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Water–Quality Assessment of the Eastern Iowa Basins—Nitrogen, Phosphorus, Suspended Sediment, and Organic Carbon In Surface Water, 1996–98

NATIONAL WATER–QUALITY ASSESSMENT PROGRAM

Water-Resources Investigations Report 01–4175

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

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By Kent D. Becher, Stephen J. Kalkhoff, Douglas J. Schnoebelen, Kimberlee K. Barnes, and Von E. Miller

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U.S. GEOLOGICAL SURVEY

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FOREWORD

The U.S. Geological Survey (USGS) is committed to serve the Nation with accurate and timely scientific information that helps enhance and protect the overall quality of life, and facilitates effective management of water, biological, energy, and mineral resources. Information on the quality of the Nation's water resources is of critical interest to the USGS because it is so integrally linked to the long-term availability of water that is clean and safe for drinking and recreation and that is suitable for industry, irrigation, and habitat for fish and wildlife. Escalating population growth and increasing demands for the multiple water uses make water availability, now measured in terms of quantity *and* quality, even more critical to the long-term sustainability of our communities and ecosystems.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program to support national, regional, and local information needs and decisions related to water-quality management and policy. Shaped by and coordinated with ongoing efforts of other Federal, State, and local agencies, the NAWQA Program is designed to answer: What is the condition of our Nation's streams and ground water? How are the conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues. NAWQA results can contribute to informed decisions that result in practical and effective water-resource management and strategies that protect and restore water quality.

Since 1991, the NAWQA Program has implemented interdisciplinary assessments in more than 50 of the Nation's most important river basins and aquifers, referred to as Study Units. Collectively, these Study Units account for more than 60 percent of the overall water use and population served by public water supply, and are representative of the Nation's major hydrologic landscapes, priority ecological resources, and agricultural, urban, and natural sources of contamination.

Each assessment is guided by a nationally consistent study design and methods of sampling and analysis. The assessments thereby build local knowledge about water-quality issues and trends in a particular stream or aquifer while providing an understanding of how and why water quality varies regionally and nationally. The consistent, multi-scale approach helps to determine if certain types of water-quality issues are isolated or pervasive, and allows direct comparisons of how human activities and natural processes affect water quality and ecological health in the Nation's diverse geographic and environmental settings. Comprehensive assessments on pesticides, nutrients, volatile organic compounds, trace metals, and aquatic ecology are developed at the national scale through comparative analysis of the Study-Unit findings.

The USGS places high value on the communication and dissemination of credible, timely, and relevant science so that the most recent and available knowledge about water resources can be applied in management and policy decisions. We hope this NAWQA publication will provide you the needed insights and information to meet your needs, and thereby foster increased awareness and involvement in the protection and restoration of our Nation's waters.

The NAWQA Program recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for a fully integrated understanding of watersheds and for cost-effective management, regulation, and conservation of our Nation's water resources. The Program, therefore, depends extensively on the advice, cooperation, and information from other Federal, State, interstate, Tribal, and local agencies, non-government organizations, industry, academia, and other stakeholder groups. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch
Associate Director for Water

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CONVERSION FACTORS, VERTICAL DATUM, and ABBREVIATIONS

Multiply	By	To obtain
	Length	
millimeter (mm)	0.3937	inch
centimeter (cm)	0.03937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
	Area	
square meter (m^2)	10.76	square foot
square hectometer (hm^2)	2.471	acre
square kilometer (km^2)	0.3861	square mile
	Volume	
cubic hectometer (hm^3)	810.7	acre-foot
liter (L)	33.82	ounce
milliliter (mL)	0.0338	ounce
	Flow	
cubic meter per second (m^3/s)	35.31	cubic foot per second
cubic meter per second per square kilometer [$(m^3/s)/km^2$]	91.46	cubic foot per second per square mile
	Mass	
kilogram (kg)	2.205	pound
metric ton	1.102	ton, short
kilogram per day (kg/d)	2.205	pound per day
kilogram per hectare (kg/ha)	0.8924	pound per acre
kilogram per square kilometer (kg/km^2)	5.711	pound per square mile
kilogram per square kilometer per year [$(kg/km^2)/yr$]	5.711	pound per square mile per year
gram per kilogram (g/kg)	0.0160	ounce per pound
	Concentration	
milligram per liter (mg/L)	1.0	parts per million

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

$$° F = 1.8 (° C) + 32$$

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L).

Water year is the 12-month period from October 1 through September 30 and is designated by the year in which it ends. For example, the water year ending September 30, 1996, is called water year 1996.

Abbreviation	Description
DOC	dissolved organic carbon
EIWA	Eastern Iowa Basins Assessment
GIS	geographic information system
LOWESS	locally weighted scatterplot smoothing
MCL	maximum contaminant level
MRL	minimum reporting limit
NAWQA	National Water-Quality Assessment
NWQL	National Water-Quality Laboratory
RPD	relative percentage difference
SAS	Statistical Analysis System
SOC	suspended organic carbon
STATSGO	State Soil Geographic data base
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
N	nitrogen
P	phosphorus
°C	degrees Celsius
°F	degrees Fahrenheit
cm	centimeter
m	meter
km	kilometer
hm	hectometer
mg/L	milligram per liter
kg/d	kilogram per day
kg/ha	kilogram per hectare
yr	year
<	less than

GLOSSARY

Ammonia. A compound of nitrogen and hydrogen (NH_3) that is a common by-product of animal waste. Ammonia readily converts to nitrate in soils and streams.

Analyte. A specific compound or element of interest undergoing chemical analysis.

Atmospheric deposition. The transfer of substances from the air to the surface of the Earth, either in wet form (rain, fog, snow, dew, frost, hail) or in dry form (gases, aerosols, particles).

Base flow. Sustained, low flow in a stream; ground-water discharge is the source of base flow in most places.

Basic-fixed site. Site on a stream at which streamflow is measured and samples are collected for temperature, specific conductance, pH, dissolved oxygen, nutrients, major ions, pesticides, suspended sediment, and organic carbon to assess the broad-scale spatial and temporal character and transport of inorganic and organic constituents of stream water in relation to hydrologic conditions and environmental setting.

Constituent. A chemical or biological substance in water, sediment, or biota that can be measured by an analytical method.

Detection limit. The concentration below which a particular analytical method cannot determine, with a high degree of certainty, a concentration of an analyte.

Drainage area. The area, measured in a horizontal plane, which is enclosed by a drainage divide.

Drainage basin. The portion of the surface of the Earth that contributes water to a stream through overland runoff, including tributaries and impoundments.

Drinking-water regulation or guideline. A threshold concentration in a public drinking-water supply, designed to protect human health. As defined here, regulations are U.S. Environmental Protection Agency regulations that specify the maximum contamination levels for public water systems required to protect the public welfare; guidelines have no regulatory status and are issued in an advisory capacity.

Environmental sample. A water sample collected from a stream or river for the purpose of chemical, physical, or biological characterization of the sampled resource.

Equal-width increment (EWI) sample. A composite sample across a section of stream with equal spacing between verticals and equal transit rates within each vertical that yields a representative sample of stream conditions.

Erosion. The process whereby materials of the Earth's crust are loosened, dissolved, or worn away and simultaneously moved from one place to another.

Eutrophication. The process by which water becomes enriched with nutrients, most commonly phosphorus and nitrogen.

Field equipment blank. A solution of water that contains analytes of interest below detection limits and is subjected to all aspects of sample collection, processing, preservation, transportation, and laboratory handling as an environmental sample but is collected at the sampling site immediately before the environmental sample.

Hypoxia. Seasonal depletion of dissolved oxygen (less than 2.0 milligrams per liter) within a water body, which is related to eutrophication of the water body. Most aquatic species cannot survive at such low oxygen levels.

Indicator site. Stream sampling site located at an outlet of a drainage basin with relatively homogeneous land use and physiographic conditions; indicator sites have drainage areas ranging from 320 to 1,080 square kilometers within the Eastern Iowa Basins.

Integrator site. Stream sampling site located at an outlet of a drainage basin that contains multiple environmental settings. Integrator sites are located on major rivers with drainage areas ranging form 6,050 to 32,400 square kilometers within the Eastern Iowa Basins.

Intensive-fixed site. A basic-fixed site with increased sampling frequency during selected seasonal periods and analysis of dissolved pesticides for 1 year.

Karst. A type of topography that results from dissolution and collapse of carbonate rocks such as limestone and dolomite and characterized by closed depressions or sinkholes, caves, and underground drainage.

Load. General term that refers to a material or constituent in solution, in suspension, or in transport; usually expressed in terms of mass or volume.

Loess. Homogeneous, fine-grained sediment made up primarily of silt and clay and deposited over a wide area (typically by wind).

Maximum contaminant level (MCL). Maximum permissible level of a contaminant in water that is delivered to any user of a public water system. MCLs are enforceable regulations established by the U.S. Environmental Protection Agency.

Mean. The average of a set of observations, unless otherwise specified.

Mean discharge. The arithmetic average of individual daily average discharges during a specific period, usually daily, monthly, or annually.

Median. The middle or central value in a distribution of data ranked in order of magnitude. The median also is known as the 50th percentile.

Minimum reporting limit (MRL). The smallest measured concentration of a constituent that may be reliably reported by an analytical method. The minimum reporting level is generally higher than the detection limit because of unpredictable matrix effects for different waters.

Nitrate. An ion consisting of nitrogen and oxygen (NO_3^-). Nitrate is a nutrient and is very soluble in water.

Nonpoint source. A pollution source that cannot be defined as originating from discrete points, such as pipe discharge. Areas of fertilizer and pesticide applications, atmospheric deposition, manure, and natural inputs from plants are types of nonpoint-source pollution.

Nutrient. Chemical element that is essential to plant and animal nutrition. Nitrogen and phosphorus are nutrients that are important to aquatic life, but in high concentrations, they can be contaminants in water. These nutrients occur in a variety of forms. Both are affected by chemical and biological processes that can change their form and can transfer them to or from water, soil, biological organisms, and the atmosphere.

Overland flow. The part of surface runoff flowing over land surfaces toward stream channels.

Phosphorus. A nutrient essential for growth that can play a key role in simulating aquatic growth in lakes and streams.

Point source. A source of chemical, physical, biological input to a water body at a discrete location such as a discharge pipe, drainage ditch, tunnel, well, concentrated livestock operation, or floating craft.

Quality assurance. Evaluation of quality-control data to allow quantitative determination of the quality of chemical data collected during a study. Techniques used to collect, process, and analyze water samples are evaluated.

Reference site. Site at the headwater of a drainage basin that has been minimally affected by humans.

Sediment. Particles, derived from rocks or biological materials, that have been transported by a fluid or other natural process, suspended or settled in water.

Split sample. A sample prepared by dividing it into two or more equal volumes, where each volume is considered a separate sample but representative of the entire sample.

Study unit. A major hydrologic system of the United States in which NAWQA studies are focused. NAWQA study units are geographically defined by a combination of ground- and surface-water features and usually encompass more than 10,000 square kilometers.

Synoptic sites. Sites sampled during short time periods (1 week or less) to evaluate the spatial distribution of water quality during specified hydrologic conditions.

Tile drain (line). A buried perforated pipe designed to remove excess water from soils.

Yield. The mass of material or constituent transported by a river in a specified period of time divided by the drainage area of the river basin.

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Abstract

Twelve sites on streams and rivers in the Eastern Iowa Basins study unit were sampled monthly and during selected storm events from March 1996 through September 1998 to assess the occurrence, distribution, and transport of nitrogen, phosphorus, suspended sediment, and organic carbon as part of the U.S. Geological Survey's National Water-Quality Assessment Program. One site was dropped from monthly sampling after 1996. Dissolved nitrogen and phosphorus were detected in every water sample collected. Nitrate accounted for 92 percent of the total dissolved nitrogen. About 22 percent of the samples had nitrate concentrations that exceeded the U.S. Environmental Protection Agency's maximum contaminant level of 10 milligrams per liter as nitrogen for drinking-water regulations. The median concentration of total dissolved nitrogen for surface water in the study unit was 7.2 milligrams per liter. The median total phosphorus concentration for the study unit was 0.22 milligram per liter. About 75 percent of the total phosphorus concentrations exceeded the U.S. Environmental Protection Agency recommended total phosphorus concentration of 0.10 milligram per liter or less to minimize algal growth. Median suspended sediment and dissolved organic-carbon concentrations for the study unit were 82 and 3.5 milligrams per liter, respectively.

Median concentrations of nitrogen, phosphorus, and suspended sediment varied annually and seasonally. Nitrogen, phosphorus, and suspended-sediment concentrations increased each year of the study due to increased precipitation and runoff. Median concentrations of dissolved organic carbon were constant from 1996 to 1998. Nitrogen concentrations were typically higher in the spring after fertilizer application and runoff. During winter, nitrogen concentrations typically increased when there was little in-stream processing by biota. Nitrogen and phosphorus concentrations decreased in late summer when there was less runoff and in-stream processing of nitrogen and phosphorus was high. Dissolved organic carbon was highest in February and March when decaying vegetation and manure were transported during snowmelt. Suspended-sediment concentrations were highest in early summer (May–June) during runoff and lowest in January when there was ice cover with very little overland flow contributing to rivers and streams. Based on historical and study-unit data, eastern Iowa streams and rivers are impacted by both nonpoint and point-source pollution.

Indicator sites that have homogeneous land use, and geology had samples with significantly higher concentrations of total dissolved nitrogen (median, 8.2 milligrams per liter) than did samples from integrator sites (median, 6.2 milligrams per liter) that were more heterogeneous in land use and geology. Samples from integrator sites

typically had significantly higher total phosphorus and suspended-sediment concentrations than did samples from indicator sites. Typically, there was very little difference in median dissolved organic-carbon concentrations in samples from indicator and integrator sites.

Concentrations of nitrogen and phosphorus varied across the study unit due to land use and physiography. Basins that are located in areas with a higher percentage of row-crop agriculture typically had samples with higher nitrogen concentrations. Basins that drain the Southern Iowa Drift Plain and the Des Moines Lobe typically had samples with higher total phosphorus and suspended-sediment concentrations.

Total nitrogen loads increased each year from 1996 through 1998 in conjunction with increased concentrations and runoff. Total phosphorus loads in the Skunk River Basin decreased in 1997 due to less runoff and decreased sediment transport, but increased in 1998 due to higher runoff and increased sediment transport. Total nitrogen and total phosphorus loads varied seasonally. The highest loads typically occurred in early spring and summer after fertilizer application and runoff. Loads were lowest in January and September when there was typically very little runoff to transport nitrogen and phosphorus in the soil to the rivers and streams.

Total nitrogen loads contributed to the Mississippi River from the Eastern Iowa Basins during 1996, 1997, and 1998 were 97,600, 120,000, and 234,000 metric tons, respectively. Total phosphorus loads contributed to the Mississippi River from the Eastern Iowa Basins during 1996, 1997, and 1998 were 6,860, 4,550, and 8,830 metric tons, respectively. Suspended-sediment loads contributed to the Mississippi River from the Eastern Iowa Basins during 1996, 1997, and 1998 were 7,480,000, 4,450,000, and 8,690,000 metric tons, respectively. The highest total nitrogen and total phosphorus yields typically occurred in samples from indicator sites. Sampling sites located in drainage basins with higher row-crop percentage typically had higher nitrogen and phosphorus yields. Sites that were located in the Des Moines Lobe and the Southern Iowa Drift Plain typically had higher phosphorus yields, probably due to physiographic features (for example, erodible soils, steeper slopes).

Synoptic samples collected during low and high base flow had nitrogen, phosphorus, and organic-carbon concentrations that varied spatially and seasonally. Comparisons of water-quality data from six basic-fixed sampling sites and 19 other synoptic sites suggest that the water-quality data from basic-fixed sampling sites were representative of the entire study unit during periods of low and high base flow when most streamflow originates from ground water.

INTRODUCTION

The Eastern Iowa Basins (EIWA) study unit (fig. 1) is 1 of 15 U.S. Geological Survey (USGS) National Water-Quality Assessment Program (NAWQA) study units activated in 1994 (fig. 1). Information on water-quality conditions in the EIWA is necessary for planning and management. Part of the assessment of the study unit addressed surface-water conditions. Specific surface-water-quality issues of primary concern in the EIWA include degradation of aquatic ecosystems, soil erosion (sediment), and elevated concentrations of nitrogen, phosphorus, organic carbon, and synthetic organic compounds (including pesticides) (Iowa Department of Natural Resources, 1994; Kalkhoff, 1994; Hallberg and others, 1996; Goolsby and others, 1997).

Importance of Nitrogen, Phosphorus, Suspended Sediment, and Organic Carbon

Nitrogen and phosphorus compounds can occur naturally at small concentrations in stream water (Hem, 1985). In addition, nitrogen and phosphorus can be introduced into the environment from sources such as chemical fertilizer, animal manure, wastewater effluent, atmospheric deposition, soil mineralization, and legume fixation.

Nitrogen compounds are a water-quality concern primarily because they contribute to aquatic plant growth, eutrophication, and toxicity. Algae generally prefer ammonia over nitrate for growth (Brezonik, 1973, p. 11), but both the reduced species of nitrogen

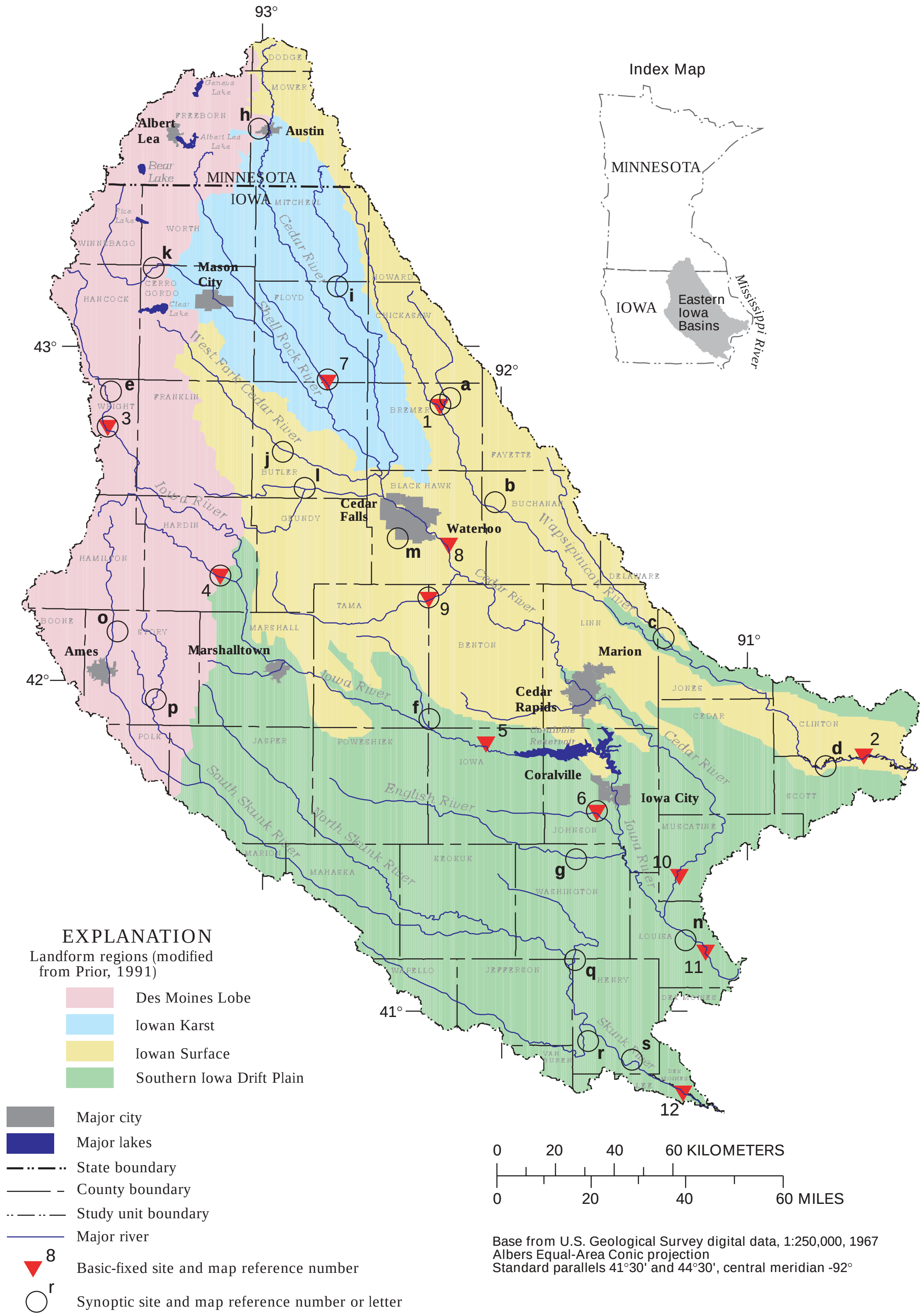


Figure 1. Landform regions and surface-water-quality sampling sites in the Eastern Iowa Basins study unit.

(ammonia and organic nitrogen) and the oxidized species (nitrite and nitrate) can be used as nutrients for algal growth.

Considerable concern in recent years has been expressed over health effects of nitrate in drinking water (Neill, 1989). Nitrite and nitrate have been linked to infantile methemoglobinemia (whereby the blood loses its ability to transport oxygen) and are suspected of causing the formation of carcinogenic nitrosamines and nitrosamides (Neill, 1989). In addition, an association between nitrate in drinking water and bladder cancer in women has been identified (Weyer and others, 2001). The maximum contaminant level (MCL) for drinking water established by the U.S. Environmental Protection Agency (USEPA) is 10 mg/L of nitrate as nitrogen (U.S. Environmental Protection Agency, 1996).

Phosphorus compounds are a water-quality concern because, like nitrogen, phosphorus is an essential nutrient for plant growth. To prevent the excessive growth of aquatic plants in water bodies, the USEPA recommends that total phosphorus concentrations not exceed 0.10 mg/L as phosphorus (U.S. Environmental Protection Agency, 1986). About 95 percent of the phosphorus transported by rivers is adsorbed to sediment (Maybeck, 1982). However, algae and other aquatic plants most readily use the soluble or dissolved compounds of phosphorus. Sources of phosphorus include wastewater-treatment-plant effluent, detergents, manure, fertilizers, and sediment from surface-water runoff.

The Midwestern United States has been identified as a major contributor of nitrogen and phosphorus to the Mississippi River (Goolsby and others, 1997). In nutrient-poor freshwater, inorganic phosphate is often the factor limiting the growth of aquatic plants and algae. However, nitrate as nitrogen tends to become the limiting factor when phosphorus is plentiful (Allen, 1995, p. 89). Recent studies in the Gulf of Mexico have indicated areas with small dissolved-oxygen concentrations (less than 2.0 mg/L), a condition known as hypoxia. The occurrence of hypoxia in the Gulf of Mexico has been linked to nitrogen and phosphorus loads discharged from the Mississippi River (Turner and Rabalais, 1994; Goolsby and others, 1999). Increases in nitrogen and phosphorus loads to the Gulf of Mexico can promote the excessive growth of algae which eventually die and decompose, depleting the water column of dissolved oxygen, which can kill or otherwise adversely affect fish and other aquatic life.

Sediment is a water-quality concern because it can fill reservoirs, prevent sunlight from penetrating the water to reach aquatic plants, and adsorb and transport many toxic compounds. Suspended sediment originates from erosion within streams and on uplands. Phosphorus is one of the constituents that tends to adsorb to sediment.

The organic layer in soils is a major source of soluble organic compounds (Drever, 1988). Organic carbon is a water-quality concern because it plays a major role in chemical processes and the transport of trace metals. Dissolved organic carbon (DOC) and suspended organic carbon (SOC) are normally present in surface water from decaying vegetation, living organisms suspended in the water column such as algae and bacteria, sewage, and manure.

Purpose and Scope

Water-quality data presented in this report were collected at 12 surface-water-quality sites from March 1996 through September 1998 as part of the EIWA NAWQA. The objectives of this report are to: (1) summarize nitrogen, phosphorus, suspended-sediment, and organic-carbon data in drainage basins both spatially and temporally during 1996–98; (2) compare nitrogen, phosphorus, suspended-sediment, and organic-carbon concentrations among drainage basins and relate differences to land use, basin physical characteristics, streamflow, and human factors; and (3) estimate loads and yields of total nitrogen, total phosphorus, and suspended sediment transported by rivers and streams. Twelve sites were sampled during the first year of the study (1996) and 11 were sampled during the last 2 years of the study (1997–98). In addition, results from synoptic studies conducted in 25 small watersheds (310–1,480 km^2) during high and low base-flow conditions are discussed.

Schnoebelen and others (1999) summarized historical surface-water nitrogen and phosphorus data in the EIWA study unit collected by various agencies from 1970 through 1995. The present EIWA study updates nitrogen and phosphorus findings within the study unit for the sampling period (1996–98) and expands information to drainage basins where limited water-quality data were available. In addition, EIWA water-quality data will be useful for national comparisons with other NAWQA study units.

