ANALYSIS OF DATA ON NUTRIENTS AND ORGANIC COMPOUNDS IN GROUND WATER IN THE UPPER SNAKE RIVER BASIN, IDAHO AND WESTERN WYOMING, 1980–91

By MICHAEL G. RUPERT

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GORDON P. EATON, Director

For additional information write to:

District Chief
U.S. Geological Survey, WRD
230 Collins Road
Boise, ID 83702-4520

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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
foot squared per day[1] (ft^2/d)	0.09290	meter squared per day
gallon per minute (gal/min)	0.06309	liter per second
inch (in.)	25.4	millimeter
megawatthour (MWh)	3,600,000,000	joule
mile (mi)	1.609	kilometer
pound	0.4536	kilogram
square mile (mi^2)	2.590	square kilometer
ton	0.9072	megagram

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$°C = (5/9)\ (°F-32)$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 — a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated water-quality units:

µg/L micrograms per liter
mg/L milligrams per liter

[1]The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness. This mathematical expression reduces to foot squared per day, which is used in this report.

Analysis of Data on Nutrients and Organic Compounds in Ground Water in the Upper Snake River Basin, Idaho and Western Wyoming, 1980–91

By Michael G. Rupert

Abstract

Nutrient and organic compound data from the U.S. Geological Survey and the U.S. Environmental Protection Agency STORET data bases provided information for development of a preliminary conceptual model of spatial and temporal ground-water quality in the upper Snake River Basin. Nitrite plus nitrate (as nitrogen; hereafter referred to as nitrate) concentrations exceeded the Federal drinking-water regulation of 10 milligrams per liter in three areas in Idaho: the Idaho National Engineering Laboratory, the area north of Pocatello (Fort Hall area), and the area surrounding Burley. Water from many wells in the Twin Falls area also contained elevated (greater than 2 milligrams per liter) nitrate concentrations. Water from domestic wells contained the highest median nitrate concentrations; water from industrial and public-supply wells contained the lowest. Nitrate concentrations decreased with increasing well depth, increasing depth to water (unsaturated thickness), and increasing depth below water table (saturated thickness). Kjeldahl nitrogen concentrations decreased with increasing well depth and depth below water table. The relation between kjeldahl nitrogen concentrations and depth to water was poor.

Nitrate and total phosphorus concentrations in water from wells were correlated among three hydrogeomorphic regions in the upper Snake River Basin. Concentrations of nitrate were statistically higher in the eastern Snake River Plain and local aquifers than in the tributary valleys. There was no statistical difference in total phosphorus concentrations among the three hydrogeomorphic regions.

Nitrate and total phosphorus concentrations were correlated with land-use classifications developed using the Geographic Information Retrieval and Analysis System. Concentrations of nitrate were statistically higher in areas of agricultural land than in areas of rangeland. There was no statistical difference in concentrations between rangeland and urban land and between urban land and agricultural land. There was no statistical difference in total phosphorus concentrations among any of the land-use classifications.

Nitrate and total phosphorus concentrations also were correlated with land-use classifications developed by the Idaho Department of Water Resources for the Idaho part of the upper Snake River Basin. Nitrate concentrations were statistically higher in areas of irrigated agriculture than in areas of dryland agriculture and rangeland. There was no statistical difference in total phosphorus concentrations among any of the Idaho Department of Water Resources land-use classifications.

Data were sufficient to assess long-term trends of nitrate concentrations in water from only eight wells: four wells north of Burley and four wells northwest of Pocatello. The trend in nitrate concentrations in water from all wells is upward.

The following organic compounds were detected in ground water in the upper Snake River Basin: cyanazine, 2,4-D DDT, dacthal, diazinon, dichloropropane, dieldrin, malathion, and metribuzin. Of 211 wells sampled for organic compounds, water from 17 contained detectable concentrations.

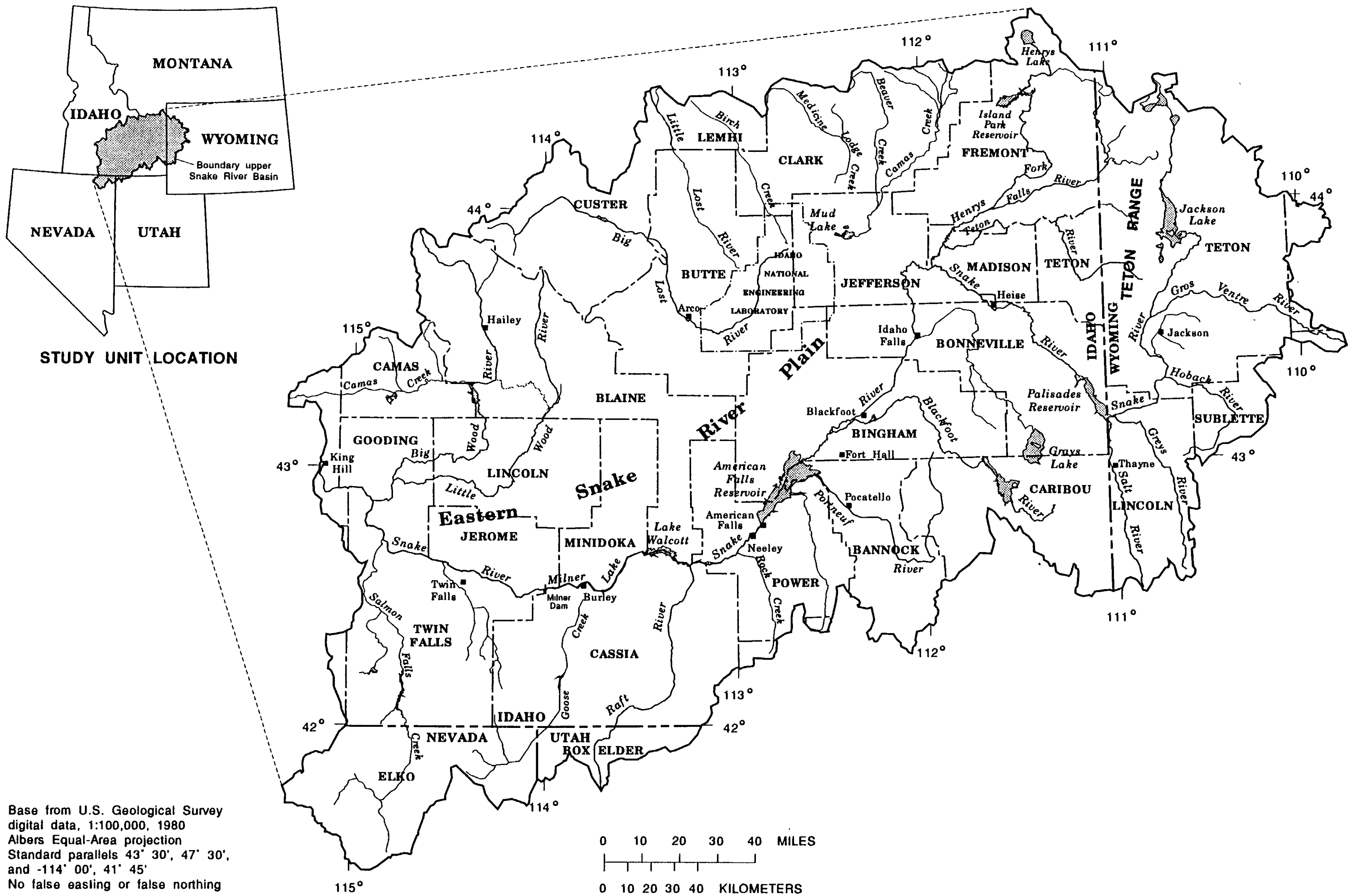

Figure 1. Location of study area.

INTRODUCTION

In 1991, the U.S. Geological Survey (USGS) began full-scale implementation of the National Water-Quality Assessment (NAWQA) Program. The long-term goals of the program are to (1) provide a nationally consistent description of current water-quality conditions for a large part of the Nation's water resources; (2) define long-term trends in water quality; and (3) identify, to the extent possible, the major factors that affect observed water-quality conditions and trends (Leahy and others, 1990, p. 1).

The design of the program enables integration of the information into a nationally consistent data base for comparisons of water-quality data over a large range of geographic and hydrologic conditions. The general concepts for full-scale implementation of the NAWQA Program are outlined in a report by Hirsch and others (1988). Sixty study units across the United States were selected to incorporate between 60 and 70 percent of the Nation's usable water supply. Investigations will occur in three phases. Work on the first 20 study units began in 1991; work on the second and third sets of 20 study units will begin in 1994 and 1997, respectively.

The upper Snake River Basin was selected for the first phase of 20 study units, and assessment of the basin began in 1991. Intensive monitoring and analysis will proceed through fiscal year 1994, followed by a 5-year, less intensive, data-collection phase.

Purpose and Scope

Analyses of nutrient and organic compound data for ground water in the upper Snake River Basin are described in this report. Data for 1980 through 1991 were compiled and analyzed to develop a preliminary conceptual model of the spatial and temporal patterns of nutrient and organic compound concentrations. The conceptual model will be used to guide additional data collection during the ensuing parts of the study.

Only those data on nutrients and organic compounds in ground water that could be readily accessed in computer format from an agency-wide data base were evaluated. These data were from a variety of different projects, each with their own specific study design and sampling procedures.

Acknowledgments

The author acknowledges the agencies and organizations that assisted in the collection of data used in this report: Idaho Department of Agriculture; Idaho Department of Commerce; Idaho Department of Health and Welfare, Division of Environmental Quality; Idaho Department of Water Resources; University of Idaho, Agricultural Experiment Station; University of Idaho, Research and Extension Center; U.S. Environmental Protection Agency, Regions VIII and X; and U.S. Soil Conservation Service.

DESCRIPTION OF THE UPPER SNAKE RIVER BASIN

The upper Snake River Basin study unit covers 35,800 mi^2 and extends from western Wyoming to south-central Idaho (fig. 1). The basin includes parts of Idaho, Wyoming, Nevada, and Utah, and consists of 24 major tributaries to the Snake River. The predominant physiographic feature is the eastern Snake River Plain, which is about 55 mi wide and 320 mi long.

Population and Economy

The 1990 population was about 420,000: 396,000 in Idaho and 24,000 in Wyoming (Idaho Department of Commerce, 1992). Principal cities include Idaho Falls (population about 43,900); Pocatello (population about 46,100); and Twin Falls (population about 27,600). County populations for 1970, 1980, and 1990, including growths and declines during 1980–90, are shown in table 1. Not all counties are totally within the study unit boundary.

The economy in the Wyoming part of the basin is based predominantly on tourism and agriculture. The economy in the Idaho part of the basin is based predominantly on agriculture, agricultural-related industries, and support of research at the Idaho National Engineering Laboratory (INEL).

Physiography

The upper Snake River Basin includes parts of six western ecoregions (Omernik, 1986) — the Northern and Middle Rockies, the northeastern part of the Snake River Basin, the Wyoming Basin, the Northern Basin

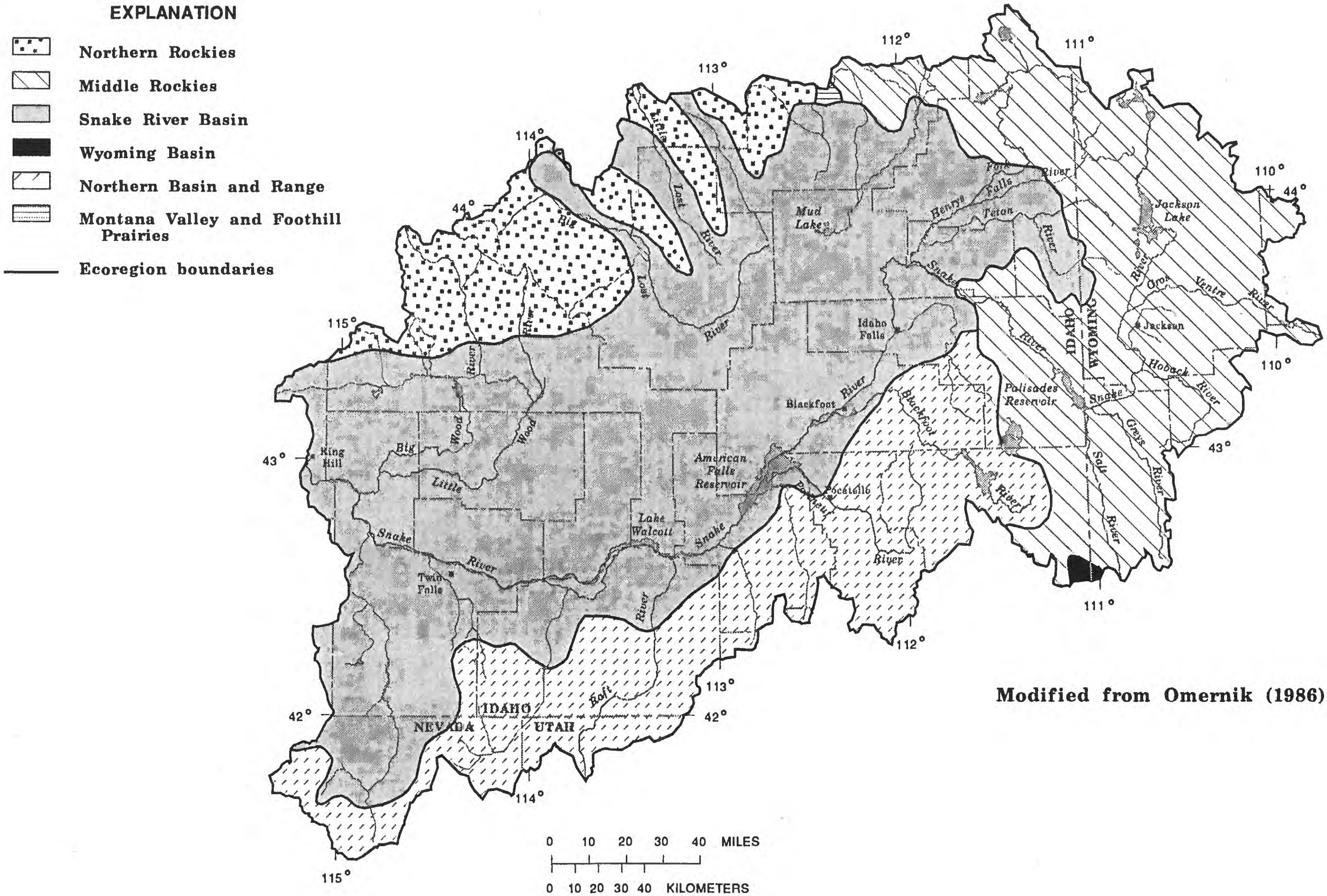

Figure 2. Ecoregions in the upper Snake River Basin.

Table 1. Population changes in the upper Snake River Basin

[Data from Census of Agriculture (Idaho Department of Commerce, 1992); counties with a small percentage of land area in the basin were excluded; <, less than; –, no data available]

County	Population			Population growth or decline 1980–90	
	1970	1980	1990	No.	Percent
		Idaho			
Bannock	52,200	65,421	66,026	605	1
Bingham	29,167	36,489	37,583	1,094	3
Blaine	5,749	9,841	13,552	3,711	38
Bonneville	52,457	65,980	72,207	6,227	9
Butte	2,925	3,342	2,918	-424	-13
Camas	728	818	727	-91	-11
Caribou	6,534	8,695	6,963	-1,732	-20
Cassia	17,017	19,427	19,532	105	1
Clark	741	798	762	-36	-5
Custer	2,967	3,385	4,133	748	22
Fremont	8,710	10,813	10,937	124	1
Gooding	8,645	11,874	11,633	-241	-2
Jefferson	11,740	15,304	16,543	1,239	8
Jerome	10,253	14,840	15,138	298	2
Lemhi	5,566	7,460	6,899	-561	-8
Lincoln	3,057	3,436	3,308	-128	-4
Madison	13,452	19,480	23,674	4,194	22
Minidoka	15,731	19,718	19,361	-357	-2
Power	4,864	6,844	7,086	242	4
Teton	2,351	2,897	3,439	542	19
Twin Falls	41,807	52,927	53,580	653	1
Idaho total	–	379,789	396,001	16,212	4
		Wyoming			
Lincoln	–	12,177	12,625	448	4
Teton	–	9,355	11,172	1,817	19
Wyoming total	–	21,532	23,797	2,265	11
Grand total	–	401,321	419,798	18,477	5

and Range, and the Montana Valley and Foothill Prairies (fig. 2). Land-surface altitudes range from about 2,500 ft above sea level at the western edge of the basin to 13,770 ft in the mountainous eastern part of the basin in Wyoming.

Areas in the northern and northwestern parts of the basin are characterized by high mountains exceeding 12,000 ft in altitude and deep intermontane valleys composed of volcanic and sedimentary rocks. The relatively flat eastern Snake River Plain lies in the central and western parts of the basin and ranges in altitude from 2,500 to 6,000 ft.

Predominant vegetation includes cedar, fir, and pine forests in the mountains and sagebrush and bunchgrass on the hills and in valleys. Large parts of the eastern Snake River Plain consist of exposed basalt of Quaternary age that is devoid of vegetation.

Climate

The climate in most of the basin is semiarid. Mean annual precipitation ranges from less than 10 in. on the valley floor to as much as 70 in. on the southern part of the Teton Range (fig. 3).

The source of most precipitation is from airmasses moving inland from the Pacific Ocean (Kjelstrom, 1992). During summer months, the central and eastern parts of the basin are affected by sporadic thunderstorms resulting from the subtropical flow of air from the Gulf of Mexico and the Pacific Ocean.

The basin is characterized by moderately to severely cold winters and hot, dry summers. Mean annual temperature at Idaho Falls is 43.7°F; mean annual temperature at Twin Falls is 47.3°F. Average annual air temperatures in the Wyoming part of the basin range from about 35° to 40°F; maximum temperatures are near 90°F and minimum temperatures are near 30°F. The average length of the growing season in the basin ranges from about 120 to 160 days.

Water Use

Idaho ranks third in the Nation for total water use behind California and Texas. In 1990, water use in the upper Snake River Basin was about 15.1 million acre-ft — 68 percent of Idaho's total withdrawals of 22 million acre-ft. Irrigated agriculture used more than 14.5 million acre-ft on 2.5 million acres of land in the eastern Snake River Plain in 1990 (M.A. Maupin, U.S. Geological Survey, written commun., 1992). Other major offstream water uses are municipal supply, industry, and livestock production. Major instream uses are hydroelectric power production and aquaculture.

