ASSESSMENT OF SELECTED CONSTITUENTS IN SURFACE WATER OF THE UPPER SNAKE RIVER BASIN, IDAHO AND WESTERN WYOMING, WATER YEARS 1975–89

By GREGORY M. CLARK

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Multiply	By	To obtain
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
inch (in.)	2.54	centimeter
inch per year (in/yr)	2.54	centimeter per year
mile (mi)	1.609	kilometer
million gallons per day (Mgal/d)	0.04381	cubic meter per second
pound	0.4536	kilogram
square mile (mi^2)	2.590	square kilometer
ton	907.18	kilogram
ton per year (ton/yr)	907.18	kilogram per year

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/kg	microgram per kilogram
µg/L	microgram per liter
mg/L	milligram per liter

Assessment of Selected Constituents in Surface Water of the Upper Snake River Basin, Idaho and Western Wyoming, Water Years 1975–89

By Gregory M. Clark

Abstract

In 1991, a water-quality investigation of the upper Snake River Basin was initiated as part of the U.S. Geological Survey's National Water-Quality Assessment Program. The initial task of the assessment was to compile and analyze available nutrient, suspended sediment, and pesticide data collected in the basin. For analysis of nutrients and suspended sediment, data collected during water years 1980–89 were used. For pesticides, an additional 5 years of data were included for a total assessment period encompassing water years 1975–89.

Nearly 9,000 analyses of nutrients and suspended sediment from more than 450 stations were retrieved from the U.S. Environmental Protection Agency STORET and U.S. Geological Survey WATSTORE data bases. Nineteen stations had sufficient analyses for quantitative assessment. Of the 19 stations analyzed, 4 are located on relatively unaffected stream reaches, 8 are at or near mouths of tributary basins affected by agricultural activities, and 7 are on the main stem of the Snake River.

Data indicate that nitrite plus nitrate and total phosphorus concentrations generally increased in a downstream direction along the Snake River; concentrations were largest at the mouths of drainage basins tributary to the Snake River. Water-quality stations were categorized as unaffected or minimally affected, agriculturally affected, or main stem to compare nutrient concentrations between drainage basins of differing land use/land cover. Concentrations of nitrite plus nitrate, total nitrogen, dissolved orthophosphate, and total phosphorus were significantly ($p<0.05$) larger at agriculturally affected and main-stem stations than at unaffected stations; and concentrations of nitrite plus nitrate, total nitrogen, and total phosphorus at agriculturally affected stations were significantly larger than at main-stem stations. Significant differences in seasonal concentrations of some nutrient species also were noted.

Few suspended sediment and pesticide data were available for the study basin. Only six stations had sufficient data for quantitative assessment of suspended sediment. A direct positive relation exists between suspended sediment concentration and streamflow; concentrations are largest in April, May, and June at high streamflow. Most of the pesticide data compiled from STORET and WATSTORE were collected during water years 1975–79. Only 33 pesticide samples, excluding samples collected for a Rural Clean Water Program, were collected from surface water and bottom sediment during water years 1980–89. Bottom sediment collected near the mouth of the Henrys Fork during the late 1970's had the largest concentrations of pesticides in the basin; DDT, DDD, and DDE concentrations exceeded 10 micrograms per kilogram.

Mass movement of nutrients and suspended sediment in the upper Snake River Basin is controlled primarily by changes in streamflow. Between two and three times as much total nitrogen, total phosphorus, and suspended sediment were transported out of the basin in water year 1984 (high-flow year) compared with 1989 (low-flow year). Reservoirs on the main stem of the Snake River probably trap much of the nutrient and most of the suspended sediment load generated from upper parts of the basin.

A more extensive data-collection program in the upper Snake River Basin is needed to address a number of water-quality issues. These include an analysis of effects of land use on the quality of surface water; quantification of mass movement of nutrients and suspended sediment at key locations in the basin; distribution of aquatic organisms; and temporal and spatial distribution of pesticides in surface water, bottom sediment, and biota.

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 (or lack of trends) in water quality, and (3) identify and describe the major factors that affect observed water-quality conditions and trends.

The design of the program enables integration of information into a nationally consistent data base for comparisons of water-quality data over a large range of geographic and hydrologic conditions. 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 be done in three phases: the first 20 study units began in 1991, the second 20 will begin in 1994, and the final 20 study units will begin in 1997.

The upper Snake River Basin in eastern Idaho and western Wyoming was one of the first-phase study units selected. Assessment of water quality in the basin began in 1991 and will continue with intensive monitoring and analysis through 1995, at which time less intensive data collection will continue.

The purpose of this report is to describe the quality of surface water in the upper Snake River Basin on the basis of nutrient, suspended sediment, and pesticide data collected by various agencies through water year 1989 (October 1, 1988, to September 30, 1989). Recent data (water years 1980–89 for nutrients and suspended sediment and water years 1975–89 for pesticides) were compiled and synthesized to develop a preliminary conceptual model of the spatial and temporal patterns of specific water-quality parameters in the basin. The conceptual model will be used to guide future data-collection efforts.

This report emphasizes the quantity and quality of available data for the study basin, the regional water-quality characteristics of the basin, the presence or lack of long-term water-quality trends, and correlations between nutrient concentrations and land use. Because elevated nutrient, suspended sediment, and pesticide concentrations usually are indicative of effects of land use, and because of interest in these constituents on a national scale, only these constituents are addressed in this report.

DESCRIPTION OF THE UPPER SNAKE RIVER BASIN

The Snake River in the upper Snake River Basin drains an area of approximately 35,800 mi^2 from its headwaters near the southern border of Yellowstone National Park in Wyoming to the basin outlet at King Hill in south-central Idaho (fig. 1). The upper Snake River Basin includes parts of 4 States and 24 major subbasins tributary to the Snake River.

The total 1990 population in the basin was about 391,000: 378,000 in Idaho and 13,000 in Wyoming (Kevin McCollum, Wyoming Department of Administration and Information, written commun., 1991; Alan Porter, Idaho Department of Commerce, written commun., 1991). Principal cities include Idaho Falls (population 43,900), Pocatello (population 46,100), and Twin Falls (population 27,600). The economy in the Wyoming part of the basin is based predominantly on tourism and, in the Idaho part of the basin, on irrigated agriculture. The environmental setting of the upper Snake River Basin is discussed comprehensively in a report by M.A. Maupin (USGS, written commun., 1992).

Physiography

The upper Snake River Basin is composed primarily of parts of four northwestern ecoregions described by Omernik and Gallant (1986). These include the Snake

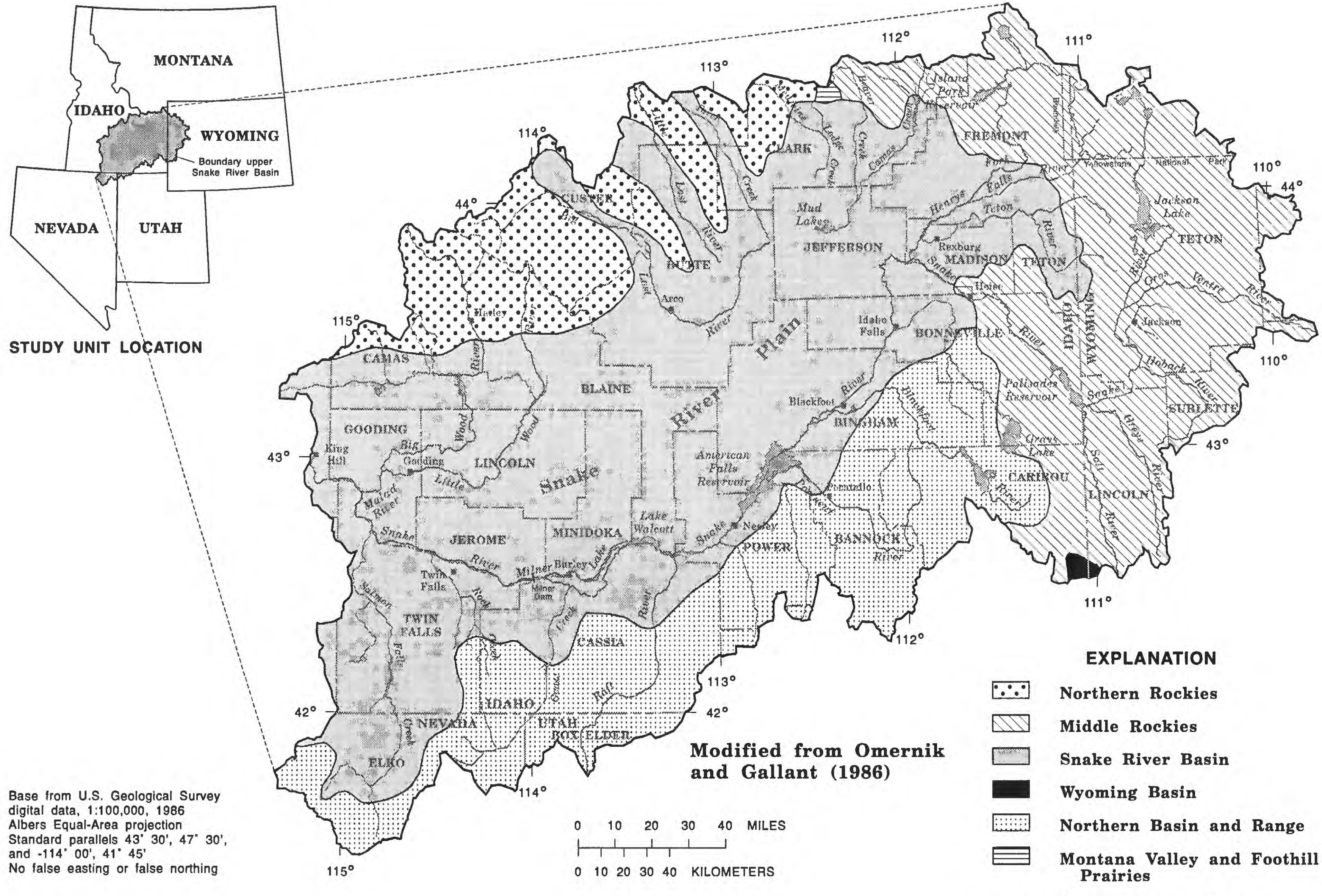

Figure 1. Location of upper Snake River Basin and ecoregions.

River Basin/High Desert ecoregion, the Northern and Middle Rocky Mountains ecoregions, and the Northern Basin and Range ecoregion. Land surface elevation ranges 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.

Major landforms include the heavily forested Yellowstone Plateau of volcanic origin in the northeastern part of the basin and the complexly folded and faulted sedimentary mountain ranges in the southeastern part. Areas in the northern and northwestern parts of the basin are characterized by high mountains that exceed 12,000 ft in elevation and deep, intermontane valleys composed of volcanic and sedimentary rocks. A predominant feature in the central and western parts of the basin is the relatively flat Snake River Plain, a structural downwarp filled with Quaternary basaltic lava flows and bounded by interbedded sedimentary deposits (Whitehead, 1986, sheet 1).

Climate and Vegetation

The climate in most of the upper Snake River Basin is semiarid; mean annual precipitation generally ranges from 6 to 16 in. The source of most precipitation is airmasses moving inland from the Pacific Ocean (Kjelstrom, 1992, p. 3). 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. Mean annual precipitation from 1948 to 1990 at Idaho Falls (elevation 4,710 ft) and Twin Falls (3,745 ft), Idaho, was 10.1 and 10.6 in., respectively. Mean annual precipitation in the mountainous northern and eastern parts of the basin is generally greater than at lower elevations in the basin. Mean annual precipitation from 1948 to 1990 at Hailey, Idaho (5,330 ft), and Jackson, Wyoming (6,244 ft), was 15.9 and 15.6 in., respectively.

Mean annual temperature from 1948 to 1990 at Idaho Falls and Twin Falls, Idaho, was 43.7°F and 47.3°F, respectively. January and July are typically the coldest and warmest months of the year, respectively. The average length of the growing season ranges from about 120 to 160 days, depending on latitude and elevation.

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

Surface-Water Hydrology

The elevation of the Snake River in the upper Snake River Basin ranges from about 6,800 ft upstream from Jackson Lake in Wyoming to about 2,500 ft at the basin outlet at King Hill. The average gradient of the Snake River over this 453-mi reach is approximately 9.5 ft/mi. From Jackson Lake to Milner Dam, the average gradient is 7.6 ft/mi and the elevation of the river surface is generally within 100 ft of the elevation of the adjacent land surface. From Milner Dam to King Hill, the gradient increases to 17.1 ft/mi, and the river becomes entrenched in canyons as deep as 700 ft below the adjacent land surface (Kjelstrom, 1986, sheet 1). In this lower reach of the river, numerous dams and falls exist.

In 1990, streamflow was measured at 98 gaging stations in the upper Snake River Basin, including 18 on the main stem of the Snake River. Streamflow characteristics at 20 gaging stations in the basin (fig. 2) are summarized in table 1. The mean annual volume of water discharging from Wyoming is 5.1 million acre-ft as measured at the Snake River near Heise gaging station. As the Snake River flows onto the Snake River Plain, it is joined by the Henrys Fork, the largest tributary in the upper Snake River Basin. The Henrys Fork discharges approximately 1.5 million acre-ft of water annually to the Snake River. Downstream from the confluence with the Henrys Fork, the six largest south-side tributaries to the Snake River, in downstream order, are Willow Creek, the Blackfoot River, the Portneuf River, Goose Creek, Rock Creek, and Salmon Falls Creek. Combined, these six tributaries discharge 0.7 million acre-ft of water annually to the Snake River (Kjelstrom, 1986, sheet 2). Another 1.1 million acre-ft of water is generated annually from northern tributary valleys between the Henrys Fork and Little Wood River (Kjelstrom, 1986, sheet 2). Streamflow from these rivers, primarily from the Big Lost and Little Lost Rivers and Birch and Camas Creeks, does not reach the Snake River directly as surface water. Instead, the

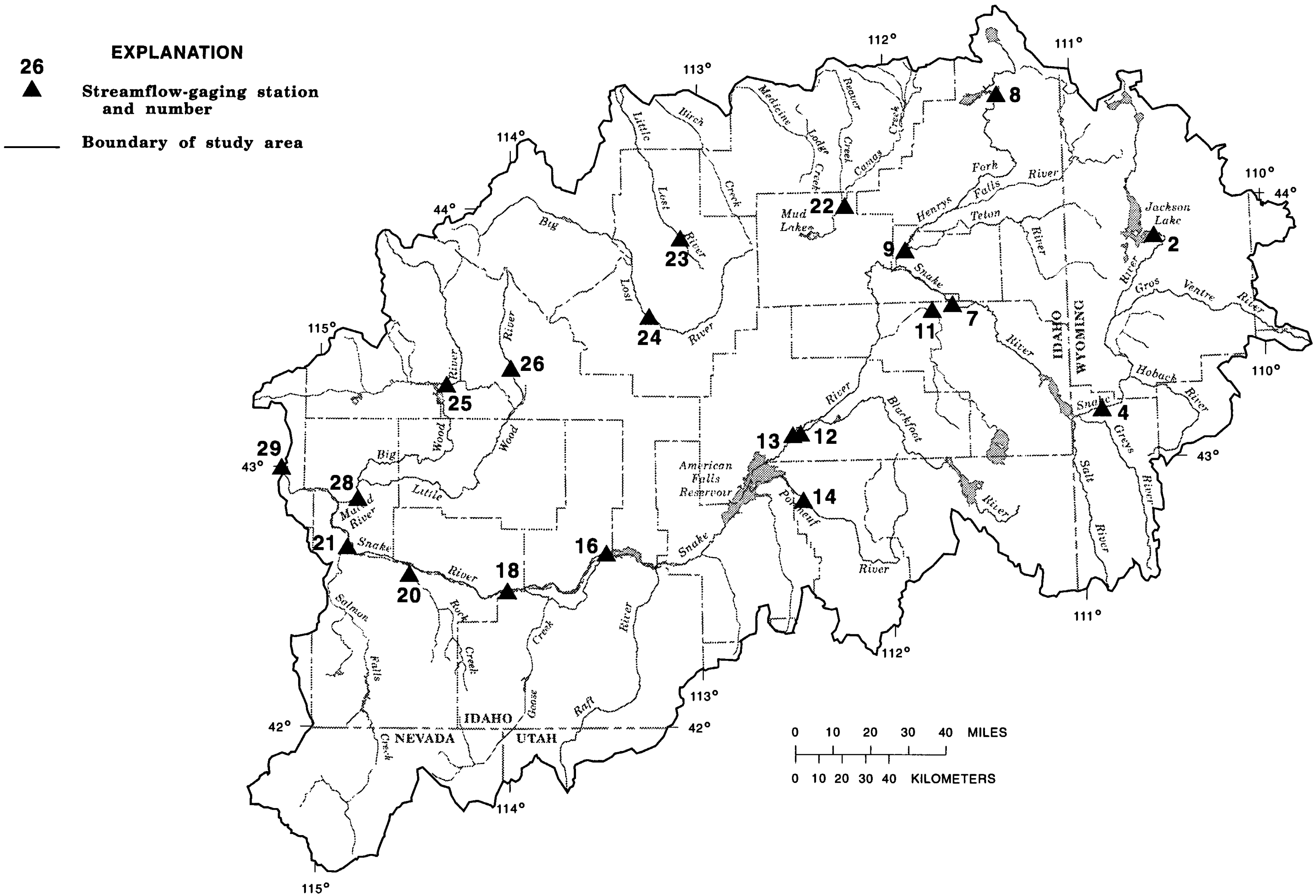

Figure 2. Locations of gaging stations selected for characterization of streamflow in the upper Snake River Basin.

Table 1. Streamflow characteristics for selected gaging stations in the upper Snake River Basin

[Sampling station number refers to figure 2; ft³/s, cubic feet per second; acre-ft/yr, acre-feet per year; mi², square miles; in/yr, inches per year; exceedance frequency, percentage of time discharge was equaled or exceeded; gaging stations are in Idaho unless otherwise indicated; WY, Wyoming]

Sampling station No.	Gaging station No.	Gaging station name	Period of record used (water years)	Annual mean streamflow		Drainage area (mi²)	Mean annual runoff (in/yr)	Streamflow at given percent exceedance frequency (ft³/s)		
				(ft³/s)	(acre-ft/yr, millions)			90	50	10
2	13011000	Snake River near Moran, WY	1904–90	1,440	1.0	807	24.2	17	495	4,480
4	13022500	Snake River near Alpine, WY	1938, 1954–90	4,560	3.3	3,460	17.9	1,320	2,440	11,100
7	13037500	Snake River near Heise	1911–90	6,990	5.1	7,770	12.2	1,980	4,310	15,300
8	13042500	Henrys Fork near Island Park	1934–90	614	.44	481	17.3	13	520	1,300
9	13056500	Henrys Fork near Rexburg	1910–90	2,070	1.5	2,920	9.63	934	1,730	3,670
11	13058000	Willow Creek near Ririe	1904, 1918–20, 1963–79, 1986–90	153	.11	627	3.32	3.0	59	414
12	13068500	Blackfoot River near Blackfoot	1932–37, 1941–90	160	.11	1,295	1.68	19	129	338
13	13069500	Snake River near Blackfoot	1911–15, 1917–90	4,850	3.5	11,310	5.83	1,000	3,260	11,400
14	13075500	Portneuf River at Pocatello	1899, 1913–16, 1918–90	283	.20	1,250	3.08	67	248	537
16	13081500	Snake River near Minidoka	1911–90	6,700	4.9	15,700	5.80	1,300	6,230	11,900
18	13088000	Snake River at Milner	1910–90	3,260	2.4	17,180	2.58	15	1,210	9,190
20	13093000	Rock Creek near Twin Falls	1923–46, 1984–90	212	.15	277	10.4	125	205	304
21	13108150	Salmon Falls Creek near Hagerman	1971–90	166	.12	2,120	1.06	69	159	245
22	13112000	Camas Creek at Camas	1927–70, 1972–82, 1984–85, 1989–90	35	.025	400	1.19	.01	5.0	104
23	13119000	Little Lost River near Howe	1941–81, 1986–90	77	.055	703	1.49	28	68	146
24	13132500	Big Lost River near Arco	1947–61, 1967–80, 1983–90	109	.079	1,410	1.05	.10	43	285
25	13141000	Big Wood River near Bellevue	1916, 1922, 1940–41, 1943–90	308	.22	824	5.08	45	110	848
26	13148500	Little Wood River near Carey	1926–42, 1944–90	154	.11	312	6.71	5.0	68	407
28	13152500	Malad River near Gooding	1917–22, 1938–41, 1943–90	299	.22	2,990	1.36	20	114	782
29	13154500	Snake River at King Hill	1910–90	10,900	7.9	35,800	4.14	6,980	9,360	17,000

water percolates into a regional aquifer and eventually discharges as spring flow to the Snake River near the outlet of the basin. Mean annual flow to the Snake River from the Big Wood and Little Wood Rivers, which drain the northwestern part of the basin and join to form the Malad River, is approximately 0.22 million acre-ft. The volume of water that leaves the basin at King Hill averaged 7.9 million acre-ft/yr from 1910 to 1990.

Flow-duration curves for selected gaging stations in the upper Snake River Basin indicate that streamflows during water years 1980–89 were, in general, slightly larger than long-term streamflows (fig. 3). A larger percentage of low flows at the Snake River near Heise gaging station from 1980 to 1989, compared with historical streamflows, was probably the result of construction of Palisades Reservoir directly upstream from the station in 1956. Streamflow releases from Palisades Reservoir since 1956 have been kept at low-flow conditions during the fall and winter months while the reservoir is filling. Annual mean streamflows during

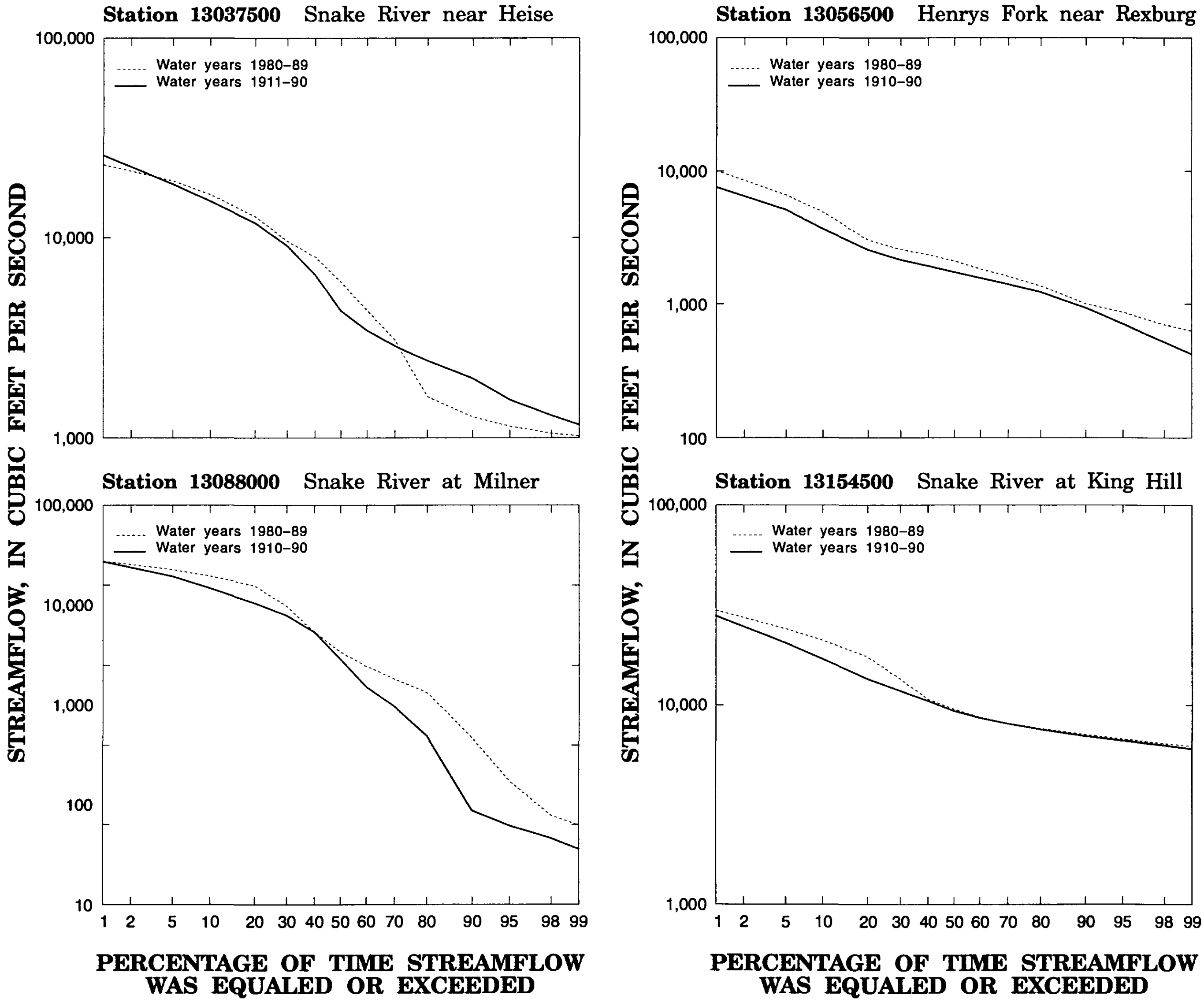

Figure 3. Flow-duration curves for selected gaging stations in the upper Snake River Basin for period of record and for water years 1980–89.

water years 1980–89 at the same gaging stations (fig. 4) indicate that during the early and late 1980's, streamflows were smaller than average, and during the mid-1980's, streamflows were larger than average.

