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National Water-Quality Assessment Program

Response of Stream Chemistry During Base Flow to Gradients of Urbanization in Selected Locations Across the Conterminous United States, 2002–04

Scientific Investigations Report 2007–5083

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

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Foreword

The U.S. Geological Survey (USGS) is committed to providing the Nation with credible scientific information that helps to enhance and protect the overall quality of life and that facilitates effective management of water, biological, energy, and mineral resources (http://www.usgs.gov/). Information on the Nation's water resources is critical to ensuring long-term availability of water that is safe for drinking and recreation and is suitable for industry, irrigation, and fish and wildlife. Population growth and increasing demands for water make the availability of that water, now measured in terms of quantity and quality, even more essential to the long-term sustainability of our communities and ecosystems.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program in 1991 to support national, regional, State, and local information needs and decisions related to water-quality management and policy (http://water.usgs.gov/nawqa). The NAWQA Program is designed to answer: What is the condition of our Nation's streams and ground water? How are 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 and priorities. From 1991–2001, the NAWQA Program completed interdisciplinary assessments and established a baseline understanding of water-quality conditions in 51 of the Nation's river basins and aquifers, referred to as Study Units (http://water.usgs.gov/nawqa/studyu.html).

Multiple national and regional assessments are ongoing in the second decade (2001–2012) of the NAWQA Program as 42 of the 51 Study Units are reassessed. These assessments extend the findings in the Study Units by determining status and trends at sites that have been consistently monitored for more than a decade, and filling critical gaps in characterizing the quality of surface water and ground water. For example, increased emphasis has been placed on assessing the quality of source water and finished water associated with many of the Nation's largest community water systems. During the second decade, NAWQA is addressing five national priority topics that build an understanding of how natural features and human activities affect water quality, and establish links between sources of contaminants, the transport of those contaminants through the hydrologic system, and the potential effects of contaminants on humans and aquatic ecosystems. Included are topics on the fate of agricultural chemicals, effects of urbanization on stream ecosystems, bioaccumulation of mercury in stream ecosystems, effects of nutrient enrichment on aquatic ecosystems, and transport of contaminants to public-supply wells. These topical studies are conducted in those Study Units most affected by these issues; they comprise a set of multi-Study-Unit designs for systematic national assessment. In addition, national syntheses of information on pesticides, volatile organic compounds (VOCs), nutrients, selected trace elements, and aquatic ecology are continuing.

The USGS aims to disseminate credible, timely, and relevant science information to address practical and effective water-resource management and strategies that protect and restore water quality. We hope this NAWQA publication will provide you with insights and information to meet your needs, and will foster increased citizen awareness and involvement in the protection and restoration of our Nation's waters.

The USGS 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 cost-effective management, regulation, and conservation of our Nation's water resources. The NAWQA Program, therefore, depends on advice and information from other agencies—Federal, State, regional, interstate, Tribal, and local—as well as nongovernmental organizations, industry, academia, and other stakeholder groups. Your assistance and suggestions are greatly appreciated.

Robert M. Hirsch
Associate Director for Water

Contents

Figures

Appendix 1

Tables

Conversion Factors, Datum, and Acronyms

Multiply	By	To obtain
	Length	
micrometer (µm)	0.00003937	inch (in)
centimeter (cm)	0.3937	inch (in)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6215	mile (mi)
	Area	
square meter (m^2)	0.0002471	acre
	Volume	
liter (L)	0.2642	gallon (gal)
milliliter (mL)	1,000	microliter (µL)
	Mass	
kilogram (kg)	2.205	pound, avoirdupois (lb)
kilogram (kg)	0.001102	ton [short, US] (t)
	Application rate	
kilogram per square meter per year ($kg/m^2/yr$)	4.460	ton [short, US] per acre per year (t/acre/yr)

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

°F=(1.8×°C)+32

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

°C=(°F-32)/1.8

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

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

Acronyms

10^{-6} CRC	U.S. Environmental Protection Agency 10^{-6} cancer risk concentration
AI	acute-invertebrate benchmark
AWQC-AL	ambient water-quality criteria for protection of aquatic organisms
CI	chronic-invertebrate benchmark
EC_{50}	50-percent effect concentration
GIS	geographic information system
LHA	U.S. Environmental Protection Agency lifetime health advisory
HBSL	health-based screening level
LC_{50}	50-percent lethal concentration
LOC	level of concern
LOWESS	locally weighted scatterplot smooth
MCL	U.S. Environmental Protection Agency Maximum Contaminant Level
NAWQA	National Water-Quality Assessment Program
NOAA	National Oceanic and Atmospheric Administration
NLCD	national land-cover data set
PTI	pesticide toxicity index
SDWR	U.S. Environmental Protection Agency Secondary Drinking-Water Regulation
UII	urban intensity index
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	volatile organic compound
WWTP	wastewater-treatment plant

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Abstract

During 2002–2004, the U.S. Geological Survey's National Water-Quality Assessment Program conducted a study to determine the effects of urbanization on stream water quality and aquatic communities in six environmentally heterogeneous areas of the conterminous United States— Atlanta, Georgia; Raleigh-Durham, North Carolina; Milwaukee-Green Bay, Wisconsin; Dallas-Fort Worth, Texas; Denver, Colorado; and Portland, Oregon. This report compares and contrasts the response of stream chemistry during base flow to urbanization in different environmental settings and examines the relation between the exceedance of water-quality benchmarks and the level of urbanization in these areas. Chemical characteristics studied included concentrations of nutrients, dissolved pesticides, suspended sediment, sulfate, and chloride in base flow.

In three study areas where the background land cover in minimally urbanized basins was predominantly forested (Atlanta, Raleigh-Durham, and Portland), urban development was associated with increased concentrations of nitrogen and total herbicides in streams. In Portland, there was evidence of mixed agricultural and urban influences at sites with 20 to 50 percent urban land cover. In two study areas where agriculture was the predominant background land cover (Milwaukee-Green Bay and Dallas-Fort Worth), concentrations of nitrogen and herbicides were flat or decreasing as urbanization increased. In Denver, which had predominantly shrub/grass as background land cover, nitrogen concentrations were only weakly related to urbanization, and total herbicide concentrations did not show any clear pattern relative to land cover—perhaps because of extensive water management in the study area. In contrast, total insecticide concentrations increased with increasing urbanization in all six study areas, likely due to high use of insecticides in urban applications and, for some study areas, the proximity of urban land cover to the sampling sites. Phosphorus concentrations increased with urbanization only in Portland; in Atlanta and Raleigh-Durham, leachate from septic tanks may have increased phosphorus concentrations in basins with minimal urban development. Concentrations of suspended sediment were only weakly associated with urbanization, probably because this study analyzed only base-flow samples, and the bulk of sediment loads to streams is transported in storm runoff rather than base flow. Sulfate and chloride concentrations increased with increasing urbanization in four study areas (Atlanta, Raleigh-Durham, Milwaukee-Green Bay, and Portland), likely due to increasing contributions from urban sources of these constituents. The weak relation between sulfate and chloride concentrations and urbanization in Dallas-Fort Worth and Denver was likely due in part to high sulfate and chloride concentrations in groundwater inflow, which would have obscured any pattern of increasing concentration with urbanization.

Pesticides often were detected at multiple sites within a study area, so that the pesticide "signature" for a given study area—the mixtures of pesticides detected, and their relative concentrations, at streams within the study area—tended to show some pesticides as dominant. The type and concentrations of the dominant pesticides varied markedly among sites within a study area. There were differences between pesticide signatures during high and low base-flow conditions in five of the six study areas. Normalization of absolute pesticide concentrations by the pesticide toxicity index (a relative index indicating potential toxicity to aquatic organisms) dramatically changed the pesticide signatures, indicating that the pesticides with the greatest potential to adversely affect cladocerans or fish were not necessarily the pesticides detected at the highest concentrations.

In a screening-level assessment, measured contaminant concentrations in individual base-flow water samples were compared with various water-quality benchmarks. One or more recommended Ecoregional nutrient criteria were exceeded at about 70 percent of the 173 total sites—less often for sites with less than about 3 percent urban land cover; these criteria are intended to represent baseline conditions for surface water that is minimally affected by human activities. Secondary drinking-water regulations for pH, sulfate, and chloride were exceeded at 24 sites, indicating some possibility of taste and odor problems at these sites if the stream water were to be used as drinking water without treatment. Otherwise, benchmarks were rarely exceeded: one or more human-health benchmarks was exceeded at 15 sites (for nitrate, atrazine, dieldrin, or simazine), and aquatic-life benchmarks at 12 sites

(for pH, chloride, ammonia, chlorpyrifos, diazinon, and malathion). Benchmark exceedances were not related to the degree of urbanization, except that the dieldrin exceedances always occurred at sites with more than 60-percent urban land cover. Comparison of ambient stream water concentrations to human-health benchmarks (which apply to lifetime consumption of drinking water), as was done in this study, is not appropriate for human exposure assessment, but serves only to put the data in a human-health context. Because this study sampled stream water only twice per year during base-flow conditions, it is likely that the contaminant occurrence and benchmark exceedance rates described here may underestimate occurrence and exceedances in individual ambient water samples collected at other times, such as in peak pesticide- or fertilizer-use periods or during storm events or irrigation return flow.

The response of stream-water quality in base flow to urbanization differed by chemical constituent and by environmental setting. In areas where land cover in minimally urbanized basins was predominantly forest or shrub/grass, urbanization generally was associated with increasing chemical concentrations, although other nonurban factors may have been related to chemical concentrations as well. In areas where minimally urbanized basins were already affected by other stressors, such as agriculture, water management, or inflow of relatively saline ground water, the effects of urbanization were less clear. Maintenance or protection of stream quality may be addressed by identifying all important stressors and supplementing the management practices currently used in urbanizing areas with additional steps to mitigate the effects of these other stressors.

Introduction

Background

Impervious surfaces—impenetrable surfaces such as parking lots, rooftops, and roads—can alter the movement of water above and below the land surface in urbanizing areas. Impervious surfaces prevent rainfall from infiltrating into soil and ground water, leading to increased runoff to streams. Runoff can transport contaminants from a variety of urban sources, including automobiles (hydrocarbons and metals); rooftops (metals); wood preservatives (hydrocarbons); construction sites (sediment and any adsorbed contaminants); and golf courses, parks, and residential areas (pesticides, nutrients, bacteria) (for example, Pitt and others, 1995; House and others, 1993). During dry weather, contaminants can enter the stream from additional sources including wastewater-treatment plants, industrial discharge, leaking septic systems, ground water, and dry atmospheric deposition. Concentrations of some contaminants may be higher during dry periods than wet periods because rainwater can dilute concentrations during wet periods (Burton and Pitt, 2002).

Nutrients

Increased concentrations and loads of nutrients in streams long have been associated with urbanization (Haith, 1976; Klein, 1979; Heany and Huber, 1984; U.S. Environmental Protection Agency, 2000e). With more than 75 percent of the current population of the United States living in urban areas, urban development has led to the potential for increased phosphorus and nitrogen loading to streams (Paul and Meyer, 2001).

The U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) Program found that ammonia and phosphorus concentrations were higher downstream from urban areas than from areas with other land uses and were often high enough to warrant concerns about fish toxicity (Mueller and others, 1995; Mueller and Helsel, 1996). These increased concentrations likely were due to upstream sewage effluent (Graffy and others, 1996). Total phosphorus concentrations measured in urban streams across the country generally were found to be as high as those in agricultural streams; concentrations in 70 percent of urban streams measured in the NAWQA program exceeded U.S. Environmental Protection Agency (USEPA) guidelines for preventing nuisance algal growth (Miller and Hamilton, 2001).

Nutrient sources in urban areas include discharge from wastewater-treatment plants (WWTP) and industrial point sources, leachate from septic tanks, land application of sludge and fertilizer, and atmospheric deposition of nitrogen derived from fuel combustion. Acid rain is a particular concern in the northeastern United States and may contribute substantial nitrate to surface water (Mueller and others, 1995). Heisig (2000) reported that increasing nitrate concentrations in base flow in southeastern New York were associated with increasing density of housing served by septic tanks. Nutrient budgets calculated for the major streams of the Chesapeake Bay basin indicated that urban runoff generally was the second largest source of nitrogen after agricultural runoff and that point sources also contributed substantial phosphorus loads to steams draining to Chesapeake Bay (Sprague and others, 2000). In addition to increased source loading of nutrients, enhanced nutrient transport has been associated with landscape changes caused by urban development. Impervious-surface coverage of as little as 5 percent of the drainage area has been associated with increased nutrient concentrations (Roy and others, 2003; Schoonover and others, 2005). Increased impervious area, drainage alteration, soil compaction, and other physical changes caused by urbanization may contribute to increased transport of nutrients (House and others, 1993; Booth and others, 2002).

The causes of nutrient enrichment in urban streams go beyond increased source loading and enhanced transport. Alteration of the ecosystem may lead to decreased benthic nutrient uptake (Meyer and others, 2005; Walsh and others, 2005). The complex multivariate nature of changes in stream quality caused by urbanization is reflected only in part by changes in stream nutrient chemistry (Cuffney and others, 2005).

Pesticides

The amount of pesticides used in the United States in 2001 exceeded 544 million kg (1.2 billion lb), with nearly one-third of that amount resulting from nonagricultural use in industrial, commercial, and residential areas (Kiely and others, 2004). Total pesticide concentrations in streams generally are higher in agricultural areas than in urban areas, but seasonal peak concentrations are of longer duration in urban areas (Gilliom, 2001). In addition, herbicides and insecticides commonly used in urban areas are frequently detected in urban streams (Phillips and Bode, 2004; Bailey and others, 2000; Hoffman and others, 2000), often at higher concentrations than in agricultural streams (Gilliom and others, 2006; Crawford, 2001). Organochlorine pesticides, whose uses have been restricted or discontinued since the 1970s, were detected in streambed sediment and fish tissue in agricultural and urban streams, often in greater numbers or at higher concentrations in urban or mixed urban and agricultural streams (Black and others, 2000; Parker and others, 2000; Pereira and others, 1996; Tate and Heiny, 1996).

Herbicides are the most common type of pesticide found in agricultural streams, whereas insecticides are the most common type found in urban streams (Fuhrer and others, 1999). Estimates of herbicide and insecticide mass contributed to streams by agricultural and urban areas have indicated that contributions of herbicides from agricultural areas likely are far greater than those from urban areas, but that contributions of insecticides from urban areas may be similar to those from agricultural areas (Hoffman and others, 2000). The USGS NAWQA Program found that diazinon, chlorpyrifos, carbaryl, and malathion accounted for most insecticide detections in urban streams during 1992–2001; diazinon and carbaryl were the most frequently detected (Gilliom and others, 2006).

These detections likely reflect contributions from a combination of residential, commercial, and industrial sources. The most commonly used insecticides within the home and garden sector in 2001 were diazinon, carbaryl, and malathion, and the most commonly used insecticides in the commercial and industrial sector were chlorpyrifos and malathion (Kiely and others, 2004). Among industrial, commercial, and residential areas, concentrations of diazinon have been found to be highest in residential streams (Bailey and others, 2000). Whether from industrial, commercial, or residential sources, pesticides in urban streams have the potential to harm aquatic life. In results from the NAWQA Program, 83 percent of urban stream sites nationwide had concentrations that exceeded one or more aquatic-life benchmarks (Gilliom and others, 2006).

Suspended Sediment

As basins urbanize, landscape disturbance and increased runoff associated with increased impervious area can lead to increased sediment loading to streams. The Wisconsin Department of Natural Resources estimated that the typical erosion rate for construction sites is 8 to 10 kg/m^2/yr compared to 0.22 to 2.2 kg/m^2/yr for farmland (Johnson and Juengst, 1997). Goldman and others (1986) estimate that erosion from construction sites puts 7.26 x10^{10} kg of sediment into receiving waters each year. A study in an urban stream basin in Austin, Texas, concluded that concentrations of sediment in stormwater greatly increased with increasing impervious area—median concentrations of total suspended solids in samples collected during rising stage from a rural stream were 6 mg/L compared to 4,100 mg/L in similar samples from urban streams (Veenhuis and Slade, 1990).

In addition to increased sediment loading to the stream from surface runoff, widening and incision of the stream channel can occur in urban areas. A study of an urbanizing basin in Wisconsin found changes in morphology, increased erosion and sediment loading, lowering of mean streambed elevation by almost 0.6 m, and widening of mean channel width by 35 percent (Krug and Goddard, 1986). Streambank erosion can be another large source of sediment in urban streams; measurements from 1983 to 1993 in an urban basin in southern California indicated that stream channel erosion furnished about two-thirds of the total sediment yield (Trimble, 1997).

Sediment can transport adsorbed pollutants and nutrients to streams (Stone and Droppo, 1994) and affect the health of aquatic organisms. In addition, reduced light penetration in streams with higher sediment concentrations can impair photosynthesis. Sediment also can damage critical aquatic habitat and interfere with feeding and reproduction in fish by clogging gills and burying eggs.

Sulfate and Chloride

Sulfate in urban areas can be derived from natural and anthropogenic sources, including weathering of rocks, combustion of fossil fuels (including coal, oil, and diesel), discharge from industrial sources (including smelting of sulfide ores, tanneries, and pulp and textile mills), and discharge from WWTPs (Hem, 1985). Combustion of fossil fuels accounts for a majority of sulfur in the atmosphere, which can return to the surface as sulfate through precipitation or dry deposition. Increases in sulfate concentrations in the Great Lakes and the lower Mississippi River have occurred in the last century as a result of increased industrial and agricultural activities (Hem, 1985). Although necessary in small concentrations for plant growth, at higher concentrations sulfate can contribute to the release of metals from streambed sediments and increases in stream pH that can affect aquatic organisms.

Chloride concentrations in urban streams have been found to increase as a function of impervious surface area, exceeding tolerance levels for aquatic organisms in some areas

(Kaushal and others, 2005). Chloride also has been found to be a good surrogate for the amount of anthropogenic activity in urban basins (Herlihy and others, 1998). Chloride is not subject to any substantial natural attenuation (Environment Canada, 2001), and its accumulation and persistence in streams may affect aquatic organisms and water quality. Chloride can contribute to the release of metals from streambed sediments and in high concentrations can be toxic to fish and plants.

Chloride enters urban streams from several sources including weathering of rocks containing chloride, discharge from WWTPs, and surface runoff in areas where chloride is used for deicing roads and parking lots. Sodium chloride is the most widely used road and parking lot deicer in the United States. According to the Federal Highway Administration, there were 4 million km of paved roads in the United States in 2000, and deicer use ranged from 7.2×10^9 to 11×10^9 kg annually (Kunze and Sroka, 2004). Approximately 55 percent of chloride in deicers is transported in surface runoff, and the remaining 45 percent typically infiltrates through soils into ground water (Church and Friesz, 1993). Chloride also may be present in particulate matter from vehicle exhaust (Lough and others, 2005). Sodium chloride commonly is used in water softeners, and chloride concentrations in discharge from WWTPs may be high in locations where water softeners are used frequently in homes and businesses. Ferric chloride, ferrous chloride, and sodium hypochlorite also are used in many WWTPs during the treatment process (Santa Clarita Valley Joint Sewerage System, 2002)

NAWQA Study on the Effects of Urbanization on Stream Ecosystems

Many previous studies have focused on either very pristine or highly developed areas; little is known about how the gradual progression of urban development between these two extremes affects stream-water quality. In addition, previous studies have linked urbanization to water-quality changes in environmentally homogenous regions; few have compared the response of water quality to urbanization in areas of differing climate, physiography, geology, and soils. As a result, in 2000, the USGS NAWQA program began three pilot studies to examine the regional effects of urbanization on the physical, chemical, and biological characteristics of stream ecosystems in three environmentally diverse metropolitan areas—Boston, Massachusetts; Birmingham, Alabama; and Salt Lake City, Utah (Tate and others, 2005). Within each metropolitan area, study basins were chosen to minimize natural variability among basins due to factors such as geology, altitude, and climate and to maximize coverage among basins of different degrees of urban development, ranging from minimally to highly developed. Aquatic assemblages, physical habitat, and water chemistry were sampled using the same protocols so that these ecological responses to urbanization could be compared among study areas (Tate and others, 2005). Results from these studies are available in Short and others (2005), Potapova and others (2005), Cuffney and others (2005), and Meador and others (2005).

In 2002, a second round of urban-gradient studies began in six other areas of the conterminous United States— Atlanta, Georgia; Raleigh-Durham, North Carolina; Milwaukee-Green Bay, Wisconsin; Dallas-Fort Worth, Texas; Denver, Colorado; and Portland, Oregon (fig. 1). This second round of studies expanded on the three pilot studies to include metropolitan areas with additional environmental characteristics, and additional physical, chemical, and biological aspects of the stream ecosystems were examined.

Purpose and Scope

This report includes the results from the stream-chemistry component of the second round of studies from 2002 to 2004 and describes the response of stream chemistry during base flow to gradients of urbanization. Chemical characteristics examined included nutrient, dissolved pesticide, suspended-sediment, sulfate, and chloride concentrations. The objectives of the stream-chemistry component of the study were to: (1) compare and contrast the response of stream chemistry during base flow to urbanization in different environmental settings; and (2) examine the relation between the exceedance of water-quality benchmarks and the level of urbanization.

Description of the Study Areas

Background (undeveloped) land cover in the six study areas varied considerably (Falcone and others, 2007) (fig. 2). In the Atlanta and Raleigh-Durham study areas, the predominant background land cover was forest, with some agricultural land cover interspersed. In the Milwaukee-Green Bay study area, agriculture was almost exclusively the background land cover. In the Dallas-Fort Worth study area, the background land cover was agriculture (primarily pasture) and shrub/grass to a lesser extent. In the Denver study area, the predominant background land cover was shrub/grass with some agricultural land cover interspersed. In the Portland study area, background land cover was a nearly equal mixture of forest, agriculture, and shrub/grass.

The overall level of urbanization in the study basins generally was highest in the Raleigh-Durham and Denver study areas and lowest in the Dallas-Fort Worth study area (Falcone and others, 2007). In the Milwaukee-Green Bay and Denver study areas, the majority of basins had a disproportionate shift of urban development closer to the sampling site; Dallas-Fort Worth had the fewest number of basins with this characteristic (Falcone and others, 2007). The amount of urban land cover in the riparian buffer as compared to the basin as a whole was lowest in the Atlanta and Dallas-Fort Worth study areas and highest in the Denver study area (Falcone and others, 2007). In all study areas, urban land cover generally was increasing more rapidly than population (Falcone and others, 2007).

Figure 1. Location of the study areas.

A general description of the six study areas follows (Falcone and others, 2007). These descriptions are based on the basins included in this study and may not be representative of the larger metropolitan areas.

Atlanta

The Atlanta study area was in north-central Georgia and portions of eastern Alabama and contained numerous metropolitan areas, including the cities of Atlanta and Marietta (fig. 1). Study basins were located entirely in the USEPA Piedmont Level III Ecoregion (Omernik, 1987), specifically in the Southern Inner and the Southern Outer Piedmont Level IV Ecoregions (U.S. Environmental Protection Agency, 2006a). The study area is characterized by gently rolling topography and dissected irregular plains, with altitudes ranging from about 100 to 465 m (above NAVD 88) (U.S. Geological Survey, 2005a). The climate is warm and humid, with a mean annual precipitation of about 131 cm and a mean annual air temperature of about 16.6 ºC (Daymet, 2005). Streams are typified by low to moderate gradients with cobble, gravel, and sandy substrates. Streamflow in the Southern Inner and Outer Piedmont Ecoregions generally is highest in the winter when rainfall primarily is derived from slow-moving frontal systems and lowest in late summer and fall when fast-moving thunderstorms are more prevalent. Potential natural vegetation in the Southern Inner and Outer Piedmont Ecoregions is oak–hickory–pine forest; however, current (2007) land use and land cover includes forested areas in silviculture as well as in agricultural production of hay, cattle, and poultry. The economy is well diversified, and although it includes industrial activities, it contains more commercial and service-oriented activity than heavy industry (McKnight, 2001).

Raleigh-Durham

The Raleigh-Durham study area was in north-central North Carolina and contained numerous metropolitan areas, including the cities of Raleigh, Durham, and Winston-Salem (fig. 1). Study basins were located entirely in the USEPA Piedmont Level III Ecoregion (Omernik, 1987), specifically in the Northern Outer Piedmont, Southern Outer Piedmont, and Carolina Slate Belt Level IV Ecoregions (U.S. Environmental Protection Agency, 2006a). The study area is characterized by irregular plains with some hills, with altitudes ranging from about 50 to 315 m (above NAVD 88) (U.S. Geological Survey, 2005a). The climate is warm and humid, with a mean annual precipitation of about 118 cm and a mean annual air temperature of about 15.0 ºC (Daymet, 2005). Rainfall is evenly distributed throughout the year, with slightly more rainfall in July and August and slightly less in October through December (Daymet, 2005). Streams in all three Level IV Ecoregions have low to moderate gradients and typically have gravel to cobble substrate. Streamflow typically is highest in the winter months

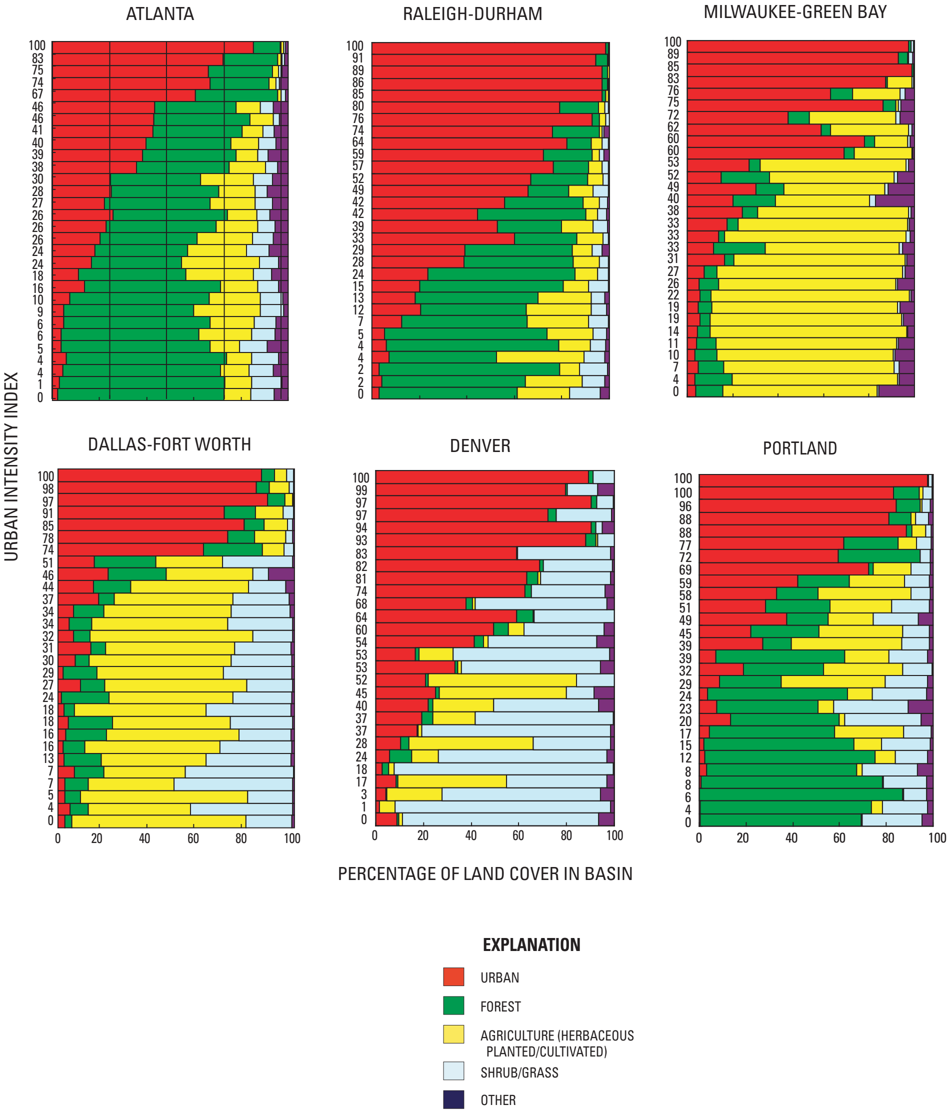

Figure 2. Land cover for basins in the Atlanta, Raleigh-Durham, Milwaukee-Green Bay, Dallas-Fort Worth, Denver, and Portland study areas, 2001.

when deciduous vegetation is dormant and lowest in late summer. Rock and soil types in the Northern and Southern Outer Piedmont Ecoregions are similar, typically gneiss, schist, and granite, covered by saprolite and deep clay subsoils. Rocks in the Carolina Slate Belt Ecoregion tend to be finer-grained and less metamorphosed than the other two regions and soils are silty and silty clay. Land use of the area has undergone major transformations from oak-hickory-pine forest to agricultural lands, back to forest, and now to urban and suburban lands. At one time, the region was heavily farmed for cotton, tobacco, corn, and wheat and many areas suffered moderate to severe erosion of the silt/clay soils (Trimble, 1974). More recently, the economy has diversified, with heavier industry—primarily textiles, tobacco, chemicals, and furniture—dominating in the western part of the study area.

Milwaukee-Green Bay

The Milwaukee-Green Bay study area was in southeastern Wisconsin and contained numerous metropolitan areas, including the cities of Milwaukee, Green Bay, Oshkosh, and Racine (fig. 1). Study basins were primarily in the USEPA Southeastern Wisconsin Till Plains Level III Ecoregion (Omernik, 1987), although they also included areas in the Central Corn Belt Plains and North Central Hardwood Forests Ecoregions. The pre-settlement vegetation types of the Southeastern Wisconsin Till Plains Ecoregion were a mixture of hardwood forest (north), oak savannas (west), and tall-grass prairies (south). The land surface is characterized by glacial outwash plains, lacustrine basins, and level to rolling till plains and includes extensive wetlands. Altitudes in the study area range from 175 to 370 m (above NAVD 88) (U.S. Geological Survey, 2005a). The climate is characterized by cool, dry winters and moderate summers, with a mean annual precipitation of about 85 cm and a mean annual air temperature of about 7.5 ºC (Daymet, 2005). Most of the precipitation falls between May and September (Daymet, 2005). Highest streamflows usually occur in March through May as a result of snowmelt or a combination of rain and snowmelt; however, summer thunderstorms also can produce flood peaks that exceed snowmelt peaks. Dairy and livestock farming with associated corn and soybean production represents the dominant land use in the region (Peters and others, 1997); the economy also includes industrial manufacturing (McKnight, 2001).

Dallas-Fort Worth

The Dallas-Fort Worth study area was in north-central Texas and contained numerous metropolitan areas, including the cities of Dallas and Fort Worth (fig. 1). The study area was in the upper drainage of the Trinity River basin, in the USEPA Texas Blackland Prairies and East Central Texas Plains Level III Ecoregions (Omernik, 1987). Study basins were located primarily in the Texas Blackland Prairies Ecoregion. The Texas Blackland Prairies Ecoregion is underlain by chalks, marls, limestones, and shales and is a rolling to level plain with natural vegetation dominated by little bluestem, yellow Indiangrass, sugar hackberry, bur oak, elm, and eastern cottonwood. Altitude in the study area ranges from about 80 to 270 m (above NAVD 88) (U.S. Geological Survey, 2005a). The climate is semiarid, with precipitation falling primarily in the spring and from summer thunderstorms. Mean annual precipitation is about 105 cm and mean annual air temperature is about 18.2 ºC (Daymet, 2005). Streamflow in the study area is affected by reservoirs, intrabasin transfers, diversion of water for municipal water supply, and discharge from WWTPs. Smaller streams generally are intermittent. Land cover includes grassland, pasture, row crops, and urban areas. The economy includes finance, oil, transportation, aerospace, electronics, cattle, railways, and agriculture (McKnight, 2001).

Denver

The Denver study area was in north-central Colorado and southeastern Wyoming and contained numerous metropolitan areas, including the cities of Denver, Boulder, Fort Collins, and Cheyenne (fig. 1). Study basins were almost entirely in the USEPA Western High Plains Level III Ecoregion (Omernik, 1987), although one basin included a small area in the Southwestern Tablelands Ecoregion. Altitude in the study area ranges from about 1,465 to 2,545 m (above NAVD 88) (U.S. Geological Survey, 2005a); however, it is bordered by the Southern Rockies Ecoregion to the west, where altitudes are considerably higher. The climate is dry, with precipitation affected by topography. Most precipitation on the plains results from rainfall, primarily between April and September; however, during late spring and early summer, streamflow also is fed by snowmelt from the mountains, where snow falls during the winter. Mean annual precipitation is about 43 cm and mean annual air temperature is about 8.1 ºC (Daymet, 2005). A complex network of canals and pipes moves water between different areas for municipal water supply, agricultural irrigation, and power generation (Sprague and others, 2006). Land cover in the study area is dominated by grassland and agriculture in the plains, with conifer forest in the western mountains. The economy is diversified and includes agriculture, mining, and industry (McKnight, 2001).

Portland

The Portland study area was in western Oregon and parts of southern Washington and contained numerous metropolitan areas, including the cities of Portland, Salem, Corvallis, and Eugene (fig. 1). Study basins were primarily in the USEPA Willamette Valley Level III Ecoregion (Omernik, 1987), although they also included areas in the Coast Range and Cascades Ecoregions. The Willamette Valley Ecoregion is characterized as a broad, lowland valley with a mosaic of vegetation of rolling prairies, deciduous and coniferous forests, and extensive wetlands. Landforms consist of terraces and flood plains that are interlaced and surrounded by rolling hills. Altitude in the study area ranges from 0 to 1,330 m (above NAVD 88) (U.S. Geological Survey, 2005a) in the foothills of the Cascade Mountains. The climate is characterized by cool, wet winters and warm, dry summers with a mean annual precipitation of about 145 cm and a mean annual air temperature of about 11.1 ºC (Daymet, 2005). Most of the precipitation falls between October and April. Highest streamflows are recorded from November to March and lowest streamflows occur in summer and fall. The economy includes forestry, fruit and wheat farming, dairying, and wood and food processing (McKnight, 2001).

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Approach

Within each study area, about 30 sites representing minimal natural variability and a range of urbanization were selected. Water samples were collected twice at each site, once during low base-flow conditions and once during high base-flow conditions. Methods of site selection, sample collection, and data analysis are described as follows.

Geographic Information System Data

Using a Geographic Information System (GIS), about 300 urban and environmental variables were used to aid in site selection and data analysis (Falcone and others, 2007). Basin boundaries in most cases were derived from USGS 30-m resolution National Elevation Data (U.S. Geological Survey, 2005a) and in a small number of cases were refined from higher resolution data. Most variables were derived based on basin boundaries (basin-level variables); however, several categories of variables were calculated on finer scales (riparian- and segment-level variables). Streams were based on the USGS National Hydrography Data 1:100,000 stream set (U.S. Geological Survey, 2005b). The GIS-derived variables fell into 11 broad categories:

(1) Population and housing: Counts of basin population and population density were calculated based on 2000 Census block-level data (GeoLytics, 2001). All other Census variables (demographic, labor, income, and housing characteristics) were calculated based on 2000 Census block-group data. In addition, four socioeconomic indices were derived based on principal component ordination of 63 Census variables, as

described in McMahon and Cuffney (2000). Each socioeconomic index represented a positive association with a subset of those variables and varied between study areas.

(2) Climate: Basin-level mean air temperature and precipitation statistics were derived from 1-km resolution Daymet model data (Daymet, 2005), which represented temperature and precipitation averages over an 18-year period from 1980 to 1997. These data were obtained from terrain-adjusted daily climatological observations.

(3) Ecologic and hydrologic regions: Ecologic Region boundaries were based on USEPA level III Ecoregions for all study areas (Omernik, 1987). Additional level IV boundaries were used in the Raleigh-Durham, Milwaukee-Green Bay, and Dallas-Fort Worth study areas. Hydrologic Region boundaries were based on USGS Hydrologic Landscape Regions (Winter, 2001)).

(4) Infrastructure: Road data were based on Census 2000 Topologically Integrated Geographic Encoding and Reference line roads (GeoLytics, 2001). Point-source dischargers were derived from USEPA National Pollutant Discharge Elimination System locations (U.S. Environmental Protection Agency, 2005f). Toxic release locations were derived from the USEPA Toxic Release Inventory (U.S. Environmental Protection Agency, 2005i). Dam location data were based on the U.S. Army Corps of Engineers National Inventory of Dams (U.S. Army Corps of Engineers, 1996).

(5) Land cover 2001, basin level: The 2001 land-cover data were based on the National Land Cover Data (NLCD) 2001 data set (for the Atlanta and Raleigh-Durham study areas) (U.S. Geological Survey, 2005c), National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (Portland study area) (National Oceanic and Atmospheric Administration, 2005), or derived using methods and protocols identical to those used in the NLCD 2001 program (Milwaukee-Green Bay, Denver, and Dallas-Fort Worth study areas) (U.S. Geological Survey, 2006a). Likewise, NOAA land-cover data for the Portland study area were produced using NLCD 2001 protocols, but these data contained slightly different class structures that were recoded to match the NLCD 2001 classes. The NLCD 2001 is a 30-m resolution data set based primarily on Landsat-7 Enhanced Thematic Mapper imagery covering the period from 1999 to 2002. The NLCD 2001 program also contains a subpixel-percentage impervious-surface data layer, which was acquired or derived from imagery.

(6) Land cover 2001, riparian level: NLCD 2001 land-cover statistics were derived for riparian buffer based on the National Hydrography Data stream lines for the entire basin. The riparian buffer was defined as the area covering 100 m to each side of the stream centerline.

(7) Land cover 2001, distance weighted: Land cover in a number of basins was not spatially distributed evenly throughout the basin. Some basins had a small percentage of basin-level urban land use, but in the lower part of the basin near the sampling site, the percentage of urban land use was much higher. To address this finding, distance-weighted land-cover data were calculated for each basin. The distance-weighted data were NLCD 2001 basin-level data re-weighted according to distance from the sampling site. Pixels representing land cover close to the sampling site were given a higher weight than those farther away; weights were calculated as the inverse distance from the sampling site. Distance-weighted land cover for each class then was calculated based on the distance-weighted data and normalized to 100 percent. The result was a percentage for each class that captured its spatial proximity to the sampling site.

(8) Land cover 2001, segment level: NLCD 2001 land-cover statistics were derived for the riparian zone (100 m on each side of stream centerline) of the segment of stream just upstream from the sampling location. The distance upstream was a function of the basin area. Segment statistics also were calculated for non-land cover physical characteristics—sinuosity, gradient, mean distance to nearest road, and density of road and stream intersections on the length of the segment.

(9) Land cover 1992, basin level: The 1992 land-cover data were based on the NLCD 1992 data set.

(10) Landscape pattern: Landscape-pattern metrics characterizing the shape, size, and spatial configuration of land-cover patches were derived using the FRAGSTATS software package (McGarigal and others, 2002). FRAGSTATS metrics were calculated for patches of each land-cover class. An additional metric (basin-shape index) was calculated based on the entire basin boundary.

(11) Soils and topography: Soil properties were derived from the U.S. Department of Agriculture State Soil Geographic data base (U.S. Department of Agriculture, 1994). Topographic characteristics were derived from USGS 30-m resolution National Elevation Data (U.S. Geological Survey, 2005a).

Site Selection

About 30 sites within each study area were selected on the basis of two major factors: (1) variability in natural landscape features and (2) gradient in the degree of urbanization.

Variability in Natural Landscape Features

Within each study area, sites were selected to minimize natural variability between basins to reduce the potential for natural factors to confound the interpretation of the chemical response along the urban land-use gradient (Falcone and others, 2007). GIS-derived data were used to identify candidate basins in each area with similar environmental characteristics. Basin boundaries were delineated based on USGS 30-m National Elevation Data (U.S. Geological Survey, 2005a). The major initial filtering criteria for natural landscape features were ecoregion, soils, and topography. USEPA Ecoregions (Omernik, 1987) provided a coarse framework of relatively homogenous climate, altitude, soils, geology, and vegetation (Tate and others, 2005). Most candidate basins for each study area fell within a single USEPA level III Ecoregion. Cluster analysis (Everitt and others, 2001) of climate, altitude, slope, soils, vegetation, and geology variables then was performed to group the candidate basins on the basis of environmental characteristics. From the resulting clusters, a final set of candidate basins was identified with similar natural landscape features. Each study area had a different number of final candidate basins (Atlanta–217; Raleigh-Durham–1,245; Milwaukee-Green Bay–51; Dallas-Fort Worth–57; Denver–162; Portland–171), but all were selected with the same goal of minimizing natural variability.

Gradient in the Degree of Urbanization

Rather than studying a single site over a long period as it urbanized, the goal of this study was to look at a larger number of sites that ranged from minimally to highly developed over a short time. In theory, the pattern of the chemical response among environmentally homogenous sites spanning a range of urbanization in space could reflect the same pattern of response that would be seen as a minimally disturbed site urbanized over time. Therefore, the second consideration for site selection was the need to obtain study sites that covered a gradient of urbanization from minimally to highly developed.

Previous studies of urban ecosystems have suggested that land use alone is not an adequate measure of urbanization (McMahon and Cuffney, 2000; Grove and Burch, 1997). In this study, land cover, infrastructure, and socioeconomic variables were integrated in a multimetric urban intensity index (UII) that was used to represent overall urbanization. A UII value was calculated for each of the basins by using a five-step procedure described in McMahon and Cuffney (2000). In brief, the procedure consisted of the following: (1) adjusting urban variables for basin size and measurement units, (2) range standardizing the original variables so the values ranged from 0 to 100, (3) retaining variables correlated with population density and uncorrelated with basin area and adjusting the variables so they all increased with increasing population density, (4) averaging retained variables across each site to obtain a UII, and (5) range standardizing the UII at each site so the values collectively ranged from 0 to 100. The criteria used in determining whether variables were correlated with population density varied among study areas; details are provided in Falcone and others (2007). The final variables included in the UII for each metropolitan area also are provided in Falcone and others (2007).

Once the candidate sites were identified through cluster analysis and the UII values were calculated for each, field reconnaissance took place to ground-truth the GIS data and to evaluate logistical issues, such as site access and safety conditions. Some sites were relocated short distances up or downstream to provide better access, to obtain reaches with cobble or riffle substrate, or to minimize local effects from wastewater-treatment-plant effluent, major diversions, or upstream reservoir releases. Some sites automatically were excluded based upon evidence that the stream was ephemeral. Other sites were excluded if access permissions could not be obtained from landowners. Ultimately, about 30 sites were selected in each study area; these sites were selected to be as evenly distributed as possible between minimally and highly developed conditions. The desired number of sites was set at about 30 for each study area because when a sample size is greater than 25–30, the sampling distribution of the mean becomes approximately normal (Hogg and Tanis, 1993). The final list of sites in each study area is provided in Falcone and others (2007).

Data Collection

Environmental Samples

Environmental water-chemistry samples were collected from October 2002 through September 2004. Samples were collected twice at each site, once during low base-flow conditions and once during high base-flow conditions (table 1). In addition, 10 out of the approximately 30 sites included in each study area were sampled bimonthly for 1 year to document potential seasonal variability in the response of base-flow chemistry to urbanization that may have been missed by sampling only twice at the majority of sites. The results from the samples collected during high and low base-flow conditions are the focus of this report; the results from the bimonthly sampling to evaluate seasonal variability are presented and discussed briefly in Appendix 1. For this report, the low base-flow period was defined as a period in which, under average climatic conditions, there are few precipitation events; the high base-flow period was defined as a period in which, under average climatic conditions, there are more frequent precipitation events and streamflow is derived to a greater degree from recent rain and(or) snowfall. The low and high base-flow periods were determined based on seasonal variability in streamflow and climate, as summarized in the “Description of the Study Areas” section.

Table 1. Dates of sample collection during high and low base-flow conditions for each of the six study areas.

Study area	High base-flow sample	Low base-flow sample
Atlanta, Georgia	March 2003	September 2003
Raleigh-Durham, North Carolina	February 2003	July 2003
Milwaukee-Green Bay, Wisconsin	May – June 2004	August 2004
Dallas-Fort Worth, Texas	May 2004	February 2004
Denver, Colorado	June 2003	August 2003
Portland, Oregon	May 2004	August 2004

In the Raleigh-Durham, Milwaukee-Green Bay, and Dallas-Fort Worth study areas, a slightly different set of sites was sampled during low base-flow conditions than during high base-flow conditions because some sites went dry between the two sampling periods and some sites that were sampled once were later deemed inappropriate for subsequent sampling of aquatic communities (Falcone and others, 2007). In some instances, a dropped site was replaced with another site with similar urban characteristics; in other instances, no replacement was made. Although water-chemistry conditions can vary substantially between base-flow and storm-runoff conditions because of differing transport mechanisms and instream dilution capacities, the scope of this study was not large enough to fully characterize chemical conditions during base flow and stormflow runoff.

All sites were sampled for nutrients, dissolved pesticides and pesticide degradates, suspended sediment, sulfate, and chloride in water (table 2). In addition, field measurements were obtained for water temperature, dissolved oxygen, pH, specific conductance, and discharge at the time of sampling. Water samples were collected using standardized depth- and width-integrating techniques and were processed and preserved onsite using standard methods described in U.S. Geological Survey (variously dated). Samples were filtered prior to analysis of dissolved constituents, including pesticides (0.7-µm pore diameter) and some nutrients (0.45-µm pore diameter), to remove suspended particulate matter. Nutrient and pesticide samples were analyzed at the USGS National Water-Quality Laboratory in Denver, Colo., by using methods described in Fishman (1993) and Zaugg and others (1995), respectively. Suspended-sediment samples were analyzed at USGS Water Science Center Sediment Laboratories in Louisiana, Iowa, and Kentucky, and at the USGS Cascades Volcano Observatory in Washington (Guy, 1969). Water-chemistry data are available in the USGS National Water Information System, accessible at *http://waterdata.usgs.gov/nwis/qw*.

Quality-Control Samples

Quality-control samples, including field blanks, replicates, and laboratory spikes, were collected throughout the study. Quality-control data are presented in Appendix 2. Overall, 57 field blanks were collected to identify the presence and magnitude of any contamination, 23 replicates were collected to evaluate variability due to sample collection and processing and laboratory analysis, and 21 field spikes were collected to evaluate bias in the recovery of pesticides. More detail on quality-control design and sampling for surface-water studies in the NAWQA program is available in Mueller and others (1997).

Data Analysis

Data Compilation

Whenever possible, chemical samples were collected during base-flow conditions. Some samples, however, were collected during unavoidable or unanticipated elevated streamflow conditions caused by snowmelt, reservoir releases, or localized storm runoff. Examination of the hydrographs at each site indicates that less than about 15 percent of the samples were collected during elevated streamflow conditions; these samples were collected at sites covering a wide range of UII values. Such samples will increase the nonurban-related variability in the data. However, these were not high-leverage or influential points, and they were retained in the data set to maintain coverage over the urban gradient.

Total nitrogen was calculated for each sample by summing either: (1) total Kjeldahl nitrogen and dissolved nitrite-plus-nitrate or (2) dissolved ammonia, dissolved nitrite-plus-nitrate, and particulate nitrogen. If all addends were censored, total nitrogen was censored to the maximum of the censoring levels; if one was uncensored and the others were censored, total nitrogen was set equal to the uncensored value; if two were uncensored and the other was censored, total nitrogen was set equal to the sum of the uncensored values. Total herbicide and total insecticide concentrations were calculated for each sample as the sum of their respective components. Censored values were set to zero and estimated values were used without modification during these calculations.

A pesticide toxicity index (PTI) value, which takes into account the presence of multiple pesticides in a sample (Munn and Gilliom, 2001), also was calculated for each sample. The PTI combines information on exposure of aquatic biota to pesticides (measured concentrations of pesticides in stream water) with toxicity estimates (results from laboratory toxicity studies) to produce a relative index value for a sample or stream. The PTI value was computed for each sample of stream water by summing the toxicity quotients for all pesticides detected in the sample. The toxicity quotient was the measured concentration of a pesticide in a stream sample divided by its median toxicity concentration from bioassays (such as a 50-percent lethal concentration [LC_{50}] or a 50-percent effect concentration [EC_{50}]). Separate PTI values were computed for fish and cladocerans (commonly referred to as water fleas). In this report, PTI values were computed using median toxicity concentrations obtained from Munn and others (2006).

The PTI has several important limitations. First, the PTI approach assumes that toxicity is additive and combines toxicity-weighted concentrations of pesticides from multiple chemical classes without regard to mode of action. This approach, likewise, does not account for synergistic or antagonistic effects. Moreover, toxicity values are based on bioassays of acute exposure and do not include effects of chronic exposure. Environmental factors that can affect bioavailability and toxicity (such as dissolved organic carbon and temperature) are not accounted for in the PTI. The PTI is limited to pesticides measured in the water column; hydrophobic pesticides may be underrepresented in potential toxicity (especially to benthic organisms). Because toxicity values from different sources vary, there is considerable uncertainty in the relative toxicity of pesticides with only a few bioassays available (the number of bioassays varied among pesticides from 1 to 165 for a given

Table 2. Chemical constituents analyzed in base-flow samples.

[USGS, U.S. Geological Survey; na, not applicable; mg/L, milligrams per liter; N, nitrogen; P, phosphorus; µg/L, micrograms per liter; MCPA, (4-chloro-2-methyphenoxy) acetic acid; MCPB, Thistol]

Constituent	USGS parameter code	Chemical class	Pesticide use	Parent compound
Ammonia plus organic (Kjeldahl) nitrogen, water, unfiltered (mg/L as N)	00625	na	na	na
Nitrite plus nitrate, water, filtered (mg/L as N)	00631	na	na	na
Ammonia, water, filtered (mg/L as N)	00608	na	na	na
Particulate nitrogen, suspended in water (mg/L as N)	49570	na	na	na
Nitrate, water, filtered (mg/L as N)	00618	na	na	na
Phosphorus, water, unfiltered (mg/L as P)	00665	na	na	na
Orthophosphate, water, filtered (mg/L as P)	00671	na	na	na
1-Naphthol, water, filtered, recoverable (µg/L)	49295	Phenol	Degradate	Carbaryl, napropamide
2,6-Diethylaniline, water, filtered, recoverable (µg/L)	82660	Degradate	Degradate	Alachlor
2-[(2-Ethyl-6-methylphenyl)-amino]-1-propanol, water, filtered, recoverable (µg/L)	61615	Aniline	Degradate	Metolachlor
2-Chloro-2’,6’-diethylacetanilide, water, filtered, recoverable (µg/L)	61618	Acetanilide	Degradate	Alachlor
2-Chloro-4-isopropylamino-6-amino-s-triazine, water, filtered, recoverable (µg/L)	04040	Triazine	Degradate	Atrazine
2-Ethyl-6-methylaniline, water, filtered, recoverable (µg/L)	61620	Aniline	Degradate	Metolachlor
3,4-Dichloroaniline, water, filtered, recoverable (µg/L)	61625	Aniline	Degradate	Diuron/propanil/linuron/neburon
4-Chloro-2-methylphenol, water, filtered, recoverable (µg/L)	61633	Phenol	Degradate	MCPA/MCPB
Acetochlor, water, filtered, recoverable (µg/L)	49260	Acetanilide	Herbicide	na
Alachlor, water, filtered, recoverable (µg/L)	46342	Acetanilide	Herbicide	na
Atrazine, water, filtered, recoverable (µg/L)	39632	Triazine	Herbicide	na
Azinphos-methyl oxygen analog, water, filtered, recoverable (µg/L)	61635	Organophosphate	Degradate	Azinphos-methyl
Azinphos-methyl, water, filtered, recoverable (µg/L)	82686	Organophosphate	Insecticide	na
Benfluralin, water, filtered, recoverable (µg/L)	82673	Dinitroaniline	Herbicide	na
Carbaryl, water, filtered, recoverable (µg/L)	82680	Carbamate	Insecticide	na
Chlorpyrifos oxygen analog, water, filtered, recoverable (µg/L)	61636	Organophosphate	Degradate	Chlorpyrifos
Chlorpyrifos, water, filtered, recoverable (µg/L)	38933	Organophosphate	Insecticide	na
cis-Permethrin, water, filtered, recoverable (µg/L)	82687	Pyrethroid	Insecticide	na
Cyfluthrin, water, filtered, recoverable (µg/L)	61585	Pyrethroid	Insecticide	na
Cypermethrin, water, filtered, recoverable (µg/L)	61586	Pyrethroid	Insecticide	na
Dacthal (DCPA), water, filtered, recoverable (µg/L)	82682	Chlorobenzoic acid ester	Herbicide	na
Desulfinyl fipronil, water, filtered, recoverable (µg/L)	62170	Phenyl pyrazole	Degradate	Fipronil
Diazinon oxygen analog, water, filtered, recoverable (µg/L)	61638	Organophosphate	Degradate	Diazinon

Table 2. Chemical constituents analyzed in base-flow samples.—Continued

[USGS, U.S. Geological Survey; na, not applicable; mg/L, milligrams per liter; N, nitrogen; P, phosphorus; µg/L, micrograms per liter; MCPA, (4-chloro-2-methyphenoxy) acetic acid; MCPB, Thistol]

Constituent	USGS parameter code	Chemical class	Pesticide use	Parent compound
Diazinon, water, filtered, recoverable (µg/L)	39572	Organophosphate	Insecticide	na
Dicrotophos, water, filtered, recoverable (µg/L)	38454	Organophosphate	Insecticide	na
Dieldrin, water, filtered, recoverable (µg/L)	39381	Organochlorine	Insecticide/degradate	Aldrin
Dimethoate, water, filtered, recoverable (µg/L)	82662	Organophosphate	Insecticide	na
Ethion monoxon, water, filtered, recoverable (µg/L)	61644	Organophosphate	Degradate	Ethion
Ethion, water, filtered, recoverable (µg/L)	82346	Organophosphate	Insecticide	na
Fenamiphos sulfone, water, filtered, recoverable (µg/L)	61645	Organophosphate	Degradate	Fenamiphos
Fenamiphos sulfoxide, water, filtered, recoverable (µg/L)	61646	Organophosphate	Degradate	Fenamiphos
Fenamiphos, water, filtered, recoverable (µg/L)	61591	Organophosphate	Nematocide	na
Desulfinylfipronil amide, water, filtered, recoverable (µg/L)	62169	Phenyl pyrazole	Degradate	Fipronil
Fipronil sulfide, water, filtered, recoverable (µg/L)	62167	Phenyl pyrazole	Degradate	Fipronil
Fipronil sulfone, water, filtered, recoverable (µg/L)	62168	Phenyl pyrazole	Degradate	Fipronil
Fipronil, water, filtered, recoverable (µg/L)	62166	Phenyl pyrazole	Insecticide	na
Fonofos oxygen analog, water, filtered, recoverable (µg/L)	61649	Organophosphate	Degradate	Fonofos
Fonofos, water, filtered, recoverable (µg/L)	04095	Organophosphate	Insecticide	na
Hexazinone, water, filtered, recoverable (µg/L)	04025	Triazine	Herbicide	na
Iprodione, water, filtered, recoverable (µg/L)	61593	Dicarboximide	Fungicide	na
Isofenphos, water, filtered, recoverable (µg/L)	61594	Organophosphate	Insecticide	na
Malaoxon, water, filtered, recoverable (µg/L)	61652	Organophosphate	Degradate	Malathion
Malathion, water, filtered, recoverable (µg/L)	39532	Organophosphate	Insecticide	na
Metalaxyl, water, filtered, recoverable (µg/L)	61596	Amino acid derivative	Fungicide	na
Methidathion, water, filtered, recoverable (µg/L)	61598	Organophosphate	Insecticide	na
Methyl paraoxon, water, filtered, recoverable (µg/L)	61664	Organophosphate	Degradate	Methyl parathion
Methyl parathion, water, filtered, recoverable (µg/L)	82667	Organophosphate	Insecticide	na
Metolachlor, water, filtered, recoverable (µg/L)	39415	Acetanilide	Herbicide	na
Metribuzin, water, filtered, recoverable (µg/L)	82630	Triazine	Herbicide	na
Myclobutanil, water, filtered, recoverable (µg/L)	61599	Triazole	Fungicide	na
Pendimethalin, water, filtered, recoverable (µg/L)	82683	Dinitroaniline	Herbicide	na
Phorate oxygen analog, water, filtered, recoverable (µg/L)	61666	Organophosphate	Degradate	Phorate
Phorate, water, filtered, recoverable (µg/L)	82664	Organophosphate	Insecticide	na

Table 2. Chemical constituents analyzed in base-flow samples.—Continued

[USGS, U.S. Geological Survey; na, not applicable; mg/L, milligrams per liter; N, nitrogen; P, phosphorus; µg/L, micrograms per liter; MCPA, (4-chloro-2-methyphenoxy) acetic acid; MCPB, Thistol]

Constituent	USGS parameter code	Chemical class	Pesticide use	Parent compound
Phosmet oxygen analog, water, filtered, recoverable (µg/L)	61668	Organophosphate	Degradate	Phosmet
Phosmet, water, filtered, recoverable (µg/L)	61601	Organophosphate	Insecticide	na
Prometon, water, filtered, recoverable (µg/L)	04037	Triazine	Herbicide	na
Prometryn, water, filtered, recoverable (µg/L)	04036	Triazine	Herbicide	na
Pronamide, water, filtered, recoverable (µg/L)	82676	Amide	Herbicide	na
Simazine, water, filtered, recoverable (µg/L)	04035	Triazine	Herbicide	na
Tebuthiuron, water, filtered, recoverable (µg/L)	82670	Urea	Herbicide	na
Terbufos oxygen analog sulfone, water, filtered, recoverable (µg/L)	61674	Organophosphate	Degradate	Terbufos
Terbufos, water, filtered, recoverable (µg/L)	82675	Organophosphate	Insecticide	na
Terbuthylazine, water, filtered, recoverable (µg/L)	04022	Triazine	Herbicide	na
Trifluralin, water, filtered, recoverable (µg/L)	82661	Dinitroaniline	Herbicide	na
Dichlorvos, water, filtered, recoverable (µg/L)	38775	Organophosphate	Insecticide, fumigant, degradate	Naled
pH, water, unfiltered (standard units)	00400	na	na	na
Suspended sediment concentration (mg/L)	80154	na	na	na
Sulfate, water, filtered (mg/L)	00945	na	na	na
Chloride, water, filtered (mg/L)	00940	na	na	na

taxonomic group). Finally, not all important local species were included in bioassays. Despite its limitations, the PTI approach can be a useful tool for examining pesticide mixtures in streams—such as in investigating relations between concentrations of multiple pesticides detected in a stream and the quality of aquatic ecosystems. It also provides a mechanism for considering the potential contribution to toxicity of pesticides that do not have established benchmarks for aquatic life. The PTI does not indicate whether water in a sample or stream is toxic; however, its value can be used to rank or compare the relative potential toxicity of different samples or different streams.

Quality-Control Analysis

Quality-control samples, including blanks, replicates, and laboratory spikes, were evaluated prior to data analysis (Appendix 2). Concentrations in the blanks generally were below the laboratory reporting levels; two blanks from the Raleigh-Durham study area had total ammonia plus organic (Kjeldahl) nitrogen concentrations greater than the reporting level. Because the main focus of the data analysis in this report is comparing responses among sites (as opposed to looking at chemical characteristics at a single site), this isolated, low-level contamination likely did not substantially influence the results.

The mean relative percent difference (relative percent difference =|A-B|/[(A+B)/2], where A is the environmental sample concentration and B is the replicate sample concentration) between the paired replicate samples was greater than 10 percent for particulate nitrogen, total phosphorus, 2-chloro-4-isopropylamino-6-amino-s-triazine, 3,4-dichloroaniline, 4-chloro-2-methylphenol, desulfinyl fipronil, diazinon, dieldrin, prometon, tebuthiuron, and suspended sediment, indicting that for these constituents, the variability in concentration due to field and laboratory procedures may have been greater than the variability in concentration between some sites. Concentrations of other constituents were consistent between the paired replicate samples; mean relative percent differences were less than 10 percent.

Phosmet and phosmet oxygen analog had false negatives (no detections in spike) in nine pesticide spikes from multiple study areas, likely indicating a systemic problem in the laboratory. As a result, phosmet and phosmet oxygen analog were treated as missing in all environmental samples. Two constituents (2-[(2-ethyl-6-methylphenyl)-amino]-1-propanol and iprodione) had false negatives from sites in the Atlanta study area, indicating that something at those sites may have caused incorrect quantitation; these constituents were treated as missing in all environmental samples from the affected sites only.

When a given constituent shows a false negative in a spike, there is a chance that true, detectable concentrations are being reported as censored in environmental samples. In environmental samples with reported detections, the constituent is most likely present but the reported concentration may be biased low. When a false negative occurs, treating detectable environmental concentrations as missing results in a loss of information. However, because the main focus of the data analysis is comparing responses among sites (as opposed to looking at chemical characteristics at a single site), the possibility of false negatives in censored environmental samples would introduce too much uncertainty.

Mean spike recoveries of less than 50 percent were found for 1-naphthol, 2-chloro-4-isopropylamino-6-amino-s-triazine, dicrotophos, dimethoate, iprodione, phosmet oxygen analog, and phosmet. Recoveries consistently were low among all spikes for phosmet and phosmet oxygen analog, dimethoate, dicrotophos, and 2-chloro-4-isopropylamino-6-amino-s-triazine; low but consistent recoveries are suitable for the data analysis in this study. Recoveries were much more variable for 1-naphthol (mean of 27 percent, standard deviation of 22 percent) and iprodione (mean of 32 percent, standard deviation of 24 percent); this degree of variability was not acceptable for the data analysis in this study. As a result, 1-naphthol and iprodione were treated as missing in all environmental samples.

Patterns of Response to Urbanization

Correlation analysis was used to assess the strength of the relation between each chemical constituent and the percentage of urban land cover in the basin. Because of the potential for nonlinear relations, Spearman's rho, which is based on the ranks of the values and thus can account for monotonic curvilinearity, was used as the measure of correlation. Spearman's rho is dimensionless and scaled to range from -1 to 1 (Helsel and Hirsch, 1992). When there was no correlation between the concentration of a chemical and the percentage of urban land cover in the basin, Spearman's rho equaled 0; when the chemical concentration increased as the percentage of urban land cover in the basin increased, Spearman's rho was positive; when they varied in opposite directions, Spearman's rho was negative. In this application, the results of significance tests may be inaccurate because single test *p*-values can underestimate the probability of error when many dependent correlations (that is, comparisons to the same variable) are tested (Van Sickle, 2003). In addition, the sample size within each study area was small relative to the variance, resulting in low power to detect real correlations; rejecting the null hypotheses (*x* and *y* are not correlated) would likely be far less common than not rejecting the null hypothesis (Parkhurst, 2001). As a result, the focus in this report is on the strength of the relations instead of the apparent significance of the relations. Relative classifications of the strength of the relations were based on the range of correlation values in the data for the six study areas. Typically, relations were described as "strong" if the absolute value of Spearman's rho was approximately 0.5 or greater, although the use of an absolute threshold value to characterize "strong" relations (for example, in which a correlation coefficient of 0.50 was "strong" and 0.49 was "weak") was rejected as arbitrary.

A scatterplot with a locally weighted scatterplot smooth (LOWESS) also was made to examine the pattern of the relation between each chemical constituent and the percentage of urban land cover in the basin (urban land cover as used here is the aggregated NLCD 2001 level 1 “developed” category, including developed open space and low-, medium-, and high-intensity development). Comparisons were made among study areas to examine the response of water chemistry to urbanization in different environmental settings.

The strengths of these relations also were compared during high and low base-flow conditions within each study area to examine the influence of hydrologic variability on the response of water chemistry to urbanization. When the sites sampled during high and low base-flow conditions differed (Raleigh-Durham, Milwaukee-Green Bay, and Dallas Fort-Worth), Fisher’s test for nonoverlapping correlations (Fisher, 1921) was used to test whether the correlations between the percentage of urban land cover in the basin and chemical concentrations at high base flow were significantly different from the correlation between the percentage of urban land cover in the basin and chemical concentrations at low base flow. When the sites sampled during high and low base-flow conditions were the same (Atlanta, Denver, and Portland), the method described in Meng and others (1992) for overlapping correlations was used. The strengths of the relations during high and low base-flow conditions were considered significantly different if the *p*-value for Fisher’s or Meng’s test was less than or equal to 0.05. These tests likely were subject to the same low-power limitation as was the Spearman’s rank correlation analysis; therefore, the null hypothesis of Fisher’s and Meng’s test (correlations during high and low base-flow conditions were not different) may have been rejected less frequently than would have occurred if more data were available. In some instances, the relation between two variables was “strong” (absolute value of Spearman’s rho was approximately 0.5 or greater) during one base-flow condition and “weak” (absolute value of Spearman’s rho was less than approximately 0.5) during the other base-flow condition, but the results from the Fisher’s or Meng’s test indicated there was no statistically significant difference. In these instances, no distinction could be made between the strength of these relations during interpretation—lacking evidence to the contrary, if one relation was strong, both were considered to be strong.

Because the multimetric UII values were range standardized using values at just the sites within each study area, and because a different set of urban variables was used to calculate the UII in each study area, these local UII values were not directly comparable across study areas. To create a common basis for comparing sites across all study areas, a common UII was developed by using the same urban variables to calculate the UII at all sites in all study areas and then range standardizing across all of these sites (Falcone and others, 2007). However, local differences led to difficulties in identifying consistent, representative urban gradients in individual study areas and in creating common UII values that corresponded to the local UII values used during site selection (Falcone and others, 2007). As a result, neither the local UII values nor the common UII values were used in the data analysis for this report. Instead, the response of water chemistry to urbanization was examined by using the percentage of urban land cover in the basin as a surrogate for “urbanization.” The percentage of urban land cover in the basin does not reflect simultaneous urban influences as the UII does, but because it was consistently derived in all study areas, it is directly comparable across environmental settings. With this approach, differences among environmental settings in the relation between water chemistry and urbanization can be attributed to regional differences in the gradient of urban land cover without the potential confounding influence of regional differences in the calculation of the UII. Spearman’s rank correlations between the local UII and the percentage of urban land cover in the basin were high (0.98 in Atlanta, 0.98 in Raleigh-Durham, 0.98 in Milwaukee-Green Bay, 0.87 in Dallas-Fort Worth, 0.96 in Denver, and 0.97 in Portland); therefore, any differences in interpretation should be minimal in all study areas.

Spearman’s rank correlation analysis also was used to assess the strength of the association between each chemical variable and additional urban and landscape variables. The goal of this analysis was to determine which urban variables were most strongly associated with the chemical variables and to identify any nonurban landscape variables that may have been confounding the response to urbanization. Of the approximately 300 urban and landscape variables produced to aid in site selection and data analysis, 22 are highlighted in this report (table 3). (See Sprague and others (2006) for a full list of urban and landscape variables produced to aid in site selection and data analysis). These 22 variables were selected from among groups of related variables (for example, road density was chosen from among road length, road-area index, road-traffic index, road-area density, road-traffic density, and road density; the percentage of forested land cover in the basin was strongly related to the percentage of urban land cover in the basin, so only the percentage of urban land cover in the basin was highlighted) or in lieu of a group of categorical variables that each contained a large number of zeros (for example, a variable representing the sand content of the soil was chosen in lieu of individual soil texture classification and hydrologic soil groups). As with the percentage of urban land cover in the basin, Fisher’s test for nonoverlapping correlations and the method described in Meng and others (1992) for overlapping correlations were used to test whether the correlations between these additional urban and landscape features and chemical concentrations were significantly different during high base-flow and low base-flow conditions.

