

Nitrates in Ground Water

A Continuing Issue for Idaho Citizens



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<http://www2.state.id.us/deq/>

NITRATES IN GROUND WATER

A CONTINUING ISSUE FOR IDAHO CITIZENS

Executive Summary

This report summarizes the current known status of nitrate in Idaho's ground water. Numerous papers have assessed the concerns related to nitrate in ground water such as the occurrence of nitrogen in ground water, best management practices to reduce nitrate pollution and nitrogen fertilizer application rates. This report summarizes some of this data and provides additional information on the extent of nitrate pollution, the estimated costs resulting from nitrate pollution, nitrate sources and nitrate trends in Idaho. It is a general resource paper to help familiarize the citizens with the issue of nitrate in Idaho's ground water.

Nitrate is the most widespread ground water contaminant in Idaho and the most common contaminant found in public water supply systems. It has a federal drinking water Maximum Contaminant Level (MCL) and Idaho ground water quality concentration standard of 10 milligrams per liter (mg/l) or 10 parts per million (ppm) for nitrate-nitrogen. The standards are based on studies assessing the risk of developing methemoglobinemia or "blue baby syndrome" in infants as a result of exposure to nitrates.

About 3% of Idaho's wells sampled through the Ambient Statewide Ground Water Quality Monitoring Program have nitrate-nitrogen concentrations exceeding the MCL. Exceedances are not uniform across the state, however. Nitrate is rarely detected in areas with few nitrate pollution sources, such as much of northern Idaho. It is more frequently detected in wells located in irrigated agricultural parts of the state where nitrate usage is more common. On a statewide basis, it is estimated that 93% of the nitrate detected is from agricultural sources (fertilizer, manure, and legumes). Septic systems and other sources contribute an estimated 1% and 5% respectively.

Most private wells in Idaho have not been tested for nitrates. Idaho does not regulate these private wells. However, the Idaho Department of Environmental Quality (IDEQ) does regulate public water systems in Idaho and requires testing for nitrate-nitrogen. Currently, fifty public water systems drawing water from 121 wells show elevated nitrate levels (greater than 2 mg/l nitrate). Installation of nitrate removal systems has cost communities millions of dollars while ongoing maintenance and chemicals cost citizens several thousand dollars per year per system.

Research shows the problem is getting worse. As ground water quality changes and more wells are affected, costs to private well owners and municipalities will increase. For areas across the state that show significant groundwater degradation due to nitrate contamination, IDEQ and other agencies will work with the citizens to develop and implement strategies to reduce the nitrate levels in the ground water and to prevent additional contamination.

NITRATES IN GROUND WATER

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Introduction

The Idaho Department of Environmental Quality (IDEQ), the Idaho State Department of Agriculture (ISDA), and the Idaho Department of Water Resources (IDWR) agree that nitrate is the most widespread preventable ground water contaminant in Idaho and that the problem is increasing in extent and severity. Over 95% of the drinking water consumed in Idaho is supplied by ground water and because this resource is so vital, strategies that eliminate or minimize nitrate contamination in the environment are critical. This paper presents available information on the extent and potential effects of nitrate contamination of Idaho's ground water.

What is ground water?

Ground water is the water under the earth's surface that flows freely through tiny pores and cracks in rock and soil. Ground water supplies 95% of the water used in Idaho households and the municipal drinking water used by 204 cities and towns. About six billion gallons of ground water are withdrawn every day in Idaho for drinking, agriculture, and industrial processing uses (Figure 1). Ground water is important not only for the beneficial uses noted in Figure 1, but also because it provides recharge to streams, rivers, lakes and wetlands.

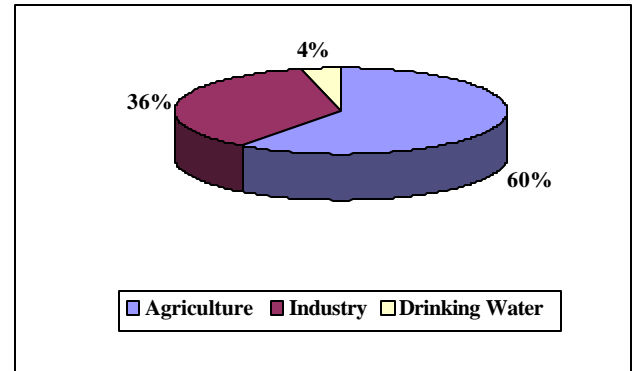


Figure 1. General ground water use in Idaho

Ground water comes from a variety of sources, primarily rain and snowmelt percolating down through the soil. Ground water usually is in motion, flowing from upland areas of recharge to lower areas where it may discharge to a spring, a stream or other body of surface water. Ground water nearly always contains more dissolved minerals than nearby streams, although both originate as precipitation. The main reason for this is that water passing through the soil dissolves large amounts of carbon dioxide gas generated by soil microorganisms decomposing organic matter. This gas produces a weak carbonic acid solution that attacks carbonate and silicate minerals of calcium, magnesium and sodium, causing them to dissolve. Ground water also stays in contact with the surrounding rocks much longer than surface water, which allows more time for chemical reactions to occur.

In addition to dissolved minerals, infiltrating water carries organic matter from the soil down to the ground water. Organic acids, formed through the decay of organic matter, bacteria, fungi and viruses, may be leached to the ground water. For the most part, these natural organic compounds and living organisms are attached to or filtered out by mineral grains so that, after traveling a short distance (e.g., a few tens of feet), most organic matter is removed from ground water. Where ground water flows through large openings, such as can exist in limestone or volcanic rock, organic matter and organisms may persist over longer distances.

Why is contamination a concern?

First and foremost, contamination is a concern because it can affect human health and the environment. Contamination of ground water by human activity is a severe problem because contaminants generally travel unnoticed until detected in a water supply well. Once contaminated,

the extent of the contamination must be determined in order to assess how widespread the problem is. Often, it is so large that it is difficult and expensive to clean up. The contaminants are often dispersed in the ground water, difficult to remove, and may persist for decades. In almost all cases, ground water contamination prevention is simpler and cheaper than clean up.

Contaminants include an almost endless list of inorganic chemicals (nitrates, iron, etc.), synthetic organic chemicals (pesticides), petroleum products, biological matter, and radioactive compounds. Even physical characteristics such as heat can be detrimental. The impacts on ground water may range from relatively harmless aesthetic effects, such as unpleasant taste, to imminent health hazards.

The magnitude and complexity of ground water problems continue to grow. For this reason, expanded efforts are needed to ensure adequate ground water data and information, and to bring ground water into the mainstream of planning, management and decision-making at all levels of government. Nitrate is the most common contaminant across Idaho and for that reason, it is considered a high priority concern.

What is nitrate?

Nitrate (NO_3^-) is one of the chemical forms of nitrogen. It coexists with other forms of nitrogen in a complex cycle. Nitrogen in soil and water originates from atmospheric deposition, application of fertilizer, manure, waste material and dead plant and animal tissue. Under aerobic (occurring in the presence of oxygen) conditions, nitrate is a fairly stable form of nitrogen. Ammonium (NH_4^+) and organic nitrogen are other nitrogen forms that frequently convert quickly to nitrate.

Most of the nitrogen on earth is in the atmosphere, which consists of 78% N_2 gas. Other forms of nitrogen, originating mainly from power plant emissions, internal combustion engines, fertilizer and manure, also occur in the atmosphere (Energy Information Administration, 1997). These include nitrogen oxides (NO_x and N_2O), nitric acid (HNO_3) and ammonia (NH_3). Atmospheric nitrogen interacts with the earth's surface when N_2 is "fixed" (changed chemically) by legumes or lightning, or when pollutants are dispersed in precipitation.

In most natural systems, inorganic nitrogen is a scarce nutrient. Plants efficiently use available nitrate and losses to ground water and surface water are minimal. In agricultural systems, nitrate is added to increase yield and production of non-legume crops and it may be present in amounts exceeding what plants are able to use. As a result, excess nitrate can leach into ground water or be washed into surface water. Nitrate in soil and water also may eventually cycle to the atmosphere by a process that occurs under anaerobic (occurring in the absence of free oxygen) conditions called denitrification.

