MAJOR SOURCES OF NITROGEN INPUT AND LOSS IN THE UPPER SNAKE RIVER BASIN, IDAHO AND WESTERN WYOMING, 1990

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FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for a specific contamination problem; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 60 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch
Chief Hydrologist

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FIGURES

TABLE

CONVERSION FACTORS

Multiply	By	To obtain
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
gallon	3.785	liter
gallon per minute (gal/min)	0.06309	liter per second
mile (mi)	1.609	kilometer
million gallons (Mgal)	3.785	million liters
pound (lb)	0.4536	kilogram
square foot	0.0929	square meter
square mile (mi^2)	2.590	square kilometer
ton (short)	907.2	kilogram

MAJOR SOURCES OF NITROGEN INPUT AND LOSS IN THE UPPER SNAKE RIVER BASIN, IDAHO AND WESTERN WYOMING, 1990

By Michael G. Rupert

Abstract

Total nitrogen input and loss from cattle manure, fertilizer, legume crops, precipitation, and domestic septic systems in the upper Snake River Basin, Idaho and western Wyoming, were estimated by county for water year 1990. 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 basin where excess nitrogen is produced.

The results of the input estimations suggest that domestic septic systems account for less than 1 percent of the total nitrogen input in the basin and precipitation accounts for 6 percent. The remaining 93 percent is produced by cattle manure (29 percent), fertilizer (45 percent), and legume crops (19 percent). Input from cattle manure, fertilizer, and legume crops varies widely among counties and reflects differences in land-use practices such as different cropping patterns and numbers of dairies and feedlots.

Residual total nitrogen was estimated by subtracting loss due to cattle manure storage and application, crop uptake, and decomposition of previous-year nonleguminous crop residue (chaff) from all nitrogen input in the basin. Positive mean values of residual total nitrogen in most counties suggest that more total nitrogen is input than is lost. This residual total nitrogen is available for runoff to surface water or leaching to ground water. Three out of four counties where mean values of residual total nitrogen were highest (Cassia, Gooding, and Twin Falls) are located in the western part of the basin, where eutrophication in the Snake River is evident and ground water from many wells contains anomalously high nitrate concentrations. Ground water in the fourth county (Bingham), which includes the Fort Hall area north of Pocatello, also contains high nitrate concentrations.

A mass balance of total nitrogen input and loss in Gooding, Jerome, Lincoln, and Twin Falls Counties suggests that more than 6,000,000 kg (6,600 tons) of total nitrogen is input in this four-county area than is discharged by the Snake River. This excess nitrogen probably is utilized by aquatic vegetation in the Snake River (causing eutrophication), stored as nitrogen in soil, stored as nitrate in the ground water and eventually discharged through the springs, utilized by noncrop vegetation, and lost through denitrification.

INTRODUCTION

Nitrite plus nitrate concentrations in ground water exceed the U.S. Environmental Protection Agency maximum contaminant level of 10 milligrams per liter (mg/L) in several locations in the upper Snake River Basin (Rupert, 1994; Parliman and Young, 1987, 1988, 1989; Young, Parliman, and Jones, 1987; Young, Parliman, and O'Dell, 1987). The primary health hazard of high concentrations of nitrite plus nitrate in drinking water is methemoglobinemia, or blue baby syndrome, which is characterized by a reduced ability of the blood to carry oxygen. High concentrations of nitrite plus nitrate in drinking water also may be implicated with a high incidence of non-Hodgkin's lymphoma (Weisenburger, 1991, p. 309).

Excess ammonia, nitrate, and organic nitrogen in surface water in the basin can lead to excessive aquatic plant growth, which can cause eutrophication and impair beneficial uses of water resources. Excessive aquatic plant growth has impaired hydropower generation, fisheries, and recreational use in the middle reach of the Snake River near Twin Falls (Idaho Department of Health and Welfare, 1994, p. 59).

Concern over nitrite, nitrate, and ammonia in the Snake River Basin has generated interest in determining the nonpoint sources of nitrogen and their relative magnitude of input to surface and ground water.

Purpose and Scope

This report presents estimates of the amount of nitrogen input and loss in the upper Snake River Basin, Idaho and western Wyoming. Data were insufficient to include every source of input and loss in the basin; only the major nonpoint sources are addressed. 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 basin where excess nitrogen is produced.

Estimations of input and loss were made by county; data were insufficient to make the estimations at a larger scale. Amounts of total nitrogen instead of nitrite, nitrate, or ammonia were estimated so that the relative amount of nitrogen input or lost by each source could be compared. Because it was not possible to determine the exact amount of nitrogen input or lost by each source, maximum and minimum probable values were estimated to bracket the possible ranges. The estimations were made under the assumption that land-use practices in the region have remained fairly constant for the last 10 years.

Acknowledgments

The author acknowledges the assistance and information provided by personnel from the following agencies: Idaho Agricultural Statistics Service; Idaho Department of Agriculture; Idaho Department of Health and Welfare, Division of Environmental Quality; University of Idaho, Cooperative Extension Service; University of Idaho, Agricultural Research Service; and Fremont County Planning Commission, Wyoming.