There is an important limitation in the interpretation of the relations between chemical concentrations and landscape variables in this study. In the hypothetical case of a strong relation between total nitrogen concentrations and the landscape variable basin slope in the Denver study area, basin slope would not necessarily be strongly related to total nitrogen concentrations in the greater (unsampled) Denver-Fort Collins-Cheyenne area. The 28 sites in the Denver study area were chosen to cover an urban gradient with the intent of minimizing variability in natural landscape features, such as basin slope. As a result, the range of basin slope covered by the

Table 3. Spearman's rank correlations between (*A*) total nitrogen concentrations, (*B*) dissolved nitrate concentrations, (*C*) total phosphorus concentrations, and (*D*) dissolved orthophosphate concentrations during high and low base flow and selected urban and landscape variables.

[Values in bold are significantly different during high and low base-flow conditions. HUDEN, 2000 housing unit density; ROADDEN, road density; POPDENKM, 2000 population density; LPI_2, largest urban patch index; PLA_2, percentage of like adjacencies (urban); P_NLCD1_2, percentage of urban land cover in basin; P_NLCD1_B2, percentage of urban land cover in buffer; NLCD_IS, mean percent impervious surface in basin; NLCD_BIS, mean percent impervious surface in buffer; PHU_G60, percentage of housing units built prior to 1939; SEG_RMD, mean distance from stream segment to nearest road; SLOPE_X, mean basin slope; P_NLCD1_8, percentage of herbaceous planted/cultivated land cover in basin; P_NLCD1_B8, percentage of herbaceous planted/cultivated land cover in buffer; P_NLCD1_5, percentage of shrub/grass land cover in basin; P_NLCD1_B5, percentage of shrub/grass land cover in buffer; P_NLCD1_9, percentage of wetland land cover in basin; P_NLCD1_B9, percentage of wetland land cover in buffer; WET_MEAN, mean value of wetness index across all cells in basin; SNDH, mean high-range sand (soil); WTDH, mean high-range depth to water table; KFCAVE, mean soil erodibility factor (K factor)]

(A) Total nitrogen concentrations

Variable code	Variable short name	High base flow						Low base flow					
		Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland	Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland
							Urban variables						
HUDEN	Housing density	0.56	0.48	0.05	0.02	0.05	0.67	0.59	0.56	-0.25	-0.09	0.01	0.77
ROADDEN	Road density	0.52	0.60	0.07	0.08	0.03	0.65	0.57	0.58	-0.17	-0.05	0.04	0.73
POPDENKM	Population density	0.57	0.47	0.08	0.02	0.08	0.69	0.59	0.55	-0.23	-0.09	0.08	0.76
LPI_2	Patch size of urban land area	0.61	0.63	0.22	0.11	0.13	0.73	0.63	0.60	-0.19	-0.04	0.11	0.80
PLA_2	Homogeneity of urban land area	0.67	0.64	0.19	0.11	0.14	0.68	0.64	0.56	-0.27	-0.01	0.10	0.79
P_NLCD1_2	Urban land cover in basin	0.61	0.64	0.18	0.10	0.13	0.75	0.63	0.60	-0.23	-0.07	0.09	0.80
P_NLCD1_B2	Urban land cover in buffer	0.61	0.64	0.16	0.08	0.01	0.71	0.62	0.57	-0.21	-0.08	0.05	0.77
NLCD_IS	Impervious area in basin	0.64	0.63	0.21	0.11	0.12	0.73	0.64	0.49	-0.23	-0.09	0.10	0.80
NLCD_BIS	Impervious area in buffer	0.66	0.62	0.21	0.16	-0.02	0.70	0.66	0.46	-0.19	-0.05	0.04	0.77
PHU_G60	Housing age	-0.56	0.46	-0.04	-0.09	-0.34	-0.39	-0.60	0.42	0.25	0.07	-0.22	-0.49
SEG_RMD	Distance from stream to nearest road	-0.22	-0.39	-0.04	-0.31	-0.28	0.09	-0.20	-0.37	0.20	0.03	-0.19	0.07

Table 3. Spearman's rank correlations between (*A*) total nitrogen concentrations, (*B*) dissolved nitrate concentrations, (*C*) total phosphorus concentrations, and (*D*) dissolved orthophosphate concentrations during high and low base flow and selected urban and landscape variables.

[Values in bold are significantly different during high and low base-flow conditions. HUDEN, 2000 housing unit density; ROADDEN, road density; POPDENKM, 2000 population density; LPI_2, largest urban patch index; PLA_2, percentage of like adjacencies (urban); P_NLCD1_2, percentage of urban land cover in basin; P_NLCD1_B2, percentage of urban land cover in buffer; NLCD_IS, mean percent impervious surface in basin; NLCD_BIS, mean percent impervious surface in buffer; PHU_G60, percentage of housing units built prior to 1939; SEG_RMD, mean distance from stream segment to nearest road; SLOPE_X, mean basin slope; P_NLCD1_8, percentage of herbaceous planted/cultivated land cover in basin; P_NLCD1_B8, percentage of herbaceous planted/cultivated land cover in buffer; P_NLCD1_5, percentage of shrub/grass land cover in basin; P_NLCD1_B5, percentage of shrub/grass land cover in buffer; P_NLCD1_9, percentage of wetland land cover in basin; P_NLCD1_B9, percentage of wetland land cover in buffer; WET_MEAN, mean value of wetness index across all cells in basin; SNDH, mean high-range sand (soil); WTDH, mean high-range depth to water table; KFCAVE, mean soil erodibility factor (K factor)]

(A) Total nitrogen concentrations

Variable code	Variable short name	High base flow						Low base flow					
		Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland	Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland
Lanscape variables													
SLOPE_X	Basin slope	0.01	-0.40	-0.04	0.10	-0.24	-0.80	-0.10	-0.44	0.15	-0.11	-0.34	-0.79
P_NLCD1_8	Agricultural land cover in basin	-0.20	-0.46	0.03	0.01	-0.12	0.21	-0.12	-0.48	-0.03	0.38	0.15	0.14
P_NLCD1_B8	Agricultural land cover in buffer	-0.10	-0.43	0.18	0.05	-0.09	0.17	-0.09	-0.42	-0.01	0.37	0.09	0.14
P_NLCD1_5	Shrub/grass land cover in basin	-0.62	-0.57	0.02	-0.18	-0.06	-0.73	-0.65	-0.47	-0.11	-0.02	-0.13	-0.78
P_NLCD1_B5	Shrub/grass land cover in buffer	-0.52	-0.55	0.03	-0.22	0.09	-0.68	-0.58	-0.43	-0.18	0.07	0.00	-0.77
P_NLCD1_9	Wetland land cover in basin	-0.10	-0.44	**-0.31**	0.18	0.14	0.08	0.00	-0.51	**0.25**	0.26	0.07	-0.07
P_NLCD1_B9	Wetland land cover in buffer	-0.12	-0.47	-0.26	0.25	0.14	-0.06	0.00	-0.47	0.23	0.36	0.08	-0.14
WET_MEAN	Basin-wetness index	-0.05	0.18	-0.04	-0.04	0.02	0.74	0.05	0.19	-0.15	0.07	0.33	0.70
SNDH	Sand content in soil	**-0.11**	-0.17	**-0.41**	0.33	-0.04	-0.28	**0.18**	0.10	**0.33**	0.36	-0.06	-0.33
WTDH	Depth to water table	0.44	0.18	-0.34	-0.15	-0.03	-0.36	0.42	0.29	0.08	-0.32	-0.02	-0.41
KFCAVE	Soil erodibility	0.31	-0.47	0.22	0.05	0.27	0.39	0.29	-0.58	-0.09	0.13	0.56	0.39

Table 3. Spearman's rank correlations between (*A*) total nitrogen concentrations, (*B*) dissolved nitrate concentrations, (*C*) total phosphorus concentrations, and (*D*) dissolved orthophosphate concentrations during high and low base flow and selected urban and landscape variables.—Continued

[Values in bold are significantly different during high and low base-flow conditions. HUDEN, 2000 housing unit density; ROADDEN, road density; POPDENKM, 2000 population density; LPI_2, largest urban patch index; PLA_2, percentage of like adjacencies (urban); P_NLCD1_2, percentage of urban land cover in basin; P_NLCD1_B2, percentage of urban land cover in buffer; NLCD_IS, mean percent impervious surface in basin; NLCD_BIS, mean percent impervious surface in buffer; PHU_G60, percentage of housing units built prior to 1939; SEG_RMD, mean distance from stream segment to nearest road; SLOPE_X, mean basin slope; P_NLCD1_8, percentage of herbaceous planted/cultivated land cover in basin; P_NLCD1_B8, percentage of herbaceous planted/cultivated land cover in buffer; P_NLCD1_5, percentage of shrub/grass land cover in basin; P_NLCD1_B5, percentage of shrub/grass land cover in buffer; P_NLCD1_9, percentage of wetland land cover in basin; P_NLCD1_B9, percentage of wetland land cover in buffer; WET_MEAN, mean value of wetness index across all cells in basin; SNDH, mean high-range sand (soil); WTDH, mean high-range depth to water table; KFCAVE, mean soil erodibility factor (K factor)]

(B) Dissolved nitrate concentrations

Variable code	Variable short name	High base flow						Low base flow					
		Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland	Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland
						Urban variables							
HUDEN	Housing density	0.55	0.42	0.08	0.10	0.11	0.60	0.58	0.33	-0.27	-0.08	0.03	0.70
ROADDEN	Road density	0.55	0.52	0.10	0.16	0.05	0.59	0.57	0.41	-0.19	-0.05	0.07	0.68
POPDENKM	Population density	0.58	0.40	0.11	0.08	0.14	0.63	0.59	0.32	-0.25	-0.10	0.10	0.69
LPI_2	Patch size of urban land area	0.59	0.54	0.27	0.16	0.14	0.67	0.64	0.43	-0.21	-0.06	0.13	0.73
PLA_2	Homogeneity of urban land area	0.63	0.51	0.24	0.15	0.16	0.60	0.63	0.40	-0.29	-0.03	0.09	0.72
P_NLCD1_2	Urban land cover in basin	0.59	0.55	0.21	0.15	0.13	0.68	0.63	0.43	-0.25	-0.08	0.11	0.74
P_NLCD1_B2	Urban land cover in buffer	0.59	0.55	0.20	0.17	0.01	0.65	0.63	0.43	-0.23	-0.08	0.06	0.70
NLCD_IS	Impervious area in basin	0.61	0.49	0.25	0.16	0.12	0.67	0.64	0.36	-0.25	-0.11	0.12	0.75
NLCD_BIS	Impervious area in buffer	0.64	0.48	0.27	0.23	-0.02	0.63	0.68	0.36	-0.22	-0.07	0.04	0.70
PHU_G60	Housing age	-0.60	0.59	-0.01	-0.15	-0.32	-0.31	-0.66	0.56	0.25	0.05	-0.30	-0.40
SEG_RMD	Distance from stream to nearest road	-0.16	-0.47	-0.08	-0.37	-0.34	0.14	-0.16	-0.49	0.22	0.02	-0.13	0.15

Table 3. Spearman's rank correlations between (*A*) total nitrogen concentrations, (*B*) dissolved nitrate concentrations, (*C*) total phosphorus concentrations, and (*D*) dissolved orthophosphate concentrations during high and low base flow and selected urban and landscape variables.—Continued

[Values in bold are significantly different during high and low base-flow conditions. HUDEN, 2000 housing unit density; ROADDEN, road density; POPDENKM, 2000 population density; LPI_2, largest urban patch index; PLA_2, percentage of like adjacencies (urban); P_NLCD1_2, percentage of urban land cover in basin; P_NLCD1_B2, percentage of urban land cover in buffer; NLCD_IS, mean percent impervious surface in basin; NLCD_BIS, mean percent impervious surface in buffer; PHU_G60, percentage of housing units built prior to 1939; SEG_RMD, mean distance from stream segment to nearest road; SLOPE_X, mean basin slope; P_NLCD1_8, percentage of herbaceous planted/cultivated land cover in basin; P_NLCD1_B8, percentage of herbaceous planted/cultivated land cover in buffer; P_NLCD1_5, percentage of shrub/grass land cover in basin; P_NLCD1_B5, percentage of shrub/grass land cover in buffer; P_NLCD1_9, percentage of wetland land cover in basin; P_NLCD1_B9, percentage of wetland land cover in buffer; WET_MEAN, mean value of wetness index across all cells in basin; SNDH, mean high-range sand (soil); WTDH, mean high-range depth to water table; KFCAVE, mean soil erodibility factor (K factor)]

(B) Dissolved nitrate concentrations

Variable code	Variable short name	High base flow						Low base flow					
		Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland	Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland
						Landscape variables							
SLOPE_X	Basin slope	**0.25**	-0.40	-0.10	0.22	-0.24	-0.75	**-0.02**	-0.42	0.20	-0.07	-0.48	-0.72
P_NLCD1_8	Agricultural land cover in basin	-0.11	-0.43	0.02	-0.03	-0.09	0.17	-0.11	-0.33	-0.03	0.38	0.23	0.05
P_NLCD1_B8	Agricultural land cover in buffer	0.10	-0.43	0.17	0.00	-0.08	0.11	-0.01	-0.32	-0.02	0.36	0.16	0.04
P_NLCD1_5	Shrub/grass land cover in basin	-0.59	-0.52	0.01	-0.19	-0.02	-0.67	-0.66	-0.36	-0.10	-0.03	-0.13	-0.70
P_NLCD1_B5	Shrub/grass land cover in buffer	-0.51	-0.55	0.04	-0.27	0.13	-0.60	-0.60	-0.42	-0.17	0.05	-0.06	-0.68
P_NLCD1_9	Wetland land cover in basin	-0.23	-0.53	**-0.36**	0.16	0.11	0.09	-0.04	-0.56	**0.27**	0.25	0.00	-0.09
P_NLCD1_B9	Wetland land cover in buffer	-0.20	-0.52	**-0.33**	0.23	0.11	-0.06	-0.02	-0.63	**0.26**	0.34	0.02	-0.16
WET_MEAN	Basin-wetness index	-0.21	0.19	0.00	-0.11	**0.07**	0.68	-0.09	0.23	-0.20	0.05	**0.48**	0.62
SNDH	Sand content in soil	-0.03	-0.09	**-0.50**	0.31	-0.04	-0.22	0.04	0.05	**0.34**	0.29	-0.12	-0.27
WTDH	Depth to water table	0.31	0.19	-0.35	-0.12	-0.08	-0.30	0.39	0.23	0.15	-0.27	-0.02	-0.37
KFCAVE	Soil erodibility	0.22	-0.47	0.30	0.03	**0.29**	0.34	0.33	-0.46	-0.09	0.09	**0.70**	0.30

Table 3. Spearman's rank correlations between (A) total nitrogen concentrations, (B) dissolved nitrate concentrations, (C) total phosphorus concentrations, and (D) dissolved orthophosphate concentrations during high and low base flow and selected urban and landscape variables.—Continued

[Values in bold are significantly different during high and low base-flow conditions. HUDEN, 2000 housing unit density; ROADDEN, road density; POPDENKM, 2000 population density; LPI_2, largest urban patch index; PLA_2, percentage of like adjacencies (urban); P_NLCD1_2, percentage of urban land cover in basin; P_NLCD1_B2, percentage of urban land cover in buffer; NLCD_IS, mean percent impervious surface in basin; NLCD_BIS, mean percent impervious surface in buffer; PHU_G60, percentage of housing units built prior to 1939; SEG_RMD, mean distance from stream segment to nearest road; SLOPE_X, mean basin slope; P_NLCD1_8, percentage of herbaceous planted/cultivated land cover in basin; P_NLCD1_B8, percentage of herbaceous planted/cultivated land cover in buffer; P_NLCD1_5, percentage of shrub/grass land cover in basin; P_NLCD1_B5, percentage of shrub/grass land cover in buffer; P_NLCD1_9, percentage of wetland land cover in basin; P_NLCD1_B9, percentage of wetland land cover in buffer; WET_MEAN, mean value of wetness index across all cells in basin; SNDH, mean high-range sand (soil); WTDH, mean high-range depth to water table; KFCAVE, mean soil erodibility factor (K factor)]

(C) Total phosphorus concentrations

Variable code	Variable short name	High base flow						Low base flow					
		Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland	Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland
						Urban variables							
HUDEN	Housing density	0.08	0.01	-0.61	-0.06	0.26	**0.65**	0.23	0.17	-0.22	0.22	0.34	0.76
ROADDEN	Road density	0.00	0.01	-0.63	-0.13	0.31	0.61	0.16	0.19	-0.28	0.17	0.30	0.65
POPDENKM	Population density	0.01	0.02	-0.62	-0.08	0.26	0.67	0.15	0.20	-0.20	0.21	0.35	0.76
LPI_2	Patch size of urban land area	0.08	0.03	-0.61	-0.08	0.38	0.65	0.22	0.10	**-0.13**	0.25	0.36	0.75
PLA_2	Homogeneity of urban land area	0.13	0.04	-0.61	-0.07	0.40	0.66	0.28	0.12	**-0.15**	0.27	0.41	0.76
P_NLCD1_2	Urban land cover in basin	0.07	0.05	-0.58	-0.06	0.38	0.64	0.22	0.14	**-0.16**	0.25	0.35	0.71
P_NLCD1_B2	Urban land cover in buffer	0.07	0.00	-0.64	-0.15	0.33	0.60	0.19	0.10	**-0.23**	0.10	0.34	0.69
NLCD_IS	Impervious area in basin	0.06	0.08	-0.56	-0.08	0.39	0.65	0.22	0.16	**-0.12**	0.25	0.37	0.73
NLCD_BIS	Impervious area in buffer	0.06	0.10	-0.61	-0.11	0.34	0.61	0.21	0.11	**-0.10**	0.14	0.35	0.69
PHU_G60	Housing age	0.01	-0.21	0.44	0.05	-0.32	-0.30	-0.10	-0.06	0.21	-0.15	-0.19	-0.42
SEG_RMD	Distance from stream to nearest road	0.07	0.12	0.56	0.01	-0.33	-0.11	-0.11	0.21	0.14	-0.11	-0.33	-0.05
						Landscape variables							
SLOPE_X	Basin slope	-0.69	-0.09	-0.19	-0.35	**-0.29**	-0.53	**-0.37**	0.09	-0.47	-0.21	**0.11**	-0.61
P_NLCD1_8	Agricultural land cover in basin	0.02	0.13	0.66	0.15	-0.21	0.04	**-0.08**	-0.04	0.34	-0.02	**-0.36**	0.11
P_NLCD1_B8	Agricultural land cover in buffer	-0.12	0.22	0.67	0.23	-0.18	0.02	**-0.17**	0.03	0.43	0.02	-0.32	0.03

Table 3. Spearman's rank correlations between (A) total nitrogen concentrations, (B) dissolved nitrate concentrations, (C) total phosphorus concentrations, and (D) dissolved orthophosphate concentrations during high and low base flow and selected urban and landscape variables.—Continued

[Values in bold are significantly different during high and low base-flow conditions. HUDEN, 2000 housing unit density; ROADDEN, road density; POPDENKM, 2000 population density; LPI_2, largest urban patch index; PLA_2, percentage of like adjacencies (urban); P_NLCD1_2, percentage of urban land cover in basin; P_NLCD1_B2, percentage of urban land cover in buffer; NLCD_IS, mean percent impervious surface in basin; NLCD_BIS, mean percent impervious surface in buffer; PHU_G60, percentage of housing units built prior to 1939; SEG_RMD, mean distance from stream segment to nearest road; SLOPE_X, mean basin slope; P_NLCD1_8, percentage of herbaceous planted/cultivated land cover in basin; P_NLCD1_B8, percentage of herbaceous planted/cultivated land cover in buffer; P_NLCD1_5, percentage of shrub/grass land cover in basin; P_NLCD1_B5, percentage of shrub/grass land cover in buffer; P_NLCD1_9, percentage of wetland land cover in basin; P_NLCD1_B9, percentage of wetland land cover in buffer; WET_MEAN, mean value of wetness index across all cells in basin; SNDH, mean high-range sand (soil); WTDH, mean high-range depth to water table; KFCAVE, mean soil erodibility factor (K factor)]

(C) Total phosphorus concentrations

Variable code	Variable short name	High base flow						Low base flow					
		Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland	Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland
						Landscape variables							
P_NLCD1_5	Shrub/grass land cover in basin	-0.18	-0.07	-0.35	-0.09	-0.14	-0.56	**-0.16**	-0.20	-0.23	-0.37	**-0.07**	-0.66
P_NLCD1_B5	Shrub/grass land cover in buffer	-0.11	0.02	-0.56	0.02	-0.17	-0.59	**-0.10**	-0.11	-0.33	-0.19	**-0.05**	-0.69
P_NLCD1_9	Wetland land cover in basin	0.47	0.16	0.33	0.07	0.19	0.16	**0.37**	0.02	-0.15	0.31	**0.15**	0.05
P_NLCD1_B9	Wetland land cover in buffer	0.39	0.03	0.27	0.06	0.23	0.11	**0.29**	0.11	-0.22	0.41	0.13	-0.02
WET_MEAN	Basin-wetness index	0.54	0.15	0.17	0.34	**0.35**	0.47	**0.40**	-0.07	0.49	0.26	**-0.04**	0.52
SNDH	Sand content in soil	0.10	-0.11	0.22	0.07	**-0.18**	-0.67	**0.23**	0.09	-0.11	0.19	-0.24	-0.77
WTDH	Depth to water table	0.42	-0.08	0.24	-0.26	**-0.12**	-0.77	**0.36**	0.11	0.18	-0.24	-0.22	-0.77
KFCAVE	Soil erodibility	0.42	0.03	-0.33	0.36	**0.47**	0.63	**0.28**	-0.16	-0.10	0.34	0.15	0.73

Table 3. Spearman's rank correlations between (A) total nitrogen concentrations, (B) dissolved nitrate concentrations, (C) total phosphorus concentrations, and (D) dissolved orthophosphate concentrations during high and low base flow and selected urban and landscape variables.—Continued

[Values in bold are significantly different during high and low base-flow conditions. HUDEN, 2000 housing unit density; ROADDEN, road density; POPDENKM, 2000 population density; LPI_2, largest urban patch index; PLA_2, percentage of like adjacencies (urban); P_NLCD1_2, percentage of urban land cover in basin; P_NLCD1_B2, percentage of urban land cover in buffer; NLCD_IS, mean percent impervious surface in basin; NLCD_BIS, mean percent impervious surface in buffer; PHU_G60, percentage of housing units built prior to 1939; SEG_RMD, mean distance from stream segment to nearest road; SLOPE_X, mean basin slope; P_NLCD1_8, percentage of herbaceous planted/cultivated land cover in basin; P_NLCD1_B8, percentage of herbaceous planted/cultivated land cover in buffer; P_NLCD1_5, percentage of shrub/grass land cover in basin; P_NLCD1_B5, percentage of shrub/grass land cover in buffer; P_NLCD1_9, percentage of wetland land cover in basin; P_NLCD1_B9, percentage of wetland land cover in buffer; WET_MEAN, mean value of wetness index across all cells in basin; SNDH, mean high-range sand (soil); WTDH, mean high-range depth to water table; KFCAVE, mean soil erodibility factor (K factor)]

(D) Dissolved orthophosphate concentrations

Variable code	Variable short name	High base flow						Low base flow					
		Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland	Atlanta	Raleigh-Durham	Milwakee-Green Bay	Dallas-Fort Worth	Denver	Portland
							Urban variables						
HUDEN	Housing density	**0.16**	-0.33	-0.53	0.05	-0.01	0.58	**-0.34**	-0.12	-0.33	0.08	0.22	0.60
ROADDEN	Road density	**0.18**	-0.30	-0.56	-0.05	-0.03	0.47	**-0.35**	-0.03	-0.35	0.03	0.19	0.50
POPDENKM	Population density	**0.15**	-0.32	-0.55	0.01	0.02	0.57	**-0.34**	-0.13	-0.30	0.04	0.23	0.60
LPI_2	Patch size of urban land area	0.18	-0.30	-0.48	-0.06	-0.05	0.58	-0.23	-0.05	-0.25	0.07	0.26	0.61
PLA_2	Homogeneity of urban land area	0.17	-0.28	-0.49	-0.08	0.04	0.59	-0.20	-0.04	-0.28	0.11	0.33	0.61
P_NLCD1_2	Urban land cover in basin	0.17	-0.29	-0.48	-0.01	-0.05	0.55	-0.24	-0.03	-0.29	0.09	0.25	0.58
P_NLCD1_B2	Urban land cover in buffer	0.18	-0.31	-0.53	0.01	-0.08	0.52	-0.25	-0.05	-0.33	-0.02	0.24	0.53
NLCD_IS	Impervious area in basin	0.12	-0.23	-0.45	-0.07	-0.03	0.57	-0.27	0.06	-0.24	0.06	0.29	0.60
NLCD_BIS	Impervious area in buffer	0.12	-0.27	-0.48	0.04	-0.06	0.52	-0.25	0.06	-0.22	0.02	0.25	0.54
PHU_G60	Housing age	0.08	**-0.26**	0.53	-0.10	**0.35**	-0.30	0.25	**0.31**	0.34	-0.13	**-0.11**	-0.29
SEG_RMD	Distance from stream to nearest road	**-0.30**	0.04	0.48	-0.18	-0.07	0.14	**0.36**	0.14	0.22	-0.03	-0.19	0.15
							Landscape variables						
SLOPE_X	Basin slope	-0.23	-0.14	-0.31	-0.13	-0.21	-0.49	-0.28	-0.16	-0.35	0.08	0.01	-0.54
P_NLCD1_8	Agricultural land cover in basin	-0.24	0.26	0.66	-0.06	0.11	**-0.14**	-0.09	0.16	0.42	-0.01	-0.21	-0.02
P_NLCD1_B8	Agricultural land cover in buffer	-0.29	0.26	0.71	-0.01	0.13	**-0.18**	-0.14	0.31	0.49	0.00	-0.20	**-0.07**

Table 3. Spearman's rank correlations between (A) total nitrogen concentrations, (B) dissolved nitrate concentrations, (C) total phosphorus concentrations, and (D) dissolved orthophosphate concentrations during high and low base flow and selected urban and landscape variables.—Continued

[Values in bold are significantly different during high and low base-flow conditions. HUDEN, 2000 housing unit density; ROADDEN, road density; POPDENKM, 2000 population density; LPI_2, largest urban patch index; PLA_2, percentage of like adjacencies (urban); P_NLCD1_2, percentage of urban land cover in basin; P_NLCD1_B2, percentage of urban land cover in buffer; NLCD_IS, mean percent impervious surface in basin; NLCD_BIS, mean percent impervious surface in buffer; PHU_G60, percentage of housing units built prior to 1939; SEG_RMD, mean distance from stream segment to nearest road; SLOPE_X, mean basin slope; P_NLCD1_8, percentage of herbaceous planted/cultivated land cover in basin; P_NLCD1_B8, percentage of herbaceous planted/cultivated land cover in buffer; P_NLCD1_5, percentage of shrub/grass land cover in basin; P_NLCD1_B5, percentage of shrub/grass land cover in buffer; P_NLCD1_9, percentage of wetland land cover in basin; P_NLCD1_B9, percentage of wetland land cover in buffer; WET_MEAN, mean value of wetness index across all cells in basin; SNDH, mean high-range sand (soil); WTDH, mean high-range depth to water table; KFCAVE, mean soil erodibility factor (K factor)]

(D) Dissolved orthophosphate concentrations

Variable code	Variable short name	High base flow						Low base flow					
		Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland	Atlanta	Raleigh-Durham	Milwakee-Green Bay	Dallas-Fort Worth	Denver	Portland
Landscape variables													
P_NLCD1_B5	Shrub/grass land cover in buffer	-0.08	0.06	-0.59	-0.11	0.02	-0.49	0.12	0.26	-0.36	-0.17	-0.12	-0.53
P_NLCD1_9	Wetland land cover in basin	**-0.13**	0.22	0.10	0.02	0.34	0.01	**0.52**	-0.03	-0.04	0.25	0.20	0.03
P_NLCD1_B9	Wetland land cover in buffer	**-0.19**	0.10	-0.01	0.00	0.32	-0.07	**0.42**	-0.01	-0.12	0.39	0.15	-0.07
WET_MEAN	Basin-wetness index	0.18	0.28	0.22	0.22	0.33	0.38	0.27	0.08	0.38	-0.01	0.00	0.43
SNDH	Sand content in soil	0.15	-0.41	0.00	-0.09	-0.01	-0.52	0.00	-0.13	-0.04	0.09	-0.19	-0.56
WTDH	Depth to water table	0.28	-0.28	0.35	0.00	-0.16	-0.69	-0.05	-0.17	0.25	-0.16	-0.12	-0.67
KFCAVE	Soil erodibility	0.15	0.34	-0.21	0.11	0.19	0.50	0.10	0.02	-0.13	0.15	0.05	0.57

study basins may not be representative of the range in basin slope encountered in the greater Denver-Fort Collins-Cheyenne area. If that full range in basin slope had been covered by the study basins, the strength of the relation between total nitrogen concentrations and basin slope might have been significantly different (as likely also would be the strength of the relation between total nitrogen concentrations and urbanization). The relations with landscape variables were determined in this study to identify potential confounding influences along the urban gradient and to examine how those influences varied among environmental settings.

The analyses described previously were repeated for each chemical constituent under 12 scenarios. Each of the six study areas was examined independently, with the high base-flow and low base-flow data examined separately.

Benchmark Exceedances

Chemical concentrations were compared to water-quality benchmarks in a screening-level assessment of the potential importance of nutrients, pesticides, pH, sulfate, and chloride to human health and aquatic life in each study area. The screening-level assessment is not a substitute for risk assessment, which includes many more factors, such as additional avenues of exposure. The screening-level results are intended primarily to identify areas for further investigation and as a tool to assess the relative potential for effects in relation to urbanization in different environmental settings.

Human-Health and Drinking-Water Benchmarks

Four types of human-health benchmarks were used to assess the potential for nutrients and pesticides in base flow to affect human health. Of the constituents that were sampled, one or more human-health benchmarks currently (2007) are available for four nutrients (Appendix 3), 36 of the 41 pesticides, and none of the 24 pesticide degradates (Appendix 4) measured in this study. Technically, these benchmarks apply to finished drinking water consumed over a lifetime, whereas this study measured nutrients and pesticides in relatively few samples of stream water over a year; for the most part, these stream sites were not near drinking-water intakes. Therefore, these human-health benchmarks were not used to evaluate actual human exposure to contaminants or to ascertain violation of any drinking-water standards, but rather as general reference levels for putting measured concentrations in a human-health context.

In addition to the four types of human-health benchmarks for nutrients and pesticides, pH and concentrations of sulfate and chloride were compared with USEPA secondary drinking-water regulations (SDWRs), which pertain to the cosmetic and aesthetic effects of drinking water (Appendix 3). As with the human-health benchmarks for nutrients and pesticides, SDWRs apply to finished drinking water; as a result, the SDWRs have been used as general benchmarks or reference levels in this report.

The four types of human-health benchmarks and relevant SDWRs used in this study are as follows:

- **USEPA Maximum Contaminant Level (MCL)**—The maximum permissible concentration of a contaminant in water that is delivered to any user of a public-water system. This is an enforceable standard issued by USEPA under the Safe Drinking Water Act and is established on the basis of health effects and other factors (analytical and treatment technologies, and cost). As noted above, MCLs are used in this report as general benchmarks; the sampling design of this study does not meet the sampling and analytical conditions required to ascertain violation of drinking-water standards. MCLs are available for three nutrients and three pesticides (U.S. Environmental Protection Agency, 2006b) analyzed for this study (Appendixes 3 and 4).

- **USEPA Lifetime Health Advisory (LHA)**—The concentration of a chemical in drinking water that is not expected to cause any adverse, noncarcinogenic effects over a lifetime exposure. A health advisory is a human-health guideline (issued in advisory capacity), not a legally enforceable Federal standard. It assumes lifetime consumption of 2 L of water per day by a 70-kg adult, and that 20 percent of total exposure to the contaminant comes from drinking water (80 percent is assumed to come from other sources). LHA values are available for 1 nutrient and for 14 unregulated pesticides (that is, pesticides without MCLs) (U.S. Environmental Protection Agency, 2006b) analyzed for this study (Appendixes 3 and 4).

- **USEPA 10^{-6} Cancer Risk Concentration (10^{-6} CRC)**—The concentration of a chemical in drinking water corresponding to an excess estimated lifetime cancer risk of 1 in a million (10^{-6}). These human-health guidelines are calculated from the estimated cancer potency, which is derived using a conservative (protective) model of carcinogenesis, so that the cancer risk is an upper-limit estimate. The definition of “acceptable” level of cancer risk is a policy issue, not a scientific one. USEPA reviews individual State and Tribal policies on cancer risk levels as part of its oversight of water-quality standards under the Clean Water Act. USEPA’s policy is to accept measures adopted by States to limit cancer risk to the range of 10^{-6} to 10^{-4} (U.S. Environmental Protection Agency, 1992). The concentration corresponding to a cancer risk of 10^{-6} was used as the benchmark for the screening-level assessment in this study, consistent with the protective nature of such assessments. Values of 10^{-6} CRC are available for four unregulated pesticides (U.S. Environmental Protection Agency, 2005d, 2006b) analyzed for this study (Appendix 4).

- **USGS Health-Based Screening Level (HBSL)**—An estimate of concentration (for a noncarcinogen) or concentration range (for a carcinogen) in water that may be of potential human-health concern, if exceeded. HBSLs are nonenforceable benchmarks that were developed by the USGS in collaboration with USEPA and others using USEPA methodologies for establishing drinking-water guidelines and the most current, USEPA peer-reviewed, publicly available human-health toxicity information (Toccalino and others, 2003, 2006). HBSLs were derived for unregulated pesticides only (those without USEPA MCLs) and on the basis of health effects only, to assist with evaluation of concentrations of unregulated pesticides in water-quality assessments. Note that, for contaminants that are likely or potential carcinogens, the HBSL assumes a specific cancer risk. Consistent with the 10^{-6} CRC values, in this study HBSL values for carcinogens assumed a 10^{-6} cancer risk. HBSLs are available for 33 pesticides (many of which also have LHA or 10^{-6} CRC values), but not for any nutrients (U.S. Geological Survey, 2006b) analyzed for this study (Appendix 4).

- **USEPA Secondary Drinking-Water Regulations (SDWR)**—Nonenforceable Federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor, or color) of drinking water. SDWRs are drinking-water benchmarks, but not human-health benchmarks. They are available for pH, chloride, and sulfate (U.S. Environmental Protection Agency, 2006b) (Appendix 3).

Human-health benchmarks were selected for each constituent as follows—if available, the MCL was used as the human-health benchmark. For constituents with no MCL, comparisons were made with all applicable guidelines (LHA, 10^{-6} CRC, and(or) HBSL). For this report, human-health and SDWR benchmarks were compared to constituent concentrations in individual samples because too few samples were collected to compute annual mean concentrations.

Aquatic-Life Benchmarks

Benchmarks for assessing the potential for nutrients, pesticides, pH, and chloride in base flow to adversely affect aquatic life fall into two groups: (1) USEPA ambient water-quality criteria for the protection of aquatic life (AWQC-AL), which were developed by the USEPA Office of Water and are available for selected nutrients, pesticides, pH, and chloride; and (2) additional pesticide benchmarks derived from toxicity values in pesticide registration and risk-assessment documents prepared by the USEPA Office of Pesticide Programs. One or more aquatic-life benchmarks are available for one nutrient, pH, chloride, (Appendix 3), and 37 of the 65 pesticides and degradates (Appendix 4) measured in this study.

Ambient Water-Quality Criteria for Aquatic Organisms

The USEPA Office of Water derives aquatic-life criteria for priority pollutants and other selected contaminants under acute and chronic exposure conditions. Each acute and chronic criterion specifies a threshold concentration for unacceptable potential for effects, an averaging period, and an acceptable frequency of exceedance. AWQC-ALs are available for one nutrient, pH, chloride, 4 of the 41 pesticides, and none of the 24 pesticide degradates measured for this study (Appendixes 3 and 4). For ammonia, numeric criteria values were calculated for each water sample because the criteria are a function of pH, temperature, and the presence of salmonids at the site (U.S. Environmental Protection Agency, 2006c).

- **Acute AWQC-AL**—The highest concentration of a chemical to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. Except where a locally important species is very sensitive, aquatic organisms should not be unacceptably affected if the 1-hour average concentration does not exceed the acute criterion more than once every 3 years, on average. The intent is to protect 95 percent of a diverse group of organisms.

- **Chronic AWQC-AL**—The highest concentration of a chemical to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect. Except where a locally important species is very sensitive, aquatic organisms should not be unacceptably affected if the 4-day average concentration does not exceed the chronic criterion more than once every 3 years, on average. The intent is to protect 95 percent of a diverse group of organisms.

Toxicity Values from Pesticide Risk Assessments

For pesticides, acute and chronic AWQC-ALs were supplemented by up to seven benchmarks derived from aquatic toxicity values in the USEPA Office of Pesticide Programs' pesticide registration and risk-assessment documents (Appendix 4). Six toxicity values and their associated benchmarks pertain to a specific type of organism (fish, invertebrates, or plants) and exposure period (acute or chronic). The seventh—for chronic aquatic-community effects—was available for only one pesticide (atrazine). The USGS derived these benchmarks from USEPA toxicity values using USEPA procedures, and the benchmark values were reviewed by USEPA. Briefly, to compute each benchmark, the lowest of the applicable toxicity values was selected and then multiplied by the appropriate USEPA level of concern (LOC), so that the benchmark corresponds to the acute or chronic risk level defined by the U.S. Environmental Protection Agency (2005h). More detail on calculation of benchmarks is provided in Gilliom and others (2006). One or more benchmarks derived from USEPA's aquatic-life toxicity values are available for 33 of the 41 pesticides and 3 of the 24 pesticide degradates measured in this study.

All acute benchmarks are intended for comparison with instantaneous, or maximum, contaminant concentrations, whereas chronic benchmarks are intended for comparison with mean concentrations over an averaging period (specified, as follows, under each definition). The seven types of benchmarks based on USEPA's aquatic-life toxicity values are listed, as follows:

- **Acute fish**—The lowest tested LC_{50} for acute (typically 96-hour) toxicity tests with freshwater fish, multiplied by the LOC of 0.5.
- **Chronic fish**—The lowest no-observed-adverse-effects concentration, or the lowest-observed-adverse-effects concentration if a no-observed-adverse-effects concentration is not available, for freshwater fish in early life-stage or full life-cycle tests. Intended for comparison with 60-day average pesticide concentrations, multiplied by the LOC of 1.0.
- **Acute invertebrate**—The lowest tested LC_{50} or EC_{50} for acute (typically 48- or 96-hour) toxicity tests with freshwater invertebrates, multiplied by the LOC of 0.5.
- **Chronic invertebrate**—The lowest no-observed-adverse-effects concentration, or the lowest-observed-adverse-effects concentration if a no-observed-adverse-effects concentration is not available, for freshwater invertebrates in life-cycle tests, multiplied by the LOC of 1.0. Intended for comparison with 21-day average pesticide concentrations.
- **Acute nonvascular plant**—The lowest tested EC_{50} for freshwater nonvascular plants (algae) in acute toxicity tests (typically less than 10 days), multiplied by the LOC of 1.0.
- **Acute vascular plant**—The lowest tested EC_{50} for freshwater vascular plants in acute toxicity tests (typically less than 10 days), multiplied by the LOC of 1.0.
- **Chronic aquatic community**—Computed only for atrazine by USEPA, this endpoint includes community-level effects on aquatic plants and indirect effects on fish and aquatic invertebrates that could result from disturbance of the plant community. Intended for comparison with 60-day average atrazine concentrations.

In this study, all aquatic-life benchmarks were compared to constituent concentrations in individual base-flow samples. Although chronic aquatic-life benchmarks are intended to be compared with average concentrations over a longer time period (see above), insufficient data were available in this study to compute average concentrations over the desired time periods (4 to 60 days). As a result, the screening-level assessment in this study may overestimate the potential for effects; however, this assessment is consistent with the screening-level objective to use a sensitive screen to identify sites with potential for effects. However, because each site had so few samples collected (two per year), these samples were unlikely to capture peak concentrations of constituents; therefore, the screening-level assessment in this report probably underestimates potential for adverse effects on aquatic life.

Ecoregional Nutrient Criteria

Nutrient concentrations were compared with USEPA's recommended Ecoregional criteria, which are numerical values associated with the prevention and assessment of eutrophic conditions (Appendix 3). They represent surface-water conditions that are minimally affected by human activities and are suggested baselines for use by States and Tribes to identify problem areas, serve as a basis for State and Tribal water-quality criteria for nutrients, and evaluate relative success in reducing eutrophication (U.S. Environmental Protection Agency, 2002a). Two nutrients measured in this study (total nitrogen and total phosphorus) have Ecoregional criteria for rivers and streams, which are available for each of 14 Ecoregions in the United States (U.S. Environmental Protection Agency, 2002g).

Because nutrients typically manifest their effects over an extended time, such as a growing season, the frequency of sampling should be adequate to characterize long-term conditions and an appropriate averaging period should be used (U.S. Environmental Protection Agency, 2006d). In this study, however, the number of water samples collected at each site (two per year) was insufficient to compute meaningful mean or median concentrations, so nutrient concentrations in each individual sample were compared to Ecoregional criteria as part of the screening-level assessment.

Response of Stream Chemistry to Gradients of Urbanization

Results from the analysis of the relations between each chemical constituent and the percentage of urban land cover in the basin are presented in the following sections. In addition, the strengths of the relation between each chemical constituent and urban and landscape variables within each study area are compared during high and low base-flow conditions to examine the influence of hydrologic variability on the response of water chemistry to urbanization. In some instances, the relation between two variables was "strong" (absolute value of Spearman's rho was approximately 0.5 or greater) during one base-flow condition and "weak" (absolute value of Spearman's rho was less than approximately 0.5) during the other base-flow condition, but the results from the Fisher's or Meng's test indicated there was no statistically significant difference between base-flow conditions. In these instances, no distinction could be made between the strength of these relations during interpretation—lacking evidence to the contrary, if one relation was strong, both were considered to be strong. Finally, chemical concentrations are compared to water-quality benchmarks in a screening-level assessment of the potential importance of nutrients, pesticides, pH, sulfate, and chloride to human health and aquatic life in each study area. The screening-level assessment is not a substitute for risk assessment, which includes many more factors, such as additional avenues of exposure. The screening-level results are intended primarily to identify areas for further investigation and as a tool to assess the relative potential for effects in relation to urbanization in different environmental settings.

Patterns of Response to Urbanization

Nutrients

Nitrogen

In Atlanta, total nitrogen and nitrate concentrations increased with increasing urban land cover in the basin (fig. 3A and B). A pattern of increase in concentration with initial urbanization followed by considerable variation in concentration at higher percentages of urban land cover was evident during high and low base-flow conditions for nitrogen. Total nitrogen and nitrate concentrations also increased as most measures of urbanization—including housing density, road density, population density, patch size and homogeneity of urban land area, urban land cover in the basin and buffer, and impervious area in the basin and the buffer—increased, and decreased as a measure of housing age increased (table 3A and B). In general, the relations with urban variables were stronger than with the landscape variables. Shrub/grass land cover was the only landscape variable strongly related to total nitrogen and nitrate concentrations, which decreased as the percentage of shrub/grass land cover in the basin and buffer increased. This relation may reflect a reduction in agricultural influences on nitrogen concentrations as abandoned agricultural fields in the study area reverted to forested and shrub/grass land cover prior to development; shrub/grass and forested land cover were strongly related to one another in the Atlanta study area.

In Raleigh-Durham, total nitrogen concentrations increased with increasing urban land cover in the basin; the relation between nitrate concentrations and urban land cover in the basin was slightly weaker (fig. 3A and B). The responses of nitrogen concentrations to urban land cover in the basin did not show the initial increases evident in Atlanta; some nitrogen concentrations in basins with minimal urban development were higher in Raleigh-Durham than in Atlanta. Total nitrogen concentrations also increased as most measures of urbanization—including housing density, road density, population density, patch size and homogeneity of urban land area, urban land cover in the basin and buffer, and impervious area in the basin and the buffer—increased (table 3A). In general, the relations between nitrate concentrations and these measures of urbanization were slightly weaker (table 3B). The relations with urban variables were slightly stronger than with the landscape variables for both nitrogen constituents. However, total nitrogen and nitrate concentrations also were strongly and negatively related to the percentage of shrub/grass land cover in the basin and buffer, and nitrate concentrations were negatively related to the percentage of wetland land cover in the basin and buffer. The relations with shrub/grass land cover may reflect the reversion of agricultural fields to forested and shrub/grass land cover prior to development; shrub/grass and forested land cover were strongly related to one another in this study area. The relations between nitrate and wetlands may have been related to denitrification, as wetlands can promote denitrification (Seitzinger and others, 2006). Wetlands in the greater Raleigh-Durham metropolitan area usually are associated with the least-developed land areas.

In general, the strongest relations of nitrogen to urban and landscape variables were observed in Portland (table 3A and B). The pattern of response to the percentage of urban land cover in the basin was similar to that observed for Atlanta—an initial increase in concentration of total nitrogen and nitrate with urbanization, followed by considerable variation and a plateau in concentration at higher percentages of urban land cover (fig. 3A and B). Notably, nitrogen concentrations in basins with minimal urban development were lower in Portland than in Atlanta, indicating that the Atlanta basins had nonurban nitrogen sources, such as agricultural runoff or atmospheric deposition. In Portland, concentrations of total nitrogen and nitrate also increased as many other measures of urbanization—including housing density, road density, population density, patch size and homogeneity of urban land area, urban land cover in the buffer, and impervious area in the basin and buffer—increased. Concentrations of total nitrogen and nitrate increased as basin slope decreased, as the basin-wetness index increased, and as the percentage of shrub/grass land cover in the basin and buffer decreased. Conceptually, slope and wetness index are inversely proportional—a higher wetness index usually indicates flatter land and conditions more conducive to saturation during streamflow generation. Generally in the Portland study area, as basin slope increased and the basin-wetness index decreased, the background shrub/grass and forested land cover also increased.

Relations between total nitrogen and nitrate concentrations and urbanization were weak in Milwaukee-Green Bay, Dallas-Fort Worth, and Denver (fig. 3A and B, table 3A and B). Relations between total nitrogen and nitrate concentrations and landscape variables also were weak in these three areas; the one exception was a strong positive relation between nitrogen concentrations and soil erodibility in Denver during low base-flow conditions (table 3A and B). This relation may reflect increased mobility of water and dissolved nitrate through loose, friable, erodible soil that may be found in some of these basins. A notable distinction of the Milwaukee-Green Bay, Dallas-Fort Worth, and Denver areas is that the nitrogen concentrations in basins with minimal urban development were considerably higher than in the Atlanta, Raleigh-Durham, and Portland areas, and they showed a high degree of variation in concentration in the highly developed basins. In the Milwaukee-Green Bay and Dallas-Fort Worth areas,

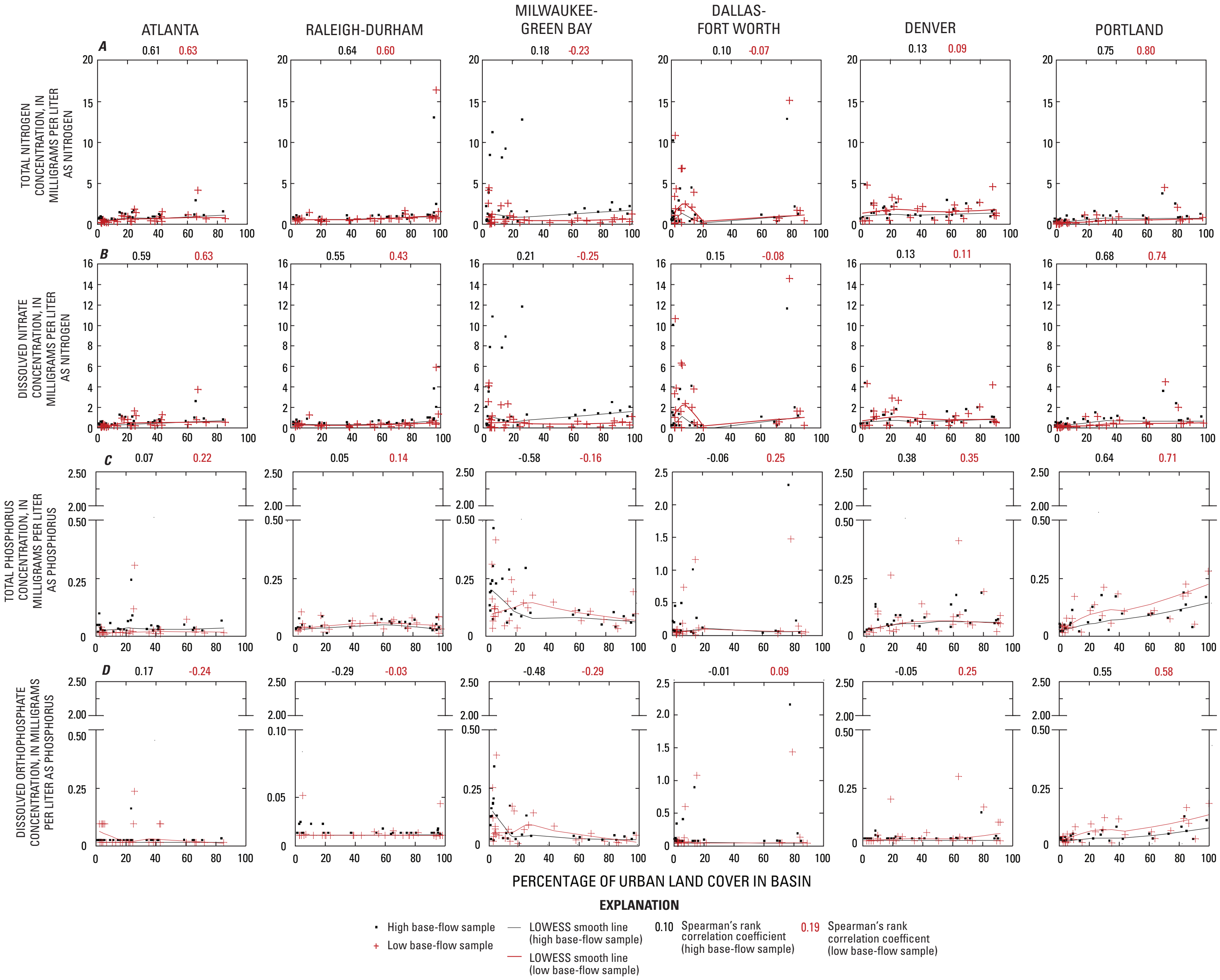

Figure 3. (*A*) Total nitrogen, (*B*) dissolved nitrate, (*C*) total phosphorus, and (*D*) dissolved orthophosphate concentrations during high and low base flow compared to the percentage of urban land cover in the basin in the Atlanta, Raleigh-Durham, Milwaukee-Green Bay, Dallas-Fort Worth, Denver, and Portland study areas. (LOWESS, locally weighted scatterplot smooth.)

agriculture was a predominant background land cover in basins with minimal urban development; agricultural fertilizer and farm-animal manure may be a source of the elevated concentrations in these basins. Nitrogen concentrations in the Denver study area were particularly variable across the gradient of development. The extensive water management in the Denver study area may account for this variation; movement and storage of water in the upstream drainage areas may have led to a disconnect between the land surface and streams, resulting in concentrations that were to some degree independent of land-cover characteristics (Sprague and others, 2006).

The results for total nitrogen and nitrate concentrations indicate that management strategies to control nitrogen in urban areas may need to consider background, pre-development land cover. Particularly if the developing area was previously in agricultural land cover, nutrient concentrations may be high even before development occurs.

Phosphorus

The relation between phosphorus concentrations and urban and landscape variables was weak in Atlanta, Raleigh-Durham, Dallas-Fort Worth, and Denver, with a few exceptions—total phosphorus concentrations increased as basin slope decreased and the basin-wetness index increased in Atlanta during high base-flow conditions (table 3C and D). Phosphorus concentrations in Raleigh-Durham were moderate at all levels of urbanization; concentrations in Atlanta generally were low, although there were a few particularly high values (fig. 3C and D). Phosphorus tends to bind to suspended sediment, which is generally present at low concentrations during base flow but can be at higher concentrations in stormwater runoff. Characterization of the effect of urbanization on phosphorus concentrations, therefore, is incomplete without a measure of the response at high flow across the urban gradient. The greater sediment-associated transport of phosphorus at high flows as compared to nitrogen in part may account for the differences in the response of nitrogen and phosphorus concentrations to urbanization. In addition, basins with greater slopes in Atlanta may be more effectively scoured than basins with lower slopes, removing phosphorus bound to sediment and thus decreasing total phosphorus concentrations. The effects of scouring may have contributed to the stronger negative relation between slope and total phosphorus concentrations during high base-flow conditions as compared to low base-flow conditions in Atlanta (table 3C); more scour may have been occurring during periods of more recent stormwater runoff. The response of phosphorus concentrations to all urban and landscape variables was statistically similar during high and low base-flow conditions in all other areas, with the exception of a small number of urban and landscape variables for which the relations, although statistically different, were both weak. Finally, no detailed accounting was made in this study of decreased benthic nutrient uptake by alteration of the ecosystem caused by urban development. Ecosystem differences between study areas likely played an important role in regional differences in the observed responses to urbanization.

The strongest relation between total phosphorous and orthophosphate and both urban and landscape variables was observed in Portland (table 3C and D). The same measures of urbanization that were strongly associated with increases in nitrogen concentrations—including housing density, road density, population density, patch size and homogeneity of urban land area, urban land cover in the basin and buffer, and impervious area in the basin and buffer—generally were related to increases in total phosphorous and orthophosphate concentrations. In Portland, phosphorus concentrations generally were low in basins with minimal urban development, but were high in more urban basins (fig. 3C and D). The clear response observed for Portland may be source related—the principal sources for phosphorus are natural geologic sources, fertilizer, animal manure, and sewage. The low phosphorus concentrations in minimally developed basins may be due to fewer sewage or animal manure inputs compared to more developed basins. In contrast, inputs of sewage from septic tanks in particular may have boosted concentrations in lesser developed basins in Raleigh-Durham and Atlanta. Similar landscape variables were related to nitrogen and phosphorus concentrations as well; concentrations of total phosphorus and orthophosphate increased as basin slope and the percentage of shrub/grass land cover in the basin and buffer decreased. Unlike nitrogen, concentrations of total phosphorus and orthophosphate also increased as measures of the sand content in soil and the depth to the water table decreased and as soil erodibility increased. Phosphorous readily binds to particulate organic material, so areas with greater soil erodibility and lower permeability may have experienced increased particle-associated phosphorus transport in Portland. Shrub/grass land typically is less susceptible to soil erosion than agricultural or urban land, which may explain the negative relation between phosphorus concentrations and the percentage of shrub/grass land cover. Greater depths to the water table may exist in drier areas with less soil erosion or in areas less likely to be used for urban development.

The response of total phosphorous concentrations to urbanization was distinctly different in Milwaukee-Green Bay as compared to the other study areas (fig. 3C and D, table 3C and D). Concentrations of total phosphorus decreased as measures of urbanization—including housing density, road density, population density, patch size and homogeneity of urban land area, urban land cover in the basin and buffer, and impervious area in the basin and the buffer—increased, and increased as the distance from the stream to the nearest road increased. Concentrations of total phosphorous in basins with minimal urban development were high in Milwaukee-Green Bay relative to the other study areas and decreased substantially as urbanization increased. Land use in the basins with minimal urban development in Milwaukee-Green Bay included substantial agriculture, including dairy farming; animal waste is an important source of phosphorus in agricultural areas. Concentrations of total phosphorous and orthophosphate increased as the percentage of agricultural land cover in the basin and buffer increased. High in-stream phosphorous concentrations in heavily fertilized agricultural or dairy farm areas of the Milwaukee-Green Bay study area may have resulted from runoff of particle-associated phosphorus. As agricultural areas were developed and application of fertilizer to cropland and(or) animal manure production was reduced, the phosphorus sources were removed and not replaced with urban sources of the same magnitude, likely resulting in less phosphorus runoff to streams. Although nitrogen inputs may have followed a similar pattern to that of phosphorus, urban inputs of nitrogen in more developed basins may have been as high as the likely agricultural inputs. The net result of high agricultural nitrogen inputs in areas of minimal urban development and high urban nitrogen inputs in more developed areas is a flat response across the urban gradient for nitrogen concentrations.

As in Milwaukee-Green Bay, concentrations of total phosphorous and orthophosphate in basins with minimal urban development were relatively high in Dallas-Fort Worth, probably because of the high percentage of agricultural land cover in these basins (fig. 3C and D, table 3C and D). Variation in phosphorous concentrations was greater, however, in the more developed basins in Dallas-Fort Worth than in Milwaukee-Green Bay, and overall, there were no strong relations between phosphorus concentrations and measures of urbanization in Dallas-Fort Worth. Phosphorus concentrations in Dallas-Fort Worth generally were high in the minimally developed agricultural basins, possibly due to animal-waste inputs, and in the urban basins, possibly due to septic inputs. The net response across the urban gradient is highly variable concentrations without a discernable trend. As with nitrogen, there were no strong relations between phosphorus concentrations and any landscape variables.

Concentrations of total phosphorous and orthophosphate in Denver were low relative to the other study areas and showed little to no response to increasing urbanization (fig. 3C and D, table 3C and D). Unlike nitrogen, concentrations of phosphorus were not strongly related to soil erodibility or any other landscape variable, perhaps because of the influence of water-management practices in the Denver area on phosphorus concentrations. This factor was not accounted for in the study design.

The results for phosphorus concentrations indicate that management strategies to control phosphorus in urban areas need to take background, pre-development land cover into account. When intensely farmed areas are converted to urban areas, there initially may be a reduction in nutrient loading to streams, followed by increased loading with further development. In addition, because of the association of phosphorus with sediment, phosphorus management logically can be coupled with sedimentation controls. Finally, urban effects are evident almost immediately with development or at very low levels of land-use change; nutrient management strategies may need to consider multiple facets of urban development (for example, road density, impervious area, and fragmentation of the landscape). In areas where background land cover already has had discernable effects on stream nutrient loading, as in agricultural areas, nutrient management strategies also may need to consider both agricultural and urban influences.

Pesticides

Total Herbicide Concentrations

In Atlanta, total herbicide concentrations increased as the percentage of urban land cover in the basin increased (fig. 4A). The two highest concentrations were measured during high base-flow conditions at sites with 20 to 40 percent urban land cover, but the overall pattern of increasing concentrations with increasing urban land cover held during high base-flow conditions in March and low base-flow conditions in September (table 1). Total herbicide concentrations also increased as most measures of urbanization—including housing density, road density, population density, patch size and homogeneity of urban land area, urban land cover in the buffer, and impervious area in the basin and the buffer—increased and decreased as a measure of housing age increased (table 4A). In general, the relations with urban variables were stronger than with the landscape variables; notable exceptions were the decrease in total herbicide concentrations as the percentage of shrub/grass land cover in the basin increased and as the depth to the water table decreased. The response to all urban and landscape variables was statistically similar during high and low base-flow conditions.

In Raleigh-Durham, total herbicide concentrations also increased as the percentage of urban land cover in the basin increased (fig. 4A). In general, the highest concentrations during high base-flow conditions in February and low base-flow conditions in July were measured at sites with 60 to 100 percent urban land cover. Total herbicide concentrations also increased as most measures of urbanization—including housing density, road density, population density, patch size and homogeneity of urban land area, urban land cover in the buffer, and impervious area in the basin and the buffer—increased (table 4A). The relations with urban variables generally were stronger than with the landscape variables, with the exception of the increase in total herbicide concentrations as the percentages of both agricultural and shrub/grass land covers in the basin and the buffer decreased. The response to all urban and landscape variables was statistically similar during high and low base-flow conditions, with the exception of the percentage of shrub/grass land cover in the basin, which was more strongly related to total herbicide concentrations during high base-flow conditions in February.

In Milwaukee-Green Bay, the relation between total herbicide concentrations and the percentage of urban land cover in the basin was weak (fig. 4A). In general, the highest concentrations were measured during high base-flow conditions in May and June. In both high base-flow conditions and low base-flow conditions in August, the highest concentrations were measured at sites with 0 to 20 percent urban land cover.

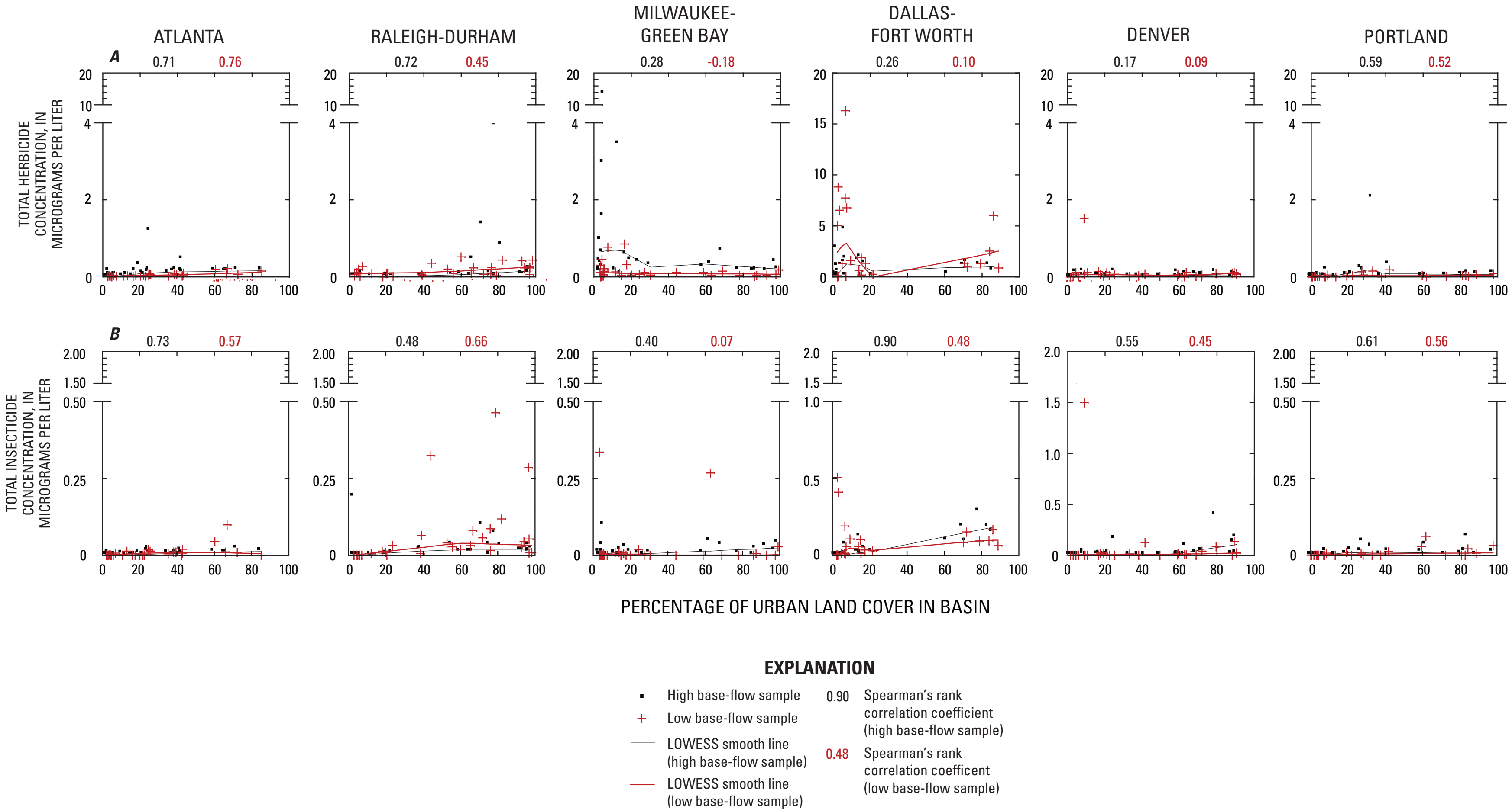

Figure 4. (*A*) Total herbicide and (*B*) total insecticide concentrations during high and low base flow compared to the percentage of urban land cover in the basin in the Atlanta, Raleigh-Durham, Milwaukee-Green Bay, Dallas-Fort Worth, Denver, and Portland study areas. (LOWESS, locally weighted scatterplot smooth.)

Table 4. Spearman's rank correlations between (A) total herbicide concentrations and (B) total insecticide concentrations during high and low base flow and selected urban and landscape variables.