What is the current status of nitrate in Idaho ground water?

Results from the first eight years of monitoring for the Statewide Ambient Ground Water Quality Monitoring Program indicate that Idaho ground water quality has been impacted by nitrate in some areas. This monitoring program tests approximately 1,500 sampling locations (wells and springs) annually. Only 3% of the sampled sites had nitrate results greater than the MCL of 10 mg/l or 10 ppm as nitrate-nitrogen; however, another 30% of Idaho's wells have impacted levels of nitrate between 2 and 10 mg/l. Initial trend data show that nitrate concentrations increased at more than

half of the sites tested in both the First and Second Rounds. Approximately 33% of the sites show decreasing levels of nitrates while the remaining sites show no change (Neely and Crockett, 1999).

Concentrations of nitrate in ground water are not uniform across the state. Nitrate is rarely detected in forested areas while contamination levels are generally higher in agricultural and populated areas of the state. The South-central, Southwest, and the southern and eastern edges of the Eastern Snake River Plain areas have the highest percentage of impacted sites. This is consistent with Neely and Crockett's (1999) findings of nitrate levels in agricultural regions of the state. Finally, septic systems have caused nitrate pollution in high-density unsewered subdivisions and urban runoff is an increasing source of nitrogen in populated areas of Idaho.

In 1996, IDEQ formed the Ground Water Quality Monitoring Technical Committee, as outlined in the Idaho Ground Water Quality Plan. This Committee, comprised of technical representatives from 11 state and federal agencies, was developed to: analyze trends in Idaho's ground water quality; implement regional and local monitoring in cooperation with other agencies; prioritize monitoring projects; prepare a comprehensive statewide approach to identifying contaminant detection and source response; ensure quality assurance; and inform and educate the public on statewide contamination issues. The committee preliminarily identified 33 areas in Idaho that show degraded ground water quality due to nitrate contamination (Figure 2). These areas range in size from 1,171 to 309,717 acres and in estimated populations from 113 to 225,383 persons (Table 1).

What are the concerns about nitrate in ground water?

Human Health

Exposure to nitrate in concentrations over the 10 mg/l MCL has been associated with a condition called methemoglobinemia or "blue-baby syndrome" in infants six months of age and younger (EPA, 1990a). Nitrate in drinking water used to make baby formula is converted to nitrite in the baby's stomach. Nitrite changes hemoglobin (that part of the blood that carries oxygen to the cells) to methemoglobin which is unable to bind with oxygen, thus depriving the cells of oxygen. In extreme cases it can cause death. While methemoglobinemia is a serious condition when it occurs, the number of cases treated prior to hospitalization has not been documented and is thought to be low. In fact, no studies of nitrate-induced methemoglobinemia have been reported since the 1990 EPA publication (National Research Council, 1995). The absence of reports might in part be due to the lack of requirements for reporting cases of methemoglobinemia (personal communication with Christine Hahn, M.D., 2001).

Several investigators nationally have studied the chronic health and reproductive impacts of drinking nitrate contaminated water. Recent studies have implicated nitrate exposure as a possible risk factor associated with non-Hodgkin's lymphoma, gastric cancer, hypertension, thyroid disorder and birth defects (Gilli, et. al., 1984, Scragg, 1982, Rademacher, 1992). A recent investigation conducted by local public health officials in La Grange County, Indiana implicated nitrate-contaminated drinking water as the possible cause of several miscarriages (Schubert et. al., 1997). For various reasons, it is difficult to show a relationship between nitrate and nitrite intake from drinking water and cancer or birth defects (National Research Council, 1995). This is due in part because humans are exposed to nitrate and nitrite from many sources other than drinking water, so individual exposures vary widely. Many dietary factors, such as antioxidants inhibit nitrosamine (the actual carcinogenic compounds) formation from nitrite. Finally, the epidemiological studies that have been conducted to date suffer from a variety of limitations, such as lack of historic exposure measurements, small sample size, and confounding by concomitant exposures.

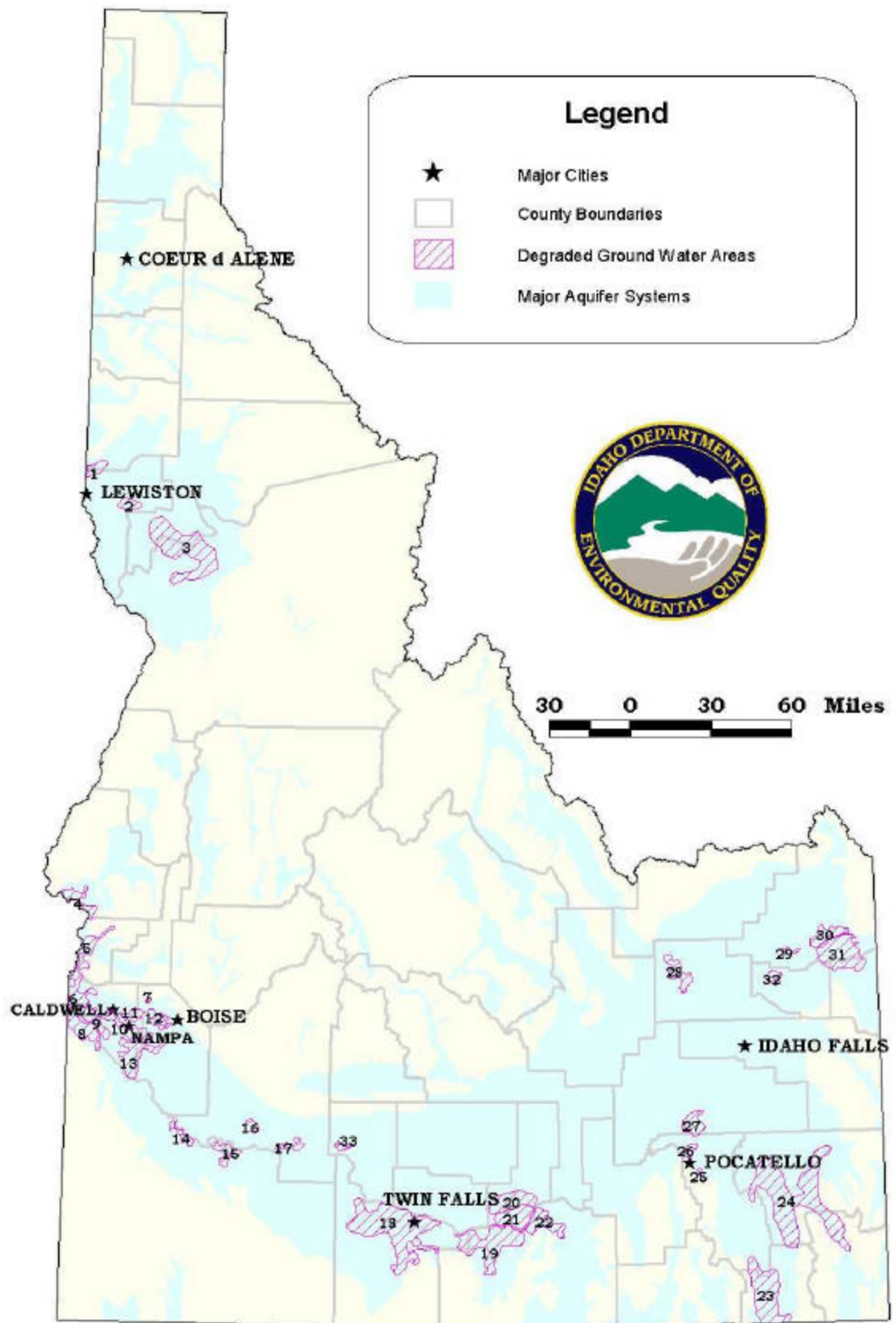


Figure 2. Areas with ground water quality degradation due to nitrate contamination, (Young, 2000).

