1999

Mass Flux of Agricultural Nonpoint-Source Pollutants in a Conduit-Flow-Dominated Karst Aquifer, Logan County, Kentucky

James C. Currens
University of Kentucky, currens@uky.edu

Kentucky Geological Survey
James C. Cobb, State Geologist and Director
University of Kentucky, Lexington

Mass Flux of Agricultural Nonpoint-Source Pollutants in a Conduit-Flow-Dominated Karst Aquifer, Logan County, Kentucky

James C. Currens

Report of Investigations 1 **https://doi.org/10.13023/kgs.ri01.12** **Series XII, 1999**

Kentucky Geological Survey
James C. Cobb, State Geologist and Director
University of Kentucky, Lexington

Mass Flux of Agricultural Nonpoint-Source Pollutants in a Conduit-Flow-Dominated Karst Aquifer, Logan County, Kentucky

James C. Currens

Report of Investigations 1 https://doi.org/10.13023/kgs.ri01.12 Series XII, 1999

Mission Statement

The Kentucky Geological Survey at the University of Kentucky is a State-mandated organization whose mission is the collection, preservation, and dissemination of information about mineral and water resources and the geology of the Commonwealth. KGS has conducted research on the geology and mineral resources of Kentucky for more than 150 years, and has developed extensive public databases for oil and natural gas, coal, water, and industrial minerals that are used by thousands of citizens each year. The Survey's efforts have resulted in topographic and geologic map coverage for Kentucky that has not been matched by any other state in the Nation.

One of the major goals of the Kentucky Geological Survey is to make the results of basic and applied research easily accessible to the public. This is accomplished through the publication of both technical and nontechnical reports and maps, as well as providing information through open-file reports and public databases.

Acknowledgments
Edited by—Margaret Luther Smath
Photography—James C. Currens
Cover design—Collie Rulo
Drafting—Terry D. Hounshell
Word Processing—Shirley D. Dawson

For further information contact:
Manager, Office of Communications and Technology Transfer
Kentucky Geological Survey
228 Mining and Mineral Resources Building
University of Kentucky
Lexington, KY 40506-0107

ISSN 0075-5591

Contents

Contents (Continued)

Plates

Figures

Figures (Continued)

Tables

Mass Flux of Agricultural Nonpoint-Source Pollutants in a Conduit-Flow-Dominated Karst Aquifer, Logan County, Kentucky

James C. Currens

Abstract

Changes in water quality in a karst ground-water basin used intensively for agriculture are being measured before, during, and after the implementation of best management practices (BMP's) and other management practices, to determine the success of such programs in protecting ground water. The study was divided into three phases. The results of the first two phases are included in this report and cover research conducted between August 1990 and October 1994. During phase I of the study the overall ground-water quality of the basin and its hydrogeology were investigated. Phase II began monitoring the water quality at Pleasant Grove Spring before BMP implementation.

The Pleasant Grove Spring Basin in southern Logan County, Ky., was selected for study because it is largely free of nonagricultural pollution sources. About 70 percent of the watershed is in crop production and 22 percent is pasture. The area of the karst drainage basin is approximately 10,054 acres (4,069 hectares), as determined by ground-water dye tracing. Ground-water flow in the basin is divided into a diffuse (slow) flow regime and a conduit (fast) flow regime. The diffuse and conduit flow regimes have a major influence on the timing of contaminant peaks and valleys during storms.

Nitrate is the most widespread, persistent contaminant in the basin, but concentrations average 5.2 mg/L basinwide and generally do not exceed maximum contaminant levels (MCL's) set by the U.S. Environmental Protection Agency for drinking water. Atrazine has been consistently detected in low concentrations, and other pesticides occasionally are detected. Concentrations of triazines (including atrazine) and alachlor have exceeded drinking-water MCL's during spring flooding. Maximum concentrations of triazines, carbofuran, metolachlor, and alachlor in samples from Pleasant Grove Spring were 44.0, 7.4, 9.6, and 6.1 µg/L, respectively. Flow-weighted average concentrations for 1992–93 were 4.91 µg/L for atrazine-equivalent triazines and 5.0 mg/L for nitrate-nitrogen. Averages for 1993–94 were 0.97 µg/L and 5.7 mg/L, respectively. The difference in atrazine-equivalent triazine concentration between the 2 years may be either the result of weather conditions or crop patterns.

Bacteria counts always exceed standards for drinking water and occasionally exceed standards for drinking-water supplies. Basinwide, samples averaged 465 fecal coliform colony-forming units per 100 ml (col/100 ml) and 1,891 fecal streptococci col/100 ml; maximum counts were 14,000 and 24,000 col/100 ml, respectively. Bacteriological speciation failed to identify the source of high bacteria counts at Pleasant Grove Spring, but showed that the bacteria are not indigenous to the natural environment of the basin.

Suspended sediment discharging from Pleasant Grove Spring has had an adverse impact on aquatic biota downstream.

In the Pleasant Grove Spring Basin, ground water for human consumption is adversely affected by contamination from triazines and bacteria. Implemented BMP's should focus on reduction of runoff, disposal of animal waste, and efficient application of nutrients. A public education program on ground-water protection would also be beneficial.

Introduction

Karst aquifers are the water-bearing zones in terrains characterized by sinkholes, sinking streams, and caves. Ground water in karst aquifers occurs in partially to completely water-filled caverns, joints, and other fractures in the otherwise relatively impermeable limestone bedrock, and in soil mantling the solution-etched bedrock. Almost all ground water in karst basins eventually flows into caverns, from which it flows to discharge at a spring. Karst aquifers are notoriously sensitive to ground-water pollution because runoff from contaminant sources on the surface often enters the aquifer directly through sinking streams and sinkholes, without filtration.

The most productive agricultural region in Kentucky follows the karst plain that extends in a belt from west-central Kentucky, south to the Tennessee state line, then west across the southwestern quarter of Kentucky. Large farms produce corn, wheat, soybeans, tobacco, milo, rye, and barley from the thick and fertile soil overlying a gently rolling landscape. Logan County, the location of this study, produced more than $71 million in crop and livestock receipts in 1992, making it the sixth-ranking county in the State (Kentucky Agricultural Statistics Service, 1993). Not coincidentally, some of the most serious ground-water contamination problems in the State occur in these same areas (Nitzkin and Henry, 1971; Kentucky Division of Water, 1988). Recently, water supply has become a significant limitation on economic development in Logan County (Joseph L. Taraba, University of Kentucky College of Agriculture, oral commun., 1996).

Purpose

Because agriculturally derived contaminants have been detected in municipal drinking-water supplies, as well as in domestic water wells, public concerns about the impact of agriculturally derived pollutants in general have been heightened. Pesticides are the primary safety concern, but fertilizers also play a role in the degradation of ground-water supplies. Furthermore, in karst areas, sediment eroded from fields and animal waste washed from pastures and feedlots also pollute ground water. Conduit springs supply most of the base flow to surface streams in karst regions, from which many municipal suppliers obtain their water source. Regulating farming practices, however, would lower productivity and increase the costs of food. The purpose of this research is to determine if programs and farming practices already in existence can be used to effectively protect ground water in karst aquifers from agriculturally derived contaminants, without resorting to regulation. If voluntary programs are effective, then both the public safety and the independence of farmers can be protected.

Protection techniques and farm management strategies to safeguard both surface- and ground-water quality and to minimize soil erosion have been developed and tested at plot, field, and farm scales. The Pleasant Grove Spring karst ground-water basin was chosen to test whether a program to install new or modified best management practices (BMP's) and an education program to enhance public attitudes about ground water will improve the quality of water in a karst ground-water basin at a large scale. This report summarizes the results of phase I (field reconnaissance and watershed mapping) and phase II (water-quality characterization and quantification before BMP implementation). Data in this report were collected between August 1990 and October 1994. Additional data are available through the hydrologic database at the Kentucky Geological Survey.

Acknowledgments

The author wishes to thank the University of Kentucky College of Agriculture and the U.S. Environmental Protection Agency, who provided financial support for this research, via the Kentucky Division of Water, Nonpoint-Source Program. Bill Johnson, of the Logan County office of the Natural Resources Conservation Service, provided invaluable help in contacting farmers, acquiring crop and chemical-use data, and field support. Stan Asbridge, of the Consolidated Farm Services Agency, loaned annual aerial photographs of crops, and his staff provided training in their interpretation. Steve Crabtree, of the Boone County office of the Natural Resources and Conservation Service, digitized land-use maps and calculated crop areas. Mark Coyne, of the University of Kentucky College of Agriculture, conducted valuable bacterial speciation analyses. Joe Meiman, of Mammoth Cave National Park, conducted scanning fluorometer analyses. More than 40 area farmers graciously allowed access to their property and helped locate springs and other karst features. Without the farmers' interest and cooperation, this research would not have been possible, and their help is gratefully acknowledged.

Reconnaissance sampling and watershed mapping began in February 1991 when funding was received through the University of Kentucky College of Agriculture from Kentucky Senate Bill 271. Most equipment purchases and roughly half of the analytical costs through spring 1992 were paid for by SB-271 funds. Additional funding was received in April 1992 through the Kentucky Division of Water (Memorandum of Agreement 011399) from the U.S. Environmental Protection Agency's Nonpoint-Source Program (section 319 of the Clean Water Act). Phase II funding was received in September 1993, also through the 319 program (Memorandum of Agreement 012875).

Study Area Description

General Setting

The study area is centered in south-central Logan County. Pleasant Grove Spring is about 9 mi (14.5 km) south of Russellville (Fig. 1). The study area includes parts of the Russellville, Dennis, Dot, and Adairville 7.5-minute quadrangles. Pleasant Grove Creek flows south

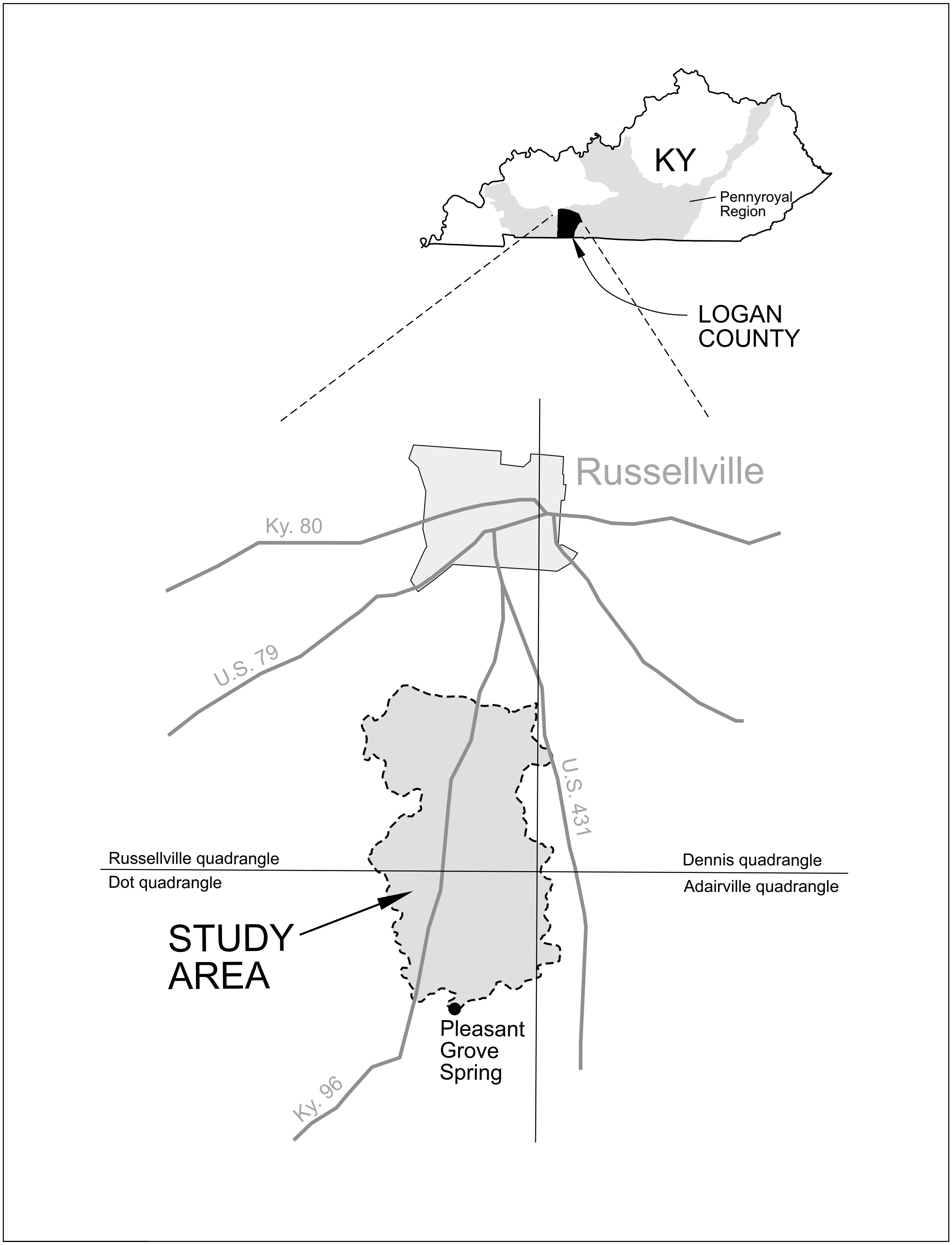


Figure 1. Location of the Pleasant Grove Spring drainage basin.

1.5 mi (2.4 km) to the Red River from its origin at Pleasant Grove Spring. For the purposes of this report, reaches of surface flow in the headwaters area of the basin, upstream of major swallow holes, are collectively called Upper Pleasant Grove Creek.

Figure 2. Example of a large crop field in the study area.

Pleasant Grove Spring Basin lies entirely within the Mississippian Plateaus physiographic region, which is developed on thick carbonates of Late Mississippian age. Topography in the study area is mature karst, with abundant sinkholes, sinking streams, karst windows, and springs. Land surfaces are gently rolling, except on the steep rims of scattered deep sinkholes, providing excellent conditions for large-scale farming. Land use in the basin is almost entirely agricultural. The primary row crops are corn, wheat, and soybeans, planted in a 2-year rotation (Fig. 2). Minor crops include hay, tobacco, milo, rye, and barley. Livestock production includes beef (1,300 to 1,400 head) and dairy cattle (200 to 300 head) and swine (1,000 to 1,200 head).

Geology and Hydrogeology

The geology of the area was mapped by Rainey (1965), Shawe (1966a, b), and Miller (1968). Only two mapped units, the St. Louis Limestone and the overlying Ste. Genevieve Limestone, occur at the surface in the basin. Exposures of these units are generally poor. The upper 70 ft (21 m) of the St. Louis Limestone is exposed along stream channels and in deep sinkholes in the southern end of the basin. Although the St. Louis is a relatively pure, thick-bedded, oolitic to micritic limestone, it also contains thin, argillaceous-carbonate and shale beds and both bedded and nodular chert. Because of limited outcrop and drill-hole data, the boundary between the St. Louis and the overlying Ste. Genevieve is mapped at the highest occurrence of a relatively thick and widespread horizon of chert. This unit is probably the stratigraphic equivalent of the Lost River Chert (Garland R. Dever Jr., Kentucky Geological Survey, oral commun., 1994).

The Ste. Genevieve Limestone is a very pure, thick-bedded, oolitic to micritic limestone with scattered, thin-bedded chert layers, primarily near its base. The lower 197 ft (60 m) of the Ste. Genevieve Limestone is exposed in the basin.

Geologic structures in the study area are modest. Strata dip gently to the northwest at 60 ft / mi (11.4 m / km) (Fig. 3) into the Illinois Basin. No faults are mapped within the drainage basin; however, significant faulting occurs to the north, and obvious lineaments of sinkholes within and near the basin suggest the possibility of unmapped faults.

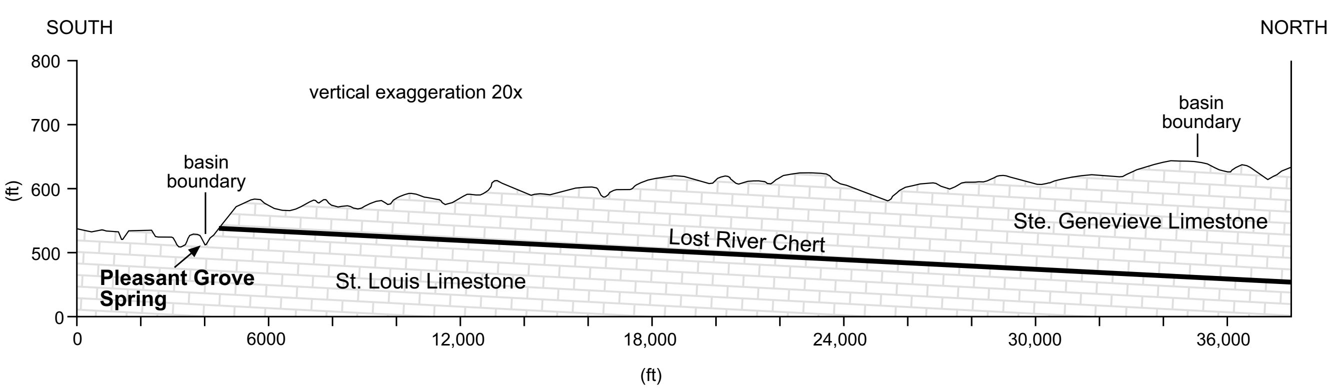


Figure 3. South–north geologic cross section of the study area showing the approximate position of the Lost River Chert (after Cupp, 1994; reprinted with permission of the author).

Previous hydrogeologic investigations in the area are highly generalized (Brown and Lambert, 1962; Van Couvering, 1962). Pleasant Grove Spring was sampled by the U.S. Geological Survey in 1982 (Rene Garcia, written commun., 1994). Ground-water flow in the basin is through enlarged joints, bedding planes, and karst conduits. Flow on the surface persists in the northern end of the study area through most of the year, gradually ceasing headward as drought periods lengthen. Flow in the southern end of the basin is exclusively underground, except that scattered deep sinkholes allow access to flowing water during extreme high flow. Domestic and agricultural water supplies traditionally have come from springs and wells; some residents have recently obtained public water supplies, however—partly because of deteriorating water quality. Man-made ponds and naturally plugged sinkholes provide additional water supplies for livestock.