[Values in bold are significantly different during high and low base-flow conditions. HUDEN, 2000 housing unit density; ROADDEN, road density; POPDENKM, 2000 population density; LPI_2, largest urban patch index; PLA_2, percentage of like adjacencies (urban); P_NLCD1_2, percentage of urban land cover in basin; P_NLCD1_B2, percentage of urban land cover in buffer; NLCD_IS, mean percent impervious surface in basin; NLCD_BIS, mean percent impervious surface in buffer; PHU_G60, percentage of housing units built prior to 1939; SEG_RMD, mean distance from stream segment to nearest road; SLOPE_X, mean basin slope; P_NLCD1_8, percentage of herbaceous planted/cultivated land cover in basin; P_NLCD1_B8, percentage of herbaceous planted/cultivated land cover in buffer; P_NLCD1_5, percentage of shrub/grass land cover in basin; P_NLCD1_B5, percentage of shrub/grass land cover in buffer; P_NLCD1_9, percentage of wetland land cover in basin; P_NLCD1_B9, percentage of wetland land cover in buffer; WET_MEAN, mean value of wetness index across all cells in basin; SNDH, mean high-range sand (soil); WTDH, mean high-range depth to water table; KFCAVE, mean soil erodibility factor (K factor)]

(A) Total herbicide concentrations

Variable code	Variable short name	High base flow						Low base flow					
		Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland	Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland
Urban variables													
HUDEN	Housing density	0.67	0.64	-0.33	0.28	0.12	0.59	0.74	0.27	-0.18	0.08	0.04	0.52
ROADDEN	Road density	0.65	0.67	-0.40	0.29	0.09	0.56	0.73	0.36	-0.22	0.19	0.08	0.52
POPDENKM	Population density	0.68	0.66	-0.32	0.28	0.12	0.61	0.74	0.29	-0.19	0.09	0.09	0.52
LPI_2	Patch size of urban land area	0.71	0.72	-0.30	0.24	0.19	0.59	0.75	0.44	-0.17	0.09	0.12	0.54
PLA_2	Homogeneity of urban land area	0.70	0.70	-0.26	0.37	0.24	0.62	0.74	0.47	-0.19	0.13	0.07	0.57
P_NLCD1_2	Urban land cover in basin	0.71	0.72	-0.28	0.26	0.17	0.59	0.76	0.45	-0.18	0.10	0.09	0.52
P_NLCD1_B2	Urban land cover in buffer	0.73	0.72	-0.37	0.11	0.06	0.57	0.74	0.46	-0.26	-0.02	0.02	0.53
NLCD_IS	Impervious area in basin	0.69	0.67	-0.21	0.36	0.17	0.58	0.75	0.48	-0.12	0.16	0.09	0.53
NLCD_BIS	Impervious area in buffer	0.74	0.67	-0.19	0.19	0.06	0.59	0.74	0.47	-0.13	-0.01	-0.01	0.54
PHU_G60	Housing age	-0.71	0.12	0.32	-0.27	-0.27	-0.32	-0.59	0.45	0.14	-0.17	-0.26	-0.14
SEG_RMD	Distance from stream to nearest road	-0.44	-0.23	0.28	0.07	-0.33	-0.18	-0.53	-0.31	0.28	-0.13	-0.36	-0.22
Landscape variables													
SLOPE_X	Basin slope	0.12	-0.20	-0.50	-0.06	-0.27	-0.67	-0.03	-0.54	-0.52	-0.03	-0.43	-0.55
P_NLCD1_8	Agricultural land cover in basin	-0.34	-0.57	0.62	0.21	-0.13	0.47	-0.52	-0.22	0.40	0.39	0.09	0.37

Table 4. Spearman's rank correlations between (A) total herbicide concentrations and (B) total insecticide concentrations during high and low base flow and selected urban and landscape variables.—Continued

[Values in bold are significantly different during high and low base-flow conditions. HUDEN, 2000 housing unit density; ROADDEN, road density; POPDENKM, 2000 population density; LPI_2, largest urban patch index; PLA_2, percentage of like adjacencies (urban); P_NLCD1_2, percentage of urban land cover in basin; P_NLCD1_B2, percentage of urban land cover in buffer; NLCD_IS, mean percent impervious surface in basin; NLCD_BIS, mean percent impervious surface in buffer; PHU_G60, percentage of housing units built prior to 1939; SEG_RMD, mean distance from stream segment to nearest road; SLOPE_X, mean basin slope; P_NLCD1_8, percentage of herbaceous planted/cultivated land cover in basin; P_NLCD1_B8, percentage of herbaceous planted/cultivated land cover in buffer; P_NLCD1_5, percentage of shrub/grass land cover in basin; P_NLCD1_B5, percentage of shrub/grass land cover in buffer; P_NLCD1_9, percentage of wetland land cover in basin; P_NLCD1_B9, percentage of wetland land cover in buffer; WET_MEAN, mean value of wetness index across all cells in basin; SNDH, mean high-range sand (soil); WTDH, mean high-range depth to water table; KFCAVE, mean soil erodibility factor (K factor)]

(A) Total herbicide concentrations

Variable code	Variable short name	High base flow						Low base flow					
		Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland	Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland
Landscape variables													
P_NLCD1_B8	Agricultural land cover in buffer	-0.14	-0.60	0.62	0.34	-0.07	0.37	-0.43	-0.23	0.43	0.33	0.02	0.34
P_NLCD1_5	Shrub/grass land cover in basin	-0.59	**-0.72**	-0.16	-0.53	-0.08	-0.81	-0.43	**-0.30**	-0.33	-0.43	-0.24	-0.72
P_NLCD1_B5	Shrub/grass land cover in buffer	-0.49	-0.70	-0.27	-0.20	0.08	-0.75	-0.35	-0.33	-0.38	-0.16	-0.04	-0.66
P_NLCD1_9	Wetland land cover in basin	-0.11	-0.40	-0.03	0.22	0.14	-0.13	-0.14	-0.38	-0.23	0.19	-0.07	-0.08
P_NLCD1_B9	Wetland land cover in buffer	-0.12	-0.26	-0.10	0.28	0.22	-0.25	-0.15	-0.44	-0.24	0.28	-0.02	-0.27
WET_MEAN	Basin-wetness index	-0.13	0.02	0.56	0.11	0.08	**0.65**	0.03	0.31	0.55	0.05	0.28	**0.47**
SNDH	Sand content in soil	0.03	0.15	-0.05	0.03	0.03	-0.49	-0.02	-0.24	0.01	0.13	0.04	-0.41
WTDH	Depth to water table	0.55	0.38	-0.03	0.02	-0.06	-0.30	0.45	0.03	-0.08	0.04	0.13	-0.26
KFCAVE	Soil erodibility	0.47	-0.49	-0.35	0.05	0.22	0.54	0.19	-0.45	-0.23	-0.05	0.42	0.49

Table 4. Spearman’s rank correlations between (A) total herbicide concentrations and (B) total insecticide concentrations during high and low base flow and selected urban and landscape variables.—Continued

[Values in bold are significantly different during high and low base-flow conditions. HUDEN, 2000 housing unit density; ROADDEN, road density; POPDENKM, 2000 population density; LPI_2, largest urban patch index; PLA_2, percentage of like adjacencies (urban); P_NLCD1_2, percentage of urban land cover in basin; P_NLCD1_B2, percentage of urban land cover in buffer; NLCD_IS, mean percent impervious surface in basin; NLCD_BIS, mean percent impervious surface in buffer; PHU_G60, percentage of housing units built prior to 1939; SEG_RMD, mean distance from stream segment to nearest road; SLOPE_X, mean basin slope; P_NLCD1_8, percentage of herbaceous planted/cultivated land cover in basin; P_NLCD1_B8, percentage of herbaceous planted/cultivated land cover in buffer; P_NLCD1_5, percentage of shrub/grass land cover in basin; P_NLCD1_B5, percentage of shrub/grass land cover in buffer; P_NLCD1_9, percentage of wetland land cover in basin; P_NLCD1_B9, percentage of wetland land cover in buffer; WET_MEAN, mean value of wetness index across all cells in basin; SNDH, mean high-range sand (soil); WTDH, mean high-range depth to water table; KFCAVE, mean soil erodibility factor (K factor)]

(B) Total insecticide concentrations

Variable code	Variable short name	High base flow						Low base flow					
		Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland	Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland
					Urban variables								
HUDEN	Housing density	0.68	0.54	0.42	**0.88**	0.48	0.65	0.58	0.77	0.10	**0.38**	0.44	0.59
ROADDEN	Road density	0.68	0.50	0.31	**0.89**	0.47	0.63	0.55	0.69	0.06	**0.51**	0.41	0.58
POPDENKM	Population density	0.69	0.55	0.44	**0.89**	0.50	0.66	0.55	0.78	0.09	**0.39**	0.44	0.58
LPI_2	Patch size of urban land area	0.73	0.49	0.32	**0.88**	0.55	0.62	0.57	0.65	0.05	**0.47**	0.45	0.56
PLA_2	Homogeneity of urban land area	0.72	0.43	0.40	**0.89**	0.51	0.65	0.51	0.65	0.09	**0.45**	0.48	0.52
P_NLCD1_2	Urban land cover in basin	0.73	0.48	0.40	**0.90**	0.55	0.61	0.57	0.66	0.07	**0.48**	0.45	0.56
P_NLCD1_B2	Urban land cover in buffer	0.74	0.45	0.25	**0.85**	0.44	0.60	0.57	0.62	0.08	**0.39**	0.40	0.54
NLCD_IS	Impervious area in basin	0.72	0.36	0.41	**0.89**	0.54	0.60	0.55	0.60	0.10	**0.42**	0.44	0.54
NLCD_BIS	Impervious area in buffer	0.73	0.42	0.34	**0.87**	0.42	0.61	0.56	0.56	0.08	**0.32**	0.36	0.55
PHU_G60	Housing age	-0.59	-0.15	-0.39	**-0.78**	-0.43	-0.34	-0.47	-0.19	0.00	**-0.33**	-0.25	-0.14
SEG_RMD	Distance from stream to nearest road	-0.47	-0.13	-0.09	-0.70	-0.59	-0.14	-0.28	-0.26	-0.27	-0.32	-0.59	-0.12
					Landscape variables								
SLOPE_X	Basin slope	-0.03	0.06	-0.13	-0.07	-0.34	-0.48	-0.13	0.15	-0.11	-0.31	-0.01	-0.46
P_NLCD1_8	Agricultural land cover in basin	-0.44	-0.54	-0.30	**-0.63**	-0.44	0.27	-0.40	-0.69	-0.07	**0.05**	-0.54	-0.06

Table 4. Spearman’s rank correlations between (A) total herbicide concentrations and (B) total insecticide concentrations during high and low base flow and selected urban and landscape variables.—Continued

[Values in bold are significantly different during high and low base-flow conditions. HUDEN, 2000 housing unit density; ROADDEN, road density; POPDENKM, 2000 population density; LPI_2, largest urban patch index; PLA_2, percentage of like adjacencies (urban); P_NLCD1_2, percentage of urban land cover in basin; P_NLCD1_B2, percentage of urban land cover in buffer; NLCD_IS, mean percent impervious surface in basin; NLCD_BIS, mean percent impervious surface in buffer; PHU_G60, percentage of housing units built prior to 1939; SEG_RMD, mean distance from stream segment to nearest road; SLOPE_X, mean basin slope; P_NLCD1_8, percentage of herbaceous planted/cultivated land cover in basin; P_NLCD1_B8, percentage of herbaceous planted/cultivated land cover in buffer; P_NLCD1_5, percentage of shrub/grass land cover in basin; P_NLCD1_B5, percentage of shrub/grass land cover in buffer; P_NLCD1_9, percentage of wetland land cover in basin; P_NLCD1_B9, percentage of wetland land cover in buffer; WET_MEAN, mean value of wetness index across all cells in basin; SNDH, mean high-range sand (soil); WTDH, mean high-range depth to water table; KFCAVE, mean soil erodibility factor (K factor)]

(B) Total insecticide concentrations

Variable code	Variable short name	High base flow						Low base flow					
		Atlanta	**Raleigh-Durham**	**Milwaukee-Green Bay**	**Dallas-Fort Worth**	**Denver**	**Portland**	**Atlanta**	**Raleigh-Durham**	**Milwaukee-Green Bay**	**Dallas-Fort Worth**	**Denver**	**Portland**
							Landscape variables						
P_NLCD1B8	Agricultural land cover in buffer	-0.32	-0.48	-0.33	-0.55	-0.42	0.19	-0.41	-0.63	-0.02	-0.03	-0.53	-0.06
P_NLCD1_5	Shrub/grass land cover in basin	-0.54	-0.51	0.17	-0.78	-0.28	-0.67	-0.31	-0.66	0.13	-0.59	-0.16	-0.62
P_NLCD1_B5	Shrub/grass land cover in buffer	-0.44	-0.39	0.22	**-0.76**	-0.22	-0.66	-0.27	-0.59	0.15	**-0.31**	-0.18	-0.65
P_NLCD1_9	Wetland land cover in basin	-0.24	-0.06	-0.39	0.06	-0.04	0.07	-0.05	-0.27	-0.22	0.11	-0.09	-0.22
P_NLCD1_B9	Wetland land cover in buffer	-0.25	0.02	-0.39	0.02	-0.03	0.02	-0.09	-0.18	-0.31	0.17	-0.16	-0.14
WET_MEAN	Basin-wetness index	-0.01	-0.05	0.13	0.38	0.27	0.43	0.16	-0.22	0.05	0.39	-0.01	0.46
SNDH	Sand content in soil	-0.01	0.18	-0.24	-0.06	-0.26	**-0.76**	0.19	0.33	-0.09	0.03	-0.27	**-0.24**
WTDH	Depth to water table	0.54	0.28	-0.12	-0.08	-0.06	-0.55	0.35	0.43	0.02	-0.06	-0.19	-0.32
KFCAVE	Soil erodibility	0.42	0.03	0.12	0.09	0.30	**0.57**	0.18	-0.24	-0.06	-0.04	0.09	**0.14**

The relation between total herbicide concentrations and most urban and landscape variables was weak, with the exception of the increase in concentration as the percentages of agricultural land cover in the basin and buffer and the basin-wetness index increased (table 4A). The response to all urban and landscape variables was statistically similar during high and low base-flow conditions.

In Dallas-Fort Worth, the relation between total herbicide concentrations and the percentage of urban land cover in the basin also was weak (fig. 4A). In general, higher concentrations were measured during low base-flow conditions in February than during high base-flow conditions in May. In addition, during low base-flow conditions, the highest concentrations were measured at sites with 0 to 10 percent and 80 to 90 percent urban land cover; during high base-flow conditions, the highest concentrations were measured at sites with 0 to 10 percent urban land cover only. The relation between total herbicide concentrations and most urban and landscape variables was weak, with the exception of the decrease in concentrations as the percentage of shrub/grass land cover in the basin increased (table 4A). The response to all urban and landscape variables was statistically similar during high and low base-flow conditions.

In Denver, the relation between total herbicide concentrations and the percentage of urban land cover in the basin also was weak (fig. 4A). The highest concentration was measured during low base-flow conditions at a site with very little urban land cover, and overall, there was a lack of a consistent pattern with increasing urban land cover during both high base-flow conditions in June and low base-flow conditions in August. The relation between total herbicide concentrations and all urban and landscape variables was weak (table 4A).

In Portland, total herbicide concentrations increased as the percentage of urban land cover in the basin increased (fig. 4A). In general, the highest concentrations during high base-flow conditions in May and low base-flow conditions in August were measured at sites with 35 to 45 percent urban land cover, where the percentage of agriculture in the basins was highest, indicating mixed agricultural and urban influences at these sites. Total herbicide concentrations increased as most measures of urbanization—including housing density, road density, population density, patch size and homogeneity of urban land area, urban land cover in the buffer, and impervious area in the basin and the buffer—increased (table 4A). The negative relations between total herbicide concentrations and basin slope and the percentage of shrub/grass land cover in the basin and buffer and the positive relation between concentrations and the basin-wetness index and soil erodibility generally were as strong as the relations with the urban variables (table 4A). The response to all urban and landscape variables was statistically similar during high and low base-flow conditions, with the exception of the basin-wetness index, which was more strongly related to total herbicide concentrations during high base-flow conditions in May.

When the responses of individual study areas were compared, two distinct groups were evident. Total herbicide concentrations increased as most measures of urbanization increased in Atlanta, Raleigh-Durham, and Portland; in contrast, relations between total herbicide concentrations and urbanization were weak in Milwaukee-Green Bay, Dallas-Fort Worth, and Denver. In Atlanta, Raleigh-Durham, and Portland, a predominant background (nonurban) land cover was forested, and urban land cover increased as forested land cover decreased (fig. 2). In Portland, there was evidence of mixed agricultural and urban influences at sites with 20 to 50 percent urban land cover; however, the overall relation between herbicide concentrations and urbanization was strong. The increase in total herbicide concentrations in these three study areas generally followed the change in land cover from forested to urban, with isolated exceptions in Atlanta and Portland in basins with relatively higher percentages of agricultural land cover (fig. 4A). The same measures of urbanization were related to total herbicide concentrations in Atlanta, Raleigh-Durham, and Portland, with the exception of housing age (table 4A). In Atlanta, total herbicide concentrations decreased as a measure of housing age increased; this relation did not hold in Raleigh-Durham or Portland. Many older homes in the Atlanta study area were in rural areas; as a result, housing age may be representative of nonurban land cover in this relation. The preponderance of older homes in rural areas, however, may be an artifact of the basin selection for this study rather than a reflection of land-development patterns in the greater Atlanta area.

In Milwaukee-Green Bay, the background land cover was predominantly agriculture; the majority of study sites had 50 to 60 percent agricultural land cover and very little forested or shrub/grass land cover (fig. 2). Urban land cover increased as agricultural land cover decreased, reflecting the conversion of agricultural to urban land in the Milwaukee-Green Bay area. Total herbicide concentrations in Milwaukee-Green Bay decreased somewhat as most measures of urbanization increased and as agricultural land cover in the basin and buffer decreased. In the semiarid Dallas-Fort Worth area, agriculture also was one of the predominant background land covers, along with shrub/grass land cover (fig. 2). Similar to forested areas, typically there is little herbicide application in shrub/grass land areas. The presence of shrub/grass lands contributed to a nonlinear relation between total herbicide concentrations and urban land cover in Dallas-Fort Worth (fig. 3A); total herbicide concentrations were highest in basins with low urban and relatively high agricultural land cover, then decreased sharply as agricultural land cover decreased and shrub/grass land cover increased, and finally increased slightly again as urban land cover increased and both agricultural and shrub/grass land cover decreased in the most urbanized basins. In Denver, the predominant background land cover was shrub/grass land (fig. 2). However, total herbicide concentrations did not increase or decrease in a clear pattern relative to any type of land cover (table 4A) or to any other urban or landscape variables. In Denver, it appears that concentrations are related to a factor or factors not measured in this study; one possibility may be the extensive water management in the greater

Denver metropolitan area. The movement and storage of water in the upstream drainage areas may have disrupted the transport of herbicides to the sampling sites, resulting in concentrations that to some degree were independent of basin-level urban and landscape characteristics (Sprague and others, 2006).

Different landscape variables were related to total herbicide concentrations in the six study areas (table 4A). In Raleigh-Durham, total herbicide concentrations decreased as the percentage of agricultural land cover in the basin and buffer increased. Because the percentage of agricultural land cover was small compared to the combined percentages of forested and urban land cover (fig. 2), this relation likely reflected the larger increase in forested land cover and decrease in urban land cover as agricultural land cover increased. Similarly, in Portland, total herbicide concentrations decreased as the percentage of shrub/grass land cover in the buffer increased; this relation likely reflected the larger increase in forested land cover and decrease in urban land cover as shrub/grass land cover increased (fig. 2). In contrast, agriculture was the predominant land use in the majority of basins in Milwaukee-Green Bay, and the increase in total herbicide concentrations as the percentages of agricultural land cover in the basin and buffer increased likely was a direct reflection of agricultural influences in that area. In Portland, total herbicide concentrations decreased as basin slope increased and as the basin-wetness index decreased (conceptually, slope and wetness index are inversely proportional—a higher wetness index usually indicates flatter land and conditions more conducive to saturation during precipitation, which then results in streamflow generation). The negative relation between total herbicide concentrations and basin slope and the positive relation between concentrations and the basin-wetness index likely reflected the increase in the background forested and shrub/grass land cover as basin slope increased and the basin-wetness index decreased in Portland. These relations were not observed in most other areas, likely because the variability in these two landscape variables was greatest in Portland (Falcone and others, 2007).

The response of total herbicide concentrations to all urban and landscape variables was statistically similar during high and low base-flow conditions, with the exception of the percentage of shrub/grass land cover in the basin in Raleigh-Durham, which was more strongly related to total herbicide concentrations during high base-flow conditions in February, and the basin-wetness index in Portland, which was more strongly related to total herbicide concentrations during high base-flow conditions in May. In both areas, the differences may have been due to higher herbicide application rates and more frequent, sustained rainfall events in the high base-flow months.

The results for total herbicide concentrations indicate that strategies to control herbicide transport to streams in urbanizing areas may be most effective when developed locally. In addition, in areas where agricultural land may be converted to urban land, such strategies may need to consider both agricultural and urban influences.

Total Insecticide Concentrations

Although total insecticide concentrations were lower than total herbicide concentrations in Atlanta, Raleigh-Durham, and Portland, the pattern and strength of the response of total insecticide concentrations to urbanization generally was similar to that of total herbicide concentrations (fig. 4B, table 4B). Total insecticide concentrations increased as most measures of urbanization increased, generally following the decrease in forested land cover and the increase in urban land cover. The same measures of urbanization—including housing density, road density, population density, patch size and homogeneity of urban land area, urban land cover in the basin and buffer, and impervious area in the basin and the buffer—were related to total insecticide concentrations in all three areas, with the exception of housing age (table 4B). In Atlanta, total insecticide concentrations decreased as a measure of housing age increased; this relation did not hold in Raleigh-Durham or Portland. Many older homes in the Atlanta study area were in rural areas; as a result, housing age may be representative of nonurban land cover in this relation. The preponderance of older homes in rural areas, however, may be an artifact of the basin selection for this study rather than a reflection of land-development patterns in the greater Atlanta area.

In contrast, the pattern and strength of the response of total insecticide concentrations to urbanization generally was different from that of total herbicide concentrations in Milwaukee-Green Bay, Dallas-Fort Worth, and Denver (fig. 4B, table 4B). In Milwaukee-Green Bay, like total herbicide concentrations, the relations between total insecticide concentrations and measures of urbanization were weak. However, unlike total herbicide concentrations, total insecticide concentrations increased somewhat as most measures of urbanization increased and as agricultural land cover in the basin and buffer decreased (table 4B). In Dallas-Fort Worth, total insecticide concentrations were more strongly related to measures of urbanization than were total herbicide concentrations, particularly during high base-flow conditions in May. Likewise, in Denver, total insecticide concentrations generally increased as most measures of urbanization increased, whereas there were no clear patterns in total herbicide concentrations as urbanization increased.

In Milwaukee-Green Bay and Denver, most study basins had a disproportionate amount of urban land cover in the lowland portion of the drainage area near the sampling sites (Falcone and others, 2007). In addition, although the contribution of herbicides from agricultural areas likely is far greater than from urban areas, contributions of insecticides from urban areas may be similar to those from agricultural areas (Hoffman and others, 2000). Therefore, the proximity of urban areas to the sampling sites may have led to stronger relations between total insecticide concentrations and urbanization as compared to total herbicide concentrations, because much of the herbicide loading may have originated further upstream. In addition, with a large contribution of insecticides likely originating from areas in close proximity to the sampling sites in Denver, the transport of insecticides to the sampling sites may have been less affected by the movement and storage of water in the upstream drainage area than the transport of herbicides. In Dallas-Fort Worth, numerous herbicides were detected in all study basins, but very few insecticides were detected in the 10 basins with the lowest percentage of urban land cover (see the following section “Individual Pesticide Detections and Pesticide Toxicity Index” for more detail). Therefore, it appears that insecticides may be selectively applied in more urbanized basins in the Dallas-Fort Worth study area.

The response of total insecticide concentrations to landscape variables generally was similar to that of total herbicide concentrations in Atlanta, Raleigh-Durham, Denver, and Portland (table 4B). In Milwaukee-Green Bay, the relation between the percentage of agricultural land cover in the basin and buffer and total insecticide concentrations was opposite in direction and somewhat weaker compared to total herbicide concentrations; this outcome may have been due to the greater relative use of insecticides in urban areas in close proximity to the sites. In Dallas-Fort Worth, the relations between total insecticide concentrations and agricultural and shrub/grass land cover in the basin and buffer were negative and somewhat stronger compared to total herbicide concentrations. Shrub/grass and agriculture were the predominant background land covers in Dallas-Fort Worth (fig. 2); as the percentage of the background land cover decreased, urban land cover increased, contributing to the strong negative relations with shrub/grass and agricultural land cover and the strong positive relations with urban land cover. These relations were stronger for total insecticide concentrations than for total herbicide concentrations in part because insecticides may be selectively applied in more urbanized basins in the Dallas-Fort Worth study area, whereas herbicides may be more widely applied across all of the basins in this study area.

The response of total insecticide concentrations to all urban and landscape variables was statistically similar during high and low base-flow conditions in all study areas except Dallas-Fort Worth and Portland (table 4B). In Dallas-Fort Worth, total insecticide concentrations were more strongly related to most measures of urbanization, the percentage of agricultural land cover in the basin, and the percentages of shrub/grass land cover in the basin and buffer during high base-flow conditions in May than during low base-flow conditions in February. This difference may have been due in part to more frequent, sustained rainfall events in May contributing to higher rates of runoff. In Portland, total insecticide concentrations were more strongly related to measures of sand content in the soil and soil erodibility during high base-flow conditions in May. The stronger positive relation with soil erodibility and the stronger negative relation with sand content in the soil during high base-flow conditions indicated that areas with greater soil erodibility and lower permeability may have experienced increased particle-associated insecticide transport during periods of greater recent surface runoff in Portland. Although there are exceptions, many insecticides tend to sorb more strongly to particulate material than herbicides (Gilliom and others, 2006); the difference in sorption may explain why a difference between low and high base-flow conditions was observed for insecticide concentrations but not for herbicide concentrations.

The results for total insecticide concentrations indicate that, in contrast to herbicides, strategies to control insecticide transport to streams in urbanizing areas may be effective when developed nationally, although consideration of local factors likely will improve the outcome. In addition, such strategies may need to consider the potential for surface runoff of insecticides from impervious areas.

Individual Pesticide Detections and Pesticide Toxicity Index

The concentrations of individual pesticides detected at each site within the six study areas are shown in figures 5 through 16 as a function of the percentage of urban land cover in the basin. Each stacked bar graph of pesticide concentrations in stream water (the top graph, figs. 5-16) shows a certain pesticide “signature” for that study area—a pattern that reflects the pesticides used within the study area, as well as (to some degree) the extent of urbanization within the basin. In addition, patterns in individual pesticide concentrations after normalization by the PTI for both cladocerans (the middle graph, figs. 5-16) and fish (the bottom graph, figs. 5-16) are shown.

Comparison of the pesticide signatures among study areas showed some similarities and some differences. In Atlanta, pesticide concentrations generally increased with increasing urban land cover within the basin under both high and low base-flow conditions, except that the highest pesticide concentrations occurred at about 25 percent urban land cover (at high base flow); the detections at this site were largely herbicides (figs. 5 and 6). At high base flow, the pesticide signature was dominated by the triazine herbicides simazine and atrazine. Low base-flow samples contained a greater variety of pesticides, including atrazine and simazine, plus additional herbicides prometon and tebuthiuron, the herbicide degradate 3,4-dichloroaniline (“other herbicides,” fig. 6A), and the insecticides carbaryl and fipronil.

Both Raleigh-Durham and Portland showed somewhat similar patterns to Atlanta (figs. 7, 8, 15, 16). Pesticide concentrations were higher at moderately to highly urbanized sites High base-flow samples were dominated by one or two triazine herbicides, either simazine (Atlanta, Raleigh-Durham) and(or) atrazine (Atlanta, Portland), whereas there was a greater variety of pesticides in low base-flow samples. In addition to atrazine and simazine, pesticides detected at low base flow in Portland and Raleigh-Durham included the herbicides hexazinone (“other herbicides,” figs. 8A and 16A), metolachlor, and prometon, and the insecticides carbaryl and diazinon. One site in Raleigh-Durham also had the herbicide

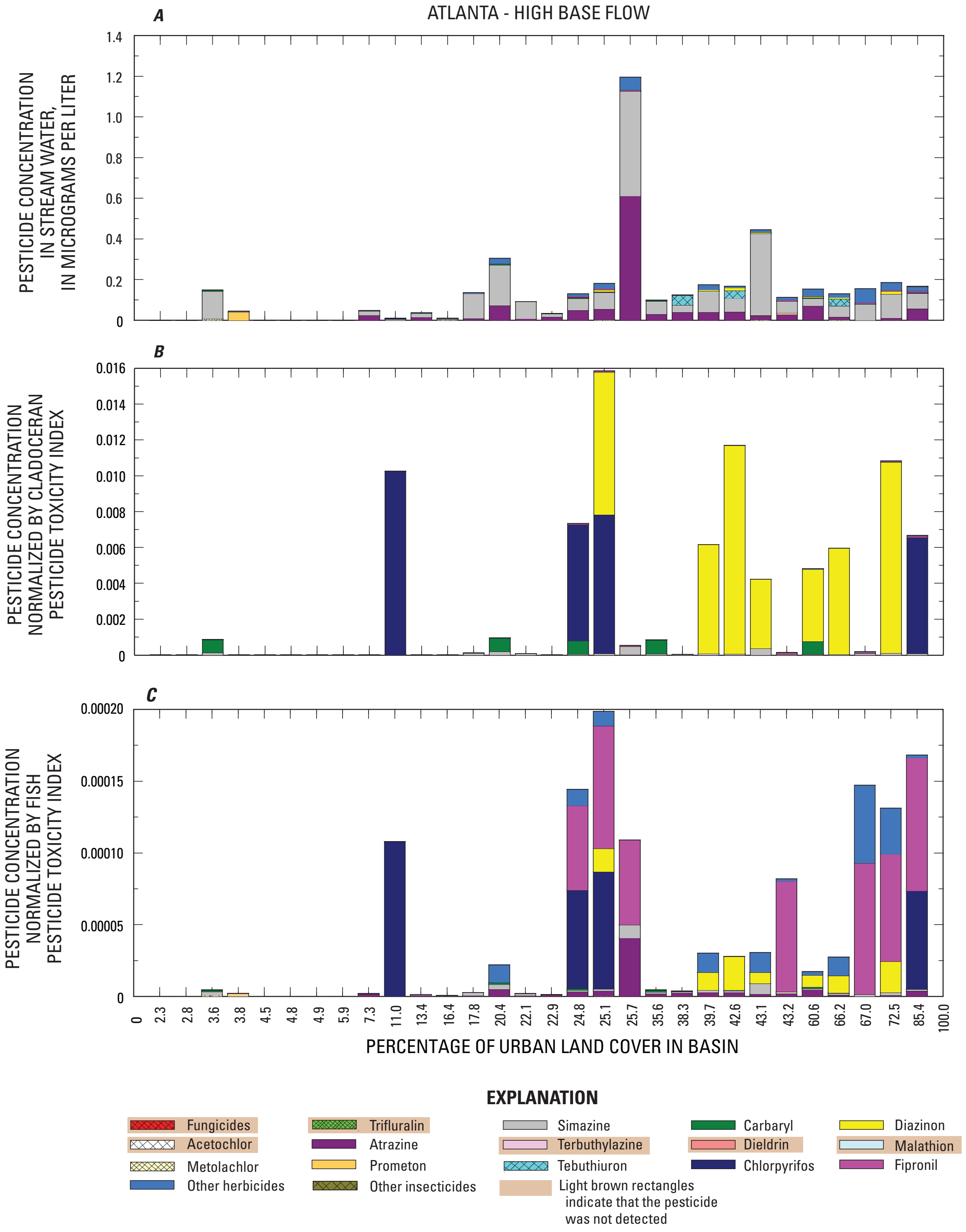

Figure 5. Pesticide concentrations (*A*) measured in stream water, (*B*) normalized by the cladoceran pesticide toxicity index, and (*C*) normalized by the fish pesticide toxicity index during high base-flow conditions compared to the percentage of urban land cover in the basin in the Atlanta study area. Note different y-axis scales.

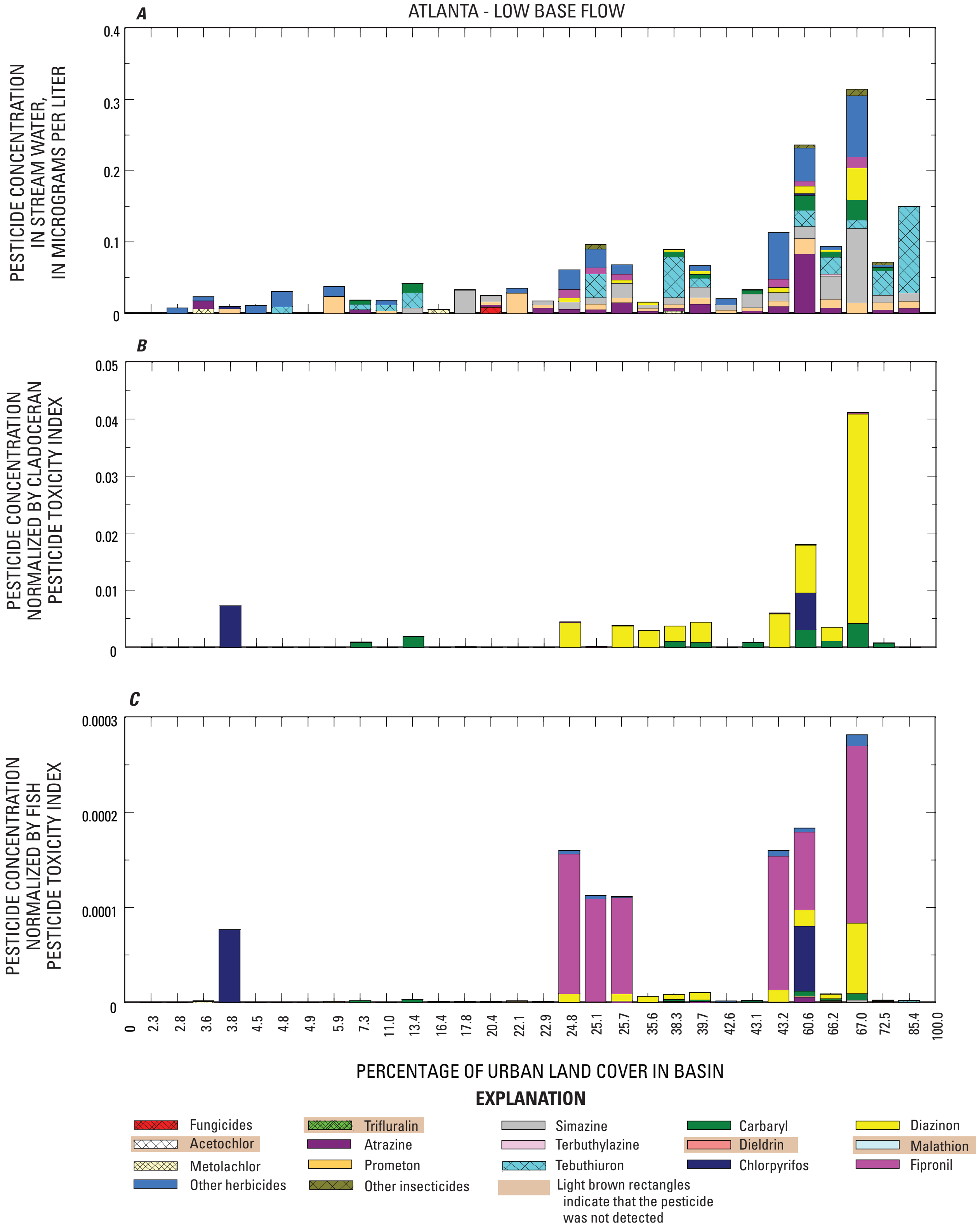

Figure 6. Pesticide concentrations (*A*) measured in stream water, (*B*) normalized by the cladoceran pesticide toxicity index, and (*C*) normalized by the fish pesticide toxicity index during low base-flow conditions compared to the percentage of urban land cover in the basin in the Atlanta study area. Note different y-axis scales.

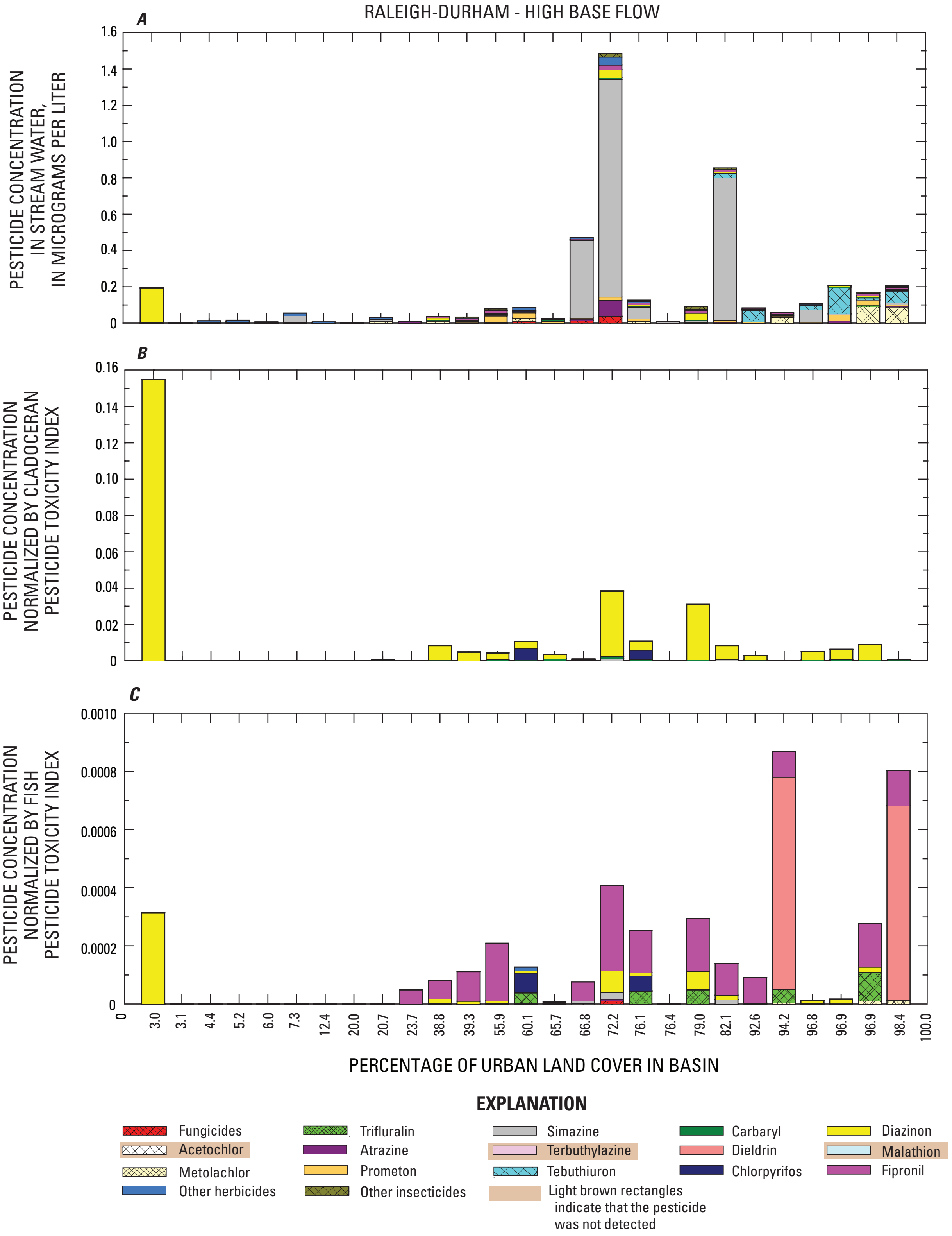

Figure 7. Pesticide concentrations (*A*) measured in stream water, (*B*) normalized by the cladoceran pesticide toxicity index, and (*C*) normalized by the fish pesticide toxicity index during high base-flow conditions compared to the percentage of urban land cover in the basin in the Raleigh-Durham study area. Note different y-axis scales.

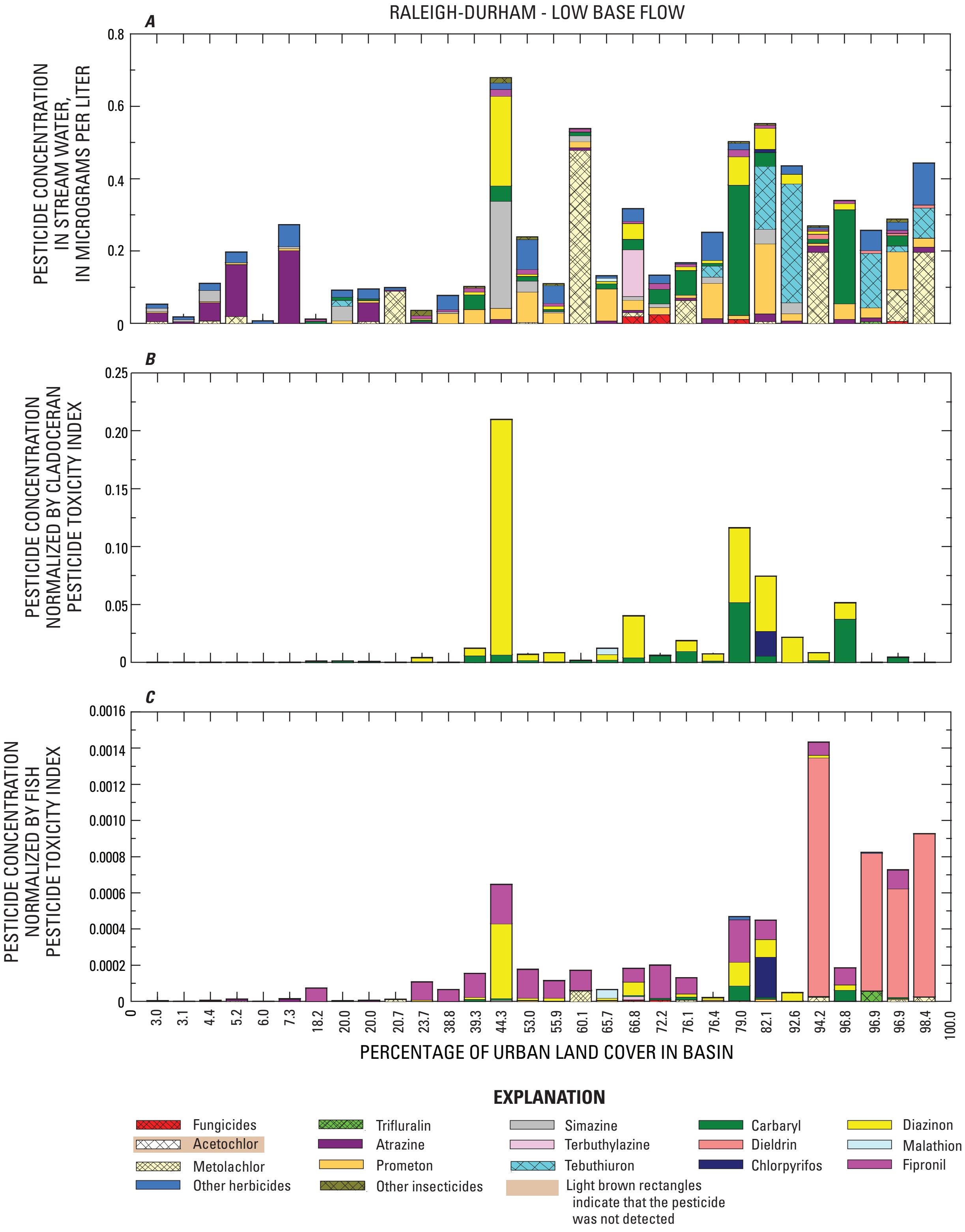

Figure 8. Pesticide concentrations (*A*) measured in stream water, (*B*) normalized by the cladoceran pesticide toxicity index, and (*C*) normalized by the fish pesticide toxicity index during low base-flow conditions compared to the percentage of urban land cover in the basin in the Raleigh-Durham study area. Note different y-axis scales.

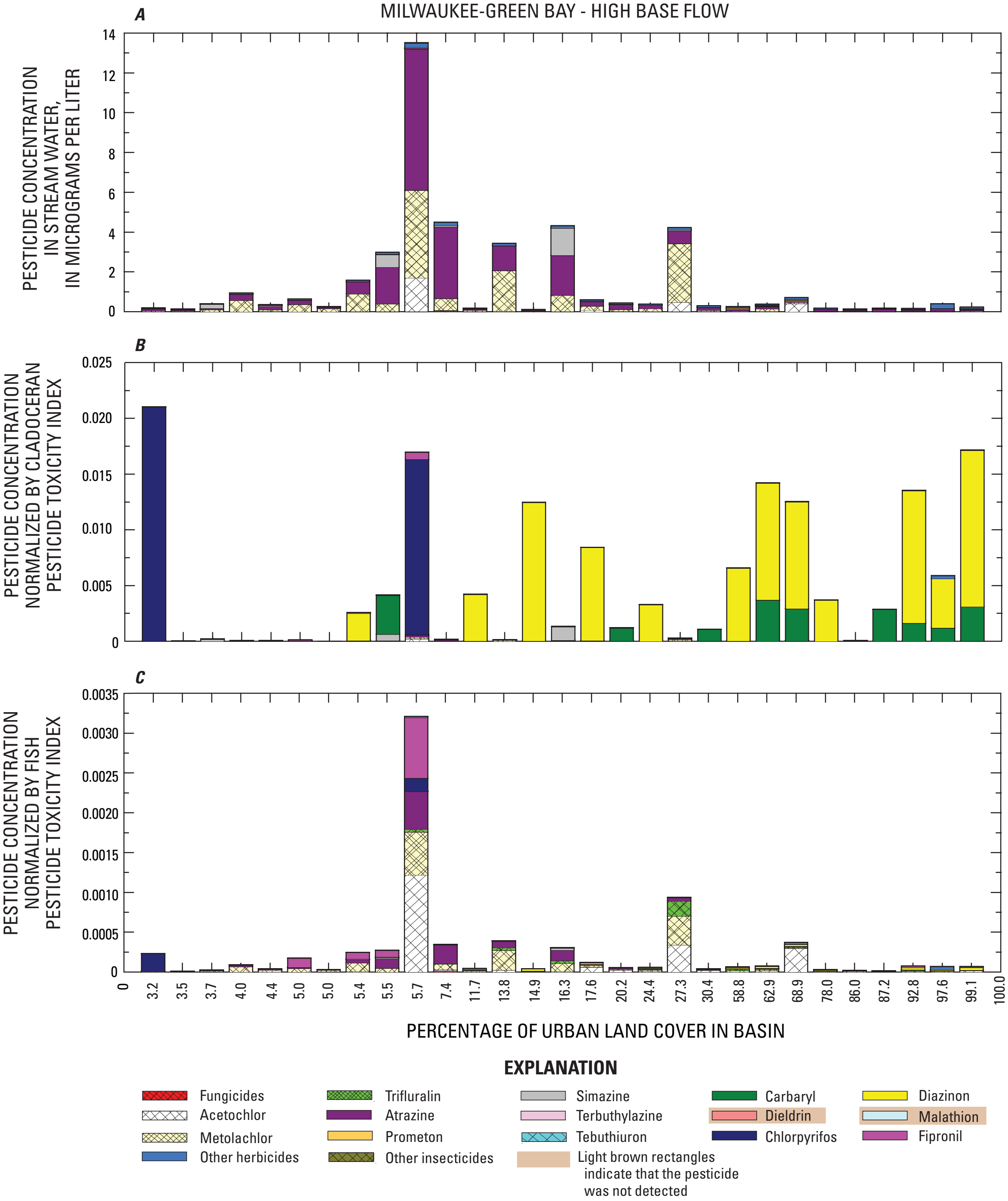

Figure 9. Pesticide concentrations (*A*) measured in stream water, (*B*) normalized by the cladoceran pesticide toxicity index, and (*C*) normalized by the fish pesticide toxicity index during high base-flow conditions compared to the percentage of urban land cover in the basin in the Milwaukee-Green Bay study area. Note different y-axis scales.

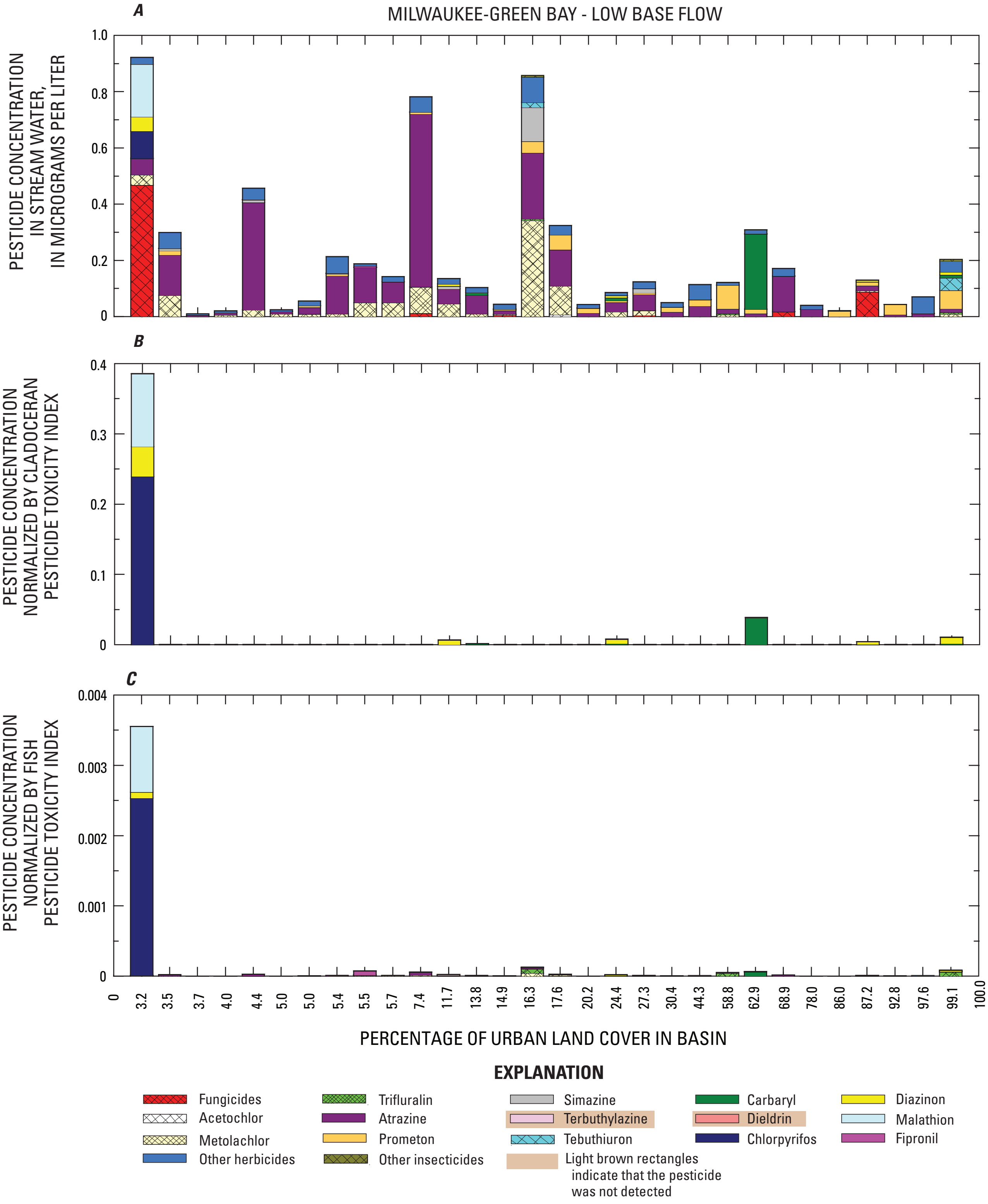

Figure 10. Pesticide concentrations (*A*) measured in stream water, (*B*) normalized by the cladoceran pesticide toxicity index, and (*C*) normalized by the fish pesticide toxicity index during low base-flow conditions compared to the percentage of urban land cover in the basin in the Milwaukee-Green Bay study area. Note different y-axis scales.

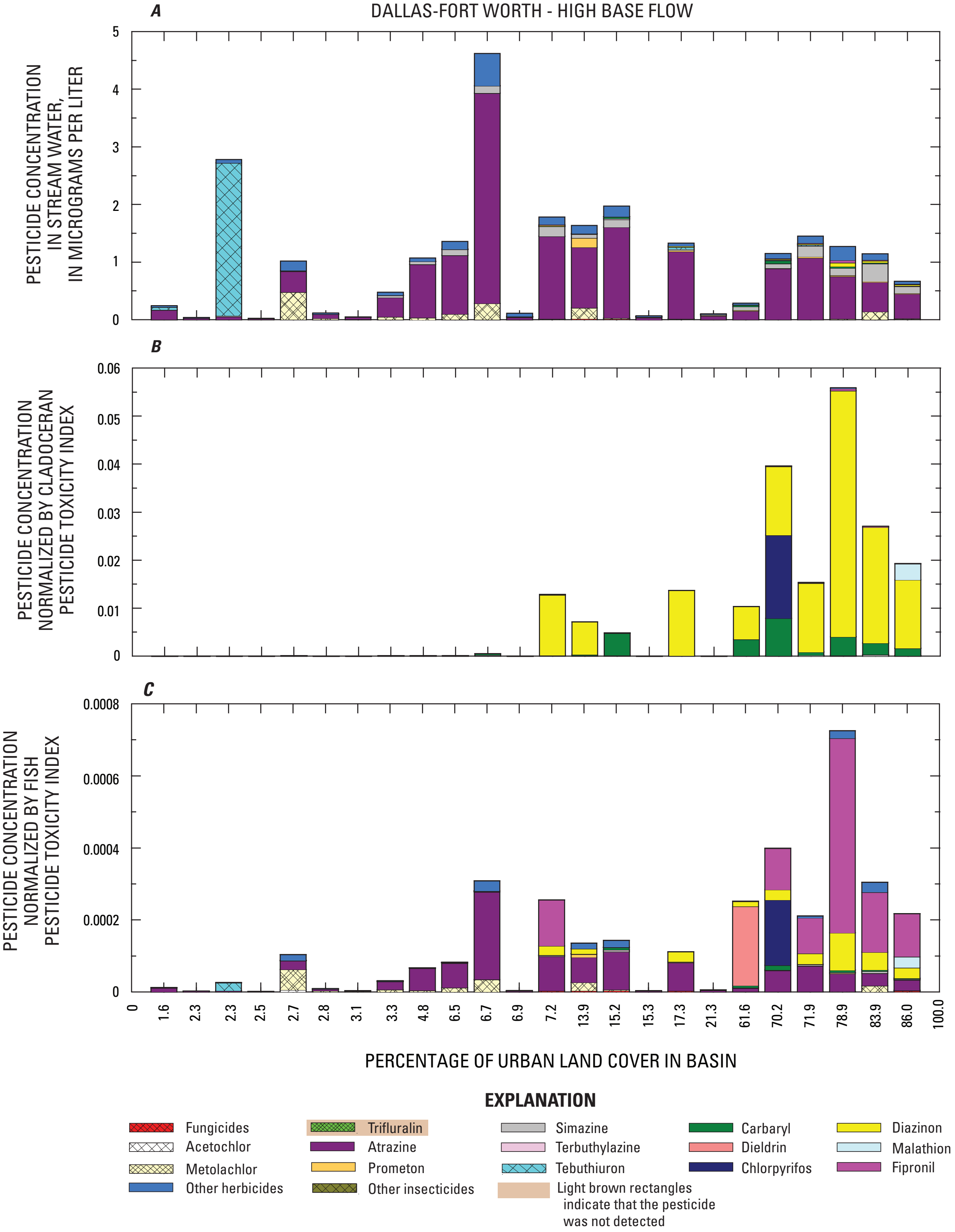

Figure 11. Pesticide concentrations (*A*) measured in stream water, (*B*) normalized by the cladoceran pesticide toxicity index, and (*C*) normalized by the fish pesticide toxicity index during high base-flow conditions compared to the percentage of urban land cover in the basin in the Dallas-Fort Worth study area. Note different y-axis scales.

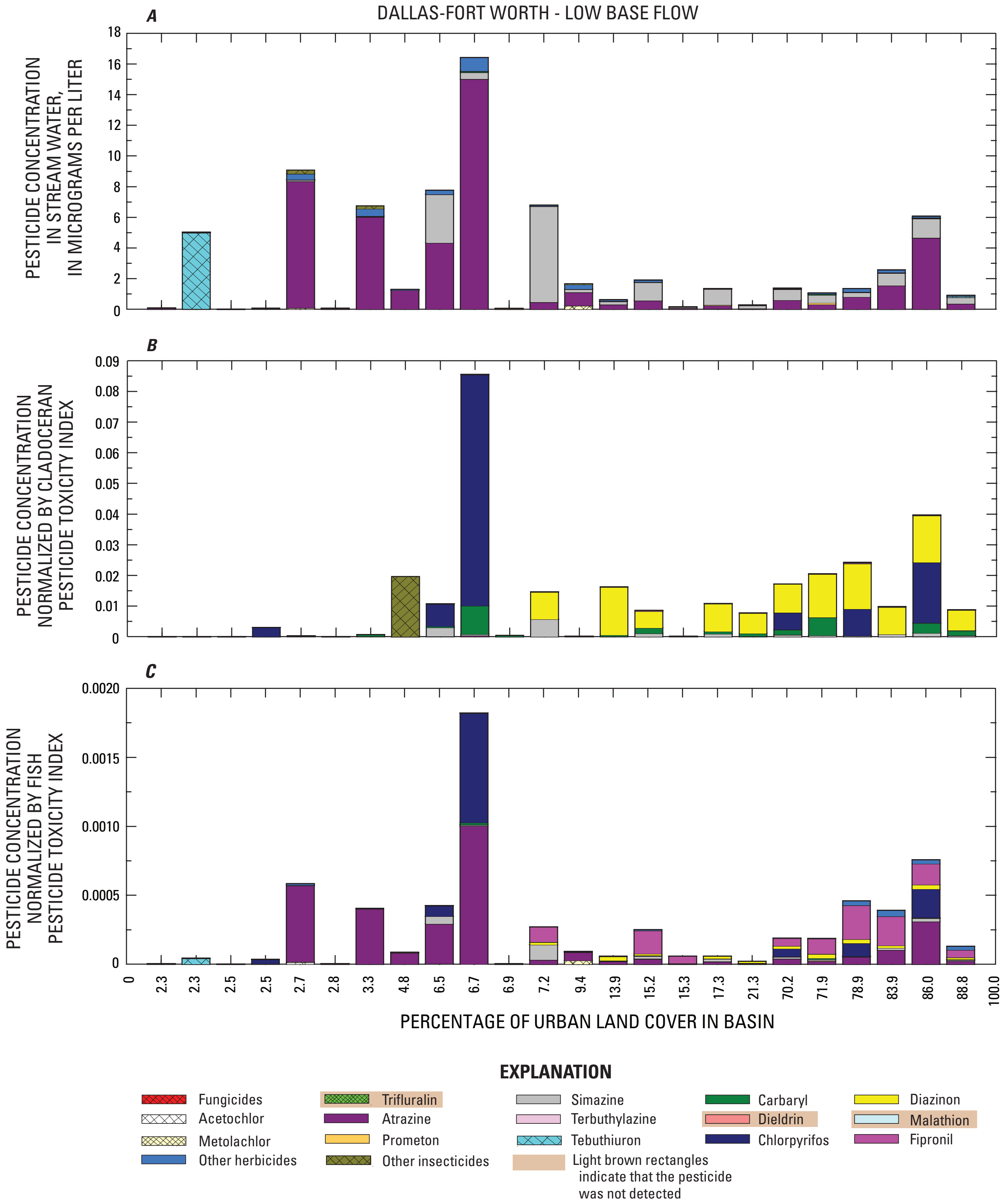

Figure 12. Pesticide concentrations (*A*) measured in stream water, (*B*) normalized by the cladoceran pesticide toxicity index, and (*C*) normalized by the fish pesticide toxicity index during low base-flow conditions compared to the percentage of urban land cover in the basin in the Dallas-Fort Worth study area. Note different y-axis scales.

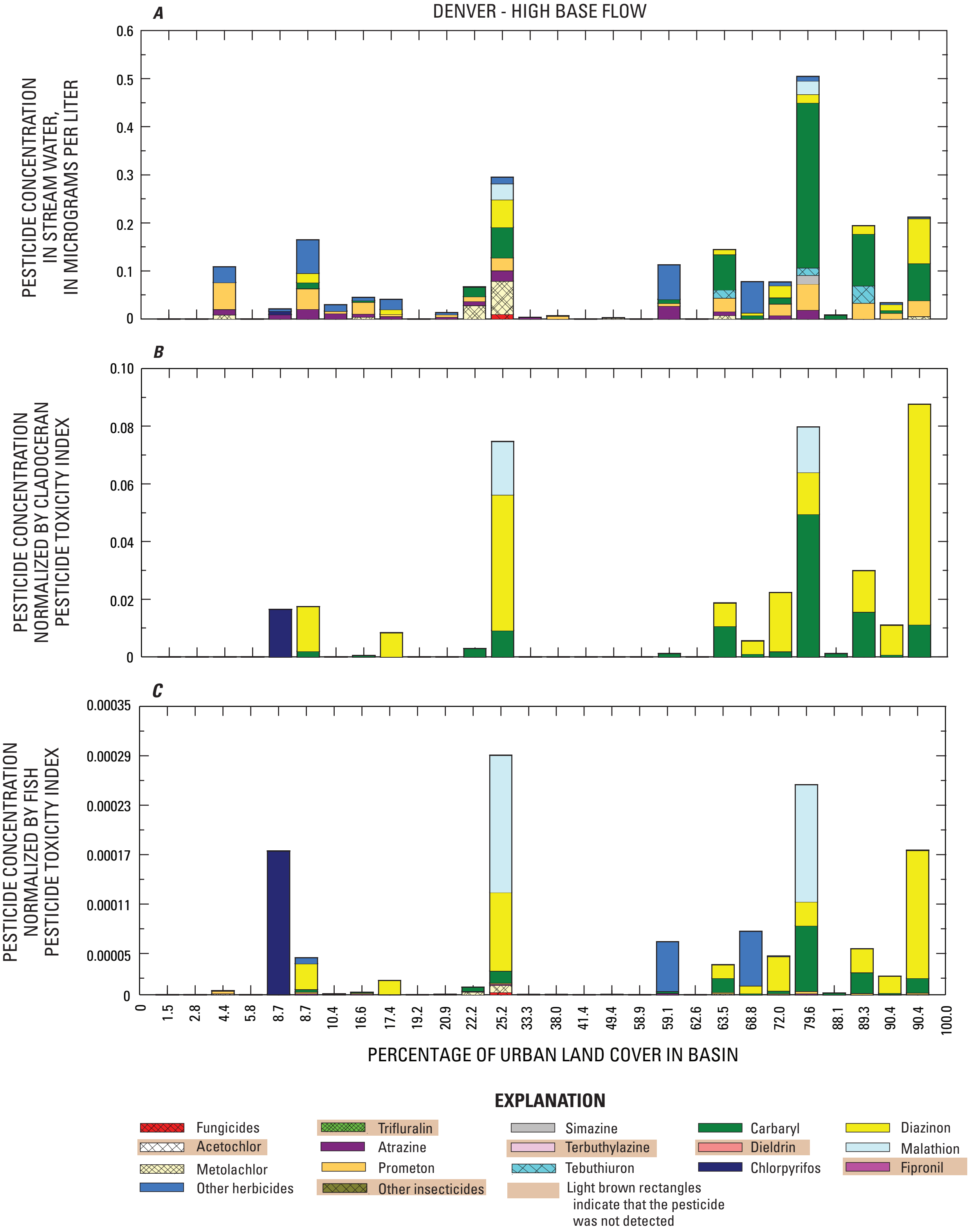

Figure 13. Pesticide concentrations (*A*) measured in stream water, (*B*) normalized by the cladoceran pesticide toxicity index, and (*C*) normalized by the fish pesticide toxicity index during high base-flow conditions compared to the percentage of urban land cover in the basin in the Denver study area. Note different y-axis scales.

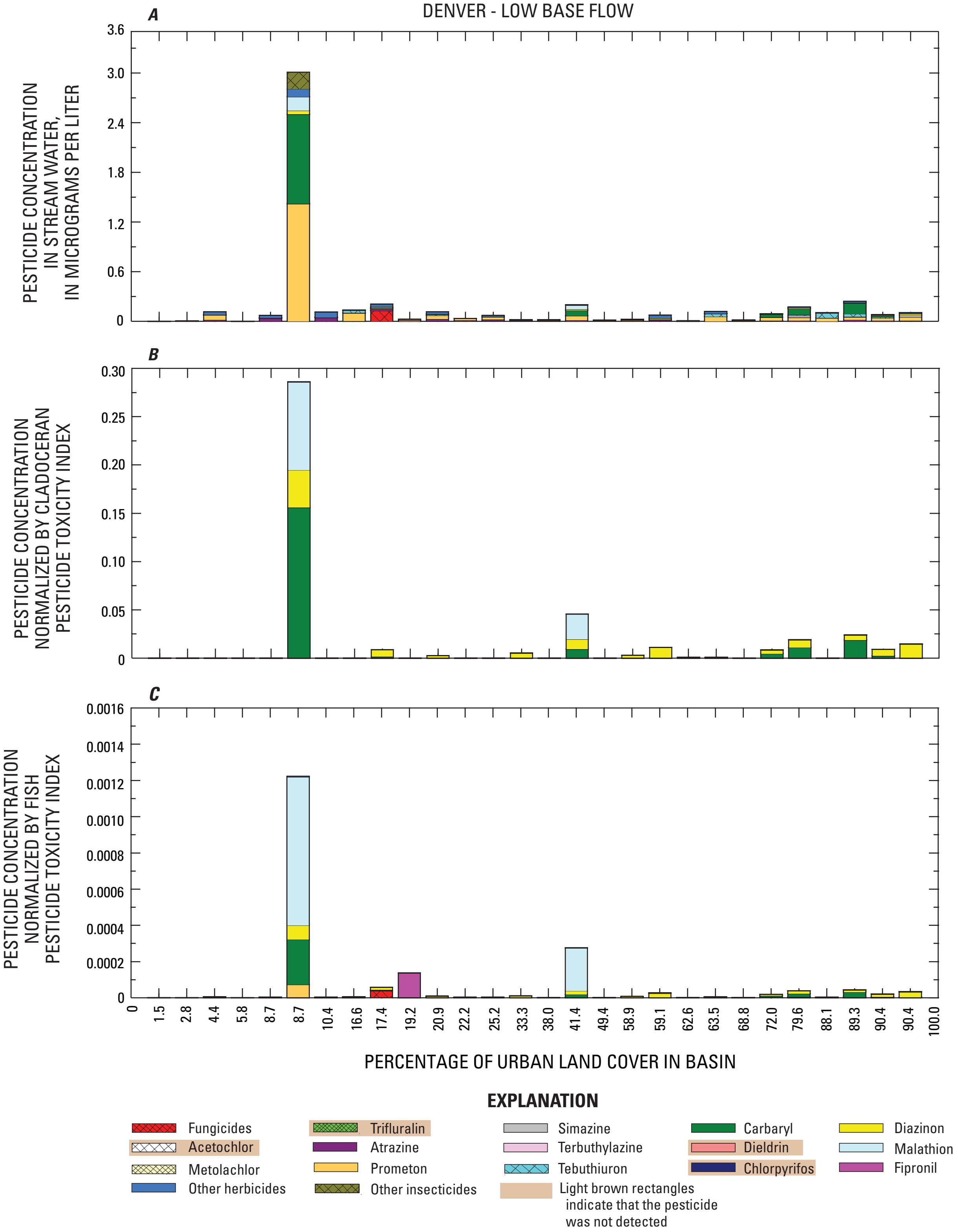

Figure 14. Pesticide concentrations (*A*) measured in stream water, (*B*) normalized by the cladoceran pesticide toxicity index, and (*C*) normalized by the fish pesticide toxicity index during low base-flow conditions compared to the percentage of urban land cover in the basin in the Denver study area. Note different y-axis scales.