DESCRIPTION OF STUDY UNIT

Hydrology

The EIWA study unit consists of four major drainage basins and covers about 49,700 km^2 (Kalkhoff, 1994). The major drainage basins are the Wapsipinicon River Basin (6,100 km^2), the Cedar River Basin (20,200 km^2), the Iowa River Basin (12,200 km^2), and the Skunk River Basin (11,200 km^2) (fig. 1). The four major rivers in the study unit have their headwaters in the northwestern part of the study unit and flow to the southeast, discharging to the Mississippi River. The Wapsipinicon River originates in southeastern Minnesota and is about 362 km long, with an average basin width of about 16 km. The Cedar River originates in southern Minnesota and forms the largest basin in the study unit. The Cedar River Basin ranges from 32 to 96 km in width. The Cedar River joins the Iowa River about 48 km upstream from the confluence of the Iowa and Mississippi Rivers. The Iowa River originates in north-central Iowa and averages 32 km in width. Together, the Cedar and Iowa River Basins cover 32,380 km^2 and drain about 64 percent of the study unit. The Skunk River originates in central Iowa and averages 39 km in width.

Overland flow and ground-water discharge are the major sources of streamflow. Flooding occurs as a result of rapid spring melting of the snowpack, often combined with rainfall, or thunderstorm activity. Droughts can result from the shift of the normal seasonal atmospheric storm track by high-pressure conditions, a block or decrease in moist airflows, or lack of thunderstorm development.

Interflow is that part of subsurface flow that moves at shallow depths and reaches the surface stream channel in a relatively short period of time and, therefore, commonly is considered part of overland flow. During a storm period, interflow slowly increases up to the end of the storm period, followed by a gradual recession (Viessman and others, 1989). Tile drains (lines) beneath fields can enhance the subsurface-drainage component of flow to streams. Yearly total streamflow from the study unit averages 11,350 hm^3 (Kalkhoff, 1994). The mean annual streamflow from the Wapsipinicon River Basin, the Cedar-Iowa River Basins, and the Skunk River Basin averages about 1,360, 7,770, and 2,220 hm^3, respectively.

Landforms

The EIWA study unit includes three major landform regions (Des Moines Lobe, Iowan Surface, Southern Iowa Drift Plain) (Prior, 1991) and one subregion (Iowan Karst, a subregion of the Iowan Surface) that are based on distinct spatial differences in topography, geology, soils, and vegetation (figs. 1 and 2). These regions are broadly coincident with ecoregions and subecoregions of Iowa (Griffith and others, 1994).

The Des Moines Lobe, in the western part of the study unit, is one of the youngest landforms in Iowa and is characterized by low local relief (15–30 m) on the land surface. The Des Moines Lobe was formed by the last glaciation in Iowa approximately 12,000 to 14,000 years ago (Wisconsinan age) and has been altered only slightly since that time (Prior, 1991). The topography consists of predominantly flat and slightly rolling land broken by arcuate bands of “knob and kettle” terrain (Buchmiller and others, 1985). Historically, ponds and wetlands and poor drainage characterized the Des Moines Lobe. Extensive ditching and tiling of fields during 1900–20 augmented the natural surface drainage in this area. The potential natural vegetation is bluestem prairie (Griffith and others, 1994); corn and soybean crop production presently (2001) dominates. Stream development is poor with many small, low-gradient streams that drain into a few larger rivers. Surficial material consists of glacial till that has an average thickness of about 30 m, and alluvium in association with the larger streams. Surficial loess is absent (fig. 2).

The Iowan Surface is characterized by gently rolling topography with long slopes and low relief (15–30 m). Drainage is well developed, although streams generally have slight gradients (fig. 2). Surficial material consists of pre-Illinoian-age (500,000 to 700,000 years old) glacial till covered by a thin veneer of windblown loess that transitions from little to none in the north to thicker deposits on the ridges in the south with alluvium near the streams (Prior, 1991). Potential natural vegetation includes bluestem prairie and oak-hickory forest; corn and soybean crop production presently (2001) dominates the land surface (Prior, 1991; Griffith and others, 1994).

The Iowan Karst is a subregion of the Iowan Surface where dissolution of soluble limestone and dolomite bedrock under a thin or nonexistent cover of glacial drift has caused localized collapse of the land surface resulting in karst topography with numerous sinkholes. The surface drainage is well developed,

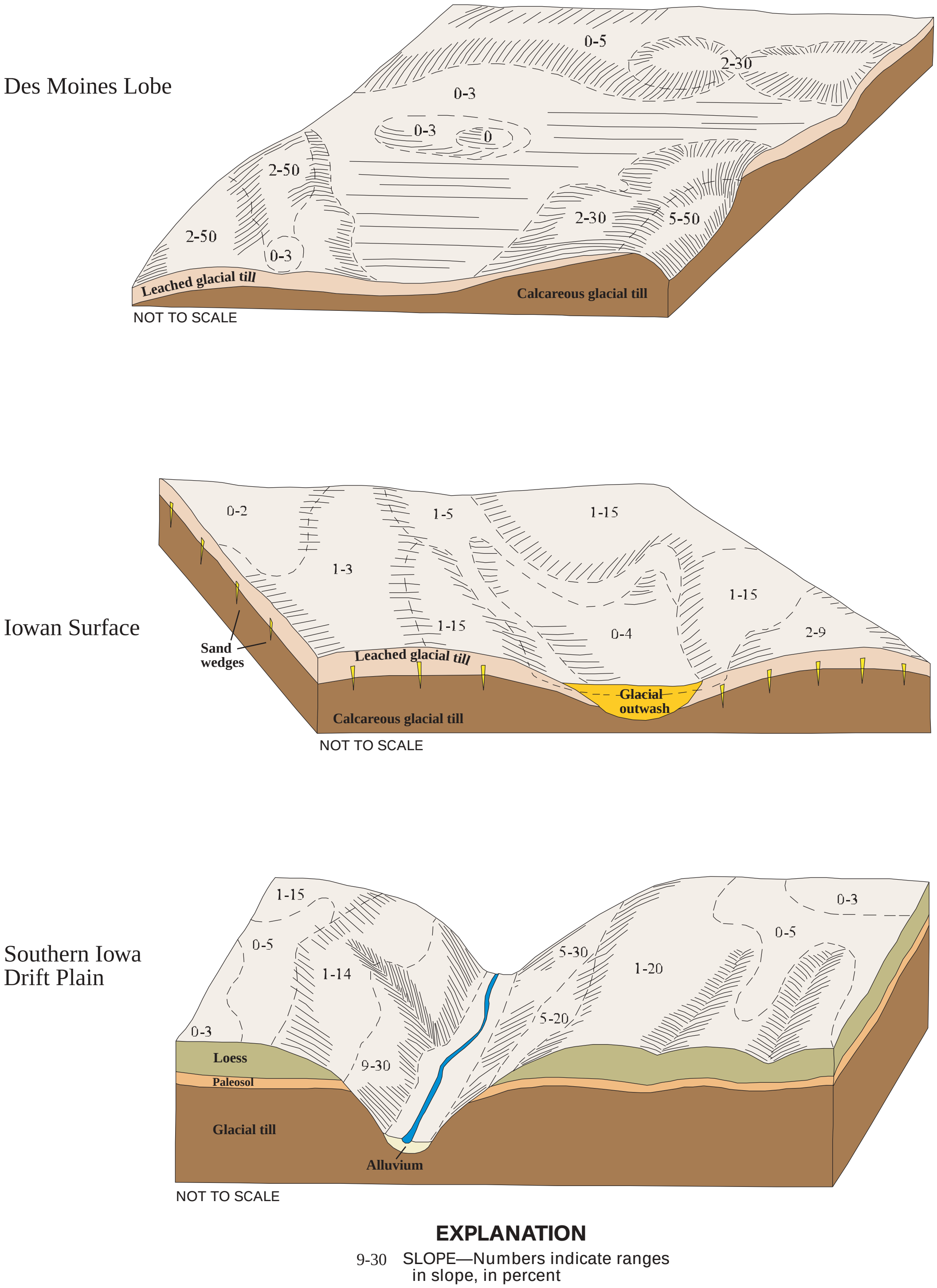


Figure 2. Physiography of landform regions in the Eastern Iowa Basins study unit (modified from Oschwald and others, 1965).

although local direct infiltration to bedrock is common. This area is used extensively for agriculture, and some fields are drained through agricultural drainage wells (gravity based). Field tile lines are connected to these drainage wells and may become conduits for surface runoff to enter the underlying bedrock. Floyd County, Iowa, located in the Cedar River Basin, has the most registered agricultural drainage wells in the EIWA study unit (Libra and others, 1996). Sinkholes, a natural feature of the Iowan Karst, can affect ground-water quality in a manner similar to agricultural drainage wells.

The Southern Iowa Drift Plain is characterized by steeply rolling terrain with moderate relief (30–91 m) separated by flat, tabular divides (fig. 2). Surficial material consists of pre-Illinoian glacial deposits mantled by loess. Soils on the lower slopes commonly are derived from till, whereas soils on the higher slopes and upland flats are derived from loess. Alluvium is found in association with streams that form a well-developed drainage pattern. Potential natural vegetation includes bluestem prairie and oak-hickory forests (Griffith and others, 1994); the land presently (2001) is used for agriculture.

Climate

The climate in the study unit is continental, with large differences in seasonal temperatures that result in distinct winter and summer seasons. Primary climatic effects in the EIWA study unit are warm, moist air from the Gulf of Mexico and surges of cold, dry air from Canada, which predominate in the summer and winter, respectively (U.S. Department of Commerce, 1959). Mean monthly temperatures range from –16° C for the lows in January to 28° C for the highs in July (Wendland and others, 1992). The growing season (generally April–September) lasts about 127 days and is characterized by mean temperatures of 19° C in the southern part of the EIWA study unit to 16° C in the northern part.

Precipitation occurs mostly as rain associated with thunderstorms that occur from April through September. About 71 percent of the annual rainfall occurs during this period (Harry Hillaker, Iowa Department of Agriculture and Land Stewardship, oral commun., 2000). Peak precipitation occurs in June and diminishes sharply during the autumn. Precipitation during the cooler months of the year generally is of long duration and of moderate or low intensity, whereas precipitation during the late spring and summer tends to be of shorter duration and higher intensity. Snow during the colder winter months can remain on the land surface from December to March. The mean annual precipitation ranges from 76 cm in the north to 94 cm in the southeastern part of the study unit (Wendland and others, 1992).

Land Use

Land use is based primarily on agriculture and agriculture-related industry, accounting for 92.9 percent of the land use in the study unit (fig. 3). Other land uses are forests (4.0 percent), urban (1.8 percent), and other (1.3 percent). The principal crops are corn, soybeans, oats, hay, and pasture on unirrigated land. Iowa ranked first in the Nation in the production of corn and soybeans in 1995 and 1996 (Sands and Holden, 1996, 1997).

In addition to row-crop agriculture, Iowa produces large quantities of hogs, cattle, sheep, and poultry. Iowa hog production ranked first in the Nation in 1995 (14.4 million head) and 1996 (12.2 million head) (Sands and Holden, 1996, 1997). Numerous confined-feeding hog facilities began operation in the 1990’s in the study unit. Figure 3 shows the location of regulated livestock facilities in the EIWA study unit, and the majority of these facilities are for hog production. Confined-feeding facilities must obtain permits from the Iowa Department of Natural Resources before construction if the facility is designed for an animal weight capacity higher than 181,440 kg bovine or 90,720 kg for other animal species (Iowa Department of Natural Resources, 1998). The numbers of hog facilities have doubled since 1993 in the upstream parts of the Iowa River and Skunk River Basins (fig. 3). The potential negative effects of these hog-production facilities on water quality are not known and are of concern.

The use of chemical fertilizers to increase crop production increased in the United States from 1970 to 1994 (Goolsby and Battaglin, 1995). Fertilizer use in eastern Iowa has paralleled the national trend. In recent years, fertilizer (nitrogen) application rates on corn in Iowa decreased from 1985 (162 kg/ha) to 1994 (135 kg/ha), but application rates then increased from 134 kg/ha in 1995 to 148 kg/ha in

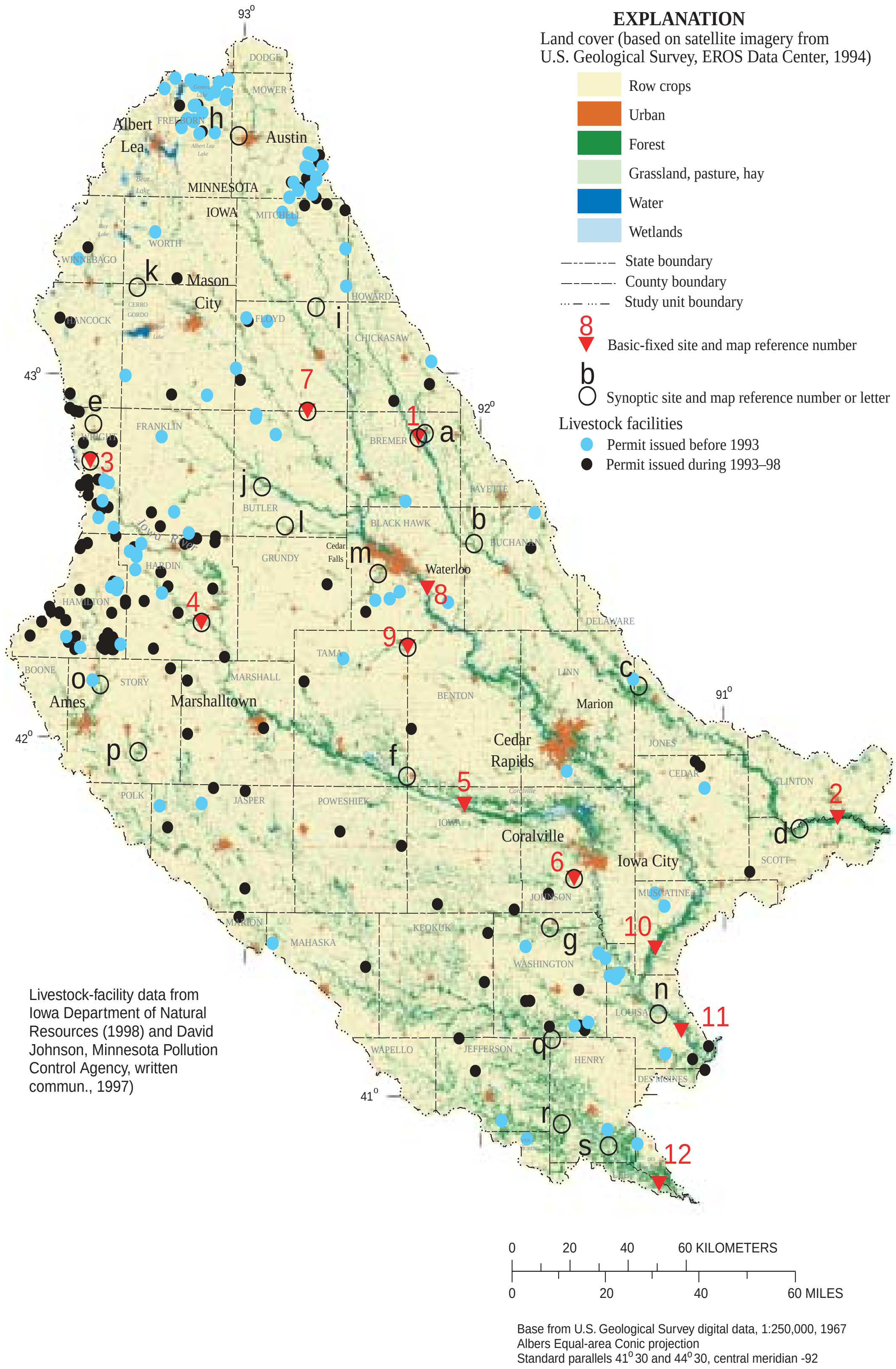


Figure 3. Land cover and location of permitted livestock facilities in relation to surface-water-quality sampling sites in the Eastern Iowa Basins study unit.

1996 (G.R. Hallberg, University of Iowa Hygienic Laboratory, written commun., 1997). Application rates in 1997 and 1998 were 136 kg/ha and 148 kg/ha, respectively (U.S. Department of Agriculture, 1998, 1999).

METHODS AND DATA ANALYSIS

Twelve basic-fixed surface-water-quality sites were selected on rivers and streams following the NAWQA sampling design protocol (Hirsch and others, 1988; Kalkhoff, 1994) to serve as indicator or integrator sites (table 1, fig. 1). Indicator sites represent smaller drainage basins (320 to 1,080 km^2) with relatively homogeneous land use and geology. Integrator sites represent larger drainage basins (6,050 to 32,400 km^2) and are affected by combinations of land use and geology. The basic-fixed sites were monitored continuously for stream discharge and sampled monthly to assess the broad-scale spatial and temporal character of water-quality constituents. In addition, three basic-fixed sites, the Iowa River near Rowan (site 3, fig. 1), Wolf Creek near Dysart (site 9, fig. 1), and the Iowa River at Wapello (site 11, fig. 1), were sampled weekly in the spring and early summer of 1997 and biweekly at the end of the summer of 1997 (intensive sites, table 1) to determine short-term fluctuations and variability of selected constituents.

The indicator sites (table 1, fig. 1) were selected to represent typical drainage basins in the three major landforms—Iowa River near Rowan (site 3, fig. 1)–Des Moines Lobe; Wolf Creek near Dysart (site 9, fig. 1)–Iowan Surface; Flood Creek near Powersville (site 7, fig. 1)–Iowan Karst (a subregion of the Iowan Surface); and Old Mans Creek near Iowa City (site 6, fig. 1)–Southern Iowa Drift Plain. The primary difference between indicator sites is physiographic (soils, topography, and geology) as the land use within these areas is consistently about 95 percent agriculture (table 1). In addition, the Wapsipinicon River near Tripoli (site 1, fig. 1) was selected as a reference site because the drainage basin retains a higher percentage of its stream-corridor wetlands compared to other basins in the study unit (table 1). The South Fork Iowa River near New Providence (site 4, fig. 1) was selected as an indicator site to assess the effects of large-scale, hog-confinement facilities on stream-water quality.

Integrator sites (table 1) were sampled to assess broad-scale spatial and temporal differences in water-quality characteristics in basins that contain a mixture of land use and geologic features. Water-quality sampling of the Cedar River near Conesville (site 10, fig. 1) was moved about 8 km upstream because of bridge construction in October 1996. Water-quality data collected from this upstream location were considered to be equivalent to data collected from the downstream location because there are no major tributaries or urban areas draining into the river within the 8-km reach. Water-quality sampling of the Cedar River at Gilbertville (site 8, fig. 1) was discontinued in March 1997 after one full year of sampling because the site did not have a continuous gaging station.

Eleven basic-fixed sites were sampled monthly beginning in March 1996 and ending in September 1998. Additional samples were collected near peak river stage after significant rainfall events. The intensive sites were sampled weekly beginning in April 1997 (fertilizer application period and early growing season) and biweekly from July 1997 through November 1997 (after fertilizer application and middle to late growing season).

Samples also were collected at 25 synoptic sites during low base-flow and high base-flow conditions in August 1997 and May 1998 (fig. 1, table 1) to better define spatial variability. The synoptic sampling included six indicator basic-fixed sites. The low base-flow samples were collected as part of the NAWQA Midwest Regional synoptic study (Sorenson and others, 1999) conducted by personnel from the Upper Mississippi River Basin, EIWA, and the Lower Illinois River Basin NAWQA study units. Candidate sampling sites were selected for drainage basin areas generally larger than 260 km^2 and smaller than 2,600 km^2. All basins represented by the synoptic samples had at least 85 percent agricultural land use (table 1); agricultural land use among all surface-water-quality sampling sites in the study averaged more than 90 percent. Drainage basin selection criteria also included moderately well drained soils (more than 50 percent of the basin area in the State Soil Geographic data base (STATSGO) soil hydrologic groups A or B) to poorly drained soils (more than 50 percent of the basin area in STATSGO soil hydrologic groups C or D) (Sorenson and others, 1999).

Table 1. Description of surface-water-quality monitoring sites in the Eastern Iowa Basins study unit

[<, less than]

Map reference number or letter (fig. 1)	Site number	Site name	Drainage area (square kilometers)	Site type[1]	Land use in contributing drainage area (percent)[3]				
					Agriculture	Urban	Forested	Wetland	Other (barren/ water)
1	05420680	Wapsipinicon River near Tripoli, IA	900	bfs, ind, syn	88.5	1.8	5.1	4.2	0.3
2	05422000	Wapsipinicon River near De Witt, IA	6,050	bfs, int	87.4	2.1	7.2	2.7	.6
3	05449500	Iowa River near Rowan, IA	1,080	bfs, intens, ind, syn	94.6	1.8	1.6	1.5	.6
4	05451210	South Fork Iowa River near New Providence, IA	580	bfs, ind, syn	95.1	1.5	2.6	.7	<.1
5	05453100	Iowa River at Marengo, IA	7,240	bfs, int	91.0	2.5	3.9	2.1	.6
6	05455100	Old Mans Creek near Iowa City, IA	520	bfs, ind, syn	91.9	2.6	4.4	1.0	.1
7	05461390	Flood Creek near Powersville, IA	320	bfs, ind, syn	95.3	1.1	2.8	.8	<.1
8	05464020	Cedar River at Gilbertville, IA[2]	13,600	bfs, int	90.7	3.0	3.5	1.9	.9
9	05464220	Wolf Creek near Dysart, IA	770	bfs, intens, ind, syn	95.6	1.8	1.9	.6	.1
10	05465000	Cedar River near Conesville, IA	20,200	bfs, int	89.5	3.3	4.4	1.9	.9
11	05465500	Iowa River at Wapello, IA	32,400	bfs, intens, int	89.0	3.1	4.9	2.1	.9
12	05474000	Skunk River at Augusta, IA	11,200	bfs, int	87.1	2.9	7.7	1.8	.5
a	05420720	East Fork Wapsipinicon River near Tripoli, IA	370	syn	90.4	1.3	5.0	3.0	.2
b	05420900	Little Wapsipinicon River at Littleton, IA	380	syn	89.0	2.3	7.4	1.1	.2
c	05421700	Buffalo Creek near Stone City, IA	600	syn	90.1	2.2	6.6	1.6	.2
d	05421870	Mud Creek near Donahue, IA	310	syn	94.7	2.2	2.8	.2	<.1
e	05449200	East Branch Iowa River at Belmond, IA	500	syn	95.4	1.8	1.5	.9	.3
f	05452020	Salt Creek at Belle Plaine, IA	560	syn	93.0	2.4	3.6	1.0	.1
g	05455500	English River near Kalona, IA	1,500	syn	91.2	2.5	4.7	1.3	.2
h	05456510	Turtle Creek at Austin, MN	400	syn	90.7	1.9	3.4	1.7	2.2
i	05457950	Little Cedar River near Floyd, IA	610	syn	93.4	1.3	3.4	1.5	.2
j	05458870	Maynes Creek near Kelsey, IA	350	syn	95.0	1.1	3.0	.7	.1
k	05459300	Winnebago River near Fertile, IA	760	syn	91.4	2.0	2.6	3.3	.7
l	05462770	Beaver Creek near Parkersburg, IA	370	syn	95.5	1.4	2.3	.7	.1
m	05463510	Black Hawk Creek at Waterloo, IA	850	syn	95.4	2.0	1.4	1.0	.1
n	05465310	Long Creek near Columbus Junction, IA	400	syn	90.8	2.3	6.3	.6	.1
o	05469980	South Skunk River near Story City, IA	570	syn	94.0	3.1	1.9	.6	.4
p	05471120	East Branch Indian Creek near Iowa Center, IA	330	syn	93.6	2.2	3.3	.7	.2
q	05473060	Crooked Creek at Coppock, IA	740	syn	90.5	2.4	6.2	.7	.1
r	05473400	Cedar Creek near Oakland Mills, IA	1,400	syn	85.4	2.2	10.0	2.2	.2
s	05473550	Big Creek near Lowell, IA	420	syn	87.2	3.3	8.2	1.2	.1

[1]Site type: bfs, basic-fixed site, sampled monthly; ind, indicator site representing drainage basins of 320 to 1,080 square kilometers; int, integrator site representing drainage basins of 6,050 to 32,400 square kilometers; intens, intensive site sampled weekly in spring and early summer 1997 and biweekly at end of summer 1997; syn, synoptic site.

[2]Cedar River at Gilbertville was discontinued as a basic-fixed site in March 1997.

[3]Land-use data from Hitt, 1994.