Table 1. Degraded Ground Water Quality Areas (Nitrate)

# *	Name of GWQMA	Estimated Area (acres)	Estimated Population Served By Public Water System	Regional Office
1	Clearwater Uplands – Cow Creek	18,123	775	Lewiston
2	Clearwater Plateau – Upper Lapwai Creek	17,229	600	Lewiston
3	Clearwater Plateau – Central	181,305	686	Lewiston
4	Scott Creek / Mann Creek	31,465	5,853	Boise
5	Payette Valley – Fruitland Area	30,522	2,725	Boise
6	Boise Valley – West Canyon	42,728	2,043	Boise
7	Boise Valley – Eagle / Star	1,718	0	Boise
8	Homedale / Murphy – Northwest	50,784	840	Boise
9	Mountain Home – Northwest	25,533	1,118	Boise
10	Boise Valley – Nampa / Caldwell	42,214	73,759	Boise
11	Boise Valley – North Nampa	14,259	3,886	Boise
12	Boise Valley – Boise / Meridian	18,058	225,383	Boise
13	Mountain Home – Can Ada	62,195	1,349	Boise
14	Bruneau / Grandview – Grandview Area	13,996	450	Boise
15	Bruneau / Grandview – North Central	24,084	0	Boise
16	Mountain Home – Central	11,223	262	Boise
17	Mountain Home – Southeast	14,317	1,656	Boise
18	Salmon Falls Creek / Rock Creek	243,831	47,687	Twin Falls
19	Goose Creek / Golden Valley	122,713	11,412	Twin Falls
20	Raft River & Marsh Creek	43,223	375	Twin Falls
21	Snake River Plain – South Minidoka	53,032	24,557	Twin Falls
22	Snake River Plain – A/B Irrigation District	60,968	575	Twin Falls
23	Cache Valley	129,085	620	Pocatello
24	Southeast Aquifer	309,717	5,942	Pocatello
25	Portneuf – Black Cliffs Area	2,515	260	Pocatello
26	Portneuf – Pocatello / Chubback Area	10,100	63,527	Pocatello
27	Snake Plain – Fort Hall Area	32,145	0	Pocatello
28	Snake Plain – Mud Lake Area	36,579	1,134	Idaho Falls
29	Snake Plain – St. Anthony Area	6,686	0	Idaho Falls
30	Snake Plain / Teton Basin – Ashton Area	34,249	1,611	Idaho Falls
31	Teton Basin – North Central	106,397	113	Idaho Falls
32	Teton Basin – Hibbard Area	10,868	1,409	Idaho Falls
33	Snake River Plain – North of Bliss	6,753	0	Twin Falls

* Numbering of areas does not represent priority or ranking of areas.

** Acreage of areas may change as more data becomes available

Livestock Health

Nitrate intake by dairy cattle is related to the levels found in forage and drinking water. According to research conducted on dairy cattle (Crowley et. al., 1974), nitrate-nitrogen in drinking water at levels under 10 mg/l is safe for animals. Between 10-20 mg/l nitrate-nitrogen, water is safe for livestock unless their feed has high nitrate levels. Problems for livestock can occur between 20 - 40 mg/l nitrate-nitrogen if feed contains more than 1,000 ppm. If well water is between 40-100 mg/l nitrate-nitrogen, feed should be low in nitrate, well balanced and fortified with vitamin A. At levels between 100 - 200 mg/l nitrate-nitrogen in water, studies report decreased appetite (Mahler, et. al, 1990, Taylor, et. al., 1990).

Aquatic Life

Nitrate does not appear to be acutely toxic to adult fish except at extremely high concentrations where mortality is due to salinity effects (USEPA, 1977). However, available research indicates that nitrate concentrations lower than the drinking water standard cause substantial egg and fry mortality in some salmonid fish species (Kincheloe et. al., 1979). When rearing trout or warm water species, the US Fish and Wildlife Service recommends nitrate levels not exceed 3 mg/l (Piper, et. al., 1982). Tadpoles exposed to nitrate at the drinking water standard show decreased appetite, sluggishness and paralysis prior to death (Hecnar, 1995).

Surface Water

Ground water can carry nitrogen (in the form of nitrate) into surface water bodies through recharge and spring discharges. Plant-available nitrogen and phosphorus in surface water promotes excessive growth of weeds and algae. This process is called "eutrophication." Nitrate supplied by ground water discharge may cause increases in rooted aquatic plants (Lillie and Barko, 1990, Rodgers, et. al., 1995).

Compelling evidence indicates the amount of nitrate entering surface water from ground water is increasing in Idaho. A cumulative impacts study conducted in the Thousand Springs area of the Eastern Snake River Plain in July 2000 (Baldwin, et. al., 2000) evaluated nitrogen water quality data for springs that discharge along the north side of the Snake River canyon. These springs are the regional discharge points for the Eastern Snake River Plain aquifer. In fact, these springs provide significant recharge to the Snake River, estimates range from 2 to 20 inches per year during 1976 to 1980 (Garabedian, 1992). One of the objectives of the study was an estimation of the total nitrogen load from the various identified sources. The results, using a linear regression analysis, indicate that nitrate+nitrite concentrations showed statistically significant increases for all five springs from 1991 or 1994 through 1999. As determined by Baldwin, the five major sources of nitrogen loading to the surface water in this area were estimated to be: commercial fertilizer (54%), cattle manure (combined dairy and beef, 42%), legume crops (2 %), human waste (1%), and precipitation (1%) (Figure 3).

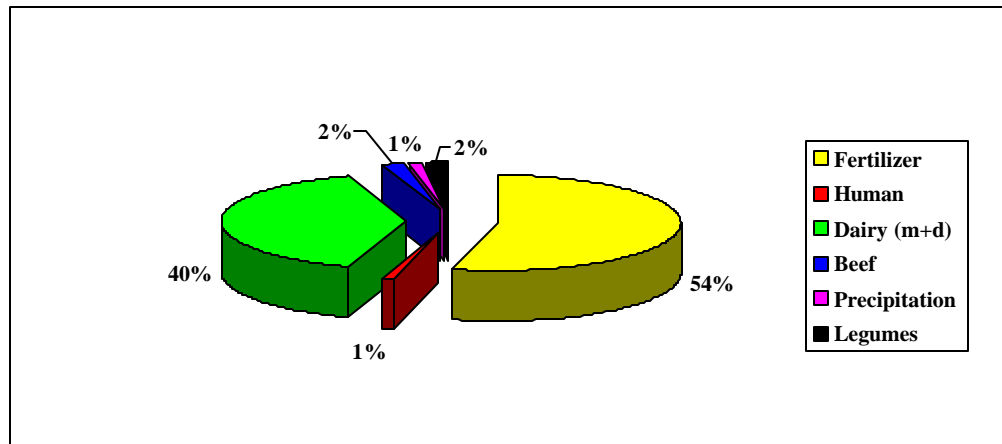


Figure 3. Percentage estimates of nitrogen load from various sources in Box Canyon area.

According to EPA (1990b) and Idaho Agricultural Statistics (2000), the following land use changes occurred in the study area:

- nitrogen fertilizers use, 17 percent decrease for Gooding and Jerome Counties during the period 1985 to 1991;

- irrigated acreage, 5 percent increase for Gooding County, 12 percent increase for Jerome County during the period of 1987 to 1997;
- total number of cattle, 109 percent increase for Gooding County and, 92 percent increase for Jerome County during the period of 1986 to 2000.

The land use changes indicate that while nitrogen fertilizer use has decreased, this may have been offset by an increase in number of irrigated acres and a large increase in the number of cattle in the area. Other surface water studies in the state support Baldwin's findings of increasing nitrate discharges from ground water sources (Ingham, 1996, Bureau of Reclamation, 1984). More investigation into this form of nitrate transfer is warranted.

What are the sources of nitrate to ground water?

Estimates of nitrogen input to soil in Idaho show that fertilizer contributes the greatest amount of total nitrogen, followed by cattle and dairy manure, legume crops, precipitation, and domestic septic systems (Figure 4). Approximately 93% of the nitrogen input originates from agricultural sources-- legumes, manure and commercial fertilizer. Another 5% of the nitrogen comes from atmospheric sources including combustion of gasoline in automobiles and lightning. The remaining 2% comes from septage, sludge disposal and other sources.

An estimated 223,349 tons of nitrogen fertilizer were deposited on Idaho's surface from July 1, 1996 through June 30, 1997 (The Fertilizer Institute, 2000). During this period Idaho ranked 22nd in the nation for the amount of nitrogen fertilizer applied to the soil.