The basin contains 71 percent of all irrigated acreage in Idaho in 1990. Potatoes, wheat, sugarbeets, hay, and barley are the predominant crops. In 1980, 8.5 million acre-ft of surface water and 1.9 million acre-ft of ground water (Goodell, 1988, p. E23–E27) were used to irrigate approximately 2.3 million acres (Garabedian, 1993, p. F6). In 1990, 7.9 million acre-ft of surface water and 6.6 million acre-ft of ground water were used to irrigate 2.5 million acres (M.A. Maupin, U.S. Geological Survey, written commun., 1992). Wyoming

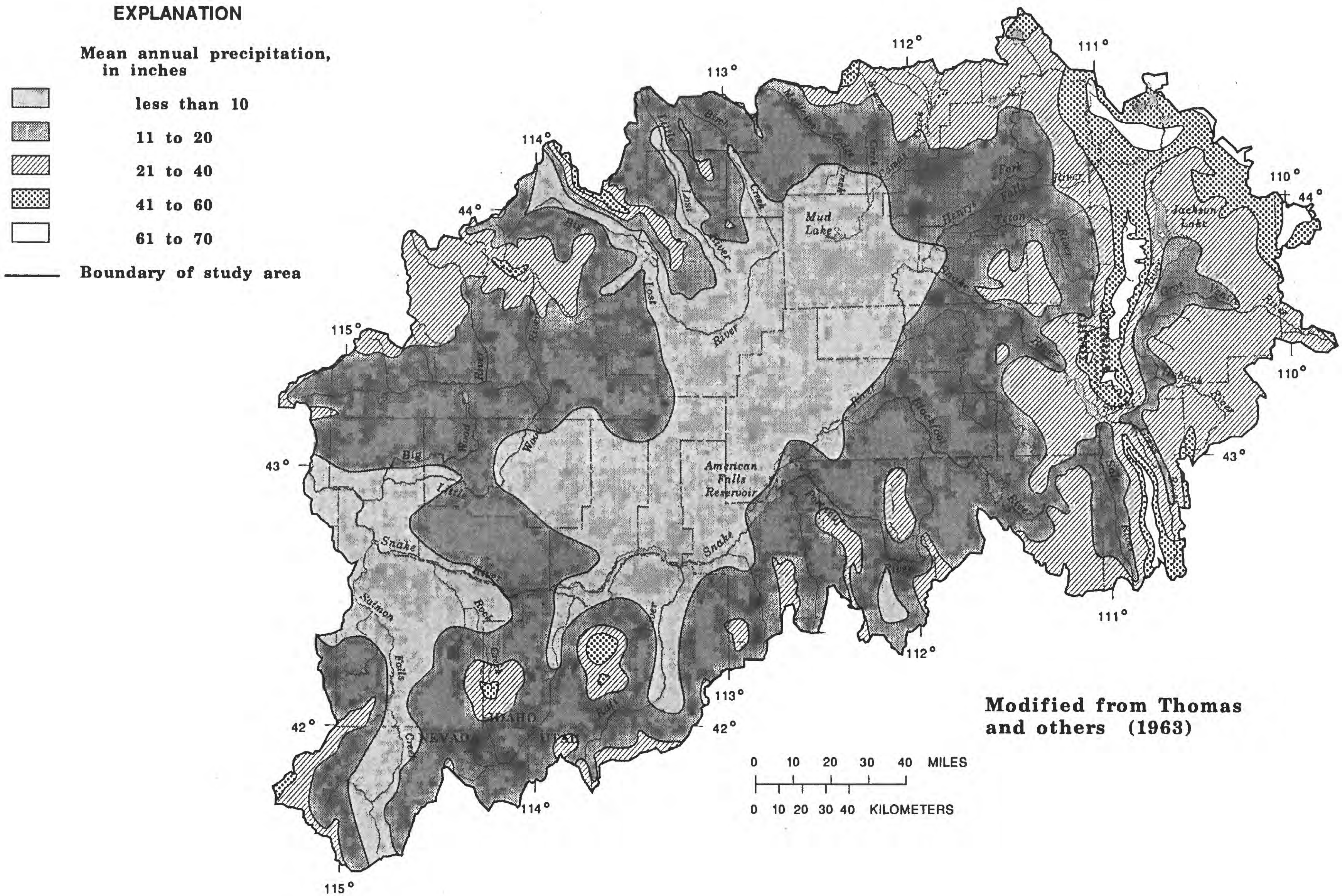

Figure 3. Mean annual precipitation in the upper Snake River Basin.

agriculture within the basin is small in comparison; 0.1 million acres were irrigated by 0.3 million acre-ft of surface water in 1990.

Hydroelectric power generation is the largest nonconsumptive water use in the upper Snake River Basin. The basin contains 15 major hydroelectric facilities—roughly half of Idaho's hydroelectric facilities. Goodell (1988, p. 42) estimated that 39.4 million acre-ft was used to produce about 2 million MWh on the eastern Snake River Plain in 1980.

Aquaculture is the second-largest nonconsumptive water use in Idaho. Idaho aquaculture is ranked first in the Nation for commercial trout production, providing 76 percent of the national liveweight production, or about 45 million pounds annually (Idaho Agricultural Statistics Service, 1992). Most of the aquaculture facilities are located at spring discharges along the middle Snake River, a 94-mi reach between Milner Dam and King Hill. Trout production uses 80 to 90 percent of the spring flow between Milner Dam and King Hill.

Industrial uses of water include food processing, fertilizer production, concrete production, cooling, and employee sanitation (Goodell, 1988, p. E37). Food-processing industries are concentrated in the Idaho Falls, Burley, and Twin Falls areas. Fertilizer- and concrete-manufacturing companies are located in the Pocatello area. Contrary to the national trend, Idaho uses a much greater amount of ground water than surface water for industrial uses (M.A. Maupin, U.S. Geological Survey, written commun., 1992). Estimated industrial withdrawals in 1990 were about 188,500 acre-ft from ground water, 68,000 acre-ft from surface water, and 4,200 acre-ft from public-supply deliveries (USGS National Water Data Storage and Retrieval System).

Geohydrology

The upper Snake River Basin can be subdivided into four hydrogeomorphic regions (developed from Whitehead, 1986, 1992): eastern Snake River Plain, local aquifers, tributary valleys, and eastern valleys (fig. 4). Hydrogeomorphic regions have a distinctive combination of hydrogeologic and areal characteristics, such as geology, geomorphology, and physiography, which can impart a typical set of water-quality patterns (Hamilton and others, 1991, p. 30).

The eastern Snake River Plain contains a regional aquifer composed primarily of fractured basalt, although some isolated aquifers of alluvium and silicic volcanic rocks also are present, particularly on the eastern margin. Overlying the eastern Snake River Plain basalt aquifer are local alluvial aquifers with distinctive water-quality characteristics. Only the most extensive local aquifers are included in this classification. Bounding the eastern Snake River Plain are a series of smaller tributary valleys that are a major source of recharge to the eastern Snake River Plain aquifer through seepage from streams and underflow. These tributary valleys are underlain primarily by alluvium, although basalt and silicic volcanic rocks also are present. The eastern valleys include Jackson Hole and the Salt River Valley of Wyoming and also are underlain primarily by alluvium.

Greater emphasis is placed on the eastern Snake River Plain in the following sections because this region has the most water-quality data and the greatest amount of water use.

EASTERN SNAKE RIVER PLAIN

The eastern Snake River Plain is underlain predominantly by basalt of the Snake River Group of Quaternary age. Basalt is generally less than 10 ft below land surface in the central part of the eastern plain and is generally less than 100 ft below land surface elsewhere. Geophysical data and drillers' logs indicate that Quaternary basalt in the central part of the eastern plain is as much as 5,000 ft thick (Whitehead, 1992, p. B1).

The layered basalt flows in the eastern Snake River Plain contain and yield exceptionally large volumes of water to wells and springs. Wells open to less than 100 ft of the aquifer yield as much as 7,000 gal/min; yields of 2,000 to 3,000 gal/min with only a few feet of drawdown are common (Whitehead, 1992; Lindholm, 1993), making yields from the eastern Snake River Plain aquifer some of the largest in the Nation. Transmissivity commonly exceeds 100,000 ft^2/d and locally is as much as 1,000,000 ft^2/d (Whitehead, 1992, p. B22).

Regionally, ground water in the eastern plain moves from northeast to southwest (fig. 5) and discharges to the Snake River from many large springs (Lindholm and others, 1988). The potentiometric surface descends 2,000 ft along a 200-mi-long flowpath at an average gradient of 10 ft/mi. Flow velocities average approximately 10 ft/d (Robertson and others, 1974, p. 13). Average residence time of water in the aquifer is 200 to 250 years (Wood and Low, 1988). Depth to first-encountered ground water ranges from less than 3 ft in

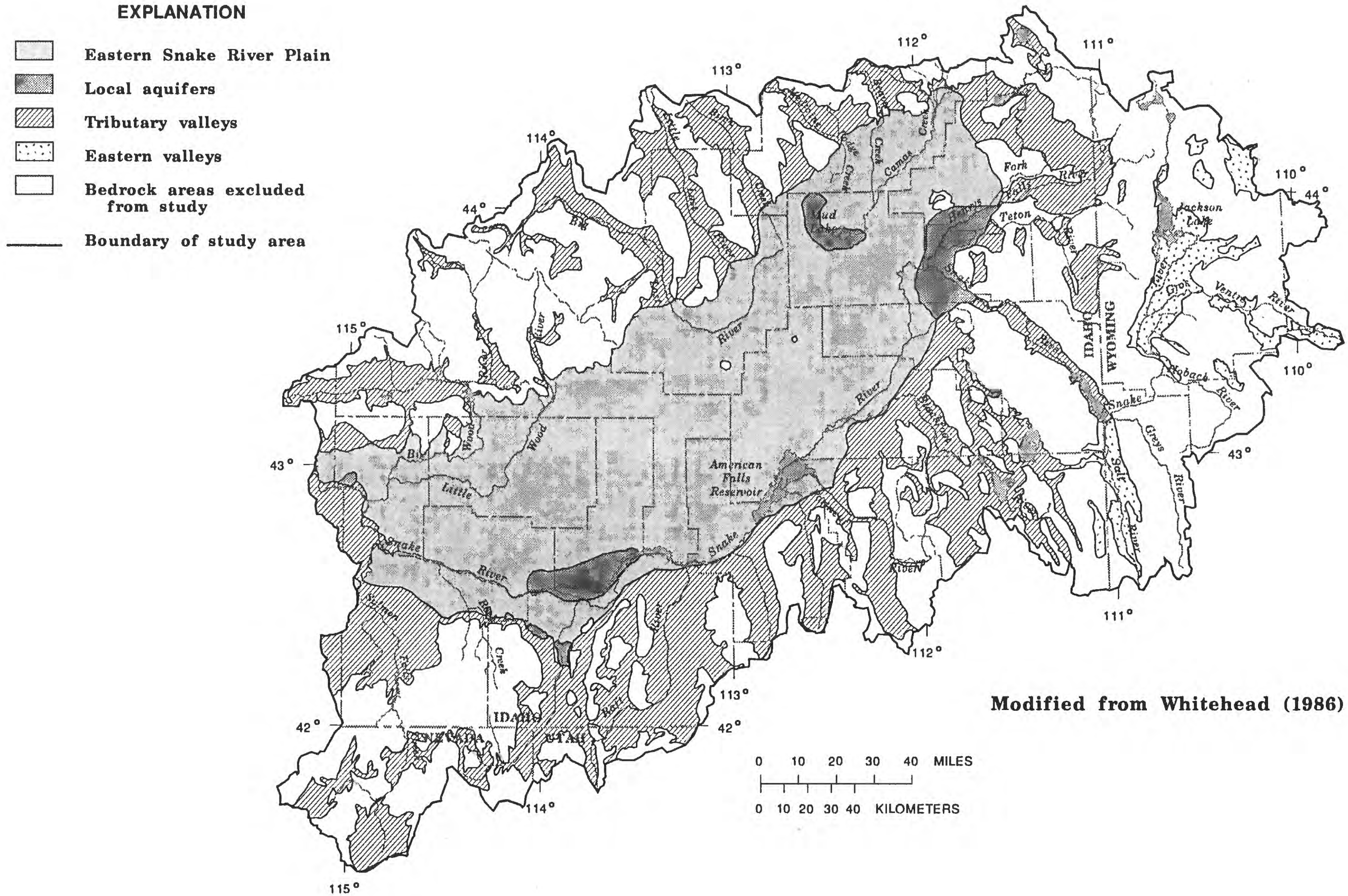

Figure 4. Hydrogeomorphic regions in the upper Snake River Basin.

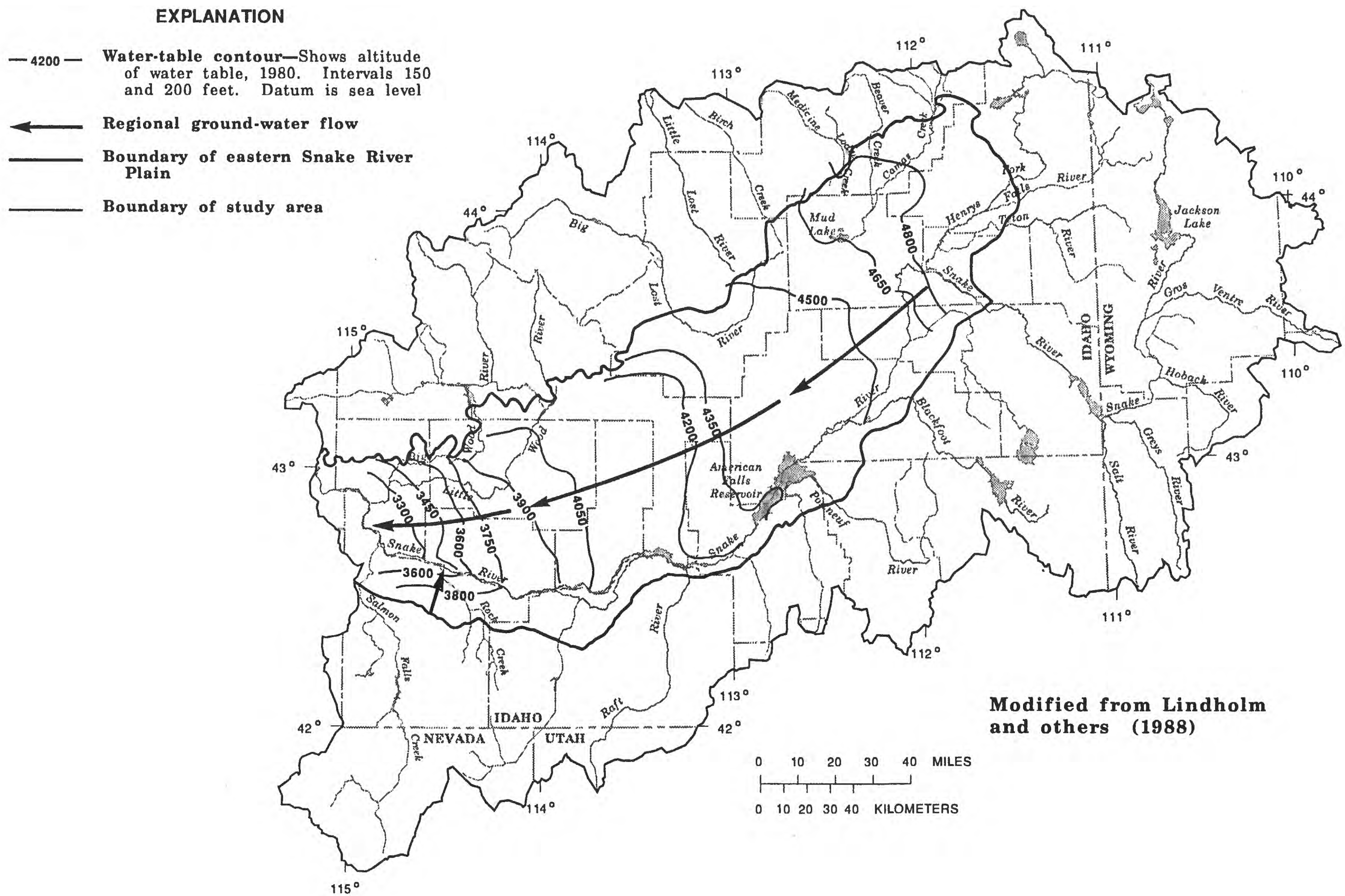

Figure 5. Regional water table of the eastern Snake River Plain aquifer, spring 1980.

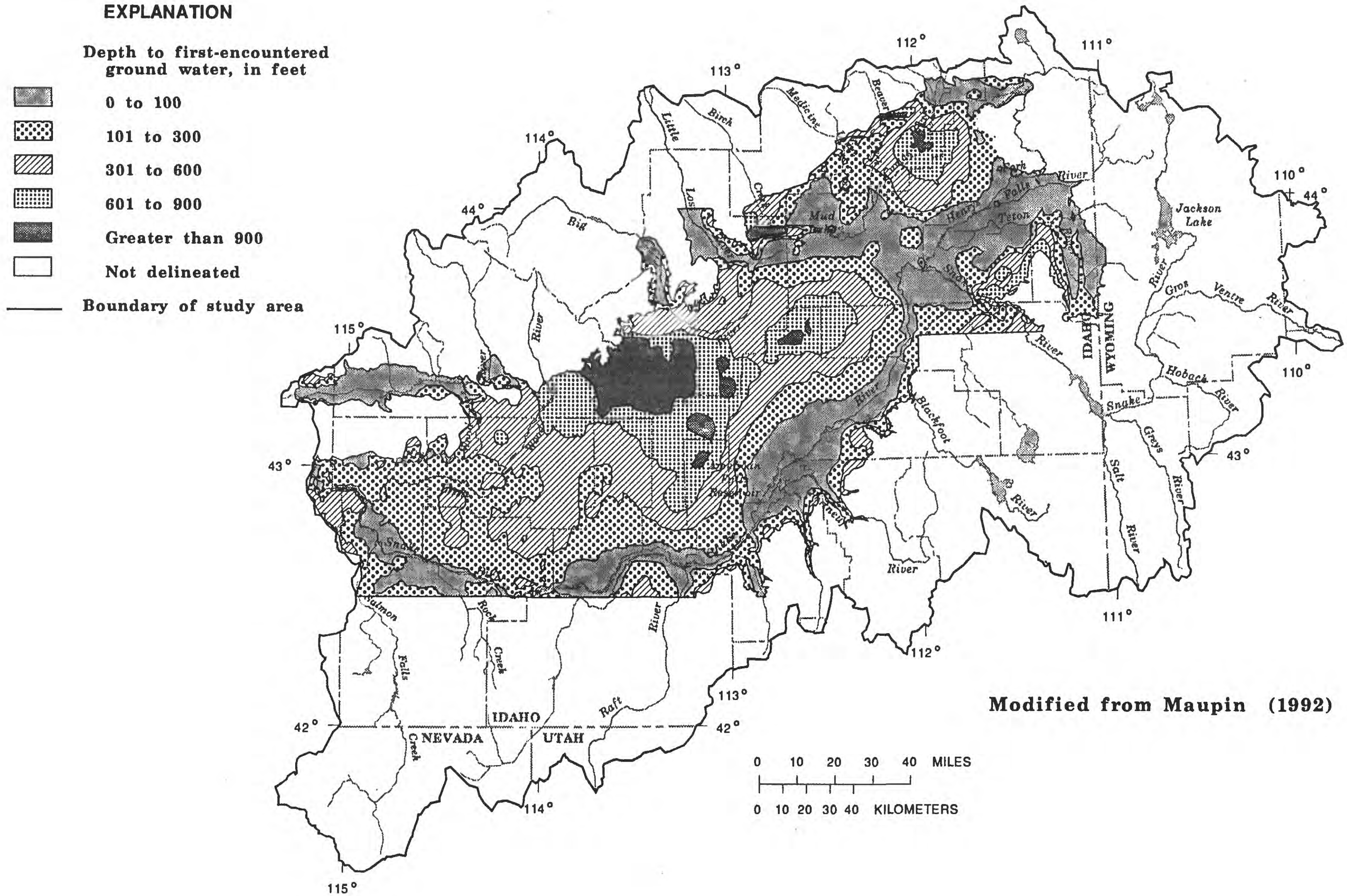

Figure 6. Depth to first-encountered ground water in the eastern Snake River Plain, 1980–88.

alluvium along the Snake River (Maupin, 1992) to 1,000 ft in the north-central part of the eastern plain (fig. 6).