Sample Collection and Chemical Analysis

A complete discussion of the collection and processing of surface-water samples is described in Shelton (1994). All surface-water samples were obtained by collecting depth-integrated subsamples at equally spaced vertical sections across the stream (Ward and Harr, 1990) to integrate water-quality differences within the stream. Samples for analysis of organic carbon were collected using a single-point depth-integrated sampler. At each surface-water-quality sampling site, a minimum of 10 equally spaced, depth-integrated water samples were collected using cable-mounted or hand-held samplers (Shelton, 1994). During ice conditions, samples were collected from at least three equal-width vertical sections. Laboratory analysis for nutrients, suspended sediment, and organic carbon was done using methods described by Fishman (1993) and Guy (1969).

Streamflow discharge was obtained from instantaneous discharge measurements or from discharge records obtained from continuous-recording gaging stations located at each of the sites. Measurements of specific conductance, pH, water temperature, and dissolved oxygen were made at equal-width increments across the stream cross section. The median value for each was recorded as the field-determined value.

Quality Assurance and Quality Control

The NAWQA quality-control design is described in detail by Mueller and others (1997). Equipment-blank samples of deionized water certified to be free of organic compounds and inorganic compounds were passed through all sampling equipment during February or March for each year of the sampling to verify initial cleanliness. About 13 percent of the total samples collected for the EIWA study were used for quality assurance (field-blank and replicate samples).

A field-blank sample is a specific type of blank sample used to demonstrate that: (1) equipment has been adequately cleaned to remove contamination introduced by previous use; (2) sample collection and processing have not resulted in contamination; and (3) sample handling, transport, and laboratory analysis have not introduced contamination (Mueller, 1998). The same type of deionized water that was used for equipment-blank samples was used for field-blank samples collected by passing the deionized water through all pumps, filter plates, and filters to verify cleanliness of sampling equipment.

The objective of collecting replicate samples was to estimate the precision of concentration values from sample processing and analysis. Laboratory analyses of organic constituents generally are more variable than analyses of inorganic constituents. Each replicate sample is an aliquot of the environmental water sample processed through the cone splitter, passed through the same sample equipment, and processed in the same manner.

Table 2 summarizes quality-assurance data for field-blank and replicate samples. Field-blank sample concentrations for nitrogen and phosphorus constituents were typically equivalent to the minimum reporting limit (MRL) or within a few hundredths of a milligram per liter of the MRL. This indicates that there was very little, if any, cross contamination of samples from sampling equipment. Low levels of DOC were detected in all 15 blank samples. Low-level contamination from DOC may have originated from methanol that was used in the sampling and decontamination for pesticides, from ineffective decontamination of sampling equipment between samples, or from laboratory grade blank water that contained some organic compounds. SOC was detected in 71 percent of samples, but the concentrations were close to the MRL.

Replicate samples were compared to the environmental samples by calculating relative percentage differences (RPD). In general, replicate concentrations for all constituents were generally within 10 percent of the environmental sample. RPD between replicate concentrations was calculated by using the following equation:

$$RPD = \left|S_1 - S_2\right| / \left(S_1 + S_2 / 2\right) \times 10, \qquad (1)$$

where

S_1 is the concentration from the environmental sample; and

S_2 is the concentration from the replicate sample.

Table 2. Summary of field-blank and replicate-sample quality-assurance data for nitrogen, phosphorus, suspended sediment, and organic carbon in the Eastern Iowa Basins study unit, March 1996–September 1998

[MRL, minimum reporting limit; mg/L, milligrams per liter; N, nitrogen; P, phosphorus; RPD, relative percentage difference; <, less than; --, no data]

Constituent	MRL	Number of blank samples	Maximum concentration (mg/L)	Median concentration (mg/L)	Number of blank samples with concentrations greater than MRL	Number of replicate samples	Median RPD	Number of replicate samples with greater than 10 percent RPD
Ammonia (as N), dissolved	[1]0.015	11	0.03	<0.02	4	31	1.7	7
Ammonia (as N) plus organic nitrogen, total	.1	11	<.10	<.10	0	31	4.5	7
Ammonia (as N) plus organic nitrogen, dissolved	.1	11	<.10	<.10	0	31	2.9	7
Nitrite (as N), dissolved	.01	11	.02	<.01	2	31	4.5	10
Nitrite plus nitrate (as N), dissolved	.05	11	.08	.06	6	31	1.5	1
Phosphorus (as P), total	.01	11	.03	<.01	1	31	4.9	8
Orthophosphate (as P), dissolved	.01	11	.02	<.01	3	31	1.3	7
Phosphorus (as P), dissolved	.01	11	.02	<.01	1	31	7.1	13
Suspended sediment	.1	--	--	--	--	21	4.9	8
Organic carbon, dissolved	.1	15	2.1	.4	15	23	1.9	10
Organic carbon, suspended	.1	14	.30	.1	10	23	8.2	6

[1]The MRL for dissolved ammonia was increased to 0.02 mg/L in November 1997.

The median RPD for nitrogen, phosphorus, suspended sediment, DOC, and SOC ranged from 1.3 to 8.2 percent. The number of replicate samples for each constituent with RPDs greater than 10 percent is listed in table 2. When comparing the small concentrations and the slight differences between some replicate samples, the RPDs can be relatively large, which is the case for the majority of the RPDs that are greater than 10 percent.

Statistics

Water-quality data were analyzed by a variety of graphical and statistical methods. Quality-assurance data such as replicate samples were removed from the data set before statistical analysis to avoid biasing the data. If a constituent was reported as a less than value, the value was set to one-half of the detection limit for that constituent. For example, if a dissolved nitrate concentration was reported as less than 0.1 mg/L, it would be set to 0.05 mg/L for statistical calculations. The Statistical Analysis System (SAS) software package was used to calculate summary statistics such as mean, median, minimum and maximum concentrations, and quartiles (Statistical Analysis System, 1990). In addition, boxplots were used to show the central tendency and variability of data. In a boxplot diagram, a box is drawn from the 25th to the 75th percentile concentrations, and the median is drawn as a horizontal line in the box. Vertical lines are extended beyond the box to data values less than or equal to 1.5 times the interquartile ranges outside the quartile. In addition, data values are marked as outliers with asterisks and circles for values beyond the vertical lines.

Nonparametric statistics were used because the water-quality data were not normally distributed. Statistical analysis for Spearman’s rank correlation, the Wilcoxon rank-sum test, the Kruskal-Wallis test, and analysis of variance test (on the ranks) were used for comparison of water-quality data (probability less than or equal to 0.05 was used to indicate statistical significance) among sites (Statistical Analysis System, 1990). The null hypothesis of no relation between variables was rejected if the probability of obtaining the correlation by chance was less than or equal to 0.05. In addition, only samples that were collected during the first week of the month from each site were used in the nonparametric analyses. To avoid bias and to have similar sample size for comparison, samples that were collected at specific sites weekly and biweekly were removed from data sets when running the Wilcoxon rank-sum, Krustal-Wallis test, and analysis of variance test.

Relation of Constituent Concentration and Streamflow

Schnoebelen and others (1999) plotted historical concentration and streamflow for many of the EIWA sampling sites by using data collected from 1970 through 1995. Data from the present study (1996–98) appends historical concentration and streamflow data compiled for the Iowa River at Wapello (site 11, fig. 1) illustrated in Schnoebelen and others (1999). That site was a sampling site common to both studies.

To improve visualization of nonlinear relations in the concentration and streamflow data, LOWESS (locally weighted scatterplot smoothing) lines (Cleveland, 1979; Helsel and Hirsch, 1992) were calculated and plotted for nitrite plus nitrate and total phosphorus. The LOWESS lines illustrate relations between concentrations and streamflow that are difficult to discern in a typical scatterplot. The LOWESS line is computed by fitting a weighted least-squares equation to the concentration and streamflow data (Helsel and Hirsch, 1992, p. 288–291). The “smoothing” used to calculate the LOWESS line is a particularly useful technique because no assumptions about linearity of the data are required. The smoothing algorithm uses nearby data points to calculate a “smoothed value” for every data point. Each nearby data point is weighted so that the more distant points affect the smoothed value less than points that are closer. A line then is drawn through the smoothed values. The number of nearby points used to calculate a smoothed value is controlled by the smoothness factor. A smoothness factor of 0.5 was used for all LOWESS trend lines in this report. This means that the closest 50 percent of all the data points were used to calculate each smoothed value.

Hydrograph Separation

Sources of streamflow at the time of sampling were estimated by separating streamflow hydrographs into their base-flow and surface-water-runoff components using the USGS program HYSEP (Sloto and Crouse, 1996) and the Base-Flow Indicator (BFI) program (Wahl and Wahl, 1995). The data were used for comparisons of base flow for the low base-flow and high base-flow synoptic studies.

Load Calculations

The 1996–98 annual loads for total nitrogen (dissolved nitrite plus nitrate plus total ammonia plus organic nitrogen) and total phosphorus were estimated for each sampling site by using a minimum variance unbiased estimator (Cohn and others, 1989). The Fortran program ESTIMATOR (Cohn and others, 1989) uses daily mean discharge and periodic nitrogen and phosphorus concentrations to estimate the annual and monthly loads for a site. The following equation was applied to the estimation of loads for each site:

$$\begin{aligned} 1\text{n}\ (N) = {} & B_0 + B_1\ 1\text{n}(Q) + B_2\ 1\text{n}(Q)^2 + B_3 T \\ & + B_4 T^2 + B_5 \sin(2\pi T) + B_6 \cos(2\pi T) + \varepsilon \end{aligned} \tag{2}$$

where

N = estimated load, in kilograms per day;

B_0, B_1, B_2, B_3, B_4, B_5, B_6 = regression coefficients;

Q = daily mean stream discharge, in cubic feet per second;

T = time, in decimal years; and

ε = error term.

The same regressors for load calculations were used for each site for consistency between sites and with other national studies (Donald Goolsby, U.S. Geological Survey, oral commun., 1998) within the Mississippi River Basin. The squares of the multiple correlation coefficient (R^2) and the plots of residuals were used to determine which regression equation had the best fit for the load model. The nearer that R^2 is to 1, the better the fitted equation explains the variation in the data. Water-quality data from January 1996 through December 1998 were used in the model calibration. The data set consisted of at least one water-quality sample per month at each site, with the exception of January and February 1996 and October through December 1998 when no water-quality data were collected for any of the sites. Water-sample collection occurred on a monthly basis including high-flow event samples that covered a wide range of streamflow and seasonal concentrations. In addition, the 3 years of the study included a below-normal year, a normal year, and an above-normal year for runoff. Thus, the sampling covered a wide range of streamflow, runoff, and seasonal conditions that adequately represented the study unit.

To run ESTIMATOR, daily mean discharges (for each day of the month) for the complete water year must be entered into the model. The South Fork Iowa River near New Providence (site 4), Flood Creek near Powersville (site 7), and Wolf Creek near Dysart (site 9) were established in late October of 1995 and thus did not have daily mean discharge records for the early part of October 1995. The Wapsipinicon River near Tripoli (site 1) was not established until the middle of April 1996 and did not have daily mean discharge from October 1995 to the middle of April 1996. Because 1997 was a normal runoff year for most of the study unit, 1997 daily mean discharge data were used for South Fork Iowa River near New Providence, Flood Creek near Powersville, Wolf Creek near Dysart, and Wapsipinicon River near Tripoli where these sites had missing daily mean discharge data in water year 1996. Water year 1996 was a below-normal year for runoff in the study unit, so the 1996 loads for the four sites (South Fork Iowa River near New Providence, Flood Creek near Powersville, Wolf Creek near Dysart, and Wapsipinicon River near Tripoli) probably are biased high during the winter months and for total load estimates for water year 1996. However, when running the model, the time period that had water-quality data (March 1996 through September 1998) was used for calibration. The use of the 1997 daily mean discharge data for these four sites probably had only a minimal effect on the overall constituent loads in the drainage basins because the data represented a low-flow period.

The 1996–98 annual loads for suspended sediment were estimated for the Wapsipinicon River near Dewitt (site 2), Iowa River at Wapello (site 11), and the Skunk River at Augusta (site 12) using the program SEDCALC (Koltun and others, 1994). USGS and U.S. Army Corps of Engineers observers at these three sites collected daily suspended-sediment samples. SEDCALC load estimates (calendar year) for the Iowa River at Wapello (site 11) and Skunk River at Augusta (site 12) were obtained from May and others (1996, 1997, 1998) and Nalley and others (1999). Suspended-sediment data for the Wapsipinicon River near Dewitt (site 2) were obtained from the U.S. Army Corps of Engineers and calculated using the SEDCALC program.

The determination of daily sediment concentrations and daily loads was accomplished by first plotting the instantaneous sediment concentrations and discharge daily unit values. A curve was developed between points, mainly by straight-line interpolation, with additional points added to better define breaks in the concentration curve. SEDCALC calculates an equal-interval sediment discharge using the following equation:

$$Q_s = Q_w C k \tag{3}$$

where

Q_s = instantaneous suspended-sediment discharge, in tons per day;

Q_w = instantaneous stream discharge, in cubic feet per second;

C = instantaneous suspended-sediment concentration, in milligrams per liter; and

k = a units conversion constant (0.0027).

After equal-interval sediment discharges have been computed, daily sediment discharges are determined by numerical integration. The integration is accomplished by summing the equal-interval instantaneous sediment discharges for the calendar day and dividing by the number of intervals per day. For this report, tons per year were converted to metric tons per year.

CONCENTRATIONS OF NITROGEN, PHOSPHORUS, SUSPENDED SEDIMENT, AND ORGANIC CARBON

Overall Occurrence of Concentrations

Four hundred and fifty-five samples were collected at 12 basic-fixed sites in the EIWA study unit from March 1996 through September 1998. Table 3 summarizes the statistical data for each constituent collected. Summary statistics for each basic-fixed site are given in the Appendix at the end of the report. Water-quality data collected in the EIWA study unit are published in data reports by Akers and others (1999, 2000). Nitrogen, phosphorus, and suspended-sediment concentrations are affected by many environmental and human factors such as climate, in-stream processes, soils, and proximity to sources, land use, and magnitude of runoff events. DOC concentrations in rivers vary with the size of the river, climate, and the nature of vegetation in the river basin (Thurman, 1985).

At least one form of dissolved nitrogen and phosphorus was detected in every sample. The frequency of detection of individual dissolved nitrogen compounds ranged from 65 to 98 percent. Dissolved phosphorus was detected in 90 percent of the samples collected. DOC and suspended sediment were detected in 100 percent of the samples collected. SOC was detected in 99.8 percent of the samples collected. The high percentage of detection for nitrogen and phosphorus in EIWA rivers and streams is not unexpected because there are many potential sources of these constituents.

Nitrogen

Nitrogen in the EIWA streams and rivers is present mainly as dissolved nitrate. About 92 percent of the median total dissolved nitrogen concentration was in the form of nitrate. Dissolved ammonia concentrations ranged from less than 0.015 to 1.2 mg/L, with a median concentration of 0.03 mg/L. Dissolved nitrite concentrations ranged from less than 0.01 to 0.25 mg/L, with a median concentration of 0.04 mg/L. Nitrite plus nitrate concentrations ranged from less than 0.05 to 22 mg/L, with a median concentration

Table 3. Statistical summary of nitrogen, phosphorus, suspended-sediment, and organic-carbon concentrations in the Eastern Iowa Basins study unit, March 1996–September 1998

[mg/L; milligrams per liter; N, nitrogen; P, phosphorus; <, less than]

Constituent	Number of samples	Number of detections	Concentrations (mg/L)				
			Minimum	25th percentile	Median	75th percentile	Maximum
Ammonia (as N), dissolved	455	294	<0.015[4]	<0.02	0.03	0.09	1.2
Ammonia and organic nitrogen (as N), total	455	450	<.1	.6	1.1	1.7	7.5
Ammonia and organic nitrogen, dissolved	455	425	<.1	.3	.4	.6	3.1
Organic nitrogen (as N),[2] dissolved	455	425	<.1	.2	.36	.05	1.9
Nitrite (as N), dissolved	455	436	<.01	.04	.04	.06	.25
Nitrite plus nitrate (as N), dissolved	455	448	<.05	3.6	6.6	9.7	22.
Nitrate (as N),[1] dissolved	455	448	<.05	3.6	6.6	9.7	22.
Nitrogen (as N), total,[3] dissolved	455	455	.2	4.4	7.2	10.	22.
Phosphorus (as P), dissolved	455	409	<.01	.04	.08	.13	1.4
Orthophosphate (as P), dissolved	455	409	<.01	.03	.08	.13	1.3
Phosphorus (as P), total	455	455	.01	.1	.22	.34	3.4
Suspended sediment	454	454	.3	33	82	181	3,500
Organic carbon, dissolved	446	446	.8	2.8	3.5	4.4	44
Organic carbon, suspended	449	448	<.1	.8	1.6	4.2	17

[1]Dissolved nitrite plus nitrate minus dissolved nitrite.
[2]Dissolved ammonia and organic nitrogen minus dissolved ammonia.
[3]Dissolved nitrite plus nitrate plus dissolved ammonia and organic nitrogen.
[4]Dissolved ammonia minimum reporting level was increased to 0.02 mg/L in November 1997.

of 6.6 mg/L. About 22 percent (101 out of 455) of the nitrate samples collected exceeded the USEPA MCL of 10 mg/L for drinking water. Dissolved ammonia and organic-nitrogen concentrations ranged from less than 0.10 to 3.1 mg/L, with a median concentration of 0.4 mg/L. Dissolved organic-nitrogen concentrations ranged from less than 0.10 to 1.9 mg/L, with a median concentration of 0.36 mg/L. Total ammonia and organic-nitrogen concentrations ranged from less than 0.1 to 7.5 mg/L, with a median concentration of 1.1 mg/L. Total dissolved nitrogen concentrations ranged from 0.2 to 22 mg/L, with a median concentration of 7.2 mg/L.

Phosphorus and Sediment

Dissolved phosphorus concentrations ranged from less than 0.01 to 1.4 mg/L, with a median concentration of 0.08 mg/L. Dissolved orthophosphate concentrations ranged from less than 0.01 to 1.3 mg/L, with a median concentration of 0.08 mg/L. Total phosphorus concentrations ranged from 0.01 to 3.4 mg/L, with a median concentration of 0.22 mg/L. About 75 percent of the total phosphorus concentrations (341 out of 455 samples) exceeded the USEPA recommended concentration of 0.1 mg/L to prevent excessive growth of aquatic plants in water bodies (U.S. Environmental Protection Agency, 1986). Suspended-sediment concentrations ranged from less than 0.3 to 3,500 mg/L, with a median concentration of 82 mg/L.

Organic Carbon

Excluding water draining swamps and wetlands, the normal range in DOC concentrations for natural water is from about 2 to 15 mg/L, with a mean of about 4 to 6 mg/L (Degens, 1982). DOC concentrations in water draining swamps and wetlands range from about 5 to 60 mg/L, with a mean of 25 mg/L (Thurman, 1985). DOC concentrations in EIWA samples ranged from 0.8 to 44 mg/L, with a median concentration of 3.5 mg/L. The highest concentration of 44 mg/L occurred at Wolf Creek near Dysart (site 9) in May of 1997 during an increase in flow. SOC concentrations ranged from less than 0.1 to 17 mg/L, with a median concentration of 1.6 mg/L.

Relations Between Constituent Concentrations and Streamflow

Streamflow in the EIWA varied during the study with generally below-normal flows in 1996, normal flows in 1997 (with the exception of the Southern Iowa Drift Plain), and above-normal flows in 1998. The streamflows varied across the study unit with varying rainfall, as figure 4 shows. Figure 4 shows the historical monthly fiftieth percentile of long-term discharge and the 1996–98 streamflows from selected sites across the study unit. Iowa River near Rowan (site 3), which is located in the northwestern part of the study unit, and the Iowa River at Wapello (site 11), which is located in the southeastern part of the study unit, showed a similar pattern of rainfall and streamflow. The southern part of the study unit (Southern Iowa Drift Plain) was extremely dry in 1997 as figure 4 indicates. The timing of rainfall-runoff events and location of runoff events affects the concentrations and transport of constituents. In 1997, the southern part of the study unit received less runoff than the rest of the study unit, which is reflected in the constituent concentrations that are discussed later in this section.

Annual Variations

Concentrations of nitrogen and phosphorus compounds, suspended sediment, and organic carbon varied annually. Median concentrations of all nitrogen and phosphorus compounds, with the exception of dissolved ammonia, increased from 1996 to 1998. Figure 5 shows boxplots of yearly concentrations for total dissolved nitrogen, total phosphorus, suspended sediment, and DOC. The increases in concentrations follow the trend for overall increased streamflow from 1996 to 1998 for the study unit. Median total dissolved nitrogen concentrations increased from 4.7 mg/L in 1996 to 6.7 mg/L in 1997 and to 9.4 mg/L in 1998. Median total phosphorus concentrations increased from 0.18 mg/L in 1996 to 0.21 mg/L in 1997 and to 0.26 mg/L in 1998. Median suspended-sediment concentrations increased each year (62 mg/L in 1996, 71 mg/L in 1997, and 125 mg/L in 1998). Median DOC concentrations remained the same from 1996 to 1998 with a concentration of 3.5 mg/L. SOC did not follow the same trends as the other constituents. The median SOC concentration decreased from 1.90 mg/L in 1996 to 1.4 mg/L in 1997 and then increased to 2.0 mg/L in 1998.

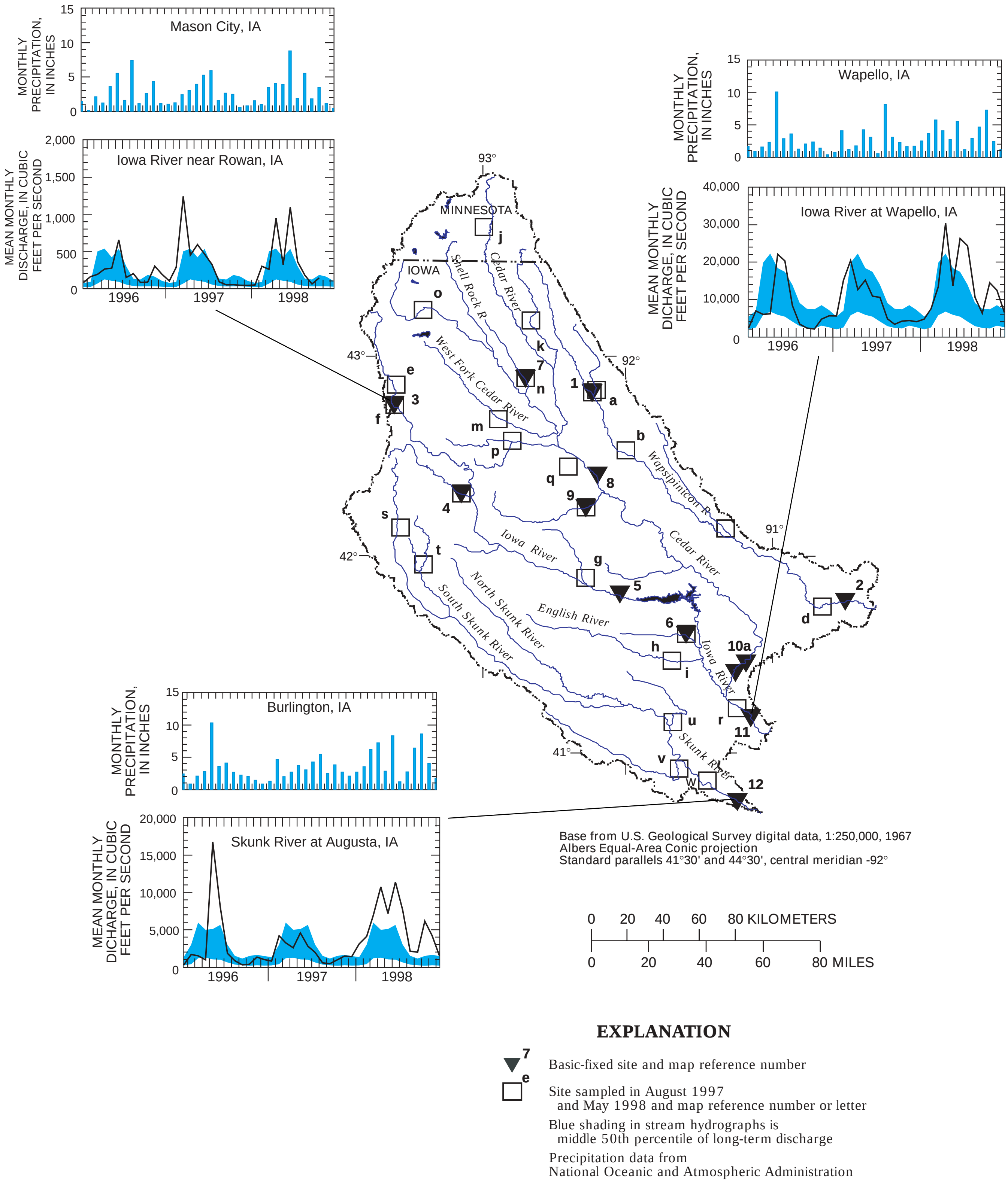


Figure 4. Graphs of precipitation and discharge at selected sites in the Eastern Iowa Basins study unit, 1996–98, and map showing site locations.