For the reader's convenience, the names of some karst features not commonly used are defined here. A *swallow hole* is an opening in a stream channel into which a stream may partially or totally sink. An *estavelle* functions as a swallow hole when the water table is low; quick runoff from storms sinks into the estavelle until the water table rises to the elevation of the surface. When the water table is high during prolonged rains, the estavelle acts as a spring. A *blue hole* is any deep clear pool of water in a karst area. The most common use of the term "blue hole" is for a spring rising from some depth under pressure. A *karst window* is a sinkhole with a spring on one end and a swallow hole on the other, connected by a short reach of surface-flowing water.

Soils

Soils in the basin are Pembroke-Crider association, derived from loess and limestone residuum (Dye and others, 1975). They are silt loams, moderately permeable, with deep root zones. The soils may be as much as 76 in. (2 m) thick to the base of the subsoil. Except where loess is preserved, the soils exhibit the terra rossa coloration typical of karst, especially in the subsoil, suggesting significant iron content. There are no reported pans (layers of semiconsolidated soil particles that retard water infiltration) in either the Pembroke or Crider.

PREVIOUS RESEARCH

The leaching of agricultural chemicals from soils or into ground water and the overland flow of soil, animal waste, and chemicals into streams in nonkarst settings have been documented for decades (Lichtenstein, 1958; Johnston and others, 1967; White and others, 1967; Hall and others, 1972; Dao and others, 1979; Thomas and Phillips, 1979; Cohen and others, 1986; Canter, 1987; Libra, 1987; Wartenberg, 1988; Magette and others, 1988; Smith and others, 1988). The mechanisms of movement and the relative significance of leaching in various soils and agricultural settings are subjects of several papers (Thomas, 1972; Thomas and Phillips, 1979; Cohen and others, 1986; Canter, 1987; Smith and others, 1988). Studies of field runoff into streams have shown adverse impacts by agricultural chemicals where soil erosion is high (Sharpley and Syers, 1979; Baker, 1980). The transport characteristics, leaching characteristics, and degradation products of pesticides are beyond the scope of this report, and the reader is referred to the literature for details on these subjects.

None of the chemical leaching studies cited above were specifically directed toward the special hydrogeologic conditions of karst, and the presence of agricultural chemicals in karst ground water in concentrations warranting concern has only recently been questioned. Several widely published studies investigating agricultural chemicals in a karst aquifer were conducted in the Big Spring Basin, Iowa, however (Hallberg and others, 1983, 1984; Libra and others, 1986). Big Spring discharges from the Galena aquifer, which has a significant diffuse-flow component characterized by fewer direct inflow points than found in most karst aquifers and relatively long residence times. Hallberg and others (1983, 1984) and Libra and others (1986) found nitrate in significant concentrations (flow-weighted mean of 45 mg/L as nitrate), but atrazine never exceeded 5.1 µg/L and averaged 0.28 µg/L. They thought nitrate infiltration was related to diffuse recharge, whereas atrazine infiltration was induced by inflow to sinkholes and sinking streams. They also observed a seasonal cycle in nitrate concentration. Studies by Boyer and Pasquarell (1994) and Steele and Smith (1994) found a direct relationship between aquifer vulnerability, land use, and agricultural chemical concentrations. Because karst conduits can transport significant quantities of sediment, agricultural chemical adsorption on soil particles and their subsequent erosion may play a significant role in contaminant transport in karst aquifers. Therefore, karst aquifers may be doubly contaminated from direct runoff and diffuse infiltration.

Studies in Kentucky prior to 1991 on agricultural nonpoint-source pollution in karst aquifers are master's theses (Devilbiss, 1981; Tucker, 1982; Brown, 1985). Tucker (1982) found that nitrate concentrations increased during high flow and that sediment and bacteria discharges were significant. In contrast, Brown (1985) found that nitrate concentrations decreased during high flow. Both authors noted seasonal cycles in nitrate concentration.

More recent nonpoint-source pollution studies in karst basins in Kentucky include the Mammoth Cave

Water-Quality Special Project (Meiman, 1991) and several projects sited in the Inner Blue Grass Region (Felton, 1991; Hampson, 1994; Keagy and others, 1994a, b). Felton (1991) found that nitrate concentration varied seasonally at Garretts Spring, but pesticides occurred only in very low concentrations. Hampson (1994) and Keagy and others (1994a, b) found several pesticides and nitrate in wells. Meiman (1991) correlated land use with water quality and noted the presence of triazines during spring storms and high bacteria levels in watersheds draining areas that included both agriculture and suburban development. Bacteria levels in the forested Buffalo Creek Basin in Mammoth Cave National Park, however, averaged 85 colonies per 100 ml (col / 100 ml) of fecal coliform (Joe Meiman, Mammoth Cave National Park, oral commun., 1994). Boyer and Pasquarell (1994) found mean bacteria counts of less than 1 col / 100 ml of fecal coliform in a pristine karst basin in southeastern West Virginia.

Monitoring karst springs for natural water-quality constituents to identify the source and transport mechanisms of contaminants is a well-established technique (Ashton, 1966; Atkinson, 1973; Meiman, 1985; Ogden, 1988; White, 1988). By continuously recording parameters such as water temperature and conductivity at karst springs, inferences can be made about the origin of the water carrying a sampled contaminant. For example, if the water temperature rises and the conductivity simultaneously decreases during runoff from a summer storm, the water discharging from the spring can be associated more with warm, less mineralized runoff from the precipitation. Any contaminant that increases in concentration during this period can also be associated with the runoff, whereas a contaminant that is diluted can be associated with ground water in storage in the karst aquifer. Concentrations of contaminants associated with ground-water stores can be expected to be higher during low flow (Meiman, 1985).

METHODOLOGY

General Strategy

The ultimate goal of this study is to demonstrate whether a program to improve best management practices on farms overlying a karst aquifer will improve ground-water quality. This is to be evaluated by measuring changes in the quality of water discharged from Pleasant Grove Spring each year. Logistics, a limited budget, and public relations had a major influence on project design. For example, an annual census of actual pesticide application in the basin would have had both a poor response and created an atmosphere of distrust among farmers. Also, because of the size of the watershed, such a detailed survey was beyond budgetary limitations.

Changes in water quality were evaluated by following trends in mean concentrations, flow-weighted means, and annual mass flux of contaminants over several years. The total annual mass flux of suspected contaminants was estimated by multiplying discharge calculated from stage records by concentrations determined by analysis of samples. The flow-weighted mean is the total mass of a chemical discharged, divided by the total volume of water discharged. The mass flux was determined for 2 full years before BMP's were implemented to provide a basis for estimating variability in the flux. Samples were also analyzed for indicators of other sources of pollution, such as volatile organics, laundry detergent ingredients, and bacteria species. Although longer monitoring before implementation of BMP's would have been desirable, it was not practical because of cost.

Implementation of BMP's and other management practices began in the spring of 1995. Monitored changes in the quality of water discharging from Pleasant Grove Spring should become apparent during the 3-year BMP implementation period. Trends in mass flux and in the concentration of less quantifiable contaminants should indicate the success or failure of the BMP program.

Assumptions

It was assumed that (1) all ground-water discharged from the basin can be accounted for at Pleasant Grove Spring, (2) the precision of measuring mass flux on an annual basis is adequate to detect changes in water quality induced by changes in land use, (3) pesticides most commonly used in the basin are quantifiable by relatively inexpensive analytical techniques, (4) nonagricultural sources of contamination in the basin are minimal, (5) farmers would allow access to their property for monitoring and would participate in a BMP implementation program, and (6) funding would be obtained through the U.S. Department of Agriculture for implementation of the BMP program. All of these assumptions have either proved true or the exceptions have been manageable.

Land-Use Mapping

A generalized land-use assessment (Fig. 4) was prepared by the Logan County Soil Conservation Service (now called the Natural Resources Conservation Service), a branch of the U.S. Department of Agriculture (USDA). Annual land-use maps showing crops grown in the basin from 1991 through 1994 were prepared by the Kentucky Geological Survey from aerial photographs taken for the USDA Agricultural Stabilization and Conservation Service. The maps were digitized and the total crop areas were calculated using GRASS geographic information system software.

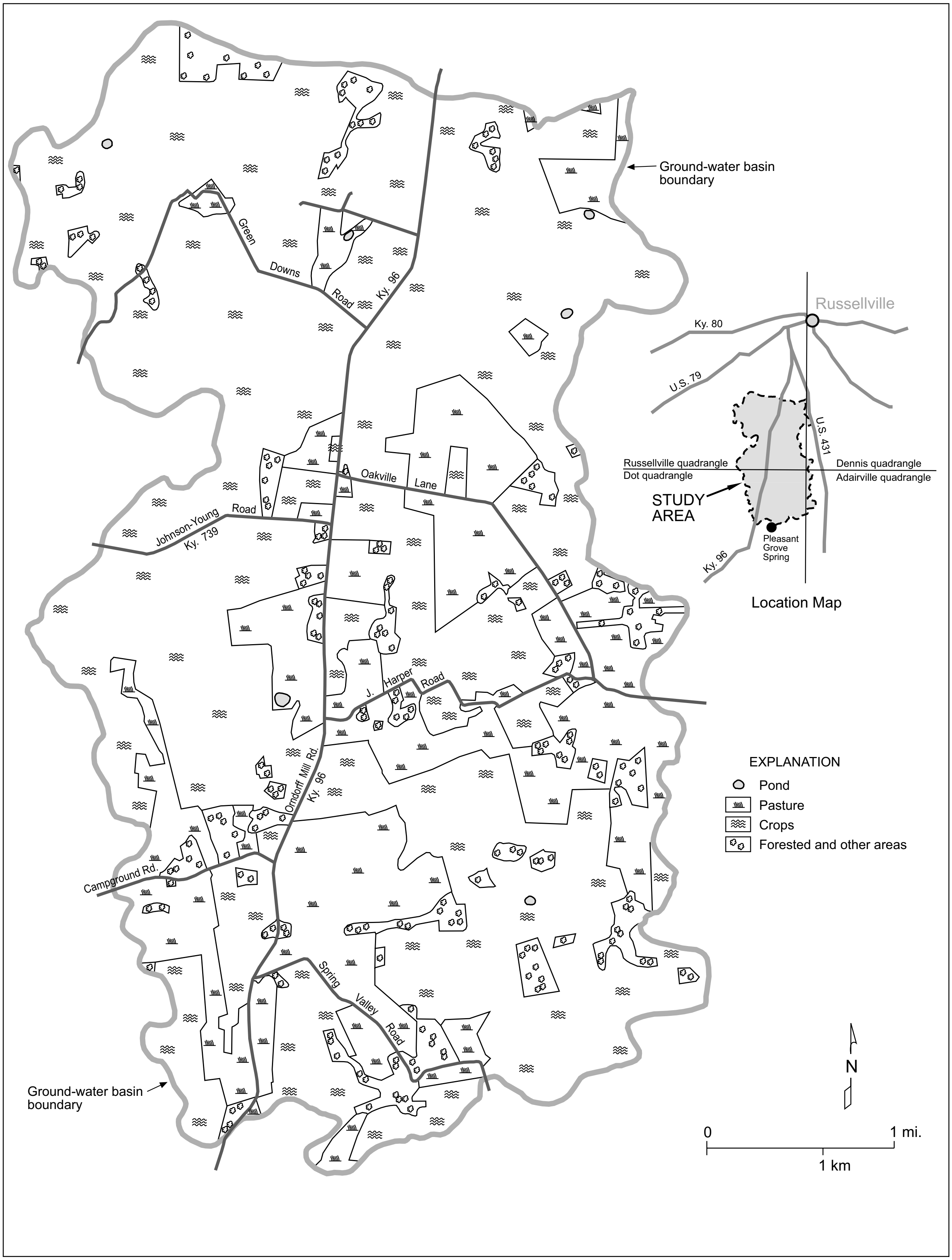


Figure 4. Generalized land use as of February 1992.

Chemical Use

Modern agricultural practices require the use of large amounts of herbicides, insecticides, and fertilizers. No-till cropping, a method of killing noncrop plants with herbicides instead of plowing, is perhaps the most effective technique used by farmers to minimize soil erosion. Data on pesticide sales for distributors in Logan County were used as a relative indicator of trends in the use of pesticides. More than 66,000 lb (30 metric tons) of atrazine alone is sold in Logan County annually (Ernest Collins, Kentucky Division of Pesticides, oral commun., 1993).

Chemical application rates recommended by the USDA for the South Logan County Conservation District and by the University of Kentucky College of Agriculture–Cooperative Extension Service were used to estimate percentages lost from fields. The average recommended application rate for nitrogen fertilizer for all crops in the Pleasant Grove Spring Basin is 137 lb / acre (154 kg / hectare [hc]) of nitrate-nitrogen, and the recommended rate for atrazine for corn is 2.5 lb / acre of 80 percent active ingredient (2.8 kg / hc). Pesticide application rates are summarized in Table 1.

Ground-Water Dye Tracing

Springs and suitable input points for ground-water dye tracing were identified during field reconnaissance. More than 70 karst features (sinking streams, caves, springs, karst windows, and estavelles) were located, and many were used during the tracing program (see Figure 4 and Plates 1 and 2 for the locations of cultural, physiographic, and hydrologic features). A boat was used to locate springs along Whippoorwill Creek and Little Whippoorwill Creek. Many features were reported by area residents, and several features were located from aerial photographs.

Ground-water basin boundaries were mapped by conducting ground-water dye traces to Pleasant Grove and surrounding springs. Standardized tracing techniques were used (Aley and Fletcher, 1976; Thrailkill and others, 1983; Jones, 1984; Davis and others, 1985; Quinlan, 1987; Mull and others, 1988). Traces used four fluorescent dyes: fluorescein (C.I. Acid Yellow 73), rhodamine WT (Acid Red 388), Diphenyl Brilliant Flavine (C.I. Direct Yellow 96), and Tinopal CBS-X (optical brightening agent 351) (Smart, 1984). Straight-line distances traced ranged from 1,500 to 28,000 ft (457 to 8,534 m). Fluorescein and Tinopal were introduced into swallow holes as dry powder, Direct Yellow was mixed with water in the field, and rhodamine was poured in as a concentrated solution. Direct Yellow was 20 percent active ingredient by weight, rhodamine a 20 percent solution, and other tracers were 100 percent active ingredient. Springs were monitored for dye emergence with packets of activated carbon charcoal and bleached cotton broadcloth ribbons (“bow ties”) attached to concrete anchors (Currens, 1993). Dye was released from the charcoal with a solution of ammonia hydroxide, water, and 1-propanol. Inspection of the elutant and cotton bow ties (or “bugs”) was done visually using an ultraviolet lamp. Weak positive traces from rhodamine or fluorescein were confirmed using a Turner Designs[1] model 10 filter fluorometer. Quantitative dye traces are under way.

Optical Brightener Detection

To estimate relative concentrations of optical brightener in Pleasant Grove Spring and Leslie Page karst window, cotton fabric was mounted on frames (Thrailkill and others, 1983) and deployed in the springs for 2-week periods. The brightening agents sorb on cotton fabric and fluoresce in ultraviolet light (at wavelengths greater than 450 nm). The detectors were placed in July 1993 and July and August 1994 at Pleasant Grove Spring, Leslie Page karst window, and David Dotson spring. The detectors were washed and dried and delivered to the National Park Service at Mammoth Cave, Ky., where they were analyzed for fluorescence using a Shimaduzu model RF5000u scanning fluorometer.

Monitoring Equipment

Monitoring equipment installed at Pleasant Grove Spring between May 20 and June 3, 1992, continuously records the quality of the discharge at 10-minute intervals (Fig. 5). A Yellow Springs Instruments (YSI) model 3800 water-quality logger records water temperature, pH, conductivity, dissolved oxygen, turbidity, and barometric pressure. The logger also records a point-discharge velocity from a Marsh-McBirney 201-D water-flow meter. A Telog model 2109 water-level recorder independently records the stage. A portable Isco, Inc., automatic water sampler has also been installed to collect storm samples. A model 2900 Isco water sampler collects samples at closely spaced, regular intervals, generally 12 hours. Monitoring equipment at each of the upstream sites consists of a staff gage and Telog model 2109e water-level recorder. Battery-powered Isco samplers are temporarily installed as needed. All of the Telog data loggers are battery powered. The YSI 3800 water-quality logger and Marsh-McBirney 201-D wa-

[1]The use of manufacturer and trademark names does not constitute an endorsement of the product by KGS or the University of Kentucky; these names are included for reference only.

Table 1. Purpose of and application rates for pesticides commonly used in Logan County (1992 sales greater than 2,200 lb), and detectable by the KGS water-quality laboratory.			
Pesticide	*Purpose*	*Application Rate Maximum per Acre**	*Time of Application*
atrazine	corn, pre-emergent herbicide	2.5 lb. @ 80%	mid-April
butylate	corn, pre-plant herbicide	7 pints	early April
metolachlor	corn, pre-emergent herbicide	2 pints	
alachlor	corn, pre-emergent herbicide	2 pints	
cyanazine	corn, pre-plant herbicide	2 quarts	April
pendimethalin	corn, pre-emergent herbicide	3 pints	April
carbofuran	corn, insecticide	5 lb.	May and June
permethrin	soybean, insecticide	6.8 oz.	
linuron	soybean, pre-emergent herbicide	1 lb.	
trifluralin	soybean, pre-emergent herbicide	2.25 pints	
chlorpyrifos	soybean, insecticide	1.5 pints	June and July
2,4-D	corn, post-emergent herbicide	1.5 pints	May and June
endosulfan I & II	tobacco, insecticide		
*Martin and Green, 1992; Bill Johnson, NRCS Logan County office, oral commun., 1992			

ter-flow meter are normally powered by commercial line power, but have battery backup. The Isco samplers at Pleasant Grove Spring are powered by either batteries or line power.

A simple weather station was also installed at Pleasant Grove Spring. A Telog model 2107 pulse recorder records from a Rain Wise tipping bucket gage, and a Telog model 2103 ambient temperature recorder records the air temperature. A nonrecording rain gage is used as a check on the tipping bucket. Both loggers record at 10-minute intervals.

