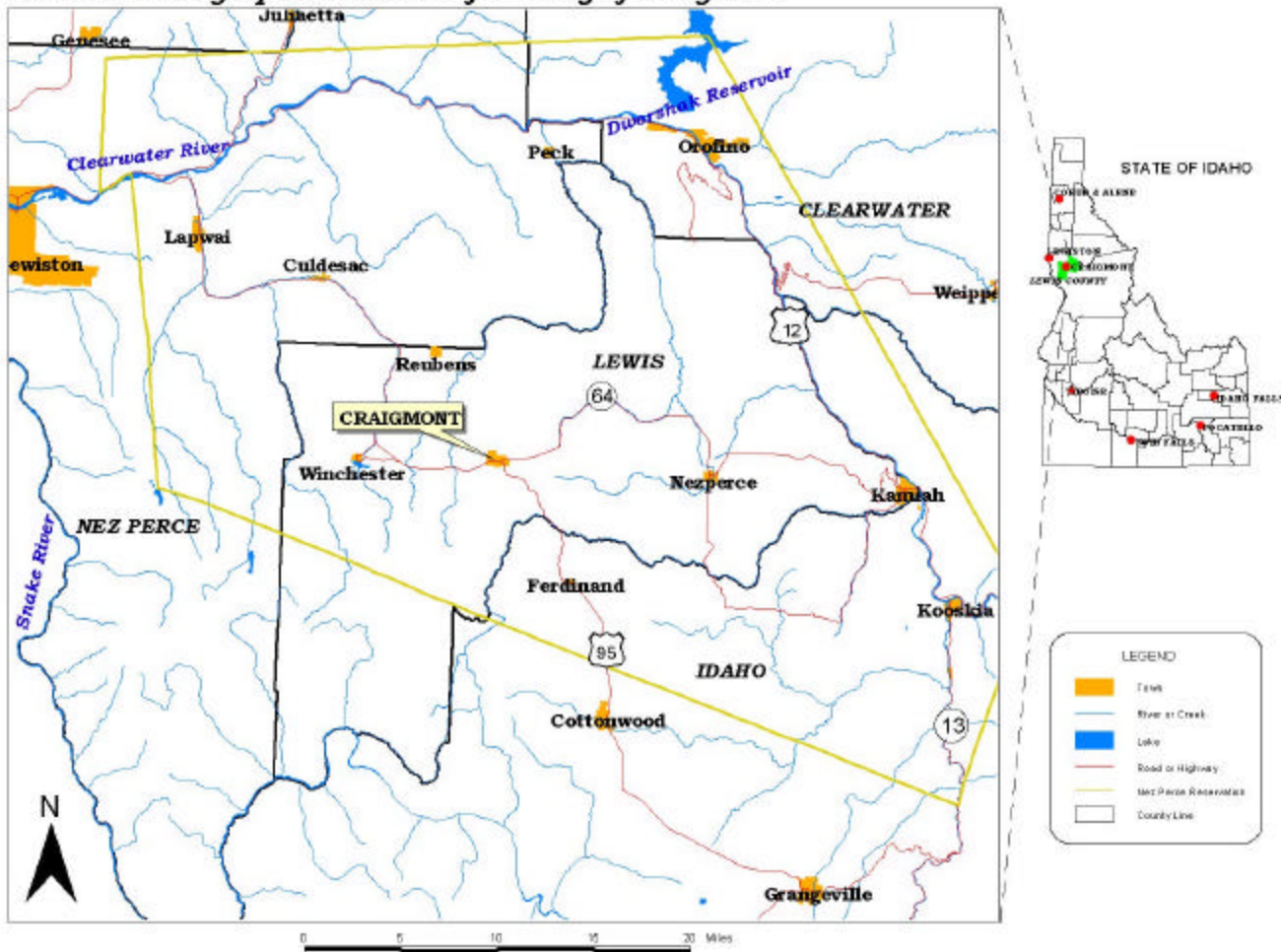
Craigmont is located in Lewis County within the Nez Perce Tribe 1863 Treaty Boundary (Figure 1). Craigmont is a community of approximately 550 people that provides municipal drinking water and sewer service to its residents. A regional ground water study conducted by DEQ in 1998 (*A Reconnaissance of Nitrite/Nitrate in Camas Prairie Ground Water, Lewis and Idaho County* [Bentz, 1998]), evaluating the extent of nitrate contamination on the Camas Prairie, indicated the Craigmont area had elevated levels of nitrate in the ground water.