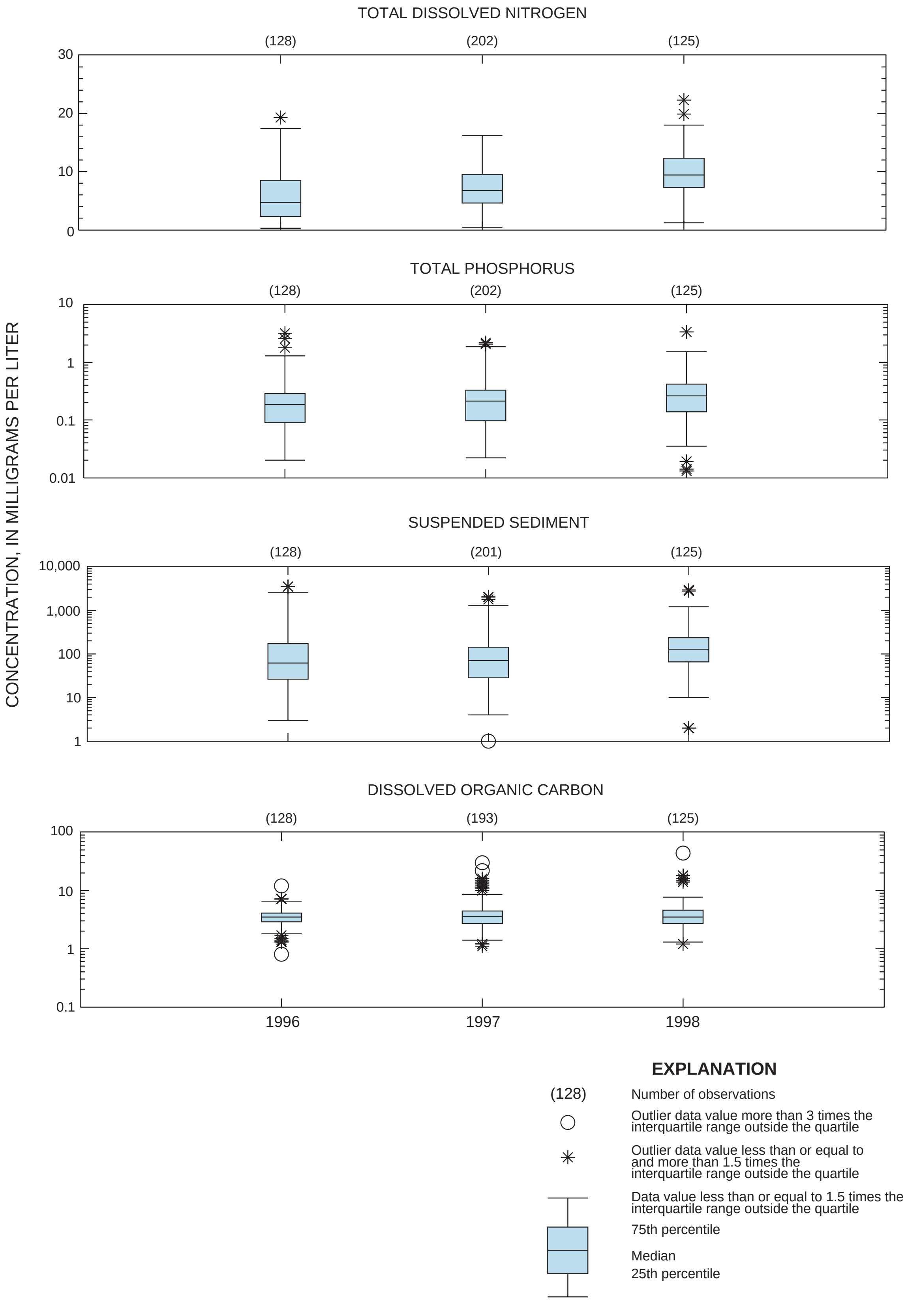


Figure 5. Yearly concentrations of selected constituents in surface-water samples in the Eastern Iowa Basins, 1996–98.

Seasonal Variations

Concentrations of nitrogen, phosphorus, suspended sediment, and organic carbon varied seasonally in surface-water samples from the EIWA. Boxplots of monthly concentrations for total dissolved nitrogen, total phosphorus, suspended sediment, and DOC are presented in figure 6. Median total dissolved nitrogen concentrations were highest during May (9.7 mg/L) and June (11.5 mg/L). The maximum total dissolved nitrogen concentration occurred in June (22 mg/L) in a sample from the South Fork Iowa River near New Providence (site 4). The median total dissolved nitrogen concentrations decreased from August (6.0 mg/L) to October (0.7 mg/L). The median total dissolved nitrogen concentration increased again in November (6.8 mg/L), December (7.6 mg/L), and January (7.8 mg/L), followed by a gradual decrease in February (6.7 mg/L) and March (5.4 mg/L).

Higher median concentrations of total dissolved nitrogen in the spring and early summer (April–June) probably result from the transport of nitrate accumulated in the soil after the application of chemical fertilizers and manure during the spring and previous autumn. The excess nitrate is transported to rivers and streams from spring snowmelt and rainfall events. In the late summer and early autumn (August–October), total dissolved nitrogen concentrations decrease because crops and other vegetation have utilized much of the fertilizer and because there is less runoff from rainfall to transport the nitrogen and phosphorus. During stable hydrologic conditions in the late summer, relatively low dissolved nitrogen and phosphorus concentrations have been measured in Iowa streams that contained substantial amounts of algae, as indicated by phytoplankton chlorophyll-*a* concentrations (Sorenson and others, 1999). Isenhart and Crumpton (1989) also reported significant losses of nitrate in a central Iowa stream from algal nitrogen assimilation during low-flow conditions during August.

During late autumn, fertilizers were applied to about 47 percent of the land used for row-crop production in the EIWA (Iowa Agricultural Statistics, 1996, 1997, 1998a). The percentage of row-crop acreage that received autumn fertilizer application increased from 31 percent in 1996 to 60 percent in 1998 (Iowa Agricultural Statistics, 1996, 1997, 1998a). The timing of chemical fertilizer and manure application with runoff events is important to the transport of nitrogen and phosphorus within the study unit. The total dissolved nitrogen concentrations increased during late autumn because crops and vegetation are not growing or using the nitrogen at that time, the rate of uptake by algal and aquatic plants decreases with the lower water temperature and shorter days, and ground water containing nitrogen is a significant component of streamflow during base-flow conditions. Dissolved nitrate concentrations in the study unit commonly exceeded the USEPA MCL of 10 mg/L for nitrate as nitrogen during high flows after spring fertilizer application and during low flows in the winter. The MCL refers to drinking-water supplies; and the Iowa Department of Natural Resources and the USEPA are currently developing nutrient criteria for Iowa streams (U.S. Environmental Protection Agency, 1998).

Median total phosphorus concentrations varied on a seasonal basis from 0.09 to 0.36 mg/L (fig. 6). Median total phosphorus concentrations were slightly higher during February (0.33 mg/L) and March (0.36 mg/L) than the rest of the year. In addition, the maximum concentration of total phosphorus was detected in March (3.4 mg/L) in a sample from Old Mans Creek near Iowa City (site 6). The lowest median concentration of total phosphorus was detected in December (0.09 mg/L). The higher total phosphorus concentrations during February and March may be related to increased runoff from snowmelt which transports sediment and phosphorus. In addition, manure that was applied to the frozen fields during the winter may be a source of the increased phosphorus during this time period.

Suspended-sediment concentrations followed the trend of precipitation and streamflow. During high runoff, suspended-sediment concentrations increased across the study unit. Median suspended-sediment concentrations were highest in May (132 mg/L), June (204 mg/L), and July (133 mg/L) when the most intense storm events usually occur. The maximum concentration of suspended sediment occurred in May (3,500 mg/L) in a sample from the Skunk River at Augusta (site 12). Median suspended-sediment concentrations were the lowest during January (17 mg/L) when the rivers and streams are ice covered and streamflow is mostly from ground water. Median suspended-sediment concentrations increased in March (106 mg/L) when there was increased precipitation and very little vegetation in the fields to hold sediment in place.

DOC had a similar seasonal pattern as total phosphorus. Median DOC concentrations varied on a seasonal basis from 2.7 to 5.0 mg/L (fig. 6).

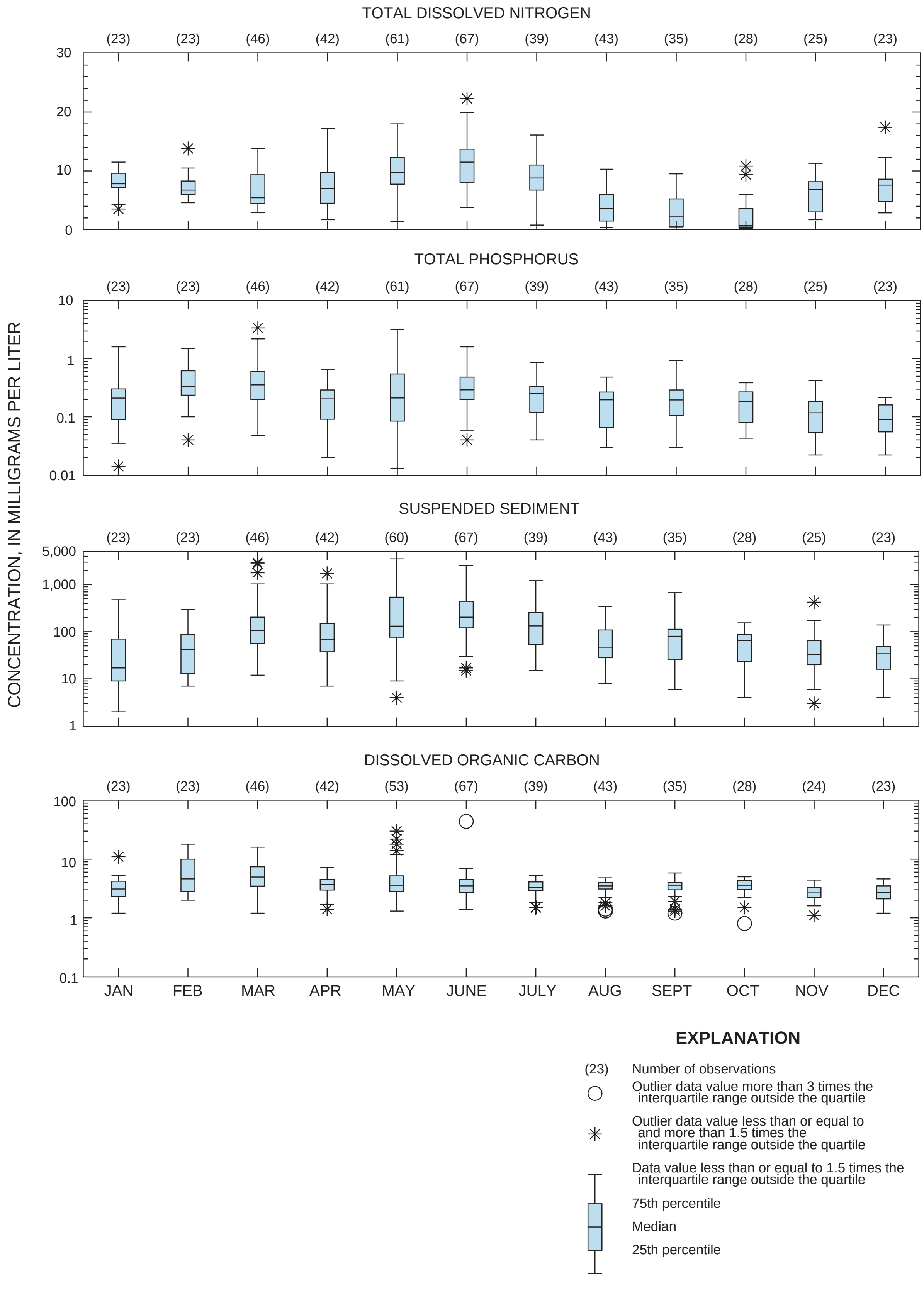


Figure 6. Monthly variability of selected constituents in surface-water samples in the Eastern Iowa Basins study unit, March 1996–September 1998.

Median DOC concentrations were highest during February (4.6 mg/L) and March (5.0 mg/L). The lowest median concentration of DOC was detected in December (2.7 mg/L). The higher median DOC concentrations in February and March may be due to decaying vegetation held in place over the winter and then released during snowmelt. Decaying crop residue and DOC originating from manure also may be a source of the higher median concentrations.

Nonpoint and Point Sources

Schnoebelen and others (1999) reported that, in general, nitrogen and phosphorus concentrations in surface-water samples from the EIWA study unit during 1970–95 were not linearly related to streamflow. Figure 7 shows the same relation in samples from the Iowa River at Wapello (site 11), which drains about 64 percent of the EIWA study unit. The concentrations of nutrients associated with nonpoint sources generally increased as streamflow increased because of runoff and(or) agricultural tile-drain flow, reflecting a positive relation between concentration and streamflow (fig. 7A). The increase in concentration occurred only up to a certain level beyond which concentrations then decreased with increasing streamflow. The decrease in concentration at the higher rates of streamflow is probably due to dilution of the nitrate once it has reached a maximum rate of release. These nonpoint relations are complex and are affected by antecedent soil conditions, timing of fertilizer application, land cover, and the location, duration, and intensity of precipitation.

The opposite effect typically is observed for point-source constituents. Concentrations of constituents associated with point-source locations tend to decrease in the stream due to dilution as streamflow increases, reflecting in a negative relation between concentration and streamflow. Rivers and stream point-source inputs often have higher concentrations at the lowest streamflows because point-source contaminants discharged to the stream can remain constant and are not diluted during periods of low streamflow. Schnoebelen and others (1999) reported a permitted point-source location upstream from the Iowa River at Wapello site. Figure 7B represents a typical LOWESS line of a point source of phosphorus during low-flow conditions.

Spatial Variability

Nitrogen

Median total dissolved nitrogen concentrations in samples from the indicator sites ranged from 6.3 to 10 mg/L (fig. 8). Median total dissolved nitrogen concentrations in samples from integrator sites ranged from 4.2 to 6.9 mg/L (fig. 8). The median total dissolved nitrogen concentration in samples from all of the integrator sites was 6.2 mg/L compared to 8.2 mg/L in samples from all the indicator sites. The lowest median concentration for total dissolved nitrogen of 4.2 mg/L was from the Cedar River at Gilbertville (site 8), which had only 1 year (1996) of data collection. Samples from the Cedar River near Conesville (site 10) had the lowest median concentration of 5.5 mg/L for the 3-year sampling period. Samples from the Cedar River near Conesville (site 10) had a lower median concentration of total dissolved nitrogen than the rest of the sites, perhaps due to its morphologic features. The Cedar River is wide and shallow compared to the Iowa River. Therefore, there is more surface area for light penetration to promote algal growth and more contact with bed material for denitrification in the Cedar River compared to the Iowa River. These differences support more in-stream processing of nutrients in the Cedar River.

Total dissolved nitrogen concentrations in samples from indicator sites South Fork Iowa River near New Providence (site 4), Flood Creek near Powersville (site 7), and Wolf Creek near Dysart (site 9) were significantly higher ($p < 0.05$, Kruskal-Wallis test) than in samples from the rest of the indicator and integrator sites, with the exception of the Iowa River near Rowan (site 3). The lower total dissolved nitrogen concentrations in samples from integrator sites relate to many factors, including the amount and type of riparian zones, the effects of in-stream processing by plants, and the amount of groundwater discharge.

There may be several reasons for the higher total dissolved nitrogen concentrations in samples from South Fork Iowa River near New Providence (site 4), Flood Creek near Powersville (site 7), and Wolf Creek near Dysart (site 9). All three of these sites have at least 80 percent of their total drainage basin areas used for row-crop agriculture. There

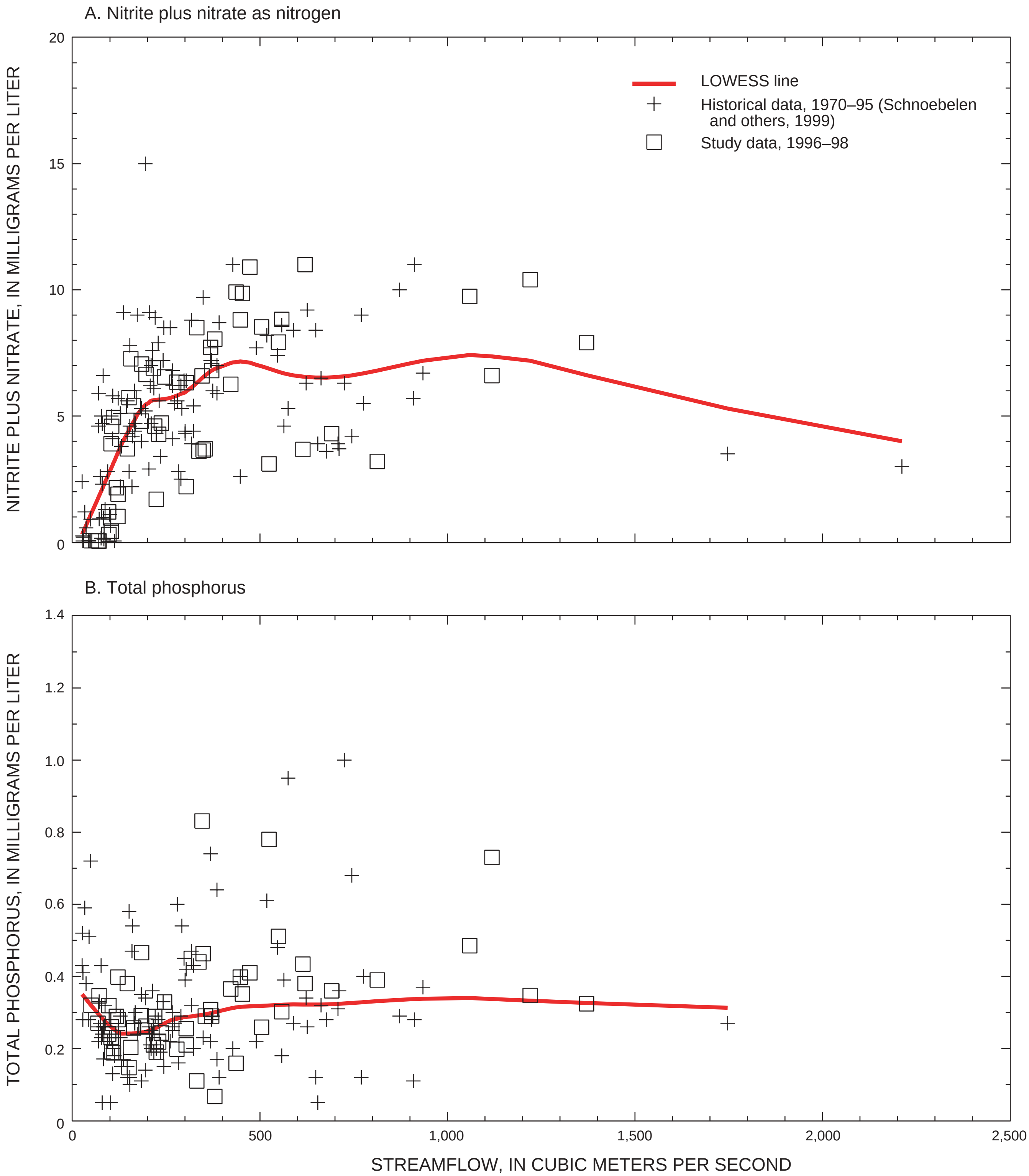
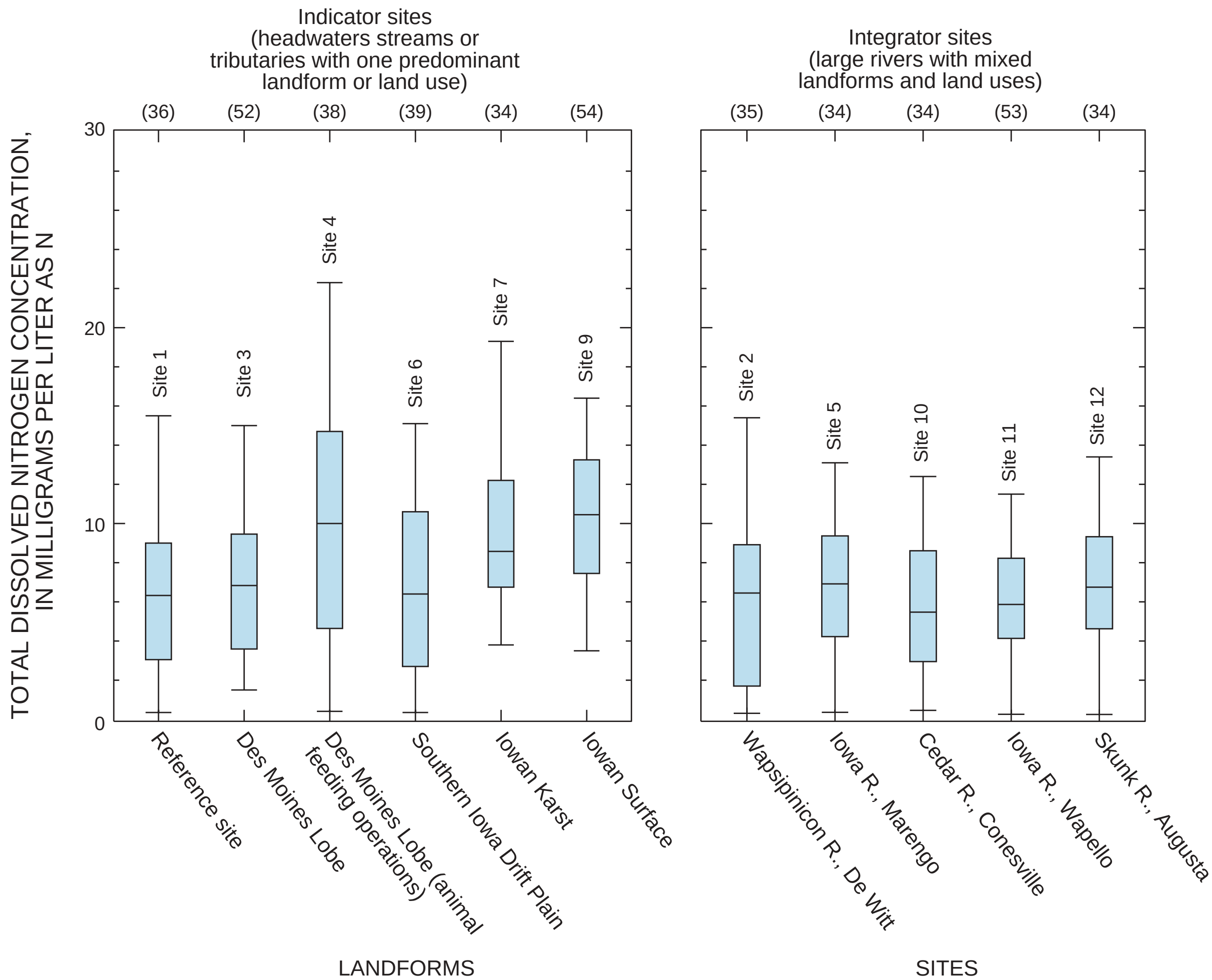


Figure 7. Relations between nitrite plus nitrate and total phosphorus concentrations and streamflow in the Iowa River at Wapello, Iowa (site 11), 1970–98.



EXPLANATION

(36) Number of observations

○ Outlier data value more than 3 times the interquartile range outside the quartile

✳ Outlier data value less than or equal to 3 and more than 1.5 times the interquartile range outside the quartile

Data value less than or equal to 1.5 times the interquartile range outside the quartile

75th percentile

Median

25th percentile

Figure 8. Total nitrogen concentrations for indicator and integrator sites in surface-water samples from the Eastern Iowa Basins study unit, March 1996–September 1998.

is a correlation between total dissolved nitrogen concentrations and row-crop agricultural practices as indicated in figure 9. However, the correlation coefficient (R^2) of 0.59 suggests other factors also affect the water quality at these sites.

Another explanation for higher total dissolved nitrogen concentrations in samples from the South Fork Iowa River near New Providence (site 4) may be that the sampling site is located in an area of intense hog production (site 4, fig. 3). Since 1987, approximately 23 large-scale hog facilities have been permitted in this drainage basin (Iowa Department of Natural Resources, 1998). Also, the South Fork Iowa River has significantly higher ($p < 0.05$, Kruskal-Wallis test) total nitrogen concentrations than the Iowa River near Rowan, which is located in the same physiographic region (Des Moines Lobe) and has similar row-crop percentages. By comparison with Iowa River near Rowan, the combination of row-crop agriculture and large-scale animal feeding operations might explain the water-quality variations within the South Fork Iowa River Basin.