Records from all water-level recorders are nearly 100 percent complete. The overall record from the YSI 3800 logger is approximately 79 percent complete because of power outages, lightning strikes, and other minor malfunctions. The Marsh-McBirney flow meter has been damaged by lightning and its cable has been damaged by objects discharging from the spring and from handling, resulting in a 60 percent complete record. The dissolved oxygen and turbidity probes have also occasionally failed or become fouled, resulting in 67 and 57 percent complete records, respectively.

Discharge Measurements

Discharge measurements were made by the partial sections method and wading (Buchanan and Somers, 1976), using a Marsh-McBirney 2000 magnetic water flow meter. Measurements were made during reconnaissance sampling to provide instantaneous discharge data to accompany analytical data. Discharge measurements continue to be made at monitoring stations so that rating curves for continuous discharge calculation can be developed (Fig. 6). Discharge data for Pleasant Grove Spring were used to develop a rating curve by correlating stage observations with discharge (Fig. 7). The stage at which flow stops (gage zero flow—GZF) at Pleasant Grove Spring was determined by calculating the stage axis intercept of zero flow on an arithmetic graph of stage versus discharge; this was done because discharge has never approached zero at Pleasant Grove Spring. The GZF for

Figure 5. Instrumentation, supported by a pier, in the mouth of Pleasant Grove Spring. Storage shed housing data loggers and other equipment is in the background.

Figure 6. Discharge measurements being made at Pleasant Grove Spring during the May 1993 high-flow event.

other sites was either determined in the same manner or was directly observed, if possible. The continuous stage record was then used to calculate a continuous discharge hydrograph. A similar process was also used for Leslie Page karst window. The discharge-stage relationship is controlled by the channel cross section at all stations except Upper Pleasant Grove Creek, where a box culvert supporting Johnson-Young Road controls the relationship. In June 1994 beavers built a dam on Upper Pleasant Grove Creek a few hundred feet downstream of the box culvert, which changed the control of the stage-discharge relationship. This situation required replacement of the earlier discharge and stage observations. Because the George Delaney swallow hole site is normally dry from July to November each year, the collection of sufficient discharge data to develop a rating curve has been delayed. Discharge measurements are reported in Appendix A.

Sample-Collection Methods

Water samples were collected using field protocols and quality-control practices of the U.S. Geological Survey (1982) and the U.S. Environmental Protection Agency (EPA) (1983). All samples collected by dipping were with the mouth of the bottle facing upstream (ASTM D3370). All sample containers were new, and intermediate containers were not used. All sampling equipment was cleaned in compliance with EPA method 507 (revision 2.0, paragraph 4.1.1) (U.S. EPA, 1989). The equipment was washed with tap water and laboratory detergent, rinsed with tap water, rinsed three times with distilled water, and final-rinsed with reagent-grade acetone instead of oven drying. Sample containers and preservation methods are detailed in Appendix B.

For the reconnaissance samples and other samples collected for comprehensive analysis, conductivity, pH, and temperature were measured in the field, and pH and conductivity were also measured in the laboratory. Because of the logistical constraints imposed by the simultaneous collection of bacteria samples and discharge data, only samples for total analysis were collected during the reconnaissance sampling.

The collection of samples for dissolved constituents, including pesticides, was begun in October 1993 at Pleasant Grove Spring. These samples were collected with a peristaltic pump directly from the rise pool of the spring; intermediate containers were not used. Samples for analysis of dissolved constituents were pumped through a stainless steel and Teflon filter stand equipped with Teflon tubing. The stand and tubing were assembled and sealed immediately after cleaning for later transport to the field.

High-flow samples were collected by an Isco model 3700 automatic sampler directly from the rise pool of the spring. The sampler and its containers were decontaminated before each field deployment, according to EPA method 507. Intake tubing and screen were assembled and sealed for transport immediately after cleaning. Upon installation, each sampler was purged with water from the sample site, and intake lines were left empty. Samplers were activated by a water-pres-

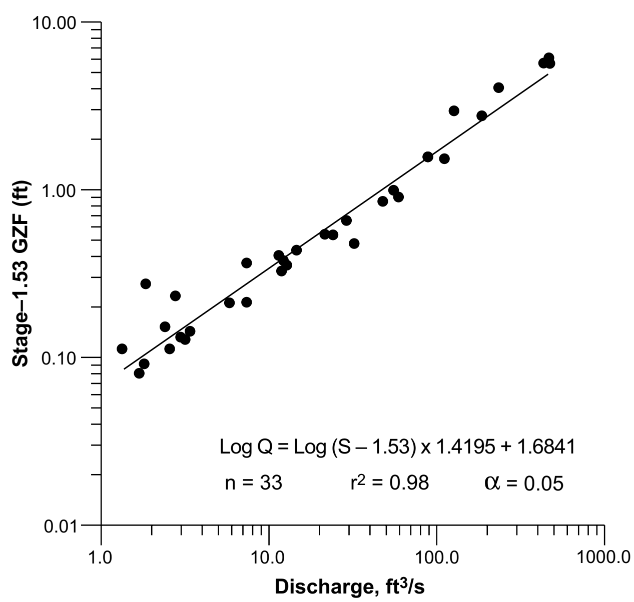


Figure 7. Stage versus discharge rating curve for Pleasant Grove Spring.

ence sensor. The sampler is programmed to rinse the intake lines three times when activated, before filling the sample container.

Wells were not systematically sampled, but a few samples were collected from wells as opportunities arose. Samples from domestic wells in use were collected directly into the sample container from the faucet nearest the well after pumping until temperature and conductivity stabilized. Samples from abandoned wells were collected with a bailer after purging with a portable pump.

Rainwater samples were collected for pesticide and nitrate analysis using a ring stand and glass funnels deployed away from trees and buildings. An 8-in.-diameter glass funnel emptied into a 4-in.-diameter funnel covered with a stainless-steel screen. The spout of the smaller funnel fit tightly into the 2-cm-diameter mouth of a sample bottle, in order to minimize evaporation.

Sampling Schedule

The sampling schedule initially consisted of synoptic monthly sampling, but was later modified to emphasize storm samples at selected sites. The phase I synoptic samples, analyzed for a comprehensive suite of constituents, were collected at six sites for water-quality reconnaissance. These sites are Pleasant Grove Spring, Spring Valley karst window, George Delaney swallow hole, Shackelford Spring, The Canyon karst window, and Flowers estavelle (Thad Flowers blue hole) (Plate 1). During some months, sites were not sampled because they were dry or because ponding from flooding prevented access to moving water. Samples were not collected on other occasions because of holiday schedules at laboratories and other logistical issues. During the no-cost extension periods between project phases (April 1993–September 1993 and September 1994–March 1995), sampling schedules were modified to minimize cost.

During phase II, the sampling schedule emphasized accounting for mass flux of constituents at Pleasant Grove Spring and at a new site, Leslie Page karst window. Leslie Page karst window was added as a monitoring site in the spring of 1993 to replace The Canyon karst window as a small sub-basin monitoring station. One other new site, Joe Harper water well, was added to monitor for the area of origin for pollutants. Joe Harper water well is a natural estavelle that has been lined with masonry for use as a well. It is near The Canyon karst window and is only sampled when flowing water in The Canyon karst window is inaccessible because of flooding.

Also during phase II, sampling at two of the phase I sites (Shackelford Spring and Thad Flowers blue hole) was discontinued and sampling at The Canyon karst window was temporarily suspended. A monitoring station on Upper Pleasant Grove Creek at Johnson-Young Road, 2,500 ft (760 m) downstream of Shackelford Spring, replaced Shackelford Spring as a monitoring site. Shackelford Spring was abandoned because it was in a remote location, its discharge was difficult to measure accurately, the site was a poor location for a continuous stage recorder, and the property owner was reluctant to continue to allow access. Similar problems were encountered at Thad Flowers blue hole. The Upper Pleasant Grove Creek site is on the public right-of-way and has the benefit of a bridge to control discharge. Also, in contrast to Shackelford Spring, which represents ground-water discharge from the headwaters area, Upper Pleasant Grove Creek represents the quality and quantity of most discharge from the area.

Monthly comprehensive sampling continued at Pleasant Grove Spring during phase II, but other samples were collected more frequently for less exhaustive analysis. Base-flow grab samples were collected during low flow at Pleasant Grove Spring on a schedule that varied from biweekly in the spring to monthly in the late summer, fall, and winter. Event samples, which were analyzed for total suspended solids and total dissolved solids in addition to the base-flow constituents, were collected at Pleasant Grove Spring during high flow. Event samples were initially collected every 20 minutes, then over incrementally longer periods as the stage receded. An attempt was made to collect a suite of event samples for every storm causing a 0.1 ft (3 cm) or greater rise in stage at Pleasant Grove Spring from mid-March to July 1995. Samples for bacteria, ammonia, nitrite, and orthophosphate were not collected during storms because samples had to be left in the Isco samplers longer than the holding times recommended for these constituents. Failure of the Isco samplers because of power outages, premature activation of the sampler, and flooding of the sampler caused some high-flow events to be missed.

Sampling at Leslie Page karst window included quarterly comprehensive, base-flow, and event samples. Stage response at Leslie Page karst window was frequently so minor that the Isco sampler failed to detect the rise in stage and did not collect samples. This sampler was reprogrammed to collect samples every 12 hours.

Rainwater samples were collected in May and June of 1992, 1993, and 1994. Deployment periods for the rain sampler were as long as a month, but most were deployed for specific storms and were retrieved within 12 hours.

Generally, samples were collected from domestic wells only on an ad hoc basis, in response to requests from owners. One abandoned domestic well called

Miller School House well (see Plate 2, Kentucky Division of Water identification number AKGW-17158), on the east-central margin of the basin near Oakville, was added as a control sampling point that was unlikely to intercept any agricultural chemicals. The well is cased with steel from ground level to the top of bedrock and is approximately 84 ft (26 m) deep. The only protection from surface contamination is a limestone rock laid over the hole.

Analytical Methods and Quality Control

All major-ion and pesticide analyses were performed at the Kentucky Geological Survey's water-quality laboratory. Comprehensive samples were analyzed for major ions, nutrients, and pesticides. Event samples were analyzed for nitrate, total dissolved solids, total suspended solids, and pesticides by enzyme-linked immunosorbent assay (ELISA). Base-flow samples were analyzed for nitrate and pesticides by ELISA. Precipitation samples were analyzed by gas chromatography (GC) or ELISA, depending on available sample volume. Cations were determined on an inductively coupled plasma spectrometer, and anions were determined on an ion chromatograph. Total alkalinity was determined in the laboratory with an autotitrator. Pesticide analyses were made on a gas chromatograph using EPA methods 507 and 508. The Ogden Environmental Laboratory at Western Kentucky University in Bowling Green conducted bacterial determinations. Bacteria counts were determined by multiple-tube fermentation and most-probable-number statistical estimation until May 1992, when the laboratory changed to membrane filter techniques (EPA methods 9222D and 9230B). Samples collected for streptococci speciation were filtered and cultured by Ogden laboratory and sent to the University of Kentucky College of Agriculture for speciation. Volatile organic compounds were determined by the water-quality laboratory at Heidelberg College, Tiffin, Ohio. See Appendix B for a complete list of analytical methods, detection limits, and discussion of the ELISA method.

Field equipment was checked for proper operation before each field trip. Conductivity and pH meters were calibrated or compared with standards at the beginning of each sampling day. Permanently installed water-quality meters were calibrated monthly. The Marsh-McBirney flow meters are factory calibrated and cannot be adjusted or calibrated by the user. All monitoring equipment is cleaned and checked monthly to ensure proper operation.

Quality-control samples included equipment blanks, trip blanks, and field blanks. Pesticide analyses were made in replicate by the laboratory as part of its internal quality assurance. Duplicate samples for nitrate and pesticide analysis were collected monthly from Pleasant Grove Spring beginning in 1994.

Quantification of ELISA

Pesticide analysis by ELISA was chosen because the number of analyses needed for mass-flux estimation was cost-prohibitive and logistically impractical by gas chromatograph. The validity of quantifying pesticide concentrations with ELISA was evaluated by analyzing split samples by GC and ELISA for triazines, alachlor, and metolachlor. Analyses for other pesticides for which ELISA kits were available (carbofuran and 2,4-D) were not compared with GC analyses because GC methods were not available. For 29 ground-water samples with atrazine concentrations determined by GC to be equal to or above the GC detection limit (0.3 µg/L), the correlation coefficient (r^2) was 0.95 for triazines (determined by ELISA) versus atrazine (determined by GC) (Fig. 8). The detection limit for triazines by ELISA was 0.046 µg/L. Another correlation was calculated for samples with atrazine concentrations between 0.3 and 1 µg/L for both GC and ELISA. Although the correlation was not as good as with higher concentrations (r^2=0.91), it still suggests that the ELISA method for detecting triazines can be used quantitatively to detect atrazine at concentrations above 0.3 µg/L, but may be valid only as a presence-absence test below that concentration. Thurman and others (1990) found a correlation of 0.99 for ground water spiked with atrazine. For all samples for which both determinations were made, the

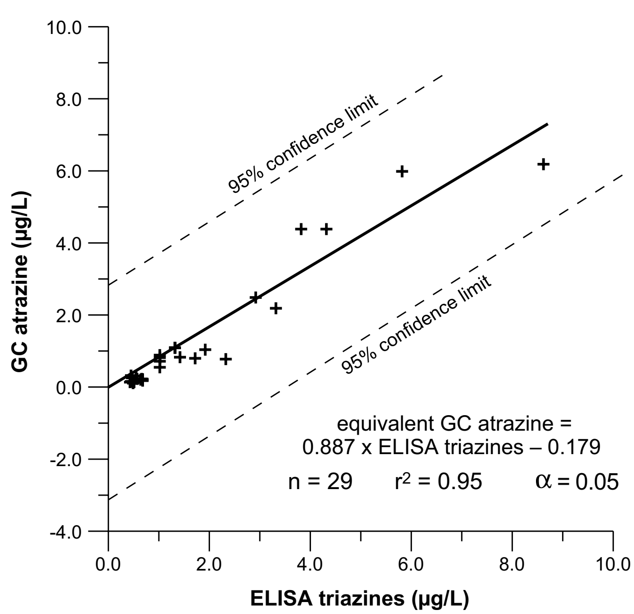


Figure 8. Cross-plot of triazine determinations by ELISA versus atrazine determinations by GC.

concentration of triazines determined by ELISA was nearly identical to that of atrazine determined by GC. This is because nearly all samples analyzed by GC have shown below-detection concentrations of cyanazine and simazine. Furthermore, the manufacturer of the ELISA kits reported that low levels of cyanazine and simazine are largely undetected by the triazine kit (Ohmicron Corp., 1991). The correlation coefficient for 19 metolachlor samples with concentrations ranging from 0.05 µg/L (the GC detection limit) to 8 µg/L was 0.80 and is significant at the 95 percent confidence level (Fig. 9). However, work under way at the Kentucky Geological Survey shows that alachlor determined by ELISA correlates poorly with alachlor determined by GC (r^2=0.34). These results suggest that the ELISA method can be used quantitatively for atrazine and metolachlor. Error bars are not shown on concentration graphs because they obscure the location of data points at the scale needed to show the range of concentrations. Standard deviation for laboratory replicates of atrazine is 0.063 at 1.0 µg/L and 0.13 for metolachlor at 1.30 µg/L.

Mass-Flux Calculation

The mass flux of agricultural chemicals discharging from Pleasant Grove Spring was estimated by multiplying the volume of water discharging during a 10-minute interval by the concentration of monitored constituents in the most recent sample, and summing the 10-minute interval flux values between samples:

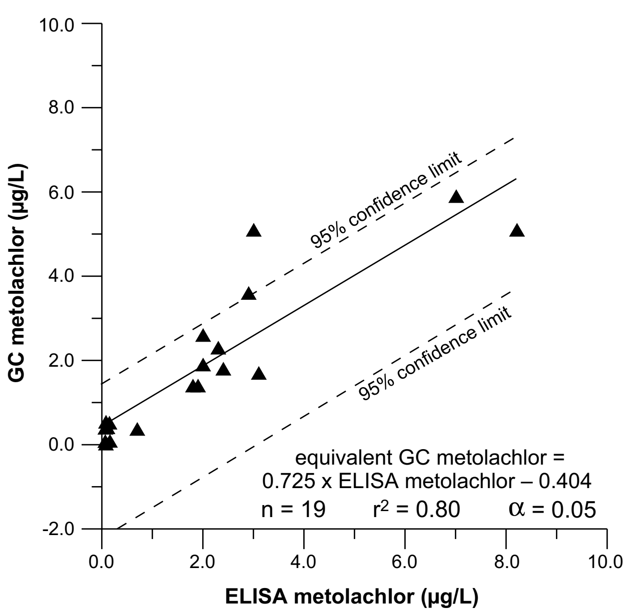


Figure 9. Cross-plot of metolachlor determinations by ELISA versus metolachlor determinations by GC.

MF_{10min}=Q x 600 s x PC
AMF = sum (MF_{10min})
Where:

MF_{10min}=mass flux during a 10-minute interval
Q=discharge in liters per second
PC=prevailing constituent concentration
AMF=the annual mass flux
sum=the summation of 10-minute mass flux increments over the water year.

Nitrate-nitrogen concentrations were used directly. An equivalent atrazine concentration was calculated from triazine determinations using the regression of triazines determined by ELISA and atrazine determined by GC, discussed above. A metolachlor-equivalent flux was estimated in the same way. Flux for suspended sediment has not been estimated because of fouling and failure of the turbidity probe. A flux for alachlor was not estimated because of the poor correlation between GC and ELISA. A carbofuran flux was estimated using ELISA analyses, but its significance is unknown because there was no GC method available at KGS for determining carbofuran concentration.

RESULTS

Land-Use Mapping

Land-use mapping shows that nearly 70 percent of the basin is crop land and another 22 percent is pasture. Between 3,000 and 3,700 acres (1,200 and 1,500 hc) of corn is grown annually. Industrial activity is absent from the basin; the only nonagricultural business is a small tractor and automobile repair garage. There is no urban development, and suburban development is limited to roughly 30 homes in the rural community of Oakville and scattered farm housing. No rail lines and only one state highway cross the basin, and there is little industrial traffic on the roads. There is no active petroleum production in the basin, and a review of the Kentucky Oil and Gas Data Repository at the Kentucky Geological Survey revealed very limited historical activity.