DESCRIPTION OF STUDY AREA

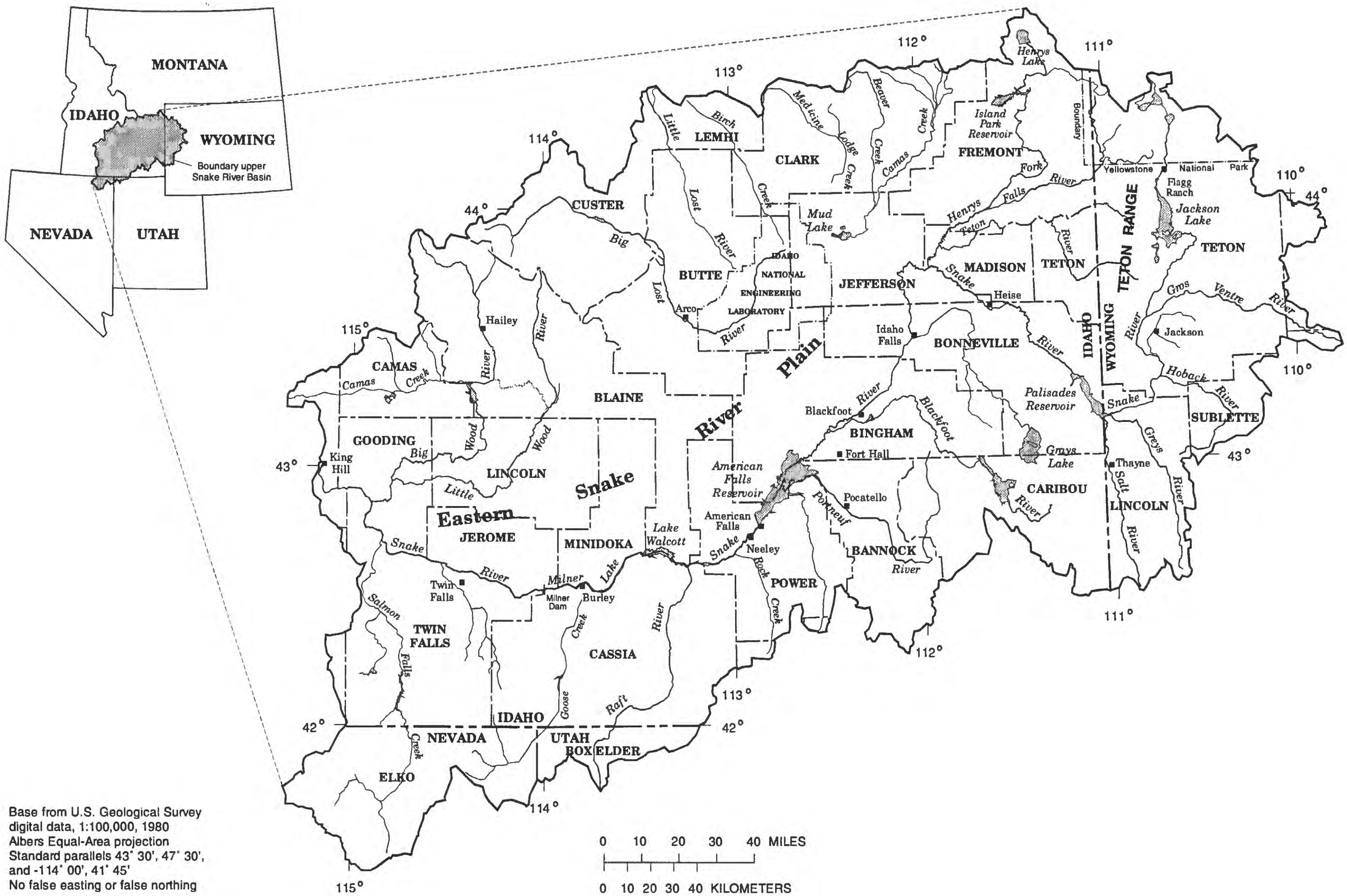
The 35,800-mi^2 upper Snake River Basin extends from Yellowstone National Park in Wyoming to King Hill in south-central Idaho (fig. 1). The 10,800-mi^2 eastern Snake River Plain is about 60 mi wide and 170 mi long. The plain is underlain by a series of highly vesicular and broken Quaternary olivine basalt flows, each averaging 20 to 25 ft in thickness; total thickness is as much as 5,000 ft. These basalt flows are highly transmissive to ground water. Ground water is discharged from the eastern Snake River Plain aquifer as spring flow and seepage to the Snake River between Milner Dam and King Hill (fig. 1). Combined spring discharge in this reach was more than 6,000 ft^3/s in 1980 (Kjelstrom, 1986).

Paleozoic sedimentary and Tertiary volcanic rocks predominate north, east, and south of the plain. Quaternary and Tertiary sedimentary and, to a lesser extent, Quaternary and Tertiary volcanic rocks predominate in the mountain valleys.

About half of the upper Snake River Basin is forest and rangeland, about one-third is irrigated agricultural land, and the remaining area is barren. Most of the 2.3 million acres of irrigated land is near the Snake River and near the mouths of tributary basins. Most cities and industrial centers are adjacent to the Snake River. Major dams and lakes in the basin store about 4.4 million acre-ft of water for irrigation of more than 1 million acres annually.

NATURALLY OCCURRING NITRATE

With the exception of precipitation, there are no known major sources of naturally occurring nitrate in the upper Snake River Basin. Mansfield (1915, p. 28) described a minor deposit of potassium nitrate in depressions and small cavities of a rhyolite formation in Blaine County. This deposit is not considered an extensive source of nitrogen in ground water or surface water of the basin.



Base from U.S. Geological Survey
digital data, 1:100,000, 1980
Albers Equal-Area projection
Standard parallels 43° 30', 47° 30',
and -114° 00', 41° 45'
No false easting or false northing

Figure 1. Location of study area.

BACKGROUND CONCENTRATIONS OF NITROGEN COMPOUNDS

Nitrate concentrations in ground water from wells that are unaffected by cattle manure, fertilizer, legume crops, or domestic septic system sources are typically less than 1 mg/L as nitrogen. Parliman (1988, p. 233) suggested that nitrite plus nitrate as nitrogen concentrations in ground water exceeding 2 mg/L probably indicate degradation of water quality from land-use activities. Nitrate and ammonia concentrations from precipitation samples collected in the basin (Maupin, 1995, fig. 7) are typically less than 0.2 mg/L and indicate that ground water recharged from precipitation and unaffected by land-use activities contains nitrate concentrations much less than 1 mg/L.

Median nitrite plus nitrate as nitrogen concentrations in surface water collected from a site unaffected by cattle manure, fertilizer, or domestic septic system sources of nitrogen (Snake River at Flagg Ranch, Wyoming) are typically less than 0.1 mg/L (Clark, 1994, table 6). Median total nitrogen concentrations are about 0.35 mg/L. These concentrations are comparable to those in precipitation (Maupin, 1995, fig. 7).

NITROGEN INPUT AND LOSS ESTIMATIONS

Nitrogen in the upper Snake River Basin is supplied by five primary nonpoint sources: cattle manure, fertilizer, legume crops, precipitation, and domestic septic systems. Industrial and municipal point-source discharge of nutrients such as effluent from industrial and wastewater-treatment facilities are also sources of nitrogen in the basin but are minor in comparison with cattle manure, fertilizer, and precipitation sources (Clark, 1994, p. 20). Nitrogen input and loss is estimated from cattle manure, fertilizer, legume crops, precipitation, and domestic septic systems so that the amount of nitrogen potentially available for runoff and leaching to surface and ground water can be determined.