Monthly water budgets based on streamflow records have been used to quantify the interaction between surface and ground water on the main stem of the Snake River between gaging stations near Heise and at King Hill (Kjelstrom, 1992). In water year 1980, streamflow gains from ground-water discharge totaled approximately 7.2 million acre-ft between Heise and King Hill. Of this total, approximately 1.9 million acre-ft (26 percent) was gained between gaging stations near Blackfoot and at Neeley, and 4.4 million acre-ft (61 percent) was gained between gaging stations at Milner and King Hill. Streamflow losses to ground water between Heise and King Hill totaled approximately 0.81 million acre-ft, of which more than 85 percent was lost between gaging stations at Heise and near Blackfoot.

Land Use

The predominant land use/land cover categories in the upper Snake River Basin are rangeland, forest land, and

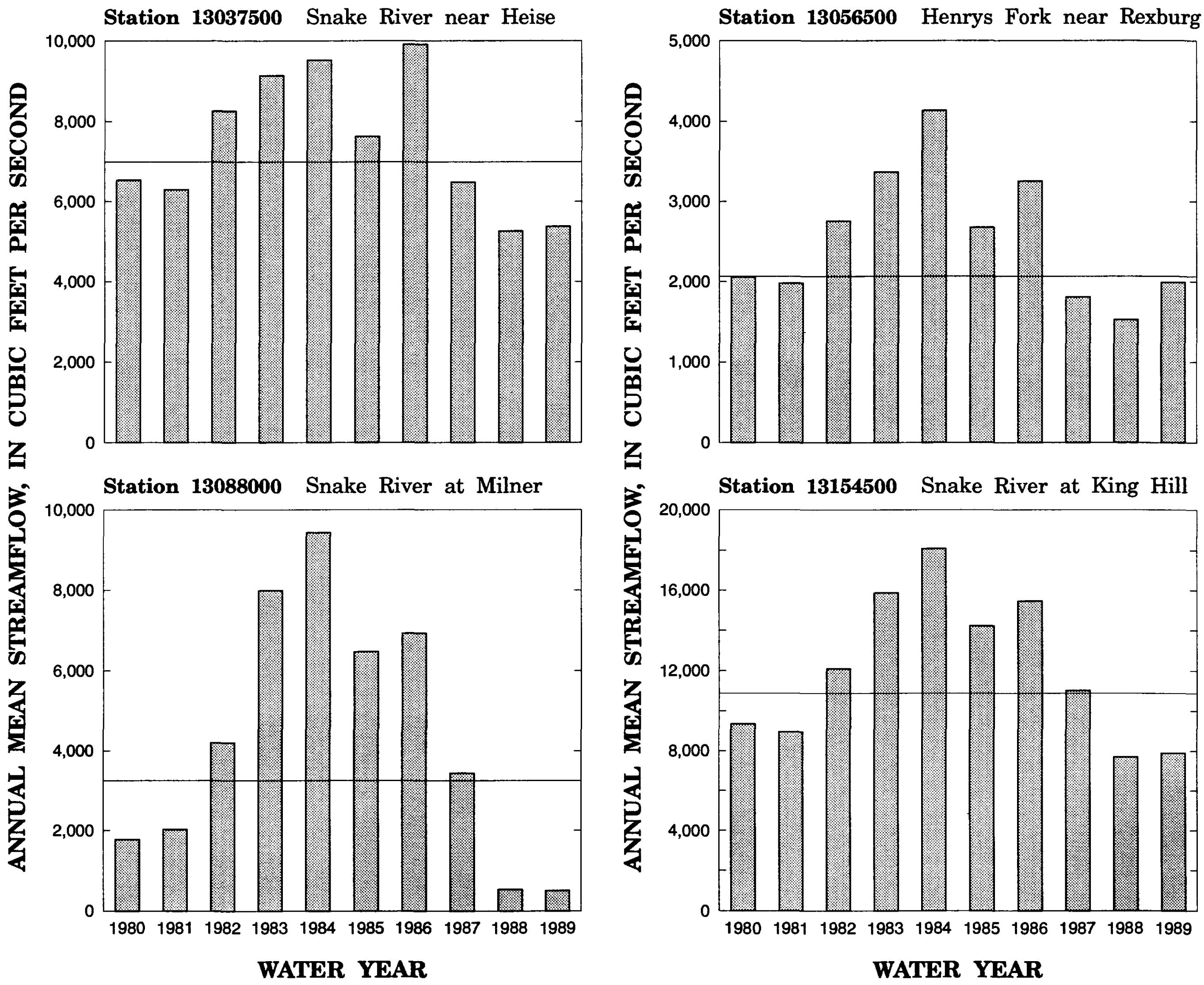

Figure 4. Annual mean streamflow at selected gaging stations in the upper Snake River Basin during water years 1980–89. (Solid horizontal line on each graph represents the mean annual streamflow for the period of record)

agricultural land (fig. 5). These three categories account for approximately 93 percent of the area in the basin (table 2). Other anthropogenic factors affecting water quality include tourism and recreation (particularly in the Wyoming part of the basin), food-processing operations, and municipal and industrial facilities. The Nation's largest commercial trout farms are located along the Snake River between Milner and King Hill. These trout farms produce more than 70 percent of the Nation's supply.

Approximately 20 percent of the upper Snake River Basin, or more than 7,000 mi^2, is used for agricultural purposes. Farming is concentrated on the Snake River Plain, primarily along the Snake River and near the mouths of tributary drainage basins. Principal crops grown in the basin in 1989 were grains, alfalfa, potatoes, and sugar beets (Idaho Agricultural Statistics Service, 1990).

The amount of fertilizer applied annually to crops depends on cropping patterns and may vary considerably from year to year. From 1985 to 1990, the average

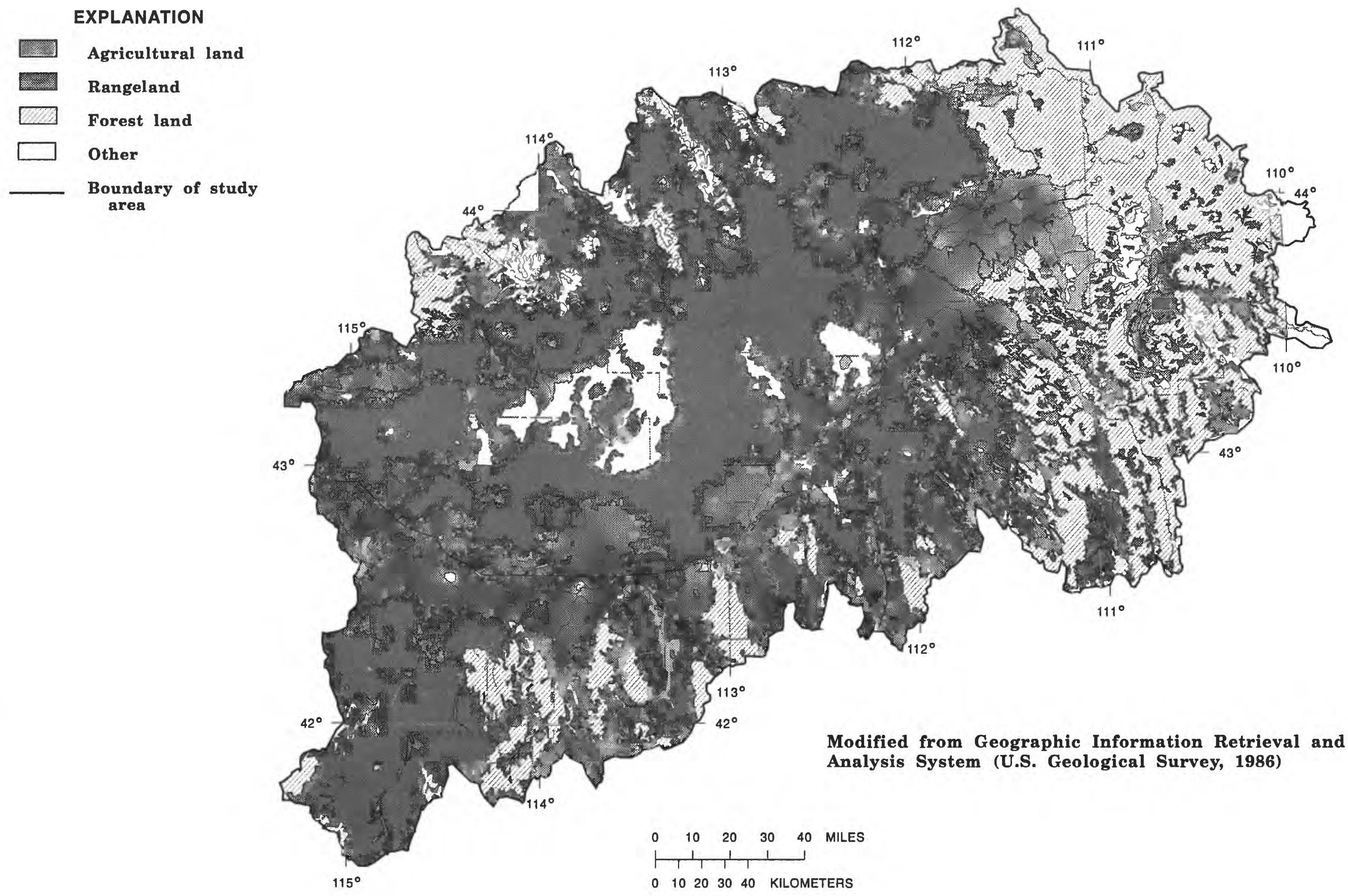

Figure 5. Spatial distribution of land use and land cover in the upper Snake River Basin, 1970.

annual amounts of nitrogen and phosphorus fertilizer used in the basin, based on county sales data, were 115,000 and 45,000 tons, respectively (U.S. Environmental Protection Agency, 1990). Areas of most intensive fertilizer use are near the mouth of the Henrys Fork and along the main stem of the Snake River downstream from its confluence with the Henrys Fork (figs. 6 and 7).

Pesticides are widely used in the upper Snake River Basin to control insects and weeds that are damaging to agriculture. Although many different types of pesticides are used in the basin, little information on their quantitative use exists. The 15 pesticides that were applied in the largest quantities, based on use estimates from 1982 to 1985, are listed in table 3. Of the 15 pesticides listed, the broadleaf herbicide 2,4-D was applied in larger quantities than all the other listed pesticides combined.

Surface-Water Use

Streamflow in the Snake River is highly regulated by dams and diversions, primarily for agricultural use and hydroelectric-power generation. Five reservoirs on the main stem of the Snake River have a combined storage capacity of more than 4 million acre-ft (Kjelstrom, 1992, p. 18). The largest reservoir on the main stem, American Falls Reservoir, has a storage capacity of 1.7 million acre-ft. Of the five main-stem reservoirs, four were constructed and filled prior to 1930. Palisades Reservoir, with a storage capacity of 1.4 million acre-ft, was filled in 1956. In addition to the storage facilities on the main stem, eight reservoirs with storage capacities of more than 50,000 acre-ft each and numerous smaller reservoirs are located on Snake River tributaries.

In 1980, approximately 8.8 million acre-ft of water was diverted from the Snake River and its tributaries by canals and pumps in the upper Snake River Basin (Goodell, 1988, p. E24–26). Of this total, 1.7 million acre-ft was diverted just downstream from Heise, and another 2.9 million acre-ft was diverted to five canals at Milner and Minidoka Dams.

Mean monthly streamflows during the 1980–89 water years for three main-stem gaging stations exhibit the seasonal effects of water use (fig. 8). Upstream from major points of diversion, streamflows at the Snake River near Heise gaging station are largest from April to August as water is released from upstream reservoirs to meet irrigation demands downstream. From September to March, controlled releases from upstream reservoirs

Table 2. Land use classifications for the upper Snake River Basin based on 1970 land use/land cover digital data

[Land use classifications from Anderson and others (1976); mi^2, square miles; underlined values are totals for Anderson Level 1 classification; <, less than]

Land use classification: Level 1	Land use classification: Level II	Area (mi^2)	Percent of total area
Agricultural land		7,315	20
	Cropland and pasture	7,293	
	Orchards, groves, vineyards, nurseries, and ornamental horticultural areas	.4	
	Confined feeding operations	5.2	
	Other agricultural land	16.8	
Rangeland		17,978	50
	Herbaceous rangeland	429	
	Shrub and brush rangeland	8,798	
	Mixed rangeland	8,751	
Forest land		8,066	23
Water		243	.7
Urban or built-up land		196	.5
Wetland		211	.6
Barren land		1,107	3.1
Tundra		555	1.6
Perennial snow or ice		.5	<.01
No data		129	.4

Table 3. Pesticides applied in the largest quantities in the upper Snake River Basin, 1982–85

[Use estimates are based on data from Gianessi and Puffer (1988). Tons applied are active ingredient, and use estimates are based on average application rates by county and crop cover within each county. Although other pesticides may have been used in larger quantities, only the top 15 of those included in Gianessi and Puffer (1988) are listed]

Pesticide	Quantity applied (tons per year)	Type of pesticide
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

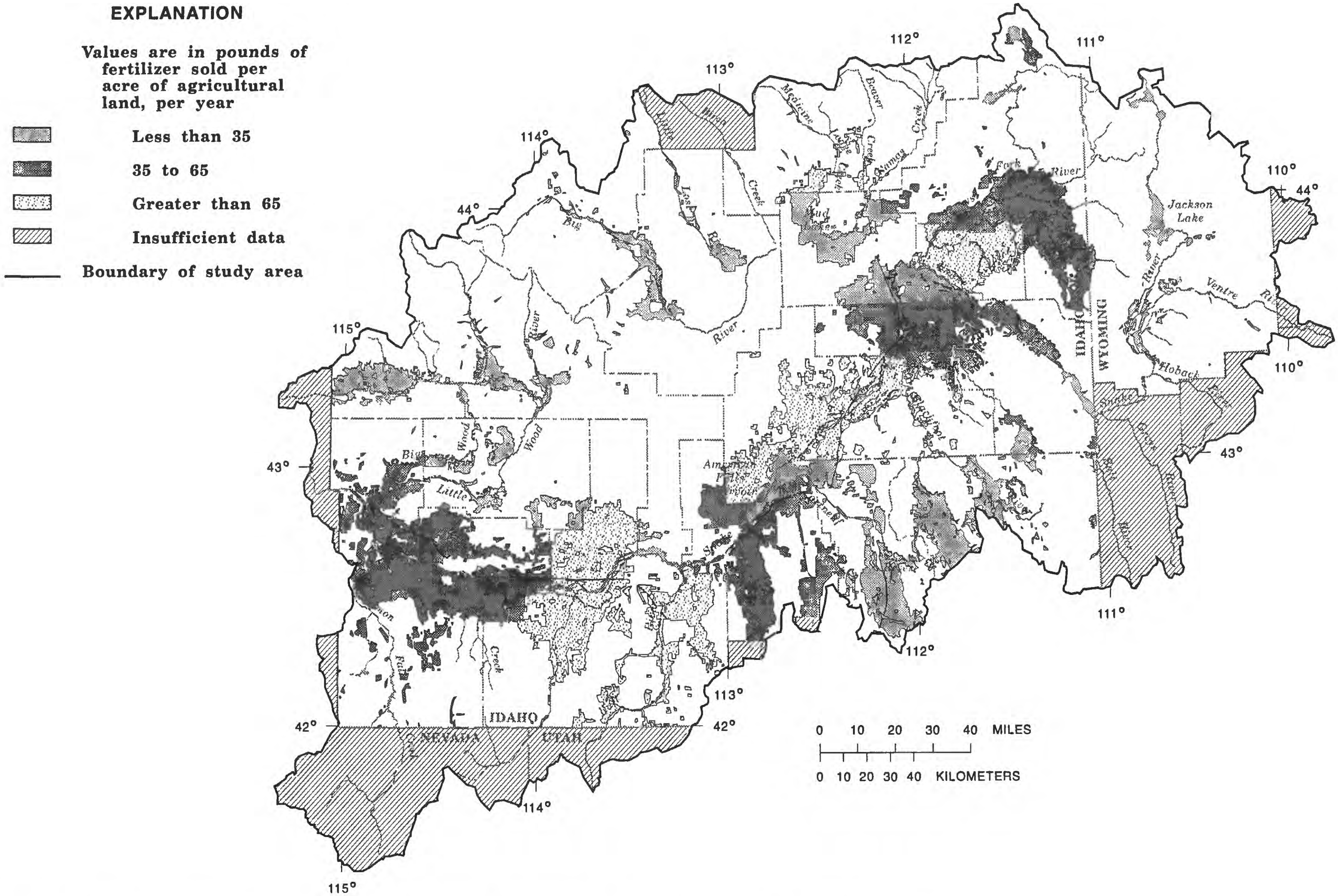

Figure 6. Nitrogen fertilizer sales in the upper Snake River Basin, by county, 1985–90. (Shaded areas represent agricultural land in each county except in counties where insufficient data exist)

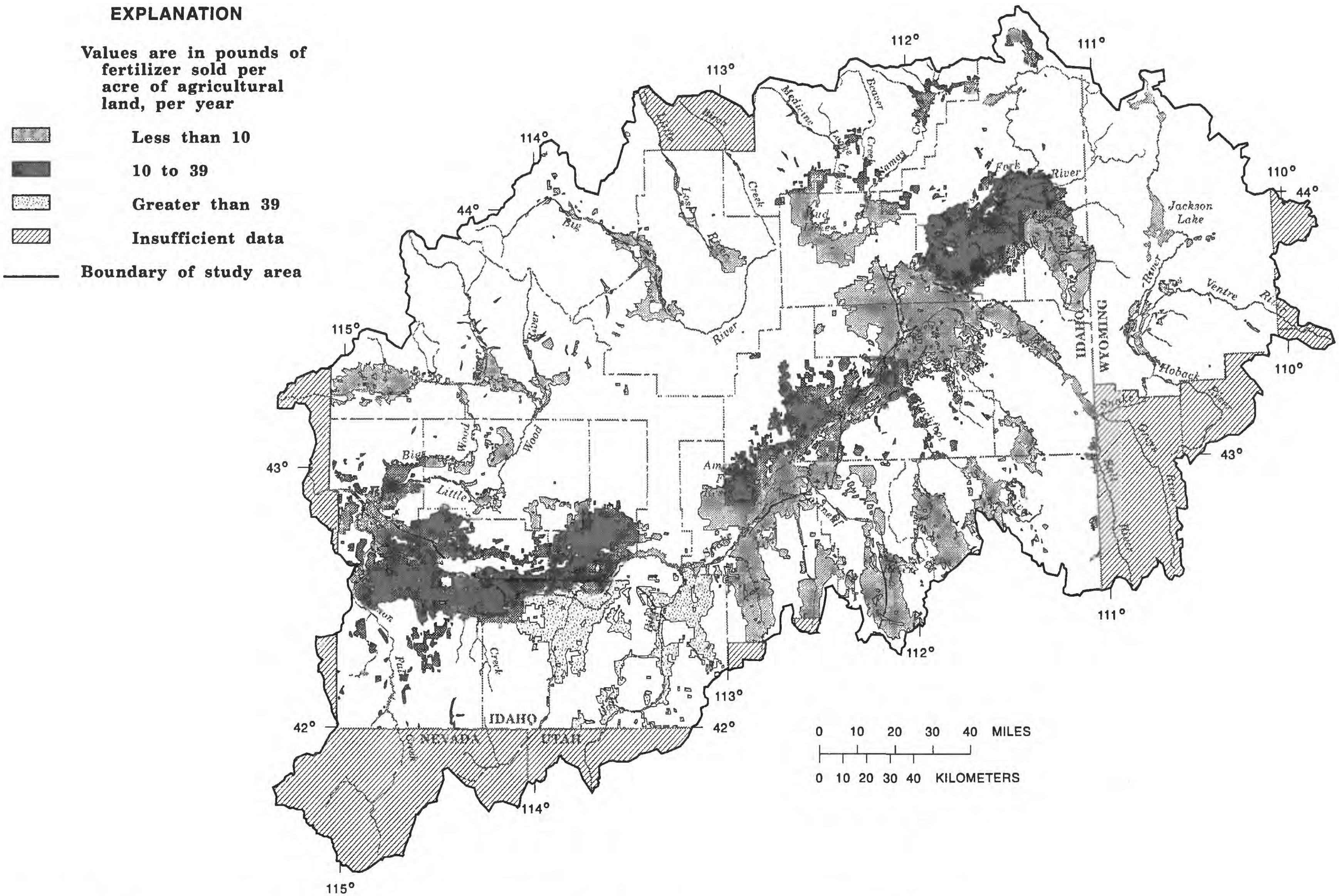

Figure 7. Phosphorus fertilizer sales in the upper Snake River Basin, by county, 1985–90. (Shaded areas represent agricultural land in each county except in counties where insufficient data exist)

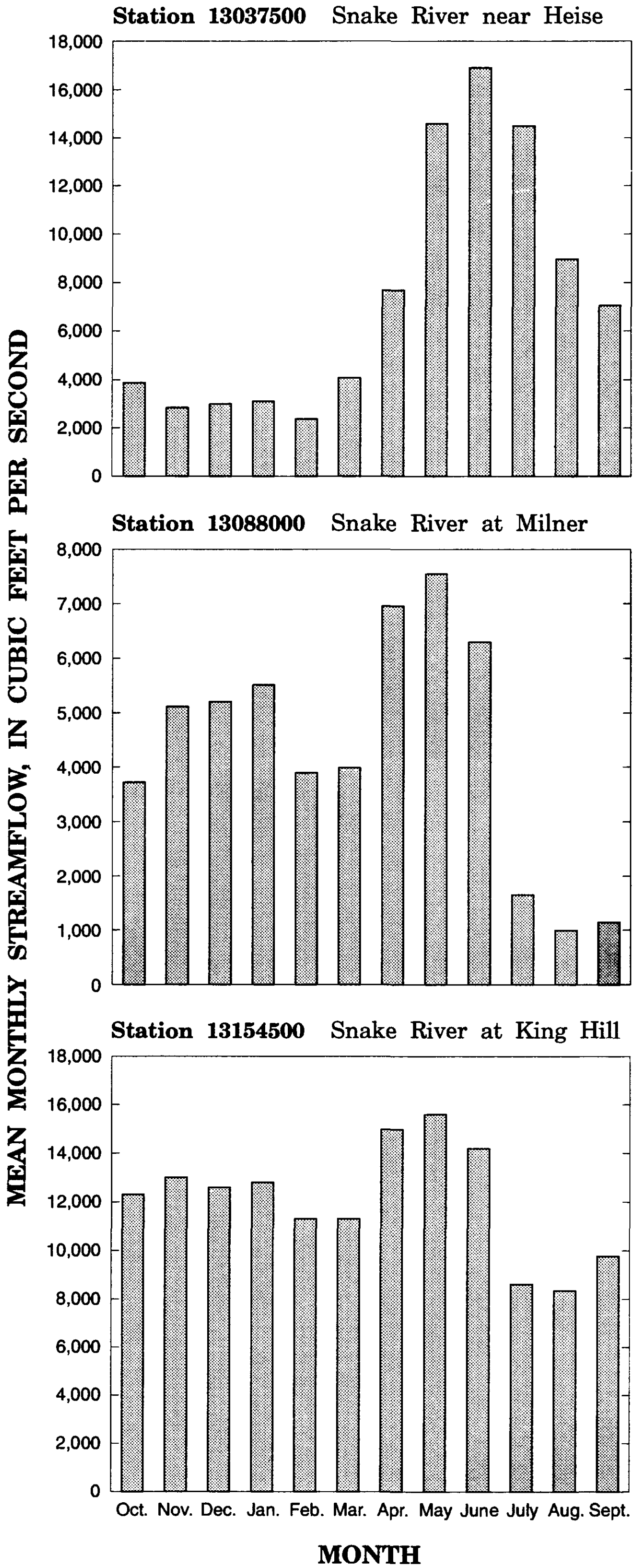

Figure 8. Mean monthly streamflow at selected gaging stations in the upper Snake River Basin, water years 1980–89.

keep streamflow at the Heise gaging station at a relatively constant minimum flow. At the Snake River at Milner gaging station, downstream from most major surface-water diversions, streamflow decreases dramatically during the summer months because nearly all the water in the Snake River is diverted for irrigation. In the late 1980's, when streamflows in the Snake River Basin were below normal, streamflows at the Milner gaging station frequently were less than 10 ft^3/s from March to September. Streamflows at the Snake River at King Hill gaging station also show a summer low-flow period due to upstream irrigation diversions. However, because of ground-water recharge to the Snake River, as discussed earlier in the report, between the Snake River at Milner and Snake River at King Hill gaging stations, mean daily streamflows leaving the basin at King Hill are generally about 6,000 to 7,000 ft^3/s larger than at Milner.