Precipitation Analyses

Of seven rain samples collected, only a few contained measurable amounts of pesticides (Appendix C). Sample RAIN0002, collected from June 17 to July 7, 1992, contained 2.8 µg/L of butylate, but triazines, atrazine, and carbofuran were not detected. Concentrations of alachlor and metolachlor in the July 7 sample did not exceed 0.18 µg/L, determined by ELISA. The July 7 sample probably was contaminated by an insect found in the bottle. The greatest concentration of triazines was from a sample collected between May 19 and June 1, 1993 (0.93 µg/L). Another sample collected between 16:00

May 18 and 08:55 May 19, 1993, contained 0.68 µg / L of triazines. These data may reflect dusty conditions caused by the unusually dry weather in the spring of 1993. Triazine concentrations averaged 0.23 µg / L. Nitrate-nitrogen was also determined for three samples collected in 1993 and 1994, and all measured less than 1 mg / L.

Hydrogeology

Ground-Water Basin Boundary Mapping. Forty-seven ground-water dye traces were conducted through March 1994 and are summarized in Appendix D. The watershed boundary was defined, and the area of the basin is estimated to cover 10,054 acres (4,069 hc). Plate 1 illustrates the basin boundary, the location of major karst features, and ground-water dye-trace vectors. The ground-water basin boundary is roughly consistent with the apparent topographic divide, except in the vicinity of Oakville, where sinkholes are closely spaced.

In addition to identifying the basin boundary, dye tracing resulted in other findings that are significant to understanding the hydrogeology of the basin. The Canyon karst window was initially chosen to represent a hypothesized small sub-basin. Dye introduced into Piper estavelle, while it was acting as a swallow hole, was detected at The Canyon karst window, suggesting influence by the larger basin. This trace and traces from Miller sinkhole and Harper karst window revealed that the catchment area of The Canyon karst window was too large to use as a sub-basin.

Another problem area lies outside of the northwest boundary of the basin. Sinkholes east of Miles karst window encroach on Upper Pleasant Grove Creek. According to area residents, much of the area north of Johnson-Young Road was marshy before drainage was channelized. The rim of the sinkhole nearest the now-channelized Upper Pleasant Grove Creek lies less than 10 ft (3 m) above the normal stage of the creek and within 200 ft (60 m) of the channel. Water from Upper Pleasant Grove Creek may spill into the sinkhole during extreme high flow, although this has not been observed by KGS personnel. Dye introduced into this normally dry sinkhole was detected at Hickory Hill karst window and Dawson Spring, outside of the Pleasant Grove Basin (Plate 1). To determine if flow from Upper Pleasant Grove Creek was diverted outside the basin, 2 L of rhodamine WT was introduced at dusk (to prevent photodegradation) into Upper Pleasant Grove Creek, during moderate flow, in the vicinity of Green Downs Road. Although all known springs along Whippoorwill Creek were monitored, dye was only detected at Pleasant Grove Spring, indicating no leakage during moderate or lower flows.

Flow duration along Upper Pleasant Grove Creek is highly seasonal. Each year Piper estavelle acts as a spring from November through May, and the combined flow from it, Shackelford Spring, and Upper Pleasant Grove Creek continues south to George Delaney swallow hole. South of George Delaney swallow hole the now-abandoned channel of a surface-flowing Pleasant Grove Creek is dry except during high flow. Johnson swallow hole, at the southern end of the abandoned channel, receives flow when the intake capacity of George Delaney swallow hole is exceeded. Flow into Johnson swallow hole was traced to Pleasant Grove Spring. During extremely high flow, however, the inflow capacity of Johnson swallow hole is also exceeded, and water discharges overland to Pleasant Grove Creek, downstream of Pleasant Grove Spring. Johnson swallow hole, George Delaney swallow hole, and Piper estavelle, along with numerous minor swallow holes, form a headward-retreating series of swallow holes diverting the surface reaches of Upper Pleasant Grove Creek underground to Pleasant Grove Spring.

Only one quantitative trace has been completed. Because this trace was the first trial to determine a rough travel time, no attempt was made to estimate the centroid of the breakthrough curve or calculate the dye recovery. Rhodamine WT (500 ml, 20 percent solution) was introduced into George Delaney swallow hole under low-flow conditions (discharge 3.3 ft^3 / s [0.1 cm^3 / s] at Pleasant Grove Spring). Dye was detected 23:40 hours after injection, and concentrations peaked after 25:50 hours. Straight-line flow velocity under these conditions is roughly 0.14 ft / s (0.04 m / s) but is expected to be much faster during high flow.

Plate 1 shows the location of King sinkhole, but with no trace vectors leading from it. Four attempts were made to trace from this sinkhole, without success. Because the trace was deemed lower priority than others being conducted at the same time, Tinopal CBS-X was used for the first three attempts. Another trace, conducted earlier in the dye-tracing program, approximately 1,000 ft (300 m) southeast of King sinkhole, in a poorly draining sinkhole, was also lost. After these traces were lost, a second boat reconnaissance was made on Whippoorwill Creek to look for a missed spring. Although some suspicious channel reaches were noted, no new springs were found. A fourth trace was attempted from King sinkhole using fluorescein, but it also failed, despite more than 25 springs and bridge crossings being monitored. Although no field evidence could be found suggesting a hidden spring, the lost traces are thought to have flowed to Whippoorwill Creek. The missing spring may rise in mid-channel of Whippoorwill Creek between Burchette Spring and Claude Blick Spring. None of the traces flowed to Pleasant Grove Spring.

To supplement the ground-water dye-trace data, a potentiometric map of the study area was prepared (Plate 2). Between June and September of 1993, more than 100 domestic wells were inventoried (Appendix E), and 30 water-level measurements were obtained (Cupp, 1994). The sparse number of water-level observations made the placement of some potentiometric contours subjective. As a broad generalization, contours in the headwaters area of the map are more widely spaced than in the conduit-flow area. The area between George Delaney swallow hole and Johnson swallow hole is problematical: the potentiometric surface and the positioning of flow routes are open to alternative interpretation. The dye trace from Johnson swallow hole did not travel through Spring Valley karst window; thus, the location of the confluence of Johnson swallow hole's conduit with the conduit from Spring Valley karst window to Pleasant Grove Spring is subjective. The confluence may be much closer to Pleasant Grove Spring, and the flow route nearly parallel to the relic valley from Johnson swallow hole to Pleasant Grove Creek. In this case, the 510-ft (155-m) potentiometric contour along the flow route from George Delaney swallow hole to Pleasant Grove Spring would be closer to the conduit. A second, narrow potentiometric low would extend from just south of George Delaney swallow hole, south to Johnson swallow hole, then to Pleasant Grove Spring. The watershed boundary between Johnson swallow hole and Pleasant Grove Spring would remain unchanged, however, because field inspection of the topography verifies that runoff from this area must bypass Pleasant Grove Spring.

Ground-Water Flow Regimes. Two ground-water flow regimes are hypothesized for the basin. An area in the northern, headwaters part of the basin is characterized by slower flow rates than in the southern part (Plate 2). Although karstic, the headwaters area exhibits characteristics suggestive of a more diffuse, slow-flow regime. The gradient of the potentiometric surface in the headwaters area is slightly more gradual than in the conduit, fast-flow-dominated area. Dye-trace travel times in the headwaters area were less than 0.005 ft/s (0.002 m/s). The water table in the slow-flow area is near ground level, as evidenced by marshes, common sinkhole ponds, and blue holes (local name for shallow sinkholes intersecting the water table, many of which function as estavelles). Wells in the area encounter water at shallow depths, typically less than 30 ft (9 m). Springs in this area are relatively small (with flow rates ranging from 0.5 to a peak of 5 ft^3/s [0.05 to 0.5 m^3/s]) and empty into surface drainage that sinks again as flow approaches the southern end of the basin.

Ground water in the southern part of the basin flows rapidly through large, efficient caves. Qualitative dye-trace travel times exceed 0.02 ft/s (0.006 m/s), indicating substantially higher underground-stream flow velocities than in the slow-flow area of the watershed. Springs in the fast (conduit) flow regime have significant increases in discharge and become turbid within a few hours of a major storm. Flow rates at Pleasant Grove Spring range from as little as 1.5 ft^3/s (42 L/s) during base flow to several hundred cubic feet per second (thousands of liters per second) during a major storm.

The slow (diffuse) flow regime is probably the result of a shallower hydraulic gradient. Low gradients in carbonate aquifers lead to relatively uniform dissolution along many joints and bedding planes, rather than concentrated solution along a headward-migrating conduit. The lower gradient could be caused by either or both of two hydrologic factors. First, the slow-flow area could be less maturely karstified because insufficient time has elapsed since Pleasant Grove Spring developed for headward progression of conduits to reach the area. However, because karst development in the Pennyroyal Region has been in progress for as long as 10 million years (Palmer, 1981), a lack of sufficient time seems unlikely. Second, an insoluble cherty zone could be retarding conduit enlargement along its outcrop. Flow to the south would be inhibited as it passes through constricted solutional openings in the carbonate rock between nodules of the nearly insoluble chert barrier. Numerous small springs emerge above this horizon, and streams sink a few hundred feet downsection of its outcrop. The retarding horizon is probably the Lost River Chert (Crawford, 1986).

Several features in the basin function as estavelles. Piper estavelle, Thad Flowers blue hole or estavelle, and Wheatfield estavelle have all changed function from springs to swallow holes sometime during the study period. Many unnamed karst features in the study area also act as estavelles. Locally, both rise-pool springs and estavelles are called blue holes (Thad Flowers blue hole, for example). Water collects in the outlet of Thad Flowers blue hole when the water table is too low for the feature to discharge but high enough to submerge the outlet. Similar conditions apply to Joe Harper water well, which discharges or accepts inflow depending on ground-water stage.

The alignment of sinkholes, the bearing of ground-water dye-trace vectors, and the orientation of passages in mapped caves (Mylroie, 1984) suggest ground water flows downgradient but parallel to the local strike until it reaches a breach in a resistant bed. At this point flow changes direction toward the local base level, Red River. Because the regional strike trends northeast–southwest and the Red River is due south of the basin, a trellised drainage pattern has developed.

Ground-Water Quality

Selected analytical results for all samples are presented in Appendices C, F, G, H, I, and J. Analyses consistently reporting concentrations below detection limits or maximum contaminant levels are not included. Those data are available through the Kentucky Geological Survey's Kentucky Ground-Water Data Repository. In order to develop a consistent format for future reports, the data in the appendices are presented as water-year annual summaries (October 1 through September 30). Summaries of descriptive statistics for each water year are also presented, but their significance as characteristic of the ground-water quality during any given year should be considered with caution. The effects of "aliasing" (the phenomenon in which a high-frequency trend can be interpreted as a low-frequency trend because the sampling was too infrequent to characterize the high-frequency trend) and variable temporal spacing of samples has a major impact on the representative validity of the statistics. Table 2 summarizes standards for drinking water, which are commonly used as criteria for evaluating the quality of ground water.

Basinwide, ground-water temperatures average 14.5°C, typical of Pleasant Grove Spring (Appendix F). Conductivities observed in the basin range from 744 microSiemens (µS) at Pleasant Grove Spring to only 20 µS at Leslie Page karst window. The pH of water in

Table 2. Maximum permissible contaminant levels for drinking water, determined by the EPA, for constituents analyzed in water samples collected from the Pleasant Grove Spring area.

Analyte	*Standard**	*Maximum Contaminant Level*	*Frequency or Comment*
INORGANICS			
Arsenic	Primary	0.05 mg/L	Annually for surface water
Barium	Primary	2.0 mg/L	Annually for surface water
Chromium	Primary	0.1 mg/L	Annually for surface water
Copper	Primary	1.3 mg/L	Variable
Lead	Primary	0.015 mg/L	Variable
Nickel	Primary	0.1 mg/L	Annually for surface water
Nitrate-N	Primary	10 mg/L	Variable
Nitrite-N	Primary	1.0 mg/L	Variable
Manganese	Secondary	0.05 mg/L	Annually for surface water
Fluoride	Secondary	2.0 mg/L	Variable
Iron	Secondary	0.3 mg/L	Annually for surface water
Sulfate	Secondary	250 mg/L	Annually for surface water
Chloride	Secondary	250 mg/L	Annually for surface water
Total dissolved solids	Secondary	500 mg/L	Annually for surface water
Zinc	Secondary	5 mg/L	Annually for surface water
BACTERIA			
Total coli	Primary	1 col/100 ml	1 sample in 40 per month
Total coli	Supply	2,000 col/100 ml	
PESTICIDES			
Alachlor	Primary	0.002 mg/L	Annually for surface water
Atrazine	Primary	0.003 mg/L	Annually for surface water
Simazine	Primary	0.004 mg/L	Annually for surface water
Carbofuran	Primary	0.04 mg/L	Annually for surface water

*The EPA water-quality standards cited are for drinking water (primary and secondary) and drinking-water supplies.

the basin, as determined in the laboratory, ranges from 5.9 to an alkaline 8.5, but is commonly nearly neutral.

Ground water in the basin is calcium-bicarbonate type. All the sites exhibit similar chemistry (Appendix G), but Thad Flowers blue hole has some of the widest ranges in chemistry because of its alternating function as a spring and a swallow hole. Ponded water at Thad Flowers blue hole is subject to heating and cooling, evaporation, deposition of animal feces, and oxygen loss, resulting in water quality uncharacteristic of other locations in the area. Total alkalinity ranges from an exceptionally low 37 mg/L (as $CaCO_3$) at Thad Flowers blue hole, to a high of 241 mg/L at Pleasant Grove Spring; 180 mg/L is a typical value for the basin. Total dissolved solids never exceeded 564 mg/L and commonly measure 260 mg/L. However, total suspended solids may exceed 2,000 mg/L during high flow. Constituents commonly affecting ground-water quality in other regions of Kentucky are only present in dilute concentrations in the Pleasant Grove Spring Basin. The maximum total iron concentration was 7.17 mg/L at Pleasant Grove Spring and came from a highly turbid sample collected during high flow. The typical iron value for sites in the basin is 0.5 mg/L. Concentrations of all other metals listed in Table 2 were below maximum contaminate levels. Sulfate (SO_4) ranges from near the lower detection limit to 26.2 mg/L, and chloride has a maximum concentration of 12.8 mg/L.

Seasonal changes at Pleasant Grove and Shackelford Springs observed during reconnaissance support the dual flow-regime model indicated by dye tracing (Fig. 10). The temperature cycle at Shackelford Spring, which is thought to drain part of the diffuse-flow area, is delayed approximately 2 months compared to Pleasant Grove Spring. Shackelford Spring has a higher temperature in late summer, however, probably caused by direct solar heating of its small rise pool during low flow. Unlike temperature, the conductivity cycle is not delayed, but Shackelford Spring has a nearly constant conductivity, which narrowly ranges between 392 and 450 µS. Pleasant Grove Spring has a larger range of 136 to 744 µS, as determined in the field, but only 241 to

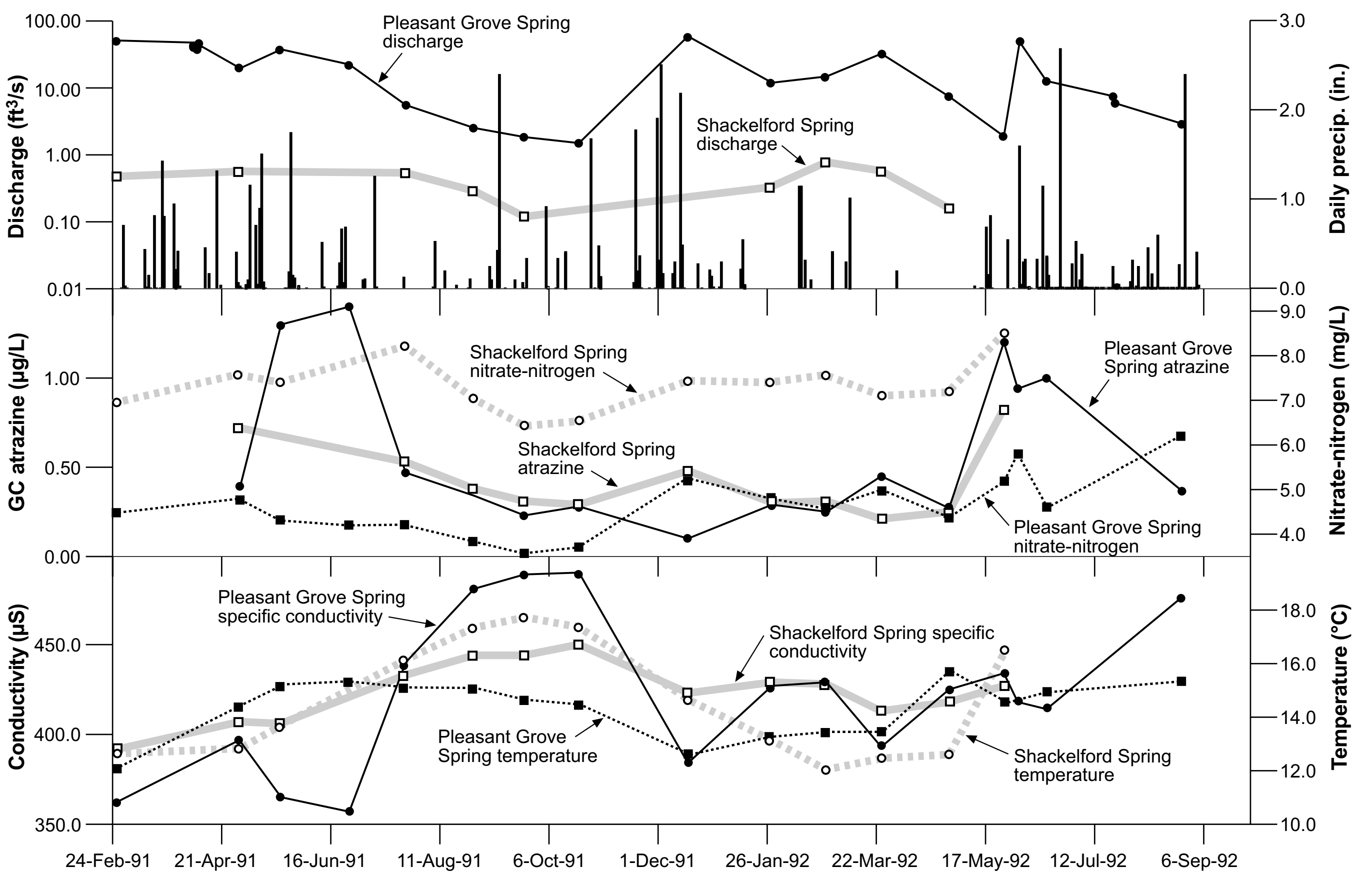


Figure 10. Discharge hydrograph and chemographs for Shackelford Spring during the time it was monitored, and comparative data for Pleasant Grove Spring. Shackelford Spring drains a headwaters area of the basin that is interpreted to have diffuse flow.