Nitrogen Input

Nitrogen input is the total amount of nitrogen supplied by cattle manure, fertilizer, legume crops, precipitation, and domestic septic systems in the basin before

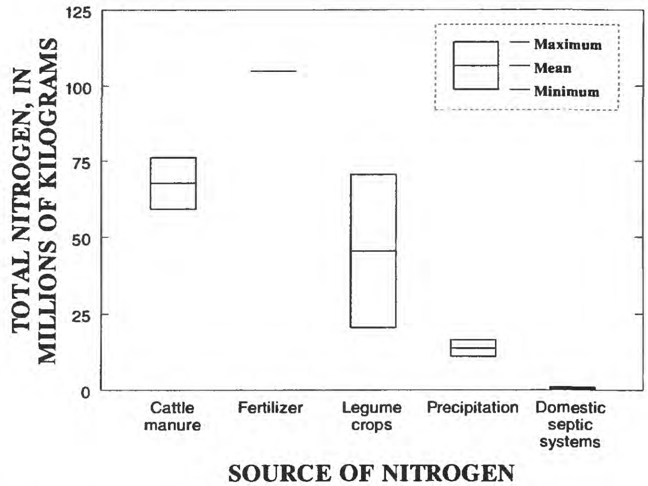


Figure 2. Maximum, mean, and minimum amounts of total nitrogen input from major sources, upper Snake River Basin. (Multiply kilograms by 1.102×10^{-3} to convert to tons)

any losses can occur. Other sources of total nitrogen such as native vegetation may be present, but data are insufficient to estimate their input. Basinwide and regional total nitrogen input from the five major sources is shown in figures 2 and 3, respectively.

CATTLE MANURE

The amount of total nitrogen input from cattle manure was estimated using methods to calculate fertilizer content of animal waste (Moore and Gamroth, 1991; Hermanson and others, 1983). The number of cattle in each county (Idaho Agricultural Statistics Service, 1990) was multiplied by the average daily amount of total nitrogen in feces and urine produced by each cow.

The amount of total nitrogen from cattle manure depends on the type of cow (beef or dairy) and the size of animal. The average dairy cow weighs between 454 and 635 kg (between 1,000 and 1,400 lb) and produces between 0.19 and 0.27 kg/day (between 0.41 and 0.59 lb/day) total nitrogen (Moore and Gamroth, 1991, p. 2; Hermanson and others, 1983, p. 3). The average beef cow weighs between 454 and 567 kg (between 1,000 and 1,250 lb) and produces between 0.15 and 0.20 kg/day (between 0.34 and 0.43 lb/day) total nitrogen. Estimations were made for maximum and minimum probable values to bracket the possible ranges.

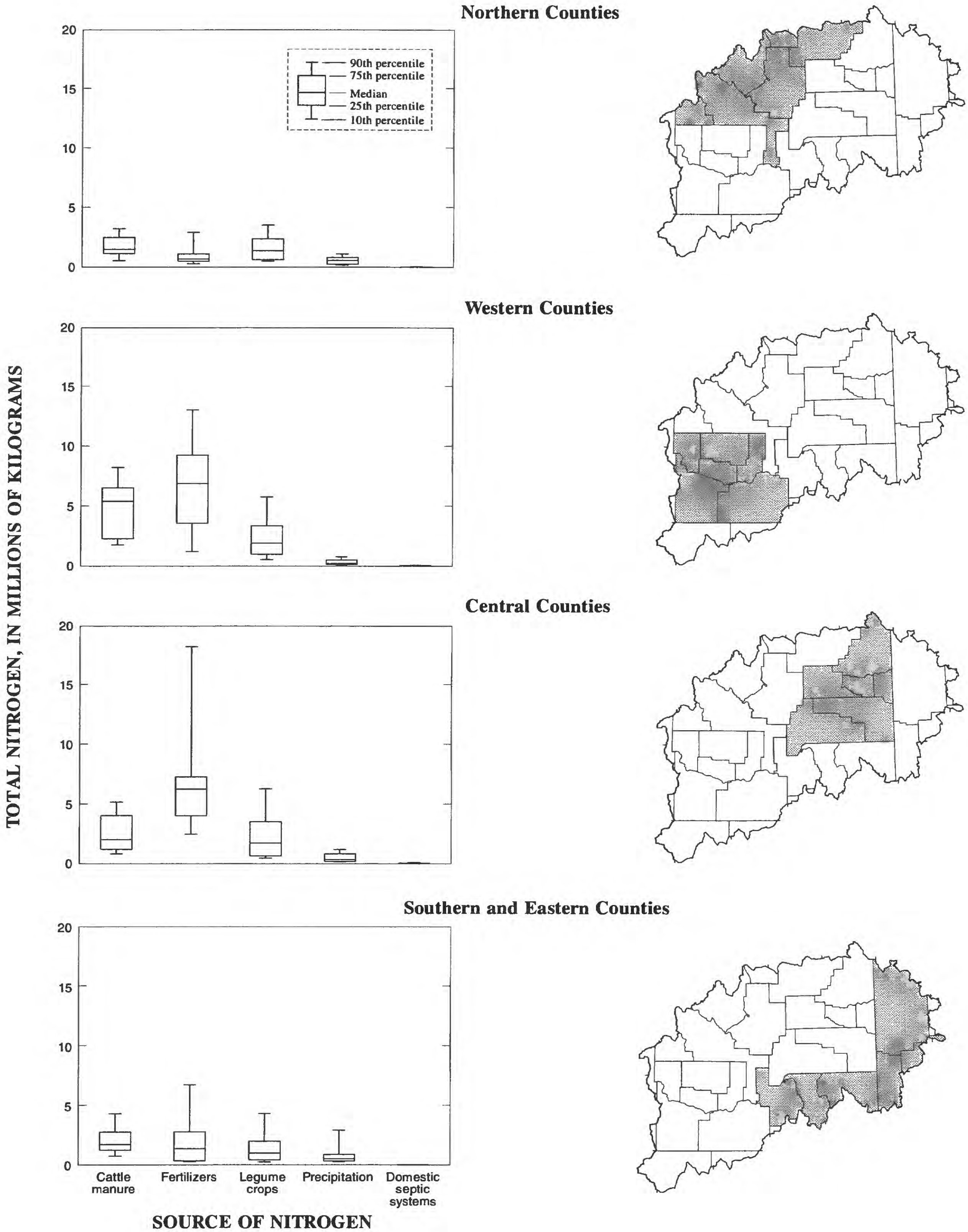


Figure 3. Total nitrogen input from major sources by region, upper Snake River Basin. (Boxplots include maximum and minimum input values for each county; multiply kilograms by 1.102×10^{-3} to convert to tons)

These input estimations do not account for movement of beef cattle to mountainous areas for summer pasture. If sufficient data existed to account for summer movement, cattle manure input estimates for northern and southern counties might increase, and estimates for western and central counties might decrease.