Surface-Water Quality

Water quality in the upper Snake River Basin is affected by a wide variety of nonpoint and point sources. In Wyoming, the most common nonpoint source problem is sediment loading caused by irrigated agriculture, rangeland grazing, land development, levee construction, road building for oil and gas development, and offroad vehicle use (Wyoming Department of Environmental Quality, 1988). In 1990, 1,688 river miles were designated for beneficial use in the Wyoming part of the Snake River Basin. Of this total, 297 miles were assessed for use support, of which 232 miles, or 78 percent, were classified as either threatened or only partially supported for at least one beneficial use (Wyoming Department of Environmental Quality, 1991).

In Idaho, land and water uses result in increased concentrations of sediment, bacteria, nutrients, and pesticides in the water column; increased organic enrichment; and alterations in water temperature. Of 5,732 river miles assessed for nonpoint source effects in the Idaho part of the basin, 2,913 river miles were affected by agriculture; 1,766 miles by hydrologic modification; 197 miles by construction activities; 35 miles by forest practices; 134 miles by mining; and 109 miles by other activities, primarily recreation (Idaho Department of Health and Welfare, 1989). Specific point

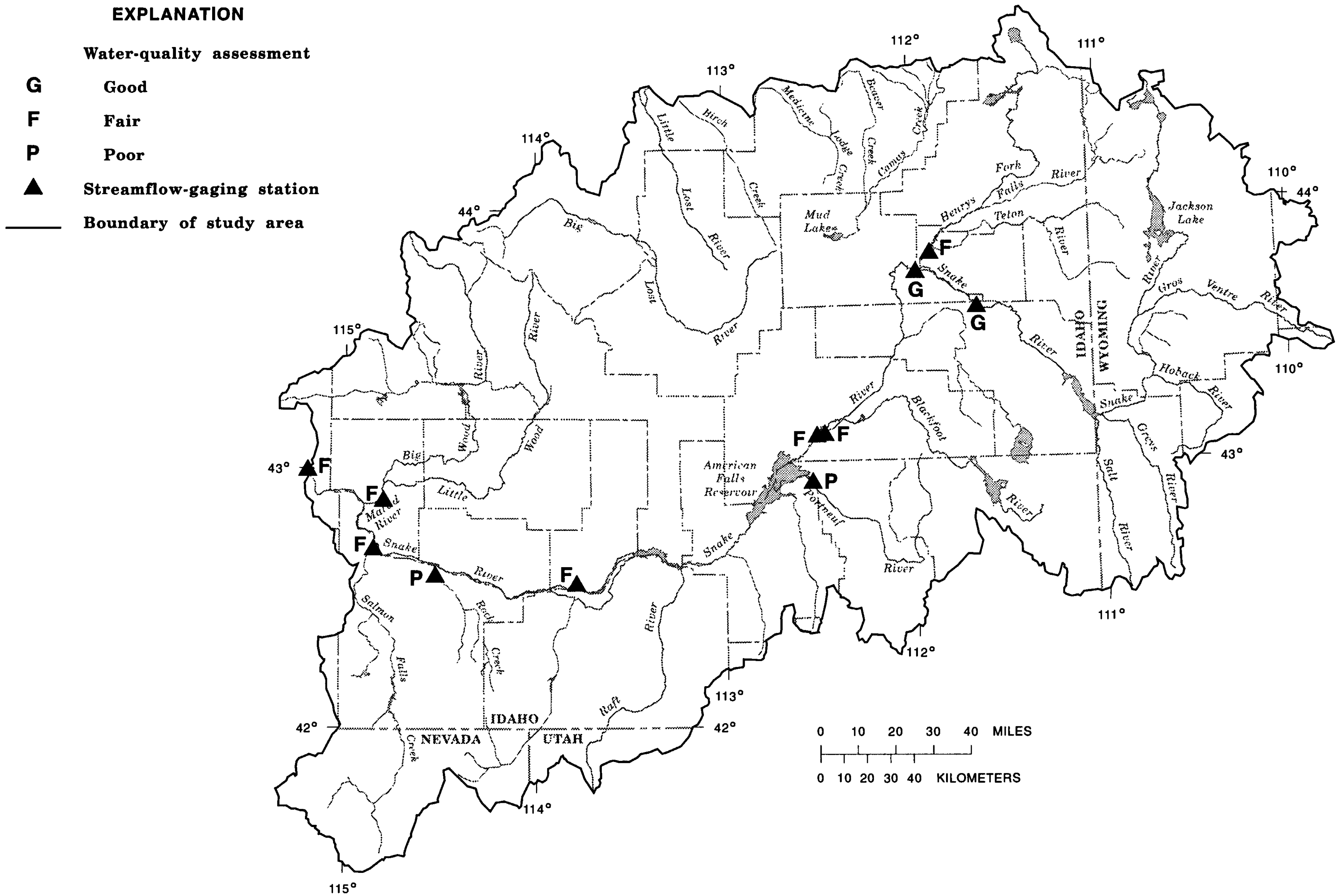

Figure 9. Idaho Department of Health and Welfare (1989) assessment of water-quality conditions in the upper Snake River Basin based on nine water-quality parameters, water years 1982–87.

sources of contaminants include effluent from municipalities, industries, fish farms, and feedlots.

Instream water quality was assessed (fig. 9) by the Idaho Department of Health and Welfare (1989) at five main-stem and six tributary gaging stations along the Snake River in Idaho. The overall water-quality condition at each station was assessed from an average of indexes for water temperature, dissolved oxygen, pH, bacteria, trophic status, esthetics, solids, metal toxicity, and ammonia toxicity, and was based on at least 1 year's monitoring data collected at least four times per year from October 1982 through October 1987. Results indicate that the overall water-quality condition of the main stem is good in the upper reaches as the Snake River enters Idaho and deteriorates downstream toward the mouth of the basin. Of the six tributaries assessed, four were rated in fair condition and two were rated in poor condition.

ASSESSMENT OF EXISTING WATER-QUALITY DATA

Nutrients (nitrogen and phosphorus species), suspended sediment, and pesticides were selected for retrospective analysis because of interest in these constituents on a national scale. Elevated concentrations of these constituents in surface water are associated with many different types of land use and can be deleterious to the biota in and esthetics of surface-water bodies.

The period selected for the assessment of nutrients and suspended sediment was water years 1980–89. Data collected during this period were assumed to be indicative of current (1992) water-quality conditions.

The quantity of pesticide data collected from surface water in the upper Snake River Basin has been minimal. Because most of the available data were collected in the late 1970's, the period of assessment for pesticides was expanded to water years 1975–89. The pesticide data discussed in this report include concentrations in surface water and bottom sediment.

Suitability of Existing Data

Water-quality data for the upper Snake River Basin compiled and used for this report are from the U.S. Environmental Protection Agency (EPA) water-quality data base STORET and the USGS data base WATSTORE. Most of the Federal and State agencies collecting water-quality information in the Snake River Basin store their data in STORET. The number of stations sampled and the numbers of samples collected for analysis of nutrients or suspended sediment in the upper Snake River Basin for water years 1980–89 are listed in table 4. The spatial distribution of sampling stations is shown in figure 10.

Most of the water-quality data collected by various State and Federal agencies during water years 1980–89 were for objectives other than long-term monitoring. For example, at many stations, numerous samples were collected over a short time span for a limited number of constituents. This was especially apparent for many stations on streams that drain areas of irrigated agriculture and on agricultural runoff drains. These stations typically were sampled for only a few months during the spring and summer when agricultural effects on water quality are most evident, making the samples biased toward periods of greatest effect. Many of the water-quality analyses in STORET did not contain an accompanying value for streamflow. Because variations in streamflow often have large effects on surface-water quality, data collected without a measurement of streamflow are of limited use. Only a few stations in STORET could be documented for sampling procedures and quality assurance, had measurements of streamflow, and had a good temporal coverage of samples collected over a wide range of streamflows.

Table 4. Number of stations sampled and number of samples collected in the upper Snake River Basin for nutrients and (or) suspended sediment, water years 1980–89

Collecting agency	No. of stations sampled	No. of samples collected
U.S. Geological Survey	180	1,339
Idaho Department of Environmental Quality	247	6,617
U.S. Bureau of Reclamation	27	454
U.S. Forest Service	16	384
Utah Health Department	3	42
Nevada Department of Conservation and Natural Resources	3	27
TOTAL	476	8,863

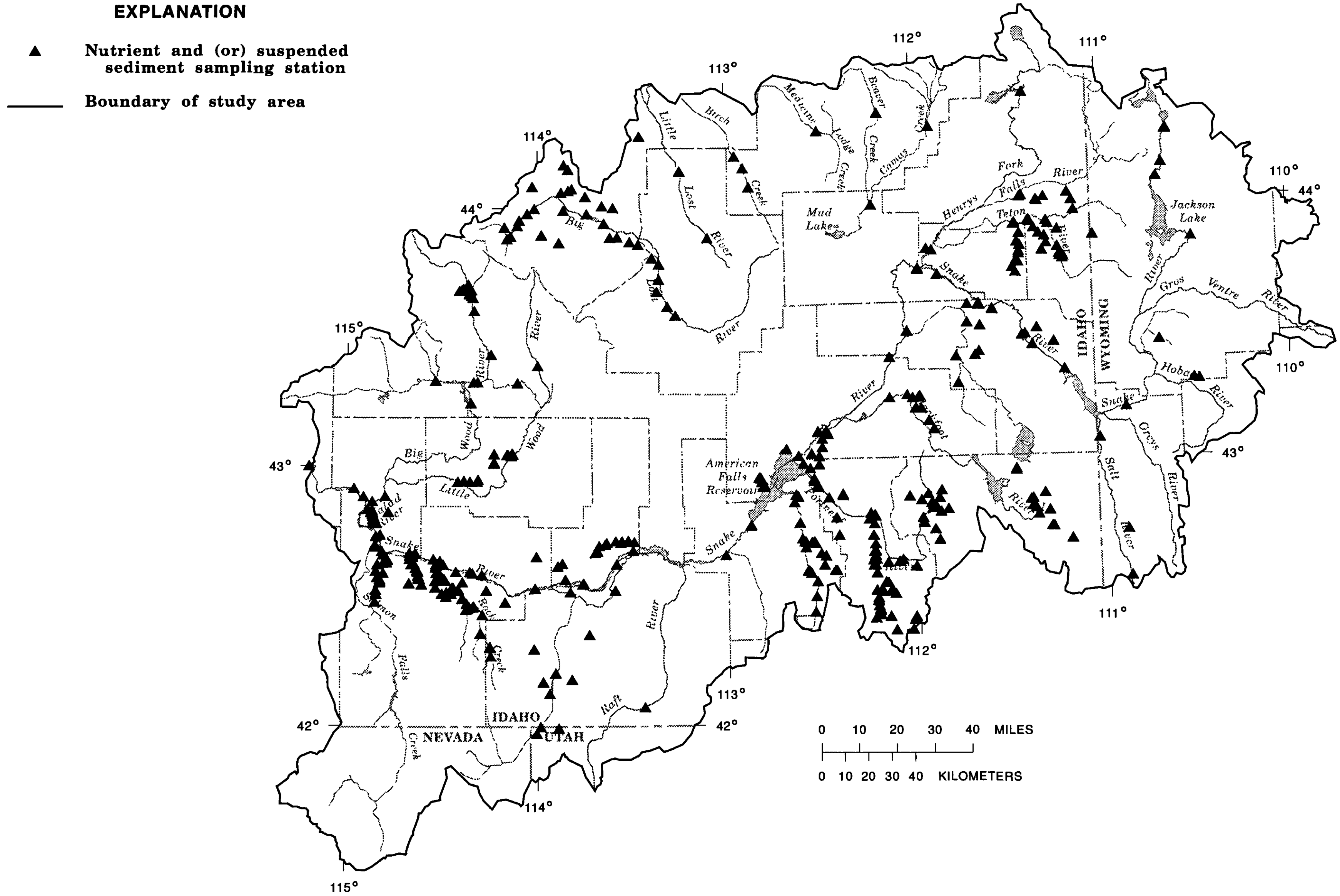

Figure 10. Stations in the upper Snake River Basin where nutrient and (or) suspended sediment samples were collected, water years 1980–89.

STORET could be documented for sampling procedures and quality assurance, had measurements of streamflow, and had a good temporal coverage of samples collected over a wide range of streamflows.

Data collected by the USGS and stored in WATSTORE contained many of the same limitations as the STORET data. However, the USGS also maintains a network of streamflow-monitoring stations, many of which are sampled for water quality on a routine basis. Unfortunately, water-quality monitoring at many of the USGS stations in the basin was discontinued in the early 1980's, resulting in an insufficient amount of data to assess water-quality conditions. In the upper Snake River Basin, the USGS operates two National Stream Quality Accounting Network (NASQAN) stations and one hydrologic bench-mark station. Water-quality data were collected at these three stations throughout water years 1980–89.

Data-Selection Criteria

Because of the limitations of the available data, only 19 stations were used for a quantitative assessment of nutrients and only 6 stations were used for an assessment of suspended sediment. Other water-quality data were used only qualitatively. Some of the data used for quantitative assessment could not be documented in terms of data-collection objectives or quality assurance. However, most of the non-USGS data were collected for statewide monitoring by the Idaho Department of Health and Welfare, Division of Environmental Quality (IDEQ). Typical sampling methodology used by IDEQ (Maret, 1990) includes collection of grab samples and submission of duplicate and spiked samples for laboratory analysis. All samples collected by IDEQ are analyzed by the Idaho Department of Health and Welfare's State water-quality laboratory, an EPA-approved lab in Boise, Idaho. For these reasons, data collected by IDEQ were assumed to be suitable for quantitative assessment.

Because different agencies may use different sampling protocols, it is often difficult to compare data between agencies. This was true for nitrite plus nitrate analyses retrieved from STORET and WATSTORE. Nitrite plus nitrate concentrations are reported as either total or dissolved, depending on whether the samples were filtered prior to analysis. Most of the samples retrieved from STORET were total analyses, whereas those retrieved from WATSTORE generally were dissolved. To determine whether differences between total and dissolved nitrite plus nitrate concentrations were significant, a regression analysis was performed on samples collected from stations used in this report and at which both analyses were performed. The correlation coefficient for 99 surface-water samples was 0.97 with a standard error of the estimated value of 0.03 mg/L for a one-to-one relation over a wide range of nitrite plus nitrate concentrations. Because of this strong correlation, STORET and WATSTORE data for nitrite plus nitrate were grouped prior to statistical analyses.

Only stations where samples were collected regularly within each year assessed and over a wide range of streamflow conditions were selected for quantitative assessment. When possible, documentation for the sampling procedures and quality assurance was retrieved. When a selected station had a large number of samples collected over a short period, analyses were deleted so that summary statistics calculated from the data set would more accurately represent water-quality conditions over the entire year and over a wide range of streamflows.

Few pesticide data for the upper Snake River Basin exist. None of the stations where pesticide data were collected and analyzed were sampled routinely, and most of these data could not be verified for quality assurance or sampling protocol. In addition, most of the pesticide data were collected during the late 1970's in response to concerns over organochlorine pesticides in surface water and bottom sediment. Because of the paucity of data and the lack of quality assurance information, a quantitative analysis of pesticides in the basin was impossible. However, a discussion based primarily on pesticide data collected during water years 1975–79 is included.

Data-Analysis Methods

Graphical and statistical procedures were used to describe and evaluate the nutrient and suspended ediment data used in this report. Methods of data analysis were dependent on data availability and whether the data were used in a qualitative or quantitative assessment. The following sections briefly describe the procedures used and under what circumstances they were applied.

QUALITATIVE ASSESSMENT

For the qualitative assessment, all available data for nutrients and suspended sediment were summarized for interpretation without screening. This approach resulted in a reasonable geographic coverage for these constituents in the basin; however, interpretation was limited to general regional comparisons and identification of areas with elevated concentrations.

The qualitative assessment was limited to a graphical display of median data values for selected nutrients and suspended sediment on a map of the basin. Only those stations with at least five analyses were plotted. To visually correlate nutrient and suspended sediment concentrations with agricultural land use, the areal extent of agricultural land also was included on the maps. Because the data in this analysis were not screened, elevated nutrient and suspended sediment concentrations do not necessarily indicate an actual problem. However, the data may be used to supplement the quantitative assessment and may be helpful as a guide for future sampling.

QUANTITATIVE ASSESSMENT

The only stations used for a quantitative assessment of nutrients and suspended sediment were those at which samples were collected routinely during most of the year and over a wide range of streamflow conditions. The samples from these stations were assumed to be representative of the same temporal and hydrologic conditions. This assumption allows interstation and intrastation comparisons, as well as grouping of stations with similar characteristics. Quantitative data were used to determine spatial, seasonal, and annual variations in constituent concentrations, correlations with land use, long-term trends in constituent concentrations, and movement of constituent loads.

Treatment of censored data

Because of advances in analytical techniques and differences in analytical methods between different laboratories, concentrations for a given constituent may have more than one reporting level. These reporting levels represent the smallest concentration at which a constituent can be confidently quantified.

For most data interpretation, nonparametric statistical procedures were used for this report. Because nonparametric procedures are based on ranking of data by their numerical value, all data values smaller than the reporting-level value (censored data) are of equal rank and were, therefore, set to the reporting-level value. If multiple reporting-level values existed in a data set, or when two or more data sets were grouped by land use or season, all censored data values were set to the largest reporting-level value.

For load calculations, censored data values were treated using an adjusted maximum likelihood estimation technique (Cohn, 1988). This technique assigns a distribution of data values below the reporting-level value to the censored data on the basis of the distribution of values above the reporting level.

Summary statistics

Summary statistics were used to evaluate the distribution of nutrient and suspended sediment concentrations at selected stations in the study basin. Percentile values were calculated at each station. Percentile values that were less than the largest reporting level at that station were set to the reporting level. Because some analytical laboratories have smaller reporting levels than others, some stations may have a tabulated percentile value for a certain constituent that is smaller than the reporting level for the same constituent at other stations.

Truncated boxplots (Helsel and Hirsch, 1992, p. 26) were used to graphically display nutrient and suspended sediment concentrations for individual stations and for data grouped by land use or season. Boxplots consist of a box drawn from the 25th to the 75th percentile (interquartile range) with a horizontal line through the box that indicates the median value of the data set. Vertical lines (whiskers) are extended from the quartile values to the 10th and 90th percentile values. Data values in the upper and lower 10th percentiles of the data set are not plotted. For stations with fewer than 10 samples, individual data values are plotted. The skew of each data set can be determined by the length of the box and whiskers above and below the median line.

Comparative statistics

Two types of nonparametric tests were used to compare groups of data to determine whether the group population distributions were significantly different from one another. The Wilcoxon rank-sum test (Helsel and Hirsch, 1992, p. 118) was used to compare two independent populations to determine whether their distributions were significantly different. The Kruskal-Wallis test (Helsel and Hirsch, 1992, p. 159) is similar to the Wilcoxon rank-sum test except that it is designed and was used in this report to compare population distributions for several independent groups of data. The Kruskal-Wallis test determines whether all group distributions are similar or whether some groups have different distributions than others.

Both the Wilcoxon rank-sum test and the Kruskal-Wallis test compute ranks on all data values pooled from all the populations being compared. The ranks are summed for individual populations, and an overall test statistic is computed and compared with tabulated values to determine whether significant differences exist between the populations. The level of confidence in each test is determined by selection of an alpha value. The smaller the value that is selected for alpha, the more confidence that is desired in a statement of statistically significant or nonsignificant differences between populations. Two-sided tests with an alpha value of 0.05 were used for all the comparative tests in this report. To determine the strength of the test, p-values for all tests were reported. The lower the p-value, the stronger the case that statistically significant differences exist between populations.

Trend tests

The seasonal Kendall trend test (Hirsch and others, 1982) was used to determine whether concentrations of selected nutrients or suspended sediment changed significantly during water years 1980–89. The seasonal Kendall test performs a trend test on each of several different seasons by comparing only data from the same season. In this way, differences between successive years are compared and seasonal differences within years are ignored. The overall test for trend is then carried out by using a summed test statistic. Data criteria outlined in a report by Lanfear and Alexander (1990) were met before the seasonal Kendall test was performed.

Concentrations of constituents commonly vary in relation to changes in streamflow. Because trend tests are used to detect changes in constituent concentrations other than those resulting from changes in streamflow, flow-adjustment procedures commonly are performed on the data prior to trend testing. For this report, a locally weighted scatterplot smoothing (LOWESS) procedure was used to adjust data for flow (Helsel and Hirsch, 1992, p. 288). However, for stations where anthropogenic activity has altered the probability distribution of streamflow, or where more than 10 percent of the data are censored, flow adjustment should not be performed. Streamflows in most parts of the upper Snake River Basin are regulated by reservoir releases and diversions. Stations on streams that are not regulated are generally those in the more nearly pristine or unaffected parts of the basin where a large percentage of the water-quality data are censored values. For these reasons, only selected constituents at two stations were adjusted for streamflow prior to trend analysis.

Constituent transport

Transport of selected nutrients and suspended sediment was estimated using a constituent transport model (T.A. Cohn and others, USGS, written commun., 1992). The model uses multiple regression to derive constituent loads on the basis of the relation of constituent concentration to several predictor variables. The form of the regression equation is:

$$ln(CQ) = I + a(lnQ) + b(t) + c[\text{sine}(2\pi T)] + d[\text{cosine}(2\pi t)],$$

where ln is natural logarithm; C is concentration, in milligrams per liter; Q is streamflow, in cubic feet per second; I is the regression intercept; t is time, in decimal years beginning at the start of the model calibration period; π is equal to 3.1416; and a, b, c, and d are regression coefficients. The time component in this equation accounts for long-term trends in constituent concentrations. Thus, if a constituent at a station exhibited a decreasing concentration during the period of assessment, the decreasing trend would be accounted for in the $b(t)$ term on the right side of the equation. The sine and cosine of time components account for seasonal variations in constituent concentrations.

The model was calibrated using instantaneous streamflow measurements and constituent concentration data collected during water years 1980–89. The best-fit regression model for total nitrogen, total phosphorus, and suspended sediment at selected stations was constructed by adding and eliminating predictor variables in the equation (stepwise regression) until a best-fit model was obtained. The best-fit model was determined, in general, to be the model with the smallest standard error and the largest coefficient of determination. Thus, not all the predictor variables were used for all the load estimates.

Once a suitable model was developed for a specific constituent at a specific station, daily streamflow values at the station were used to calculate annual loads. Values for loads were not presented when the standard error of the estimate was larger than 30 percent of the calculated load. A 90-percent confidence interval for each load estimate was calculated on the basis of the standard error of prediction for the estimated load.

ASSESSMENT OF CURRENT CONDITIONS AND LONG-TERM TRENDS

Nutrients

In this report, nutrients are defined as inorganic compounds that contain nitrogen and phosphorus. Forms of nitrogen in water include organic nitrogen, ammonia, nitrite, and nitrate. In well-oxygenated alluvial streams, nitrate is usually the dominant form of nitrogen dissolved in the water column, and only small concentrations of ammonia and nitrite are present. Phosphorus exists in nature almost exclusively as phosphate and can be present in organic compounds, in the ionic form, or as an insoluble complex with cationic metals, primarily iron, aluminum, and calcium.

In an aqueous system enriched with dissolved nitrogen and phosphorus, increased primary production can result in algal blooms and aquatic macrophyte growth. This is especially evident in water bodies where a slow current and small suspended sediment concentrations allow uninhibited penetration of light. When this plant material dies, it becomes an additional source of nitrogen and phosphorus stored as a layer of detritus in the bottom sediments. As a result of the additional detritus, biochemical oxygen demand (BOD) increases, concentrations of dissolved oxygen decrease, and concentrations of dissolved ammonia gas increase. Lack of dissolved oxygen and elevated concentrations of dissolved ammonia can be stressful to aquatic organisms. Because of this stored pool of nutrients on the bottom, excessive primary production in a river or lake can continue even when outside sources of nitrogen and phosphorus are eliminated (Waite, 1984, p. 126).

NUTRIENT INPUTS

The natural cycles of nitrogen and phosphorus can be altered by anthropogenic additions of nitrogen and phosphorus to a water body. Anthropogenic sources include applications of synthetic fertilizers, manure from cattle and other farm animals, atmospheric inputs resulting from combustion of fossil fuels, and effluent from industrial and wastewater-treatment facilities.

The average annual loads of nitrogen and phosphorus introduced to the upper Snake River Basin during 1985–90 were about 184,000 and 63,000 tons, respectively (fig. 11). Of these totals, approximately 115,000 tons of nitrogen (62 percent) and 45,000 tons of phosphorus (71 percent) came from fertilizer application (EPA, 1990). Manure production based on a cattle population of about 1.1 million (Idaho Agricultural Statistics Service, 1985–90), was the second largest input of nitrogen and phosphorus, accounting for about 30 and 27 percent of the total input, respectively. Atmospheric inputs of nitrogen were estimated using precipitation chemistry data collected at four National Atmospheric Deposition Program stations within and near the boundaries of the basin (Colorado State University, written commun., 1993). Wet deposition accounted for approximately 10,000 tons, or 5 percent of the total annual nitrogen input. Inputs of nitrogen from dry deposition were not estimated. Precipitation chemistry data for input of atmospheric phosphorus were not available. Industrial and municipal point source inputs of nutrients were small compared with nonpoint sources, accounting for only 2 and 1 percent of the total nitrogen and phosphorus load to the basin, respectively. Thirteen major (mean daily discharge of more than 0.1 Mgal/d) wastewater-treatment facilities are located on the main stem of the Snake River and its major tributaries. These facilities, with a combined mean daily discharge of 26.6 Mgal/d, annually contributed only 0.2 percent of the total nitrogen and 0.5 percent of the total phosphorus load to the upper Snake River Basin during 1985–90.

