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Water-Quality and Biological Conditions in the Lower Boise River, Ada and Canyon Counties, Idaho, 1994–2002

Scientific Investigations Report 2004–5128
Version 1.0

U.S. Department of the Interior
U.S. Geological Survey

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By Dorene E. MacCoy

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U.S. Department of the Interior
Gale A. Norton, Secretary

U.S. Geological Survey
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Conversion Factors, Water Year Definition, and Vertical Datum

Multiply	By	To obtain
acre-foot (acre-ft)	1,233.0	cubic meter (m^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km
mile (mi)	1.609	kilometer (km)
pound (lb)	0.4536	kilogram (kg)
pound per day (lb/d)	0.4536	kilogram per day (kg/d
square mile (mi^2)	2.56	square kilometer (km^2)
ton per day (ton/d)	907.18	kilogram per day (kg/d

To convert ˚C (degrees Celsius) to ˚F (degrees Fahrenheit), use the following equation:

$$˚F = (1.8\ ˚C) + (32)$$

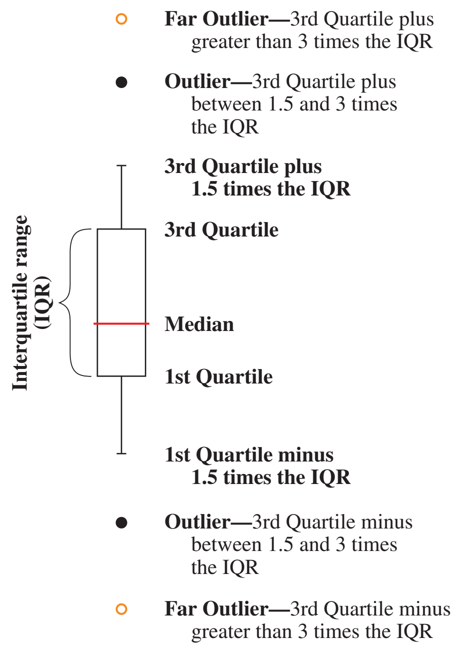
Water Year: In U.S. Geological Survey reports dealing with surface-water supply, a water year is the 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends; thus, the water year ending September 30, 2001, is called the "2001 water year."

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:

µm micrometers
mL milliliters
mg/L milligrams per liter
µS/cm microsiemens per centimeter
mg/m^2 milligrams per square meter; multiply square meters by 10.76 to obtain square feet

EXPLANATION
for boxplots shown in figures 6, 8, 9, 11, 12, 15, 18, 21, 25, 26, 28, 29, and 33



Water-Quality and Biological Conditions in the Lower Boise River, Ada and Canyon Counties, Idaho, 1994–2002

By Dorene E. MacCoy

Abstract

The water quality and biotic integrity of the lower Boise River between Lucky Peak Dam and the river's mouth near Parma, Idaho, have been affected by agricultural land and water use, wastewater treatment facility discharge, urbanization, reservoir operations, and river channel alteration. The U.S. Geological Survey (USGS) and cooperators have studied water-quality and biological aspects of the lower Boise River in the past to address water-quality concerns and issues brought forth by the Clean Water Act of 1977. Past and present issues include preservation of beneficial uses of the river for fisheries, recreation, and irrigation; and maintenance of high-quality water for domestic and agricultural uses. Evaluation of the data collected from 1994 to 2002 by the USGS revealed increases in constituent concentrations in the lower Boise in a downstream direction. Median suspended sediment concentrations from Diversion Dam (downstream from Lucky Peak Dam) to Parma increased more than 11 times, nitrogen concentrations increased more than 8 times, phosphorus concentrations increased more than 7 times, and fecal coliform concentrations increased more than 400 times. Chlorophyll-*a* concentrations, used as an indicator of nutrient input and the potential for nuisance algal growth, also increased in a downstream direction; median concentrations were highest at the Middleton and Parma sites. There were no discernible temporal trends in nutrients, sediment, or bacteria concentrations over the 8-year study.

The State of Idaho's temperature standards to protect coldwater biota and salmonid spawning were exceeded most frequently at Middleton and Parma. Suspended sediment concentrations exceeded criteria proposed by Idaho Department of Environmental Quality most frequently at Parma and at all but three tributaries. Total nitrogen concentrations at Glenwood, Middleton, and Parma exceeded national background levels; median flow-adjusted total nitrogen concentrations at Middleton and Parma were higher than those in undeveloped basins sampled nationwide by the USGS. Total phosphorus concentrations at Glenwood, Middleton, and Parma also exceeded those in undeveloped basins.

Macroinvertebrate and fish communities were used to evaluate the long-term integration of water-quality contaminants and loss of habitat in the lower Boise. Biological integrity of the macroinvertebrate population was assessed with the attributes (metrics) of Ephemeroptera, Plecoptera, and Trichoptera (EPT) richness and metrics used in the Idaho River Macroinvertebrate Index (RMI): taxa richness; EPT richness; percent dominant taxon; percent Elmidae (riffle beetles); and percent predators. Average EPT was about 10, and RMI scores were frequently below 16, which indicated intermediate or poor water quality. The number of EPT taxa and RMI scores for the lower Boise were half those for least-impacted streams in Idaho. The fine sediment bioassessment index (FSBI) was used to evaluate macroinvertebrate sediment tolerance. The FSBI scores were lower than those for a site upstream in the Boise River Basin near Twin Springs, a site not impacted by urbanization and agriculture, which indicated that the lower Boise macroinvertebrate population may be impacted by fine sediment. Macroinvertebrate functional feeding groups and percent tolerant species, mainly at Middleton and Parma, were typical of those in areas of degraded water quality and habitat.

The biological integrity of the fish population was evaluated using the Idaho River Fish Index (RFI), which consists of the 10 metrics: number of coldwater native species, percent sculpin, percent coldwater species, percent sensitive native individuals, percent tolerant individuals, number of nonindigenous species, number of coldwater fish captured per minute of electrofishing, percent of fish with deformities (eroded fins, lesions, or tumors), number of trout age classes, and percent carp. RFI scores for lower Boise sites indicated a decrease in biotic integrity of fish in a downstream direction; the lowest RFI score was at Parma, near the mouth of the river.

INTRODUCTION

Historical Alterations of Water Quality and Biological Integrity in the Lower Boise Basin

The water quality and biological integrity of the lower Boise River (herein referred to as lower Boise) have changed over time in response to natural variation and multiple human impacts caused by settlement of the study area. In the late 1800s and early 1900s, settlers began to divert water from the lower Boise for irrigation; return flows of irrigation water were an early source of water-quality degradation. During that same period, extensive mining began in the upper basin, and numerous lumber mills were operated east of Boise to supply timber for development (Stacy, 1993).

Soon after settlement, farmers recognized the need for flood control and storage of irrigation water; this need led to the 1902 "Boise Project," one of the earliest projects by the Reclamation Service (now known as the Bureau of Reclamation, or Reclamation) (Stacy, 1993). By 1906, the New York Canal and several small irrigation projects had been built as part of the Boise Project. One of Reclamation's "big dams," Arrowrock, was built in 1915 on the main-stem Boise River, 17 mi upstream from the city of Boise. The U.S. Army Corps of Engineers (Corps) built Anderson Ranch Dam in 1950 on the South Fork of the Boise River, southeast of the city of Boise, in response to the overappropriation of water rights downstream (Stacy, 1993). In 1957, the Corps built the third and final large dam, Lucky Peak, less than 10 mi upstream from the city of Boise in response to ongoing concerns of potential flooding and the need for additional irrigation water (Stacy, 1993).

Progressive urbanization around the city of Boise increased the need to treat wastewater prior its discharge to the lower Boise. The construction of sewage treatment facilities downstream from Boise in the early 1950s helped to disinfect wastewater entering the river but introduced toxic concentrations of chlorine into the river, which resulted in frequent fish kills (Stacy, 1993). In the late 1950s, the lower Boise was identified as one of the three most polluted waters in Idaho (Osborne, 1959; Chandler and Chapman, 2001). In 1976, a second outlet was proposed for installation in Lucky Peak Dam to implement a minimum flow of approximately 150 ft^3/s during winter, which helped dilute effluent. Minimum flow varied as a result of water allocations downstream (Idaho Department of Environmental Quality, 1999). Cleanup efforts have continued in the lower Boise Basin, such as upgrades to wastewater treatment and implementation of best management practices (BMPs) for urban and agricultural runoff.

Prior to construction of dams, levees, and extensive irrigation in the lower Boise Basin, a large (as wide as 0.75 mi) hyporheic zone (an area beneath the main channel where surface water interacts with ground water) provided side channels for refuge and areas ideal for salmon spawning and rearing (David Blew, Idaho Department of Water Resources, oral commun., 2002). Operation of the three Boise River dams for irrigation and flood control created a flow regime with higher than natural flows during the peak irrigation season (April through September) and lower than natural flows during the nonirrigation season (October through March). The change in hydraulic regime and construction of levees has caused the downstream part of the lower Boise to incise to the point that depositional areas and wetlands associated with the hyporheic zone have diminished (David Blew, Idaho Department of Water Resources, oral commun., 2002).

In the early 1800s, the lower Boise fishery was described as the "most renowned fishing place in the country," with large numbers of salmon (Pratt and others, 2001). The historical distribution of chinook salmon (*Onchorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*) was evaluated by the Idaho Power Company (IPC) as part of an ongoing dam relicensing effort for the Hells Canyon Complex, northwest of the city of Boise, which includes the lower Boise as an important tributary. The IPC documented evidence of chinook salmon spawning in the lower reaches of the lower Boise until the early 1860s, coincident with the time when mining and irrigation projects began (Chandler and Chapman, 2001). IPC also reported steelhead runs in the lower Boise, as well as the presence of Pacific lamprey (*Lampetra tridentatus*) in the river near Caldwell.

Within the last century, the lower reaches of the lower Boise changed from a thriving, coldwater salmon and trout fishery to a warmwater fishery. Exotic warmwater species of fish such as warmouth (*Chaenobryttus gulosus*), crappie (*Pomoxis* spp.), northern pike (*Esox lucius*), largemouth bass (*Micropterus salmoides*), and channel catfish (*Ictalurus punctatus*) were introduced into the lower Boise near the turn of the 20th century (Chandler and Chapman, 2001). These fish species are known to compete with salmon populations for food and habitat. The Hells Canyon Dam, the upper Boise River dams, lower Boise flow alterations, and water-quality impairments from urbanization, agriculture, mining, and forestry also have altered the fishery. Following construction of Hells Canyon Dam in 1967, upstream fish migration was blocked, eliminating the anadromous fishery from the lower Boise Basin (Chandler and Chapman, 2001). IPC's relicensing studies concluded that the lower Boise is no longer suitable to support salmonid spawning because of high water temperatures in the late summer and early fall (Chandler and Chapman, 2001).

Selected Previous Investigations

The impairment of water quality and biological integrity in the lower Boise and several of its tributaries has been evaluated as part of Federal and State monitoring programs; only a few of those programs are discussed in this report. On the basis of monitoring in the early 1970s, Reclamation concluded that the lower Boise entered the city of Boise with generally high-quality water but deteriorated as a result of municipal

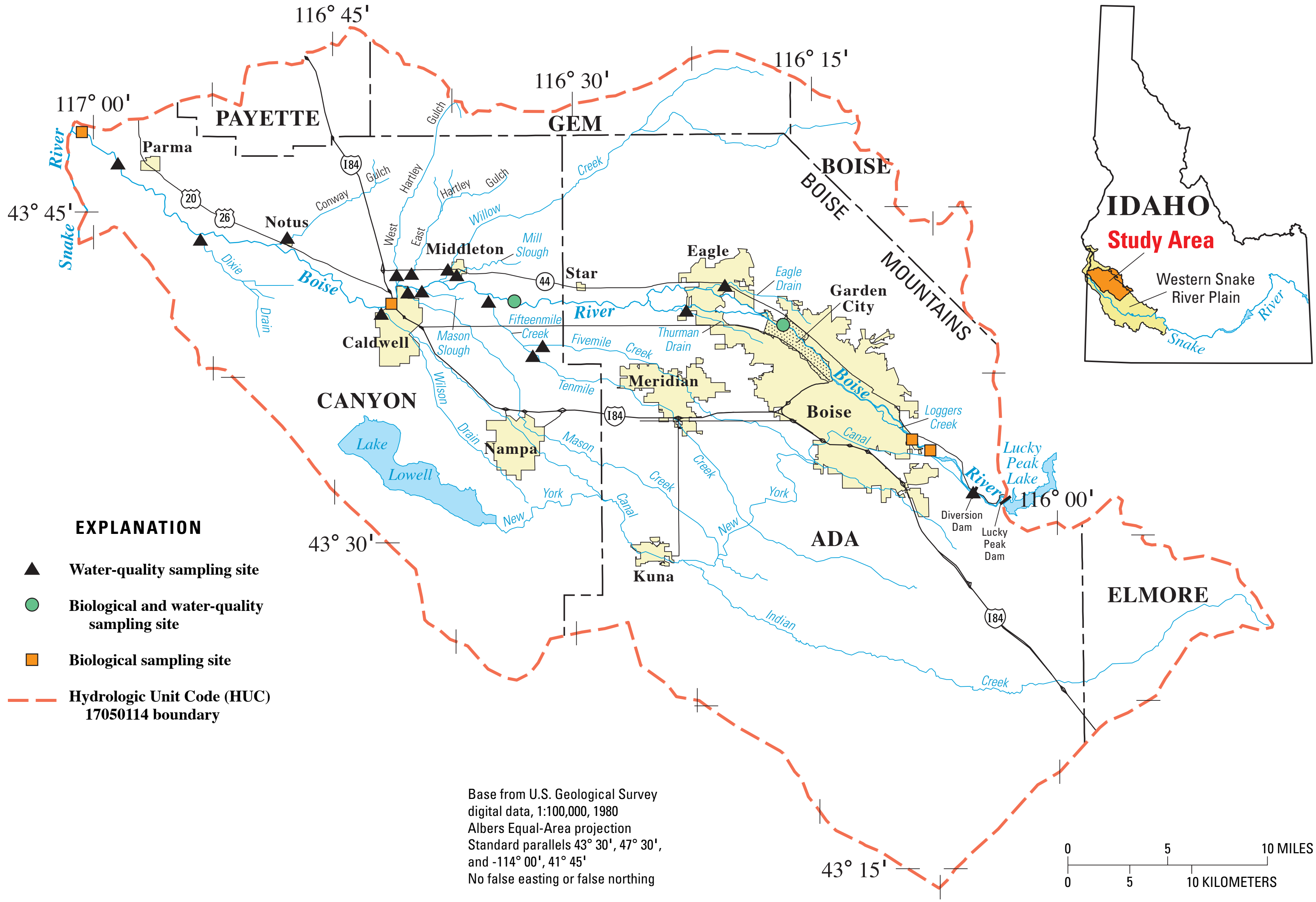


Figure 1. Location of lower Boise River Basin and biological and water-quality sampling sites, Idaho.

and industrial wastewater discharges and stormwater runoff near Boise; further deterioration occurred downstream as a result of irrigation return flows, diversions, and other wastewater discharges (Bureau of Reclamation, 1977). The primary constituents of concern in the BOR study were nutrients, fecal bacteria, suspended solids, and low dissolved oxygen in the river's lower reaches.

Subbasin contributions of sediment, nutrients, and bacteria have increased in association with increases in agriculture (Bureau of Reclamation, 1977). Conway Gulch was identified in 1982 as a subbasin contributing significant agricultural pollution to the lower Boise (Clark and Bauer, 1982). The Idaho Division (now Department) of Environmental Quality (IDEQ) conducted studies in 1988 and 1989 to assess the effectiveness of BMPs implemented under the Conway Gulch Water Quality Project to control excess nutrients and sediment. Monitoring indicated that, even with about 35 percent of the critical area under some form of BMP treatment, Conway Gulch remained a major source of sediment, nutrients, trace elements, and bacteria to the lower Boise (Ingham, 1993).

IDEQ reported in 1983 that agricultural drains in the lower Boise transported large loads of nutrients (nitrogen and phosphorus), sediment, and fecal bacteria (primarily from livestock), as well as organochlorine pesticides and polychlorinated biphenyls (PCBs), some of which also were found in fish tissue (Clark and Bauer, 1983). In 1988, the U.S. Geological Survey (USGS) evaluated the effect of multiple wastewater discharges on water quality and aquatic communities in the lower Boise (Frenzel, 1988 and 1990). Frenzel concluded that, even though effluent from these facilities was not adversely affecting macroinvertebrate populations, the whitefish (*Prosopium williamsoni*) population may have been adversely affected.

In 1989, IDEQ reported that water quality in the lower Boise steadily deteriorated from Lucky Peak Lake to the river's mouth as a result of municipal wastewater discharges and frequent irrigation withdrawals and return flows (Idaho Department of Health and Welfare, 1989). Water quality near Parma was classified as poor, due to "excessive bacteria, nutrients, sediment, metals, and elevated temperatures."

In 1993 and 1994, the USGS sampled water from five major storm-sewer outfalls that empty into the lower Boise in Boise and Garden City to assess the suitability of regional and adjusted regional models to estimate runoff volume and loads from storm-sewer outfalls (Kjelstrom, 1995). The USGS data indicated that elevated concentrations of nutrients, trace elements, organic compounds, and bacteria entered the lower Boise.

Although numerous water-quality studies of the lower Boise have been done, none were designed to quantify long-term trends, identify the major sources of nutrient, sediment, and bacterial contamination, and compare water-quality properties and constituents with standards and criteria, background conditions, and biological integrity. The study described in this report was designed to provide this information.

Study Background

The Lower Boise River Water Quality Plan (LBRWQP) was formed in 1992 to identify water-quality problems, initiate voluntary water-quality management practices, and monitor the long-term effectiveness of these practices on the water quality and biotic integrity of the lower Boise. In 1994, in

Table 1. Water-quality-limited stream segments on the lower Boise River, Idaho, listed under the Federal Clean Water Act, section 303(d) as impaired [Idaho Department of Environmental Quality, 1999]

Segment boundary	Pollutants	Beneficial uses
Diversion Dam to Star	Sediment, dissolved oxygen, oil and grease	Domestic water supply, agricultural water supply, coldwater biota, salmonid spawning, primary contact recreation, secondary contact recreation
Star to Notus	Nutrients, sediment, dissolved oxygen, temperature, bacteria	Agricultural water supply, coldwater biota, salmonid spawning, primary contact recreation
Notus to Snake River	Nutrients, sediment, dissolved oxygen, bacteria, temperature	Agricultural water supply, coldwater biota, primary contact recreation, secondary contact recreation

cooperation with IDEQ and with the support of LBRWQP, the USGS began a comprehensive, 8-year study to assess water quality and biotic integrity of the lower Boise using a combination of reconnaissance, synoptic (intensive sampling over a broad area within a short timeframe; a "snapshot"), and interval water-quality sampling, in addition to annual biological sampling. Among the numerous monitored constituents, those targeted for long-term monitoring were nutrients (phosphorus and nitrogen), suspended sediment, and bacteria. Annual sampling for algae and macroinvertebrates began in 1995. Annual sampling for fish was not done, owing to funding constraints; however, fish populations were assessed at least once during the study period at all biological sampling sites.

Section 303(d) of the Clean Water Act (CWA) requires States to develop total maximum daily load (TMDL) management plans for water bodies whose beneficial uses are impaired as a result of poor water quality. The lower Boise was added to Idaho's list of water-quality-limited streams in 1992 (table 1). To accommodate IDEQ's data needs for TMDL development, the study's original design was altered beginning in 1995. Selected drains were sampled more frequently during the beginning of the irrigation season and during initial reservoir releases in May and June. Drains not targeted in the TMDL or not exceeding water-quality standards were sampled less frequently from 1999 through 2002. In 2000, the State water-quality standard for bacteria changed from fecal coliform to *Escherichia coliform* (*E. Coli*); beginning in 1999, the USGS began monitoring for both fecal and *E. Coli*.

Purpose and Scope

This report describes results of an 8-year study to (1) document spatial and temporal trends in water quality over the course of the study; (2) identify potential sources of selected constituents; and (3) define water-quality and biological conditions in the lower Boise in relation to least-impacted rivers and to established standards and criteria.

The water-quality conditions assessed were dissolved oxygen, specific conductance, pH, temperature, suspended sediment, nutrients and associated chlorophyll-*a* concentrations, and fecal coliform and *E. Coli* bacteria concentrations. The biological conditions assessed were periphytic chlorophyll-*a*, benthic macroinvertebrate communities, and fish communities. An appendix (back of report) describes a reconnaissance of ground- and surface-water interactions conducted at selected sites in the lower Boise during March and August 2001. This study was not part of the long-term monitoring effort but was included in this report at the request of the cooperators to identify another potential source of nutrients and bacteria to the lower Boise.

Acknowledgments

The author thanks the Boise Field Office staff and data management staff for assistance with fieldwork and data compilation over the duration of the study. Special thanks go to Peter Dileanis, Greg Clark, Mark Hardy, Steve Lipscomb, Terry Maret, and Paul Woods for their technical advice throughout the data analysis and writing of this report, and to Bill Mullins, who managed the lower Boise study for the first 6 years.

The author also thanks Dave Clark and Gary Barton for their planning, data collection, and interpretive contributions to the ground- and surface-water interaction study.

DESCRIPTION OF THE LOWER BOISE BASIN

The 1,290-mi^2 lower Boise Basin is located in Ada and Canyon Counties in southwestern Idaho between Lucky Peak Dam (river mile 64) and the confluence of the Boise and Snake Rivers (river mile 395) (fig. 1). The basin contains the most industrialized and urbanized areas in Idaho. The population in Ada and Canyon Counties in 2000 was approximately 432,300 (U.S. Census Bureau, 2002), which is 33 percent of Idaho's population. This is an increase of more than 46 percent over the 1990 population in these two counties. Both population and demand for water resources in the lower Boise Basin are increasing rapidly.

The lower Boise Basin is in the northern part of the western Snake River Plain and lies in a broad, alluvium-filled basin with several steplike terraces, or benches, which are more pronounced and continuous on the south side of the river. The upper basin, upstream from Lucky Peak Dam, is mountainous and sparsely populated. Downstream from Lucky Peak Dam, the basin floor slopes northwestward at a gradient of about 10 ft/mi. The altitude of the basin near Lucky Peak Dam is about 2,800 ft above sea level; the altitude near the river mouth is about 2,200 ft (Thomas and Dion, 1974). In addition to the lower Boise, several tributaries are interconnected by a complex irrigation system of canals, laterals, and drains. Climate in the lower Boise Basin is characterized as semiarid; winters are cool and wet, and summers are warm and dry. Over the course of this study there have been years of normal precipitation (1995 to 1998, and 2000) and years of severe drought (1999, 2001, and 2002). For more information on geography, geology, and climate for the lower Boise, refer to Thomas and Dion (1974), Mullins (1998), and the lower Boise subbasin assessment (Idaho Department of Environmental Quality, 1999).

Land use and land cover in 1994 within the lower Boise Basin consisted of urban activities (4 percent); irrigated agriculture, pasture, and other agriculture-related activities (47 percent); and rangeland, water, and unclassified land (49 percent) (Kramer and others, 1994). Crops in the basin consist of alfalfa hay and seed, corn and corn seed, wheat, potatoes, onions, sugar beets, barley, spearmint and peppermint, and dry edible beans (Koberg and Griswold, 2001). Land use in the upper Boise Basin consists primarily of logging and recreation. In the past, parts of the upper basin were heavily mined for gold using shaft-mining and placer-mining methods (Stacy, 1993).

Since 1994, land use in the lower Boise Basin has undergone major changes resulting in conversions of large tracts of farmland to residential subdivisions and commercial facilities, and conversions of many residential areas in and near cities to businesses, shopping centers, and parking lots. These changes have resulted in an increase in stormwater runoff into the lower Boise and its tributaries and potential for changes in water quality in the basin (Kjelstrom, 1995). The City of Boise has worked in recent years to reduce and treat stormwater runoff. For more information on their stormwater management plan, see URL: *http://www.cityofboise.org*

DATA COLLECTION AND ANALYSIS

Surface Water

Surface-water samples were collected monthly or bimonthly during the nonirrigation season (October through March) and as often as twice a month during the irrigation season (April through September). Sampling site locations are shown in figure 1; types of samples and data collected at the sites are listed in table 2. For convenience, the four mainstem sampling sites hereafter are referred to as Diversion, Glenwood, Middleton, and Parma.

Depth- and width-integrated water samples were collected, processed, and preserved according to the methods described by Wilde and others (1999). These methods produce a composite sample that is representative of flow in a cross section. Water samples were homogenized in a churn splitter, which is designed to facilitate the withdrawal of a representative subsample from a large, composite water sample. Water samples to be analyzed for dissolved constituents were filtered through 0.45-μm-pore-size capsule filters certified to be free from contamination. Samples for nutrient analysis were acidified with sulfuric acid and were chilled at 4°C until analysis to prevent reduction or loss of target analytes.

Samples were analyzed by USGS laboratories or in the field. Nutrients were analyzed by the USGS National Water-Quality Laboratory according to methods described by Fishman (1993) and quality-assurance/quality-control protocols described by Pritt and Raese (1995). Suspended sediment was analyzed by the USGS Cascades Volcano Observatory Sediment Laboratory using methods described by Guy (1969). At the time of sample collection, specific conductance, pH, dissolved oxygen (DO) and water temperature were measured at the center of the stream by using calibrated electrometric meters or multiparameter meters.

Discharge was measured for all samples. For sites not equipped with continuous water stage recorders, instantaneous stream discharge was measured at the time of sample collection using methods described by Rantz and others (1982). Continuous water temperature data were collected hourly during intermittent intervals at the five biological sites using Hobo continuous temperature recorders from Onset Computer Corporation.

Water samples for bacterial analysis were collected near the center of the stream. Fecal coliform bacteria concentrations were measured using membrane-filter methods and are reported as colonies per 100 mL of sample (Wilde and others, 1999). *E. Coli* concentrations were measured using the Colilert Quantitray method by Idaho Department of Health and Welfare, Boise Laboratory, and reported as most probable number (MPN) per 100 mL (Eaton and others, 1999). Both fecal coliform and *E. Coli* standards are reported as organisms per 100 mL, which is considered equivalent to colonies and MPN per 100 mL in this report.

The methods used to evaluate nutrient data were graphical and statistical. Data distributions were displayed graphically by using truncated boxplots (Helsel and Hirsch, 1992). These plots show five percentiles of the data distribution: 10^{th}, 25^{th}, 50^{th} (median), 75^{th}, and 90^{th}. Individually, boxplots can indicate properties of the distribution, such as spread and skewness. Side-by-side boxplots can be used to visually compare two or more data distributions.

Frequency of sample collection was not consistent within and between seasons, and data distributions for most constituents did not appear to be normally distributed. Differences in standard deviations between sites and seasons indicated obvious variations in spread; therefore, nonparametric statistical methods were chosen to test for differences among groups of data. The Kruskal-Wallis test was used to test for differences in median values using the 95-percent confidence interval ($\alpha = 0.05$). The correlation between constituents was determined using Spearman correlation coefficients. A correlation was determined to be significant when a coefficient exceeded the critical value (Zar, 1974). Letters were placed beside selected boxplots near the median of each plot to show the results of a multiple comparison test. Plots identified by the same letter indicate that the medians were not significantly different.

This study was not designed to calculate annual loads of constituents; therefore, only instantaneous loads were summarized, and seasonal synoptic loads were used to determine the spatial distribution of constituents and identify major sources. Loads were calculated by multiplying instantaneous discharge by constituent concentration and an appropriate conversion factor for units.

If a constituent concentration was correlated with flow, a flow-adjusted concentration was calculated to reduce the influence of stream discharge in the evaluation of trend. Flow-adjusted concentrations were calculated by multiplying

Table 2. Locations and types of sampling sites on the lower Boise River and tributaries, Idaho, 1994–2002

[USGS, U.S. Geological Survey; **bold**, main-stem sites]

USGS site Identification	Site name	USGS site description	Types of samples and data collected: Sediment, nutrients, and bacteria	Periphyton	Benthic macro-invertebrates	Fish
13203510	**Diversion**	Boise River below Diversion Dam near Boise	X			
13203760	Below Diversion	Boise River at Eckert Road near Boise		X	X	
13204100	**Loggers Creek**	Boise River at Loggers Creek				X
13206000	**Glenwood**	Boise River at Glenwood Bridge near Boise	X	X	X	X
13206400	Eagle Drain	Eagle Drain at Eagle	X			
13208750	Thurman Drain	Thurman Drain near Eagle	X			
13210050	**Middleton**	Boise River near Middleton	X	X	X	X
13210795	Fivemile Creek	Fivemile Creek and Franklin Road	X			
13210660	Tenmile Creek	Tenmile Creek and Franklin Road	X			
13210815	Fifteenmile Creek	Fifteenmile Creek at mouth near Middleton	X			
132108247	Mill Slough	Mill Slough below Grade Ditch near Middleton	X			
13210835	Willow Creek	Willow Creek at Highway 44 at Middleton	X			
13210850	Mason Slough	Mason Slough at mouth near Caldwell	X			
13210985	Mason Creek	Mason Creek at mouth near Caldwell	X			
13210986	W. Hartley Drain	West Hartley Drain (Gulch) near Caldwell	X			
13210987	E. Hartley Drain	East Hartley Drain (Gulch) near Caldwell	X			
13211000	**Caldwell**	Boise River at Highway 20-26 crossing near Caldwell		X	X	X
13211445	Indian Creek	Indian Creek at mouth near Caldwell	X			
13212550	Conway Gulch	Conway Gulch at Highway 20-26 crossing at Notus	X			
13212890	Dixie Drain	Dixie Drain near Wilder	X			
13213000	**Parma**	Boise River near Parma	X			
13213030	**Below Parma**	Boise River at mouth near Parma		X	X	X

the constituent concentration by the ratio of the instantaneous discharge and the average instantaneous discharge at a site for the period of the study (1994–2002). The summary graphs of trends in flow-adjusted constituent concentrations include a smooth line using the LOWESS (LOcally WEighted Scatterplot Smooth) technique that describes the relation between X and Y without assuming linearity or normality of residuals (Cleveland, 1979; Helsel and Hirsch, 1992).

Biological

The five biological sampling sites were located as follows: (1) downstream from the Diversion Dam water-quality site, (2) just upstream from the Glenwood water-quality site, (3) downstream from the water-quality site near Middleton, (4) downstream from the Highway 20/26 crossing at Caldwell, and (5) downstream from the Parma water-quality site near the mouth of the lower Boise. Sampling site locations are shown in figure 1 and the data collected at these sites are listed in table 2.

From 1995 to 2000, periphyton and macroinvertebrate samples were collected from two locations at three different riffles within a reach. Each riffle sample was analyzed individually. This protocol was changed in 2001 to a composite of five riffle samples within a reach, which allowed for significant cost savings while producing data comparable with that of other State and Federal programs. A comparison of the reproducibility and variability of macroinvertebrate data within and between reaches is provided in the section, “Quality Control Samples.”

Periphyton samples were collected and processed using protocols developed by the USGS National Water-Quality Assessment (NAWQA) Program (Porter and others, 1993). A measured portion of the periphyton sample was filtered through a glass-fiber filter, which was wrapped in foil and placed on dry ice or in a freezer until analyzed. Chlorophyll-*a* and ash-free dry weight were analyzed by Reclamation’s Pacific Northwest Regional Laboratory in Boise, Idaho, using spectrophotometry (standard method 10200H, Eaton and others, 1999).

Semiquantitative benthic macroinvertebrate samples were collected using protocols developed by the USGS NAWQA Program (Cuffney and others, 1993). A Slack sampler (modified Surber sampler) with a 425-μm-mesh net was used to collect invertebrates from cobble substrates. Large or rare taxa were isolated from the main sample to ensure that they were not lost or damaged during laboratory processing. Samples were fixed in 10-percent buffered formalin and shipped to Aquatic Biology Associates, Inc., Corvallis, Oregon, for analysis.

Metrics (community composition attributes) were calculated for temporal and spatial site comparison as well as for comparison with sites in Idaho classified as least impacted. These metrics also were used to calculate indices that may help to identify human impacts on macroinvertebrate communities and to monitor changes in stream ecosystem health. One index used is the Idaho River Macroinvertebrate Index (RMI), which was developed using five macroinvertebrate metrics to assess water quality in rivers: taxa richness, Ephemeroptera-Plecoptera-Trichoptera (EPT) richness, percent dominant taxon, percent Elmidae (riffle beetles), and percent predators. This index also has been called the Invertebrate River Index (IRI) in previous USGS publications (Maret and others, 2001). The metric selection, index development, and scoring criteria can be found in chapter 4 of the Idaho River Ecological Assessment Framework document (Grafe, 2002).

For an index to work effectively to distinguish between water-quality conditions at sites in the lower Boise, reference, or least-impacted, sites were identified. Although the site at Diversion could be considered least impacted by urban and agricultural runoff, a true reference site does not exist for the lower Boise, owing to the effect of upstream dams and water diversions, so other least-impacted sites in Idaho were used for comparison of metrics and RMI scores. Macroinvertebrate communities were evaluated further by examining tolerances to fine sediment, functional feeding groups, and tolerant and introduced taxa.

Fish communities were assessed by electrofishing a representative reach of river using protocols developed by the USGS NAWQA Program (Meador and others, 1993). Shallow riffle areas were sampled using backpack electrofishing equipment, and deep-water areas were sampled using a drift boat, with netting crews of four to six people. Fish were identified taxonomically; measured, weighed, and examined for types and numbers of anomalies; and counted for numbers of individuals. Fish were identified onsite by Terry Maret, USGS, and Dale Allen, Idaho Department of Fish and Game (IDFG), following taxonomic protocols established by Robins and others (1991).

Sampling Frequency

Samples for water-quality analysis were collected at different intervals over the course of this study. Samples collected during mid- to high-level discharge are well represented, but few samples were collected during low discharge (fig. 2). Main-stem sites were sampled monthly during the irrigation season (April through September) and every two months during the nonirrigation season (October through March). The tributaries usually were sampled monthly during the irrigation season and intermittently during the nonirrigation season. In 1995 and 1996, additional samples were collected at all sites just prior to and just after the beginning of the irrigation season, usually in April.

To understand how the load of nutrients moves through the lower Boise, synoptic studies were done, mostly during the spring or early irrigation season when the loads were expected to be the largest. The focus of these synoptics was to identify the time that the largest load of pollutants entered the lower Boise. Irrigation season synoptics were done during

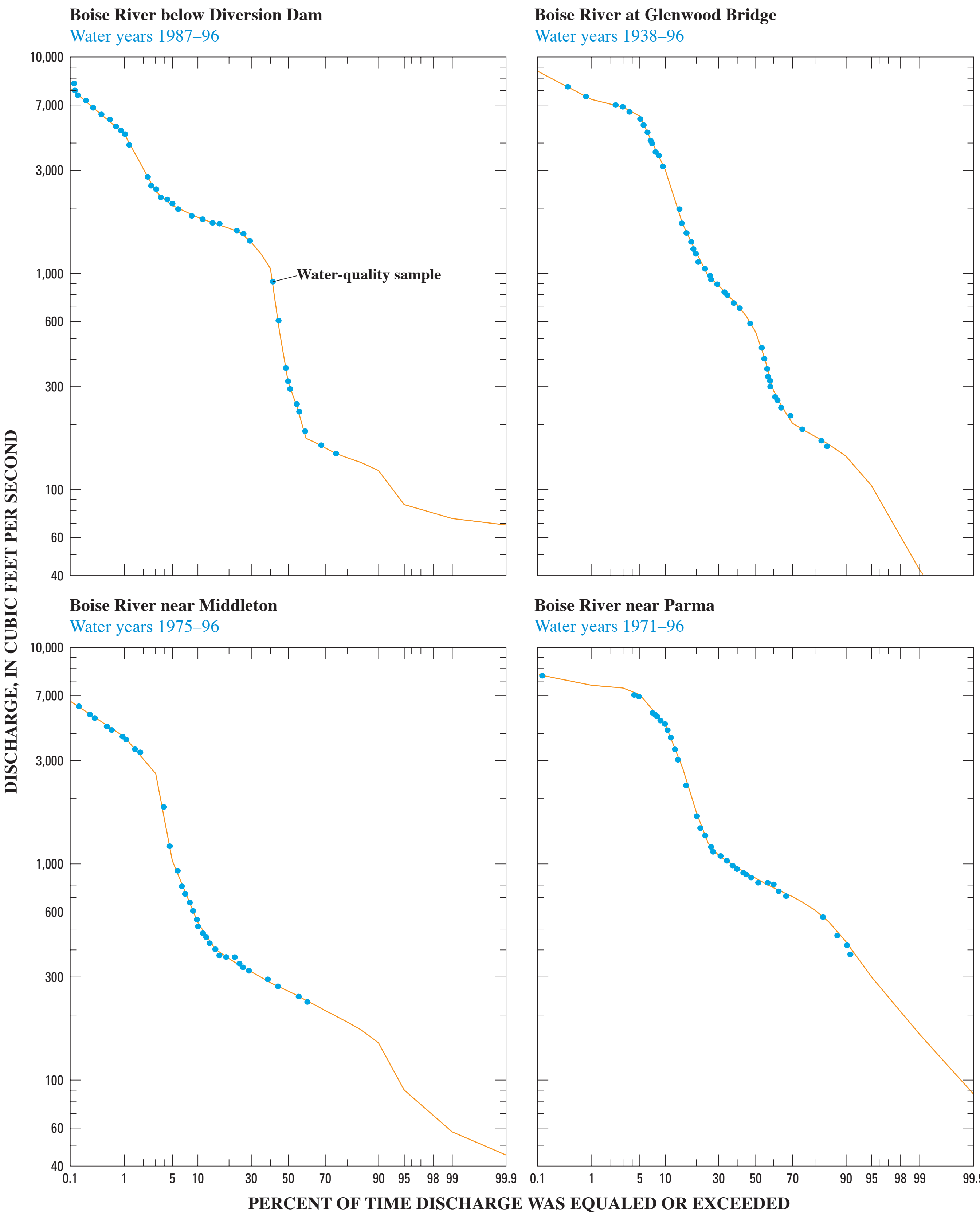


Figure 2. Discharge for period of record and discharge when water-quality samples were collected at main-stem sites on the lower Boise River, Idaho, 1994–2002.

May 1994, May 1995, May 1996, June 1997, July 1999, and May 2000. A few synoptics were added during the winter (nonirrigation season) to determine fluctuations in load during low discharge. Synoptic samples were collected over intervals of as many as 10 days during November 1994, December 1995, December 1996, December 1999, and February 2000.

Quality Control Samples

Between 6 and 10 percent of the water-quality samples collected during this study were blank or split replicates. Field blanks were used to estimate how contamination might bias analytical results. Replicate samples were used to estimate the magnitude of variability in sample results. Results of blank and split replicates are given in table 3 and evaluated in the following paragraphs.