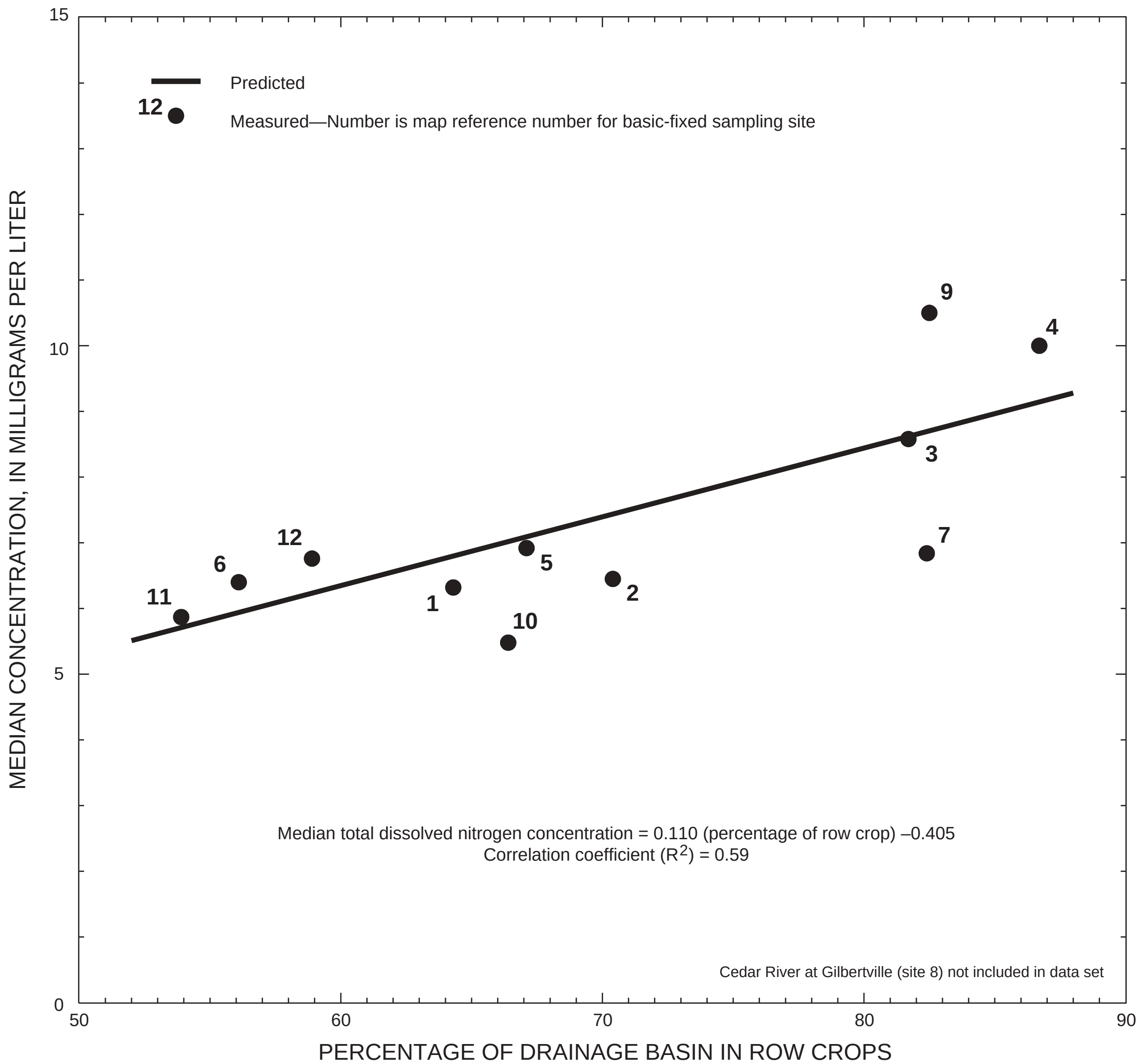


Figure 9. Relation between median total dissolved nitrogen concentrations and percentage of drainage basin in row crops in the Eastern Iowa Basins study unit.

The higher total dissolved nitrogen concentrations observed in samples from Flood Creek near Powersville (site 7, fig. 2) when compared to other sites may be due to differences in geology at the sites. Flood Creek is located in an area of karst landform where soil thickness is minimal compared to other sites. Karst landforms commonly can provide a rapid pathway for migration of water to the stream.

Wolf Creek near Dysart (site 9, fig. 2) had the second highest row-crop percentage and the highest median total dissolved nitrogen concentration. Concentrations of total dissolved nitrogen at Wolf Creek typically are higher than at most sites throughout the year. Even when concentrations decreased during late summer and autumn at other sites, Wolf Creek typically had high total dissolved nitrogen concentrations throughout the year. Initially, it was thought that Wolf Creek may have had some point-source discharge upstream from the sampling location, but a synoptic sampling of Wolf Creek and its tributaries for nitrate upstream from the sampling location proved to be inconclusive. The reason for the year-round high concentrations of total dissolved nitrogen is unknown.

Phosphorus and Sediment

Median total phosphorus concentrations in samples from indicator sites ranged from 0.07 to 0.2 mg/L (fig. 10). Median total phosphorus concentrations in samples from integrator sites ranged from 0.23 to 0.35 mg/L (fig. 10). The median total phosphorus concentration in samples from all of the integrator sites was 0.29 compared to 0.12 mg/L for samples from indicator sites. Samples from the Iowa River at Marengo (site 5) had the highest median total phosphorus concentration, 0.35 mg/L. Samples from the South Fork Iowa River near New Providence (site 4) had the lowest median total phosphorus concentration, 0.07 mg/L, but as the boxplot indicates in figure 10, South Fork Iowa River near New Providence had a wide range of total phosphorus concentrations.

Median total phosphorus concentrations were higher than 0.20 mg/L for samples from all integrator sites and typically were 0.20 mg/L or less for samples from all indicator sites. Nine of the 12 sampling sites had median total phosphorus concentrations exceeding the USEPA recommended level of 0.1 mg/L to prevent excessive growth of aquatic plants in water bodies (U.S. Environmental Protection Agency, 1986). Total phosphorus concentrations were significantly higher ($p < 0.05$, Kruskal-Wallis test) in samples from integrator sites than in samples from indicator sites. Total phosphorus concentrations in samples from the Iowa River at Marengo (site 5) and the Skunk River at Augusta (site 12) were significantly higher ($p < 0.05$) than in samples from the Wapsipinicon River near De Witt (site 2) and in samples from all of the indicator sites. The differences probably are related to physiographic features which include slope, soil erodibility, and point sources. The total phosphorus concentrations in samples from indicator sites at Iowa River near Rowan (site 3), Old Mans Creek near Iowa City (site 6), and Wolf Creek near Dysart (site 7) were significantly higher ($p < 0.05$) than samples from indicator sites Wapsipinicon River near Tripoli (site 1) and Flood Creek near Powersville (site 7).

Phosphorus commonly is strongly adsorbed to sediment. The higher median phosphorus concentrations in samples from integrator sites may be related to increased sediment transport. However, the correlation coefficient (R^2) was only 0.62 when total phosphorus concentrations were plotted against suspended-sediment concentrations in samples from integrator sites, which indicates that other factors also influence total phosphorus concentrations (fig. 11). In addition, the integrator sites represented drainage basins that typically had point-source inputs that may contribute additional phosphorus and which may explain some of the differences in total phosphorus concentration between samples from indicator and integrator sites.

Median suspended-sediment concentrations in samples from indicator sites ranged from 20 to 100 mg/L (fig. 12). Median suspended-sediment concentrations in samples from integrator sites ranged from 43 to 211 mg/L (fig. 12). Samples from the Iowa River at Marengo (site 5) had the highest median suspended-sediment concentration, 211 mg/L. The lowest median concentration of suspended sediment for the 1996–98 sampling period was 20 mg/L, in samples from the Wapsipinicon River at Tripoli (site 1).

Samples from the Iowa River at Marengo (site 5) and Skunk River at Augusta (site 12) were significantly higher ($p < 0.05$) in suspended-sediment concentrations than samples from the remaining sites, with the exception of the Iowa River at Wapello (site 11). About 75 percent of the Skunk River at

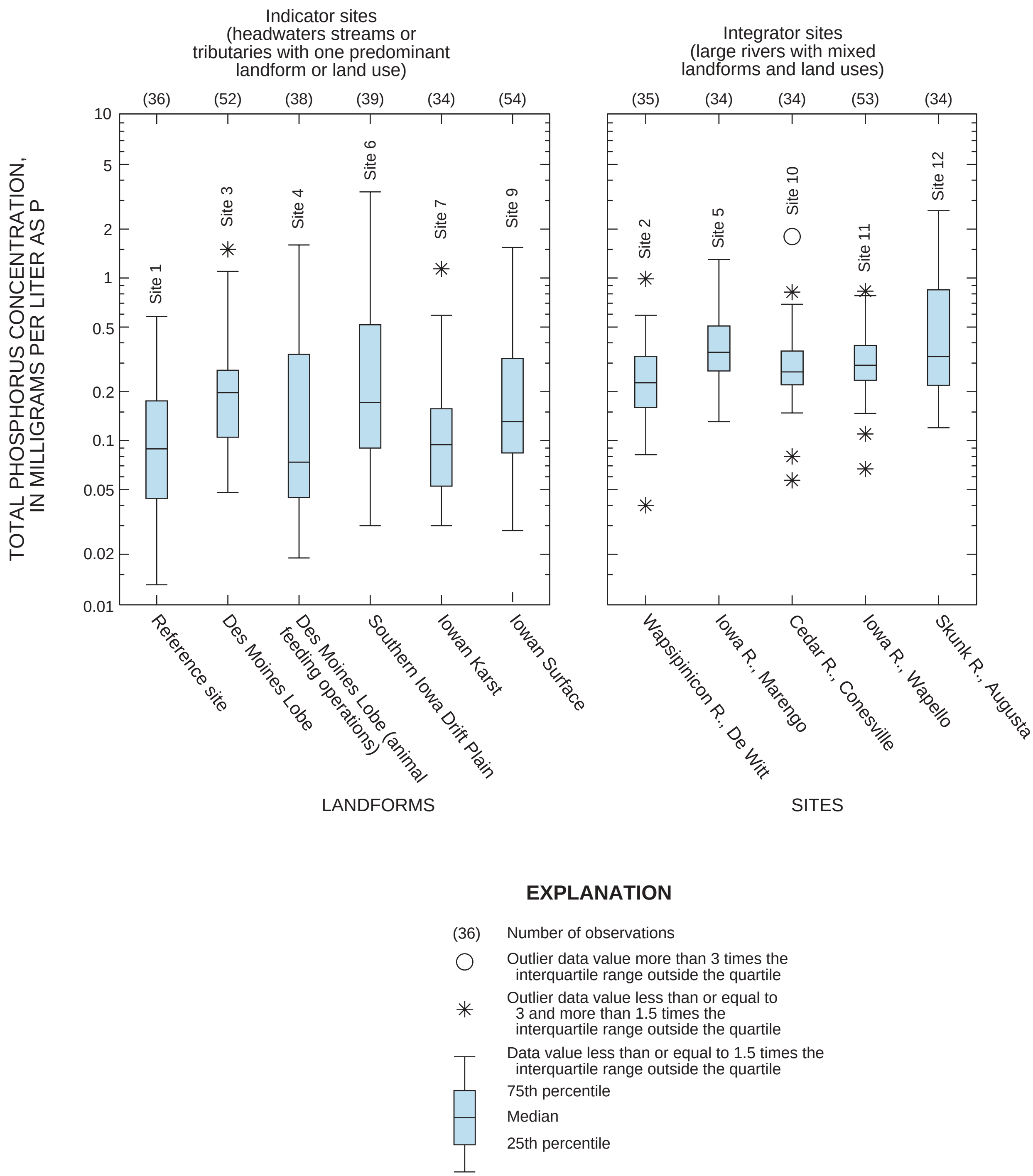


Figure 10. Total phosphorus concentrations for indicator and integrator sites in surface-water samples from the Eastern Iowa Basins study unit, March 1996–September 1998.

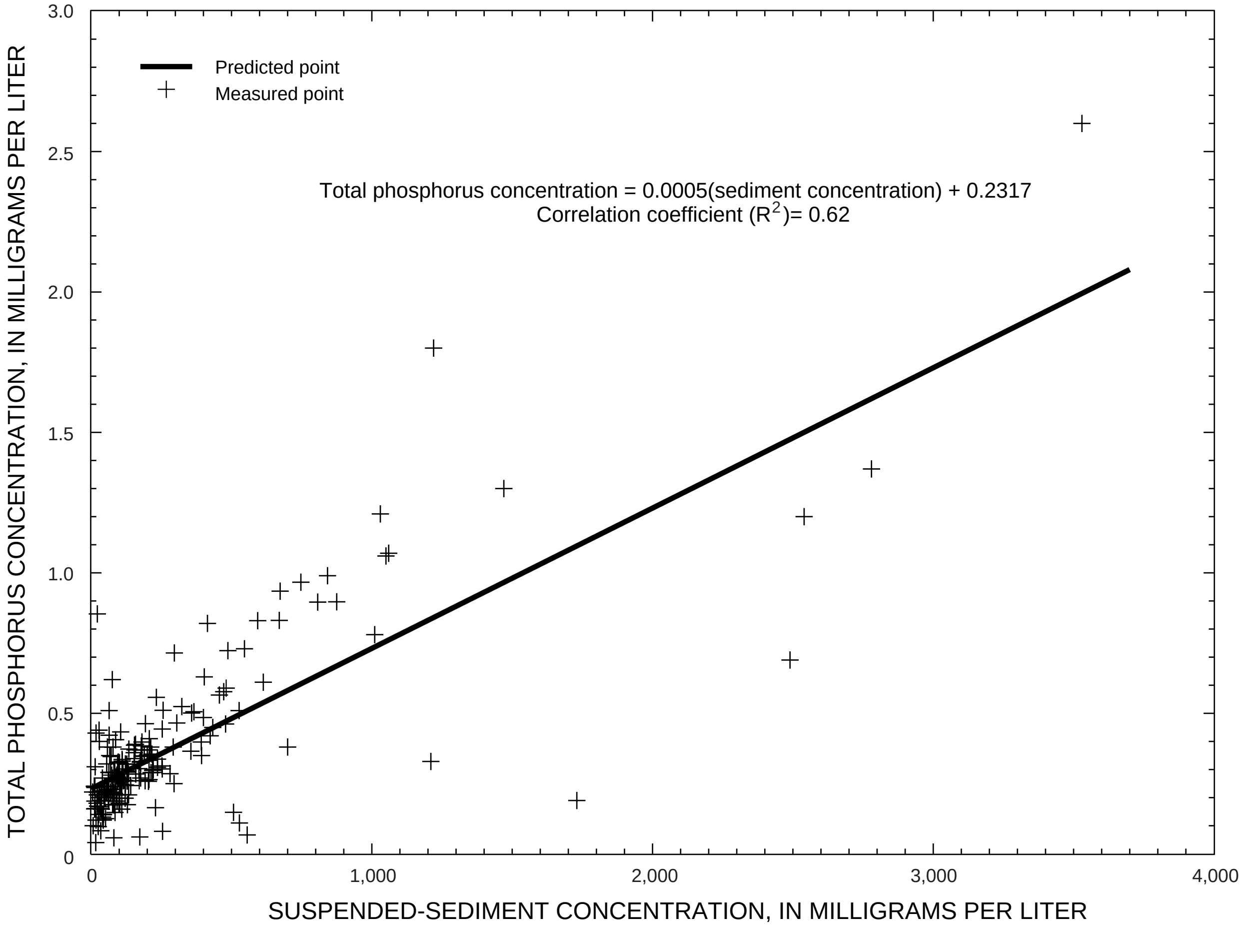


Figure 11. Relation between total phosphorus concentrations and suspended-sediment concentrations in surface-water samples from integrator sites in the Eastern Iowa Basins, March 1996–September 1998.

Augusta (site 12) drainage basin is located in the Southern Iowa Drift Plain, which has steeper slopes than the rest of the study unit and contains loess deposits that are easily eroded (Schwarz and Alexander, 1995). The Iowa River at Marengo (site 5) drainage basin is about 44 percent within the Des Moines Lobe, 37 percent within the Southern Iowa Drift Plain, and 18 percent within the Iowan Surface. Channelization upstream from Iowa River at Marengo (site 5) has caused increased channel aggradation (Eash, 1995). The channel aggradation may lead to more bank erosion, thus increasing sediment transport and increasing total phosphorus concentrations adsorbed to the sediment.

Suspended-sediment concentrations in samples from the Iowa River near Rowan (site 3) were significantly higher ($p < 0.05$) than concentrations in samples from all of the indicator sites and one integrator site, Cedar River near Conesville (site 10). It is unclear why samples from Iowa River near Rowan (site 3) had higher suspended-sediment concentrations than the rest of the indicator sites. The physical characteristics of the Iowa River near Rowan drainage basin do not suggest any characteristics that would cause higher suspended-sediment concentrations.

Suspended-sediment concentrations in samples from the Wapsipinicon River near Tripoli (site 1) were significantly lower ($p < 0.05$) than the rest of the sites in the EIWA study unit. The drainage basin represented by the Wapsipinicon River near Tripoli (site 1) has a lower percentage of row-crop agriculture (64 percent) and fewer channeled segments when compared to the rest of the study unit and contains a higher percentage of wetland and undisturbed flood plain than the rest of the drainage basins represented by the sampling sites in the study unit.

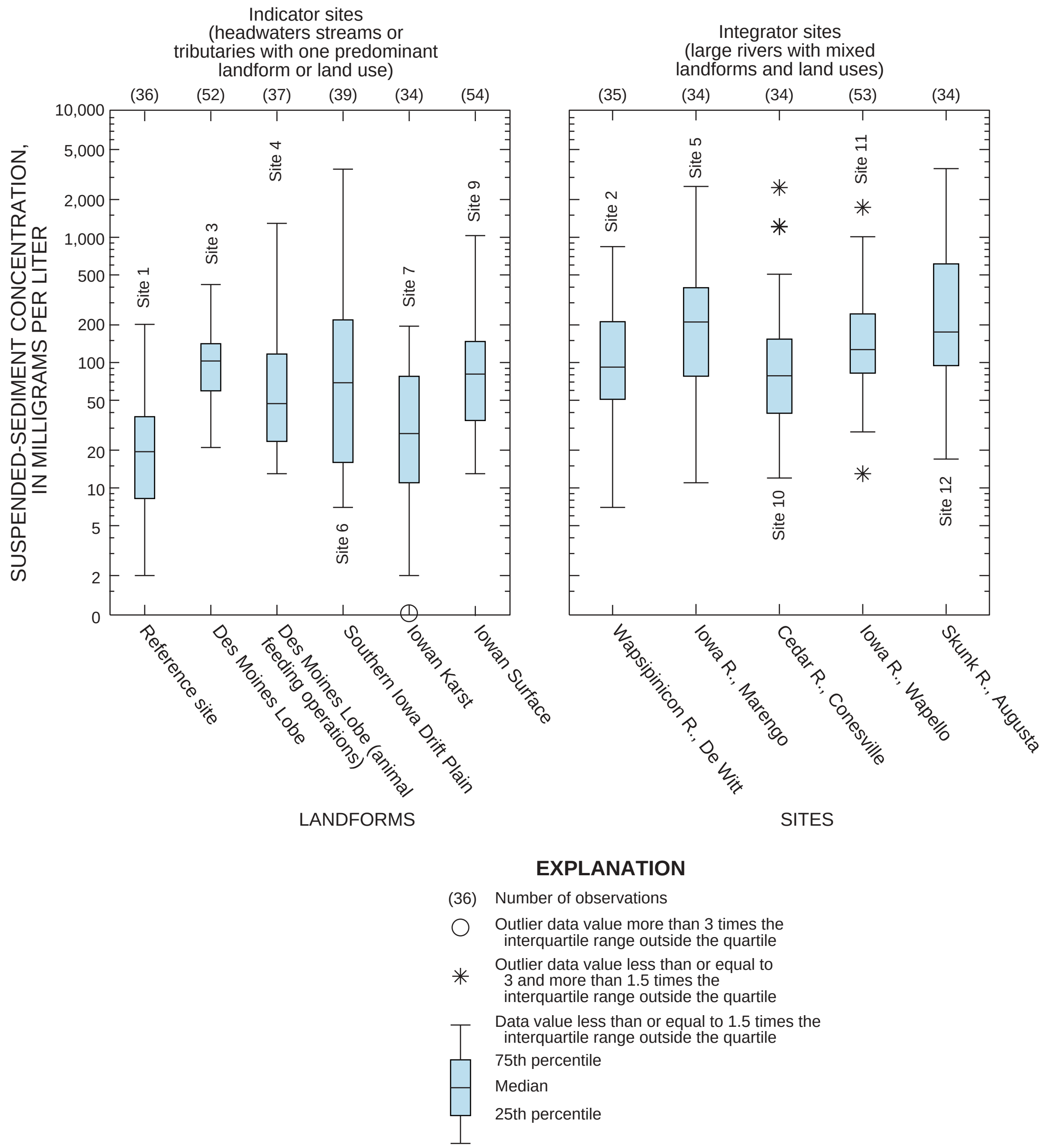


Figure 12. Suspended-sediment concentrations for indicator and integrator sites in surface-water samples from the Eastern Iowa Basins study unit, March 1996–September 1998.

Dissolved Organic Carbon

Median DOC concentration in samples from indicator sites ranged from 1.5 to 4.2 mg/L (fig. 13). Median DOC concentrations in samples from integrator sites ranged from 3.0 to 4.2 mg/L (fig. 13). The median DOC concentration in samples from all of the integrator sites was 3.6 mg/L compared to 3.5 mg/L in samples from indicator sites. The lowest median DOC concentration was 1.5 mg/L in samples from Flood Creek near Powersville (site 7). The highest DOC median concentration of 4.2 mg/L was detected in samples from the Iowa River near Rowan (site 3) and the Skunk River at Augusta (site 12).

DOC concentrations were significantly lower ($p < 0.05$) in samples from Flood Creek near Powersville (site 7) than in samples from all other basic-fixed sampling sites. This is probably due to the karst landform characterized by very thin soils. DOC concentrations were significantly higher ($p < 0.05$) in

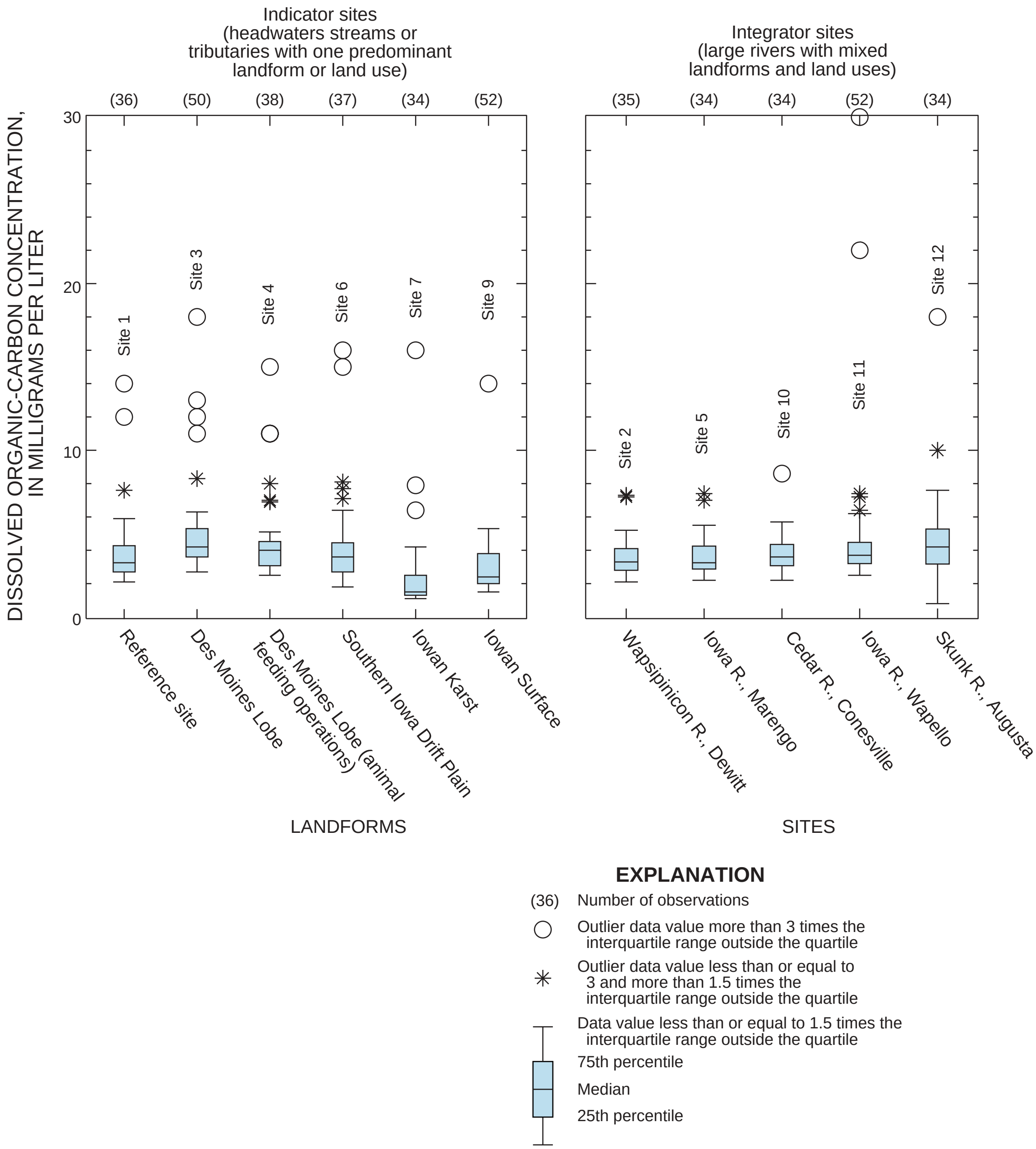


Figure 13. Dissolved organic-carbon concentrations for indicator and integrator sites in surface-water samples from the Eastern Iowa Basins study unit, March 1996–September 1998.

samples from the Iowa River near Rowan (site 3), the South Fork Iowa River near New Providence (site 4), and the Skunk River at Augusta (site 12) than in samples from most other sites. On the basis of STATSGO data (Schwarz and Alexander, 1995), the drainage basin represented by the Iowa River near Rowan (site 3) had soil samples with higher average soil organic-carbon concentrations (35 g/kg) than the rest of the drainage basins represented by sampling sites in the EIWA study unit. However, the drainage basin represented by the South Fork Iowa River near New Providence (site 4) had soil samples with the lowest average organic-carbon concentration of (4.2 g/kg), but still had surface-water samples with high DOC concentrations. The drainage basin represented by the Skunk River at Augusta (site 12) had soils with average organic-carbon concentrations of about 10 g/kg (Schwarz and Alexander, 1995).