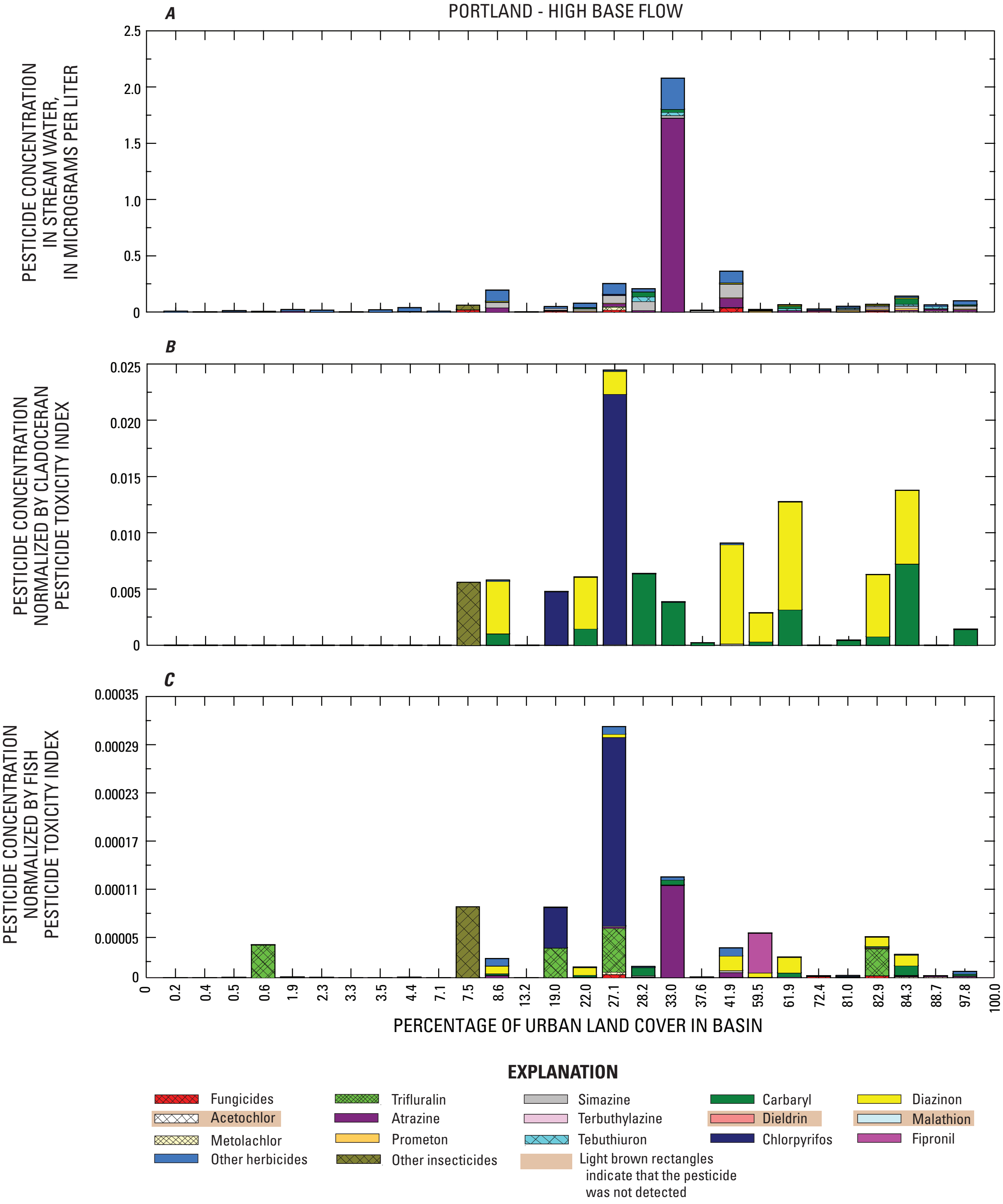

Figure 15. Pesticide concentrations (*A*) measured in stream water, (*B*) normalized by the cladoceran pesticide toxicity index, and (*C*) normalized by the fish pesticide toxicity index during high base-flow conditions compared to the percentage of urban land cover in the basin in the Portland study area. Note different y-axis scales.

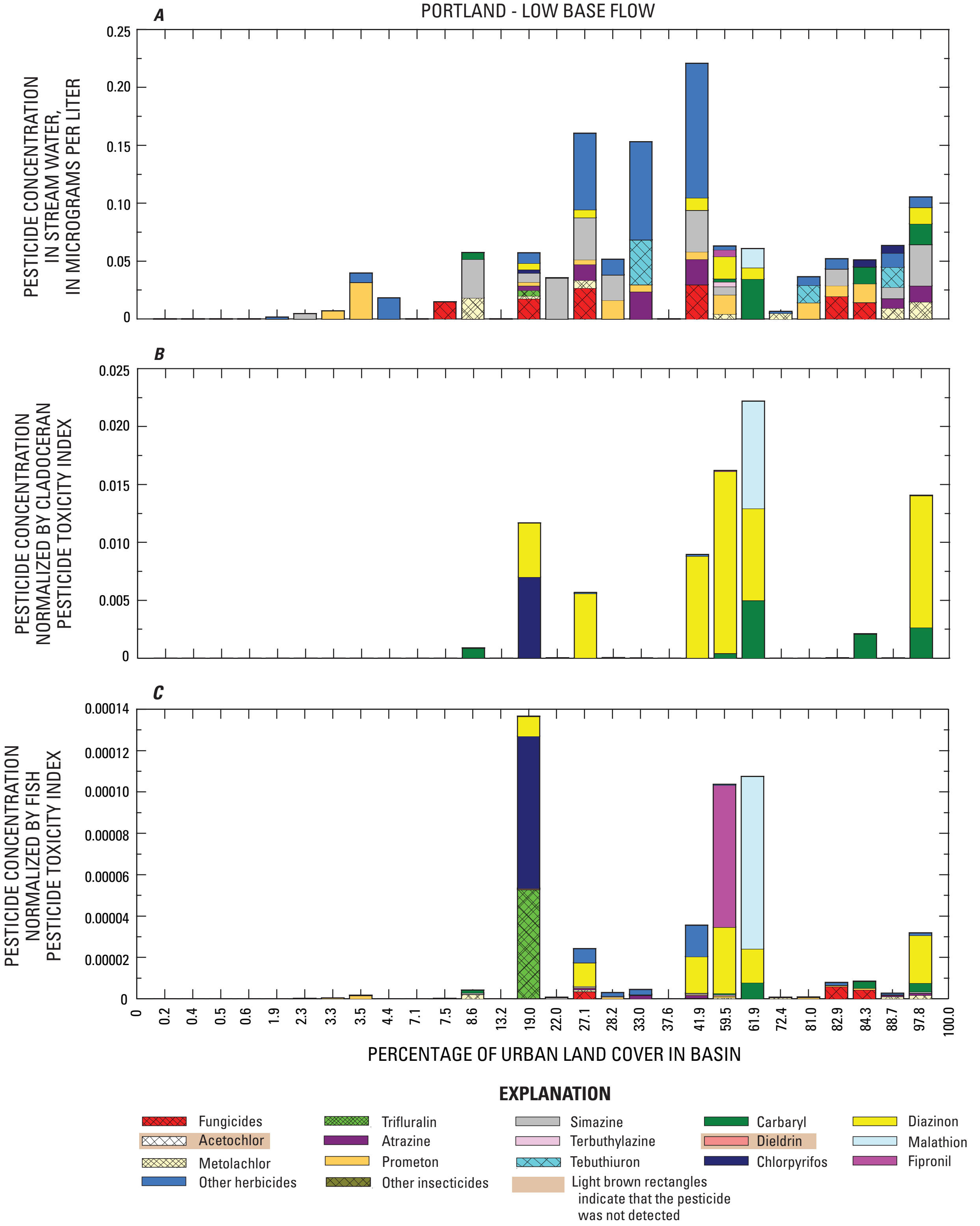

Figure 16. Pesticide concentrations (*A*) measured in stream water, (*B*) normalized by the cladoceran pesticide toxicity index, and (*C*) normalized by the fish pesticide toxicity index during low base-flow conditions compared to the percentage of urban land cover in the basin in the Portland study area. Note different y-axis scales.

terbuthylazine detected, and several Portland sites had the herbicide degradate 3,4-dichloroaniline detected ("other herbicides," fig. 16A).

The pesticide signatures in the other three study areas did not show a strong relation with urban land cover (figs. 9–14). In Milwaukee-Green Bay, pesticide concentrations were highest at sites with 0 to 20 percent urban land cover, which probably resulted from agricultural pesticide use in the less developed basins. Similar pesticides were detected under both high and low base-flow conditions, but concentrations were higher in high base-flow samples. The herbicides atrazine and metolachlor (which both have high agricultural use) dominated the pesticide signature under both high and low base-flow conditions. Additional pesticides detected included acetochlor, simazine, prometon, tebuthiuron (all herbicides with substantial urban uses) and chlorpyrifos, diazinon, and carbaryl (insecticides with substantial urban uses).

In Dallas-Fort Worth, pesticide concentrations were highest in basins with 0 to 10 percent urban land cover, then decreased sharply as agricultural land cover decreased and shrub/grass land cover increased, and finally increased slightly again as urban land cover increased and both agricultural and shrub/grass land cover decreased. Concentrations were higher under low base-flow than high base-flow conditions, with the pesticide signatures of both dominated by atrazine (which has high agricultural use) and to a lesser extent simazine and tebuthiuron.

In Denver, the highest pesticide concentrations were observed in one low base-flow sample from a site with little urban development (8.7 percent urban land cover); the predominant pesticides detected at that site were the urban herbicide prometon and the insecticides carbaryl and malathion. At high base flow, these same pesticides were often detected in Denver, along with the herbicides tebuthiuron, pendimethalin ("other herbicides," fig. 13A), simazine, and atrazine, the degradate 3,4-dichloroaniline ("other herbicides," fig. 13A), and the insecticide diazinon.

Pesticides often were detected at multiple sites within a study area, so that the pesticide "signature" for a given study area—the mixtures of pesticides detected and their relative concentrations at sites within the study area—tended to show some pesticides and some combinations of pesticides as dominant. The concentrations of the dominant pesticides varied markedly among sites within a study area. There were differences between pesticide signatures during high and low base-flow conditions in five of the six study areas; the pesticide signatures in Dallas-Fort Worth were similar under high and low base-flow conditions. A greater variety of pesticides was detected during high base-flow conditions in four of the study areas (Atlanta, Raleigh-Durham, Milwaukee-Green Bay, and Portland); however, for the two most arid study areas, high base-flow samples have a similar (Dallas-Fort Worth) or a lesser (Denver) variety of pesticides detected as compared to low base-flow samples.

Normalization of pesticide concentrations in stream water by the PTI dramatically changed the pesticide signatures (figs. 5–16), indicating that the pesticides with the greatest potential to adversely affect cladocerans or fish were not necessarily the pesticides detected at the highest concentrations. Cladocerans, which are arthropod invertebrates, are sensitive to insecticides (Maltby and others, 2005). In fact, the cladoceran-PTI-normalized plots for all six metropolitan study areas were dominated by the insecticides diazinon, chlorpyrifos, malathion, and carbaryl, with dichlorvos ("other insecticides," fig. 12B) also being important at one site in Dallas-Fort Worth and fenamiphos ("other insecticides," fig. 15B) at one site in Portland. For the organophosphate insecticides diazinon and chlorpyrifos, residential use by homeowners is being phased out by USEPA (U.S. Environmental Protection Agency, 2000a and 2005b); as a result, concentrations (and any associated adverse effects caused by these chemicals) may decline over time in urban areas. As their use is discontinued, they are likely to be replaced by other insecticides, such as carbaryl, malathion, and pyrethroid insecticides. Ultimately the potential for adverse effects on aquatic invertebrates will depend on which insecticides are used and the extent to which they reach the streams.

When normalized by fish PTI, the pesticide signatures typically differed from the signatures of both concentrations in stream water and the concentrations normalized by cladoceran PTI. The insecticides that dominated the cladoceran PTI-normalized signatures—diazinon, chlorpyrifos, malathion, and carbaryl—were still evident, but additional pesticides also were important. Fipronil, a relatively new insecticide used for structural pest control (pest control in structures such as homes, railroad cars, ships, and vehicles) and on some crops such as rice, appeared in fish-PTI plots for all six study areas, but was especially common in Atlanta, Raleigh-Durham, and Dallas-Fort Worth. The discontinued organochlorine insecticide dieldrin was important at selected urban sites in Raleigh-Durham and Dallas-Fort Worth. This pesticide is still commonly detected in stream sediment and fish across the United States; although no longer used, it is persistent, and residues remain in soils and streams from past use of aldrin (which degrades to dieldrin in the environment) and dieldrin in agriculture and urban applications, especially termite control (Gilliom and others, 2006). The nematocide fenamiphos was important at one site in Portland ("other insecticides," fig. 15C). Several herbicides also appeared in fish PTI-normalized plots, including trifluralin (Raleigh-Durham and Portland), atrazine (Atlanta, Milwaukee-Green Bay, Dallas-Fort Worth, and Portland), pendimethalin (Dallas-Fort Worth and Denver), metolachlor (Milwaukee-Green Bay and Dallas-Fort Worth), and acetochlor (Milwaukee-Green Bay).

When pesticide concentrations were normalized by cladoceran or fish PTI, the pattern of response to urbanization remained about the same. In Atlanta, Raleigh-Durham, and Portland, PTI-normalized pesticide concentrations tended to be higher in moderate to highly urbanized basins, except for one site in Raleigh-Durham (3 percent urban) where diazinon may have been an issue for both cladocerans and fish. The other three study areas did not show a consistent pattern of response to urban land cover. In Dallas-Fort Worth and Denver, high base-flow samples showed higher PTI-normalized pesticide concentrations in moderate-to-highly urbanized basins, but low base-flow samples did not. At low base-flow in Milwaukee-Green Bay, Dallas-Fort Worth, and Denver, a single site with less than 10 percent urban land cover had the highest PTI-normalized pesticide concentrations; the high relative potential toxicity largely was due to the insecticides chlorpyrifos, diazinon, malathion, and carbaryl.

The PTI is designed to indicate relative potential toxicity; it cannot be used to evaluate whether actual toxicity is occurring. Nonetheless, PTI-normalization provides information on which pesticides may be most important from a toxicity perspective to aquatic organisms in the streams sampled.

Suspended Sediment

In all six study areas, the relation between suspended-sediment concentrations and the percentage of urban land cover in the basin was weak during high and low base-flow conditions (fig. 17A). The highest concentrations of suspended sediment were not consistently present in more urbanized basins. Maximum suspended-sediment concentrations occurred during high base-flow conditions in four study areas (Atlanta, Milwaukee-Green Bay, Dallas-Fort Worth, and Denver), during low base-flow conditions in one study area (Raleigh-Durham), and during both high and low base-flow conditions in one study area (Portland).

For the most part, relations between suspended-sediment concentrations and urban and landscape variables were weak in all six study areas (table 5A). In Atlanta, suspended-sediment concentrations were positively related to the distance from the stream to the nearest road. In Atlanta and Dallas-Fort Worth, suspended-sediment concentrations were positively related to the percentage of wetlands in the basin and buffer; fine particles, such as silt and clays, may have been mobilized from wetland sediment deposits. In Milwaukee-Green Bay and Denver, suspended-sediment concentrations were negatively related to a measure of housing age. In older communities in Denver, more mature vegetative cover and lack of surface disturbance from new construction may have contributed to a decrease in the amount of sediment in runoff (Sprague and others, 2006). Likewise, well-established lawns and low-intensity traffic along streets of older, nonurban, residential areas in Milwaukee-Green Bay may have led to relatively smaller amounts of sediment in runoff. In Portland, suspended-sediment concentrations were negatively related to the percentage of shrub/grass land cover in the basin and buffer, sand content in the soil, and depth to the water table, and positively related to soil erodibility. The depth to the water table likely is greatest beneath upland areas in the stream headwaters; land use in these areas was typically forested and shrub/grass land. Forest and shrub/grass land may have been more resistant to erosion than agricultural or urban land, resulting in decreasing suspended-sediment concentrations as the percentage of forested or shrub/grass land area, or both, increased. Rainfall and snowmelt may have infiltrated readily through sandy soils, reducing the intensity of surface runoff and associated sediment transport in these urbanizing basins in Portland.

The results for suspended-sediment concentrations from this study support previous research indicating that strategies to control sediment transport to streams in urbanizing areas may need to focus on conditions during stormwater runoff to a greater degree than conditions during base flow. Base flow has been found to transport only about 1 percent of the annual suspended-sediment load in streams, whereas stormwater runoff typically transports the remaining 99 percent (Landers and others, 2002). As a result, management strategies may be most effective when considering factors related to runoff generation.

Sulfate

In Atlanta, the relation between sulfate concentrations and the percentage of urban land cover in the basin was strong during high and low base-flow conditions (fig. 17B). Sulfate concentrations increased as most measures of urbanization—including housing density, road density, population density, patch size and homogeneity of urban land area, urban land cover in the basin and buffer, and impervious area in the basin and buffer—increased (table 5B). Sulfate concentrations decreased as a measure of housing age increased. Relations with sulfate concentrations generally were stronger with the urban variables than with the landscape variables. Two notable exceptions were the negative relation with the percentage of shrub/grass land cover in the basin and buffer during high and low base-flow conditions and the negative relation with the percentage of agricultural land cover in the basin during high base-flow conditions. These relations likely reflect a decrease in background forested land cover as urban land cover increased (fig. 2).

In Raleigh-Durham, the relation between sulfate concentrations and the percentage of urban land cover in the basin also was strong during high and low base-flow conditions (fig. 17B). Sulfate concentrations increased as most measures of urbanization—including housing density, road density, population density, patch size and homogeneity of urban land area, urban land cover in the basin and buffer, impervious area in the basin and buffer, and housing age—increased (table 5B). Sulfate concentrations generally decreased with increasing distance from the stream to the nearest road. In addition to the urban variables, there were several strong relations between sulfate concentrations and landscape variables. During high and low base-flow conditions, sulfate concentrations generally decreased as the percentage of agricultural, shrub/grass, wetland land cover in the basin and buffer, and soil erodibility increased. These relations likely reflect a decrease in background forested land cover and an increase in impervious surface area as urban land cover increased (fig. 2).

In Milwaukee-Green Bay, the relation between sulfate concentrations and the percentage of urban land cover in the basin was strong (fig. 17B). Sulfate concentrations increased as most measures of urbanization—including housing density,

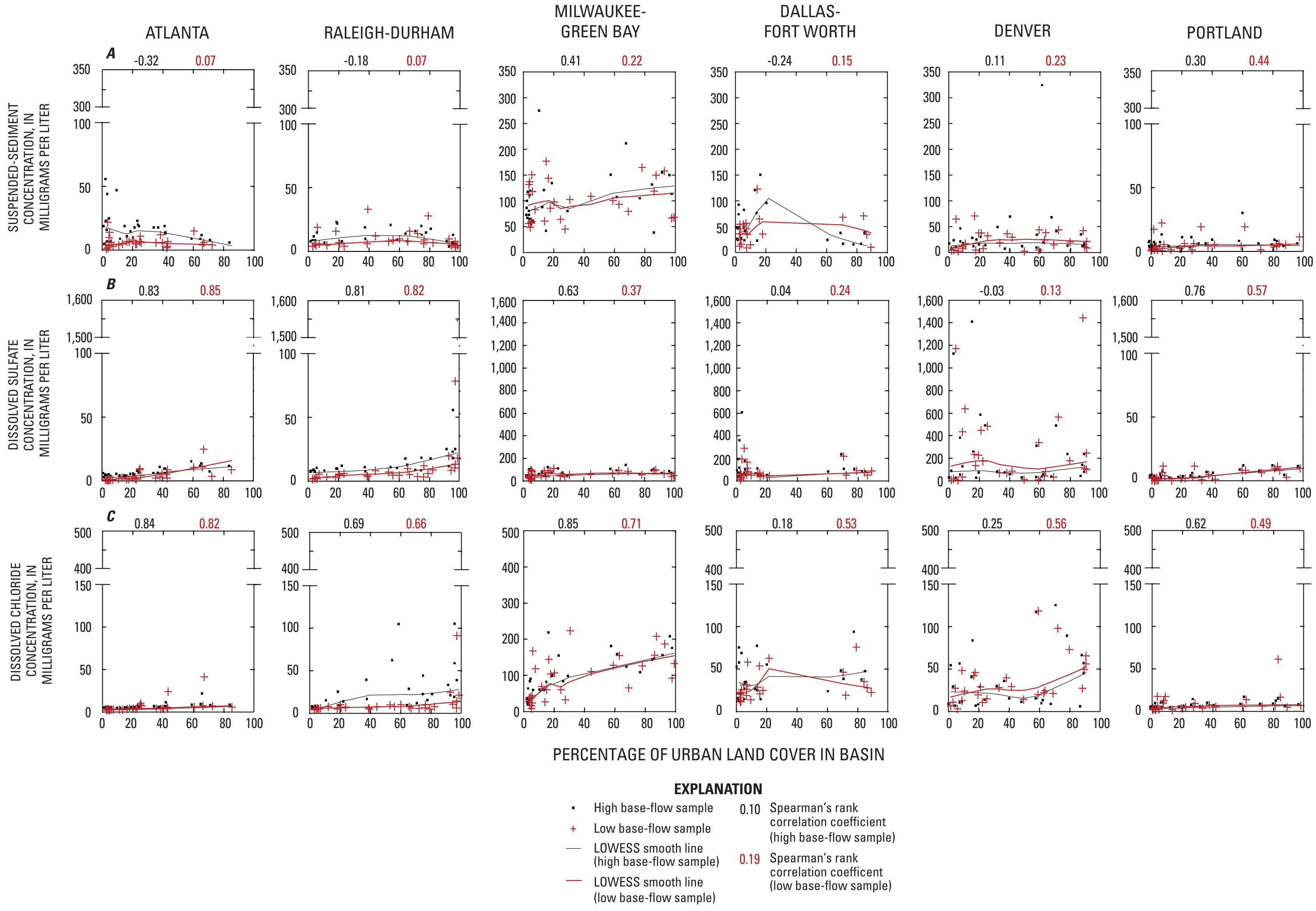

Figure 17. (*A*) Suspended-sediment, (*B*) dissolved sulfate, and (*C*) dissolved chloride concentrations during high and low base flow compared to the percentage of urban land cover in the basin in the Atlanta, Raleigh-Durham, Milwaukee-Green Bay, Dallas-Fort Worth, Denver, and Portland study areas.

Table 5. Spearman’s rank correlations between (A) suspended-sediment concentrations, (B) dissolved sulfate concentrations, and (C) dissolved chloride concentrations during high and low base flow and selected urban and landscape variables.

[Values in bold are significantly different during high and low base-flow conditions. HUDEN, 2000 housing unit density; ROADDEN, road density; POPDENKM, 2000 population density; LPI_2, largest urban patch index; PLA_2, percentage of like adjacencies (urban); P_NLCD1_2, percentage of urban land cover in basin; P_NLCD1_B2, percentage of urban land cover in buffer; NLCD_IS, mean percent impervious surface in basin; NLCD_BIS, mean percent impervious surface in buffer; PHU_G60, percentage of housing units built prior to 1939; SEG_RMD, mean distance from stream segment to nearest road; SLOPE_X, mean basin slope; P_NLCD1_8, percentage of herbaceous planted/cultivated land cover in basin; P_NLCD1_B8, percentage of herbaceous planted/cultivated land cover in buffer; P_NLCD1_5, percentage of shrub/grass land cover in basin; P_NLCD1_B5, percentage of shrub/grass land cover in buffer; P_NLCD1_9, percentage of wetland land cover in basin; P_NLCD1_B9, percentage of wetland land cover in buffer; WET_MEAN, mean value of wetness index across all cells in basin; SNDH, mean high-range sand (soil); WTDH, mean high-range depth to water table; KFCAVE, mean soil erodibility factor (K factor)]

(A) Suspended-sediment concentrations

Variable code	Variable short name	High base flow						Low base flow					
		Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland	Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland
Urban variables													
HUDEN	Housing density	**-0.38**	-0.15	0.46	**-0.31**	-0.09	0.36	**0.07**	0.11	0.21	**0.31**	0.08	0.58
ROADDEN	Road density	-0.38	-0.18	0.42	-0.25	0.03	0.35	0.05	0.08	0.18	0.24	0.22	0.42
POPDENKM	Population density	**-0.40**	-0.12	0.42	-0.27	-0.05	0.36	**0.12**	0.15	0.21	0.25	0.13	0.52
LPI_2	Patch size of urban land area	-0.30	-0.18	0.35	-0.22	0.11	0.28	0.08	0.05	0.17	0.11	0.24	0.50
PLA_2	Homogeneity of urban land area	-0.27	-0.20	0.36	-0.18	0.09	0.32	0.16	0.10	0.18	0.16	0.15	0.53
P_NLCD1_2	Urban land cover in basin	-0.32	-0.18	0.41	-0.24	0.11	0.30	0.07	0.07	0.22	0.15	0.23	0.44
P_NLCD1_B2	Urban land cover in buffer	-0.28	-0.21	0.35	**-0.34**	0.13	0.30	0.07	0.05	0.12	**0.25**	0.18	0.48
NLCD_IS	Impervious area in basin	-0.33	-0.14	0.35	-0.24	0.11	0.30	0.07	0.18	0.15	0.18	0.22	0.45
NLCD_BIS	Impervious area in buffer	-0.30	-0.13	0.27	-0.29	0.13	0.32	0.08	0.10	0.08	0.28	0.14	0.49
PHU_G60	Housing age	0.20	-0.35	-0.64	**0.34**	-0.33	-0.02	-0.10	-0.39	-0.35	**-0.28**	-0.62	-0.40
SEG_RMD	Distance from stream to nearest road	**0.57**	0.25	-0.11	0.20	0.09	-0.35	**0.18**	0.32	-0.08	-0.28	-0.04	-0.23
Landscape variables													
SLOPE_X	Basin slope	-0.57	0.36	-0.03	-0.37	-0.11	-0.10	-0.34	0.30	-0.06	-0.13	-0.21	-0.31
P_NLCD1_8	Agricultural land cover in basin	0.32	0.24	-0.39	0.45	-0.04	0.01	0.14	0.01	-0.22	-0.05	-0.07	0.19

Table 5. Spearman's rank correlations between (A) suspended-sediment concentrations, (B) dissolved sulfate concentrations, and (C) dissolved chloride concentrations during high and low base flow and selected urban and landscape variables.—Continued

[Values in bold are significantly different during high and low base-flow conditions. HUDEN, 2000 housing unit density; ROADDEN, road density; POPDENKM, 2000 population density; LPI_2, largest urban patch index; PLA_2, percentage of like adjacencies (urban); P_NLCD1_2, percentage of urban land cover in basin; P_NLCD1_B2, percentage of urban land cover in buffer; NLCD_IS, mean percent impervious surface in basin; NLCD_BIS, mean percent impervious surface in buffer; PHU_G60, percentage of housing units built prior to 1939; SEG_RMD, mean distance from stream segment to nearest road; SLOPE_X, mean basin slope; P_NLCD1_8, percentage of herbaceous planted/cultivated land cover in basin; P_NLCD1_B8, percentage of herbaceous planted/cultivated land cover in buffer; P_NLCD1_5, percentage of shrub/grass land cover in basin; P_NLCD1_B5, percentage of shrub/grass land cover in buffer; P_NLCD1_9, percentage of wetland land cover in basin; P_NLCD1_B9, percentage of wetland land cover in buffer; WET_MEAN, mean value of wetness index across all cells in basin; SNDH, mean high-range sand (soil); WTDH, mean high-range depth to water table; KFCAVE, mean soil erodibility factor (K factor)]

(A) Suspended-sediment concentrations

		High base flow						Low base flow					
Variable code	**Variable short name**	**Atlanta**	**Raleigh-Durham**	**Milwaukee-Green Bay**	**Dallas-Fort Worth**	**Denver**	**Portland**	**Atlanta**	**Raleigh-Durham**	**Milwaukee-Green Bay**	**Dallas-Fort Worth**	**Denver**	**Portland**
Landscape variables													
P_NLCD1_B8	Agricultural land cover in buffer	0.27	0.30	-0.46	0.39	-0.05	0.09	0.16	-0.13	-0.29	-0.10	-0.12	0.12
P_NLCD1_5	Shrub/grass land cover in basin	0.09	0.27	0.31	0.17	-0.14	-0.20	-0.07	-0.12	0.23	-0.02	-0.23	-0.47
P_NLCD1_B5	Shrub/grass land cover in buffer	0.12	0.36	0.28	0.35	-0.35	-0.28	-0.09	-0.08	0.11	-0.06	-0.19	-0.56
P_NLCD1_9	Wetland land cover in basin	0.62	0.35	-0.29	0.47	-0.15	0.26	0.37	0.30	0.03	0.14	-0.26	-0.04
P_NLCD1_B9	Wetland land cover in buffer	0.53	0.32	-0.16	0.60	-0.18	0.25	0.34	0.28	0.18	0.10	-0.23	-0.04
WET_MEAN	Basin-wetness index	0.49	-0.19	0.01	0.25	0.12	0.14	0.33	-0.28	-0.02	0.30	0.12	0.27
SNDH	Sand content in soil	-0.01	-0.10	-0.03	0.03	-0.08	-0.53	0.33	0.28	-0.22	-0.33	0.03	-0.65
WTDH	Depth to water table	0.10	-0.17	0.08	0.00	0.03	-0.61	0.16	0.13	-0.15	0.43	0.05	-0.53
KFCAVE	Soil erodibility	0.32	0.26	0.01	0.13	0.36	0.42	0.09	-0.06	0.26	-0.42	0.46	0.67

Table 5. Spearman's rank correlations between (A) suspended-sediment concentrations, (B) dissolved sulfate concentrations, and (C) dissolved chloride concentrations during high and low base flow and selected urban and landscape variables.—Continued

[Values in bold are significantly different during high and low base-flow conditions. HUDEN, 2000 housing unit density; ROADDEN, road density; POPDENKM, 2000 population density; LPI_2, largest urban patch index; PLA_2, percentage of like adjacencies (urban); P_NLCD1_2, percentage of urban land cover in basin; P_NLCD1_B2, percentage of urban land cover in buffer; NLCD_IS, mean percent impervious surface in basin; NLCD_BIS, mean percent impervious surface in buffer; PHU_G60, percentage of housing units built prior to 1939; SEG_RMD, mean distance from stream segment to nearest road; SLOPE_X, mean basin slope; P_NLCD1_8, percentage of herbaceous planted/cultivated land cover in basin; P_NLCD1_B8, percentage of herbaceous planted/cultivated land cover in buffer; P_NLCD1_5, percentage of shrub/grass land cover in basin; P_NLCD1_B5, percentage of shrub/grass land cover in buffer; P_NLCD1_9, percentage of wetland land cover in basin; P_NLCD1_B9, percentage of wetland land cover in buffer; WET_MEAN, mean value of wetness index across all cells in basin; SNDH, mean high-range sand (soil); WTDH, mean high-range depth to water table; KFCAVE, mean soil erodibility factor (K factor)]

(B) Dissolved sulfate concentrations

Variable code	Variable short name	High base flow						Low base flow					
		Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland	Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland
Urban variables													
HUDEN	Housing density	0.80	0.70	0.61	0.02	-0.10	**0.78**	0.84	0.71	0.33	0.22	-0.06	**0.57**
ROADDEN	Road density	0.79	0.78	0.53	0.08	-0.09	0.70	0.82	0.80	0.24	0.29	0.08	0.56
POPDENKM	Population density	0.80	0.70	0.61	0.00	-0.06	**0.76**	0.83	0.72	0.31	0.25	0.03	**0.56**
LPI_2	Patch size of urban land area	0.83	0.80	0.57	-0.03	-0.02	**0.79**	0.85	0.82	0.32	0.22	0.11	**0.57**
PLA_2	Homogeneity of urban land area	0.83	0.82	0.63	-0.01	-0.04	**0.78**	0.84	0.82	0.38	0.20	0.00	**0.58**
P_NLCD1_2	Urban land cover in basin	0.83	0.81	0.63	0.04	-0.03	**0.76**	0.85	0.82	0.37	0.24	0.13	**0.57**
P_NLCD1_B2	Urban land cover in buffer	0.83	0.85	0.53	-0.03	-0.10	**0.77**	0.86	0.84	0.25	0.13	0.06	**0.56**
NLCD_IS	Impervious area in basin	0.82	0.87	0.65	-0.02	-0.02	**0.77**	0.85	0.83	0.36	0.23	0.12	**0.59**
NLCD_BIS	Impervious area in buffer	0.82	0.88	0.61	-0.12	-0.14	**0.78**	0.87	0.82	0.31	0.07	0.02	**0.58**
PHU_G60	Housing age	-0.70	0.51	-0.69	-0.16	-0.32	-0.52	-0.77	0.50	-0.43	-0.23	-0.43	-0.49
SEG_RMD	Distance from stream to nearest road	-0.45	-0.50	-0.18	0.21	-0.05	-0.14	-0.52	-0.61	-0.14	0.05	-0.03	-0.07
Landscape variables													
SLOPE_X	Basin slope	-0.24	-0.26	-0.52	-0.03	**-0.30**	-0.52	-0.08	-0.29	-0.21	-0.19	**-0.61**	-0.38
P_NLCD1_8	Agricultural land cover in basin	**-0.68**	-0.59	-0.35	0.03	0.09	-0.22	**-0.47**	-0.62	-0.20	0.10	0.17	-0.22

Table 5. Spearman's rank correlations between (A) suspended-sediment concentrations, (B) dissolved sulfate concentrations, and (C) dissolved chloride concentrations during high and low base flow and selected urban and landscape variables.—Continued

[Values in bold are significantly different during high and low base-flow conditions. HUDEN, 2000 housing unit density; ROADDEN, road density; POPDENKM, 2000 population density; LPI_2, largest urban patch index; PLA_2, percentage of like adjacencies (urban); P_NLCD1_2, percentage of urban land cover in basin; P_NLCD1_B2, percentage of urban land cover in buffer; NLCD_IS, mean percent impervious surface in basin; NLCD_BIS, mean percent impervious surface in buffer; PHU_G60, percentage of housing units built prior to 1939; SEG_RMD, mean distance from stream segment to nearest road; SLOPE_X, mean basin slope; P_NLCD1_8, percentage of herbaceous planted/cultivated land cover in basin; P_NLCD1_B8, percentage of herbaceous planted/cultivated land cover in buffer; P_NLCD1_5, percentage of shrub/grass land cover in basin; P_NLCD1_B5, percentage of shrub/grass land cover in buffer; P_NLCD1_9, percentage of wetland land cover in basin; P_NLCD1_B9, percentage of wetland land cover in buffer; WET_MEAN, mean value of wetness index across all cells in basin; SNDH, mean high-range sand (soil); WTDH, mean high-range depth to water table; KFCAVE, mean soil erodibility factor (K factor)]

(B) Dissolved sulfate concentrations

Variable code	Variable short name	High base flow						Low base flow					
		Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland	Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland
							Landscape variables						
P_NLCD1_B8	Agricultural land cover in buffer	**-0.52**	-0.56	-0.28	-0.04	0.11	-0.10	**-0.36**	-0.59	-0.14	0.03	0.14	-0.12
P_NLCD1_5	Shrub/grass land cover in basin	-0.63	-0.62	0.43	-0.23	-0.16	**-0.63**	-0.61	-0.60	0.37	-0.34	-0.41	**-0.37**
P_NLCD1_B5	Shrub/grass land cover in buffer	-0.51	-0.58	0.40	0.00	-0.01	**-0.72**	-0.50	-0.56	0.28	-0.07	-0.28	**-0.44**
P_NLCD1_9	Wetland land cover in basin	-0.08	-0.83	**-0.66**	-0.03	-0.06	0.08	-0.15	-0.78	**-0.21**	-0.06	-0.20	0.14
P_NLCD1_B9	Wetland land cover in buffer	-0.10	-0.69	-0.62	-0.19	-0.11	0.06	-0.15	-0.68	-0.20	-0.06	-0.24	0.09
WET_MEAN	Basin-wetness index	0.22	-0.18	0.57	0.10	**0.04**	0.49	0.07	-0.10	0.25	0.34	**0.43**	0.34
SNDH	Sand content in soil	**-0.12**	0.08	-0.38	-0.45	-0.29	-0.56	**0.07**	0.14	-0.23	-0.02	-0.19	-0.47
WTDH	Depth to water table	0.53	0.41	-0.24	0.25	0.11	-0.78	0.50	0.37	-0.17	0.01	0.14	-0.65
KFCAVE	Soil erodibility	0.32	-0.60	-0.01	-0.03	0.36	0.52	0.32	-0.63	0.12	0.33	0.59	0.41

Table 5. Spearman's rank correlations between (A) suspended-sediment concentrations, (B) dissolved sulfate concentrations, and (C) dissolved chloride concentrations during high and low base flow and selected urban and landscape variables.—Continued

[Values in bold are significantly different during high and low base-flow conditions. HUDEN, 2000 housing unit density; ROADDEN, road density; POPDENKM, 2000 population density; LPI_2, largest urban patch index; PLA_2, percentage of like adjacencies (urban); P_NLCD1_2, percentage of urban land cover in basin; P_NLCD1_B2, percentage of urban land cover in buffer; NLCD_IS, mean percent impervious surface in basin; NLCD_BIS, mean percent impervious surface in buffer; PHU_G60, percentage of housing units built prior to 1939; SEG_RMD, mean distance from stream segment to nearest road; SLOPE_X, mean basin slope; P_NLCD1_8, percentage of herbaceous planted/cultivated land cover in basin; P_NLCD1_B8, percentage of herbaceous planted/cultivated land cover in buffer; P_NLCD1_5, percentage of shrub/grass land cover in basin; P_NLCD1_B5, percentage of shrub/grass land cover in buffer; P_NLCD1_9, percentage of wetland land cover in basin; P_NLCD1_B9, percentage of wetland land cover in buffer; WET_MEAN, mean value of wetness index across all cells in basin; SNDH, mean high-range sand (soil); WTDH, mean high-range depth to water table; KFCAVE, mean soil erodibility factor (K factor)]

(C) Dissolved chloride concentrations

Variable code	Variable short name	High base flow						Low base flow					
		Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland	Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland
						Urban variables							
HUDEN	Housing density	0.84	0.59	0.84	0.19	0.25	0.71	0.78	0.51	0.66	0.48	0.48	0.54
ROADDEN	Road density	0.84	0.66	0.81	0.15	**0.20**	0.56	0.76	0.63	0.68	0.51	**0.51**	0.46
POPDENKM	Population density	0.82	0.58	0.82	0.14	**0.25**	0.66	0.77	0.51	0.66	0.48	**0.52**	0.51
LPI_2	Patch size of urban land area	0.83	0.69	0.81	0.09	**0.26**	0.69	0.82	0.65	0.72	0.48	**0.58**	0.54
PLA_2	Homogeneity of urban land area	0.80	0.72	0.85	0.04	**0.28**	**0.72**	0.83	0.65	0.69	0.43	**0.55**	**0.54**
P_NLCD1_2	Urban land cover in basin	0.84	0.69	0.85	0.18	**0.25**	0.62	0.82	0.66	0.71	0.53	**0.56**	0.49
P_NLCD1_B2	Urban land cover in buffer	0.81	0.69	0.76	0.18	**0.14**	0.66	0.80	0.66	0.60	0.48	**0.47**	0.51
NLCD_IS	Impervious area in basin	0.81	0.76	0.87	0.07	**0.24**	0.64	0.81	0.66	0.70	0.47	**0.55**	0.50
NLCD_BIS	Impervious area in buffer	0.80	0.77	0.82	0.09	**0.10**	0.68	0.81	0.65	0.68	0.39	**0.41**	0.53
PHU_G60	Housing age	-0.65	0.07	-0.76	-0.20	**-0.25**	-0.40	-0.70	0.45	-0.65	-0.35	**-0.60**	-0.30
SEG_RMD	Distance from stream to nearest road	**-0.58**	-0.48	-0.45	-0.14	-0.48	-0.11	**-0.40**	-0.66	-0.47	-0.43	-0.66	-0.25
						Landscape variables							
SLOPE_X	Basin slope	0.02	-0.12	-0.32	-0.22	0.10	-0.43	-0.11	-0.37	-0.10	-0.39	-0.08	-0.30
P_NLCD1_8	Agricultural land cover in basin	-0.47	-0.56	-0.66	-0.12	-0.51	0.07	-0.40	-0.49	-0.55	-0.21	-0.63	0.04
P_NLCD1_B8	Agricultural land cover in buffer	-0.27	-0.56	-0.58	-0.16	-0.45	0.11	-0.27	-0.44	-0.48	-0.25	-0.62	0.15

Table 5. Spearman's rank correlations between (A) suspended-sediment concentrations, (B) dissolved sulfate concentrations, and (C) dissolved chloride concentrations during high and low base flow and selected urban and landscape variables.—Continued

[Values in bold are significantly different during high and low base-flow conditions. HUDEN, 2000 housing unit density; ROADDEN, road density; POPDENKM, 2000 population density; LPI_2, largest urban patch index; PLA_2, percentage of like adjacencies (urban); P_NLCD1_2, percentage of urban land cover in basin; P_NLCD1_B2, percentage of urban land cover in buffer; NLCD_IS, mean percent impervious surface in basin; NLCD_BIS, mean percent impervious surface in buffer; PHU_G60, percentage of housing units built prior to 1939; SEG_RMD, mean distance from stream segment to nearest road; SLOPE_X, mean basin slope; P_NLCD1_8, percentage of herbaceous planted/cultivated land cover in basin; P_NLCD1_B8, percentage of herbaceous planted/cultivated land cover in buffer; P_NLCD1_5, percentage of shrub/grass land cover in basin; P_NLCD1_B5, percentage of shrub/grass land cover in buffer; P_NLCD1_9, percentage of wetland land cover in basin; P_NLCD1_B9, percentage of wetland land cover in buffer; WET_MEAN, mean value of wetness index across all cells in basin; SNDH, mean high-range sand (soil); WTDH, mean high-range depth to water table; KFCAVE, mean soil erodibility factor (K factor)]

(C) Dissolved chloride concentrations

Variable code	Variable short name	High base flow						Low base flow					
		Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland	Atlanta	Raleigh-Durham	Milwaukee-Green Bay	Dallas-Fort Worth	Denver	Portland
		Landscape variables											
P_NLCD1_5	Shrub/grass land cover in basin	-0.58	-0.63	0.56	-0.21	0.05	**-0.54**	-0.57	-0.45	0.51	-0.40	-0.14	**-0.29**
P_NLCD1_B5	Shrub/grass land cover in buffer	-0.43	-0.60	0.56	-0.12	0.15	**-0.62**	-0.46	-0.47	0.43	-0.25	-0.10	**-0.39**
P_NLCD1_9	Wetland land cover in basin	**-0.28**	-0.42	-0.69	0.09	0.00	0.11	**-0.01**	-0.57	-0.41	0.14	-0.17	0.24
P_NLCD1_B9	Wetland land cover in buffer	**-0.25**	-0.41	-0.61	-0.08	-0.04	0.10	**-0.02**	-0.57	-0.24	0.12	-0.13	0.24
WET_MEAN	Basin-wetness index	-0.07	-0.03	0.32	0.31	-0.33	0.38	0.06	0.16	0.11	0.58	-0.08	0.28
SNDH	Sand content in soil	0.02	-0.10	-0.52	-0.19	-0.20	-0.69	0.02	-0.08	-0.50	0.19	-0.21	-0.54
WTDH	Depth to water table	0.49	0.37	-0.38	-0.03	-0.03	-0.77	0.49	0.21	-0.63	-0.14	0.06	-0.68
KFCAVE	Soil erodibility	0.31	-0.33	0.36	0.12	**-0.03**	0.62	0.37	-0.44	0.51	0.34	**0.29**	0.54

road density, population density, patch size and homogeneity of urban land area, urban land cover in the basin and buffer, and impervious area in the basin and buffer—increased (table 5B). Sulfate concentrations decreased as a measure of housing age increased, reflecting the effects of well-established lawns and low-intensity traffic (with lower associated fuel combustion responsible for sulfate generation) along streets of older residential areas in Milwaukee-Green Bay. Relations with sulfate concentrations generally were stronger with the urban variables than with the landscape variables. Notable exceptions were the negative relations with basin slope and the percentage of wetland land cover in the basin and buffer and the positive relation with the basin-wetness index. Wetlands in the Milwaukee-Green Bay area generally are in nonurban areas. The relation between sulfate concentrations and the percentage of wetland land cover in the basin was significantly weaker during low base-flow conditions than during high base-flow conditions in May and June, when greater amounts of recent runoff likely had transported more sulfate to streams in more developed areas.

In Dallas-Fort Worth, the relation between sulfate concentrations and the percentage of urban land cover in the basin was weak during both high and low base-flow conditions (fig. 17B). The maximum sulfate concentration was measured in a sample collected during high base-flow conditions at a minimally developed site with a substantial amount of agriculture in the upstream drainage area. Relations between sulfate concentrations and urban and landscape variables were weak during high and low base-flow conditions (table 5B).

Similarly, in Denver, the relations between sulfate concentrations and all urban and landscape variables also were weak during high and low base-flow conditions, with the exception of a negative relation with basin slope during low base-flow conditions in August (fig. 17B, table 5B); the reasons for this relation are unknown. The relation with basin slope was significantly weaker during high base-flow conditions in June, likely because of the confounding influence of natural hydrologic variability among study basins during this period. In the larger study basins originating in the mountains, snowmelt runoff increases streamflows throughout the month of June, whereas smaller study basins originating in the plains have much lower streamflows during this month (Sprague and others, 2006).

In Portland, the relation between sulfate concentrations and the percentage of urban land cover in the basin was strong during high and low base-flow conditions, although the relation was significantly stronger during high base-flow conditions (fig. 17B). In addition, sulfate concentrations increased as most measures of urbanization—including housing density, road density, population density, patch size and homogeneity of urban la nd area, percentage of urban land in the basin and in the buffer, and impervious area in the drainage basin and in the buffer—increased during high and low base-flow conditions (table 5B). The relations between sulfate concentrations and most urban variables were stronger during high base-flow conditions in May following the end of the rainy season, when constituents such as sulfate likely were transported into area streams. Relations with sulfate concentrations generally were stronger with the urban variables than with the landscape variables. Notable exceptions were the negative relations with the percentage of shrub/grass land cover in the basin and buffer during high base-flow conditions and the negative relations with basin slope, sand content of the soil, and depth to the water table during high and low base-flow conditions. These relations likely reflect decreases in forested and shrub/grass land cover as urban land cover increased; the depth to the water table increased beneath the rolling hilltops that were associated with forested and shrub/grass land cover in this area. The negative relation between sulfate concentrations and shrub/grass land cover likely was significantly stronger during high base-flow conditions than during low base-flow conditions because transport of sulfate from roads, parking lots, industrial sites, and the atmosphere likely was greater during periods of greater recent surface runoff.

The increase in sulfate concentrations as urbanization increased in Atlanta and Raleigh-Durham likely was due to increased contributions from urban sources of sulfate, such as vehicle exhaust and power-plant emissions (Couch and others, 1996), as well as to an absence of sulfate generation in, or transport from, nonurban forested or agricultural areas. Moreover, the negative relations between sulfate concentrations and the percentage of agricultural land cover in these areas might indicate that sulfate fertilizers were not consistently a large source of sulfate to these streams. The negative relation between concentrations of sulfate and housing age may be representative of land cover; many older homes in the Atlanta study area were in rural areas. However, the preponderance of older homes in rural areas may be an artifact of the basin selection for this study rather than a reflection of land-development patterns in the greater Atlanta area. In Raleigh-Durham, sulfate concentrations decreased with increasing distance from the stream to the nearest road, indicating that vehicle emissions were potentially a local source of sulfate to streams.

As with Atlanta, Raleigh-Durham, and Portland, the increase in sulfate concentrations in Milwaukee-Green Bay as urbanization increased likely was due to increased contributions from urban sources of sulfate. The predominant background land cover in the Milwaukee-Green Bay study area was agriculture; sulfur-coated urea, potassium sulfate, Epsom salt, and gypsum in fertilizer (Peters and others, 1997; Schoessow, undated) may be sources of sulfate in streams in agricultural areas. However, because of the strong relation between sulfate concentrations and urban land cover and the weak relation between sulfate concentrations and agricultural land cover, agricultural contributions in Milwaukee-Green Bay appeared to have been less influential than urban contributions. The negative relation between sulfate concentrations and a measure of housing age may have been a reflection of the lower-intensity development in older urbanized areas of Milwaukee-Green Bay.

The weak relation between sulfate concentrations and urbanization in Dallas-Fort Worth may be a function of land use and geology, and specifically, contributions of sulfate from the nonurban areas that obscure any contributions to sulfate concentrations from urban sources. The Woodbine aquifer underlies a substantial part of the Dallas-Fort Worth study area. Water from the Woodbine aquifer has sufficiently high concentrations of sulfate, iron, and manganese that the water is not potable and is instead used primarily for agricultural irrigation in the Dallas-Fort Worth study area (Reutter, 1996). Water samples collected in 1993 from 38 wells in the Woodbine aquifer had sulfate concentrations ranging from 19 to 3,400 mg/L, with a median concentration of 380 mg/L (Reutter, 1996). Other rural areas south of Dallas-Fort Worth are underlain by the Trinity aquifer and may have relatively high sulfate concentrations in base flow (Land and others, 1998). High sulfate concentrations in base flow in these rural areas may have obscured any pattern in sulfate concentrations relative to urban land cover in Dallas-Fort Worth. Likewise, in Denver, sulfate is the dominant anion in the alluvial ground water underlying parts of the study area (Bruce and McMahon, 1998). Therefore, natural sources likely obscured any pattern in sulfate concentrations relative to urban land cover in Denver.

The results for sulfate concentrations indicate that strategies to control sulfate transport to streams in urbanizing areas may be most effective when developed locally. In addition, in areas where sulfate concentrations in ground water are high, such strategies may need to consider the effects of groundwater inflow to streams.

Chloride

In Atlanta, the relation between chloride concentrations and the percentage of urban land cover in the basin was strong during high and low base-flow conditions (fig. 17C). Chloride concentrations increased as most measures of urbanization—including housing density, road density, population density, patch size and homogeneity of urban land area, percentage of urban land cover in the basin and buffer, and impervious area in the basin and buffer—increased (table 5C). There was a negative relation between chloride concentrations and a measure of housing age, likely because many older homes in the Atlanta study area were in rural areas; however, this may have been an artifact of the basin selection for this study rather than a reflection of land-development patterns in the greater Atlanta area. There also was a negative relation between chloride concentrations and distance from the stream to the nearest road, indicating that runoff from roads potentially was a local source of chloride to streams. This relation was significantly stronger during high base-flow conditions than during low base-flow conditions; transport of chloride from impervious areas such as roads and parking lots likely was greater during periods of recent surface runoff. Relations with chloride concentrations generally were stronger with the urban variables than with the landscape variables in Atlanta. The strongest relation with a landscape variable was a negative relation with the percentage of shrub/grass land cover in the basin, which may reflect changes in the background land cover.

In Raleigh-Durham, the relation between chloride concentrations and the percentage of urban land cover in the basin was strong during high and low base-flow conditions (fig. 17C). Chloride concentrations increased as most measures of urbanization—including housing density, road density, population density, patch size and homogeneity of urban land area, percentage of urban land cover in the basin and buffer, and impervious area in the basin and buffer—increased (table 5C). Relations with chloride concentrations generally were stronger with the urban variables than with the landscape variables, with the exception of the negative relations with the percentage of agriculture and shrub/grass land cover in the basin and buffer. These relations likely reflected the decrease in background land cover as urban land cover increased.

In Milwaukee-Green Bay, the relation between chloride concentrations and the percentage of urban land cover in the basin was strong during high and low base-flow conditions (fig. 17C). Chloride concentrations increased as most measures of urbanization—including housing density, road density, population density, patch size and homogeneity of urban land area, urban land cover in the basin and buffer, and impervious area in the basin and buffer—increased (table 5C). The positive relations with urbanization may be attributable to increased residential use of water softeners, vehicle exhaust, or use of salt for pavement deicing in urban areas. In addition, chloride concentrations decreased as a measure of housing age increased, possibly because residential parts of mixed residential/urban areas received less chloride from vehicle exhaust and deicing salt than did urban areas with freeway traffic and more extensive impervious areas such as parking lots. Relations with chloride concentrations generally were stronger with the urban variables than with the landscape variables. The strongest relations with the landscape variables included negative relations with the percentage of agricultural and wetland land cover in the basin and buffer and positive relations with the percentage of shrub/grass land cover in the basin and buffer. As with Atlanta and Raleigh-Durham, these relations likely reflected the increase in background land cover as urban land cover decreased.

In Dallas-Fort Worth, the relation between chloride concentrations and the percentage of urban land cover in the basin was strong (fig. 17C), though the relations between chloride concentrations and some other urban and landscape variables were weak (table 5C). These results indicate that both urban and nonurban chloride sources likely were present. Both the Trinity and Woodbine aquifers that underlie parts of the Dallas-Fort Worth study area have water with high concentrations of chloride (Land and others, 1998). High chloride concentrations in base flow in these areas may have to some degree obscured increases in chloride concentrations as urbanization increased in Dallas-Fort Worth.

In Denver, the relation between chloride concentrations and the percentage of urban land cover in the basin was significantly stronger during low base-flow conditions in August than during high base-flow conditions in June (fig. 17C). Similarly, chloride concentrations were strongly related to road density, population density, patch size and homogeneity of urban land area, urban land cover in the basin, and impervious area in the basin and negatively related to a measure of housing age during low base-flow conditions but not during high base-flow conditions (table 5C). The differences between high and low base-flow conditions likely were due to the confounding influence of natural hydrologic variability among study basins during high base-flow conditions—in the larger study basins originating in the mountains, snowmelt runoff increases streamflows throughout the month of June, whereas smaller study basins originating in the plains have much lower streamflows during this month (Sprague and others, 2006). Therefore, during this month, chloride concentrations might have been diluted by snowmelt runoff more in some basins than in others. In contrast, streamflows were uniformly low across all study basins during low base-flow conditions, and increases in chloride concentrations with urbanization potentially resulted from chloride in automobile exhaust, industrial emissions, and other urban sources. There also were negative relations between chloride concentrations and both housing age and the distance from the stream to the nearest road, possibly because older residential areas received less chloride from vehicle exhaust and runoff from roads was a local source of chloride to streams. In addition, chloride concentrations were negatively related to the percentage of agricultural land in the basin and in the buffer in Denver. Unlike in Atlanta, Raleigh-Durham, and Milwaukee-Green Bay, these relations do not reflect decreases in background land cover as urban land cover increased because increasing agricultural land cover was not proportional to decreasing urban land cover in Denver (fig. 2). Instead, this relation may reflect application of potassium chloride or increased salinity of irrigation return flow, or both, in agricultural areas.

In Portland, the relation between chloride concentrations and the percentage of urban land cover in the basin was strong (fig. 17C). Generally, chloride concentrations increased as many measures of urbanization—including housing density, road density, population density, urban land cover in the basin and buffer, and impervious area in the basin and buffer—increased (table 5C). These increases may be attributable to chloride in automobile exhaust, industrial emissions, and other urban sources. Relations with chloride concentrations generally were stronger with the urban variables than with the landscape variables in the Portland study area. However, chloride concentrations decreased with increasing percentages of shrub/grass land cover in the basin and buffer during high base-flow conditions and with increasing sand content in the soil and depth to the water table and decreasing soil erodibility during both high and low base-flow conditions. The relations with shrub/grass land cover and depth to water table likely reflected changes in the percentage of background land cover because shrub/grass land cover decreased as urban land cover increased and the mean depth to the water table increased beneath the rolling hilltops that were associated with background land cover in this area. The relation with shrub/grass land cover was significantly stronger during high base-flow conditions because transport of chloride from roads, parking lots, industrial sites, and the atmosphere likely was greater during periods of recent surface runoff. Areas with higher soil erodibility and lower permeability may have experienced increased surface runoff of chloride.

Chloride concentrations in Dallas-Fort Worth and Denver did not consistently increase with increasing urbanization. In contrast, chloride concentrations in Atlanta, Raleigh-Durham, Milwaukee-Green Bay, and Portland increased as urbanization increased, likely due in part to runoff of chloride-bearing salts applied to impervious areas for deicing (where used), wet and(or) dry deposition of chloride originating in vehicle exhaust, wet and dry deposition from industrial sources, and any discharge from WWTPs. The specific urban variables related to increasing chloride concentrations were the same among the four study areas, with the exception of housing age and distance from the stream to the nearest road. In Atlanta and Milwaukee-Green Bay, chloride concentrations decreased as a measure of housing age increased, reflecting the well-established lawns and low-intensity traffic in older residential areas in these two study areas. The specific landscape variables related to increasing chloride concentrations differed between the four study areas, but most often the relations represented decreases in background land cover as urban land cover increased.

The results for chloride concentrations indicate that strategies to control chloride transport to streams in urbanizing areas may be most effective when developed locally. In addition, in areas where chloride concentrations in ground water are high, such strategies may need to consider the effects of ground-water inflow to streams.

Comparison of the Patterns of Response to Urbanization Among Study Areas

The response of stream-water quality in base flow to urbanization differed by chemical constituent and by environmental setting. In areas where land cover in minimally urbanized basins was predominantly forest or shrub/grass, urbanization generally was associated with increasing chemical concentrations, although other nonurban factors may have been related to chemical concentrations as well. In areas where minimally urbanized basins were already affected by other stressors, such as agriculture, water management, or inflow of relatively saline ground water, the effects of urbanization were less clear. Maintenance or protection of stream quality may be addressed by identifying all important stressors and supplementing the management practices currently used in urbanizing areas with additional steps to mitigate the effects of these other stressors.

Benchmark Exceedances

Available benchmarks for nutrients included human-health benchmarks for ammonia, nitrate, and nitrite; aquatic-life benchmarks for ammonia; and Ecoregional nutrient criteria for total nitrogen and total phosphorus (Appendix 3). SDWRs were available for pH, sulfate, and chloride, and aquatic-life benchmarks were available for pH and chloride (Appendix 3). Most of the 41 pesticides analyzed in this study had both human-health benchmarks (36 pesticides) and aquatic-life benchmarks (33 pesticides), but very few of the 24 pesticide degradates analyzed had benchmarks available (none for human health, and 3 for aquatic life) (Appendix 4). The type and number of benchmark exceedances for all constituents collectively is shown in figure 18 for each site in the six study areas. Appendix 5 lists the types of benchmarks exceeded and the constituents involved at each site.

Nutrients, pH, Sulfate, and Chloride

One or more Ecoregional nutrient criteria was exceeded at about 70 percent of sites. These exceedances did not appear to be related to the degree of urbanization in the basin, except that sites with less than about 3 percent urban land cover exceeded these baseline criteria less often (fig. 18). For the sites with less than 3 percent urban land cover, one or more Ecoregional criteria were exceeded in 38 percent of samples compared with 75 percent of samples for sites with more than 3 percent urban land cover, 81 percent for sites with more than 10 percent, and 83 percent for sites with more than 25 percent urban land cover. Ecoregional nutrient criteria are intended to indicate baseline conditions in rivers and streams—that is, conditions representing minimal effects from human activities.

Other nutrient benchmarks were rarely exceeded (fig. 18). The aquatic-life benchmark for ammonia was exceeded in samples from only 1 out of 173 sites—in both low and high base-flow samples from a Raleigh-Durham site with about 97 percent urban land use in the basin (Appendix 5). Human-health benchmarks for nutrients (specifically the MCL for nitrate) were exceeded in samples from 4 of 173 sites—at two sites each in Milwaukee-Green Bay and Dallas-Fort Worth. Two of these sites were in basins containing more than 25 percent urban land cover. Samples from the other two sites, both with less than 10 percent urban land cover, also exceeded the MCL for atrazine, which indicates there may be agricultural influences at these sites. It is important to emphasize that these exceedances occurred in ambient stream water rather than in finished drinking water. The comparison with human-health and drinking-water benchmarks does not permit evaluation of human exposure, but is part of a screening-level assessment to put the data in a human-health context.

For pH, sulfate, and chloride, aquatic-life benchmarks were exceeded in samples from 8 of 173 sites; all 8 sites were in either Atlanta, Raleigh-Durham, or Dallas-Fort Worth (fig. 18). The benchmark for pH was exceeded in seven samples from seven sites in these study areas, and the benchmark for chloride was exceeded in 1 sample in Dallas-Fort Worth. One or more SDWRs for these constituents were exceeded in 31 samples from 24 sites in 5 study areas (all except Portland), indicating some possibility of taste and odor problems at these sites if the stream water were to be used as drinking water without treatment. Eleven of the 31 samples exceeded the SDWR for pH, 18 exceeded the SDWR for sulfate, and 1 sample exceeded the SDWR for chloride.

Pesticides

One or more human-health benchmarks for pesticide compounds were exceeded in 16 samples from 13 sites in 3 study areas (Raleigh-Durham, Milwaukee-Green Bay, and Dallas-Fort Worth; Appendix 5), which was only about 3 percent of total samples from the 6 study areas (fig. 18). The pesticides with concentrations greater than human-health benchmarks were atrazine (8 samples), dieldrin (7 samples), and simazine (1 sample). There was no apparent relation with degree of urbanization, with exceedances occurring at sites ranging from 3 to 98 percent urban land cover. One exception was the dieldrin exceedances, which always occurred at sites with more than 60 percent urban land cover. As previously noted, the comparison of ambient stream-water concentrations with human-health benchmarks serves to put the data in a human-health context, but is not relevant to human exposure assessment.

Aquatic-life benchmarks were exceeded in only four samples from four sites in three study areas (Raleigh-Durham, Milwaukee-Green Bay, and Denver; Appendix 5), which was only about one percent of total samples from the six study areas (fig. 18). The sites with exceedances were in basins with 3 to 44 percent urban land cover. The pesticides that exceeded these benchmarks—malathion, chlorpyrifos, and diazinon—are all insecticides with known urban uses, although urban use of chlorpyrifos and diazinon probably declined prior to and during the study period because USEPA has phased out the residential uses of these insecticides by homeowners (U.S. Environmental Protection Agency, 2000a and 2005b)

Pesticide concentrations in streams show seasonality and other temporal variability, and these temporal patterns tend to differ regionally and locally. This variability results from differences in factors such as the timing and amounts of pesticide use, climate, and the frequency and magnitude of recent runoff from rainstorms or irrigation (Gilliom and others, 2006). Because this study sampled stream water only twice per year during base-flow conditions, it is likely that pesticide concentrations in these streams reached higher concentrations than those measured here. Therefore, the pesticide occurrence and benchmark exceedance rates described in this report may underestimate exceedances in ambient stream water at other times, such as in peak pesticide-use periods or during storms or irrigation return flow. In previous results from broader sampling as part of the USGS NAWQA Program (Gilliom and others, 2006), aquatic-life benchmarks were exceeded at over

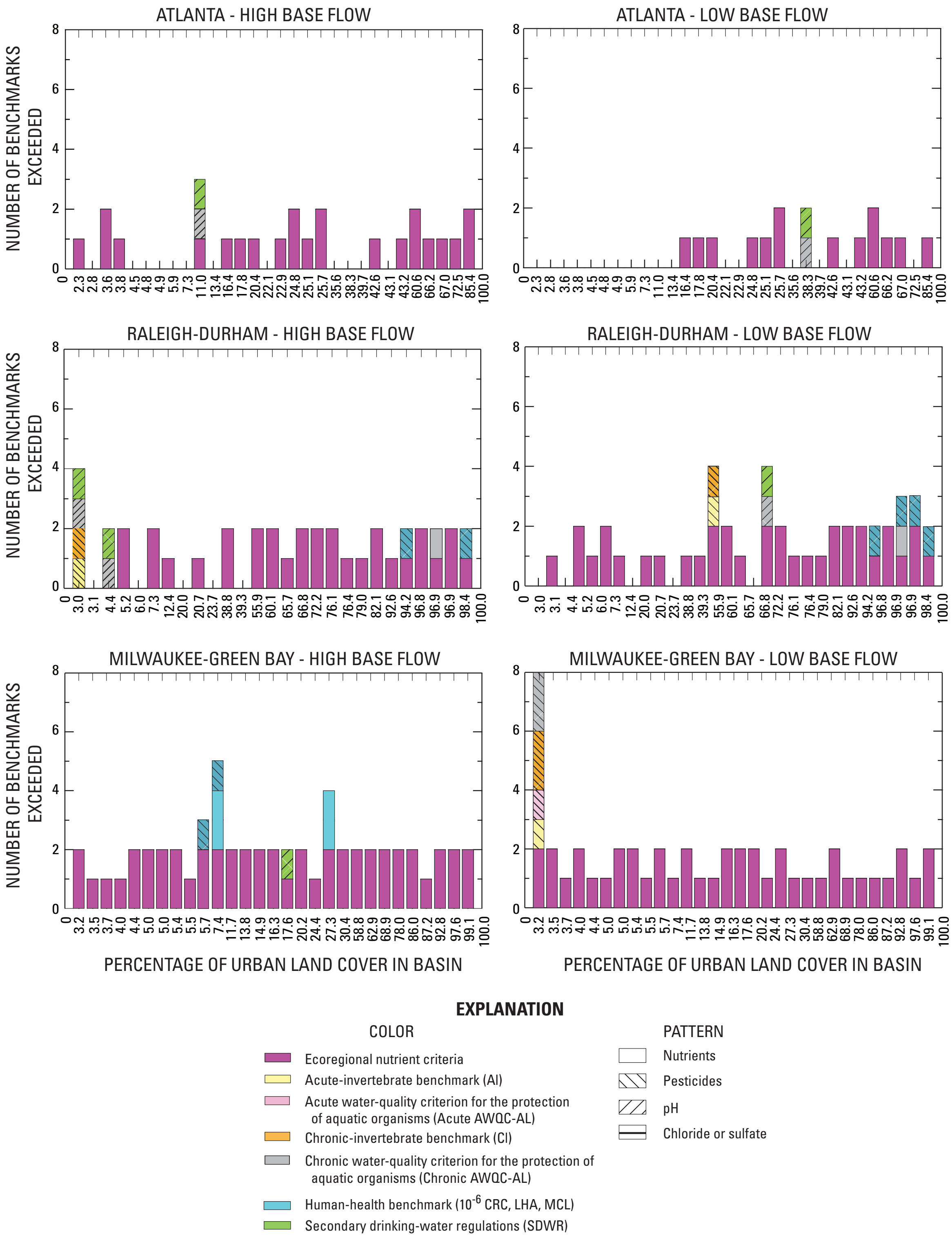

Figure 18. The number and type of benchmark exceedances for all constituents combined in the Atlanta, Raleigh-Durham, Milwaukee-Green Bay, Dallas-Fort Worth, Denver, and Portland study areas. Each bar represents the sum of each type of exceedance in each basin. Not all types of benchmarks are available for all types of constituents. See Appendixes 3 and 4 for detailed information. Data are presented in Appendix 5. 10-6 CRC, U.S. Environmental Protection Agency 10-6 cancer risk concentration; LHA, U.S. Environmental Protection Agency lifetime health advisory; MCL, U.S. Environmental Protection Agency Maximum Contaminant Level.