U.S. Highway 95 has recently been re-routed and runs just southwest of town (the old route of U.S. Highway 95 is depicted on Figure 1). Land use within Craigmont consists of residential homes, numerous professional and retail businesses, and agricultural supply facilities. Dry-land farming operations with small- to medium-sized farmsteads surround Craigmont. Wheat is the predominant crop grown in the area; secondary

crops include barley, peas, oats, canola, and alfalfa. The mean annual precipitation on the Camas Prairie is approximately 22 inches, based on precipitation records from 1961-1990 for the cities of Nez Perce and Grangeville (Idaho State Climate Services, 1999). Approximately one-half of the precipitation is received March through June. May is the wettest month, receiving approximately three inches of precipitation, and July is the driest month, receiving an average of one inch of precipitation. The mean annual temperature is approximately 46° Fahrenheit (Idaho State Climate Services, 1999). July is the warmest month with a mean temperature of 65° Fahrenheit. January is the coldest month with a mean temperature of 28° Fahrenheit. The number of frost-free days varies between 100 to 150 each year (Barker et. al., 1983).

The soils in the Craigmont area are classified as moderate- to well-drained. These characteristics indicate water infiltrates rapidly through the soil.

FIGURE 1 - Geographic Location of the City of Craigmont



Hydrogeology

The predominant geologic feature underlying the Craigmont area is the Columbia River Basalt. Approximately 34-40 million years ago, during the mid-Tertiary period, several basalt flows extruded from vents in what are now Oregon and Washington, resulting in a succession of faulted basalt layers (Castelin, 1976). These basalt flows did not extrude continuously, but were deposited such that weathering took place between flows. This weathering process produced interbeds of weathered material. The City of Craigmont wells draw water from these interbeds of weathered material.

Wellhead Protection Area Delineation

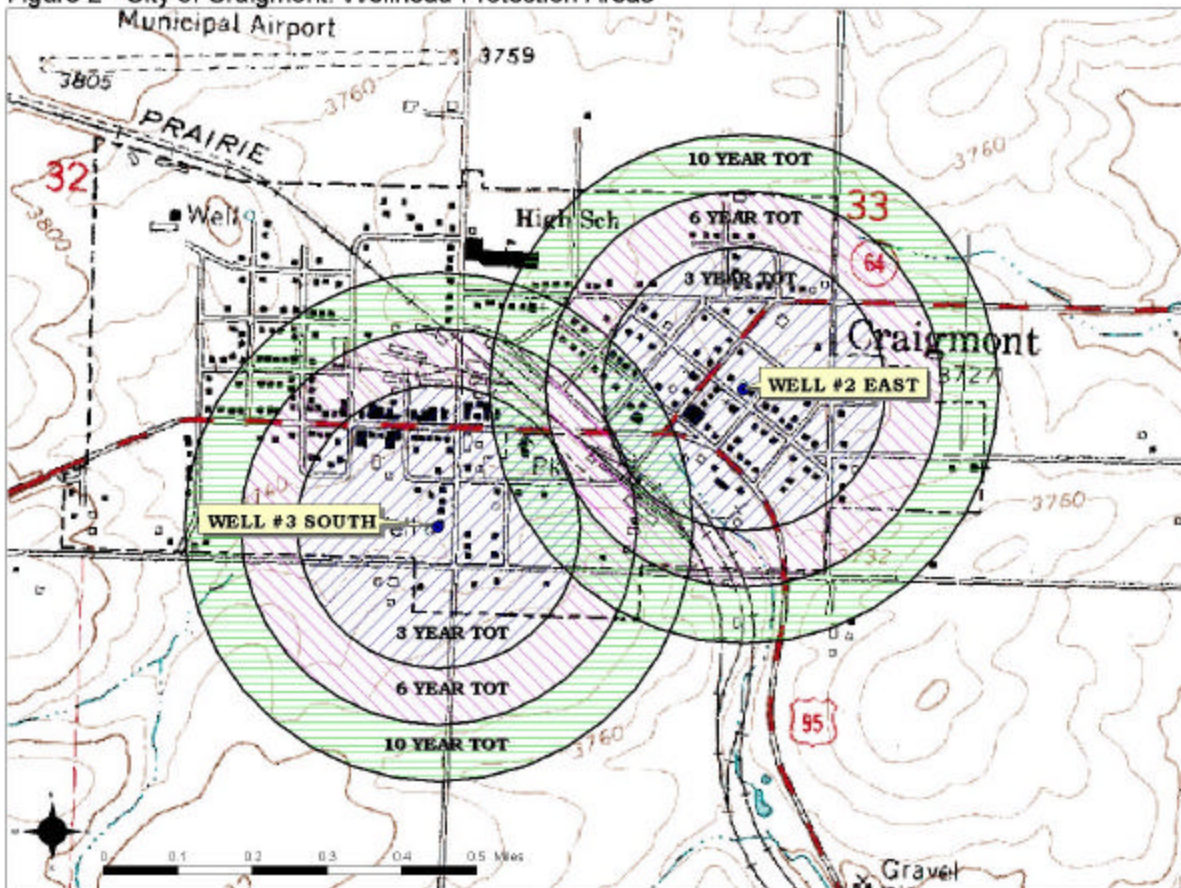
The wellhead protection areas for the active Craigmont wells were developed using the Basic Method described in Chapter 4 of the *Idaho Wellhead Protection Plan* (Idaho Division of Environmental Quality, 1997). The Refined Analytical Method was not used due to the lack of hydrogeologic information on the deep aquifer used