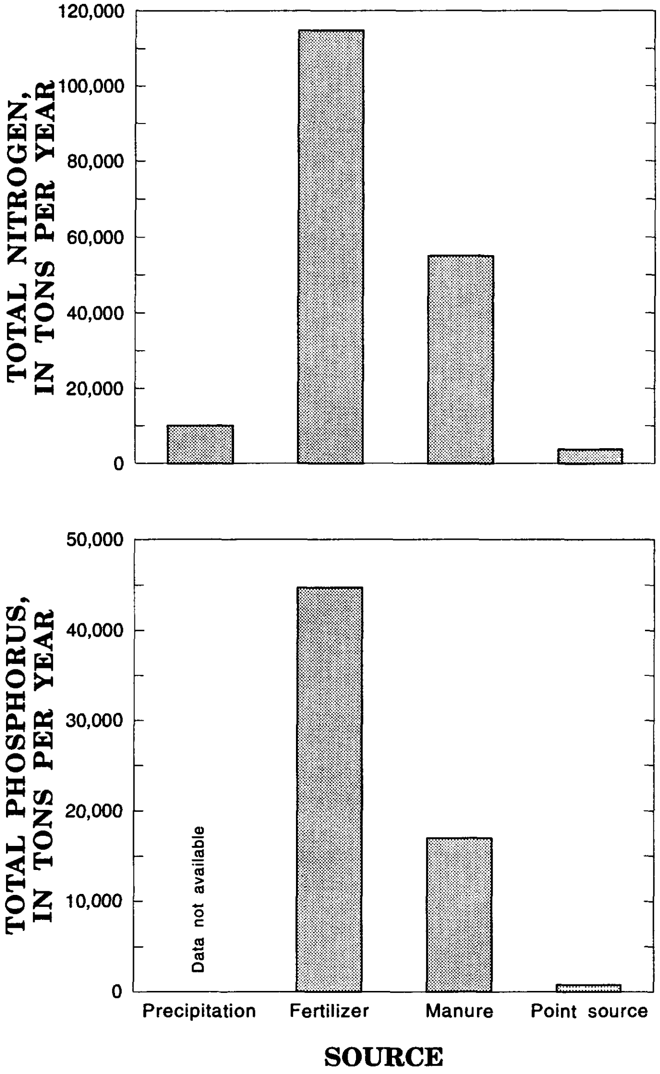

Figure 11. Source and quantity of nitrogen and phosphorus inputs to the upper Snake River Basin, 1985–90.

SPATIAL AND TEMPORAL CHARACTERISTICS OF DATA

Concentrations of nitrogen and phosphorus compounds in surface water were assessed quantitatively using data collected at 19 stations in the upper Snake River Basin (fig. 12). The stations were chosen on the basis of data-selection criteria described earlier in the report. Of the 19 stations selected for analysis, 8 are located on the main stem of the Snake River and 7 are located at or near the mouths of major tributary basins. A summary of the physical, hydrologic, and land use/land cover characteristics for each of the selected stations is given in table 5.

The temporal distribution of samples collected at the selected stations for nutrient analysis is shown in figure 13. After a steady increase in the number of nutrient samples collected from 1980 to 1983, the number of samples collected decreased dramatically. When a statewide surface-water-quality monitoring program was established in water year 1989, the number of samples collected in the upper Snake River Basin increased. Samples were collected at the 19 nutrient stations in all months during the year; however, since water year 1982, nutrient samples at the two NASQAN stations 7 and 29 (table 5) have been collected only once every 2 months, resulting in the bimonthly sampling pattern displayed in figure 13. More samples were collected during April through September (452) than during the other 6 months of the year (406) because of interest in agricultural effects on surface-water quality during the growing season.

The distribution of nutrient samples collected over the range of historical streamflows at three main-stem stations is shown in figure 14. The upper and lower deciles of flow are well represented at all but station 4, where only two samples were collected at exceedance frequencies of larger than 90 percent. The number of samples collected between exceedance frequencies of 50 and 90 percent at station 7 is small because streamflow is regulated at Palisades Reservoir upstream from the station. During the spring and summer, streamflow from Palisades Reservoir is kept at or near high-flow conditions to meet downstream irrigation demands. During nonirrigation parts of the year, streamflow is maintained at a minimum flow. Thus, streamflows at

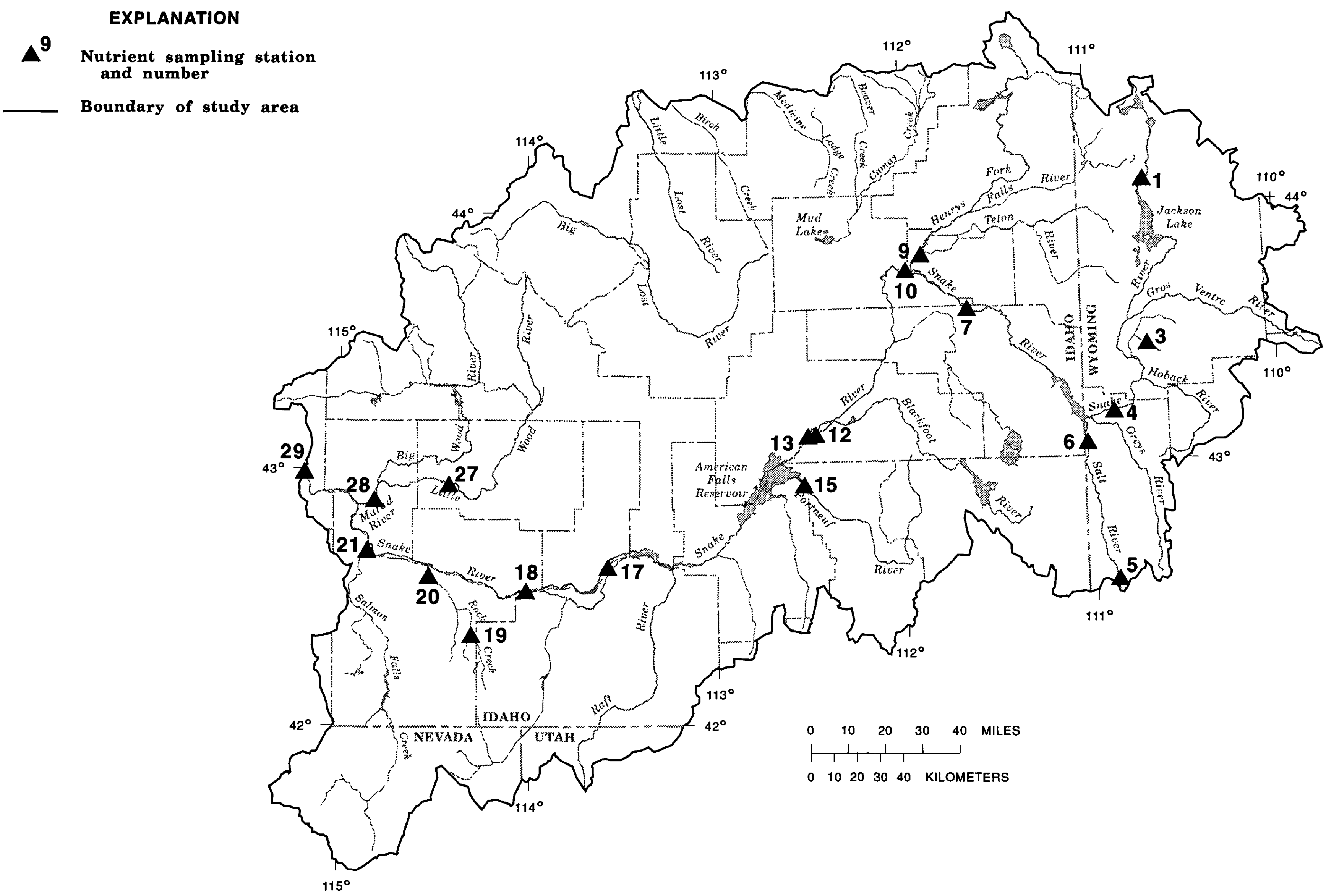

Figure 12. Locations of stations in the upper Snake River Basin selected for quantitative assessment of nutrients, water years 1980–89.

exceedance frequencies between 50 and 90 percent at the Snake River near Heise gaging station are rare.

ASSESSMENT OF CURRENT CONDITIONS

Median concentrations of nitrite plus nitrate and total phosphorus at stations in the basin with at least five analyses are shown in figures 15 and 16. Stations in the central and southern parts of the Henrys Fork tributary drainage basin, near American Falls Reservoir and in tributary drainage basins southeast of American Falls Reservoir, and near the downstream reaches of the main stem of the Snake River have the largest median concentrations of nitrite plus nitrate and total phosphorus. These stations are located mostly in areas of agricultural land use. Stations in the northern and eastern parts of the basin, where agricultural land use is less extensive, have the smallest concentrations of nitrite plus nitrate and total phosphorus. Nutrient concentrations in some areas in the basin, primarily in tributary drainages, could not be evaluated because of a lack of stations with data.

Nutrient concentrations in samples collected during water years 1980–89 at the stations used in the quantitative analysis are summarized in table 6. On the basis of median values, most of the total nitrogen in water samples from most of the stations was in the form of total or dissolved nitrite plus nitrate. Most of the remaining nitrogen probably was affiliated with organic compounds. Median concentrations of dissolved ammonia were less than 0.1 mg/L at all the stations where ammonia samples were collected.

Summary statistics in table 6 were calculated separately for total and dissolved nitrite plus nitrate. However, for boxplots, dissolved nitrite plus nitrate values were used. When dissolved nitrite plus nitrate concentrations were not available, total concentrations were substituted for construction of the boxplots.

Boxplots of nitrite plus nitrate (fig. 17) indicate that concentrations in the Snake River generally increase in a downstream direction, most likely due to inflow from tributaries, springs, and agricultural drains with elevated concentrations of nutrients. Concentrations of nitrite plus nitrate were largest in samples collected at the mouths of major tributary drainage basins with a large amount of agricultural activity (stations 20 and 21). Streamflow at station 15 near the mouth of the

Table 5. Physical, hydrologic, and land use/land cover characteristics of stations where nutrient samples were collected in the upper Snake River Basin, water years 1980–89

[Sampling station number refers to figure 12; latitude and longitude are in degrees, minutes, and seconds; mi^2, square miles; BM, hydrologic bench-mark station; NASQAN, National Stream Quality Accounting Network station; USGS, U.S. Geological Survey; IDEQ, Idaho Department of Environmental Quality; USBR, U.S. Bureau of Reclamation; U, unaffected or minimally affected by urban or agricultural land use; M, main stem; A, agriculturally affected; Fo, forest; Rg, rangeland; Wt, water; Bn, barren; Tn, tundra and ice; Ag, agriculture; stations are in Idaho unless otherwise indicated; WY, Wyoming]

Sampling station No.	Station name	Collecting agency	Latitude	Longitude	Drainage area (mi^2)	Land use/ land cover category assigned	Major land use/land cover categories as a percentage of the drainage basin area	Period of record sampled	No. of samples
1	Snake River at Flagg Ranch, WY	USGS	44°05'21"	110°41'38"	486	U	Fo-83%, Rg-8%, Wt-4%	1987–89	20
3	Cache Creek near Jackson, WY (BM)	USGS	43°27'08"	110°42'12"	10.6	U	Fo-60%, Rg-38%, Bn-2%	1980–89	78
4	Snake River near Alpine, WY	USGS	43°11'47"	110°53'18"	3,460	M	Fo-64%, Rg-24%, Tn-6%	1980–86	46
5	Salt River near Smoot, WY	USGS	42°32'35"	110°53'37"	47.8	U	Fo-71%, Rg-27%, Ag-1%	1981–85	38
6	Salt River near Etna, WY	USGS	43°04'47"	111°02'12"	829	A	Fo-51%, Rg-31%, Ag-18%	1981–86	66
7	Snake River near Heise (NASQAN)	USGS	43°36'45"	111°39'33"	7,770	M	Fo-61%, Rg-26%, Ag-6%	1980–89	71
9	Henrys Fork near Rexburg	USGS	43°49'34"	111°54'15"	2,920	A	Fo-49%, Ag-26%, Rg-19%	1988–89	9
10	Snake River near Menan	IDEQ	43°45'10"	111°58'50"	9,100	M	Fo-56%, Rg-23%, Ag-14%	1982–83	24
12	Blackfoot River near Blackfoot	USGS	43°07'50"	112°28'35"	1,295	A	Rg-62%, Fo-21%, Ag-13%	1988–89	13
13	Snake River near Blackfoot	IDEQ	43°07'31"	112°31'06"	11,310	M	Fo-45%, Rg-29%, Ag-19%	1980–83	48
15	Portneuf River at Siphon Road	IDEQ	42°56'10"	112°32'40"	1,250	A	Rg-52%, Ag-36%, Fo-10%	1980–83	48
17	Snake River at Burley	IDEQ	42°37'12"	113°35'19"	16,500	M	Rg-40%, Fo-30%, Ag-22%	1981–89	29
18	Snake River at Milner	USBR	42°31'41"	114°01'04"	17,180	M	Rg-46%, Fo-26%, Ag-20%	1988–89	25
19	Rock Creek near Rock Creek	IDEQ	42°21'17"	114°18'15"	80.0	U	Fo-67%, Rg-33%	1981–89	81
20	Rock Creek near Twin Falls	IDEQ	42°35'40"	114°31'46"	277	A	Rg-42%, Ag-41%, Fo-14%	1981–89	70
21	Salmon Falls Creek near Hagerman	IDEQ	42°41'15"	114°51'20"	2,120	A	Rg-86%, Fo-9%, Ag-5%	1980–89	55
27	Little Wood River below Shoshone	IDEQ	42°56'41"	114°25'25"	620	A	Rg-66%, Ag-15%, Bn-12%	1987–88	19
28	Malad River above Malad Canyon	IDEQ	42°53'00"	114°55'00"	2,990	A	Rg-64%, Ag-14%, Fo-13%	1980–83	48
29	Snake River at King Hill (NASQAN)	USGS	43°00'08"	115°12'06"	35,800	M	Rg-50%, Fo-23%, Ag-21%	1980–89	70

Portneuf River is derived almost exclusively from springs discharging just upstream from the sampling station. The springs are nutrient rich, reflecting a water chemistry affected by irrigated agriculture and industrialization (Perry and others, 1990).

The median dissolved nitrite plus nitrate concentration measured in water leaving the basin at station 29 (Snake River at King Hill) was 1.1 mg/L. Concentrations at the King Hill station are controlled primarily by inflow of springs, which contribute about 5,000 to 6,000 ft^3/s of flow to the Snake River between stations 18 and 29. Dissolved nitrite plus nitrate concentrations measured in spring water in this region ranged from less than 0.5 mg/L to more than 4.0 mg/L; the mean concentration was about 1.5 mg/L (W.H. Low, USGS, written commun., 1992).

Concentrations of total phosphorus, in general, also tended to increase in a downstream direction, although large differences in total phosphorus

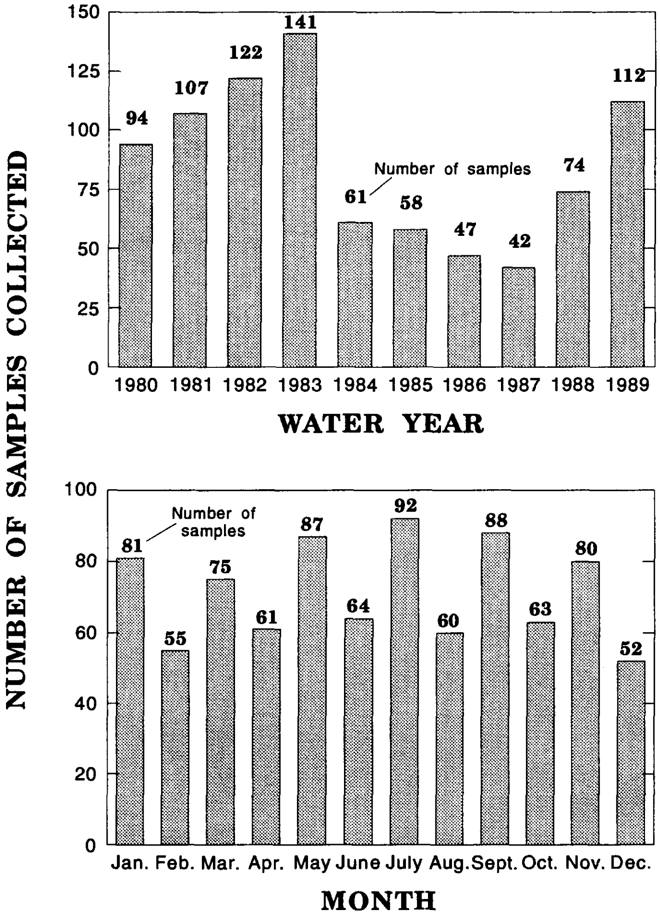

Figure 13. Temporal distribution of nutrient samples collected at stations in the upper Snake River Basin used for quantitative assessment of nutrients, water years 1980–89.

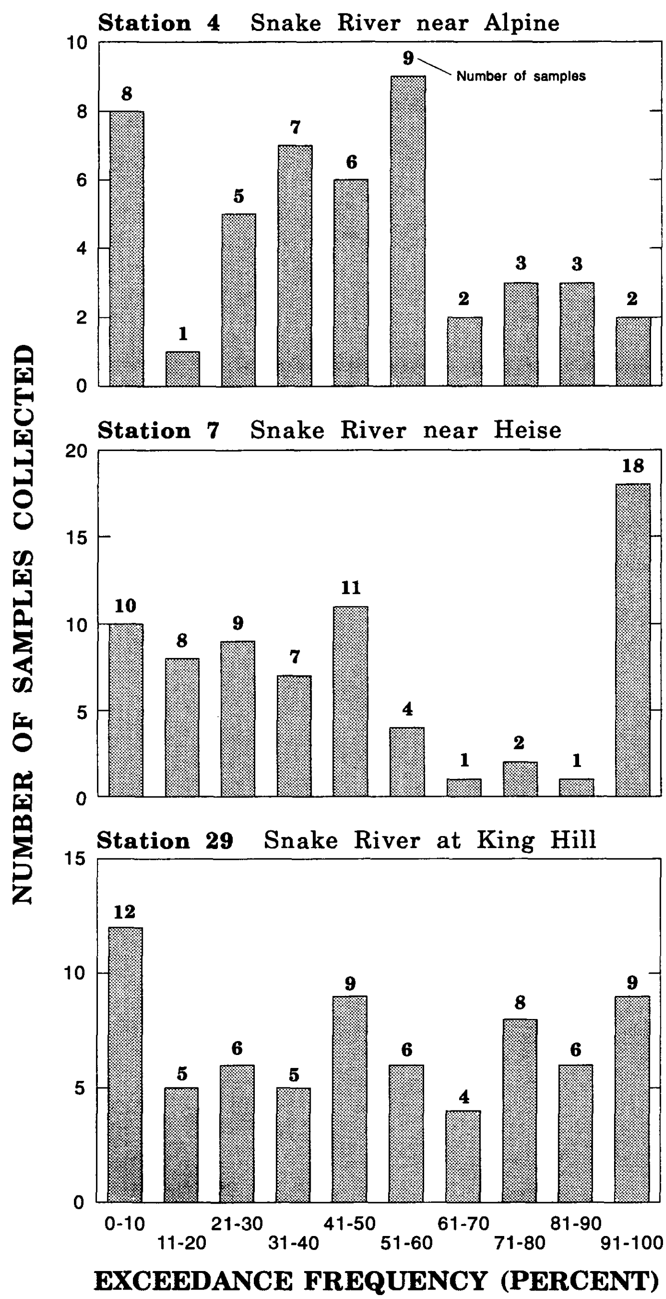

Figure 14. Distribution of nutrient samples collected over the range of historical streamflow for selected stations in the upper Snake River Basin, water years 1980–89. (Station numbers refer to figure 12 and table 5)

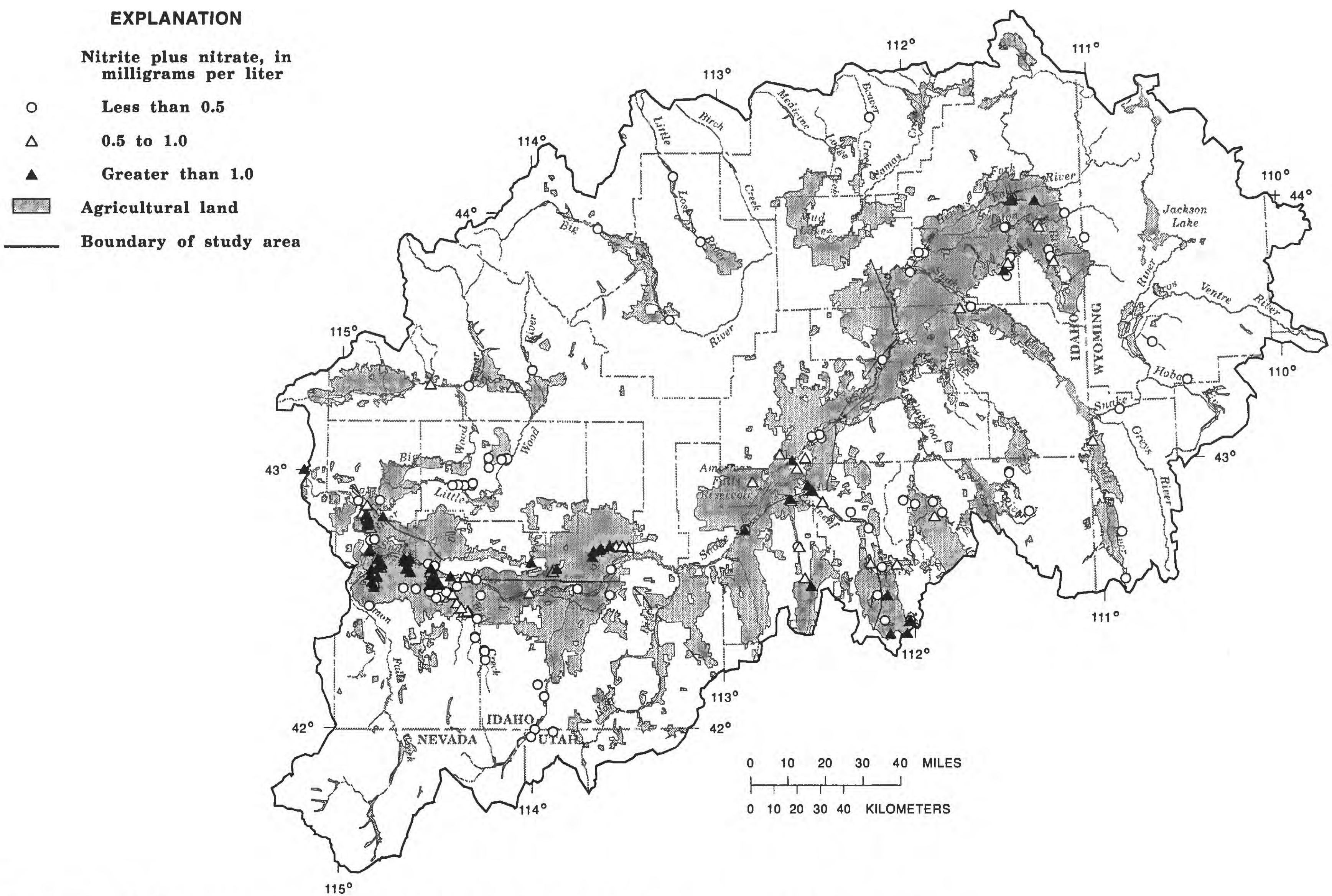

Figure 15. Median concentrations of nitrite plus nitrate at stations in the upper Snake River Basin with at least five analyses, water years 1980–89. (Total concentrations were used when dissolved concentrations were not available)

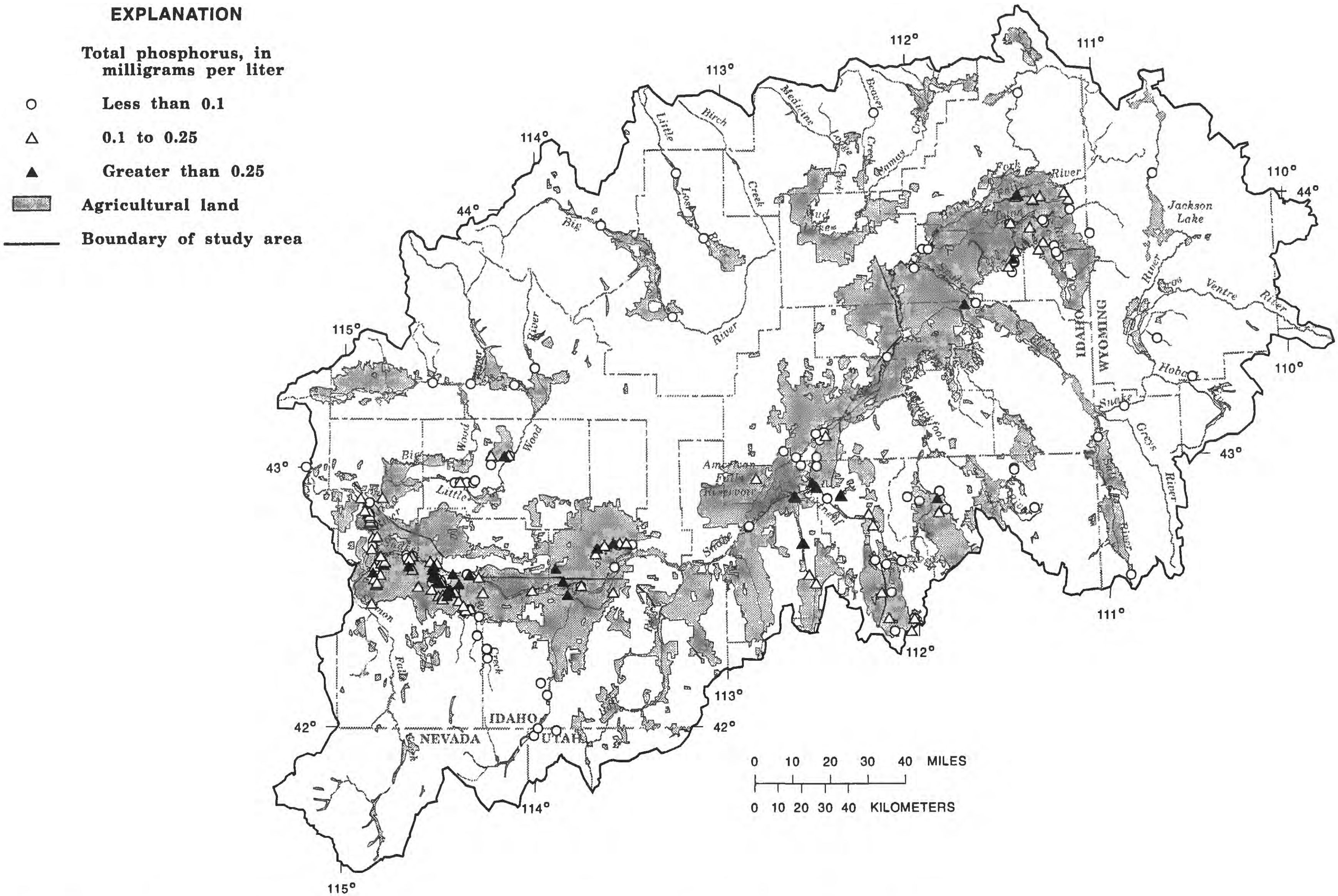

Figure 16. Median concentrations of total phosphorus at stations in the upper Snake River Basin with at least five analyses, water years 1980–89.