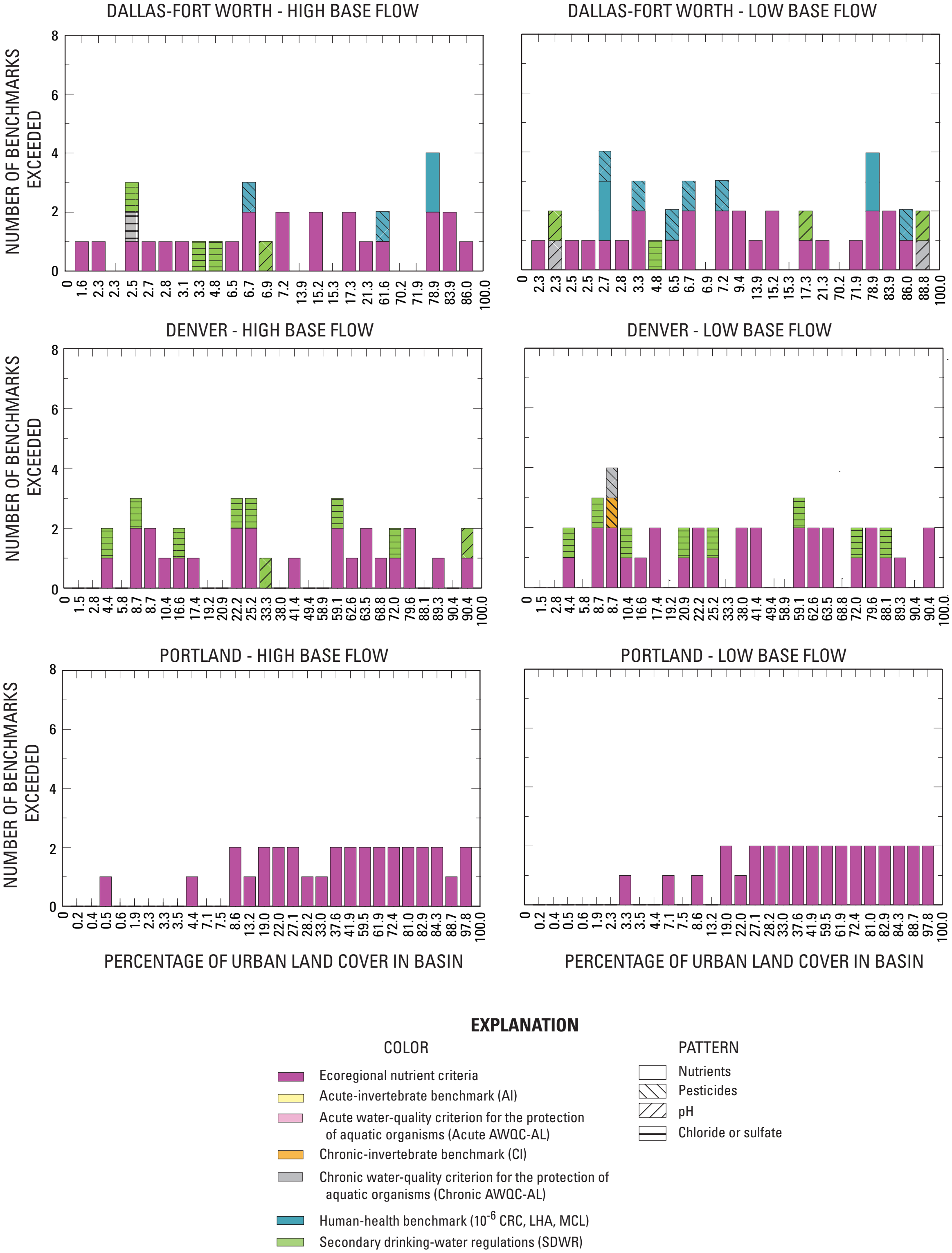

Figure 18. The number and type of benchmark exceedances for all constituents combined in the Atlanta, Raleigh-Durham, Milwaukee-Green Bay, Dallas-Fort Worth, Denver, and Portland study areas. Each bar represents the sum of each type of exceedance in each basin. Not all types of benchmarks are available for all types of constituents. See Appendixes 3 and 4 for detailed information. Data are presented in Appendix 5. 10-6 CRC, U.S. Environmental Protection Agency 10-6 cancer risk concentration; LHA, U.S. Environmental Protection Agency lifetime health advisory; MCL, U.S. Environmental Protection Agency Maximum Contaminant Level.—Continued

80 percent of sites sampled in urban areas. On the other hand, because chronic aquatic-life benchmarks (intended for comparison with 4- to 60-day average concentrations) were compared in this study with individual samples, exceedance rates described here may overestimate potential chronic toxicity.

Summary

During 2002–2004, the U.S. Geological Survey's National Water-Quality Assessment Program conducted a study to determine the effects of urbanization on stream ecosystems in six environmentally heterogeneous areas of the conterminous United States— Atlanta, Georgia; Raleigh-Durham, North Carolina; Milwaukee-Green Bay, Wisconsin; Dallas-Fort Worth, Texas; Denver, Colorado; and Portland, Oregon. This report describes the results from the stream chemistry component of the study. The objectives of this component were as follows: (1) to compare and contrast the response of stream chemistry during base flow to urbanization in different environmental settings; and (2) to examine the relation between the exceedance of water-quality benchmarks and the level of urbanization.

Within each metropolitan area, about 30 study basins were chosen to minimize natural variability between basins due to factors such as geology, altitude, and climate and to maximize coverage among basins of different degrees of urban development, ranging from minimally to highly developed. Water-quality samples were collected twice at each site, once during low base-flow conditions and once during high base-flow conditions. Chemical characteristics studied included concentrations of nutrients, dissolved pesticides and pesticide degradates, suspended sediment, sulfate, and chloride.

Nitrogen concentrations increased with urbanization in Atlanta, Raleigh-Durham, and Portland; relations between nitrogen concentrations and urbanization were weak in Milwaukee-Green Bay, Dallas-Fort Worth, and Denver. Forest was a predominant background land cover in basins with minimal urban development in Atlanta, Raleigh-Durham and Portland, and the increase in nitrogen concentrations followed the increase in urban land cover as forested land cover decreased in these areas. In contrast, nitrogen concentrations in basins with minimal urban development were considerably higher in Milwaukee-Green Bay and Dallas-Fort Worth, where agriculture was a predominant background land cover; agricultural influences may have obscured any increases in nitrogen concentrations related to urban development in these areas. Nitrogen concentrations in Denver were variable at all levels of urban development, which may have been due to the extensive water management in the study area.

There was a weak but positive relation between phosphorus concentrations and urbanization in Atlanta, Raleigh-Durham, Dallas-Fort Worth, and Denver; the strongest positive relation was observed in Portland, where basins with minimal urban development had particularly low phosphorus concentrations. It is possible that leachate from septic tanks may have increased concentrations in basins with minimal urban development in Atlanta and Raleigh-Durham. In Milwaukee-Green Bay and Dallas-Fort Worth, phosphorus concentrations were high in basins with minimal urban development because of the high percentage of agricultural land cover in these basins. In Milwaukee-Green Bay, phosphorous concentrations decreased as urbanization increased and as agricultural land cover decreased, whereas in Dallas-Fort Worth, phosphorus concentrations were similarly high in the most developed basins, leading to a weak overall relation between phosphorus and the degree of urbanization. Phosphorus concentrations in Denver were low overall relative to the other study areas and showed little distinct response to urbanization, which may have been due to the extensive water management in the study area.

The results for nutrient concentrations indicate that management strategies to control nutrients in urbanizing areas may need to consider background, pre-development land cover. Particularly if development is occurring in agricultural areas, nutrient concentrations may be high even before development occurs.

Total herbicide concentrations increased with urbanization in Atlanta, Raleigh-Durham, and Portland, generally following the decrease in forested land cover and the increase in urban land cover. In Portland, there was evidence of mixed agricultural and urban influences at sites with 20 to 50 percent urban land cover; however, the overall relation between herbicide concentrations and urbanization was strong. In contrast, relations between total herbicide concentrations and urbanization were weak in Milwaukee-Green Bay, Dallas-Fort Worth, and Denver. In Milwaukee-Green Bay, where the background land cover was predominantly agriculture, total herbicide concentrations decreased somewhat as urbanization increased and as agricultural land cover decreased. In Dallas-Fort Worth, where agriculture and shrub/grass land cover were the predominant background land covers, total herbicide concentrations were highest in basins with low urban and relatively high agricultural land cover, then decreased sharply as agricultural land cover decreased and shrub/grass land cover increased, and finally increased slightly again in the most urbanized basins. In Denver, where the predominant background land cover was shrub/grass land cover, total herbicide concentrations did not follow a clear pattern relative to any type of land cover, again possibly due to the extensive water management in the study area.

In Atlanta, Raleigh-Durham, and Portland, concentrations of total insecticides (like total herbicides) generally increased with increasing urbanization. In Milwaukee-Green Bay, Dallas-Fort Worth, and Denver, however, total insecticide concentrations were more strongly related to urbanization than were total herbicide concentrations. This relation may have been due to more intensive application of insecticides in urbanized basins, and—in Denver and Milwaukee-Green Bay—the fact that most study basins in these areas had a disproportionate amount of urban land cover in the lowland portion of the drainage area near the sampling sites, with much

of the herbicide loading originating further upstream. In Denver, the transport of urban insecticides to the nearby sampling sites may have been less affected by diversions and reservoir storage upstream than was the transport of herbicides from upstream agricultural areas.

Strategies to control herbicide transport to streams in urbanizing areas may be most effective when developed locally, and as with nutrients, such strategies may need to consider both agricultural and urban influences. Strategies to control insecticide transport to streams in urbanizing areas may be effective when developed nationally, although consideration of local factors likely will improve the outcome.

The pesticide signature for a given study area tended to show certain pesticides, and certain combinations of pesticides, as dominant, although the concentrations of the dominant pesticides varied markedly among sites within a study area. Normalization of pesticide concentrations in stream water by the pesticide toxicity index—an index of relative potential toxicity to cladocerans or fish—dramatically changed the pesticide signature, indicating that the pesticides with the greatest potential to adversely affect cladocerans or fish were not necessarily the pesticides detected at the highest concentrations.

In all six study areas, the relation between suspended-sediment concentrations and urbanization was weak. In Atlanta, Raleigh-Durham, Milwaukee-Green Bay, and Portland, there was an increase in sulfate and chloride concentrations with urbanization, likely due to increased contributions from urban sources of these constituents. In Dallas-Fort Worth and Denver, relations between sulfate concentrations and urbanization were weak. In Dallas-Fort Worth, the relation between chloride concentrations and the percentage of urban land cover in the basin was strong but the relations with other urban variables were weak; in Denver, the relation between chloride concentrations and urbanization was strong during low base-flow conditions but not during high base-flow conditions. These patterns in Dallas-Fort Worth and Denver likely were influenced in part by high sulfate and chloride concentrations in ground-water inflow, which may have obscured increases in the concentrations with increasing urbanization.

The results for suspended-sediment concentrations support previous research indicating that strategies to control sediment transport to streams in urbanizing areas may need to focus on conditions during stormwater runoff to a greater degree than conditions during base flow. The results for sulfate and chloride indicate that strategies to control their transport to streams in urbanizing areas may need to consider the effects of ground-water inflow to streams in areas where sulfate and chloride concentrations in alluvial ground water are high.

For nutrients, one or more recommended Ecoregional nutrient criteria were exceeded at about 70 percent of sites. These exceedances did not appear to be related to the degree of urbanization in the basin, except that sites with less than about three percent urban land cover less often exceeded these criteria, which represent baseline conditions for surface water that is minimally affected by human activities. Other nutrient benchmarks were rarely exceeded. The aquatic-life benchmark for ammonia was exceeded at one site in Raleigh-Durham, and the human-health benchmark for nitrate was exceeded at four sites in Milwaukee-Green Bay and Dallas-Fort Worth.

For pH, sulfate, and chloride, aquatic-life benchmarks were exceeded at eight sites in three study areas (in Atlanta, Raleigh-Durham, and Dallas-Fort Worth). One or more secondary drinking-water regulations were exceeded at 24 sites in 5 study areas (all except Portland), indicating some possibility of taste and odor problems at these sites if the stream water were to be used as drinking water without treatment.

For pesticides, one or more human-health benchmarks were exceeded by atrazine, dieldrin, or simazine at 13 sites in 3 study areas (Raleigh-Durham, Milwaukee-Green Bay, and Dallas-Fort Worth). There was no apparent relation with degree of urbanization, except that the dieldrin exceedances always occurred at sites with more than 60 percent urban land cover. Comparison of concentrations in individual ambient stream water samples with human-health benchmarks, which apply to lifetime consumption of drinking water, is not appropriate for human exposure assessment but serves only to put the data in a human-health context. Aquatic-life benchmarks were exceeded at four sites in three study areas (Raleigh-Durham, Milwaukee-Green Bay, and Denver). There was no apparent relation with urban land cover, although the pesticides that exceeded the aquatic-life benchmarks—malathion, chlorpyrifos, and diazinon—are all insecticides with known urban uses.

Because this study sampled stream water only twice per year during base-flow conditions, it is likely that nutrient and pesticide concentrations in these streams reached higher concentrations than those measured here. Therefore, the constituent occurrence and benchmark exceedance rates described in this report may underestimate exceedances at other times, such as in peak pesticide and fertilizer use-periods or during storms or irrigation return flow. On the other hand, because chronic aquatic-life benchmarks (intended for comparison with 4- to 60-day average concentrations) were compared in this study with individual samples, exceedance rates described here may overestimate potential chronic toxicity.

In summary, the response of stream-water quality in base flow to urbanization differed by chemical constituent and by environmental setting. In areas where land cover in minimally urbanized basins was predominantly forest or shrub/grass, urbanization generally was associated with increasing chemical concentrations, although other nonurban factors may have been related to chemical concentrations as well. In areas where minimally urbanized basins were already affected by other stressors, such as agriculture, water management, or inflow of relatively saline ground water, the effects of urbanization were less clear. Maintenance or protection of stream quality may be addressed by identifying all important stressors and supplementing the management practices currently used in urbanizing areas with additional steps to mitigate the effects of these other stressors.

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Appendixes

Appendix 1. Seasonal response of base-flow chemistry to urbanization.

Bimonthly water-chemistry data collected at 10 sites in each study area are shown in figures 1.1 through 1.9. Total nitrogen was calculated for each sample by summing either: (1) total Kjeldahl nitrogen and dissolved nitrite-plus-nitrate or (2) dissolved ammonia, dissolved nitrite-plus-nitrate, and particulate nitrogen. If all addends were censored, total nitrogen was censored to the maximum of the censoring levels; if one was uncensored and the others were censored, total nitrogen was set equal to the uncensored value; if two were uncensored and the other was censored, total nitrogen was set equal to the sum of the uncensored values. Total herbicide and total insecticide concentrations were calculated for each sample as the sum of their respective components. Censored values were set to zero and estimated values were used without modification during these calculations. The patterns in the response of each constituent to urbanization throughout the year are described below.

Total nitrogen concentrations (fig. 1.1)

- Seasonal variability of total nitrogen concentrations was relatively constant as urbanization increased in Atlanta, Raleigh-Durham, Denver, and Portland.

- Seasonal variability decreased as urbanization increased in Milwaukee-Green Bay and Dallas-Fort Worth, possibly because of greater agricultural influences in less developed basins in these areas.

Dissolved nitrate concentrations (fig. 1.2)

- Seasonal variability of dissolved nitrate concentrations was relatively constant as urbanization increased in Raleigh-Durham, Denver, and Portland.

- Seasonal variability decreased as urbanization increased in Atlanta, Milwaukee-Green Bay, and Dallas-Fort Worth, possibly because of greater agricultural influences in less developed basins in these areas.

Total phosphorus concentrations (fig. 1.3)

- Seasonal variability of total phosphorus concentrations was relatively constant as urbanization increased in the six study areas.

Dissolved orthophosphate concentrations (fig. 1.4)

- Seasonal variability of dissolved orthophosphate concentrations was relatively constant as urbanization increased in Raleigh-Durham, Milwaukee-Green Bay, Dallas Fort-Worth, Denver, and Portland.

- Seasonal variability decreased as urbanization increased in Atlanta.

Total herbicide concentrations (fig. 1.5)

- Seasonal variability of total herbicide concentrations was relatively constant in Denver and Portland except in one moderately developed basin in Portland.

- Seasonal variability of total herbicide concentrations increased as urbanization increased in Atlanta and Raleigh-Durham.

- Seasonal variability of total herbicide concentrations decreased with increased urbanization in Milwaukee-Green Bay and Dallas-Fort Worth, possibly because of greater agricultural influences in less developed basins in these areas.

Total insecticide concentrations (fig. 1.6)

- Seasonal variability of total insecticide concentrations was relatively constant in Milwaukee-Green Bay, Dallas-Fort Worth, Denver, and Portland, except in two basins in Denver and one basin in Portland.

- Seasonal variability of total insecticide concentrations increased as urbanization increased in Atlanta and Raleigh-Durham, with the exception of the most highly developed basins in Raleigh-Durham.

- The same agricultural influences seen in the pattern of seasonal variability in herbicides were not present with insecticides, possibly because of relatively greater use of insecticides in more developed basins.

Suspended-sediment concentrations (fig. 1.7)

- Seasonal variability of suspended-sediment concentrations was relatively constant with increasing urbanization in Atlanta, Raleigh-Durham, Milwaukee-Green Bay, Denver, and Portland, with the exception of two basins each in Atlanta and Raleigh-Durham and one basin each in Denver and Portland.

- Seasonal variability of suspended-sediment concentrations decreased with increasing urbanization in Dallas-Fort Worth.

Dissolved sulfate concentrations (fig. 1.8)

- Seasonal variability of dissolved sulfate concentrations was relatively constant as urbanization increased in Atlanta, Raleigh-Durham, Milwaukee-Green Bay, and Denver, with the exception of two basins in Milwaukee-Green Bay.

- Seasonal variability of dissolved sulfate concentrations decreased with increasing urbanization in Dallas-Fort Worth.

- Seasonal variability of dissolved sulfate concentrations increased with increasing urbanization in Portland, with the exception of two basins.

<u>Dissolved chloride concentrations (fig. 1.9)</u>

- Seasonal variability of dissolved chloride concentrations was relatively constant as urbanization increased in Atlanta, Raleigh-Durham, and Portland.
- Seasonal variability of dissolved chloride concentrations decreased with increasing urbanization in Dallas-Fort Worth.
- Seasonal variability of dissolved chloride concentrations increased with increasing urbanization in Milwaukee-Green Bay and Denver, where concentrations generally were highest in January and February. This pattern may have been related to the relatively greater use of de-icers in the colder months in these areas.

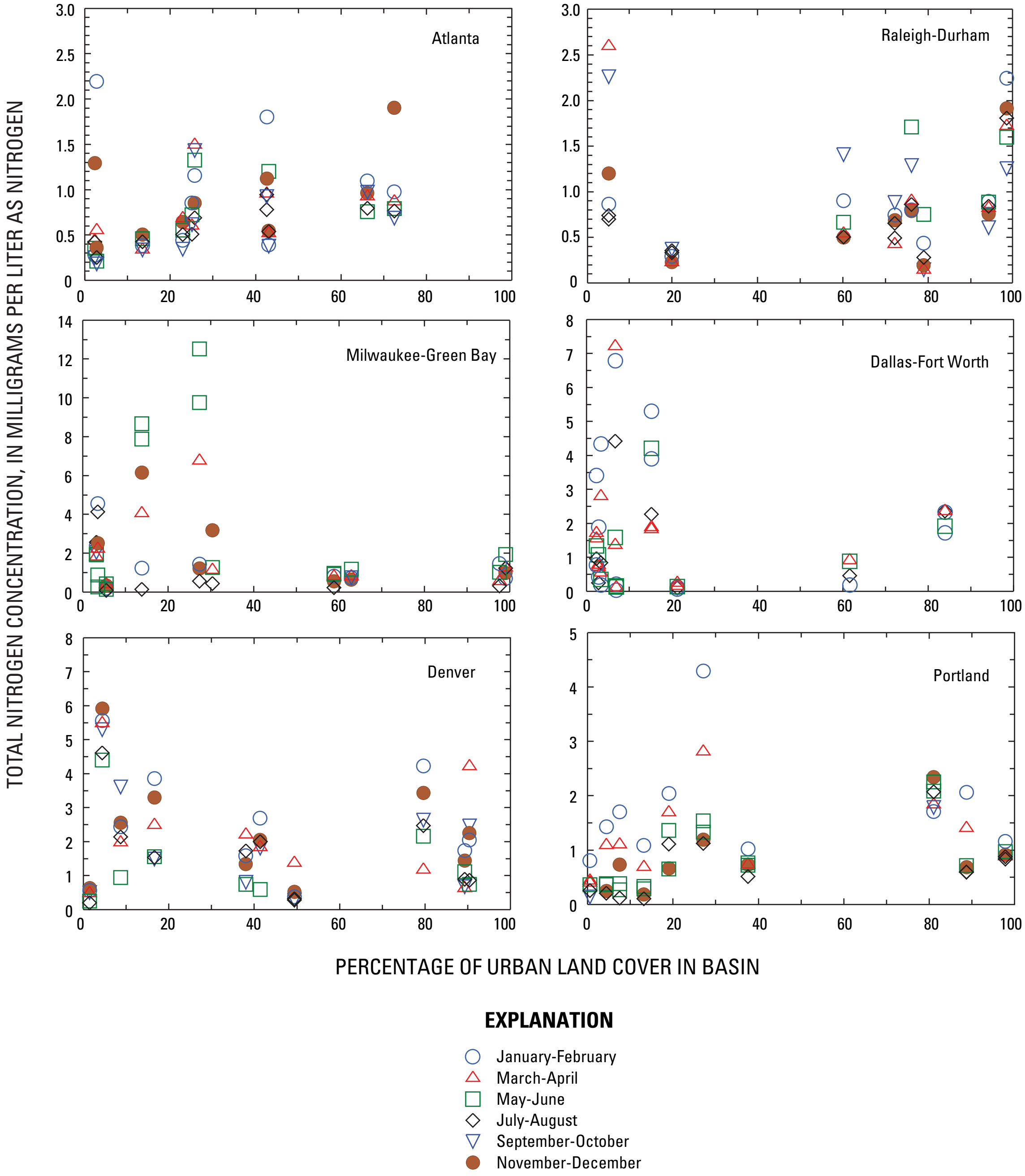

Figure 1.1. Bimonthly total nitrogen concentrations compared to the percentage of urban land cover in the basin.

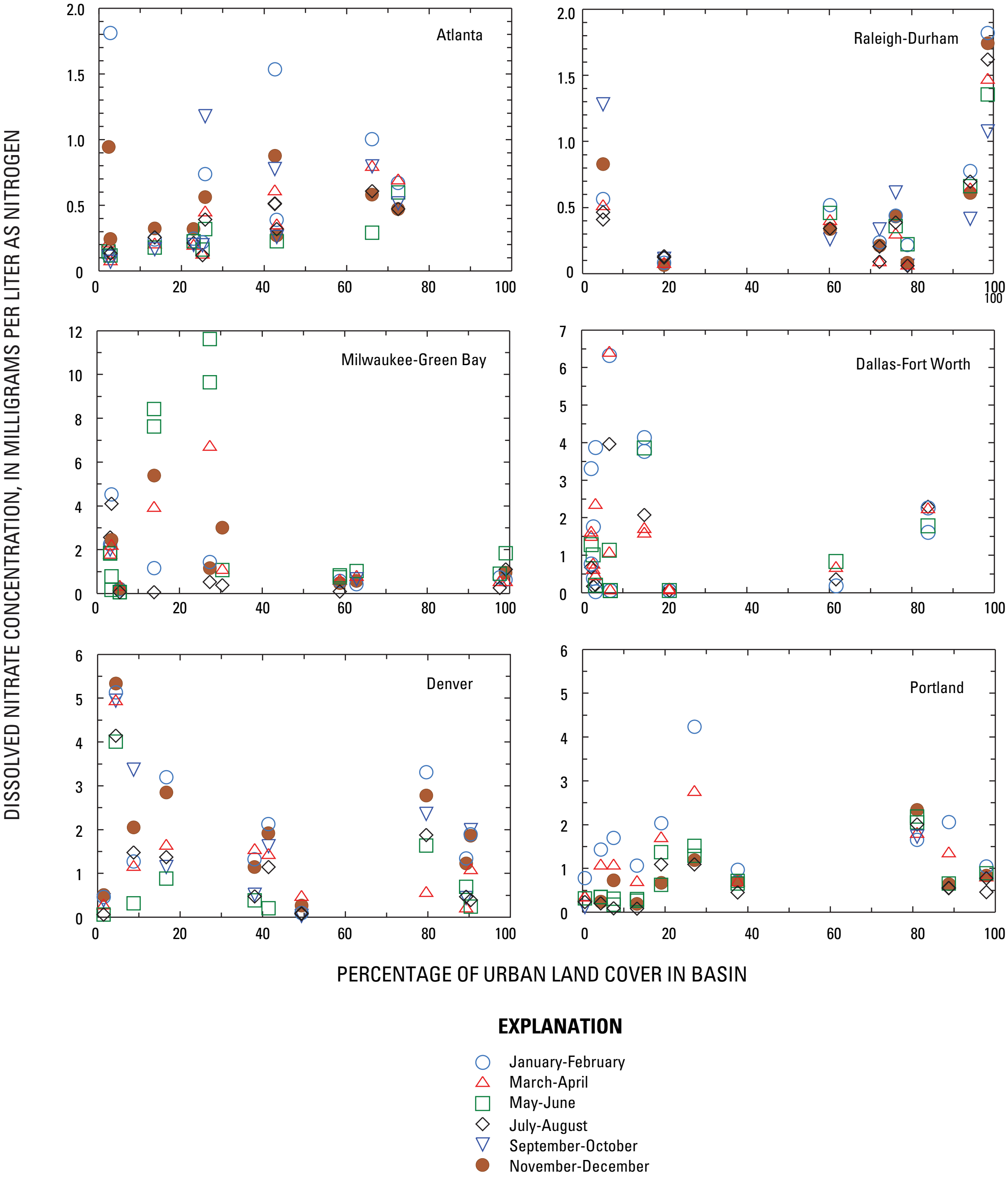

Figure 1.2. Bimonthly dissolved nitrate concentrations compared to the percentage of urban land cover in the basin.

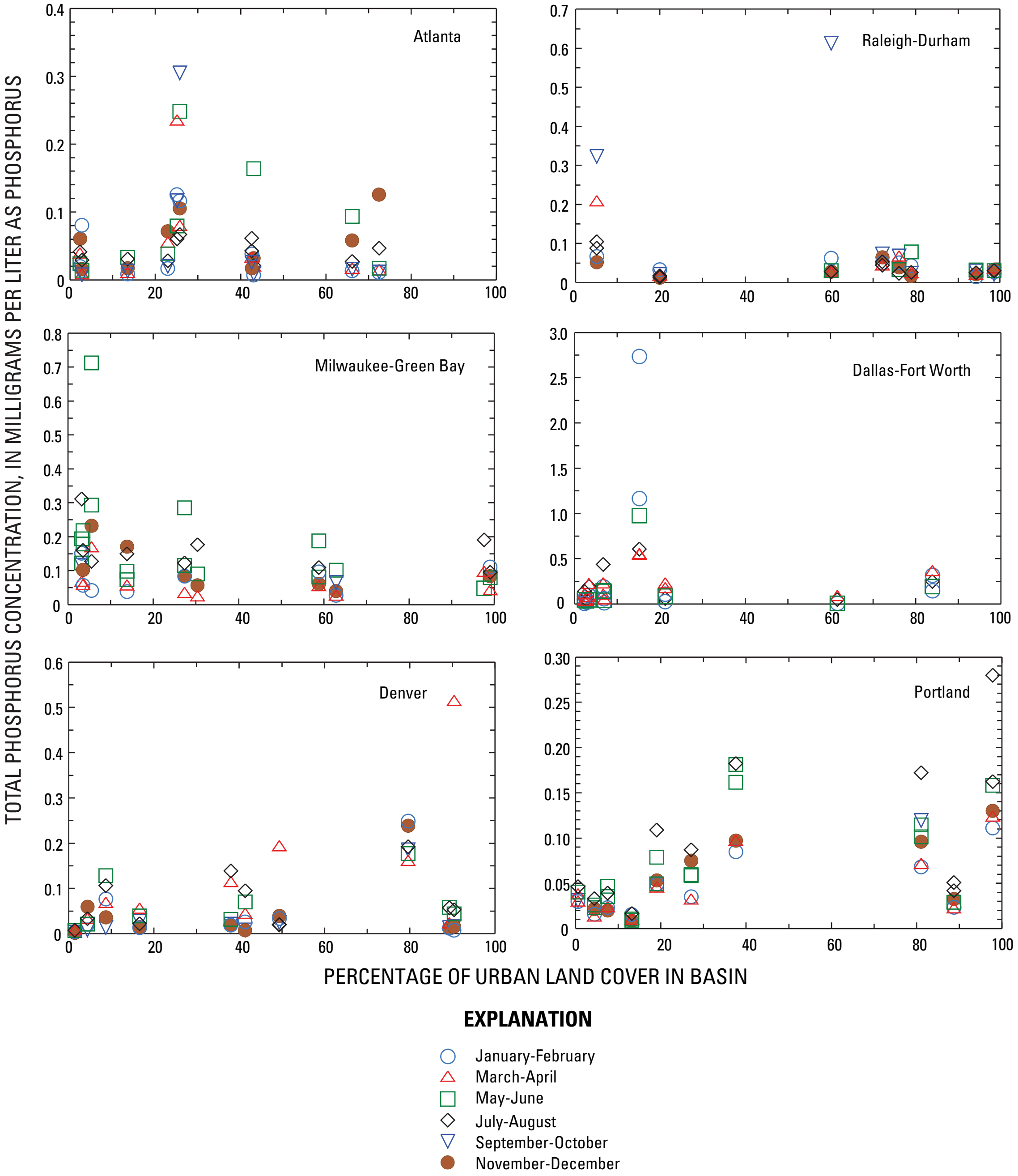

Figure 1.3. Bimonthly total phosphorus concentrations compared to the percentage of urban land cover in the basin.

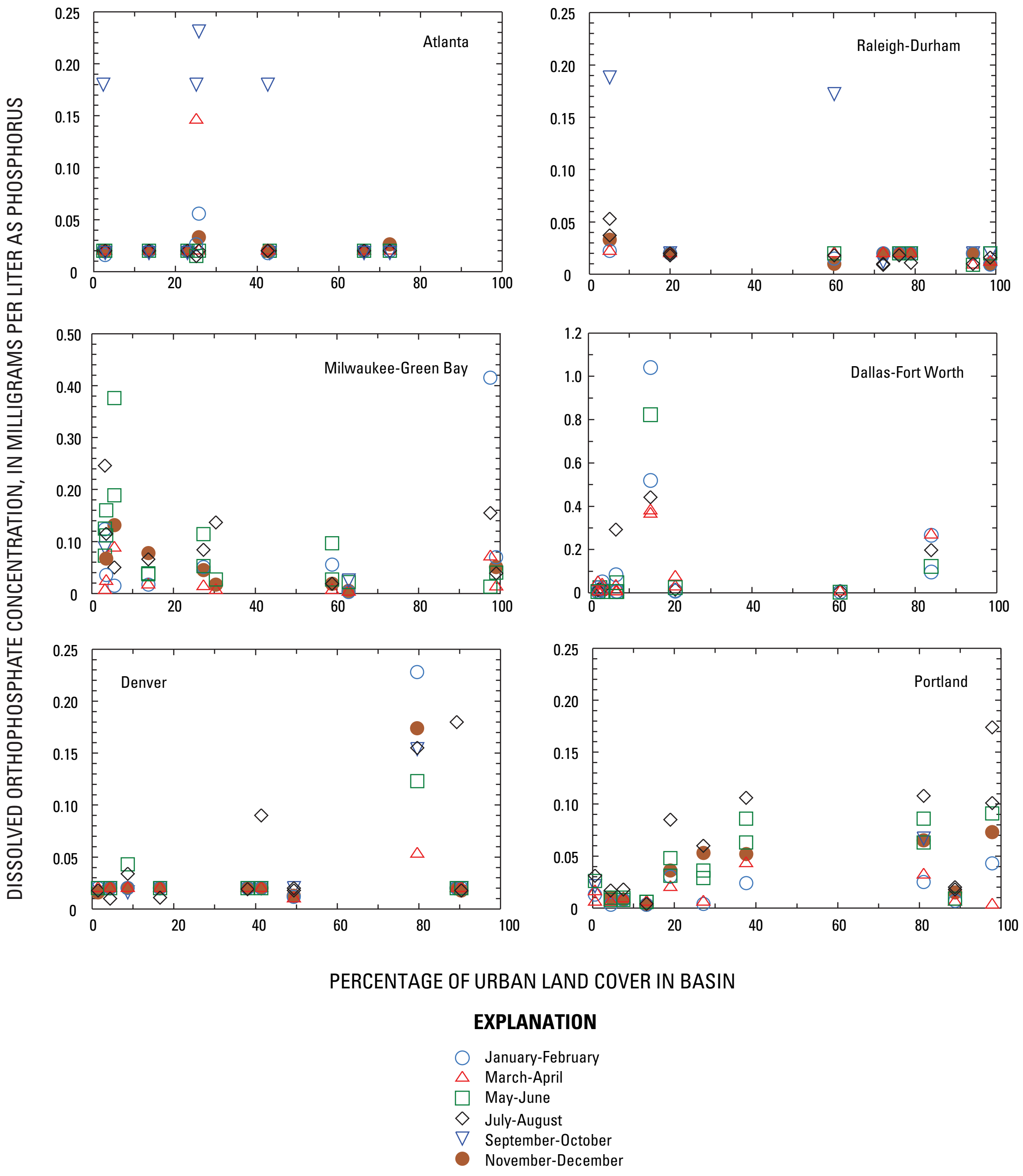

Figure 1.4. Bimonthly dissolved orthophosphate concentrations compared to the percentage of urban land cover in the basin.

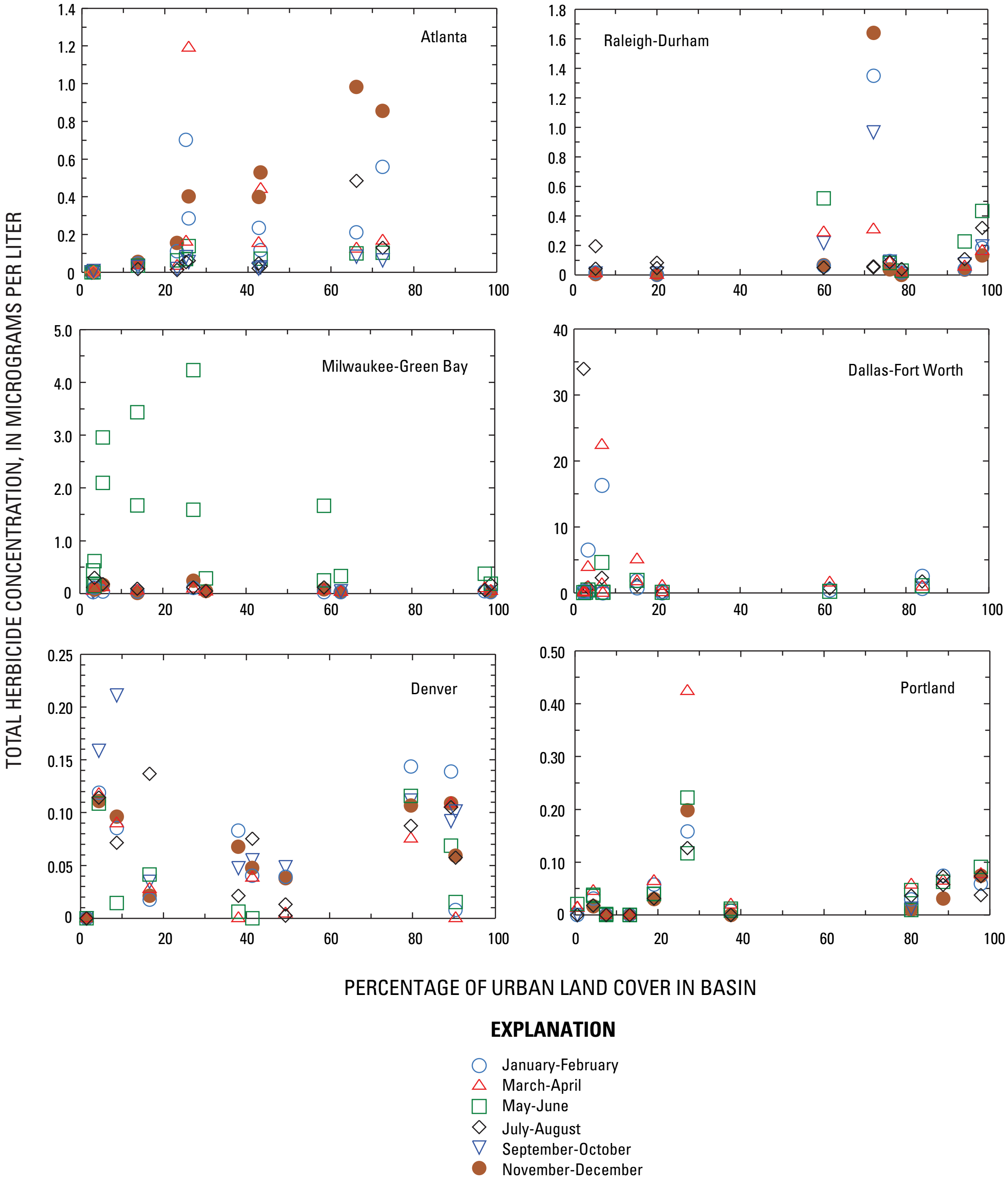

Figure 1.5. Bimonthly total herbicide concentrations compared to the percentage of urban land cover in the basin.

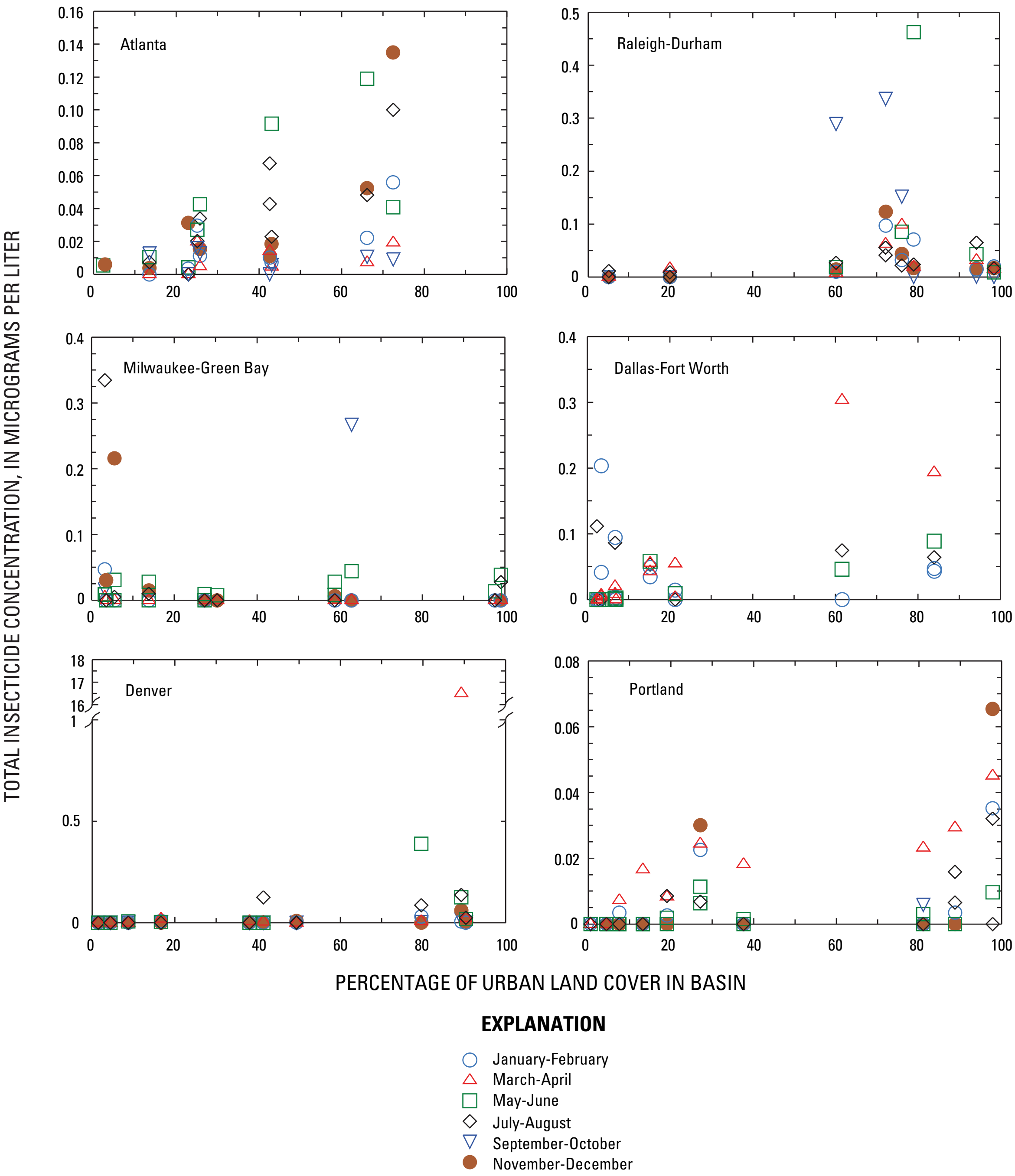

Figure 1.6. Bimonthly total insecticide concentrations compared to the percentage of urban land cover in the basin.

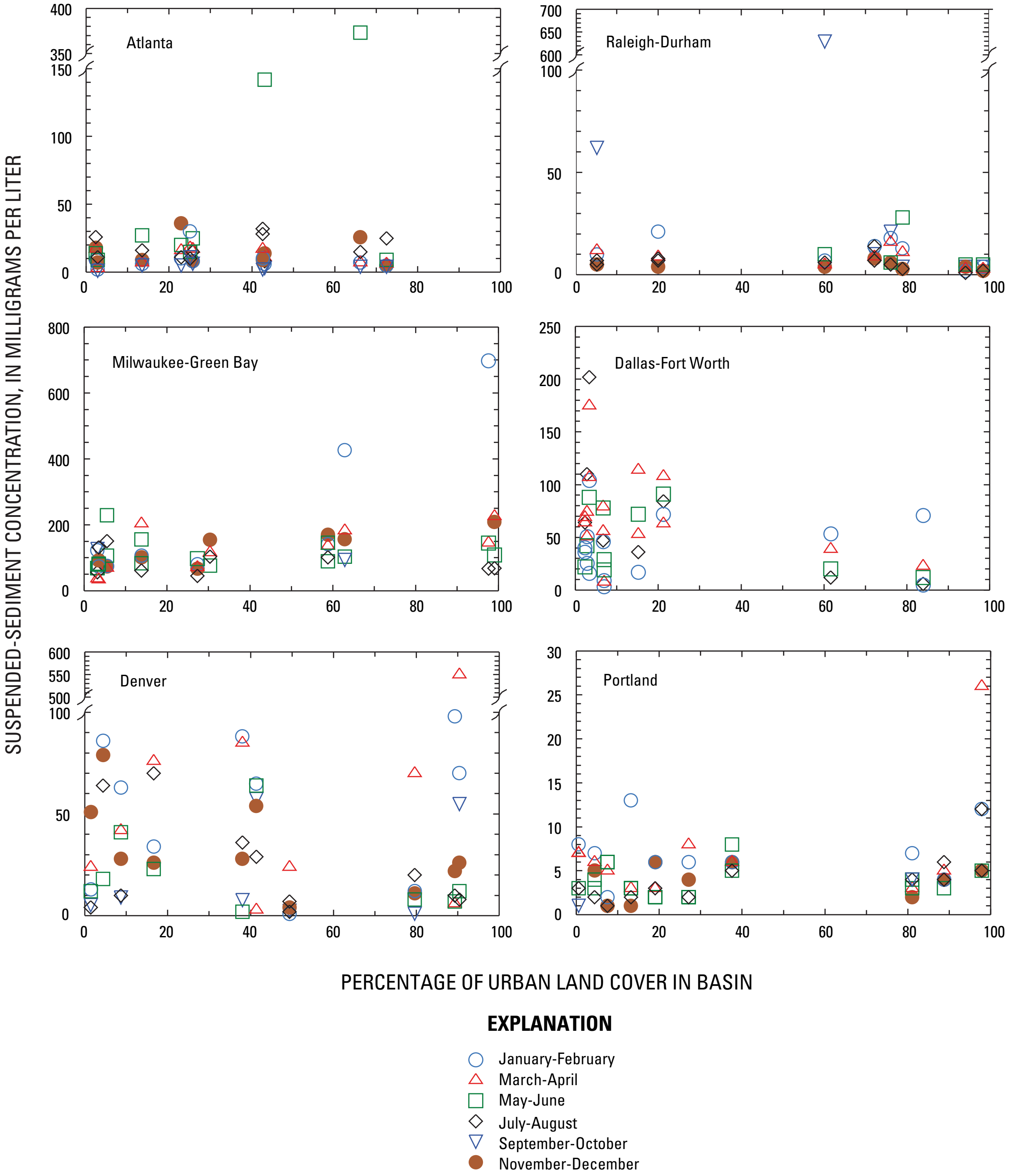

Figure 1.7. Bimonthly suspended-sediment concentrations compared to the percentage of urban land cover in the basin.

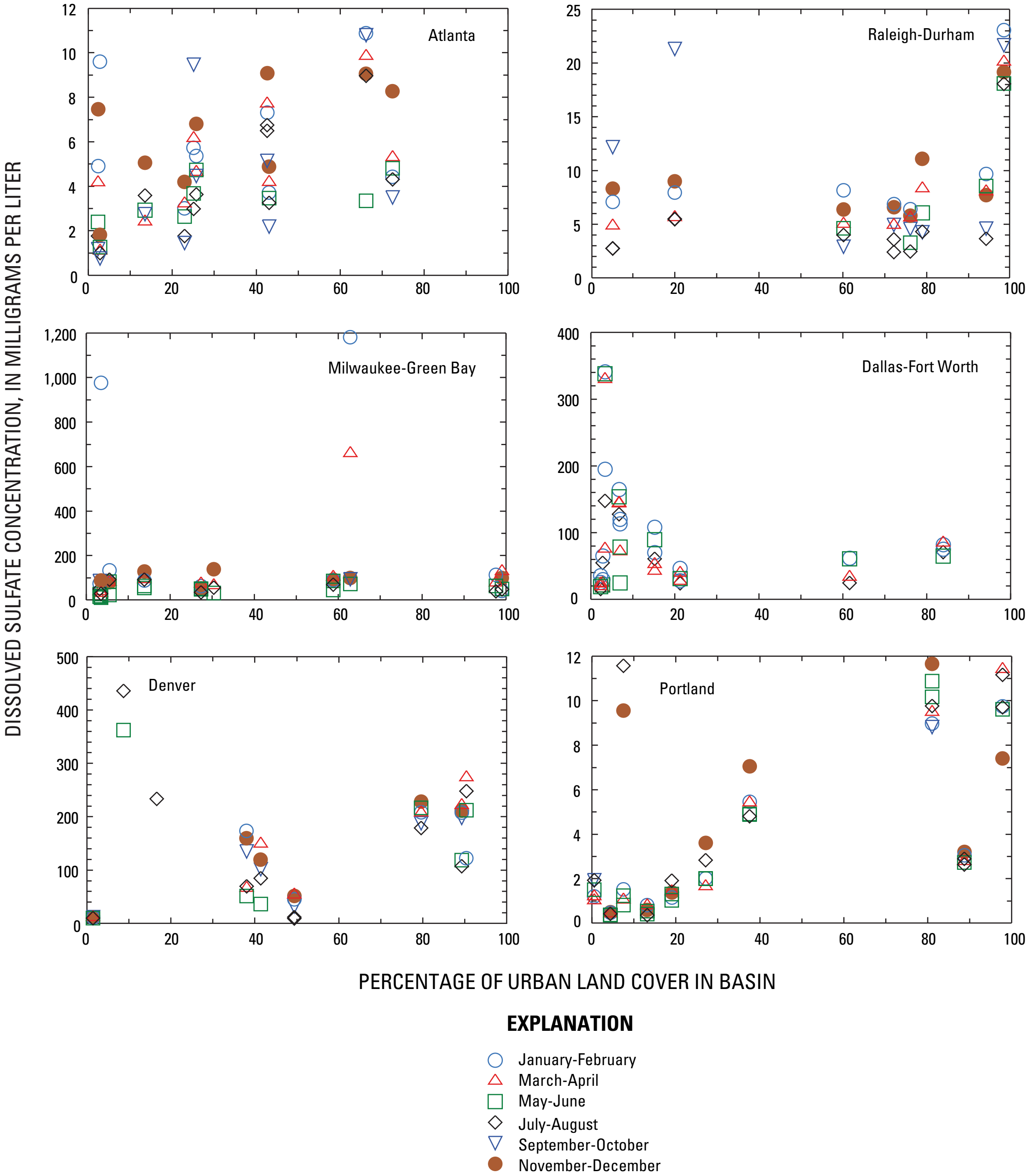

Figure 1.8. Bimonthly dissolved sulfate concentrations compared to the percentage of urban land cover in the basin.

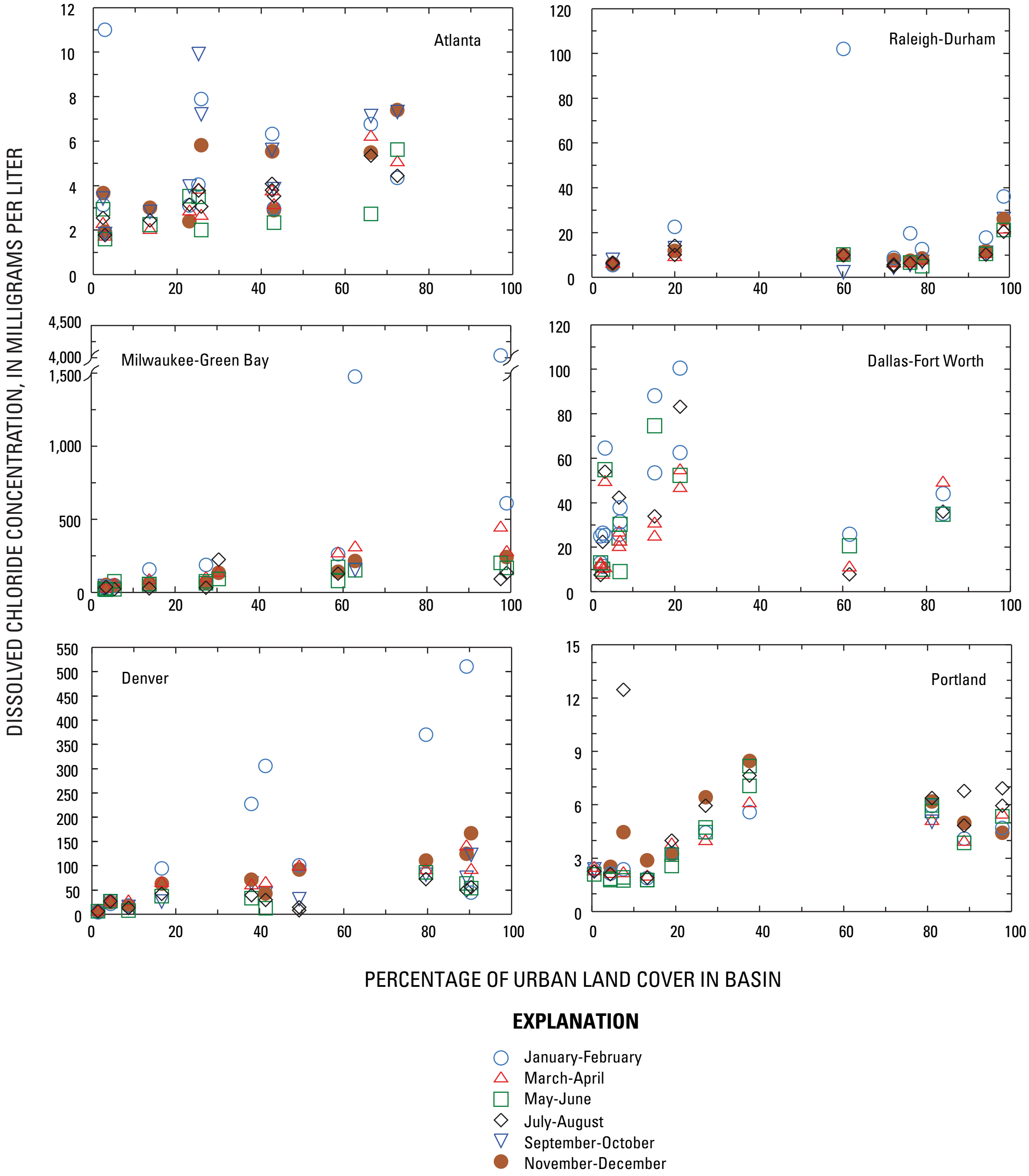

Figure 1.9. Bimonthly dissolved chloride concentrations compared to the percentage of urban land cover in the basin.

Appendix 2. Quality-control data.

Appendix 2a. Concentrations in blank samples.

[Pesticides are in units of micrograms per liter; all other constituents are in units of milligrams per liter. E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; --, not analyzed or not applicable.]

U.S. Geological Survey station number	U.S. Geological Survey station name	Sample date and time	Variable	U.S. Geological Survey parameter code						
				00625	00631	00608	49570	00665	00671	49295
				Parameter name						
				Ammonia plus organic nitrogen, water, unfiltered	Nitrite plus nitrate, water, filtered	Ammonia, water, filtered	Particulate nitrogen, suspended in water	Phosphorus, water, unfiltered	Orthophosphate, water, filtered	1-Naphthol, water, filtered, recoverable
Atlanta										
02347748	Auchumpkee Creek at Allen Road near Roberta, Ga.	2003-03-12 1332	blank	<0.1	<0.06	<0.04	--	<0.004	<0.018	--
02347748	Auchumpkee Creek at Allen Road near Roberta, Ga.	2003-09-16 1247	blank	--	--	--	<0.022	--	--	<0.0882
02217471	Beech Creek at State Road 211near Statham, Ga.	2003-09-18 1502	blank	<0.1	<0.06	<0.04	--	<0.004	<0.018	--
02338375	Centralhatchee Creek Armstrong Mill Road, Centralhatchee, Ga.	2003-03-13 0920	blank	--	--	--	<0.022	--	--	<0.0882
02337395	Dog River at North Helton Road near Winston, Ga.	2003-04-02 1217	blank	--	--	--	<0.022	--	--	--
02340282	House Creek at Georgia State Highway 103 near Whitesville, Ga	2003-09-16 1332	blank	--	--	--	<0.022	--	--	<0.0882
02335910	Rottenwood Creek (Interstate North Parkway) near Smyrna, Ga.	2003-03-14 1002	blank	<0.1	<0.06	<0.04	--	<0.004	<0.018	--
02344480	Shoal Creek near Griffin, Ga.	2003-05-21 1402	blank	--	--	--	<0.022	--	--	<0.0882
02344480	Shoal Creek near Griffin, Ga.	2003-07-18 1232	blank	--	--	--	<0.022	--	--	<0.0882
02335870	Sope Creek near Marietta, Ga.	2003-05-13 1402	blank	--	--	--	<0.022	--	--	<0.0882
Raleigh-Durham										
0208726995	Hare Snipe Creek at State Road 1822 near Leesville, N.C.	2003-01-24 1401	blank	<0.1	<0.06	<0.04	<0.022	E 0.0024	<0.018	<0.0882
0209517912	North Buffalo Creek at Greensboro, N.C.	2003-07-09 0831	blank	--	--	--	<0.022	--	--	<0.0882
0209697900	Pokeberry Creek near Pittsboro, N.C.	2003-07-01 1131	blank	--	--	--	<0.022	--	--	<0.0882
0208726370	Richlands Creek at Schenk Forest near Cary, N.C.	2003-06-30 0901	blank	--	--	--	<0.022	--	--	--
0209647280	Service Creek above Dry Creek at Burlington, N.C.	2003-07-10 0931	blank	--	--	--	<0.022	--	--	<0.0882
02087580	Swift Creek near Apex, N.C.	2002-10-17 1332	blank	0.12	<0.06	<0.04	<0.022	E 0.0022	<0.018	<0.0882
02087580	Swift Creek near Apex, N.C.	2003-02-11 0846	blank	--	--	--	--	--	--	<0.0882
02087580	Swift Creek near Apex, N.C.	2003-02-11 0847	blank	--	--	--	--	--	--	<0.0882
0209750881	Wilson Creek at Mouth near Chapel Hill, N.C.	2003-02-20 0931	blank	0.182	<0.06	<0.04	<0.022	E 0.017	<0.018	<0.0882
Milwaukee-Green Bay										
04085322	Devils River at Rosencrans Road near Maribel, Wis.	2004-08-26 1415	blank	--	<0.06	<0.04	<0.022	<0.004	<0.006	<0.0882
055437901	Fox River at River Road near Sussex, Wis.	2004-08-25 0745	blank	--	<0.06	<0.04	<0.022	<0.004	<0.006	<0.0882
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-02-03 1319	blank	--	<0.06	<0.04	--	--	<0.006	--
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-04-14 0939	blank	--	--	--	<0.022	--	--	--
04087204	Oak Creek at South Milwaukee, Wis.	2003-11-04 0944	blank	--	--	--	--	--	--	--
04087204	Oak Creek at South Milwaukee, Wis.	2003-12-01 0959	blank	--	<0.06	<0.04	--	--	<0.018	--
04087204	Oak Creek at South Milwaukee, Wis.	2004-06-01 1009	blank	--	<0.06	<0.04	--	--	<0.018	--
04086699	Pigeon Creek at Williamsburg Drive at Theinsville, Wis.	2004-08-23 0919	blank	--	--	--	<0.022	--	--	<0.0882
04087258	Pike River at County Highway A near Kenosha, Wis.	2004-06-16 1839	blank	--	<0.06	<0.04	<0.022	<0.004	<0.006	<0.0882
Dallas-Fort Worth										
08052740	Doe Branch at Fishtrap Road near Prosper, Tex.	2004-04-20 0955	blank	--	--	--	<0.022	--	--	--
08052740	Doe Branch at Fishtrap Road near Prosper, Tex.	4/30/2004 0855	blank	--	--	--	<0.022	--	--	--
08049955	Fish Creek at Belt Line Road, Grand Prairie, Tex.	2004-01-30 1019	blank	--	<0.06	<0.04	<0.022	<0.004	<0.006	<0.0882
08049490	Johnson Creek near Duncan Perry Road, Grand Prairie, Tex.	2004-01-30 0929	blank	--	<0.06	<0.04	<0.022	<0.004	<0.006	<0.0882
08063565	Mill Creek at Lowell Road near Milford, Tex.	2003-11-17 1145	blank	--	--	--	<0.022	--	--	--
08063555	South Fork Chambers Creek near Creek 102 near Maypearl, Tex.	2004-01-06 0955	blank	--	--	--	<0.022	--	--	<0.0882
08063595	South Prong Creek at Farm to Market 876 near Waxahachie, Tex.	2004-05-27 1014	blank	--	<0.06	<0.04	<0.022	<0.004	<0.006	<0.0882
08064695	Tehuacana Creek at Rural Road 27 near Wortham, Tex.	2004-05-03 1159	blank	--	--	--	--	--	--	<0.0882
08064695	Tehuacana Creek at Rural Road 27 near Wortham, Tex.	2004-05-27 1029	blank	--	<0.06	<0.04	<0.022	<0.004	<0.006	<0.0882
08057200	White Rock Creek at Greenville Avenue, Dallas, Tex.	2004-05-06 1029	blank	--	<0.06	<0.04	<0.022	<0.004	<0.006	<0.0882
Denver										
413659104370001	Bear Creek above Little Bear Creek near Phillips, Wyo.	2002-10-25 1140	blank	--	--	--	<0.022	--	--	<0.0882
393948105053501	Bear Creek below Estes Road at Lakewood, Colo.	2003-08-12 1040	blank	<0.1	<0.06	<0.04	--	<0.004	<0.018	--
06713500	Cherry Creek at Denver, Colo.	2002-10-09 0959	blank	--	--	--	--	--	--	<0.0882
06713500	Cherry Creek at Denver, Colo.	2002-10-09 1000	blank	--	--	--	<0.022	--	--	<0.0882
395707105100401	Coal Creek above McCaslin Road at Superior, Colo.	2003-06-17 0930	blank	--	--	--	<0.022	--	--	<0.0882
393613104511401	Cottonwood Creek above Newark Way at Greenwood Village, Colo.	2003-08-06 0950	blank	<0.1	<0.06	<0.04	--	<0.004	<0.018	--
410714104480101	Crow Creek above Morrie Avenue at Cheyenne, Wyo.	2003-08-19 1001	blank	--	--	--	<0.022	--	--	--
400855105090501	Dry Creek below Airport Road near Longmont, Colo.	2003-04-01 0950	blank	--	--	--	<0.022	--	--	--
403048105042701	Fossil Creek at College Avenue at Fort Collins, Colo.	2003-02-11 1220	blank	--	--	--	<0.022	--	--	--
403048105042701	Fossil Creek at College Avenue at Fort Collins, Colo.	2003-04-17 1220	blank	--	--	--	--	--	--	--
400810105071301	Left Hand Creek above Pike Road at Longmont, Colo.	2003-06-19 1000	blank	<0.1	<0.06	<0.04	--	<0.004	<0.018	--
394919105074601	Ralston Creek above Simms at Arvada, Colo.	2003-08-19 0840	blank	--	--	--	<0.022	--	--	--
395554105085601	Rock Creek above Rock Creek Parkway at Superior, Colo.	2003-06-17 1330	blank	--	--	--	--	--	--	--
Portland										
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1258	blank	--	<0.06	<0.04	<0.022	<0.004	<0.006	<0.0882
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1208	blank	--	<0.06	<0.04	<0.022	<0.004	<0.006	<0.0882
14205400	East Fork Dairy Creek near Meacham Corner, Oreg.	2004-04-29 1228	blank	--	--	--	<0.022	--	--	--
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1158	blank	--	<0.06	<0.04	<0.022	<0.004	<0.006	<0.0882
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1158	blank	--	<0.06	<0.04	<0.022	<0.004	<0.006	<0.0882
454510122424900	Whipple Creek near Salmon Creek, Wash.	2004-06-28 1148	blank	--	<0.06	<0.04	<0.022	<0.004	<0.006	<0.0882

Appendix 2. Quality-control data.

Appendix 2a. Concentrations in blank samples.—Continued

[Pesticides are in units of micrograms per liter; all other constituents are in units of milligrams per liter. E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; --, not analyzed or not applicable.]

U.S. Geological Survey parameter code										
82660	**61615**	**61618**	**04040**	**61620**	**61625**	**61633**	**49260**	**46342**	**39632**	**61635**
Parameter name										
2,6-Diethylaniline, water, filtered, re coverable	**2-[(2-Ethyl-6-methylphenyl)-amino]-1-propanol, water, filtered, recoverable**	**2-Chloro-2′,6′-diethylacetanilide, water, filtered, recoverable**	**2-Chloro-4-isopropylamino-6-amino-s-triazine, water, filtered, recoverable**	**2-Ethyl-6-methylaniline, water, filtered, recoverable**	**3,4-Dichloroaniline, water, filtered, recoverable**	**4-Chloro-2-methylphenol, water, filtered, recoverable**	**Acetochlor, water, filtered, recoverable**	**Alachlor, water, filtered, recoverable**	**Atrazine, water, filtered, recoverable**	**Azinphos-methyl oxygen analog, water, filtered, recoverable**
Atlanta										
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<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
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<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
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<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
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<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
<0.006	--	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
Raleigh-Durham										
<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
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<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.125
--	<0.1256	<0.005	--	<0.0045	<0.0045	<0.0056	--	--	--	<0.125
<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
Milwaukee-Green Bay										
<0.006	--	<0.005	<0.006	<0.0045	<0.0045	<0.0057	<0.006	<0.0045	<0.007	<0.07
<0.006	--	<0.005	<0.006	<0.0045	<0.0045	<0.0057	<0.006	<0.0045	<0.007	<0.07
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<0.006	--	<0.005	<0.006	<0.0045	<0.0045	<0.0057	<0.006	<0.0045	<0.007	<0.07
<0.006	--	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
Dallas-Fort Worth										
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<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.006	<0.006	<0.0045	<0.007	<0.016
<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.006	<0.006	<0.0045	<0.007	<0.016
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<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.006	<0.006	<0.0045	<0.007	<0.016
<0.006	--	<0.005	<0.006	<0.0045	<0.0045	<0.006	<0.006	<0.0045	<0.007	<0.016
<0.006	--	<0.005	<0.006	<0.0045	<0.0045	<0.006	<0.006	<0.0045	<0.007	<0.016
<0.006	--	<0.005	<0.006	<0.0045	<0.0045	<0.006	<0.006	<0.0045	<0.007	<0.016
<0.006	--	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
Denver										
<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
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<0.006	--	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
<0.006	--	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
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Portland										
<0.006	--	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016
<0.006	--	<0.005	<0.006	<0.0045	<0.0045	<0.0057	<0.006	<0.0045	<0.007	<0.07
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<0.006	--	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.031
<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.031
<0.006	--	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016

Appendix 2. Quality-control data.

Appendix 2a. Concentrations in blank samples.—Continued

[Pesticides are in units of micrograms per liter; all other constituents are in units of milligrams per liter. E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; --, not analyzed or not applicable.]

U.S. Geological Survey station number	U.S. Geological Survey station name	Sample date and time	Variable	U.S. Geological Survey parameter code						
				82686	82673	82680	61636	38933	82687	61585
				Parameter name						
				Azinphos-methyl, water, filtered, recoverable	Benflura-lin, water, filtered, recoverable	Carbaryl, water, filtered, recoverable	Chlorpyrifos oxygen analog, water, filtered, recoverable	Chlorpyrifos, water, filtered, recoverable	cis-Permethrin, water, filtered, recoverable	Cyfluthrin, water, filtered, recoverable
Atlanta										
02347748	Auchumpkee Creek at Allen Road near Roberta, Ga.	2003-03-12 1332	blank	--	--	--	--	--	--	--
02347748	Auchumpkee Creek at Allen Road near Roberta, Ga.	2003-09-16 1247	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
02217471	Beech Creek at State Road 211near Statham, Ga.	2003-09-18 1502	blank	--	--	--	--	--	--	--
02338375	Centralhatchee Creek Armstrong Mill Road, Centralhatchee, Ga.	2003-03-13 0920	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
02337395	Dog River at North Helton Road near Winston, Ga.	2003-04-02 1217	blank	--	--	--	--	--	--	--
02340282	House Creek at Georgia State Highway 103 near Whitesville, Ga	2003-09-16 1332	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
02335910	Rottenwood Creek (Interstate North Parkway) near Smyrna, Ga.	2003-03-14 1002	blank	--	--	--	--	--	--	--
02344480	Shoal Creek near Griffin, Ga.	2003-05-21 1402	blank	<0.05	<0.01	<0.041	<0.0562	E 0.0043	<0.006	<0.008
02344480	Shoal Creek near Griffin, Ga.	2003-07-18 1232	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
02335870	Sope Creek near Marietta, Ga.	2003-05-13 1402	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
Raleigh-Durham										
0208726995	Hare Snipe Creek at State Road 1822 near Leesville, N.C.	2003-01-24 1401	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
0209517912	North Buffalo Creek at Greensboro, N.C.	2003-07-09 0831	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
0209697900	Pokeberry Creek near Pittsboro, N.C.	2003-07-01 1131	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
0208726370	Richlands Creek at Schenk Forest near Cary, N.C.	2003-06-30 0901	blank	--	--	--	--	--	--	--
0209647280	Service Creek above Dry Creek at Burlington, N.C.	2003-07-10 0931	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
02087580	Swift Creek near Apex, N.C.	2002-10-17 1332	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
02087580	Swift Creek near Apex, N.C.	2003-02-11 0846	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
02087580	Swift Creek near Apex, N.C.	2003-02-11 0847	blank	--	--	--	<0.0562	--	--	<0.008
0209750881	Wilson Creek at Mouth near Chapel Hill, N.C.	2003-02-20 0931	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
Milwaukee-Green Bay										
04085322	Devils River at Rosencrans Road near Maribel, Wis.	2004-08-26 1415	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
055437901	Fox River at River Road near Sussex, Wis.	2004-08-25 0745	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-02-03 1319	blank	--	--	--	--	--	--	--
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-04-14 0939	blank	--	--	--	--	--	--	--
04087204	Oak Creek at South Milwaukee, Wis.	2003-11-04 0944	blank	--	--	--	--	--	--	--
04087204	Oak Creek at South Milwaukee, Wis.	2003-12-01 0959	blank	--	--	--	--	--	--	--
04087204	Oak Creek at South Milwaukee, Wis.	2004-06-01 1009	blank	--	--	--	--	--	--	--
04086699	Pigeon Creek at Williamsburg Drive at Theinsville, Wis.	2004-08-23 0919	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
04087258	Pike River at County Highway A near Kenosha, Wis.	2004-06-16 1839	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
Dallas-Fort Worth										
08052740	Doe Branch at Fishtrap Road near Prosper, Tex.	2004-04-20 0955	blank	--	--	--	--	--	--	--
08052740	Doe Branch at Fishtrap Road near Prosper, Tex.	4/30/2004 0855	blank	--	--	--	--	--	--	--
08049955	Fish Creek at Belt Line Road, Grand Prairie, Tex.	2004-01-30 1019	blank	<0.05	<0.01	<0.041	<0.06	<0.005	<0.006	<0.008
08049490	Johnson Creek near Duncan Perry Road, Grand Prairie, Tex.	2004-01-30 0929	blank	<0.05	<0.01	<0.041	<0.06	<0.005	<0.006	<0.008
08063565	Mill Creek at Lowell Road near Milford, Tex.	2003-11-17 1145	blank	--	--	--	--	--	--	--
08063555	South Fork Chambers Creek near Creek 102 near Maypearl, Tex.	2004-01-06 0955	blank	<0.05	<0.01	<0.041	<0.06	<0.005	<0.006	<0.008
08063595	South Prong Creek at Farm to Market 876 near Waxahachie, Tex.	2004-05-27 1014	blank	<0.05	<0.01	<0.041	<0.06	<0.005	<0.006	<0.008
08064695	Tehuacana Creek at Rural Road 27 near Wortham, Tex.	2004-05-03 1159	blank	<0.05	<0.01	<0.041	<0.06	<0.005	<0.006	<0.008
08064695	Tehuacana Creek at Rural Road 27 near Wortham, Tex.	2004-05-27 1029	blank	<0.05	<0.01	<0.041	<0.06	<0.005	<0.006	<0.008
08057200	White Rock Creek at Greenville Avenue, Dallas, Tex.	2004-05-06 1029	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
Denver										
413659104370001	Bear Creek above Little Bear Creek near Phillips, Wyo.	2002-10-25 1140	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
393948105053501	Bear Creek below Estes Road at Lakewood, Colo.	2003-08-12 1040	blank	--	--	--	--	--	--	--
06713500	Cherry Creek at Denver, Colo.	2002-10-09 0959	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
06713500	Cherry Creek at Denver, Colo.	2002-10-09 1000	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
395707105100401	Coal Creek above McCaslin Road at Superior, Colo.	2003-06-17 0930	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
393613104511401	Cottonwood Creek above Newark Way at Greenwood Village, Colo.	2003-08-06 0950	blank	--	--	--	--	--	--	--
410714104480101	Crow Creek above Morrie Avenue at Cheyenne, Wyo.	2003-08-19 1001	blank	--	--	--	--	--	--	--
400855105090501	Dry Creek below Airport Road near Longmont, Colo.	2003-04-01 0950	blank	--	--	--	--	--	--	--
403048105042701	Fossil Creek at College Avenue at Fort Collins, Colo.	2003-02-11 1220	blank	--	--	--	--	--	--	--
403048105042701	Fossil Creek at College Avenue at Fort Collins, Colo.	2003-04-17 1220	blank	--	--	--	--	--	--	--
400810105071301	Left Hand Creek above Pike Road at Longmont, Colo.	2003-06-19 1000	blank	--	--	--	--	--	--	--
394919105074601	Ralston Creek above Simms at Arvada, Colo.	2003-08-19 0840	blank	--	--	--	--	--	--	--
395554105085601	Rock Creek above Rock Creek Parkway at Superior, Colo.	2003-06-17 1330	blank	--	--	--	--	--	--	--
Portland										
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1258	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1208	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
14205400	East Fork Dairy Creek near Meacham Corner, Oreg.	2004-04-29 1228	blank	--	--	--	--	--	--	--
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1158	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1158	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008
454510122424900	Whipple Creek near Salmon Creek, Wash.	2004-06-28 1148	blank	<0.05	<0.01	<0.041	<0.0562	<0.005	<0.006	<0.008

Appendix 2. Quality-control data.