FERTILIZER

Input of nitrogen by county from fertilizer was based on sales estimates reported by Battaglin and Goolsby (1995, p. 4). The method used to construct fertilizer sales estimates was similar to that used by Alexander and Smith (1990). The county-level nitrogen fertilizer-sales estimates were constructed by:

1) compiling annual State fertilizer-sales data, reported in tons of active ingredient, to the National Fertilizer and Environmental Research Center of the Tennessee Valley Authority;
2) calculating the ratio of expenditures for commercial fertilizer by county, determined by the 1987 Census of Agriculture (U.S. Department of Commerce, 1989a, b), to expenditures for commercial fertilizer by State; and
3) computing annual county-level fertilizer sales, in tons of active ingredient, by multiplying estimates of annual State sales by the ratio of county expenditures to State expenditures.

LEGUME CROPS

Input of total nitrogen from previous-year legume crops (alfalfa and beans) was estimated by multiplying the number of acres of each crop grown by the amount of total nitrogen derived from these crops. Data for number of acres of alfalfa and beans grown were from the Idaho Agricultural Statistics Service (1990). The amount of total nitrogen available for the next year's crop is 11 kg/hectare (60 lb/acre) from alfalfa and 7.34 kg/hectare (40 lb/acre) from beans (Tindall, 1991). Meek (1992) estimated that as much as 41 kg/hectare (225 lb/acre) of total nitrogen can be derived from alfalfa. These estimations were made under the assumption that all legume crops are tilled under at the end of each crop year. Estimations were made for maximum and minimum values to bracket the possible range.

PRECIPITATION

Total nitrogen input from precipitation by county was estimated by determining the amount of total nitrogen supplied by both wet and dry deposition. Total nitrogen from wet deposition was estimated by multiplying total nitrogen concentrations in precipitation, the amount of precipitation, and the total land area for each county. Total nitrogen from dry deposition was estimated by multiplying the wet deposition values by a dry deposition constant. The following equation was used to estimate total nitrogen input from precipitation:

$$B = (E \times Q \times I) \times D, \qquad (1)$$

where

B = total nitrogen input from precipitation, in kilograms;
E = total nitrogen concentration in precipitation, in milligrams per liter;
Q = annual rainfall, in meters;
I = land area of each county, in square meters; and
D = dry deposition constant (unitless).

Maupin (1995, fig. 7) compiled wet deposition nitrate (NO_3 as nitrogen) and ammonia (NH_3 as nitrogen) concentrations in precipitation collected at the Craters of the Moon National Monument near Arco and at Yellowstone National Park (National Atmospheric Deposition Program, 1989) for 1981–90. Median nitrate concentrations for the two sites were 0.14 and 0.10 mg/L, respectively. Median ammonia concentrations were 0.13 and 0.08 mg/L, respectively. Therefore, total nitrogen concentrations in precipitation in the upper Snake River Basin were estimated to range from 0.18 to 0.27 mg/L. Data for 1981–90, rather than for just 1990, were used in these estimations to generate a more representative range of concentrations by including seasonal and annual fluctuations.

Total nitrogen from wet deposition for Idaho was estimated by multiplying the concentration estimates of 0.18 to 0.27 mg/L with precipitation estimates from an isohyetal map by Molnau (1995) using a geographic information system (GIS). These estimations then were separated by county. An isohyetal map by Thomas and others (1963) provided precipitation data outside Idaho. Data from the isohyetal maps were used, rather than actual 1990 precipitation point data, because the 30-year period of record used for the isohyetal maps was more representative and the map format was better suited for GIS analysis.

The wet deposition values then were multiplied by a dry deposition constant determined by Sisterson (1990), who estimated a ratio of 9 to 4 (wet deposition to dry deposition) for Idaho and 14 to 6 for Wyoming. Accordingly, wet deposition estimates for Idaho were multiplied by 1.444 and wet deposition estimates for Wyoming were multiplied by 1.429 to determine total nitrogen supplied by wet and dry deposition.

DOMESTIC SEPTIC SYSTEMS

Total 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 each county. The following equation was used to estimate the amount of total nitrogen input from domestic septic systems:

$$S = P \times H \times Y \times 365 \text{ days}, \qquad (2)$$

where

S = total nitrogen input from domestic septic systems, in kilograms;
P = total nitrogen produced daily per person, in kilograms;
H = average number of persons per household; and
Y = number of houses using domestic septic systems in each county.

Total nitrogen in typical residential wastewater was estimated to be 6 to 17 gal/min per person per day (0.01 to 0.04 lb per person per day); concentrations range from 35 to 100 mg/L (U.S. Environmental Protection Agency, 1980). County estimates of the average number of people per household and the number of homes using domestic septic systems were based on data from the 1990 census (Idaho Department of Commerce, 1992).

Nitrogen Loss

Nitrogen loss is the amount of nitrogen removed from the basin by storage and application of cattle manure, crop uptake, and decomposition of previous-year nonleguminous crop residue (chaff). Nitrogen loss is greatest from application of manure to fields and from crop uptake. Nitrogen also is lost through uptake by native vegetation and denitrification of fertilizer or domestic septic system effluent, but data are insufficient to quantify these losses.

DAIRY CATTLE MANURE

The amount of total nitrogen loss from storage and application of dairy cattle manure was estimated using methods to calculate fertilizer content of animal waste (Moore and Gamroth, 1991; Hermanson and others, 1983). Estimates of total nitrogen input from cattle manure were adjusted to account for loss during collection, storage, and application of cattle manure to fields.