Table 6. Statistical summary of nutrient concentrations at selected stations in the upper Snake River Basin, water years 1980–89

[Sampling station number refers to figure 12; mg/L, milligrams per liter; N, nitrogen; P, phosphorus; <, less than; —, values for the 10th and 90th percentiles not included for stations with fewer than 15 observations; stations are in Idaho unless otherwise indicated; WY, Wyoming]

Sampling station No.	Station name	Period of record	No. of samples	Concentration at indicated percentile, in mg/L				
				10	25	50	75	90
Nitrogen, total as N								
1	Snake River at Flagg Ranch, WY	1987–89	20	<0.300	0.300	0.350	0.575	1.600
3	Cache Creek near Jackson, WY	1981–89	65	<.300	<.300	.400	.610	.832
7	Snake River near Heise	1980–89	69	<.300	.390	.550	.720	1.100
9	Henrys Fork near Rexburg	1988–89	9	—	.300	.466	.500	—
10	Snake River near Menan	1982–83	24	.210	.275	.355	.545	.995
12	Blackfoot River near Blackfoot	1988–89	13	—	.300	.510	.740	—
13	Snake River near Blackfoot	1980–83	48	.270	.425	.745	1.075	1.730
15	Portneuf River at Siphon Road	1980–83	48	2.150	2.700	3.150	3.600	4.010
17	Snake River at Burley	1981–89	29	.380	.525	.770	1.000	1.600
18	Snake River at Milner	1988–89	24	.590	.860	1.150	1.875	2.450
19	Rock Creek near Rock Creek	1983–89	66	.051	.180	.280	.543	.937
20	Rock Creek near Twin Falls	1983–89	66	1.870	2.300	2.750	3.300	3.930
21	Salmon Falls Creek near Hagerman	1980–89	55	2.140	2.600	3.600	4.500	5.280
27	Little Wood River below Shoshone	1987–88	19	.430	.670	.930	1.000	1.400
28	Malad River above Malad Canyon	1980–83	47	.402	.530	.700	1.000	1.420
29	Snake River at King Hill	1980–89	69	1.100	1.500	1.800	2.100	2.400
Nitrogen, ammonia, dissolved as N								
1	Snake River at Flagg Ranch, WY	1987–89	20	<.010	.012	.030	.047	.059
3	Cache Creek near Jackson, WY	1981–89	65	<.010	.030	.050	.070	.104
7	Snake River near Heise	1980–89	69	<.010	.020	.040	.070	.130
18	Snake River at Milner	1988–89	25	<.010	.030	.060	.215	.338
29	Snake River at King Hill	1980–89	69	<.010	.020	.050	.070	.120
Nitrogen, nitrite plus nitrate, total as N								
3	Cache Creek near Jackson, WY	1980–82	36	<.100	<.100	.100	.120	.173
7	Snake River near Heise	1980–81	22	<.100	<.100	.115	.165	.287
9	Henrys Fork near Rexburg	1988–89	9	—	.100	.200	.300	—
10	Snake River near Menan	1982–83	24	.064	.100	.155	.221	.370
12	Blackfoot River near Blackfoot	1988–89	13	—	<.100	.100	.200	—
13	Snake River near Blackfoot	1980–83	48	.068	.093	.183	.230	.453
15	Portneuf River at Siphon Road	1980–83	48	.858	1.150	1.680	2.045	2.506
17	Snake River at Burley	1981–89	29	.071	.140	.505	.620	.958
19	Rock Creek near Rock Creek	1983–89	66	.023	.066	.153	.280	.548
20	Rock Creek near Twin Falls	1983–89	67	1.104	1.530	2.070	2.660	3.472
21	Salmon Falls Creek near Hagerman	1980–89	55	1.650	1.980	3.140	3.970	4.580
27	Little Wood River below Shoshone	1987–88	19	.011	.038	.305	.777	.850
28	Malad River above Malad Canyon	1980–83	47	.012	.023	.148	.491	.741
29	Snake River at King Hill	1980–81	22	.608	.928	1.300	1.400	1.640
Nitrogen, nitrite plus nitrate, dissolved as N								
1	Snake River at Flagg Ranch, WY	1987–89	20	<.100	<.100	<.100	<.100	.460
3	Cache Creek near Jackson, WY	1980–89	78	<.100	<.100	<.100	.120	.160
4	Snake River near Alpine, WY	1980–86	46	<.100	<.100	<.100	.160	.557
5	Salt River near Smoot, WY	1981–85	38	<.100	<.100	<.100	.100	.300
6	Salt River near Etna, WY	1981–86	66	.370	.600	.900	1.350	1.990
7	Snake River near Heise	1980–89	71	<.100	<.100	.130	.170	.208
9	Henrys Fork near Rexburg	1989	6	—	<.100	.215	.265	—
12	Blackfoot River near Blackfoot	1988–89	10	—	<.100	.145	.240	—
18	Snake River at Milner	1988–89	25	<.100	.200	.700	1.300	1.834
29	Snake River at King Hill	1980–89	69	.450	.960	1.100	1.300	1.600
Phosphorus, total as P								
1	Snake River at Flagg Ranch, WY	1987–89	20	<.010	.010	.020	.037	.077
3	Cache Creek near Jackson, WY	1980–89	78	<.010	.010	.020	.040	.060
4	Snake River near Alpine, WY	1980–86	46	.010	.010	.030	.043	.090
5	Salt River near Smoot, WY	1981–85	38	<.010	.010	.030	.040	.139
6	Salt River near Etna, WY	1980–86	66	<.010	.010	.040	.093	.206
7	Snake River near Heise	1980–89	71	<.010	.010	.020	.050	.100
9	Henrys Fork near Rexburg	1988–89	9	—	.015	.030	.050	—
10	Snake River near Menan	1982–83	24	.050	.050	.050	.095	.125
12	Blackfoot River near Blackfoot	1988–89	13	—	.035	.050	.055	—
13	Snake River near Blackfoot	1980–83	48	.050	.060	.110	.140	.408
15	Portneuf River at Siphon Road	1980–83	48	.279	.310	.420	.507	.615
17	Snake River at Burley	1981–89	29	.050	.060	.080	.100	.130
18	Snake River at Milner	1988–89	25	.075	.110	.140	.260	.318
19	Rock Creek near Rock Creek	1982–89	81	.050	.050	.050	.070	.118
20	Rock Creek near Twin Falls	1983–89	69	.060	.090	.160	.245	.315
21	Salmon Falls Creek near Hagerman	1980–89	55	.050	.080	.100	.150	.184
27	Little Wood River below Shoshone	1987–88	19	.050	.050	.090	.140	.180
28	Malad River above Malad Canyon	1980–83	48	.060	.082	.130	.160	.211
29	Snake River at King Hill	1980–89	70	.041	.060	.070	.090	.119
Phosphorus, dissolved as P								
1	Snake River at Flagg Ranch, WY	1987–89	20	<.010	<.010	.010	.025	.048
3	Cache Creek near Jackson, WY	1981–89	64	.010	.010	.020	.030	.050
7	Snake River near Heise	1980–89	69	<.010	<.010	.010	.030	.050
29	Snake River at King Hill	1980–89	70	.020	.040	.050	.060	.070
Phosphorus, orthophosphate, dissolved as P								
1	Snake River at Flagg Ranch, WY	1987–89	20	<.010	<.010	.015	.027	.039
3	Cache Creek near Jackson, WY	1980–89	57	<.010	.010	.020	.030	.050
7	Snake River near Heise	1982–89	47	<.010	<.010	.020	.030	.050
9	Henrys Fork near Rexburg	1988–89	9	—	<.010	<.010	.015	—
12	Blackfoot River near Blackfoot	1988–89	13	<.010	<.010	<.010	<.010	.020
17	Snake River at Burley	1989	6	—	.080	.080	.085	—
18	Snake River at Milner	1988–89	25	.020	.023	.062	.190	.292
19	Rock Creek near Rock Creek	1982–89	79	<.010	.013	.021	.033	.041
20	Rock Creek near Twin Falls	1983–89	70	.016	.023	.038	.052	.068
21	Salmon Falls Creek near Hagerman	1988–89	8	—	.080	.125	.175	—
27	Little Wood River below Shoshone	1987–88	18	<.010	.010	.027	.075	.136
29	Snake River at King Hill	1982–89	48	.020	.030	.040	.060	.070

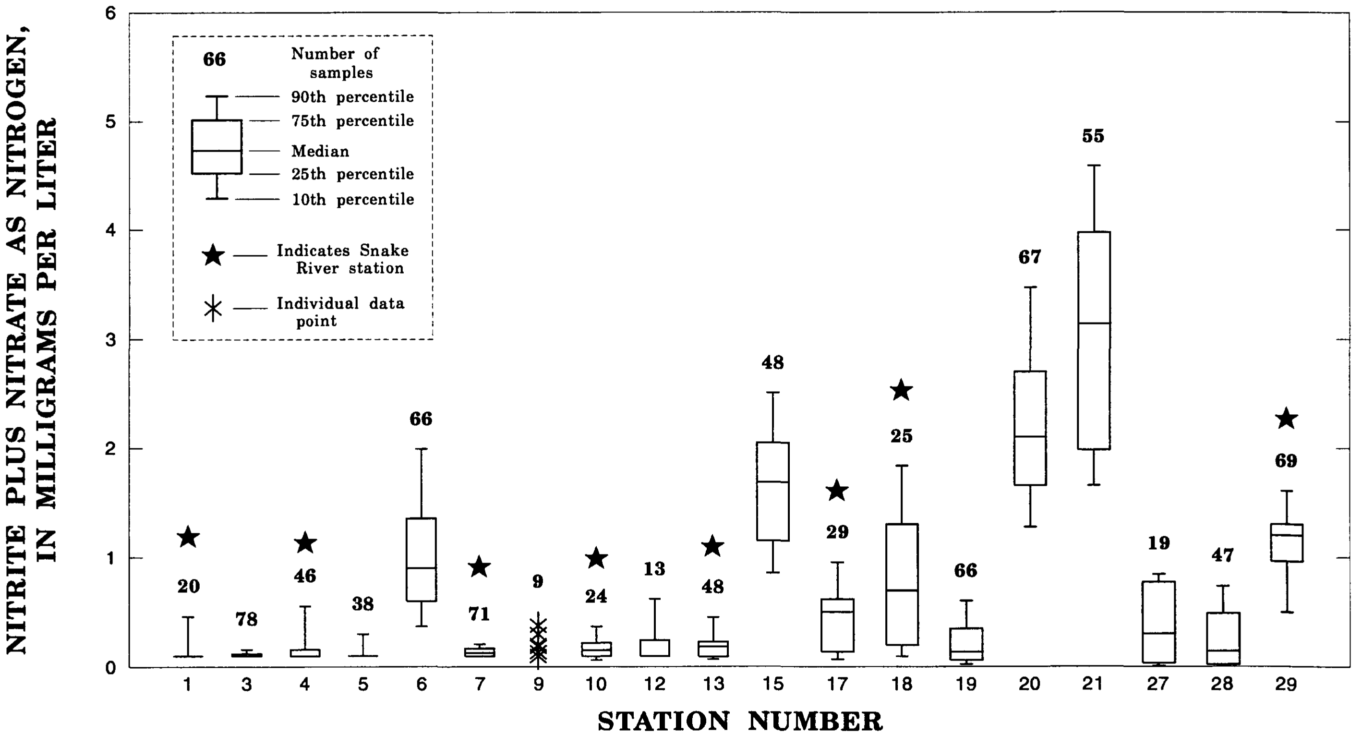

Figure 17. Concentrations of nitrite plus nitrate at stations in the upper Snake River Basin used for quantitative assessment of nutrients, water years 1980–89. (Station numbers refer to figure 12 and table 5. Total concentrations were used for plots when dissolved concentrations were not available; all concentrations are below the 10 milligrams per liter national standard. When data set had fewer than 10 samples, individual values were plotted)

concentrations between stations in the headwaters of the basin and downstream stations were not apparent (fig. 18). This is probably due to retention of phosphorus in main-stem reservoirs and dilution from spring inflows. Median concentrations of total phosphorus did not exceed 0.2 mg/L at any of the stations except 15, near the mouth of the Portneuf River. Elevated concentrations of total phosphorus at station 15 probably are attributable to phosphate-ore processing plants upstream from the station. Phosphate ions probably leach to the ground water upstream from station 15 and ultimately discharge to the river in spring flow.

CORRELATIONS WITH LAND USE

The stations used in the quantitative assessment were classified according to the primary type of land use affecting the water quality at the station (table 5). Because only 19 stations were available for quantitative assessment, the stations were classified as unaffected or minimally affected, agriculturally affected, or main stem. The four stations classified as unaffected were those where upstream urban or agricultural land use did not occur. Eight stations on tributaries to the Snake River were classified as being affected primarily by agriculture, although some small effects from urban land use also may exist. The spatial relation of the stations to agricultural land use is shown in figure 19. Samples collected from stations on the main stem of the Snake River (excluding station 1) are cumulatively affected by multiple anthropogenic factors and are classified separately as main-stem stations.

Differences in concentrations of nitrite plus nitrate, dissolved ammonia, total nitrogen, dissolved ortho-

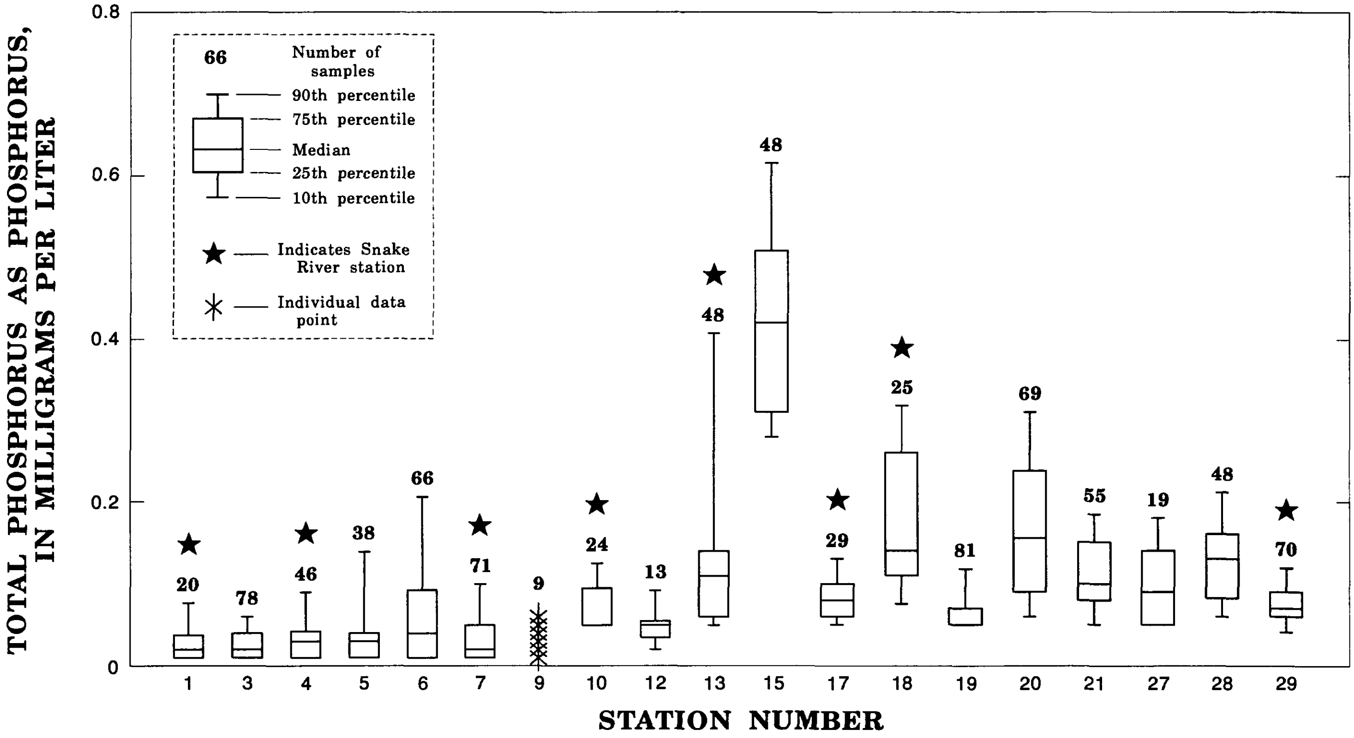

Figure 18. Concentrations of total phosphorus at stations in the upper Snake River Basin used for quantitative assessment of nutrients, water years 1980–89. (Station numbers refer to figure 12 and table 5. When data set had fewer than 10 samples, individual values were plotted)

phosphate, and total phosphorus among the unaffected stations, the agriculturally affected stations, and the main-stem stations were assessed (fig. 20). Stations classified as agriculturally affected had significantly larger concentrations of nitrite plus nitrate, total nitrogen, dissolved orthophosphate, and total phosphorus ($p<0.05$) compared with concentrations at unaffected stations, and had significantly larger concentrations of nitrite plus nitrate, total nitrogen, and total phosphorus compared with the main-stem stations. Concentrations of dissolved orthophosphate were not significantly different between the agriculturally affected and main-stem stations. Main-stem stations had significantly larger concentrations of nitrite plus nitrate, total nitrogen, dissolved orthophosphorus, and total phosphorus compared with unaffected stations. Differences in dissolved ammonia concentrations between unaffected and main-stem stations were not significant. Sample analyses for dissolved ammonia were not available in a sufficient quantity at agriculturally affected stations for comparative statistical analysis.

In two tributary drainage basins, samples were collected at stations upstream and downstream from areas of intensive agriculture: Rock Creek in Idaho (fig. 21) and the Salt River in Wyoming (fig. 22). Significant differences exist between the upstream and downstream concentrations of nitrite plus nitrate at the Rock Creek and Salt River stations and between total nitrogen, dissolved orthophosphate, and total phosphorus at the Rock Creek stations. Concentrations of total phosphorus were not significantly different between the upstream and downstream stations on the Salt River, possibly due to the ubiquitous phosphate-rich Phosphoria Formation throughout the southeastern part of the upper Snake River Basin (U.S. Department of the Interior and U.S. Department of Agriculture, 1977,

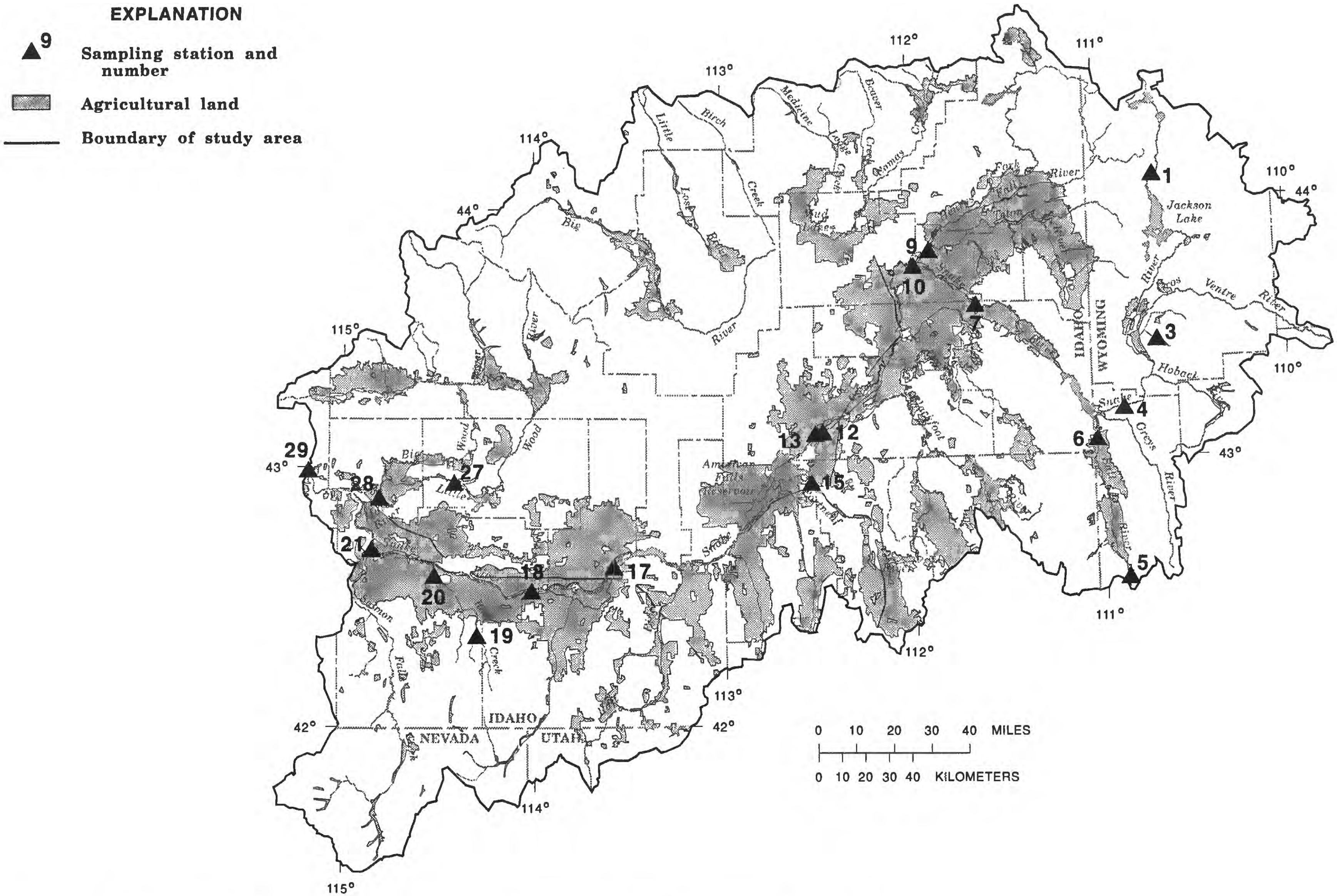

Figure 19. Spatial relation of sampling stations to agricultural land in the upper Snake River Basin. (Station numbers refer to table 5)