Lindholm (1993) made the following estimates of recharge to the eastern Snake River Plain aquifer for 1980: (1) surface-water irrigation, 4.84 million acre-ft; (2) tributary drainage basin underflow, 1.44 million acre-ft; (3) precipitation on the plain, 0.70 million acre-ft; (4) Snake River losses, 0.69 million acre-ft; and (5) tributary and canal losses, 0.39 million acre-ft. Lindholm (1993) also made the following estimates of discharge from the eastern Snake River Plain aquifer for 1980: (1) spring flow, 7.08 million acre-ft; and (2) pumpage, 1.14 million acre-ft. About two-thirds of the water from spring flow discharges to the Snake River between Milner Dam and King Hill (Lindholm and others, 1988), and the other third discharges between Blackfoot and Neeley (Mundorff and others, 1964). Lindholm (1993) estimated that ground-water discharge exceeded recharge by 0.1 to 0.16 million acre-ft in 1980.

Average annual ground-water discharge (mainly spring flow) along the north side of the Snake River between Milner Dam and King Hill increased considerably from 1910 through the early 1950's (fig. 7). The increase is attributed to recharge from surface-water irrigation north and east of the springs (Kjelstrom, 1992). Since the 1950's, ground-water discharge has decreased because of a combination of increasing ground-water withdrawals for irrigation (Moreland, 1976, p. 9), more efficient irrigation practices such as conversion from flood to sprinkler irrigation, and local droughts (Kjelstrom, 1992). Water levels in wells reflect the same long-term downward trend (Kjelstrom, 1992).

LOCAL AQUIFERS

Local aquifers in the eastern Snake River Plain (Lindholm and others, 1988; Young, 1984) have distinctive water-quality characteristics. Only the most extensive local aquifers are included in this classification; others exist but are insignificant for regional water-quality characterization.

In an area north of Burley, a clay layer about 60 to 120 ft below the surface creates a local aquifer. Recharge to this aquifer is predominantly from infiltration of irrigation water. According to local accounts, a local aquifer did not exist prior to construction of the irrigation network from Lake Walcott in 1907. Local information indicates that several wells completed in this system go dry during the winter when the diversion or use of irrigation water ceases. These wells become operational less than 2 weeks after irrigation canals are refilled in the spring.

TRIBUTARY VALLEYS

Tributary valleys north, south, and east of the eastern Snake River Plain are a source of recharge to the eastern Snake River Plain aquifer through seepage from streams and ground-water underflow. A more complete description of these tributary valleys is provided in a report by Mundorff and others (1964).

The principal tributary valleys north and east of the eastern Snake River Plain (fig. 1) are Teton River, Birch Creek, Little Lost River, Big Lost River, Little Wood River, Big Wood River, and Camas Creek. Prominent north-trending mountains separate these valleys. Aquifer materials are predominantly alluvium. Near the mouths of many of the valleys, basaltic lava flows of the Snake River Group interfinger with and overlie the alluvium. The Big Lost River, Little Lost River, and Birch Creek lose all their water to the eastern Snake River Plain aquifer near their mouths.

The southern tributary valleys are broad, northward-sloping basins that merge with the eastern Snake River Plain. The principal valleys are Portneuf River, Rock Creek (south of American Falls), Raft River, and Goose Creek (fig. 1). Prominent north-trending mountains separate these valleys. Aquifer materials are allu-

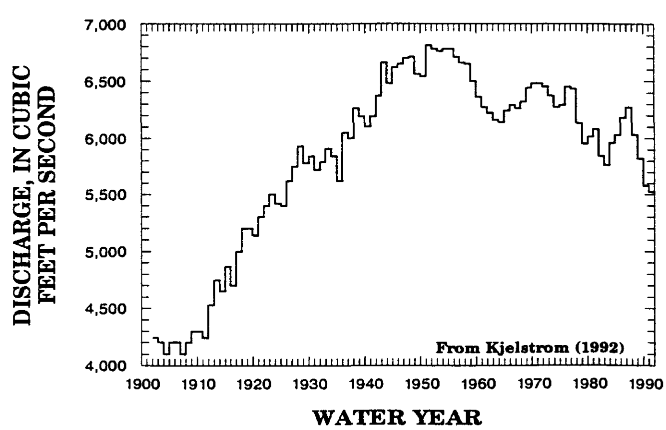

Figure 7. Average annual ground-water discharge (mainly spring flow) along the northern side of the Snake River between Milner Dam and King Hill. (A water year is a 12-month period beginning October 1 and ending September 30 of the following year)

vium and basalt. Much of the basalt is correlative with the Snake River Group (Mundorff and others, 1964).

EASTERN VALLEYS

The principal eastern valleys are Jackson Hole and the Salt River (fig. 1). Primary aquifer materials in Jackson Hole are fluvial deposits, glacial outwash, and coarse-grained alluvial fan deposits (Cox, 1975). Most aquifers are unconfined, although perched aquifers may exist locally. The alluvial aquifers in Jackson Hole are recharged by precipitation and seepage from local streams (Cox, 1974). Recharge is greatest in late spring and summer, during and just after spring runoff.

The Salt River Valley, also termed the Star Valley, is in the far western part of Wyoming (fig. 1). The principal water-bearing formation is a thick deposit of Pleistocene gravel (Walker, 1965). Most water in the gravel is unconfined. Recharge is predominantly from irrigation water, infiltration of rainfall and snowmelt, and seepage from streams along the margins of the valleys. Along the eastern margin of the valley, ground water in the bedrock recharges the Pleistocene gravel along fractures and faults (Lines and Glass, 1975). Recharge is greatest during spring snowmelt (Walker, 1965). The direction of water movement through the gravel is probably similar to surface drainage patterns—toward the center of the valleys and in a downstream direction (Lines and Glass, 1975). Ground water discharges to the Salt River from springs and seeps throughout most of the valley (Walker, 1965).

Potential Sources of Contamination

The Idaho Department of Health and Welfare (1989, p. 17) considers the following activities the greatest risks to ground-water quality in Idaho (in descending order of risk): petroleum storage and handling; feedlots and dairies; landfills and hazardous waste sites; land application of wastewater; hazardous material handling and use; pesticide handling and use; land application of

Table 2. Estimated use of nitrogen and phosphorus fertilizers in the upper Snake River Basin, 1985–89

[Data from U.S. Environmental Protection Agency (1990); amounts in tons; counties with a small percentage of land area in the basin were excluded]

County	Nitrogen use					Phosphorus use				
	1985	1986	1987	1988	1989	1985	1986	1987	1988	1989
Idaho										
Bannock	2,815	2,442	2,438	2,458	2,723	1,051	896	972	953	1,124
Bingham	22,196	19,256	19,221	19,378	21,465	8,283	7,066	7,665	7,512	8,862
Blaine	1,046	907	906	913	1,011	390	333	361	354	418
Bonneville	8,870	7,695	7,681	7,744	8,578	3,310	2,824	3,063	3,002	3,541
Butte	1,356	1,177	1,174	1,184	1,312	506	432	468	459	541
Camas	585	508	507	511	566	218	186	202	198	234
Caribou	3,425	2,971	2,966	2,990	3,312	1,278	1,090	1,183	1,159	1,367
Cassia	15,932	13,822	13,796	13,909	15,407	5,946	5,072	5,502	5,392	6,361
Clark	3,544	3,075	3,069	3,094	3,428	1,323	1,128	1,224	1,200	1,415
Custer	336	291	291	293	325	125	107	116	114	134
Fremont	6,786	5,887	5,876	5,924	6,562	2,532	2,160	2,343	2,297	2,709
Gooding	4,364	3,786	3,779	3,810	4,220	1,628	1,389	1,507	1,477	1,742
Jefferson	4,902	4,253	4,245	4,280	4,740	1,829	1,561	1,693	1,659	1,957
Jerome	6,530	5,665	5,655	5,701	6,315	2,437	2,079	2,255	2,210	2,607
Lemhi	627	544	543	548	607	234	200	217	212	250
Lincoln	1,477	1,281	1,279	1,290	1,428	551	470	510	500	590
Madison	8,479	7,356	7,343	7,403	8,200	3,164	2,699	2,928	2,870	3,385
Minidoka	10,248	8,890	8,874	8,947	9,910	3,824	3,262	3,539	3,468	4,091
Power	8,201	7,114	7,101	7,160	7,931	3,060	2,611	2,832	2,775	3,274
Teton	3,024	2,624	2,619	2,640	2,924	1,129	963	1,044	1,023	1,207
Twin Falls	11,291	9,795	9,777	9,857	10,919	4,214	3,595	3,899	3,821	4,508
Wyoming										
Lincoln	223	196	154	135	157	71	74	42	29	55
Teton	182	159	125	110	128	58	60	35	23	45

sewage and sludge; surface runoff; waste pits, ponds, and lagoons; radioactive substances; fertilizer application; septic-tank systems; mining (including oil and gas drilling); wells (injection, geothermal, and domestic); and silviculture.

Several thousand (exact number is not known) injection wells are used to dispose of excess irrigation water, urban runoff, and septic-tank effluent from lands overlying the basalt of the eastern Snake River Plain aquifer (Yee and Souza, 1987, p. 49). Contaminants introduced by some of the injection wells reportedly have degraded the water in nearby domestic wells (Graham and others, 1978; Graham, 1979). Seitz and others (1977) indicated that water disposed to injection wells can move appreciable distances through the aquifer.

Low-level radioactive wastes and nitrogen-containing compounds were injected into deep wells open to the eastern Snake River Plain aquifer at the INEL. Those injection wells have been abandoned, and the wastes now are disposed to percolation ponds (Yee and Souza, 1987). Monitoring wells operated by the USGS have been sampled since the early 1950's to trace the spread of contaminants at the INEL. Tritium, the most mobile contaminant, has migrated downgradient about 7.5 mi from the source areas and extends over an area of about 30 mi^2 (Schneider and Trask, 1982, p. 86). The INEL was designated a superfund site on November 21, 1989.

Mining and processing phosphate ore pose a potential problem in the area northeast of Soda Springs (Yee and Souza, 1987). Aquifers in this area are not well defined, and the effects of mining on ground water are not known. Increased concentrations of arsenic, boron, zinc, and alpha and beta activity have been reported in a shallow alluvial aquifer underlying a phosphate ore processing plant northwest of Pocatello (Yee and Souza, 1987, p. 49).

Fertilizer and pesticide use poses a potential threat to water quality in the upper Snake River Basin, although few data are available on their use. Fertilizer use by county during 1985 through 1989 (table 2) was estimated by the U.S. Environmental Protection Agency (1990). The estimates were derived from county fertilizer expenditures reported in the 1987 Census of Agriculture (U.S. Department of Commerce, 1987). Alexander and Smith (1990) estimated fertilizer use by county during 1980–85 on the basis of total fertilized acres reported in the 1982 Census of Agriculture (U.S. Department of Commerce, 1982).

Gianessi and Puffer (1988) estimated organic compound use on the basis of acres of principal crops grown and organic compound-use coefficients (table 3). Estimates of acres grown of a particular crop were based on the 1982 Census of Agriculture (U.S. Department of Commerce, 1982). Organic compound-use coefficients were derived from the 1982 Crop and Livestock Pesticide Usage Survey (Duffy, 1983).

Clark (1989) summarized the major organic compounds used in the Twin Falls County area (table 4) on the basis of data from local agricultural extension agents.

SOURCES OF WATER-QUALITY DATA

All automated sources of comprehensive ground-water quality data were compiled and examined for errors. Sources for this study unit were the USGS data base and the U.S. Environmental Protection Agency (USEPA) STORET data base. All ground-water quality data files were converted to Geographic Information System (GIS) data files to assist in correlating water quality with land use and hydrogeomorphic regions.

Data from filtered and unfiltered (dissolved and total) duplicate nitrite plus nitrate (as nitrogen; hereafter referred to as nitrate) samples were compared to

Table 3. Estimated use of selected organic compounds in the upper Snake River Basin

[Data from Gianessi and Puffer (1988). Only the 15 most used organic compounds are listed; other organic compounds may be used in greater quantities in the basin. Amounts are in tons of active ingredients applied per year. Estimates are for entire basin]

Organic compound	Estimated amount applied	Use
2,4-D	460	Herbicide
Phorate	60	Insecticide
Trifluralin	45	Herbicide
Alachlor	29	Herbicide
Disulfoton	29	Insecticide
Carbaryl	29	Insecticide
Methamidophos	29	Insecticide
Carbofuran	25	Insecticide
Chlorothalonil	23	Fungicide
Ethoprop	22	Insecticide
Methyl parathion	10	Insecticide
Parathion	9.6	Insecticide
Metolachlor	8.2	Herbicide
Atrazine	7.6	Herbicide
Diazinon	5.3	Insecticide

examine differences between the two sample-treatment techniques. A regression of 43 duplicate samples from the USGS data base had a slope of 1 and an r^2 value of 0.989. A paired t-test of the same data set had a t-test statistic of -0.737 and a p-value of 0.465. Both the regression and the paired t-test suggest there is no significant difference between filtered and unfiltered samples. Therefore, for the purposes of this report, filtered USGS samples and unfiltered USEPA samples were considered comparable.

Mean values were used for wells with multiple analyses. Mean values are similar to median values for the purposes of this report because more than 70 percent of the wells had only one analysis, and only 23 percent had four or more analyses. Mean values were used instead of the most recent analysis for each well to represent water quality for average conditions during the 1980's.

U.S. Geological Survey Data

Ground-water quality data were compiled from USGS data bases for Idaho and Wyoming for January 1, 1980, through May 1, 1990. This ending date was chosen because of changes in analytical methods for nitrate and phosphorus by the USGS National Water Quality Laboratory. Data were compiled only for wells with a known total depth, screen location, or pump location.

The data were divided into two discrete groups: miscellaneous studies and nitrate studies. The miscellaneous studies comprise data compiled from all previous USGS investigations (excluding the nitrate studies), each with its own procedure for well selection, sampling, and quality assurance/quality control.

The nitrate studies comprise data on nitrate in ground water in areas where elevated concentrations were documented (Parliman and Young, 1987, 1988, 1989; Young, Parliman, and Jones, 1987; Young, Parliman, and O'Dell, 1987). Ground-water samples were analyzed onsite for nitrate concentrations. A duplicate sample was collected for laboratory analysis if the field concentrations were generally 4 mg/L or greater. Because only laboratory data are entered into the USGS data base, data from these studies are biased to wells in which water generally contains nitrate concentrations of 4 mg/L or greater. The data set contains no field analyses and is treated independently of other data sets to account for the biases.

Table 4. Organic compounds used in the Rock Creek area, Twin Falls County

[Data from Clark (1989)]

Organic compound and use	
Algicide	**Fungicide**
Acrolein	Benomyl
Copper sulfate[1]	Captan
Xylene	Metiram
	Triadimefon
Herbicide	
Alachlor	EPTC
Atrazine	Glyphosate
Cycloate	Hexazinone
Dicamba	Oryzalin
Difenzoquat methyl sulfate	Pebulate
2,4-D	Pronamide
DCPA	Simazine
Ethalfluralin	Trifluralin
Insecticide	
Aldicarb	Dimethoate
Azinphosmethyl	Disulfoton
Carbaryl	Malathion
Carbofuran	Permethrin
Diazinon	Phorate

[1]Copper sulfate is an inorganic compound but was listed because of its wide use an an algicide.

Idaho Statewide Ground-Water Quality Monitoring Program Data

Ground-water quality data were compiled from the Idaho Statewide Ground-Water Quality Monitoring Program for 1990 and 1991. The program is a cooperative project between the USGS and the Idaho Department of Water Resources (IDWR). Primary objectives of the program are to (1) characterize the ground-water quality in Idaho's aquifers, (2) identify trends in ground-water quality within individual aquifers, and (3) identify aquifers or geographic areas where water-quality problems may exist or be emerging (Idaho Department of Water Resources, 1991; Neely and Crockett, 1992). The water-quality data generated by the program are stored in the USGS data base. The first ground-water samples were collected from 97 wells statewide during the summer of 1990. Since then, the program has been expanded to include about 400 wells statewide annually. Water from each well is sampled for specific conductance, pH, temperature, fecal coliform, alkalinity, common ions, nutrients, trace elements, radioactivity and radionuclides, and selected organic compounds. Data for 1990 and 1991 from 197 wells in the basin are included in this report.

Wells were selected by the Idaho Statewide Ground-Water Quality Monitoring Program using a statistically based stratified-random approach. The State was subdivided into 22 hydrogeologic subareas on the basis of aquifer type, water chemistry, and ground-water flow characteristics (Neely and Crockett, 1992). Ten of these subareas are in the upper Snake River Basin.

The number of wells in each subarea was determined by the Idaho Statewide Ground-Water Quality Monitoring Program using the Neyman Optimal Allocation method (Snedecor and Cochran, 1967). This method takes into account the population within each subarea (census data), the size of the subarea, and the variability of water quality (specific conductance). Subareas with the most sites were those with the greatest population, area, and variation in water quality.

Within the subareas, townships and wells within townships were selected randomly by the Idaho Statewide Ground-Water Quality Monitoring Program. Only wells that met the following criteria were selected: (1) known depth, (2) complete driller's log, (3) adequate construction standards, (4) operational pump, and (5) completed in one aquifer. The types of wells selected were irrigation, domestic, industrial, and municipal, and were completed at various depths. Monitoring wells constructed to detect contamination from a specific source were not selected.