Field-blank samples were collected by passing certified analyte-free water through all sampling equipment used for collecting and processing samples. These samples were submitted for laboratory analyses along with the environmental samples (standard field samples). Analyte concentrations less than 25 percent of the lowest concentration in environmental samples were considered insignificant for interpretive purposes. If analyte concentrations in blank samples exceeded 25 percent of the lowest environmental sample concentration, the results were verified by the National Water Quality Laboratory (NWQL) and examined further to determine how this level of contamination could affect data interpretation. Although slight nutrient contamination was detected in some of the blank samples, concentrations were minimal and did not affect

Table 3. Quality control sample summary for samples collected in the lower Boise River and tributaries, Idaho, 1994–2002

[mg/L, milligrams per liter; N, nitrogen; P, phosphorus; QC, quality control; <, less than; Average standard deviation, samples with no detections and sample pair outliers were disregarded because they would not affect the overall standard deviation of the environmental samples; quality control limits for replicate pairs: concentration 0–5 mg/L, 1X detection limit difference acceptable; concentration 5–20 mg/L, 2X detection limit difference acceptable]

Constituent	Method reporting limit (mg/L)	Total No. of samples	Percent total QC samples	No. of blanks	No. of detections in field blanks	Range of detection in blanks (mg/L)	No. of replicate pairs used in variability calculation	No. exceeding quality control limits for replicate pairs	Average standard deviation of replicates, mg/L (range of environmental concentration)	Within data quality limits
Nitrogen, dissolved ammonia (mg/L as N)	0.041	829	6	14	2	<0.002-0.06	30	0	0.003 (all)	yes
Nitrogen, dissolved ammonia plus organic (mg/L as N)	0.1	251	8	2	none		15	0	0.005 (all)	yes
Nitrogen, total ammonia plus organic (mg/L as N)-Kjeldahl	0.1	817	8	5	none		56	0	0.05 (all)	yes
Nitrogen, dissolved nitrite plus nitrate (mg/L as N)	0.06	829	9	14	none		57	3	0.02 (all)	yes
Phosphorus, total (mg/L as P)	0.04	254	8	5	1	<0.01-0.01	52	2	0.009 (all)	yes
Phosphorus, dissolved (mg/L as P)	0.038	829	10	1	none		22	0	0.008 (all)	yes
Orthophosphorus, dissolved (mg/L as P)	0.018	817	9	14	3	<0.001-0.02	54	1	0.002 (all)	yes

Table 4. Percent reproducibility of selected metrics between replicate macroinvertebrate samples collected at selected sites on the lower Boise River, Idaho, 1995–99

[EPT, Ephemeroptera, Plecoptera, and Trichoptera]

Year	Site	EPT taxa	Total taxa	Density
1995	Diversion	80	82	54
	Glenwood	89	80	72
	Middleton	67	81	61
	Caldwell	67	70	32
	Parma	86	87	81
1996	Diversion	88	88	56
	Glenwood	67	95	98
	Middleton	100	92	10
	Caldwell	80	46	36
	Parma	67	76	49
1997	Diversion	77	70	33
	Glenwood	60	90	92
	Middleton	82	88	58
	Caldwell	88	76	42
	Parma	88	79	82
1998	Diversion	100	95	34
	Glenwood	82	95	84
	Middleton	75	93	62
	Caldwell	75	96	78
	Parma	80	92	43
1999	Diversion	67	63	69
	Glenwood	78	82	76
	Middleton	62	74	21
	Caldwell	57	81	41
	Parma	67	88	22
Average reproducibility		77	82	55

data interpretation. Ammonia and orthophosphorus concentrations were detected in two and three blanks, respectively, and exceeded 25 percent of the lowest environmental concentrations. Two ammonia concentrations (0.04 and 0.06 mg/L as nitrogen) were only slightly above the method-reporting limit and did not exceed 25 percent of the lowest environmental concentrations. Orthophosphorus concentrations in three blanks were near the method-reporting limits and 10 times less than 25 percent of the lowest environmental concentrations.

The variability determined by using field replicates was assumed to be the true standard deviation (field variability) for all possible samples at all concentrations. Quality control limits for acceptable differences between replicates was dependent on the concentration of the analyte above the reporting limit. For analyte concentrations between 0 and 5 times the reporting limit, a difference of one reporting limit was allowed, and for a detection between 5 and 20 times the reporting limit, a maximum difference of the greater of 2 times the reporting limit, or 20 percent relative percent difference, was acceptable. Concentrations more than 20 times the reporting limit should not exceed a relative percent difference of 10 percent. Relative percent difference is the absolute difference between replicates divided by the average of the two times 100.

Three sample pairs exceeded quality control limits for nitrite plus nitrate, two for total phosphorus, and one for orthophosphorus; these results were verified by the NWQL. Most of the differences in these sample pairs were the result of a detection of an analyte in one sample and no detection in the replicate. These data were removed from the dataset prior to analysis, even though the concentrations were close to median values and probably would not have affected the data interpretation.

The biological sampling protocol for periphyton and macroinvertebrates was revised in 2001 to reduce sample processing costs and to allow comparability of the data with those of other biological sampling programs in Idaho, such as the statewide water-quality monitoring program (Maret and others, 2001) and the NAWQA Program. The original sampling protocol required that samples be collected from two different locations (subsites) from each of three separate riffles within a sampling reach to determine variability among riffles and reach locations. The subsite samples contained similar chlorophyll-*a* concentrations; therefore, only macroinvertebrate populations were compared for reproducibility and similarity. To ensure that combining the separate riffle samples would not reduce the adequacy of the data for comparison of water-quality conditions between sites and within a reach, macroinvertebrate samples were compared using percent reproducibility (Rabeni and others, 1999). Within- and between-reach variability was examined using the Quantitative Similarity Index (QSI; Shackleford, 1988). Percent reproducibility (percent R) was calculated using the equation:

$$\text{Percent R} = 100\ \text{Min}(M_1, M_2)/\text{Max}(M_1, M_2),$$

where M_1 and M_2 are values for a metric from the 1st and 2nd subsites.

The percent reproducibility for EPT taxa, total taxa, and density comparison for each site from 1995 to 1999 is listed in table 4. The average reproducibility among samples was 77 percent for EPT, 82 percent for total taxa metrics, and 55 percent for density. The QSI identifies within- and between-reach variability by determining the similarity of assemblages or populations (Whittaker, 1970). The average QSI for each of the lower Boise sites is closer to 1 than to 0, which indicates similarity among populations at the three riffles within each site (table 5). As a result of this comparison, beginning in 2001, a

Table 5. Quantitative Similarity Index (QSI) scores for macroinvertebrate data collected at selected sites on the lower Boise River, Idaho, 1995–99

[0, totally different assemblages; 1, identical assemblages; calculated for triplicate samples within a reach and between reaches]

Year	QSI Diversion	QSI Glenwood	QSI Middleton	QSI Caldwell	QSI Parma	Average QSI, all sites by year	QSI between sites
1999	0.57	0.82	0.59	0.85	0.57	0.68	0.13
1998	0.67	0.84	0.71	0.61	0.66	0.70	0.12
1997	0.48	0.78	0.70	0.73	0.77	0.69	0.24
1996	0.84	0.76	0.73	0.30	0.59	0.64	0.03
1995	0.76	0.51	0.56	0.38	0.63	0.57	0.16
Site average QSI	0.66	0.74	0.66	0.57	0.64		

single sample of a composite of five riffle samples within a reach, similar to the NAWQA sampling protocol (Cuffney and others, 1993), was used for periphyton and macroinvertebrate collection. The between-site QSI scores were closer to 0 than to 1, which indicates dissimilar populations.

Taxonomy of sculpin (*cottus* sp.) and dace (*Rhinichthys* sp.) was verified by Dr. Carl E. Bond and Dr. Douglas F. Markel, Oregon State University, Corvallis, and by Dr. Gordon Haas, University of British Columbia, Vancouver, Canada. Specimens of selected species were retained for reference and verification of field identifications. A voucher collection is located in the Orma J. Smith Museum of Natural History, Albertson College, Caldwell, Idaho.

HYDROLOGIC CONDITIONS

Surface Water

Flow in the Boise River between Lucky Peak Dam and the mouth is controlled primarily by reservoir regulation, irrigation withdrawals and return flows, and seepage of shallow ground water (Thomas and Dion, 1974). The three reservoirs upstream in the Boise River Basin have a combined storage capacity of approximately 1 million acre-ft and are managed primarily for irrigation and flood control and secondarily for recreation and power generation (Mullins, 1998). Some storage is assigned to salmonid flow augmentation in Lucky Peak Lake, as required by the National Marine Fisheries Service (NMFS) 1995 Biological Opinion for the Snake River Basin (Bureau of Reclamation, accessed March 2002, at URL: *http://www.usbr.gov/dataweb/html/boise.html*). Flood-control releases from Lucky Peak Lake and irrigation return flows in the spring in the lower basin result in higher streamflows that can last from January through June and persist all the way to the Snake River. The highest instantaneous discharge recorded during this study was about 8,000 ft^3/s measured at Glenwood in the spring of 1998. In years of severe and (or) consecutive drought, late winter and spring discharge remains low except for short periods of time. Irrigation releases typically begin in mid-April (or following flood releases from Lucky Peak Dam during high-discharge years) and continue through mid-October. The annual and mean monthly discharges for the period of record, following construction of the upstream dams, at two sites on the lower Boise at Glenwood and Parma illustrate the wide variation between water years and the regulated monthly discharge in the river (fig. 3). Water is diverted from the lower Boise at several locations, and 12 major irrigation tributaries examined in this report discharge to the Boise River between Lucky Peak Lake and the mouth (fig. 4).

Ground Water

The widespread application of irrigation water, which began in 1863, has significantly altered the near-surface ground-water system in the basin. Ground-water levels were reported to have risen as much as 140 ft in some areas in the early 1900s (Nace and others, 1957). Most of the recharge to the ground water results from the downward percolation of precipitation and irrigation water. Other sources of recharge include leakage from irrigation canals, laterals, and septic tank systems (Thomas and Dion, 1974). The general direction of ground-water movement in the lower Boise Basin is toward

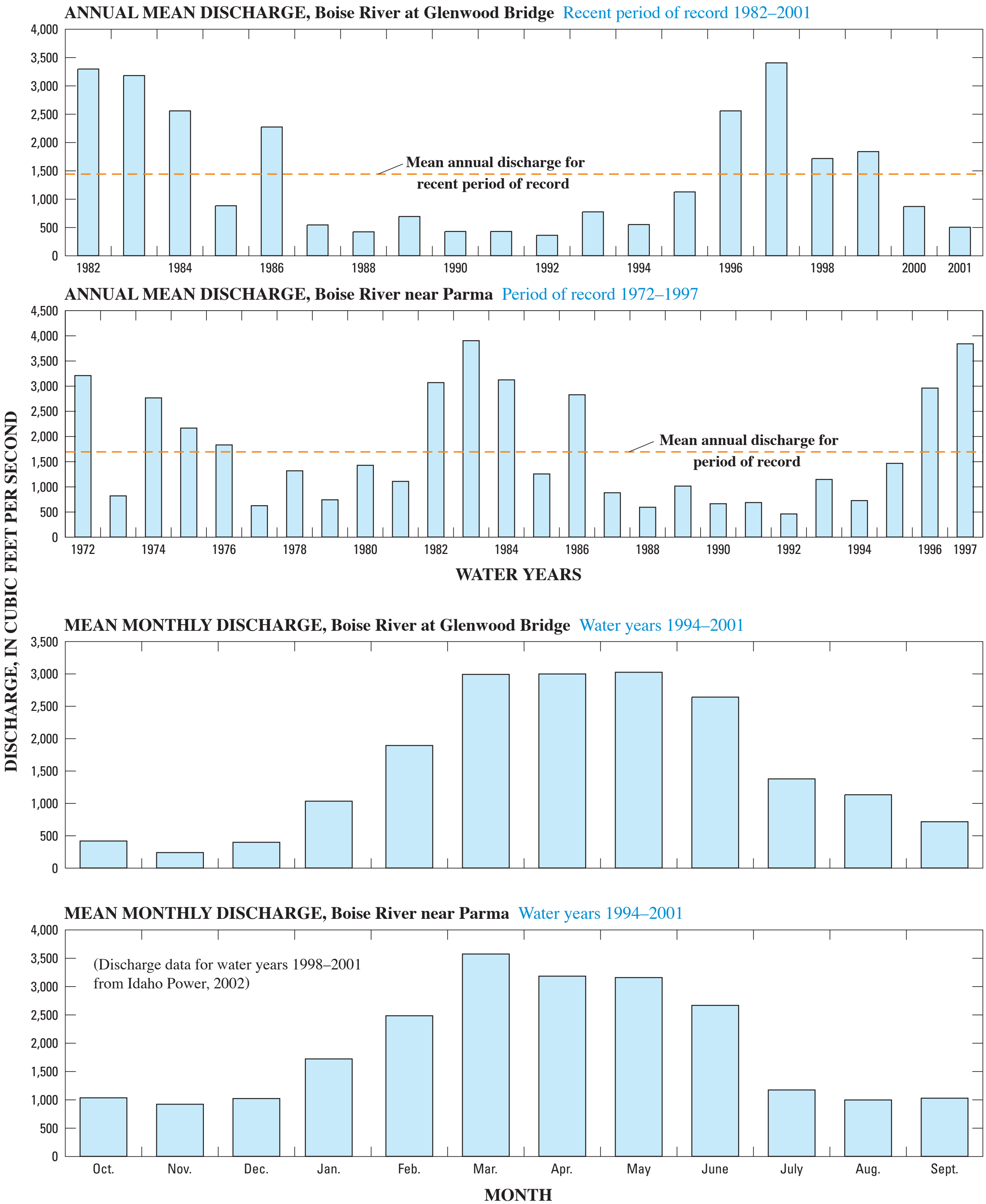


Figure 3. Annual mean and mean monthly discharge for the Boise River at Glenwood Bridge and near Parma, Idaho.

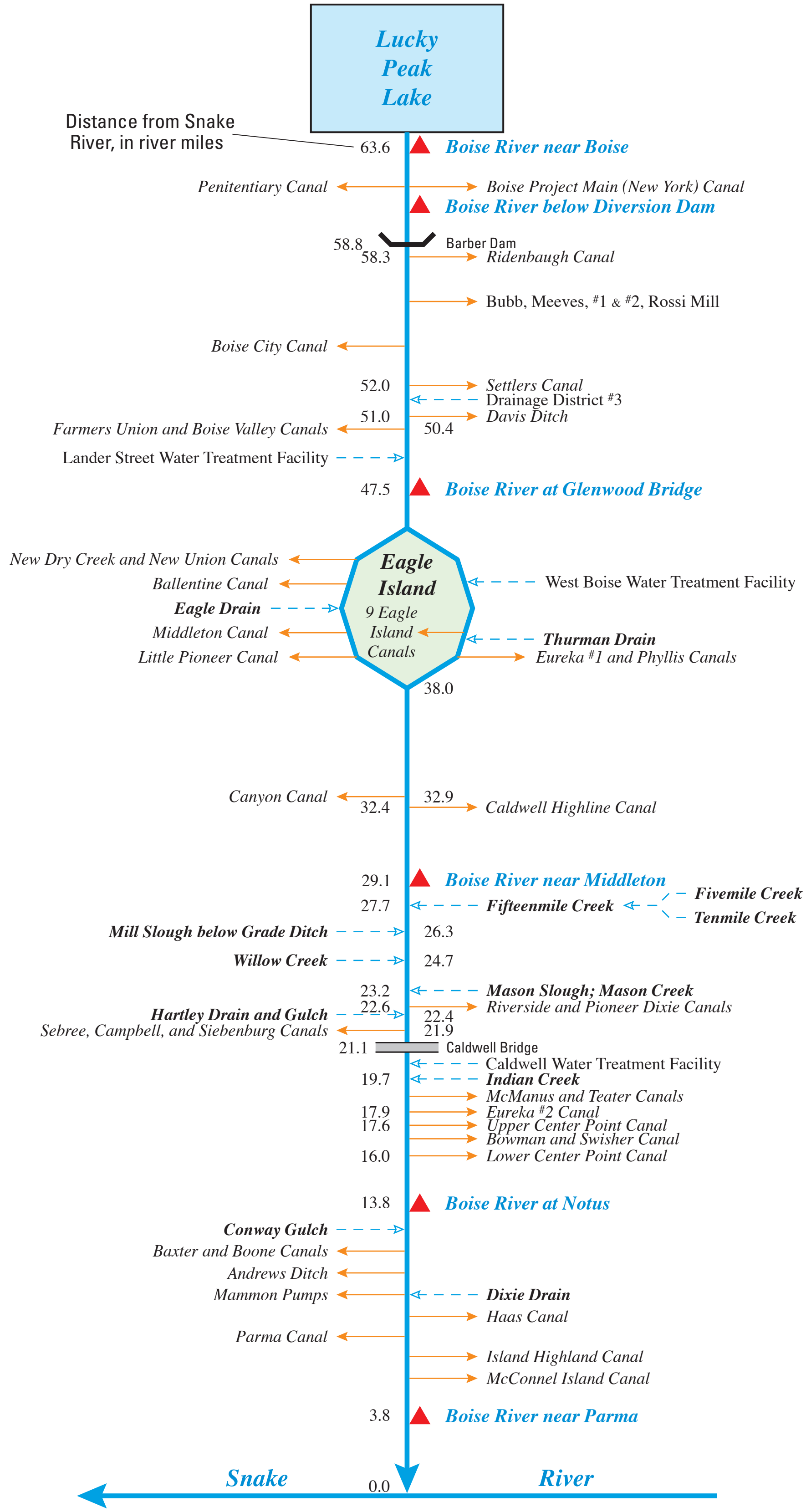


Figure 4. Schematic diagram of diversions, drains, and tributaries along the Boise River from Lucky Peak Lake to the Snake River, Idaho. (Modified from Warnick and Brockway, 1974)

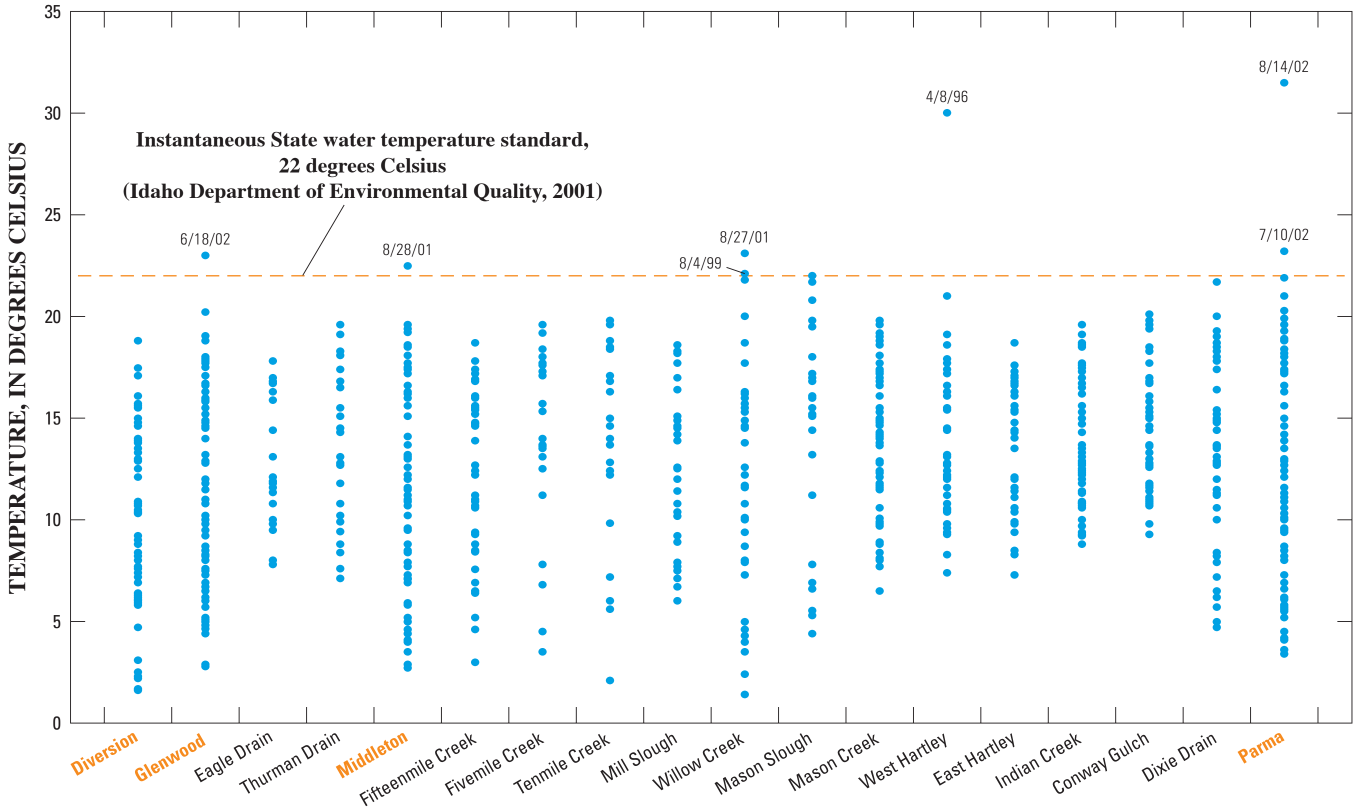


Figure 5. Instantaneous temperature at selected sites on the lower Boise River and tributaries, Idaho, 1994–2002. (Site names in **gold** are main-stem sites)

the river, although the tributaries may locally influence the ground-water systems (Boyle, 2001).

The near-surface ground water discharges to the lower Boise directly as seepage and indirectly through tributary streams and drains, primarily Fifteenmile Creek, Mason Creek, Indian Creek, and Dixie Drain (Thomas and Dion, 1974). During most winters, nearly all the discharge to the lower Boise between Lucky Peak Lake and the mouth is from ground water (Thomas and Dion, 1974). The post-irrigation season contribution of this direct and indirect ground-water discharge is about 300,000 acre-ft, roughly equivalent to the usable storage in Lucky Peak Lake or Arrowrock Reservoir (Thomas and Dion, 1974). More recent information on ground-water movement can be accessed on the Idaho Department of Water Resources (IDWR) Website at URL: *http://www.idwr.state.id.us/tvalley/ground_water/ground_water.htm*

Geothermal water (temperature greater than 29ºC) is present along faults at the base of the foothills, underlying the regional ground-water system in parts of the lower Boise Basin, and does not appear to affect the nonthermal water quality of the lower Boise. The location and movement of geothermal water along the lower Boise front are summarized by the Idaho Water Resources Research Institute at URL: *http://boise.uidaho.edu/iwrri*

Previous local and regional ground-water studies have identified elevated nutrient concentrations. The Idaho Department of Agriculture completed a study on ground- and surface-water interactions within the Mason Creek drainage (Fox and others, 2002) and concluded that the ground water in this basin is hydraulically connected to Mason Creek and seasonally contributes both phosphorus and nitrate to the river. A reconnaissance study of ground- and surface-water interactions in the lower Boise by the USGS in 2001 identified nutrient inputs from shallow ground water. Data collected during this reconnaissance are given in the appendix. Elevated nitrate concentrations have been reported in regional ground water by IDEQ (Boyle, 2001), and USGS (Parliman and Spinazola, 1998).

WATER-QUALITY CONDITIONS

General Water Properties

Temperature, dissolved oxygen, pH, and specific conductance were measured at all sites where water-quality samples were collected in the lower Boise. Continuous temperature measurements also were collected at selected sites. Summary statistics for general water properties (temperature, dissolved oxygen, pH, and specific conductance) and all water-quality

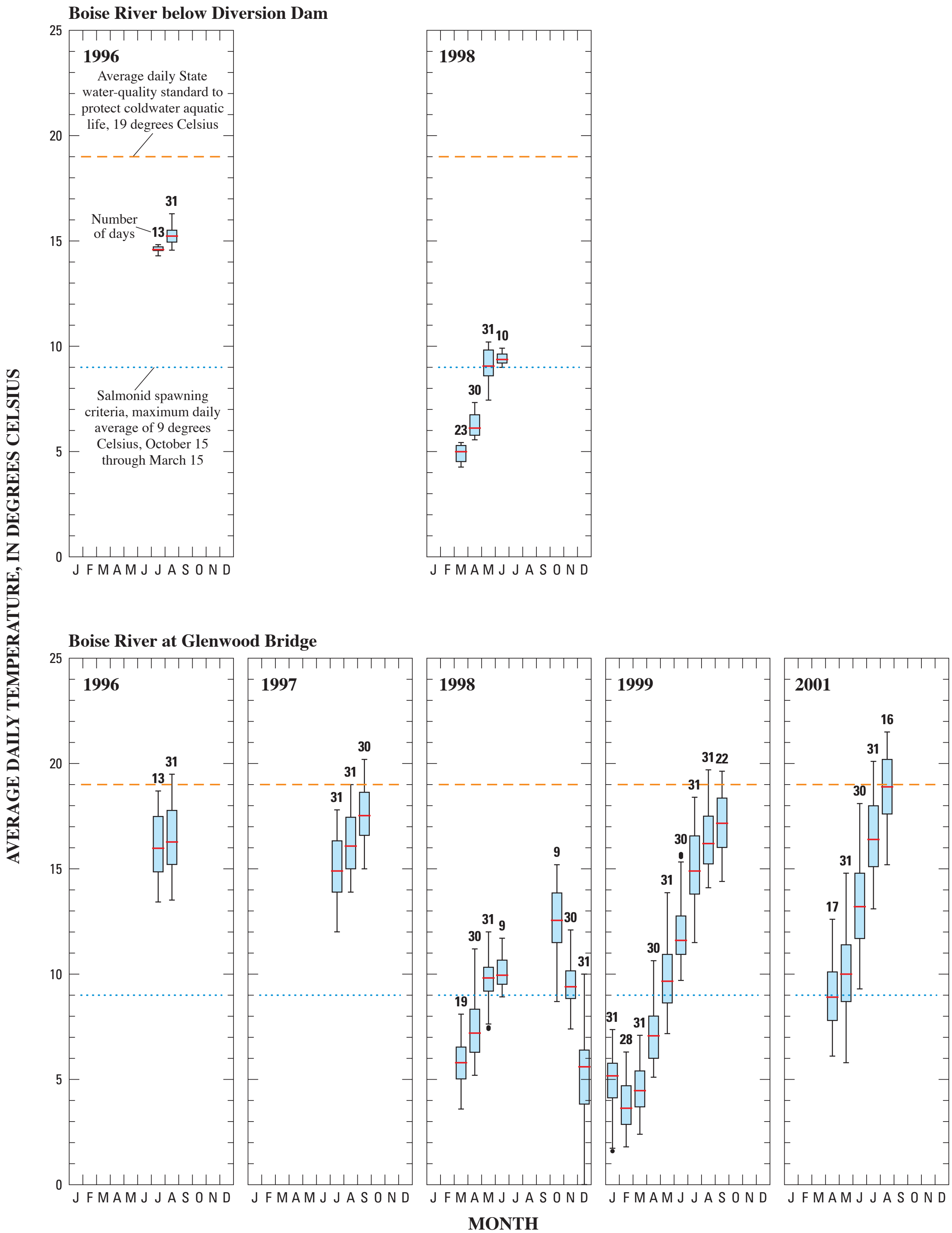


Figure 6. Average daily temperature from continuous temperature recorders at selected sites and times on the lower Boise River, Idaho.

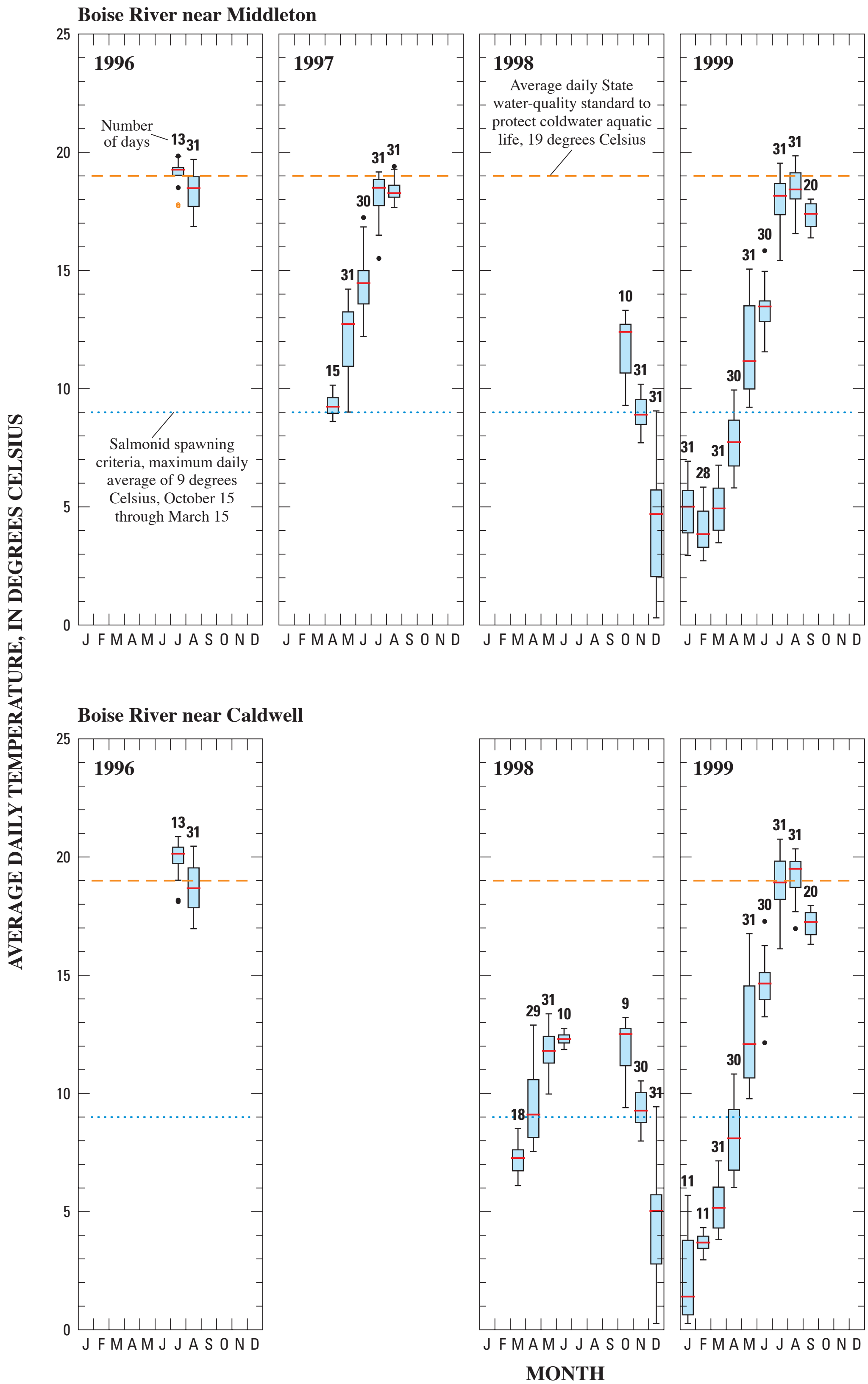


Figure 6. Average daily temperature from continuous temperature recorders at selected sites and times on the lower Boise River, Idaho—Continued.

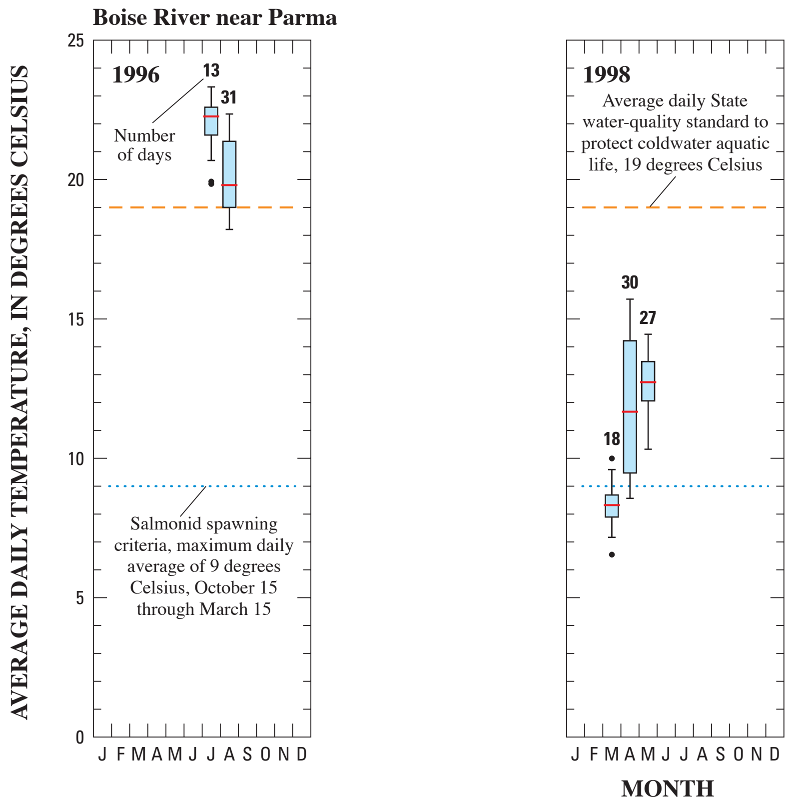


Figure 6. Average daily temperature from continuous temperature recorders at selected sites and times on the lower Boise River, Idaho—Continued.

constituents measured in the lower Boise from 1994 to 2002 are given in table 6. References to criteria, State standards, recommended levels, and background concentrations are described in the section, “Water Properties and Concentrations of Constituents in Relation to Criteria, State Standards, Local Recommendations, and Guidelines.”

The overall range in instantaneous temperature measurements in the lower Boise was 1.6°C at Diversion in February 2002 to 31.5°C at Parma in August 2002 (table 6, fig. 5). The instantaneous temperatures in the tributaries ranged from about 1°C in Willow Creek in February 1996 to 30°C at West Hartley Gulch in April 1996 (fig. 5).

Spatial and temporal comparisons of water temperature at the lower Boise biological sampling sites were hampered by the short-term and intermittent continuous temperature measurements. Continuous temperature measurements are statistically summarized in figure 6. Median daily average temperature at Diversion, measured in 1996 and 1998, ranged from about 5°C in March 1998 to about 15°C in August 1996. Temperatures were monitored more frequently at the Glenwood site during 1996–99 and in 2001; median daily average temperatures ranged from 3.5°C in February 1999 to 19°C in August 2001. Middleton temperatures were measured intermittently during 1996–99; median daily average temperatures ranged from about 4°C in February 1999 to about 19°C in July 1996. Caldwell temperatures were measured intermittently during 1996 and 1998–99; median daily average temperatures ranged from 1.5°C in January 1999 to about 20°C in July 1996. Temperatures at Parma were measured for fewer than 2 months in 1996 and fewer than 3 months in 1999; median daily average temperatures ranged from about 8°C in March 1998 to about 22°C in July 1996 (fig. 6).

Instantaneous measurements of DO concentrations in the lower Boise ranged from about 6.7 mg/L in July 1997 to 16.2 mg/L in December 1999; these minimum and maximum concentrations were both measured at Parma (table 6). Instantaneous DO saturation ranged from 77 percent at Parma to 146 percent at Glenwood (table 6).

Supersaturated DO conditions indicated that photosynthetic production of DO by aquatic plants (phytoplankton, periphyton, and aquatic macrophytes) was in excess of oxygen demands from respiration and decomposition at all the main-stem sites at some time during the study. Dissolved oxygen was supersaturated (>100 percent) at all the main-stem water-quality sampling sites during more than half of the measurements at each site (fig. 7). DO saturation exceeded 150 percent at Middleton in June, July, and August, and two times in October (fig. 7). DO saturation also exceeded 150 percent at Parma in August. Diel DO measurements were collected over one 24-hour period at the four main-stem sites in August 1997. DO saturation during that period was greater than 75 percent.

Table 6. Summary statistics for data collected at water-quality sampling sites on the lower Boise River, Idaho, 1994–2002

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; C, Celsius; N, nitrogen; P, phosphorus; mg/m², milligrams per square meter; mL, milliliters; MPN, most probable number]

Constituent	Diversion				Glenwood				Middleton				Parma			
	No. of samples	Mean	Median	Range	No. of samples	Mean	Median	Range	No. of samples	Mean	Median	Range	No. of samples	Mean	Median	Range
Instantaneous discharge, cubic feet per second	61	2,165	1,780	144 - 7,800	75	1,629	951	167 - 7,140	57	1,101	445	170 - 5,640	65	1,921	1,110	377 - 8,000
Dissolved oxygen, mg/L	60	11.5	11.6	9.1 - 14.6	74	11.5	11.4	8.4 - 15.8	57	12.1	11.7	8.8 - 15.7	64	10.4	10.2	6.7 - 16.2
Dissolved oxygen saturation, percent	60	110	107	97 - 145	74	115	116	95 - 146	57	119	115	90 - 116	64	106	102	77 - 138
pH, standard units	61	7.6	7.6	6.6 - 8.5	74	8.0	8.0	7.0 - 8.9	56	8.1	8.0	6.7 - 9.1	64	8.1	8.0	7.3 - 8.9
Specific conductance, µS/cm	61	74	75	51 - 109	75	100	90	52 - 197	57	163	136	74 - 314	64	351	343	128 - 585
Water temperature, degrees C	61	10.0	9.2	1.6 - 18.8	75	11.6	11.5	2.8 - 23.0	57	11.6	12	2.7 - 22.5	64	12.6	12.1	3.4 - 31.5
Dissolved ammonia, mg/L as N	61	0.03	0.02	0.02 - 0.07	75	0.03	0.02	0.004 - 0.07	57	0.03	0.02	0.02 - 0.10	62	0.04	0.04	0.02 - 0.21
Total ammonia plus organic, mg/L as N	61	0.16	0.17	0.09 - 0.26	75	0.23	0.20	0.10 - 0.53	57	0.29	0.27	0.13 - 0.64	62	0.50	0.48	0.20 - 1.21
Dissolved nitrite plus nitrate, mg/L as N	61	0.11	0.10	0.05 - 0.31	75	0.34	0.26	0.05 - 1.5	57	1.09	0.5	0.18 - 3.0	62	2.08	1.62	0.42 - 4.56
Total nitrogen, mg/L as N	61	0.27	0.26	0.15 - 0.51	75	0.56	0.45	0.18 - 1.90	57	1.37	0.89	0.38 - 3.51	62	2.57	2.17	0.62 - 5.33
Percent dissolved nitrogen	61	39	38	18 - 68	75	39	57	28 - 79	57	70	66	44 - 92	62	76	75	41 - 94
Total nitrogen load, pounds per day	61	3,629	2,250	151 - 19,250	75	3,710	2,230	650 - 19,980	57	4,550	3,760	856 - 14,820	62	18,990	17,171	4,180 - 51,930
Total phosphorus, mg/L as P	61	0.03	0.04	0.01 - 0.09	75	0.11	0.09	0.02 - 0.38	57	0.25	0.15	0.03 - 0.85	62	0.29	0.30	0.08 - 0.55
Dissolved orthophosphorus, mg/L as P	61	0.02	0.01	0.01 - 0.027	75	0.09	0.07	0.01 - 0.371	57	0.22	0.13	0.02 - 0.8	62	0.23	0.22	0.06 - 0.51
Percent dissolved orthophosphorus	61	54	45	17 - 100	75	75	80	8 - 100	57	81	88	14 - 100	62	75	76	40 - 100
Total phosphorus load, pounds per day	61	400	220	13 - 3,400	75	560	440	82 - 2,690	57	770	710	230 - 3,780	62	2,300	1,980	550 - 7,320
Average chlorophyll-*a*, mg/m²	8	9	6	<1 - 21	8	116	108	22-267	8	264	271	23-477	8	159	173	13-300
Suspended sediment, mg/L	58	6	4	1 - 38	71	12	5	1 - 107	52	15	6	2 - 211	63	53	45	8 - 245
Suspended sediment load, tons per day	58	40	10	1-720	71	90	10	1 - 1,020	52	90.0	10	2.3 - 2,060	63	320.0	140	18 - 1,560
Fecal coliform, colonies per 100 mL	57	2	1	1 - 29	70	89	43	4 - 1,030	53	216	73	3 - 3,950	59	697	440	44 - 3,600
E. Coli, MPN per 100 mL	17	2	1	1 - 8	19	33	23	2 - 150	20	311	42	3 - 4,800	18	208	79	21 - 1,000

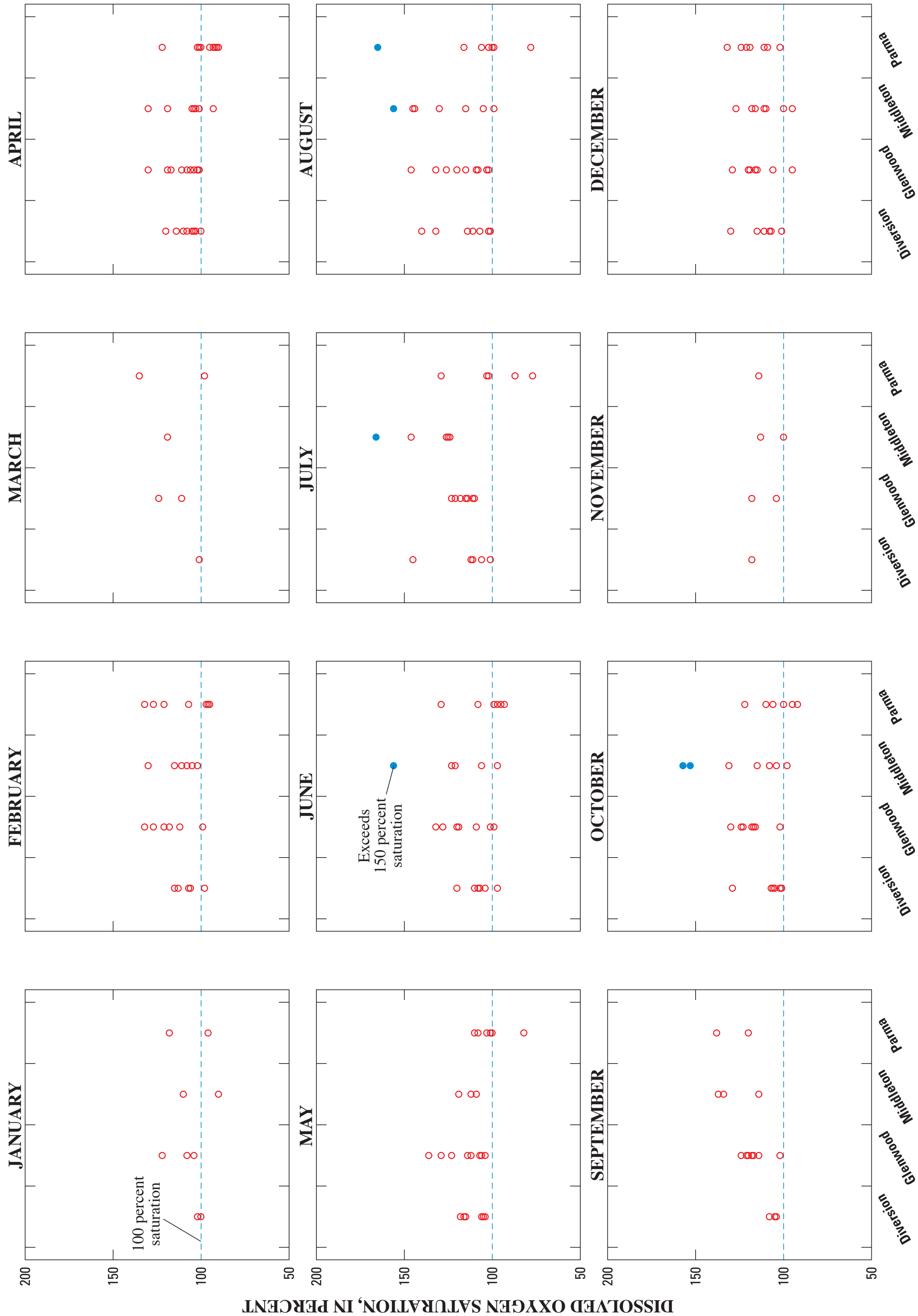


Figure 7. Percent dissolved oxygen saturation from instantaneous dissolved oxygen measurements at main-stem sites on the lower Boise River, Idaho, 1994–2002.