by the Craigmont water system. Comparison of the wellhead protection delineation methods was originally planned to evaluate if collection of site-specific hydrogeologic information is scientifically or economically justified.

The wellhead protection areas for the City of Craigmont wells are composed of four zones (IA, IB, II, and III). Zone IA, the sanitary setback zone, extends 50 feet from the well. The outer boundaries of the three remaining zones are defined according to the distance the ground water will travel within specific time periods. Zone 1B corresponds to the three-year time-of-travel area, Zone II corresponds to the six-year time-of-travel area, and Zone III corresponds to the ten-year time-of-travel area. Therefore, for example, it would take three years for water to travel from the outermost point of the Zone IB to the well.

The wellhead protection area zones are designed so that appropriate levels of management can be applied to contaminant sources within those zones. Typically, more stringent management practices are applied to contaminant sources closer to a well and less stringent management practices are applied to contaminant

Figure 2 - City of Craigmont: Wellhead Protection Areas



sources further from a well. Ideally, all contaminant sources within a wellhead protection area are managed in a manner to prevent contamination from reaching the water supply well.

Wellhead protection areas created with the Basic Method use generalized hydrogeologic information for the major aquifer types in Idaho and the well pumping rate. The delineation of a wellhead protection area involves drawing circles around the well for the three-, six-, and ten-year time-of-travel boundaries. The radius for each time-of-travel boundary is determined from pumping rate tables contained in the *Idaho Wellhead Protection Plan* (Idaho Division of Environmental Quality, 1997) that are specific for each generalized Idaho aquifer type. This method is used when site-specific data are not available.

The Craigmont wellhead protection areas were determined using the Columbia River Basalt aquifer type and a pumping rate of 500 gallons per minute for both wells. Table 4.8b in the *Idaho Wellhead Protection Plan* (Idaho Division of Environmental Quality, 1997) was used to determine the radii of the wellhead protection area zones. The radii for Zone 1B, Zone II, and Zone III extend 1000 feet, 1400 feet, and 1800 feet, respectively. The wellhead protection areas are shown in the City of Craigmont source water assessment report and the City of Craigmont wellhead protection plan.

Potential Sources of Nitrate

Nonpoint sources of contamination are difficult to identify because they are associated with everyday activities and occur on an area-wide basis. Typically, contamination results when a large mass of contaminant is dispersed over a large area. No single release may be enough to affect ground water quality, but the cumulative effects of widespread releases may adversely impact ground water quality. The use of nitrogen fertilizer over a large area is an example of a nonpoint source of pollution. Other nonpoint sources of contamination include subdivisions with a high septic system density, fertilizer and manure applications on agricultural land, and legume crops. Dry-land agricultural operations that use fertilizers, pesticides, and herbicides appear to be the primary potential sources of contamination surrounding Craigmont.