TRANSPORT OF NITROGEN, PHOSPHORUS, AND SUSPENDED SEDIMENT

Loads

Load is the mass of a constituent passing through a stream transect per given unit of time. Loads for all of the nitrogen and phosphorus compounds were estimated for 1996–98 for 11 of the 12 (table 4) basic-fixed sites using a minimum variance unbiased estimator (ESTIMATOR; Cohn and others, 1989). For this report, only total nitrogen and total phosphorus are reported because they represent total loads for the main nutrient compounds of concern.

Annual and monthly loads were calculated for 11 basic-fixed sites. Cedar River at Gilbertville (site 8) had only 1 year of concentration data and no discharge data; therefore, loads were not calculated for this site. Values of the squares of multiple correlation coefficient (R^2) ranged from 0.91 to 0.97 for the total nitrogen model and ranged from 0.82 to 0.95 for the total phosphorus model. The equations with lower R^2 values may still provide satisfactory estimates of loads, even with a regression that does not have an ideal fit (Cohn and others, 1992). The calculated loads are strictly estimates used to characterize differences between drainage basins in the EIWA study unit and loads that are transported to the Mississippi River.

Iowa River at Wapello (site 11), which represents drainage from 64 percent of the study unit, had the highest estimated total nitrogen load for each year (1996, 57,600 metric tons; 1997, 75,100 metric tons; 1998, 154,000 metric tons) and the highest estimated total phosphorus load in 1997 (3,120 metric tons). Skunk River at Augusta (site 12) had the highest estimated total phosphorus loads in 1996 and 1998 (3,960 and 4,140 metric tons, respectively). The highest total nitrogen load at an indicator site was in 1998 at Wolf Creek near Dysart (site 9) (4,780 metric tons). Old Mans Creek near Iowa City (site 6) had the highest total phosphorus load at an indicator site in 1996 with a load of 390 metric tons. During 1996, a large spring runoff event occurred that transported large loads of total phosphorus from this watershed.

Total nitrogen loads typically increased every year for each site during the study period with only a few exceptions (Old Mans Creek and Skunk River in 1997), which were probably related to less runoff. The Iowa River at Wapello (site 11) includes flow and nutrient loads from both the Cedar and Iowa River Basins because the rivers join about 16 km upstream from Wapello. The Cedar River contributes the higher percentage of the total nitrogen load between the two rivers, possibly due to its larger drainage area. The Iowa River upstream from the confluence with the Cedar River contributed an estimated 44 percent (25,700 metric tons) in 1996, 30 percent (22,900 metric tons) in 1997, and 37 percent (57,000 metric tons) in 1998 of the total nitrogen load estimated at the Iowa River at Wapello. Total phosphorus loads did not increase each year for every site listed in table 4 and were more variable with runoff events that moved large sediment loads.

Estimated total nitrogen and total phosphorus loads varied seasonally both at indicator sites and integrator sites (figs. 14 and 15). Estimated loads for total nitrogen and total phosphorus at the 11 basic-fixed sites listed in table 4 followed a similar seasonal trend as did concentrations. The highest loads typically occurred in early spring and summer after fertilizer applications and runoff. Estimated loads began to decrease in the late summer and autumn as the available nitrogen and phosphorus were processed by plants as less runoff was available to transport the nitrogen and phosphorus. The loads then increased again in late autumn and early winter after autumn application of fertilizer and lack of processing due to vegetation die-off and dormancy. Total estimated monthly loads were lowest in January and September when there is typically very little runoff to transport nitrogen and phosphorus in the soil to streams and rivers. Loads increased in February when snowmelt transported nitrogen and phosphorus to rivers and streams. Some of the sites had higher total estimated loads in the autumn of 1998 than in the spring of 1998. The autumn of 1998 was relatively wet and had higher nitrogen and phosphorus concentrations than in 1996 and 1997.

The three major basins draining eastern Iowa and southeastern Minnesota (Wapsipinicon River, Iowa River [includes the Cedar River], and Skunk River) contributed an estimated total of 97,600 metric tons of nitrogen and 6,860 metric tons of phosphorus to the Mississippi River in 1996. Estimated loads of total nitrogen and total phosphorus transported into the Mississippi River in 1996 represent about 19 percent of the estimated sources of nitrogen and 9 percent of the estimated sources of phosphorus (Becher and others, 2000). However, these estimations of sources

Table 4. Estimated total nitrogen and total phosphorus loads and yields for streams in the Eastern Iowa Basins study unit, 1996–98

[kg/km^2, kilograms per square kilometer]

Site name (map reference number)	Year	Total nitrogen		Total phosphorus	
		Load (metric tons)	Yield (kg/km^2)	Load (metric tons)	Yield (kg/km^2)
Wapsipinicon River near Tripoli (1)	1996	2,040	2,260	66	73
	1997	2,830	3,150	63	70
	1998	3,570	3,960	85	95
Wapsipinicon River near De Witt (2)	1996	9,990	1,650	540	89
	1997	21,700	3,580	440	73
	1998	31,100	5,120	760	130
Iowa River near Rowan (3)	1996	1,490	1,380	44	41
	1997	2,210	2,050	96	88
	1998	3,150	2,920	140	130
South Fork Iowa River near New Providence (4)	1996	1,040	1,890	39	68
	1997	2,000	3,440	100	180
	1998	3,790	6,540	240	420
Iowa River at Marengo (5)	1996	11,900	1,650	760	100
	1997	19,300	2,670	720	100
	1998	35,500	4,900	1,140	160
Old Mans Creek near Iowa City (6)	1996	1,600	3,080	390	750
	1997	920	1,780	150	280
	1998	3,170	6,100	170	320
Flood Creek near Powersville (7)	1996	240	760	2.2	7
	1997	610	1,910	20	62
	1998	1,510	4,730	12	36
Wolf Creek near Dysart (9)	1996	1,050	1,360	26	33
	1997	1,920	2,490	47	62
	1998	4,780	6,200	180	230
Cedar River near Conesville (10)	1996	31,900	1,580	1,560	77
	1997	52,200	2,580	1,860	92
	1998	97,000	4,800	2,470	120
Iowa River at Wapello (11)	1996	57,600	1,650	2,360	73
	1997	75,100	2,320	3,120	96
	1998	154,000	4,740	3,930	120
Skunk River at Augusta (12)	1996	30,000	2,680	3,960	350
	1997	23,500	2,100	990	89
	1998	49,400	4,410	4,140	370

did not include estimation of a mass balance of inputs and outputs within the basins. Soil mineralization and nitrogen fixation by legumes can be a significant source of nitrogen (Burkhart and James, 1999). In 1997, an estimated 120,000 metric tons of nitrogen and 4,550 metric tons of phosphorus were transported to the Mississippi River from EIWA. The lower load for phosphorus in 1997 compared to 1996 probably is related primarily to less intense rains and lack of rain in the Skunk River Basin, which resulted in lower sediment concentrations to transport the phosphorus that adsorbs to the sediment particles. In 1998, an estimated 234,000 metric tons of nitrogen and 8,830 metric tons of phosphorus were transported to the Mississippi River. The higher loads of nitrogen and phosphorus in 1998 compared to previous years (1996–97) can be attributed to higher concentrations and higher runoff.

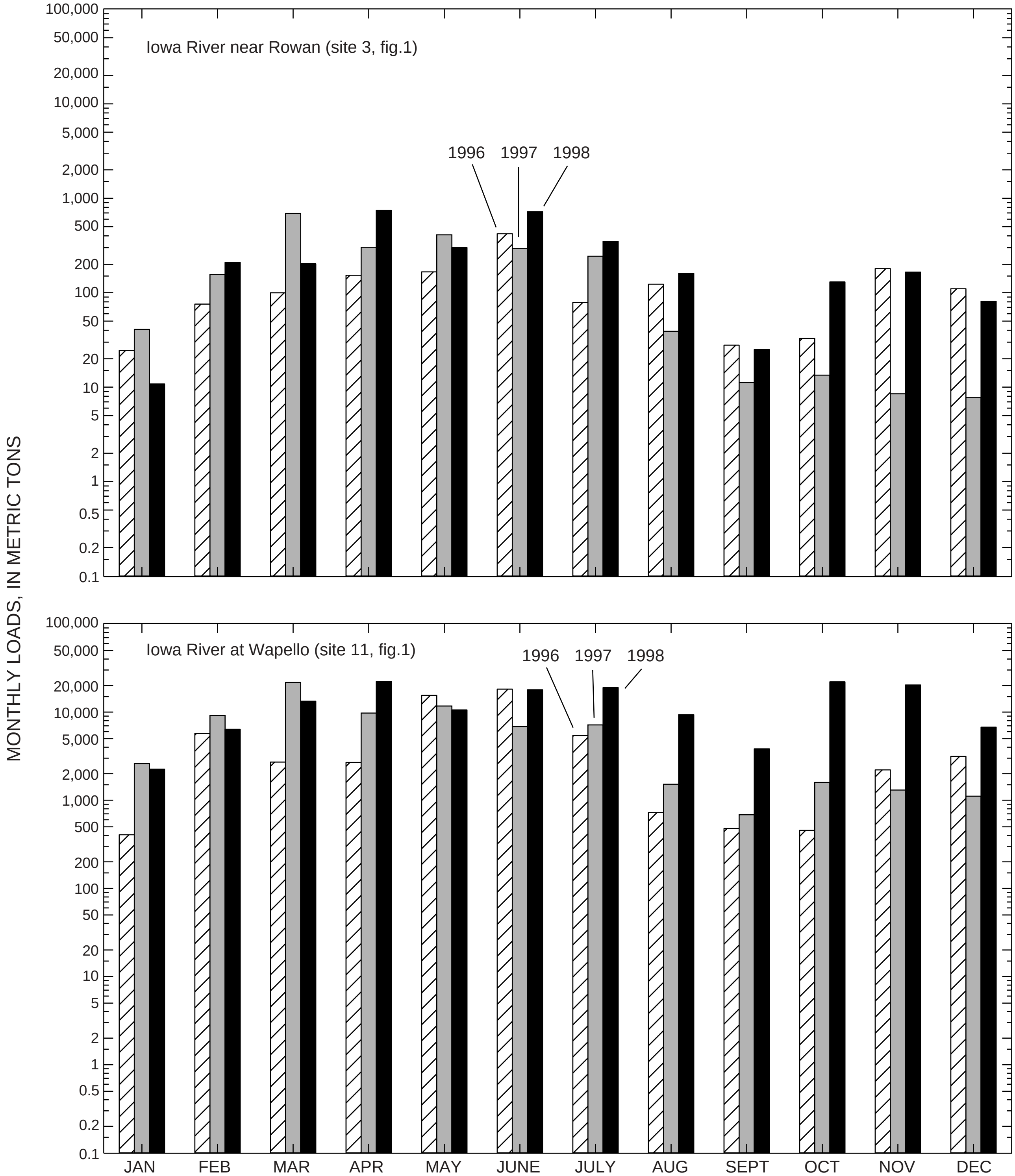


Figure 14. Estimated monthly loads of total nitrogen at selected sampling sites in the Eastern Iowa Basins study unit, 1996–98.

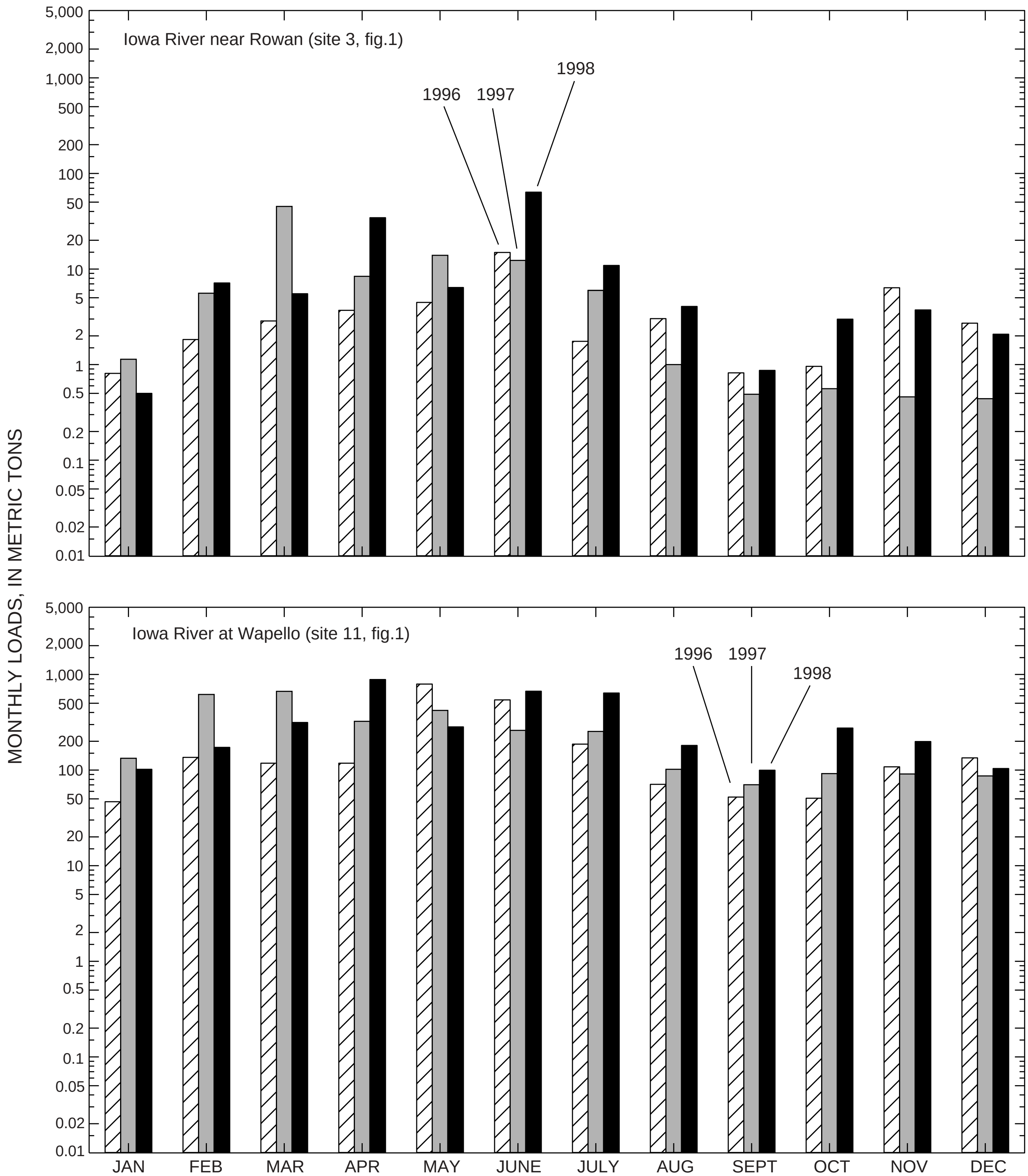


Figure 15. Estimated monthly loads for total phosphorus at selected sampling sites in the Eastern Iowa Basins study unit, 1996–98.

Goolsby and others (1999) reported that the average estimated total nitrogen load was 74,200 metric tons for the Iowa River at Wapello (site 11) from 1980 to 1996 and was 22,450 metric tons for the Skunk River at Augusta (site 12). The historical average total nitrogen load for these two sites was less than the total nitrogen loads estimated in this report for 1996 through 1998, with the exception of the Iowa River at Wapello (site 11), which was less than (57,600 metric tons) the historical average in 1996. In addition, Goolsby and others (1999) reported that the average total phosphorus load for 1980–96 was 3,076 metric tons for the Iowa River at Wapello (site 11) and 1,338 metric tons for Skunk River at Augusta (site 12). Estimated total phosphorus loads for the Iowa River at Wapello (site 11) were less than the 1980–96 average in 1996 and greater than the 1980–96 average in 1997 and 1998. Estimated total phosphorus loads for the Skunk River at Augusta (site 12) were greater than the 1980–96 average in 1996 and 1998 but less than the 1980–96 average in 1997.

Suspended-sediment loads were calculated for the three sites (Wapsipinicon River near De Witt, Iowa River at Wapello, and Skunk River at Augusta) that were near the mouths of the main river systems in the EIWA. These three sites had daily suspended-sediment samples collected by observers at each site. Table 5 lists the estimated suspended-sediment loads for these three sites. Sediment transport is highly variable and is highly dependent on timing of runoff events. In 1996, sediment transport was high during the late winter and spring during runoff events when there was very little vegetation to hold sediment in place. Sediment transport was generally lower throughout the EIWA in 1997 when there were few major runoff events during the late winter and early spring. In 1998, sediment transport increased due to runoff events, especially in the Skunk River Basin. The Skunk River Basin drains the Southern Iowa Drift Plain, which has easily erodible loess deposits. The Skunk River at Augusta (site 12, fig. 1) had the highest load of the 3 years with 5,300,000 metric tons transported in 1998. The total suspended-sediment load transported from these three sites to the Mississippi River from 1996 to 1998 was 7,480,000, 4,450,000, and 8,690,000, respectively.

Table 5. Estimated suspended-sediment loads and yields for selected rivers in the Eastern Iowa Basins study unit, 1996–98

[km^2, square kilometer]

Site name (map reference number)	Year	Suspended sediment Load (metric tons)	Suspended sediment Yield (metric tons/km^2)
Wapsipinicon River near De Witt (2)	1996	580,000	95.4
	1997	450,000	74.0
	1998	490,000	80.6
Iowa River at Wapello (11)	1996	3,000,000	92.6
	1997	1,800,000	55.6
	1998	2,900,000	89.5
Skunk River at Augusta (12)	1996	3,900,000	348
	1997	2,200,000	196
	1998	5,300,000	473

Yields

Yield is the mass of a constituent that has been transported from a unit of area per specific amount of time ($(kg/km^2)/yr$). Table 4 lists the estimated yields for 11 basic-fixed sites for 1996–98. Indicator sites typically had higher yields for total nitrogen than did integrator sites. The South Fork Iowa River near New Providence (site 4) had the highest estimated total nitrogen yield (6,540 kg/km^2 in 1998). Flood Creek near Powersville (site 7) had the lowest estimated total nitrogen yield (760 kg/km^2 in 1996) during a dry year when there were many days with no flow. Total nitrogen yields typically increased every year for each site during the study period with only a few exceptions (Old Mans Creek and Skunk River in 1997), which were probably related to less runoff. This can be attributed to the overall increase in runoff and higher concentrations each year of the study. The average estimated total nitrogen yields for the Cedar River and the Iowa River during the study period were about the same [2,990 and 2,900 $(kg/km^2)/yr$, respectively]. Figure 16 shows the 3-year average nitrogen and phosphorus yields for each site in the study unit.

Old Mans Creek near Iowa City (site 6) had the highest estimated total phosphorus yield of 750 kg/km^2, in 1996. Flood Creek near Powersville (site 7) had the lowest estimated total phosphorus yield

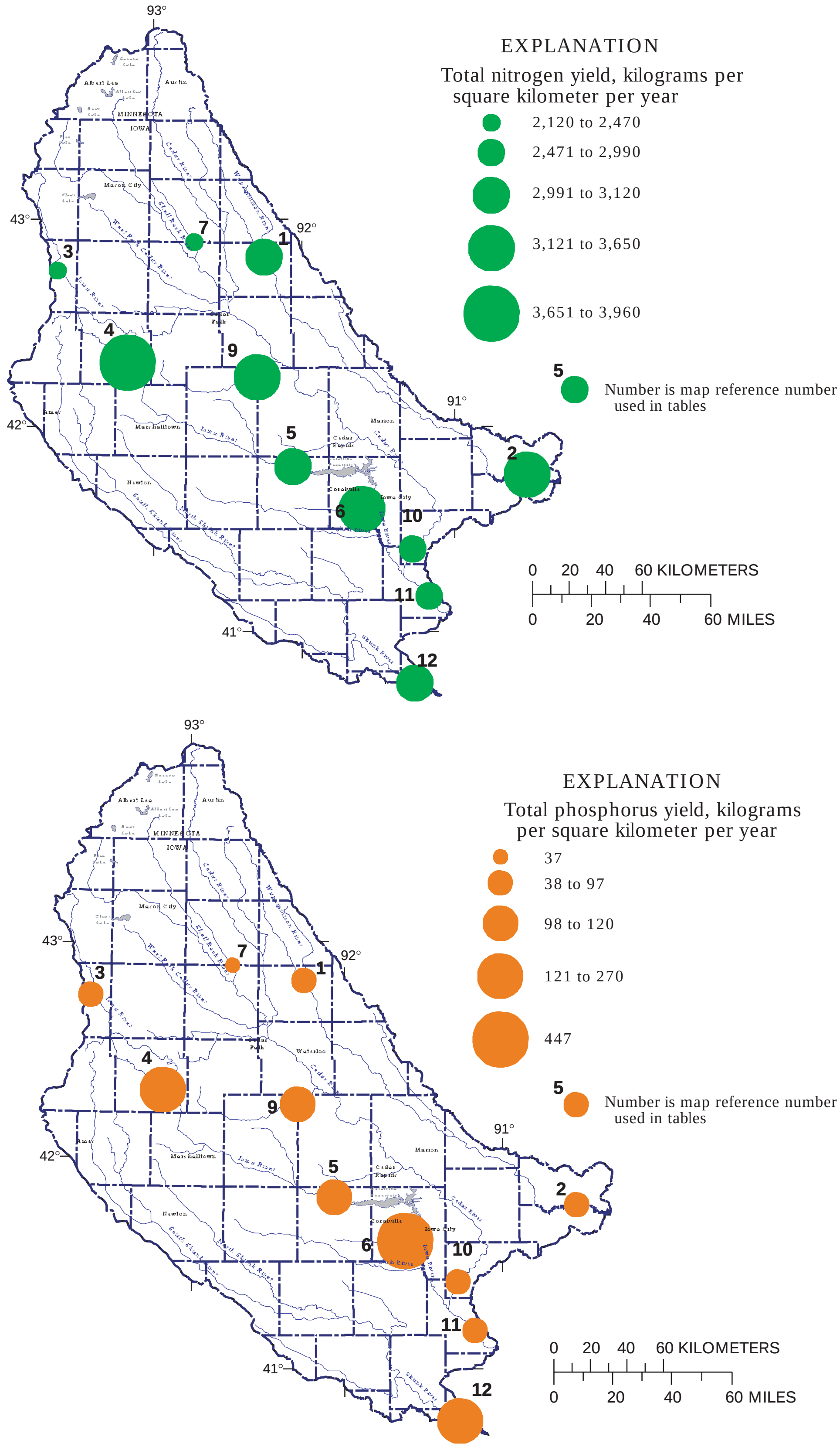


Figure 16. Three-year average estimated yields of total nitrogen and total phosphorus in the Eastern Iowa Basins study unit, 1996–98.

of 7 kg/km^2 in 1996. Again, this low yield can be attributed to low flow in Flood Creek during 1996. The 11 basic-fixed sites in table 4 typically had increases in total phosphorus yields for each year of the study with a few exceptions. In 1997, Old Mans Creek near Iowa City (site 6) and the Skunk River at Augusta (site 12) had lower total phosphorus yields than in 1996 and 1998. This was due to less runoff and less intense rain events in the associated drainage basins. However, with the exception of 1997, the drainage basins represented by Old Mans Creek near Iowa City (site 6) and Skunk River at Augusta (site 12) had higher estimated total phosphorus yields than other drainage basins within the study unit. Samples from these two sites had higher suspended-sediment concentrations during runoff events than did samples from the other sites, which may explain the higher total phosphorus yields at these two sites. In addition, Old Mans Creek near Iowa City (site 6) and Skunk River at Augusta (site 12) mainly drain the Southern Iowa Drift Plain, which consists of loess deposits that erode relatively easily, which can increase sediment and phosphorus loads to rivers and streams.