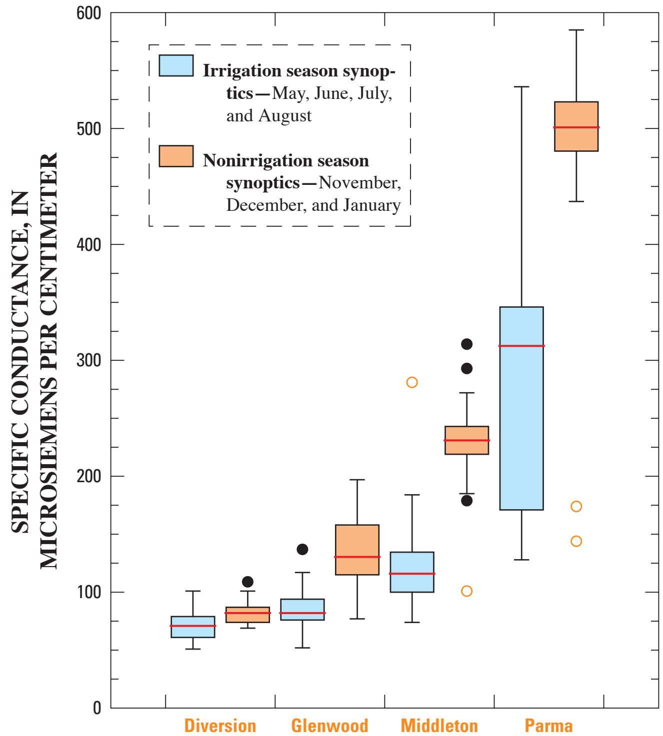


Figure 8. Statistical summary of instantaneous specific conductance measurements from seasonal synoptics at main-stem sites on the lower Boise River, Idaho, 1994–2002.

The overall range of pH at the main-stem sites was 6.6 at Diversion in June 1997 to 9.1 at Middleton in June 2001. Median pH values were within the range of 7.6 to 8.0 (table 6).

Instantaneous measurements of specific conductance ranged from 51 µS/cm at Diversion to 585 µS/cm at Parma (table 6). Specific conductance during the seasonal synoptics at main-stem sites was compared to determine differences in a downstream direction (fig. 8). Specific conductance was higher during the nonirrigation season synoptics than during the irrigation season synoptics, especially at Middleton and Parma (fig. 8). Specific conductance at Diversion remained low, with medians below 100 µS/cm, during both seasons. Median specific conductance was highest during both seasons at Parma, about 310 µS/cm during the irrigation season and 500 µS/cm during the nonirrigation season (fig. 8). During the nonirrigation season, specific conductance increased significantly (Kruskal-Wallis test, $\alpha = 0.05$, $p < 0.001$) at the four main-stem sites in a downstream direction. The substantial increase in specific conductance between Middleton and Parma is associated with increased agricultural land use; high specific conductance in rivers of Idaho has been correlated with agricultural activity (Clark, 1994; Maret and others, 1997; Maret and others, 2001). The increase during the nonirrigation season also could be due to wastewater treatment facility discharge, seepage of ground water containing dissolved constituents, or lack of dilution of suspended material as a result of low discharge. The specific conductance measured at all sites was negatively correlated with discharge (Spearman correlation, two-tailed test, $\alpha = 0.05$) (table 7); specific conductance was higher at low discharge. The specific conductance measured at Diversion was positively correlated with suspended sediment concentrations, and specific conductance at Glenwood, Middleton, and Parma was negatively correlated with suspended sediment (table 7). The positive correlation with suspended sediment may be the result of dam operation, whereas the negative correlation may be the result of dilution from runoff.

Suspended Sediment

Sediment can affect both the geomorphology of a river and its biological communities and also transports adsorbed constituents such as nutrients, metals, and organics. The U.S. Environmental Protection Agency (1998) has identified sediment as the single most widespread cause of impairment to the Nation's rivers and streams, lakes, reservoirs, ponds, and estuaries; Rowe and others (1999) reported sediment to be the largest water-quality problem in Idaho.

Suspended Sediment Concentrations

The median instantaneous concentrations of suspended sediment measured at Diversion, Glenwood, and Middleton were below 10 mg/L but significantly increased (Kruskal-Wallis, $\alpha = 0.05$, $p < 0.001$) from Middleton (median of 6 mg/L) to Parma (median of 45 mg/L) (fig. 9). A statistical summary of suspended sediment concentrations is shown in table 6.

Low concentrations at Diversion (range from 1 to 38 mg/L) reflect the sediment-trapping capability at the reservoirs upstream. The reduction in sediment load just downstream from reservoirs can lead to significant channel degradation and armoring of substrates (Wood and Armitage, 1997). Also, impoundments tend to moderate high discharge downstream and, thereby, limit a river's natural ability to flush out fine sediments and prevent armoring and embeddedness.

The main sources of suspended sediment to the lower Boise are the tributaries downstream from Middleton, which can carry a concentration of as much as 1,600 mg/L (Willow Creek) (fig. 9). The wide variation in suspended sediment concentrations in these tributaries may reflect the agricultural and irrigation practices in the basin.

Suspended sediment concentration tended to increase with increased discharge, and nitrogen and phosphorus concentrations tended to decrease with increased suspended sediment concentration at the three lowest main-stem sites. Suspended sediment concentrations were significantly positively correlated with discharge (Spearman correlation, two-tailed test, $\alpha = 0.05$) at Glenwood, Middleton, and Parma (table 7), where high stream velocities can be expected to erode and transport more suspended sediment. Suspended sediment was

Table 7. Spearman correlation matrix for discharge, nutrients, sediment, and specific conductance measured at the main-stem sites on the lower Boise River, Idaho, 1994–2002

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; significant differences in **bold**; negative numbers indicate negative relation between constituents]

Site name and critical coefficient	Constituent	Discharge (ft^3/s)	Total nitrogen	Total phosphorus	Suspended sediment	Specific conductance (µS/cm)
Diversion	Discharge					
critical coefficient = 0.266	Total nitrogen	**0.358**				
n = 55	Total phosphorus	-0.095	-0.263			
	Suspended sediment	0.071	0.237	0.006		
	Specific conductance	**-0.526**	-0.110	0.028	**0.273**	
	Fecal coliform	-0.137	0.055	0.178	0.195	-0.045
Glenwood	Discharge					
critical coefficient = 0.241	Total nitrogen	**-0.744**				
n = 67	Total phosphorus	**-0.787**	**0.633**			
	Suspended sediment	**0.631**	**-0.355**	**-0.524**		
	Specific conductance	**-0.843**	**0.737**	**0.702**	**-0.479**	
	Fecal coliform	0.201	-0.039	0.115	-0.230	-0.004
Middleton	Discharge					
critical coefficient, 0.279	Total nitrogen	**-0.840**				
n = 50	Total phosphorus	**-0.863**	**0.920**			
	Suspended sediment	**0.488**	**-0.466**	**-0.501**		
	Specific conductance	**-0.900**	**0.942**	**0.919**	**-0.504**	
	Fecal coliform	**0.370**	**-0.418**	**-0.405**	0.141	**-0.421**
Parma	Discharge					
critical coefficient = 0.264	Total nitrogen	**-0.795**				
n = 57	Total phosphorus	**-0.824**	**0.910**			
	Suspended sediment	**0.317**	**-0.461**	**-0.321**		
	Specific conductance	**-0.868**	**0.931**	**0.858**	**-0.544**	
	Fecal coliform	0.259	**-0.377**	**-0.309**	**0.465**	**-0.345**

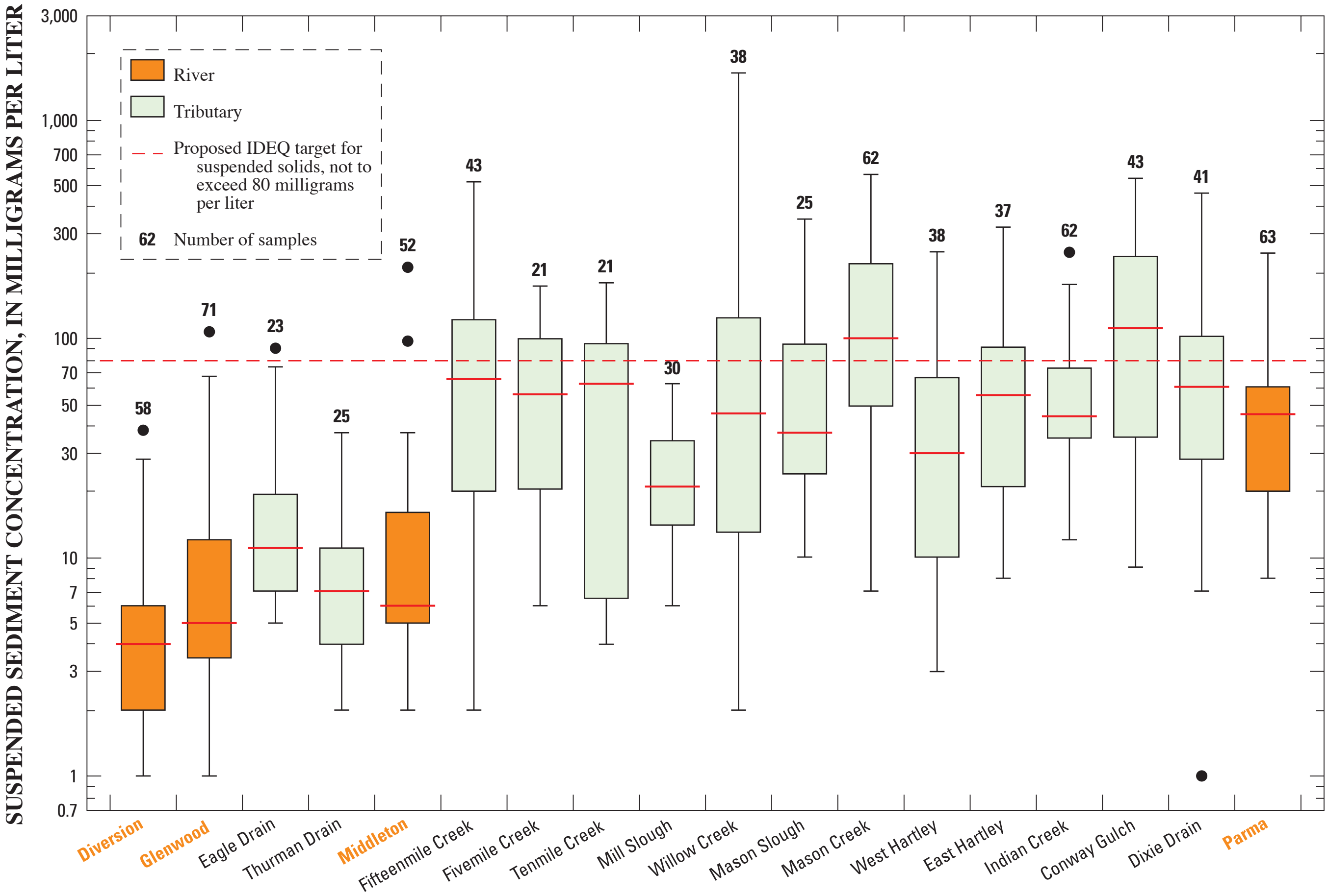


Figure 9. Statistical summary of suspended sediment concentration at selected sites on the lower Boise River and tributaries, Idaho, 1994–2002. (IDEQ, Idaho Department of Environmental Quality; site names in **gold** are main-stem sites)

negatively correlated with nitrogen and phosphorus concentrations at Glenwood, Middleton, and Parma (table 7). This negative correlation may result from mobilization of sediment and dilution of nutrients at high discharge.

The highest median concentrations of suspended sediment in the tributaries were measured at Conway Gulch (110 mg/L) and Mason Creek (100 mg/L) (fig. 9). Maximum concentrations were measured at Willow Creek (1,630 mg/L), Mason Creek (560 mg/L), Conway Gulch (538 mg/L), and Fifteenmile Creek (518 mg/L). On the basis of previous investigations, discharge was the main factor influencing suspended sediment in tributaries (Bureau of Reclamation, 1977; Clark and Bauer, 1982; Ingham, 1993).

Seasonal and Long-Term Trends in Suspended Sediment Concentrations

Suspended sediment was significantly positively correlated with discharge at Glenwood, Middleton, and Parma (table 7); therefore, concentrations were flow adjusted prior to trend analysis. Suspended sediment concentrations at Diversion were at or near detection; thus, no trend analysis was done for this site.

There was no significant trend in flow-adjusted suspended sediment during the irrigation or nonirrigation season at Glenwood, Middleton, and Parma over the duration of this study (fig. 10). However, there was a large difference in suspended sediment concentration between the irrigation and nonirrigation seasons.

The presence of a significantly ($p<0.001$) higher flow-adjusted concentration of suspended sediment at Glenwood, Middleton, and Parma during the irrigation season supports the fact that irrigation return flow is the major source of suspended sediment to the lower Boise. Flow-adjusted suspended sediment concentrations were higher during the irrigation seasons of 1994–96 at Glenwood and Middleton, and 1994 and 1995 at Parma. This difference may be the result of more frequent sampling during synoptics at the beginning of the irrigation season, which captured the first flush of sediments from tributaries. The increase in flow-adjusted concentrations at high discharge also may be a result of the exponential increase

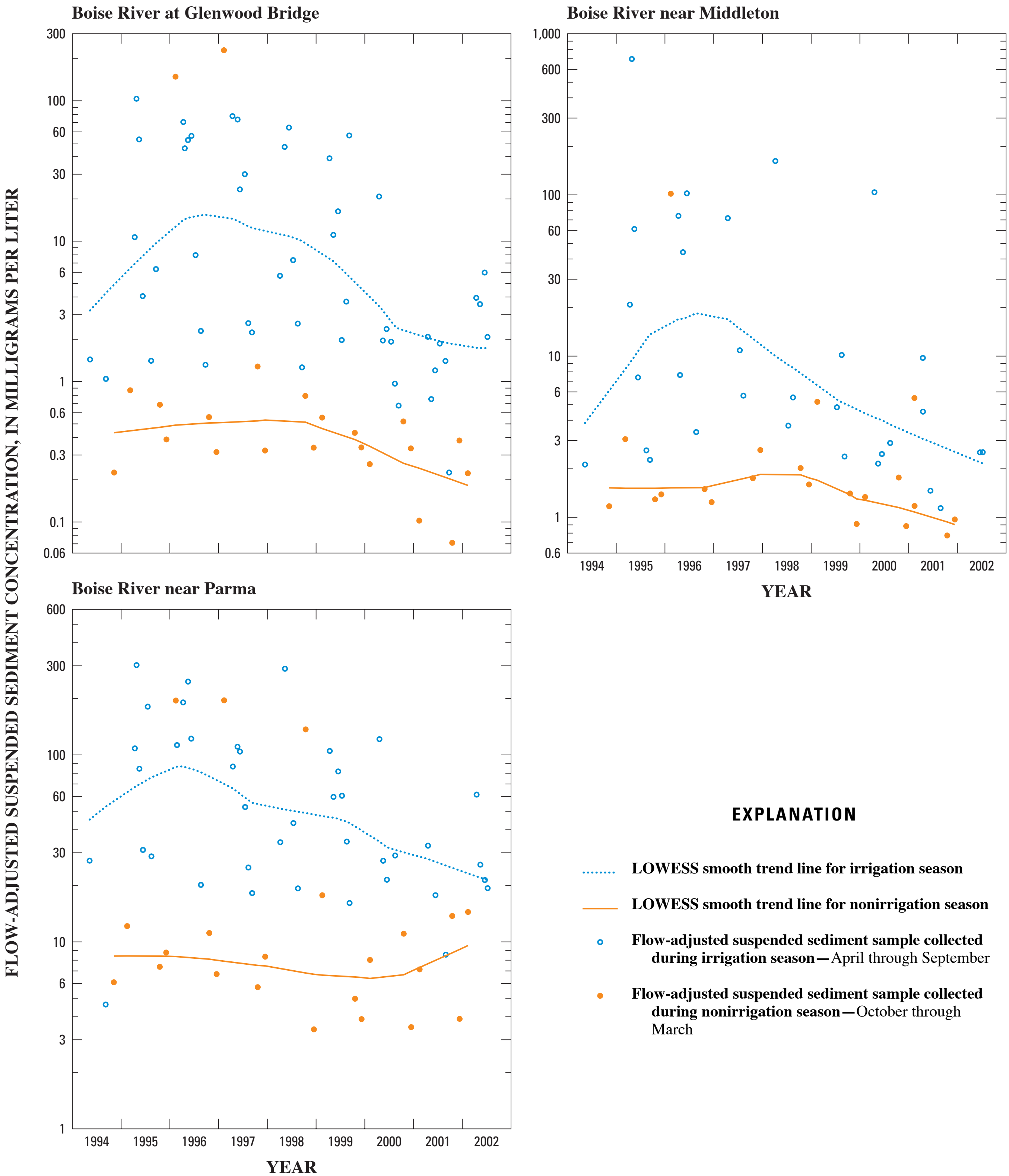


Figure 10. Flow-adjusted suspended sediment concentration with seasonal LOWESS smooth trend lines for selected main-stem sites on the lower Boise River, Idaho, 1994–2002.

in the power of the river (its ability to move sediment) with velocity, which would make any trend during high discharge difficult to identify.

Suspended Sediment Loads

Suspended sediment load increased downstream and was larger during the irrigation season. The largest suspended sediment load at Diversion, about 1.4 million lb/d, or 720 ton/d, was measured during February 1997 when a discharge of about 7,000 ft^3/s carried a suspended sediment concentration of about 38 mg/L (table 6). The largest suspended sediment load measured at Parma during April 1995 was more than 3 million lb/d, or 1,500 ton/d.

The median load of suspended sediment carried by the lower Boise during both the irrigation and nonirrigation seasonal synoptics increased by more than an order of magnitude from Diversion to Parma; the largest increase was between Middleton and Parma (fig. 11A). Synoptic suspended sediment loads at the main-stem sites were significantly larger ($p < 0.001$) during the irrigation season than during the nonirrigation season (figs. 11A and 11B).

The tributaries contributed the largest loads to the lower Boise during the irrigation season synoptics. Suspended sediment load from river and tributary sites as a percentage of the total suspended sediment load at Parma is shown in figure 11B. During the irrigation season synoptics, the largest loads were from Mason Creek. This site contributed between 10 and 80 percent of the load measured at Parma.

During the nonirrigation season synoptics, suspended sediment loads from the tributaries varied; the largest loads (about 10,000 lb/d) were from Mason and Indian Creeks. Indian Creek, at times, contributed more than 50 percent of the load measured at Parma. The percent contribution of suspended sediment loads from tributaries to the lower Boise during seasonal synoptics is not absolute, owing to many irrigation withdrawals between the tributaries and Parma.

Nitrogen

Nitrogen is an essential nutrient for aquatic plants, and in aquatic ecosystems, nitrogen commonly exists in the following forms: dissolved molecular nitrogen (N_2), nitrogen-containing organic compounds, ammonia (NH_3), ammonium (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-). The nitrogen forms analyzed for this study were total nitrogen (nitrogen ammonia plus organic nitrogen, commonly called kjeldahl nitrogen, and dissolved nitrite plus nitrate) and dissolved inorganic nitrogen (ammonia and nitrite plus nitrate); all forms are reported as nitrogen. The dissolved fraction is determined from the filtrate that passes through a 0.45-µm filter.

Total nitrogen in the lower Boise is mainly dissolved nitrite plus nitrate; dissolved nitrogen composed as much as 94 percent of the total nitrogen at Parma (table 6). Dissolved ammonia concentrations were a small percentage of dissolved nitrogen in the river and were often less than the reporting limit; therefore, the term "dissolved nitrogen" in this report refers only to dissolved nitrite plus nitrate.

Nitrogen Concentrations

Total nitrogen concentrations at main-stem sites increased downstream (fig. 12). Median concentrations during water years 1994 through 2002 ranged from 0.26 mg/L at Diversion to 2.17 mg/L at Parma (table 6). Total nitrogen concentrations increased significantly ($p < 0.001$) between Glenwood and Parma; the highest concentration among the four main-stem sites was 5.33 mg/L, measured at Parma.

Median concentrations of total nitrogen were higher overall in tributaries than at the main-stem sites (fig. 12). The highest median concentrations of total nitrogen were measured at Mason Creek (4.1 mg/L), Indian Creek (4.1 mg/L), and Conway Gulch (4.0 mg/L). Idaho State Department of Agriculture (ISDA) determined that nitrate concentrations in Mason Creek increased as a result of shallow ground-water input and that the highest concentrations usually were measured during high discharge at the beginning of the irrigation season (Fox and others, 2002). Total nitrogen concentrations in Indian Creek varied widely and ranged from 2.8 to 9.1 mg/L. Total nitrogen concentrations in Conway Gulch ranged from 3.0 to 6.7 mg/L. Conway Gulch, as stated in the "Introduction," has been studied extensively and has been documented as one of the largest contributors of pollutants affecting the lower Boise (Ingham, 1993). The second-highest concentration of total nitrogen (8.2 mg/L) was measured at Fivemile Creek, although the median concentration at this site was only 3.0 mg/L.

Total nitrogen was significantly positively correlated with discharge at Diversion and was significantly negatively correlated with discharge at Glenwood, Middleton, and Parma (table 7); therefore, concentrations were adjusted for flow prior to trend analysis. Flow-adjusted concentrations of total nitrogen in the lower Boise ranged from less than 0.005 mg/L at Diversion to 5 mg/L at Parma (fig. 13). The highest flow-adjusted concentrations of total nitrogen at Diversion and Glenwood (about 0.03 and 2.3 mg/L, respectively) were measured during the winter of 1997; the highest at Middleton (2.5 mg/L) was measured in spring 1995; and the highest at Parma (5.0 mg/L) was measured in spring 1998. The median percent dissolved nitrogen, which makes up most of the total nitrogen concentration in the river, increased significantly ($p < 0.001$) from 38 percent at Diversion to 75 percent at Parma (table 6).

The proportion of particulate nitrogen (total nitrogen minus dissolved inorganic nitrogen) usually increased at the beginning of the irrigation season. One of the largest increases at the main-stem sites occurred during extremely high discharge in 1996 and 1997 (fig. 13). In December 1996, the particulate nitrogen concentrations at Glenwood, Middleton, and Parma were approximately 1 mg/L higher than the dissolved nitrogen concentrations and may have been asso-

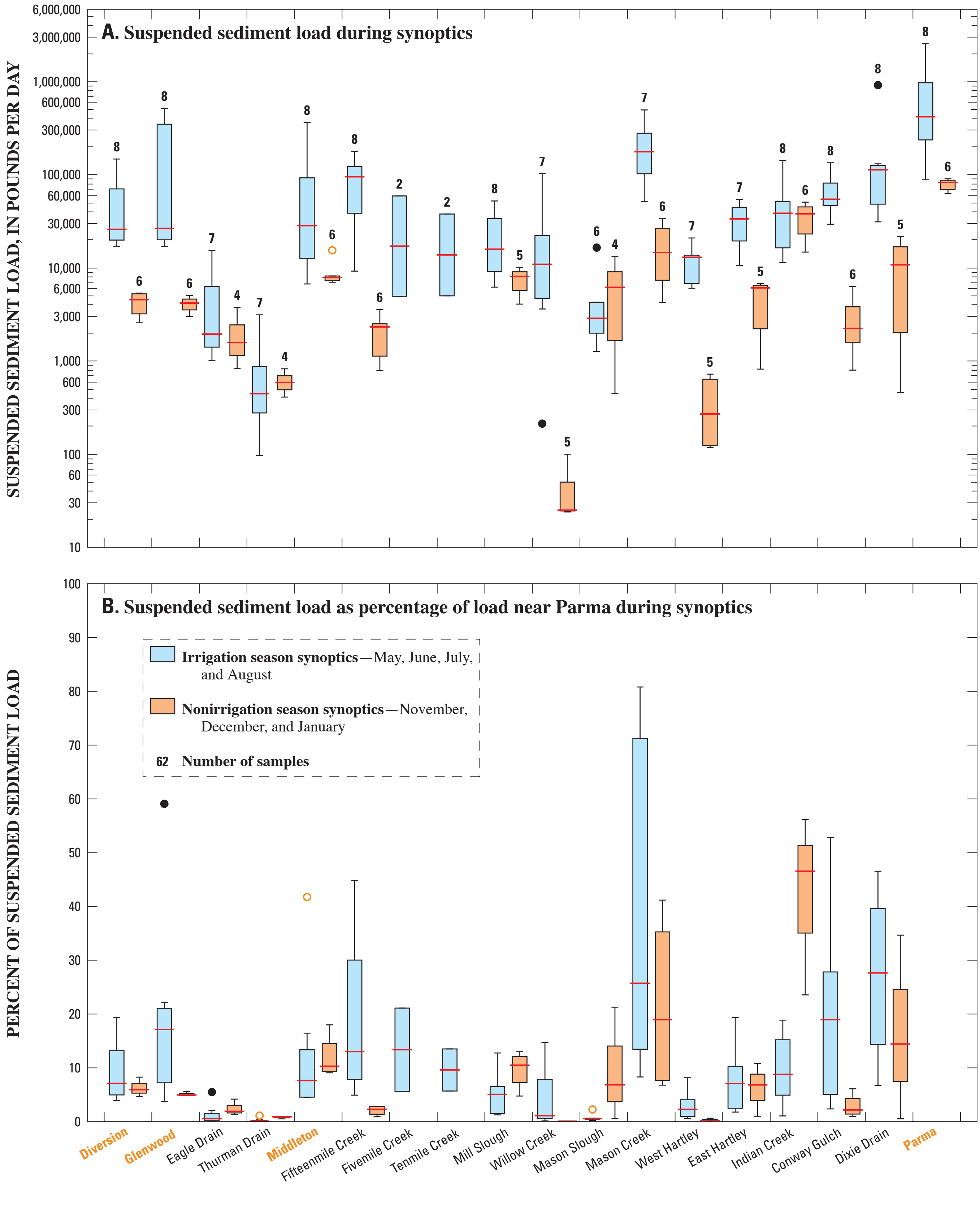


Figure 11. Seasonal suspended sediment load (A) and suspended sediment load as a percentage of the load near Parma (B) from synoptic data collected at selected sites on the lower Boise River and tributaries, Idaho, 1994–2002. (Site names in **gold** are main-stem sites)

ciated with the larger sediment load from erosion and overland runoff.

Seasonal and Long-Term Trends in Nitrogen Concentrations

There were no apparent trends in nitrogen concentration during the study, but differences during the irrigation season were apparent at some sites. Trends in total nitrogen concentrations during irrigation and nonirrigation seasons were analyzed using LOWESS smooth trend lines, and differences between sites and seasons were analyzed using Spearman correlation coefficients. No significant trends in flow-adjusted total nitrogen at Diversion, Glenwood, Middleton, and Parma were apparent (fig. 14). Concentrations at Glenwood were higher during the irrigation season, whereas concentrations at Middleton and Parma were higher during the nonirrigation season; however, there were no significant differences in flow-adjusted total nitrogen between seasons at those sites. Flow-adjusted total nitrogen concentrations increased during the irrigation season at Diversion from 1994 to 1996, at Glenwood from 1994 to 1997, at Middleton from 1994 to 1997, and at Parma from 1994 to 1996. This apparent increase could have been the result of more frequent synoptic sampling at the beginning of the irrigation season prior to 1997 or the mobility of particulate nitrogen during high discharge in 1996 and 1997. The more frequent sampling and high-discharge years did not affect the conclusion of an overall lack of a trend during the 8-year period.

Nitrogen Loads

Instantaneous loads of total nitrogen measured between 1994 and 2002 at Diversion ranged from about 150 to 19,250 lb/d (table 6). Total nitrogen loads at Glenwood ranged from 650 to near 20,000 lb/d; loads at Middleton ranged from 860 to near 14,800 lb/d; and loads at Parma ranged from 4,180 to near 52,000 lb/d.

The largest increase in nitrogen load during the synoptic sampling was downstream from Middleton. The instantaneous

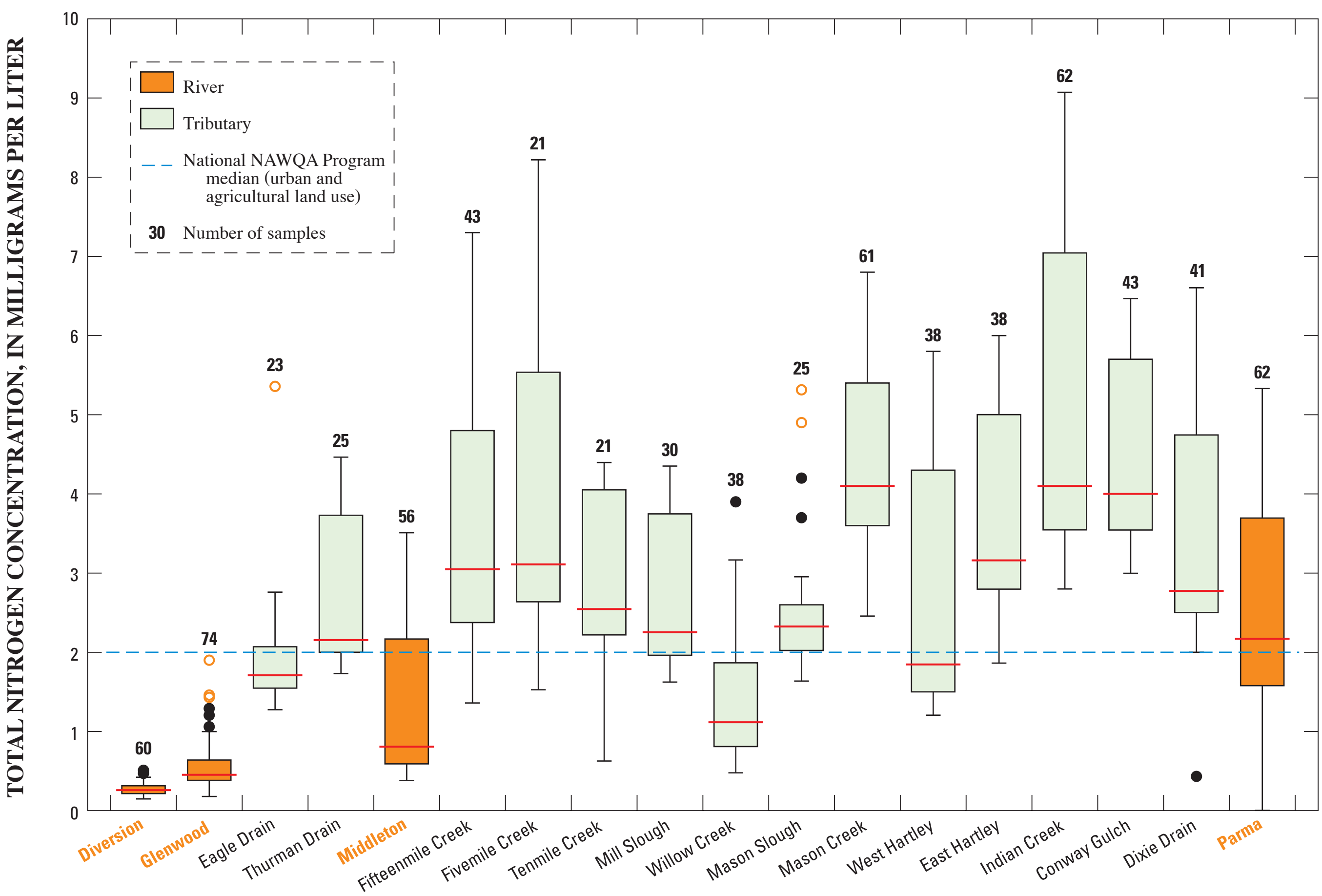


Figure 12. Statistical summary of total nitrogen concentration at selected sites on the lower Boise River and tributaries, Idaho, 1994–2002. (National USGS NAWQA Program median values accessed March 2003 at URL: *http://water.usgs.gov/nawqa/nutrients/datasets/nutconc2000/#sw*; NAWQA, National Water-Quality Assessment; USGS, U.S. Geological Survey; site names in **gold** are main-stem sites.

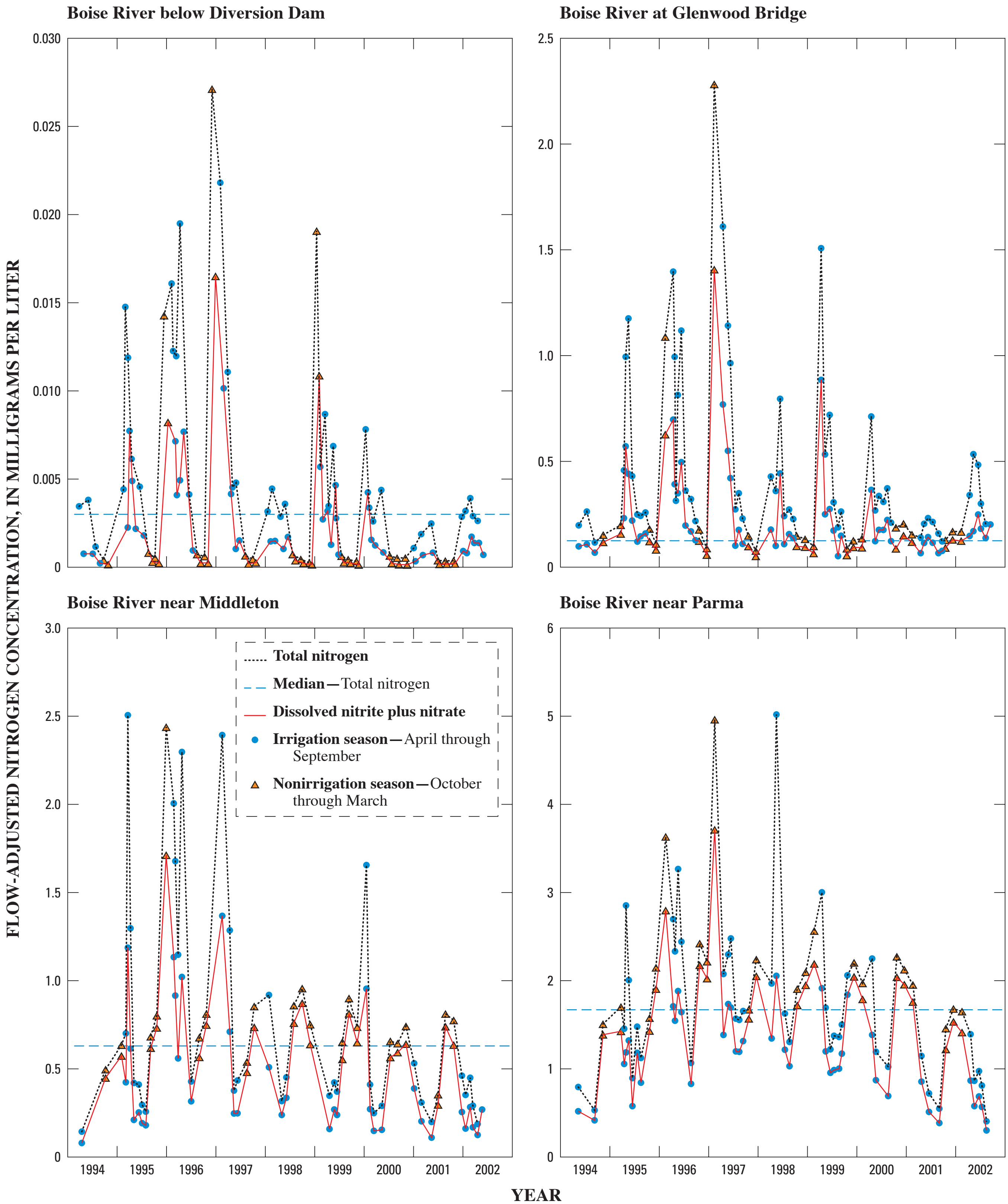


Figure 13. Flow-adjusted total nitrogen and dissolved nitrite plus nitrate concentrations at main-stem sites on the lower Boise River, Idaho, 1994–2002.