547 µS as determined in the laboratory from samples. A Piper diagram of total analyses of major ions (Appendix H) shows no major difference in water chemistry, however (Fig. 11), which supports the concept that the diffuse-flow area sustains base flow in the conduit-flow area.

There are some important differences between Pleasant Grove and Shackelford Springs. Shackelford Spring has significantly lower bacteria counts, possibly reflecting diffuse recharge. Average concentration of nitrate is significantly higher at Shackelford Spring, whereas triazines are higher at Pleasant Grove Spring. Both triazine and nitrate concentrations show less variability at Shackelford Spring than at Pleasant Grove Spring. Collectively, these characteristics support the diffuse-flow conceptual model for the catchment area of Shackelford Spring in the headwaters area of the basin.

Pesticides. Pesticides have been found in basin ground water in detectable quantities by both GC and ELISA (Appendix I). For a list of pesticides used in Logan County and for which analyses were conducted, see Table 1. Atrazine (by GC) and triazines (by ELISA) are the most commonly detected pesticides, and are found

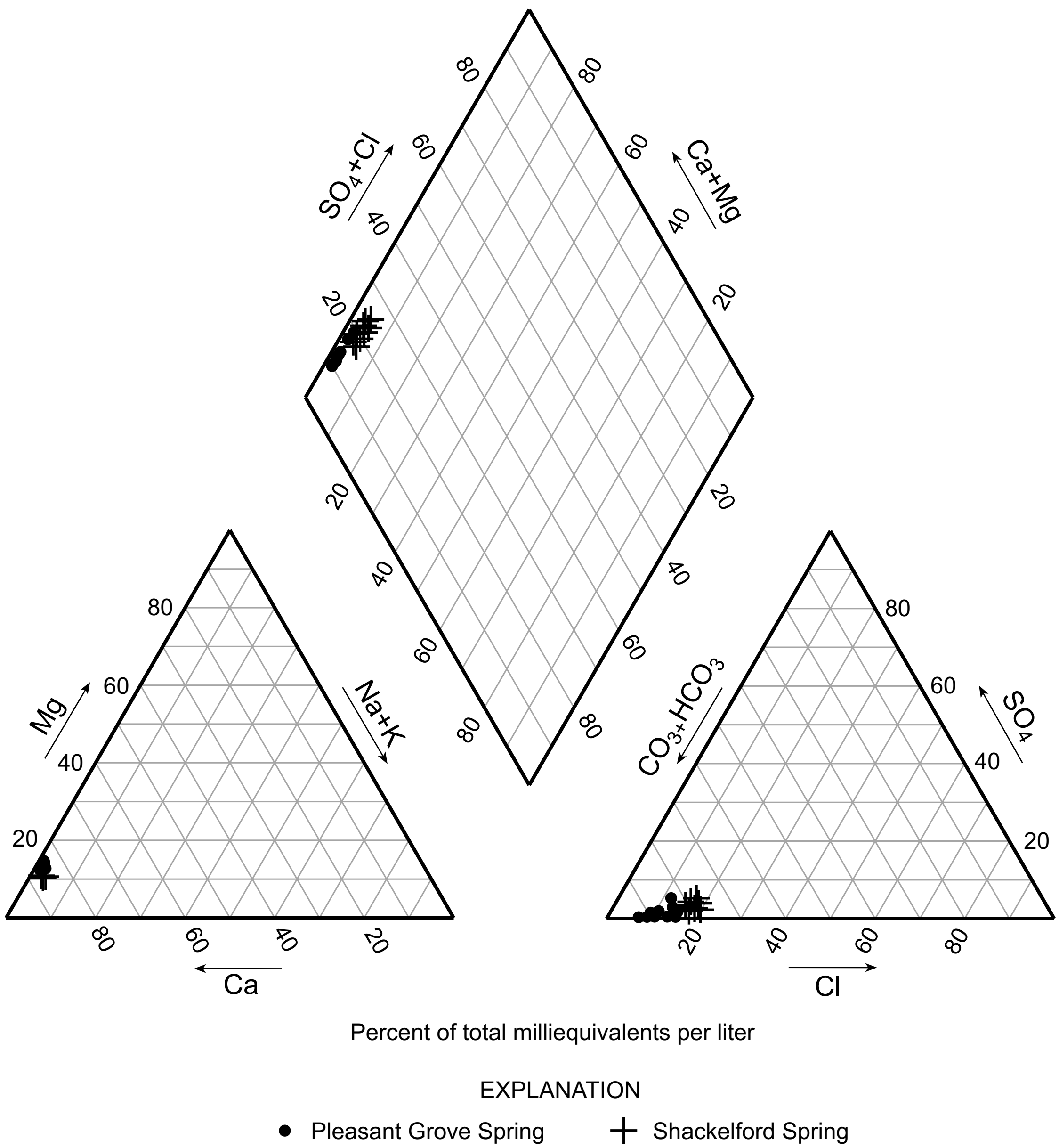


Figure 11. Piper diagram of major ionic constituents for Pleasant Grove and Shackelford Springs. All analyses are for total constituents.

in the highest concentrations of any pesticides. Only triazines and alachlor have exceeded the EPA's maximum contaminant level (MCL). The highest concentration of pesticide detected (44.0 µg/L of triazines at Pleasant Grove Spring on May 4, 1993) exceeded the MCL by an order of magnitude. A second sample collected the same day contained 28.0 µg/L of atrazine (determined by GC). These samples were collected during a major high-flow event following an extended dry period during planting season. During the early stages of the project, alachlor concentrations as determined by ELISA were considered only a presence-absence test, and therefore are not reported in Appendix I. The maximum alachlor concentration observed was determined by ELISA, however, and was 12.0 µg/L. The sample was taken during the May 1993 high-flow event. Maximum concentrations of alachlor (GC determined), metolachlor (ELISA determined), and carbofuran (ELISA determined) detected were 6.1, 9.6, and 7.4 µg/L, respectively. Simazine was found only on rare occasions, but once at concentrations as high as 4.5 µg/L. Other pesticides for which MCL's have not been determined (butylate, trifluralin, metribuzin, malathion, endosulfan I, and endosulfan II) have been detected, but at very low concentrations (less than 0.6 µg/L). Some pesticides used in substantial quantities in the basin, such as 2,4-D, have short degradation half-lives (less than 30 days) in soil or water and have thus not been detected.

Several pesticides for which KGS does not have the ability to analyze are also used in large quantities in the basin. Four of these are important because of possible health issues and the quantity used in the area. Glyphosate, the fourth most commonly sold pesticide in Logan County, is an herbicide used on both corn and soybeans. Sales data for 1993 indicate over 40,000 lb (18 metric tons) were sold, but glyphosate has a small leaching potential. Three pesticides used in the county are among those considered a priority environmental or health concern by the EPA: betazon, disulfoton, and acifluorfen. Betazon and acifluorfen are herbicides used for soybeans and have moderate leaching potential. Disulfoton is an insecticide used for corn and has a small leaching potential. Sales in Logan County for all three were less than 8,300 lb (3.7 metric tons), but disulfoton has an MCL of only 0.3 µg/L. All three have a relatively short half-life, less than 30 days in soil. The importance of these pesticides as a ground-water contaminant in the Pleasant Grove Spring Basin is unknown.

The highest concentrations and most frequent pesticide detections occur from mid-March through June, after spring chemical application. Except for atrazine, concentrations above detection limit seldom occur during the fall and winter. Triazine concentrations decrease continuously during the fall and winter, reaching a minimum in February or early March. Figure 12 shows observations and triazine and nitrate analyses for Pleasant Grove Spring during phase I. The more widely spaced temperature and conductivity data shown on Figure 12 were collected before May 1992 and reflect discrete sampling prior to installation of monitoring equipment. Continuous monitoring began in May 1992 and produced the greater detail in the curves after that date. Precipitation data through December 1992 are daily totals from a volunteer station in Russellville, and may not reflect actual precipitation in the basin, particularly during summer months.

Nutrients. Nitrate-nitrogen is widespread and persistent in ground water in the basin. The average recommended application rate is 137 lb of nitrogen per acre of crop land (154 kg/hc) annually. Nitrate concentrations in ground water within the Pleasant Grove Spring Basin are typically low, however, only 3 to 5 mg/L. Maximum concentration for the basin to date is 10.8 mg/L at the Upper Pleasant Grove Creek sampling point in December 1993 (Appendix G). Shackelford Spring had the highest average nitrate-nitrogen concentration from April 1992 to March 1993 during phase I (7.39 mg/L). The highest nitrate-nitrogen concentration recorded for Pleasant Grove Spring (7.82 mg/L) occurred in December 1993 at the recession of two closely spaced and significant rainfalls. The minimum value at Pleasant Grove Spring (2.37 mg/L) occurred April 11, 1994, during the largest discharge event gaged at the spring. The minimum value measured in the basin was the nitrate detection limit of 0.02 mg/L and was from the same sample as the highest ammonia concentration discussed below.

Nitrite, ammonia, and orthophosphate were also determined for monthly samples, but have not been determined in event samples because of logistical constraints caused by limited holding time. At Thad Flowers blue hole nitrite concentrations from samples collected from ponded water during a period of no flow (sample number TFBH0004) never exceeded 0.43 mg/L. Ammonia never exceeded 4.46 mg/L, and orthophosphate never exceeded 0.48 mg/L; these were the highest ammonia and orthophosphate concentrations detected in the basin. Basinwide, nitrite averaged 0.04 mg/L, ammonia 0.24 mg/L, and orthophosphate 0.05 mg/L in 1990–91. The orthophosphate concentrations at Pleasant Grove Spring averaged 0.07 mg/L. Boyer and Pasquarell (1994) found average nitrate-nitrogen concentrations of 0.1 mg/L in a forested karst ground-water basin, and 0.61 mg/L in another karst basin that is 80 percent forest. Concentrations of 0.007 mg/L of elemental phosphorus (0.021 mg/L orthophosphate) are considered natural (Verduin, 1970);

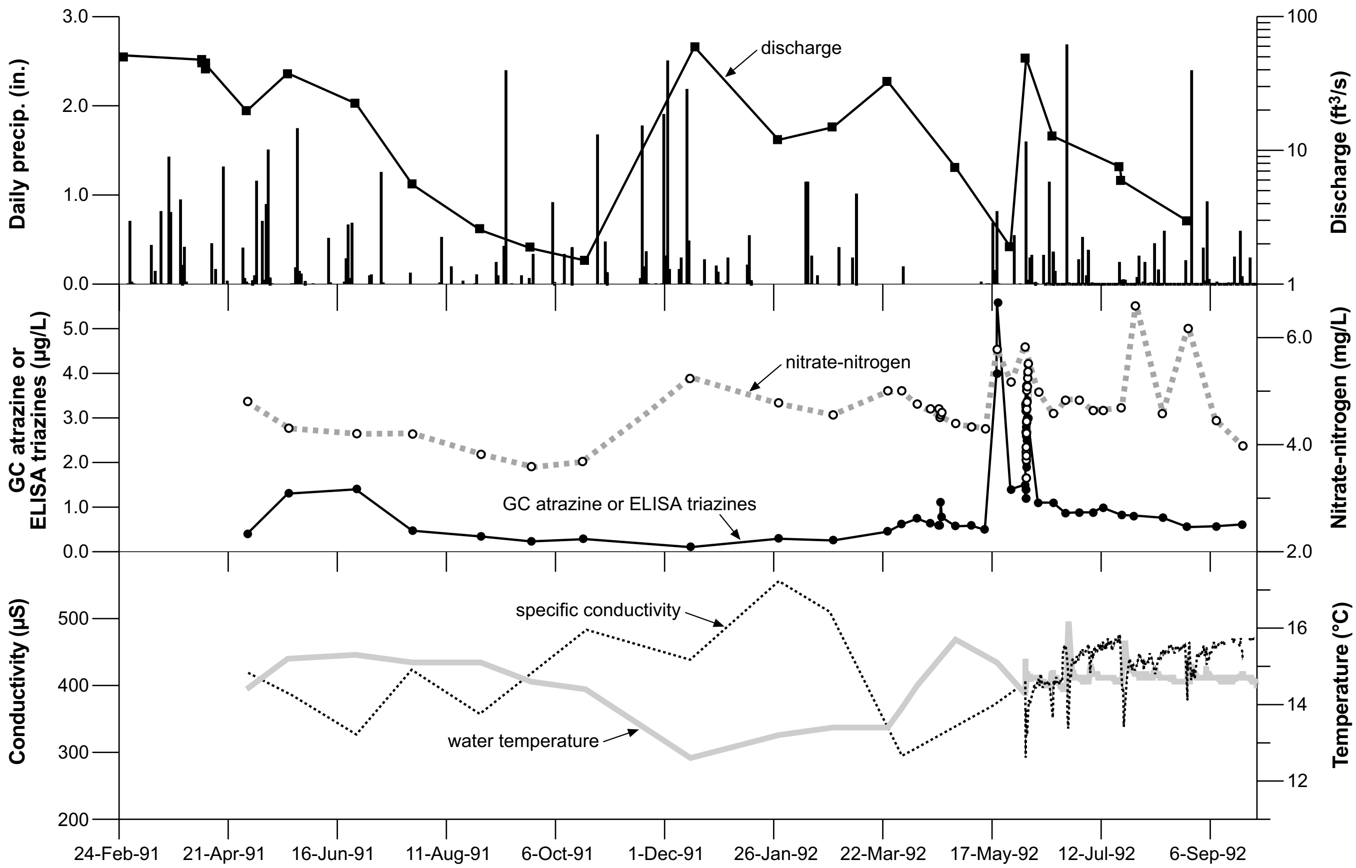


Figure 12. Discharge hydrograph, temperature, conductivity, nitrate-nitrogen concentration, and combined atrazine concentration before April 1992 (determined by GC) and triazine concentration after April 1992 (determined by ELISA) for the 1991–92 water year and the preceding 8 months at Pleasant Grove Spring.

higher concentrations may overstimulate the growth of aquatic plants.

Bacteria. Basinwide, bacteria counts always exceed the EPA's drinking-water standard of 1 colony-forming unit per 100 ml (col / 100 ml) and frequently exceed the standard for water-supply sources (2,000 col / 100 ml) by hundreds of colonies. Samples collected during phases I and II averaged 465 col / 100 ml of fecal coliform and 1,891 col / 100 ml of fecal streptococci; maximum counts were 14,000 and 24,000 col / 100 ml, respectively. High fecal coliform and fecal streptococci counts, and *Salmonella* counts ranging from 0 to 28,000 col / 100 ml were found at The Canyon karst window (Haszler, 1993). The magnitude of the *Salmonella* counts indicates fecal contamination. Ground-water dye tracing and water-quality data suggest that The Canyon karst window receives flow from both the vicinity of Oakville and areas with significant cattle concentrations.

Figures 13 and 14 show bacteria counts taken at Pleasant Grove Spring during phase I and phase II. Bacteria counts of samples collected at Pleasant Grove Spring prior to June 1992 averaged 617 col / 100 ml of fecal coliform and 3,444 col / 100 ml of fecal streptococci (Appendix J). The highest counts occurred during the late summer and late winter during phase I. Bacteria counts between March 1994 and October 1994 averaged 425 col / 100 ml of fecal coliform and 889 col / 100 ml of fecal streptococci. Fecal coliform to fecal streptococci ratios for Pleasant Grove Spring suggest domestic sewage is the predominant source during flow recession, but animal waste prevails during the majority of the year. The highest counts determined during phase II occurred within a few days of major springtime high-flow events. Generally, fecal streptococci were predominant in the first major high-flow event following an extended dry period, whereas fecal coliform were either simultaneously high or predominated during flow recession of the next high-flow event. The reduction in average fecal streptococci between the phase I and phase II sampling periods, from 3,444 to 889 col / 100 ml, may be attributable to a facility to handle animal waste, built

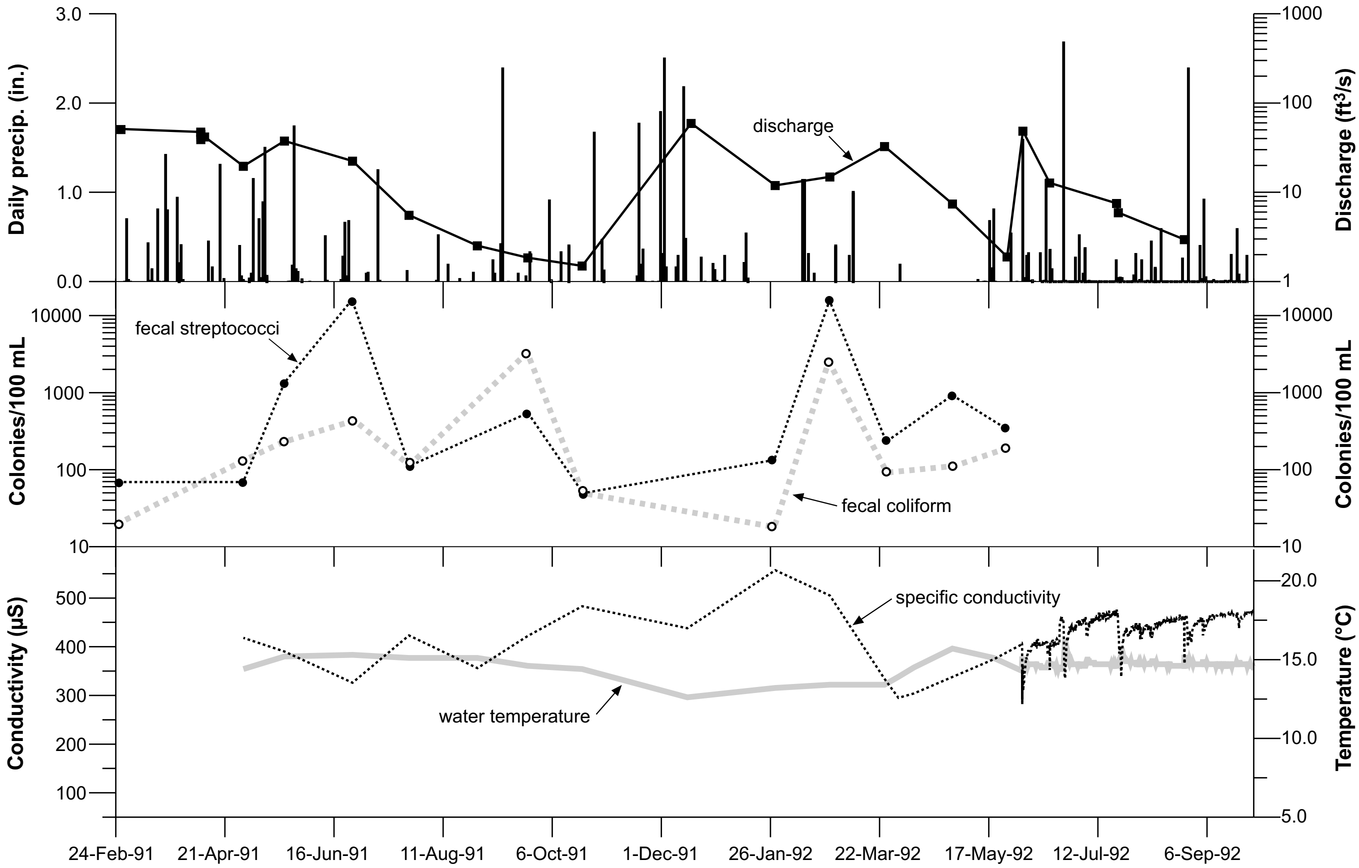


Figure 13. Line plot of phase I bacteria counts, temperature, conductivity, and discharge for Pleasant Grove Spring.

at a farm on Upper Pleasant Grove Creek between July 1992 and July 1993.