U.S. Environmental Protection Agency Data

The USEPA STORET data base contains data from the USEPA; the Idaho Department of Health and Wel-

Table 5. Selected sources of nutrient and organic compound data for wells in the upper Snake River Basin, 1980–91

Agency	Program name	Period of record	No. of wells	Total No. of analyses	Well depth and well type available
	Nutrient data				
Idaho Department of Water Resources and U.S. Geological Survey	Idaho Statewide Ground-Water Quality Monitoring Program.	1990–91	197	197	Yes
U.S. Geological Survey	U.S. Geological Survey nitrate studies.	1988–89	121	129	Yes
U.S. Geological Survey	U.S. Geological Survey miscellaneous studies. All programs except the Idaho Statewide Ground-Water Quality Monitoring Program and the U.S. Geological Survey nitrate studies.	1980–90	485	1,262	Yes
U.S. Environmental Protection Agency	Includes information from the U.S. Bureau of Reclamation; U.S. Environmental Protection Agency, Region X; and Idaho Department of Health and Welfare, Division of Environmental Quality.	1980–90	182	887	No
	Organic compound data				
U.S. Geological Survey	U.S. Geological Survey miscellaneous studies.	1987–91	210	650	Yes
U.S. Environmental Protection Agency STORET	Rock Creek project.	1988–90	1	8	No

Table 6. Summary statistics, from all data sources, of nutrient data for wells in the upper Snake River Basin

[Includes data from the U.S. Geological Survey miscellaneous and nitrate studies, the Idaho Statewide Ground-Water Quality Monitoring Program, and the U.S. Environmental Protection Agency STORET data base; concentrations are in milligrams per liter; mean concentration was used for wells with multiple analyses for all calculations of percentiles; maximum reporting levels are listed for constituents with multiple reporting levels; <, less than]

Constituent	No. of wells sampled	Maximum reporting level	Minimum concentration measured	Percentile 10	Percentile 25	Percentile 50	Percentile 75	Percentile 90	Maximum concentration measured
Nitrite, as nitrogen	373	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.012	6.00
Nitrite plus nitrate, dissolved, as nitrogen	740	<.10	<.10	.20	.60	1.4	3.9	8.1	76
Nitrite plus nitrate, total, as nitrogen	188	<.10	<.10	1.0	1.4	2.2	4.0	5.3	6.9
Nitrogen ammonia, dissolved, as nitrogen	412	<.010	<.010	<.010	<.010	<.010	.025	.070	7.3
Nitrogen ammonia, total, as nitrogen	177	<.010	<.010	<.010	<.010	<.010	<.010	.020	.90
Kjeldahl nitrogen, total, as nitrogen	233	<.20	<.20	.23	.35	.60	1.1	1.9	8.6
Phosphorus, dissolved	54	<.010	<.010	<.010	.014	.030	.060	.500	130
Phosphorus, total	472	<.010	<.010	<.010	.011	.024	.040	.070	16
Orthophosphorus, as phosphorus	430	<.010	<.010	<.010	<.010	.015	.023	.040	30

fare, Division of Environmental Quality (DEQ); and the U.S. Bureau of Reclamation (USBR). Data were retrieved for January 1, 1980, through April 30, 1990. The STORET data base does not contain information on well properties such as depth, screened interval, pump location, or aquifer type. Accordingly, STORET data were not used for comparisons between well depth and ground-water quality.

NUTRIENT DATA

The following sections summarize the nutrient data analyzed in this report. In the summary tables, boxplots, and nonparametric statistical comparisons, all values less than the analytical reporting level were set equal to their respective reporting level and were treated with equal ranking in the nonparametric statistical calculations. If multiple reporting levels existed, all values less than the reporting level were set to the highest reporting level.

Truncated boxplots are used in several figures to summarize the distribution of the data sets (Helsel and Hirsch, 1992, p. 24). Horizontal lines in the "body" of each boxplot correspond to data at the 25th, 50th, and 75th percentiles. The "whiskers" on the ends of each box correspond to data at the 10th and 90th percentiles. The largest and smallest 10 percent of the data are not shown.

Table 7. Summary statistics for nutrient data for wells in the upper Snake River Basin, based on results of U.S. Geological Survey nitrate studies, 1988–89

[Data do not include information from the U.S. Geological Survey miscellaneous studies, the Idaho Statewide Ground-Water Quality Monitoring Program, or the U.S. Environmental Protection Agency STORET data base; concentrations are in milligrams per liter; mean concentration was used for wells with multiple analyses for all calculations of percentiles; maximum reporting levels are listed for constituents with multiple reporting levels; —, insufficient data; <, less than]

Constituent	No. of wells sampled	Maximum reporting level	Minimum concentration measured	Percentile 10	Percentile 25	Percentile 50	Percentile 75	Percentile 90	Maximum concentration measured
Nitrite, as nitrogen	—	—	—	—	—	—	—	—	—
Nitrite plus nitrate, dissolved, as nitrogen	121	<0.10	0.40	4.6	6.2	8.4	11	18	76
Nitrite plus nitrate, total, as nitrogen	—	—	—	—	—	—	—	—	—
Nitrogen ammonia, dissolved, as nitrogen	5	<.010	<.010	<.010	<.010	<.010	.025	.030	.030
Nitrogen ammonia, total, as nitrogen	—	—	—	—	—	—	—	—	—
Kjeldahl nitrogen, total, as nitrogen	119	<.20	<.20	.40	.50	1.0	1.5	2.6	4.2
Phosphorus, dissolved	—	—	—	—	—	—	—	—	—
Phosphorus, total	8	<.010	.020	.020	.023	.035	.048	.200	.200
Orthophosphorus, as phosphorus	—	—	—	—	—	—	—	—	—

Table 8. Summary statistics for nutrient data for wells in the upper Snake River Basin, based on results of U.S. Geological Survey miscellaneous studies, 1980–90

[Data do not include information from the U.S. Geological Survey nitrate studies, the Idaho Statewide Ground-Water Quality Monitoring Program, or the U.S. Environmental Protection Agency STORET data base; concentrations are in milligrams per liter; mean concentration was used for wells with multiple analyses for all calculations of percentiles; maximum reporting levels are listed for constituents with multiple reporting levels; <, less than]

Constituent	No. of wells sampled	Maximum reporting level	Minimum concentration measured	Percentile 10	25	50	75	90	Maximum concentration measured
Nitrite, as nitrogen	218	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.012	6.00
Nitrite plus nitrate, dissolved, as nitrogen	481	<.10	<.10	<.10	.40	1.0	2.7	5.4	65
Nitrite plus nitrate, total, as nitrogen	7	<.10	.30	.30	1.1	1.6	1.9	5.9	5.9
Nitrogen ammonia, dissolved, as nitrogen	241	<.010	<.010	<.010	<.010	.015	.030	.080	7.3
Nitrogen ammonia, total, as nitrogen	7	<.010	<.010	<.010	<.010	<.010	<.010	.030	.030
Kjeldahl nitrogen, total, as nitrogen	142	<.20	<.20	.20	.30	.42	.61	1.1	8.6
Phosphorus, dissolved	54	<.010	<.010	<.010	.014	.030	.060	.500	130
Phosphorus, total	176	<.010	<.010	<.010	<.010	.020	.040	.078	16
Orthophosphorus, as phosphorus	234	<.010	<.010	<.010	<.010	.012	.024	.100	30

Statistical Summaries of Nutrient Data

The sources of nutrient and organic compound data are listed in table 5, and an overall summary of nutrient data from all sources is shown in table 6. Summary statistics for nutrient data from individual data sets are shown in tables 7 through 10 so data from programs with distinct well selection techniques and geographic areas of interest could be differentiated. Some wells were sampled for more than one program—individual analyses are included with each data set to maintain consistency. Locations of wells with nutrient data from all data sets are shown in figure 8.

Nutrient data from the USGS nitrate studies and miscellaneous studies are summarized in tables 7 and 8, respectively. Wells sampled for the USGS nitrate studies have the highest median nitrate and kjeldahl nitrogen concentrations among all the data sets. Nitrate concentrations in wells sampled for the USGS nitrate studies and miscellaneous studies are shown in figures 9 and 10, respectively.

Summary statistics for nutrient data from the Idaho Statewide Ground-Water Quality Monitoring Program for calendar years 1990 through 1991 are shown in table 9. These data are considered to be the most representative of nutrient concentrations in the basin due to the statistically based stratified-random well selection approach. Nitrate concentrations in wells sampled for the Idaho Statewide Ground-Water Quality Monitoring Program are shown in figure 11.

Summary statistics for nutrient data from the USEPA STORET data base from January 1980 through

Table 9. Summary statistics for nutrient data for wells in the upper Snake River Basin, based on results of the Idaho Statewide Ground-Water Quality Monitoring Program, calendar years 1990–91

[Data do not include information from the U.S. Geological Survey miscellaneous or nitrate studies or the U.S. Environmental Protection Agency STORET data base; concentrations are in milligrams per liter; maximum reporting levels are listed for constituents with multiple reporting levels; —, insufficient data; <, less than]

Constituent	No. of wells sampled	Maximum reporting level	Minimum concentration measured	Percentile 10	25	50	75	90	Maximum concentration measured
Nitrite, as nitrogen	163	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.040
Nitrite plus nitrate, dissolved, as nitrogen	197	<.10	<.10	<.10	.70	1.5	3.3	5.8	23
Nitrite plus nitrate, total, as nitrogen	3	<.10	1.5	1.5	1.5	1.8	2.6	2.6	2.6
Nitrogen ammonia, dissolved, as nitrogen	181	<.010	<.010	<.010	<.010	<.010	<.010	.030	2.30
Nitrogen ammonia, total, as nitrogen	—	—	—	—	—	—	—	—	—
Kjeldahl nitrogen, total, as nitrogen	—	—	—	—	—	—	—	—	—
Phosphorus, dissolved	—	—	—	—	—	—	—	—	—
Phosphorus, total	170	<.010	<.010	<.010	<.010	.020	.040	.060	.400
Orthophosphorus, as phosphorus	163	<.010	<.010	<.010	<.010	<.010	.020	.050	.500

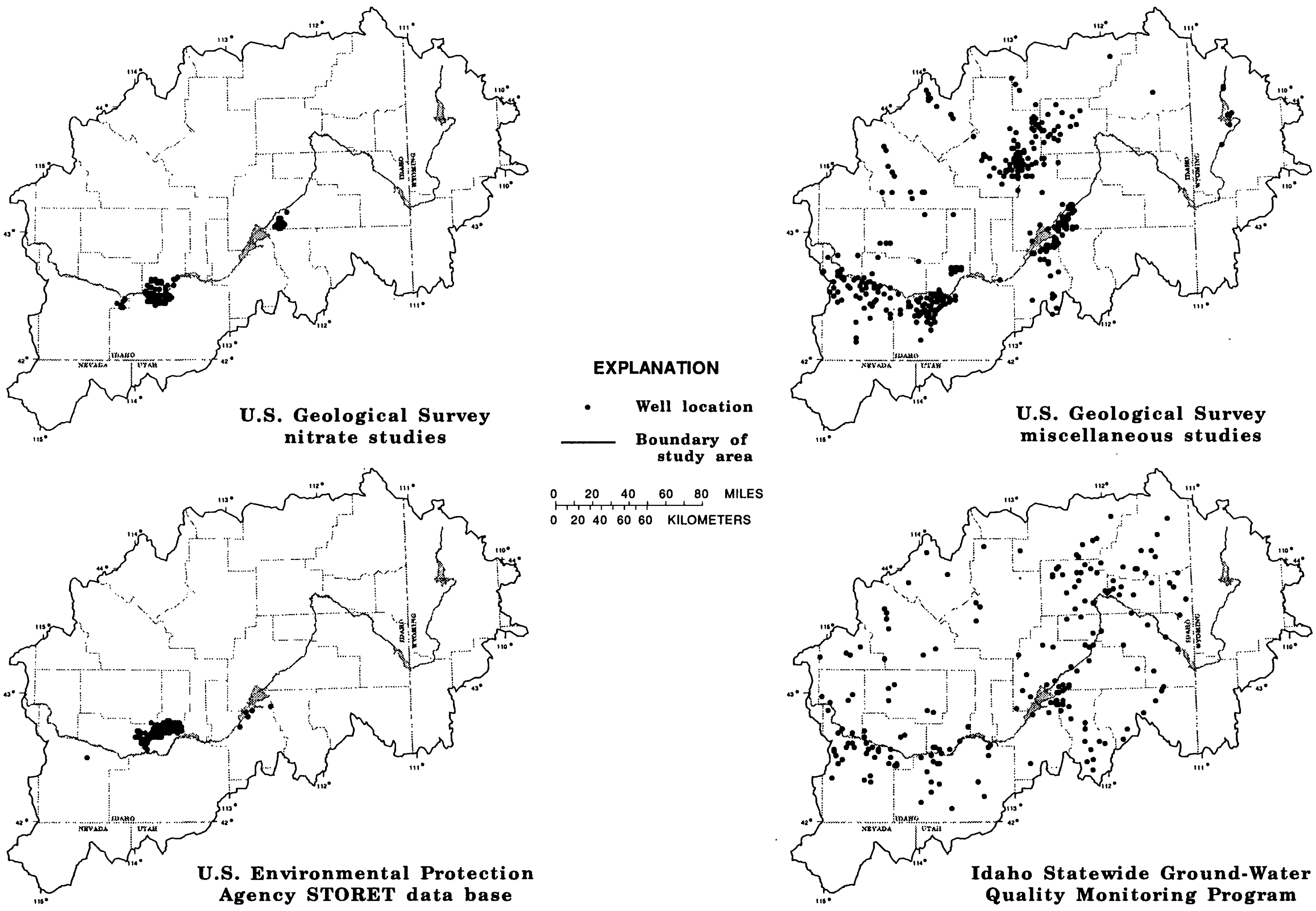

Figure 8. Locations of wells in the upper Snake River Basin with nutrient data. (Data are from the U.S. Geological Survey nitrate and miscellaneous studies, the U.S. Environmental Protection Agency STORET data base, and the Idaho Statewide Ground-Water Quality Monitoring Program)

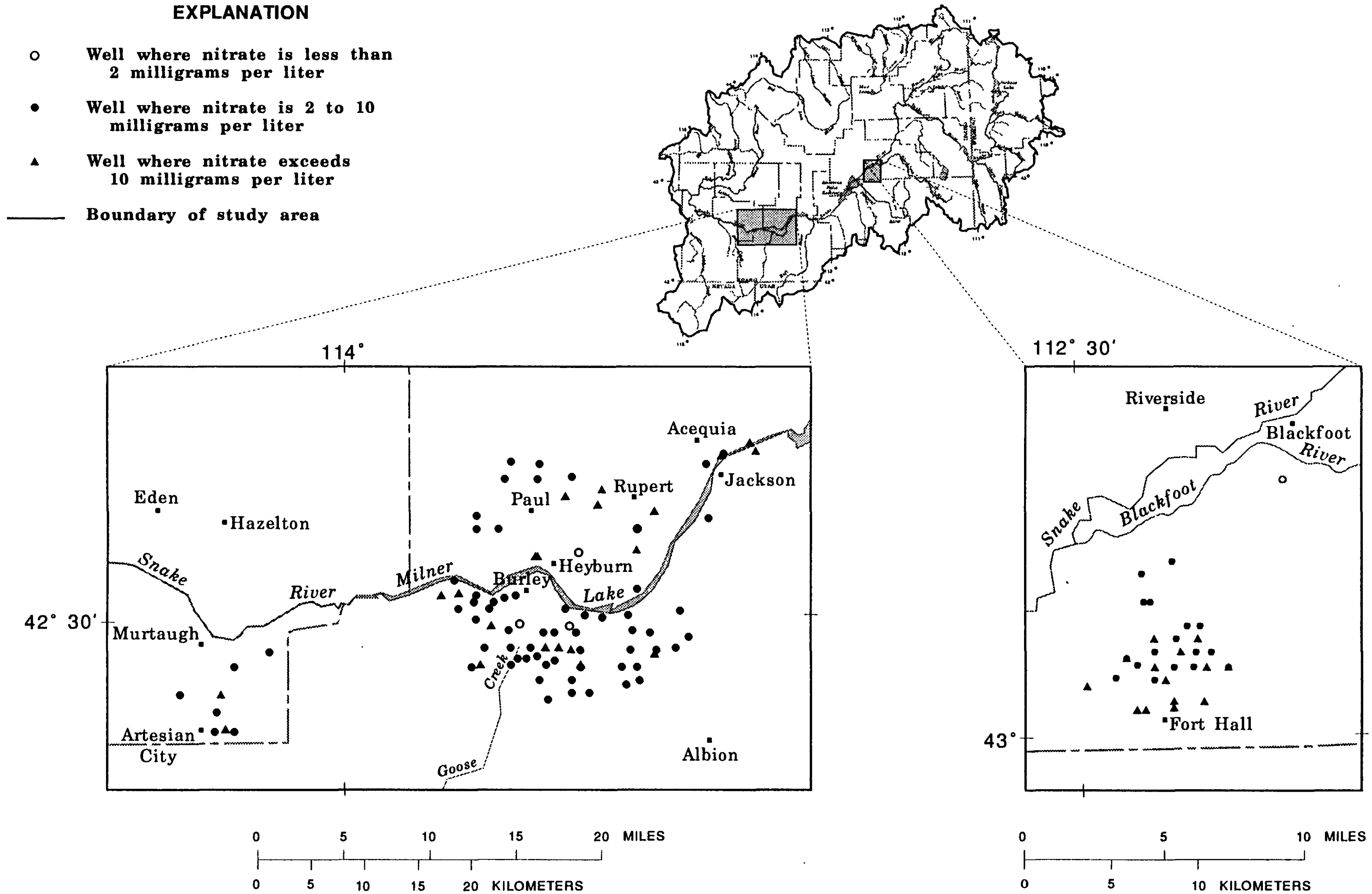

Figure 9. Nitrate concentrations in water from wells in the upper Snake River Basin sampled for the U.S. Geological Survey nitrate studies, 1988–89.

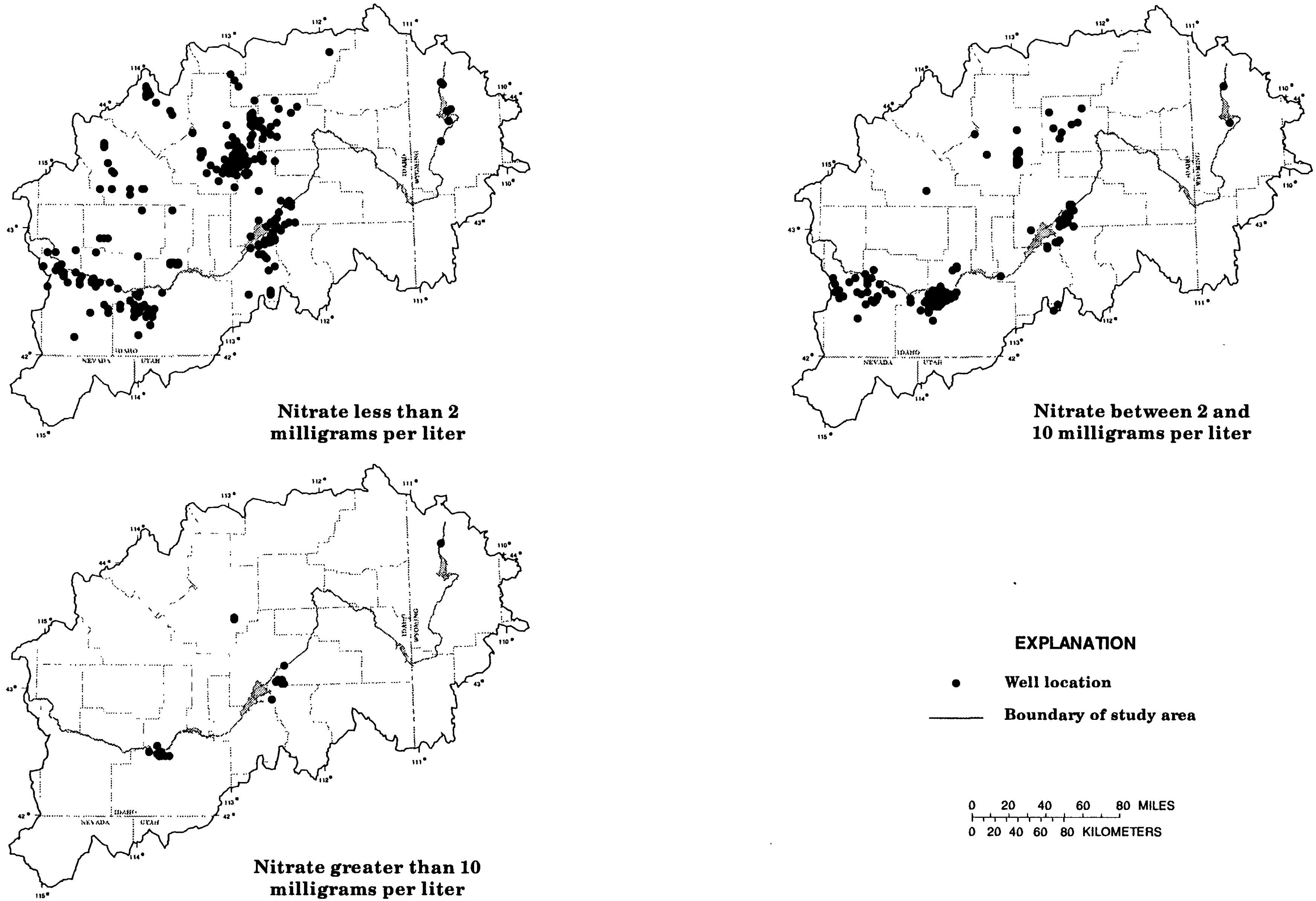

Figure 10. Nitrate concentrations in water from wells in the upper Snake River Basin sampled for the U.S. Geological Survey miscellaneous studies, 1980–90.