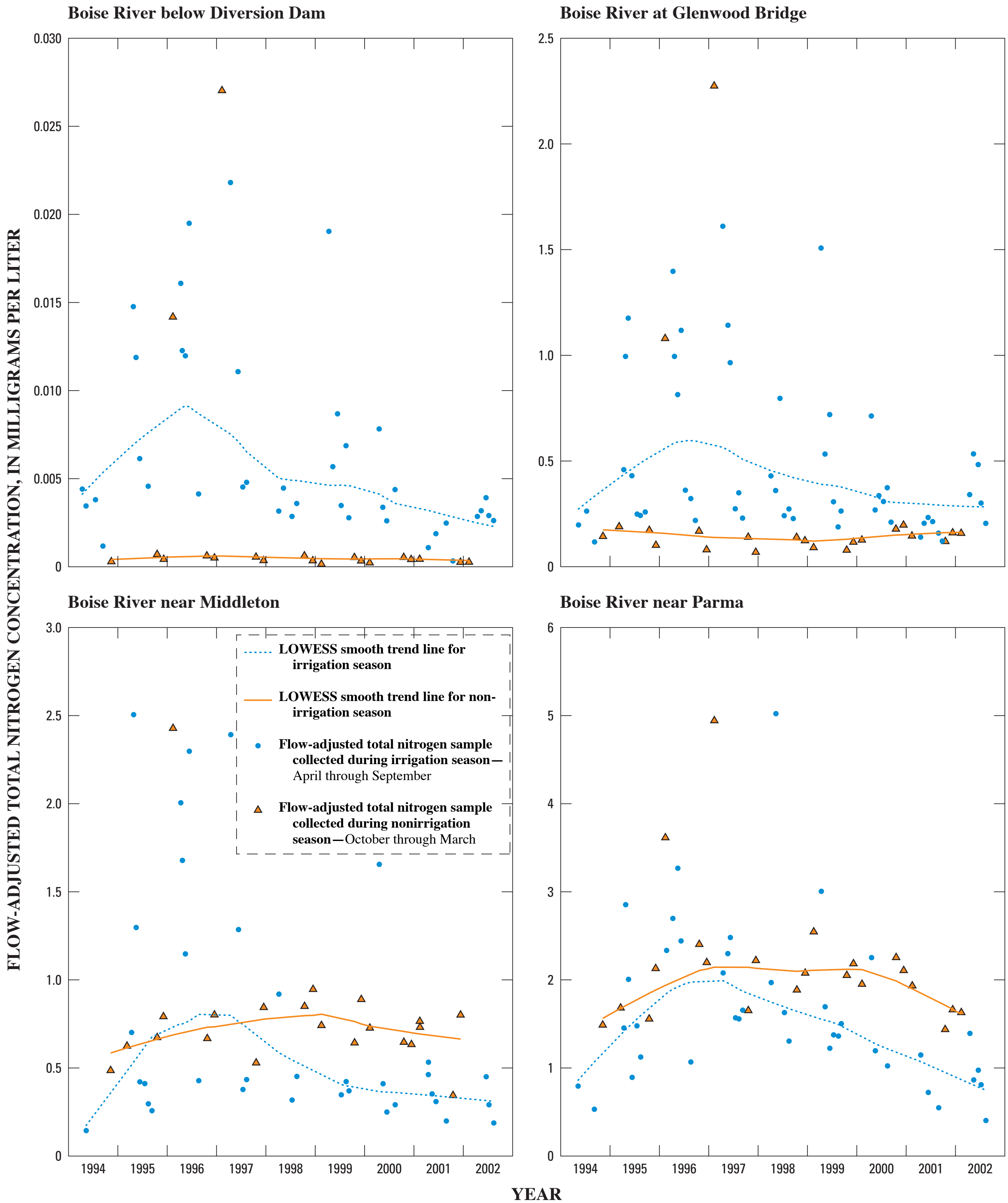


Figure 14. Flow-adjusted total nitrogen concentration with seasonal LOWESS smooth trend lines for main-stem sites on the lower Boise River, Idaho, 1994–2002.

loads of total nitrogen during synoptic sampling did not vary widely at Diversion, Glenwood, and Middleton; during the irrigation season, the median loads at all three sites were near 3,000 lb/d (fig. 15). The nitrogen load progressively increased downstream from Middleton during both seasons; the median load between Middleton and Parma increased almost five times (to more than 17,000 lb/d) during the irrigation season but was even larger during the nonirrigation season (near 5,000 and 20,000 lb/d, respectively).

With the exception of Indian Creek, tributaries contributed most of the nitrogen load during the irrigation season (fig. 12). Median nitrogen loads measured at tributaries downstream from Middleton, such as Mason Creek (about 2,500 and 2,000 lb/d during the irrigation and nonirrigation seasons, respectively), were similar to loads at upstream main-stem sites (fig. 15). This similarity could be due to the low discharge and high nitrogen concentration in these tributaries. At Indian Creek, the median load was largest (8,200 lb/d) during the nonirrigation season.

The proportionate contributions of nitrogen from subbasins of the lower Boise were estimated by calculating the nitrogen load contributions from individual main-stem and tributary sites as a percentage of the total load measured at Parma during the seasonal synoptics (fig. 15B). During the irrigation season, the basin upstream from the Middleton site contributed a median load of 20 percent of the total nitrogen load at Parma and the basin downstream from Middleton contributed 80 percent. During the nonirrigation season, the basin upstream from Glenwood contributed less than 5 percent of the total load, whereas the basin upstream from Middleton contributed a median of about 22 percent of the total load at Parma.

Among the tributary sites, Mason Creek and Dixie Drain contributed the highest median percentages (about 20 percent) of the total load during the irrigation season. Although the percent load contributions from tributaries generally were larger during the irrigation season than during the nonirrigation season, Indian Creek consistently contributed nearly 40 percent of the total nitrogen load during the nonirrigation season. The percent contribution of total nitrogen load at Parma from tributaries during seasonal synoptics is not absolute, owing to many irrigation withdrawals between the tributaries and Parma.

Most of the bioavailable nitrogen at the Parma site during the nonirrigation season was from tributaries. To identify the potential bioavailable fraction of total nitrogen entering and being transported in the lower Boise, both particulate and dissolved inorganic nitrogen were analyzed in main-stem and tributary samples collected during the February and May 2000 synoptics (figs. 16 and 17). During the February synoptic (nonirrigation season), the total nitrogen load at Diversion was 200 lb/d and was composed of about 30 percent dissolved inorganic nitrogen (fig. 16). Downstream, the total nitrogen load at Parma increased by two orders of magnitude (20,000 lb/d) and was composed of about 80 percent dissolved inorganic nitrogen. Of the 20,000 lb/d total nitrogen at Parma, tributaries contributed 14,200 lb/d, wastewater treatment facilities contributed about 5,000 lb/d (City of Boise, written commun., 2002), and approximately 800 lb/d was lost, probably owing to withdrawals or plant uptake. Much of the total nitrogen load from tributaries was dissolved.

Most of the bioavailable nitrogen at the Parma site during the irrigation season also was from the tributaries. During the May synoptic (irrigation season), the total nitrogen load at Diversion was 2,400 lb/d, of which about 50 percent was dissolved (fig. 17). Downstream from Diversion, inputs from urban and agricultural sources resulted in a total nitrogen load at Parma of 12,400 lb/d, of which 75 percent was dissolved. Of the 12,400 lb/d total nitrogen measured at Parma, the tributaries contributed 13,680 lb/d, wastewater treatment facilities contributed 5,600 lb/d (City of Boise, written commun., 2002), and 6,880 lb/d was lost, probably owing to irrigation withdrawals or plant uptake.

The portion of particulate nitrogen at main-stem and tributary sites was larger during the May synoptic (fig. 17) than during the February synoptic (fig. 16). The larger portion of particulate nitrogen measured at the main-stem and tributary sites during the May 2000 synoptic probably resulted from erosion and overland runoff. The total nitrogen load at Parma during the May synoptic was about 60 percent of the load at that site during the February synoptic.

Phosphorus

Like nitrogen, phosphorus is an essential nutrient for the metabolism of aquatic plants. Eutrophication research has focused heavily on phosphorus because it is the nutrient typically found to have the smallest supply-to-demand ratio and is often a limiting factor in plant growth. As such, phosphorus is often the nutrient responsible for accelerated eutrophication in freshwater streams and lakes (Mueller and Helsel, 1996).

Forms of phosphorus examined in this study were total phosphorus and dissolved orthophosphorus (herein referred to as orthophosphorus). Total phosphorus is composed of orthophosphorus and particulate phosphorus, which may include organic and inorganic components. Orthophosphorus is determined from the filtrate that passes through a 0.45-μm filter.

Phosphorus Concentrations

Median concentrations of total phosphorus increased downstream, and total phosphorus measured at main-stem sites was composed mainly of orthophosphorus. Total phosphorus concentrations at main-stem sites during water years 1994 through 2002 ranged from < 0.01 mg/L at Diversion to 0.85 mg/L at Middleton, where the range in concentrations was widest, 0.03 to 0.85 mg/L (table 6). At Diversion, the median was 0.04 mg/L; at Parma, the median was 0.30 mg/L (table 6, fig. 18). The median percentage of orthophosphorus

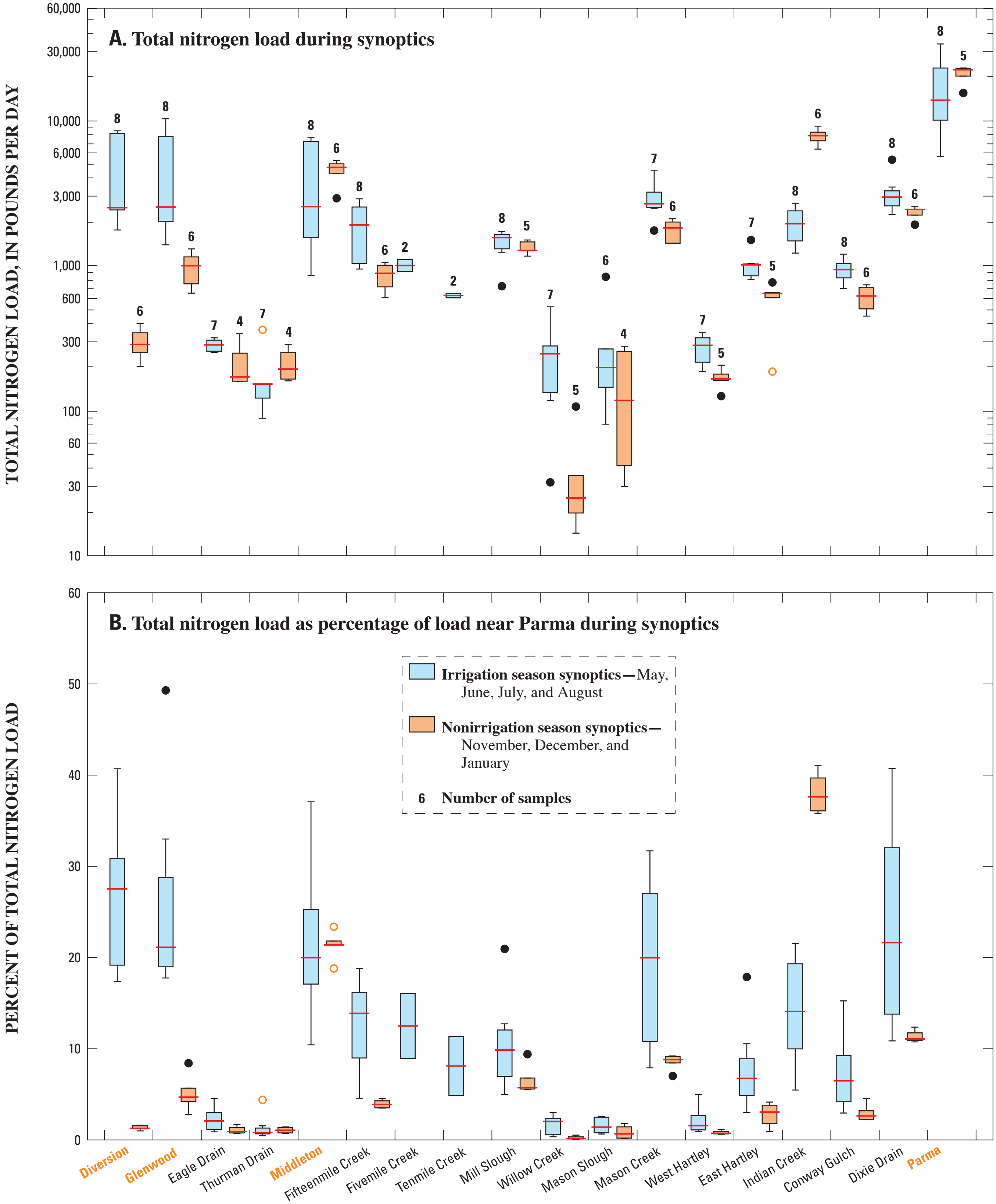


Figure 15. Statistical summary of instantaneous seasonal total nitrogen load (A) and total nitrogen load as a percentage of the load near Parma (B) from synoptic data collected at selected sites on the lower Boise River and tributaries, Idaho, 1994-2002. (Site names in **gold** are main-stem sites)

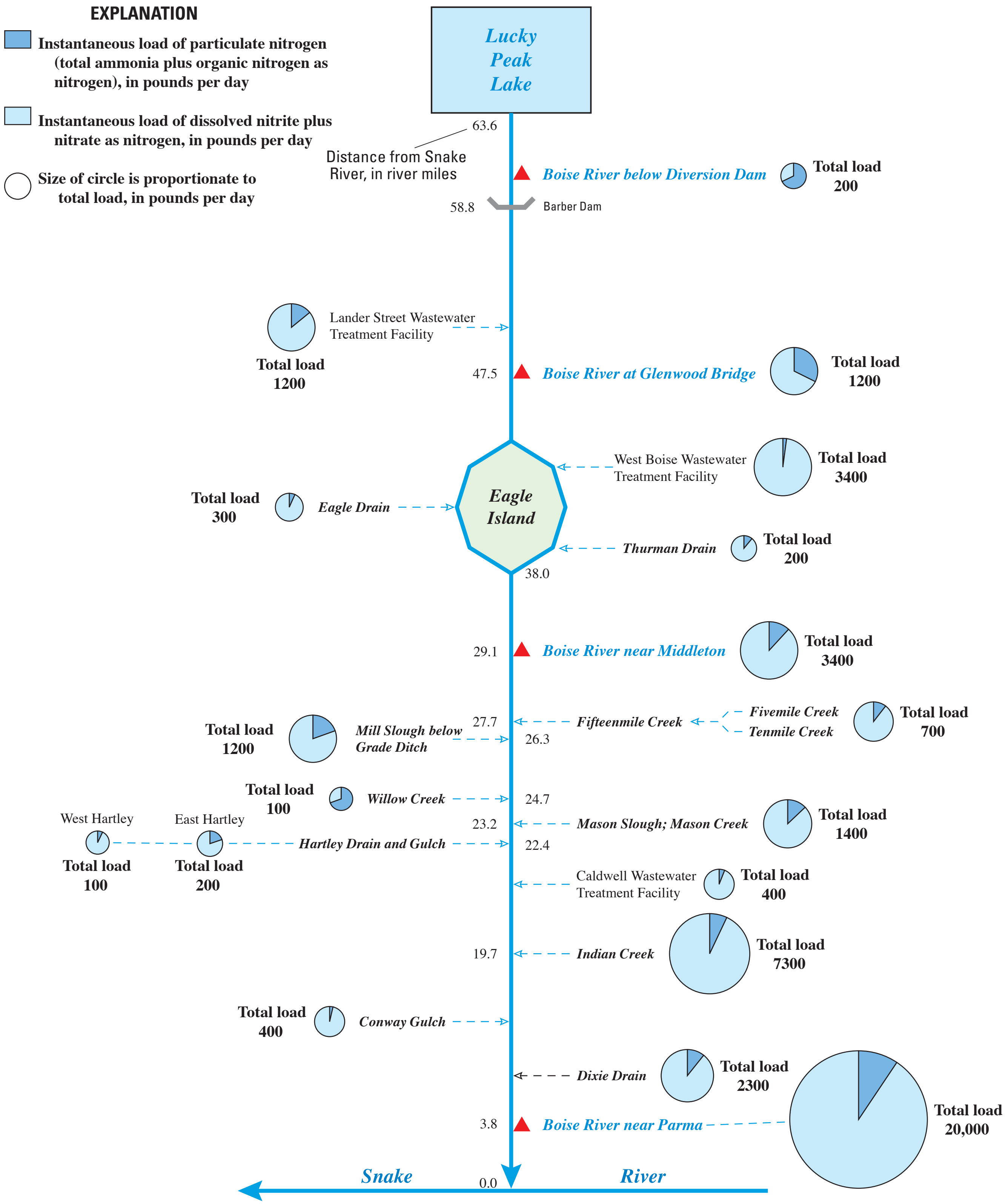


Figure 16. Total nitrogen load at selected lower Boise River and tributary sites, Idaho, calculated from instantaneous concentration and discharge, nonirrigation season, February 8–16, 2000 (Dixie Drain, January 13, 2000). (Wastewater treatment facility data from February 8, 2000, from the City of Boise, written communication, December 2002. No flow data for Star, Notus, Middleton, and Parma treatment facilities or Eagle and Nampa fish hatcheries on this date; therefore, no loads were calculated for these facilities)

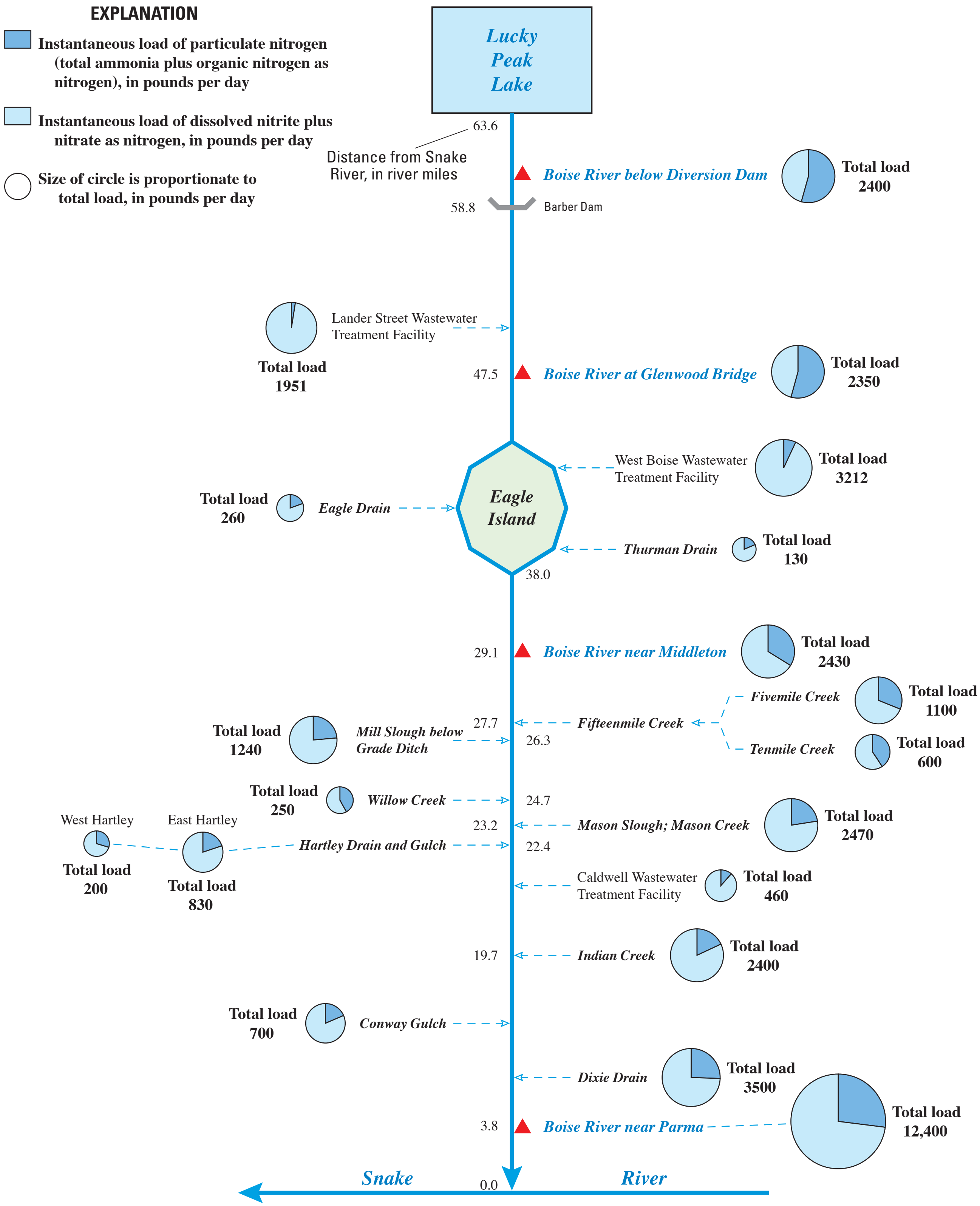


Figure 17. Total nitrogen load at selected lower Boise River and tributary sites, Idaho, calculated from instantaneous concentration and discharge, irrigation season, May 16–18, 2000. (Wastewater treatment facility data from May 16, 2000, from the City of Boise, written communication, December 2002. No flow data for Star, Notus, Middleton, and Parma treatment facilities or Eagle and Nampa fish hatcheries on this date; therefore, no loads were calculated for these facilities)

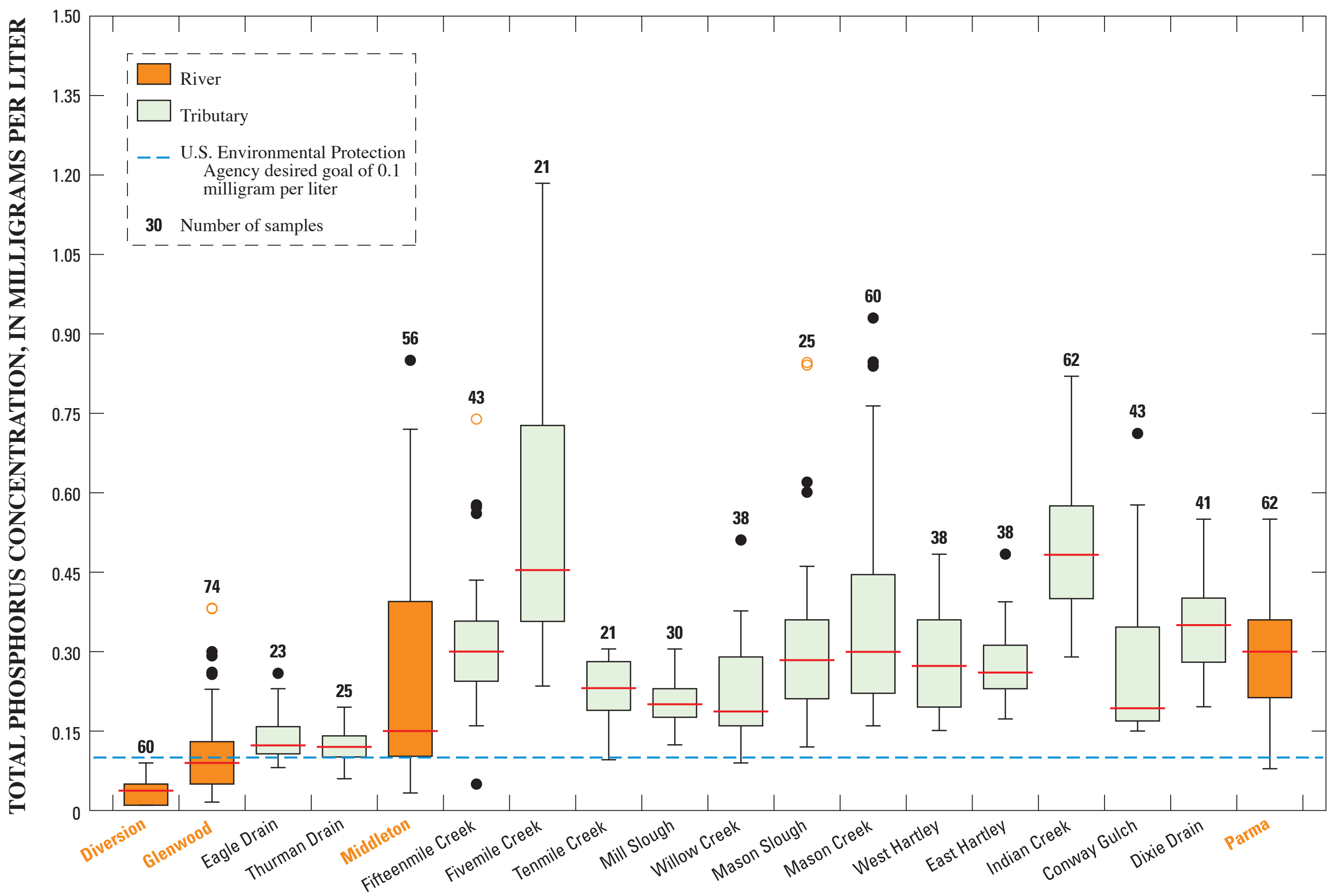


Figure 18. Statistical summary of total phosphorus concentration at selected sites on the lower Boise River and tributaries, Idaho, 1994–2002. (Site names in **gold** are main-stem sites)

ranged from 45 percent at Diversion to 88 percent at Middleton (table 6).

Tributaries between Middleton and Parma contributed most of the higher total phosphorus concentrations to the lower Boise (fig. 18). The highest concentrations were measured at Fivemile Creek (1.2 mg/L), at Mason Creek (0.93 mg/L), at Mason Slough (0.85 mg/L), and at Indian Creek (0.82 mg/L). Median concentrations at the tributaries ranged from about 0.14 mg/L at Thurman Drain to 0.48 mg/L at Indian Creek.

Total phosphorus concentrations were significantly negatively correlated with discharge at Glenwood, Middleton, and Parma (Spearman correlation, two-sided test, $\alpha = 0.05$, table 7); therefore, concentrations were adjusted for flow prior to trend analysis. The flow-adjusted concentrations of total phosphorus tended to be higher during the irrigation season, with the exception of concentrations in samples collected during the extreme high discharge in 1997 at Glenwood and Parma (fig. 19). The mobilization of particulate phosphorus during this high discharge resulted in orthophosphorus concentrations at these sites that were half those of total phosphorus. According to Mueller and Helsel (1996), erosion of streambanks during high discharge can add a considerable amount of particulate phosphorus to streams. During the nonirrigation season, total phosphorus concentrations at Glenwood, Middleton, and Parma were composed mainly of orthophosphorus.

Seasonal and Long-Term Trends in Phosphorus Concentrations

No significant trends in flow-adjusted total phosphorus were apparent at Glenwood, Middleton, and Parma (fig. 20). Trends in total phosphorus concentrations during irrigation and nonirrigation seasons were analyzed using LOWESS smooth trend lines, and differences between sites and seasons were analyzed using Spearman correlation coefficients. Trends were analyzed for all main-stem sites except Diversion, where concentrations of total phosphorus were at or near the reporting limit.

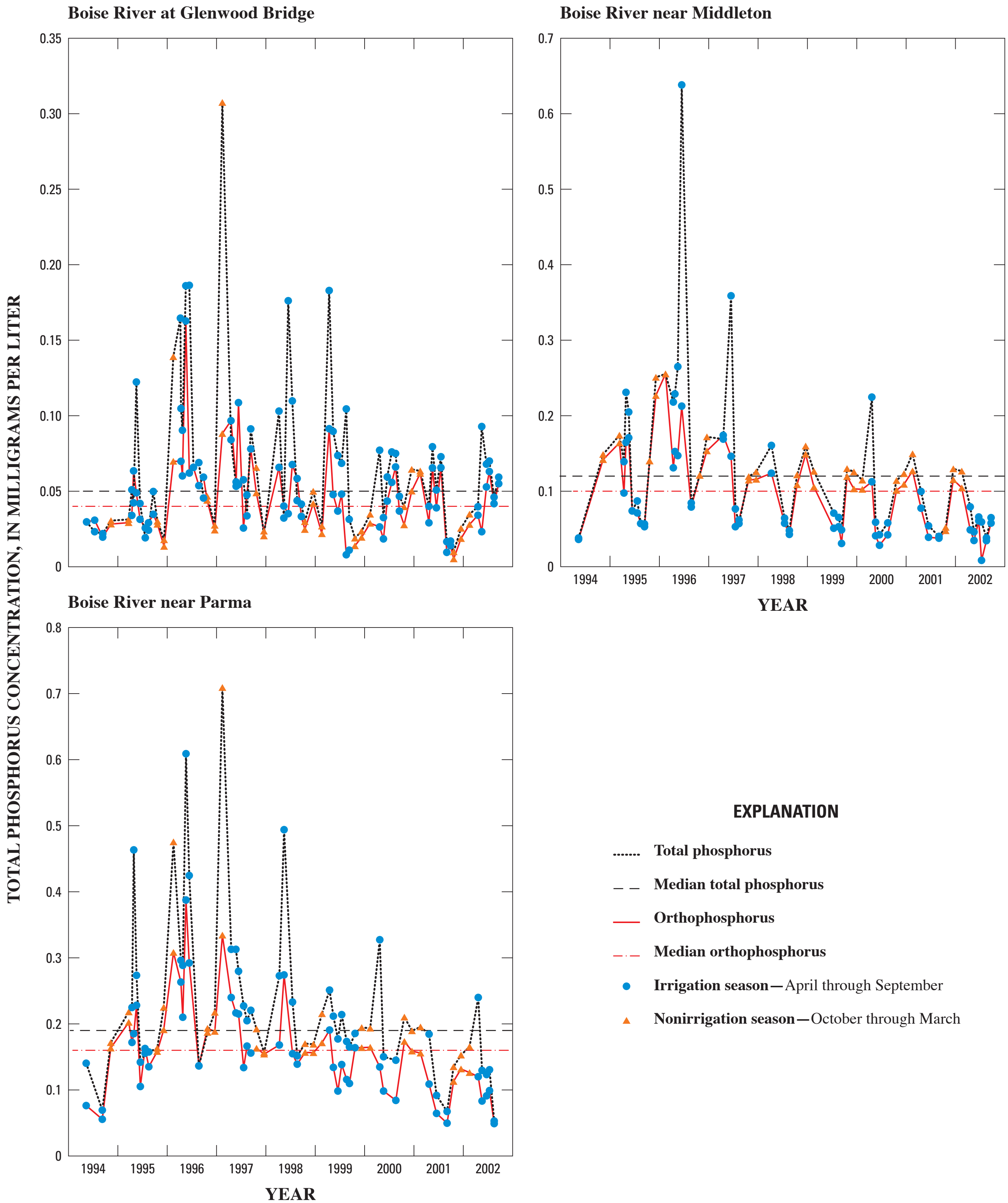


Figure 19. Flow-adjusted total phosphorus and orthophosphorus concentration at selected main-stem sites on the lower Boise River, Idaho, 1994–2002.

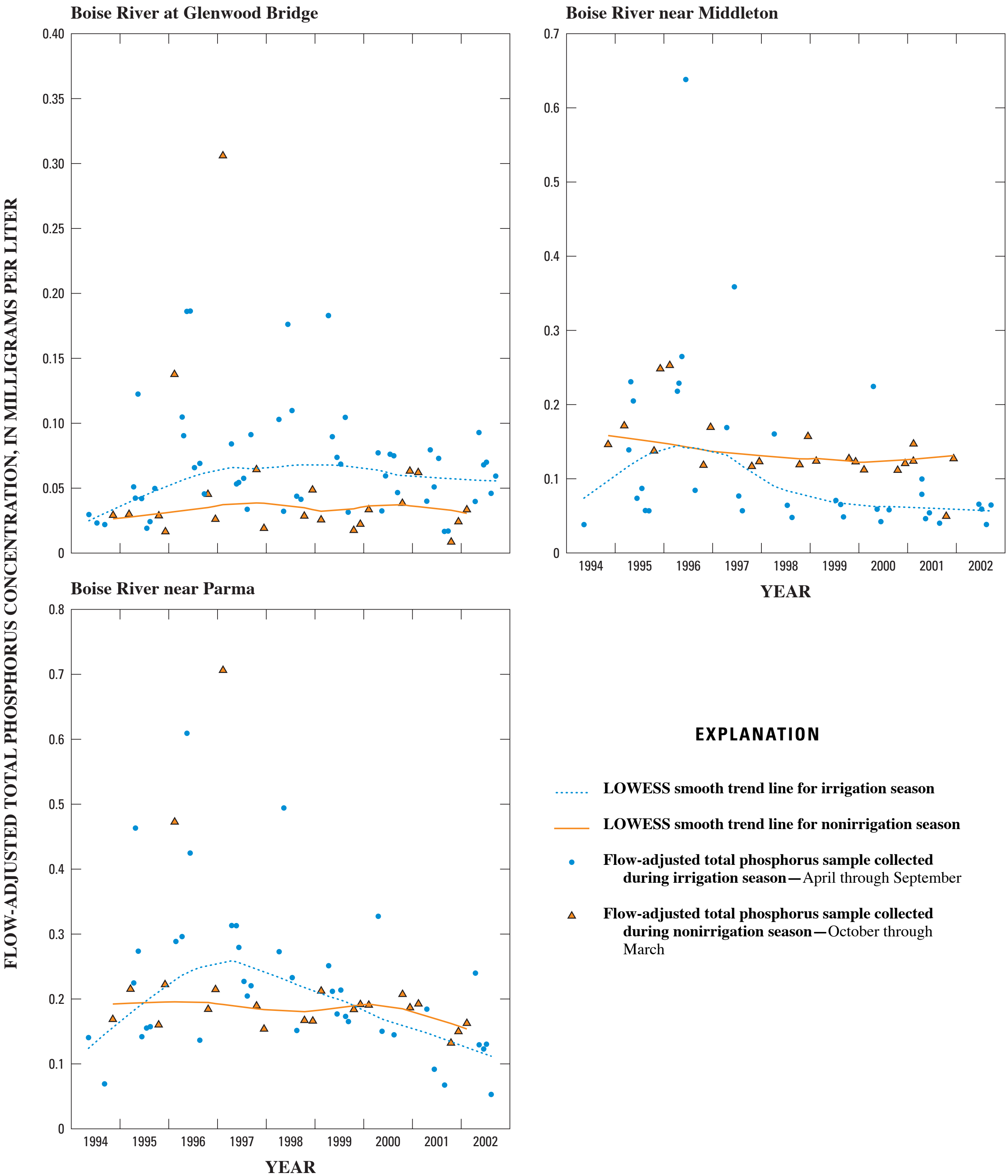


Figure 20. Flow-adjusted total phosphorus concentration with seasonal LOWESS smooth trend lines for selected main-stem sites on the lower Boise River, Idaho, 1994–2002.

Flow-adjusted concentrations at Glenwood were significantly higher ($p < 0.002$) during the irrigation season than during the nonirrigation season. In contrast, flow-adjusted concentrations at Middleton were higher during the nonirrigation season, but not significantly higher. An increasing flow-adjusted concentration of total phosphorus was apparent at Middleton during the irrigation season from 1994 to 1996 and at Parma from 1994 to 1997. This apparent increase could have been the result of more frequent synoptic sampling at the beginning of the irrigation season prior to 1997 or the mobility of particulate phosphorus during high discharge in 1996 and 1997. Seasonal differences in flow-adjusted total phosphorus concentrations at Parma were not significant.

Phosphorus Loads

Total phosphorus loads at Diversion ranged from near 10 lb/d to 3,400 lb/d; at Glenwood, from 80 to near 2,700 lb/d; at Middleton, from 230 to near 3,800 lb/d; and at Parma from 550 to near 7,300 lb/d (table 6). The median total phosphorus loads at the four main-stem sites progressively increased downstream; the highest median load, near 2,000 lb/d, was measured at Parma (table 6).

During the irrigation season synoptics, the median loads of total phosphorus at Diversion and Parma were about 350 and 2,000 lb/d, respectively; during the nonirrigation season synoptics, the loads were about 30 and 2,000 lb/d, respectively (fig. 21A). The median total phosphorus load at Glenwood during the irrigation season (about 400 lb/d) was larger than during the nonirrigation season (200 lb/d). In contrast, the median total phosphorus load at Middleton during the nonirrigation season (about 800 lb/d) was larger than during the irrigation season (about 400 lb/d). The median total phosphorus load at Parma was the same during both seasons (fig. 21A).

Although discharge in the tributaries was lower than at the main-stem sites, tributaries between Middleton and Parma contributed most of the larger median total phosphorus concentrations to the lower Boise (fig. 18). The median total phosphorus loads measured at the tributaries were larger during the irrigation season except at Indian Creek, where the median load was larger (500 lb/d) during the nonirrigation season (fig. 21A). Among the tributaries, Mason Creek had the largest median load during the irrigation season (near 400 lb/d).

The major sources of phosphorus in the basin were identified by calculating the phosphorus load contributions from individual main-stem and tributary sites as a percentage of the total load measured at Parma during the seasonal synoptics (fig. 21B). During the irrigation season, the basin upstream from Middleton contributed a median load of 24 percent of the total phosphorus load at Parma. During the nonirrigation season, the basin upstream from Middleton contributed a median load of 45 percent of the total load at Parma.

Among the tributary sites, Mason Creek and Dixie Drain contributed the largest median loads of 20 and 25 percent, respectively, of the total load during the irrigation season. Although the percent load contributions from tributaries generally were larger during the irrigation season than during the nonirrigation season, Indian Creek consistently contributed about 25 percent of the total phosphorus load during the nonirrigation season. As with suspended sediment and total nitrogen, the percent contribution of total phosphorus load at Parma from tributaries is not absolute, owing to many irrigation withdrawals between the tributaries and Parma.

To identify the potential bioavailable fraction of total phosphorus entering and being transported in the lower Boise, both particulate and dissolved orthophosphorus were analyzed in main-stem and tributary samples collected during the February and May 2000 synoptics (figs. 22 and 23).

During the February synoptic (nonirrigation season), the total phosphorus load at Diversion was 30 lb/d, of which about 30 percent was orthophosphorus (fig. 22). Downstream at Parma, the phosphorus load increased to 2,000 lb/d, of which about 80 percent was orthophosphorus. Wastewater treatment facilities contributed 1,070 lb/d, nearly all of which was orthophosphorus. The tributaries contributed 1,290 lb/d, primarily as orthophosphorus, and 350 lb/d was lost, probably owing to withdrawals or plant uptake.

During the May synoptic (irrigation season), the load of total phosphorus at Diversion was 520 lb/d, of which about 20 percent was orthophosphorus (fig. 23). Downstream from Diversion, inputs from urban and agricultural sources resulted in a total phosphorus load at Parma of 1,550 lb/d, of which about 65 percent was orthophosphorus. Of the 1,550 lb/d of total phosphorus measured at Parma, wastewater treatment facilities contributed 1,220 lb/d, tributaries contributed 1,780 lb/d, and 1,450 lb/d was lost, probably owing to irrigation withdrawals or plant uptake. The proportion of particulate phosphorus was larger during the May synoptic than during the February synoptic, probably owing to erosion and overland runoff caused by elevated discharge. The total phosphorus load at Parma during the May synoptic was about 80 percent of the load at that site during the February synoptic.

Indicators of and Probable Controls on Algae Growth

In the lower Boise, the growth of aquatic plants is largely associated with periphyton. Periphyton consists of plant material attached to submerged substrate in standing or running water. Periphyton appears as a thin film on rocks in fast-flowing streams or as long strands of algae in slower moving water (Welch, 1980). Periphyton can represent a large percentage of the primary production in freshwater (Welch, 1980).

Chlorophyll-*a* (Chla) is the primary photosynthetic pigment of periphyton and, as such, is used as an estimator of periphyton biomass. Chla concentration in aquatic plants can be used as a biological indicator of nutrient levels in natural water and can be used as a tool to assess nutrient impact on beneficial uses.