Speciated bacteria colonies were identified from samples collected in April and May of 1994 from Pleasant Grove Spring, The Canyon karst window, Joe Harper water well, and Leslie Page karst window in an attempt to clarify the origin of the streptococci (*Enterococcus*) bacteria. The associations were ambiguous for domestic animal or human sources, but came from warm-blooded animals (Mark Coyne, UK College of Agriculture, written commun., September 16, 1994). No isolates were found for *Streptococcus equinus* or *Streptococcus bovis,* indicators of horses and cattle, perhaps because these bacteria species die rapidly. A small percentage of the enterococci present are associated with wildlife. The data suggested that the bacteria were not coming from soils or insects. Therefore, the highest Pleasant Grove Spring Basin counts are not of natural origin.

Optical Brighteners (Domestic Sewage). Optical brightening agents common in laundry detergent are frequently found in karst springs and indicate the presence of domestic sewage (Thrailkill and others, 1983; Quinlan, 1987). To identify the source of high bacteria counts, cotton fabric dye detectors were exposed to flow from three springs in an attempt to measure the relative concentration of optical brighteners. Bacteria counts indicated that Leslie Page karst window was free of human or animal waste, whereas David Dotson Spring was polluted. Although all three deployment periods were during base flow, modest high-flow events (less than 10.0 ft^3/s [0.3 m^3/s] maximum discharge at Pleasant Grove Spring) occurred during both of the 1994 deployments.

For all three deployments, no significant difference was found in the fluorescence of any of the exposed detectors and unexposed detectors prepared as controls (Joe Meiman, Mammoth Cave National Park, oral commun., 1994). The low-flow conditions prevailing during the detector deployment probably reduced the transport of brightener into ground water. Alhajjar (1990) found that optical brightening agents did not pass through septic-system drain fields in a glacial-drift setting. Bow-tie fabric dye detectors placed in David Dotson Spring during phase I were commonly positive for brightener, however, as determined by visual ex-

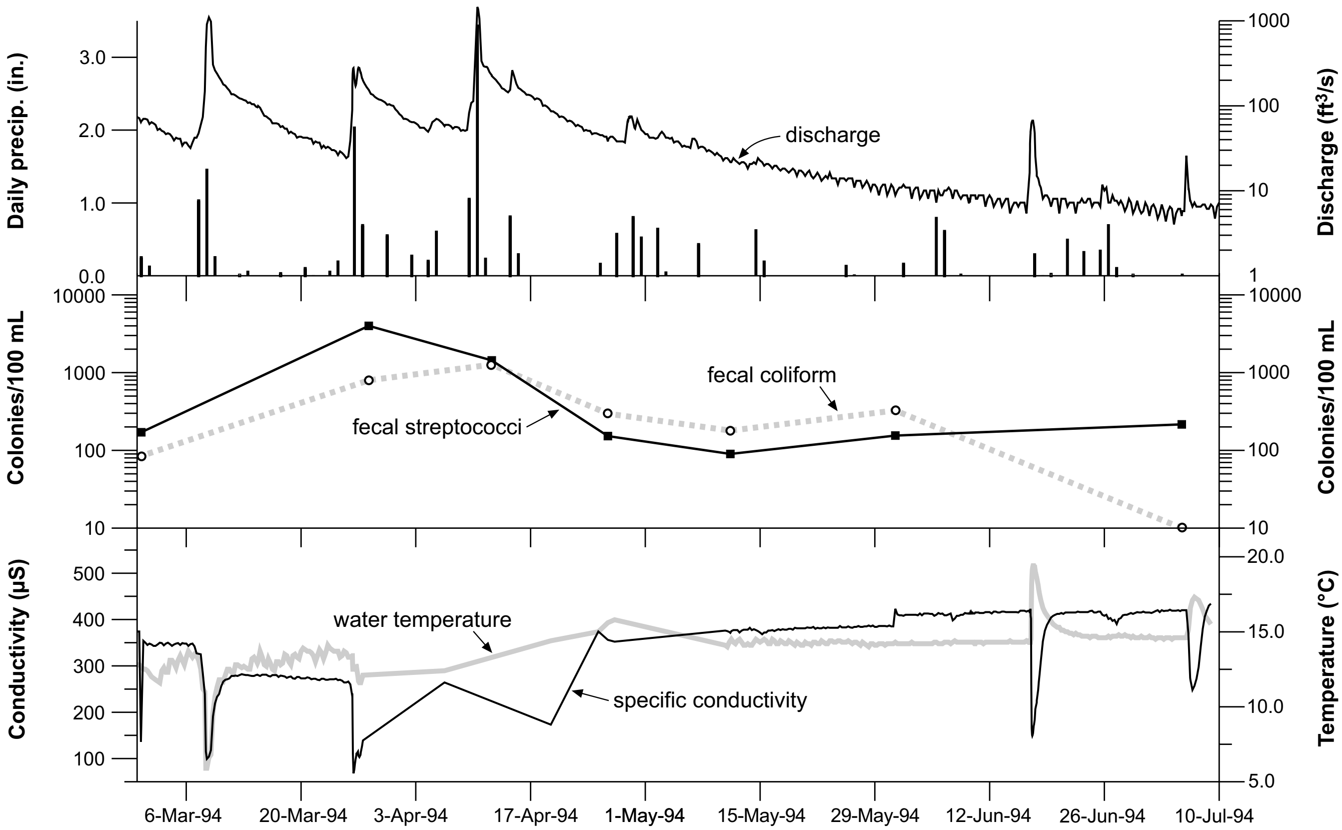


Figure 14. Line plot of phase II bacteria counts, temperature, conductivity, and discharge for Pleasant Grove Spring beginning in March 1994.

amination with an ultraviolet lamp. In addition, a fragment of steel wool, probably from a kitchen scrubbing pad, was discovered entangled on a dye-detector anchor in June 1991 at Pleasant Grove Spring.

Volatile Organic Compounds (Petroleum). Samples were also collected to measure volatile organic compounds on two occasions at Pleasant Grove Spring, Leslie Page karst window, and Billy Poore Spring, which is outside the drainage basin (Plate 1). Leslie Page karst window was thought to be pristine and Billy Poore Spring possibly polluted. Analyses were performed for 59 compounds, including vinyl chloride, benzene, carbon tetrachloride, styrene, toluene, xylene, and naphthalene. The samples were collected in 1993 during the May 4 high-flow event, and August 3, during base flow. Only 1,2,3 trichloropropane was above detection limits in any of the samples; it is an ingredient in the Styrofoam packing material used to ship the samples.

Effect on Drinking-Water Supplies. Because water from Pleasant Grove Spring is not used for human consumption, the chemical contaminants discharged from the spring might be assumed to be irrelevant for human health. The presence of constituents at the spring, however, may reflect the overall quality of the water in the aquifer. If so, private water supplies at other points might be affected. Although the systematic sampling of domestic ground-water supplies in the basin was not budgeted for, some samples were acquired in the course of the research. Samples were collected from three domestic wells in the area (identified as LDWW, MMWW, and MHWW in Appendix C). These wells contained up to 3.2 μg / L of triazines. Samples of treated and raw water were also collected in April 1994 from the Adairville water treatment plant (identified by the prefix CAWW in Appendix C), located 4 mi (6.4 km) south of Pleasant Grove Spring. Although the water plant withdraws its supply from the South Fork of Red River, and is not downstream of Pleasant Grove Spring, the flow in South Fork is maintained by other karst springs draining similar agricultural lands. Both samples of water contained more than 1.0 μg / L of triazines. These data suggest agricultural chemicals are having an impact on water used for human consumption in the region.

Only one sample has been collected to date from Miller School House well. Although the well is poorly constructed and in the community of Oakville, the sample showed the well to be relatively free of agricultural chemicals, probably because of its location near the basin boundary. The sample was collected in April 1994 and was below detection level for all analyzed pesticides, by both ELISA and GC. Nitrate-nitrogen concentration was only 1.45 mg/L.

Flow Regimes and Contaminants. The dual groundwater flow regimes in Pleasant Grove Spring drainage basin have significant implications for movement of contaminants in ground water. The diffuse-flow (slow-flow) area, which is estimated to represent slightly less than half of the basin, drains into the conduit-flow-dominated area of the basin. Contaminants in the diffuse-flow part of the aquifer seem to persist in the ground water for many months. However, because of the quick travel time in the fast-flow regime, contaminants carried into it during storms move rapidly through the system. Also, the residual contaminants stored in the smaller conduits and epikarst are diluted and flushed out. The conjunction of the plots of atrazine concentrations for Shackelford and Pleasant Grove Springs during base-flow conditions in the late summer of 1991 (Fig. 10) suggests that the slow-flow area acts as a reservoir for contaminants, which slowly trickle out into the fast-flow part of the system, causing a background level of contamination to be maintained throughout the basin.

Annual Mass Flux of Pesticides and Nitrate at Pleasant Grove Spring

The results of the annual mass flux measurements for the 1992–93 and 1993–94 water years are shown in Figures 15 and 16, and mass totals are summarized in Table 3. These results reveal the potential for a wide range of concentrations and flow-weighted averages from year to year. An understanding of the causes of variation in the mass flux of nitrate and atrazine is essential to accurately assessing changes attributable to BMP installation.

Figures 15 and 16 show precipitation and discharge hydrographs, triazine and nitrate-nitrogen concentration, and atrazine-equivalent triazine and nitrate-nitrogen flux for the 1992–93 and 1993–94 water years at

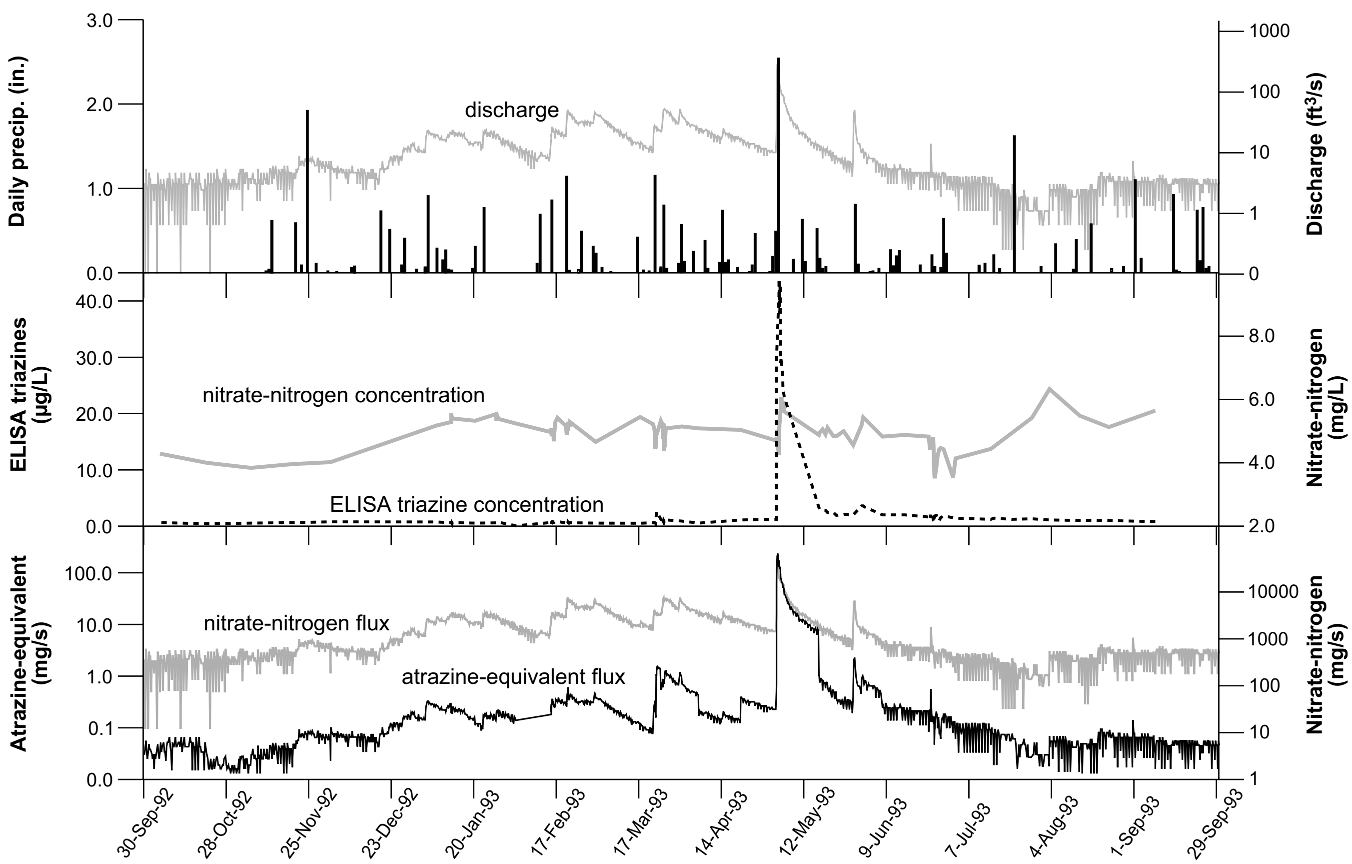


Figure 15. Plot of precipitation, discharge, nitrate-nitrogen concentration, nitrate-nitrogen flux, triazine concentration (determined by ELISA), and atrazine-equivalent triazine flux for Pleasant Grove Spring for the 1992–93 water year.

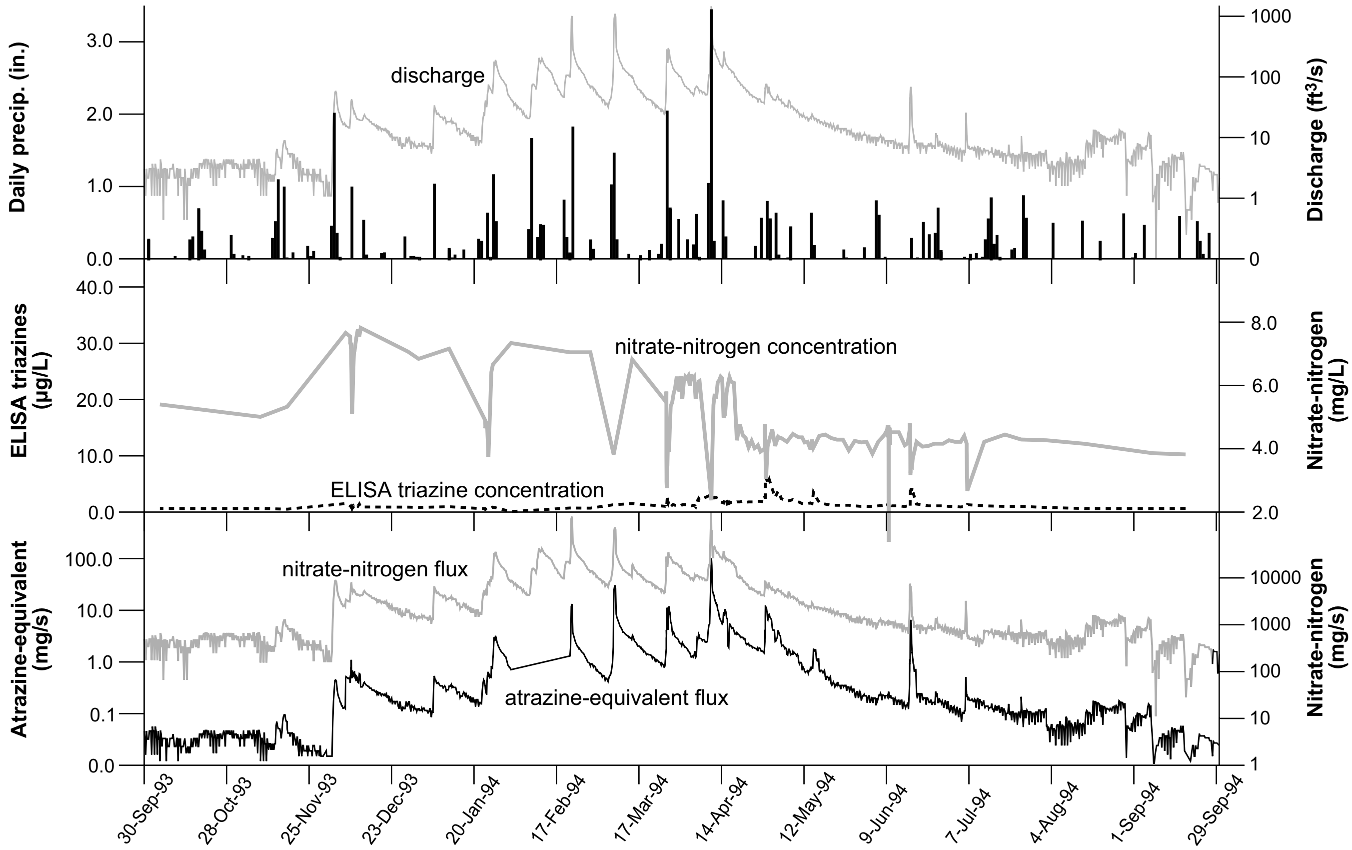


Figure 16. Plot of precipitation, discharge, nitrate-nitrogen concentration, nitrate-nitrogen flux, triazine concentration (determined by ELISA), and atrazine-equivalent triazine flux for Pleasant Grove Spring for the 1993–94 water year.