Manure estimates were calculated using nitrogen content of animal waste (between 0.41 and 0.59 lb/day for dairy cows and between 0.34 and 0.43 lb/day for beef cattle) multiplied by the number of animals reported by Idaho Agricultural Statistics Service for 1997.

Nitrogen input from legumes (60 lb/acre for alfalfa and 40 lb/acre for beans) was based on data compiled on the number of acres of crops grown during 1997. These estimations were made under the assumption that all legume crops are tilled under at the end of each crop year (Idaho Agricultural Statistics Service, 1997).

Nitrogen input from domestic septic systems was estimated by multiplying the average amount of total nitrogen generated per person by the average number of persons per household and the number of households using domestic septic systems in Idaho (Idaho Department of Commerce, 1997). Estimating the number of homes using septic systems since the 1990 census was done by compiling information on building permits issued for unincorporated areas of the state and making estimates using this information. Since the 1990 census, there has been rapid growth in many parts of Idaho. While most of this growth has occurred within incorporated areas providing sewer services, there has been growth in several rural or unincorporated areas of the state, including areas outside of the City of Coeur d'Alene, the Wood River area, Kootenai County as well as others (Telephone conversation with Richard Twight, Idaho Department of Commerce, 2000).

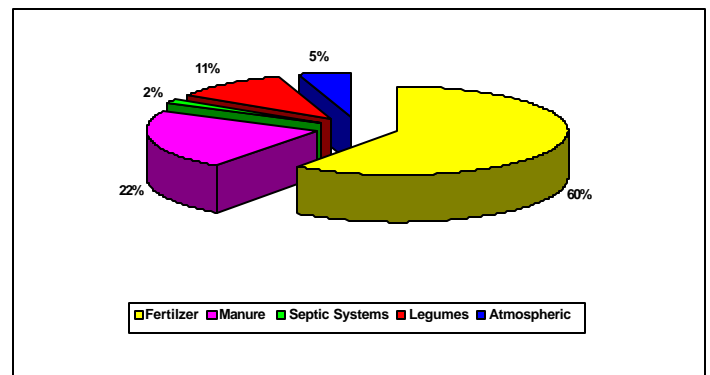


Figure 4. Nitrogen inputs to Idaho soils by percent

Total nitrogen deposited by precipitation was estimated using the same methods employed by Rupert (1994). Since rain/snowfall patterns have not changed dramatically in the past ten years, it is not surprising that this contribution to the overall nitrate input has not changed significantly.

It is important to keep in mind when reviewing the data that nitrogen input is the total amount of nitrogen supplied by manure, fertilizer, legume crops, precipitation, and domestic septic systems in the state before any losses can occur. Other sources of total nitrogen such as native vegetation or waste water land application also may be present, but data are insufficient to estimate their input. Calculations performed to estimate total nitrogen loss from storage and application of cattle manure, crop uptake, and decomposition of previous-year non-leguminous crop residue have been done in certain geographic areas of Idaho (Rupert, 1994). The purpose of these estimations was to rank input of nitrogen by source, determine the amount of total nitrogen potentially available to both ground and surface water through leaching and runoff, and identify areas in the area where excess nitrogen was produced. The conclusions of this study indicate that more total nitrogen is input to the system than is lost.

Based on earlier estimates (Rupert, 1994), roughly 10% of the total nitrogen added to Idaho soils each year leaches to ground water as nitrate. Though agriculture is the largest source on a statewide basis, other sources can be locally important. Nitrate loading from septic systems in dense, unsewered subdivisions can be as high as some of the most intensive agricultural operations (Boyle, 1995).

How long has the problem been around?

Nitrate pollution at very low levels has probably existed in Idaho waters since settlement times. However, both in Idaho and other agricultural states, increasing nitrate pollution is a relatively recent phenomenon and is correlated with the increasing use of nitrogen fertilizers over the last 30 to 40 years (Hallberg, 1989; Hallberg et. al., 1989). Baldwin's study showed a direct link between increasing nitrogen inputs on agricultural lands and water quality in the Thousand Springs, Snake River Watershed, (Baldwin, et. al., 2000).

Similar patterns have been observed in some public supply wells with long-term records such as one of the City of Pocatello's municipal wells located in southeastern Idaho (Figure 5). Many public supply wells show fluctuating levels of nitrates, often exceeding the standard of 10 mg/l, for long periods of time.

Compared with public supply wells, most privately owned wells are not routinely monitored for water quality. Single family private wells may show high variable trends in nitrate concentration. A good illustration of this can be found in Figure 6, a private well with long-term sampling records. A linear regression analysis of the nitrate data was conducted for this private well located southwest of Jerome. The well, which is approximately 170 feet deep, has been sampled from 1 to 25 times per year for 12 years. The regression results show there is a statistically significant increasing trend in nitrate concentration at the 95% confidence level.

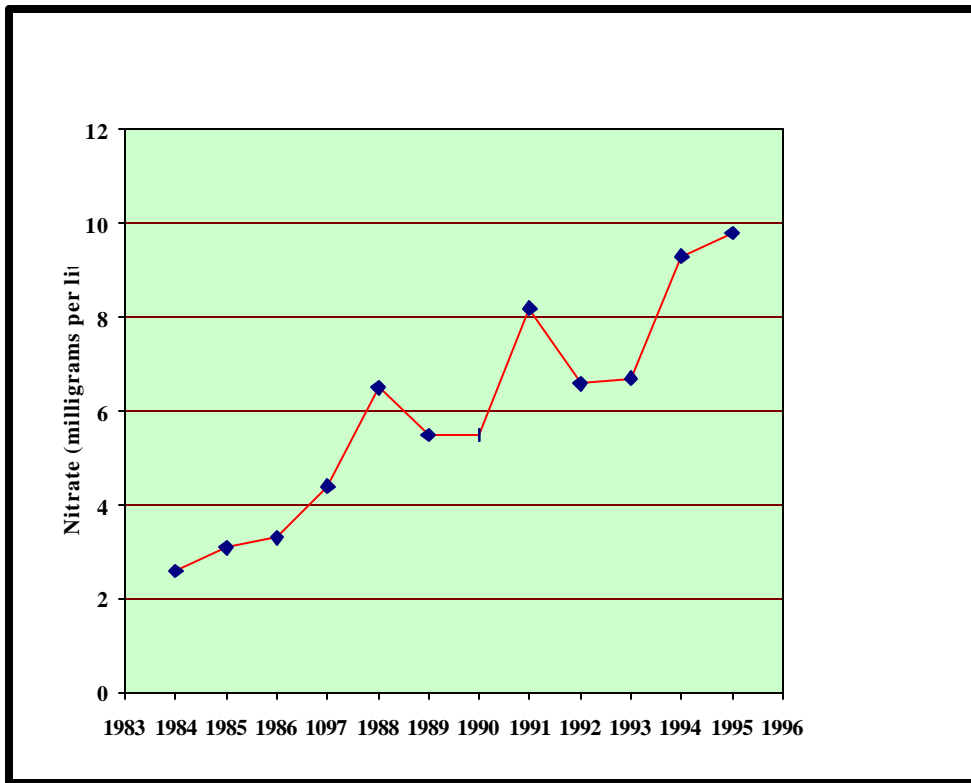


Figure 5. Increasing nitrate trends in Pocatello public supply well (DWIMS, 2000)