April 1990 are shown in table 10. Most STORET wells with nutrient data are in the A&B Irrigation District north of Burley (fig. 12). Nitrate concentrations increase in a downgradient direction in this area. This increase in concentrations presumably is due to loadings from land-use practices in the area. Future studies are planned to examine water quality in the A&B Irrigation District in greater detail.

Nitrate Problem Areas

Nitrate concentrations exceed the Federal drinking-water regulation of 10 mg/L in four areas: the INEL, the area north of Pocatello (Fort Hall area), the area surrounding Burley, and the area north of Jackson Lake (fig. 10).

The INEL is a U.S. Department of Energy nuclear research facility. High concentrations of nitrate at this facility are from discharge of nitrogen-containing wastewater into an injection well (Orr and Cecil, 1991, p. 42). The injection well was used from 1952 to 1984 but has since been abandoned and plugged. The wastewater now is discharged to an infiltration pond. Historical ground-water concentrations of nitrate were as much as 65 mg/L. Since the decommissioning of the injection well, nitrate concentrations have decreased below the Federal drinking-water regulation of 10 mg/L.

The predominant land use in the Fort Hall area is agriculture. Depth to water averages about 40 ft below land surface and the soils are sandy (D.J. Parliman, U.S. Geological Survey, oral commun., 1992). The shallow depth to water and sandy soils facilitate ground-water recharge from irrigation and are the principal factors contributing to the high nitrate concentrations.

Most high nitrate concentrations in the Burley area are in water from wells in the locally perched aquifer. Depth to water typically ranges from less than 5 to 30 ft. Predominant land use is agriculture. The possible sources of nitrate are agricultural fertilizers, effluent from confined-animal feeding operations and food-processing industries, and septic tanks.

The source of high nitrate concentrations in water from the well north of Jackson Lake is nearby sewage-disposal ponds (H.W. Young, U.S. Geological Survey, oral commun., 1994).

Nitrate concentrations exceed 2 mg/L in water from wells in the Twin Falls area. These concentrations suggest degradation of water quality as a result of land-use activities (Parliman, 1988, p. 233). Possible sources of nitrate are agricultural fertilizers, effluent from confined-animal feeding operations and food-processing industries, and septic tanks.

Relations Among Nutrient Concentrations, Well Use, Well Depth, Depth to Water, and Hydrogeomorphic Region

Relations among nitrate concentrations, well use, well depth, and depth to water are shown in figure 13. Data are from the USGS nitrate studies, USGS miscellaneous studies, and Idaho Statewide Ground-Water Quality Monitoring Program. Most wells are domestic,

Table 10. Summary statistics for nutrient data for wells in the upper Snake River Basin, based on results of the U.S. Environmental Protection Agency STORET data base, January 1980 through April 1990

[Data do not include information from the U.S. Geological Survey miscellaneous or nitrate studies or the Idaho Statewide Ground-Water Quality Monitoring Program; concentrations are in milligrams per liter; mean concentration was used for wells with multiple analyses for all calculations of percentiles; maximum reporting levels are listed for constituents with multiple reporting levels; —, insufficient data; <, less than]

Constituent	No. of wells sampled	Maximum reporting level	Minimum concentration measured	Percentile 10	Percentile 25	Percentile 50	Percentile 75	Percentile 90	Maximum concentration measured
Nitrite, as nitrogen	—	—	—	—	—	—	—	—	—
Nitrite plus nitrate, dissolved, as nitrogen	—	—	—	—	—	—	—	—	—
Nitrite plus nitrate, total, as nitrogen	178	<0.10	<0.01	1.0	1.4	2.3	4.1	5.3	6.9
Nitrogen ammonia, dissolved, as nitrogen	—	—	—	—	—	—	—	—	—
Nitrogen ammonia, total, as nitrogen	170	<.010	<.010	<.010	<.010	<.010	<.010	.020	.900
Kjeldahl nitrogen, total, as nitrogen	—	—	—	—	—	—	—	—	—
Phosphorus, dissolved	—	—	—	—	—	—	—	—	—
Phosphorus, total	137	<.010	<.050	.020	.020	.030	.050	.060	.100
Orthophosphorus, as phosphorus	142	<.010	<.010	<.010	<.010	.020	.020	.030	.090

EXPLANATION

- ○ Well where nitrate is less than 2 milligrams per liter
- ● Well where nitrate is 2 to 10 milligrams per liter
- ▲ Well where nitrate exceeds 10 milligrams per liter
- —— Boundary of study area

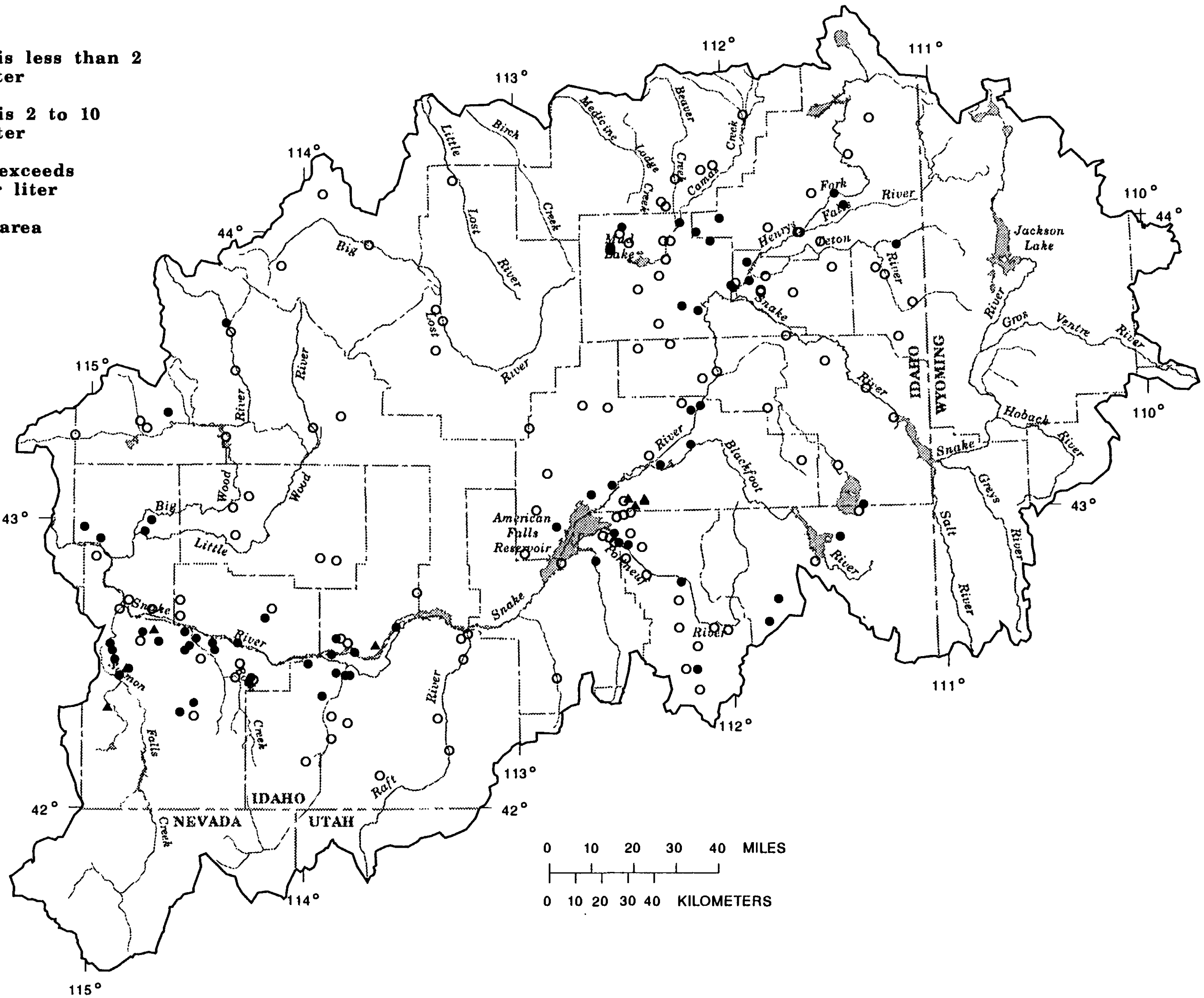

Figure 11. Nitrate concentrations in water from wells in the upper Snake River Basin sampled for the Idaho Statewide Ground-Water Quality Monitoring Program, 1990–91.

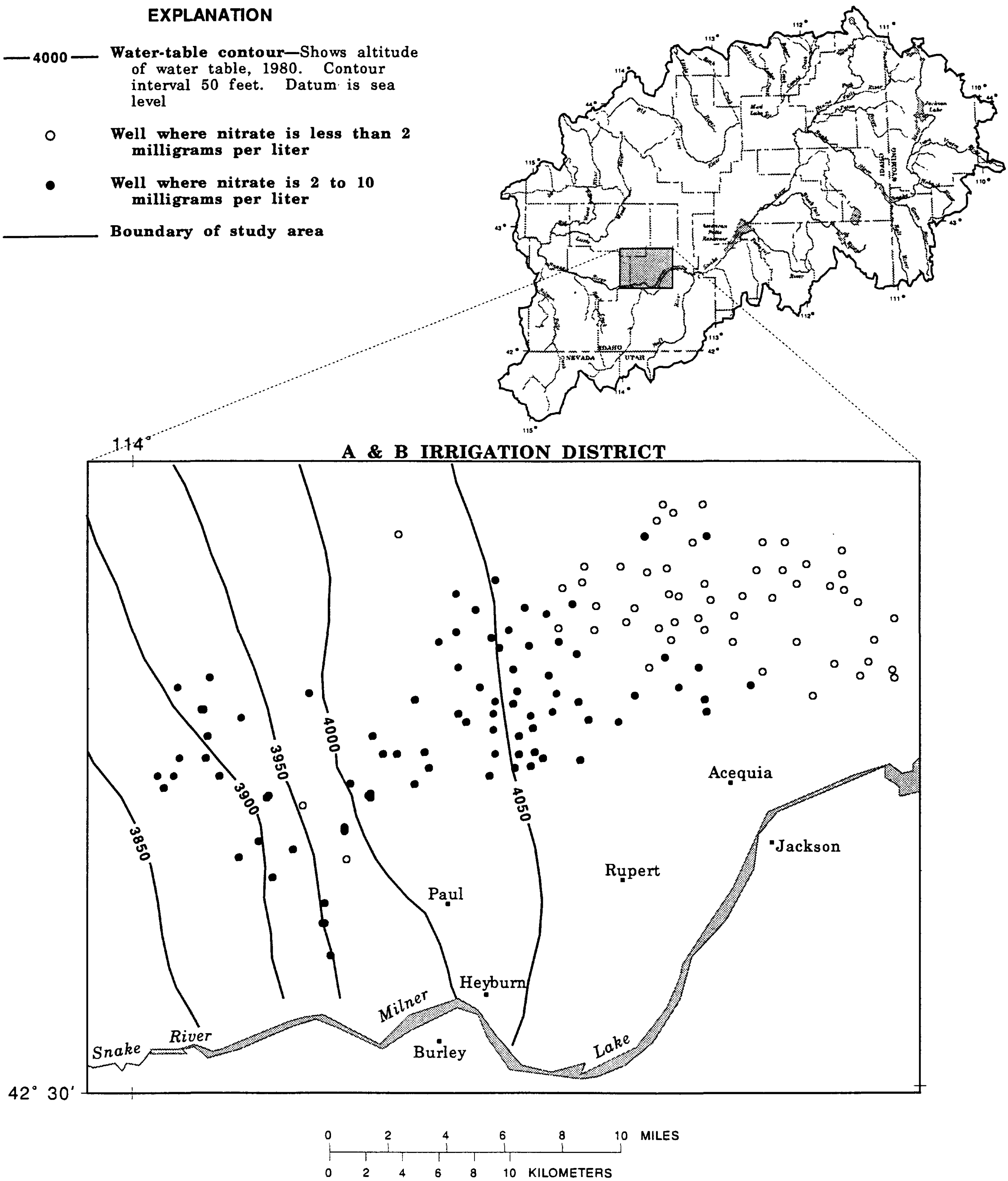

Figure 12. Nitrate concentrations in water from wells in the upper Snake River Basin listed in the U.S. Environmental Protection Agency STORET data base, January 1980 through April 1990. (Water-level contours modified from Lindholm and others, 1988)

unused, and irrigation wells. The shallowest are typically domestic wells and the deepest are industrial and unused wells. Domestic and public-supply wells have the shallowest median water levels. Domestic wells generally contain the highest median nitrate concentrations. It was not possible to compare ammonia, total phosphorus, dissolved phosphorus, and orthophosphorus concentrations with well use because most concentrations are near the reporting level.

Relations among hydrogeomorphic region, well depth, and depth to water are shown in figure 14. Data are from the USGS nitrate studies, USGS miscellaneous studies, and Idaho Statewide Ground-Water Quality Monitoring Program. Most wells are on the eastern Snake River Plain. The shallowest wells and water levels are in the local aquifers, and the deepest wells and water levels are on the eastern Snake River Plain.

Relations Among Nutrient Concentrations, Well Depth, Depth to Water, and Depth Below Water Table

Rélations between nitrate concentrations and well depth in the upper Snake River Basin were examined

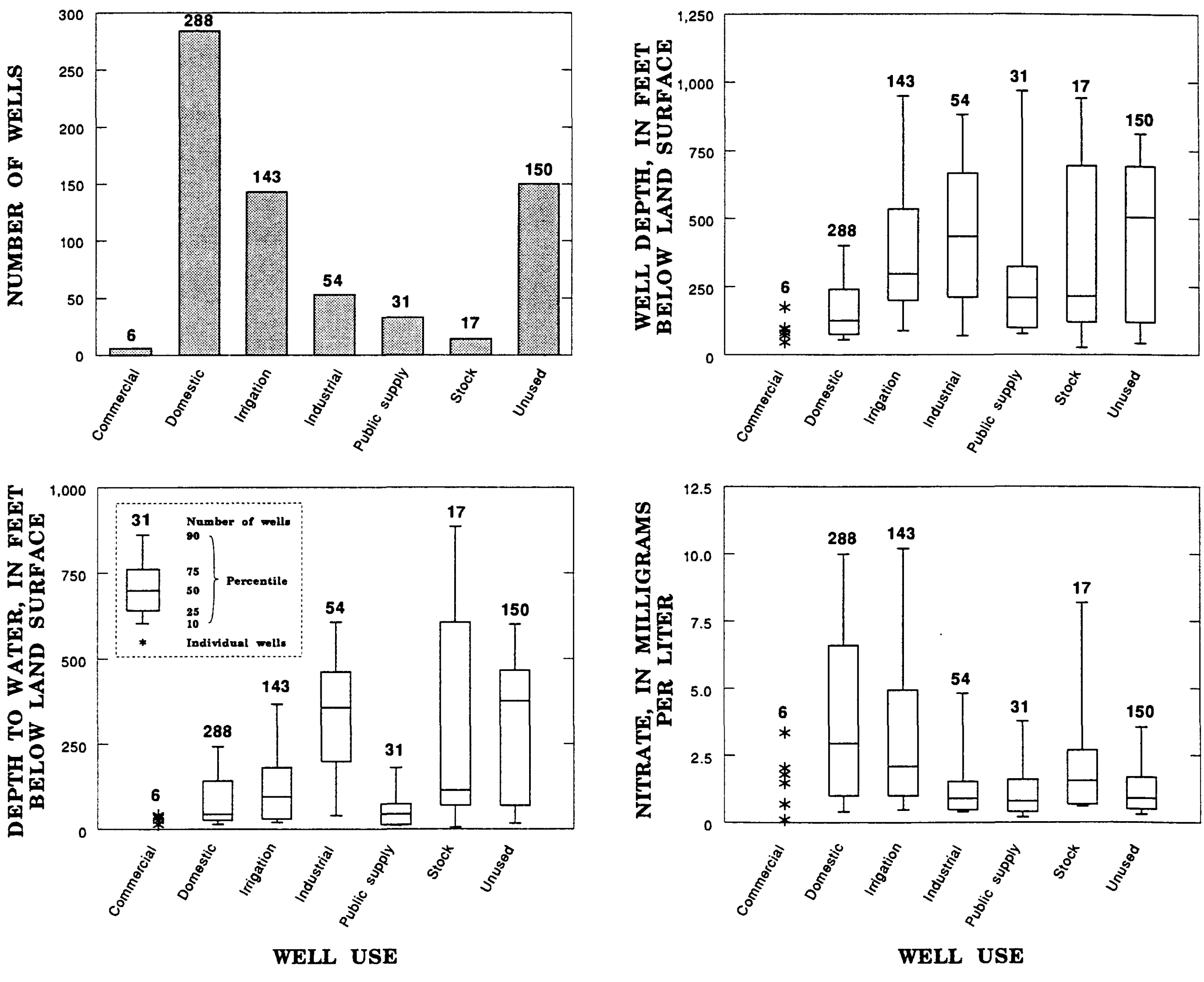

Figure 13. Relations among nitrate concentrations, well use, well depth, and depth to water in the upper Snake River Basin. (Data are from the U.S. Geological Survey nitrate and miscellaneous studies and the Idaho Statewide Ground-Water Quality Monitoring Program. The 10th and 90th percentiles are not shown for categories with fewer than 15 wells)

by using data from the USGS nitrate studies, USGS miscellaneous studies, and the Idaho Statewide Ground-Water Quality Monitoring Program (fig. 15). Many of the wells are open hole (uncased) and data on depth of pumps were not always available. Pumps in these open holes were assumed to be set near the bottom of the well and to be withdrawing the most water from the bottom of the well.

A smoothing curve was calculated using the locally weighted scatterplot smoothing (LOWESS) method (Helsel and Hirsch, 1992, p. 288). The Spearman's rho rank-order test was performed on all relations. Spearman's rho is a nonparametric statistical test (Helsel and Hirsch, 1992, p. 217) used to measure the strength of an increasing or decreasing relation between the two variables of interest. If after performing the test, the resulting p-value is less than 0.05, the relation is significant at the 95-percent confidence interval.