Appendix 2a. Concentrations in blank samples.—Continued

[Pesticides are in units of micrograms per liter; all other constituents are in units of milligrams per liter. E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; --, not analyzed or not applicable.]

U.S. Geological Survey parameter code													
61586	**82682**	**62170**	**62170**	**61638**	**39572**	**38454**	**39381**	**82662**	**61644**	**82346**	**61645**	**61646**	**61591**
Parameter name													
Cypermethrin, water, filtered, recoverable	**DCPA, water, filtered, recoverable**	**Desulfinyl fipronil, water, filtered, re-coverable**	**Desulfinyl fipronil, water, filtered, recoverable**	**Diazinon oxygen analog, water, filtered, recoverable**	**Diazinon, water, filtered, recoverable**	**Dicrotophos, water, filtered, recoverable**	**Dieldrin, water, filtered, recoverable**	**Dimethoate, water, filtered, recoverable**	**Ethion monoxon, water, filtered, recoverable**	**Ethion, water, filtered, recover-able**	**Fenamiphos sulfone, water, filtered, recover-able**	**Fenamiphos sulfoxide, water, filtered, re-coverable**	**Fenami-phos, water, filtered, re-coverable**
Atlanta													
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<0.0086	<0.003	<0.004	<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
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<0.0086	<0.003	<0.004	<0.004	<0.04	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
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<0.0086	<0.003	<0.004	<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
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<0.0086	<0.003	<0.004	<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.125	<0.029
<0.0086	<0.003	<0.004	<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
<0.0086	<0.003	<0.004	<0.004	--	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
Raleigh-Durham													
<0.0086	<0.003	<0.004	<0.004	<0.04	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
<0.0086	<0.003	<0.004	<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
<0.0086	<0.003	<0.004	<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
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<0.0086	<0.003	<0.004	<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
<0.0086	<0.003	<0.004	<0.004	--	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
<0.0086	<0.003	<0.004	<0.004	--	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	--	<0.029
<0.0086	--	--	--	--	--	<0.0843	--	<0.0061	<0.0336	<0.004	<0.0077	--	<0.029
<0.0086	<0.003	<0.004	<0.004	<0.04	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
Milwaukee-Green Bay													
<0.0086	<0.003	<0.012	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.002	<0.004	<0.0491	<0.0387	<0.029
<0.0086	<0.003	<0.012	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.002	<0.004	<0.0491	<0.0387	<0.029
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<0.0086	<0.003	<0.012	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.002	<0.004	<0.0491	<0.0387	<0.029
<0.0086	<0.003	<0.012	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
Dallas-Fort Worth													
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<0.0086	<0.003	<0.012	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
<0.0086	<0.003	<0.012	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
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<0.0086	<0.003	<0.012	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
<0.0086	<0.003	<0.012	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
<0.0086	<0.003	<0.012	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
<0.0086	<0.003	<0.012	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
<0.0086	<0.003	<0.012	<0.012	--	<0.005	<0.0843	<0.009	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
Denver													
<0.0086	<0.003	<0.004	<0.004	<0.04	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
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<0.0086	<0.003	<0.004	<0.004	--	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
<0.0086	<0.003	<0.004	<0.004	--	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
<0.0086	<0.003	<0.004	<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
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Portland													
<0.0086	<0.003	<0.012	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
<0.0086	<0.003	<0.012	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.002	<0.004	<0.0491	<0.0387	<0.029
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<0.0086	<0.003	<0.012	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
<0.0086	<0.003	<0.012	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
<0.0086	<0.003	<0.012	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029

Appendix 2. Quality-control data.

Appendix 2a. Concentrations in blank samples.—Continued

[Pesticides are in units of micrograms per liter; all other constituents are in units of milligrams per liter. E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; --, not analyzed or not applicable.]

U.S. Geological Survey station number	U.S. Geological Survey station name	Sample date and time	Variable	U.S. Geological Survey parameter code					
				62169	62167	62168	62166	61649	04095
				Parameter name					
				Desulfinylfipronil amide, water, filtered, recoverable	Fipronil sulfide, water, filtered, recoverable	Fipronil sulfone, water, filtered, recoverable	Fipronil, water, filtered, recoverable	Fonofos oxygen analog, water, filtered, recoverable	Fonofos, water, filtered, recoverable
Atlanta									
02347748	Auchumpkee Creek at Allen Road near Roberta, Ga.	2003-03-12 1332	blank	--	--	--	--	--	--
02347748	Auchumpkee Creek at Allen Road near Roberta, Ga.	2003-09-16 1247	blank	<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027
02217471	Beech Creek at State Road 211near Statham, Ga.	2003-09-18 1502	blank	--	--	--	--	--	--
02338375	Centralhatchee Creek Armstrong Mill Road, Centralhatchee, Ga.	2003-03-13 0920	blank	<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027
02337395	Dog River at North Helton Road near Winston, Ga.	2003-04-02 1217	blank	--	--	--	--	--	--
02340282	House Creek at Georgia State Highway 103 near Whitesville, Ga	2003-09-16 1332	blank	<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027
02335910	Rottenwood Creek (Interstate North Parkway) near Smyrna, Ga.	2003-03-14 1002	blank	--	--	--	--	--	--
02344480	Shoal Creek near Griffin, Ga.	2003-05-21 1402	blank	<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027
02344480	Shoal Creek near Griffin, Ga.	2003-07-18 1232	blank	<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027
02335870	Sope Creek near Marietta, Ga.	2003-05-13 1402	blank	<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027
Raleigh-Durham									
0208726995	Hare Snipe Creek at State Road 1822 near Leesville, N.C.	2003-01-24 1401	blank	<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027
0209517912	North Buffalo Creek at Greensboro, N.C.	2003-07-09 0831	blank	<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027
0209697900	Pokeberry Creek near Pittsboro, N.C.	2003-07-01 1131	blank	<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027
0208726370	Richlands Creek at Schenk Forest near Cary, N.C.	2003-06-30 0901	blank	--	--	--	--	--	--
0209647280	Service Creek above Dry Creek at Burlington, N.C.	2003-07-10 0931	blank	<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027
02087580	Swift Creek near Apex, N.C.	2002-10-17 1332	blank	<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027
02087580	Swift Creek near Apex, N.C.	2003-02-11 0846	blank	<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027
02087580	Swift Creek near Apex, N.C.	2003-02-11 0847	blank	--	--	--	--	<0.0021	--
0209750881	Wilson Creek at Mouth near Chapel Hill, N.C.	2003-02-20 0931	blank	<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027
Milwaukee-Green Bay									
04085322	Devils River at Rosencrans Road near Maribel, Wis.	2004-08-26 1415	blank	<0.029	<0.013	<0.024	<0.016	<0.0029	<0.0027
055437901	Fox River at River Road near Sussex, Wis.	2004-08-25 0745	blank	<0.029	<0.013	<0.024	<0.016	<0.0029	<0.0027
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-02-03 1319	blank	--	--	--	--	--	--
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-04-14 0939	blank	--	--	--	--	--	--
04087204	Oak Creek at South Milwaukee, Wis.	2003-11-04 0944	blank	--	--	--	--	--	--
04087204	Oak Creek at South Milwaukee, Wis.	2003-12-01 0959	blank	--	--	--	--	--	--
04087204	Oak Creek at South Milwaukee, Wis.	2004-06-01 1009	blank	--	--	--	--	--	--
04086699	Pigeon Creek at Williamsburg Drive at Theinsville, Wis.	2004-08-23 0919	blank	<0.029	<0.013	<0.024	<0.016	<0.0029	<0.0027
04087258	Pike River at County Highway A near Kenosha, Wis.	2004-06-16 1839	blank	<0.029	<0.013	<0.024	<0.016	<0.0021	<0.0027
Dallas-Fort Worth									
08052740	Doe Branch at Fishtrap Road near Prosper, Tex.	2004-04-20 0955	blank	--	--	--	--	--	--
08052740	Doe Branch at Fishtrap Road near Prosper, Tex.	4/30/2004 0855	blank	--	--	--	--	--	--
08049955	Fish Creek at Belt Line Road, Grand Prairie, Tex.	2004-01-30 1019	blank	<0.029	<0.013	<0.024	<0.016	<0.0021	<0.0027
08049490	Johnson Creek near Duncan Perry Road, Grand Prairie, Tex.	2004-01-30 0929	blank	<0.029	<0.013	<0.024	<0.016	<0.0021	<0.0027
08063565	Mill Creek at Lowell Road near Milford, Tex.	2003-11-17 1145	blank	--	--	--	--	--	--
08063555	South Fork Chambers Creek near Creek 102 near Maypearl, Tex.	2004-01-06 0955	blank	<0.029	<0.013	<0.024	<0.016	<0.0021	<0.0027
08063595	South Prong Creek at Farm to Market 876 near Waxahachie, Tex.	2004-05-27 1014	blank	<0.029	<0.013	<0.024	<0.016	<0.0021	<0.0027
08064695	Tehuacana Creek at Rural Road 27 near Wortham, Tex.	2004-05-03 1159	blank	<0.029	<0.013	<0.024	<0.016	<0.0021	<0.0027
08064695	Tehuacana Creek at Rural Road 27 near Wortham, Tex.	2004-05-27 1029	blank	<0.029	<0.013	<0.024	<0.016	<0.0021	<0.0027
08057200	White Rock Creek at Greenville Avenue, Dallas, Tex.	2004-05-06 1029	blank	<0.029	<0.013	<0.024	<0.016	<0.0021	<0.0027
Denver									
413659104370001	Bear Creek above Little Bear Creek near Phillips, Wyo.	2002-10-25 1140	blank	<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027
393948105053501	Bear Creek below Estes Road at Lakewood, Colo.	2003-08-12 1040	blank	--	--	--	--	--	--
06713500	Cherry Creek at Denver, Colo.	2002-10-09 0959	blank	<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027
06713500	Cherry Creek at Denver, Colo.	2002-10-09 1000	blank	<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027
395707105100401	Coal Creek above McCaslin Road at Superior, Colo.	2003-06-17 0930	blank	<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027
393613104511401	Cottonwood Creek above Newark Way at Greenwood Village, Colo.	2003-08-06 0950	blank	--	--	--	--	--	--
410714104480101	Crow Creek above Morrie Avenue at Cheyenne, Wyo.	2003-08-19 1001	blank	--	--	--	--	--	--
400855105090501	Dry Creek below Airport Road near Longmont, Colo.	2003-04-01 0950	blank	--	--	--	--	--	--
403048105042701	Fossil Creek at College Avenue at Fort Collins, Colo.	2003-02-11 1220	blank	--	--	--	--	--	--
403048105042701	Fossil Creek at College Avenue at Fort Collins, Colo.	2003-04-17 1220	blank	--	--	--	--	--	--
400810105071301	Left Hand Creek above Pike Road at Longmont, Colo.	2003-06-19 1000	blank	--	--	--	--	--	--
394919105074601	Ralston Creek above Simms at Arvada, Colo.	2003-08-19 0840	blank	--	--	--	--	--	--
395554105085601	Rock Creek above Rock Creek Parkway at Superior, Colo.	2003-06-17 1330	blank	--	--	--	--	--	--
Portland									
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1258	blank	<0.029	<0.013	<0.024	<0.016	<0.0021	<0.0027
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1208	blank	<0.029	<0.013	<0.024	<0.016	<0.0029	<0.0027
14205400	East Fork Dairy Creek near Meacham Corner, Oreg.	2004-04-29 1228	blank	--	--	--	--	--	--
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1158	blank	<0.029	<0.013	<0.024	<0.016	<0.0021	<0.0027
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1158	blank	<0.029	<0.013	<0.024	<0.016	<0.0021	<0.0027
454510122424900	Whipple Creek near Salmon Creek, Wash.	2004-06-28 1148	blank	--	--	--	--	<0.0021	<0.0027

Appendix 2. Quality-control data.

Appendix 2a. Concentrations in blank samples.—Continued

[Pesticides are in units of micrograms per liter; all other constituents are in units of milligrams per liter. E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; --, not analyzed or not applicable.]

U.S. Geological Survey													
04025	**61593**	**61594**	**61652**	**39532**	**61596**	**61598**	**61664**	**82667**	**39415**	**82630**	**61599**	**82683**	**61666**
Parameter name													
Hexazinone, water, filtered, recoverable	**Iprodione, water, filtered, recoverable**	**Isofenphos, water, filtered, recoverable**	**Malaoxon, water, filtered, recoverable**	**Malathion, water, filtered, recoverable**	**Metalaxyl, water, filtered, recoverable**	**Methidathion, water, filtered, recoverable**	**Methyl paraoxon, water, filtered, recoverable**	**Methyl parathion, water, filtered, recoverable**	**Metolachlor, water, filtered, recoverable**	**Metribuzin, water, filtered, recoverable**	**Myclobutanil, water, filtered, recoverable**	**Pendimethalin, water, filtered, recoverable**	**Phorate oxygen analog, water, filtered, recoverable**
Atlanta													
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<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006	<0.008	<0.022	<0.0973
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--	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006	<0.008	<0.022	<0.0973
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<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006	<0.008	<0.022	<0.0973
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<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006	<0.008	<0.022	<0.0973
<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006	<0.008	<0.022	<0.0973
<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006	<0.008	<0.022	<0.0973
Raleigh-Durham													
--	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006	<0.008	<0.022	<0.0973
<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006	<0.008	<0.022	<0.0973
<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006	<0.008	<0.022	<0.0973
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<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006	<0.008	<0.022	<0.0973
<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006	<0.008	<0.022	<0.0973
<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006	<0.008	<0.022	<0.0973
<0.0129	<1.4223	<0.0034	<0.008	--	<0.0051	<0.0058	<0.0299	--	--	--	<0.008	--	<0.0973
--	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006	<0.008	<0.022	<0.0973
Milwaukee-Green Bay													
<0.0129	<0.387	<0.0034	<0.0298	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006	<0.008	<0.022	<0.1048
<0.0129	<0.387	<0.0034	<0.0298	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006	<0.008	<0.022	<0.1048
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<0.0129	<0.387	<0.0034	<0.0298	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006	<0.008	<0.022	<0.1048
<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006	<0.008	<0.022	<0.0973
Dallas-Fort Worth													
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<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006	<0.008	<0.022	<0.0973
<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006	<0.008	<0.022	<0.0973
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<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006	<0.008	<0.022	<0.0973
<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006	<0.008	<0.022	<0.0973
<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006	<0.008	<0.022	<0.0973
<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006	<0.008	<0.022	<0.0973
<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006	<0.008	<0.022	<0.0973
Denver													
--	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006	<0.008	<0.022	<0.0973
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<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006	<0.008	<0.022	<0.0973
<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006	<0.008	<0.022	<0.0973
<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006	<0.008	<0.022	<0.0973
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Portland													
<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006	<0.008	<0.022	<0.0973
<0.0129	<0.387	<0.0034	<0.0298	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006	<0.008	<0.022	<0.1048
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<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006	<0.008	<0.022	<0.0973
<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006	<0.008	<0.022	<0.0973
<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006	<0.008	<0.022	<0.0973

Appendix 2. Quality-control data.

Appendix 2a. Concentrations in blank samples.—Continued

[Pesticides are in units of micrograms per liter; all other constituents are in units of milligrams per liter. E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; --, not analyzed or not applicable.]

U.S. Geological Survey station number	U.S. Geological Survey station name	Sample date and time	Variable	U.S. Geological Survey parameter code				
				82664	61668	61601	04037	04036
				Parameter name				
				Phorate, water, filtered, recoverable	Phosmet oxygen analog, water, filtered, recoverable	Phosmet, water, filtered, recoverable	Prometon, water, filtered, recoverable	Prometryn, water, filtered, recoverable
Atlanta								
02347748	Auchumpkee Creek at Allen Road near Roberta, Ga.	2003-03-12 1332	blank	--	--	--	--	--
02347748	Auchumpkee Creek at Allen Road near Roberta, Ga.	2003-09-16 1247	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
02217471	Beech Creek at State Road 211near Statham, Ga.	2003-09-18 1502	blank	--	--	--	--	--
02338375	Centralhatchee Creek Armstrong Mill Road, Centralhatchee, Ga.	2003-03-13 0920	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
02337395	Dog River at North Helton Road near Winston, Ga.	2003-04-02 1217	blank	--	--	--	--	--
02340282	House Creek at Georgia State Highway 103 near Whitesville, Ga	2003-09-16 1332	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
02335910	Rottenwood Creek (Interstate North Parkway) near Smyrna, Ga.	2003-03-14 1002	blank	--	--	--	--	--
02344480	Shoal Creek near Griffin, Ga.	2003-05-21 1402	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
02344480	Shoal Creek near Griffin, Ga.	2003-07-18 1232	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
02335870	Sope Creek near Marietta, Ga.	2003-05-13 1402	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
Raleigh-Durham								
0208726995	Hare Snipe Creek at State Road 1822 near Leesville, N.C.	2003-01-24 1401	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
0209517912	North Buffalo Creek at Greensboro, N.C.	2003-07-09 0831	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
0209697900	Pokeberry Creek near Pittsboro, N.C.	2003-07-01 1131	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
0208726370	Richlands Creek at Schenk Forest near Cary, N.C.	2003-06-30 0901	blank	--	--	--	--	--
0209647280	Service Creek above Dry Creek at Burlington, N.C.	2003-07-10 0931	blank	<0.011	<0.125	<0.0079	<0.015	<0.0054
02087580	Swift Creek near Apex, N.C.	2002-10-17 1332	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
02087580	Swift Creek near Apex, N.C.	2003-02-11 0846	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
02087580	Swift Creek near Apex, N.C.	2003-02-11 0847	blank	--	<0.0553	<0.0079	--	<0.0054
0209750881	Wilson Creek at Mouth near Chapel Hill, N.C.	2003-02-20 0931	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
Milwaukee-Green Bay								
04085322	Devils River at Rosencrans Road near Maribel, Wis.	2004-08-26 1415	blank	<0.011	<0.0553	<0.0079	<0.005	<0.0054
055437901	Fox River at River Road near Sussex, Wis.	2004-08-25 0745	blank	<0.011	<0.0553	<0.0079	<0.005	<0.0054
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-02-03 1319	blank	--	--	--	--	--
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-04-14 0939	blank	--	--	--	--	--
04087204	Oak Creek at South Milwaukee, Wis.	2003-11-04 0944	blank	--	--	--	--	--
04087204	Oak Creek at South Milwaukee, Wis.	2003-12-01 0959	blank	--	--	--	--	--
04087204	Oak Creek at South Milwaukee, Wis.	2004-06-01 1009	blank	--	--	--	--	--
04086699	Pigeon Creek at Williamsburg Drive at Theinsville, Wis.	2004-08-23 0919	blank	<0.011	<0.0553	<0.0079	<0.005	<0.0054
04087258	Pike River at County Highway A near Kenosha, Wis.	2004-06-16 1839	blank	<0.011	<0.0553	<0.0079	<0.005	<0.0054
Dallas-Fort Worth								
08052740	Doe Branch at Fishtrap Road near Prosper, Tex.	2004-04-20 0955	blank	--	--	--	--	--
08052740	Doe Branch at Fishtrap Road near Prosper, Tex.	4/30/2004 0855	blank	--	--	--	--	--
08049955	Fish Creek at Belt Line Road, Grand Prairie, Tex.	2004-01-30 1019	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
08049490	Johnson Creek near Duncan Perry Road, Grand Prairie, Tex.	2004-01-30 0929	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
08063565	Mill Creek at Lowell Road near Milford, Tex.	2003-11-17 1145	blank	--	--	--	--	--
08063555	South Fork Chambers Creek near Creek 102 near Maypearl, Tex.	2004-01-06 0955	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
08063595	South Prong Creek at Farm to Market 876 near Waxahachie, Tex.	2004-05-27 1014	blank	<0.011	--	<0.0079	<0.015	<0.0054
08064695	Tehuacana Creek at Rural Road 27 near Wortham, Tex.	2004-05-03 1159	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
08064695	Tehuacana Creek at Rural Road 27 near Wortham, Tex.	2004-05-27 1029	blank	<0.011	--	--	<0.015	<0.0054
08057200	White Rock Creek at Greenville Avenue, Dallas, Tex.	2004-05-06 1029	blank	<0.011	<0.0553	<0.0079	<0.005	<0.0054
Denver								
413659104370001	Bear Creek above Little Bear Creek near Phillips, Wyo.	2002-10-25 1140	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
393948105053501	Bear Creek below Estes Road at Lakewood, Colo.	2003-08-12 1040	blank	--	--	--	--	--
06713500	Cherry Creek at Denver, Colo.	2002-10-09 0959	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
06713500	Cherry Creek at Denver, Colo.	2002-10-09 1000	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
395707105100401	Coal Creek above McCaslin Road at Superior, Colo.	2003-06-17 0930	blank	<0.011	<0.0553	<0.0079	<0.015	<0.0054
393613104511401	Cottonwood Creek above Newark Way at Greenwood Village, Colo.	2003-08-06 0950	blank	--	--	--	--	--
410714104480101	Crow Creek above Morrie Avenue at Cheyenne, Wyo.	2003-08-19 1001	blank	--	--	--	--	--
400855105090501	Dry Creek below Airport Road near Longmont, Colo.	2003-04-01 0950	blank	--	--	--	--	--
403048105042701	Fossil Creek at College Avenue at Fort Collins, Colo.	2003-02-11 1220	blank	--	--	--	--	--
403048105042701	Fossil Creek at College Avenue at Fort Collins, Colo.	2003-04-17 1220	blank	--	--	--	--	--
400810105071301	Left Hand Creek above Pike Road at Longmont, Colo.	2003-06-19 1000	blank	--	--	--	--	--
394919105074601	Ralston Creek above Simms at Arvada, Colo.	2003-08-19 0840	blank	--	--	--	--	--
395554105085601	Rock Creek above Rock Creek Parkway at Superior, Colo.	2003-06-17 1330	blank	--	--	--	--	--
Portland								
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1258	blank	<0.011	<0.0553	<0.0079	<0.005	<0.0054
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1208	blank	<0.011	--	<0.0079	<0.005	<0.0054
14205400	East Fork Dairy Creek near Meacham Corner, Oreg.	2004-04-29 1228	blank	--	--	--	--	--
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1158	blank	<0.011	--	<0.0079	<0.005	<0.0054
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1158	blank	<0.011	<0.0553	<0.0079	<0.005	<0.0054
454510122424900	Whipple Creek near Salmon Creek, Wash.	2004-06-28 1148	blank	<0.011	--	--	<0.005	<0.0054

Appendix 2. Quality-control data.

Appendix 2a. Concentrations in blank samples.—Continued

[Pesticides are in units of micrograms per liter; all other constituents are in units of milligrams per liter. E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; --, not analyzed or not applicable.]

U.S. Geological Survey parameter code											
82676	**04035**	**82670**	**61674**	**82675**	**04022**	**04022**	**82661**	**38775**	**80154**	**00945**	**00940**
Parameter name											
Propyzamide, water, filtered, recoverable	**Simazine, water, filtered, recoverable**	**Tebuthiuron, water, filtered, recoverable**	**Terbufos oxygen analog sulfone, water, filtered, recoverable**	**Terbufos, water, filtered, recoverable**	**Terbuthylazine, water, filtered, recoverable**	**Terbuthylazine, water, filtered, recoverable**	**Trifluralin, water, filtered, recoverable**	**Dichlorvos, water, filtered, recoverable**	**Suspended sediment concentration**	**Sulfate, water, filtered**	**Chloride, water, filtered**
Atlanta											
--	--	--	--	--	--	--	--	--	--	<0.18	<0.2
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
--	--	--	--	--	--	--	--	--	--	<0.18	<0.2
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
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<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
--	--	--	--	--	--	--	--	--	--	<0.18	<0.2
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
Raleigh-Durham											
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	<1	<0.18	<0.2
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
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<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	1	<0.18	E 0.19
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
--	--	--	<0.0676	--	<0.0102	<0.0102	--	<0.0118	--	--	--
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
Milwaukee-Green Bay											
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	<1	<0.18	<0.2
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<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	<0.18	E 0.12
Dallas-Fort Worth											
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<0.0041	<0.005	<0.005	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	<0.2	<0.2
<0.0041	<0.005	<0.005	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	<0.2	<0.2
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<0.0041	<0.005	<0.005	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
<0.0041	<0.005	<0.005	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	E 0.1	<0.2
<0.0041	<0.005	<0.005	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
<0.0041	<0.005	<0.005	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	<0.2	<0.2
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
Denver											
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
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<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	--	--
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Portland											
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	<1	<0.18	<0.2
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	<1	<0.18	<0.2
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<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	--	<0.18	<0.2
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	<1	<0.18	<0.2
<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.0102	<0.009	<0.0118	<1	<0.18	<0.2

Appendix 2. Quality-control data.

Appendix 2b. Relative percent difference between replicate samples.—Continued

[Pesticides are in units of micrograms per liter; all other constituents are in units of milligrams per liter. RPD, relative percent difference; E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; --, not analyzed or not applicable.]

U.S. Geological Survey station number	U.S. Geological Survey station name	Sample date and time	Variable	U.S. Geological Survey parameter code 00625	00631	00608	49570	00665	00671
				Parameter name: Ammonia plus organic nitrogen, water, unfiltered	Nitrite plus nitrate, water, filtered	Ammonia, water, filtered	Particulate nitrogen, suspended in water	Phosphorus, water, unfiltered	Ortho-phosphate, water, filtered
Atlanta									
02337395	Dog River at North Helton Road near Winston, Ga.	2003-07-08 1200	replicate	0.171	0.256	0.041	0.068	0.0306	<0.02
02337395	Dog River at North Helton Road near Winston, Ga.	2003-07-08 1207	replicate	--	--	--	--	--	--
			RPD	--	--	--	--	--	--
02346358	Turnpike Creek near Milner, Ga.	2003-09-17 0930	replicate	0.192	0.225	<0.041	0.044	0.0131	<0.018
02346358	Turnpike Creek near Milner, Ga.	2003-09-17 0937	replicate	--	--	--	--	--	--
			RPD	--	--	--	--	--	--
Raleigh-Durham									
0208500600	Strouds Creek at St Marys Road near Hillsborough, N.C.	2003-07-07 0830	replicate	0.221	0.133	<0.04	<0.022	0.0172	<0.02
0208500600	Strouds Creek at St Marys Road near Hillsborough, N.C.	2003-07-07 0831	replicate	--	--	--	<0.022	--	--
			RPD	--	--	--	--	--	--
0208732610	Pigeon House Br at Crabtree Boulevard at Raleigh, N.C.	2002-12-19 1100	replicate	0.164	1.749	0.058	<0.022	0.0331	E0.01
0208732610	Pigeon House Br at Crabtree Boulevard at Raleigh, N.C.	2002-12-19 1101	replicate	0.187	1.758	0.062	<0.022	0.0339	E0.009
			RPD	13	1	7	--	2	11
02100634	Vestal Creek near Asheboro, N.C.	2003-07-08 0915	replicate	0.331	0.149	<0.04	0.066	0.0438	<0.02
02100634	Vestal Creek near Asheboro, N.C.	2003-07-08 0916	replicate	--	--	--	0.055	--	--
			RPD	--	--	--	18	--	--
0211583580	Bowen Branch near Mouth at Winston-Salem, N.C.	2003-07-09 1030	replicate	10.445	6.012	10.326	0.037	0.0105	<0.02
0211583580	Bowen Branch near Mouth at Winston-Salem, N.C.	2003-07-09 1031	replicate	--	--	--	0.031	--	--
			RPD	--	--	--	18	--	--
Milwaukee-Green Bay									
04081897	Sawyer Creek at Westhaven Road at Oshkosh, Wis.	2004-05-19 0930	replicate	--	8.544	E0.022	0.108	0.0737	0.037
04081897	Sawyer Creek at Westhaven Road at Oshkosh, Wis.	2004-05-19 0931	replicate	--	8.425	E0.021	0.073	0.0714	0.037
			RPD	--	1	5	39	3	0
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-06-01 1320	replicate	--	0.962	<0.04	0.058	0.0484	0.013
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-06-01 1321	replicate	--	--	--	0.085	--	--
			RPD	--	--	--	38	--	--
04087030	Menomonee River at Menomonee Falls, Wis.	2004-06-10 1210	replicate	--	1.105	E0.034	0.127	0.0902	0.027
04087030	Menomonee River at Menomonee Falls, Wis.	2004-06-10 1211	replicate	--	1.11	E0.038	0.13	0.188	0.025
			RPD	--	0	11	2	70	8
04087204	Oak Creek at South Milwaukee, Wis.	2004-05-13 1141	replicate	--	0.771	0.043	--	--	0.023
04087204	Oak Creek at South Milwaukee, Wis.	2004-05-13 1142	replicate	--	--	--	--	--	--
			RPD	--	--	--	--	--	--
Dallas-Fort Worth									
08049955	Fish Creek at Belt Line Road, Grand Prairie, Tex.	2004-05-20 1505	replicate	--	0.397	0.075	0.111	0.0411	0.007
08049955	Fish Creek at Belt Line Road, Grand Prairie, Tex.	2004-05-20 1506	replicate	--	0.42	0.07	0.11	0.042	<0.006
			RPD	--	6	7	1	2	--
Denver									
393948105053501	Bear Creek below Estes Road at Lakewood, Colo.	2003-02-10 1245	replicate	0.262	1.324	0.044	0.027	0.0189	<0.02
393948105053501	Bear Creek below Estes Road at Lakewood, Colo.	2003-02-10 1246	replicate	--	--	--	0.023	--	--
			RPD	--	--	--	16	--	--
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	2003-08-13 1100	replicate	0.412	0.479	E0.03	0.07	0.0576	<0.18
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	2003-08-13 1101	replicate	--	--	--	--	--	--
			RPD	--	--	--	--	--	--
394921105015701	Little Dry Creek below Lowell Street near Westminster, Colo.	2002-12-11 0930	replicate	0.371	1.877	<0.041	0.033	0.0161	<0.018
394921105015701	Little Dry Creek below Lowell Street near Westminster, Colo.	2002-12-11 0931	replicate	--	--	--	0.033	--	--
			RPD	--	--	--	0	--	--
395554105085601	Rock Creek above Rock Creek Parkway at Superior, Colo.	2003-08-21 1145	replicate	1.324	0.089	0.103	0.085	0.263	0.19
395554105085601	Rock Creek above Rock Creek Parkway at Superior, Colo.	2003-08-21 1146	replicate	1.341	0.091	0.115	--	0.267	0.202
			RPD	1	2	11	--	2	6
400217105123701	Boulder Creek below 61st Street near Boulder, Colo.	2002-12-10 0950	replicate	0.256	0.267	<0.041	0.116	0.0395	E0.013
400217105123701	Boulder Creek below 61st Street near Boulder, Colo.	2002-12-10 0951	replicate	--	--	--	0.14	--	--
			RPD	--	--	--	19	--	--
403356105024001	Spring Creek at Edora Park at Fort Collins, Colo.	2003-08-27 1130	replicate	0.466	1.012	0.041	0.194	0.0915	0.026
403356105024001	Spring Creek at Edora Park at Fort Collins, Colo.	2003-08-27 1131	replicate	--	--	--	--	--	--
			RPD	--	--	--	--	--	--
413659104370001	Bear Creek above Little Bear Creek near Phillips, Wyo.	2003-04-02 1100	replicate	0.219	0.266	<0.04	0.025	0.0052	<0.02
413659104370001	Bear Creek above Little Bear Creek near Phillips, Wyo.	2003-04-02 1101	replicate	0.254	0.265	<0.04	--	0.0065	<0.02
			RPD	15	0	--	--	22	--
Portland									
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1250	replicate	--	0.902	E0.031	E0.038	0.1584	0.091
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1251	replicate	--	0.9	E0.032	E0.033	0.0233	0.089
			RPD	--	0	3	14	149	2
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1200	replicate	--	0.206	<0.04	<0.022	0.0333	0.017
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1201	replicate	--	0.215	<0.04	<0.022	0.0315	0.017
			RPD	--	4	--	--	6	0
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1150	replicate	--	4.244	<0.04	0.05	0.0349	E0.004
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1151	replicate	--	4.22	<0.04	0.047	0.0358	E0.005
			RPD	--	1	--	6	3	22
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1150	replicate	--	1.791	<0.04	0.046	0.0699	0.032
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1151	replicate	--	1.807	<0.04	0.049	0.0684	0.032
			RPD	--	1	--	6	2	0
454510122424900	Whipple Creek near Salmon Creek, Wash.	2004-06-28 1140	replicate	--	0.663	<0.04	0.059	0.1811	0.086
454510122424900	Whipple Creek near Salmon Creek, Wash.	2004-06-28 1141	replicate	--	0.64	<0.04	0.049	0.178	0.083
			RPD	--	4	--	19	2	4
Summary statistics for relative percent difference between replicate samples									
Mean				10	2	7	15	24	6
Standard deviation				7	2	3	12	46	7
Maximum				15	6	11	39	149	22
Minimum				1	0	3	0	2	0

Appendix 2. Quality-control data.

Appendix 2b. Relative percent difference between replicate samples.—Continued

[Pesticides are in units of micrograms per liter; all other constituents are in units of milligrams per liter. RPD, relative percent difference; E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; --, not analyzed or not applicable.]

U.S. Geological Survey parameter code										
49295	**82660**	**61615**	**61618**	**04040**	**61620**	**61625**	**61633**	**49260**	**46342**	**39632**
Parameter name										
1-Naphthol, water, filtered, recoverable	**2,6-Diethylaniline, water, filtered, recoverable**	**2-[(2-Ethyl-6-methylphenyl)-amino]-1-propanol, water, filtered, recoverable**	**2-Chloro-2′,6′-diethylacetanilide, water, filtered, recoverable**	**2-Chloro-4-isopropylamino-6-amino-s-triazine, water, filtered, recoverable**	**2-Ethyl-6-methylaniline, water, filtered, recoverable**	**3,4-Dichloroaniline, water, filtered, recoverable**	**4-Chloro-2-methylphenol, water, filtered, recoverable**	**Acetochlor, water, filtered, recoverable**	**Alachlor, water, filtered, recoverable**	**Atrazine, water, filtered, recoverable**
Atlanta										
<0.0882	<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	0.0071
<0.0882	<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	E0.0039
--	--	--	--	--	--	--	--	--	--	58
<0.0882	<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007
<0.0882	<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007
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Raleigh-Durham										
<0.0882	<0.006	<0.1256	<0.005	E0.0022	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007
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<0.0882	<0.006	<0.126	<0.005	E0.0081	<0.0045	E0.0024	<0.0056	<0.006	<0.0045	E0.0054
<0.0882	<0.006	<0.126	<0.005	E0.0076	<0.0045	E0.0026	<0.0056	<0.006	<0.0045	E0.0044
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<0.0882	<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.008
<0.0882	<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.008
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<0.0882	<0.006	<0.1256	<0.005	<0.006	<0.0045	0.0371	<0.0056	<0.006	<0.0045	0.0105
<0.0882	<0.006	<0.1256	<0.005	E0.0068	<0.0045	0.0324	<0.0056	<0.006	<0.0045	0.0097
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Milwaukee-Green Bay										
<0.0882	<0.006	--	<0.005	E0.0806	<0.0045	E0.0041	E0.0044	0.0152	0.0084	0.653
<0.0882	<0.006	--	<0.005	E0.0778	<0.0045	E0.0042	E0.0045	0.0144	0.0082	0.634
--	--	--	--	4	--	2	2	5	2	3
--	<0.006	--	<0.005	E0.0102	<0.0045	0.187	--	0.0144	<0.005	0.07
--	<0.006	--	--	E0.0252	--	--	--	0.0141	<0.005	0.0688
--	--	--	--	85	--	--	--	2	--	2
<0.0882	<0.006	--	<0.005	E0.0493	<0.0045	0.0069	<0.0056	0.0282	0.0066	0.122
<0.0882	<0.006	--	<0.005	E0.0485	<0.0045	0.006	<0.0056	0.03	<0.005	0.128
--	--	--	--	2	--	14	--	6	--	5
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Dallas-Fort Worth										
<0.0882	<0.006	--	<0.005	E0.062	<0.0045	<0.0045	E0.0077	<0.006	<0.005	0.882
<0.0882	<0.006	--	<0.005	E0.063	<0.004	<0.004	E0.005	<0.006	<0.005	0.907
--	--	--	--	2	--	--	43	--	--	3
Denver										
E0.0046	<0.006	<0.126	<0.005	E0.0025	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	E0.0027
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E0.0237	<0.006	<0.1256	<0.005	E0.0047	<0.0045	E0.0036	E0.0049	<0.006	<0.0045	0.0189
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<0.0882	<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	0.0075
<0.0882	<0.006	<0.126	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	0.0078
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<0.0882	<0.006	<0.1256	<0.005	E0.0097	<0.0045	<0.0045	E0.0249	<0.006	<0.0045	0.0238
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<0.0882	<0.006	<0.1256	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	0.0085
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<0.0882	<0.006	<0.1256	<0.005	E0.0062	<0.0045	<0.0045	E0.0165	<0.006	<0.0045	<0.007
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<0.0882	<0.006	<0.126	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007
<0.0882	<0.006	<0.126	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007
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Portland										
<0.0882	<0.006	--	<0.005	E0.0096	<0.0045	0.0227	<0.0056	<0.006	<0.005	0.0177
<0.0882	<0.006	--	<0.005	E0.0095	<0.0045	0.0128	<0.0056	<0.006	<0.005	0.0177
--	--	--	--	1	--	56	--	--	--	0
<0.0882	<0.006	--	<0.005	E0.001	<0.0045	<0.0045	<0.0057	<0.006	<0.005	<0.007
<0.0882	<0.006	--	<0.005	E0.0007	<0.0045	<0.0045	<0.0057	<0.006	<0.005	E0.0023
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<0.0882	<0.006	<0.1256	<0.005	E0.004	<0.0045	0.0613	<0.0056	<0.006	<0.005	0.0297
<0.0882	<0.006	<0.1256	<0.005	E0.0035	<0.0045	0.0508	<0.0056	<0.006	<0.005	0.0273
--	--	--	--	13	--	19	--	--	--	8
<0.0882	<0.006	--	<0.005	E0.005	<0.0045	E0.002	<0.0056	<0.006	<0.005	E0.0027
<0.0882	<0.006	--	<0.005	E0.0043	<0.0045	E0.0018	<0.0056	<0.006	<0.005	E0.0027
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<0.0882	<0.006	--	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.005	<0.007
<0.0882	<0.006	--	<0.005	<0.006	<0.0045	<0.0045	<0.0056	<0.006	<0.005	<0.007
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Summary statistics for relative percent difference between replicate samples										
--	--	--	--	18	--	18	22	5	2	10
--	--	--	--	27	--	18	28	2	--	17
--	--	--	--	85	--	56	43	6	2	58
--	--	--	--	1	--	2	2	2	2	0

Appendix 2. Quality-control data.
Appendix 2b. Relative percent difference between replicate samples.—Continued

[Pesticides are in units of micrograms per liter; all other constituents are in units of milligrams per liter. RPD, relative percent difference; E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; --, not analyzed or not applicable.]

U.S. Geological Survey station number	U.S. Geological Survey station name	Sample date and time	Variable	U.S. Geological Survey parameter code				
				61635	82686	82673	82680	61636
				Parameter name				
				Azinphos-methyl oxygen analog, water, filtered, recoverable	Azinphos-methyl, water, filtered, recoverable	Benfluralin, water, filtered, recoverable	Carbaryl, water, filtered, recoverable	Chlorpyrifos oxygen analog, water, filtered, recoverable
Atlanta								
02337395	Dog River at North Helton Road near Winston, Ga.	2003-07-08 1200	replicate	<0.125	<0.05	<0.01	E0.0074	<0.0562
02337395	Dog River at North Helton Road near Winston, Ga.	2003-07-08 1207	replicate	<0.016	<0.05	<0.01	E0.0068	<0.0562
			RPD	--	--	--	8	--
02346358	Turnpike Creek near Milner, Ga.	2003-09-17 0930	replicate	--	<0.05	<0.01	<0.041	<0.0562
02346358	Turnpike Creek near Milner, Ga.	2003-09-17 0937	replicate	--	<0.05	<0.01	<0.041	<0.0562
			RPD	--	--	--	--	--
Raleigh-Durham								
0208500600	Strouds Creek at St Marys Road near Hillsborough, N.C.	2003-07-07 0830	replicate	<0.016	<0.05	<0.01	E0.0089	<0.0562
0208500600	Strouds Creek at St Marys Road near Hillsborough, N.C.	2003-07-07 0831	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
0208732610	Pigeon House Br at Crabtree Boulevard at Raleigh, N.C.	2002-12-19 1100	replicate	<0.016	<0.05	<0.01	E0.0036	<0.0562
0208732610	Pigeon House Br at Crabtree Boulevard at Raleigh, N.C.	2002-12-19 1101	replicate	<0.016	<0.05	<0.01	E0.0038	<0.0562
			RPD	--	--	--	5	--
02100634	Vestal Creek near Asheboro, N.C.	2003-07-08 0915	replicate	<0.016	<0.05	<0.01	<0.041	<0.0562
02100634	Vestal Creek near Asheboro, N.C.	2003-07-08 0916	replicate	<0.016	<0.05	<0.01	<0.041	<0.0562
			RPD	--	--	--	--	--
0211583580	Bowen Branch near Mouth at Winston-Salem, N.C.	2003-07-09 1030	replicate	<0.016	<0.05	<0.01	<0.041	<0.0562
0211583580	Bowen Branch near Mouth at Winston-Salem, N.C.	2003-07-09 1031	replicate	<0.016	<0.05	<0.01	<0.041	<0.0562
			RPD	--	--	--	--	--
Milwaukee-Green Bay								
04081897	Sawyer Creek at Westhaven Road at Oshkosh, Wis.	2004-05-19 0930	replicate	<0.016	<0.05	<0.01	E0.0125	<0.0562
04081897	Sawyer Creek at Westhaven Road at Oshkosh, Wis.	2004-05-19 0931	replicate	<0.016	<0.05	<0.01	E0.0146	<0.0562
			RPD	--	--	--	15	--
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-06-01 1320	replicate	<0.016	<0.05	<0.01	E0.0083	<0.0562
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-06-01 1321	replicate	--	<0.05	<0.01	E0.0078	--
			RPD	--	--	--	6	--
04087030	Menomonee River at Menomonee Falls, Wis.	2004-06-10 1210	replicate	<0.016	<0.05	<0.01	E0.0073	<0.0562
04087030	Menomonee River at Menomonee Falls, Wis.	2004-06-10 1211	replicate	<0.016	<0.05	<0.01	E0.0075	<0.0562
			RPD	--	--	--	3	--
04087204	Oak Creek at South Milwaukee, Wis.	2004-05-13 1141	replicate	--	--	--	--	--
04087204	Oak Creek at South Milwaukee, Wis.	2004-05-13 1142	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
Dallas-Fort Worth								
08049955	Fish Creek at Belt Line Road, Grand Prairie, Tex.	2004-05-20 1505	replicate	<0.03	<0.05	<0.01	E0.0541	<0.0562
08049955	Fish Creek at Belt Line Road, Grand Prairie, Tex.	2004-05-20 1506	replicate	<0.02	<0.05	<0.01	E0.06	<0.06
			RPD	--	--	--	10	--
Denver								
393948105053501	Bear Creek below Estes Road at Lakewood, Colo.	2003-02-10 1245	replicate	<0.016	<0.05	<0.01	<0.041	<0.0562
393948105053501	Bear Creek below Estes Road at Lakewood, Colo.	2003-02-10 1246	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	2003-08-13 1100	replicate	<0.016	<0.05	<0.01	E0.13	<0.0562
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	2003-08-13 1101	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
394921105015701	Little Dry Creek below Lowell Street near Westminster, Colo.	2002-12-11 0930	replicate	<0.016	<0.05	<0.01	<0.041	<0.0562
394921105015701	Little Dry Creek below Lowell Street near Westminster, Colo.	2002-12-11 0931	replicate	<0.016	<0.05	<0.01	<0.041	<0.0562
			RPD	--	--	--	--	--
395554105085601	Rock Creek above Rock Creek Parkway at Superior, Colo.	2003-08-21 1145	replicate	<0.016	<0.05	<0.01	E0.0095	<0.0562
395554105085601	Rock Creek above Rock Creek Parkway at Superior, Colo.	2003-08-21 1146	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
400217105123701	Boulder Creek below 61st Street near Boulder, Colo.	2002-12-10 0950	replicate	<0.016	<0.05	<0.01	E0.0083	<0.0562
400217105123701	Boulder Creek below 61st Street near Boulder, Colo.	2002-12-10 0951	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
403356105024001	Spring Creek at Edora Park at Fort Collins, Colo.	2003-08-27 1130	replicate	<0.016	<0.05	<0.01	E0.0061	<0.0562
403356105024001	Spring Creek at Edora Park at Fort Collins, Colo.	2003-08-27 1131	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
413659104370001	Bear Creek above Little Bear Creek near Phillips, Wyo.	2003-04-02 1100	replicate	<0.016	<0.05	<0.01	<0.041	<0.0562
413659104370001	Bear Creek above Little Bear Creek near Phillips, Wyo.	2003-04-02 1101	replicate	<0.016	<0.05	<0.01	<0.041	<0.0562
			RPD	--	--	--	--	--
Portland								
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1250	replicate	<0.016	<0.05	<0.01	E0.0096	<0.0562
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1251	replicate	<0.016	<0.05	<0.01	E0.0096	<0.0562
			RPD	--	--	--	0	--
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1200	replicate	<0.07	<0.05	<0.01	<0.041	<0.0562
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1201	replicate	<0.07	<0.05	<0.01	<0.041	<0.0562
			RPD	--	--	--	--	--
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1150	replicate	<0.031	<0.05	<0.01	E0.0068	<0.0562
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1151	replicate	<0.031	<0.05	<0.01	E0.0073	<0.0562
			RPD	--	--	--	7	--
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1150	replicate	<0.016	<0.05	<0.01	E0.0232	<0.0562
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1151	replicate	<0.016	<0.05	<0.01	E0.0208	<0.0562
			RPD	--	--	--	11	--
454510122424900	Whipple Creek near Salmon Creek, Wash.	2004-06-28 1140	replicate	<0.016	<0.05	<0.01	<0.041	<0.0562
454510122424900	Whipple Creek near Salmon Creek, Wash.	2004-06-28 1141	replicate	<0.016	<0.05	<0.01	<0.041	<0.0562
			RPD	--	--	--	--	--
Summary statistics for relative percent difference between replicate samples								
Mean				--	--	--	7	--
Standard deviation				--	--	--	5	--
Maximum				--	--	--	15	--
Minimum				--	--	--	0	--

Appendix 2. Quality-control data.

Appendix 2b. Relative percent difference between replicate samples.—Continued

[Pesticides are in units of micrograms per liter; all other constituents are in units of milligrams per liter. RPD, relative percent difference; E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; --, not analyzed or not applicable.]

U.S. Geological Survey parameter code										
38933	82687	61585	61586	82682	62170	61638	39572	38454	39381	82662
Parameter name										
Chlorpyrifos, water, filtered, recoverable	cis-Permethrin, water, filtered, recoverable	Cyfluthrin, water, filtered, recoverable	Cypermethrin, water, filtered, recoverable	DCPA, water, filtered, recoverable	Desulfinyl fipronil, water, filtered, recoverable	Diazinon oxygen analog, water, filtered, recoverable	Diazinon, water, filtered, recoverable	Dicrotophos, water, filtered, recoverable	Dieldrin, water, filtered, recoverable	Dimethoate, water, filtered, recoverable
Atlanta										
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061
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<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061
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Raleigh-Durham										
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061
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<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.04	<0.005	<0.0843	0.0082	<0.0061
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.04	<0.005	<0.0843	0.0068	<0.0061
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<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061
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<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.01	<0.005	<0.0843	0.0076	<0.0061
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061
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Milwaukee-Green Bay										
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061
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<0.005	<0.006	<0.008	<0.0086	<0.003	<0.012	--	0.0054	<0.0843	<0.009	<0.0061
<0.005	<0.006	--	--	<0.003	<0.012	--	E0.0037	--	<0.009	--
--	--	--	--	--	--	--	37	--	--	--
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.012	<0.01	<0.009	<0.0843	<0.009	<0.0061
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.012	<0.01	<0.009	<0.0843	<0.009	<0.0061
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--	--	--	--	--	--	--	--	--	--	--
Dallas-Fort Worth										
0.0069	<0.006	<0.008	<0.0086	<0.003	E0.0033	<0.01	0.0175	<0.0843	<0.009	<0.0061
0.006	<0.006	<0.008	<0.009	<0.003	E0.004	<0.01	0.019	<0.08	<0.009	<0.006
14	--	--	--	--	19	--	8	--	--	--
Denver										
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.04	<0.005	<0.0843	<0.0048	<0.0061
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--	--	--	--	--	--	--	--	--	--	--
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.01	0.0063	<0.0843	<0.0048	<0.0061
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<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.04	0.0066	<0.0843	<0.0048	<0.0061
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.04	0.0069	<0.0843	<0.0048	<0.0061
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<0.005	<0.006	<0.008	<0.0086	E0.0011	<0.004	<0.01	0.009	<0.0843	<0.0048	<0.007
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--	--	--	--	--	--	--	--	--	--	--
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.04	<0.005	<0.0843	<0.0048	<0.0061
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--	--	--	--	--	--	--	--	--	--	--
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061
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--	--	--	--	--	--	--	--	--	--	--
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.04	<0.005	<0.0843	<0.0048	<0.0061
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.004	<0.04	<0.005	<0.0843	<0.0048	<0.0061
--	--	--	--	--	--	--	--	--	--	--
Portland										
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061
--	--	--	--	--	--	--	--	--	--	--
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.012	<0.006	<0.005	<0.0843	<0.009	<0.0061
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.012	<0.006	<0.005	<0.0843	<0.009	<0.0061
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0.0134	<0.006	<0.008	<0.0086	<0.003	<0.012	<0.01	<0.005	<0.0843	E0.0023	<0.0061
0.0126	<0.006	<0.008	<0.0086	<0.003	<0.012	<0.01	<0.005	<0.0843	E0.003	<0.0061
6	--	--	--	--	--	--	--	--	26	--
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061
<0.005	<0.006	<0.008	<0.0086	<0.003	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061
--	--	--	--	--	--	--	--	--	--	--
<0.005	<0.006	<0.03	<0.03	<0.003	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061
<0.005	<0.006	<0.03	<0.03	<0.003	<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061
--	--	--	--	--	--	--	--	--	--	--
Summary statistics for relative percent difference between replicate samples										
10	--	--	--	--	19	--	17	--	23	--
6	--	--	--	--	--	--	18	--	5	--
14	--	--	--	--	19	--	37	--	26	--
6	--	--	--	--	19	--	4	--	19	--

Appendix 2. Quality-control data.
Appendix 2b. Relative percent difference between replicate samples.—Continued

[Pesticides are in units of micrograms per liter; all other constituents are in units of milligrams per liter. RPD, relative percent difference; E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; --, not analyzed or not applicable.]

U.S. Geological Survey station number	U.S. Geological Survey station name	Sample date and time	Variable	U.S. Geological Survey parameter code				
				61644	82346	61645	61646	61591
				Parameter name				
				Ethion monoxon, water, filtered, recoverable	Ethion, water, filtered, recoverable	Fenamiphos sulfone, water, filtered, recoverable	Fenamiphos sulfoxide, water, filtered, recoverable	Fenamiphos, water, filtered, recoverable
Atlanta								
02337395	Dog River at North Helton Road near Winston, Ga.	2003-07-08 1200	replicate	<0.0336	<0.004	<0.0077	<0.125	<0.029
02337395	Dog River at North Helton Road near Winston, Ga.	2003-07-08 1207	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
			RPD	--	--	--	--	--
02346358	Turnpike Creek near Milner, Ga.	2003-09-17 0930	replicate	<0.0336	<0.004	<0.0077	--	<0.029
02346358	Turnpike Creek near Milner, Ga.	2003-09-17 0937	replicate	<0.0336	<0.004	<0.0077	--	<0.029
			RPD	--	--	--	--	--
Raleigh-Durham								
0208500600	Strouds Creek at St Marys Road near Hillsborough, N.C.	2003-07-07 0830	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
0208500600	Strouds Creek at St Marys Road near Hillsborough, N.C.	2003-07-07 0831	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
0208732610	Pigeon House Br at Crabtree Boulevard at Raleigh, N.C.	2002-12-19 1100	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
0208732610	Pigeon House Br at Crabtree Boulevard at Raleigh, N.C.	2002-12-19 1101	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
			RPD	--	--	--	--	--
02100634	Vestal Creek near Asheboro, N.C.	2003-07-08 0915	replicate	<0.0336	<0.004	<0.0312	<0.031	<0.029
02100634	Vestal Creek near Asheboro, N.C.	2003-07-08 0916	replicate	<0.0336	<0.004	<0.0312	<0.031	<0.029
			RPD	--	--	--	--	
0211583580	Bowen Branch near Mouth at Winston-Salem, N.C.	2003-07-09 1030	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
0211583580	Bowen Branch near Mouth at Winston-Salem, N.C.	2003-07-09 1031	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
			RPD	--	--	--	--	--
Milwaukee-Green Bay								
04081897	Sawyer Creek at Westhaven Road at Oshkosh, Wis.	2004-05-19 0930	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
04081897	Sawyer Creek at Westhaven Road at Oshkosh, Wis.	2004-05-19 0931	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
			RPD	--	--	--	--	--
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-06-01 1320	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-06-01 1321	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
04087030	Menomonee River at Menomonee Falls, Wis.	2004-06-10 1210	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
04087030	Menomonee River at Menomonee Falls, Wis.	2004-06-10 1211	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
			RPD	--	--	--	--	--
04087204	Oak Creek at South Milwaukee, Wis.	2004-05-13 1141	replicate	--	--	--	--	--
04087204	Oak Creek at South Milwaukee, Wis.	2004-05-13 1142	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
Dallas-Fort Worth								
08049955	Fish Creek at Belt Line Road, Grand Prairie, Tex.	2004-05-20 1505	replicate	<0.0336	<0.004	<0.03	--	<0.029
08049955	Fish Creek at Belt Line Road, Grand Prairie, Tex.	2004-05-20 1506	replicate	<0.03	<0.004	<0.03	--	<0.03
			RPD	--	--	--	--	--
Denver								
393948105053501	Bear Creek below Estes Road at Lakewood, Colo.	2003-02-10 1245	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
393948105053501	Bear Creek below Estes Road at Lakewood, Colo.	2003-02-10 1246	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	2003-08-13 1100	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	2003-08-13 1101	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
394921105015701	Little Dry Creek below Lowell Street near Westminster, Colo.	2002-12-11 0930	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
394921105015701	Little Dry Creek below Lowell Street near Westminster, Colo.	2002-12-11 0931	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
			RPD	--	--	--	--	--
395554105085601	Rock Creek above Rock Creek Parkway at Superior, Colo.	2003-08-21 1145	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
395554105085601	Rock Creek above Rock Creek Parkway at Superior, Colo.	2003-08-21 1146	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
400217105123701	Boulder Creek below 61st Street near Boulder, Colo.	2002-12-10 0950	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
400217105123701	Boulder Creek below 61st Street near Boulder, Colo.	2002-12-10 0951	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
403356105024001	Spring Creek at Edora Park at Fort Collins, Colo.	2003-08-27 1130	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
403356105024001	Spring Creek at Edora Park at Fort Collins, Colo.	2003-08-27 1131	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
413659104370001	Bear Creek above Little Bear Creek near Phillips, Wyo.	2003-04-02 1100	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
413659104370001	Bear Creek above Little Bear Creek near Phillips, Wyo.	2003-04-02 1101	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
			RPD	--	--	--	--	--
Portland								
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1250	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1251	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
			RPD	--	--	--	--	--
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1200	replicate	<0.002	<0.004	<0.0491	<0.0387	<0.029
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1201	replicate	<0.002	<0.004	<0.0491	<0.0387	<0.029
			RPD	--	--	--	--	--
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1150	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1151	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
			RPD	--	--	--	--	--
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1150	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1151	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
			RPD	--	--	--	--	--
454510122424900	Whipple Creek near Salmon Creek, Wash.	2004-06-28 1140	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
454510122424900	Whipple Creek near Salmon Creek, Wash.	2004-06-28 1141	replicate	<0.0336	<0.004	<0.0077	<0.031	<0.029
			RPD	--	--	--	--	--
Summary statistics for relative percent difference between replicate samples								
Mean				--	--	--	--	--
Standard deviation				--	--	--	--	--
Maximum				--	--	--	--	--
Minimum				--	--	--	--	--

Appendix 2. Quality-control data.

Appendix 2b. Relative percent difference between replicate samples.—Continued

[Pesticides are in units of micrograms per liter; all other constituents are in units of milligrams per liter. RPD, relative percent difference; E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; --, not analyzed or not applicable.]

U.S. Geological Survey parameter code										
62169	62167	62168	62166	61649	04095	04025	61593	61594	61652	39532
Parameter name										
Desulfinylfipronil amide, water, filtered, recoverable	Fipronil sulfide, water, filtered, recoverable	Fipronil sulfone, water, filtered, recoverable	Fipronil, water, filtered, recoverable	Fonofos oxygen analog, water, filtered, recoverable	Fonofos, water, filtered, recoverable	Hexazinone, water, filtered, recoverable	Iprodione, water, filtered, recoverable	Isofenphos, water, filtered, recoverable	Malaoxon, water, filtered, recoverable	Malathion, water, filtered, recoverable
Atlanta										
<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027	<0.0129	<1.4223	<0.0034	<0.008	<0.027
<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027	<0.0129	<1.4223	<0.0034	<0.008	<0.027
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<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027	E0.0066	<1.4223	<0.0034	<0.008	<0.027
<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027	E0.0065	<1.4223	<0.0034	<0.008	<0.027
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Raleigh-Durham										
<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027	0.0166	<1.4223	<0.0034	<0.008	<0.027
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<0.009	<0.005	<0.005	E0.0052	<0.0021	<0.0027	--	<1.4223	<0.0034	<0.008	<0.027
<0.009	<0.005	<0.005	E0.0053	<0.0021	<0.0027	--	<1.4223	<0.0034	<0.008	<0.027
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<0.009	<0.005	<0.006	E0.0053	<0.0021	<0.0027	0.0391	<1.4223	<0.0034	<0.008	<0.027
<0.009	<0.005	<0.006	<0.007	<0.0021	<0.0027	0.0373	<1.4223	<0.0034	<0.008	<0.027
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<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027	0.0177	<1.4223	<0.0034	<0.008	<0.027
<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027	0.0176	<1.4223	<0.0034	<0.008	<0.027
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Milwaukee-Green Bay										
<0.029	<0.013	<0.024	<0.016	<0.0021	<0.003	<0.0129	<1.4223	<0.0034	<0.008	E0.0158
<0.029	<0.013	<0.024	<0.016	<0.0021	<0.003	<0.0129	<1.4223	<0.0034	<0.008	E0.0156
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<0.029	<0.013	<0.024	<0.016	<0.0021	<0.003	<0.0129	<1.4223	<0.0034	<0.008	<0.027
<0.029	<0.013	<0.024	<0.016	--	<0.003	--	--	--	--	<0.027
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<0.029	<0.013	<0.024	<0.016	<0.0021	<0.003	<0.0129	<1.4223	<0.0034	<0.008	<0.027
<0.029	<0.013	<0.024	<0.016	<0.0021	<0.003	<0.0129	<1.4223	<0.0034	<0.008	<0.027
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Dallas-Fort Worth										
<0.029	<0.013	<0.024	E0.0095	<0.0021	<0.003	0.0154	<1.4223	<0.0034	<0.008	<0.027
<0.029	<0.013	<0.024	E0.01	<0.002	<0.003	0.019	<1.4223	<0.003	<0.008	<0.027
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Denver										
<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027	--	<1.4223	<0.0034	<0.008	<0.027
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<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027	<0.0129	<1.4223	<0.0034	<0.008	<0.027
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<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027	--	<1.4223	<0.0034	<0.008	<0.027
<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027	--	<1.4223	<0.0034	<0.008	<0.027
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<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027	<0.0129	<1.4223	<0.0034	<0.008	<0.027
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<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027	--	<1.4223	<0.0034	<0.008	<0.027
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<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027	<0.0129	<1.4223	<0.0034	<0.008	<0.027
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<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027	--	<1.4223	<0.0034	<0.008	<0.027
<0.009	<0.005	<0.005	<0.007	<0.0021	<0.0027	--	<1.4223	<0.0034	<0.008	<0.027
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Portland										
<0.029	<0.013	<0.024	<0.016	<0.0021	<0.003	<0.0129	<1.4223	<0.0034	<0.008	<0.027
<0.029	<0.013	<0.024	<0.016	<0.0021	<0.003	<0.0129	<1.4223	<0.0034	<0.008	<0.027
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<0.029	<0.013	<0.024	<0.016	<0.0029	<0.003	0.0172	<0.387	<0.0034	<0.0298	<0.027
<0.029	<0.013	<0.024	<0.016	<0.0029	<0.003	0.0147	<0.387	<0.0034	<0.0298	<0.027
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<0.029	<0.013	<0.024	<0.016	<0.0021	<0.003	0.0159	<1.4223	<0.0034	<0.008	<0.027
<0.029	<0.013	<0.024	<0.016	<0.0021	<0.003	0.0149	<1.4223	<0.0034	<0.008	<0.027
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<0.029	<0.013	<0.024	<0.016	<0.0021	<0.003	<0.0129	<1.4223	<0.0034	<0.008	<0.027
<0.029	<0.013	<0.024	<0.016	<0.0021	<0.003	<0.0129	<1.4223	<0.0034	<0.008	<0.027
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<0.029	<0.013	<0.024	<0.016	<0.0021	<0.003	<0.0129	<1.4223	<0.0034	<0.008	<0.027
<0.029	<0.013	<0.024	<0.016	<0.0021	<0.003	<0.0129	<1.4223	<0.0034	<0.008	<0.027
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Summary statistics for relative percent difference between replicate samples										
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Appendix 2. Quality-control data.

Appendix 2b. Relative percent difference between replicate samples.—Continued

[Pesticides are in units of micrograms per liter; all other constituents are in units of milligrams per liter. RPD, relative percent difference; E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; --, not analyzed or not applicable.]