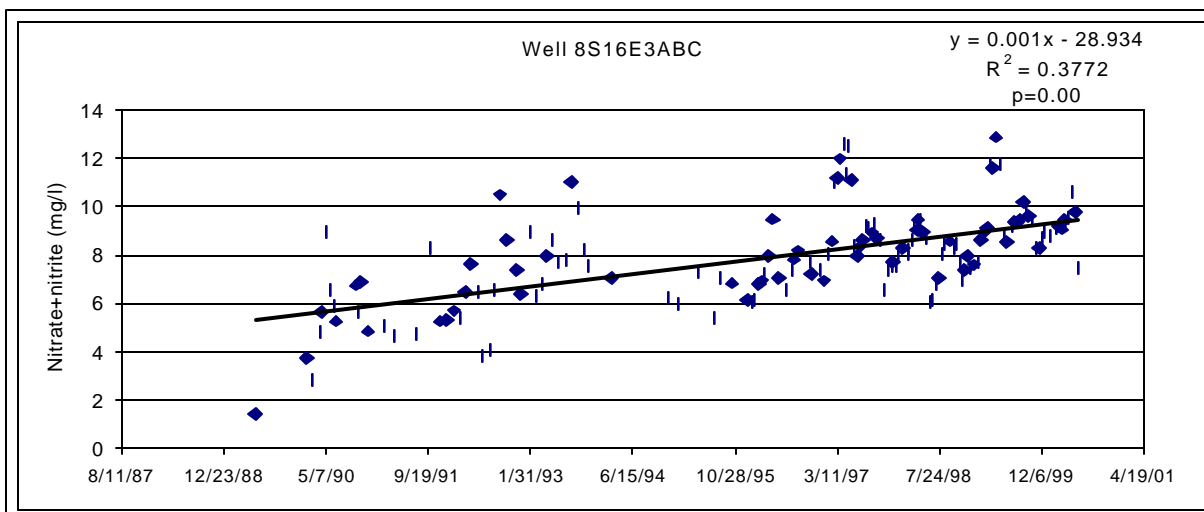


Figure 6. Regression for complete data set for private well southwest of Jerome (Baldwin, et. al., 2000).

Approximately 36% of Idaho households depend on private well water (telephone conversation with Richard Twight, Idaho Department of Commerce). Using 1990 census data, approximately 372,600 persons obtain their water from private wells. These wells are not regulated under Idaho law for water quality and therefore less is known about the status of these wells statewide. However, the *Idaho Private Wellhead Sampling Program* was initiated by the Idaho Farm Bureau in 1990. The study is conducted on a voluntary basis and private well owners are encouraged to donate a sample of their well water for testing. Confidentiality of sample sites and landowners is

maintained. Several agencies participated in various aspects of the study including ISDA, the Soil Conservation Service, University of Idaho-CES, USGS, and IDEQ. Samples were collected from farms and other rural residents on private wells. Location data on sample points are not available and results are for county or multiple counties only. Table 2. presents partial sampling results of known findings to date. The Idaho Farm Bureau is continuing to monitor private wells.

Table 2. Private Well Sampling Results (Idaho Farm Bureau, 1999)

Project Counties	Project Year	# of Wells	Nitrate Results for Project Area		
			% > 2 mg/l	% > 5 mg/l	% > 10 mg/l
Ada	1991	253	81	16	2
Benewah, Latah	1991	77	32	13	5
Bonner	1991	65	14	9	0
Bonneville	1992	49	41	2	0
Canyon	1991	450	60	27	8
Cassia, Minidoka, Jerome	1990	355	78	25	4
Elmore, Owyhee	1992	250	41	26	10
Franklin, Caribou	1997	59	32	10	2
Fremont	1993	117	50	27	11
Jefferson, Madison, Teton	1993	212	35	8	1
Lemhi, Butte, Custer	1994	155	18	4	1
Oneida	1998	43	40	14	0
Payette, Gem	1991	164	48	12	5
Twin Falls	1991	186	81	25	3
Washington	1995	89	70	57	30
Total: 25 Counties		2,524	55%	21%	6%

The Idaho Farm Bureau’s efforts indicate that approximately 6% of private wells that were sampled exhibit nitrate levels over the drinking water standard of 10 mg/l. Another 21% have concentrations showing impacts at greater than 5 mg/l (Mahler R.L., and K.A. Loeffelman, 1999).

Figure 7. indicates the increasing risk of ground water contamination potential from nitrate sources nationwide, but does not show actual nitrate contamination of ground water. Water quality testing is necessary to determine actual nitrate concentration. Nitrate concentration in ground water generally increases with higher nitrogen input and higher aquifer vulnerability. People who live in areas shown in red on the map and who consume shallow ground water are more likely to have an increased risk for nitrate contamination through drinking high-nitrate water. Median nitrate concentration and percent of wells from which water exceeds the MCL of 10 mg/l for nitrate are highest in areas with high nitrogen input and high aquifer vulnerability (red areas).

Nitrate contamination generally decreases with increasing depth to ground water after a certain level. Median nitrate concentration and percent of wells from which water exceeds the MCL are highest for shallow ground water (up to 100 feet deep). The water table in shallow wells is closer to the land surface and to potential sources of contamination, such as fertilizers and septic systems. In contrast, contamination is less likely to occur in deeper ground water bearing zones because contaminants have farther to travel vertically and can be slowed or stopped by impermeable layers (Mueller and others, 1995).

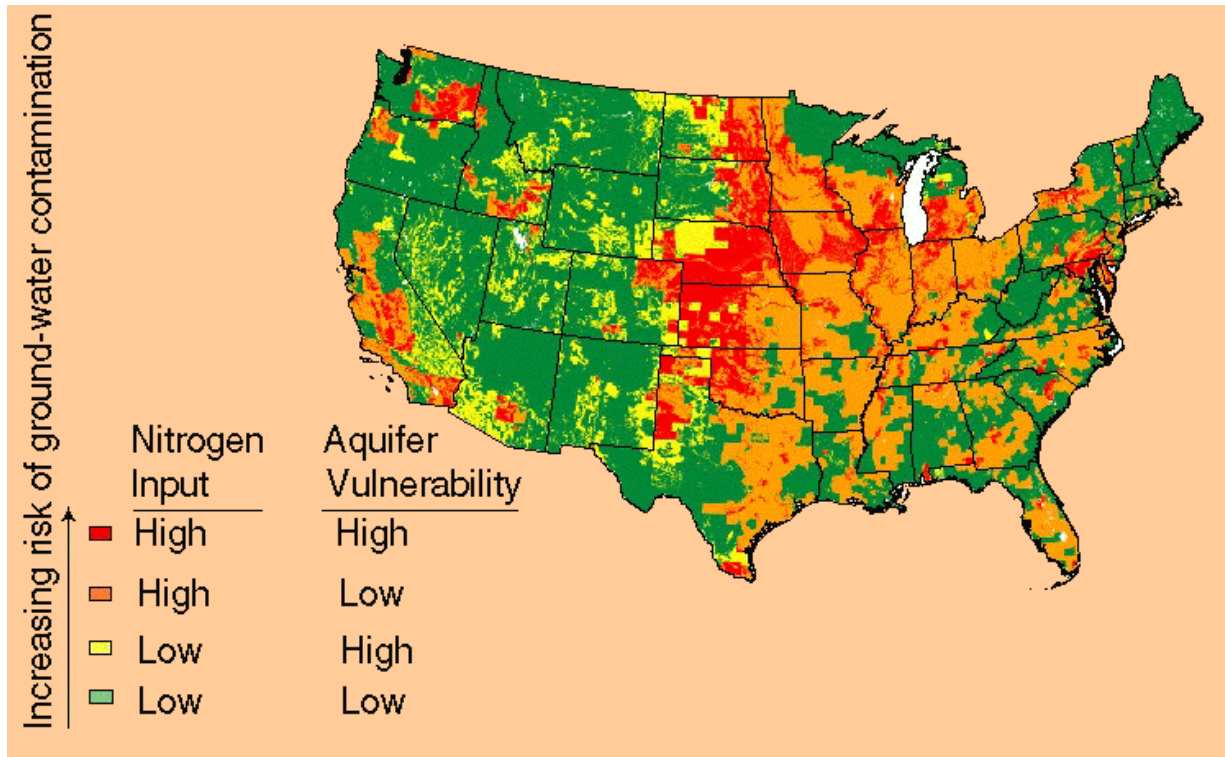


Figure 7. Increasing US and Idaho fertilizer-N input (USGS).

While nitrogen is needed to increase plant productivity and farm profitability, some farmers have applied more nitrogen to crops than is necessary to optimize yields. A survey of more than 1,500 midwestern farmers found that two out of three farmers purchased more nitrogen fertilizer than their crops needed (Shepard, et. al., 1997). For example, farmers on average used an excess of 40 pounds per acre of nitrogen beyond university recommendations for growing corn. This average number is conservative in that it doesn't account for residual soil nitrate, it only accounts for first-year legume and manure nitrogen credits, it assumes no incorporation of manure and the lowest value was used when a range was presented for manure or legume credits.