Pleasant Grove Spring. The general pattern of occurrence for triazines and nitrate from 1992 to 1994 is similar to the pattern from phase I monitoring (Fig. 12). In general, triazines are present in significant concentrations after springtime application, but also persist in detectable quantities well into the winter. Nitrate-nitrogen concentrations are greatest during base-flow conditions in the late fall and winter. Concentrations of atrazine-equivalent triazines exceeded the atrazine MCL only during three high-flow events in the spring of 1993 and four times during the spring of 1994, which emphasizes the importance of the relative timing of pesticide application and rainfall (Baker, 1980).

Total annual precipitation, discharge, mass flux of nitrate and atrazine-equivalent triazines, crop, and other relevant data are presented in Table 3. The average discharge rate for water years 1992–93 and 1993–94 was 23.6 ft^3/s (0.7 m^3/s). For the two years, the flow-weighted averages of triazines at Pleasant Grove Spring, expressed as atrazine-equivalent, were 4.91 µg/L and

Table 3. Summary of annual precipitation, discharge, and agricultural chemical mass flux in the Pleasant Grove Spring Basin.

				Crop Acres		*Nitrate*			*Triazine*	*Atrazine-Equivalent*	
Water Year	*Precipitation (in.)*	*Discharge (ft^3)*	*Percent Runoff*	*Corn*	*Total Row*	*Average Concentration (mg/L)*	*Mass Flux (kg)*	*Flow-Weighted Average (mg/L)*	*Average Concentration (µg/L)*	*Mass Flux (kg)*	*Flow-Weighted Average (µg/L)*
1991–92[1]	> 39.52[2]	NA	NA	3,042	7,154	4.2	NA	NA	1.64	NA	NA
1992–93	34.58	3.6×10^8	28.7	2,925	7,164	4.98	51,105	5.0	4.84	50.16	4.91
1993–94	52.2	11.3×10^8	59.4	3,473	7,201	4.86	183,643	5.7	1.84	30.75	0.97

[1]Continuous monitoring began in May and June 1992. Sampling began in February 1991.

[2]Data from Russellville volunteer station. Incomplete record.

0.97 µg / L, respectively. For nitrate-nitrogen, flow-weighted average concentrations were less variable: 5.0 mg / L for 1992–93 and 5.7 mg / L for 1993–94. Approximately 11.5 percent of applied nitrogen fertilizer (15.86 lb / acre of row crop [17.79 kg / hc]) was discharged at Pleasant Grove Spring during 1992–93, whereas only 0.033 lb / acre (0.037 kg / hc) of atrazine-equivalent triazines per acre of corn, or 1.65 percent of the estimated atrazine applied, was discharged. Total nitrate-nitrogen mass flux was significantly higher in 1993–94 than in 1992–93 and significantly lower for atrazine-equivalent in 1993–94 than in 1992–93 (Table 3). The nitrate-nitrogen flux for all years represents the minimum nitrogen flux, because nitrite, ammonia, and organic nitrogen were not determined for samples collected during storms or routine base flow beyond phase I. The atrazine-equivalent flux for 1993–94 represents 1.0 percent of the estimated atrazine applied, whereas the nitrate flux represents an astounding 64.7 lb / acre (72.5 kg / hc) or 47.2 percent of the estimated 137 lb / acre (154 kg / hc) of applied nitrate-nitrogen. Precipitation in 1992–93 was 34.6 in. (88 cm), but in 1992–93 increased to 52.2 in. (209 cm).

The annual flux of metolachlor and carbofuran at Pleasant Grove Spring must be considered a gross estimate because the correlation between ELISA- and GC-determined metolachlor concentration was not as strong as for triazines, and no GC method for detecting carbofuran was available at KGS. In 1992–93 the annual metolachlor discharge at Pleasant Grove Spring was 15 lb (6.8 kg), and carbofuran was 1 lb (0.5 kg). In 1993–94 the annual mass discharged was 2 lb (0.9 kg) for metolachlor and 7 lb (3.2 kg) for carbofuran. The decrease in metolachlor may be the result of weather conditions, but the increase in carbofuran is unexplained.

The striking contrast in triazine concentration and flux in May 1993 and May 1994 is not yet understood. For both years, annual mass-flux totals were substantially less for alachlor, carbofuran, and metolachlor than for atrazine-equivalent triazines. Also, the mass flux of nitrate was substantially greater in 1993–94 than in the previous year. Three possible causes for the change in triazine flux are reduced use, shifts in crop patterns, and enhanced degradation caused by weather conditions. Enhanced degradation of atrazine and increased leaching of nitrate in wet years have been noted by several authors (Johnston and others, 1967; Baker and others, 1978; Dao and others, 1979; Baker, 1980). The relatively wet spring of 1993–94 may have resulted in both greater degradation of atrazine, and more numerous but less intense runoff events during the 1993–94 application season than in 1992–93.

The distribution of crops within the basin may affect the efficiency of triazine-laden runoff in reaching streams and eventually ground water. Although crop maps have been prepared, the areal distribution of the crops from year to year has not been studied thus far. Corn tends to dominate the headwaters area of Upper Pleasant Grove Creek during some years, however. Upper Pleasant Grove Creek receives surface runoff from immediately adjacent fields and discharges flow into the ground at George Delaney swallow hole and other points. This may provide a direct route for triazine transport into ground water during the years corn is concentrated along Upper Pleasant Grove Creek.

Another possible explanation of a change in pesticide flux is a change in total herbicide use by farmers. An annual census of actual chemical applications was beyond the scope of this research, but sales data for pesticides can provide a sense of overall trends in chemical use. A total of 90,082 lb of atrazine was sold in Logan County in 1992, whereas 67,789 lb was sold in 1993 (Ernest Collins, Kentucky Division of Pesticides, oral commun., 1994), a 25 percent reduction. Corn production was only 80 acres (32 hc) greater during 1993–94, however—an insignificant increase. Carbofuran sold in Logan County decreased from 9,323 lb (4,229 kg) in 1992 to 6,194 lb (2,810 kg) in 1993, and metolachlor increased from 35,112 lb (15,927 kg) in 1992 to 44,374 lb (20,128 kg) in 1993. At a meeting with farmers in the study area in February 1993, the project was explained and they were asked if they would support changes in BMP's. At this meeting, preliminary data on the 1992–93 atrazine concentrations were released, possibly influencing farmers to use less atrazine. Pleasant Grove Spring Basin is only 3 percent of the area of Logan County, however—hardly sufficient to account for a 25 percent reduction in sales throughout the county. Statewide, atrazine sales increased modestly from 1992 to 1993. Also, there is no demonstrable link between general sales data and pesticide use within the basin.

A complete nitrogen budget for the basin was beyond the resources of this research, but some generalizations can be made. There is no domestic waste-water collection system in the basin, and all sewage is disposed of privately. Assuming each resident adds 5.15 lb (2.34 kg) of nitrogen to the ground water per year (Canter and Knox, 1985), only about a ton per year (912 kg / yr) would be added by the estimated 390 residents in the basin, a comparatively small amount. Likewise, net deposition for all livestock would be nearly zero because most forage and feed grain is grown in the basin. Nitrogen gain from atmospheric deposition may be significant, however. Precipitation samples collected in 1993–94 at Pleasant Grove Spring had a depth-weighted average concentration of 0.31 mg / L of nitrate-nitrogen, suggesting that 3.0 lb per acre (3.5 kg / hc) of nitrate-nitrogen is deposited annually by precipitation alone. A total atmospheric deposition rate of 5 lb per year per acre (5.7 kg / yr / hc) is commonly assumed for Kentucky (Gary Felton, UK College of Agriculture, oral commun., 1995). At this rate, 50,270 lb (22,802 kg) of nitrogen is deposited by precipitation in the basin per year, equivalent to half of the 1992–93 nitrate-nitrogen flux from Pleasant Grove Spring! Even if all of the atmospheric nitrogen deposited in the basin is discharged as nitrate from Pleasant Grove Spring, however, the remaining nitrate flux would still represent 6.3 percent of the nitrogen applied as fertilizer in the basin.

The amount of nitrogen removed from the basin is thought to be small except for the nitrogen exported by harvesting and discharged from Pleasant Grove Spring. Because ammonia and nitrite were only found in small concentrations during phase I, and water discharging from Pleasant Grove Spring is well oxygenated, denitrification in ground water is thought to be minor. The significance of denitrification at feed lots and manure lagoons is unknown, but there are few of these facilities in the basin. Approximately 7,000 acres (2,833 hc) of the basin is in row crop production. Of this, typically 3,000 acres (1,214 hc) is in soybeans, which obtain most of their nitrogen from the soil, although they also fix nitrogen from the atmosphere. The annual nitrogen loss from the watershed via harvesting is unknown, but it is likely much larger than the combined nitrogen gains outlined above because of the large acreage of row crops harvested.

In summary, the cause of variability in pesticide flux has not been identified. Possible causes include weather conditions, changes in the amounts and types applied, and cropping patterns. Nitrate-nitrogen flux is more constant. With the exception of atmospheric deposition and fertilizer, the amount of nitrogen added to the basin is small, and with the exception of harvest and nitrate-nitrogen discharged at Pleasant Grove Spring, nitrogen losses from the basin are probably small. Since crop uptake exceeds atmospheric deposition, the result is a net loss from the watershed, which must be replaced by fertilizers. At an average application rate of 137 lb / acre (154 kg / hc), approximately 440 tons (400,000 kg) of nitrogen is applied to corn, wheat, and tobacco each year. Although the specific source of the nitrate-nitrogen discharged from Pleasant Grove Spring has not been demonstrated and the nitrate-nitrogen flux cannot be entirely attributed to nitrogen applied to crops, fertilizer remains the most probable source of nitrate-nitrogen in ground water.

Annual Flux at Upstream Sites. Stage records and flow data at Upper Pleasant Grove Creek and George Delaney swallow hole were not satisfactory for the estimation of mass flux. Flux was estimated for Leslie Page karst window, but both flow monitoring and sampling were not as complete as the initial site assessment suggested was possible. Nevertheless, estimates were calculated for Leslie Page karst window for 1993–94 (Fig. 17). The nitrate-nitrogen flux was 4.9 short tons (4.5 metric tons) or a flow-weighted average of 7.04 mg / L. Pesticide flux for atrazine-equivalent triazines was 1.83 lb (0.83 kg) or 1.3 µg / L flow-weighted average; metolachlor was 0.04 lb (0.02 kg) or 0.04 µg / L flow-weighted average. The carbofuran flux was nearly zero. Although the catchment of Leslie Page karst window has not been mapped, average discharge indicates it is relatively small. Also, the fields immediately surrounding the site were mostly wheat and soybeans in 1993–94, which reduced the quantity of atrazine used in the vicinity that year.

High-Flow Events at Pleasant Grove Spring. Numerous authors have demonstrated the critical importance of sampling karst springs at closely spaced intervals during high-flow events to quantify natural constituents and detect pollutants (Ashton, 1966; Quinlan and Alexander, 1987; Ogden, 1988). An attempt was made to sample every high-flow event during the planting season. The event samples were supplemented and bracketed by manually collected base-flow samples. Some high-flow events were supplemented with manual samples. In addition, several fall and winter high-flow events were sampled during the 1992–93 water year. A common feature of many of the resulting graphs is that whereas major runoff events resulted in lowered nitrate-nitrogen concentrations, triazine concentrations generally increased. Increased mass flux of both atrazine-equivalent triazines and nitrate-nitrogen is caused by the large increase in discharge. Concentrations of pesticides at Pleasant Grove Spring are commonly two orders of magnitude greater during springtime, high-flow events than during winter events. Also, most chemographs for storms during planting season show a positive relationship between total suspended solids and triazines during peak discharge. Cross-plots of total suspended solids versus triazines show no correlation, however, and there is no apparent difference in atrazine concentrations in filtered and unfiltered water samples from Pleasant Grove Spring. The apparent relationship between triazines and sediment for many Pleasant Grove Spring chemographs is caused by both constituents being common to runoff, rather than the sorption of atrazine on filterable sediment. The travel time for pesticides in runoff from the headwaters of the basin to Pleasant Grove Spring is less than a day.

An excellent example of increased triazine concentration and decreased nitrate-nitrogen concentration during high flow is the June 1992 event (Fig. 18). Approximately 1.6 in. (4 cm) of rain was recorded at the

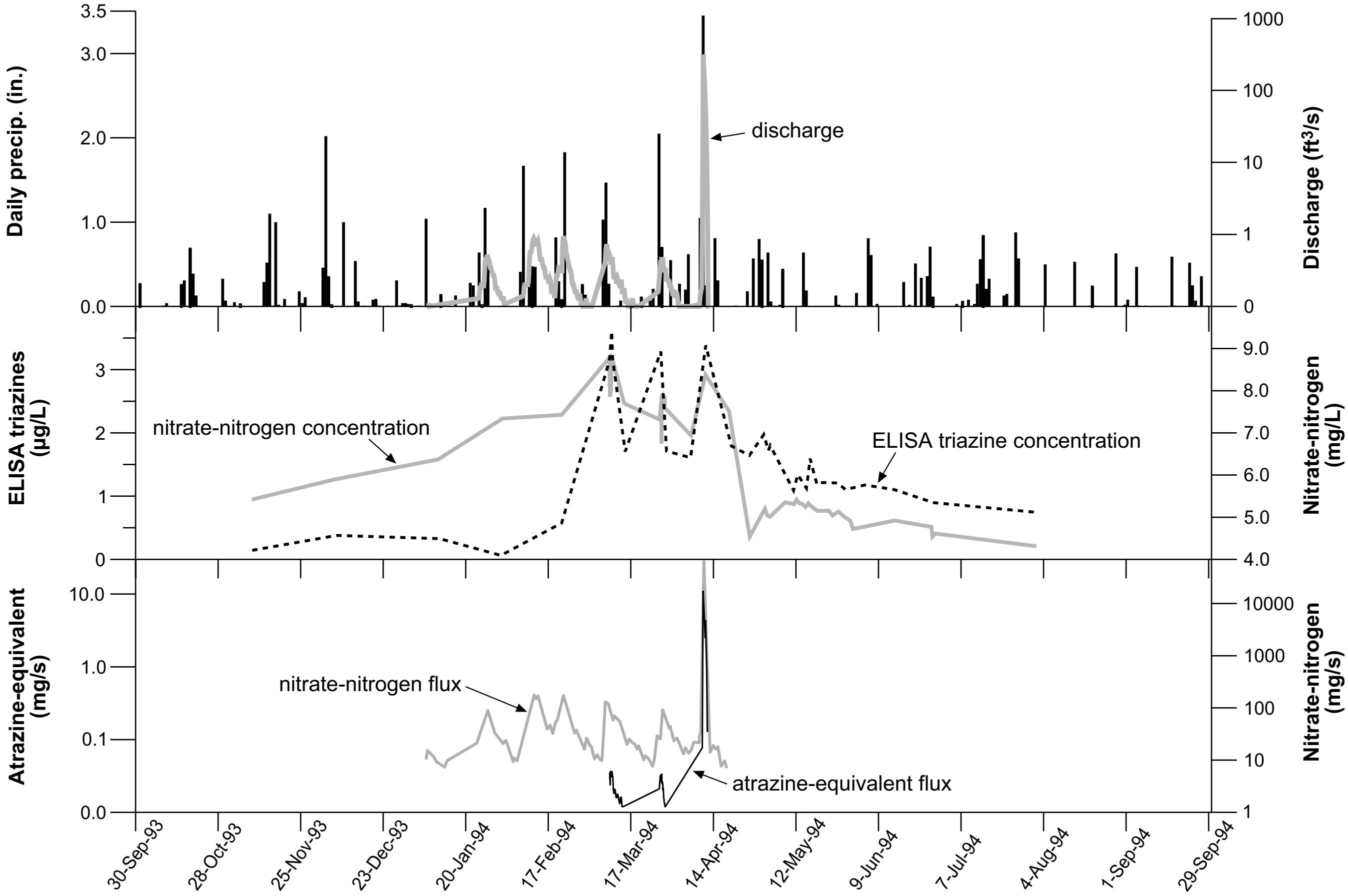


Figure 17. Plot of precipitation, discharge, nitrate-nitrogen concentration, nitrate-nitrogen flux, triazine concentration (determined by ELISA), and atrazine-equivalent triazine flux for Leslie Page karst window for the 1993–94 water year.

Russellville volunteer station between 19:00 on June 3 and 19:00 on June 4. Following the first rise in discharge, a small decrease in triazine concentration occurred, followed by a series of sharp rises in concentration that corresponded to dramatic increases in suspended sediment. The peaks in sediment also corresponded to decreases in nitrate concentration. During the recession, suspended sediment decreased significantly, nitrate-nitrogen increased to pre-event levels, and triazine steadily increased, then dropped off toward pre-event concentrations. The relationship between sediment, nitrate-nitrogen, and triazines indicates that runoff diluted the nitrate, while carrying significant concentrations of triazines.

Data from two storms in February 1993 show somewhat different results (Fig. 19). The February 15 storm accumulated 0.87 in. (2.2 cm) of rain over 17 hours at the Pleasant Grove Spring gage. Daytime temperatures were above 40°F (4.4°C), but dipped below freezing on the morning of February 17. The discharge hydrograph and chemographs show only moderate increases in discharge and turbidity, whereas specific conductivity, triazine content, and nitrate-nitrogen content decreased. The February 21 storm was more intense, resulting in 1.12 in. (2.84 cm) of rain accumulating in only 5 hours. Temperatures were above freezing. While specific conductivity went down, stage and turbidity increased significantly. Triazine concentration increased slightly, but overall both triazines and nitrate-nitrogen changed little in concentration. Discharge and turbidity increased dramatically in the case of the February 21 storm, although cover on the fields was largely unchanged between storms. Comparison of the two February storms revealed that although the triazine concentrations continued to be much lower than those measured during the planting season, the remaining triazines, nitrate, and significant sediment loss are mobilized more by storms that are relatively intense.