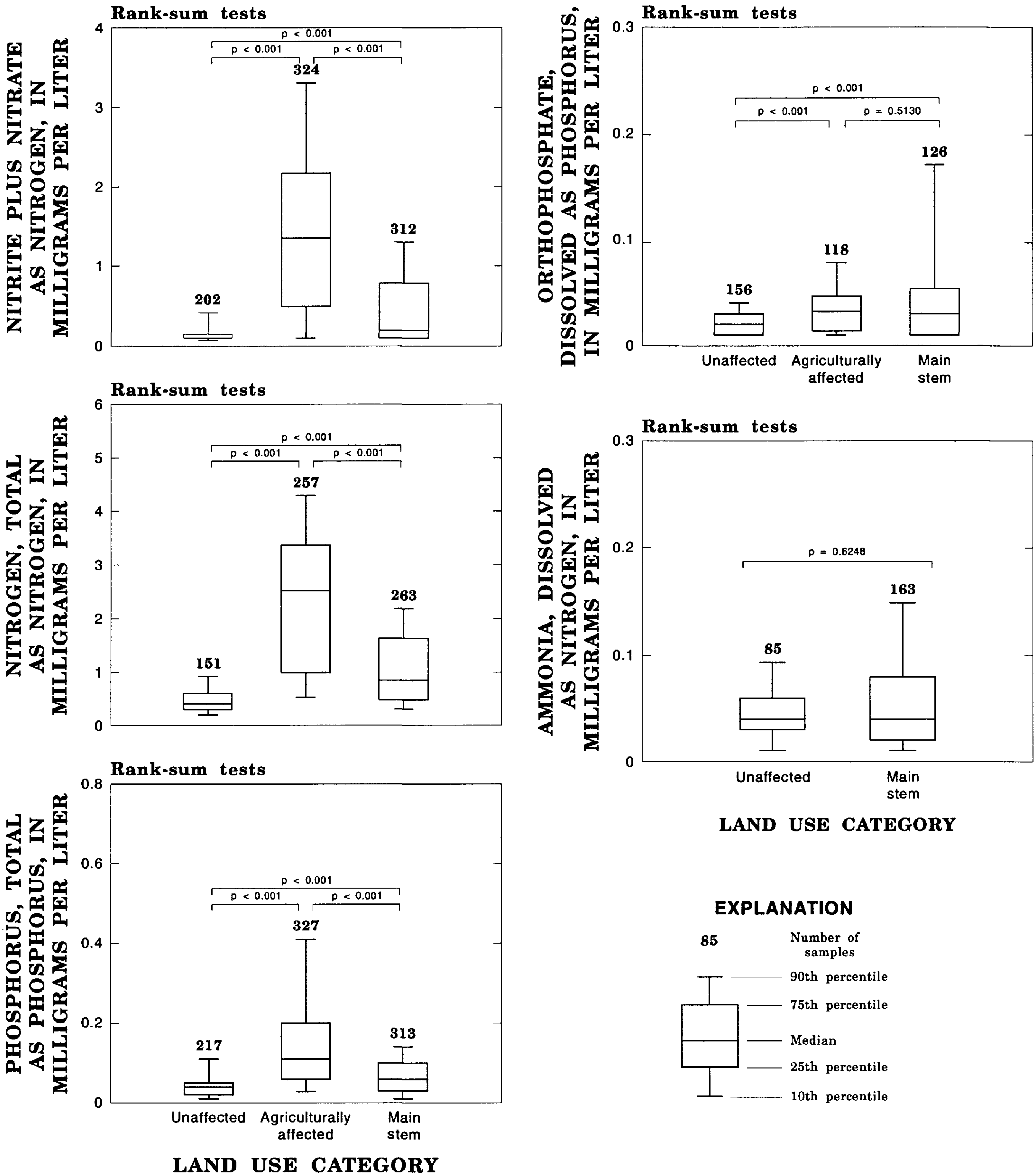

Figure 20. Concentrations of selected nutrients at stations in the upper Snake River Basin categorized by upstream land use/land cover, water years 1980–89. (Land use/land cover categories are from table 5. For nitrite plus nitrate, total concentrations were used when dissolved concentrations were not available. For the three rank-sum tests for each constituent, p-values less than 0.05 indicate significant differences in constituent concentrations between land use/land cover categories)

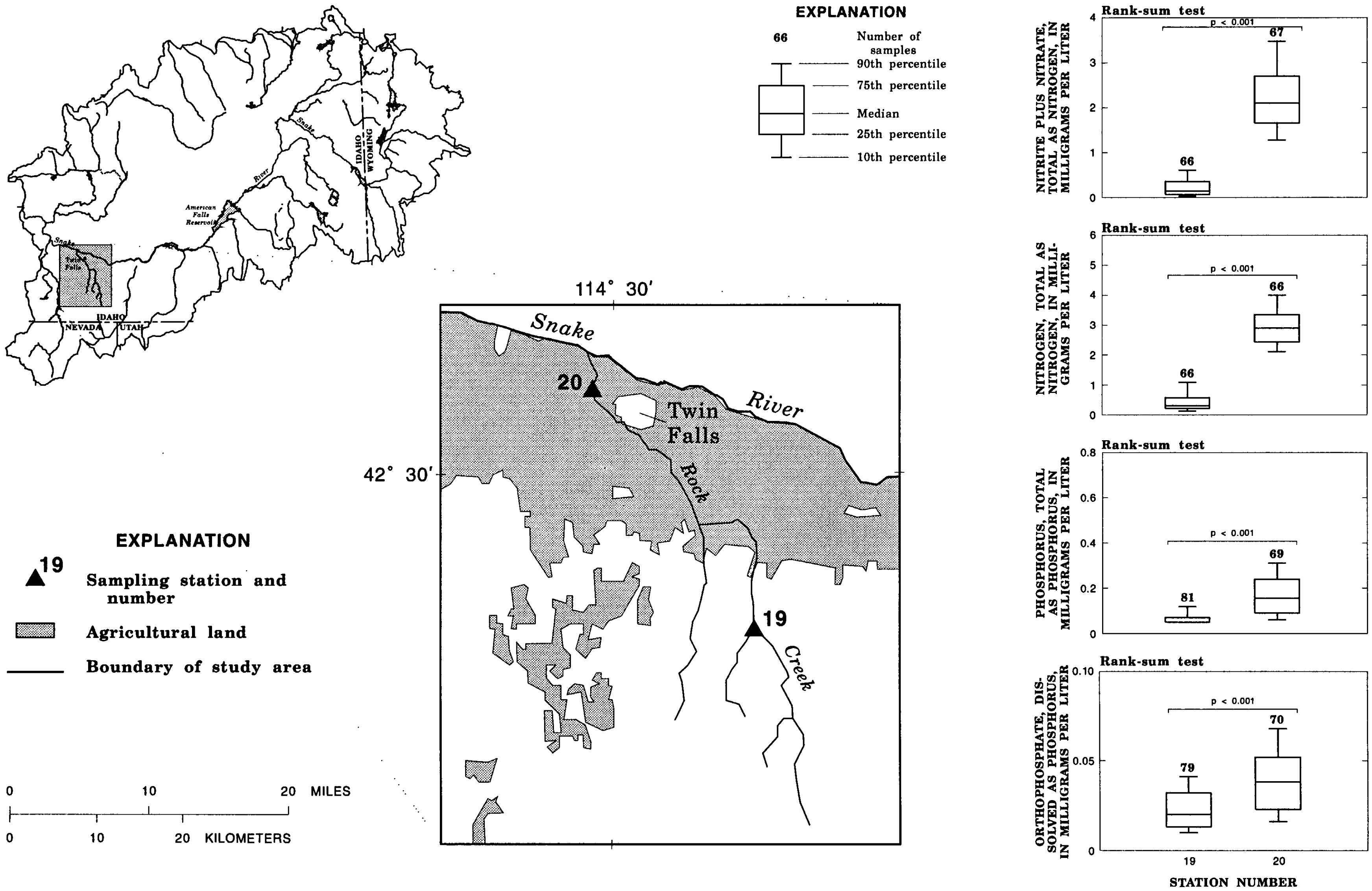

Figure 21. Concentrations of selected nutrients collected from Rock Creek at stations upstream and downstream from areas of intensive agriculture, water years 1980–89. (Station numbers refer to figure 12 and table 5. For rank-sum tests between stations, p-values less than 0.05 indicate significant differences in constituent concentrations between stations)

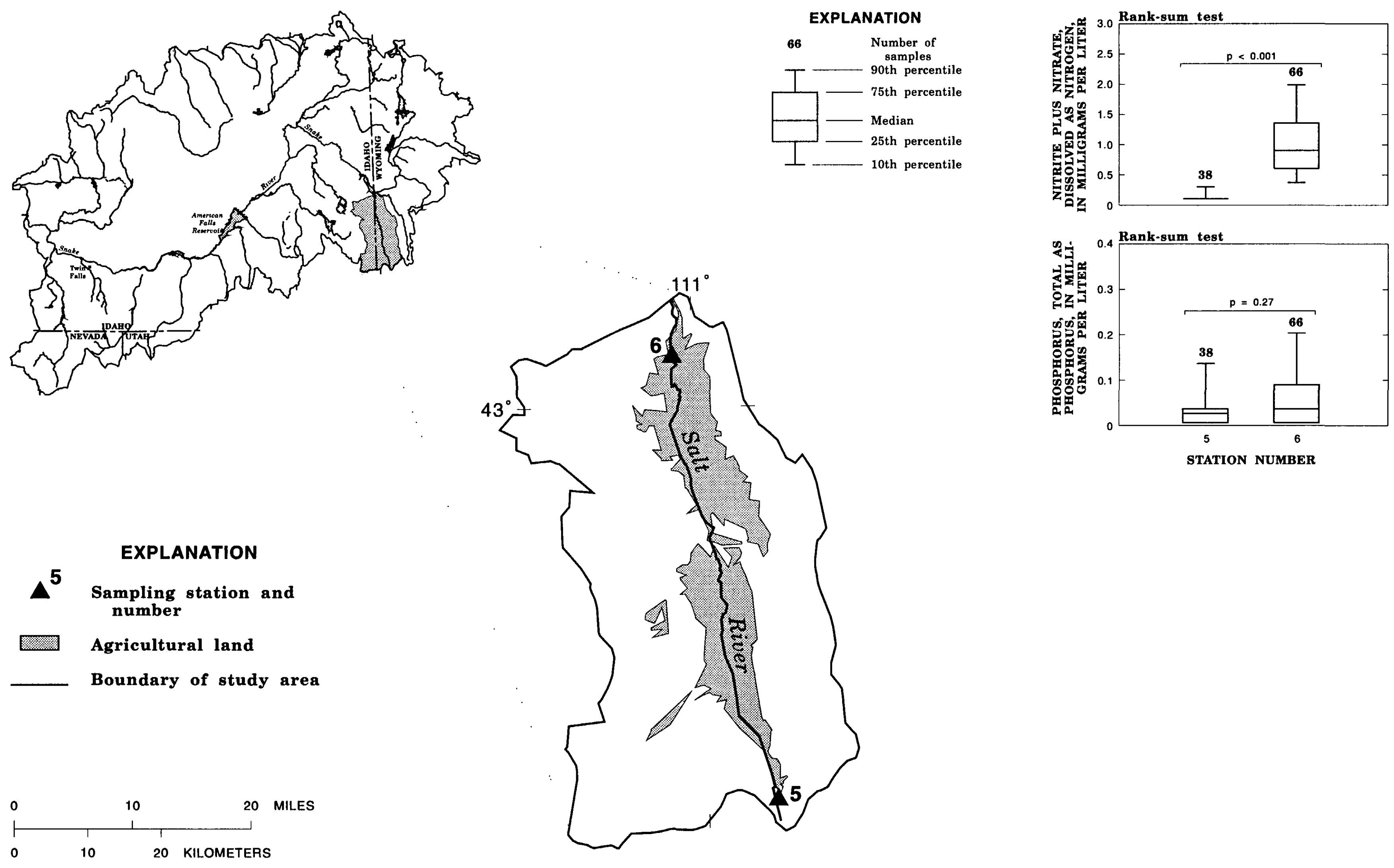

Figure 22. Concentrations of selected nutrients collected from the Salt River at stations upstream and downstream from areas of intensive agriculture, water years 1980–89. (Station numbers refer to figure 12 and table 5. For rank-sum tests between stations, p-values less than 0.05 indicate significant differences in constituent concentrations between stations)

p. I–40). Differences in concentrations of dissolved ammonia in both basins and in concentrations of total nitrogen and orthophosphate in the Salt River Basin could not be assessed due to a lack of data.

Concentrations of nitrite plus nitrate, total nitrogen, and total phosphorus show seasonal variations at unaffected stations and at agriculturally affected stations (figs. 23 and 24). At unaffected stations, nitrite plus nitrate and total nitrogen concentrations are slightly larger from April to June, possibly due to flushing of residual nitrogen from soils during snowmelt. At the agriculturally affected stations, concentrations of nitrite plus nitrate and total nitrogen are smallest from April to June. The smaller nitrite plus nitrate and total nitrogen concentrations during the spring months at stations affected by agriculture most likely result from the combined effects of dilution from increased streamflow and uptake of excess nitrate by aquatic plants. As streamflows decrease later in the summer, ground water, which is a source of nitrogen to streams in parts of the Snake River Basin, becomes an increasingly important component of streamflow, and nitrite plus nitrate and total nitrogen concentrations in the water column increase. In addition, aquatic plants die and mineralize, contributing additional nitrogen to streams.

Concentrations of total phosphorus at unaffected stations, as well as at agriculturally affected stations, are largest from April to June. The most likely explanation is that total phosphorus concentrations typically display a direct relation to concentrations of suspended sediment, due to the presence of insoluble calcium, aluminum, and iron phosphate minerals associated with the sediment (Waite, 1984, p. 119). Because suspended sediment concentrations are usually largest in the spring as a result of snowmelt and agricultural runoff, concentrations of total phosphorus in surface-water samples are also largest during the spring. Concentrations of dissolved orthophosphate and ammonia at unaffected stations and dissolved orthophosphate at agriculturally affected stations showed no significant differences in seasonal concentrations (figs. 23 and 24).

TRENDS

At only five of the stations in the upper Snake River Basin were data for water years 1980–89 sufficient to assess trends in nutrient concentrations. Results of the trend tests are presented in table 7. Assessment of trends in total phosphorus concentrations at stations sampled by the USGS was limited to data collected during water years 1982–89 because of a positive bias in sample concentrations detected in the USGS water-quality laboratory during water years 1980–81 (Alexander and others, 1993).

Because of flow regulation on the main stem of the Snake River and on the downstream sections of Rock Creek, only the Cache Creek and Rock Creek near Rock Creek stations were adjusted for streamflow. Even at these two stations, flow was adjusted only when at least 90 percent of the data were uncensored. Significant downward trends ($p<0.05$) in nutrient concentrations were noted at three stations: dissolved nitrite plus nitrate at Cache Creek near Jackson, total phosphorus at Rock Creek near Twin Falls, and dissolved orthophosphate at Rock Creek near Rock Creek. The reasons for the downward trends in nutrient concentrations at Cache Creek and Rock Creek near Rock Creek are not clear because both of these stations are relatively unaffected by upstream land use. At the Rock Creek near Twin Falls station, a decreasing trend in total phosphorus

Table 7. Trend-test results for nutrients and suspended sediment at selected stations in the upper Snake River Basin, water years 1980–89

[Sampling station number refers to figure 12; N, nitrogen; P, phosphorus; stations are in Idaho unless otherwise indicated; WY, Wyoming; <, less than]

Sampling station No.	Station name	Period of trend assessment	Flow adjusted	Trend	Probability level
Nitrogen, nitrite plus nitrate, dissolved as N					
3	Cache Creek near Jackson, WY	1980–89	No	Downward	0.04
7	Snake River near Heise	1980–89	No	None	.29
29	Snake River at King Hill	1980–89	No	None	.18
Phosphorus, total as P					
3	Cache Creek near Jackson, WY	1982–89	Yes	None	.15
7	Snake River near Heise	1982–89	No	None	.28
19	Rock Creek near Rock Creek	1982–89	No	None	.10
20	Rock Creek near Twin Falls	1983–89	No	Downward	.04
29	Snake River at King Hill	1982–89	No	None	.16
Phosphorus, orthophosphate, dissolved as P					
3	Cache Creek near Jackson, WY	1980–89	No	None	.54
7	Snake River near Heise	1980–89	No	None	.32
19	Rock Creek near Rock Creek	1982–89	Yes	Downward	<.01
20	Rock Creek near Twin Falls	1983–89	No	None	.75
29	Snake River at King Hill	1980–89	No	None	.62
Suspended sediment					
3	Cache Creek near Jackson, WY	1980–89	Yes	None	.48
7	Snake River near Heise	1980–89	No	None	.19
19	Rock Creek near Rock Creek	1982–89	Yes	None	.48
20	Rock Creek near Twin Falls	1983–89	No	Downward	<.01
29	Snake River at King Hill	1980–89	No	None	.94

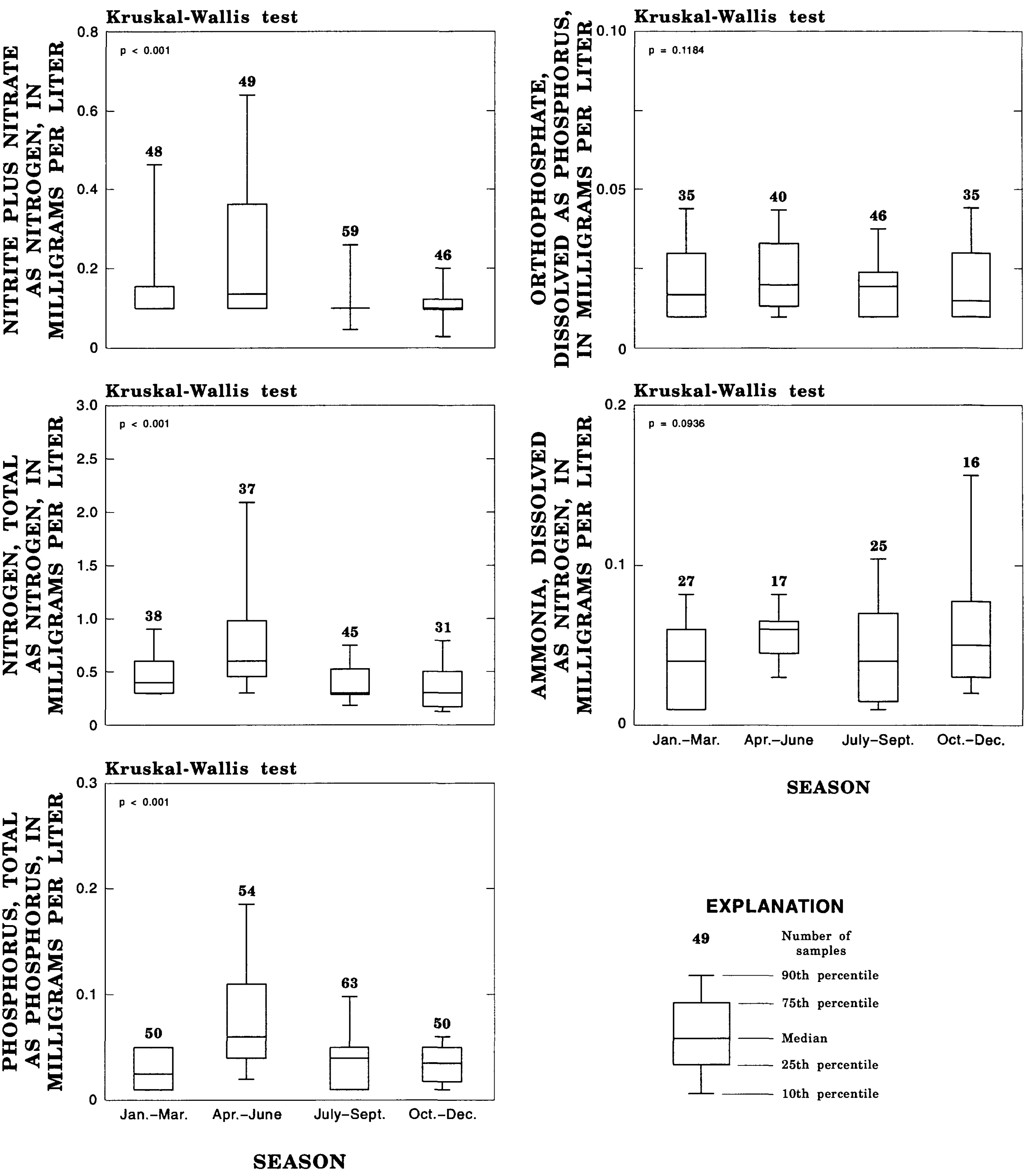

Figure 23. Seasonal concentrations of selected nutrients at stations in the upper Snake River Basin categorized as unaffected or minimally affected by urban or agricultural land use, water years 1980–89. (For nitrite plus nitrate, total concentrations were used when dissolved concentrations were not available. For Kruskal-Wallis tests between seasons, p-values less than 0.05 indicate significant seasonal differences in constituent concentrations)

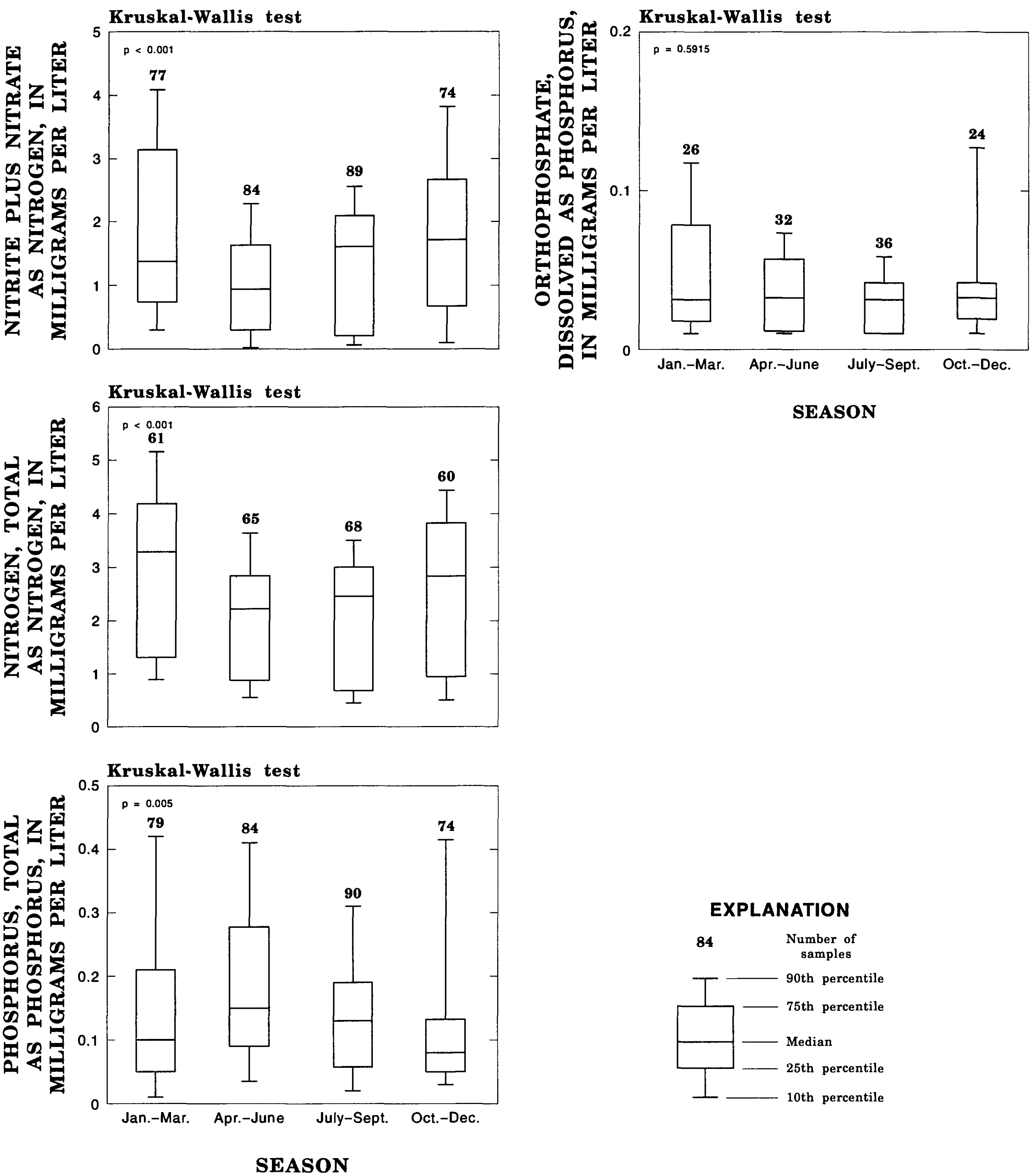

Figure 24. Seasonal concentrations of selected nutrients at stations in the upper Snake River Basin categorized as agriculturally affected, water years 1980–89. (For nitrite plus nitrate, total concentrations were used when dissolved concentrations were not available. For Kruskal-Wallis tests between seasons, p-values less than 0.05 indicate significant seasonal differences in constituent concentrations)

concentrations was noted, but not in dissolved orthophosphate. This indicates that the phosphorus at the station is probably in an insoluble form associated with suspended sediment. The decreasing trend in total phosphorus, therefore, is probably due to the implementation of best management practices to reduce suspended sediment as part of a Rural Clean Water Program (RCWP) in the Rock Creek drainage basin from 1981 to 1991 (Yankey and others, 1991).