What's the future for nitrate in ground water?

Without a reduction in nitrate loading to ground water, nitrate concentration in Idaho ground water will likely increase and nitrate pollution will likely affect larger areas and larger volumes of ground water and surface water. This is because, in many parts of Idaho, older ground water (thousand of years old) originating before the use of chemical fertilizers and having low levels of nitrate is being discharged to the surface, and is now being replenished with younger ground water that has higher levels of nitrate. The net effect is that the average nitrate concentration in Idaho ground water will likely continue to increase. This is supported by IDWR's findings of an increase in nitrate from First Round sampling to Second Round sampling (Neely, K.W. and J.K. Crockett, 1999).

What are the tangible costs of nitrate pollution and who bears them?

The tangible cost of nitrate contamination of ground water can be measured as the cost of water treatment for public, noncommunity (schools for example) and private well systems. These costs are borne by taxpayers, utility customers and well owners. Ground water is the source of water for approximately 95% of the public water supply well systems in Idaho; the remaining 5% of public

systems get their water from surface water sources. Public drinking water wells are regulated under the Safe Drinking Water Act, which requires nitrate-nitrogen levels to be below the MCL of 10 mg/l. There are a number of regulated public drinking water wells in Idaho that have reported nitrate concentrations exceeding the MCL of 10 mg/l. In fact, over 50 public water systems accounting for 121 water sources in Idaho show elevated nitrates levels (greater than 5 mg/l), about 3% of these are over the drinking water standard of 10 mg/l. (DWIMS, 2000). These systems have few choices in order to stay in compliance. They can install nitrate removal systems or drill new wells at a total cost to municipal ratepayers in excess of thousands of dollars. This amount does not include the annual cost of maintaining the systems. Some public water systems are choosing to purchase their water from other municipalities at a higher cost than it took them to originally supply clean drinking water through their own wells (EPA, 1995b).

EPA estimates the cost to clean-up a single public drinking water system ranges from \$.5 million to \$2.4 million and depends on the amount of water that is being treated (EPA, 1995b). In Massachusetts, for example, it cost a local municipality \$1.7 million to treat a contaminated wellfield that pumped approximately 5 million gallons per day and \$750,000 to treat another city's wellfield that used 1.5 million gallons per day (New England Interstate Water Pollution Control Commission, 1996).

For a small to middle-sized community, an average anion exchange treatment system may cost over \$630,000 to install and an additional \$9,400 per year for salt. In addition, 1.2 million gallons of water are needed for regeneration of the system (National Research Council, 1994). This water is wasted, as it is not potable after regenerating the system.

There is no way to estimate the cost to private well owners who have nitrate contamination. Boiling water containing nitrate will actually increase the nitrate concentration levels. Bottled water, reverse osmosis or ion exchange units may be the least expensive alternatives for nitrate contaminated private wells.

What's the current legal framework for addressing nitrate in ground water?

The Ground Water Quality Protection Act of 1989

Comprehensive protection of the ground water resource is provided through the implementation of the *Ground Water Quality Protection Act of 1989*, the *Idaho Ground Water Quality Plan*, and the *Ground Water Quality Rule*. Protection can be achieved through a variety of processes outlined in the *Idaho Ground Water Quality Plan* and the *Ground Water Quality Rule*, including, if necessary, the re-categorization of aquifers or portions of aquifers to ensure stricter controls. Ground water programmatic efforts include monitoring and site assessment, public education, pollution prevention, technical and financial assistance, remediation of contaminated sites, and outreach. The *Ground Water Quality Rule* (IDAPA 58, Title 01, Chapter 11) is the overriding Idaho statute which establishes authority for ground water protection through numerical enforcement standards applicable to all Idaho agencies and programs. The enforcement standard is the health-based concentration of a substance at which a facility regulated by state agencies must take action to reduce the level of the substance in ground water. Once enforcement standards are established, all state agencies must manage their regulatory programs to comply.

The Safe Drinking Water Act (SDWA)

Under the SDWA, EPA is authorized to ensure that water is safe for human consumption. To support this effort, SDWA gives EPA the authority to promulgate MCLs that define safe levels for

some contaminants in public drinking water supplies. IDEQ received primary delegation for this program and oversees the administration of public drinking water systems in Idaho. The federal MCL for nitrate-nitrogen in drinking water is 10 mg/l - the same as Idaho's current ground water quality standard. Public water systems monitor for nitrate and must meet the MCL.

What are current management strategies for nitrate pollution?

The following entities are involved in nitrogen management efforts in Idaho:

- The University of Idaho and its Cooperative Extension Service provide research information and educational programs on nitrate sampling, *Best Management Practices for Nitrogen Management to Protect Ground Water, Idaho Wellhead Survey for Nitrates; 1990 – 1999*, nutrient management research information through its College of Agriculture, and many additional publications. The University of Idaho's Nutrient and Pest Management program is an educational effort based on soil testing programs and soil fertility recommendations by soil type and crop. For more information please visit the website: <http://www.uidaho.edu/wq/> or contact the Cooperative Extension Service at (208) 885-7025.
- The ISDA is responsible for implementing *IDPA 02 Title 03, Chapter 4, Chemigation Rules*, that provide for regulation of the irrigation systems that are utilized for the application of pesticides and fertilizers. This includes backflow prevention standards, licensing, inspections, and training programs. ISDA developed the agriculture portion of the Idaho Ground Water Quality Plan in 1996. This portion of the Plan directs ISDA to use the feedback loop when addressing contamination to ground water caused by agricultural operations (Idaho Ground Water Quality Plan, 1996). Also, ISDA is responsible for the formation and facilitation of the Agricultural Ground Water Quality Coordination Committee, which was established to help implement the state's agricultural ground water program. The Soil Conservation Commission can provide additional help through its Conservation Districts. For more information please visit the website: <http://www.agri.state.id.us/> or contact ISDA at (208) 332-8500.
- The Federal Natural Resources Conservation Service coordinates and implements the Agricultural Conservation Program which is administered to restore and protect land and water resources and preserve the environment. This program uses cost sharing of best management practices and outreach efforts to reduce nutrient loads from agriculture and provides nutrient management planning and engineering technical support. For additional information please visit the national website: <http://www.nrcs.usda.gov/> or contact the Natural Resource Conservation Service at (208) 378-5700.
- IDEQ's programs and activities for ground water nonpoint source controls and implementation of best management practices are contained in Section 319 of the Clean Water Act that requires states to develop and implement a nonpoint source management program. Ground Water is included in Idaho's recently revised and EPA-approved *Idaho Nonpoint Source Management Plan* (IDEQ, 2000). The Plan addresses the following ground water related sources: agriculture, septic systems, urban runoff and industrial chemicals. The *Idaho Nonpoint Source Management Program* cost shares the use of best management practices to protect water quality by reducing the amount of nutrients (nitrates) from urban and rural sources. For more information please visit the IDEQ website: <http://www2.state.id.us/deq/> or contact IDEQ at (208) 373-0502.