				U.S. Geological Survey parameter code				
				61596	61598	61664	82667	39415
				Parameter name				
U.S. Geological Survey station number	U.S. Geological Survey station name	Sample date and time	Variable	Metalaxyl, water, filtered, recoverable	Methidathion, water, filtered, recoverable	Methyl paraoxon, water, filtered, recoverable	Methyl parathion, water, filtered, recoverable	Metolachlor, water, filtered, recoverable
Atlanta								
02337395	Dog River at North Helton Road near Winston, Ga.	2003-07-08 1200	replicate	<0.0051	<0.0058	<0.0299	<0.006	<0.013
02337395	Dog River at North Helton Road near Winston, Ga.	2003-07-08 1207	replicate	<0.0051	<0.0058	<0.0299	<0.006	<0.013
			RPD	--	--	--	--	--
02346358	Turnpike Creek near Milner, Ga.	2003-09-17 0930	replicate	<0.0051	<0.0058	<0.0299	<0.006	<0.013
02346358	Turnpike Creek near Milner, Ga.	2003-09-17 0937	replicate	<0.0051	<0.0058	<0.0299	<0.006	<0.013
			RPD	--	--	--	--	--
Raleigh-Durham								
0208500600	Strouds Creek at St Marys Road near Hillsborough, N.C.	2003-07-07 0830	replicate	<0.0051	<0.0058	<0.0299	<0.006	<0.013
0208500600	Strouds Creek at St Marys Road near Hillsborough, N.C.	2003-07-07 0831	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
0208732610	Pigeon House Br at Crabtree Boulevard at Raleigh, N.C.	2002-12-19 1100	replicate	<0.0051	<0.0058	<0.0299	<0.006	0.0541
0208732610	Pigeon House Br at Crabtree Boulevard at Raleigh, N.C.	2002-12-19 1101	replicate	<0.0051	<0.0058	<0.0299	<0.006	0.0537
			RPD	--	--	--	--	1
02100634	Vestal Creek near Asheboro, N.C.	2003-07-08 0915	replicate	<0.0051	<0.0058	<0.0299	<0.006	<0.013
02100634	Vestal Creek near Asheboro, N.C.	2003-07-08 0916	replicate	<0.0051	<0.0058	<0.0299	<0.006	<0.013
			RPD	--	--	--	--	
0211583580	Bowen Branch near Mouth at Winston-Salem, N.C.	2003-07-09 1030	replicate	<0.0051	<0.0058	<0.0299	<0.006	<0.013
0211583580	Bowen Branch near Mouth at Winston-Salem, N.C.	2003-07-09 1031	replicate	<0.0051	<0.0058	<0.0299	<0.006	<0.013
			RPD	--	--	--	--	--
Milwaukee-Green Bay								
04081897	Sawyer Creek at Westhaven Road at Oshkosh, Wis.	2004-05-19 0930	replicate	<0.0051	<0.0058	<0.0299	<0.015	0.877
04081897	Sawyer Creek at Westhaven Road at Oshkosh, Wis.	2004-05-19 0931	replicate	<0.0051	<0.0058	<0.0299	<0.015	0.855
			RPD	--	--	--	--	3
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-06-01 1320	replicate	<0.0051	<0.0058	<0.0299	<0.015	0.0198
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-06-01 1321	replicate	--	--	--	<0.015	0.019
			RPD	--	--	--	--	4
04087030	Menomonee River at Menomonee Falls, Wis.	2004-06-10 1210	replicate	<0.0051	<0.0058	<0.0299	<0.015	0.0494
04087030	Menomonee River at Menomonee Falls, Wis.	2004-06-10 1211	replicate	<0.0051	<0.0058	<0.0299	<0.015	0.0513
			RPD	--	--	--	--	4
04087204	Oak Creek at South Milwaukee, Wis.	2004-05-13 1141	replicate	--	--	--	--	--
04087204	Oak Creek at South Milwaukee, Wis.	2004-05-13 1142	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
Dallas-Fort Worth								
08049955	Fish Creek at Belt Line Road, Grand Prairie, Tex.	2004-05-20 1505	replicate	<0.0051	<0.0058	<0.0299	<0.015	E0.0038
08049955	Fish Creek at Belt Line Road, Grand Prairie, Tex.	2004-05-20 1506	replicate	<0.005	<0.006	<0.03	<0.015	E0.004
			RPD	--	--	--	--	5
Denver								
393948105053501	Bear Creek below Estes Road at Lakewood, Colo.	2003-02-10 1245	replicate	<0.0051	<0.0058	<0.0299	<0.006	<0.013
393948105053501	Bear Creek below Estes Road at Lakewood, Colo.	2003-02-10 1246	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	2003-08-13 1100	replicate	<0.0051	<0.0058	<0.0299	<0.006	<0.013
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	2003-08-13 1101	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
394921105015701	Little Dry Creek below Lowell Street near Westminster, Colo.	2002-12-11 0930	replicate	<0.0051	<0.0058	<0.0299	<0.006	<0.013
394921105015701	Little Dry Creek below Lowell Street near Westminster, Colo.	2002-12-11 0931	replicate	<0.0051	<0.0058	<0.0299	<0.006	<0.013
			RPD	--	--	--	--	--
395554105085601	Rock Creek above Rock Creek Parkway at Superior, Colo.	2003-08-21 1145	replicate	<0.0051	<0.0058	<0.0299	<0.006	<0.013
395554105085601	Rock Creek above Rock Creek Parkway at Superior, Colo.	2003-08-21 1146	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
400217105123701	Boulder Creek below 61st Street near Boulder, Colo.	2002-12-10 0950	replicate	<0.0051	<0.0058	<0.0299	<0.006	E0.0073
400217105123701	Boulder Creek below 61st Street near Boulder, Colo.	2002-12-10 0951	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
403356105024001	Spring Creek at Edora Park at Fort Collins, Colo.	2003-08-27 1130	replicate	<0.0051	<0.0058	<0.0299	<0.006	<0.013
403356105024001	Spring Creek at Edora Park at Fort Collins, Colo.	2003-08-27 1131	replicate	--	--	--	--	--
			RPD	--	--	--	--	--
413659104370001	Bear Creek above Little Bear Creek near Phillips, Wyo.	2003-04-02 1100	replicate	<0.0051	<0.0058	<0.0299	<0.006	<0.013
413659104370001	Bear Creek above Little Bear Creek near Phillips, Wyo.	2003-04-02 1101	replicate	<0.0051	<0.0058	<0.0299	<0.006	<0.013
			RPD	--	--	--	--	--
Portland								
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1250	replicate	<0.0051	<0.0058	<0.0299	<0.015	E0.0049
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1251	replicate	<0.0051	<0.0058	<0.0299	<0.015	E0.0048
			RPD	--	--	--	--	2
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1200	replicate	<0.0051	<0.0058	<0.0299	<0.015	<0.013
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1201	replicate	<0.0051	<0.0058	<0.0299	<0.015	<0.013
			RPD	--	--	--	--	--
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1150	replicate	E0.0045	<0.0058	<0.0299	<0.015	0.0288
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1151	replicate	E0.0045	<0.0058	<0.0299	<0.015	0.0253
			RPD	0	--	--	--	13
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1150	replicate	<0.0051	<0.0058	<0.0299	<0.015	E0.004
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1151	replicate	<0.0051	<0.0058	<0.0299	<0.015	E0.0042
			RPD	--	--	--	--	5
454510122424900	Whipple Creek near Salmon Creek, Wash.	2004-06-28 1140	replicate	<0.0051	<0.0058	<0.0299	<0.015	<0.013
454510122424900	Whipple Creek near Salmon Creek, Wash.	2004-06-28 1141	replicate	<0.0051	<0.0058	<0.0299	<0.015	<0.013
			RPD	--	--	--	--	--
Summary statistics for relative percent difference between replicate samples								
Mean				0	--	--	--	5
Standard deviation				--	--	--	--	4
Maximum				0	--	--	--	13
Minimum				0	--	--	--	1

Appendix 2. Quality-control data.

Appendix 2b. Relative percent difference between replicate samples.—Continued

[Pesticides are in units of micrograms per liter; all other constituents are in units of milligrams per liter. RPD, relative percent difference; E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; --, not analyzed or not applicable].

U.S. Geological Survey parameter code										
82630	61599	82683	61666	82664	61668	61601	04037	04036	82676	04035
Parameter name										
Metribuzin, water, filtered, recoverable	Myclobutanil, water, filtered, recoverable	Pendimethalin, water, filtered, recoverable	Phorate oxygen analog, water, filtered, recoverable	Phorate, water, filtered, recoverable	Phosmet oxygen analog, water, filtered, recoverable	Phosmet, water, filtered, recoverable	Prometon, water, filtered, recoverable	Prometryn, water, filtered, recoverable	Propyzamide, water, filtered, recoverable	Simazine, water, filtered, recoverable
Atlanta										
<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	<0.015	<0.0054	<0.0041	0.0111
<0.006	<0.008	<0.022	<0.0973	<0.011	<0.125	<0.0079	<0.015	<0.0054	<0.0041	0.0093
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<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	E0.004	<0.0054	<0.0041	<0.005
<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	E0.0044	<0.0054	<0.0041	<0.005
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Raleigh-Durham										
<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	E0.0078	<0.0054	<0.0041	0.0403
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<0.006	<0.008	<0.045	<0.0973	<0.011	<0.0553	<0.0079	E0.009	<0.0054	<0.0041	0.0056
<0.006	<0.008	<0.045	<0.0973	<0.011	<0.0553	<0.0079	E0.0105	<0.0054	<0.0041	0.0057
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<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	0.028	<0.0054	<0.0041	E0.0046
<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	0.0285	<0.0054	<0.0041	<0.005
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<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	0.0275	<0.0054	<0.0041	<0.005
<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	0.0253	<0.0054	<0.0041	<0.005
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Milwaukee-Green Bay										
<0.006	<0.008	<0.022	<0.0973	<0.011	--	<0.0079	E0.0182	<0.0054	<0.004	0.0087
<0.006	<0.008	<0.022	<0.0973	<0.011	--	<0.0079	E0.0121	<0.0054	<0.004	0.0086
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<0.006	<0.008	E0.012	<0.0973	<0.011	<0.0553	<0.0079	0.0431	<0.0054	<0.004	<0.0053
<0.006	--	<0.022	--	<0.011	--	--	0.0416	--	<0.004	<0.0058
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<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	0.0138	<0.0054	<0.004	0.0116
<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	0.0147	<0.0054	<0.004	0.012
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Dallas-Fort Worth										
<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	0.0092	<0.0054	<0.004	0.08
<0.006	<0.01	<0.022	<0.1	<0.011	<0.0553	<0.0079	0.01	<0.005	<0.004	0.084
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Denver										
<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	0.0462	<0.0054	<0.0041	E0.0014
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<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	0.0324	<0.0054	<0.0041	0.0059
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<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	0.0518	<0.0054	<0.0041	<0.005
<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	0.0555	<0.0054	<0.0041	<0.005
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<0.006	0.13	<0.022	<0.0973	<0.011	<0.0553	<0.0079	<0.015	<0.0054	<0.009	<0.005
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<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	0.0221	<0.0054	<0.0041	<0.005
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<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	0.0564	<0.0054	<0.0041	<0.005
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<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	<0.015	<0.0054	<0.0041	<0.005
<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	<0.015	<0.0054	<0.0041	<0.005
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Portland										
<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	0.0078	<0.0054	<0.004	0.0243
<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	0.0077	<0.0054	<0.004	0.0236
--	--	--	--	--	--	--	1	--	--	3
<0.006	<0.008	<0.022	<0.1048	<0.011	--	<0.0079	<0.005	<0.0054	<0.004	<0.005
<0.006	<0.008	<0.022	<0.1048	<0.011	--	<0.0079	<0.005	<0.0054	<0.004	<0.005
--	--	--	--	--	--	--	--	--	--	--
<0.006	0.013	<0.022	<0.0973	<0.011	<0.0553	<0.0079	E0.0023	<0.0054	<0.004	0.0113
<0.006	0.0131	<0.022	<0.0973	<0.011	<0.0553	<0.0079	E0.0019	<0.0054	<0.004	0.0105
--	1	--	--	--	--	--	19	--	--	7
<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	0.0094	<0.0054	<0.004	0.0087
<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	0.007	<0.0054	<0.004	0.008
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<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	<0.009	<0.0054	<0.004	0.0082
<0.006	<0.008	<0.022	<0.0973	<0.011	<0.0553	<0.0079	<0.008	<0.0054	<0.004	0.0077
--	--	--	--	--	--	--	--	--	--	6
Summary statistics for relative percent difference between replicate samples										
--	1	--	--	--	--	--	12	--	--	6
--	--	--	--	--	--	--	12	--	--	5
--	1	--	--	--	--	--	40	--	--	18
--	1	--	--	--	--	--	1	--	--	1

Appendix 2. Quality-control data.

Appendix 2b. Relative percent difference between replicate samples.—Continued

[Pesticides are in units of micrograms per liter; all other constituents are in units of milligrams per liter. RPD, relative percent difference; E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; --, not analyzed or not applicable.]

U.S. Geological Survey station number	U.S. Geological Survey station name	Sample date and time	Variable	U.S. Geological Survey parameter code								
				82670	61674	82675	04022	82661	38775	80154	00945	00940
				Parameter name								
				Tebuthiuron, water, filtered, recoverable	Terbufos oxygen analog sulfone, water, filtered, recoverable	Terbufos, water, filtered, recoverable	Terbuthylazine, water, filtered, recoverable	Trifluralin, water, filtered, recoverable	Dichlorvos, water, filtered, recoverable	Suspended sediment concentration	Sulfate, water, filtered	Chloride, water, filtered
Atlanta												
02337395	Dog River at North Helton Road near Winston, Ga.	2003-07-08 1200	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	16	3.59	2.44
02337395	Dog River at North Helton Road near Winston, Ga.	2003-07-08 1207	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	--	--	--
			RPD	--	--	--	--	--	--	--	--	--
02346358	Turnpike Creek near Milner, Ga.	2003-09-17 0930	replicate	E0.0077	<0.0676	<0.017	<0.0102	<0.009	<0.0118	4	1.6	2.78
02346358	Turnpike Creek near Milner, Ga.	2003-09-17 0937	replicate	E0.0061	<0.0676	<0.017	<0.0102	<0.009	<0.0118	--	--	--
			RPD	23	--	--	--	--	--	--	--	--
Raleigh-Durham												
0208500600	Strouds Creek at St Marys Road near Hillsborough, N.C.	2003-07-07 0830	replicate	0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	7	5.51	10.01
0208500600	Strouds Creek at St Marys Road near Hillsborough, N.C.	2003-07-07 0831	replicate	--	--	--	--	--	--	--	--	--
			RPD	--	--	--	--	--	--	--	--	--
0208732610	Pigeon House Br at Crabtree Boulevard at Raleigh, N.C.	2002-12-19 1100	replicate	E0.0484	<0.0676	<0.017	<0.0102	<0.009	<0.0118	2	19.17	26.06
0208732610	Pigeon House Br at Crabtree Boulevard at Raleigh, N.C.	2002-12-19 1101	replicate	E0.0576	<0.0676	<0.017	<0.0102	<0.009	<0.0118	4	19.1	25.56
			RPD	17	--	--	--	--	--	67	0	2
02100634	Vestal Creek near Asheboro, N.C.	2003-07-08 0915	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	6	4.41	6.01
02100634	Vestal Creek near Asheboro, N.C.	2003-07-08 0916	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	--	4.36	6.39
			RPD	--	--	--	--	--	--	--	1	6
0211583580	Bowen Branch near Mouth at Winston-Salem, N.C.	2003-07-09 1030	replicate	0.151	<0.0676	<0.017	<0.0102	E0.0053	<0.0118	4	78.39	91.16
0211583580	Bowen Branch near Mouth at Winston-Salem, N.C.	2003-07-09 1031	replicate	0.142	<0.0676	<0.017	<0.0102	<0.009	<0.0118	--	--	--
			RPD	6	--	--	--	--	--	--	--	--
Milwaukee-Green Bay												
04081897	Sawyer Creek at Westhaven Road at Oshkosh, Wis.	2004-05-19 0930	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	156	63.55	56.89
04081897	Sawyer Creek at Westhaven Road at Oshkosh, Wis.	2004-05-19 0931	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	110	63.04	56.19
			RPD	--	--	--	--	--	--	35	1	1
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-06-01 1320	replicate	0.0199	<0.0676	<0.017	<0.0102	<0.009	<0.0118	145	63.75	200.97
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-06-01 1321	replicate	0.0329	--	<0.017	--	<0.009	--	--	--	--
			RPD	49	--	--	--	--	--	--	--	--
04087030	Menomonee River at Menomonee Falls, Wis.	2004-06-10 1210	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	76	31.92	91.45
04087030	Menomonee River at Menomonee Falls, Wis.	2004-06-10 1211	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	64	31.77	92.43
			RPD	--	--	--	--	--	--	17	0	1
04087204	Oak Creek at South Milwaukee, Wis.	2004-05-13 1141	replicate	--	--	--	--	--	--	247	23.87	88.27
04087204	Oak Creek at South Milwaukee, Wis.	2004-05-13 1142	replicate	--	--	--	--	--	--	--	--	--
			RPD	--	--	--	--	--	--	--	--	--
Dallas-Fort Worth												
08049955	Fish Creek at Belt Line Road, Grand Prairie, Tex.	2004-05-20 1505	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	33	214.97	45.33
08049955	Fish Creek at Belt Line Road, Grand Prairie, Tex.	2004-05-20 1506	replicate	0.084	<0.07	<0.02	<0.01	<0.009	<0.01	--	215	44.4
			RPD	--	--	--	--	--	--	--	0	2
Denver												
393948105053501	Bear Creek below Estes Road at Lakewood, Colo.	2003-02-10 1245	replicate	0.0301	<0.0676	<0.017	<0.0102	<0.009	<0.0118	88	173.08	227.58
393948105053501	Bear Creek below Estes Road at Lakewood, Colo.	2003-02-10 1246	replicate	--	--	--	--	--	--	--	--	--
			RPD	--	--	--	--	--	--	--	--	--
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	2003-08-13 1100	replicate	0.0347	<0.0676	<0.017	<0.0102	<0.009	<0.0118	10	107.21	49.39
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	2003-08-13 1101	replicate	--	--	--	--	--	--	--	--	--
			RPD	--	--	--	--	--	--	--	--	--
394921105015701	Little Dry Creek below Lowell Street near Westminster, Colo.	2002-12-11 0930	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	26	694.57	167.47
394921105015701	Little Dry Creek below Lowell Street near Westminster, Colo.	2002-12-11 0931	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	--	--	--
			RPD	--	--	--	--	--	--	--	--	--
395554105085601	Rock Creek above Rock Creek Parkway at Superior, Colo.	2003-08-21 1145	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	4	134.18	45.6
395554105085601	Rock Creek above Rock Creek Parkway at Superior, Colo.	2003-08-21 1146	replicate	--	--	--	--	--	--	2	134.78	44.94
			RPD	--	--	--	--	--	--	67	0	1
400217105123701	Boulder Creek below 61st Street near Boulder, Colo.	2002-12-10 0950	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	4	51.4	92.32
400217105123701	Boulder Creek below 61st Street near Boulder, Colo.	2002-12-10 0951	replicate	--	--	--	--	--	--	--	--	--
			RPD	--	--	--	--	--	--	--	--	--
403356105024001	Spring Creek at Edora Park at Fort Collins, Colo.	2003-08-27 1130	replicate	E0.0342	<0.0676	<0.017	<0.0102	<0.009	<0.0118	38	82.42	24.56
403356105024001	Spring Creek at Edora Park at Fort Collins, Colo.	2003-08-27 1131	replicate	--	--	--	--	--	--	--	--	--
			RPD	--	--	--	--	--	--	--	--	--
413659104370001	Bear Creek above Little Bear Creek near Phillips, Wyo.	2003-04-02 1100	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	24	11.77	5.39
413659104370001	Bear Creek above Little Bear Creek near Phillips, Wyo.	2003-04-02 1101	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	--	11.76	5.23
			RPD	--	--	--	--	--	--	--	0	3
Portland												
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1250	replicate	E0.0043	<0.0676	<0.017	<0.0102	<0.009	<0.0118	5	9.61	5.35
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1251	replicate	E0.0037	<0.0676	<0.017	<0.0102	<0.009	<0.0118	6	9.51	5.46
			RPD	15	--	--	--	--	--	18	1	2
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1200	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	2	0.42	2.11
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1201	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	2	0.41	2.11
			RPD	--	--	--	--	--	--	0	2	0
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1150	replicate	<0.016	<0.0676	<0.017	<0.0102	E0.005	<0.0118	6	2.02	4.44
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1151	replicate	<0.016	<0.0676	<0.017	<0.0102	E0.005	<0.0118	8	2.05	4.44
			RPD	--	--	--	--	0	--	29	1	0
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1150	replicate	0.0242	<0.0676	<0.017	<0.0102	E0.0013	<0.0118	3	9.5	5.08
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1151	replicate	0.0193	<0.0676	<0.017	<0.0102	E0.0015	<0.0118	5	9.49	5.15
			RPD	23	--	--	--	14	--	50	0	1
454510122424900	Whipple Creek near Salmon Creek, Wash.	2004-06-28 1140	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	8	4.92	8.17
454510122424900	Whipple Creek near Salmon Creek, Wash.	2004-06-28 1141	replicate	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118	7	4.94	8.07
			RPD	--	--	--	--	--	--	13	0	1
Summary statistics for relative percent difference between replicate samples												
Mean				22	--	--	--	7	--	33	1	2
Standard deviation				15	--	--	--	10	--	24	1	2
Maximum				49	--	--	--	14	--	67	2	6
Minimum				6	--	--	--	0	--	0	0	0

Appendix 2. Quality-control data.
Appendix 2c. Percent recovery of spiked pesticide compounds.

[All spike and environmental samples are in units of micrograms per liter. E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; M, presence of material verified, but not quantified; --, not analyzed or not applicable.]

U.S. Geological Survey station number	U.S. Geological Survey station name	Sample date and time	Variable	U.S. Geological Survey parameter code				
				49295	82660	61615	61618	04040
				Parameter name				
				1-Naphthol, water, filtered, recoverable	2,6-Diethylaniline, water, filtered, recoverable	2-[(2-Ethyl-6-methylphenyl)-amino]-1-propanol, water, filtered, recoverable	2-Chloro-2′,6′-diethylacetanilide, water, filtered, recoverable	2-Chloro-4-isopropylamino-6-amino-s-triazine, water, filtered, recoverable
Atlanta								
02338523	Hillabahatchee Creek at Thaxton Road near Franklin, Ga.	2003-07-15 1516	spike	E 0.105	0.111	<0.1256	0.129	E 0.0739
02338523	Hillabahatchee Creek at Thaxton Road near Franklin, Ga.	2003-07-15 1515	environmental	<0.0882	<0.006	<0.1256	<0.005	<0.006
			percent recovery	92	97	--	112	64
02335870	Sope Creek near Marietta, Ga.	2003-09-09 1131	spike	--	0.12	--	--	E 0.0529
02335870	Sope Creek near Marietta, Ga.	2003-09-09 1141	spike	E 0.0158	--	0.138	0.12	--
02335870	Sope Creek near Marietta, Ga.	2003-09-09 1130	environmental	<0.0882	<0.006	<0.1256	<0.005	E 0.003
			percent recovery	14	105	120	105	44
02334885	Suwanee Creek at Suwanee, Ga.	2003-07-08 1531	spike	E 0.0235	0.107	E 0.154	0.126	E 0.0524
02334885	Suwanee Creek at Suwanee, Ga.	2003-07-08 1530	environmental	<0.0882	<0.006	<0.1256	<0.005	<0.006
			percent recovery	20	93	134	110	46
02344797	White Oak Creek at Cannon Road near Raymond, Ga.	2003-07-15 1301	spike	E 0.0772	0.112	0.131	0.126	E 0.0676
02344797	White Oak Creek at Cannon Road near Raymond, Ga.	2003-07-15 1300	environmental	E 0.0116	<0.006	<0.1256	<0.005	E 0.0052
			percent recovery	57	98	114	110	54
Raleigh-Durham								
0208725055	Black Creek at Weston Parkway near Cary, N.C.	2003-08-25 1301	spike	E 0.0148	0.108	0.178	0.122	E 0.0612
0208725055	Black Creek at Weston Parkway near Cary, N.C.	2003-08-25 1300	environmental	<0.0882	<0.006	<0.1256	<0.005	<0.006
			percent recovery	13	94	155	106	53
02085430	Deep Creek near Moriah, N.C.	2003-07-16 0905	spike	E 0.0488	0.101	0.368	0.121	E 0.0651
02085430	Deep Creek near Moriah, N.C.	2003-07-16 0900	environmental	<0.0882	<0.006	<0.31	<0.005	E 0.0181
			percent recovery	43	88	321	106	41
02097464	Morgan Creek near White Cross, N.C.	2003-07-15 1205	spike	E 0.0471	0.101	E 0.123	0.106	E 0.0759
02097464	Morgan Creek near White Cross, N.C.	2003-07-15 1200	environmental	<0.0882	<0.006	<0.1256	<0.005	E 0.0291
			percent recovery	41	88	107	92	41
02087580	Swift Creek near Apex, N.C.	2003-08-25 1003	spike	--	0.106	--	--	E 0.032
02087580	Swift Creek near Apex, N.C.	2003-08-25 1004	spike	E 0.0339	--	0.172	0.121	--
02087580	Swift Creek near Apex, N.C.	2003-08-25 1005	spike	--	--	--	--	E 0.0359
02087580	Swift Creek near Apex, N.C.	2003-08-25 1000	environmental	<0.0882	<0.006	<0.1256	<0.005	<0.006
			percent recovery	30	92	150	106	31
Milwaukee-Green Bay								
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-02-03 1321	spike	--	0.0749	--	--	E 0.043
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-02-03 1320	environmental	--	<0.006	--	<0.005	<0.006
			percent recovery	--	65	--	--	37
Dallas-Fort Worth								
08063555	South Fork Chambers Creek near Creek 102 near Maypearl, Tex.	2004-03-31 1002	spike	E 0.01	0.1	--	0.12	E 0.154
08063555	South Fork Chambers Creek near Creek 102 near Maypearl, Tex.	2004-03-31 1000	environmental	<0.0882	<0.006	--	<0.005	E 0.1
			percent recovery	9	87	--	105	47
Denver								
400217105123701	Boulder Creek below 61st Street near Boulder, Colo.	2003-08-14 1122	spike	E 0.0256	0.1	E 0.0912	0.118	E 0.0541
400217105123701	Boulder Creek below 61st Street near Boulder, Colo.	2003-08-14 1120	environmental	<0.0882	<0.006	<0.1256	<0.005	<0.006
			percent recovery	22	87	80	103	47
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	2002-12-09 1222	spike	E 0.0236	0.096	E 0.0988	0.112	E 0.0803
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	2002-12-09 1220	environmental	E 0.0094	<0.006	<0.126	<0.005	<0.0063
			percent recovery	12	84	86	98	70
Portland								
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1253	spike	E 0.0234	0.09	--	0.116	E 0.0494
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1250	environmental	<0.0882	<0.006	--	<0.005	E 0.0096
			percent recovery	20	78	--	101	35
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1203	spike	E 0.021	0.109	--	0.117	E 0.0551
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1200	environmental	<0.0882	<0.006	--	<0.005	E 0.001
			percent recovery	18	95	--	102	47
14206950	Fanno Creek at Durham, Oreg.	2004-04-29 1023	spike	--	--	--	0.106	--
14206950	Fanno Creek at Durham, Oreg.	2004-04-29 1020	environmental	--	<0.006	--	<0.005	E 0.0061
			percent recovery	--	--	--	92	--
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1153	spike	E 0.0211	0.0947	--	0.118	E 0.0559
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1150	environmental	<0.0882	<0.006	--	<0.005	E 0.005
			percent recovery	18	83	--	103	44
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1153	spike	E 0.023	0.0989	E 0.0916	0.104	E 0.0533
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1150	environmental	<0.0882	<0.006	<0.1256	<0.005	E 0.004
			percent recovery	20	86	80	91	43
454510122424900	Whipple Creek near Salmon Creek, Wa	2004-06-28 1143	spike	E 0.0091	0.102	--	0.116	E 0.0467
454510122424900	Whipple Creek near Salmon Creek, Wa	2004-06-28 1140	environmental	<0.0882	<0.006	--	<0.005	<0.006
			percent recovery	8	89	--	101	41
Summary statistics for percent reovery of spiked compounds								
Mean percent recovery				27	89	135	102	46
Standard deviation of percent recovery				22	9	71	6	10
Maximum percent recovery				92	105	321	112	70
Minimum percent recovery				8	65	80	91	31
Number of times compound was not detected in spike				0	0	1	0	0

Appendix 2. Quality-control data.
Appendix 2c. Percent recovery of spiked pesticide compounds.—Continued

[All spike and environmental samples are in units of micrograms per liter. E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; M, presence of material verified, but not quantified; --, not analyzed or not applicable.]

U.S. Geological Survey parameter code										
61620	**61625**	**61633**	**49260**	**46342**	**39632**	**61635**	**82686**	**82673**	**82680**	**61636**
Parameter name										
2-Ethyl-6-methylaniline, water, filtered, recoverable	**3,4-Dichloroaniline, water, filtered, recoverable**	**4-Chloro-2-methylphenol, water, filtered, recoverable**	**Acetochlor, water, filtered, recoverable**	**Alachlor, water, filtered, recoverable**	**Atrazine, water, filtered, recoverable**	**Azinphos-methyl oxygen analog, water, filtered, recoverable**	**Azinphos-methyl, water, filtered, recoverable**	**Benfluralin, water, filtered, recoverable**	**Carbaryl, water, filtered, recoverable**	**Chlorpyrifos oxygen analog, water, filtered, recoverable**
Atlanta										
E 0.103	0.0871	E 0.0787	0.136	0.101	0.135	E 0.0861	E 0.121	0.102	E 0.124	E 0.0769
<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016	<0.05	<0.01	<0.041	<0.0562
90	76	69	119	88	118	75	106	89	108	67
--	--	--	0.123	0.116	0.117	--	E 0.142	0.1	E 0.144	--
E 0.112	0.0841	E 0.0597	--	--	--	E 0.0629	--	--	--	E 0.0384
<0.0045	<0.0045	<0.0056	<0.006	<0.0045	E 0.0048	<0.016	<0.05	<0.01	E 0.005	<0.0562
98	73	52	107	101	98	55	124	87	121	33
E 0.101	0.0696	E 0.0537	0.131	0.124	0.133	E 0.0805	E 0.125	0.102	E 0.146	E 0.0924
<0.0045	<0.0045	<0.0056	<0.006	<0.0045	E 0.004	<0.125	<0.05	<0.01	E 0.0281	<0.0562
88	61	47	114	108	112	70	109	89	103	81
E 0.104	0.0769	E 0.0744	0.139	0.1	0.163	E 0.101	E 0.13	0.108	E 0.168	E 0.0857
<0.0045	<0.0045	E 0.0015	<0.006	<0.0045	0.0314	<0.016	<0.05	<0.01	E 0.0284	<0.0562
91	67	64	121	87	115	88	113	94	122	75
Raleigh-Durham										
E 0.104	0.0756	E 0.0616	0.124	0.119	0.126	E 0.0902	E 0.12	0.0887	E 0.1	E 0.0326
<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016	<0.05	<0.01	<0.041	<0.0562
91	66	54	108	104	110	79	105	77	87	28
E 0.0984	0.0651	E 0.0549	0.125	0.141	0.172	E 0.0986	E 0.123	0.102	E 0.162	E 0.0837
<0.0045	<0.0045	<0.0056	<0.006	<0.0045	0.0505	<0.016	<0.05	<0.01	<0.041	<0.0562
86	57	48	109	123	106	86	107	89	141	73
E 0.101	0.0755	E 0.0496	0.119	0.12	0.254	E 0.0858	E 0.128	0.0888	E 0.118	E 0.0818
<0.0045	<0.0045	<0.0056	<0.006	<0.0045	0.143	<0.016	<0.05	<0.01	<0.041	<0.0562
88	66	43	104	105	97	75	112	77	103	71
--	--	--	0.126	0.13	0.0957	--	E 0.191	0.082	E 0.111	--
E 0.104	0.0727	E 0.0532	--	--	--	E 0.0732	--	--	--	E 0.0797
--	--	--	--	--	E 0.0728	--	--	--	--	--
<0.0045	0.0078	<0.0056	<0.006	<0.0045	E 0.0064	<0.016	<0.05	<0.01	<0.041	<0.0562
91	57	46	110	113	58	64	167	72	97	69
Milwaukee-Green Bay										
--	--	--	0.13	0.129	0.148	--	E 0.182	0.12	E 0.23	--
<0.0045	<0.0045	<0.0056	<0.006	<0.005	0.0222	<0.016	<0.05	<0.01	<0.041	<0.0562
--	--	--	113	112	110	--	159	105	201	--
Dallas-Fort Worth										
E 0.101	0.089	E 0.059	0.125	0.151	0.807	E 0.07	E 0.1	0.088	E 0.11	E 0.07
<0.0045	0.0061	<0.0056	<0.006	0.0294	0.675	<0.016	<0.05	<0.01	E 0.0028	<0.0562
88	72	51	109	106	115	61	87	77	93	61
Denver										
E 0.102	0.0697	E 0.0554	0.123	0.121	0.127	E 0.0775	E 0.114	0.0824	E 0.1	E 0.0621
<0.0045	<0.0045	<0.0056	<0.006	<0.0045	<0.007	<0.016	<0.05	<0.01	<0.041	<0.0562
89	61	48	107	106	111	68	99	72	87	54
E 0.0819	0.0779	E 0.0736	0.117	0.141	0.117	E 0.0986	E 0.154	0.0787	E 0.182	E 0.0421
<0.0045	<0.0045	<0.0056	<0.006	<0.0045	0.0104	<0.016	<0.05	<0.01	E 0.0597	<0.0562
71	68	64	102	123	93	86	134	69	107	37
Portland										
E 0.0878	0.0742	E 0.0461	0.121	0.116	0.136	E 0.0785	E 0.101	0.108	E 0.144	E 0.0896
<0.0045	0.0227	<0.0056	<0.006	<0.005	0.0177	<0.016	<0.05	<0.01	E 0.0096	<0.0562
77	45	40	106	101	103	68	88	94	117	78
E 0.111	0.0694	E 0.0653	0.111	0.11	0.122	E 0.0533	E 0.094	0.0742	E 0.097	E 0.0137
<0.0045	<0.0045	<0.0057	<0.006	<0.005	<0.007	<0.07	<0.05	<0.01	<0.041	<0.0562
97	61	57	97	96	106	46	82	65	85	12
E 0.102	0.0692	E 0.0424	--	--	--	E 0.0948	--	--	--	E 0.0608
<0.0045	0.0056	<0.0056	<0.006	<0.005	0.0124	<0.016	<0.05	<0.01	E 0.0499	<0.0562
89	55	37	--	--	--	83	--	--	--	53
E 0.088	0.0727	E 0.0558	0.117	0.112	0.119	E 0.112	E 0.123	0.0878	E 0.19	E 0.0879
<0.0045	E 0.002	<0.0056	<0.006	<0.005	E 0.0027	<0.016	<0.05	<0.01	E 0.0232	<0.0562
77	62	49	102	98	101	98	107	77	145	77
E 0.0928	0.124	E 0.0536	0.0891	0.0962	0.146	E 0.096	E 0.101	0.075	E 0.174	E 0.0559
<0.0045	0.0613	<0.0056	<0.006	<0.005	0.0297	<0.031	<0.05	<0.01	E 0.0068	<0.0562
81	55	47	78	84	101	84	88	65	146	49
E 0.0968	0.0661	E 0.0506	0.114	0.113	0.117	E 0.147	E 0.13	0.0821	E 0.119	E 0.0644
<0.0045	<0.0045	<0.0056	<0.006	<0.005	<0.007	<0.016	<0.05	<0.01	<0.041	<0.0562
84	58	44	99	99	102	128	113	72	104	56
Summary statistics for percent reovery of spiked compounds										
87	62	51	106	103	103	77	112	81	116	57
7	8	9	10	11	14	19	23	12	29	20
98	76	69	121	123	118	128	167	105	201	81
71	45	37	78	84	58	46	82	65	85	12
0	0	0	0	0	0	0	0	0	0	0

Appendix 2. Quality-control data.
Appendix 2c. Percent recovery of spiked pesticide compounds.— Continued

[All spike and environmental samples are in units of micrograms per liter. E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; M, presence of material verified, but not quantified; --, not analyzed or not applicable.]

U.S. Geological Survey station number	U.S. Geological Survey station name	Sample date and time	Variable	U.S. Geological Survey parameter code				
				38933	82687	61585	61586	82682
				Parameter name				
				Chlorpyrifos, water, filtered, recoverable	cis-Permethrin, water, filtered, recoverable	Cyfluthrin, water, filtered, recoverable	Cypermethrin, water, filtered, recoverable	DCPA, water, filtered, recoverable
Atlanta								
02338523	Hillabahatchee Creek at Thaxton Road near Franklin, Ga.	2003-07-15 1516	spike	0.123	0.0833	E 0.0776	E 0.0768	0.128
02338523	Hillabahatchee Creek at Thaxton Road near Franklin, Ga.	2003-07-15 1515	environmental	<0.005	<0.006	<0.008	<0.0086	<0.003
			percent recovery	107	73	68	67	112
02335870	Sope Creek near Marietta, Ga.	2003-09-09 1131	spike	0.109	0.0743	--	--	0.107
02335870	Sope Creek near Marietta, Ga.	2003-09-09 1141	spike	--	--	E 0.0817	E 0.0776	--
02335870	Sope Creek near Marietta, Ga.	2003-09-09 1130	environmental	<0.005	<0.006	<0.008	<0.0086	<0.003
			percent recovery	95	65	71	68	93
02334885	Suwanee Creek at Suwanee, Ga.	2003-07-08 1531	spike	0.122	0.0912	E 0.0846	E 0.0848	0.127
02334885	Suwanee Creek at Suwanee, Ga.	2003-07-08 1530	environmental	<0.005	<0.006	<0.008	<0.0086	<0.003
			percent recovery	106	80	74	74	111
02344797	White Oak Creek at Cannon Road near Raymond, Ga.	2003-07-15 1301	spike	0.128	0.0832	E 0.082	E 0.0796	0.125
02344797	White Oak Creek at Cannon Road near Raymond, Ga.	2003-07-15 1300	environmental	<0.005	<0.006	<0.008	<0.0086	<0.003
			percent recovery	112	73	72	69	109
Raleigh-Durham								
0208725055	Black Creek at Weston Parkway near Cary, N.C.	2003-08-25 1301	spike	0.11	0.0944	E 0.0829	E 0.0812	0.117
0208725055	Black Creek at Weston Parkway near Cary, N.C.	2003-08-25 1300	environmental	<0.005	<0.006	<0.008	<0.0086	<0.003
			percent recovery	96	82	72	71	102
02085430	Deep Creek near Moriah, N.C.	2003-07-16 0905	spike	0.122	0.0812	E 0.0958	E 0.0795	0.12
02085430	Deep Creek near Moriah, N.C.	2003-07-16 0900	environmental	<0.005	<0.006	<0.008	<0.0086	<0.003
			percent recovery	106	71	84	69	105
02097464	Morgan Creek near White Cross, N.C.	2003-07-15 1205	spike	0.115	0.0793	E 0.0818	E 0.0852	0.121
02097464	Morgan Creek near White Cross, N.C.	2003-07-15 1200	environmental	<0.005	<0.006	<0.008	<0.0086	<0.003
			percent recovery	100	69	71	74	106
02087580	Swift Creek near Apex, N.C.	2003-08-25 1003	spike	0.0975	0.0619	--	--	0.0989
02087580	Swift Creek near Apex, N.C.	2003-08-25 1004	spike	--	--	E 0.0683	E 0.0668	--
02087580	Swift Creek near Apex, N.C.	2003-08-25 1005	spike	--	--	--	--	--
02087580	Swift Creek near Apex, N.C.	2003-08-25 1000	environmental	<0.005	<0.006	<0.008	<0.0086	<0.003
			percent recovery	85	54	60	58	86
Milwaukee-Green Bay								
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-02-03 1321	spike	0.149	0.0674	--	--	0.119
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-02-03 1320	environmental	<0.005	<0.006	<0.008	<0.0086	<0.003
			percent recovery	130	59	--	--	104
Dallas-Fort Worth								
08063555	South Fork Chambers Creek near Creek 102 near Maypearl, Tex.	2004-03-31 1002	spike	0.113	0.053	E 0.062	E 0.063	0.116
08063555	South Fork Chambers Creek near Creek 102 near Maypearl, Tex.	2004-03-31 1000	environmental	<0.005	<0.006	<0.008	<0.0086	<0.003
			percent recovery	99	46	54	55	101
Denver								
400217105123701	Boulder Creek below 61st Street near Boulder, Colo.	2003-08-14 1122	spike	0.111	0.0832	E 0.0695	E 0.0653	0.121
400217105123701	Boulder Creek below 61st Street near Boulder, Colo.	2003-08-14 1120	environmental	<0.005	<0.006	<0.008	<0.0086	<0.003
			percent recovery	97	73	61	57	106
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	2002-12-09 1222	spike	0.108	E 0.0796	E 0.103	E 0.0924	0.122
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	2002-12-09 1220	environmental	<0.005	<0.006	<0.008	<0.0086	<0.003
			percent recovery	94	69	90	81	106
Portland								
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1253	spike	0.116	0.0574	E 0.0762	E 0.0735	0.119
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1250	environmental	<0.005	<0.006	<0.008	<0.0086	<0.003
			percent recovery	101	50	66	64	104
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1203	spike	0.098	0.0636	E 0.0532	E 0.0533	0.116
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1200	environmental	<0.005	<0.006	<0.008	<0.0086	<0.003
			percent recovery	85	55	46	46	101
14206950	Fanno Creek at Durham, Oreg.	2004-04-29 1023	spike	--	--	E 0.0754	E 0.0614	--
14206950	Fanno Creek at Durham, Oreg.	2004-04-29 1020	environmental	<0.005	<0.006	<0.008	<0.0086	<0.003
			percent recovery	--	--	66	54	--
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1153	spike	0.108	0.0778	E 0.0977	E 0.088	0.108
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1150	environmental	<0.005	<0.006	<0.008	<0.0086	<0.003
			percent recovery	94	68	85	77	94
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1153	spike	0.123	0.0615	E 0.0713	E 0.0671	0.114
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1150	environmental	0.0134	<0.006	<0.008	<0.0086	<0.003
			percent recovery	96	54	62	59	99
454510122424900	Whipple Creek near Salmon Creek, Wa	2004-06-28 1143	spike	0.107	0.0734	E 0.1	E 0.0879	0.12
454510122424900	Whipple Creek near Salmon Creek, Wa	2004-06-28 1140	environmental	<0.005	<0.006	<0.03	<0.03	<0.003
			percent recovery	93	64	87	77	105
Summary statistics for percent reovery of spiked compounds								
Mean percent recovery				100	65	70	66	103
Standard deviation of percent recovery				11	10	12	10	6
Maximum percent recovery				130	82	90	81	112
Minimum percent recovery				85	46	46	46	86
Number of times compound was not detected in spike				0	0	0	0	0

Appendix 2. Quality-control data.

Appendix 2c. Percent recovery of spiked pesticide compounds.— Continued

[All spike and environmental samples are in units of micrograms per liter. E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; M, presence of material verified, but not quantified; --, not analyzed or not applicable.]

U.S. Geological Survey parameter code										
62170	61638	39572	38454	39381	82662	61644	82346	61645	61646	61591
Parameter name										
Desulfinyl fipronil, water, filtered, recoverable	Diazinon oxygen analog, water, filtered, recoverable	Diazinon, water, filtered, recoverable	Dicrotophos, water, filtered, recoverable	Dieldrin, water, filtered, recoverable	Dimethoate, water, filtered, recoverable	Ethion monoxon, water, filtered, recoverable	Ethion, water, filtered, recoverable	Fenamiphos sulfone, water, filtered, recoverable	Fenamiphos sulfoxide, water, filtered, recoverable	Fenamiphos, water, filtered, recoverable
Atlanta										
0.13	0.116	0.124	E 0.0728	0.0963	E 0.0422	E 0.124	0.12	0.117	E 0.108	0.111
<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
113	101	108	63	84	37	108	105	102	94	97
--	--	0.111	--	0.117	--	--	--	--	--	--
--	--	--	E 0.0473	--	E 0.0298	E 0.096	0.0941	E 0.124	E 0.086	0.111
<0.004	--	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
--	--	97	41	102	26	84	82	108	75	97
0.112	0.111	0.125	E 0.046	0.117	E 0.0286	E 0.119	0.126	0.136	E 0.11	E 0.141
<0.004	<0.01	0.0079	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.125	<0.029
98	97	102	40	102	25	104	110	119	96	123
0.13	0.12	0.124	E 0.067	0.103	E 0.0294	E 0.14	0.13	0.143	E 0.167	0.154
<0.004	<0.01	0.0055	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
113	105	103	58	90	26	122	113	125	146	134
Raleigh-Durham										
0.122	0.0997	0.0992	E 0.0404	0.108	E 0.0293	E 0.11	0.128	E 0.123	E 0.107	E 0.101
<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
106	87	87	35	94	26	96	112	107	93	88
0.146	0.124	0.121	E 0.0439	0.103	E 0.0281	E 0.145	0.128	0.16	E 0.137	0.196
<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
127	108	106	38	90	25	126	112	140	119	171
0.12	0.103	0.114	E 0.0297	0.127	E 0.0266	E 0.116	0.119	0.125	E 0.0601	E 0.128
<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
105	90	99	26	111	23	101	104	109	52	112
0.0077	--	0.12	--	0.139	--	--	--	--	--	--
--	--	--	E 0.0446	--	E 0.026	E 0.109	0.0999	0.13	E 0.0888	0.126
--	--	--	--	--	--	--	--	--	--	--
0.006	--	E 0.0041	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
1	--	101	39	121	23	95	87	113	77	110
Milwaukee-Green Bay										
0.149	--	0.119	--	0.109	--	--	--	--	--	--
<0.012	--	<0.005	<0.0843	<0.009	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
130	--	104	--	95	--	--	--	--	--	--
Dallas-Fort Worth										
0.118	0.11	0.113	E 0.03	0.104	E 0.029	E 0.11	0.104	0.136	E 0.05	0.14
<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
103	96	99	26	91	25	96	91	119	44	122
Denver										
0.116	0.0969	0.11	E 0.0383	0.135	E 0.0261	E 0.108	0.124	0.0984	E 0.0712	0.12
<0.004	<0.01	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
101	84	96	33	118	23	94	108	86	62	105
0.102	0.11	0.121	E 0.0456	0.103	E 0.0458	E 0.118	0.105	0.154	E 0.0976	0.144
<0.004	<0.04	<0.005	<0.0843	<0.0048	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
89	96	106	40	90	40	103	92	134	85	126
Portland										
0.129	0.107	0.11	E 0.0388	0.0914	E 0.0242	E 0.112	0.108	0.137	E 0.103	0.149
<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
112	93	96	34	80	21	98	94	119	90	130
0.111	0.0735	0.106	E 0.0259	0.134	E 0.0284	E 0.084	0.102	0.0731	E 0.0683	0.086
<0.012	<0.006	<0.005	<0.0843	<0.009	<0.0061	<0.002	<0.004	<0.0491	<0.0387	<0.029
97	64	92	23	117	25	73	89	64	60	75
--	--	--	E 0.0308	--	E 0.0232	E 0.0881	0.088	0.106	E 0.0746	0.0996
<0.012	--	0.008	<0.0843	<0.009	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
--	--	--	27	--	20	77	77	92	65	87
0.112	0.1	0.102	E 0.0469	0.0972	E 0.0305	E 0.118	0.118	0.154	E 0.102	0.13
<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
98	87	89	41	85	27	103	103	134	89	113
0.12	0.0922	0.0956	E 0.0336	0.0886	E 0.0229	E 0.0905	0.0852	0.134	E 0.106	0.111
<0.012	<0.01	<0.005	<0.0843	E 0.0023	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
105	80	83	29	75	20	79	74	117	92	97
0.123	0.0909	0.105	E 0.0424	0.113	E 0.0258	0.122	0.112	E 0.132	E 0.107	E 0.103
<0.012	<0.01	<0.005	<0.0843	<0.009	<0.0061	<0.0336	<0.004	<0.0077	<0.031	<0.029
107	79	92	37	99	22	106	98	115	93	90
Summary statistics for percent reovery of spiked compounds										
100	91	98	37	97	25	98	97	112	84	110
28	11	7	11	14	5	14	13	19	25	23
130	108	108	63	121	40	126	113	140	146	171
1	64	83	23	75	20	73	74	64	44	75
0	0	0	0	0	0	0	0	0	0	0

Appendix 2. Quality-control data.
Appendix 2c. Percent recovery of spiked pesticide compounds.— Continued

[All spike and environmental samples are in units of micrograms per liter. E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; M, presence of material verified, but not quantified; --, not analyzed or not applicable.]

U.S. Geological Survey station number	U.S. Geological Survey station name	Sample date and time	Variable	U.S. Geological Survey parameter code				
				62169	62167	62168	62166	61649
				Parameter name				
				Desulfinylfipronil amide, water, filtered, recoverable	Fipronil sulfide, water, filtered, recoverable	Fipronil sulfone, water, filtered, recoverable	Fipronil, water, filtered, recoverable	Fonofos oxygen analog, water, filtered, recoverable
			Atlanta					
02338523	Hillabahatchee Creek at Thaxton Road near Franklin, Ga.	2003-07-15 1516	spike	E 0.154	0.136	0.113	E 0.144	E 0.119
02338523	Hillabahatchee Creek at Thaxton Road near Franklin, Ga.	2003-07-15 1515	environmental	<0.009	<0.005	<0.005	<0.007	<0.0021
			percent recovery	134	119	99	126	104
02335870	Sope Creek near Marietta, Ga.	2003-09-09 1131	spike	--	--	E 0.0054	--	--
02335870	Sope Creek near Marietta, Ga.	2003-09-09 1141	spike	--	--	--	--	E 0.102
02335870	Sope Creek near Marietta, Ga.	2003-09-09 1130	environmental	E 0.004	<0.005	<0.005	<0.007	<0.0021
			percent recovery	--	--	5	--	89
02334885	Suwanee Creek at Suwanee, Ga.	2003-07-08 1531	spike	E 0.139	0.119	0.11	E 0.124	E 0.109
02334885	Suwanee Creek at Suwanee, Ga.	2003-07-08 1530	environmental	<0.009	<0.005	<0.005	E 0.0069	<0.0021
			percent recovery	121	104	96	102	95
02344797	White Oak Creek at Cannon Road near Raymond, Ga.	2003-07-15 1301	spike	E 0.173	0.139	0.127	E 0.181	E 0.118
02344797	White Oak Creek at Cannon Road near Raymond, Ga.	2003-07-15 1300	environmental	<0.009	<0.005	<0.005	<0.007	<0.0021
			percent recovery	151	121	111	158	103
			Raleigh-Durham					
0208725055	Black Creek at Weston Parkway near Cary, N.C.	2003-08-25 1301	spike	E 0.158	0.137	0.126	0.113	E 0.109
0208725055	Black Creek at Weston Parkway near Cary, N.C.	2003-08-25 1300	environmental	<0.009	E 0.0079	<0.005	E 0.0158	<0.0021
			percent recovery	138	113	110	85	95
02085430	Deep Creek near Moriah, N.C.	2003-07-16 0905	spike	E 0.163	0.144	0.128	E 0.162	E 0.116
02085430	Deep Creek near Moriah, N.C.	2003-07-16 0900	environmental	<0.009	<0.005	<0.005	<0.007	<0.0021
			percent recovery	142	126	112	141	101
02097464	Morgan Creek near White Cross, N.C.	2003-07-15 1205	spike	E 0.134	0.124	0.109	E 0.132	E 0.0852
02097464	Morgan Creek near White Cross, N.C.	2003-07-15 1200	environmental	<0.009	<0.005	<0.006	<0.007	<0.0021
			percent recovery	117	108	95	115	74
02087580	Swift Creek near Apex, N.C.	2003-08-25 1003	spike	--	0.0093	0.0089	E 0.0148	--
02087580	Swift Creek near Apex, N.C.	2003-08-25 1004	spike	--	--	--	--	E 0.116
02087580	Swift Creek near Apex, N.C.	2003-08-25 1005	spike	--	--	--	--	--
02087580	Swift Creek near Apex, N.C.	2003-08-25 1000	environmental	<0.009	0.007	0.009	E 0.0152	<0.0021
			percent recovery	--	--	--	--	101
			Milwaukee-Green Bay					
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-02-03 1321	spike	E 0.181	0.137	0.138	E 0.225	--
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-02-03 1320	environmental	<0.029	<0.013	<0.024	<0.016	<0.0021
			percent recovery	158	119	120	196	--
			Dallas-Fort Worth					
08063555	South Fork Chambers Creek near Creek 102 near Maypearl, Tex.	2004-03-31 1002	spike	E 0.128	0.122	0.098	E 0.151	E 0.107
08063555	South Fork Chambers Creek near Creek 102 near Maypearl, Tex.	2004-03-31 1000	environmental	<0.029	<0.013	<0.024	<0.016	<0.0021
			percent recovery	112	106	85	132	93
			Denver					
400217105123701	Boulder Creek below 61st Street near Boulder, Colo.	2003-08-14 1122	spike	E 0.13	0.113	0.108	E 0.106	E 0.0895
400217105123701	Boulder Creek below 61st Street near Boulder, Colo.	2003-08-14 1120	environmental	<0.009	<0.005	<0.005	<0.007	<0.0021
			percent recovery	113	99	94	92	78
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	2002-12-09 1222	spike	0.147	0.119	0.112	0.12	E 0.0944
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	2002-12-09 1220	environmental	<0.009	<0.005	<0.005	<0.007	<0.0021
			percent recovery	128	104	98	105	82
			Portland					
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1253	spike	E 0.126	0.133	0.103	E 0.16	E 0.106
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1250	environmental	<0.029	<0.013	<0.024	<0.016	<0.0021
			percent recovery	110	116	90	140	92
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1203	spike	E 0.104	0.1	0.0972	E 0.0891	E 0.079
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1200	environmental	<0.029	<0.013	<0.024	<0.016	<0.0029
			percent recovery	91	87	85	78	69
14206950	Fanno Creek at Durham, Oreg.	2004-04-29 1023	spike	--	--	--	--	E 0.0887
14206950	Fanno Creek at Durham, Oreg.	2004-04-29 1020	environmental	<0.029	<0.013	<0.024	<0.016	<0.0021
			percent recovery	--	--	--	--	77
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1153	spike	E 0.148	0.123	0.102	E 0.143	E 0.11
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1150	environmental	<0.029	<0.013	<0.024	<0.016	<0.0021
			percent recovery	129	107	89	125	96
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1153	spike	E 0.136	0.118	0.0968	E 0.124	E 0.0927
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1150	environmental	<0.029	<0.013	<0.024	<0.016	<0.0021
			percent recovery	119	103	84	108	81
454510122424900	Whipple Creek near Salmon Creek, Wa	2004-06-28 1143	spike	E 0.134	0.133	0.144	E 0.142	E 0.0914
454510122424900	Whipple Creek near Salmon Creek, Wa	2004-06-28 1140	environmental	<0.029	<0.013	<0.024	<0.016	<0.0021
			percent recovery	117	116	126	124	80
			Summary statistics for percent reovery of spiked compounds					
Mean percent recovery				125	110	94	122	89
Standard deviation of percent recovery				17	10	27	30	11
Maximum percent recovery				158	126	126	196	104
Minimum percent recovery				91	87	5	78	69
Number of times compound was not detected in spike				0	0	0	0	0

Appendix 2. Quality-control data.
Appendix 2c. Percent recovery of spiked pesticide compounds.— Continued

[All spike and environmental samples are in units of micrograms per liter. E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; M, presence of material verified, but not quantified; --, not analyzed or not applicable.]

U.S. Geological Survey parameter code											
04095	**04025**	**61593**	**61594**	**61652**	**39532**	**61596**	**61598**	**61664**	**82667**	**39415**	**82630**
Parameter name											
Fonofos, water, filtered, recoverable	**Hexazinone, water, filtered, recoverable**	**Iprodione, water, filtered, recoverable**	**Isofenphos, water, filtered, recoverable**	**Malaoxon, water, filtered, recoverable**	**Malathion, water, filtered, recoverable**	**Metalaxyl, water, filtered, recoverable**	**Methidathion, water, filtered, recoverable**	**Methyl paraoxon, water, filtered, recoverable**	**Methyl parathion, water, filtered, recoverable**	**Metolachlor, water, filtered, recoverable**	**Metribuzin, water, filtered, recoverable**
Atlanta											
0.116	0.126	E 0.019	0.142	0.12	0.127	0.125	0.123	E 0.103	0.119	0.13	0.124
<0.0027	<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006
101	110	17	124	105	111	109	107	90	104	113	108
0.106	--	--	--	--	0.13	--	--	--	0.115	0.126	0.0938
--	0.105	<1.4223	0.103	0.102	--	0.119	0.096	E 0.081	--	--	--
<0.0027	<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006
92	92	--	90	89	113	104	84	71	100	110	82
0.111	0.123	E 0.0287	0.119	0.112	0.121	0.112	0.119	E 0.0952	0.11	0.128	0.102
<0.0027	<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006
97	107	25	104	98	106	98	104	83	96	112	89
0.119	0.137	E 0.0278	0.138	0.131	0.131	0.123	0.128	E 0.0969	0.126	0.13	0.118
<0.0027	<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006
104	119	24	120	114	114	107	112	84	110	113	103
Raleigh-Durham											
0.0951	0.126	E 0.0183	0.115	0.0836	0.104	0.116	0.112	E 0.0807	0.0704	0.121	0.0967
<0.0027	<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006
83	110	16	100	73	91	101	98	70	61	106	84
0.11	0.128	E 0.02	0.161	0.121	0.128	0.131	0.117	E 0.101	0.106	0.132	0.0961
<0.0027	<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	E 0.007	<0.006
96	112	17	140	106	112	114	102	88	92	109	84
0.103	0.114	E 0.0304	0.116	0.105	0.114	0.111	0.111	E 0.0935	0.103	0.136	0.097
<0.0027	<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	0.0198	<0.006
90	99	27	101	92	99	97	97	82	90	101	85
0.113	--	--	--	--	0.107	--	--	--	0.152	0.118	0.0825
--	0.103	E 0.022	0.0963	0.124	--	0.117	0.107	E 0.104	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
<0.0027	<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	E 0.0051	<0.006
99	90	19	84	108	93	102	93	91	133	98	72
Milwaukee-Green Bay											
0.122	--	--	--	--	0.176	--	--	--	0.164	0.133	0.0735
<0.003	<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006
106	--	--	--	--	153	--	--	--	143	116	64
Dallas-Fort Worth											
0.104	0.113	M	0.134	0.096	0.101	0.129	0.108	E 0.09	0.107	0.141	0.097
<0.003	<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.015	0.0187	<0.006
91	99	--	117	84	88	112	94	78	93	107	85
Denver											
0.102	0.106	E 0.0224	0.119	0.0872	0.104	0.116	0.119	E 0.0763	0.0918	0.124	0.0933
<0.0027	<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	E 0.0057	<0.006
89	92	20	104	76	91	101	104	67	80	103	81
0.0928	--	E 0.133	0.114	0.113	0.123	0.0925	0.118	E 0.0591	0.0974	0.127	0.105
<0.0027	--	E 0.0252	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.006	<0.013	<0.006
81	--	94	99	99	107	81	103	52	85	111	92
Portland											
0.104	0.109	E 0.0586	0.128	0.127	0.114	0.123	0.103	E 0.107	0.128	0.123	0.0901
<0.003	<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.015	E 0.0049	<0.006
91	95	51	112	111	99	107	90	93	112	103	79
0.101	0.102	E 0.0117	0.101	0.0684	0.0882	0.105	0.11	E 0.0612	0.0772	0.11	0.088
<0.003	0.0172	<0.387	<0.0034	<0.0298	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006
88	74	10	88	60	77	92	96	53	67	96	77
--	0.0939	E 0.0222	0.0842	0.0871	--	0.0978	0.0904	E 0.0651	--	--	--
<0.003	<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.015	E 0.0082	<0.006
--	82	19	73	76	--	85	79	57	--	--	--
0.0976	0.124	E 0.0392	0.127	0.105	0.111	0.115	0.118	E 0.0942	0.11	0.116	0.097
<0.003	<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.015	E 0.004	<0.006
85	108	34	111	92	97	100	103	82	96	98	85
0.0921	0.117	E 0.0872	0.114	0.0976	0.104	0.114	0.0936	E 0.0758	0.0957	0.138	0.0858
<0.003	0.0159	<1.4223	<0.0034	<0.008	<0.027	E 0.0045	<0.0058	<0.0299	<0.015	0.0288	<0.006
80	88	76	99	85	91	95	82	66	83	95	75
0.101	0.118	E 0.0348	0.128	0.101	0.111	0.126	0.093	E 0.083	0.0921	0.116	0.0901
<0.003	<0.0129	<1.4223	<0.0034	<0.008	<0.027	<0.0051	<0.0058	<0.0299	<0.015	<0.013	<0.006
88	103	30	112	88	97	110	81	72	80	101	79
Summary statistics for percent reovery of spiked compounds											
92	99	32	105	91	102	101	96	75	96	105	84
8	12	24	16	15	17	9	10	13	21	7	11
106	119	94	140	114	153	114	112	93	143	116	108
80	74	10	73	60	77	81	79	52	61	95	64
0	0	1	0	0	0	0	0	0	0	0	0

Appendix 2. Quality-control data.
Appendix 2c. Percent recovery of spiked pesticide compounds.— Continued

[All spike and environmental samples are in units of micrograms per liter. E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; M, presence of material verified, but not quantified; --, not analyzed or not applicable.]

U.S. Geological Survey station number	U.S. Geological Survey station name	Sample date and time	Variable	U.S. Geological Survey parameter code				
				61599	82683	61666	82664	61668
				Parameter name				
				Myclobutanil, water, filtered, recoverable	Pendimethalin, water, filtered, recoverable	Phorate oxygen analog, water, filtered, recoverable	Phorate, water, filtered, recoverable	Phosmet oxygen analog, water, filtered, recoverable
Atlanta								
02338523	Hillabahatchee Creek at Thaxton Road near Franklin, Ga.	2003-07-15 1516	spike	0.119	0.138	E 0.126	0.0869	E 0.0039
02338523	Hillabahatchee Creek at Thaxton Road near Franklin, Ga.	2003-07-15 1515	environmental	<0.008	<0.022	<0.0973	<0.011	<0.0553
			percent recovery	104	120	110	76	3
02335870	Sope Creek near Marietta, Ga.	2003-09-09 1131	spike	--	0.125	--	0.0937	--
02335870	Sope Creek near Marietta, Ga.	2003-09-09 1141	spike	0.109	--	E 0.0832	--	<0.0553
02335870	Sope Creek near Marietta, Ga.	2003-09-09 1130	environmental	<0.008	<0.022	<0.0973	<0.011	<0.0553
			percent recovery	95	109	73	82	--
02334885	Suwanee Creek at Suwanee, Ga.	2003-07-08 1531	spike	0.124	0.13	E 0.0988	0.0927	<0.0553
02334885	Suwanee Creek at Suwanee, Ga.	2003-07-08 1530	environmental	<0.008	<0.022	<0.0973	<0.011	<0.0553
			percent recovery	108	113	86	81	--
02344797	White Oak Creek at Cannon Road near Raymond, Ga.	2003-07-15 1301	spike	0.131	0.15	E 0.136	0.101	<0.0553
02344797	White Oak Creek at Cannon Road near Raymond, Ga.	2003-07-15 1300	environmental	<0.008	<0.022	<0.0973	<0.011	<0.0553
			percent recovery	114	131	119	88	--
Raleigh-Durham								
0208725055	Black Creek at Weston Parkway near Cary, N.C.	2003-08-25 1301	spike	0.129	0.0948	E 0.0556	0.0851	<0.0553
0208725055	Black Creek at Weston Parkway near Cary, N.C.	2003-08-25 1300	environmental	<0.008	<0.022	<0.0973	<0.011	<0.0553
			percent recovery	112	83	48	74	--
02085430	Deep Creek near Moriah, N.C.	2003-07-16 0905	spike	0.125	0.148	E 0.115	0.0863	<0.0553
02085430	Deep Creek near Moriah, N.C.	2003-07-16 0900	environmental	<0.008	<0.022	<0.0973	<0.011	<0.0553
			percent recovery	109	129	100	75	--
02097464	Morgan Creek near White Cross, N.C.	2003-07-15 1205	spike	0.123	0.118	E 0.0972	0.0969	<0.0553
02097464	Morgan Creek near White Cross, N.C.	2003-07-15 1200	environmental	<0.008	<0.022	<0.0973	<0.011	<0.0553
			percent recovery	107	103	85	84	--
02087580	Swift Creek near Apex, N.C.	2003-08-25 1003	spike	--	0.121	--	0.0792	--
02087580	Swift Creek near Apex, N.C.	2003-08-25 1004	spike	0.116	--	E 0.0748	--	<0.0553
02087580	Swift Creek near Apex, N.C.	2003-08-25 1005	spike	--	--	--	--	--
02087580	Swift Creek near Apex, N.C.	2003-08-25 1000	environmental	0.0156	<0.022	<0.0973	<0.011	<0.0553
			percent recovery	88	106	65	69	--
Milwaukee-Green Bay								
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-02-03 1321	spike	--	0.151	--	0.108	--
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	2004-02-03 1320	environmental	<0.008	<0.022	<0.0973	<0.011	--
			percent recovery	--	132	--	94	--
Dallas-Fort Worth								
08063555	South Fork Chambers Creek near Creek 102 near Maypearl, Tex.	2004-03-31 1002	spike	0.112	0.113	E 0.1	0.097	--
08063555	South Fork Chambers Creek near Creek 102 near Maypearl, Tex.	2004-03-31 1000	environmental	<0.008	<0.022	<0.0973	<0.011	--
			percent recovery	98	99	87	85	--
Denver								
400217105123701	Boulder Creek below 61st Street near Boulder, Colo.	2003-08-14 1122	spike	0.127	0.105	E 0.0802	0.0826	E 0.0078
400217105123701	Boulder Creek below 61st Street near Boulder, Colo.	2003-08-14 1120	environmental	<0.008	<0.022	<0.0973	<0.011	<0.0553
			percent recovery	111	92	70	72	7
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	2002-12-09 1222	spike	0.125	0.117	E 0.0958	0.0702	E 0.0922
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	2002-12-09 1220	environmental	<0.008	<0.022	<0.0973	<0.011	<0.0553
			percent recovery	109	102	84	61	80
Portland								
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1253	spike	0.111	0.144	E 0.11	0.0884	E 0.0373
450022123012400	Claggett Creek at Keizer, Oreg.	2004-05-13 1250	environmental	<0.008	<0.022	<0.0973	<0.011	<0.0553
			percent recovery	97	126	96	77	33
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1203	spike	0.106	0.0832	E 0.0609	0.0676	<0.0511
452231122200000	Deep Creek near Sandy, Oreg.	2004-08-17 1200	environmental	<0.008	<0.022	<0.1048	<0.011	--
			percent recovery	92	73	53	59	--
14206950	Fanno Creek at Durham, Oreg.	2004-04-29 1023	spike	0.0887	--	E 0.068	--	<0.0553
14206950	Fanno Creek at Durham, Oreg.	2004-04-29 1020	environmental	<0.008	<0.022	<0.0973	<0.011	<0.0553
			percent recovery	77	--	59	--	--
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1153	spike	0.116	0.125	E 0.108	0.0883	E 0.0058
452526122364400	Kellogg Creek at Milwaukie, Oreg.	2004-03-10 1150	environmental	<0.008	<0.022	<0.0973	<0.011	<0.0553
			percent recovery	101	109	94	77	5
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1153	spike	0.0992	0.109	E 0.0814	0.0612	E 0.029
452337122243500	North Fork Deep Creek at Barton, Oreg.	2004-01-14 1150	environmental	0.013	<0.022	<0.0973	<0.011	<0.0553
			percent recovery	75	95	71	53	25
454510122424900	Whipple Creek near Salmon Creek, Wa	2004-06-28 1143	spike	0.13	0.103	E 0.101	0.0843	<0.0553
454510122424900	Whipple Creek near Salmon Creek, Wa	2004-06-28 1140	environmental	<0.008	<0.022	<0.0973	<0.011	<0.0553
			percent recovery	113	90	88	74	--
Summary statistics for percent reovery of spiked compounds								
Mean percent recovery				101	106	82	75	26
Standard deviation of percent recovery				12	17	19	11	29
Maximum percent recovery				114	132	119	94	80
Minimum percent recovery				75	73	48	53	3
Number of times compound was not detected in spike				0	0	0	0	9

Appendix 2. Quality-control data.