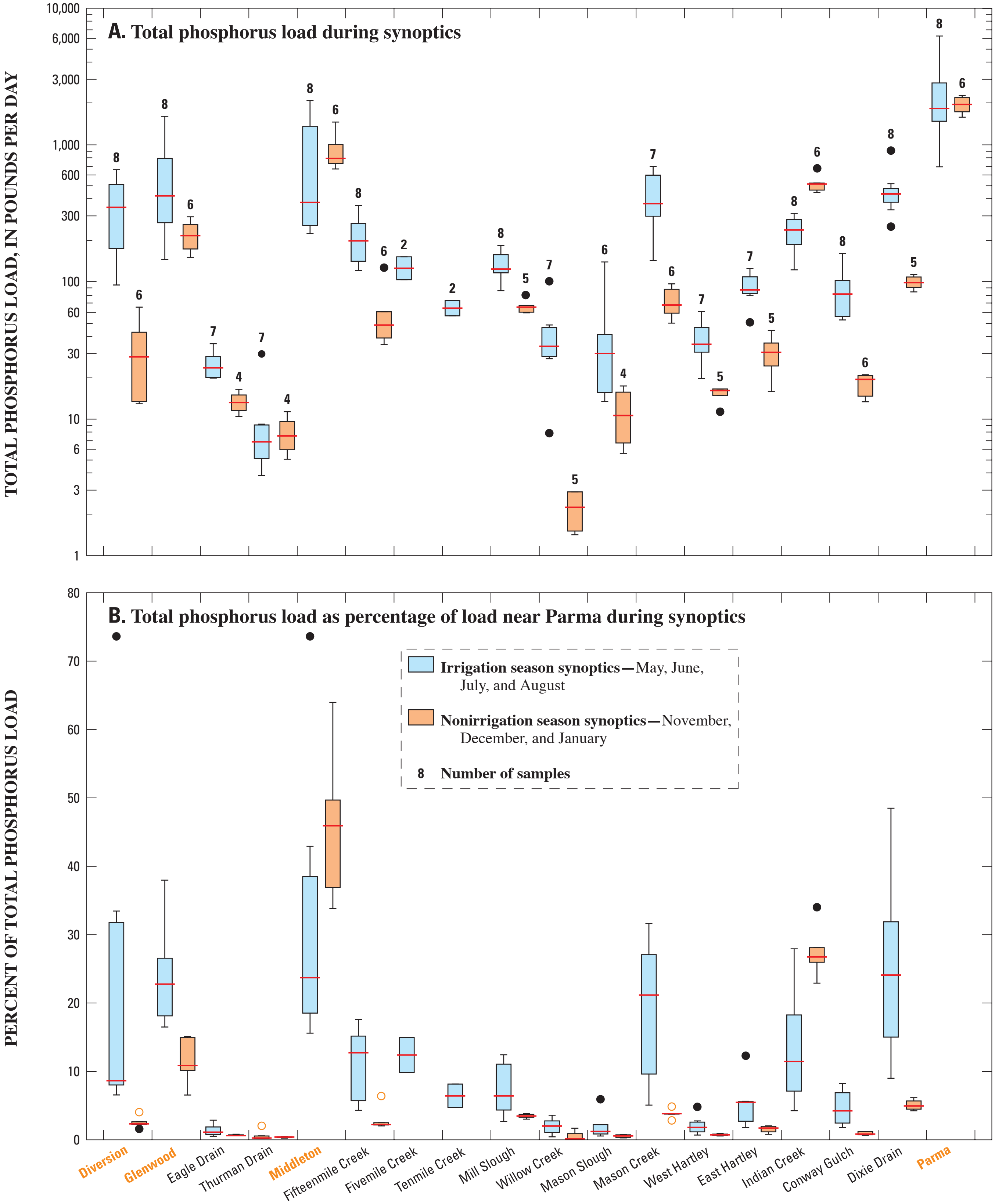


Figure 21. Statistical summary of seasonal total phosphorus load (A) and total phosphorus load as a percentage of the load near Parma (B) from synoptic data collected at selected sites on the lower Boise River and tributaries, Idaho, 1994-2002. (Site names in **gold** are main-stem sites)

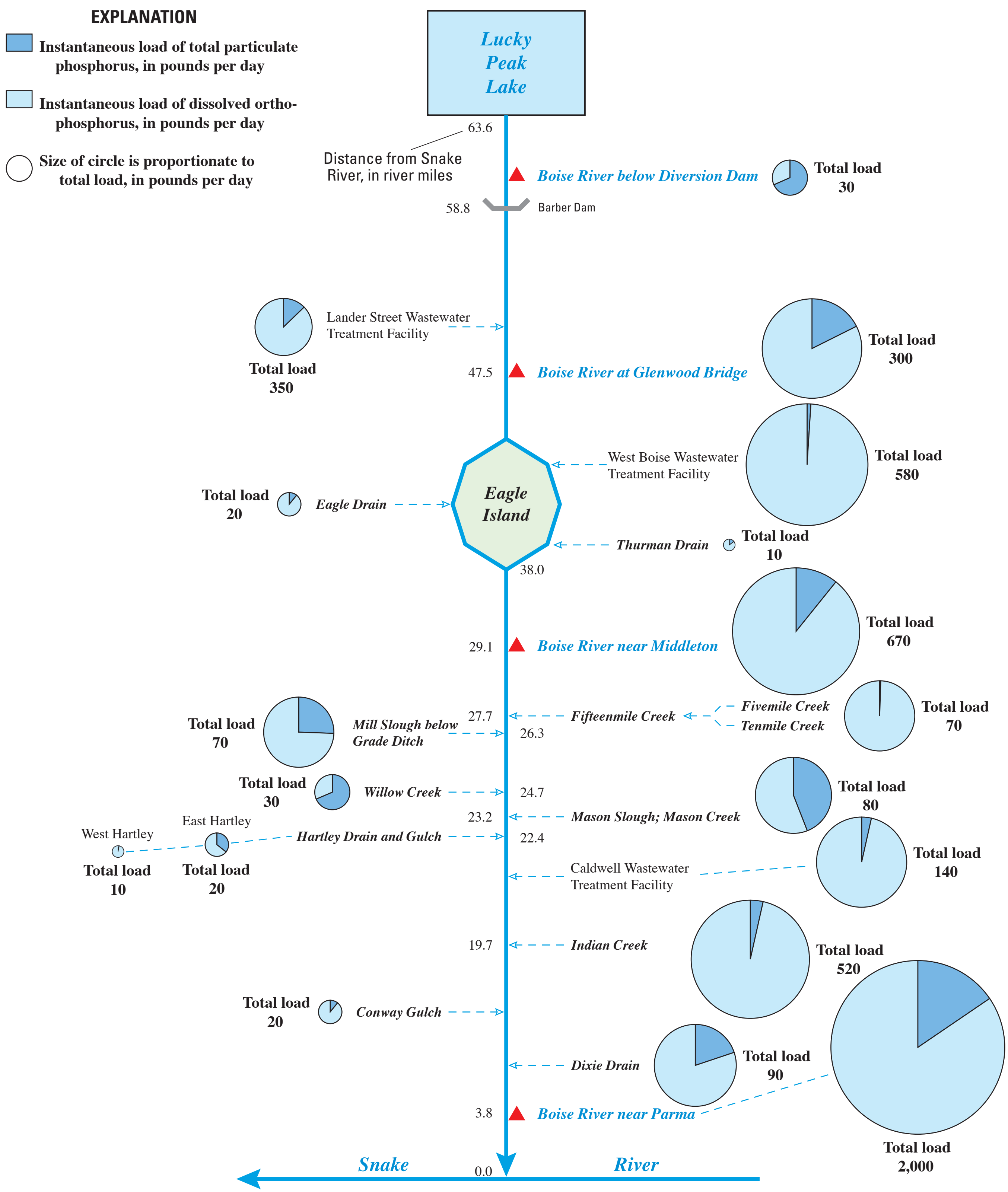


Figure 22. Total phosphorus load at selected lower Boise River and tributary sites, Idaho, calculated from instantaneous concentration and discharge, nonirrigation season, February 8–16, 2000 (Dixie Drain, January 13, 2000). (Wastewater treatment facility data from the City of Boise, written communication, December 2002. No flow data for Star, Notus, Middleton, and Parma treatment facilities or Eagle and Nampa fish hatcheries on this date; therefore, no loads were calculated for these facilities)

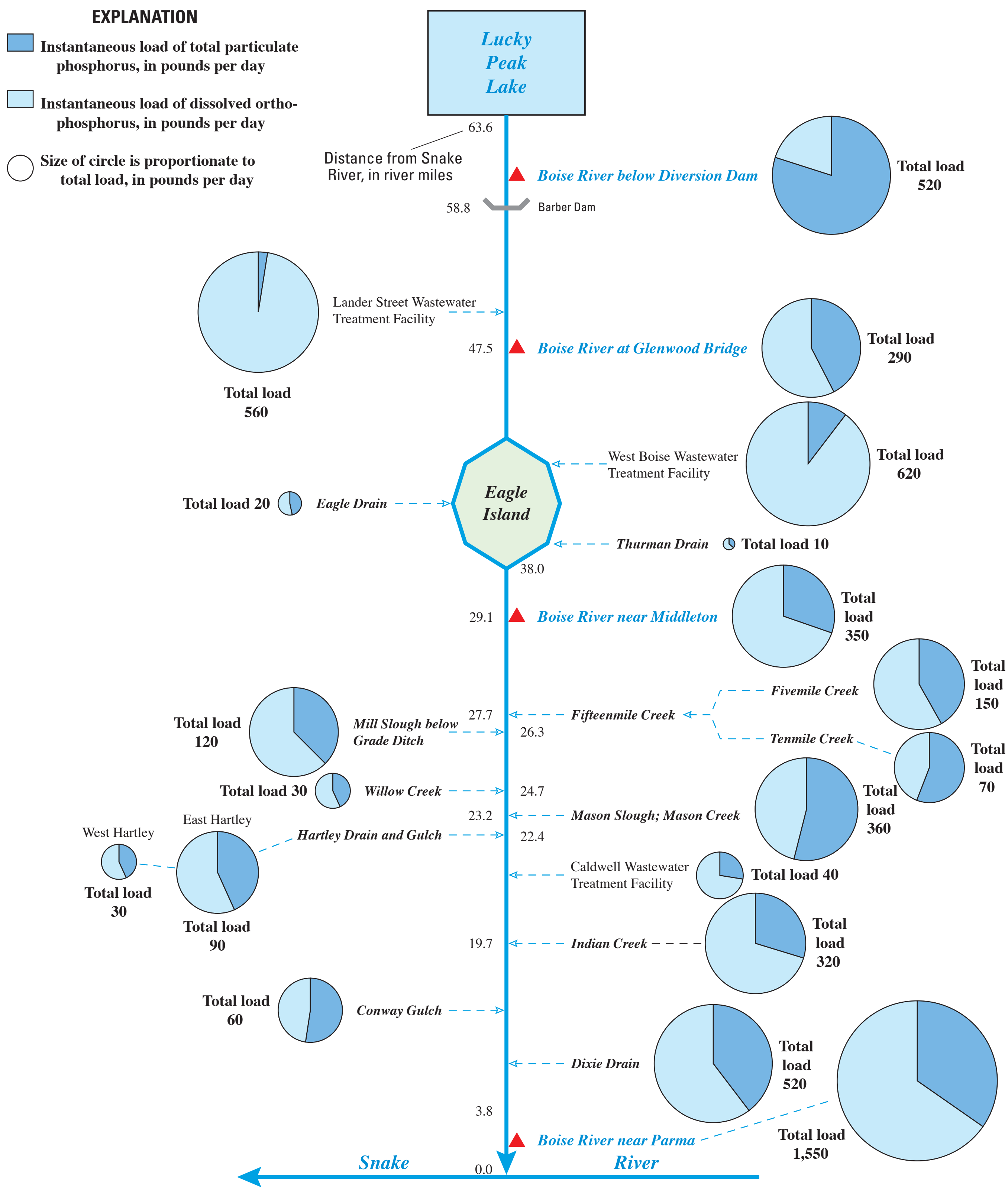


Figure 23. Total phosphorus load at selected lower Boise River and tributary sites, Idaho, calculated from instantaneous concentration and discharge, irrigation season, May 16–18, 2000. (Wastewater treatment facility data from the City of Boise, written communication, December 2002. No flow data for Star, Notus, Middleton, and Parma treatment facilities or Eagle and Nampa fish hatcheries on this date; therefore, no loads were calculated for these facilities)

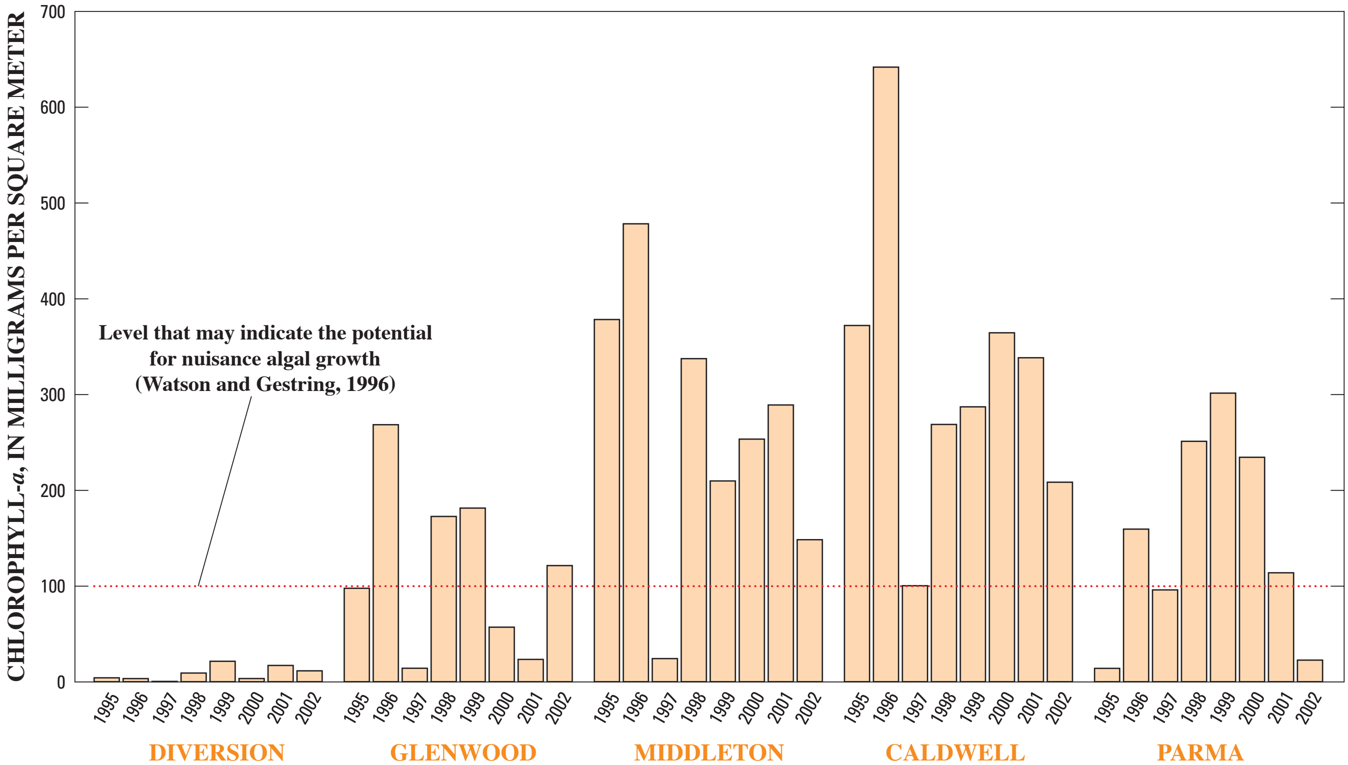


Figure 24. Periphyton chlorophyll-*a* concentration at selected biological sampling sites on the lower Boise River, Idaho, 1995–2002.

Chla concentrations from periphyton samples were determined at five biological sampling sites in the lower Boise (fig. 1). These sites differ from the main-stem water-quality sites because samples were collected from riffle areas not necessarily located at the water-quality sampling locations. Periphyton samples were collected mainly in the fall (September to early November); however, in 1997, additional samples were collected in August and, in 2001, additional samples were collected during the winter months (December and January) to determine algal growth during different seasons. Only the fall samples were used for comparison. At the time of biological sampling, the following water-quality properties and habitat metrics were measured: DO, pH, water temperature, specific conductance, sample depth and velocity, dominant and subdominant substrate, percent embeddedness, and average percent open canopy.

Average Chla concentrations at main-stem sites ranged from <1 mg/m^2 at Diversion to 477 mg/m^2 at Middleton (table 6). Median concentrations were lowest at Diversion (6 mg/m^2), increased to 108 mg/m^2 at Glenwood, peaked at 271 mg/m^2 at Middleton, and declined to 173 mg/m^2 at Parma (table 6). Spatial and temporal variations in Chla from 1995 to 2002 are illustrated in figure 24.

Chla concentration at Glenwood during most years was low compared with that at downstream sites. Although the Glenwood site is characterized by a well-defined riffle area and low suspended sediment (discussed in earlier sections), this site is subject to fluctuations in discharge, and some of the riffle areas become dewatered at different times of the year. In addition, the riffle sampled at Glenwood also has less open canopy than the other sampling locations have (table 8). In 1996, the two highest Chla concentrations (650 and 500 mg/m^2) were measured at Caldwell and Middleton, respectively. The elevated 1996 concentrations were followed by much lower ones in 1997 at Caldwell and Middleton. The low Chla in 1997 may have been the result of scouring of substrate by high discharge in 1997. The Caldwell site is subject to backwater from a side pool created upstream from a bridge, and the higher Chla concentrations in 1996 may reflect impact from these backwater areas.

Nutrient availability can limit periphyton growth and Chla concentrations. The limiting nutrient concept of Liebig (Welch, 1980) states that the ultimate yield of a crop will be limited by the essential nutrient that is most scarce in the environment relative to the needs of the organism. This concept, in concert with the stoichiometry of the photosynthesis equation, led to formulation of nitrogen-to-phosphorus ratios

Table 8. Water-quality constituents and habitat metrics at selected sites on the lower Boise River, Idaho, 1995–2002

[mg/L, milligrams per liter; C, Celsius; µS/cm, microsiemens per centimeter; m/s, meters per second; mm, millimeters; >, greater than; <, less than; multiply millimeters by 0.03937 to obtain inches; multiply meters per second by 3.281 to obtain feet per second; multiply meters by 3.281 to obtain feet; --, measurement not collected; cobble, >64 - 256 mm, gravel, >2 - 64 mm, sand, >0.063 - 2 mm, silt, <0.063 mm; percent open canopy taken from clinometer measurements of right and left bank canopy angles]

Site	Date	Dissolved oxygen, mg/L	pH, standard units	Water temperature, degrees C	Specific conductance, µS/cm	Average depth, m	Average velocity, m/s	Dominant substrate	Sub-dominant substrate	Percent em-beddness	Average percent open canopy
Diversion	10/2/95	9.4	8.1	16.4	70	0.27	0.74	cobble	gravel	5 to 25	--
	10/28/96	10.1	8.0	10.0	--	0.23	0.55	gravel	gravel	5 to 25	--
	10/24/97	10.0	8.2	12.4	77	0.16	0.65	cobble	gravel	5 to 25	63
	10/27/98	9.9	8.3	12.4	88	0.16	0.73	cobble	gravel	5 to 25	68
	11/1/99	10.7	8.7	9.5	76	0.20	0.56	cobble	gravel	5 to 25	64
	10/4/00	9.3	8.2	16.1	--	0.21	0.63	cobble	gravel	25 to 50	--
	11/5/01	10.7	8.3	11.7	94	0.18	0.33	cobble	gravel	5 to 25	85
	10/25/02	10.7	7.6	10.4	88	0.19	0.62	cobble	gravel	<5	85
Glenwood	10/3/95	10.1	7.8	15.6	90	0.25	0.59	cobble	gravel	5 to 25	--
	10/29/96	9.6	7.4	10.3	101	0.21	0.65	cobble	gravel	5 to 25	--
	10/24/97	11.5	8.1	10.7	124	0.18	0.80	cobble	gravel	5 to 25	34
	10/29/98	11.6	8.5	11.7	134	0.13	0.50	cobble	gravel	5 to 25	45
	11/2/99	11.9	8.8	10.6	123	0.18	0.66	cobble	gravel	5 to 25	59
	10/3/00	10.1	7.2	15.6	125	0.28	0.82	cobble	gravel	5 to 25	--
	9/27/01	9.0	8.5	19.4	145	0.16	0.69	cobble	sand	5 to 25	55
	10/24/02	12.2	8.5	12.0	143	0.19	0.68	cobble	gravel	5 to 25	47
Middleton	10/2/95	9.4	7.7	14.1	171	0.20	0.58	cobble	gravel	50 to 75	--
	10/30/96	11.9	8.3	10.6	366	0.22	0.60	cobble	gravel	25 to 50	--
	10/29/97	11.5	8.4	10.7	198	0.16	0.74	cobble	gravel	25 to 50	77
	11/2/98	13.0	8.3	9.8	229	0.14	0.71	cobble	gravel	25 to 50	84
	11/3/99	13.7	8.7	9.8	214	0.11	0.43	cobble	gravel	25 to 50	84
	10/24/00	11.9	8.6	--	237	0.25	0.56	cobble	sand	50 to 75	--
	1/7/02	12.4	7.6	5.0	281	0.20	0.59	cobble	gravel	25 to 50	72
	10/31/02	15.4	9.5	6.3	233	--	0.58	cobble	gravel	50 to 75	74
Caldwell	10/5/95	--	8.5	12.4	276	0.19	0.63	cobble	sand	50 to 75	--
	10/31/96	10.8	7.9	9.3	308	0.16	0.40	cobble	sand	25 to 50	--
	10/29/97	10.7	8.1	11.3	342	0.18	0.61	cobble	gravel	25 to 50	74
	11/4/98	10.5	8.0	9.5	363	0.18	0.40	cobble	gravel	50 to 75	70
	11/4/99	12.3	8.4	10.7	350	0.16	0.56	cobble	gravel	25 to 50	74
	10/25/00	12.5	8.5	12.1	387	0.22	0.58	cobble	sand	50 to 75	--
	2/6/02	13.6	7.8	3.2	385	0.22	0.51	cobble	gravel	50 to 75	80
	10/24/02	8.7	7.7	12.0	341	0.24	0.65	cobble	gravel	50 to 75	76
Parma	10/4/95	10.5	9.0	12.8	403	0.24	0.59	gravel	cobble	50 to 75	--
	10/31/96	11.8	8.5	11.0	467	0.21	0.53	gravel	cobble	50 to 75	--
	10/31/97	11.9	8.2	12.6	493	0.18	0.75	gravel	cobble	25 to 50	77
	11/12/98	13.4	8.3	8.7	216	0.21	0.64	gravel	cobble	50 to 75	85
	11/18/99	10.4	8.3	11.0	522	0.20	0.71	cobble	gravel	25 to 50	74
	10/26/00	10.2	7.7	11.9	533	0.23	0.86	cobble	gravel	25 to 50	--
	1/11/02	12.6	8.5	5.0	520	0.21	0.87	cobble	gravel	25 to 50	90
	10/23/02	9.9	8.3	12.3	494	0.29	--	cobble	silt	50 to 75	87

(N:P). These ratios have been used extensively in eutrophication studies to determine whether nitrogen or phosphorus was the nutrient most likely to limit phytoplankton growth. The atomic ratio of nitrogen to phosphorus, 16N:1P, in the photosynthesis equation corresponds to a mass ratio of 7.2N:1P. Typically, N:P values are calculated using the biologically available forms of these two nutrients, dissolved nitrogen and orthophosphorus. If N:P (by weight) is less than 7.2, then nitrogen may be limiting, whereas if N:P exceeds 7.2, then phosphorus may be limiting (Ryding and Rast, 1989).

The median ratios of dissolved inorganic nitrogen to orthophosphorus for the main-stem sites ranged from 3.7 to 7.2 during the irrigation season and from 4.3 to 10.5 during the nonirrigation season (fig. 25). Diversion tended to be nitrogen limited during most of the irrigation season (median ratio of 5.5) and phosphorus limited (median ratio of 8.0) during the nonirrigation season. Glenwood and Middleton tended to be nitrogen limited during the irrigation season (median ratios of 3.7 and 4.2, respectively) as well as during the nonirrigation season (median ratios of 4.3 and 5.8, respectively). Parma was co-limited by nitrogen and phosphorus during the irrigation season (median ratio of 7.2) and limited by phosphorus during the nonirrigation season (median ratio of 10.5). The high N:P ratios (larger than 20) at Diversion, Glenwood, and Middleton were calculated with nutrient concentrations that were near their reporting limits and, therefore, may not accurately indicate nutrient limitation.

The N:P ratios at the main-stem sites indicate nutrient limitation, either by nitrogen or phosphorus (fig. 25), but high concentrations of both dissolved inorganic nitrogen and orthophosphorus were measured at Glenwood, Middleton, and Parma (table 6). These high concentrations of both nitrogen and phosphorus indicate an adequate nutrient supply for production of periphytic biomass; the limitation indicated by the nutrient ratio applies largely to the rate of nutrient uptake by periphyton.

Chla concentrations can be affected by factors other than nutrient availability, such as seasonal changes in temperature and light intensity, substrate or habitat availability, high discharge, and grazing by macroinvertebrates (Kelly and Whitton, 1998). Cold winter temperatures and summer riparian shading may limit plant growth and Chla concentrations.

The lower Chla concentrations at Glenwood may be a factor of increased canopy cover (table 8). Light attenuation also can be limited with increased suspended sediment. Wood and Armitage (1997) indicated that the large suspended sediment load transported through the lower Boise may prevent periphyton and rooted macrophytes from inhabiting reaches where they were present historically or would naturally be expected.

The lack of riffle habitat at Parma may have limited Chla concentrations; samples were collected from the channel margin, which is subject to frequent water-level fluctuations. The river near Parma is incised and is subject to high-velocity discharge, and banks are eroding and sloughing. Velocity is an important physical variable because of its partial role in determining substrate composition, which influences periphyton communities (Munn and others, 2002). Also, the riffle areas sampled at Middleton, Caldwell, and Parma were as much as 75 percent embedded (table 8), which could affect Chla concentrations. Excessive grazing of periphyton by macroinvertebrates does not seem to be limiting the concentration of Chla.

Water Properties and Concentrations of Constituents Compared with Criteria, State Standards, Local Recommendations, and Guidelines

The quality of water is sometimes determined by comparing measured water properties and constituent concentrations with published criteria or standards. This comparison helps water managers and policy makers prioritize and manage water quality in different hydrologic and land-use settings (U.S. Geological Survey, 1999). There are only a few established criteria and standards that can be applied to the constituents examined in this report; therefore, recommended levels, background concentrations, and national medians are also used for comparison. U.S. Environmental Protection Agency

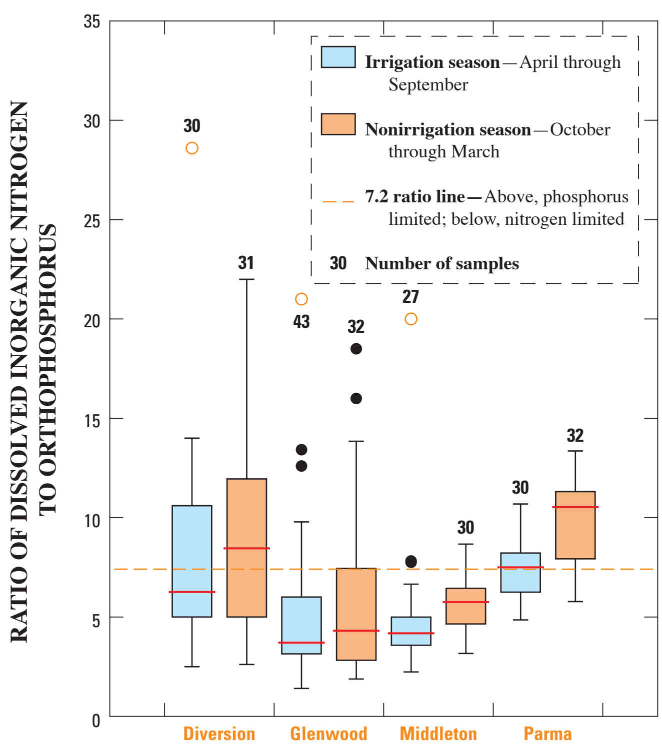


Figure 25. Statistical summary of dissolved inorganic nitrogen and orthophosphorus ratio at main-stem sites on the lower Boise River, Idaho, 1994–2002.

Table 9. Standards, criteria, recommended levels, and background concentrations for water-quality properties and constituents in the lower Boise River, Idaho

[C, Celsius; mg/L, milligrams per liter; mg/m^2, milligrams per square meter; mL, milliliters; NTE, not to exceed; AD, average daily; SS, salmonid spawning period (lower Boise River mountain whitefish spawning between October 15 and March 15); NMT, no more than; d, days; NAWQA, National Water-Quality Assessment; --, no comparison used; PC, primary contact, May 1 through September 30; SC, secondary contact, year-round]

Property or constituent	EPA criteria	State of Idaho water-quality standard	Lower Boise River site-specific requirement	Recommended level	Background concentration	NAWQA national median
Temperature (degrees C)	--	NTE 22, AD 19, SS NTE 13, SS AD 9[a]	--	--	--	--
Dissolved oxygen (mg/L)	--	--	SS 6 [a]	--	--	--
Dissolved oxygen saturation (percent)	--	--	SS 75[a]	--	--	--
pH (standard units)	--	6.5 - 9.5[a]	--	--	--	--
Total nitrogen (mg/L)	--	--	--	0.3[g]	2 (as nitrate)[c]	1.0[f]
Flow-adjusted total nitrogen (mg/L)	--	--	--	--	--	0.26[e] 2.0[d]
Total phosphorus (mg/L)	0.1[f]	--	--	0.02 [g]	0.006[i]	--
Flow-adjusted total phosphorus (mg/L)	--	--	--	--	--	0.02[d,e]
Orthophosphorus (mg/L)	--	--	--	--	--	0.01[d,e]
Suspended sediment (mg/L)	--	(proposed)[b] 50 NMT 60d, 80 NMT 14d	--	--	--	--
Fecal coliform (organisms/100 mL)	--	PC, NTE 500 SC, NTE 800	--	--	--	--
E. Coli (organisms/100 mL)	--	PC, NTE 406 SC, NTE 576	--	--	--	--
Chlorophyll-*a* (mg/m^2)	--	--	--	100[h]	20[h]	--

a Idaho Department of Environmental Quality, 2001, accessed March 5, 2003.

b Rowe and Essig, 1999; Idaho Department of Environmental Quality, 1999.

c Boyle, 2001.

d National Water-Quality Assessment national analysis of nutrient concentrations in streams and rivers *http://water.usgs.gov/nawqa/nutrients/datasets/nutconc2000/#SW*

e Clark and others, 2000.

f U.S. Geological Survey, 1999.

g Watson and Gestring, 1996.

h Nordin, 1985; Welch and others 1987; Watson and Gestring, 1996.

i Smith and others, 2003.

(EPA) water-quality criteria, Idaho State water-quality standards with specific requirements for the lower Boise, recommended levels below which aquatic organisms may be adversely affected, background concentrations, and national medians for selected water-quality properties and constituents measured in the lower Boise are presented in table 9. These values are subject to change as legislation and research information is updated.

The State of Idaho water-quality standard for the coldwater aquatic life beneficial use states that maximum daily water temperature should not exceed 22°C and maximum daily average temperature should not exceed 19°C as a result of human activities. Instantaneous temperature was measured in conjunction with collection of water-quality samples. Four temperature measurements at Glenwood, Middleton, and Parma exceeded the 22°C standard (fig. 5).

Continuous temperature was measured at intermittent intervals at the five biological sampling sites (fig. 6). Inconsistent measurements of summer temperature did not allow for trend analysis or a complete evaluation of exceedance of the standard.

The Diversion site is very cold, reflecting the discharge from the bottom of Lucky Peak Lake. Thermal regime influences distribution patterns, lifecycle phenomena, trophic relations, and behavioral responses of aquatic insects (Ward and Kondratieff, 1992). The minimal temperature variation at this site may not allow some fish and invertebrates to complete their lifecycles (Merritt and Cummins, 1984). The effect of cold hypolimnetic water on downstream aquatic communities in the lower Boise has not been fully examined.

Temperatures at Glenwood, Middleton, Caldwell, and Parma exceeded the daily average coldwater aquatic life standard of 19°C (fig. 6). Temperatures at Glenwood and Middleton intermittently exceeded the State standard, and temperatures at Caldwell exceeded the standard more than half of the time during sampling periods in July and August 1996 and 1999. Temperatures at the site near Parma exceeded the coldwater aquatic life standard most of the time during the sampling period in July and August 1996 (fig. 6).

Salmonid spawning is a beneficial use designated for the lower Boise between Diversion and the confluence of Indian Creek (Caldwell). This beneficial use requires that temperatures not exceed 13°C and that the maximum daily average temperature not exceed 9°C during local salmonid spawning periods (between October 15 and March 15) (Idaho Department of Environmental Quality, 2001, p. 139).

Temperatures at the main-stem sites exceeded the salmonid spawning standard of 9°C. The salmonids found in the lower Boise are mountain whitefish (*Prosopium williamsoni*), which typically spawn from October through February; and rainbow trout (*Onchorhynchus mykiss*) and brown trout (*Salmo trutta*), which typically spawn from fall to spring. Therefore, between Diversion and Caldwell, the salmonid spawning standard must be met between October 15 and March 15 to protect mountain whitefish (Idaho Department of Environmental Quality, 1999). No dates or areas of the river have been designated for application of the salmonid spawning standard to rainbow or brown trout, but these species usually spawn in the upper reaches and tributaries of the lower Boise in spring (Jeff Dillon, Idaho Department of Fish and Game, oral commun., 2003). Temperature in two segments of the lower Boise—Star to Notus, and Notus to the mouth—exceeded the standards and was listed as a pollutant on the 1998 303(d) list (Idaho Department of Environmental Quality, 1998).

The instantaneous DO at the four main-stem sites met the site-specific DO requirement (the lesser of 6 mg/L or 75 percent of saturation) for the lower Boise from Veterans State Park (in Garden City) to the mouth during the salmonid spawning period, October 15 to March 15 (Idaho Department of Environmental Quality, 2001).

DO at Parma (6.7 mg/L and 77 percent saturation) in July 1997 fell below the standard but not at the time of potential salmonid spawning in the river. Daytime DO saturation often exceeded 100 percent (fig. 7), indicating that nighttime respiration might cause DO saturation levels to exceed the standard in the early morning hours. Of the DO measurements collected during this study, DO saturation exceeded 150 percent at Middleton once in each month of June, July, and August and twice in October, and DO saturation at Parma exceeded 150 percent once in August (fig. 7). Continuous DO data were not consistently collected at the lower Boise biological sampling sites during this study; thus, it was not possible to conclude that standards would not be exceeded. In future studies, more frequent collection of continuous DO data would help to evaluate whether DO exceeds the standard during spawning periods.

All instantaneous pH measurements collected in the lower Boise were within the range of 6.5 to 9.5, which is the State of Idaho pH standard for coldwater biota (Idaho Department of Environmental Quality, 2001, p. 138).

IDEQ set proposed suspended sediment standards of 50 mg/L for no more than 60 days and 80 mg/L for no more than 14 days to preserve beneficial uses (Idaho Department of Environmental Quality, 1999; Rowe and others, 1999). Daily suspended sediment samples were not collected during this study but, for interpretive purposes, instantaneous suspended sediment concentrations in samples collected during this study were compared with the proposed standard of 80 mg/L.

Suspended sediment exceeded 80 mg/L at least once at the three lowest main-stem sites, once at Glenwood (September 1999), and twice at Middleton (April 1995 and 1998). Suspended sediment at Parma exceeded 80 mg/L in 10 out of 63 measurements, mostly at the beginning of the irrigation season in April and May (fig. 9). Concentrations of suspended sediment also exceeded 80 mg/L at all but three of the tributaries sampled during this study. Median concentrations of suspended sediment in Mason Creek and Conway Gulch exceeded 80 mg/L; median concentrations at Mason Creek exceeded 80 mg/L in more than 50 percent of the samples collected.

About one-fourth and one-half of the total nitrogen concentrations measured at Glenwood and Middleton, respectively, and most total nitrogen concentrations measured at Parma exceeded 1.0 mg/L (fig. 12). A nationwide water-quality study of undeveloped basins by the USGS (1999) reported a median total nitrogen concentration of 1.0 mg/L (Mueller and Helsel, 1996; U.S. Geological Survey, 1999).

The flow-adjusted total nitrogen concentration in at least one sample from the three lowest main-stem sites exceeded concentrations from comparable or undeveloped sites nationwide. The median flow-adjusted total nitrogen concentration measured from 1990 to 1995 in samples from 85 relatively undeveloped basins across the country was 0.26 mg/L (table 9) (Clark and others, 2000); median flow-adjusted total nitrogen concentrations at Middleton (0.63 mg/L) and at Parma (1.67 mg/L) exceeded 0.26 mg/L (fig. 13). The national median flow-adjusted concentration of total nitrogen in 142 streams in agricultural and urban watersheds sampled as part of the NAWQA Program was approximately 2.0 mg/L (accessed March 2003 at URL: *http://water.usgs.gov/nawqa/nutrients/datasets/nutconc2000/#SW*). Of the flow-adjusted total nitrogen concentrations measured in this study, one at Glenwood, five at Middleton, and more than 30 percent of the measurements at Parma exceeded 2.0 mg/L (fig. 13).

Total phosphorus concentrations at or above 0.02 mg/L have been reported in association with nuisance algal growth (Watson and Gestring, 1996; Welch and others, 1989; Delong and Brusven, 1992); total phosphorus concentrations in the lower Boise often exceeded 0.02 mg/L (fig. 18). No national criteria have been established for phosphorus concentrations in water; however, to control eutrophication, the EPA recommends that total phosphorus not exceed 0.1 mg/L in streams that do not directly discharge into lakes or reservoirs (Mueller and Helsel, 1996). About half of the total phosphorus concentrations measured at Glenwood and nearly all the concentrations measured at Middleton and Parma exceeded 0.1 mg/L (fig. 18). A nationwide water-quality study of undeveloped basins by the USGS reported a median total phosphorus concentration of 0.1 mg/L (Mueller and Helsel, 1996; U.S. Geological Survey, 1999). During this study, the only total phosphorus concentrations less than 0.1 mg/L were measured at Diversion. Regional background concentrations of less than 0.006 mg/L for total phosphorus have been reported in the xeric West (Smith and others, 2003).

The median flow-adjusted concentrations of total phosphorus and orthophosphorus in relatively undeveloped basins across the country were 0.02 and 0.01 mg/L, respectively (Clark and others, 2000); the median flow-adjusted total phosphorus concentrations at Glenwood (0.05 mg/L), Middleton (0.12 mg/L), and Parma (0.19 mg/L) all exceeded 0.02 mg/L. Similarly, flow-adjusted orthophosphorus concentrations at Glenwood (0.04 mg/L), Middleton (0.10 mg/L), and Parma (0.16 mg/L) exceeded the undeveloped basin concentrations.

The elevated concentrations of periphytic Chla measured in the lower Boise may indicate an excess of nutrients and the potential for nuisance algal growth. A guidance document on nutrient and algal criteria development (U.S. Environmental Protection Agency, 2000) recommended three ways to evaluate the issue: (1) use of reference streams to identify background concentrations of periphyton, (2) application of local relations between nutrient levels and biomass (Chla), and (3) use of thresholds identified in scientific literature to help develop nutrient criteria or, in this case, the potential for nuisance algal growth. These three approaches were used to interpret the Chla data for the lower Boise.

Chla concentrations less than 20 mg/m^2 were reported as background, or were measured in least-impacted rivers in Idaho (Cushing and others, 1983; Robinson and others, 2000), which include tributaries of the Middle Fork Salmon River (a large wilderness area with minimal human impact). In September 2000, a Chla concentration of 7 mg/m^2 was measured at the Boise River at Twin Springs, a water-quality monitoring site that may be considered a least-impacted site upstream from the dams on the Boise River (USGS NWIS WEB: *http://water.usgs.gov/nawqa/nutrients/datasets/nutconc2000/*). In contrast, Chla concentrations measured at the lower Boise main-stem sites at Glenwood, Middleton, Caldwell, and Parma exceeded the 7 mg/m^2 background concentration (fig. 24). The Chla concentration at Caldwell of about 640 mg/m^2 in 1996 was nearly 100 times the background concentration (fig. 24).

Dissolved inorganic nitrogen and orthophosphorus concentrations measured in September (1995–2002) at all main-stem biological sampling sites were correlated with Chla concentrations (Spearman rank correlations 0.57 and 0.61, respectively, n = 32, critical value of 0.35), indicating the potential for nuisance algal growth in the lower Boise.

The scientific literature has identified thresholds that indicate nuisance algal growth with different concentrations of Chla measured in periphyton. The British Columbia Ministry of the Environment recommends algal concentrations below 50 mg/m^2 Chla to protect recreation and esthetics and below 100 mg/m^2 to protect against undesirable changes in the biotic community (Nordin, 1985). Welch and others (1987) found that filamentous algal species tend to dominate communities with Chla concentrations above 100 mg/m^2 and that nuisance algal growth may occur above 100 to 150 mg/m^2. Studies of the Clark Fork in western Montana determined that attached algae at times interfered with beneficial uses (Watson and Gestring, 1996). These investigators concluded that algal Chla concentrations higher than 100 mg/m^2 were unacceptable unless high concentrations were natural or not problematic for a particular site. Watson and Gestring (1996) also stated that algal concentrations in the Clark Fork would not attain nuisance levels if summer nutrient concentrations stayed below 0.3 mg/L total nitrogen and 0.02 mg/L total phosphorus. Nutrients at all main-stem lower Boise sites exceeded those concentrations where average Chla concentrations were higher than 100 mg/m^2.