GROUND WATER SAMPLING

The ground water sampling was conducted in November 1998. Five wells were sampled for major ions (bicarbonate alkalinity, chloride, sulfate, calcium, magnesium, potassium, and sodium), nitrate (NO₃ as nitrogen), total ammonia (as nitrogen), nitrogen isotope, total coliform bacteria, and *E-coli* bacteria.

A scan for specific pesticides/herbicides commonly used in the area was conducted using EPA Methods 515.1 and 525.2.

All samples were collected in containers provided by the Idaho Bureau of Laboratories (state lab). The state lab in Boise completed all analyses except for the stable nitrogen isotope ratios. Coastal Science Laboratories, Inc. in Austin, Texas performed the nitrogen isotope analyses. Due to laboratory errors, some of the major ion analyses were not performed on samples from Well 2-East and Well 3-South.

Ground water samples were collected from outside faucets or taps as close as possible to the wellhead to reduce the potential for contamination from plumbing and hoses. All wells were pumped prior to sample collection to remove water from the well and ensure that the water samples were representative of aquifer conditions. The specific conductance and temperature of the purged water were measured to monitor water chemistry. Field measurements were continued until water quality parameters stabilized, indicating water from the aquifer, not stagnant water from the well casing, was being discharged. Samples were not field filtered, but were acidified and chilled as needed for preservation.

General Ground Water Quality

The major ion chemistry was evaluated because the chemical composition of ground water is a function of the mineral composition of the aquifer material as well as the residence time in the aquifer. Therefore, the major ion chemistry sometimes can be used as an indicator of the rock type of the aquifer. Major ions, such as chloride and sulfate, can also be indicators of contamination associated with human activities. The other analyses—nitrate, nitrogen isotope, ammonia, pesticides, and bacteria—are used as indicators of different types of contamination from a variety of anthropogenic activities.

The specific pesticide analytes include atrazine; Dalapon; Dinoseb; pentachlorophenol; Picloram; 2,4,5-TP; chlorsulfan; dichlofop; and sulfometuron methyl.

Nitrogen Isotopes

The nitrogen stable isotope ratio analysis was conducted on the samples to identify sources of nitrate in the ground water. The nitrogen isotope test provides a measurement of the ratio of the two most abundant isotopes of nitrogen, ¹⁵N and ¹⁴N. The ratio of these two isotopes is a useful indicator of sources of nitrogen contamination because unique ¹⁵N/¹⁴N ratios are associated with each of the predominant sources of nitrogen contamination.

Isotopes of an element have the same number of protons but different numbers of neutrons. Elements have a predominant isotope and less abundant isotopes. The standard notation for identifying different isotopes is to write the sum of the number of protons and neutrons in the upper left corner of the symbol of the element (e.g., ¹H=common hydrogen with one proton and zero neutrons; ³H=[tritium] hydrogen with one proton and two neutrons).

The nitrogen isotopes ¹⁵N and ¹⁴N constitute an isotope pair. The lighter isotope ¹⁴N is significantly more abundant in the environment than ¹⁵N. In the atmosphere there is one atom of ¹⁵N per 273 atoms of ¹⁴N (Drever, 1988). The ratio of the heavier isotope to that of the lighter isotope in a substance can provide useful information because slight differences in the mass of the isotopes cause slight differences in their behavior. Stable isotopes are measured as the ratio of the two most abundant isotopes of a given element. Isotope values for nitrogen and other elements are presented in the delta notation:

$$\delta^{15}\text{N} = \left\{ \left[\left(\frac{^{15}\text{N}/^{14}\text{N}}{\text{sample}} \right) \left(\frac{^{15}\text{N}/^{14}\text{N}}{\text{air}} \right) - 1 \right] \times 1000 \right.$$

The δ -value is expressed as parts per thousand or per mil (‰) difference from the reference. For example, a $\delta^{15}\text{N}$ value of +10 per mil has 10 parts per thousand (one percent) more ¹⁵N than the reference. A positive δ -value is said to be “enriched” or “heavy,” while a negative δ -value is said to be “depleted” or “light.” The reference standard for the stable isotopes of nitrogen (¹⁵N/¹⁴N) is atmospheric nitrogen (Clark and Fritz, 1997).