The South Fork Iowa River near New Providence (site 4) had large increases in estimated total nitrogen and total phosphorus yields each year of the study. This site had the highest yields for total nitrogen and total phosphorus in 1998, which may reflect the large number of hog confinement operations in this drainage basin, which in turn may be affecting the water quality. Other drainage basins that have a high number of hog confinement operations, such as the Iowa River near Rowan (site 3), showed similar increasing total nitrogen and total phosphorus yields, but not as substantial as the South Fork Iowa River near New Providence (site 4).

Goolsby and others (1999) reported that the average estimated total nitrogen yield for 1980–96 at the Iowa River at Wapello sampling site (site 11) was 2,290 (kg/km^2)/yr and at the Skunk River at Augusta (site 12) was 2,020 (kg/km^2)/yr. Estimated total nitrogen yields at the Iowa River at Wapello (site 11) and Skunk River at Augusta (site 12) were greater than the 1980–96 average from 1996–98, with the exception of the Iowa River at Wapello (site 11, fig. 1), which was less than (1,650 kg/km^2) the historical nitrogen yield (table 4). The average total phosphorus yield for 1980–96 at the Iowa River at Wapello sampling site (site 11) was 94.9 (kg/km^2)/yr and 120.5 (kg/km^2)/yr for the Skunk River at Augusta (site 12) sampling site. Estimated total phosphorus yields for Iowa River at Wapello (site 11) were less than the 1980–96 average in 1996 but were higher than average in 1997 and 1998. Estimated total phosphorus yields for the Skunk River at Augusta (site 12) were higher than the 1980–86 average in 1996 and 1998 but were lower than the 1980–86 average in 1997 [89 (kg/km^2)/yr].

Skunk River at Augusta (site 12, fig. 1) had the highest estimated suspended-sediment yield of 473 metric tons/km^2 in 1998. Iowa River at Wapello (site 11, fig. 1) had the lowest estimated suspended-sediment yield of 55.6 metric tons/km^2 in 1997. The average suspended-sediment yields for the Wapsipinicon River near De Witt (site 2, fig. 1), Iowa River at Wapello (site 11, fig. 1), and the Skunk River at Augusta (site 12) were 83, 79, and 339 (metric tons/km^2)/yr, respectively. Again, the variation in suspended-sediment yields in the EIWA is due to runoff events and the landform type that the watershed drains.

SYNOPTIC STUDIES

Two synoptic studies were conducted to better understand water quality and variability during low base-flow and high base-flow conditions in medium-sized (320–1,300 km^2) drainage basins of the EIWA study unit. Hydrographs of stream discharge and ground-water inflow at surface-water-quality sampling sites distributed from north to south across the study unit (fig. 17) show that ground water contributed most of the streamflow during the synoptic sampling periods (August 1997 and May 1998). The median stream discharge per unit drainage area was more than five times higher during the high base-flow sampling in May 1998 [0.046 (m^3/s)/km^2] than during the low base-flow sampling in August 1997 [0.008 (m^3/s)/km^2]. Ground water may have been contributed by direct infiltration from adjacent aquifers or from tile-line flow. Streamflow during the low base-flow period in August 1997 was characterized by decreasing stream discharge. During the month before sampling, rainfall produced little runoff. Although streamflow was decreasing and consisted primarily of ground-water inflow in the weeks before sampling in May 1998, several storms in April produced substantial runoff events before sampling.

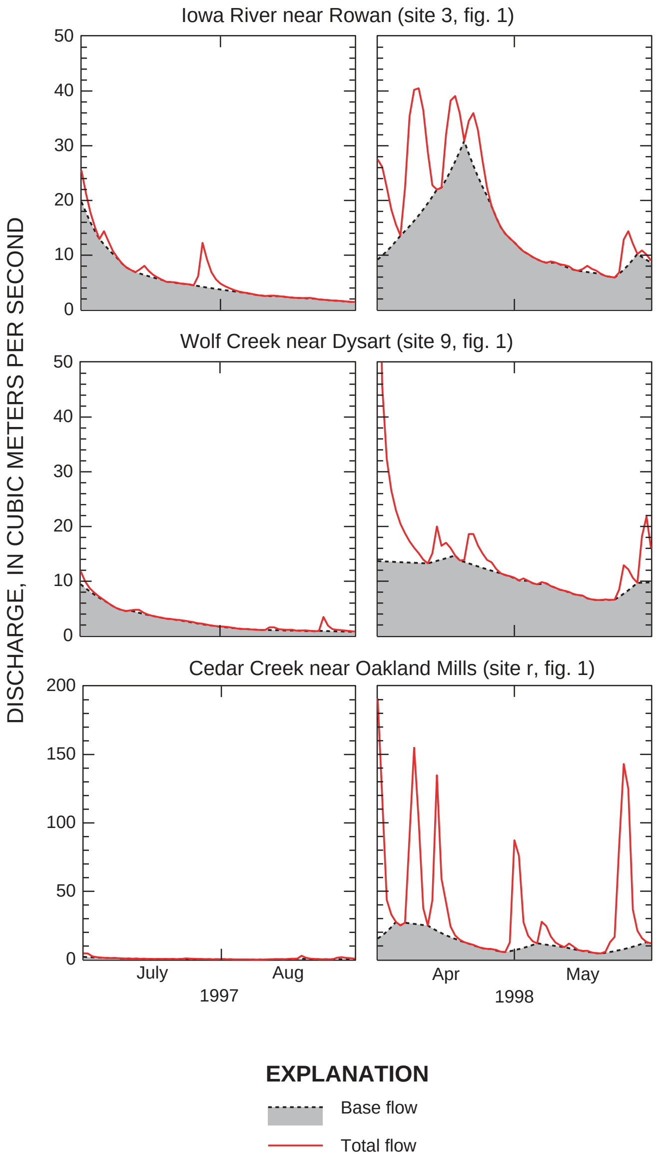


Figure 17. Base flow and total flow at three surface-water-quality sampling sites during low and high base-flow conditions in the Eastern Iowa Basins study unit, July and August 1997 and April and May 1998.

With the exception of stream discharge and dissolved-oxygen concentrations, overall stream conditions at the time of sampling were very similar (table 6). Specific conductance, pH, water temperature, and suspended sediment were not significantly different ($p > 0.05$) during the two synoptic sampling periods. However, samples from the streams did contain higher dissolved-oxygen concentrations and were more highly oxygen saturated during the August 1997 low base-flow sampling. Stable flow conditions and possibly lower turbidity in late summer than in spring may have been conducive to the growth of oxygen-producing plants and algae in the streams.

Variability Among Basic-Fixed and Synoptic Sites

Six basic-fixed/synoptic sites on medium-sized drainage basins (320–1,300 km^2) were selected initially to represent the range of environmental settings found in the EIWA study unit. The settings generally vary due to differences in landforms and agricultural land-use practices. The drainage basins of the six basic-fixed/synoptic sites (sites 1, 3, 4, 6, 7, and 9) account for about 5 percent of the drainage area of the EIWA study unit. The representativeness of the entire study unit by these basic-fixed/synoptic sites is unknown. Comparison of water-quality data among the six basic-fixed/synoptic sites and the 19 synoptic sites would answer this question, at least for the conditions during the synoptic sampling periods. The synoptic drainage basins represent about 30 percent of the EIWA study unit.

Comparison of water-quality data suggests that the water quality from the six basic-fixed/synoptic sites is representative of the entire study unit during periods of low and high base flow when most streamflow originates from ground water. None of the concentrations of nitrogen and phosphorus compounds analyzed were significantly different ($p < 0.05$, Kruskal-Wallis test) in samples from the 19 synoptic sites than in samples from basic-fixed/synoptic sites. Selected nitrogen, phosphorus, and organic-carbon compounds are shown in relation to the type of site in figure 18. Although not significantly different, concentrations in samples from the 19 synoptic sites were generally more variable than in samples from the basic-fixed/synoptic sites. Increased variability is at least partially due to the larger number of synoptic sites.

Only water temperature was significantly different between the basic-fixed/synoptic and synoptic sites. The median water temperature was significantly less ($p < 0.05$, Kruskal-Wallis test) in samples from the basic-fixed/synoptic sites (18.2° C) than in samples from the 19 synoptic sites (21.0° C) during low base flow. The reason for this difference is unknown.

Table 6. Statistical summary of selected physical properties and chemical constituents in samples from 25 synoptic sites in the Eastern Iowa Basins study unit, August 1997 (low base flow) and May 1998 (high base flow)

[<, less than detection limit indicated]

Constituent	Base-flow type	Property or constituent value			Coefficient of variation
		Minimum	Median	Maximum	
Physical properties					
Stream discharge, in cubic meters per second	Low	0.11	0.79	2.1	0.61
	High	49.	119	147	.59
Specific conductance, in microsiemens per centimeter at 25 degrees Celsius	Low	396	573	1,220	.27
	High	436	590	792	.15
pH, in standard units	Low	7.5	8.0	8.4	.03
	High	7.7	8.0	8.2	.02
Water temperature, in degrees Celsius	Low	15.5	20.5	25.5	.11
	High	15.0	20.5	24.0	.11
Dissolved oxygen, in milligrams per liter	Low	4.9	9.4	13.8	.22
	High	6.8	8.1	9.2	.08
Dissolved oxygen, percent saturation	Low	56	106	168	.24
	High	79	91	106	.08
Suspended sediment, in milligrams per liter	Low	6.	40	330	1.2
	High	12	86	171	.58
Constituent concentrations, in milligrams per liter					
Ammonia (as N), dissolved	Low	<.015	<.015	1.3	3.4
	High	<.02	.04	.08	.56
Ammonia ammonia plus organic nitrogen (as N), total	Low	.20	.39	2.1	.81
	High	.17	.40	.78	.47
Organic nitrogen, dissolved	Low	.12	.39	1.0	.54
	High	.15	.38	.71	.41
Nitrite plus nitrate (as N), dissolved	Low	.05	1.5	8.3	1.0
	High	8.5	12	14	.15
Nitrogen (as N), total, dissolved	Low	.46	2.3	8.5	.74
	High	8.9	12	15	.15
Phosphorus (as P), dissolved	Low	<.01	.04	.31	1.1
	High	<.01	.06	.13	.70
Orthophosphate (as P), dissolved	Low	<.10	.04	.31	1.4
	High	<.10	.03	.09	1.1
Phosphorus (as P), total	Low	<.01	.12	.16	1.1
	High	.02	.10	.32	.63
Organic carbon, dissolved	Low	1.6	3.7	7.5	.42
	High	1.3	2.3	5.1	.34
Organic carbon, suspended	Low	.30	.80	4.5	.88
	High	.60	1.2	2.7	.49

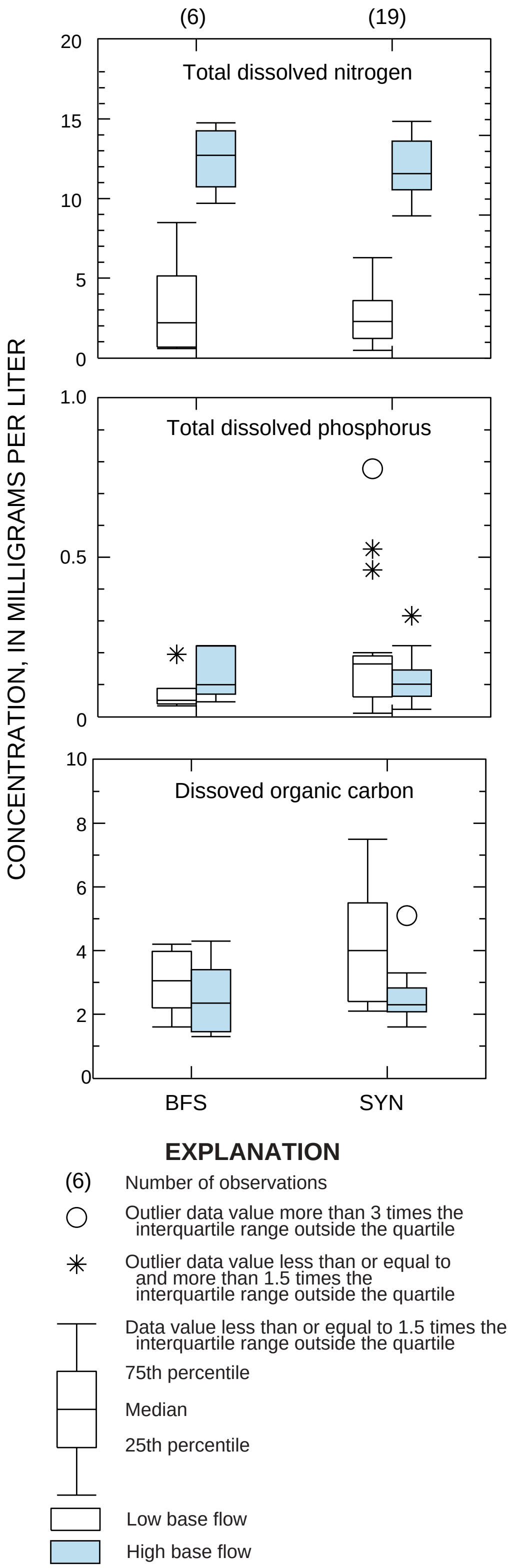


Figure 18. Concentrations of selected nitrogen, phosphorus, and organic-carbon compounds in samples from 6 basic-fixed sites (BFS) and 19 synoptic (SYN) sites during low and high base flow.

Spatial Variability

Although water quality did not vary among the basic-fixed/synoptic and synoptic sites, spatial variability was evident during both low and high base-flow conditions. Much of the spatial variability was related to landform type and geologic and hydrologic differences among drainage basins. Nitrogen and phosphorus concentrations were significantly different ($p < 0.05$) in samples from sites in at least one landform region in the study unit (table 7) during low and high base-flow conditions. Orthophosphorus was the only constituent that had similar concentrations in samples from all landform regions for both base-flow periods.

Ammonia, organic-nitrogen, phosphorus, and organic-carbon compounds commonly transported on and with suspended sediment were generally present in higher concentrations in drainage basins on the Des Moines Lobe and the Southern Iowa Drift Plain than in basins draining the Iowan Surface and Iowan Karst. Even though median concentrations of suspended sediment were low (less than 110 mg/L) (table 7) in samples from the Des Moines Lobe and Southern Iowa Drift Plain, suspended-sediment and DOC concentrations were generally higher than those in stream samples from the Iowan Surface and Iowan Karst. The presence of higher concentrations of organic compounds (organic enrichment) suggest one or more of the following: (1) biological production by algae, zooplankton, and bacteria; (2) input of organic compounds from soils with higher organic content; and (3) input of organic compounds from animal-feeding operations. Determining the source of organic enrichment is beyond the scope of this report, but a combination of the three sources may be possible.

In contrast, nitrite plus nitrate concentrations varied among landform regions only during low base-flow conditions. Nitrite plus nitrate concentrations were high throughout the study unit during the high base-flow sampling in May 1998 (fig. 19). Nitrate plus nitrite concentrations were higher than 10 mg/L at all but three sites. The highest nitrite plus nitrate concentrations were in samples from streams draining parts of the Iowan Surface and Iowan Karst in the northern part of the study unit. During low base-flow sampling (August 1997), algal populations, as indicated by chlorophyll-*a* concentrations, were inversely related to dissolved nitrate concentrations. This relation suggests that when conditions are conducive for growth, algal production may be a factor in reducing nitrogen in streams.

Table 7. Median concentrations of selected nitrogen constituents in samples from 25 synoptic sites in relation to landform region in the Eastern Iowa Basins study unit, August 1997 (low base flow) and May 1998 (high base flow)

[Concentrations are in milligrams per liter except chlorophyll-*a*; N, nitrogen; P, phosphorus; <, less than]

Constituent	Base-flow type (bold type indicates concentrations in one or more landforms are significantly different)	Median concentrations in samples from each landform region (defined by Prior, 1991)			
		Des Moines Lobe (7 sites)	Iowan Karst (2 sites)	Iowan Surface (9 sites)	Southern Iowa Drift Plains (7 sites)
Ammonia (as N), dissolved	**Low**	<0.015	<0.015	<0.015	0.08
	High	.05	.03	.04	.05
Ammonia plus organic nitrogen (as N), total	**Low**	1.1	.3	.5	1.2
	High	1.1	.3	.6	.7
Organic nitrogen, dissolved	**Low**	.4	.3	.2	.4
	High	.6	.2	.3	.3
Nitrite plus nitrate (as N), dissolved	**Low**	1.5	5.2	3.4	.2
	High	13	12	11	12
Nitrogen, total dissolved	**Low**	1.8	5.4	3.6	1.2
	High	14	12	11	12
Phosphorus (as P), dissolved	Low	.04	.03	.04	.08
	High	.06	.03	.04	.08
Orthophosphate (as P), dissolved	Low	.03	.02	.03	.06
	High	.02	.07	.01	.06
Phosphorus (as P), total	**Low**	.18	.02	.05	.2
	High	.10	.09	.06	.1
Sediment, suspended	**Low**	69	14.5	21.5	72
	High	109	22	71.0	61
Organic carbon, dissolved	**Low**	4.1	2.0	2.4	5.2
	High	3.0	1.6	2.1	2.3
Organic carbon, suspended	**Low**	.6	.6	.5	2.5
	High	1.4	.6	1.2	1.2
Chlorophyll-*a* (micrograms per liter)	Low	72	15	13	50
	High	29	3.7	8.0	12

Variability Among Base-Flow Conditions

Three of the 10 selected nitrogen and phosphorus compounds had significant concentration differences between the low base flow in August 1997 and high base flow in May of 1998. Concentrations of dissolved ammonia and nitrite plus nitrate were significantly higher ($p < 0.05$, Kruskal-Wallis test) during high base flow than during low base flow (table 6). The higher concentrations may be due to the availability of nitrogen for transport to streams in spring. More than 90 percent of the corn acres had been fertilized (Iowa Agricultural Statistics, 1998b) in the autumn of 1997 and the spring of 1998, with a statewide average application of 14,800 kg/km^2 of nitrogen (U.S. Department of Agriculture, 1999) before sampling took place. Manure, another source of nitrogen and phosphorus, commonly is applied in the autumn after harvest and in early spring before planting. The availability of nitrogen and phosphorus in a drainage basin decreases during the summer because of uptake by plants and possible denitrification in underlying aquifers. Ground-water inflow from tile lines, which have been shown to transport substantial amounts of nitrogen (Soenksen, 1996; Cambardella and others, 1999), normally decreases during late summer due

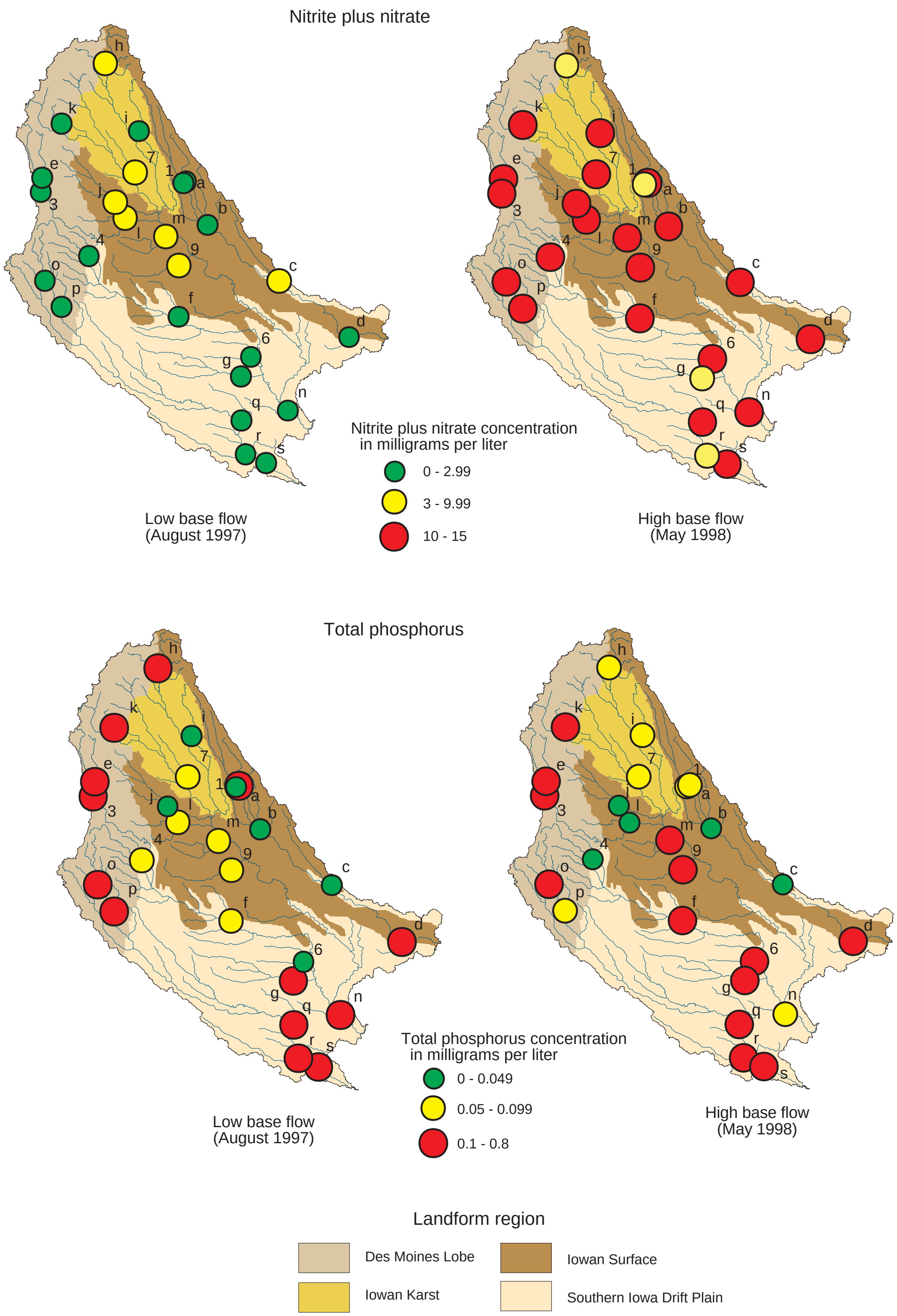


Figure 19. Spatial variability of nitrate and total phosphorus concentrations during low and high base-flow conditions in the Eastern Iowa Basins study unit.

to reduced precipitation and increased evapotransporation. The pattern follows the seasonal trend described in the “Seasonal Variations” section of this report.

Although concentrations of many nitrogen and phosphorus compounds were similar, the relative variability was higher during low base flow in late summer than during high base flow in late spring. Higher variability may be due to the effects of differences in geologic and hydrologic factors among landform regions.

SUMMARY

Twelve streams and rivers in the Eastern Iowa Basins (EIWA) study unit were sampled monthly from March 1996 through September 1998 for nitrogen, phosphorus, suspended sediment, and organic carbon. One sampling location was discontinued after 1996.

At least one compound of dissolved nitrogen and phosphorus was detected in every sample. About 92 percent of nitrogen was in the form of nitrate. About 22 percent of the nitrate concentrations exceeded the U.S. Environmental Protection Agency maximum contaminant level of 10 mg/L as N for drinking water. Total nitrogen concentrations ranged from 0.20 to 22 mg/L, with a median concentration of 7.2 mg/L. Dissolved phosphorus was predominately in the form of orthophosphate. Total phosphorus concentrations ranged from 0.01 to 3.4 mg/L, with a median concentration of 0.22 mg/L. About 75 percent of the total phosphorus concentrations exceeded the U.S. Environmental Protection Agency recommended total phosphorus concentration of 0.1 mg/L to minimize algal growth. Suspended-sediment concentrations ranged from less than 0.1 to 3,500 mg/L, with a median concentration of 82 mg/L. Dissolved organic-carbon (DOC) concentrations ranged from 0.80 to 44 mg/L, with a median concentration of 3.5 mg/L.