A strong correlation ($p < 0.05$) exists among nitrate concentrations, total well depth, depth to water (unsaturated thickness), and depth below water table (saturated thickness) (fig. 15). These correlations suggest that nitrate concentrations in ground water decrease with increasing well depth, increasing depth to water, and increasing depth below water table. This correlation does not imply that well depth, depth to water, or depth below water table is the causal factor in nitrate concentrations. The actual cause for the decrease in concentration with depth is not readily apparent from available data but probably involves a complex relation among source of nitrate, interaction with aquifer materials, and (or) nitrification/denitrification processes.

The LOWESS smooth in the relation between nitrate and depth to water shows a positive slope for depths less than 100 ft, suggesting that nitrates may actually increase with increasing depth in this range. A similar anomaly exists at depths less than 300 ft for the relation between nitrate and depth below water table. It is not known if the positive slope is due to hydrogeologic factors or is an artifact of clustering of many wells less than 300 ft deep. Future studies may help determine the cause of the anomalies.

A strong relation also exists among kjeldahl nitrogen concentrations (organic nitrogen plus ammonia), total well depth, and depth below water table (fig. 16). This relation suggests that kjeldahl nitrogen concentrations decrease with increasing well depth and depth below water table. The relation between kjeldahl nitrogen concentrations and depth to water was poor, sug-

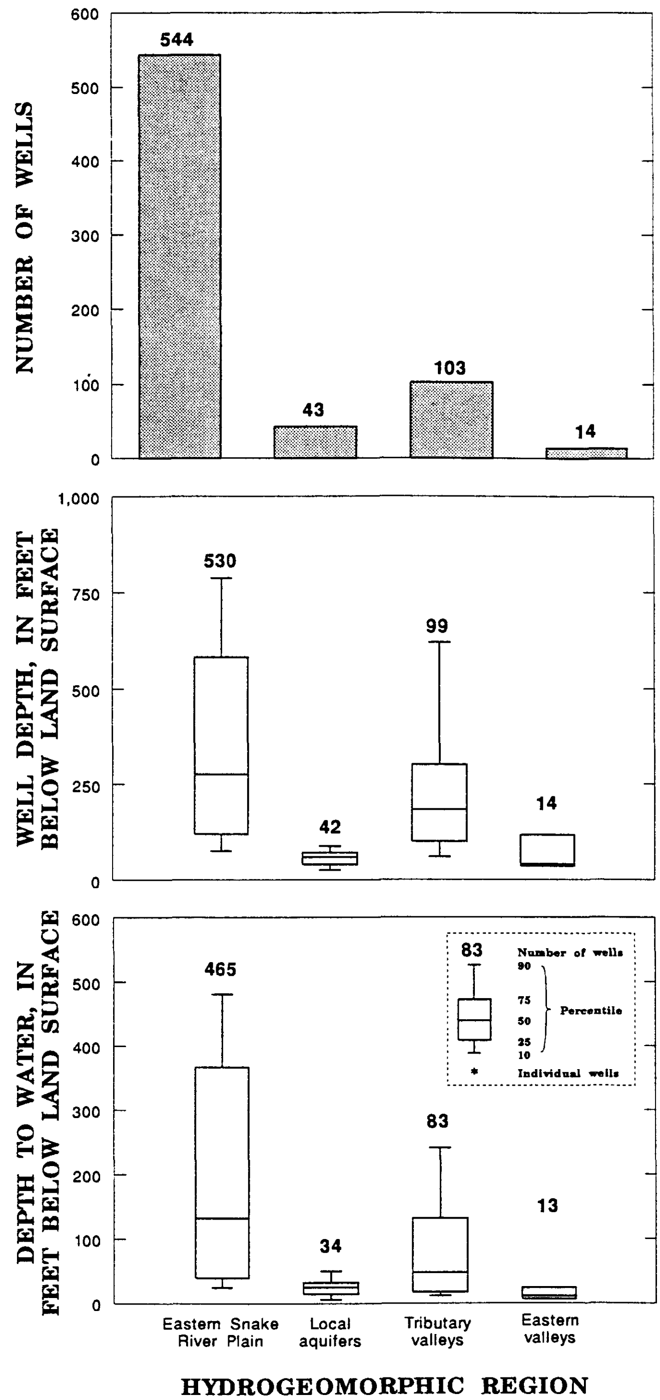

Figure 14. Relations among hydrogeomorphic region, well depth, and depth to water in the upper Snake River Basin. (Data are from the U.S. Geological Survey nitrate and miscellaneous studies and the Idaho Statewide Ground-Water Quality Monitoring Program. The 10th and 90th percentiles are not shown for categories with fewer than 15 wells)

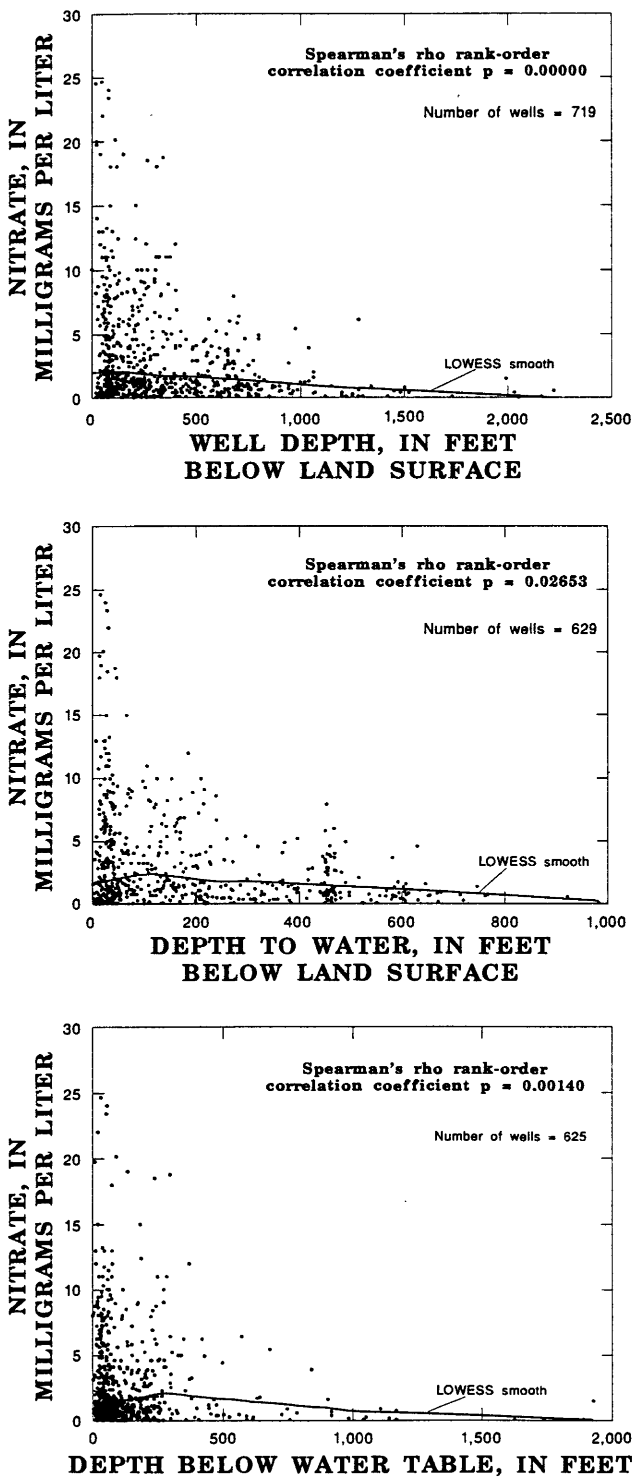

Figure 15. Relations among nitrate concentrations, well depth, depth to water, and depth below water table in the upper Snake River Basin.

gesting that depth to water does not affect concentrations.

No significant relations of ammonia, total phosphorus, dissolved phosphorus, and orthophosphorus concentrations with total well depth, depth to water, and depth below water table were observed.

Relations Among Nutrient Concentrations, Hydrogeomorphic Regions, and Land Use

Idaho Statewide Ground-Water Quality Monitoring Program data were used to relate nutrient concentrations with hydrogeomorphic regions and land use. These data were used because of the statistical approach to selection of well sites. Relations were made with a GIS.

The Kruskal-Wallis nonparametric statistical test was used to compare nitrate concentrations with hydrogeomorphic regions and land use. The test determines whether a statistical difference exists between the various data groups; for example, whether nitrate concentrations in areas of agriculture are statistically different from concentrations in areas of rangeland. The Kruskal-Wallis test ranks the data sets from the smallest observation to the largest (Iman and Conover, 1983), then tests whether the medians from each set are statistically different. If the p-value is less than 0.05, then the data sets are significantly different at the 95-percent confidence level.

All wells were evaluated to assure that they were within their respective hydrogeomorphic region or land-use classification. The regional ground-water flow direction was evaluated at each well to assure that no upgradient sources may be causing incorrect results. It was not possible to evaluate potential localized point-source effects and local variations in ground-water flow directions.

HYDROGEOMORPHIC REGIONS

Nitrate concentrations in tributary valleys are statistically lower than in the eastern Snake River Plain and the local aquifers (fig. 17). Many of the tributary valleys are upgradient sources of recharge to the eastern Snake River Plain and have not been affected as much by land-use activities. There was no statistical difference in total phosphorus concentrations among the three hydrogeomorphic regions. Data were insufficient to observe differences in kjeldahl nitrogen, ammonia, dissolved phosphorus, or orthophosphorus concentrations among the three hydrogeomorphic regions. Comparisons were not made with the eastern valleys because wells in Wyoming were not sampled for the Idaho Statewide Ground-Water Quality Monitoring Program.

LAND USE

Nitrate and total phosphorus concentrations were correlated with land-use data using a GIS. Land-use data were obtained from the USGS and the IDWR. The USGS used the Geographic Information Retrieval and Analysis System (GIRAS) to develop land-use data from mid-1970's high-altitude aerial photography. The land-use classifications were consistent with the Anderson Level I classifications (U.S. Geological Survey, 1986). Primary classifications for the basin are agricultural land, rangeland, and urban land (fig. 18).

Relations among nitrate concentrations and GIRAS land-use classifications are shown in figure 19. Nitrate concentrations in areas of agricultural land are statisti-

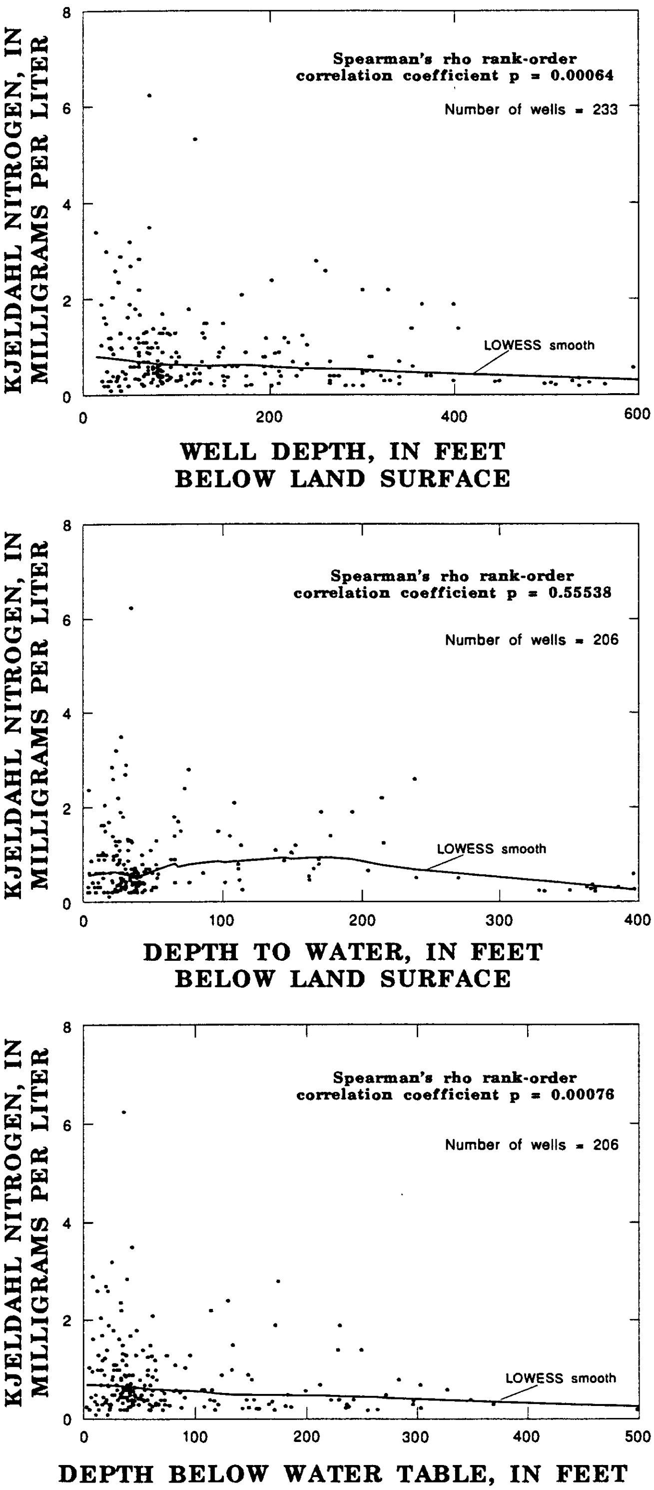

Figure 16. Relations among kjeldahl nitrogen concentrations, well depth, depth to water, and depth below water table in the upper Snake River Basin.

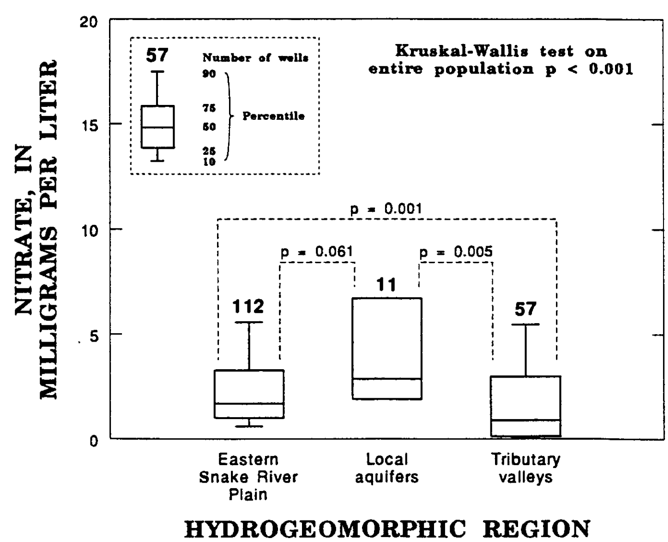

Figure 17. Nitrate concentrations in water from wells in hydrogeomorphic regions in the upper Snake River Basin, 1990 and 1991. (Data are from the Idaho Statewide Ground-Water Quality Monitoring Program. Dashed lines indicate results of individual Kruskal-Wallis tests between hydrogeomorphic regions. The 10th and 90th percentiles are not shown for categories with fewer than 15 wells)

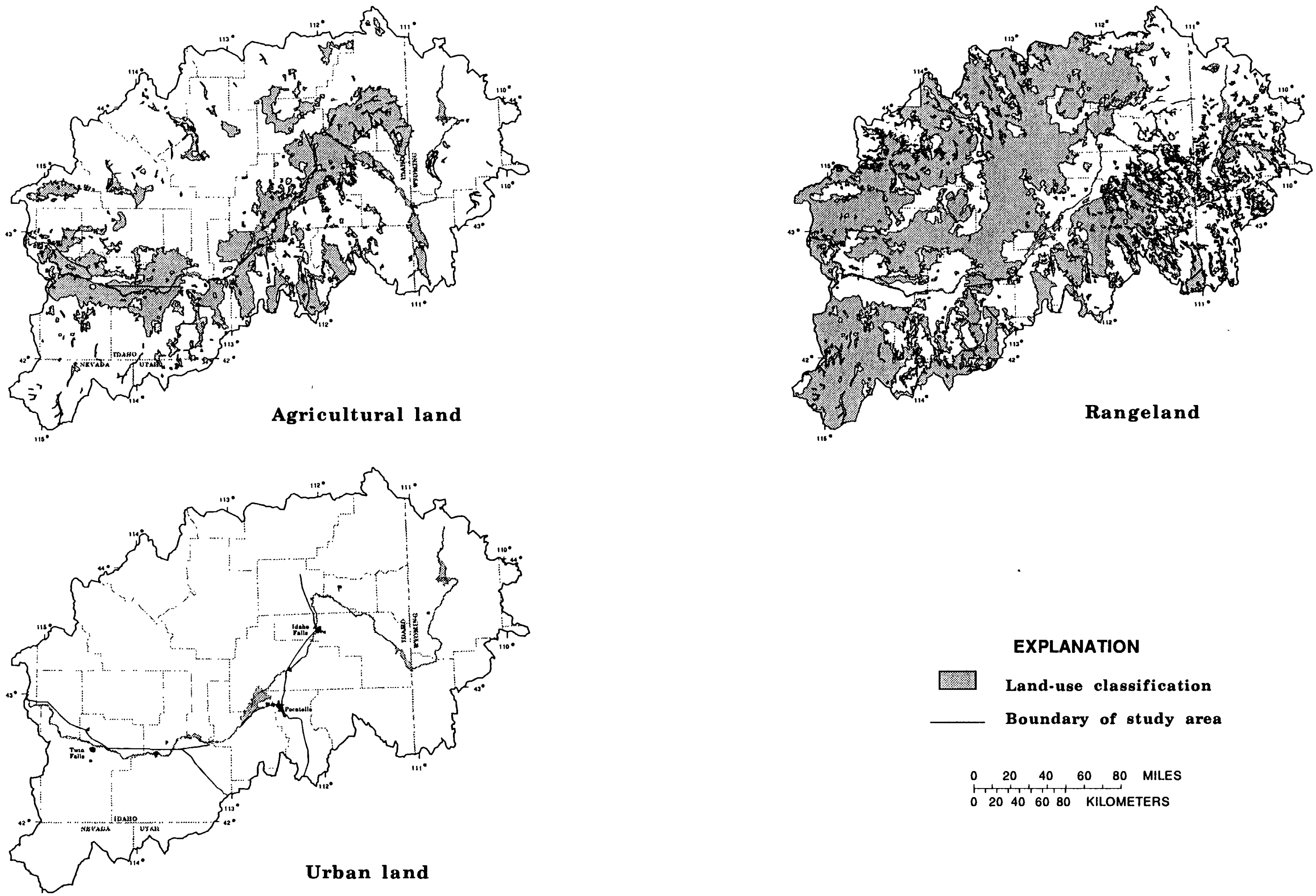

Figure 18. Major land-use classifications in the upper Snake River Basin developed from the mid-1970's Geographic Information Retrieval and Analysis System coverages (U.S. Geological Survey, 1986).

cally higher than in areas of rangeland ($p < 0.05$). There was no statistical difference in concentrations between rangeland and urban land and between urban land and agricultural land. There was no statistical difference in total phosphorus concentrations among any of the land-use classifications. Data were insufficient to observe differences in kjeldahl nitrogen, ammonia, dissolved phosphorus, or orthophosphorus concentrations among the land-use classifications.

Nitrate and total phosphorus concentrations also were correlated with land-use classifications developed by the IDWR (fig. 20). IDWR combined the data from three sources: a map denoting vegetation types; a map differentiating between flood- and surface-irrigation methods; and a map differentiating dryland agriculture from irrigated agriculture (Rupert and others, 1991, p. 12). IDWR did not develop land-use classifications for areas in Wyoming, Utah, and Nevada.