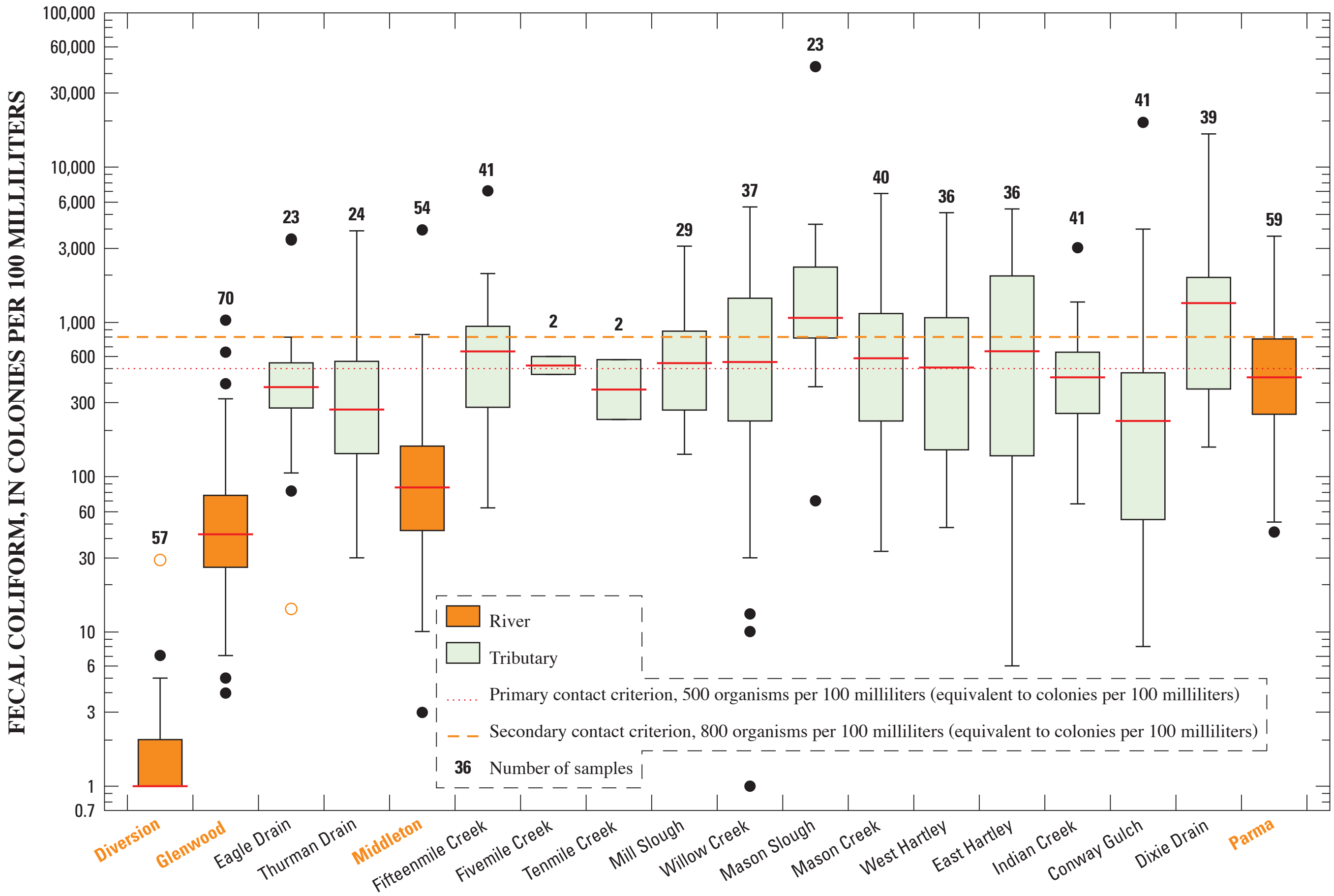


Figure 26. Statistical summary of fecal coliform concentration at selected sites on the lower Boise River and tributaries, Idaho, 1994–2002. (Primary and secondary contact criteria from Idaho Department of Environmental Quality, 2001, Reference b, Idaho Water Quality Standards and Wastewater Treatment Requirements; site names in **gold** are main-stem sites.

Fecal Coliform and *E. Coli* Bacteria

Presence of fecal coliform and *E. Coli* bacteria can indicate the possible presence of pathogens in water. Potential sources in the lower Boise include wastewater treatment effluent, agricultural runoff, urban and residential runoff, and domestic animal and wildlife waste. When this study began in 1994, the bacteria standards were based on concentrations of fecal coliform bacteria, which were also used to develop the TMDL for the lower Boise. The State of Idaho changed the water-quality standard in 2000 from fecal coliform to *E. Coli* bacteria (Idaho Department of Environmental Quality, 2001). This report on the lower Boise study includes a discussion of both fecal coliform and *E. Coli* bacteria; however, trend analysis was done only for fecal coliform because only 2 years of *E. Coli* data were collected.

Fecal Coliform Concentrations

Fecal coliform concentrations increased significantly between Diversion and Glenwood (median increase from 1 to 43 colonies/100 mL, $p < 0.001$) and between Middleton and Parma (median increase from 73 to 440 colonies/100 mL, $p < 0.001$). Median concentrations of fecal coliform during water years 1994 through 2002 at the four main-stem sites ranged from 1 colony/100 mL at Diversion to 440 colonies/100 mL at Parma (table 6, fig. 26). Concentrations of fecal coliform at the four main-stem sites ranged from 1 to 3,950 colonies/100 mL; the highest concentrations were measured at Middleton and Parma. The maximum concentration of 3,950 colonies/100 mL was measured at Middleton in August 2000, and the second-highest concentration of 3,600 colonies/100 mL was measured at Parma in June 1996.

Tributaries between Middleton and Parma contributed high concentrations of fecal coliform to the lower Boise. Maximum concentrations at all tributaries except at Fivemile and Tenmile Creeks were higher than 1,000 colonies/100 mL (fig. 26). These two sites were sampled only twice during this study and both are tributaries of Fifteenmile Creek, where the median fecal coliform concentration was near 600 colonies/100 mL. Median concentrations were highest at Dixie Drain (1,328 colonies/100 mL) and Mason Slough (1,067 colonies/100 mL) (fig. 26). The highest overall concentration of fecal coliform bacteria, almost 45,000 colonies/100 mL, was measured at Mason Slough. The next-highest concentrations, 16,500 and 19,600 colonies/100 mL, were measured at Dixie Drain and Conway Gulch, respectively.

Seasonal and Long-Term Trends in Fecal Coliform Concentrations

No significant trends in flow-adjusted fecal coliform concentration (fig. 27) were detected at Glenwood, Middleton, and Parma during either the irrigation or nonirrigation seasons. Small concentrations of fecal coliform that would not pose a threat to human health were collected at Diversion. Flow-adjusted concentrations at Middleton and Parma were significantly higher ($p < 0.002$) during the irrigation season than during the nonirrigation season. Flow-adjusted concentrations of fecal coliform increased during the irrigation season at Middleton and Parma from 1994 to 1996 and decreased during both the irrigation and nonirrigation seasons at Parma from 1999 to 2002. These changes did not affect the overall 8-year trend results.

Fecal Coliform Loads

Instantaneous loads of fecal coliform were calculated and expressed as the number of colonies that would pass a site per second. The resulting loads were quite large; therefore, exponential notation was used when referring to loads of bacteria.

Instantaneous loads of fecal coliform measured during synoptics between 1994 and 2002 at the four main-stem sites (fig. 28A) varied over about 5 orders of magnitude (10^5 colonies/s at Diversion to 10^9 colonies/s at Parma). Median loads of fecal coliform measured at Diversion, Glenwood, Middleton, and Parma were largest during the irrigation season compared to the nonirrigation season, often by an order of magnitude. Loads at Parma during the irrigation season ranged from 10^8 to one measurement of more than 10^9 colonies/s, the highest fecal coliform load measured in the lower Boise.

During the irrigation season synoptics, fecal coliform load increased significantly ($p < 0.001$) between Diversion and Glenwood and between Middleton and Parma (fig. 28A). The load also increased significantly during the nonirrigation season among all sites in a downstream direction.

Tributaries contributed a considerable portion of the fecal coliform load measured at Parma during both seasonal synoptics; their contribution during the irrigation season was significantly ($p < 0.001$) larger than during the nonirrigation season (fig. 28A). The median load of fecal coliform was largest (10^8 colonies/s) at Dixie Drain during the irrigation season synoptics; the load at all other tributaries exceeded a median of 10^6 colonies/s during the irrigation season synoptics and 10^5 colonies/s during the nonirrigation season synoptics.

The major sources of fecal coliform in the basin were identified by measuring the fecal coliform load contributions from individual main-stem and tributary sites as a percentage of the total load measured at Parma during the seasonal synoptics (similar to nutrient load analysis) (fig. 28B). During the irrigation season, the basin upstream from Glenwood contributed a median of less than 10 percent of the fecal coliform load, and the basin upstream from Middleton contributed a median of greater than 10 percent of the load measured at Parma. The tributaries contributed most of the load during the irrigation season; Dixie Drain contributed the largest median load of greater than 20 percent.

During the nonirrigation season, Indian Creek contributed the largest median load (about 20 percent) and all other drains each contributed less than 10 percent of the load measured at Parma. Mason Creek contributed the widest range of the load measured at Parma during both seasons. Several withdrawals downstream from this tributary may impact the load measured at Parma.

E. Coli Concentrations

E. Coli was analyzed only for samples collected from October 1999 through October 2002; therefore, trend analyses of flow-adjusted concentrations and loads were not calculated. *E. Coli* concentrations from the lower Boise and tributaries are summarized in figure 29, and concentration ranges are given in table 6.

The highest *E. Coli* concentration among main-stem sites (4,800 MPN/100 mL) was measured at Middleton. The highest median concentration (79 MPN/100 mL) was measured at Parma. Tributaries to the lower Boise contributed high concentrations of *E. Coli*; the highest median concentrations were measured at Mason Slough (about 800 MPN/100 mL) and Dixie Drain (about 700 MPN/100 mL) (fig. 29). The maximum concentrations of *E. Coli*, about 20,000 MPN/100 mL, were measured at Conway Gulch and Dixie Drain.

Fecal Coliform and *E. Coli* Concentrations Compared with Criteria

The lower Boise has a designated use of primary contact recreation; the tributaries are designated for secondary contact recreation. In water designated for primary contact recreation, the Idaho water-quality standards require that concentrations of fecal coliform between May 1 and September 30 (1) not exceed 500 organisms/100 mL at any time, (2) not exceed 200 organisms/100 mL in more than 10 percent of the total samples collected over a 30-day period, or (3) not exceed a geometric mean of 50 organisms/100 mL based on a minimum of five samples collected over a 30-day period (Idaho Depart-

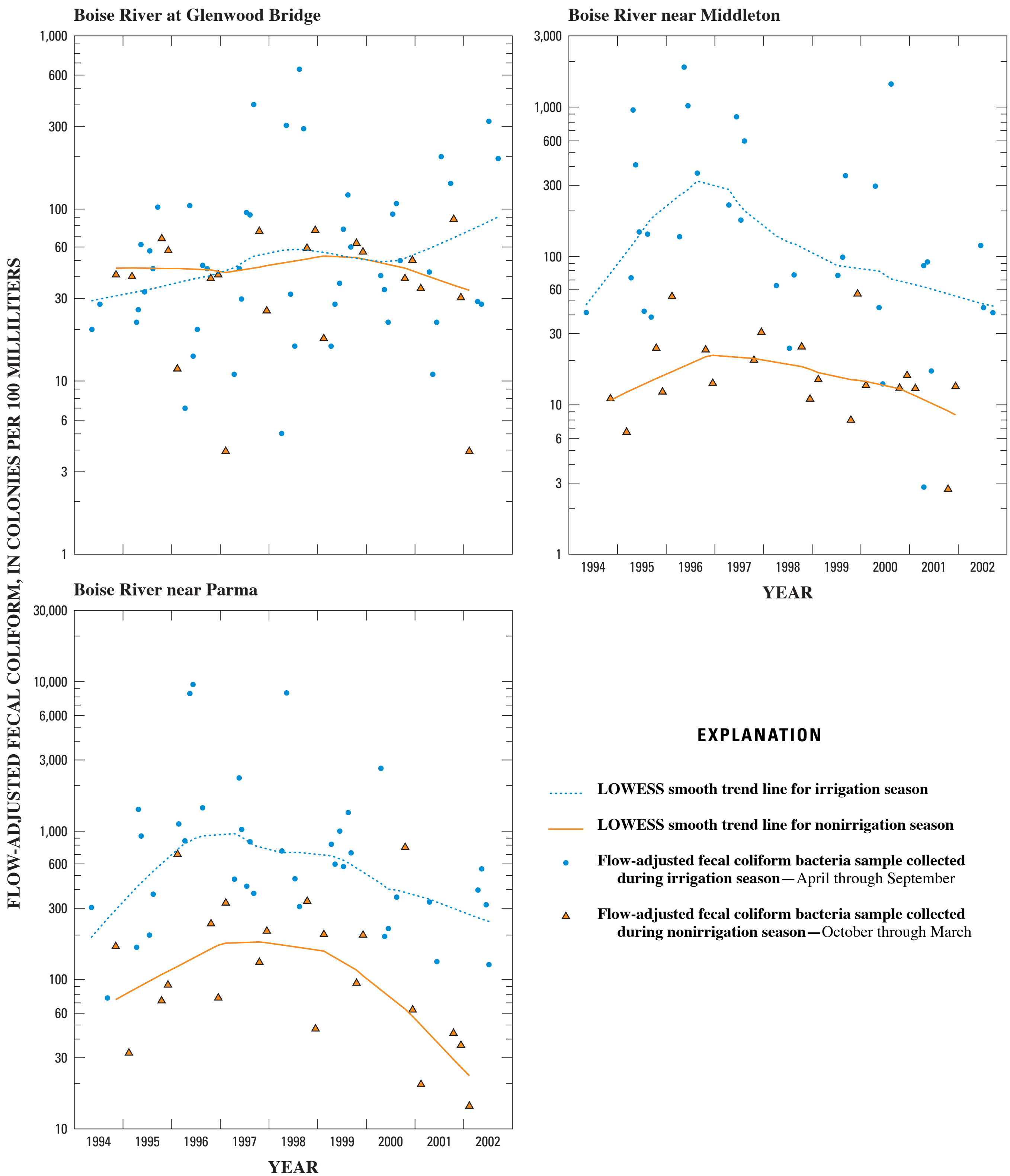


Figure 27. Flow-adjusted fecal coliform bacteria concentration with seasonal LOWESS smooth trend lines for selected main-stem sites on the lower Boise River, Idaho, 1994–2002.

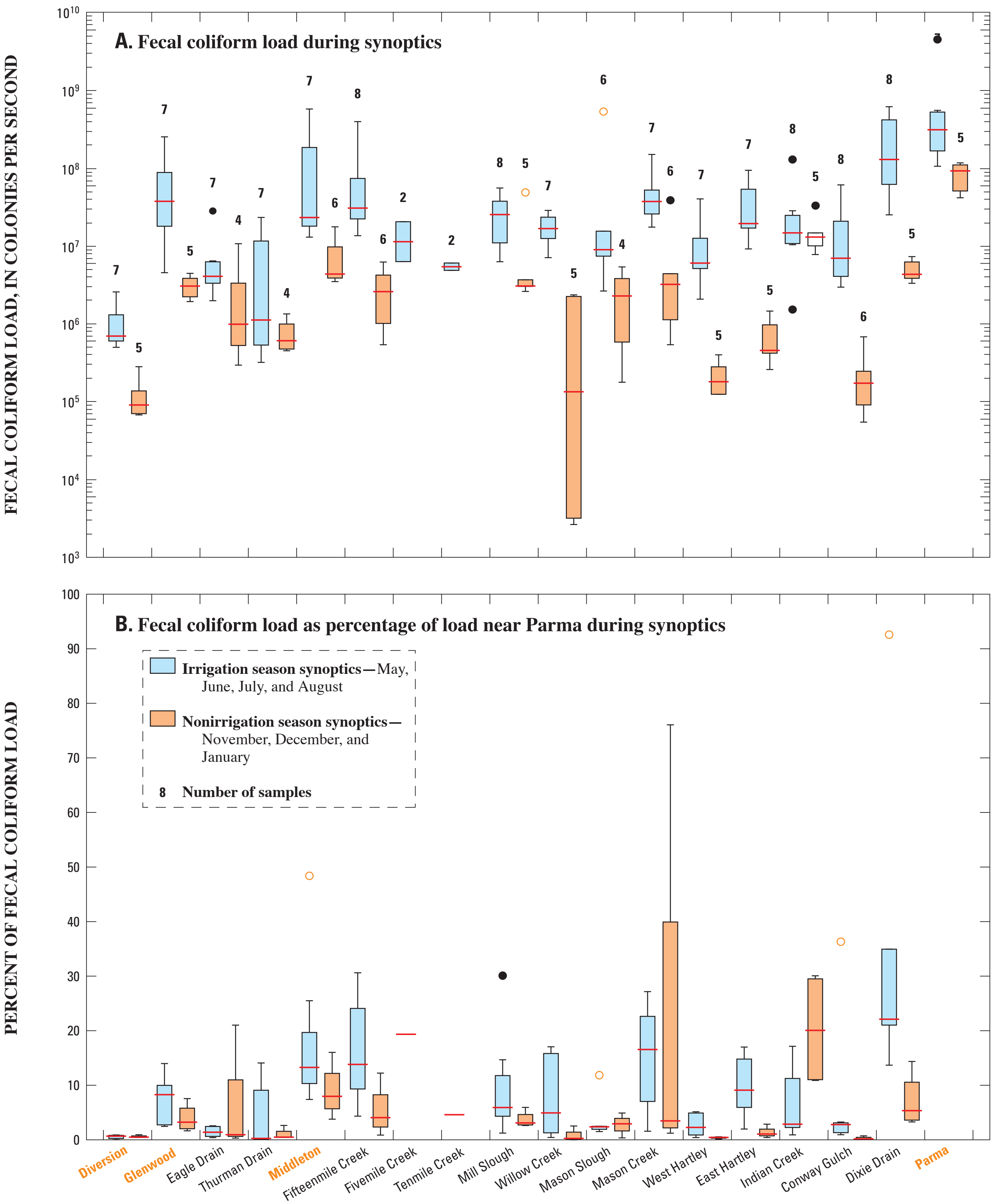
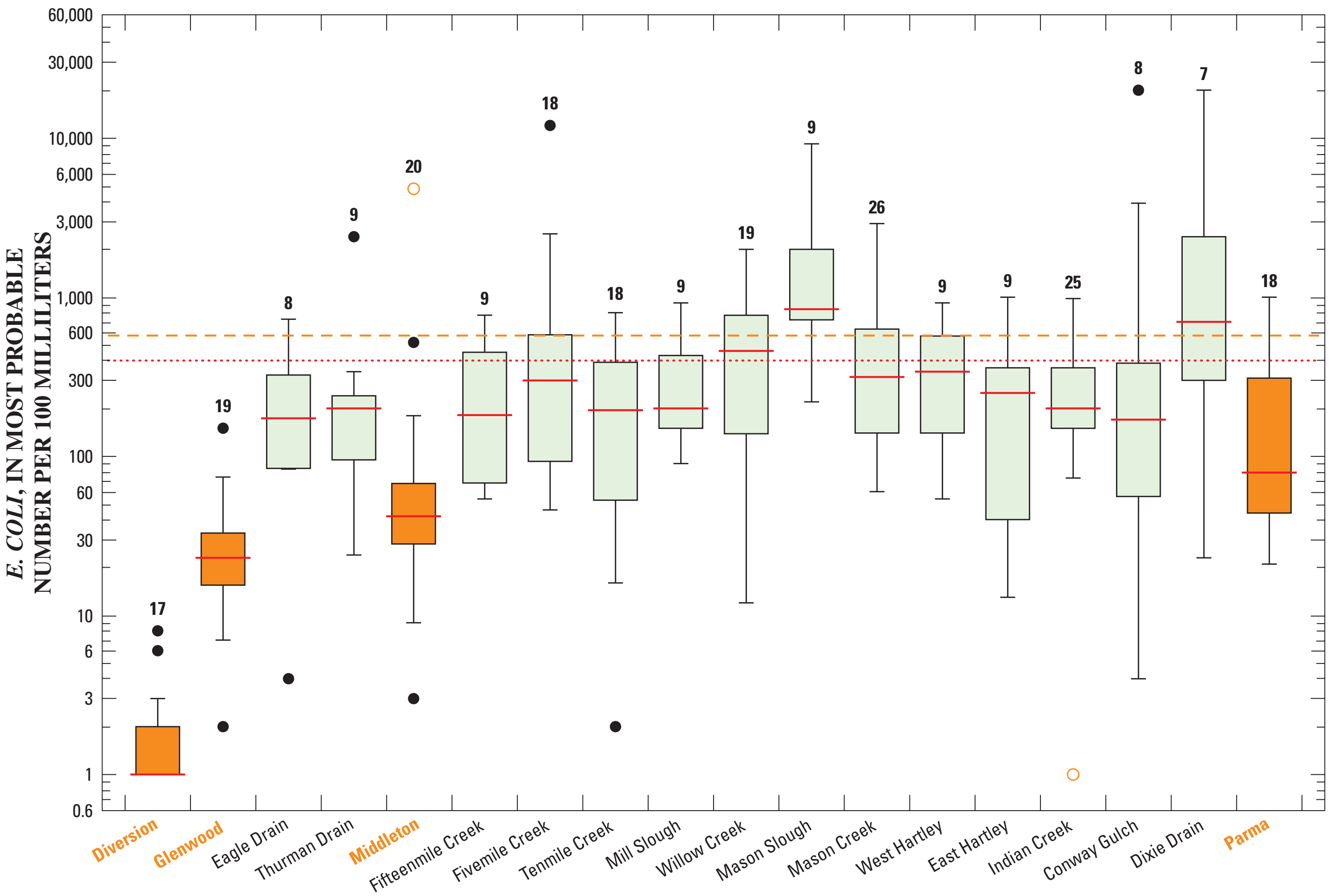


Figure 28. Statistical summary of seasonal fecal coliform load (A) and fecal coliform load as a percentage of the load near Parma (B) from synoptic data collected at selected sites on the lower Boise River and tributaries, Idaho, 1994–2002. (Site names in **gold** are main-stem sites)

ment of Environmental Quality, 2001). Standards for secondary contact recreation apply year round and require that fecal coliform concentrations (1) not exceed 800 organisms/100 mL at any time, (2) not exceed 400 organisms/100 mL in more than 10 percent of the total samples collected over a 30-day period, or (3) not exceed a geometric mean of 200 organisms/100 mL based on a minimum of five samples collected over a 30-day period (Idaho Department of Environmental Quality, 2001). The not-to-exceed requirements listed for the primary and secondary contact recreation standards were used for comparison with the instantaneous fecal coliform concentrations measured in the lower Boise.

Two samples at Glenwood exceeded the primary contact recreation standard for fecal coliform bacteria during this study. Samples at Middleton and Parma also exceeded the primary contact standard (fig. 26). The highest median fecal coliform concentration (about 400 colonies/100 mL) among the main-stem sites was measured at Parma, but the concentration did not exceed the standard. Although instantaneous concentrations at 12 of the 14 tributaries sampled exceeded the secondary contact standard, only the median concentrations at Mason Slough (about 1,000 colonies/100 mL) and Dixie Drain (about 1,500 colonies/100 mL) exceeded the standard.

As with fecal coliform, the primary contact standard for *E. Coli* concentrations in the lower Boise also applies from



EXPLANATION

River

Tributary

Primary contact criterion, 406 organisms per 100 milliliters (equivalent to most probable number per 100 milliliters)

Secondary contact criterion, 576 organisms per 100 milliliters (equivalent to most probable number per 100 milliliters)

19 Number of samples

Figure 29. *E. Coli* bacteria concentration at selected sites on the lower Boise River and tributaries, Idaho, 1999–2002. (Primary and secondary contact criteria from Idaho Department of Environmental Quality, 2001, Reference b, Idaho Water Quality Standards and Wastewater Treatment Requirements; site names in **gold** are main-stem sites)

May 1 through September 30; *E. Coli* concentrations are not to exceed 406 organisms/100 mL or the geometric mean of 126 organisms/100 mL based on five samples collected every 3 to 5 days over a 30-day period (Idaho Department of Environmental Quality, 2001). The secondary contact standard applies year round and requires that *E. Coli* concentrations not exceed 576 organisms/100 mL or the geometric mean of 126 organisms/100 mL based on five samples collected every 3 to 5 days over a 30-day period (Idaho Department of Environmental Quality, 2001). The not-to-exceed standards, 406 and 576 organisms/100 mL, were used to evaluate lower Boise *E. Coli* concentrations because continuous samples were not collected.

E. Coli concentrations at Diversion and Glenwood did not exceed primary contact recreation standards at any time during this study (fig. 29), but concentrations at Middleton and Parma did exceed the primary contact standard. The highest median *E. Coli* concentration (about 80 MPN/100 mL) and one of the highest concentrations (1,000 MPN/100 mL) among the main-stem sites were measured at Parma. The highest *E. Coli* instantaneous concentration, about 5,000 MPN/100 mL, was measured at Middleton. This concentration was an outlier because the median was only about 50 MPN/100 mL. *E. Coli* concentrations at all tributaries exceeded the secondary contact standard of 406 organisms/100 mL at least once. Median concentrations of *E. Coli* exceeded the secondary standard only at Mason Slough (about 800 MPN/100 mL) and Dixie Drain (about 700 MPN/100 mL).

BIOLOGICAL CONDITIONS

Aquatic organisms directly respond to and integrate the composite effects of multiple environmental factors such as discharge, water quality, substrate quality, habitat, and food supply. As such, measurements of a single abiotic factor typically do not result in an ecologically significant explanation of human disturbance (Relyea and others, 2000). Therefore, several biological and habitat variables need to be examined to tell a more meaningful story. The Administrative Rules of the State of Idaho (Idaho Department of Environmental Quality, 2001) state that biological parameters can be used to evaluate the status of beneficial use support and may include, but are not limited to, evaluation of aquatic macroinvertebrates. Those evaluations include the following: EPT, Hilsenhoff Biotic Index, measures of functional feeding groups, and the variety and number of fish or other aquatic life.

A review of published studies indicated that macroinvertebrate communities are likely to be affected by environmental factors such as temperature, reduced habitat, fine sediments and other pollutants, and higher specific conductance, all of which were measured in the lower Boise during this study. Agricultural practices and metropolitan areas can impact macroinvertebrate communities by increases in fine sediment and other pollutants associated with urban and agricultural runoff (Karr and Chu, 1999). Suspended sediments in the water column increase turbidity, thereby limiting light penetration and potentially reducing primary productivity (Newcombe and MacDonald, 1991; Waters, 1995; Wood and Armitage, 1997). Newcombe and MacDonald (1991), and Newcombe and Jensen (1996) described several studies in which excessive sediment was associated with sublethal and behavioral effects on both fish and macroinvertebrates. Streams affected by agriculture in the upper Snake River Basin contained more tolerant fish species; their abundance was correlated with high specific conductance (Maret and others, 1997). High conductivities measured in rivers in Idaho have been correlated with agricultural activity and low numbers of macroinvertebrate taxa (Clark, 1994; Maret and others, 1997; Maret and others, 2001). Although suspended sediment was not positively correlated with specific conductance at Glenwood, Middleton, and Parma (table 7), elevated concentrations of each of these properties may affect aquatic communities.

Lack of suitable habitat and high water velocities also can affect biological communities. High embeddedness (greater than 50 percent), as measured in the lower reaches of the lower Boise (table 8), can reduce benthic habitat by decreasing the interstitial space and oxygen transfer in the streambed, which can decrease survival of certain fish species (Waters, 1995). Water velocity is also an important physical variable influencing benthic communities because of its effect on substrate composition (Munn and others, 2002).

Benthic Macroinvertebrate Metrics and Indices

Macroinvertebrates were collected at five sites in the lower Boise beginning in the fall of 1995. The 1995 through 2000 data were assessed using the following individual metrics: EPT taxa, percent abundance in each functional feeding group, and percent tolerant taxa. Data also were assessed using indices of the impact of fine sediment on macroinvertebrate communities, and the RMI, which includes the following metrics: taxa richness, EPT richness, percent dominant taxon, percent Elmidae, and percent predators (Grafe and others, 2002). The calculated metrics can be found in table 10.

EPT taxa is a traditional metric that consistently has been used to identify human-impacted versus least-impacted streams. Species in these families are known to be intolerant to a variety of impacts including extreme temperature variations, high suspended sediment concentrations or turbidity, and high concentrations of organic waste or other pollutants. However, some of the species in these families may be highly tolerant to pollutants; for example, the mayfly, *Trichorythodes minutus* (*T. minutus*), is known to be tolerant to fine sediment. This species has opercular gills that protect the remaining gills from silt deposition (Ward and Kondratieff, 1992). Despite the abundance of tolerant species, EPT richness (number of taxa) appears, in most cases, to be a good indicator of overall habitat and water quality (Wisseman, 1996).

Table 10. Selected macroinvertebrate metrics calculated from taxa collected at biological sampling sites on the lower Boise River, Idaho, 1995–2000

[EPT, Ephemeroptera, Plecoptera, Trichoptera; sp., species]

Metric	Diversion						Glenwood					
Year sampled	1995	1996	1997	1998	1999	2000	1995	1996	1997	1998	1999	2000
Abundance	10,640	6,067	11,670	20,238	25,222	5,134	14,664	4,342	10,735	11,292	14,943	6,920
Total taxa (richness)	20	15	28	17	19	31	24	18	23	21	22	24
EPT abundance	8,500	4,747	10,095	17,948	10,153	4,055	10,964	3,659	8,807	9,192	13,065	5,183
EPT taxa	12	11	16	11	12	15	12	10	12	12	10	8
Plecoptera abundance	5	13	9	45	27	8	9	85	121	306	498	16
Plecoptera taxa	1	1	1	1	1	1	2	1	1	1	2	2
Ephemeroptera abundance	2,654	1,390	2,627	6,750	4,689	2,298	3,889	403	734	1,468	1,366	477
Ephemeroptera taxa	7	6	7	5	5	6	8	6	7	7	5	3
Trichoptera abundance	5,841	3,344	7,459	11,153	5,437	1,749	7,066	3,171	7,952	7,418	11,201	4,687
Trichoptera taxa	4	4	8	5	6	8	3	3	4	4	3	3
Hilsenhoff Biotic Index	5	5	4	5	5	5	5	4	4	4	4	4
Percent 1 sp. dominant	48.3	51.8	58.8	52.1	56.1	3.7	45.4	69.3	72.1	65.1	73.5	65.4
Percent 3 sp. dominant	80.4	87.2	80.7	82.6	86.9	66.6	72.9	79.4	82.3	79.1	84.9	81.3
Percent 5 sp. dominant	86.9	92.1	88.0	89.6	93.3	75.3	81.5	85.5	89.9	86.7	90.2	74.7
Percent Elmidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent collector-gatherers	25.3	24.0	19.5	31.7	17.4	45.6	37.9	11.3	12.7	18.2	13.7	12.7
Percent collector-filterers	63.2	69.0	66.9	59.5	76.7	35.3	48.7	74.0	73.8	65.5	75.4	67.3
Percent scrapers	5.3	4.4	9.9	5.8	4.4	6.6	6.8	6.9	5.0	4.4	2.9	9.8
Percent predators	1.3	0.2	0.8	0.7	0.4	0.4	1.9	4.0	5.5	0.7	6.0	6.0
Percent parasites	2.4	0.4	0.8	0.8	0.9	4.5	2.4	1.2	1.9	4.2	1.6	5.7
Percent *Baetis tricaudatus*	20	19	15	25	12	33	18	6	5	10	8	6
Percent *Hydropsyche*	48	52	59	52	19	30	45	69	72	65	74	65
Percent *Tricorythodes minutus* of all taxa	17	0	0	0	0	0	2	0	0	0	0	0
Percent tolerant	3.33	2.10	2.82	2.28	2.03	2.67	5.08	3.72	1.63	0.63	0.82	2.44
Percent chironomids (midges)	5	5	3	3	2	9	8	8	11	10	7	8
Percent Glossosomatidae	3	1	0	0	0	2	0	0	1	0	1	0

Table 10. Selected macroinvertebrate metrics calculated from taxa collected at biological sampling sites on the lower Boise River, Idaho, 1995–2000—Continued

Metric	Middleton						Caldwell					
Year sampled	1995	1996	1997	1998	1999	2000	1995	1996	1997	1998	1999	2000
Abundance	12,524	3,870	12,613	12,540	13,990	5,048	12,035	1,516	3,452	3,658	2,528	4,023
Total taxa (richness)	31	33	27	26	27	40	23	33	30	27	20	25
EPT abundance	10,226	3,118	8,514	9,147	10,889	2,816	7,291	515	2,101	1,973	1,099	2,287
EPT taxa	13	13	15	12	12	14	6	5	9	9	7	7
Plecoptera abundance	0	0	182	251	396	0	0	0	0	2	0	0
Plecoptera taxa	0	0	1	1	1	0	0	0	0	1	0	0
Ephemeroptera abundance	5,639	460	1,636	2,482	3,183	673	1,563	101	239	677	43	120
Ephemeroptera taxa	5	6	7	6	7	6	4	4	6	4	4	4
Trichoptera abundance	4,587	2,658	6,696	6,414	7,310	2,143	5,728	414	1,862	1,294	1,056	2,167
Trichoptera taxa	8	7	7	5	4	8	2	1	3	4	3	3
Hilsenhoff Biotic Index	5	5	5	5	5	5	5	6	5	5	5	5
Percent 1 sp. dominant	29.6	64.9	50.8	46.7	48.2	31.3	46.9	27.8	53.5	34.4	41.6	53.6
Percent 3 sp. dominant	67.3	75.7	72.8	64.8	65.0	53.1	73.2	72.2	77.4	62.8	80.3	81.4
Percent 5 sp. dominant	79.3	82.1	81.7	74.7	74.6	46.5	83.2	82.6	84.0	77.5	90.0	79.4
Percent Elmidae	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Percent collector-gatherers	50.9	21.5	33.7	35.3	34.3	33.9	37.7	56.8	30.4	43.0	42.6	31.3
Percent collector-filterers	36.5	68.0	53.2	51.3	52.7	40.0	49.4	28.7	54.8	37.9	42.1	52.0
Percent scrapers	1.8	0.9	1.6	1.3	1.8	12.6	0.6	5.2	5.2	10.9	3.8	1.7
Percent predators	2.5	1.8	3.3	5.3	4.8	4.8	3.5	1.1	3.2	1.2	5.2	5.2
Percent parasites	5.0	1.4	4.0	3.8	3.9	6.5	4.3	0.9	2.2	5.0	4.8	9.7
Percent *Baetis tricaudatus*	6	6	7	5	6	1	1	1	2	2	0	0
Percent *Hydropsyche*	30	65	51	47	48	31	47	27	54	34	42	54
Percent *Tricorythodes minutus* of all taxa	22	3	3	10	10	11	10	2	2	14	0	1
Percent tolerant	29.63	7.38	5.30	14.43	14.44	22.46	11.38	7.53	4.72	17.15	1.72	2.99
Percent chironomids (midges)	10	17	27	14	13	15	27	42	29	15	47	29
Percent Glossosomatidae	0	0	0	0	0	0	0	0	0	0	0	0

Table 10. Selected macroinvertebrate metrics calculated from taxa collected at biological sampling sites on the lower Boise River, Idaho, 1995–2000—Continued

Metric	Parma					
Year sampled	1995	1996	1997	1998	1999	2000
Abundance	17,886	5,491	7,752	8,905	9,981	3,975
Total taxa (richness)	22	27	32	30	25	34
EPT abundance	14,686	3,784	6,300	7,549	6,371	2,414
EPT taxa	7	9	10	11	9	12
Plecoptera abundance	0	0	0	0	0	0
Plecoptera taxa	0	0	0	0	0	0
Ephemeroptera abundance	11,338	1,597	3,756	5,257	3,190	1,852
Ephemeroptera taxa	4	6	6	7	5	7
Trichoptera abundance	3,348	2,187	2,544	2,292	3,181	562
Trichoptera taxa	3	3	4	4	4	5
Hilsenhoff Biotic Index	5	5	4	4	5	5
Percent 1 sp. dominant	42.0	39.5	32.3	48.3	31.6	5.9
Percent 3 sp. dominant	69.0	76.5	71.6	77.0	51.5	54.7
Percent 5 sp. dominant	83.7	87.6	82.9	83.6	45.4	58.9
Percent Elmidae	0.3	0.3	0.2	0.1	0.1	1.2
Percent collector-gatherers	69.9	48.9	46.8	61.6	48.3	62.3
Percent collector-filterers	19.2	41.6	34.0	26.0	40.9	14.5
Percent scrapers	7.6	2.2	14.8	7.8	6.5	14.3
Percent predators	0.5	0.2	0.1	0.4	1.0	1.0
Percent parasites	1.4	0.6	0.9	1.9	0.6	3.5
Percent *Baetis tricaudatus*	8	3	3	1	8	5
Percent *Hydropsyche*	18	39	32	25	32	6
Percent *Tricorythodes minutus* of all taxa	42	19	32	48	11	29
Percent tolerant	48.94	21.42	39.82	55.15	15.76	33.93
Percent chironomids (midges)	12	26	10	6	23	19
Percent Glossosomatidae	1	0	0	0	0	8

The average number of EPT taxa in the lower Boise was less than half the average number at four least-impacted, similar-sized rivers in Idaho. The number of EPT taxa in the lower Boise ranged from 5 at Caldwell in 1996 to 16 at Diversion in 1997, and the average was about 10 (fig. 30). The average number of EPT taxa from four least-impacted sites (the St. Joe River at Calder, the Big Lost River near Chilly, the South Fork Payette River at Lowman, and Johnson Creek at Yellow Pine) was 27 (Maret and others, 2001). Plecoptera (stonefly) taxa in the lower Boise were underrepresented; they were scarce at Diversion, Glenwood, and Middleton and absent at Caldwell and Parma, except for one taxa found at Caldwell in 1998. Stoneflies are mostly predators and are intolerant to fine sediment and scouring discharge (Wisseman, 1996). Ephemeroptera taxa were well represented at the five biological sites and were the most dominant of the EPT taxa at Parma.