Concentrations of nitrogen and phosphorus varied both annually and seasonally and were related to precipitation, runoff, and fertilizer application. Precipitation and runoff varied during the 3-year study. In 1996, the study unit received below-normal precipitation and runoff. In 1997, precipitation and runoff were normal except for the southern part of the study unit, which received less precipitation and runoff. In 1998, precipitation and runoff were above normal. All nitrogen and phosphorus compounds, with the exception of dissolved ammonia, showed increases in median concentrations from 1996 to 98. Median concentrations of suspended-sediment increased from 1996 to 1998. Median concentrations of DOC remained the same from 1996 to 1998.

Concentrations of nitrogen, phosphorus, and suspended sediment varied seasonally, and concentrations were higher in the spring after fertilizer application and runoff events. In winter, nitrogen and phosphorus concentrations increased when there was little in-stream processing by biota. Nitrogen and phosphorus concentrations decreased in late summer when there was less runoff and in-stream processing of nitrogen and phosphorus was high. Suspended-sediment concentrations were highest in early summer during runoff events and lowest in January when there was ice cover with very little overland flow. DOC concentrations were highest in February and March when decaying vegetation and manure were transported to streams during snowmelt events.

Historical and study-unit data indicate there are trends that show both nonpoint- and point-source pollution in eastern Iowa streams and rivers. Typically, for nonpoint sources, the chemical concentrations increase as runoff increases. A decrease in concentration at the highest rate of streamflow indicates that after extended periods of runoff, nitrate available for transport to streams changes little, and further rainfall and runoff dilute the nitrate concentrations. Compound concentrations for point sources typically are high during low flow and decrease as flow increases due to dilution.

Samples from indicator sites that have homogeneous land use and geology had significantly higher ($p < 0.05$) concentrations of total dissolved nitrogen (median, 8.2 mg/L) than did samples from integrator sites (median, 6.2 mg/L) that are more heterogeneous in land use and geology. Samples from integrator sites had significantly higher ($p < 0.05$) total phosphorus concentrations (median, 0.29 mg/L) than did samples from indicator sites (median, 0.12 mg/L). Integrator sites had significantly ($p < 0.05$) higher suspended-sediment concentrations (median, 114 mg/L) than did indicator sites (median, 55 mg/L). There was little difference in median concentrations of DOC in samples from indicator and integrator sites (3.5 and 3.6 mg/L, respectively).

Statistical analysis of chemical concentrations indicated that there were differences in water quality for nitrogen, phosphorus, and suspended sediment among sites, which are related to land use and differences in landform regions. Drainage basins with large percentages of row-crop agriculture and animal-feeding operations typically had higher nitrogen concentrations than did drainage basins with lower percentages of row-crop agriculture and animal-feeding operations. Basins that drain the Des Moines Lobe and Southern Iowa Drift Plain typically had higher total phosphorus and suspended-sediment concentrations than did other basins in this study.

Total nitrogen and total phosphorus loads were typically proportional to the size of the drainage basin. Total nitrogen loads increased each year from 1996 through 1998 in conjunction with increased concentrations and runoff. Total phosphorus loads decreased in 1997 due to less runoff in the southern part of the study unit, which contributes large sediment concentrations. Total nitrogen and total phosphorus loads vary seasonally. The highest loads typically occurred in early spring and summer after fertilizer application and runoff. The loads were typically lowest in January and September when there was very little runoff to transport nitrogen and phosphorus adsorbed to the soil to the rivers and streams.

Total nitrogen loads contributed to the Mississippi River from the EIWA from 1996, 1997, and 1998 were 97,600, 120,000, and 234,000 metric tons, respectively. Total phosphorus loads contributed to the Mississippi River from the EIWA during 1996, 1997, and 1998 were 6,860, 4,550, and 8,830 metric tons, respectively. Suspended-sediment loads contributed to the Mississippi River from the EIWA during 1996, 1997, and 1998 were 7,480,000, 4,450,000, and 8,690,00 metric tons, respectively. The highest total nitrogen and total phosphorus yields typically occurred at indicator sites that were dominated by row-crop agriculture land use and within a single landform region. Sampling sites located in drainage basins with a higher row-crop percentage and that contained more animal-feeding operations typically had higher yields of total nitrogen. In addition, landform regions are a determining factor in yields. Sites that were on the Des Moines Lobe and the Southern Iowa Drift Plain typically had higher total phosphorus yields than sites on the Iowan Surface and Iowan Karst.

Synoptic sampling during low base-flow and high base-flow conditions in 25 selected sites indicated that there were no water-quality differences among samples collected from six indicator basic-fixed sites and 19 other synoptic-sampling sites; thus the six basic-fixed sites selected as indicator sites were representative of the entire study unit. There were spatial differences in compound concentrations in samples from the 25 synoptic-sampling sites. Ammonia, organic nitrogen, and phosphorus—chemicals commonly transported by and with suspended sediment—were present in higher concentrations in basins draining the Des Moines Lobe and Southern Iowa Drift Plain than in basins draining the Iowa Surface and Iowa Karst. Concentrations of nitrogen and phosphorus were generally higher during high base-flow conditions than during low base-flow conditions.

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APPENDIX

Appendix table. Statistical summary of nitrogen, phosphorus, suspended-sediment, and organic-carbon concentrations in the Eastern Iowa Basins study unit, March 1996–September 1998

[MCL, Maximum Contamination Level; RAL, recommended action level; N, nitrogen; P, phosphorus; na, not applicable; <, less than]

Constituent	Number of samples	Number of detections	Number of detections greater than MCL or RAL	Concentrations, in milligrams per liter				
				Minimum	25th percentile	Median	75th percentile	Maximum
Site 1—Wapsipinicon River near Tripoli (indicator site, fig. 1)								
Ammonia (as N), dissolved	36	21	na	<0.02	<0.02	0.03	0.08	0.88
Ammonia plus organic nitrogen (as N), total	36	36	na	.2	.5	.6	1.0	3.0
Ammonia plus organic nitrogen (as N), dissolved	36	36	na	<.1	.3	.4	.1	2.2
Organic nitrogen,[2] dissolved	36	35	na	.2	.2	.3	.6	1.4
Nitrite (as N), dissolved	36	34	na	<.01	.02	.04	.06	.15
Nitrite plus nitrate (as N), dissolved	36	35	na	.11	2.8	5.6	8.5	15
Nitrate (as N),[1] dissolved	36	35	4	<.02	2.8	5.5	8.4	15
Nitrogen (as N), total,[3] dissolved	36	36	na	.4	3.1	6.3	9.0	16
Phosphorus (as P), dissolved	36	30	na	<.01	.02	.03	.06	.37
Orthophosphate (as P), dissolved	36	32	na	<.01	.02	.03	.06	.29
Phosphorus (as P), total	36	36	15	.01	.05	.09	.17	.58
Suspended sediment	36	36	na	2.0	8.5	20	36	200
Organic carbon, dissolved	36	36	na	2.1	2.7	3.2	4.2	14
Organic carbon, suspended	35	35	na	.3	.4	.9	1.4	5.0
Site 2—Wapsipinicon River near De Witt (integrator site, fig. 1)								
Ammonia (as N), dissolved	35	18	na	<.02	<.02	.02	.07	.46
Ammonia plus organic nitrogen (as N), total	35	35	na	.3	1.0	1.7	2.0	3.0
Ammonia plus organic nitrogen (as N), dissolved	35	33	na	<.1	.3	.4	.5	1.2
Organic nitrogen,[2] dissolved	35	33	na	.2	.2	.3	.5	1.1
Nitrite (as N), dissolved	35	34	na	<.01	.02	.03	.04	.09
Nitrite plus nitrate (as N), dissolved	35	35	na	.11	1.4	6.2	8.7	15
Nitrate (as N),[1] dissolved	35	35	8	.09	1.4	6.1	8.7	15
Nitrogen (as N), total,[3] dissolved	35	35	na	.3	1.7	6.4	8.9	15
Dissolved phosphorus (as P)	35	27	<.01	<.01	.05	.09	.23	na
Orthophosphate (as P), dissolved	35	29	na	<.01	.01	.06	.09	.22
Phosphorus (as P), total	35	35	32	.04	.16	.23	.33	.99
Suspended sediment	35	35	na	7.0	51	92	210	840
Organic carbon, dissolved	35	35	na	2.1	2.8	3.3	4.1	7.3
Organic carbon, suspended	35	34	na	.2	1.4	2.8	5.0	5.0

Appendix table. Statistical summary of nitrogen, phosphorus, suspended-sediment, and organic-carbon concentrations in the Eastern Iowa Basins study unit, March 1996–September 1998—Continued

[MCL, Maximum Contamination Level; RAL, recommended action level; N, nitrogen; P, phosphorus; na, not applicable; <, less than]

Constituent	Number of samples	Number of detections	Number of detections greater than MCL or RAL	Concentrations, in milligrams per liter				
				Minimum	25th percentile	Median	75th percentile	Maximum
Site 3—Iowa River near Rowan (indicator site, fig. 1)								
Ammonia (as N), dissolved	52	35	na	<0.02	<0.02	0.04	0.10	1.2
Ammonia plus organic nitrogen (as N), total	52	52	na	.2	.7	1.0	1.5	3.9
Ammonia plus organic nitrogen (as N), dissolved	52	51	na	<.1	.4	.4	.6	2.7
Organic nitrogen,[2] dissolved	52	51	na	.2	.3	.4	.5	1.6
Nitrite (as N), dissolved	52	51	na	<.01	.03	.04	.06	.14
Nitrite plus nitrate (as N), dissolved	52	52	na	1.2	3.0	6.3	9.0	14
Nitrate (as N),[1] dissolved	52	52	9	1.2	3.0	6.3	9.0	14
Nitrogen (as N), total[3] dissolved	52	52	na	1.5	3.7	6.8	9.4	15
Phosphorus (as P), dissolved	52	51	na	<.01	.06	.09	.13	1.4
Orthophosphate (as P), dissolved	52	50	na	<.01	.06	.09	.12	1.1
Phosphorus (as P), total	52	52	41	.05	.11	.2	.27	1.5
Suspended sediment	52	52	na	13	60	100	140	420
Organic carbon, dissolved	51	51	na	2.7	3.6	4.2	5.3	18
Organic carbon, suspended	50	50	na	.3	.7	1.4	2.6	5.0
Site 4—South Fork Iowa River near New Providence (indicator site, fig. 1)								
Ammonia (as N), dissolved	38	25	na	<.02	<.02	.04	.08	1.1
Ammonia plus organic nitrogen (as N), total	38	38	na	.4	.5	.6	1.4	5.6
Ammonia plus organic nitrogen (as N), dissolved	38	38	na	.2	.3	.4	.6	2.4
Organic nitrogen,[2] dissolved	38	38	na	.2	.3	.4	.5	1.4
Nitrite (as N), dissolved	38	35	na	<.01	.02	.04	.07	.14
Nitrite plus nitrate (as N), dissolved	38	38	na	.02	4.2	9.5	14	22
Nitrate (as N),[1] dissolved	38	37	17	.02	4.1	9.5	14	22
Nitrogen (as N), total[3] dissolved	38	38	na	.4	5.0	10	15	22
Phosphorus (as P), dissolved	38	30	na	<.01	.02	.04	.16	1.4
Orthophosphate (as P), dissolved	38	32	na	<.01	.01	.06	.14	1.3
Phosphorus (as P), total	38	38	16	.02	.05	.07	.34	1.6
Suspended sediment	37	37	na	13	24	47	110	1,900
Organic carbon, dissolved	38	38	na	2.5	3.1	4.0	4.5	15
Organic carbon, suspended	38	38	na	.4	.6	.9	1.9	5.0

Appendix table. Statistical summary of nitrogen, phosphorus, suspended-sediment, and organic-carbon concentrations in the Eastern Iowa Basins study unit, March 1996–September 1998—Continued

[MCL, Maximum Contamination Level; RAL, recommended action level; N, nitrogen; P, phosphorus; na, not applicable; <, less than]

Constituent	Number of samples	Number of detections	Number of detections greater than MCL or RAL	Concentrations, in milligrams per liter				
				Minimum	25th percentile	Median	75th percentile	Maximum
Site 5—Iowa River at Marengo (integrator site, fig. 1)								
Ammonia (as N), dissolved	34	21	na	<0.02	<0.02	0.03	0.06	0.43
Ammonia plus organic nitrogen (as N), total	34	34	na	.3	1.1	1.4	1.9	3.8
Ammonia plus organic nitrogen (as N), dissolved	34	33	na	<.1	.3	.4	.6	1.2
Organic nitrogen,[2] dissolved	34	33	na	.1	.3	.4	.5	.8
Nitrite (as N), dissolved	34	33	na	<.01	.02	.03	.05	.13
Nitrite plus nitrate (as N), dissolved	34	33	na	<.05	3.9	6.5	8.9	13
Nitrate (as N),[1] dissolved	34	32	4	<.05	3.9	6.5	8.9	13
Nitrogen (as N), total[3] dissolved	34	34	na	.4	4.5	6.9	9.3	13
Phosphorus (as P), dissolved	34	31	na	<.01	.08	.13	.16	.40
Orthophosphate (as P), dissolved	34	30	na	<.01	.06	.12	.16	.37
Phosphorus (as P), total	34	34	34	.13	.27	.35	.51	1.3
Suspended sediment	34	34	na	11	81	211	390	2,500
Organic carbon, dissolved	34	34	na	2.2	2.9	3.2	3.8	7.4
Organic carbon, suspended	34	34	na	.1	1.3	3.0	4.3	5.1
Site 6—Old Mans Creek near Iowa City (indicator site, fig. 1)								
Ammonia (as N), dissolved	39	35	na	<.02	.03	.08	.14	1.2
Ammonia plus organic nitrogen (as N), total	39	38	na	<.1	.5	.7	1.6	7.5
Ammonia plus organic nitrogen (as N), dissolved	39	39	na	.2	.3	.4	.7	3.1
Organic nitrogen,[2] dissolved	39	39	na	.1	.3	.4	.6	1.9
Nitrite (as N), dissolved	39	37	na	<.01	.03	.05	.09	.25
Nitrite plus nitrate (as N), dissolved	39	37	na	<.05	2.20	4.90	10	15
Nitrate (as N),[1] dissolved	39	37	10	.04	2.2	4.9	10	15
Nitrogen (as N), total[3] dissolved	39	39	na	.4	2.7	6.4	11	15
Phosphorus (as P), dissolved	39	39	na	.01	.05	.08	.11	.91
Orthophosphate (as P), dissolved	39	38	na	<.01	.04	.06	.11	.85
Phosphorus (as P), total	39	39	25	.03	.09	.17	.52	3.4
Suspended sediment	39	39	na	7.0	16	69	220	3,500
Organic carbon, dissolved	39	39	na	1.8	2.9	3.6	4.4	16
Organic carbon, suspended	38	38	na	.2	.8	1.1	1.9	10

Appendix table. Statistical summary of nitrogen, phosphorus, suspended-sediment, and organic-carbon concentrations in the Eastern Iowa Basins study unit, March 1996–September 1998—Continued

[MCL, Maximum Contamination Level; RAL, recommended action level; N, nitrogen; P, phosphorus; na, not applicable; <, less than]

Constituent	Number of samples	Number of detections	Number of detections greater than MCL or RAL	Concentrations, in milligrams per liter				
				Minimum	25th percentile	Median	75th percentile	Maximum
Site 7—Flood Creek near Powersville (indicator site, fig. 1)								
Ammonia (as N), dissolved	34	22	na	<0.02	<0.02	0.03	0.06	0.96
Ammonia plus organic nitrogen (as N), total	34	30	na	<.1	.2	.4	.8	2.9
Ammonia plus organic nitrogen (as N), dissolved	34	24	na	<.1	<.1	.2	.3	2.3
Organic nitrogen,[2] dissolved	34	24	na	1.1	1.3	1.5	2.4	16
Nitrite (as N), dissolved	34	33	na	<.01	.03	.04	.07	.18
Nitrite plus nitrate (as N), dissolved	34	34	na	3.3	6.3	8.4	12	19
Nitrate (as N),[1] dissolved	34	34	10	3.2	6.2	8.3	12	19
Nitrogen (as N), total[3] dissolved	34	34	na	3.8	6.8	8.6	12	19
Phosphorus (as P), dissolved	34	33	na	<.01	.06	.07	.09	.98
Orthophosphate (as P), dissolved	34	33	na	<.01	.06	.08	.09	.92
Phosphorus (as P), total	34	34	15	.03	.05	.09	.16	1.1
Suspended sediment	34	34	na	.3	11	28	75	200
Organic carbon, dissolved	34	34	na	1.1	1.3	1.5	2.4	16
Organic carbon, suspended	34	34	na	.1	.3	.6	1.0	3.0
Site 8—Cedar River at Gilbertville (integrator site, fig. 1)								
Ammonia (as N), dissolved	12	9	na	<.02	<.02	.04	.26	.80
Ammonia plus organic nitrogen (as N), total	12	12	na	.6	1.0	1.3	1.6	3.1
Ammonia plus organic nitrogen (as N), dissolved	12	11	na	<.1	.3	.5	.6	1.1
Organic nitrogen,[2] dissolved	12	11	na	.2	.3	.3	.4	.5
Nitrite (as N), dissolved	12	12	na	.03	.03	.04	.06	.08
Nitrite plus nitrate (as N), dissolved	12	12	na	1.8	3.2	3.8	6.2	11
Nitrate (as N),[1] dissolved	12	12	1	1.7	3.2	3.7	6.2	11
Nitrogen (as N), total[3] dissolved	12	12	na	2.1	3.4	4.2	7.0	12
Phosphorus (as P), dissolved	12	8	na	<.01	<.01	.07	.15	.21
Orthophosphate (as P), dissolved	12	9	na	<.01	<.01	.08	.14	.23
Phosphorus (as P), total	12	12	11	.06	.18	.22	.24	.51
Suspended sediment	12	12	na	5.0	23	43	62	190
Organic carbon, dissolved	12	12	na	2.5	2.7	3.0	3.6	4.0
Organic carbon, suspended	12	12	na	.2	.8	2.0	4.4	5.0

Appendix table. Statistical summary of nitrogen, phosphorus, suspended-sediment, and organic-carbon concentrations in the Eastern Iowa Basins study unit, March 1996–September 1998—Continued

[MCL, Maximum Contamination Level; RAL, recommended action level; N, nitrogen; P, phosphorus; na, not applicable; <, less than]

Constituent	Number of samples	Number of detections	Number of detections greater than MCL or RAL	Concentrations, in milligrams per liter				
				Minimum	25th percentile	Median	75th percentile	Maximum
Site 9—Wolf Creek near Dysart (indicator site, fig. 1)								
Ammonia (as N), dissolved	54	31	na	<0.02	<0.02	0.02	0.09	0.40
Ammonia plus organic nitrogen (as N), total	54	54	na	.2	.4	.6	1.2	4.2
Ammonia plus organic nitrogen (as N), dissolved	54	42	na	<.1	.2	.3	.5	.9
Organic nitrogen,[2] dissolved	54	42	na	.1	.2	.3	.4	.6
Nitrite (as N), dissolved	54	53	na	<.01	.03	.04	.06	.12
Nitrite plus nitrate (as N), dissolved	54	54	na	3.2	6.9	10	13	16
Nitrate (as N),[1] dissolved	54	54	27	3.1	6.9	10	13	16
Nitrogen (as N), total[3] dissolved	54	54	na	3.5	7.6	10	13	16
Phosphorus (as P), dissolved	54	53	na	<.01	.04	.08	.10	.34
Orthophosphate (as P), dissolved	54	54	na	<.01	.04	.07	.10	.29
Phosphorus (as P), total	54	54	33	.03	.08	.13	.32	1.5
Suspended sediment	54	54	na	13	35	81	150	1,000
Organic carbon, dissolved	53	53	na	1.5	2.0	2.4	3.8	44
Organic carbon, suspended	53	53	na	.3	.7	1.2	2.5	5.0
Site 10—Cedar River near Conesville (integrator site, fig. 1)								
Ammonia (as N), dissolved	34	21	na	<.02	<.02	.03	.10	.94
Ammonia plus organic nitrogen (as N), total	34	34	na	.3	1.0	1.6	2.3	5.4
Ammonia plus organic nitrogen (as N), dissolved	34	34	na	.2	.3	.4	.6	1.5
Organic nitrogen,[2] dissolved	34	34	na	.2	.3	.4	.5	.9
Nitrite (as N), dissolved	34	34	na	.01	.02	.03	.03	.06
Nitrite plus nitrate (as N), dissolved	34	34	na	.13	2.7	4.9	8.0	12
Nitrate (as N),[1] dissolved	34	34	2	.11	2.6	4.9	8.0	12
Nitrogen (as N), total[3] dissolved	34	34	na	.5	3.1	5.5	8.6	12
Phosphorus (as P), dissolved	34	27	na	<.01	.01	.12	.21	.31
Orthophosphate (as P), dissolved	34	28	na	<.01	.02	.11	.18	.26
Phosphorus (as P), total	34	34	32	.06	.22	.26	.35	1.8
Suspended sediment	34	34	na	12	40	78	150	2,500
Organic carbon, dissolved	34	34	na	2.2	3.1	3.6	4.3	8.6
Organic carbon, suspended	33	33	na	.3	1.4	4.5	5.0	17

Appendix table. Statistical summary of nitrogen, phosphorus, suspended-sediment, and organic-carbon concentrations in the Eastern Iowa Basins study unit, March 1996–September 1998—Continued

[MCL, Maximum Contamination Level; RAL, recommended action level; N, nitrogen; P, phosphorus; na, not applicable; <, less than]

Constituent	Number of samples	Number of detections	Number of detections greater than MCL or RAL	Concentrations, in milligrams per liter				
				Minimum	25th percentile	Median	75th percentile	Maximum
Site 11—Iowa River at Wapello (integrator site, fig. 1)								
Ammonia (as N), dissolved	53	33	na	<0.02	<0.02	0.03	0.08	0.84
Ammonia plus organic nitrogen (as N), total	53	53	na	.4	1.1	1.5	2.0	3.4
Ammonia plus organic nitrogen (as N), dissolved	53	51	na	<.1	.3	.3	.5	2.1
Organic nitrogen,[2] dissolved	53	51	na	.2	.3	.3	.4	1.3
Nitrite (as N), dissolved	53	48	na	<.01	.02	.03	.04	.13
Nitrite plus nitrate (as N), dissolved	53	52	na	.02	3.6	5.4	7.7	11
Nitrate (as N),[1] dissolved	53	52	3	<.10	3.6	5.9	8.9	12
Nitrogen (as N), total[3] dissolved	53	53	na	.3	4.2	5.9	8.1	12
Phosphorus (as P), dissolved	53	46	na	<.01	.01	.12	.21	.31
Orthophosphate (as P), dissolved	53	43	na	<.01	.02	.08	.14	.47
Phosphorus (as P), total	53	53	52	.07	.24	.29	.38	.83
Suspended sediment	53	53	na	13	84	130	240	1,700
Organic carbon, dissolved	52	52	na	2.5	3.2	3.7	4.4	30
Organic carbon, suspended	53	53	na	.3	1.4	4.5	5.0	17
Site 12—Skunk River at Augusta (integrator site, fig. 1)								
Ammonia (as N), dissolved	34	23	na	<.02	<.02	.03	.12	.79
Ammonia plus organic nitrogen (as N), total	34	34	na	.5	.9	1.3	3.8	7.0
Ammonia plus organic nitrogen (as N), dissolved	34	34	na	.2	.3	.4	.7	1.5
Organic nitrogen,[2] dissolved	34	34	na	.2	.3	.4	.5	1.3
Nitrite (as N), dissolved	34	32	na	<.01	.02	.03	.06	.11
Nitrite plus nitrate (as N), dissolved	34	32	na	.02	3.7	6.0	8.9	13
Nitrate (as N),[1] dissolved	34	34	6	.04	3.6	5.9	8.9	13
Nitrogen (as N), total[3] dissolved	34	34	na	.2	4.7	6.8	9.2	13
Phosphorus (as P), dissolved	34	33	na	<.01	.11	.14	.16	.38
Orthophosphate (as P), dissolved	34	32	na	<.01	.10	.14	.16	.36
Phosphorus (as P), total	34	34	34	.12	.22	.33	.83	2.6
Suspended sediment	34	34	na	17	99	180	600	3,500
Organic carbon, dissolved	34	34	na	.8	3.2	4.2	5.2	18
Organic carbon, suspended	34	34	na	.3	1.7	3.9	5.0	10

[1]Dissolved nitrite plus nitrate minus dissolved nitrite.
[2]Dissolved ammonia plus organic nitrogen minus dissolved ammonia.
[3]Dissolved nitrite plus nitrate plus dissolved ammonia plus organic nitrogen.

Becher and others—Water-Quality Assessment of the Eastern Iowa Basins—Nitrogen, Phosphorus, Suspended Sediment, and Organic Carbon in Surface Water, 1996–98

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