Appendix 2c. Percent recovery of spiked pesticide compounds.— Continued

[All spike and environmental samples are in units of micrograms per liter. E, estimated (value is between the method detection limit and the laboratory reporting level); <, less than; M, presence of material verified, but not quantified; --, not analyzed or not applicable.]

U.S. Geological Survey parameter code										
61601	**04037**	**04036**	**82676**	**04035**	**82670**	**61674**	**82675**	**04022**	**82661**	**38775**
Parameter name										
Phosmet, water, filtered, recoverable	**Prometon, water, filtered, recoverable**	**Prometryn, water, filtered, recoverable**	**Propyzamide, water, filtered, recoverable**	**Simazine, water, filtered, recoverable**	**Tebuthiuron, water, filtered, recoverable**	**Terbufos oxygen analog sulfone, water, filtered, recoverable**	**Terbufos, water, filtered, recoverable**	**Terbuthylazine, water, filtered, recoverable**	**Trifluralin, water, filtered, recoverable**	**Dichlorvos, water, filtered, recoverable**
Atlanta										
E 0.0047	0.132	0.13	0.104	0.13	E 0.198	0.139	0.116	0.129	0.113	E 0.0858
<0.0079	<0.015	<0.0054	<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118
4	115	113	91	113	173	121	101	112	99	75
--	0.134	--	0.117	0.125	0.184	--	0.0828	--	0.105	--
<0.0079	--	0.12	--	--	--	0.11	--	--	--	E 0.0415
<0.0079	E 0.0102	<0.0054	<0.0041	0.0105	0.0343	<0.0676	<0.017	<0.0102	<0.009	<0.0118
--	108	105	102	100	131	96	72	--	92	36
<0.0079	0.123	0.123	0.114	0.131	E 0.159	0.122	0.105	0.126	0.11	E 0.0671
<0.0079	E 0.0072	<0.0054	<0.0041	0.0094	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118
--	101	107	99	106	139	106	92	110	96	59
<0.0079	0.143	0.132	0.0988	0.145	E 0.191	0.153	0.111	0.125	0.121	E 0.0699
<0.0079	E 0.008	<0.0054	<0.0041	0.0155	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118
--	118	115	86	113	167	133	97	109	106	61
Raleigh-Durham										
<0.0079	0.166	0.122	0.104	0.12	E 0.108	0.0884	0.086	0.117	0.1	E 0.0604
<0.0079	0.0403	<0.0054	<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118
--	110	106	91	105	94	77	75	102	87	53
<0.0079	0.124	0.142	0.116	0.144	0.143	0.149	0.114	0.115	0.117	E 0.0696
<0.0079	E 0.0029	<0.0054	<0.0041	0.0319	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118
--	106	124	101	98	125	130	99	100	102	61
<0.0079	0.113	0.117	0.107	0.109	E 0.132	0.12	0.0955	0.123	0.0956	E 0.0851
<0.0079	E 0.0053	<0.0054	<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118
--	94	102	93	95	115	105	83	107	83	74
--	0.116	--	0.0943	0.0849	0.117	--	0.0659	--	0.0881	--
<0.0079	--	0.13	--	--	--	0.126	--	0.133	--	E 0.0556
--	--	--	--	--	E 0.2432	--	--	--	--	--
<0.0079	0.02	<0.0054	<0.0041	0.0091	E 0.0111	<0.0676	<0.017	<0.0102	<0.009	<0.0118
--	84	113	82	66	202	110	57	116	77	48
Milwaukee-Green Bay										
--	0.183	--	0.138	0.126	0.205	--	0.102	--	0.126	--
--	<0.005	<0.0054	<0.004	<0.005	0.0242	<0.0676	<0.017	<0.0102	<0.009	<0.0118
--	160	--	120	110	158	--	89	--	110	--
Dallas-Fort Worth										
--	0.13	0.131	0.106	0.143	0.143	0.11	0.09	0.13	0.091	E 0.07
--	<0.005	<0.0054	<0.004	0.0164	E 0.004	<0.0676	<0.017	<0.0102	<0.009	E 0.0017
--	113	114	92	110	121	96	78	113	79	60
Denver										
E 0.0066	0.128	0.124	0.106	0.113	0.137	0.0976	0.0906	0.126	0.0893	E 0.0554
<0.0079	E 0.0074	<0.0054	<0.0041	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118
6	105	108	92	99	119	85	79	110	78	48
E 0.0836	0.155	0.127	0.107	0.125	0.146	0.12	0.0949	0.109	0.0767	E 0.0266
<0.0079	0.0449	<0.0054	<0.0041	0.0097	0.0441	<0.0676	<0.017	<0.0102	<0.009	<0.0118
73	96	111	93	101	89	105	83	95	67	23
Portland										
E 0.0184	0.119	0.128	0.107	0.138	0.116	0.122	0.0925	0.122	0.114	E 0.0653
<0.0079	0.0078	<0.0054	<0.004	0.0243	E 0.0043	<0.0676	<0.017	<0.0102	<0.009	<0.0118
16	97	112	93	99	97	106	81	106	99	57
<0.0079	0.106	0.113	0.1	0.113	0.107	0.0698	0.0771	0.123	0.08	E 0.0476
<0.0079	<0.005	<0.0054	<0.004	<0.005	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118
--	92	99	87	99	93	61	67	107	70	42
<0.0079	--	0.101	--	--	--	0.0958	--	0.109	--	E 0.0553
<0.0079	0.0139	<0.0054	<0.004	0.0182	E 0.0145	<0.0676	<0.017	E 0.0038	<0.009	<0.0118
--	--	88	--	--	--	84	--	92	--	48
E 0.0081	0.122	0.128	0.102	0.126	E 0.175	0.123	0.0997	0.12	0.1	E 0.0528
<0.0079	0.0094	<0.0054	<0.004	0.0087	0.0242	<0.0676	<0.017	<0.0102	E 0.0013	<0.0118
7	98	112	89	102	131	107	87	105	86	46
E 0.0283	0.113	0.128	0.104	0.127	0.0829	0.124	0.0818	0.113	0.0854	E 0.045
<0.0079	E 0.0023	<0.0054	<0.004	0.0113	<0.016	<0.0676	<0.017	<0.0102	E 0.005	<0.0118
25	97	112	91	101	72	108	71	99	70	39
E 0.012	0.109	0.122	0.104	0.119	0.144	E 0.0996	0.0899	0.119	0.0812	E 0.0595
<0.0079	<0.009	<0.0054	<0.004	0.0082	<0.016	<0.0676	<0.017	<0.0102	<0.009	<0.0118
10	95	106	91	97	126	87	78	104	71	52
Summary statistics for percent reovery of spiked compounds										
20	105	109	94	101	127	101	82	105	87	52
24	17	8	9	11	34	19	12	7	14	13
73	160	124	120	113	202	133	101	116	110	75
4	84	88	82	66	72	61	57	92	67	23
9	0	0	0	0	0	0	0	0	0	0

Appendix 3. Water-quality benchmarks for nutrients, sulfate, chloride, and pH.

[Benchmarks are for protection of human health and prevention of cosmetic/aesthetic effects from drinking water consumption, for protection of aquatic life, and for prevention of eutrophication. All benchmarks are from the U.S. Environmental Protection Agency. LHA, lifetime health advisory; MCL, maximum contaminant level; SDWR, secondary drinking water regulation; USEPA, U.S. Environmental Protection Agency; AWQC-AL, ambient water-quality criteria for protection of aquatic organisms; mg/L, milligrams per liter; —, no benchmark available; MIN, minimum of; T, temperature]

Constituent	Human-health benchmarks for drinking water [1]		SDWRs (cosmetic and aesthetic effects of drinking water) [1]	Aquatic-life benchmarks [2]		Ecoregional nutrient criteria [3]
	Value (mg/L, except for pH)	Type	Value (mg/L, except for pH)	Acute AWQC-AL	Chronic AWQC-AL	Value (mg/L)
Ammonia	30	LHA	—	(4) Varies	(5) Varies	—
Nitrite+nitrate	10	MCL	—	—	—	—
Nitrate	10	MCL	—	—	—	—
Nitrite	1	MCL	—	—	—	—
Total nitrogen	—	—	—	—	—	(6)Varies
Total phosphorus	—	—	—	—	—	(7) Varies
pH	—	—	6.5–8.5	—	6.5–9.0	—
Chloride	—	—	250	860	230	—
Sulfate	—	—	250	—	—	—

[1] From U.S. Environmental Protection Agency (2006b).

[2] From U.S. Environmental Protection Agency (2006c).

[3] From U.S. Environmental Protection Agency (2002a,g). These recommended criteria represent conditions of surface waters that have minimal effects caused by human activities.

[4] The acute AWQC-AL is calculated for each site depending on pH and whether salmonids are present at the site. It is intended for comparison with 1-hour average concentration.

Where salmonid fish are present: Acute AWQC-AL = $[0.275/(1 + 10^{(7.204\text{-pH})})] + [39.0/(1 + 10^{(\text{pH-}7.204)})]$

Where salmonid fish are not present: Acute AWQC-AL = $[0.411/(1 + 10^{(7.204\text{-pH})})] + [58.4/(1 + 10^{(\text{pH-}7.204)})]$

[5] The chronic AWQC-AL is calculated for each site, depending on pH and temperature. Fish early-life stages are assumed to be present at all sites. It is intended for comparison with 30-day average concentration

Chronic AWQC-AL = $\{[0.0577/(1 + 10^{(7.688\text{-pH})})] + [2.487/(1 + 10^{(\text{pH-}7.688)})]\}$ x MIN $(2.85, 1.45 \bullet 10^{(0.028 \bullet (25\text{-T})})$

[6] Recommended ecoregional criteria are 0.69 mg/L for Atlanta and Raleigh-Durham, 0.54 mg/L for Milwaukee-Green Bay, 0.88 mg/L for Dallas-Fort Worth and Denver, and 0.31 mg/L for Portland.

[7] Recommended ecoregional criteria are 0.03656 mg/L for Atlanta and Raleigh-Durham, 0.03300 mg/L for Milwaukee-Green Bay, 0.06700 mg/L for Dallas-Fort Worth and Denver, and 0.04700 mg/L for Portland.

Appendix 4. Water-quality benchmarks for pesticide compounds.

[For pesticide compounds in water, benchmarks are for protection of human health and aquatic life. All benchmarks are from the U.S. Environmental Protection Agency or are derived from U.S. Environmental Protection Agency methods and toxicity values. Common synonyms are listed in parentheses in column 1. Environmental concentration, the measured or calculated concentration statistic that is appropriate for comparison with the benchmark; 10^{-6} CRC, 10^{-6} cancer risk concentration; EC_{50}, 50-percent effect concentration; LHA, lifetime health advisory; IRED, Interim Reregistration Eligibility Decision; HBSL, health-based screening level; $HBSL_{High}$, high end of HBSL range; $HBSL_{Low}$, low end of HBSL range; LC_{50}, 50-percent lethal concentration; LOC, level of concern; LOEC, lowest-observed-effects concentration; MCL, maximum contaminant level; NOAEC, no-observed-adverse-effects concentration; NOEC, no-observed-effects concentration; RED, Reregistration Eligibility Decision; USEPA, U.S. Environmental Protection Agency; AWQC-AL, ambient water-quality criteria for protection of aquatic organisms; µg/L, microgram per liter; >, greater than; <, less than; —, no benchmark available]

Pesticide compound (common synonym)	Human-health benchmarks (µg/L)				Aquatic-life benchmarks (µg/L)									
	USEPA drinking-water standards and guidelines (Office of Water)		Health-based screening levels for unregulated pesticides derived using USEPA toxicity values and methods		USEPA ambient water-quality criteria for aquatic organisms (Office of Water)		Toxicity values from pesticide risk assessments, derived from USEPA REDs and ecological risk assessments (Office of Pesticide Programs)							
	Value[1]	Type	HBSL Low[2]	HBSL High[2]	Acute AWQC-AL[3]	Chronic AWQC-AL[3]	Acute-Fish[4]	Chronic-Fish[5]	Acute-Invertebrate[6]	Chronic-Invertebrate[7]	Acute-Nonvascular plant[8]	Acute-Vascular plant[9]	Chronic aquatic community[10]	References
Benchmark intended to be compared to this concentration:	Annual mean	—	Annual mean	Annual mean	Individual sample	4-day average	Individual sample	60-day average	Individual sample	21-day average	Individual sample	Individual sample	60-day average	—
Alachlor	2	MCL	—	—	—	—	900	187	1,600	110	1.64	—	—	USEPA (1998d)
Atrazine	3	MCL	—	—	—	—	2,650	62	360	62	32	18	17.5	USEPA (2003a, 2003c)
Azinphos-methyl (Guthion)	—	—	10	10	—	0.01	0.18	[11] 0.36	0.08	[11] 0.16	—	—	—	USEPA (2005a)
Benfluralin	—	—	4	4	—	—	15.85	1.9	1,090	[12] 15.5	[13] 100	—	—	USEPA (2004c)
Carbaryl	40	10^{-6} CRC	40	4,000	—	—	[14] 125	[14] 210	2.55	1.5	1,100	—	—	USEPA (2003b, 2004b)
Chlorpyrifos	2	LHA	2	2	0.083	0.041	0.9	0.57	0.05	0.04	140	—	—	USEPA (2000b, 2002b)
Cypermethrin	—	—	4	4	—	—	0.195	0.14	0.21	0.069	—	—	—	USEPA (2005g)
Dacthal (DCPA)	70	LHA	70	70	—	—	15,000	—	13,500	—	[13] 11,000	[13] 11,000	—	USEPA (1998e)

Appendix 4. Water-quality benchmarks for pesticide compounds.—Continued

[For pesticide compounds in water, benchmarks are for protection of human health and aquatic life. All benchmarks are from the U.S. Environmental Protection Agency or are derived from U.S. Environmental Protection Agency methods and toxicity values. Common synonyms are listed in parentheses in column 1. Environmental concentration, the measured or calculated concentration statistic that is appropriate for comparison with the benchmark; 10^{-6} CRC, 10^{-6} cancer risk concentration; EC_{50}, 50-percent effect concentration; LHA, lifetime health advisory; IRED, Interim Reregistration Eligibility Decision; HBSL, health-based screening level; $HBSL_{High}$, high end of HBSL range; $HBSL_{Low}$, low end of HBSL range; LC_{50}, 50-percent lethal concentration; LOC, level of concern; LOEC, lowest-observed-effects concentration; MCL, maximum contaminant level; NOAEC, no-observed-adverse-effects concentration; NOEC, no-observed-effects concentration; RED, Reregistration Eligibility Decision; USEPA, U.S. Environmental Protection Agency; AWQC-AL, ambient water-quality criteria for protection of aquatic organisms; µg/L, microgram per liter; >, greater than; <, less than; —, no benchmark available]

Pesticide compound (common synonym)	Human-health benchmarks (µg/L)				Aquatic-life benchmarks (µg/L)									
	USEPA drinking-water standards and guidelines (Office of Water)		Health-based screening levels for unregulated pesticides derived using USEPA toxicity values and methods		USEPA ambient water-quality criteria for aquatic organisms (Office of Water)		Toxicity values from pesticide risk assessments, derived from USEPA REDs and ecological risk assessments (Office of Pesticide Programs)							
	Value[1]	Type	HBSL Low[2]	HBSL High[2]	Acute AWQC-AL[3]	Chronic AWQC-AL[3]	Acute-Fish[4]	Chronic-Fish[5]	Acute-Invertebrate[6]	Chronic-Invertebrate[7]	Acute-Nonvascular plant[8]	Acute-Vascular plant[9]	Chronic aquatic community[10]	References
Benchmark intended to be compared to this concentration:	Annual mean	—	Annual mean	Annual mean	Individual sample	4-day average	Individual sample	60-day average	Individual sample	21-day average	Individual sample	Individual sample	60-day average	—
Diazinon	1	LHA	1	1	—	—	45	[15]0.55	[14,16] 0.1	[14] 0.17	3,700	—	—	USEPA (2000c, 2004a)
Dichlorvos	—	—	0.4	0.4	—	—	91.5	5.2	0.035	0.0058	14,000	—	—	USEPA (2002f)
Ethion	—	—	4	4	—	—	36.5	[13] 0.013	0.028	—	—	—	—	USEPA (1998h)
Fenamiphos	2	LHA	0.7	0.7	—	—	4.75	3.8	0.95	0.12	—	—	—	USEPA (2001, 2002d)
Fenamiphos sulfone	—	—	—	—	—	—	586.5	—	—	—	—	—	—	USEPA (2001)
Fenamiphos sulfoxide	—	—	—	—	—	—	1,000	—	3.75	—	—	—	—	USEPA (2001)
Fonofos	10	LHA	10	10	—	—	—	—	—	—	—	—	—	—
Hexazinone	400	LHA	400	400	—	—	137,000	17,000	75,800	29,000	7.0	37.4	—	USEPA (1994b)
Iprodione	—	—	0.8	80	—	—	1,550	260	120	[14] 170	2,000	—	—	USEPA (1998f)
Isofenphos	—	—	6	6	—	—	650	61	1.95	[17] 0.22	—	—	—	USEPA (1998a)
Malathion	100	LHA	20	20	—	0.1	2	[11] 4	0.25	0.06	—	—	—	USEPA (2000d)

Appendix 4. Water-quality benchmarks for pesticide compounds.—Continued

[For pesticide compounds in water, benchmarks are for protection of human health and aquatic life. All benchmarks are from the U.S. Environmental Protection Agency or are derived from U.S. Environmental Protection Agency methods and toxicity values. Common synonyms are listed in parentheses in column 1. Environmental concentration, the measured or calculated concentration statistic that is appropriate for comparison with the benchmark; 10^{-6} CRC, 10^{-6} cancer risk concentration; EC_{50}, 50-percent effect concentration; LHA, lifetime health advisory; IRED, Interim Reregistration Eligibility Decision; HBSL, health-based screening level; $HBSL_{High}$, high end of HBSL range; $HBSL_{Low}$, low end of HBSL range; LC_{50}, 50-percent lethal concentration; LOC, level of concern; LOEC, lowest-observed-effects concentration; MCL, maximum contaminant level; NOAEC, no-observed-adverse-effects concentration; NOEC, no-observed-effects concentration; RED, Reregistration Eligibility Decision; USEPA, U.S. Environmental Protection Agency; AWQC-AL, ambient water-quality criteria for protection of aquatic organisms; μg/L, microgram per liter; >, greater than; <, less than; —, no benchmark available]

Pesticide compound (common synonym)	Human-health benchmarks (μg/L)				Aquatic-life benchmarks (μg/L)									
	USEPA drinking-water standards and guidelines (Office of Water)		Health-based screening levels for unregulated pesticides derived using USEPA toxicity values and methods		USEPA ambient water-quality criteria for aquatic organisms (Office of Water)		Toxicity values from pesticide risk assessments, derived from USEPA REDs and ecological risk assessments (Office of Pesticide Programs)							
	Value[1]	Type	HBSL Low[2]	HBSL High[2]	Acute AWQC-AL[3]	Chronic AWQC-AL[3]	Acute-Fish[4]	Chronic-Fish[5]	Acute-Invertebrate[6]	Chronic-Invertebrate[7]	Acute-Nonvascular plant[8]	Acute-Vascular plant[9]	Chronic aquatic community[10]	References
Benchmark intended to be compared to this concentration:	Annual mean	—	Annual mean	Annual mean	Individual sample	4-day average	Individual sample	60-day average	Individual sample	21-day average	Individual sample	Individual sample	60-day average	—
Metalaxyl	—	—	600	600	—	—	65,000	9,100	14,000	1,270	140,000	92,000	—	USEPA (1994c)
Methidathion	—	—	1	1	—	—	1.1	[11,18] 2.2	1.5	0.66	—	—	—	USEPA (2002e)
Metolachlor	700	LHA	70	70	—	—	1,950	780	12,550	—	—	—	—	USEPA (1995a)
Metribuzin	70	LHA	90	90	—	—	21,000	3,000	2,100	1,290	8.7	130	—	USEPA (1998g)
Pendimethalin	—	—	70	70	—	—	69	6.3	140	14.5	5.4	12.5	—	USEPA (1997)
cis-Permethrin	—	—	[19] 4	[19] 400	—	—	[19] 0.395	[19] 0.30	[14,19] 0.0195	[14,19] 0.039	—	—	—	USEPA (2005c)
Phorate	—	—	4	4	—	—	0.5	[11] 1	0.30	0.21	1,300	—	—	USEPA (1998c, 1999b)
Phosmet	—	—	8	8	—	—	35	3.2	1.0	0.75	—	—	—	USEPA (1998b)
Prometon	100	LHA	100	100	—	—	—	—	—	—	—	—	—	—
Prometryn	—	—	300	300	—	—	1,450	— [20]	9,295	1,000	1.0	11.8	—	USEPA (1996a)
Pronamide (Propyzamide)	2	10^{-6} CRC	1	100	—	—	36,000	—	[13] 2,800	—	760	—	—	USEPA (1994a)

Appendix 4. Water-quality benchmarks for pesticide compounds.—Continued

[For pesticide compounds in water, benchmarks are for protection of human health and aquatic life. All benchmarks are from the U.S. Environmental Protection Agency or are derived from U.S. Environmental Protection Agency methods and toxicity values. Common synonyms are listed in parentheses in column 1. Environmental concentration, the measured or calculated concentration statistic that is appropriate for comparison with the benchmark; 10^{-6} CRC, 10^{-6} cancer risk concentration; EC_{50}, 50-percent effect concentration; LHA, lifetime health advisory; IRED, Interim Reregistration Eligibility Decision; HBSL, health-based screening level; $HBSL_{High}$, high end of HBSL range; $HBSL_{Low}$, low end of HBSL range; LC_{50}, 50-percent lethal concentration; LOC, level of concern; LOEC, lowest-observed-effects concentration; MCL, maximum contaminant level; NOAEC, no-observed-adverse-effects concentration; NOEC, no-observed-effects concentration; RED, Reregistration Eligibility Decision; USEPA, U.S. Environmental Protection Agency; AWQC-AL, ambient water-quality criteria for protection of aquatic organisms; µg/L, microgram per liter; >, greater than; <, less than; —, no benchmark available]

Pesticide compound (common synonym)	Human-health benchmarks (µg/L)				Aquatic-life benchmarks (µg/L)									
	USEPA drinking-water standards and guidelines (Office of Water)		Health-based screening levels for unregulated pesticides derived using USEPA toxicity values and methods		USEPA ambient water-quality criteria for aquatic organisms (Office of Water)		Toxicity values from pesticide risk assessments, derived from USEPA REDs and ecological risk assessments (Office of Pesticide Programs)							
	Value[1]	Type	HBSL Low[2]	HBSL High[2]	Acute AWQC-AL[3]	Chronic AWQC-AL[3]	Acute-Fish[4]	Chronic-Fish[5]	Acute-Invertebrate[6]	Chronic-Invertebrate[7]	Acute-Nonvascular plant[8]	Acute-Vascular plant[9]	Chronic aquatic community[10]	References
Benchmark intended to be compared to this concentration:	Annual mean	—	Annual mean	Annual mean	Individual sample	4-day average	Individual sample	60-day average	Individual sample	21-day average	Individual sample	Individual sample	60-day average	—
Tebuthiuron	500	LHA	1000	1000	—	—	53,000	9,300	148,500	21,800	50	135	—	USEPA (1994d)
Terbufos	0.4	LHA	0.4	0.4	—	—	0.385	[11] 0.77	0.1	0.030	—	—	—	USEPA (1999c)
Terbuthylazine	—	—	2	2	—	—	1,700	—	25,450	—	—	—	—	USEPA (1995b)

[1] From U.S. Geological Environmental Protection Agency (2006b), unless noted otherwise.

[2] From U.S. Geological Survey (2006b). For potential carcinogens, both the low and high ends of the HBSL range are reported, which correspond to maximum acceptable cancer risk of 1 in a million and 1:10,000, respectively. For noncarcinogens, the HBSL value is shown in both $HBSL_{Low}$ and $HBSL_{HIGH}$ columns. HBSLs are not derived for pesticides with MCLs.

[3] From U.S. Environmental Protection Agency (2006c).

[4] Benchmark = Toxicity value x LOC. For acute fish, toxicity value is usually the lowest 96-hour LC_{50} in a standardized test (usually with rainbow trout, fathead minnow, or bluegill), and the LOC is 0.5.

[5] Benchmark = Toxicity value x LOC. For chronic fish, toxicity value is usually the lowest NOAEC from a life-cycle or early-life-stage test (usually with rainbow trout or fathead minnow), and the LOC is 1.

[6] Benchmark = Toxicity value x LOC. For acute invertebrate, toxicity value is usually the lowest 48- or 96-hour EC_{50} or LC_{50} in a standardized test (usually with midge, scud, or daphnids), and the LOC is 0.5.

[7] Benchmark = Toxicity value x LOC. For chronic invertebrates, toxicity value is usually the lowest NOAEC from a life-cycle test with invertebrates (usually with midge, scud, or daphnids), and the LOC is 1.

[8] Benchmark = Toxicity value x LOC. For acute nonvascular plants, toxicity value is usually a short-term (typically less than 10 days) lowest tested EC_{50} (usually with green algae or diatoms), and the LOC is 1.0.

[9] Benchmark = Toxicity value x LOC. For acute vascular plants, toxicity value is usually a short-term (typically less than 10 days) lowest tested EC_{50} (usually with duckweed) and the LOC is 1.0.

[10] Exceedance of this benchmark concentration, as an average for any 60-day period, could cause community-level effects on aquatic plants and indirect effects on fish and aquatic invertebrates from disturbance of the aquatic-plant community.

[11] The chronic benchmark is based on the acute-toxicity value (which was lower than the lowest available chronic-toxicity value), and therefore may underestimate chronic toxicity.

[12] This benchmark has greater uncertainty than usual because of methods used or conditions in the underlying toxicity study.

[13] Because the underlying toxicity value is a “greater-than” value (such as >265,000), this benchmark may overestimate toxicity.

[14] Although the underlying acute-toxicity value is greater than or equal to the chronic-toxicity value, the acute benchmark is lower than the chronic benchmark because acute- and chronic-toxicity values were multiplied by LOC values of 0.5 and 1.0, respectively.

[15] Because the underlying toxicity value is a “less-than” value (such as <1,500), this benchmark may underestimate toxicity.

[16] During public comment on draft ambient water-quality criteria that are under development by USEPA, public comment noted an atypical distribution of the acute-toxicity data for diazinon. If data from the second most sensitive study were used (U.S. Environmental Protection Agency, 2000c), rather than the most sensitive study, then the benchmark would change from 0.1 to 0.4 µg/L.

[17] Benchmark is based on the toxicity value used in USEPA’s risk assessment (U.S. Environmental Protection Agency, 1998a). However, if done today, USEPA would estimate a NOEC rather than use the LOEC (Elizabeth Behl, U.S. Environmental Protection Agency, written commun., 2006).

[18] Benchmark is based on the toxicity value used in USEPA’s IRED assessment (U.S. Environmental Protection Agency, 2002e). However, if done today, USEPA would use a different method to estimate a NOEC (Elizabeth Behl, U.S. Environmental Protection Agency, written commun., 2006).

[19] Toxicity values and benchmarks apply to permethrin. Because this study measured only the cis isomer of permethrin in water, comparison with benchmarks may underestimate potential toxicity.

[20] No benchmark was developed because the toxicity value used in the RED (U.S. Environmental Protection Agency, 1996a) was from an unacceptable study and should not have been used (Elizabeth Behl, U.S. Environmental Protection Agency, written commun., 2006).

Appendix 5. Site-specific exceedances of water-quality benchmarks.

[Sites are listed by percentage of urban land cover in the basin. Only those sites with concentrations that exceeded one or more water-quality benchmarks are listed. AI, Acute-invertebrate benchmark; A-AWQC-AL, acute ambient water-quality criterion for protection of aquatic organisms; CI, Chronic-invertebrate benchmark; 10^{-6} CRC, cancer risk concentration at 10^{-6} cancer risk; C-AWQC-AL, chronic ambient water-quality criterion for protection of aquatic organisms; HBSL-Low, low end of health-based screening level range; MCL, Maximum Contaminant Level; SDWR, Secondary Drinking-Water Regulations; SW, Southwest; TN, total nitrogen; TP, total phosphorus; U.S., United States; +, plus (refers to summed concentrations); —, not applicable]

U.S. Geological Survey station number	U.S. Geological Survey station name	Base-flow condition	Urban land cover in the basin, in percent	Constituents exceeding human-health benchmarks (benchmark type) [1]	Constituents exceeding SDWRs [2]	Constituents exceeding aquatic-life benchmarks (benchmark type) [1]	Constituents exceeding recommended ecoregional nutrient criteria [2]
			Atlanta				
02347748	Auchumpkee Creek at Allen Road near Roberta, Ga.	High	2.3	—	—	—	TP
02213450	Little Tobesofkee Creek near Bolingbroke, Ga.	High	3.6	—	—	—	TN, TP
02221000	Murder Creek near Monticello, Ga.	High	3.8	—	—	—	TP
02346358	Turnpike Creek near Milner, Ga.	High	11.0	—	pH	pH (C-AWQC-AL)	TP
02217471	Beech Creek at State Road 211 near Statham, Ga.	High	16.4	—	—	—	TN
02218700	Apalachee River near Bethlehem, Ga.	High	17.8	—	—	—	TN
02217293	Little Mulberry River at State Road 211 near Hoschton, Ga.	High	20.4	—	—	—	TN
02344480	Shoal Creek near Griffin, Ga.	High	22.9	—	—	—	TP
02204468	Walnut Creek at Airline Road near Mcdonough, Ga.	High	24.8	—	—	—	TN, TP
02344737	Whitewater Creek at Willow Pond Road near Fayetteville, Ga.	High	25.1	—	—	—	TP
02344797	White Oak Creek at Cannon Road near Raymond, Ga.	High	25.7	—	—	—	TN, TP
02334885	Suwanee Creek at Suwanee, Ga.	High	42.6	—	—	—	TN
02204230	Big Cotton Indian Creek at State Road 138 near Stockbridge, Ga.	High	43.2	—	—	—	TN
02336728	Utoy Creek at Great Southwest Parkway near Atlanta, Ga.	High	60.6	—	—	—	TN, TP
02336635	Nickajack Creek at U.S. Highway 78/278 near Mableton, Ga.	High	66.2	—	—	—	TN
02206314	Jackson Creek at Lester Road near Lilburn, Ga.	High	67.0	—	—	—	TN
02335870	Sope Creek near Marietta, Ga.	High	72.5	—	—	—	TN
02335910	Rottenwood Creek (Interstate North Parkway) near Smyrna, Ga.	High	85.4	—	—	—	TN, TP
02217471	Beech Creek at State Road 211 near Statham, Ga.	Low	16.4	—	—	—	TN
02218700	Apalachee River near Bethlehem, Ga.	Low	17.8	—	—	—	TN
02217293	Little Mulberry River at State Road 211 near Hoschton, Ga.	Low	20.4	—	—	—	TN
02204468	Walnut Creek at Airline Road near Mcdonough, Ga.	Low	24.8	—	—	—	TN
02344737	Whitewater Creek at Willow Pond Road near Fayetteville, Ga.	Low	25.1	—	—	—	TP
02344797	White Oak Creek at Cannon Road near Raymond, Ga.	Low	25.7	—	—	—	TN, TP

Appendix 5. Site-specific exceedances of water-quality benchmarks.—Continued

[Sites are listed by percentage of urban land cover in the basin. Only those sites with concentrations that exceeded one or more water-quality benchmarks are listed. AI, Acute-invertebrate benchmark; A-AWQC-AL, acute ambient water-quality criterion for protection of aquatic organisms; CI, Chronic-invertebrate benchmark; 10^{-6} CRC, cancer risk concentration at 10^{-6} cancer risk; C-AWQC-AL, chronic ambient water-quality criterion for protection of aquatic organisms; HBSL-Low, low end of health-based screening level range; MCL, Maximum Contaminant Level; SDWR, Secondary Drinking-Water Regulations; SW, Southwest; TN, total nitrogen; TP, total phosphorus; U.S., United States; +, plus (refers to summed concentrations); —, not applicable]

U.S. Geological Survey station number	U.S. Geological Survey station name	Base-flow condition	Urban land cover in the basin, in percent	Constituents exceeding human-health benchmarks (benchmark type) [1]	Constituents exceeding SDWRs [2]	Constituents exceeding aquatic-life benchmarks (benchmark type) [1]	Constituents exceeding recommended ecoregional nutrient criteria [2]
02344340	Morning Creek at State Road 54 near Fayetteville, Ga.	Low	38.3	—	pH	pH (C-AWQC-AL)	
02334885	Suwanee Creek at Suwanee, Ga.	Low	42.6	—	—	—	TN
02204230	Big Cotton Indian Creek at State Road 138 near Stockbridge, Ga.	Low	43.2	—	—	—	TN
02336728	Utoy Creek at Great Southwest Parkway near Atlanta, Ga.	Low	60.6	—	—	—	TN, TP
02336635	Nickajack Creek at U.S. Highway 78/278 near Mableton, Ga.	Low	66.2	—	—	—	TN
02206314	Jackson Creek at Lester Road near Lilburn, Ga.	Low	67.0	—	—	—	TN
02335910	Rottenwood Creek (Interstate North Parkway) near Smyrna, Ga.	Low	85.4	—	—	—	TN
		Raleigh-Durham					
02081190	Tar River near Berea, N.C.	High	3.0	—	pH	pH (C-AWQC-AL), Diazinon (AI, CI)	
02085430	Deep Creek near Moriah, N.C.	High	4.4	—	pH	pH (C-AWQC-AL)	
02097464	Morgan Creek near White Cross, N.C.	High	5.2	—	—	—	TN, TP
0209665990	Rock Creek Above Rock Creek Tributary near Whitsett, N.C.	High	7.3	—	—	—	TN, TP
0208501535	Strouds Creek at St Marys Road near Hillsborough, N.C.	High	12.4	—	—	—	TN
0209665940	Rock Creek Tributary at Stoney Creek Golf Course near Sedalia, N.C.	High	20.7	—	—	—	TP
02100634	Vestal Creek near Asheboro, N.C.	High	38.8	—	—	—	TN, TP
02100294	Hasketts Creek below Penwood Branch near Asheboro, N.C.	High	55.9	—	—	—	TN, TP
0208726370	Richlands Creek at Schenk Forest near Cary, N.C.	High	60.1	—	—	—	TN, TP
0209647280	Service Creek above Dry Creek at Burlington, N.C.	High	65.7	—	—	—	TP
02099238	Bull Run at NC 29/70 near Jamestown, N.C.	High	66.8	—	—	—	TN, TP
02087580	Swift Creek near Apex, N.C.	High	72.2	—	—	—	TN, TP
0208726995	Hare Snipe Creek at State Road 1822 near Leesville, N.C.	High	76.1	—	—	—	TN, TP
02099480	Richland Creek near Archdale, N.C.	High	76.4	—	—	—	TN
0208725055	Black Creek at Weston Parkway near Cary, N.C.	High	79.0	—	—	—	TP

Appendix 5. Site-specific exceedances of water-quality benchmarks.—Continued

[Sites are listed by percentage of urban land cover in the basin. Only those sites with concentrations that exceeded one or more water-quality benchmarks are listed. AI, Acute-invertebrate benchmark; A-AWQC-AL, acute ambient water-quality criterion for protection of aquatic organisms; CI, Chronic-invertebrate benchmark; 10^{-6} CRC, cancer risk concentration at 10^{-6} cancer risk; C-AWQC-AL, chronic ambient water-quality criterion for protection of aquatic organisms; HBSL-Low, low end of health-based screening level range; MCL, Maximum Contaminant Level; SDWR, Secondary Drinking-Water Regulations; SW, Southwest; TN, total nitrogen; TP, total phosphorus; U.S., United States; +, plus (refers to summed concentrations); —, not applicable]

U.S. Geological Survey station number	U.S. Geological Survey station name	Base-flow condition	Urban land cover in the basin, in percent	Constituents exceeding human-health benchmarks (benchmark type) [1]	Constituents exceeding SDWRs [2]	Constituents exceeding aquatic-life benchmarks (benchmark type) [1]	Constituents exceeding recommended ecoregional nutrient criteria [2]
0209679804	Little Alamance Creek at State Road 2309 near Graham, N.C.	High	82.1	—	—	—	TN, TP
0209651815	Branch Creek below NC54 near Graham, N.C.	High	92.6	—	—	—	TN
02087304	SW Prong Beaverdam Creek at Raleigh, N.C.	High	94.2	Dieldrin (10^{-6} CRC, HBSL-Low)	—	—	TN
0209647295	Dry Creek above Service Creek at Burlington, N.C.	High	96.8	—	—	—	TN, TP
0211583580	Bowen Branch near Mouth at Winston-Salem, N.C.	High	96.9	—	—	Ammonia (C-AWQC-AL)	TN
0209517912	North Buffalo Creek at Greensboro, N.C.	High	96.9	—	—	—	TN, TP
0208732610	Pigeon House Br at Crabtree Boulevard at Raleigh, N.C.	High	98.4	Dieldrin (10^{-6} CRC, HBSL-Low)	—	—	TN
0209695780	Brooks Creek at Eddie Perry Road near Bynum, N.C.	Low	3.1	—	—	—	TN
02097464	Morgan Creek near White Cross, N.C.	Low	5.2	—	—	—	TN, TP
0209697900	Pokeberry Creek near Pittsboro, N.C.	Low	6.0	—	—	—	TP
0209665990	Rock Creek above Rock Creek Tributary near Whitsett, N.C.	Low	7.3	—	—	—	TN, TP
0208794025	Camp Branch above State Road 1390 near Holly Springs, N.C.	Low	18.2	—	—	—	TP
0208500600	Strouds Creek at St Marys Road near Hillsborough, N.C.	Low	20.0	—	—	—	TN
0209665940	Rock Creek Tributary at Stoney Creek Golf Course near Sedalia, N.C.	Low	20.7	—	—	—	TP
02100634	Vestal Creek near Asheboro, N.C.	Low	38.8	—	—	—	TP
0208758440	Dutchmans Branch at State Road 1386 near McCullers Crossroads, N.C.	Low	39.3	—	—	—	TP
02097355	Bolin Creek above Franklin Street near Chapel Hill, N.C.	Low	44.3	—	—	Diazinon (AI, CI)	TN, TP
02081510	Foundry Branch at Mouth near Oxford, N.C.	Low	53.0	—	—	—	TN, TP
02100294	Hasketts Creek Below Penwood Branch near Asheboro, N.C.	Low	55.9	—	—	—	TP
0209647280	Service Creek above Dry Creek at Burlington, N.C.	Low	65.7	—	pH	pH (C-AWQC-AL)	TN, TP
02099238	Bull Run at NC 29/70 near Jamestown, N.C.	Low	66.8	—	—	—	TN, TP

Appendix 5. Site-specific exceedances of water-quality benchmarks.—Continued

[Sites are listed by percentage of urban land cover in the basin. Only those sites with concentrations that exceeded one or more water-quality benchmarks are listed. AI, Acute-invertebrate benchmark; A-AWQC-AL, acute ambient water-quality criterion for protection of aquatic organisms; CI, Chronic-invertebrate benchmark; 10^{-6} CRC, cancer risk concentration at 10^{-6} cancer risk; C-AWQC-AL, chronic ambient water-quality criterion for protection of aquatic organisms; HBSL-Low, low end of health-based screening level range; MCL, Maximum Contaminant Level; SDWR, Secondary Drinking-Water Regulations; SW, Southwest; TN, total nitrogen; TP, total phosphorus; U.S., United States; +, plus (refers to summed concentrations); —, not applicable]

U.S. Geological Survey station number	U.S. Geological Survey station name	Base-flow condition	Urban land cover in the basin, in percent	Constituents exceeding human-health benchmarks (benchmark type) [1]	Constituents exceeding SDWRs [2]	Constituents exceeding aquatic-life benchmarks (benchmark type) [1]	Constituents exceeding recommended ecoregional nutrient criteria [2]
02087580	Swift Creek near Apex, N.C.	Low	72.2	—	—	—	TP
0208726995	Hare Snipe Creek at State Road 1822 near Leesville, N.C.	Low	76.1	—	—	—	TN
02099480	Richland Creek near Archdale, N.C.	Low	76.4	—	—	—	TN
0208725055	Black Creek at Weston Parkway near Cary, N.C.	Low	79.0	—	—	—	TN, TP
0209679804	Little Alamance Creek at State Road 2309 near Graham, N.C.	Low	82.1	—	—	—	TN, TP
0209651815	Branch Creek Below NC54 near Graham, N.C.	Low	92.6	—	—	—	TN, TP
02087304	SW Prong Beaverdam Creek at Raleigh, N.C.	Low	94.2	Dieldrin (10^{-6} CRC, HBSL-Low)	—	—	TN
0209647295	Dry Creek above Service Creek at Burlington, N.C.	Low	96.8	—	—	—	TN, TP
0211583580	Bowen Branch near Mouth at Winston-Salem, N.C.	Low	96.9	Dieldrin (10^{-6} CRC, HBSL-Low)	—	Ammonia (C-AWQC-AL)	TN
0209517912	North Buffalo Creek at Greensboro, N.C.	Low	96.9	Dieldrin (10^{-6} CRC, HBSL-Low)	—	—	TN, TP
0208732610	Pigeon House Branch at Crabtree Boulevard at Raleigh, N.C.	Low	98.4	Dieldrin (10^{-6} CRC, HBSL-Low)	—	—	TN
			Milwaukee-Green Bay				
040853145	Black Creek at Curran Road near Denmark, Wis.	High	3.2	—	—	—	TN, TP
04085188	Rio Creek at Pheasant Road near Rio Creek, Wis.	High	3.5	—	—	—	TP
04085270	Jambo Creek at Jambo Creek Road near Mishicot, Wis.	High	3.7	—	—	—	TP
04085322	Devils River at Rosencrans Road near Maribel, Wis.	High	4.0	—	—	—	TP
040851932	Kewaunee River Tributary at Lowell Road near Luxemburg, Wis.	High	4.4	—	—	—	TN, TP
040854395	Point Creek at Ucker Point Road near Newton, Wis.	High	5.0	—	—	—	TN, TP
04085455	Meeme River at Washington Road near Cleveland, Wis.	High	5.0	—	—	—	TN, TP

Appendix 5. Site-specific exceedances of water-quality benchmarks.—Continued

[Sites are listed by percentage of urban land cover in the basin. Only those sites with concentrations that exceeded one or more water-quality benchmarks are listed. AI, Acute-invertebrate benchmark; A-AWQC-AL, acute ambient water-quality criterion for protection of aquatic organisms; CI, Chronic-invertebrate benchmark; 10^{-6} CRC, cancer risk concentration at 10^{-6} cancer risk; C-AWQC-AL, chronic ambient water-quality criterion for protection of aquatic organisms; HBSL-Low, low end of health-based screening level range; MCL, Maximum Contaminant Level; SDWR, Secondary Drinking-Water Regulations; SW, Southwest; TN, total nitrogen; TP, total phosphorus; U.S., United States; +, plus (refers to summed concentrations); —, not applicable]

U.S. Geological Survey station number	U.S. Geological Survey station name	Base-flow condition	Urban land cover in the basin, in percent	Constituents exceeding human-health benchmarks (benchmark type)[1]	Constituents exceeding SDWRs[2]	Constituents exceeding aquatic-life benchmarks (benchmark type)[1]	Constituents exceeding recommended ecoregional nutrient criteria[2]
04078085	Black Otter Creek near Hortonville, Wis.	High	5.4	—	—	—	TN, TP
040851325	Baird Creek at Superior Road at Green Bay, Wis.	High	5.5	—	—	—	TP
04085068	Ashwaubenon Creek near Little Rapids, Wis.	High	5.7	Atrazine (MCL)	—	—	TN, TP
05527729	Kilbourn Ditch at 6oth Street near Kenosha, Wis.	High	7.4	Nitrite+nitrate, nitrate, atrazine (MCL)	—	—	TN, TP
04072233	Lancaster Brook at Shawano Avenue at Howard, Wis.	High	11.7	—	—	—	TN, TP
04081897	Sawyer Creek at Westhaven Road at Oshkosh, Wis.	High	13.8	—	—	—	TN, TP
04086699	Pigeon Creek at Williamsburg Drive at Theinsville, Wis.	High	14.9	—	—	—	TN, TP
040872393	Hoods Creek at Brook Road near Franksville, Wis.	High	16.3	—	—	—	TN, TP
04085046	Apple Creek at Sniderville, Wis.	High	17.6	—	pH	—	TP
055437901	Fox River at River Road near Sussex, Wis.	High	20.2	—	—	—	TN, TP
040851235	Bower Creek Tributary at Lime Kiln Road near Bellevue, Wis.	High	24.4	—	—	—	TP
04087258	Pike River at County Highway A near Kenosha, Wis.	High	27.3	Nitrite+nitrate, nitrate (MCL)	—	—	TN, TP
04087030	Menomonee River at Menomonee Falls, Wis.	High	30.4	—	—	—	TN, TP
04084429	Mud Creek at Spencer Road at Appleton, Wis.	High	58.8	—	—	—	TN, TP
04087204	Oak Creek at South Milwaukee, Wis.	High	62.9	—	—	—	TN, TP
04084468	Garners Creek at Park Street at Kaukauna, Wis.	High	68.9	—	—	—	TN, TP
0408703164	Lily Creek at Good Hope Road near Menomonee Falls, Wis.	High	78.0	—	—	—	TN, TP
040870856	Underwood Creek at Watertown Plank Road at Elm Grove, Wis.	High	86.0	—	—	—	TN, TP
04087270	Pike Creek at 43rd Street at Kenosha, Wis.	High	87.2	—	—	—	TN
04087213	Root River at Layton Avenue at Greenfield, Wis.	High	92.8	—	—	—	TN, TP
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	High	97.6	—	—	—	TN, TP
04087118	Honey Creek near Portland Avenue at Wauwatosa, Wis.	High	99.1	—	—	—	TN, TP

Appendix 5. Site-specific exceedances of water-quality benchmarks.—Continued

[Sites are listed by percentage of urban land cover in the basin. Only those sites with concentrations that exceeded one or more water-quality benchmarks are listed. AI, Acute-invertebrate benchmark; A-AWQC-AL, acute ambient water-quality criterion for protection of aquatic organisms; CI, Chronic-invertebrate benchmark; 10^{-6} CRC, cancer risk concentration at 10^{-6} cancer risk; C-AWQC-AL, chronic ambient water-quality criterion for protection of aquatic organisms; HBSL-Low, low end of health-based screening level range; MCL, Maximum Contaminant Level; SDWR, Secondary Drinking-Water Regulations; SW, Southwest; TN, total nitrogen; TP, total phosphorus; U.S., United States; +, plus (refers to summed concentrations); —, not applicable]

U.S. Geological Survey station number	U.S. Geological Survey station name	Base-flow condition	Urban land cover in the basin, in percent	Constituents exceeding human-health benchmarks (benchmark type) [1]	Constituents exceeding SDWRs [2]	Constituents exceeding aquatic-life benchmarks (benchmark type) [1]	Constituents exceeding recommended ecoregional nutrient criteria [2]
040853145	Black Creek at Curran Road near Denmark, Wis.	Low	3.2	—	—	Chlorpyrifos (A-AWQC-AL, C-AWQC-AL, AI, CI), Malathion (CI, C-AWQC-AL)	TN, TP
04085188	Rio Creek at Pheasant Road near Rio Creek, Wis.	Low	3.5	—	—	—	TN, TP
04085270	Jambo Creek at Jambo Creek Road near Mishicot, Wis.	Low	3.7	—	—	—	TN
04085322	Devils River at Rosencrans Road near Maribel, Wis.	Low	4.0	—	—	—	TN, TP
040851932	Kewaunee River Tributary at Lowell Road near Luxemburg, Wis.	Low	4.4	—	—	—	TP
040854395	Point Creek at Ucker Point Road near Newton, Wis.	Low	5.0	—	—	—	TP
04085455	Meeme River at Washington Road near Cleveland, Wis.	Low	5.0	—	—	—	TN, TP
04078085	Black Otter Creek near Hortonville, Wis.	Low	5.4	—	—	—	TN, TP
040851325	Baird Creek at Superior Road at Green Bay, Wis.	Low	5.5	—	—	—	TP
040850683	Ashwaubenon Creek at South Bridge Road near Depere, Wis.	Low	5.7	—	—	—	TN, TP
05527729	Kilbourn Ditch at 6oth Street near Kenosha, Wis.	Low	7.4	—	—	—	TP
04072233	Lancaster Brook at Shawano Avenue at Howard, Wis.	Low	11.7	—	—	—	TN, TP
04081897	Sawyer Creek at Westhaven Road at Oshkosh, Wis.	Low	13.8	—	—	—	TP
04086699	Pigeon Creek at Williamsburg Drive at Theinsville, Wis.	Low	14.9	—	—	—	TP
040872393	Hoods Creek at Brook Road near Franksville, Wis.	Low	16.3	—	—	—	TN, TP
04085046	Apple Creek at Sniderville, Wis.	Low	17.6	—	—	—	TN, TP
055437901	Fox River at River Road near Sussex, Wis.	Low	20.2	—	—	—	TN, TP
040851235	Bower Creek Tributary at Lime Kiln Road near Bellevue, Wis.	Low	24.4	—	—	—	TP
04087258	Pike River at County Highway A near Kenosha, Wis.	Low	27.3	—	—	—	TN, TP
04087030	Menomonee River at Menomonee Falls, Wis.	Low	30.4	—	—	—	TP
04087070	Little Menomonee River at Milwaukee, Wis.	Low	44.3	—	—	—	TP
04084429	Mud Creek at Spencer Road at Appleton, Wis.	Low	58.8	—	—	—	TP

Appendix 5. Site-specific exceedances of water-quality benchmarks.—Continued

[Sites are listed by percentage of urban land cover in the basin. Only those sites with concentrations that exceeded one or more water-quality benchmarks are listed. AI, Acute-invertebrate benchmark; A-AWQC-AL, acute ambient water-quality criterion for protection of aquatic organisms; CI, Chronic-invertebrate benchmark; 10^{-6} CRC, cancer risk concentration at 10^{-6} cancer risk; C-AWQC-AL, chronic ambient water-quality criterion for protection of aquatic organisms; HBSL-Low, low end of health-based screening level range; MCL, Maximum Contaminant Level; SDWR, Secondary Drinking-Water Regulations; SW, Southwest; TN, total nitrogen; TP, total phosphorus; U.S., United States; +, plus (refers to summed concentrations); —, not applicable]

U.S. Geological Survey station number	U.S. Geological Survey station name	Base-flow condition	Urban land cover in the basin, in percent	Constituents exceeding human-health benchmarks (benchmark type) [1]	Constituents exceeding SDWRs [2]	Constituents exceeding aquatic-life benchmarks (benchmark type) [1]	Constituents exceeding recommended ecoregional nutrient criteria [2]
04087204	Oak Creek at South Milwaukee, Wis.	Low	62.9	—	—	—	TN, TP
04084468	Garners Creek at Park Street at Kaukauna, Wis.	Low	68.9	—	—	—	TP
0408703164	Lily Creek at Good Hope Road near Menomonee Falls, Wis.	Low	78.0	—	—	—	TP
040870856	Underwood Creek at Watertown Plank Road at Elm Grove, Wis.	Low	86.0	—	—	—	TP
04087270	Pike Creek at 43rd Street at Kenosha, Wis.	Low	87.2	—	—	—	TN
04087213	Root River at Layton Avenue at Greenfield, Wis.	Low	92.8	—	—	—	TN, TP
040869415	Lincoln Creek at 47th Street at Milwaukee, Wis.	Low	97.6	—	—	—	TP
04087118	Honey Creek near Portland Avenue at Wauwatosa, Wis.	Low	99.1	—	—	—	TN, TP
	Dallas-Fort Worth						
08062805	Williams Creek near Farm to Market 1836 near Kemp, Tex.	High	1.6	—	—	—	TP
08063595	South Prong Creek at Farm to Market 876 near Waxahachie, Tex.	High	2.3	—	—	—	TN
08062600	Grays Creek at Creek 1603 near Rice, Tex.	High	2.5	—	Chloride	Chloride (C-AWQC-AL)	TP
08063047	Bynum Creek near Farm to Market 308 near Malone, Tex.	High	2.7	—	—	—	TN
08063565	Mill Creek at Lowell Road near Milford, Tex.	High	2.8	—	—	—	TN
08063300	Pin Oak Creek near Farm to Market 73 near Coolidge, Tex.	High	3.1	—	—	—	TP
08063555	South Fork Chambers Creek near Creek 102 near Maypearl, Tex.	High	3.3	—	Sulfate	—	
08049580	Mountain Creek near Venus, Tex.	High	4.8	—	Sulfate	—	
08059571	Wilson Creek near Gray Branch Road near Mckinney, Tex.	High	6.5	—	—	—	TN
08052740	Doe Branch at Fishtrap Road near Prosper, Tex.	High	6.7	Atrazine (MCL)	—	—	TN, TP
08064695	Tehuacana Creek at Rural Road 27 near Wortham, Tex.	High	6.9	—	pH	—	
08062020	Buffalo Creek near Farm to Market 148 near Crandall, Tex.	High	7.2	—	—	—	TN, TP
08061780	Buffalo Creek near Trinity Road at Forney, Tex.	High	15.2	—	—	—	TN, TP
08061995	Mustang Creek at Farm to Market 2757 near Crandall, Tex.	High	17.3	—	—	—	TN, TP
08057475	Parsons Slough near Davis Road near Crandall, Tex.	High	21.3	—	—	—	TP

Appendix 5. Site-specific exceedances of water-quality benchmarks.—Continued

[Sites are listed by percentage of urban land cover in the basin. Only those sites with concentrations that exceeded one or more water-quality benchmarks are listed. AI, Acute-invertebrate benchmark; A-AWQC-AL, acute ambient water-quality criterion for protection of aquatic organisms; CI, Chronic-invertebrate benchmark; 10^{-6} CRC, cancer risk concentration at 10^{-6} cancer risk; C-AWQC-AL, chronic ambient water-quality criterion for protection of aquatic organisms; HBSL-Low, low end of health-based screening level range; MCL, Maximum Contaminant Level; SDWR, Secondary Drinking-Water Regulations; SW, Southwest; TN, total nitrogen; TP, total phosphorus; U.S., United States; +, plus (refers to summed concentrations); —, not applicable]

U.S. Geological Survey station number	U.S. Geological Survey station name	Base-flow condition	Urban land cover in the basin, in percent	Constituents exceeding human-health benchmarks (benchmark type) [1]	Constituents exceeding SDWRs [2]	Constituents exceeding aquatic-life benchmarks (benchmark type) [1]	Constituents exceeding recommended ecoregional nutrient criteria [2]
08057431	Fivemile Creek near Simpson Stuart Road, Dallas, Tex.	High	61.6	Dieldrin (10^{-6} CRC, HBSL-Low)	—	—	TN
08061740	Duck Creek at Town East Boulevard near Mesquite, Tex.	High	78.9	Nitrite+nitrate, nitrate (MCL)	—	—	TN, TP
08057200	White Rock Creek at Greenville Avenue, Dallas, Tex.	High	83.9	—	—	—	TN, TP
08061536	Spring Creek at Naaman School Road near Garland, Tex.	High	86.0	—	—	—	TN
08063595	South Prong Creek at Farm to Market 876 near Waxahachie, Tex.	Low	2.3	—	—	—	TN
08062525	Walker Creek near Oil Field Road near Rosser, Tex.	Low	2.3	—	pH	pH (C-AWQC-AL)	
08062600	Grays Creek at Creek 1603 near Rice, Tex.	Low	2.5	—	—	—	TP
08063574	Big Onion Creek at Feaster Road near Bardwell, Tex.	Low	2.5	—	—	—	TN
08063047	Bynum Creek near Farm to Market 308 near Malone, Tex.	Low	2.7	Nitrite+nitrate, nitrate, atrazine (MCL)	—	—	TN
08063565	Mill Creek at Lowell Road near Milford, Tex.	Low	2.8	—	—	—	TN
08063555	South Fork Chambers Creek near Creek 102 near Maypearl, Tex.	Low	3.3	Atrazine (MCL)	—	—	TN, TP
08049580	Mountain Creek near Venus, Tex.	Low	4.8	—	Sulfate	—	
08059571	Wilson Creek near Gray Branch Road near Mckinney, Tex.	Low	6.5	Atrazine (MCL)	—	—	TN
08052740	Doe Branch at Fishtrap Road near Prosper, Tex.	Low	6.7	Atrazine (MCL)	—	—	TN, TP
08062020	Buffalo Creek near Farm to Market 148 near Crandall, Tex.	Low	7.2	Simazine (MCL)	—	—	TN, TP
08059530	Tickey Creek near Creek 400 near Princeton, Tex.	Low	9.4	—	—	—	TN, TP
08063692	Mustang Creek at Moseley Road near Ennis, Tex.	Low	13.9	—	—	—	TN

Appendix 5. Site-specific exceedances of water-quality benchmarks.—Continued

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U.S. Geological Survey station number	U.S. Geological Survey station name	Base-flow condition	Urban land cover in the basin, in percent	Constituents exceeding human-health benchmarks (benchmark type) [1]	Constituents exceeding SDWRs [2]	Constituents exceeding aquatic-life benchmarks (benchmark type) [1]	Constituents exceeding recommended ecoregional nutrient criteria [2]
08061780	Buffalo Creek near Trinity Road at Forney, Tex.	Low	15.2	—	—	—	TN, TP
08061995	Mustang Creek at Farm to Market 2757 near Crandall, Tex.	Low	17.3	—	pH	—	TP
08057475	Parsons Slough near Davis Road near Crandall, Tex.	Low	21.3	—	—	—	TP
08061952	South Mesquite Creek at Lawson Road near Mesquite, Tex.	Low	71.9	—	—	—	TP
08061740	Duck Creek at Town East Boulevard near Mesquite, Tex.	Low	78.9	Nitrite+nitrate, nitrate (MCL)	—	—	TN, TP
08057200	White Rock Creek at Greenville Avenue, Dallas, Tex.	Low	83.9	—	—	—	TN, TP
08061536	Spring Creek at Naaman School Road near Garland, Tex.	Low	86.0	Atrazine (MCL)	—	—	TN
08049490	Johnson Creek near Duncan Perry Road, Grand Prairie, Tex.	Low	88.8	—	pH	pH (C-AWQC-AL)	
Denver							
403308105001601	Boxelder Creek at Mouth near Fort Collins, Colo.	High	4.4	—	Sulfate	—	TN
400855105090501	Dry Creek below Airport Road near Longmont, Colo.	High	8.7	—	Sulfate	—	TN, TP
410714104480101	Crow Creek above Morrie Avenue at Cheyenne, Wyo.	High	8.7	—	—	—	TN, TP
400810105071301	Left Hand Creek above Pike Road at Longmont, Colo.	High	10.4	—	—	—	TN
403048105042701	Fossil Creek at College Avenue at Fort Collins, Colo.	High	16.6	—	Sulfate	—	TN
395554105085601	Rock Creek above Rock Creek Parkway at Superior, Colo.	High	17.4	—	—	—	TN
400607105094401	Dry Creek below Niwot Road at Niwot, Colo.	High	22.2	—	Sulfate	—	TN, TP
400925105023201	Spring Gulch at Sandstone Ranch Park near Longmont, Colo.	High	25.2	—	Sulfate	—	TN, TP
395324105035001	Big Dry Creek below Hyland Circle at Westminster, Colo.	High	33.3	—	pH	—	
394919105074601	Ralston Creek above Simms at Arvada, Colo.	High	41.4	—	—	—	TP
393613104511401	Cottonwood Creek above Newark Way at Greenwood Village, Colo.	High	59.1	—	Sulfate	—	TN, TP
394629105063101	Clear Creek below Kipling at Wheat Ridge, Colo.	High	62.6	—	—	—	TP
403356105024001	Spring Creek at Edora Park at Fort Collins, Colo.	High	63.5	—	—	—	TN, TP
394553105075101	Lena Gulch at Lewis Meadows Park at Wheat Ridge, Colo.	High	68.8	—	—	—	TP

Appendix 5. Site-specific exceedances of water-quality benchmarks.—Continued

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U.S. Geological Survey station number	U.S. Geological Survey station name	Base-flow condition	Urban land cover in the basin, in percent	Constituents exceeding human-health benchmarks (benchmark type) [1]	Constituents exceeding SDWRs [2]	Constituents exceeding aquatic-life benchmarks (benchmark type) [1]	Constituents exceeding recommended ecoregional nutrient criteria [2]
393557105033101	Dutch Creek at Weaver Park near Columbine Valley, Colo.	High	72.0	—	Sulfate	—	TN
06713500	Cherry Creek at Denver, Colo.	High	79.6	—	—	—	TN, TP
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	High	89.3	—	—	—	TN
394107105021001	Sanderson Gulch above Lowell Avenue at Denver, Colo.	High	90.4	—	pH	—	TN
403308105001601	Boxelder Creek at Mouth near Fort Collins, Colo.	Low	4.4	—	Sulfate	—	TN
400855105090501	Dry Creek below Airport Road near Longmont, Colo.	Low	8.7	—	Sulfate	—	TN, TP
410714104480101	Crow Creek above Morrie Avenue at Cheyenne, Wyo.	Low	8.7	—	—	Malathion (CI, C-AWQC-AL)	TN, TP
400810105071301	Left Hand Creek above Pike Road at Longmont, Colo.	Low	10.4	—	Sulfate	—	TN
403048105042701	Fossil Creek at College Avenue at Fort Collins, Colo.	Low	16.6	—	—	—	TN
395554105085601	Rock Creek above Rock Creek Parkway at Superior, Colo.	Low	17.4	—	—	—	TN, TP
402549105043101	Dry Creek at U.S. Highway 287 at Loveland, Colo.	Low	20.9	—	Sulfate	—	TN
400607105094401	Dry Creek below Niwot Road at Niwot, Colo.	Low	22.2	—	—	—	TN, TP
400925105023201	Spring Gulch at Sandstone Ranch Park near Longmont, Colo.	Low	25.2	—	Sulfate	—	TN
393948105053501	Bear Creek below Estes Road at Lakewood, Colo.	Low	38.0	—	—	—	TN, TP
394919105074601	Ralston Creek above Simms at Arvada, Colo.	Low	41.4	—	—	—	TN, TP
393613104511401	Cottonwood Creek above Newark Way at Greenwood Village, Colo.	Low	59.1	—	Sulfate	—	TN, TP
394629105063101	Clear Creek below Kipling at Wheat Ridge, Colo.	Low	62.6	—	—	—	TN, TP
403356105024001	Spring Creek at Edora Park at Fort Collins, Colo.	Low	63.5	—	—	—	TN, TP
393557105033101	Dutch Creek at Weaver Park near Columbine Valley, Colo.	Low	72.0	—	Sulfate	—	TN
06713500	Cherry Creek at Denver, Colo.	Low	79.6	—	—	—	TN, TP
403035105035301	Mail Creek near Mouth at Fort Collins, Colo.	Low	88.1	—	Sulfate	—	TN
394409105020501	Lakewood Gulch above Knox Street at Denver, Colo.	Low	89.3	—	—	—	TN
394107105021001	Sanderson Gulch above Lowell Ave at Denver, Colo.	Low	90.4	—	—	—	TN, TP
		Portland					
14205400	East Fork Dairy Creek near Meacham Corner, Oreg.	High	0.5	—	—	—	TN

Appendix 5. Site-specific exceedances of water-quality benchmarks.—Continued

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452231122200000	Deep Creek near Sandy, Oreg.	High	4.4	—	—	—	TN
451734122585400	Chehalem Creek at Newberg, Oreg.	High	8.6	—	—	—	TN, TP
454549122295800	Salmon Creek near Battleground, Wash.	High	13.2	—	—	—	TN
452414122213200	Tickle Creek near Boring, Oreg.	High	19.0	—	—	—	TN, TP
14206750	Chicken Creek near Sherwood, Oreg.	High	22.0	—	—	—	TN, TP
452337122243500	North Fork Deep Creek at Barton, Oreg.	High	27.1	—	—	—	TN, TP
14206347	Rock Creek at Quatama Road near Hillsboro, Oreg.	High	28.2	—	—	—	TP
445029122592600	Battle Creek near Turner, Oreg.	High	33.0	—	—	—	TN
454510122424900	Whipple Creek near Salmon Creek, Wash.	High	37.6	—	—	—	TN, TP
452912122291200	Johnson Creek at Circle Avenue, Oreg.	High	41.9	—	—	—	TN, TP
14211315	Tryon Creek below Nettle Creek near Lake Oswego, Oreg.	High	59.5	—	—	—	TN, TP
440257123103200	Amazon Creek near Danebo Road at Eugene, Oreg.	High	61.9	—	—	—	TN, TP
454321122352300	Curtin Creek near Vancouver, Wash.	High	72.4	—	—	—	TN, TP
452526122364400	Kellogg Creek at Milwaukie, Oreg.	High	81.0	—	—	—	TN, TP
14206435	Beaverton Creek at SW 216th Avenue near Orenco, Oreg.	High	82.9	—	—	—	TN, TP
14206950	Fanno Creek at Durham, Oreg.	High	84.3	—	—	—	TN, TP
445551123015800	Pringle Creek at Salem, Oreg.	High	88.7	—	—	—	TN
450022123012400	Claggett Creek at Keizer, Oreg.	High	97.8	—	—	—	TN, TP
454543122524900	South Scappose Creek at Scappose, Oreg.	Low	3.3	—	—	—	TP
443326123165200	Oak Creek at Corvallis, Oreg.	Low	7.1	—	—	—	TP
451734122585400	Chehalem Creek at Newberg, Oreg.	Low	8.6	—	—	—	TP
452414122213200	Tickle Creek near Boring, Oreg.	Low	19.0	—	—	—	TN, TP
14206750	Chicken Creek near Sherwood, Oreg.	Low	22.0	—	—	—	TP
452337122243500	North Fork Deep Creek at Barton, Oreg.	Low	27.1	—	—	—	TN, TP
14206347	Rock Creek at Quatama Road near Hillsboro, Oreg.	Low	28.2	—	—	—	TN, TP
445029122592600	Battle Creek near Turner, Oreg.	Low	33.0	—	—	—	TN, TP
454510122424900	Whipple Creek near Salmon Creek, Wash.	Low	37.6	—	—	—	TN, TP

Appendix 5. Site-specific exceedances of water-quality benchmarks.—Continued

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452912122291200	Johnson Creek at Circle Avenue, Oreg.	Low	41.9	—	—	—	TN, TP
14211315	Tryon Creek below Nettle Creek near Lake Oswego, Oreg.	Low	59.5	—	—	—	TN, TP
440257123103200	Amazon Creek near Danebo Road at Eugene, Oreg.	Low	61.9	—	—	—	TN, TP
454321122352300	Curtin Creek near Vancouver, Wash.	Low	72.4	—	—	—	TN, TP
452526122364400	Kellogg Creek at Milwaukie, Oreg.	Low	81.0	—	—	—	TN, TP
14206435	Beaverton Creek at SW 216th Avenue near Orenco, Oreg.	Low	82.9	—	—	—	TN, TP
14206950	Fanno Creek at Durham, Oreg.	Low	84.3	—	—	—	TN, TP
445551123015800	Pringle Creek at Salem, Oreg.	Low	88.7	—	—	—	TN, TP
450022123012400	Claggett Creek at Keizer, Oreg.	Low	97.8	—	—	—	TN, TP

[1] Benchmark values are listed in Appendix 3 for nutrients, sulfate, chloride, and pH and Appendix 4 for pesticides.

[2] Benchmark values are listed in Appendix 3.

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