The two NASQAN stations in the basin, station 7 (Snake River near Heise) and station 29 (Snake River at King Hill) showed no trends in concentrations of dissolved nitrite plus nitrate, total phosphorus, or dissolved orthophosphate. These results seem to be supported by the findings of Alexander and Smith (1990), who reported no trends in statewide fertilizer use during 1980–85.

Suspended Sediment

Elevated concentrations of suspended sediment in streams may be indicative of land use activities including logging, irrigated agriculture, grazing, mining, and recreation. Large concentrations of suspended sediment in water can cause (1) reduction in the esthetic qualities of the water, (2) filling of reservoirs and other water bodies, (3) reduction of light penetration to the detriment of many species of aquatic life, (4) blanketing of stream bottoms resulting in a loss of spawning habitat for many species of fish, and (5) sorption and transport of insoluble metals and organic compounds.

SPATIAL AND TEMPORAL CHARACTERISTICS OF DATA

At only six stations were the number of suspended sediment samples collected during water years 1980–89 sufficient for a statistical summary (table 8).

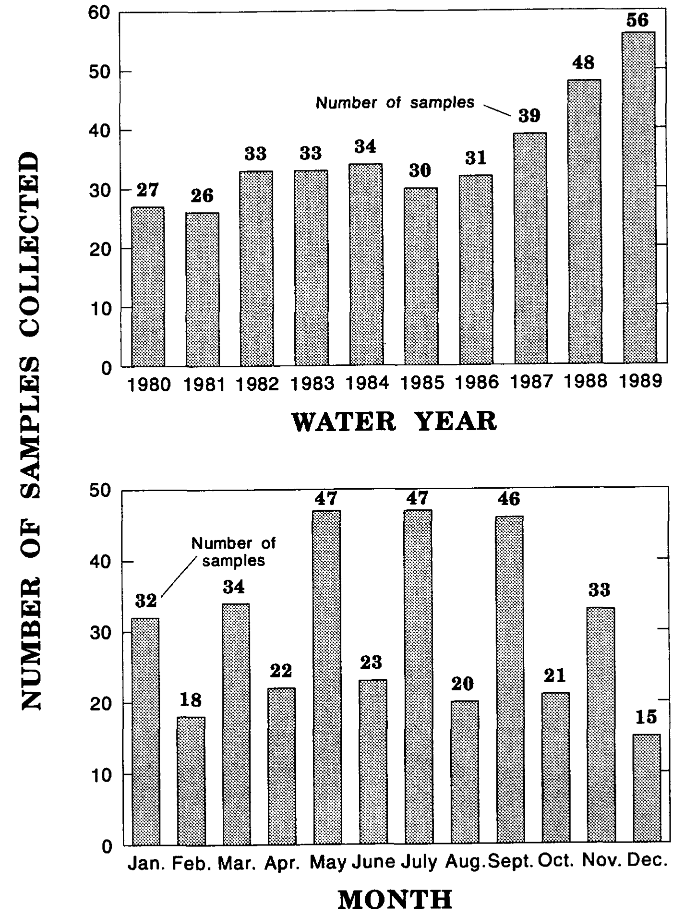

Figure 25. Temporal distribution of suspended sediment samples in the upper Snake River Basin, water years 1980–89.

Table 8. Statistical summary of suspended sediment concentrations at selected stations in the upper Snake River Basin, water years 1980–89

[Sampling station number refers to figure 12; mg/L, milligrams per liter; stations are in Idaho unless otherwise indicated; WY, Wyoming]

Sampling station No.	Station name	Period of record	No. of samples	Concentration at indicated percentile, in mg/L				
				10	25	50	75	90
1	Snake River at Flagg Ranch, WY	1987–89	17	1.8	2.0	3.0	6.0	50.4
3	Cache Creek near Jackson, WY	1980–89	73	5.0	10.5	23.0	44.0	64.6
7	Snake River near Heise	1980–89	48	3.0	7.0	13.5	37.5	59.2
19	Rock Creek near Rock Creek	1982–89	82	2.0	4.0	11.0	24.0	64.9
20	Rock Creek near Twin Falls	1983–89	68	11.0	23.5	61.0	146	216
29	Snake River at King Hill	1980–89	69	8.0	10.0	14.0	31.5	58.0

Samples collected by agencies other than the USGS are typically grab samples and are analyzed as total suspended solids. These samples were not used in the analysis of suspended sediment. Although suspended sediment samples collected for the Rock Creek RCWP by the IDEQ were grab samples, a comparison between these and depth- and width-integrated samples collected at the same stations revealed no significant difference in suspended sediment concentrations (Maret, 1990). The Rock Creek samples, therefore, are included in the quantitative assessment.

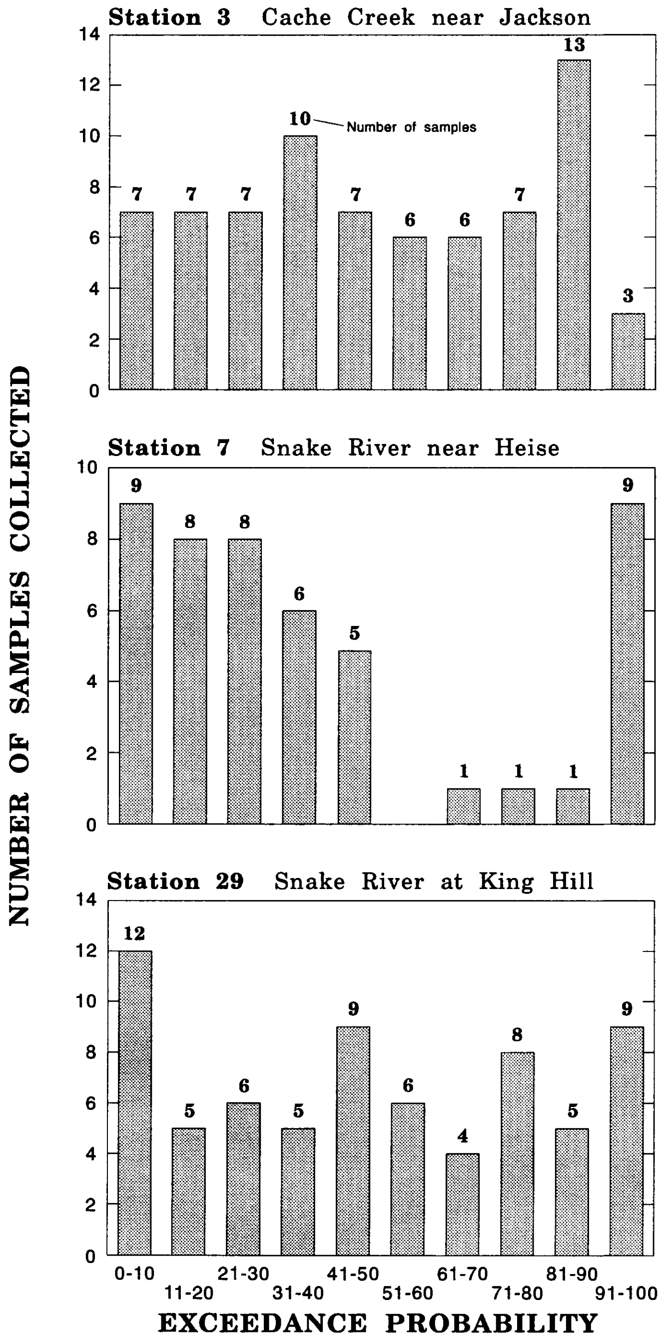

Figure 26. Distribution of suspended sediment samples collected over the range of historical streamflow for selected stations in the upper Snake River Basin, water years 1980–89. (Station numbers refer to figure 12 and table 5)

The number of samples collected for suspended sediment at the stations listed in table 8 was fairly evenly distributed throughout the 1980's (fig. 25), although during water years 1987–89, sample numbers increased because of intensified sampling at the Rock Creek stations and the start of suspended sediment sampling at the Snake River at Flagg Ranch station. The frequency of collection of suspended sediment fluctuated bimonthly, as did the collection of nutrients, as a result of the bimonthly sampling schedule at the NASQAN stations. The distribution of suspended sediment samples collected over the range of historical streamflow at three stations is shown in figure 26. With the exception of the Snake River near Heise station, which had a paucity of suspended sediment samples collected at exceedance probabilities between 50 and 90 percent, and at the Cache Creek station where only three samples were collected at an exceedance probability of larger than 90 percent, sampling was fairly well distributed throughout the range of streamflow. The lack of samples collected between the 50th to 90th percentiles at the Snake River near Heise gaging station is the result of streamflow regulation at Palisades Reservoir upstream from the station.

ASSESSMENT OF CURRENT CONDITIONS

Median concentrations of suspended sediment at stations in the basin with at least five analyses are shown in figure 27. Stations in tributary drainage basins southeast of American Falls Reservoir and near the downstream reaches of the main stem of the Snake River have the largest median concentrations of suspended sediment. These are some of the areas that also have the largest median concentrations of nitrite plus nitrate and total phosphorus (figs. 15 and 16). The reason for the slightly elevated concentrations of suspended sediment at stations in the easternmost part of the basin in

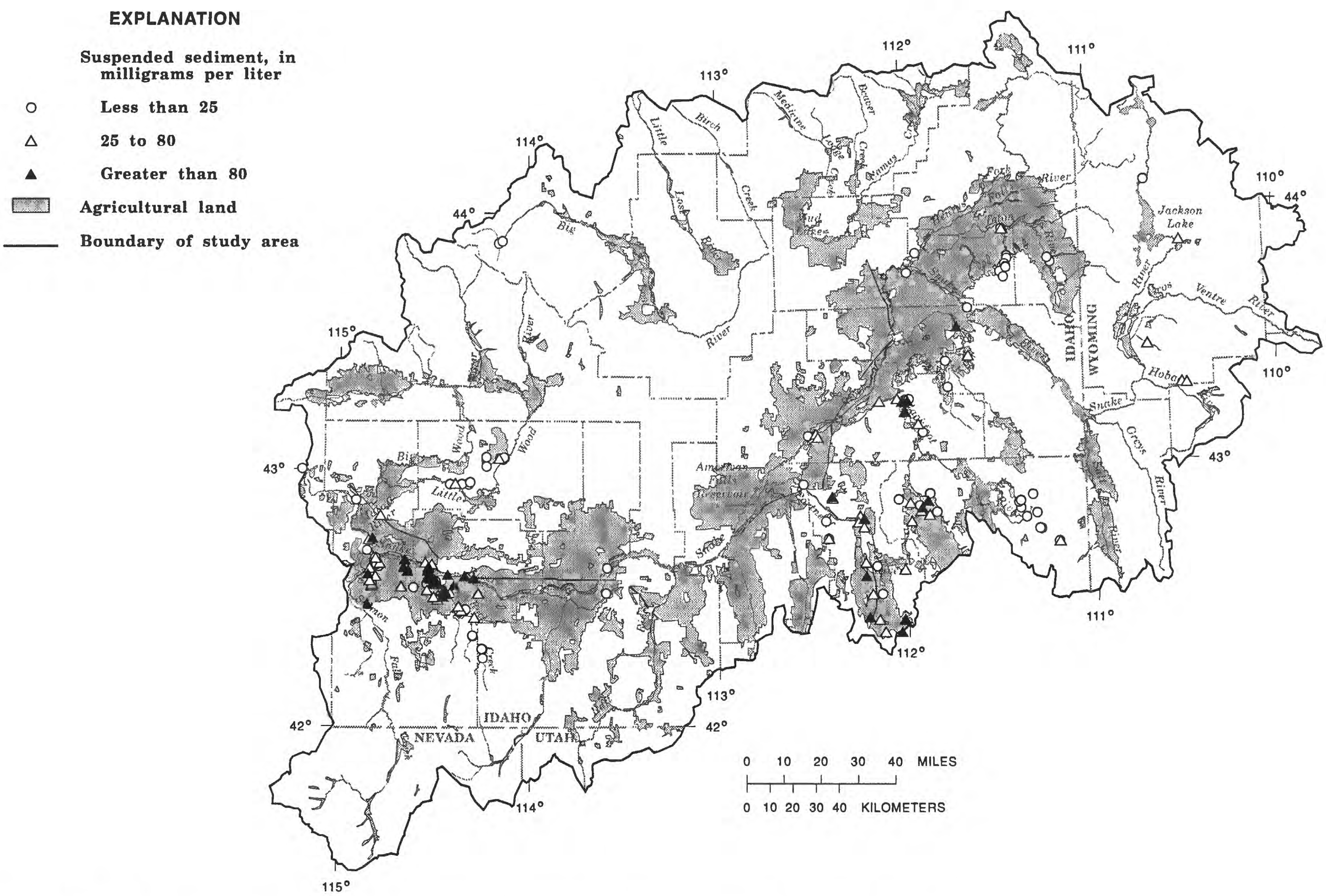

Figure 27. Median concentrations of suspended sediment at stations in the upper Snake River Basin with at least five analyses, water years 1980–89.

Wyoming is probably weathering of exposed shales of Cretaceous age, which crop out east of the Snake River in Wyoming (Whitehead, 1986, sheet 1). Suspended sediment concentrations in surface water in many areas of the basin could not be evaluated because of a lack of stations with data.

Suspended sediment concentrations at stations used for quantitative analyses and summarized in table 8 ranged from less than 1.0 to 1,290 mg/L. Station 20 near the mouth of Rock Creek had the largest median concentration among the six stations examined for suspended sediment (fig. 28). The Rock Creek near Twin Falls station is at the mouth of a basin heavily affected by irrigated agriculture and was part of the national RCWP. During 1982–88, implementation of best management practices in the Rock Creek Basin reduced loadings of suspended sediment to the Snake River during May, June, July, and August from nearly 30,000 tons/yr to about 6,500 tons/yr (Maret, 1990). A rank-sum test of the upstream station (19) and downstream station (20) on Rock Creek indicates a significant ($p<0.05$) difference between concentrations of suspended sediment at the two stations.

Station 3 at Cache Creek near Jackson is considered an unaffected station and, although the median concentration of suspended sediment is not extremely large (23.0 mg/L), it is more than twice the median concentrations at the other two unaffected suspended sediment stations (1 and 19) evaluated. The reason for the larger concentration of suspended sediment at Cache Creek, compared with concentrations at other unaffected stations, is probably weathering of exposed Cretaceous shales in the easternmost part of the basin.

Concentrations of suspended sediment at three USGS stations (3, 7, and 29) with continuous records during water years 1980–89 (fig. 29) generally followed the same temporal pattern during the period of assessment as did streamflow (fig. 4). The spread of the data shows that suspended sediment concentrations at these three stations, in general, were largest in the mid-1980's and smallest in the early and late 1980's. This pattern indicates a direct relation between suspended sediment concentrations and streamflow.

Data for the six stations used for suspended sediment analysis were combined prior to evaluating seasonal variations in suspended sediment concentrations. Concentrations of suspended sediment in April, May, and June were significantly larger than during the other three quarters of the year (fig. 30). This is probably because of the combined effects of increased

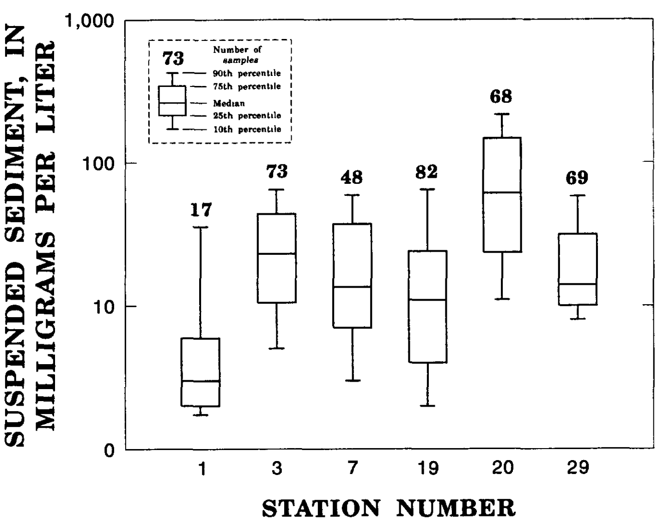

Figure 28. Concentrations of suspended sediment at stations in the upper Snake River Basin used for quantitative assessment, water years 1980–89. (Station numbers refer to figure 12 and table 5)

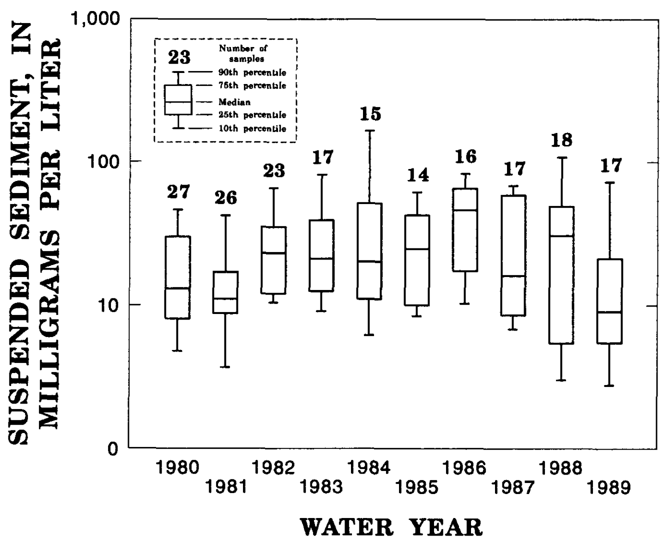

Figure 29. Concentrations of suspended sediment at stations 3, 7, and 29 in the upper Snake River Basin, water years 1980–89. (Station numbers refer to figure 12 and table 5)

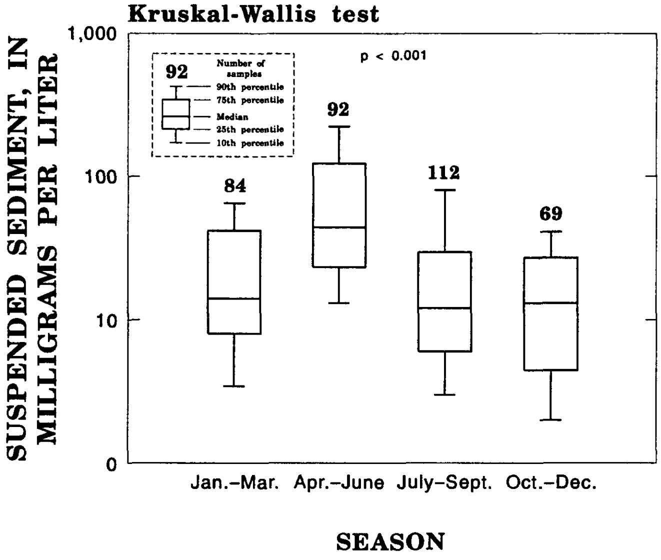

Figure 30. Seasonal concentrations of suspended sediment in the upper Snake River Basin, water years 1980–89. (For Kruskal-Wallis tests between seasons, p-values less than 0.05 indicate significant seasonal differences in constituent concentrations)

streamflows in response to snowmelt and effects from agricultural runoff. Concentrations of suspended sediment during the summer, fall, and winter were not significantly different ($p>0.05$).

TRENDS

Five stations in the upper Snake River Basin met the specifications for trend analysis of suspended sediment. Only the Rock Creek near Twin Falls station (20) had a significant ($p<0.05$) trend in suspended sediment concentration during the 1980–89 water years (table 7). The downward trend agrees with the findings of Maret (1990), who noted a downward trend at the same station using only May through August suspended sediment data collected from 1982 to 1990. The downward trend can be attributed to implementation of best management practices in 1982 for control of topsoil erosion in the basin. The absence of trends in suspended sediment concentrations at stations 3, 7, and 29 agrees with earlier USGS findings (W.H. Low, USGS, written commun., 1992).

Constituent Transport

Mean annual loads of total nitrogen, total phosphorus, and suspended sediment were estimated at four stations in the upper Snake River Basin (table 9) for water years 1984 (high-flow year), 1987 (normal or median-flow year), and 1989 (low-flow year). The selected years are based on streamflows at the stations shown in figure 4. At the Cache Creek and Rock Creek stations (3 and 20), median streamflows during 1987 and 1989 were essentially the same. The four stations where loads were calculated represent one unaffected station, one agriculturally affected station, and two main-stem Snake River stations (table 5). Other stations in the basin where water-quality data were available (1) were not USGS gaging stations and, therefore, did not have continuous flow records; (2) had water-quality data that could not be fitted to a regression model without resulting in large standard errors, compared with the estimated loads; or (3) did not have an adequate amount of water-quality data collected at large streamflows, which made formulation of a good regression model impossible. Regression coefficients and associated regression statistics for the best-fit load model at each station where loads were estimated are shown in table 10.

Except for the effect of differences in streamflow on total loads, little interpretive information could be extracted from load calculations. At the Snake River near Heise and the Snake River at King Hill stations, between two and three times as much total nitrogen, total phosphorus, and suspended sediment were discharged in 1984 as in 1989 because of larger streamflows in 1984. At the Snake River near King Hill station, the suspended sediment load was about twice as large as that at the Snake River at Heise station for the 3 years calculated. The larger load at King Hill, compared with that at Heise, is a result of larger streamflow and not larger suspended sediment concentrations, which were approximately the same at both stations during 1980–89 (table 8). At the Rock Creek station, the large decrease in total phosphorus and suspended sediment loads from 1984 to 1987 and from 1987 to 1989 are primarily a result of downward trends in the concentrations of those constituents (table 7) and not of differences in streamflow.

In a basin with numerous tributary and main-stem reservoirs, estimates of loads are necessary at many stations to determine accurately where sources and areas of accumulation of materials are located and to quantify mass movement of material in the basin. Reservoirs probably trap most, if not all, the suspended sediment that may be released from upstream areas of the basin and that otherwise would be transported to downstream stations. This also may be the case for total phosphorus, which generally is positively correlated to suspended sediment concentrations. Although total nitrogen concentrations also may be affected by reservoirs, a large part of the nitrogen mass is in the dissolved form. Total loads of nitrogen, therefore, may not be reduced as dramatically as suspended sediment and total phosphorus as water moves into and through reservoirs and other slow-moving bodies of water.

Most of the suspended sediment load at the King Hill station probably is generated from tributaries entering the Snake River within 40 mi upstream from the station and downstream from the last reservoir on the main stem of the Snake River in the upper Snake River Basin. The rest of the suspended sediment released from upstream parts of the basin probably is trapped in main-stem and tributary reservoirs. Most of the total nitrogen and total phosphorus load at King Hill probably also is generated in the lower part of the basin where

Table 9. Mean daily streamflow and estimated mean annual total nitrogen, total phosphorus, and suspended sediment loads at selected stations in the upper Snake River Basin, water years 1984, 1987, and 1989

[Sampling station number refers to figure 12; stations are in Idaho unless otherwise indicated; WY, Wyoming; N, nitrogen; P, phosphorus; load values in parentheses represent the 90-percent confidence interval of the estimate based on the standard error of prediction]

Sampling station No.	Station name	1984 water year (high flow)	1987 water year (median flow)	1989 water year (low flow)
Mean daily streamflow, in cubic feet per second				
3	Cache Creek near Jackson, WY ..	15.5	11.0	11.6
7	Snake River near Heise	9,510	6,480	5,380
20	Rock Creek near Twin Falls	254	203	201
29	Snake River at King Hill	18,100	11,000	7,880
Nitrogen, total as N, load in tons per year				
3	Cache Creek near Jackson, WY ..	9.14	6.16	6.80
	....	(7.13–11.2)	(5.16–7.15)	(5.34–8.21)
7	Snake River near Heise	6,360	3,230	2,260
	....	(5,480–7,230)	(2,680–3,780)	(1,730–2,800)
20	Rock Creek near Twin Falls	745	600	597
	....	(707–783)	(572–628)	(570–625)
29	Snake River at King Hill	31,700	20,200	13,900
	....	(27,900–35,500)	(17,800–22,600)	(11,700–16,200)
Phosphorus, total as P, load in tons per year				
3	Cache Creek near Jackson, WY ..	0.841	0.427	0.601
	....	(0.578–1.10)	(0.334–0.521)	(0.412– 0.789)
7	Snake River near Heise	438	261	222
	....	(301–574)	(189–334)	(157– 288)
20	Rock Creek near Twin Falls	80.8	29.8	23.9
	....	(67.4–94.3)	(26.9–32.7)	(19.8–28.1)
29	Snake River at King Hill	1,680	796	466
	....	(1,370–1,990)	(662–930)	(356–575)
Suspended sediment, load in tons per year				
3	Cache Creek near Jackson, WY ..	864	455	611
	....	(503–1,220)	(318–592)	(352–869)
7	Snake River near Heise	317,000	175,000	123,000
	....	(218,000–417,000)	(130,000–219,000)	(86,900–159,000)
20	Rock Creek near Twin Falls	56,300	13,500	9,350
	....	(41,600–71,100)	(11,600–15,500)	(7,060–11,700)
29	Snake River at King Hill	777,000	336,000	194,000
	....	(583,000–972,000)	(263,000–409,000)	(138,000– 250,000)

the cumulative effects from agricultural practices and other land uses are the most severe.