Several steps in the nitrogen cycle can modify the stable-isotope composition of a nitrogen-containing chemical. These changes, called fractionation, occur as a result of physical and chemical reactions. Isotopic effects, caused by slight differences in the mass of two isotopes, tend to cause the heavier isotope to remain in

the starting material of a chemical reaction. Denitrification, for example, causes the nitrate of the starting material to become isotopically heavier. Volatilization of ammonia results in the lighter isotope preferentially being lost to the atmosphere and the ammonia that remains behind becomes isotopically heavier.

These isotopic effects mean that, depending on its origin, the same compound may have different isotopic compositions. For stable isotopes to be useful in identifying sources of nitrogen contamination, the isotopic composition of the potential source materials must be distinguishable. The major potential sources of nitrogen contamination in the environment commonly have characteristic ¹⁵N/¹⁴N ratios. Typical $\delta^{15}\text{N}$ values for important sources of nitrogen contamination are presented in Table 2 (Seiler, 1996).

Table 2. Nitrogen Sources Associated with $\delta^{15}\text{N}$ Values (Seiler, 1996)

Nitrogen Source	$\delta^{15}\text{N}$ (‰)
Precipitation	-3
Commercial Fertilizer	-4 to +4
Organic Nitrogen in Soil	+4 to +9
Animal or Human Waste	> +10

(‰) = parts per thousand difference from the reference standard

RESULTS AND DISCUSSION

Numerous analytical tests were performed on the ground water samples collected during this investigation to develop multiple lines of evidence to determine if specific sources are responsible for the nitrate levels measured in the domestic wells. Well information, field parameter measurements, and analytical results for Craigmont are summarized in Tables 3 and 4 and discussed in later sections. The general chemistry of the ground water is presented first, followed by a discussion of nitrate and nitrogen isotope results. The bacteria and pesticides data are then summarized, and finally, the quality assurance results are reviewed.

Field Measurements

Water quality parameters (temperature and specific conductance [a measure of salinity, reported in mhos or in millionths of mhos, called micro (μ) mhos, per centimeter]) were monitored in the field to allow an initial evaluation of aquifer conditions. Water temperatures were approximately 51°Fahrenheit for domestic wells and approximately 58°Fahrenheit for the city wells. The specific conductance ranged from 265 to 1100 μ mhos/cm and was generally highest in water samples from the domestic wells (Table 3).

General Ground Water Chemistry

Limited major ion data are available for the wells. Laboratory errors prevented the analysis of all requested ions on samples from domestic wells DW-2 and DW-3. The available data do not appear to show significant variations in water chemistry. This supports the idea that the wells draw from geologically similar basalt material. The most significant variation in water chemistry appears to be an elevated chloride concentration in DW-2. The chloride level in DW-2 is almost twice the next highest concentration (6.48 mg/l versus 3.69 mg/l).

Table 3. Well Information and Field Parameter Measurements

Well ID	Well Type	Sample Date	Water Depth (ft)	Well Depth ¹ (ft)	Water Temp (°C)	Specific conductance (μ mhos/cm) ²
DW-1	Domestic	11/04/98	Unknown	Unknown	10	1100
DW-2	Domestic	11/04/98	19	90 – R	10	1000
DW-3	Domestic	11/04/98	20	400 – R	11	300
CW-2E	Well #2-East	11/04/98	35	173 – R	14	265
CW-3S	Well #3-South	11/04/98	536	900 – L	15	275

¹ Well depth R = depth reported by well owner, L = driller's log available

² (μ mhos/cm) = micromhos per centimeter

Table 4. Results of Laboratory Analyses on Ground Water Samples

Well #	DW-1	DW-2	DW-3	CW-2E	CW-3S
Sample Date	11/04/98	11/04/98	11/04/98	11/04/98	11/04/98
Nitrate (NO ₂ +NO ₃ -N) (mg/l)	4.12	13.2	19.7	<0.005	<0.005
Ammonia (mg/l)	NA ¹	NA	NA	0.055	0.053
Bicarbonate Alkalinity (mg/l)	185	153	107	161	158
Calcium (mg/l)	102	NA	NA	68	69.5
Chloride (mg/l)	3.14	6.48	2.31	3.69	2.85
Magnesium (mg/l)	11.8	NA	NA	10.9	11.2
Potassium (mg/l)	1.4	NA	NA	2.1	2.1
Sodium (mg/l)	21	NA	NA	26	26
Sulfate (mg/l)	10.2	NA	NA	NA	NA
Nitrate Isotope (per mil)	4.4	2.5	3.3	INS ²	INS
Total Coliform (cfu/100 ml)	0	0	25	0	0
E. Coli (cfu ³ /100 ml)	0	0	0	0	0
Pesticides	ND ⁴	ND	ND	ND	ND