The following equation was used to estimate total nitrogen loss from dairy cattle manure:

$$C = X \times T \times A \times D \times O, \qquad (3)$$

where

C = amount of total nitrogen available after losses are subtracted, in kilograms;
X = total nitrogen input from dairy cattle manure, in kilograms;
T = percentage of nitrogen retained by various cattle manure storage systems (85 to 20 percent);
A = percentage of nitrogen retained after field application (95 to 70 percent);
D = percentage of nitrogen retained after denitrification (100 to 60 percent); and
O = percentage of nitrogen not immobilized as organic nitrogen (96 to 45 percent).

The total nitrogen available for plant uptake and leaching after storage depends on the type of storage system and ranges from 85 percent (daily spreading) to 20 percent (open lagoon) (Moore and Gamroth, 1991, p. 3; Hermanson and others, 1983, p. 3).

Nitrogen can volatilize during field application (mostly as ammonia). Moore and Gamroth (1991, p. 3) estimated that between 5 and 25 percent of the total nitrogen from cattle manure applied to fields can be lost. Hermanson and others (1983, p. 6) estimated that between 5 and 30 percent can be lost.

Nitrogen can be lost by denitrification (loss of inorganic nitrogen by biological conversion to nitrogen gas). Denitrification loss ranges from 0 percent in well-drained soils to 40 percent in poorly drained soils (Moore and Gamroth, 1991, p. 3; Hermanson and others, 1983, p. 6). Because the estimations were performed by county, the types of soils present at the locations the manure was applied could not be determined. Accordingly, maximum and minimum losses were estimated to bracket the possible ranges.

Moore and Gamroth (1991, p. 4) estimated that between 4 and 25 percent of nitrogen from cattle manure applied to fields is organic nitrogen and not available for plant uptake or leaching. Hermanson and others (1983, p. 6) estimated that as much as 55 percent is organic nitrogen. This organically bound nitrogen breaks down in the soil over time and forms inorganic nitrogen, which is available for plant uptake or leaching. Hermanson and others (1983, p. 6) estimated that 20 to 25 percent of the remaining organic nitrogen will break down 2 years after application and 10 to 15 percent will break down 3 years after application. For this report, the percentage of organic nitrogen remaining after only the first year of application, the period of the greatest amount of breakdown, was used in the estimations.

BEEF CATTLE MANURE

Calculations for loss of total nitrogen from storage and application of beef (nondairy) cattle manure involve slightly different values than for dairy cattle because beef cattle graze on open rangeland as well as in feedlots and pens. There is no storage loss for cattle grazing on open rangeland because the manure is applied directly to the ground when voided by the cattle, so 100 percent of the nitrogen is retained (Moore and Gamroth, 1991, p. 3). Application loss differs because the cattle apply the manure directly to the ground; Moore and Gamroth (1991, p. 3) suggested that 85 percent of the total nitrogen is retained by cattle directly applying manure to the ground, which is between the 75 to 95 percent retained by mechanical methods of application. Denitrification and organic nitrogen losses for dairy and beef cattle manure are the same because these losses are constant once the manure is applied to the ground. All the foregoing estimates are considered conservative, because if cattle are grazing in riparian areas, manure could directly affect the water body. No data were available to determine the percentage of cattle grazing on open rangeland or in feedlots and pens, so maximum and minimum values of nitrogen loss were estimated to bracket the possible ranges.

The following equation was used to estimate total nitrogen loss from beef cattle manure:

$$C = X \times T \times A \times D \times O, \qquad (4)$$

where

C = amount of total nitrogen available after losses are subtracted, in kilograms;

X = total nitrogen input from beef cattle manure, in kilograms;

T = percentage of nitrogen retained by various cattle manure storage systems (100 to 20 percent);

A = percentage of nitrogen retained after field application (95 to 70 percent);

D = percentage of nitrogen retained after denitrification (100 to 60 percent); and

O = percentage of nitrogen not immobilized as organic nitrogen (96 to 45 percent).

CROP UPTAKE

Total nitrogen loss from crop uptake was estimated by using relations of nitrogen uptake to crop yield developed by the Idaho Cooperative Extension Service (Tindall, 1991). Crop uptake of nitrogen was estimated from actual acres and yields of crops grown (Idaho Agricultural Statistics Service, 1990). The amount of total nitrogen used by a particular crop for a given yield was multiplied by the number of crop acres producing that yield. Crop uptake was estimated for the major crops grown in each county (barley, wheat, field corn, silage corn, potatoes, and sugar beets).

The following equation was used to estimate total nitrogen loss from crop uptake:

$$U = N \times L, \qquad (5)$$

where

U = total nitrogen loss from crop uptake, in kilograms;

N = number of acres of a particular crop; and

L = amount of nitrogen used to produce a given crop yield, in kilograms per acre.

DECOMPOSITION OF PREVIOUS-YEAR CROP RESIDUE

Total nitrogen uptake from bacterial decomposition of previous-year nonleguminous crop residue (chaff) was estimated by multiplying the total acres of previous-year nonleguminous crops by a nitrogen removal factor. Crop residue decomposition can remove up to 9.2 kg/hectare (50 lb/acre) depending on crop type, soil type, and climate (Tindall, 1991). Estimations were made for total nitrogen removal of 0 and 9.2 kg/hectare (0 and 50 lb/acre) to bracket the most probable ranges.

RESULTS OF NITROGEN INPUT AND LOSS ESTIMATIONS

Results of nitrogen input estimations show that fertilizer contributes the greatest amount of total nitrogen in the basin, followed by cattle manure, legume crops, precipitation, and domestic septic systems. On the basis of mean values, domestic septic systems contribute less than 1 percent of the total nitrogen produced in the basin and regionally account for minimal input. Precipitation contributes 6 percent of the total nitrogen in the basin and represents background conditions. The remaining 93 percent is produced by cattle manure (29 percent), fertilizer (45 percent), and legume crops (19 percent).

The total nitrogen input in four regions of the basin is shown in figure 3. Input from cattle manure, fertilizer, and legume crops varies widely among counties and reflects differences in land-use practices such as different cropping patterns and numbers of dairies and feedlots. Fertilizer is the predominant source of total nitrogen input in the western and central counties, where irrigated agriculture is most intensive. Cattle manure and legume crops are the predominant sources in the northern counties. Input from cattle manure, fertilizer, and legume crops is roughly equal in the southern and eastern counties.