On the basis of IDWR land-use classifications, nitrate concentrations in ground water are statistically higher in areas of irrigated agriculture than in areas of dryland agriculture and rangeland (fig. 21). There was no statistical difference in total phosphorus concentrations among any of the land-use classifications. Data were insufficient to observe differences in kjeldahl nitrogen, ammonia, dissolved phosphorus, or orthophosphorus concentrations among the land-use classifications.

FACTORS AFFECTING RELATIONS BETWEEN NITRATE CONCENTRATIONS AND LAND USE

In many areas, ground water moves from areas of rangeland to areas of agricultural land. Nitrate concentrations are lowest in areas of rangeland (figs. 19 and 21) because few land-use activities on rangeland affect those concentrations. Nitrate concentrations are highest in areas of agricultural land, presumably because of nitrate loading from agricultural fertilizer application and irrigation. Parliman (1988, p. 233) suggested that nitrate concentrations exceeding 2 mg/L probably indicate degradation of water quality from land-use activities.

The effects of land-use changes with time can introduce inaccuracies in relations between nitrate concentrations and land use. The GIRAS land-use classifications are from the mid-1970's and the IDWR land-use classifications are from the mid-1980's. Both land-use data files are being compared with 1990 and 1991 water-quality data. The population of the upper Snake River Basin has changed only about 5 percent from 1980 to 1990 (table 1). Irrigated land has increased only slightly since the 1960's (Lindholm and Goodell, 1986), implying that agricultural land and rangeland have remained fairly constant since the 1960's. Changes in population and land use have been minor throughout the basin.

There may be a low bias of nitrate concentrations in areas of agricultural land classified using the GIRAS system (fig. 19) because dryland agriculture was combined with irrigated agriculture. Relations among nitrate concentrations and land-use classifications from the IDWR data base (fig. 21) show the lowest concentrations in the basin are in areas of dryland agriculture.

Trends of Nitrate

Few data were available to determine the long-term trends of nitrate concentrations in the upper Snake River Basin because few wells have been sampled regularly. Only four wells in the USGS data base and four wells in the USEPA STORET data base had multiple nitrate analyses (fig. 22). Long-term increases in nitrate concentrations in water from wells north of Burley and northwest of Pocatello are shown in figure 23. Depths of USGS wells range from 80 to 234 ft, and depths of water levels range from 53 to 161 ft. The USEPA STORET data base does not contain information on well properties.

In 1990, Young and Parliman (U.S. Geological Survey, written commun., 1992) collected samples quarterly for analysis of nitrate concentrations in ground water in the Burley area. They determined that concentrations varied with water levels. Concentrations decreased with rising water levels at the beginning of the irrigation season, remained low during the irrigation season, and increased with declining water levels at the end of the irrigation season. Young and Parliman suggested that the decrease in concentrations at the beginning of the irrigation season may be due to dilution from irrigation water.

Data from the few wells with multiple ammonia analyses were too scattered to observe any trends. No data were available to plot trends of nitrite, ammonia, total kjeldahl nitrogen, total phosphorus, and orthophosphorus in ground water.

ORGANIC COMPOUND DATA

Data on organic compounds in ground water were compiled from the USEPA STORET and USGS data bases for 1980 through 1991 (table 5). Locations of wells for which data on organic compounds were available are shown in figure 24. Of 211 wells sampled for organic compounds, water from 17 contained detectable concentrations (fig. 25).

The USEPA STORET data base contains data on only one well (fig. 25), which was sampled eight times during October 1988 through September 1990. Dacthal was detected in four of the eight samples; concentrations ranged from 0.03 to 0.10 μg/L. The data base contains no information on the reporting levels for analytes or for wells where organic compounds were not detected. The data base also contains no information on well depth or water level.

The type and number of organic compound analyses in the USGS miscellaneous studies data base are

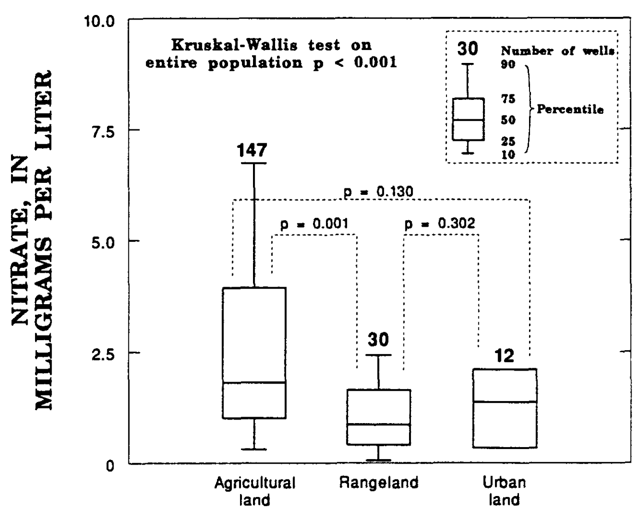

Figure 19. Nitrate concentrations in water from wells sampled during 1990 and 1991 in the upper Snake River Basin in relation to land-use classifications developed from the Geographic Information Retrieval and Analysis System. (Geographic Information Retrieval and Analysis System land-use classifications are consistent with the Anderson Level I classifications. Data are from the Idaho Statewide Ground-Water Quality Monitoring Program. Dashed lines indicate results of individual Kruskal-Wallis tests between land-use classifications. The 10th and 90th percentiles are not shown for categories with fewer than 15 wells)

Table 11. Type and number of organic compound analyses for wells in the upper Snake River Basin, 1987–91

[Data from U.S. Geological Survey miscellaneous studies; μg/L, micrograms per liter]

Organic compound	No. of wells sampled	No. of samples analyzed	Analytical reporting level (μg/L)
Alachlor, total	89	112	<0.10
Aldrin, total	92	182	<.01
Aldrin, dissolved	2	2	<.01
Ametryne	89	112	<.10
Atrazine, total	89	112	<.10
Chlordane, total	91	181	<.1
Chlordane, dissolved	2	2	<.10
Cyanazine	89	112	<.10
2,4-D, total	88	177	<.01
2,4-D, dissolved	2	2	<.01
2,4-DP	88	177	<.01
2,4-DP, dissolved	2	2	<.01
2,4,5-T, total	88	177	<.01
2,4,5-T, dissolved	2	2	<.01
DDD, total	92	182	<.01
DDD, dissolved	2	2	<.01
DDE, total	92	182	<.01
DDE, dissolved	2	2	<.01
DDT, total	91	181	<.010
DDT, dissolved	2	2	<.01
DEF (Tribufos), total	38	46	<.01
Diazinon, total	89	114	<.01
Dichloropropane	189	558	<.20
Dichloropropene	189	558	<.20
Dieldrin, total	91	181	<.010
Dieldrin, dissolved	2	2	<.01
Disyston	38	46	<.01
Endosulfan, total	91	181	<.01
Endosulfan, dissolved	2	2	<.01
Endrin, total	91	181	<.01
Endrin, dissolved	2	2	<.01
Ethion, total	89	114	<.01
Heptachlor, total	92	182	<.01
Heptachlor, dissolved	2	2	<.01
Heptachlor epoxide, total	91	181	<.01
Heptachlor epoxide, dissolved	2	2	<.01
Lindane, total	91	181	<.01
Lindane, dissolved	2	2	<.01
Malathion, total	89	114	<.01
Methomyl, total	85	116	<.5
Methoxychlor, total	91	181	<.01
Methoxychlor, dissolved	2	2	<.01
Methyl parathion, total	89	114	<.01
Metolachlor	89	112	<.10
Metribuzin	89	112	<.10
Mirex, total	92	182	<.01
Mirex, dissolved	2	2	<.01
Parathion, total	89	114	<.01
Perthane, total	91	181	<.1
Perthane, dissolved	2	2	<.10
Phorate, total	38	46	<.01
Prometone, total	89	112	<.10
Prometryne, total	89	112	<.10
Propazine	89	112	<.10
Propham, total	85	116	<.5
Sevin	85	116	<.5
Silvex, total	88	177	<.01
Silvex, dissolved	2	2	<.01
Simazine, total	89	112	<.10
Simetryne, total	89	112	<.10
Trifluralin, total	89	112	<.10
Toxaphene, total	91	181	<1.0
Toxaphene, dissolved	2	2	<1.0

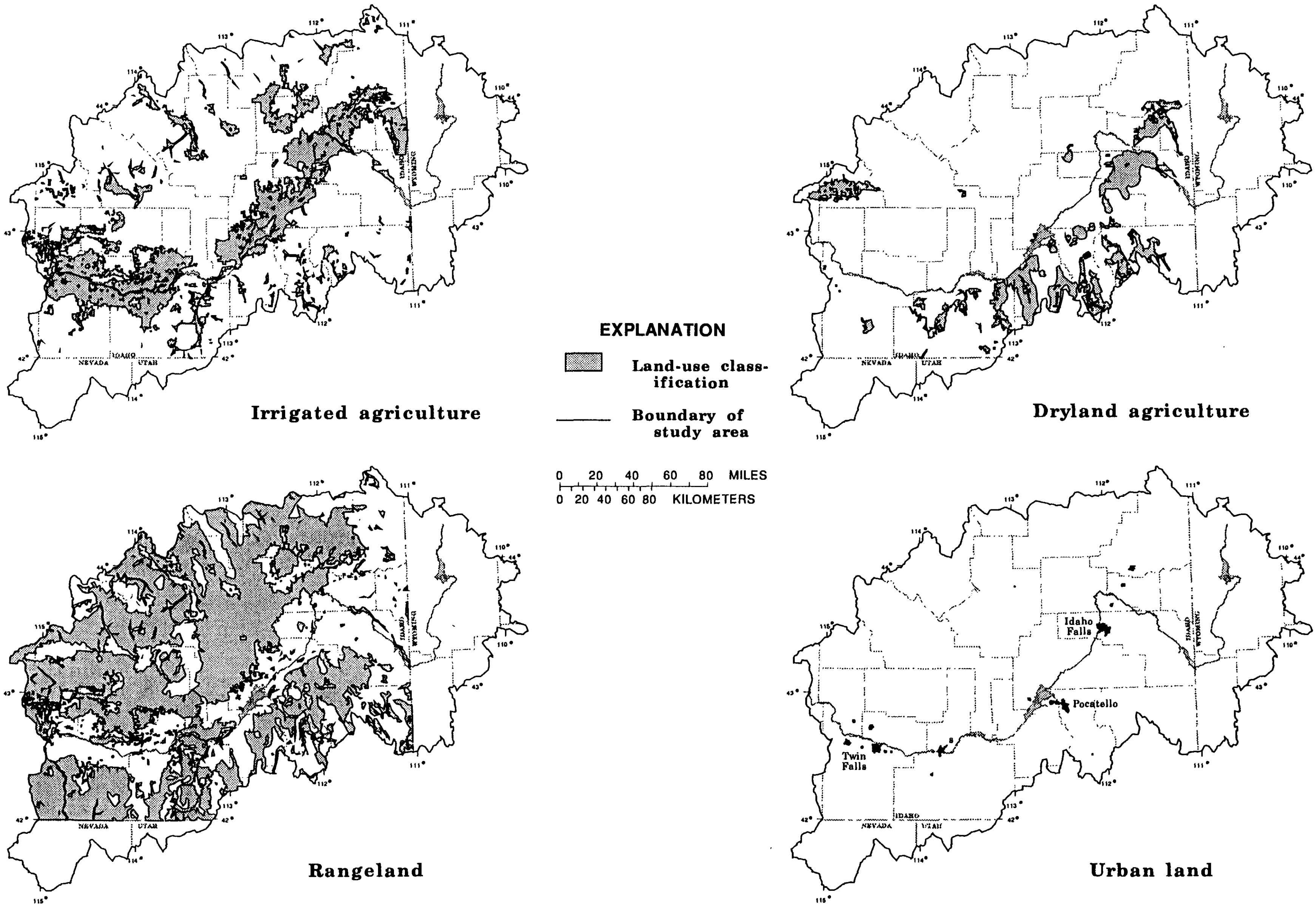

Figure 20. Major land-use classifications in the upper Snake River Basin developed by the Idaho Department of Water Resources for the mid-1980's.

summarized in table 11. Organic compound data are available only for 1987 through 1991. Of the organic compounds analyzed, cyanazine, 2,4-D, DDT, diazinon, dichloropropane, dieldrin, malathion, and metribuzin were detected in ground-water samples from the upper Snake River Basin (table 12).

Ground-water samples that contained detectable concentrations of organic compounds were collected from wells with a mean depth of 255 ft, a mean depth to water of 215 ft, and a mean depth below the water table of 63 ft. Samples with no detectable concentrations were collected from wells with a mean depth of 538 ft, a mean depth to water of 367 ft, and a mean depth below the water table of 168 ft. Data from both data bases were insufficient to determine relations among organic compounds and hydrogeomorphic regions or land use. Data also were insufficient to determine trends of organic compound concentrations.

The USEPA published a summary of selected organic compound monitoring studies in the United States (U.S. Environmental Protection Agency, 1992). The study for Idaho listed 15 wells near Burley in which water was sampled for aldicarb in 1981. There were no detections and reporting levels were not listed.

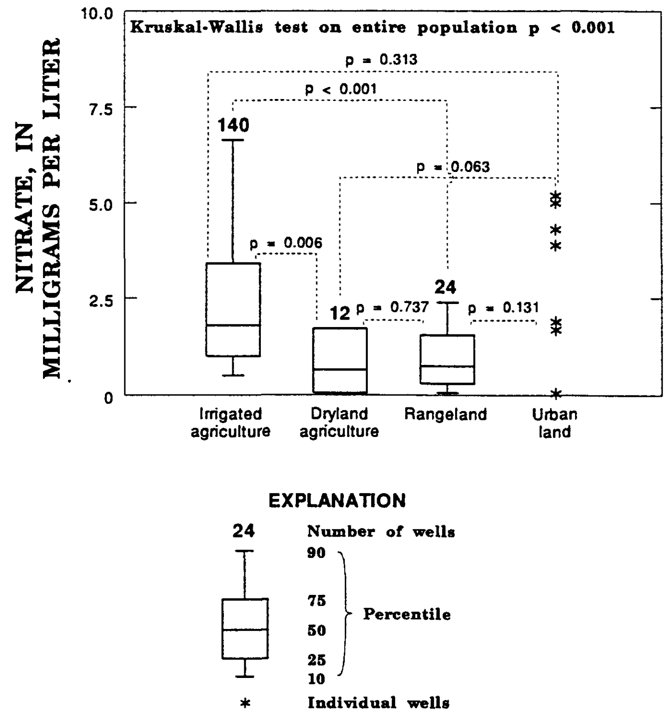

Figure 21. Nitrate concentrations in water from wells sampled during 1990 and 1991 in the upper Snake River Basin in relation to land-use classifications developed by the Idaho Department of Water Resources. (Data are from the Idaho Statewide Ground-Water Quality Monitoring Program. Dashed lines indicate results of individual Kruskal-Wallis tests between land-use classifications. The 10th and 90th percentiles are not shown for categories with fewer than 15 wells)

Table 12. Organic compounds detected in water from wells in the upper Snake River Basin, 1987–91

[Data from the U.S. Geological Survey miscellaneous studies; µg/L, micrograms per liter; <, less than]

Organic compound	No. of wells sampled	No. of samples analyzed	Analytical reporting level (µg/L)	No. of samples exceeding reporting level	Minimum concentration measured (µg/L)	Maximum concentration measured (µg/L)	Year detected	Use
Cyanazine	89	112	<0.10	1	0.10	0.10	1989	Herbicide
2,4-D, total	88	177	<.01	3	.02	.30	1989–91	Herbicide
DDT, total	91	181	<.010	3	.010	.040	1989	Insecticide
Diazinon	89	114	<.01	4	.01	.03	1989	Insecticide
Dichloropropane	189	558	<.20	2	5.9	12.0	1987–88	Nematocide
Dieldrin, total	91	181	<.010	2	.010	.020	1989	Insecticide
Malathion, total	89	114	<.01	3	.01	.02	1989	Insecticide
Metribuzin	89	112	<.10	2	.20	.30	1989	Herbicide

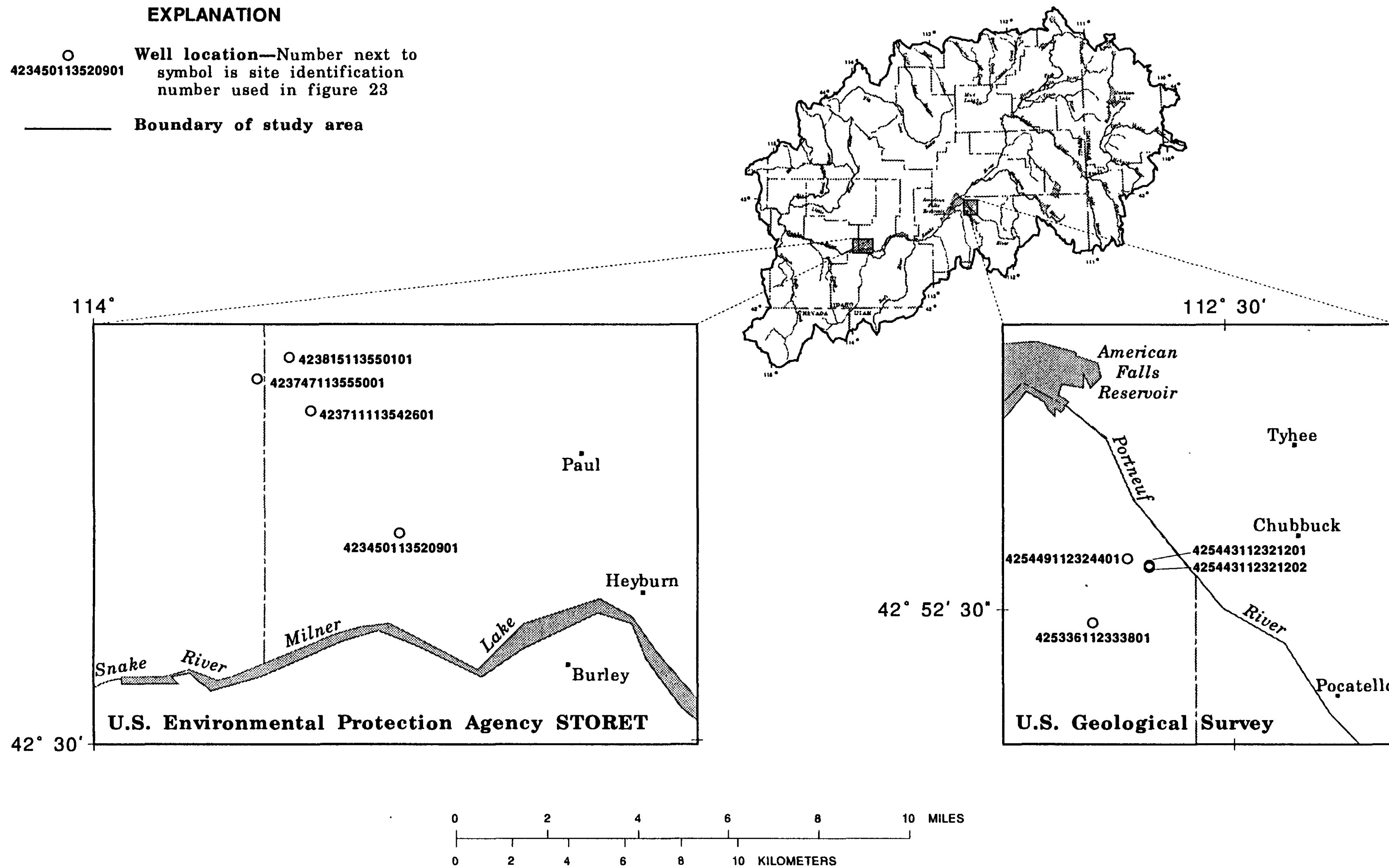

Figure 22. Locations of wells in the upper Snake River Basin for which long-term nitrate analyses are available. (Data are from the U.S. Geological Survey miscellaneous studies and the U.S. Environmental Protection Agency STORET data base)