The RMI scores for the lower Boise ranged from 9 to 17; most of the scores indicated poor water quality and impaired biotic integrity (fig. 31). The RMI score for an upstream site on the Boise River, Twin Springs above Arrowrock Reservoir, which has been affected by logging, was 17 (Maret and others, 2001). In contrast, RMI scores higher than 20 were deter-

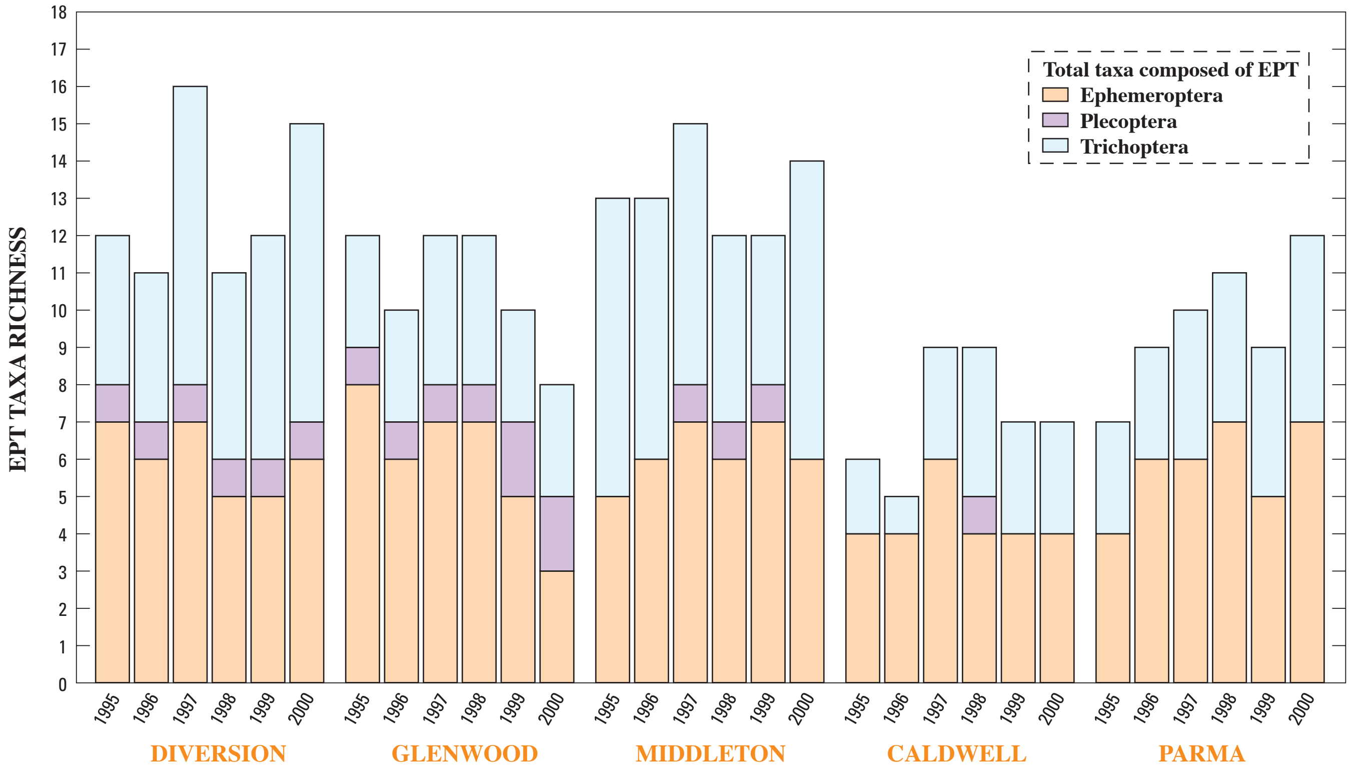


Figure 30. Ephemeroptera, Plecoptera, and Trichoptera taxa at selected biological sampling sites on the lower Boise River, Idaho, 1995–2000.

mined for similar-sized, least-impacted rivers in Idaho such as the Selway, the Middle Fork Salmon, and the South Fork Salmon Rivers (Grafe, 2002).

The RMI did not clearly distinguish water-quality gradients among lower Boise sites. Some of the metrics used to calculate the RMI could not distinguish between changes in water and habitat quality. Macroinvertebrate abundance and taxa richness were similar at all sites. Even though riffle habitat in the lower reaches was lacking, percent Elmidae (riffle beetles) and number of EPT taxa were higher than expected. The percent dominant taxon metric did not distinguish between the upstream and downstream sites because all sites were dominated by three macroinvertebrates: the net-spinning caddisfly, Hydropsychidae, collected at all sites; the relatively tolerant mayfly, *Baetis tricaudatus*, collected in the upper reaches; and the sediment-tolerant mayfly, *T. minutus*, collected in the lower reaches (table 10).

Because traditional metrics such as total aquatic macroinvertebrate densities, total taxa, EPT taxa, and general indices such as the RMI were not able to distinguish water-quality differences among lower Boise sites, additional metrics and indices were evaluated. A fine-sediment index was used to evaluate the effect of fine sediment on insect populations; additional metrics of percent functional feeding groups were used to evaluate food source and habitat quality, and the percent tolerant taxa metric was used to evaluate the effects of multiple water-quality impacts. Relyea and others (2000) developed an index to determine changes in macroinvertebrate populations directly caused by increases in inorganic sediments. The fine-sediment bioassessment index (FSBI) is not a traditional index that uses metrics to calculate a score for a site, but ranks selected macroinvertebrates as to their ability to tolerate fine sediment. The FSBI scores were assigned to macroinvertebrates that are intolerant to fine sediment, moderately intolerant, moderately tolerant, and tolerant. Although the FSBI was developed to evaluate logging impacts in Northwest streams, it did indicate that macroinvertebrates in the lower Boise were impacted by fine sediment.

The range of FSBI scores for lower Boise sites was narrow, but scores for sediment-tolerant taxa (lower FSBI scores) increased slightly in a downstream direction; scores were highest at Diversion and lowest at Caldwell (fig. 32). A comparison of the FSBI score for macroinvertebrates collected in 1997 at Twin Springs, a forested site in the upper Boise River Basin, also is plotted in figure 32. Compared with the score for the Twin Springs site, the lower Boise's lower FSBI scores indicate impacts by fine sediment. The lower scores are likely the result of regulated flows from upstream dams, which do not allow extreme high-discharge events to remove fine sediments from streambed substrates. The low FSBI scores at Diversion also may be attributable to the regulated

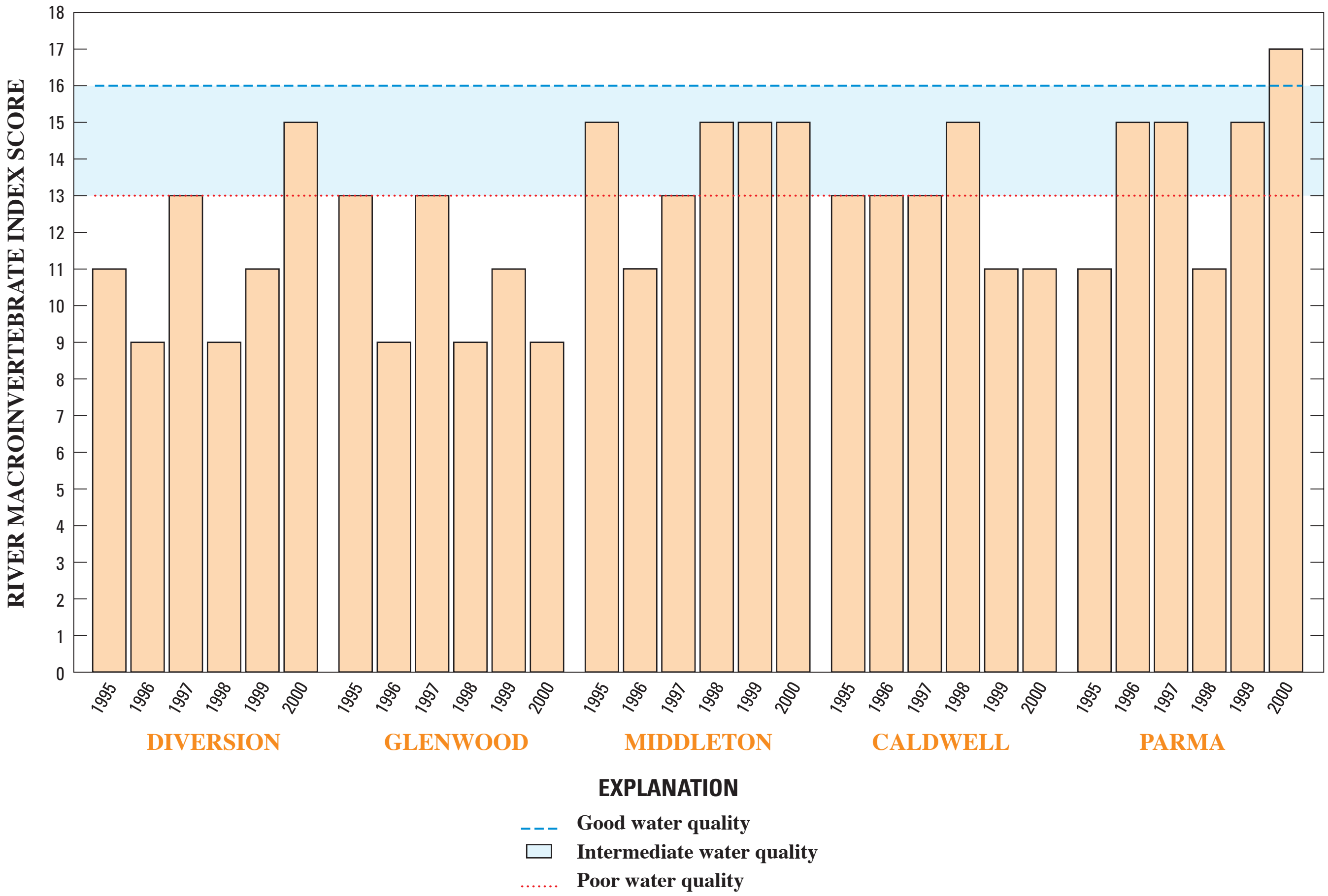


Figure 31. Idaho River Macroinvertebrate Index (RMI) scores at selected biological sampling sites on the lower Boise River, Idaho, 1995–2000. (Water-quality ratings from Grafe, 2002)

dam releases that limit recruitment of upstream gravel, which causes "armoring" of the bottom substrate.

Benthic communities can withstand short-term increases in suspended and benthic sediments and can recover rapidly (Gray and Ward, 1982; Wood and Armitage, 1997). However, continuous high levels of sediment input may completely change the natural faunal assemblage (Newcombe and MacDonald, 1991; Wood and Armitage, 1997). The highest median concentration of suspended sediment and one of the lowest FSBI scores among the main-stem sites were measured at Parma (figs. 9 and 32). The lowest FSBI score was measured at Caldwell, downstream from tributary inputs.

Some taxa affected by fine sediment were not included or emphasized in the FSBI. Chironomid taxa (midges) were not included in the FSBI owing to the substantial cost of their identification (Relyea and others, 2000). Midges are burrowers and utilize fine sediments for their habitat; thus, their populations can be expected to increase with increased fine sediment deposition. The percentage composition of midges in the lower Boise increased in a downstream direction depending on the year sampled, from 2 percent at Diversion to 47 percent at Caldwell, and would have been a helpful addition to the FSBI (table 10). Sediment-intolerant macroinvertebrates such as *Arctopsyche grandis*, *Brachycentrus*, *Glossosoma*, *Neothremma* (caddisflies), *Pteronarcys californica*, *Hesperoperla pacifica*, and *Cultus* (stoneflies) (McClelland, 1972) rarely were found in the lower Boise or were categorized in the FSBI as moderately tolerant (Relyea and others, 2000).

Recategorizing these insects may have helped distinguish the effects of fine sediment among sites on the lower Boise. For example, Glossosomatidae, a caddisfly that is very intolerant of fine sediment (Wisseman, 1996), was categorized as moderately intolerant in the index and made up a very small percent of the population in the lower reaches (table 10). Recategorization of this family could have helped distinguish the least sediment-impacted sites.

Macroinvertebrates commonly are categorized as to their predominant functional feeding groups, which can be good indicators of species adaptation to different levels of water and habitat quality. These feeding groups may consist of collectors (gatherers, filterers, and scrapers), predators, and parasites.

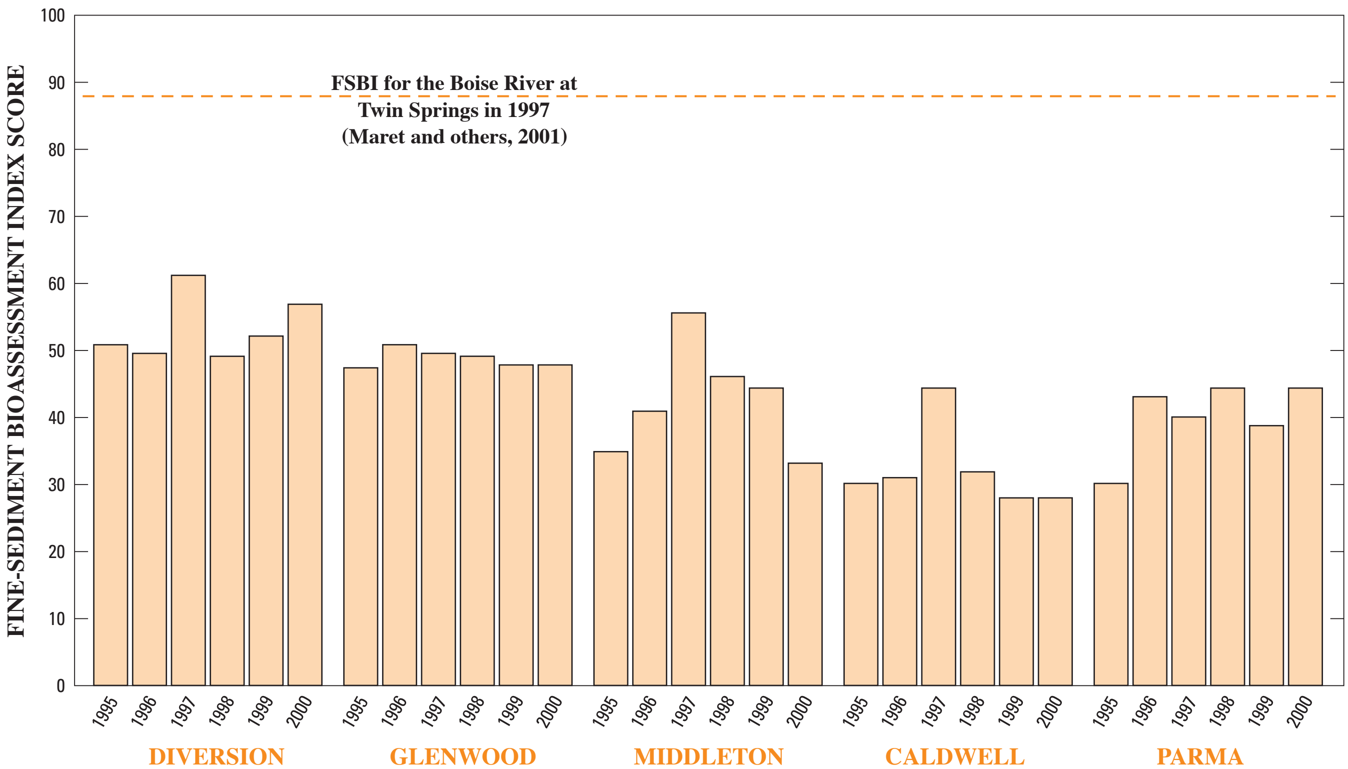


Figure 32. Fine-sediment bioassessment index (FSBI) scores at selected biological sampling sites on the lower Boise River, Idaho, 1995–2000.

Collectors of the gatherer variety significantly ($p < 0.001$) increased in the lower Boise from Glenwood to Parma (fig. 33). This is consistent with the river continuum concept presented by Vannote and others (1980) in which collectors dominate larger rivers. However, collector/gatherers that dominate areas impacted by excessive fine material are considered to be "weed" type macroinvertebrates and are indicators of poor water quality (Wisseman, 1996). The river continuum concept also illustrates that fine particulate organic matter increases naturally with increasing stream size; therefore, the number of collector/filterers should increase concurrently in a downstream direction. This was not the case for the lower Boise; collector/filterers significantly ($p < 0.001$) decreased in a downstream direction (fig. 33). The river continuum concept also indicates that human disturbance tends to change the natural biological patterns in a longitudinal aspect (Vannote and others, 1980; Waters, 1995; Wood and Armitage, 1997; Relyea and others, 2000).

In the lower Boise, the decrease in filterers from Glenwood (median of about 70 percent) to Parma (median of about 30 percent) was probably due to increased sediment and discharge. Scrapers feed on periphyton and, thus, are sensitive to fine sediment (Relyea and others, 2000; Mebane, 2001); they generally decrease in abundance with increased sedimentation. Percent scrapers in the lower Boise were lowest at Middleton even though Chla concentrations were high (fig. 24), but embeddedness was frequently at or above 50 percent (table 8). The percent composition of scrapers in the lower Boise was low overall, ranging from less than 1 to nearly 15 percent; the largest percentage was collected at Parma (fig. 33).

Although the Parma site contained minimal riffle habitat and no large, woody debris, ranges of Chla concentration were similar to those at Glenwood (table 6), and abundant macrophytes in the riffle sampled provide an adequate food base for scrapers. Predators, which include stoneflies, were the least abundant (less than 7 percent) feeding group; the median percent was highest at Glenwood (fig. 33). Parasites were most abundant at Middleton, although abundance was fewer than 6 percent. Some species, such as Baetid mayflies, can alternate their feeding habits between collector/gatherer and scrapers as food source availability varies (Merritt and Cummins, 1984; Relyea and others, 2000). *Baetis tricaudatus* was fairly abundant in the upper reaches of the lower Boise; percent abundance was lowest at Caldwell, where lack of habitat may have been a limiting factor (table 10).

Tolerant taxa in the lower Boise is another indicator of environmental disturbance because these taxa have adapted to frequent disturbances such as extreme fluctuations in discharge and increased sediment, are opportunistic feeders, and do not need a specific habitat to survive. Tolerant taxa in the lower Boise, mainly downstream from Middleton, include

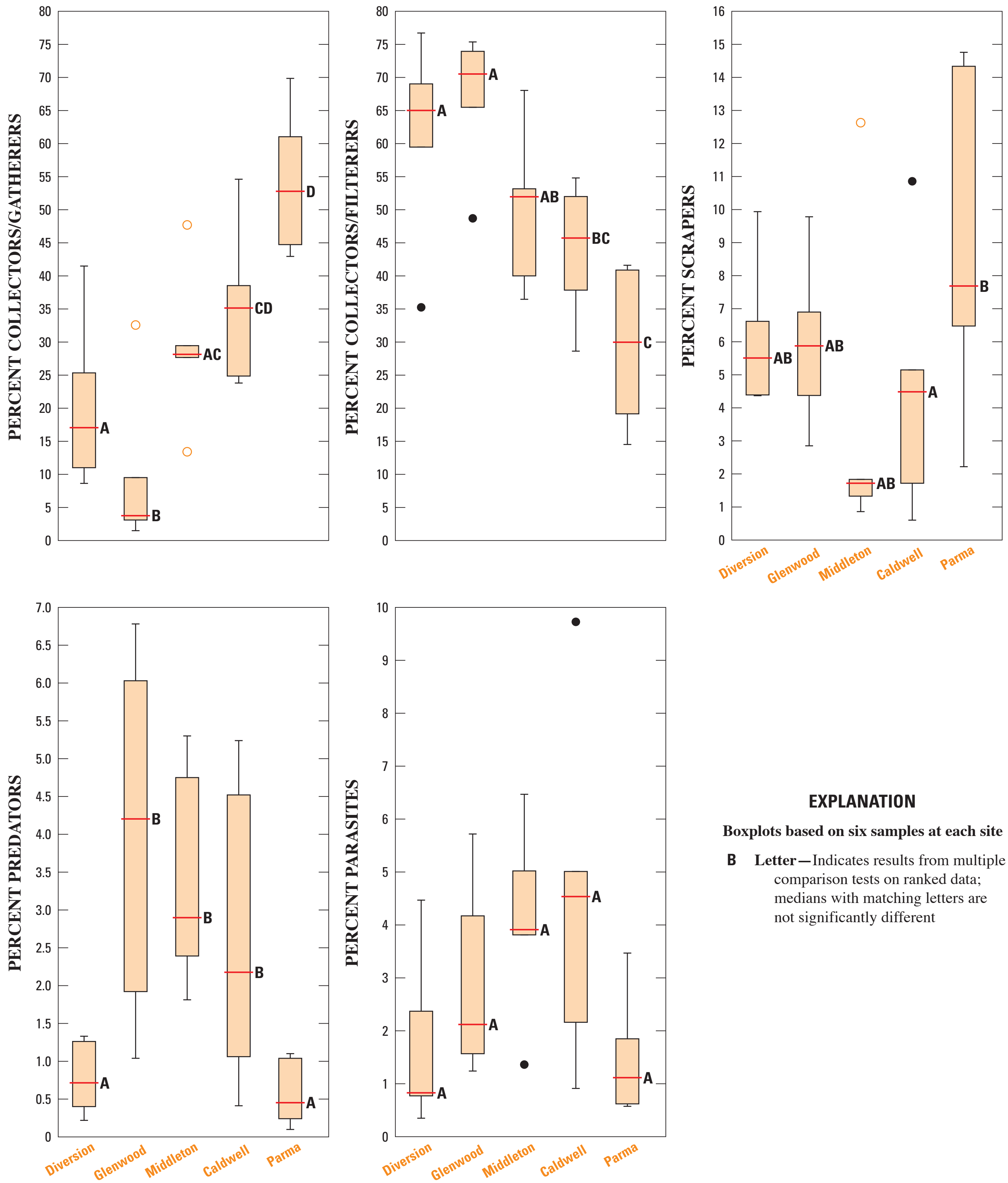


Figure 33. Percent macroinvertebrate functional feeding groups at selected biological sampling sites on the lower Boise River, Idaho, 1995–2000.

mollusks such as *Ferissia*, the invasive *Potamopyrgus antipodarum* (New Zealand mud snail), and the introduced *Radix auricularia*; tolerant crustacea such as *Hyalella azteca*; and tolerant mayflies such as *T. minutus* (Merritt and Cummins, 1984; Wisseman, 1996; Frest and Johannes, 2001) (fig. 34). *T. minutus* prefers fine sediment as opposed to coarser substrates and has been associated with habitats where silt accumulates (Ward and Kondratieff, 1992; Relyea and others, 2000). *T. minutus* in the lower Boise was highly correlated with average concentrations of suspended sediment, total nitrogen, and total phosphorus (Spearman correlations 0.80, 0.85, and 0.76, respectively, n=20, and critical value of 0.45), and has been found in rivers throughout Idaho that are impacted by agriculture (Maret and others, 2001). The high abundance of this mayfly at the downstream sites in the lower Boise indicates that siltation may be a problem.

Synergistic effects of pollutants in the lower Boise may exceed the tolerance levels of many taxa that could survive if exposed only to a single pollutant. Some taxa, such as Plecoptera, may be eliminated from a stream insect community through direct or indirect effects of sedimentation, but a combination of nutrient enrichment, flow alteration, and habitat loss can eliminate an entire community (Lemly, 1982).

Fish Communities

The IDFG annually stocks a variety of fish in the lower Boise. An average of 58,000 catchable-sized rainbow trout were stocked in the lower Boise annually between 1994 and 2001 (Fred Partridge, Idaho Department of Fish and Game, written commun., 2002). In addition to rainbow trout, about 55,000 young-of-the-year brown trout (*Salmo trutta*) were released in the lower Boise in April 1994 and 1995; in June and July 1996 and 1997, about 63,000 were released. Brown trout population has been found to be self-sustaining and has not been stocked since April 1998, when only about 5,000 were stocked (Dale Allen, Idaho Department of Fish and Game, oral commun., 1998). During the period of this study, spring/summer chinook salmon also were stocked in July 1997, an average of 575 steelhead were stocked per year from 1995 to 2001, and 30 one-pound white sturgeon (*Acipenser transmontanus*) were stocked in the pool downstream from Lucky Peak Dam in 1994.

The fish species and abundance data collected at five biological sampling sites in the lower Boise (fig. 1) are given in table 11. A list of all fish species collected in the lower Boise from this and other USGS studies can be accessed on the USGS Website *http://idaho.usgs.gov/projects/fish/index.html*

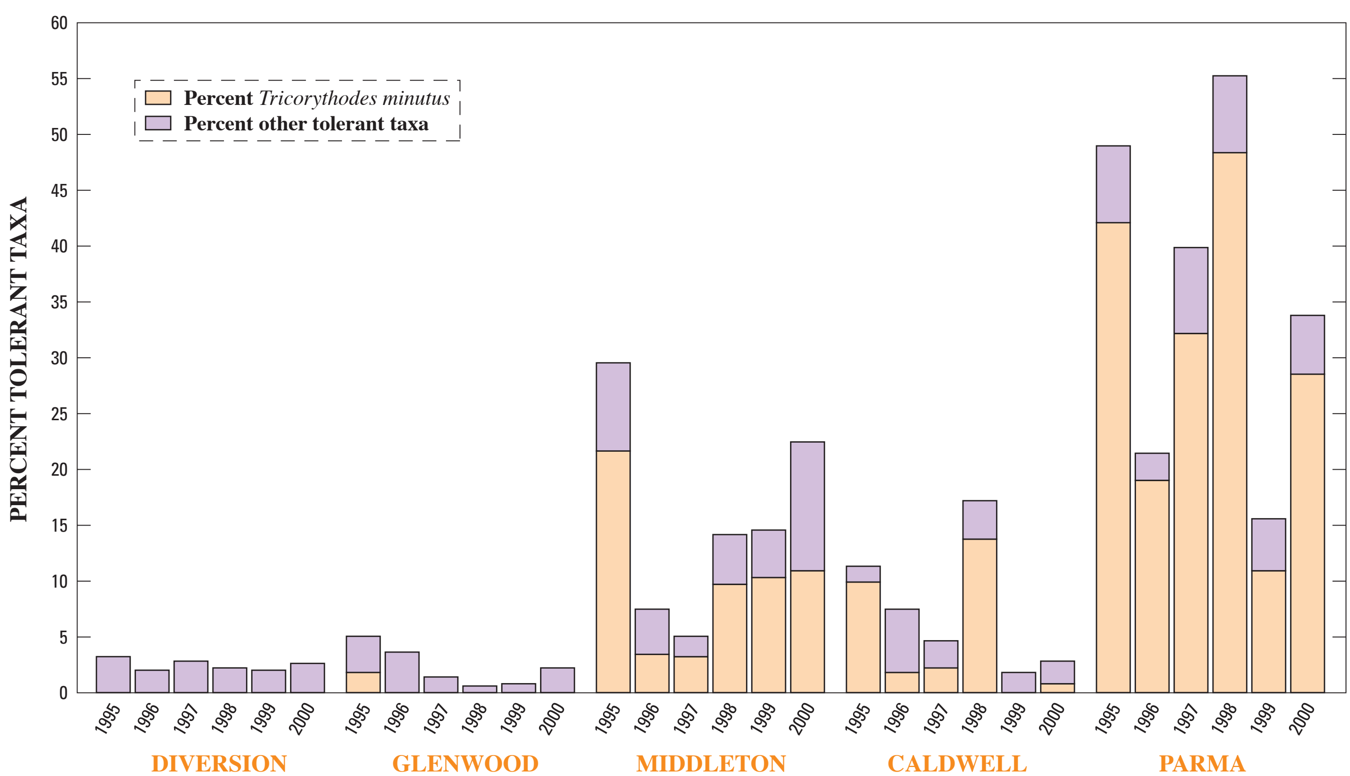


Figure 34. Percent tolerant macroinvertebrate taxa at selected biological sampling sites on the lower Boise River, Idaho, 1995–2000.

Table 11. Fish species and abundance at selected sites on the lower Boise River, Idaho, 1995–2001

[Blank columns, not collected; species characteristics from Zaroban and others, 1999; Origin: I, introduced; N, native. Tolerance: T, tolerant; I, intolerant; S, sensitive; Temp. pref., temperature preference]

Family/species	Common name	Origin	Tolerance	Adult habitat guild	Temp. pref.	Adult trophic guild	Loggers Creek	Glenwood	Glenwood	Glenwood	Middleton	Middleton	Caldwell	Parma	Parma
							Dec. 1997	Mar. 1995	Dec. 1996	Sept. 2001	Dec. 1996	Aug. 1997	Aug. 1997	Dec. 1996	Aug. 1997
Salmonidae															
Salmo trutta	Brown trout	I	I	Hider	Cold	Invertivore/ Piscivore	3	1	2	4					
Prosopium williamsoni	Mountain whitefish	N	I	Benthic	Cold	Invertivore	94	93	68	251	110	19	5	10	4
Onchorhynchus mykiss	Wild rainbow trout	N	S	Hider	Cold	Invertivore/ Piscivore	17	5	2	5	1				
Cottidae															
Cottus bairdi	Mottled sculpin	N	I	Benthic	Cold	Invertivore	65		2	24					
Cottus confusus	Shorthead sculpin	N	S	Benthic	Cold	Invertivore	53		3	5					
Catostomidae															
Catostomus columbianus	Bridgelip sucker	N	T	Benthic	Cool	Herbivore		36	30	18	12	99	18	59	69
Catostomus macrocheilus	Largescale sucker	N	T	Benthic	Cool	Omnivore		166	85	37	76	120	34	33	74
Catostomus platyrhynchus	Mountain sucker	N	I	Benthic	Cool	Herbivore		2	2	2	8				
Cyprinidae															
Cyprinus carpio	Common carp	I	T	Benthic	Warm	Omnivore					34	3	5	3	7
Acrocheilus alutaceus	Chiselmouth	N	I	Benthic	Cool	Herbivore	1		1		2	370	20		14
Ptychocheilus oregonensis	Northern pikeminnow	N	T	Water column	Cool	Invertivore/ Piscivore			2			86			13
Richardsonius balteatus	Redside shinner	N	I	Water column	Cool	Invertivore		3	16			66	120		1
Rhinichthys cataractae	Longnose dace	N	I	Benthic	Cool	Invertivore		20	26	19	33	145		13	
Rhinichthys osculus umatilla	Umatilla dace	N	I	Benthic	Cool	Invertivore	3	60	7	5	150	61		1	
Gila bicolor	Tui chub	N	T	Water column	Warm	Omnivore									24
Centrarchidae															
Lepomis macrochirus	Bluegill	I	T	Water column	Warm	Invertivore/ Piscivore						1			
Micropterus salmoides	Largemouth bass	I	T	Water column	Warm	Piscivore				3	1	9		3	2
Micropterus dolomieui	Smallmouth bass	I	I	Water column	Cool	Piscivore						1			9
Ictaluridae															
Ictalurus punctatus	Channel catfish	I	T	Benthic	Warm	Invertivore/ Piscivore							1		4

Fish Sampling Sites

Project fish-sampling sites represented only part of the lower Boise fish habitat. The lower Boise site near the mouth of Loggers Creek was the upstream-most fish sampling site for this study. The site is characterized by one long, shallow run with riffles on the upstream and downstream ends of the run. The Logger Creek site was chosen to coordinate sampling with IDFG. The absence of deep-run and pool habitat resulted in a sample that was biased toward species associated with riffle/run habitats, such as brown and rainbow trout, mountain whitefish, and sculpins; the sample lacked species associated with pools, such as suckers. Fish sampling at Middleton was conducted mainly in shallow riffles and runs, whereas the Caldwell site included deep pools and runs and contained little riffle habitat. The lower Boise at the mouth, downstream from the Parma water-quality site, was subject to high water velocities and consisted of deep- and shallow-run habitat, which made netting fish difficult. As such, sample collection was limited to channel margins in low-velocity areas.

Idaho River Fish Index

The Idaho River Fish Index (RFI) was used to evaluate fish communities sampled in the lower Boise. The RFI was developed using data collected from numerous sites and studies throughout the Northwest (Mebane, 2002). Ten metrics were evaluated for the RFI using comparisons between test sites and reference sites. The metrics tested and chosen to be used in the RFI were number of coldwater native species, percent sculpin (Cottids), percent coldwater species, percent sensitive native individuals, percent tolerant individuals, number of nonindigenous species, number of coldwater fish captured per minute of electrofishing, percent of fish with DELT (deformities, eroded fins, lesions, or tumors) anomalies, number of trout age classes, and percent carp (*Cyprinus carpio*). The index uses percent sculpin when sculpin age classes are not available. These 10 metrics were standardized by scoring them continuously from 0 to 1 and were weighted as necessary to produce an RFI score ranging from 0 to 100.

According to Mebane and others (2003), sites with scores between 75 and 100 exhibit high biotic integrity with minimal disturbance and possess an abundant and diverse assemblage of native coldwater species; sites with scores between 50 and 74 are somewhat lower quality where alien species occur more frequently and the assemblage is dominated by coldwater, native species; and sites with scores less than 50 have poor biotic integrity where coldwater and sensitive species are rare or absent and where tolerant fish predominate.

Fish were sampled intermittently in the lower Boise; thus, the fish community response to water-quality gradients over time could not be evaluated completely. Sculpin age classes were not recorded for the lower Boise samples; therefore, the percent sculpin metric was used. The RFI scores and two of the metric scores (percent sculpin and percent coldwater species) calculated for lower Boise sites are shown in figure 35.

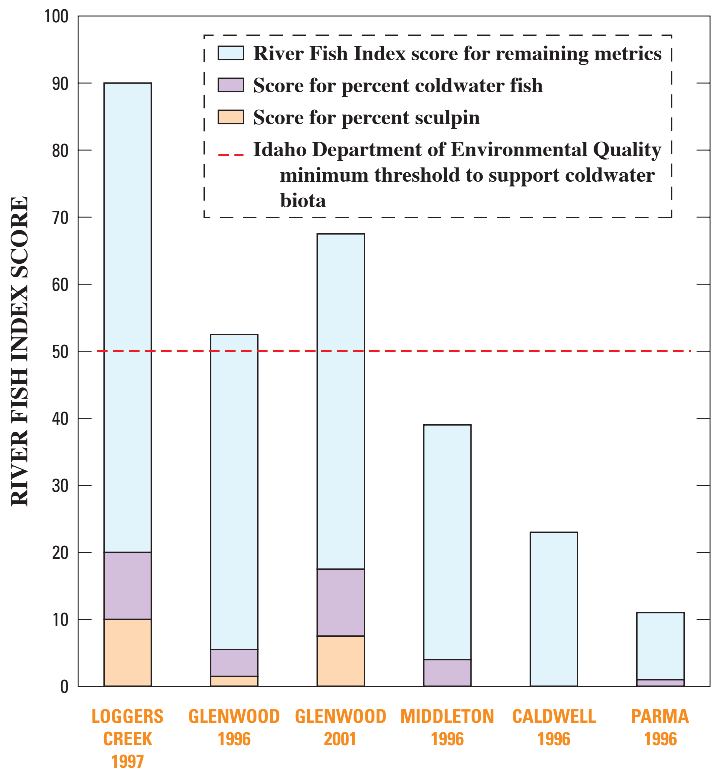


Figure 35. Idaho River Fish Index (RFI) scores at selected biological sampling sites on the lower Boise River, Idaho, 1996–2001.

The RFI scores in the lower Boise downstream from Glenwood indicated poor biotic integrity in which coldwater and sensitive species were rare or absent. RFI scores for sites from Middleton to downstream from Parma were considerably below the minimum threshold for protection of coldwater aquatic life. No sculpin and minimal coldwater species were found at sites downstream from Glenwood. Sculpins are sensitive to metals (Maret and MacCoy, 2002; Woodling and others, 2002) and other pollutants (Zaroban and others, 1999), but it is not known why sculpin were absent from these sections of the lower Boise.

Fish populations are affected by many factors, including habitat, food availability, temperature, dissolved oxygen, and pollutants. Sublethal effects on fish may include the loss of visual capability (leading to reduced feeding and depressed growth rate), reduced tolerance to disease, and decreased food base (Waters, 1995). Water temperature is considered the most important variable that directly affects fish behavior (Sauter and others, 2001). It also influences the aquatic insect community on which salmonids rely for much of their food source (Materna, 2001). Summer water temperatures in the lower Boise were above the coldwater aquatic life daily average temperature standard of 19°C at many locations (fig. 6). According to Hynes (1970), fish may be able to withstand changes in temperature, but they do need acclimation time to adjust. The temperature changes in the lower Boise appear to be controlled by seasonal water releases from the dam, irrigation return flows, and ground-water seepage; at times, there may be little or no acclimation period for different life stages of fish to adapt to temperature changes. With the minimal fish data collected for this study, it was difficult to determine the specific effects of poor water quality and habitat loss on the fish community.

SUMMARY AND CONCLUSIONS

Multiple stressors have and continue to impact the water quality and biological integrity of the lower Boise River downstream from Lucky Peak Lake to the river's mouth near Parma. Some of these factors are agricultural land and water use, wastewater treatment facility discharge, urban runoff, reservoir operations, and river channel alteration. The reaches upstream from Middleton are affected primarily by urban impacts and flow alterations, whereas downstream reaches are affected primarily by irrigation return flow. Water quality at sites downstream from Diversion Dam is affected by elevated nutrient, suspended sediment, and bacteria concentrations. Water quality degrades cumulatively in a downstream direction.

Dissolved oxygen and pH did not appear to be water-quality limiting in the lower Boise, but water temperatures exceeded the State water quality standards for native and coldwater aquatic life at Middleton and Parma. The temperatures in the reaches sampled at Middleton, Caldwell, and Parma appeared to limit the distribution of coldwater biota.

Specific conductance increased in a downstream direction throughout the year, but the higher conductivities were measured during the nonirrigation season. The significant increase in specific conductance in a downstream direction could be due to the multiple inputs from agricultural land use, wastewater treatment facilities, ground water containing dissolved constituents, or lack of dilution of suspended material during low discharge.

No significant temporal trend in suspended sediment concentration at the river sites was apparent over the 8-year study. Suspended sediment load was generally largest during the irrigation season; the largest loads were from the tributaries Indian Creek, Mason Creek, and Dixie Drain. High suspended sediment concentrations appeared to be affecting algae, macroinvertebrate populations, and fish habitat in the lower Boise.

The highest concentrations of total nitrogen, total phosphorus, suspended sediment, and bacteria in the lower Boise were measured downstream from Middleton and appeared to be associated with tributary inputs. The concentrations of nitrogen and phosphorus were mainly in the dissolved form in both the tributaries and river; the percentage of dissolved constituents increased during the nonirrigation season, likely from ground-water seepage. The nitrogen and phosphorus ratios indicated that the river was potentially nitrogen limited at Glenwood and Parma; however, nutrients were not lacking in the river because chlorophyll-*a* concentrations indicated that nutrients were adequate to sustain an abundant periphyton population, habitat permitting. No significant trends for nitrogen or phosphorus concentrations were apparent at any of the lower Boise sites, although nutrient concentrations were generally higher during the irrigation season. The loads of nitrogen and phosphorus were also generally larger during the irrigation season. At Parma, however, total phosphorus loads were similar during both the irrigation and nonirrigation seasons. Mason Creek contributed the largest loads of total nitrogen and phosphorus to Parma during the irrigation season, and Indian Creek contributed the largest loads during the nonirrigation season.

Bacteria concentrations exceeded primary contact recreation criteria at Glenwood, Middleton, and Parma and exceeded secondary contact criteria at all tributaries. No significant trend in fecal coliform bacteria concentrations was apparent in the lower Boise over this 8-year study. However, flow-adjusted fecal coliform concentrations were higher during the irrigation season than during the nonirrigation season and peaked during high discharge.

Biological communities were depressed in the lower Boise and more tolerant species inhabited the lower reaches. Ephemeroptera, Plecoptera, and Trichoptera taxa in the river were less than half those in least-impacted rivers in Idaho; few or no stoneflies were found at sites downstream from Glenwood. The Idaho River Macroinvertebrate Index indicated that water quality of the entire lower Boise was poor, but this index was not able to identify potential habitat impairment and water-quality gradients among sites. The inclusion of other site-specific metrics, such as percent tolerant or invasive macroinvertebrate species, might improve the power of the index. The fine-sediment bioassessment index indicated that the macroinvertebrate population was affected by sediment at Middleton, Caldwell, and Parma. This index may help to evaluate future sediment impact on lower Boise macroinvertebrates and help to determine benefits from implementation of sediment-reducing best management practices in the lower Boise Basin. Percentages of tolerant macroinvertebrates were highest at Middleton, Caldwell, and Parma, and the largest number of tolerant species, dominated by the mayfly, *Tricorythodes minutus*, were collected at Parma. The Idaho River Fish Index indicated that biotic integrity downstream from Glenwood was poor; few coldwater species and no sculpin (cottids) were found.

Implementation plans are currently being developed to meet the water-quality goals of the lower Boise main-stem and tributary Total Maximum Daily Loads. The biological data collected in the lower Boise demonstrated that several stressors, including poor water quality and habitat loss, were adversely affecting aquatic communities. Further water-quality and biological monitoring is needed to determine whether reduction in pollutant loads through Total Maximum Daily Load implementation will improve the water quality and biological integrity of the lower Boise.