Although domestic septic systems provide minimal nitrogen input, both basinwide (fig. 2) and regionally (fig. 3), a high density of domestic septic systems within a small area can adversely affect water quality locally.

Maximum and minimum amounts of residual total nitrogen were estimated by adding all the input from cattle manure, fertilizer, legume crops, precipitation, and domestic septic systems and subtracting loss from manure storage and application, crop uptake, and crop residue decomposition (fig. 4). Positive mean values of residual total nitrogen suggest that more total nitrogen is input than is lost. This residual total nitrogen is available for runoff to surface water or leaching to ground water.

Three out of four counties where mean values of residual total nitrogen were highest (Cassia, Gooding, and Twin Falls) are located in the western part of the basin (fig. 4). An overabundance of nitrogen and phosphorus has caused excessive aquatic plant growth in the middle reach of the Snake River (Milner Dam to King Hill), which also is located in the western part of the basin (Idaho Department of Health and Welfare, 1994, p. 59). Ground water from many wells in this part of the basin contains anomalously high concentrations of nitrate (Rupert, 1994, p. 21). Ground water in the fourth county (Bingham), which includes the Fort Hall area north of Pocatello, also contains high nitrate concentrations (Rupert, 1994, p. 21).

The dairy industry in the western part of the basin has grown tremendously; the number of dairy cattle in Gooding, Jerome, and Twin Falls Counties increased from 62,000 to 92,500 between 1990 and 1994 (Idaho Agricultural Statistics Service, 1990, 1991, 1992, 1993, 1994). This short-term increase in dairy cattle suggests that even more total nitrogen is currently (1995) produced than was estimated from the 1990 data.

Carryover of total nitrogen in the soil from previous years is not included in the nitrogen input and loss estimations. Carryover could increase residual total nitrogen estimates in all counties. Also, data were insufficient to determine whether the excess nitrogen will travel to surface water or to ground water or will remain in the soil.

MASS BALANCE OF TOTAL NITROGEN IN GOODING, JEROME, LINCOLN, AND TWIN FALLS COUNTIES

The residual total nitrogen for Gooding, Jerome, Lincoln, and Twin Falls Counties was compared with estimates of total nitrogen transported out of this four-county area by the Snake River at King Hill to determine a mass balance. These counties were selected for estimation of a mass balance because most of the nitrogen in the Snake River at King Hill is derived from sources within the four-county area. Most of the water

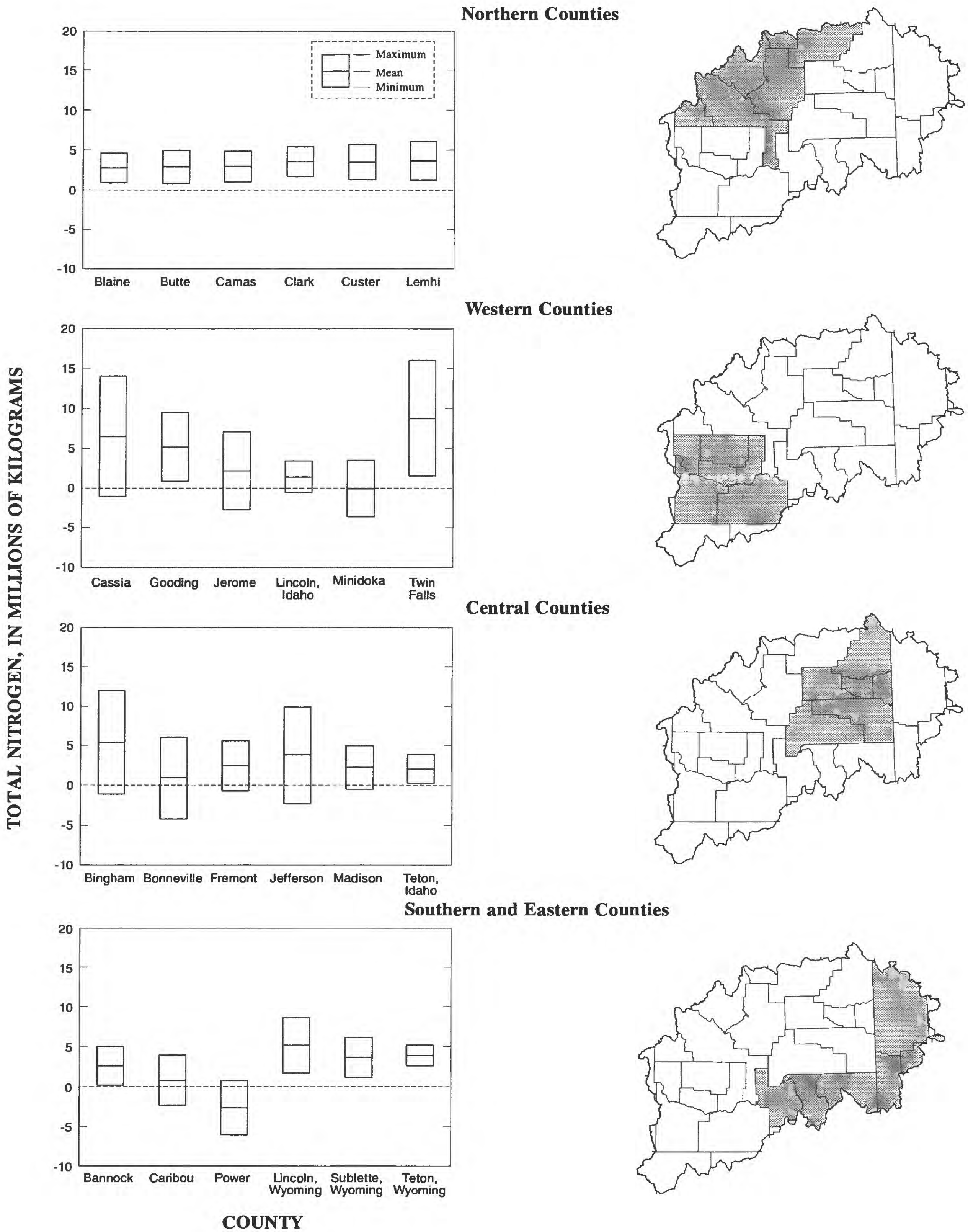


Figure 4. Residual total nitrogen by county, upper Snake River Basin. (Multiply kilograms by 1.102 x 10^{-3} to convert to tons)

from the Snake River is diverted upstream from these counties at Milner Dam for irrigation of agricultural lands north and south of the river, leaving the Snake River immediately downstream from Milner Dam dry for much of the year. The Snake River regains its flow downstream from Milner Dam from local streamflow, irrigation-return water, and ground-water discharge from numerous large springs. The local streamflow, irrigation-return water, and ground-water discharge transport substantial amounts of locally derived nitrogen to the Snake River.