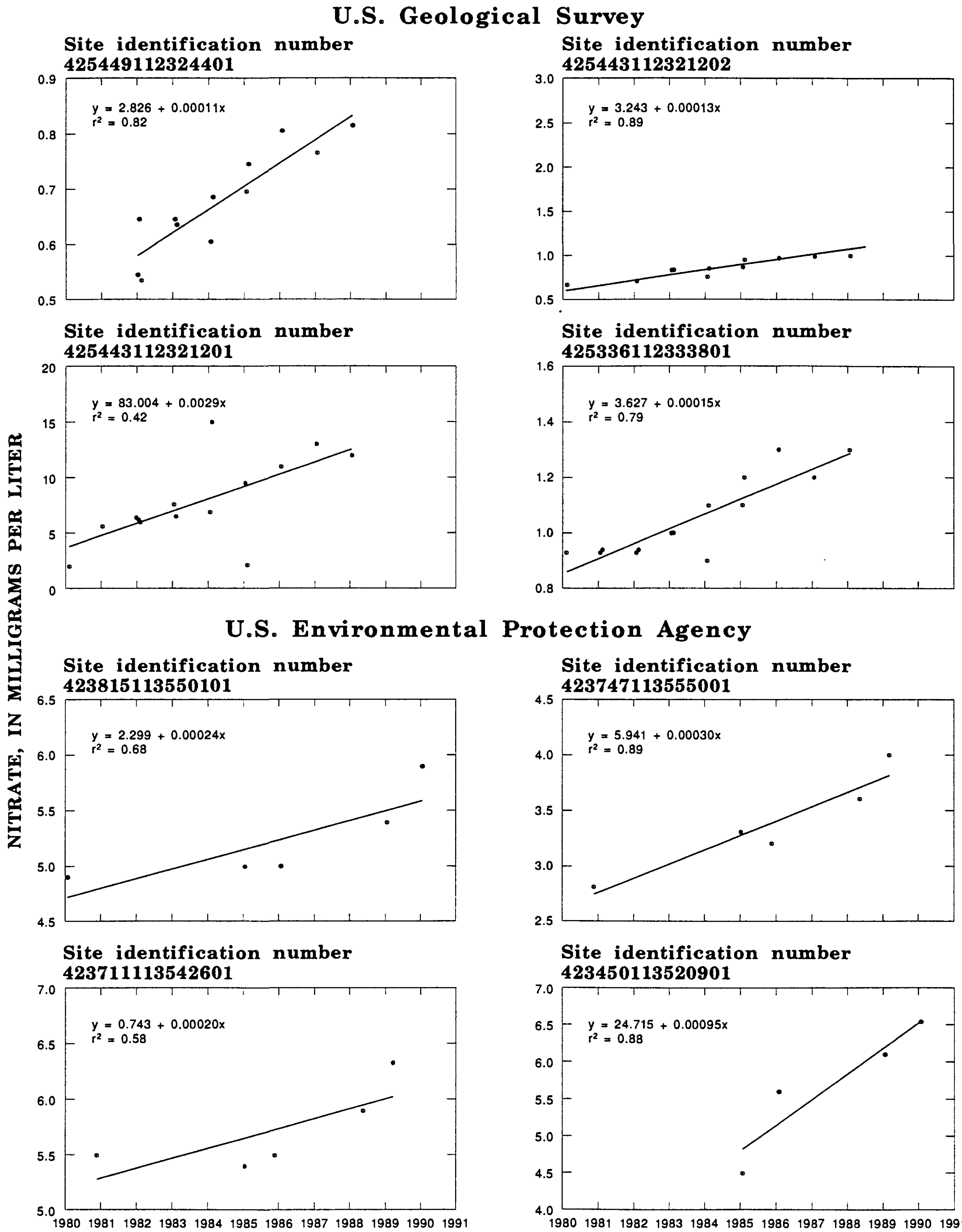

Figure 23. Long-term trends of nitrate concentrations in water from selected wells in the upper Snake River Basin. (Data from U.S. Geological Survey miscellaneous studies and the U.S. Environmental Protection Agency STORET data base; dates were converted to Julian dates starting on January 1, 1900, for regression analyses; site locations shown in figure 22)

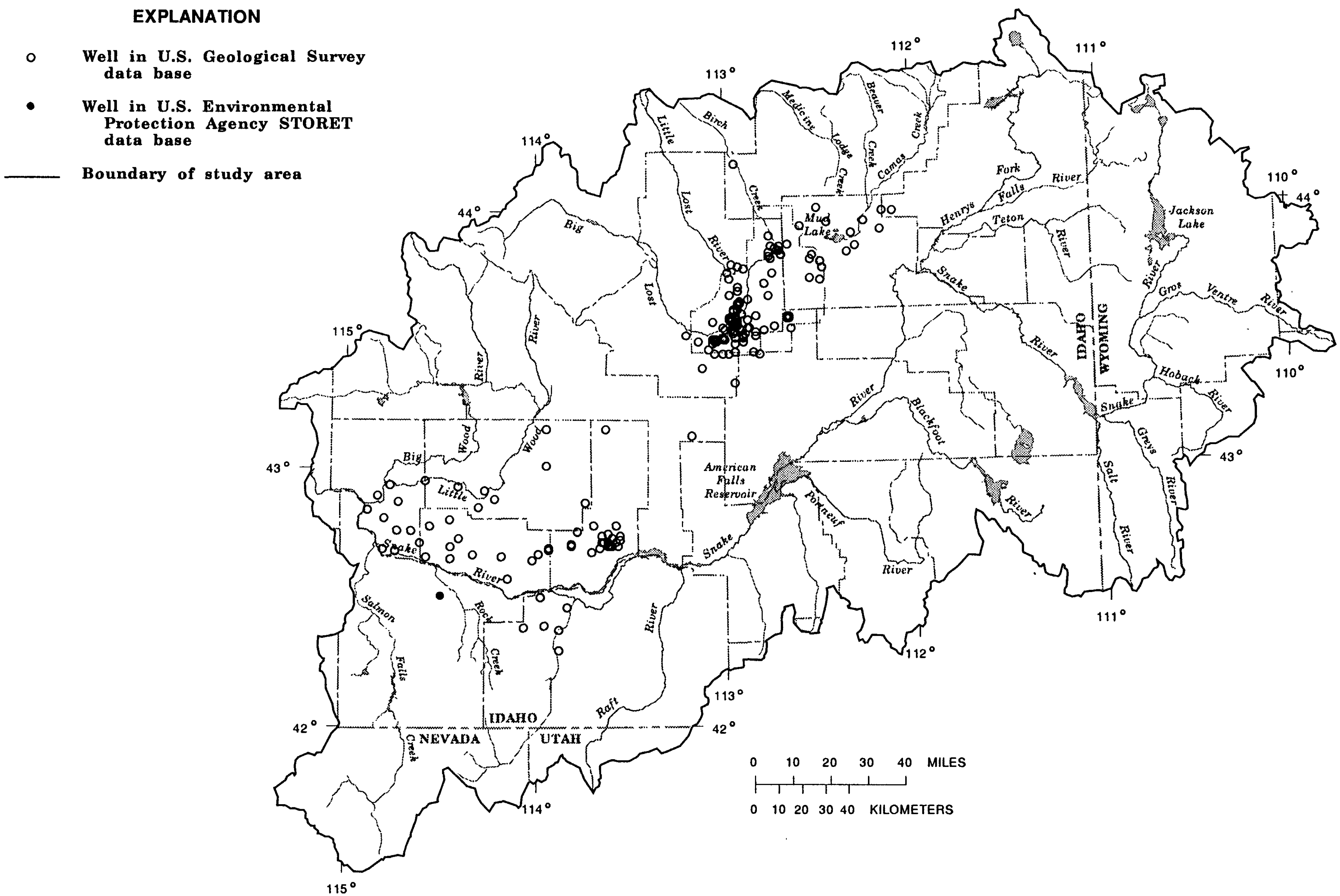

Figure 24. Locations of wells in the upper Snake River Basin for which data on organic compounds are available, 1980–91. (Data are from the U.S. Geological Survey miscellaneous studies and the U.S. Environmental Protection Agency STORET data base)

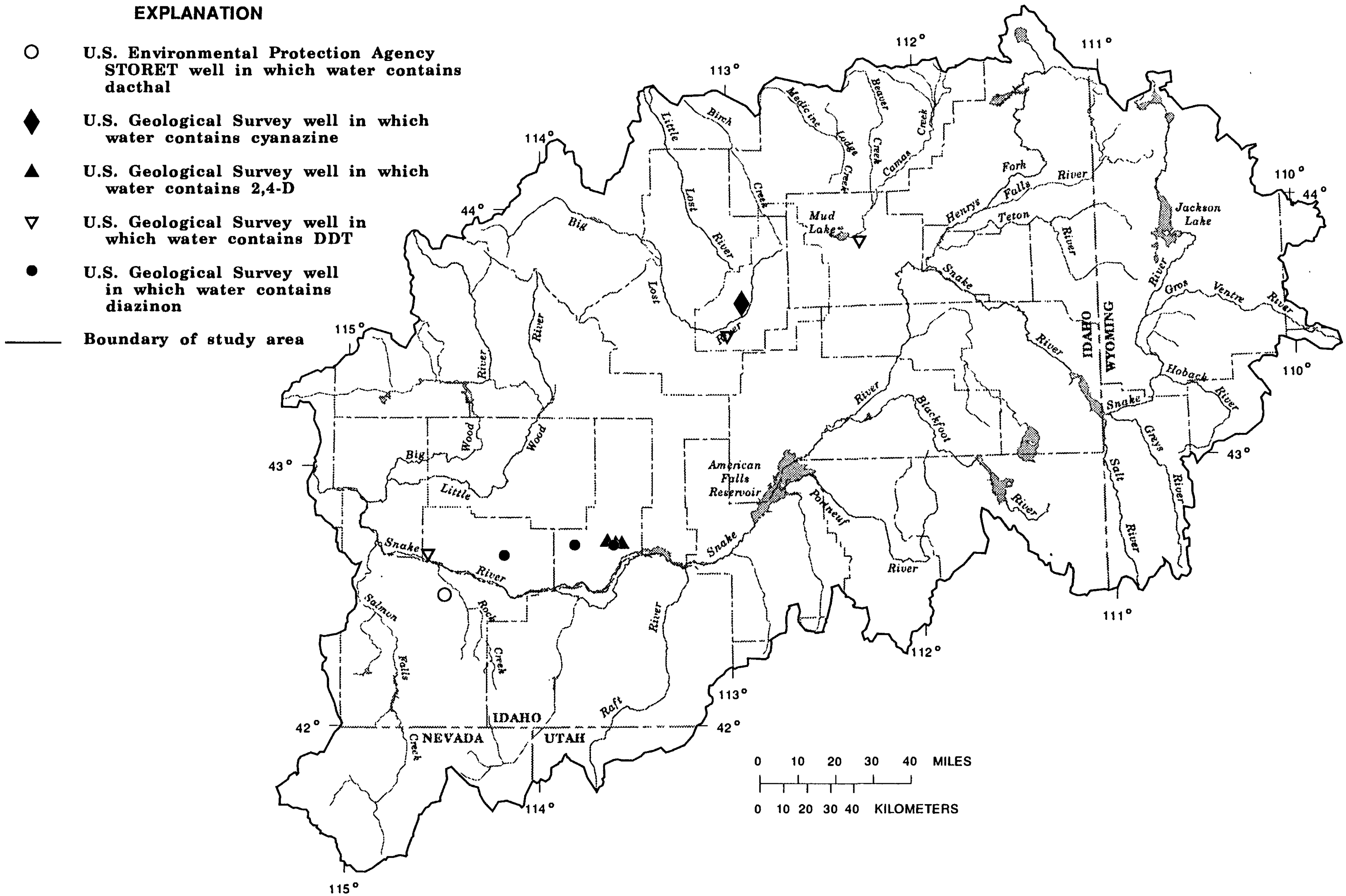

Figure 25. Locations of wells in which water contains organic compounds, upper Snake River Basin, 1980–91. (Data are from the U.S. Geological Survey miscellaneous studies and the U.S. Environmental Protection Agency STORET data base)

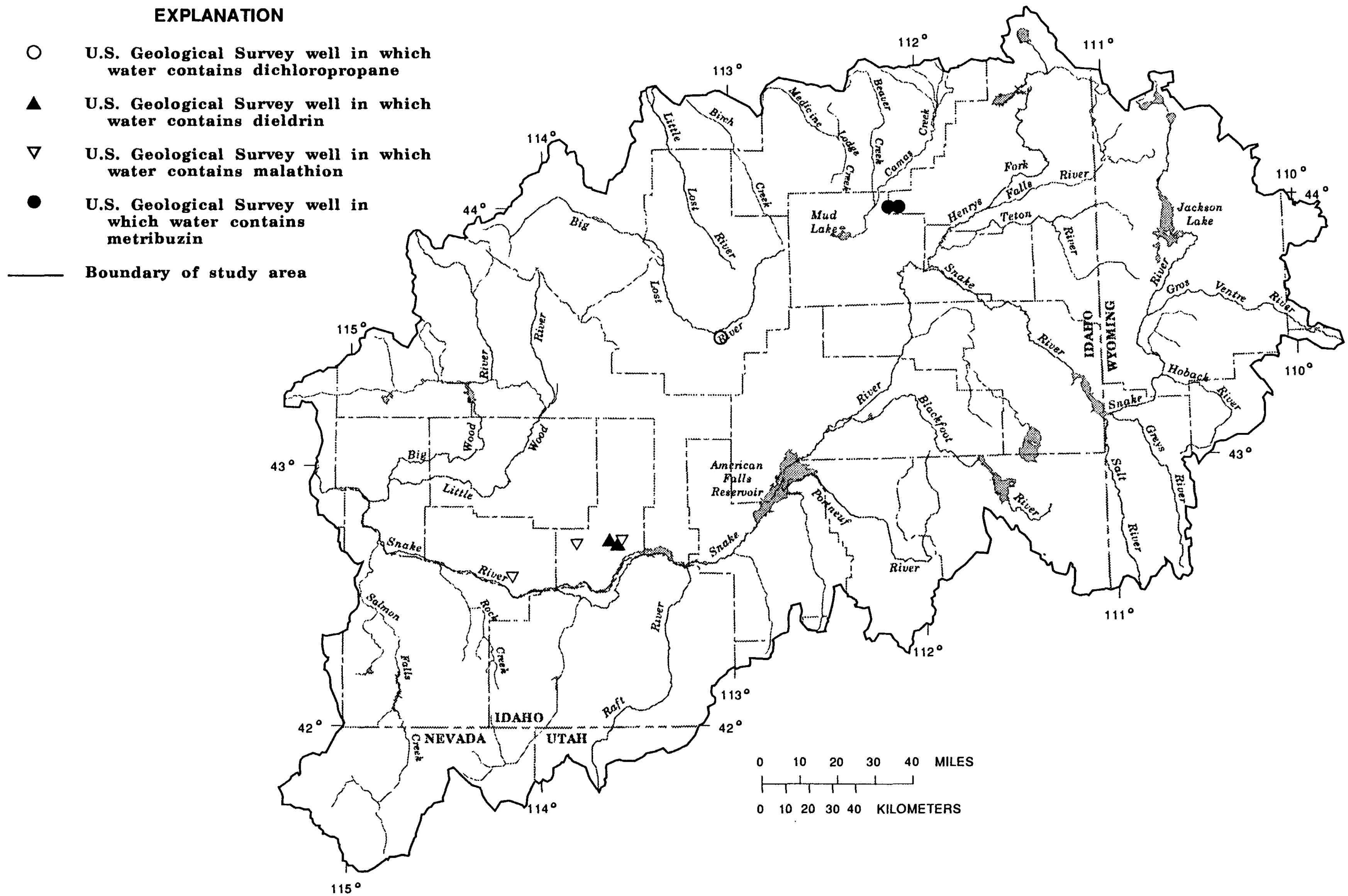

Figure 25. Locations of wells in which water contains organic compounds, upper Snake River Basin, 1980–91—Continued.

SUMMARY

Nutrient and organic compound data from the USGS and the USEPA STORET data bases provided information for development of a preliminary conceptual model of spatial and temporal ground-water quality in the upper Snake River Basin. Data from these two sources were divided into four groups so data from programs with distinct well selection techniques and geographic areas of interest could be differentiated.

Nitrate concentrations exceeded the Federal drinking-water regulation of 10 mg/L in three areas in Idaho: the INEL, the area north of Pocatello (Fort Hall area), and the area surrounding Burley. Water from many wells in the Twin Falls area also contained elevated (greater than 2 mg/L) nitrate concentrations. Water from domestic wells contained the highest median nitrate concentrations; water from industrial and public-supply wells contained the lowest. Nitrate concentrations decreased with increasing well depth, increasing depth to water, and increasing depth below water table. Kjeldahl nitrogen concentrations decreased with increasing well depth and depth below water table. The relation between kjeldahl nitrogen concentrations and depth to water was poor, suggesting that depth to water does not affect concentrations.

Nitrate and total phosphorus concentrations were correlated with three hydrogeomorphic regions of the upper Snake River Basin. Concentrations of nitrate were statistically higher in the eastern Snake River Plain and local aquifers than in the tributary valleys. There was no statistical difference in total phosphorus concentrations among the three hydrogeomorphic regions.

Nitrate and total phosphorus concentrations in ground water were correlated with land-use classifications developed using the GIRAS. Agricultural areas had statistically higher concentrations of nitrate than rangeland areas. There was no statistical difference in concentrations between rangeland and urban land and between urban land and agricultural land. There was no statistical difference in total phosphorus concentrations among any of the land-use classifications.

Nitrate and total phosphorus concentrations in ground water also were correlated with land-use classifications developed by the IDWR for the Idaho part of the upper Snake River Basin. Nitrate concentrations were statistically higher in areas of irrigated agriculture than in areas of dryland agriculture and rangeland. There was no statistical difference in total phosphorus concentrations among any of the IDWR land-use classifications.

Four wells north of Burley and four wells northwest of Pocatello were used to examine long-term trends of nitrate concentrations. Concentrations in water from all wells showed an increasing trend.

The following organic compounds were detected in ground water in the upper Snake River Basin: cyanazine, 2,4-D, DDT, dacthal, diazinon, dichloropropane, dieldrin, malathion, and metribuzin. Of 211 wells sampled for organic compounds, water from 17 contained detectable concentrations.

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