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Appendix. Reconnaissance of Ground- and Surface-Water Interactions

Introduction

The lower Boise River is a dynamic system; water is diverted from and discharged to the river at multiple points throughout its 64-mi reach from Diversion Dam to the mouth. To identify potential inputs of nutrients and bacteria from ground water, the USGS placed miniature wells, or piezometers, in the river at several locations. These instruments were put in place in March and August 2001, and measurements of dissolved oxygen, pH, specific conductance, and temperature were collected. Water samples also were collected for nutrients and bacteria analyses. The purpose of this study was to identify the potential for seepage of nutrients from ground water to the lower Boise. This was a reconnaissance effort and was not designed to determine nutrient loads from ground water along the whole segment of river.

Study Design and Sample Collection Methods

The reconnaissance of ground- and surface-water interactions consisted of measuring the differences in hydraulic heads between the surface-water stage and ground-water level at instream piezometers, measuring water-quality constituents in samples collected from instream piezometers and surface water, measuring streamflow, and collecting continuous temperature measurements from the river and riverbed. Hydraulic head measurements and water-quality analyses are listed in table 12.

Eighteen instream piezometers were installed at 11 sites at a maximum of 5.5 ft below the riverbed (fig. 36) and were placed on the right and left banks (as viewed when facing downstream) and center of the river. Piezometers consisted of precleaned, 0.5-in. (inside diameter) galvanized steel pipe. The lower 6 in. of the pipe was perforated and the tip pointed for ease of installation. Piezometers were developed using a portable peristaltic pump; water was withdrawn until water levels inside the piezometer equilibrated and the water removed was clear. Purging and sampling were done according to methods described by Wilde and others (1999). A calibrated manometer was used to measure the difference in hydraulic head between the river and ground water (Winter and others, 1988).

Ground-water flux (when the river gains from and loses to ground water) also was monitored at each site using temperature gradient methods described by Constantz (1998). Self-logging thermistors were installed at different depth intervals in one large-diameter (1.25-in.) piezometer, and one thermistor was placed in the river near the stream bottom to collect both river- and ground-water temperature data.

Results of Ground- and Surface-Water Interactions

Positive hydraulic head differences, which indicate that ground water is seeping into the river, were measured during the nonirrigation season (March) at all sites except two on the right bank—above Hartley Gulch (site 6) and Caldwell (site 7) (fig. 37). Hydraulic head differences increased during March from Diversion Dam (site 1) to the site above Mason Slough (site 5) and decreased during the irrigation season (August) from site 1 to Middleton (site 4). Also during March, hydraulic head differences were consistently higher near the right bank than near the left bank or in the center of the river at most sites.

Hydraulic head differences during March and August varied. The August hydraulic head differences show the influence of irrigation, when ground- and surface-water interaction becomes more complex. Hydraulic head, at times, was positive on one bank and negative on the other, as apparent at site 8 at Notus in August (fig. 37). The largest positive hydraulic head differences (as much as 53 mm, or 2.2 in.) between left and right bank measurements were at Parma (site 9) and below Parma (site 11) in August.

The variability in hydraulic head in the downstream reaches could be the result of ground-water pumping and irrigation application that vary over the season. Continuous temperature measurements from the right-bank piezometer at site 11 in August demonstrated the transition from gaining to losing conditions within an 18-day period (fig. 38) as river stage rose, thus indicating the complexity of ground- and surface-water interaction and the value of further monitoring of temperature for estimating nutrient flux between the river and ground water.

Concentrations of total dissolved nitrogen measured at the left-bank piezometers in March varied little, compared with the left-bank measurements in August (fig. 39). In August, approximately 2.5 mg/L of total dissolved nitrogen was measured at the site 5 left-bank piezometer, whereas the concentration was 0.5 mg/L in March. The dissolved nitrogen concentrations measured at the right-bank piezometers during both March and August were similar, although concentrations at site 8 were higher in March (near 6 mg/L) than in August (near 4.5 mg/L) (fig. 39). The positive hydraulic head differences in both March and August on the right bank at Notus

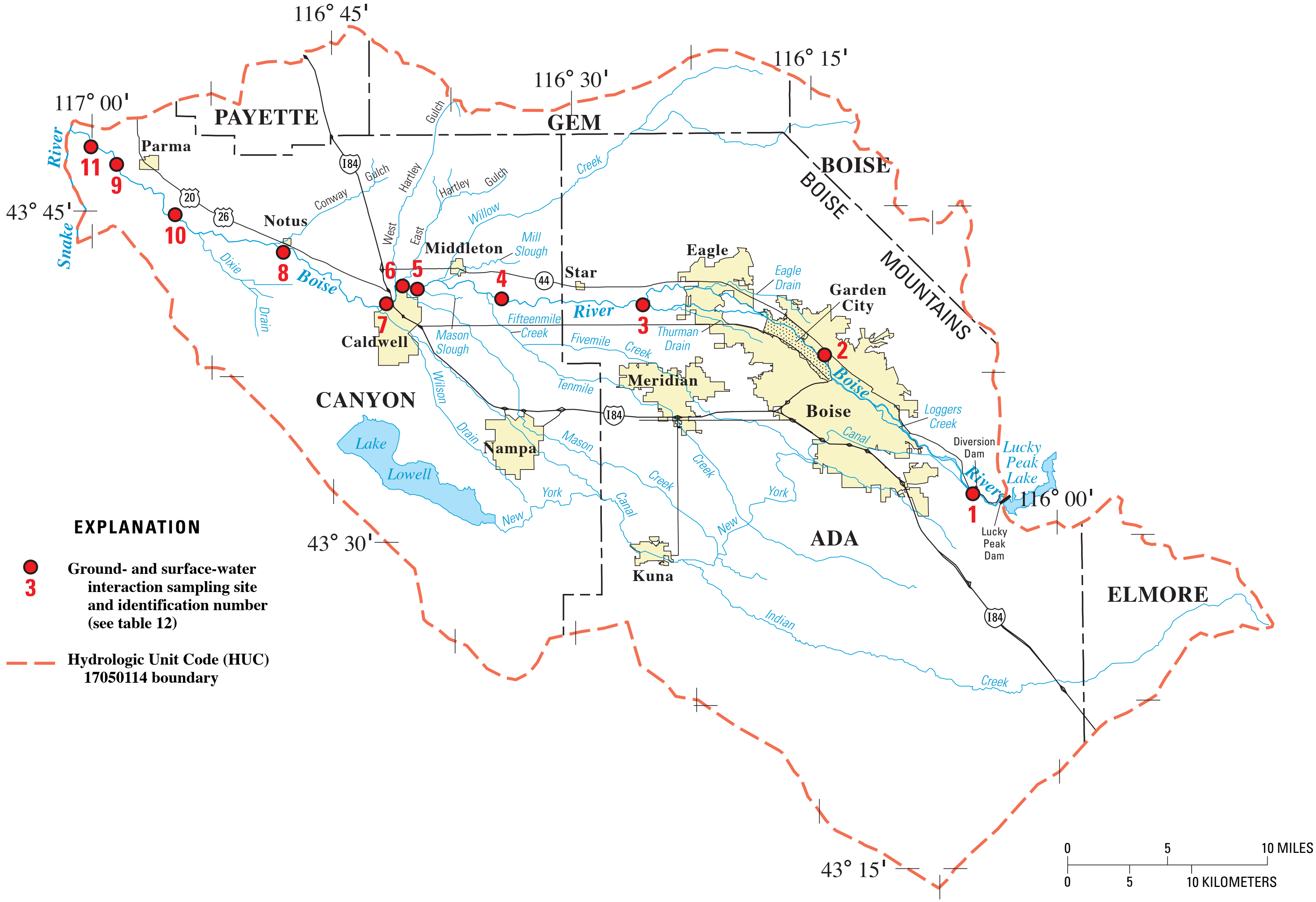

Figure 36. Location of lower Boise River Basin and Ground- and surface-water interaction sampling sites, Idaho, March and August 2001.

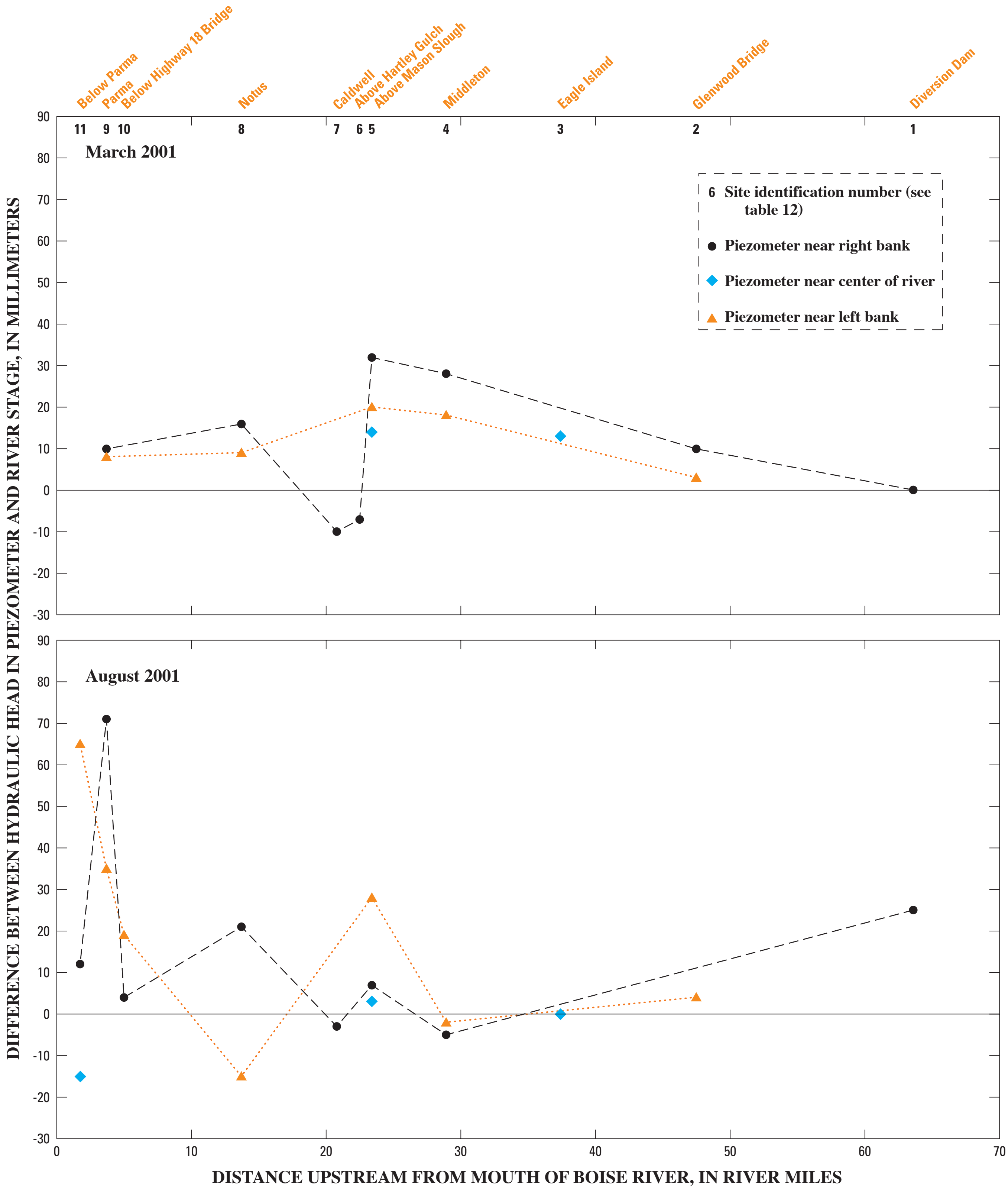

Figure 37. Difference between river stage and ground-water level (hydraulic head difference) at selected sites on the lower Boise River, Idaho, March and August 2001. (Negative values indicate ground-water head lower than surface-water stage, or a losing reach; positive values indicate surface-water stage lower than ground-water head, or a gaining reach; multiply millimeters by 0.03937 to obtain inches; measurement points are connected with lines to distinguish types of measurements and do not signify continuity between points)

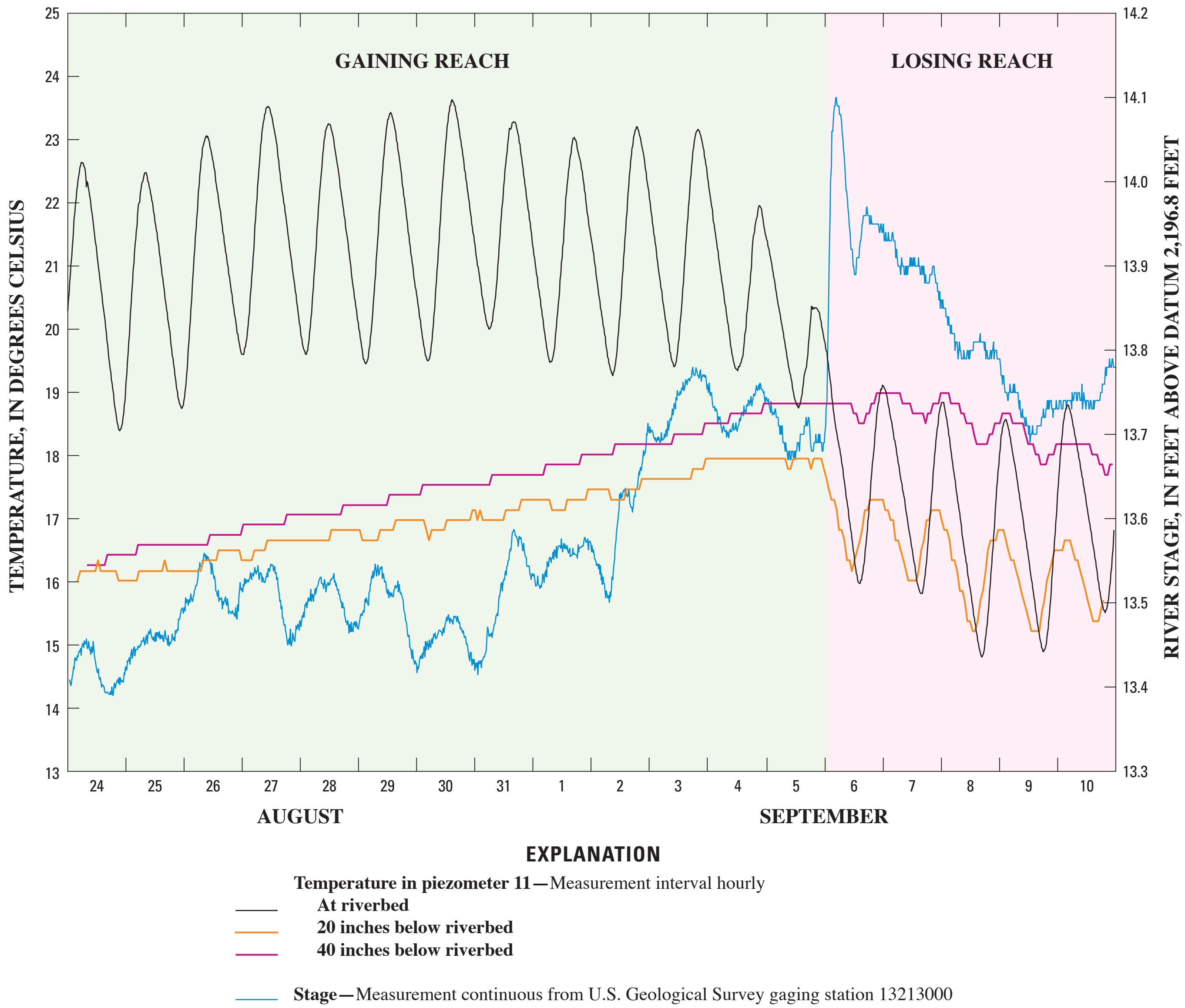

Figure 38. Continuous record of temperature for the surface water and riverbed at piezometer 11 located on the right bank of the river below Parma, and record of stage at the Boise River near Parma, Idaho, gaging station, August 24 through September 10, 2001.

(fig. 37), along with the higher dissolved nitrogen concentration, indicate that nitrogen-rich ground water is entering the lower Boise.

There were only small variations in dissolved phosphorus concentrations in March between the right-bank and left-bank piezometers. Concentrations of total dissolved phosphorus were between the reporting limit of < 0.06 mg/L and 0.38 mg/L; the highest concentration was measured at the mid-channel piezometer above Mason Slough (site 5) (fig. 40). The second-highest dissolved phosphorus concentration of 0.35 mg/L was measured at the right-bank piezometer above Hartley Gulch (site 6). All left-bank concentrations were near or less than 0.1 mg/L.

In August, concentrations of total dissolved phosphorus generally were higher at the left-bank piezometers than at the right-bank piezometers. The right-bank total dissolved phosphorus concentrations were generally less than 0.2 mg/L, except at site 9 (0.32 mg/L). The left-bank total phosphorus concentrations ranged from 0.03 to 1.07 mg/L, the highest concentration measured (fig. 40). Concentrations at piezometers in the center of the river at sites 5 and 11 were 0.35 and 0.38 mg/L, respectively.

Total nitrogen and total phosphorus loads were calculated using discharge and concentration measurements in the river at Parma (site 9) and below Parma (site 11) on August 30, 2001 (table 12). Nutrient loads were calculated to determine potential contributions from ground water within the approxi-

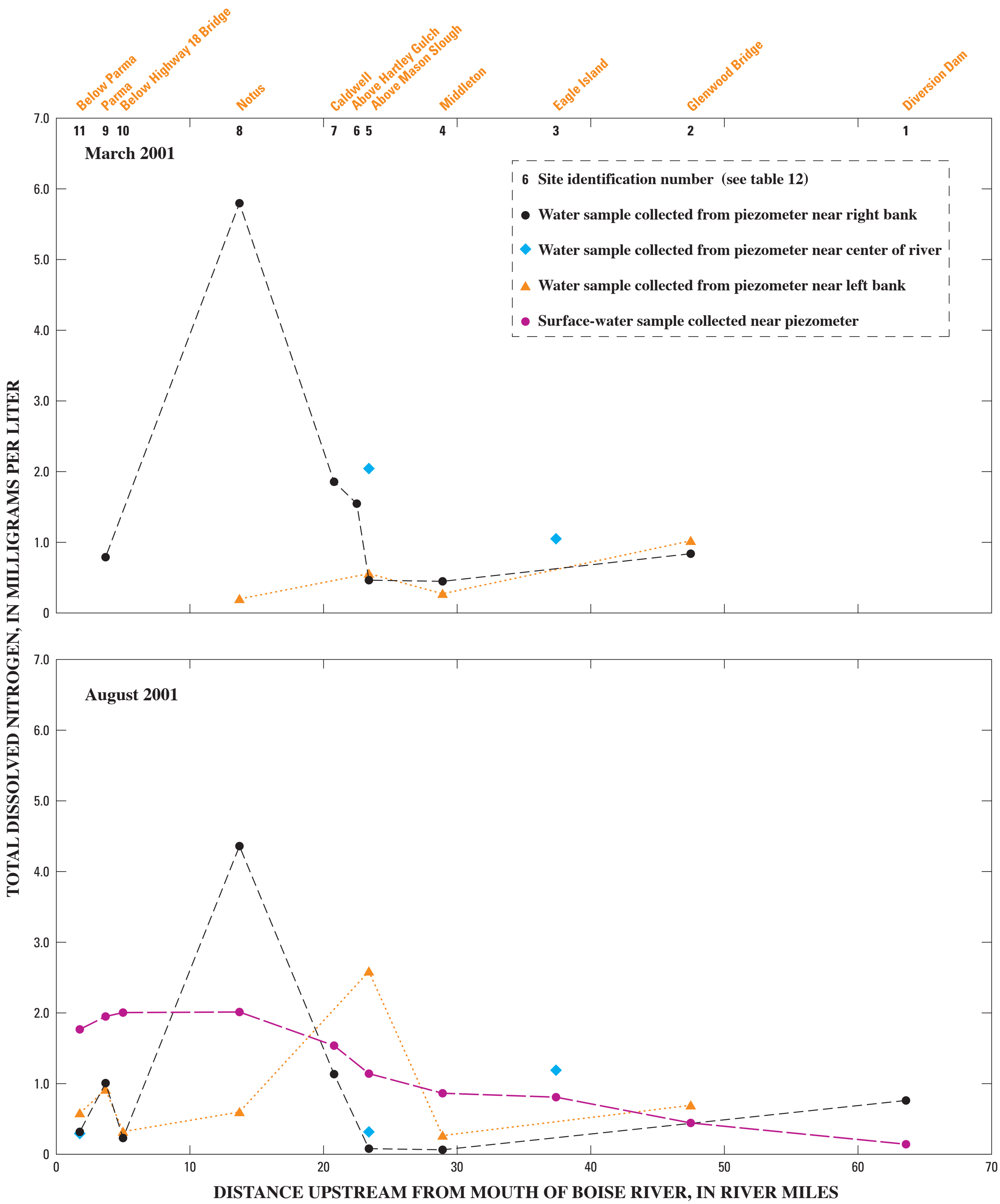

Figure 39. Dissolved nitrogen concentrations in ground- and surface-water samples at selected sites on the lower Boise River, Idaho, March and August 2001. (Measurement points are connected with lines to distinguish types of measurements and do not signify continuity between points.

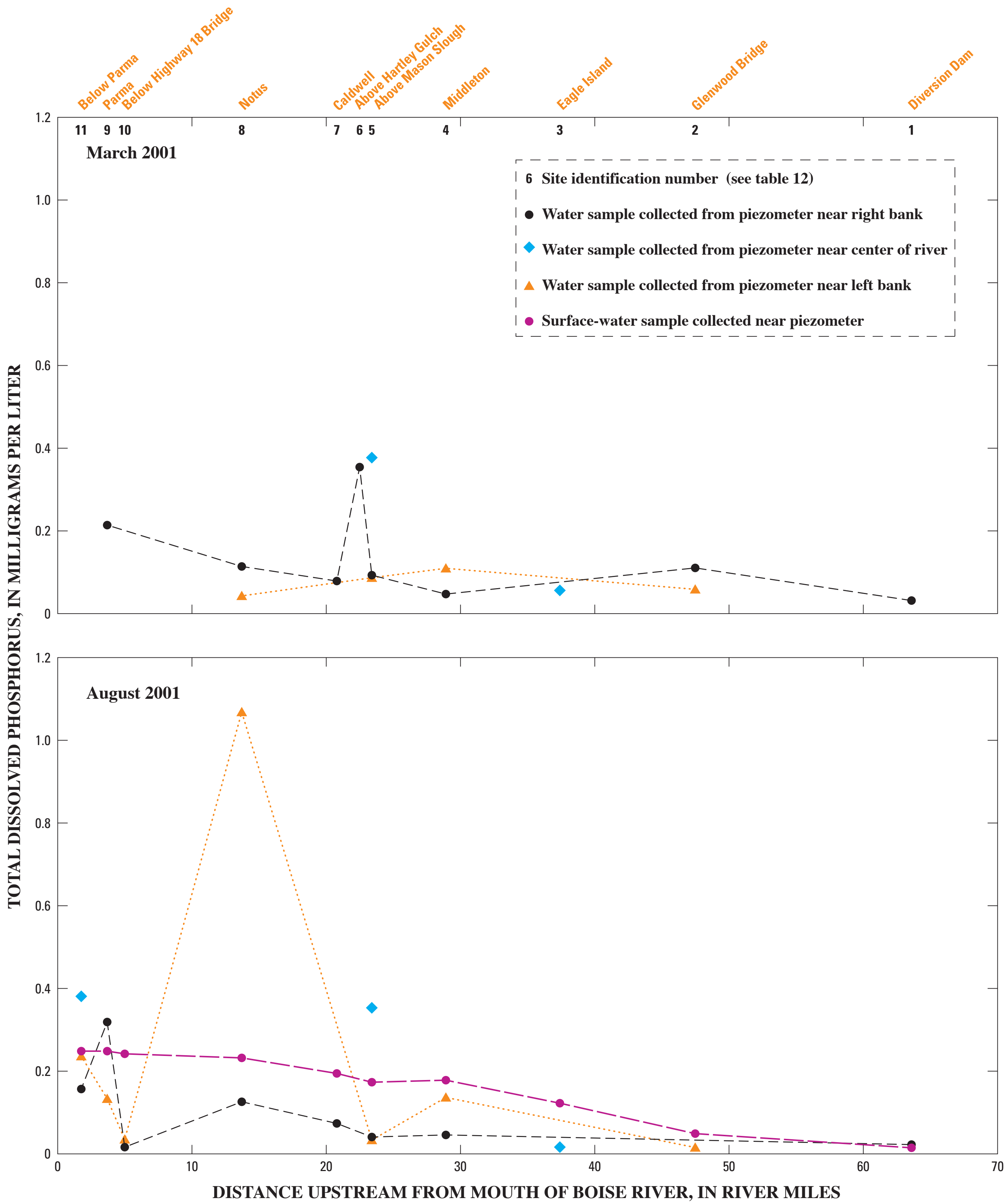

Figure 40. Dissolved phosphorus concentrations in ground- and surface-water samples at selected sites on the lower Boise River, Idaho, March and August 2001.

Table 12. Ground-water and surface-water quality data and head differences at selected sampling sites on the lower Boise River, Idaho, March and August 2001

[Water-quality properties and constituents sampled near piezometers were grab samples; XS, equal width- and depth-integrated sample taken in a cross section of the river; RB, right bank; LB, left bank; MID, middle of the river; USGS, U.S. Geological Survey; ID, identification; mm, millimeters; multiply millimeters by 0.03937 to obtain inches; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; MPN, most probable number; mL, milliliters; dissolved nutrient data in March are from whole-water samples, and in August, from filtered samples; dissolved nitrogen in ground water and river "grab" samples is the sum of filtered nitrogen ammonia plus organic nitrogen and nitrite plus nitrate; total nitrogen in surface water is the sum of unfiltered nitrogen ammonia plus organic nitrogen and nitrite plus nitrate; ND, not detected; ---, no data collected]

						Specific conductance (µS/cm)		pH		Dissolved oxygen (mg/L)		Temperature, in degrees Celsius		Total dissolved nitrogen (mg/L)		Total nitrogen (mg/L)	Total dissolved phosphorus (mg/L)		Total phosphorus (mg/L)	*E. Coli* (MPN/100 mL)	
Station name	Sample location	USGS site ID No.	Date	Hydraulic head [1] (mm)	River discharge (ft^3/s)	Ground water	Boise River	Ground water	Boise River	Ground water	Boise River	Ground water	Boise River	Ground water	Boise River	Boise River	Ground water	Boise River	Boise River	Ground water	Boise River
Diversion Dam, river mile 63.6																					
Boise River near piezometer 1	RB	433224116054300	3/19				97		---		---		5.9		---			---			---
Piezometer 1	RB	433224116054301	3/19	0		139		---		---		6.5		---			---			---	
Boise River near piezometer 1	RB	433224116054300	8/23				80		7.5		7.7		17.3		0.14			ND			3
Piezometer 1	RB	433224116054301	8/23	25		142		6.7		7.0		15.7		0.75			ND			---	
Glenwood Bridge, river mile 47.5																					
Boise River near Piezometer 2	RB	433937116163900	3/23				157		8.6		15.3		9.4		---			---			---
Piezometer 2	RB	433937116163901	3/23	10		237		6.7		4.1		10.3		0.83			0.11			---	
Boise River near Piezometer 2	LB	433937116164000	3/23				148		8.5		14.0		9.0		---			---			---
Piezometer 2	LB	433937116164001	3/23	3		264		6.6		0.7		12.1		1.02			0.06			---	
Boise River near piezometer 2	LB	433937116164000	8/27				102		8.8		9.7		20.5		0.44			0.05			38
Piezometer 2	LB	433937116164001	8/27	---		264		6.6		0.0		16.3		0.69			ND			1	
Piezometer 2	LB	433937116164001	8/24	4		---		---		---		---		---			---			---	
Eagle Island, river mile 37.4																					
Boise River near piezometer 3	MID	434050116260100	3/23				202		8.9		16.2		13.0		---			---			---
Piezometer 3	MID	434050116260101	3/23	13		231		6.5		0.6		11.3		1.04			0.05			---	
Boise River near piezometer 3	MID	434050116260100	8/23				133		8.2		10.5		19.6		0.81			0.12			65
Piezometer 3	MID	434050116260101	8/23	0		191		6.5		1.1		16.4		1.18			ND			1	

Table 12. Ground-water and surface-water quality data and head differences at selected sampling sites on the lower Boise River, Idaho, March and August 2001—Continued

						Specific conductance (µS/cm)		pH		Dissolved oxygen (mg/L)		Temperature, in degrees Celsius		Total dissolved nitrogen (mg/L)		Total nitrogen (mg/L)	Total dissolved phosphorus (mg/L)		Total phosphorus (mg/L)	*E. Coli* (MPN/100 mL)	
Station name	Sample location	USGS site ID number	Date	Hydraulic head [1] (mm)	River discharge (ft^3/s)	Ground water	Boise River	Ground water	Boise River	Ground water	Boise River	Ground water	Boise River	Ground water	Boise River	Boise River	Ground water	Boise River	Boise River	Ground water	Boise River
Middleton, river mile 28.9																					
Boise River near piezometer 4	RB	434101116343200	3/22				236		8.8		14.3		11.7		---			---			---
Piezometer 4	RB	434101116343201	3/22	28		286		6.8		0.5		9.9		0.44			0.05			---	
Boise River near piezometer 4	LB	434101116343100	3/22				232		9.0		15.0		12.5		---			---			---
Piezometer 4	LB	434101116343101	3/22	18		290		6.9		1.4		9.8		0.27			0.11			---	
Boise River near piezometer 4	LB	434101116343100	8/28				166		7.7		9.0		19.7		0.87			0.18			260
Piezometer 4	LB	434101116343101	8/28	---		463		6.8		0.0		20.1		0.26			0.14			ND	
Piezometer 4	LB	434101116343101	8/24	-2		---		---		---		---		---			---			---	
Piezometer 4	RB	434101116343201	8/24	-5		230		6.8		0.0		16.6		0.06			0.04			---	
Above Mason Slough, river mile 23.4																					
Boise River near piezometer 5	RB	434148116393800	3/20				237		9.0		13.4		12.3		---			---			---
Piezometer 5	RB	434148116393801	3/20	32		196		7.0		0.5		11.7		0.46			0.09			---	
Boise River near piezometer 5	MID	434146116393800	3/22				273		9.0		19.7		14.4		---			---			---
Piezometer 5	MID	434146116393801	3/22	14		284		7.2		0.9		10.6		2.04			0.38			---	
Boise River near piezometer 5	LB	434146116393700	3/21				279		8.3		13.3		10.6		---			---			---
Piezometer 5	LB	434146116393701	3/21	21		581		6.9		0.9		10.0		0.55			0.09			---	
Piezometer 5	RB	434148116393801	8/28	---		215		6.9		0.0		15.1		0.07			0.04			ND	
Piezometer 5	RB	434148116393801	8/24	7		---		---		---		---		---			---			---	
Piezometer 5	MID	434146116393801	8/28	---		227		7.1		0.0		20.9		0.31			0.35			ND	
Piezometer 5	MID	434146116393801	8/24	3		---		---		---		---		---			---			---	
Boise River near piezometer 5	LB	434146116393700	8/28				217		8.3		11.0		21.9		1.14			0.17			24
Piezometer 5	LB	434146116393701	8/28	---		868		6.8		0.0		18.0		2.58			0.03			ND	
Piezometer 5	LB	434146116393701	8/24	28		---		---		---		---		---			---			---	

Table 12. Ground-water and surface-water quality data and head differences at selected sampling sites on the lower Boise River, Idaho, March and August 2001—Continued

						Specific conductance (µS/cm)		pH		Dissolved oxygen (mg/L)		Temperature, in degrees Celsius		Total dissolved nitrogen (mg/L)		Total nitrogen (mg/L)	Total dissolved phosphorus (mg/L)		Total phosphorus (mg/L)	*E. Coli* (MPN/100 mL)	
Station name	Sample location	USGS site ID number	Date	Hydraulic head [1] (mm)	River discharge (ft^3/s)	Ground water	Boise River	Ground water	Boise River	Ground water	Boise River	Ground water	Boise River	Ground water	Boise River	Boise River	Ground water	Boise River	Boise River	Ground water	Boise River
Above Hartley Gulch, river mile 22.5																					
Boise River near piezometer 6	RB	434140116405600	3/21				154		8.6		16.0		12.4		---			---			---
Piezometer 6	RB	434140116405601	3/21	-7		285		7.1		1.3		10.1		1.54			0.35			---	
Caldwell, river mile 20.8																					
Boise River near piezometer 7	RB	434049116414000	3/22				228		8.7		15.2		13.7		---			---			---
Piezometer 7	RB	434049116414001	3/22	-10		404		6.9		1.8		10.2		1.85			0.08			---	
Boise River near piezometer 7	RB	434049116414000	8/24				270		7.8		8.5		18.5		1.54			0.20			300
Piezometer 7	RB	434049116414001	8/24	-3		353		6.8		0.3		18.6		1.13			0.07			34	
Notus, river mile 13.7																					
Boise River near piezometer 8	RB	434318116475100	3/21				434		8.7		16.4		13.9		---			---			---
Piezometer 8	RB	434318116475101	3/21	16		842		7.2		1.8		11.7		5.79			0.11			---	
Boise River near piezometer 8	LB	434318116474600	3/21				426		8.6		17.5		13.7		---			---			---
Piezometer 8	LB	434318116474601	3/21	9		546		7.2		1.2		11.0		0.19			0.04			---	
Piezometer 8	RB	434318116475101	8/30	---		755		7.4		0.2		17.1		4.35			0.12			ND	
Piezometer 8	RB	434318116475101	8/23	20		---		---		---		---		---			---			---	
Boise River near piezometer 8	LB	434318116474600	8/30				388		7.9		6.8		18.8		2.01			0.23			19
Piezometer 8	LB	434318116474601	8/30	---		565		7.1		---		19.8		0.59			1.07			ND	
Piezometer 8	LB	434318116474601	8/23	-15		---		---		---		---		---			---			---	

Table 12. Ground-water and surface-water quality data and head differences at selected sampling sites on the lower Boise River, Idaho, March and August 2001—Continued

						Specific conductance (µS/cm)		pH		Dissolved oxygen (mg/L)		Temperature, in degrees Celsius		Total dissolved nitrogen (mg/L)		Total nitrogen (mg/L)	Total dissolved phosphorus (mg/L)		Total phosphorus (mg/L)	*E. Coli* (MPN/100 mL)	
Station name	Sample location	USGS site ID number	Date	Hydraulic head [1] (mm)	River discharge (ft^3/s)	Ground water	Boise River	Ground water	Boise River	Ground water	Boise River	Ground water	Boise River	Ground water	Boise River	Boise River	Ground water	Boise River	Boise River	Ground water	Boise River
Below Highway 18 Bridge, river mile 5.0																					
Boise River below Highway 18 Bridge	XS	434613116571000	8/29		492		454		8.1		10.1		20.5		---	2.21		---	0.25		34
Boise River near piezometer 10	RB	434614116571000	8/22				490		8.5		11.3		21.3		---			---			---
Piezometer 10	RB	434614116571001	8/22	4		616		6.9		0.2		18.2		---			---			---	
Boise River near piezometer 10	LB	434613116571000	8/22				485		8.6		12.7		21.7		---			---			---
Piezometer 10	LB	434613116571001	8/22	19		551		7.1		0.1		15.2		---			---			---	
Boise River near piezometer 10	LB	434613116571000	8/29				454		8.1		8.9		19.9		2.01			0.24			52
Piezometer 10	RB	434614116571001	8/29	---		613		6.9		0.1		18.2		0.22			ND			ND	
Piezometer 10	LB	434613116571001	8/29	---		546	---	7.1	---	0.0	---	15.6	---	0.31	---		0.03	---		ND	---
Parma, river mile 3.7																					
Boise River near piezometer 9	RB	434703116581700	3/20				425		8.4		12.4		12.0		---			---			---
Piezometer 9	RB	434703116581701	3/20	10		485		6.9		0.6		10.3		0.73			0.21			---	
Boise River near piezometer 9	LB	434659116581600	3/20				421		8.6		13.1		12.4		---			---			---
Piezometer 9	LB	434659116581601	3/20	8		438		7.4		0.5		10.0		---			---			---	
Boise River near Parma	XS	13213000	8/30		421		460		7.9		8.3		19.6		---	2.44		---	0.30		
Piezometer 9	RB	434703116581701	8/29	---		557		7.0		0.0		21.0		1.00			0.32			ND	
Piezometer 9	RB	434703116581701	8/22	71		---		---		---		---		---			---			---	
Boise River near piezometer 9	LB	434659116581600	8/29				448		8.4		11.2		21.9		1.95			0.25			26
Piezometer 9	LB	434659116581601	8/29	---		431		6.9		0.0		15.7		0.91			0.13			ND	
Piezometer 9	LB	434659116581601	8/22	35		---		---		---		---		---			---			---	

Table 12. Ground-water and surface-water quality data and head differences at selected sampling sites on the lower Boise River, Idaho, March and August 2001—Continued

						Specific conductance (µS/cm)		pH		Dissolved oxygen (mg/L)		Temperature, in degrees Celsius		Total dissolved nitrogen (mg/L)		Total nitrogen (mg/L)	Total dissolved phosphorus (mg/L)		Total phosphorus (mg/L)	*E. Coli* (MPN/100 mL)	
Station name	Sample location	USGS site ID number	Date	Hydraulic head [1] (mm)	River discharge (ft^3/s)	Ground water	Boise River	Ground water	Boise River	Ground water	Boise River	Ground water	Boise River	Ground water	Boise River	Boise River	Ground water	Boise River	Boise River	Ground water	Boise River
Below Parma, river mile 1.75																					
Boise River below Parma	XS	434756116595300	8/30		458		460		8.3		11.8		21.5		---	2.33		---	0.3		69
Piezometer 11	RB	434757116595201	8/23	12		512		7.0		0.3		16.6		---			---			---	
Boise River near piezometer 11	MID	434757116595200	8/23				478		8.6		12.0		22.7		---			---			---
Piezometer 11	MID	434757116595202	8/23	-15		502		7.4		0.3		22.0		---			---			---	
Boise River near piezometer 11	LB	434756116595300	8/23				478		8.6		11.0		22.7		---			---			---
Piezometer 11	LB	434756116595301	8/23	65		579		7.1		0.2		16.7		---			---			---	
Boise River near piezometer 11	LB	434756116595300	8/30				443		8.3		10.8		21.4		1.77			0.25			52
Piezometer 11	RB	434757116595201	8/30	---		458		7.1		0.1		18.9		0.31			0.16			10	
Piezometer 11	MID	434757116595202	8/30	---		465		7.3		---		21.8		0.29			0.38			ND	
Piezometer 11	LB	434756116595301	8/30	---		568		7.2		0.0		18.5		0.58			0.24			ND	

[1] Difference between ground-water level and surface-water stage measured with a manometer board at instream piezometers. Negative values indicate ground-water level is lower than surface-water stage and that the river is losing water. Positive values indicate ground-water level is higher than surface-water stage and that the river is gaining water.

mately 2-mi reach. Total nitrogen load increased by 215 lb/d and total phosphorus load increased by 60 lb/d between sites 9 and 11. The increase in nutrients is likely from ground water, but further study is needed to identify unmeasured sources and input of ground water and associated dissolved constituents to other reaches of the lower Boise.

E. Coli was analyzed in samples collected from the lower Boise and at each piezometer in August 2001 (table 12). Even though the river samples contained measurable concentrations of *E. Coli*, few were detected in the piezometers. *E. Coli* was detected in piezometers at sites 2 (1 most probable number, or MPN/100 mL), 7 (34 MPN/100 mL) and 11 (10 MPN/100 mL). Bacterial input to the lower Boise from ground water appeared to be minimal, but the detection of *E. Coli* in the piezometer samples may need further investigation.

Conclusions

The reconnaissance of ground- and surface-water interactions during March and August 2001 indicated the potential for input of nutrients from ground water to the lower Boise. As a result of the dynamic nature of the lower Boise hydrology and the minimal data collected during the reconnaissance, the extent of ground-water input to the lower Boise could not be ascertained. Further research on the fluctuations between ground and surface water using temperature and mass-balance models during targeted seepage studies in specific reaches is needed to quantify the nutrient load from ground water to the lower Boise.

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