- The IDEQ wastewater program *under IDAPA 58, Title 1, Chapter 17, Wastewater – Land Application Permit Regulations*, oversees the permitting of discharges of nitrogen containing wastewater and biosolids to the land surface and potentially to ground water. The wastewater program regulates discharge of municipal and industrial wastewater to land treatment systems such as spray irrigation systems, seepage cells and ridge and furrow systems; discharge of municipal and industrial sludges, biosolids and industrial liquid wastes through land application; discharge of septage through land application; and impacts on ground water from wastewater treatment and storage lagoons leaking in excess of ground water standards. There are currently more than 100 permits that authorize wastewater application to more than 16,000 acres. About two-thirds of these permits are for Municipal Wastewater Treatment Plants, and about one-third are issued to industry, most of which are represented by agricultural food processors. The guidance and permit conditions are based on wastewater applications at agronomic rates during the growing season and on the available water capacity in the soils during the non-growing season to minimize leaching of nitrogen below the crop root zone and into ground water. For more information on this program, please visit the IDEQ website: <http://www2.state.id.us/deq/> or contact IDEQ at (208) 373-0502.
- Disposal of on-site animal waste (manure) from concentrated animal facilities is regulated through a Memorandum of Agreement between USEPA, IDEQ, and ISDA. Facilities with over one thousand animals must have an USEPA National Pollutant Discharge Elimination permit as required under federal law, if there is a discharge from the site. An NPDES permit does the following: establishes design standards and accepted animal waste management practices for the large animal feeding operations category of point sources, establishes the criteria under which permits are issued to other animal feeding operations that discharge pollutants to waters of the state. A facility smaller than one thousand animals may be required to obtain a permit if the Director determines that it is necessary. ISDA has promulgated and enforces rules for dairy operations. Non-compliance with the rules or discharge violations may result in revocation of authority to sell milk for human consumption. ISDA also conducts dairy waste inspections to prevent waste releases and evaluate waste collection, treatment, handling, disposal, and management procedures for compliance with the Clean Water Act and ISDA regulations. All releases that present a potential hazard to the human health and environment are reported immediately to IDEQ. USEPA, IDEQ, and ISDA have signed an MOU transferring the regulatory compliance responsibility for cattle feeding operations to ISDA. Currently poultry and swine operations greater than 2000 animal units are regulated by IDEQ. An MOU is under development for the transfer of responsibility of smaller poultry and swine operations to ISDA. For more information on dairies and beef operations contact ISDA at (208) 332-8550. Information and swine and poultry can be obtained by contacting IDEQ (208) 373-0502.
- Idaho's state septic system regulations *under IDAPA 58, Title 1, Chapter 03, Rules for Individual/Subsurface Sewage Disposal Systems*, and *IDAPA 58, Title 1, Chapter 15, Regulations governing the Cleaning of Septic Tanks* are fully established. Implementation is primarily through Idaho's seven health districts with technical assistance from IDEQ. The health districts implement the day-to-day activities in the program by conducting site evaluation, issuing system permits, issuing septic tank pumper licenses, and conducting inspections. This entails establishing design standards and accepted waste management practices for private septic systems, establishing the criteria under which sanitary permits are issued to build private septic systems that discharge pollutants to waters of the state, and establishing soil site evaluation standards for placement of septic systems. IDEQ responsibilities include plan and specification

reviews, heading the technical guidance committee, and reviewing new technologies and providing training courses for installer and pumpers. *The Technical Guidance Manual for Subsurface Sewage Disposal Systems* (TGM) is used to assist in site evaluations, septic tank designs, system operations and maintenance, land use planning, and implementation of best available technologies. The TGM serves as the reference for the Environmental Health Specialists, licensed installers, and professional engineers. A new Recirculating Sand Filter Section was added to the Alternative System Chapter recently. This new section addresses reducing nitrate loading to ground water by denitrifying nitrate to nitrogen gas in the recirculating tank. For additional information, please visit the IDEQ website: <http://www2.state.id.us/deq/>, contact IDEQ at (208) 373-0502 or contact your local health district.

- IDEQ's Storm Water Program is responsible for planning support through technical assistance, education, and information transfer. The goal is to protect the quality of both ground and surface water from the effects of storm water runoff. A comprehensive set of storm water runoff statewide guidances have been prepared to assist in preventing and controlling urban and suburban related pollution. The following publications are available: *Environmental Planning Tools and Techniques*, that presents a menu of measures for local planners and land use decision makers that can be incorporated at the site to better integrate comprehensive design principles into land development; and the *Catalog of Storm Water BMPs*, that provides guidance for the selection, basic design, construction, and maintenance of source and treatment control measures. The catalog is undergoing update and will be available soon on IDEQ's website. Another valuable tool for professional designers will soon be released by IDEQ called *Integrative Approaches to Linking Urban Land Use to Water Quality*. For additional information please contact IDEQ at (208) 373-0502.
- IDWR's Statewide Ambient Ground Water Quality Monitoring Program (Statewide Program) is tasked with designing and maintaining a statewide monitoring network. The Statewide Program began in 1990 with a limited prototype network of 97 monitoring sites. The IDWR developed a joint funding agreement with the USGS in 1990 to utilize their strengths in data collection and sample analyses. Since 1991, the USGS has contributed at least \$200,000 annually through federal cooperative funding. The Legislature provides IDWR with \$539,000 per year for the Statewide Program. The combined State and Federal funds enabled the addition of about 400 sites to the network each year from 1991 through 1994. By the fall of 1994, the Statewide Program network included over 1,500 monitoring sites. IDWR is responsible for analyzing the data and writing interpretative reports. The USGS provides logistical support in the field. The overall objectives of the Statewide Program are: 1) characterize the ground water quality of the state's aquifers; 2) identify trends and changes in ground water quality within the state's aquifers; and 3) identify potential ground water quality problem areas. Data collected through the Statewide Program from 1991 to 1994 is called First Round sampling and is being used to address the first objective. Data collected in 1995 through 1998 is Second round sampling and is used for trend analyses and additional characterization. For additional information, please visit the IDWR website: <http://www.idwr.state.id.us/> or contact IDWR at (208) 327-5455.

What consideration should be given to ground water in decision-making?

Ground water has often been slighted in water supply planning and management. For a long time, it was believed that ground water could not be as easily evaluated as surface water, in terms of its availability, development, chemical quality and the economics of recovery. On the contrary, new

hydrogeologic information and understanding, along with substantial progress in analytical capability, have improved the ability to plan, develop and manage ground water. Scientific analysis of ground water systems has opened the door to more effective use and protection of ground water.

Ground water hydrology is an interdisciplinary mix of the physical, biological and mathematical sciences. New concepts and methods have improved investigation and problem solution. Simulation methods developed within the past 25 years permit revealing model analysis of ground water systems and their interconnections with surface water. Modeling enables predictions of the effects of pumping and waste disposal on ground water. It also allows greater consideration of alternative management plans.

Inadequate communication between the ground water expert and the planning expert is partly responsible for the lack of integration of ground water into water resources planning. Closer affiliation of these experts is fostering increased mutual understanding of ground water and its important role in the nation's water supply. Ground water is now recognized to be a fundamental component in the comprehensive joint management of land, water and waste throughout the nation.

Future Plans

The magnitude and complexity of ground water problems continues to grow in Idaho. For this reason, increased effort and resources are needed to address them. It is critical for decisions to be made from a sound and credible scientific basis. This requires adequate ground water data, modeling and information. Decision-makers need to consider how best to bring ground water issues into the mainstream of planning, management, and policy at all levels. Ground water quality and public policy issues are the theme of IDEQ's March 2000 *Policy For Addressing Degraded Ground Water Quality Areas*. This policy will be the foundation for the work of advisory committees and agencies around the state who are charged with the development of management strategies designed to address degraded nitrate areas. For a copy of the policy please visit the IDEQ website: <http://www2.state.id.us/deq/> or contact IDEQ (208) 373-0502.

The IDEQ will implement this policy over the coming years, starting with those areas having the most significant degradation. The Ground Water Quality Monitoring Technical Committee has developed a process to rank degraded areas impacted by nitrate contamination consistent with the Policy guidelines. The USGS is providing support to this project by determining the trends in the selected nitrate-impacted areas. A pilot project is underway in the Salmon Falls/Rock Creek Ground Water Quality Area. A local advisory committee, comprised of key water users and interested citizens, was formed to develop an action plan to mitigate elevated nitrates for the affected area. This advisory committee's work will serve as a model for future advisory committees. This action plan is to be completed in June 2001. Once trends are analyzed by USGS, the degraded nitrate areas will be prioritized and IDEQ can begin working with local advisors and agencies to develop action plans in other high priority areas.

Both economic interests and environmental goals figure prominently in crafting policy to address ground water contamination. Not surprisingly, tradeoffs arise between and within economic interests and environmental goals. A policy choice to achieve one environmental objective may exacerbate or ameliorate another environmental problem. The cost benefit analysis may make certain alternatives untenable no matter how environmentally attractive they might appear. Suffice it to say, there is no simple formula and no one policy will satisfy all stakeholders. Perhaps the most critical element in ensuring the quality of Idaho's groundwater is protected is the active

participation of all stakeholders in the process of identifying and implementing reasonable and proactive, science-based solutions.