¹NA = not analyzed

²INS = insufficient nitrogen present in sample for analysis to be completed

³cfu = colony forming units

⁴ND = not detected

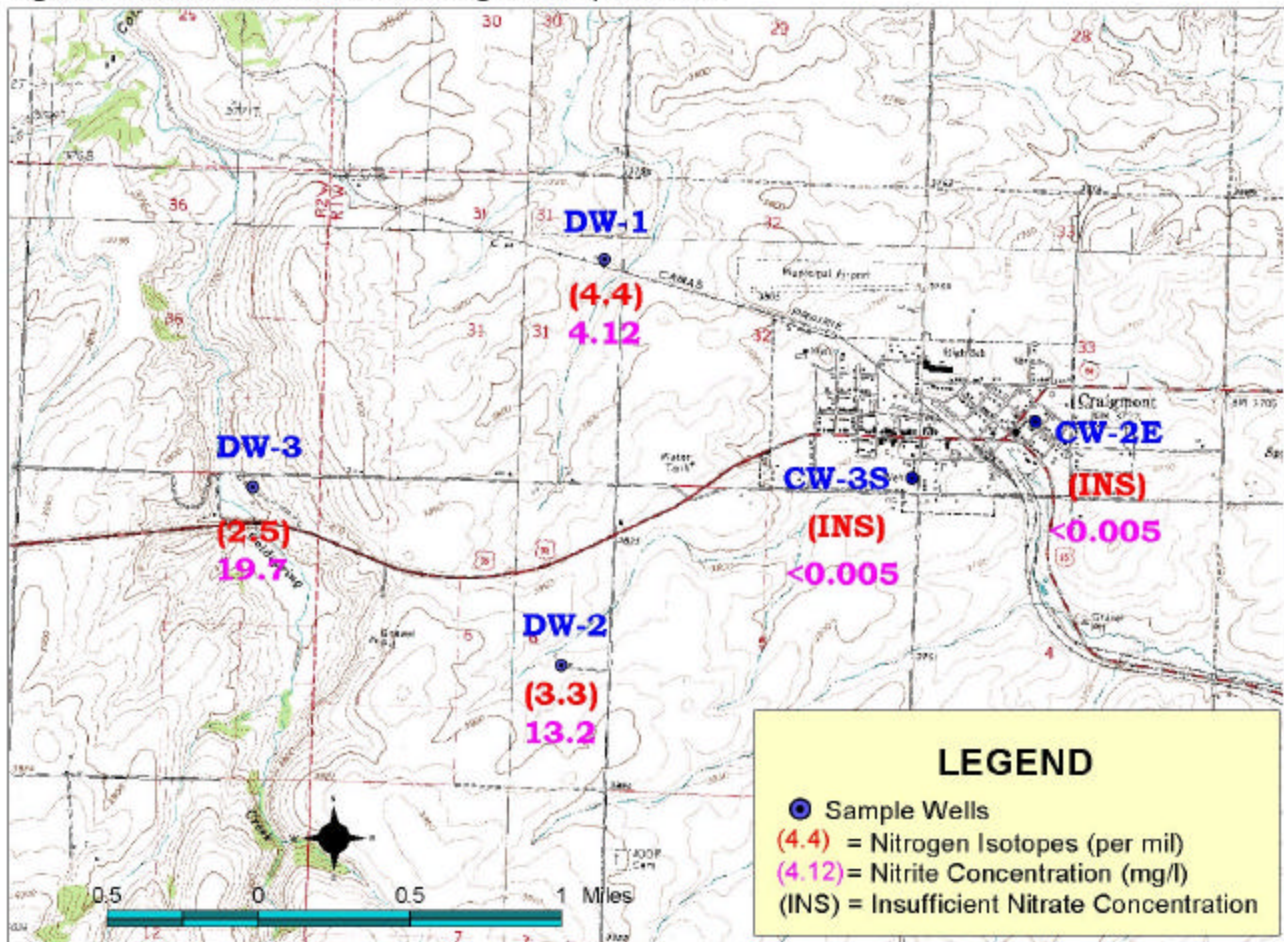
Nitrate and Ammonia Results

Nitrate was detected in the three domestic wells (DW-1, DW-2, and DW-3). Water samples from DW-2 and DW-3 contained nitrate concentrations of 13.2 mg/l and 19.7 mg/l, respectively. These concentrations are above the MCL of 10 mg/l. The water sample from DW-1 contained a nitrate concentration of 4.12 mg/l. Nitrate was not detected in the water samples collected from the city wells. However, both city wells contained low levels of ammonia. The source of the ammonia is unknown. The nitrate and ammonia results are shown in Table 4. The variations in water quality between the domestic wells and the city wells are attributable to the city wells being completed in a deeper aquifer that is not influenced by land use.

Nitrogen Isotope Results

The nitrogen isotope analyses were conducted to evaluate the causes of the elevated nitrate levels in the ground water. The nitrogen isotope $\delta^{15}\text{N}$ values varied from +2.5 ‰ to +4.4 ‰. The $\delta^{15}\text{N}$ results, coupled with the agricultural land use, suggest the elevated nitrate levels in these wells are likely a result of inorganic commercial nitrogen fertilizer leaching into the ground water (see Table 2). According to Seiler (1996) these $\delta^{15}\text{N}$ values are within or near the range indicative of commercial fertilizer sources (-4 to +4 ‰). The wells with the highest nitrate concentrations had lowest nitrogen isotope $\delta^{15}\text{N}$ values. The nitrogen isotope results are summarized in Table 4 and located on Figure 3. The water sample from DW-1 yielded a nitrogen isotope $\delta^{15}\text{N}$ value of +4.4 ‰. This value falls within the range of organic nitrogen associated with naturally occurring sources of nitrogen

Figure 3: Nitrate Concentrations/Nitrogen Isotope Results



Bacteria Results

The water samples were analyzed for total coliform bacteria as an indicator of potential bacteria contamination. Coliform bacteria are common in the environment and are not generally harmful. However, the presence of coliform may indicate the water is contaminated with organisms which can cause diarrhea, cramps, nausea, headaches, and fatigue.