Pesticides

Pesticides include a wide variety of compounds used to control plants, insects, nematodes, fungi, and other pests. Some also are used as defoliants or desiccants prior to harvesting or as growth regulators. In 1976, farms accounted for 65 percent of all pesticide use, of which about 98 percent was used on crops (Gilliom and others, 1985, p. 4). Different pesticides have markedly different chemical properties that result in different environmental behavior. Some pesticides are soluble in water whereas others are not. Some pesticides degrade rapidly in the environment whereas others are resistant to degradation and may persist for long periods. Pesticides that are insoluble, or hydrophobic, and resistant to degradation tend to accumulate on sediments and in the fat tissue of aquatic organisms and can, therefore, affect ambient water-quality conditions long after applications have ceased. Examples of hydrophobic and persistent pesticides are the organochlorine insecticides such as DDT, which can take as many as 30 years or longer to break down in soils (Verschueren, 1983, p. 438), and its metabolites, DDD and DDE. Although use of many of the organochlorine insecticides has been banned since the mid-1970's, concentrations of the parent compounds and their breakdown products persist in bottom sediment and aquatic organisms.

Recent trends in pesticide use have been toward more soluble and less persistent compounds like the triazine and chlorophenoxy-acid herbicides and carbamate insecticides. These compounds typically degrade in soils and water much more quickly than the organochlorine insecticides. For example, the estimated half-life of 2,4-D (chlorophenoxy-acid herbicide) in an aerated soil is 4 to 30 days (Biggar and Seiber, 1987, p. 126), and the estimated half-life of carbofuran (carbamate insecticide) is 9 to 11 days (Verschueren, 1983, p. 339).

DISTRIBUTION AND ASSESSMENT OF DATA

Although agricultural pesticides have been used extensively in the upper Snake River Basin, few data exist for concentrations in surface water and bottom sediment. Most of the data that do exist were collected during the late 1970's or by the IDEQ as part of the RCWP on Rock Creek during the late 1980's. Data

Table 10. Regression coefficients and associated statistical values for models used to estimate constituent transport for selected nutrients at selected stations in the upper Snake River Basin, water years 1984, 1987, and 1989

[The form of the regression equation is: $ln(CQ) = I + a(lnQ) + b(t) + c[\text{sine}(2\pi T)] + d[\text{cosine}(2\pi t)]$: where ln is natural logarithm; C is concentration, in milligrams per liter; Q is streamflow, in cubic feet per second; I is the regression intercept; t is time, in decimal years from the beginning of the calibration period for the model; π is equal to 3.1416; and a, b, c, and d are regression coefficients; the coefficient of determination represents the part of the variance explained by the regression model; sampling station number refers to figure 12; N, nitrogen; P, phosphorus; stations are in Idaho unless otherwise noted; WY, Wyoming; —, coefficient not used in the model]

Sampling station No.	Station name	Coefficient of determination (percent)	Regression coefficients					Standard error of prediction (tons per year)		
			I	*a*	*b*	*c*	*d*	1984	1987	1989
Nitrogen, total as N										
3	Cache Creek near Jackson, WY	69	2.621	1.110	—	—	—	1.22	0.603	0.872
7	Snake River near Heise	85	8.703	1.134	-0.081	—	—	532	335	324
19	Rock Creek near Twin Falls	75	7.448	.999	—	0.022	0.221	23.1	16.9	16.7
29	Snake River at King Hill	61	10.895	.886	-.020	-.056	.204	2,310	1,450	1,380
Phosphorus, total as P										
3	Cache Creek near Jackson, WY	76	-.252	1.733	—	.240	.279	.160	.057	.115
7	Snake River near Heise	65	5.525	1.362	—	—	—	83.0	44.0	39.8
19	Rock Creek near Twin Falls	81	4.411	1.702	-.107	.551	-.339	8.18	1.75	2.52
29	Snake River at King Hill	56	7.760	1.214	-.051	—	—	188	81.4	66.7
Suspended sediment										
3	Cache Creek near Jackson, WY	62	6.630	1.722	—	.236	.390	219	83.0	157
7	Snake River near Heise	74	12.223	1.305	—	1.078	.549	60,400	27,100	21,800
19	Rock Creek near Twin Falls	82	10.289	2.086	-.159	.622	-.740	8,950	1,210	1,390
29	Snake River at King Hill	70	13.430	1.920	.076	.293	.025	118,000	44,400	34,200

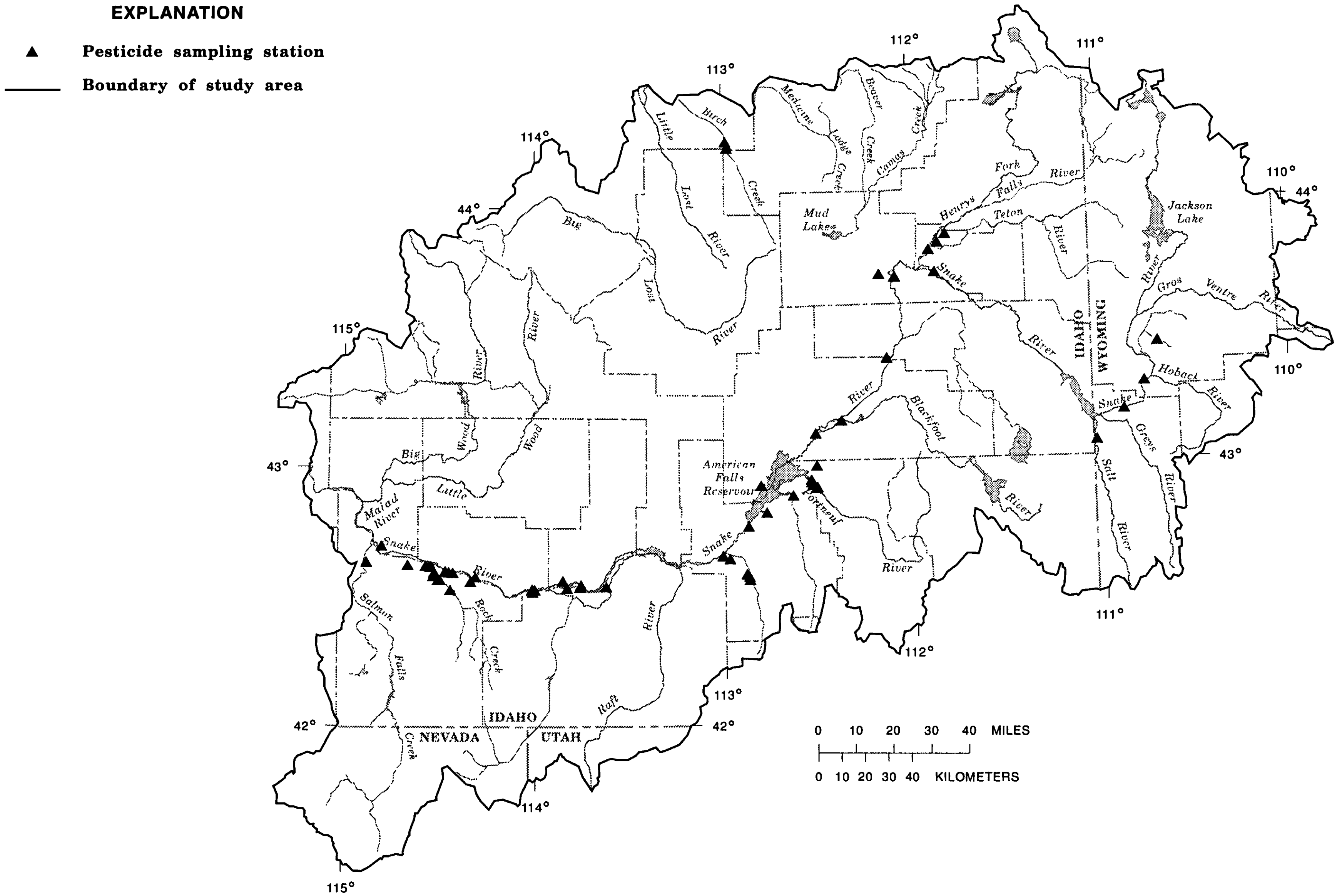

Figure 31. Stations in the upper Snake River Basin where pesticide samples were collected from surface water and bottom sediment, water years 1975–89.

Table 11. Concentrations of pesticides in surface water and bottom sediment in the upper Snake River Basin, water years 1975–89

[EPA, U.S. Environmental Protection Agency; MCL, maximum contaminant levels; µg/L, micrograms per liter; µg/kg, micrograms per kilogram; btm sed, bottom sediment; ND, not detected; —, standard not established; criteria for human health are based on report by EPA (1992); criteria for aquatic organisms are based on report by EPA (1991)]

Compound	No. of sites sampled	No. of samples collected	No. of samples with concentrations exceeding the reporting limit	Maximum concentration detected	EPA water-quality criteria: Human health MCL	EPA water-quality criteria: Aquatic organisms freshwater Acute	EPA water-quality criteria: Aquatic organisms freshwater Chronic
Organochlorine insecticides							
Aldrin, total, µg/L	35	61	0	ND	—	3.0	—
Aldrin, total, btm sed, µg/kg	30	36	0	ND	—	—	—
Chlordane, total, µg/L	34	57	2	0.40	2.0	2.4	0.0043
Chlordane, total, btm sed, µg/kg	11	25	0	ND	—	—	—
DDD, total, µg/L	32	45	5	.57	—	—	—
DDD, total, btm sed, µg/kg	12	24	6	8.3	—	—	—
p,p′ DDD, total, btm sed, µg/kg	12	12	7	15	—	—	—
DDE, total, µg/L	32	45	13	.35	—	—	—
DDE, total, btm sed, µg/kg	12	24	13	19	—	—	—
p,p′ DDE, total, btm sed, µg/kg	12	12	10	19	—	—	—
DDT, total, µg/L	32	45	11	1.6	—	—	—
DDT, total, btm sed, µg/kg	12	24	5	17	—	—	—
o,p′ DDT, total, btm sed, µg/kg	12	12	0	ND	—	—	—
p,p′ DDT, total, btm sed, µg/kg	12	12	8	38	—	—	—
Dieldrin, total, µg/L	35	61	7	.05	—	2.5	.0019
Dieldrin, total, btm sed, µg/kg	30	36	5	2.0	—	—	—
Endosulfan, total, µg/L	6	13	0	ND	—	.22	.056
Endosulfan, total, btm sed, µg/kg	2	2	0	ND	—	—	—
Endrin, total, µg/L	35	61	0	ND	2.0	.18	.0023
Endrin, total, btm sed, µg/kg	30	36	0	ND	—	—	—
Heptachlor, total, µg/L	28	55	0	ND	.4	.52	.0038
Heptachlor, total, btm sed, µg/kg	25	38	0	ND	—	—	—
Heptachlor epoxide, total, µg/L	28	55	1	.01	.2	.52	.0038
Heptachlor epoxide, total, btm sed, µg/kg	25	38	1	.10	—	—	—
Lindane, total, µg/L	35	61	20	.02	.2	—	—
Lindane, total, btm sed, µg/kg	17	26	0	ND	—	—	—
Methoxychlor, total, µg/L	9	19	0	ND	40	—	.02
Methoxychlor, total, btm sed, µg/L	14	14	0	ND	—	—	—
Mirex, total, µg/L	4	18	0	ND	—	—	.001
Mirex, total, btm sed, µg/kg	3	5	0	ND	—	—	—
Toxaphene, total, µg/L	32	57	0	ND	3.0	.73	.0002
Toxaphene, total, btm sed, µg/kg	28	33	0	ND	—	—	—
Organophosphorus insecticides							
Diazinon, total, µg/L	20	49	0	ND	—	—	—
Ethion, total, µg/L	15	35	0	ND	—	—	—
Malathion, total, µg/L	20	49	2	.01	—	—	.1
Methyl parathion, total, µg/L	16	47	0	ND	—	—	—
Methyl trithion, total, µg/L	15	35	0	ND	—	—	—
Parathion, total, µg/L	15	35	0	ND	—	.065	.013
Perthane, total, µg/L	2	5	0	ND	—	—	—
Perthane, total, btm sed, µg/kg	2	2	0	ND	—	—	—
Trithion, total, µg/L	15	35	0	ND	—	—	—
Triazine and other nitrogen-containing herbicides							
Ametryne, total, µg/L	5	6	0	ND	—	—	—
Atratone, total, µg/L	5	6	1	1.0	—	—	—
Atrazine, total, µg/L	5	16	0	ND	3.0	—	—
Cyanazine, total, µg/L	5	6	0	ND	—	—	—
Cyprazine, total, µg/L	5	6	0	ND	—	—	—
Picloram, total, µg/L	1	13	8	.03	500	—	—
Prometone, total, µg/L	5	6	0	ND	—	—	—
Prometryne, total, µg/L	5	6	0	ND	—	—	—
Propazine, total, µg/L	5	6	0	ND	—	—	—
Simazine, total, µg/L	5	6	0	ND	4.0	—	—
Simetone, total, µg/L	5	6	0	ND	—	—	—
Simetryne, total, µg/L	5	6	0	ND	—	—	—
Chlorophenoxy-acid herbicides							
2,4-D, total, µg/L	10	69	8	6.0	70	—	—
2,4-DP, total, µg/L	3	20	1	.07	—	—	—
2,4,5-T, total, µg/L	10	69	1	.10	—	—	—
Silvex, total, µg/L	10	66	0	ND	50	—	—
Other pesticides							
Dicamba, total, µg/L	1	13	3	.03	—	—	—
Pentachlorophenol, total, µg/L	3	11	5	.14	1.0	20	13

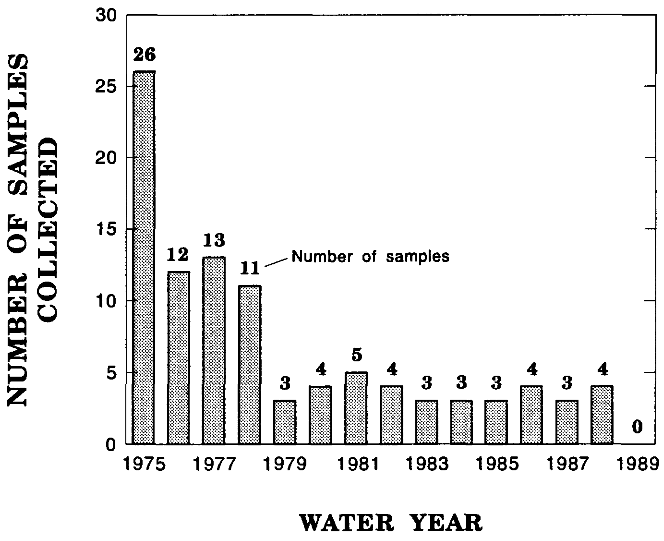

Figure 32. Number of pesticide samples collected from surface water and bottom sediment in the upper Snake River Basin, water years 1975–89.

collected for the RCWP are summarized separately at the end of this section. Few pesticide data, other than those from the RCWP, exist for water years 1980–89.

Pesticide sampling in the upper Snake River Basin during water years 1975–89 was concentrated along the main stem of the Snake River and at the mouths of major tributaries or irrigation drains (fig. 31). Sixty stations, 22 of which were on agricultural drains, were sampled for pesticide concentrations in the water or the bottom sediment. Since water year 1978, only 36 pesticide samples have been collected in the upper Snake River Basin (fig. 32), 23 of which were collected at the Salt River near Etna in Wyoming (station 6).

The primary groups of pesticides for which samples were collected and analyzed during water years 1975–89 were the organochlorine and organophosphorus insecticides (table 11). Many of the bottom-sediment samples collected in the late 1970's contained small concentrations of DDT and its associated compounds, DDD and DDE. However, only two bottom-sediment samples, both collected at the Henrys Fork near Rexburg (station 9), contained concentrations of DDT, DDE, and DDD that exceeded 10 μg/kg. Because the use of DDT has been banned since the mid-1970's, current (1992) concentrations of DDT, DDD, and DDE are probably smaller than during the late 1970's. The organochlorine insecticide lindane also was detected in numerous water samples throughout the basin, although concentrations did not exceed 0.02 μg/L. None of the compounds detected in surface water exceeded EPA water-quality criteria for human health or for acute toxicity to aquatic life. Concentrations of chlordane, dieldrin, and heptachlor epoxide did exceed EPA standards for chronic toxicity for aquatic life in at least one sample.

During 1988–90, as part of the RCWP on Rock Creek, samples were collected and analyzed for 27 pesticides at 7 agricultural tunnel drains entering Rock Creek and at a surface-water gaging station near the mouth of the drainage basin (Maret, 1990). Samples were collected three to four times per year (spring, summer, and fall) during the 3-year period. Nine of the 27 pesticides were detected at least once during the 3-year period (table 12). Only dacthal and pentachlorophenol were detected in more than three samples.

DATA NEEDS FOR FURTHER ANALYSIS

A more extensive data-collection program in the upper Snake River Basin is needed to complete a thorough analysis of current water-quality conditions. Although some data exist for assessing nutrient concentrations in the basin, data on suspended sediment and pesticide concentrations are scarce. The quantity and quality of data available for other chemical constituents in the upper Snake River Basin were not assessed in this report.

Future data-collection efforts in the upper Snake River Basin need to address a number of questions that could not be examined on the basis of available information. Although the relation of agricultural land use to nutrient concentrations could be assessed at some locations, more extensive sampling is needed to quantify agricultural effects on nutrient concentrations over a broader range of physiographic and hydrologic settings. Many of the nutrient data used in this report were collected as grab samples. Grab samples may be sufficient for characterizing concentrations of dissolved species in a well-mixed system, but for an assessment of total concentrations, or where mixing is not complete, width- and depth-integrated sampling techniques would provide a more representative sample and, thus, would be more accurate.

More nutrient and suspended sediment data on the main stem of the Snake River and on major tributaries are necessary to quantify mass movement of these constituents within the basin. This is especially true at the mouth of the Henrys Fork, which is the largest tributary to the Snake River and which is heavily affected by irrigated agriculture. More data on the main stem of the Snake River also would be valuable in assessing the effects of reservoirs on movement of materials in the basin. Because high and low streamflows are critical in assessing mass movement of material and extreme water-quality conditions, sample collection needs to be increased during these periods. Temporal variations in the water chemistry then can be evaluated and more confidently correlated to different types of natural and anthropogenic effects on surface-water quality.

Although some data exist for hydrophobic organochlorine pesticides in the basin, many of these compounds are no longer in use, and current concentrations of these pesticides are probably smaller than those presented in this report. Updated information on concentrations of these compounds in bottom sediments and biota would be helpful for future assessment. Little information exists for the more soluble organic pesticides. Because use of more water-soluble and less persistent compounds is increasing in the agricultural industry, future sampling efforts need to be geared toward collection of these kinds of pesticides.

SUMMARY

The Snake River in the upper Snake River Basin drains an area encompassing parts of four States and approximately 35,800 mi^2. The elevation of the Snake River over its 453-mi course ranges from about 6,800 ft near its headwaters upstream from Jackson Lake to about 2,500 ft at the basin outlet at King Hill. Major types of land use/land cover in the basin are rangeland,

Table 12. Concentrations of pesticides in surface water at Rock Creek, 1988–90

[Reporting limits from Yankey and others (1991); µg/L, micrograms per liter; ND, not detected]

Compound	No. of sites sampled	No. of samples collected	No. of sites with samples exceeding the reporting limit	No. of samples with concentrations exceeding the reporting limit	Reporting limit (µg/L)	Maximum concentration detected (µg/L)
Insecticides						
Aldrin, total	8	74	0	0	0.004	ND
Chlordane, total	8	74	3	3	.014	0.90
Chlorpyrifos, total	8	74	1	1	.03	.03
p,p'DDD, total	8	74	0	0	.011	ND
p,p'DDE, total	8	74	0	0	.004	ND
o,p'DDT, total	8	74	0	0	.01	ND
p,p'DDT, total	8	74	0	0	.012	ND
Diazinon, total	8	74	0	0	.60	ND
Dieldrin, total	8	74	1	1	.002	.01
Endrin, total	8	74	0	0	.006	ND
Endrin aldehyde, total	8	74	0	0	.023	ND
Ethoprop, total	8	74	0	0	1.0	ND
Heptachlor, total	8	74	1	1	.003	.005
Heptachlor epoxide, total	8	74	0	0	.08	ND
Lindane, total	8	74	1	1	.004	.01
Malathion, total	8	74	0	0	1.0	ND
Methoxychlor, total	8	74	2	2	.18	1.7
Methyl parathion, total	8	74	0	0	.03	ND
Mirex, total	8	74	0	0	.04	ND
Oxychlordane, total	8	74	0	0	.008	ND
Toxaphene, total	8	74	0	0	.24	ND
Herbicides						
Atrazine, total	8	74	0	0	.05	ND
2,4-D, total	8	74	1	1	1.2	1.2
Dacthal, total	8	74	6	14	.03	4.4
Pentachlorophenol, total	8	74	5	10	.05	.24
Silvex, total	8	74	0	0	.17	ND
2,4,5-T, total	8	74	0	0	.20	ND

forest land, and agricultural land. Streamflow in the Snake River is highly regulated by dams and diversions, primarily for agricultural use and hydroelectric-power generation. The principal cause of changes to natural water quality in the upper Snake River Basin is irrigated agriculture. Other factors that affect water quality include rangeland grazing, feedlots, industrial and municipal point sources, and recreation.

Nutrient, suspended sediment, and pesticide data were analyzed for their effects on water quality of the Snake River and its tributary basins. Data from EPA STORET and USGS WATSTORE data bases were retrieved for water years 1980–89 for analysis of nutrients and suspended sediment, and for water years 1975–89 for analysis of pesticides. A total of 8,863 samples were collected at 476 stations for analysis of nutrients and (or) suspended sediment. Only 19 of those stations had sufficient data for quantitative assessment. Only 98 samples from 60 stations, excluding samples collected for the RCWP, were collected and analyzed for pesticides during water years 1975–89. Because of a paucity of data, a quantitative assessment of pesticides was not made.

Concentrations of nitrite plus nitrate and total phosphorus generally increased in a downstream direction. The largest concentrations of these nutrients were in samples collected at the mouths of major tributary drainage basins where agriculture is the dominant land use. At the outlet of the upper Snake River Basin, nutrient concentrations are controlled primarily by spring flows, which contribute 5,000 to 6,000 ft^3/s of water to the Snake River.

Water-quality stations were categorized as unaffected or minimally affected, agriculturally affected, or main stem to compare nutrient concentrations between drainage basins of differing land use/land cover. Concentrations of nitrite plus nitrate, total nitrogen, dissolved orthophosphate, and total phosphorus were significantly ($p<0.05$) larger at agriculturally affected and main-stem stations compared with unaffected stations; and concentrations of nitrite plus nitrate, total nitrogen, and total phosphorus at agriculturally affected stations were significantly larger than at main-stem stations. Concentrations of some nutrient species also showed significant seasonal differences depending on the station type. At unaffected stations, concentrations of nitrite plus nitrate and total nitrogen were largest from April to June, whereas at agriculturally affected stations, concentrations of the same two nutrients were smallest from April to June. Total phosphorus concentrations were smallest from April to June regardless of the station type. Concentrations of dissolved ammonia and orthophosphate showed no significant seasonal variation. Significant ($p<0.05$) downward trends in concentrations of at least one nutrient species were noted at three stations in the basin during the period of assessment.

Suspended sediment data were assessed quantitatively at six stations in the upper Snake River Basin. Concentrations ranged from less than 1.0 to 1,290 mg/L. Suspended sediment concentrations at all stations were significantly larger from April to June compared with concentrations during the rest of the year. This is probably due to increased streamflows, which show a direct correlation to suspended sediment concentrations, and agricultural runoff during April, May, and June. Geology also appears to be a factor in suspended sediment concentrations in some parts of the basin. Only one station had a significant trend (downward) in suspended sediment concentrations during 1980–89.

Mass movement of nutrients and suspended sediment in the upper Snake River Basin is controlled primarily by changes in streamflow. Between two and three times as much total nitrogen, total phosphorus, and suspended sediment were transported out of the basin (Snake River at King Hill) in water year 1984 (high-flow year), compared with 1989 (low-flow year). Reservoirs on the main stem of the Snake River probably trap most of the suspended sediment generated from upper parts of the basin.

The primary pesticides sampled and analyzed during water years 1975–89 were the organochlorine and organophosphorus insecticides. Small concentrations of DDT, DDD, and DDE were detected in bottom-sediment samples throughout the basin. At only one station, however, did these concentrations exceed 10 μg/kg. Concentrations of other pesticides, based on the small amount of data, were below or near laboratory reporting levels.

A more extensive data-collection program would provide the information needed to more accurately analyze water-quality conditions in the upper Snake River Basin. Specific topics for future study may include an areal assessment of water-quality conditions over a broad range of physiographic settings and hydrologic conditions, mass movement of material through the basin, and an assessment of the distribution of pesticides in surface water, bottom sediment, and biota.

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