Most of the input of total nitrogen in the four-county area is from cattle manure, fertilizer, legume crops, precipitation, and domestic septic systems (table 1). Aquacultural facilities and wastewater-treatment plants contribute additional nitrogen (fig. 5). The aquacultural facilities contribute approximately 2,177,300 kg/year (2,400 tons/year) of total nitrogen to the Snake River upstream from King Hill (G.M. Clark, U.S. Geological Survey, oral commun., 1994). Mean annual effluent discharge to the Snake River from three wastewater-treatment plants in Jerome, Gooding, and Twin Falls Counties in 1990 was 800, 400, and 6,200 million liters (200, 100, and 1,600 Mgal), respectively (Maupin, 1995, p. 29). The average total nitrogen concentration in sewage effluent is 11.2 mg/L (Pacheco, 1993, p. II–4). Annual total nitrogen from each plant was estimated to be 8,960, 4,480, and 69,440 kg (10, 5, and 77 tons), respectively. Annual total nitrogen from aquacultural facilities and wastewater-treatment plants is approximately 2,260,000 kg (2,500 tons) (table 1).

Additional nitrogen originates upstream from Milner Dam and is transported into the four-county area by the Snake River (fig. 5). The median total nitrogen concentration in 22 water-quality samples collected from the Snake River upstream from Milner Dam between April 1993 and October 1994 was 0.5 mg/L (G.M. Clark, U.S. Geological Survey, oral commun., 1994). Median streamflow in the Snake River downstream from Milner Dam during water years 1980–90 was 97.39 m^3/s (3,439 ft^3/s). Therefore, median total nitrogen transported into the four-county area by the Snake River upstream from Milner Dam is approximately 1,500,000 kg (1,700 tons) (table 1).

Considerable amounts of total nitrogen in ground water are discharged to the Snake River from springs on the north side of the river between Milner Dam and King Hill. Part of this total nitrogen, which is naturally occurring, originates far upgradient from the four-county area and is transported into the area by regional ground-water flow (fig. 5). The source of this nitrogen is precipitation that recharged the regional aquifer at background concentrations. The other part of the total nitrogen originates as seepage from cattle manure, fertilizer, legume crops, precipitation, and domestic septic systems in the four-county area. The input of total nitrogen from overlying land use was estimated as residual total nitrogen in previous sections of this report. The naturally occurring total nitrogen from outside the four-county area was not accounted for in previous sections but is included in table 1. The median concentration of dissolved nitrite plus nitrate as nitrogen in water from wells unaffected by cattle manure, fertilizer, or domestic septic systems was approximately 0.6 mg/L. Dissolved ammonia plus organic (kjeldahl) nitrogen was typically less than the detection limit of 0.2 mg/L as nitrogen in water from those same wells. Ammonia concentrations were typically less than or slightly above the detection limit of 0.01 mg/L. If 0.6 mg/L total nitrogen is the background concentration in water in the Snake River Plain aquifer, and ground-water discharge to the Snake River from springs on the north side of the river in 1990 was approximately 156 m^3/s (5,500 ft^3/s) (Kjelstrom, 1992, fig. 2), then approximately 3,000,000 kg (3,250 tons) of naturally occurring, or background, total nitrogen was discharged to the Snake River from the springs. G.M. Clark (U.S. Geological Survey, written commun., 1995) estimated that between 6,340,000 and 7,400,000 kg (7,000 and 8,200 tons) of total nitrogen was discharged from the springs. Clark's estimates included naturally occurring nitrogen and nitrogen from land use. Comparison of the foregoing estimates for naturally occurring nitrogen with Clark's estimates shows that the naturally occurring nitrogen composes approximately 41 to 47 percent of the total nitrogen discharged from the springs.

Clark (1994, p. 42) estimated annual total nitrogen discharged by the Snake River at King Hill on the basis of nutrient concentration and streamflow for water years 1984 (high-flow year), 1987 (normal- or median-flow year), and 1989 (low-flow year). He estimated that, within a 90-percent confidence range, between 16,000,000 and 20,500,000 kg (between 17,600 and 22,600 tons) of total nitrogen was transported past King Hill (table 1) during a median-flow year when mean daily streamflow was 312 m^3/s (11,000 ft^3/s).

Input of residual total nitrogen from cattle manure, fertilizer, legume crops, and domestic septic systems

Table 1. Total nitrogen input and output, Gooding, Jerome, Lincoln, and Twin Falls Counties

[Units in kilograms (kg); multiply kilograms by 1.102 x 10^{-3} to convert to tons; total nitrogen from cattle manure, fertilizer, legume crops, precipitation, and domestic septic systems includes subtracted losses from cattle manure storage and application, crop uptake, and decomposition of previous-year nonleguminous crop residue]

Total nitrogen	Mean value	Range
Input		
Residual total nitrogen from cattle manure, fertilizer, legume crops, precipitation, and domestic septic systems	17,700,000	-900,000 to 36,200,000
Total nitrogen from aquacultural facilities and wastewater-treatment plants	2,260,000	2,260,000
Total nitrogen transported into four-county area by the Snake River upstream from Milner Dam	1,500,000	1,500,000
Naturally occurring total nitrogen in ground water transported into the four-county area by regional ground-water flow	3,000,000	3,000,000
TOTAL	24,460,000	5,860,000 to 42,960,000
Output		
Total nitrogen transported out of area by the Snake River at King Hill, median-flow year	18,250,000	16,000,000 to 20,500,000
DIFFERENCE (Input minus Output)	6,210,000	-10,140,000 to 22,460,000