The sample from DE-3, with a concentration of 25 colony-forming units per 100 milliliters (cfu/100 ml), was the only sample that contained bacteria. The samples were tested for *E-Coli* to evaluate if the bacteria contamination is associated with animal or human wastes. *E-Coli* is also an indicator that pathogens are present in the ground water. *E-Coli* bacteria were not present in any of the samples.

Pesticide Results

Water samples from the wells were analyzed for pesticides commonly applied in the area. No pesticides were detected in any of the samples. It should be noted that the laboratory tests used in this study do not encompass the entire suite of compounds present in herbicides and insecticides. Rather, the tests are used as an indicator of the potential for ground water contamination caused by herbicide and insecticide use.

CONCLUSIONS

- ◆ The shallow ground water, which serves as a potable water source for domestic well owners in the Craigmont area, contains elevated levels of nitrate. The deeper aquifer used by the Craigmont public water system is not currently impacted by nitrates.
- ◆ The nitrogen isotope analyses indicate that, at the time of sampling in November 1998, commercial fertilizer was contributing to the nitrate contained in the ground water. Other potential sources of nitrate include legume crops, human waste from septic systems, and animal wastes.
- ◆ The widespread occurrence of elevated nitrate levels suggests nonpoint sources of nitrate, such as application of commercial fertilizer on croplands, are impacting ground water quality.
- ◆ A comparison of the sizes of the areas and the number of potential contaminant sources within the different wellhead protection areas was not performed. The Refined Analytical Method could not be used to delineate the wellhead protection area due to a lack of hydrogeologic information on the deep aquifer used by the city wells.

RECOMMENDATIONS

- ◆ Ground water protection efforts should focus on managing the use of commercial fertilizer. Best management practices (BMPs) should be implemented to reduce nitrate leaching from the soil into the ground water.
- ◆ Ground water quality monitoring should be conducted concurrent with BMP implementation to evaluate the effectiveness of BMPs.
- ◆ Future land uses in the Craigmont wellhead protection area should be protective of ground water quality. A wellhead protection plan should be developed by Craigmont to provide written documentation to guide future protection efforts.

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