References

Baldwin, Joe, D. Brandt, E. Hagan, B. Wicherski, 2000. *Cumulative Impacts Assessment, Thousand Springs Area of the Eastern Snake River Plain, Idaho*. Ground Water Quality Technical Report No. 14, pgs 28 – 32.

Boyle, W., 1995. *Nitrogen Removal from Domestic Wastewater in Unsewered Areas*. University of Washington, Seattle, WA., pp. 237- 258.

Bureau of Reclamation, 1984. *Boise Valley Shallow Ground Water Quality Study*. Pacific Northwest Region, Boise, Idaho.

Crowley, J.W., N.A. Jorgensen, L.W. Kahler, L.D. Satter, W.J. Tyler, M.F. Finner, 1974. *Effect of Nitrate in Drinking Water on Reproductive and Productive Efficiency of Dairy Cattle*, Water Resources Center, University of Wisconsin Technical Report WIS WRC 74-06.

Drinking Water Information Management System (DWIMS), Idaho Department of Environmental Quality, 2000. Personal Correspondence from Howard Woods.

Energy Information Administration. *Emissions of Greenhouse Gases in the United States 1998*. USDOE, Washington, D.C., October, 1999.

Garabedian, S.P., 1992. *Hydrology and Digital Simulation of the Regional Aquifer System, Eastern snake River Plain, Idaho*. U.S. Geological Survey Professional Paper 1408-F, 102 pp., 10 plates.

Gilli, G., G. Corrao, S. Favilli, 1984. *Concentrations of nitrates in drinking water and incidence of gastric carcinomas: first descriptive study of the Piemonte region, Italy*. *Sci Tot Environ* 34:35-48.

Hahn, Christine, M.D., Idaho Department of Health and Welfare, Bureau of Clinical and Preventive Services, 2001. Personal Communication.

Hallberg, G.R. 1989. *Nitrate in Ground Water in the United States*. IN: *Nitrogen Management and Ground Water Protection*. Elsevier, Amsterdam, pp. 35-74.

Hallberg, G.R., R.D. Libra, D.J. Quade, J.P. Littke, and B.K. Nations, 1989. *Ground water Monitoring in the Big Springs Basin 1984-1987: Summary Review*: Iowa Department of Natural Resources, Geological Survey Bureau, Technical Information Series 16. 68 p.

Hecnar, S.J., 1995. *Acute and Chronic Toxicity of Ammonium Nitrate Fertilizer to Amphibians from Southern Ontario*, *Environmental Toxicology and Chemistry*, vol. 14 no. 12, pgs 2131 - 2137.

Idaho Agricultural Statistics Service, 1997. <http://www.nass.usda.gov/> State Information, Idaho.

Idaho Department of Commerce, 1997. <http://www.idoc/state/id/us/> Idaho Data Center.

Idaho Farm Bureau Federation, 1997. Idaho Private Wellhead Sampling Program. Personal Communication.

Ingham, Michael J., 1996. *Lower Payette River Agriculture Irrigation Water Return Study and Ground Water Evaluation*, Idaho Department of Environmental Quality, Water Quality Status Report No. 115, 65pp..

Kincheloe, J.W., G.A. Wedemeyer, and D.L. Koch, 1979. *Tolerance of Developing Salmonid Eggs and Fry to Nitrate Exposure*, Bulletin of Environmental Contamination and Toxicology, Vol. 3, pgs. 575-578.

Lillie, R.A., and J.W. Barko, 1990. *Influence of Sediment and Ground water on the Distribution and Biomass of Myriophyllum Spicatum L. in Devil's Lake*. Journal of Freshwater Ecology, vol. 5, no. 4, pgs. 417-426.

Mahler, R.L., E. Porter and R. Taylor, 1990. *Nitrate and Groundwater*. University of Idaho Cooperative Extension System CIS No. 872.

Mahler, R. L. and K. A. Loeffelman, 1999. *Idaho Wellhead Sampling Program – Nitrate Sampling*, University of Idaho-Cooperative Extension System, Water Quality Brochure No. WQ-39.

Mueller, D.K., P.A. Hamilton, D.R. Helsel, K.J. Hitt, and B.C. Ruddy. 1995. *Nutrients in ground water and surface water of the United States—An analysis of data through 1992*. U.S. Geological Survey –Resources Investigations Report 95-4031, 74 pp.

National Research Council, 1994. *Alternatives for Ground Water Cleanup*. Committee on Ground Water Cleanup Alternatives, Water Science and Technology Board, Commission on Geoscience, Environment, and Resources, National Research Council. National Academy Press, Washington, D.C.

National Research Council. 1995. *Nitrate and Nitrite in Drinking Water*. Washington, D.C.: National Academy Press.

Neely, K.W., and J.K. Crockett, 1999. *Nitrate in Idaho's Ground Water*. Idaho Department of Water Resources, Technical Results Summary No. 1, 12p.

New England Interstate Water Pollution Control Commission. *Source Protection: A Guidance Manual for Water Supplies in New England*. 1996

Piper, R., I.B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler, and JR. Leanard, 1982. *Fish Hatchery Management*, U.S. Fish and Wildlife Service, Washington, D.C., 517 pages.

Rademach J.J., T.B. Young, M.S. Kanarek, 1992. *Gastric cancer mortality and nitrate levels in Wisconsin drinking water*. Arch Environ Health 47:292-4.

Robertson, D.M., and D.A. Saad, 1996. *Water-Quality Assessment of the Western Lake Michigan Drainages-Analysis of Available Information on Nutrients and Suspended Sediment, Water Years 1971-90*, USGS Water Resources Investigations Report 96-4012.

Rogers, S.J., D.G. McFarland and J.W. Barko, 1995. *Evaluation of the Growth of Vallisneria Americana Michx. In Relation to Sediment Nutrient Availability, Lake and Reservoir Management*, vol. 11, no. 1, pgs. 57-66.

Rupert, Michael G., 1994. *Analysis of data on nutrients and organic compounds in ground water in the upper Snake River Basin, Idaho and western Wyoming, 1980-91*: U.S. Geological survey Water-Resources Investigations Report 94-3135. 40 pgs.

Schubert, C., L. Knobeloch, H. Anderson, C. Warzecha, and M. Kanarek, 1997. *Nitrate Contaminated Drinking Water Followback Study*, Submitted to the Wisconsin Dept. of Natural Resources and the Wisconsin Ground Water Coordinating Council. Department of Preventive Medicine, University of Wisconsin-Madison and the Wisconsin Department of Health and Family Services. 17 pages.

Scragg, R.K.R., M.M. Dorsch, A.J. McMichael, P.A. Baghurst, 1982. *Birth defects and household water supply*. Med J Aust 2:577-9.

Shepard, R., F. Madison, P. Nowak, and G. O'Keefe, 1997. *Watershed/Source Water Protection Programs Targeting Mixed Farming Systems in the Upper Midwest*, for: American Water Works Association Annual Conference, August, 1997, Seattle Washington.

Taylor, R., E. Porter and R. L. Mahler, 1990. *Drinking Water Standards*. University of Idaho Cooperative Extension System CIS No. 874.

The Fertilizer Institute, 2000. <http://www.tfi.org/> *Fertilizer Consumption By State*.

Twight, Richard, Idaho Department of Commerce, 2000. Personal Communication.

USGS, NAWQA Fact Sheet 092-96. *U.S. Areas Vulnerable to Nitrate Contamination of Ground Water*.

USEPA, 1995b. *Benefits and Cost of Prevention: Case Studies of Community Wellhead Protection*. Office of Water, Washington, DC. EPA816-B-95-002

USEPA, 1977. *Quality Criteria for Water*, US Government Printing Office, Washington DC, 20402, Stock No. 05 5 -001-01049-4.

USEPA, 1990a. *Estimated national occurrence and exposure to nitrate/nitrite in public drinking water supplies*. Prepared by Wade Miller Associates, Inc. under EPA contract nr. 68-03-3514.

USEPA, 1990b. *County-level fertilizer sales data*: Washington D.C., Policy Planning and Evaluation, PM-221, not paged.