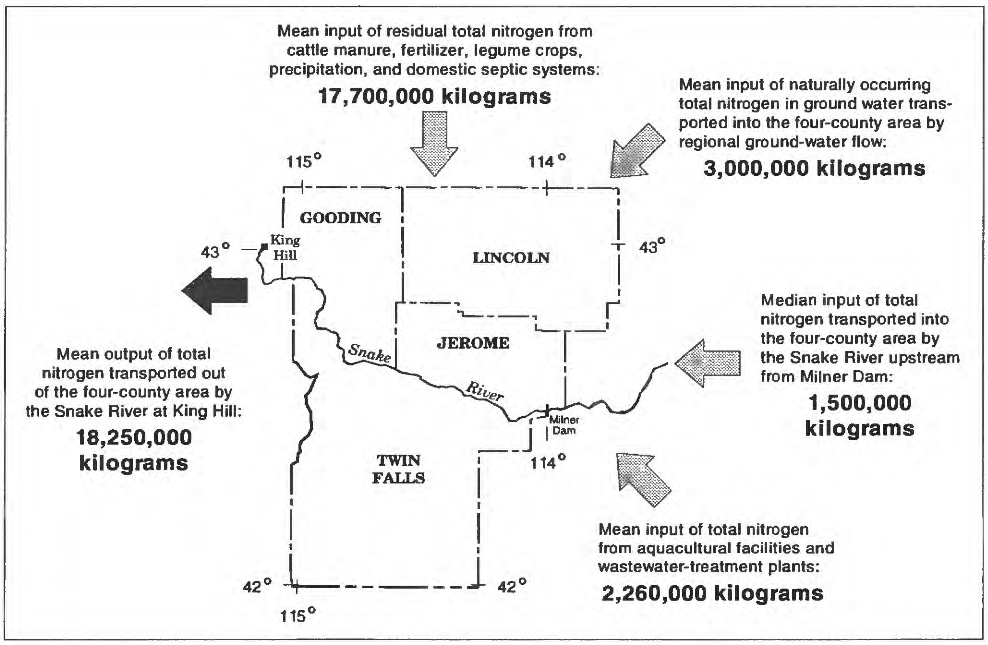


Figure 5. Total nitrogen mass balance in Gooding, Jerome, Lincoln, and Twin Falls Counties. (Multiply kilograms by 1.102 x 10^{-3} to convert to tons)

varied widely because those estimates bracketed the minimum and maximum probable values (table 1). The mean value of 17,700,000 kg (19,500 tons) is the most likely estimate for the four-county area.

The results of this mass balance suggest that more than 6,000,000 kg (6,600 tons) of total nitrogen is input in the four-county region than is discharged at King Hill. This excess nitrogen probably is utilized by aquatic vegetation in the Snake River, stored as nitrogen in soil, stored as nitrate in the ground water, and utilized by noncrop vegetation. Falter and Carlson (1994, p. 51) showed that aquatic vegetation removes nitrogen from the water column in the Snake River. Clark (1994, fig. 24 and p. 34) also suggested that aquatic vegetation removes nitrogen in the river during the growing season. Some of the nitrogen supplied by cattle manure, fertilizer, legume crops, precipitation, and domestic septic systems can be stored in the soil and is not available for runoff or leaching to surface and ground water. Another fraction of this nitrogen can leach to ground water and eventually be discharged through the springs. Additional nitrogen is utilized by vegetation other than cultivated crops, such as vegetation growing along irrigation canals and riverbanks. Nitrogen also can be lost through additional denitrification processes not accounted for in this report. Data were insufficient to estimate the amount of nitrogen lost from these sources.

SUMMARY

Calculations were performed to estimate the amount of total nitrogen input by cattle manure, fertilizer, legume crops, precipitation, and domestic septic systems in the upper Snake River Basin, Additional estimations were made to account for total nitrogen loss from storage and application of cattle manure, crop uptake, and decomposition of previous-year nonleguminous crop residue. 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 basin where excess nitrogen is produced.

Results of these estimations suggest that domestic septic systems account for less than 1 percent of the total nitrogen input in the basin and precipitation accounts for 6 percent. The remaining 93 percent is produced by cattle manure (29 percent), fertilizer (45 percent), and legume crops (19 percent). Input from cattle manure, fertilizer, and legume crops varies widely among counties and reflects differences in land-use practices such as different cropping patterns and numbers of dairies and feedlots.

Positive mean values of residual total nitrogen in most counties suggest that more total nitrogen is input than is lost. This residual total nitrogen is available for runoff to surface water or leaching to ground water. Residual total nitrogen is highest in the western part of the basin where surface- and ground-water-quality problems are evident.

A mass balance of total nitrogen input and loss in Gooding, Jerome, Lincoln, and Twin Falls Counties suggests that more than 6,000,000 kg (6,600 tons) of total nitrogen is input in this four-county area than is discharged by the Snake River. This excess nitrogen probably is utilized by aquatic vegetation in the Snake River (causing eutrophication), stored as nitrogen in soil, stored as nitrate in the ground water and eventually discharged through the springs, utilized by noncrop vegetation, and lost through denitrification.

MANAGEMENT IMPLICATIONS

These input and loss estimations suggest that more total nitrogen is input in the basin than is lost. The excess nitrogen is available for runoff and leaching to surface and ground water. In many areas, a greater percentage of crop nitrogen needs could be supplied by cattle manure and legume crops, thus subsequently reducing fertilizer usage. Reduced fertilizer usage could increase farm profitability by reducing fertilizer costs while maintaining high crop yields and potentially reducing the amount of excess nitrogen affecting surface- and ground-water quality.

The western part of the basin is currently undergoing an explosive growth in the dairy industry; the number of dairy cattle in Gooding, Jerome, and Twin Falls Counties increased from 62,000 to 92,500 between 1990 and 1994 (Idaho Agricultural Statistics Service, 1990, 1991, 1992, 1993, 1994). The growth of the dairy industry in the western part of the basin is providing additional nitrogen in an area where eutrophication problems in the Snake River are already evident and nitrate concentrations in ground water are anomalously high. Water quality in this part of the basin will continue to degrade unless nitrogen management practices are improved.

Input and loss estimations suggest that domestic septic systems provide negligible amounts of total nitrogen, particularly when compared with amounts supplied by cattle manure, fertilizer, and legume crops. Total nitrogen input from domestic septic systems is only a concern in areas with a high density of domestic septic systems.

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