In May 1993 the greatest concentration of triazines and GC-determined atrazine for Pleasant Grove Spring occurred during a high-flow event beginning in the evening of May 3 and lasting through May 4 (Fig. 20).

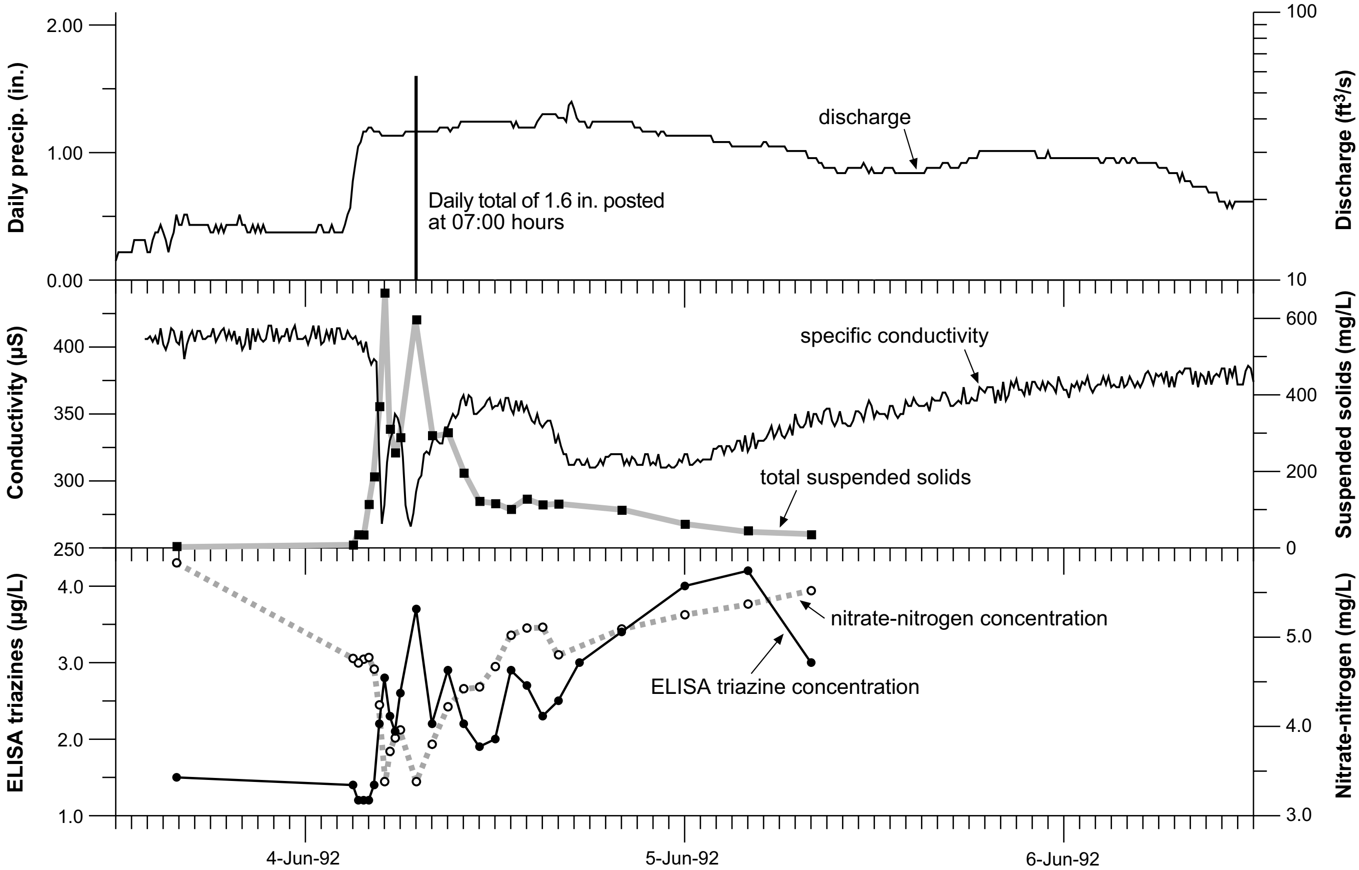


Figure 18. Discharge hydrograph and chemographs for the June 1992 high-flow event at Pleasant Grove Spring. Note the opposite deflection of the nitrate and triazine concentrations.

Approximately 3.04 in. (7.72 cm) of rain fell during the afternoon and evening of May 3. Data recorded during the event are less than ideal because the water-quality logger probes were fouled and the intake lines of the Isco samplers were crimped by the high flow velocities. No samples were collected during peak flow. The highest concentration of pesticide detected was 44.0 µg/L of triazines, in a sample collected during the early recession limb of the hydrograph. A sample collected manually the same day contained 28.0 µg/L of atrazine (GC-determined). Maximum triazine concentrations were probably greater than those measured. The event contributed at least 44.5 kg of atrazine-equivalent triazines, 88.7 percent of the 1993 annual mass flux. In addition, sediment transport during this storm was significant. Total suspended sediment concentrations reached a maximum of 202 mg/L, and turbidity values exceeded 1,000 nephelometric turbidity units (NTU's), the maximum range of the turbidity probe. Sediment was deposited to depths of 2 in. (5 cm) in the channel and on the banks of Pleasant Grove Creek for hundreds of feet downstream of the spring. At the time of the storm, a large number of fields had been simultaneously tilled, and crops had not yet emerged. A biological inventory conducted downstream of the spring in 1994 by the Kentucky Division of Water revealed that Pleasant Grove Creek was biologically impaired, probably by sediment (Sampson, 1995).

During the high-flow event on December 10, 1993, triazines were detected at Pleasant Grove Spring in concentrations as high as 1.5 µg/L, even though this was 8 months after the application season. No analyses are available for the storm on December 4, but wetting of the soil after a very dry fall (Fig. 21) may have mobilized triazines stored in the soil and diffuse-flow zone. The December 10 rainfall then would have flushed triazines into the conduit system. The concentration of triazines at Pleasant Grove Spring fell, however, as runoff flowing directly into swallow holes diluted the relatively limited mass of triazines and nitrate-nitrogen stored in the aquifer. The presence of triazines in these concentrations strongly suggests that some agricultural chemicals are being stored in ground water or soil long enough

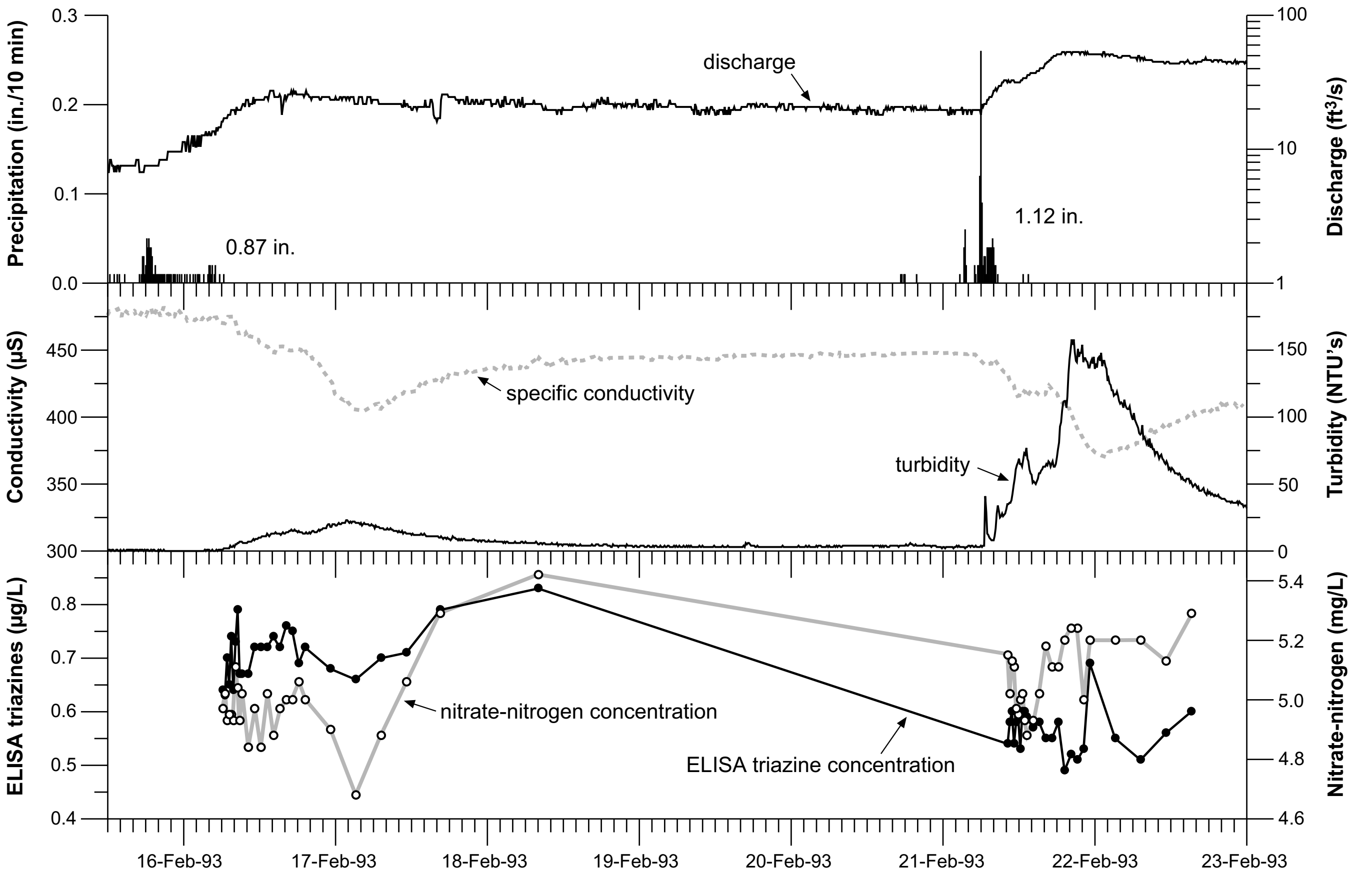


Figure 19. Discharge hydrograph and chemographs for February 1993 high-flow events at Pleasant Grove Spring showing variable response to late-winter storms of different intensity.

to expose those who drink the ground water to these compounds. This risk occurs nearly year-round.

The timing of the arrival of runoff from the headwaters of the basin at Pleasant Grove Spring is important to understanding the origin of contaminants. Only one quantitative ground-water dye trace was completed in time for this report, but water-quality records of storms have provided insight into travel times from George Delaney swallow hole, the principal insurgence during most events. A storm producing 1.04 in. (2.64 cm) of rain began at 22:40 on January 6, 1994, reached its maximum intensity at midnight, and ended by 04:00 on January 7 (Fig. 22). This storm broke a relatively dry 4-week-long period with total precipitation of only 2.3 in. (5.8 cm). Air temperature steadily fell during the early morning of January 7, and was below freezing by 09:50. The stage at the George Delaney swallow hole recorder began to rise at midnight and peaked at 07:50 on January 7 (Fig. 22). Discharge at Pleasant Grove Spring began to increase at 00:50 on January 7 and peaked at 12:10. Velocity increased synchronously with discharge. Conductivity and water temperature remained constant until 10:00, however, when small declines in both were measured, followed by rapid declines beginning at 13:00; minimum values were reached at 17:10 and 19:00, respectively. Turbidity rose rapidly at 06:00, declined to pre-event readings, then began rising again at 09:00, peaking at 15:20. The early peak in turbidity is interpreted as the arrival of runoff from fields surrounding Pleasant Grove Spring in the immediate catchment area of the rise pool. The second peak in turbidity at 15:20 and the minimum conductivity at 17:10 are interpreted as the arrival of inflow from George Delaney swallow hole. The delayed temperature minimum was caused by warming of the runoff by the thermal mass of the bedrock. Under these flow conditions, the expected travel time to Pleasant Grove Spring after a storm peak is 15 hours from George Delaney swallow hole. Average straight-line velocity from George Delaney swallow hole is 0.20 ft/s, whereas velocity along the hypothesized flow route is 0.26 ft/s; both values are in general accordance with dye traces and the monitored apparent velocity.

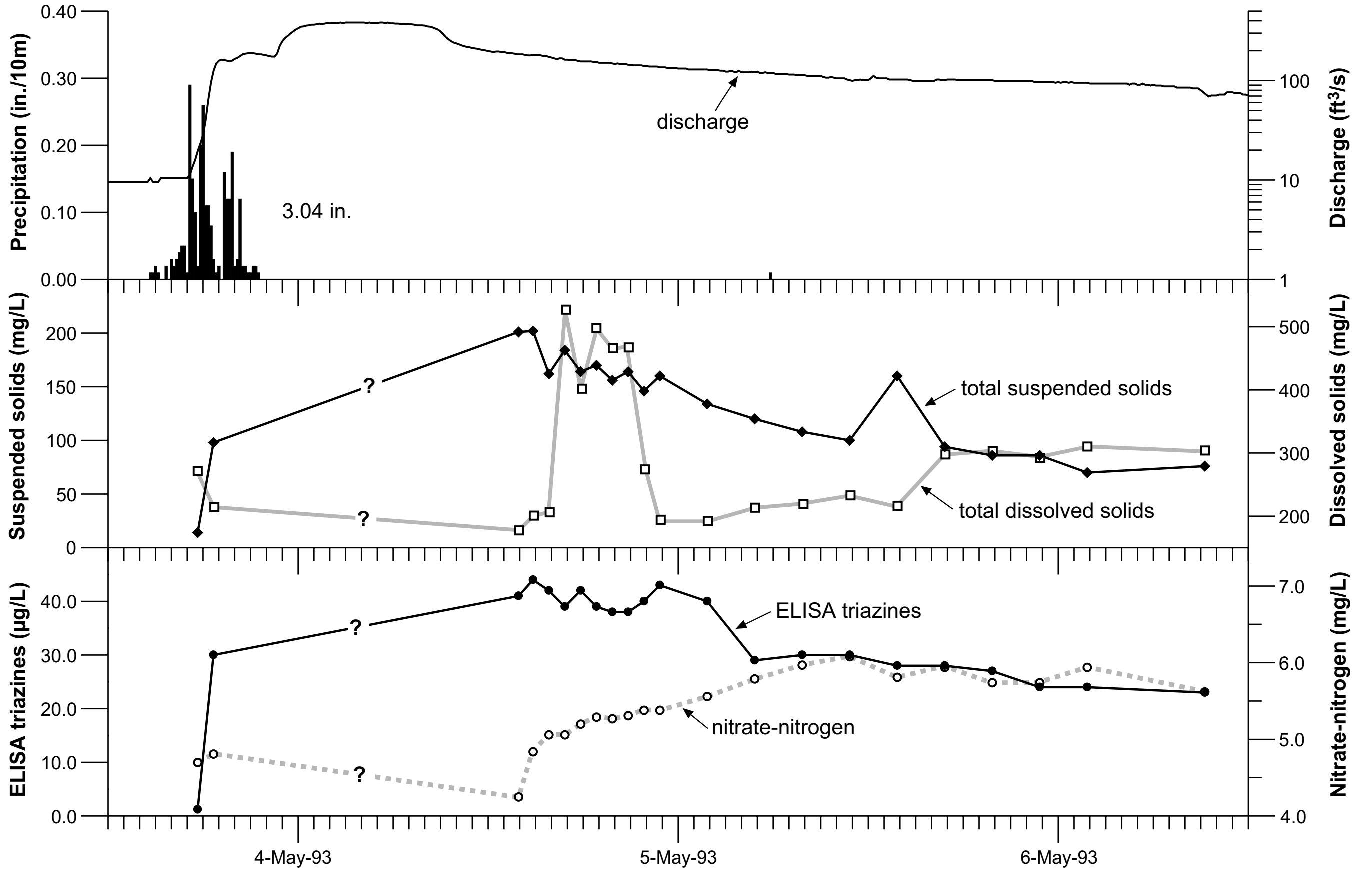


Figure 20. Chemographs and discharge hydrograph for the May 1993 high-flow event at Pleasant Grove Spring, illustrating highest triazine concentrations determined to date.

Although a sediment mass flux was not estimated because of the poor record from the turbidity probe caused by bacteria fouling, the probe generally performs well during the winter when biological growth rates are slow. High-flow events in late January 1994 revealed an apparent contradiction between periods of turbidity and high flow velocities from the spring mouth (Fig. 23). Air temperatures during all three storms in January 1994 were above freezing. Both turbidity and velocity values would be expected to be simultaneously higher if the faster flowing water were consistently entraining sediment from the conduits. On January 25 and 26, however, turbidity exceeded 100 NTU, then returned to pre-event levels of approximately 25 NTU, while velocity rose to nearly 1 ft / s. An event on January 27 raised both turbidity and velocity, as expected. Another period of rain early on January 28 again elevated velocity, but only briefly elevated turbidity, which quickly returned to pre-event levels. As in the case of the January 7 storm, conductivity and water temperature indicate that the turbidity is associated with runoff rather than mobilized sediment that has been stored in the conduits. The discordance of turbidity and velocity during the late January storms indicates that ground conditions during the storm, such as type of cover crops, amount of crop residue, depletion of loose particles by earlier storms, cohesion from wetting, and frozen ground, have a major influence on sediment loss.

Like the May 1993 event, the storm of March 27, 1994 (2.68 in. [6.8 cm] between 18:50 March 26 and 12:00 March 29), also transported significant volumes of sediment (Fig. 24). The discharge hydrograph, total suspended solids, total dissolved solids, total nitrate-nitrogen, and triazines are presented in Figure 24. This event is notable because, unlike the May event, the triazine concentrations did not synchronously rise with total suspended solids. The lack of a relationship (such as illustrated in Figure 25) is probably because the storm occurred early in the application season, when only some of the fields had had chemicals applied to them.

Figure 25 also illustrates the maximum total suspended sediment concentration sampled from Pleasant Grove Spring to date, 2,278 mg / L. This sample was col-

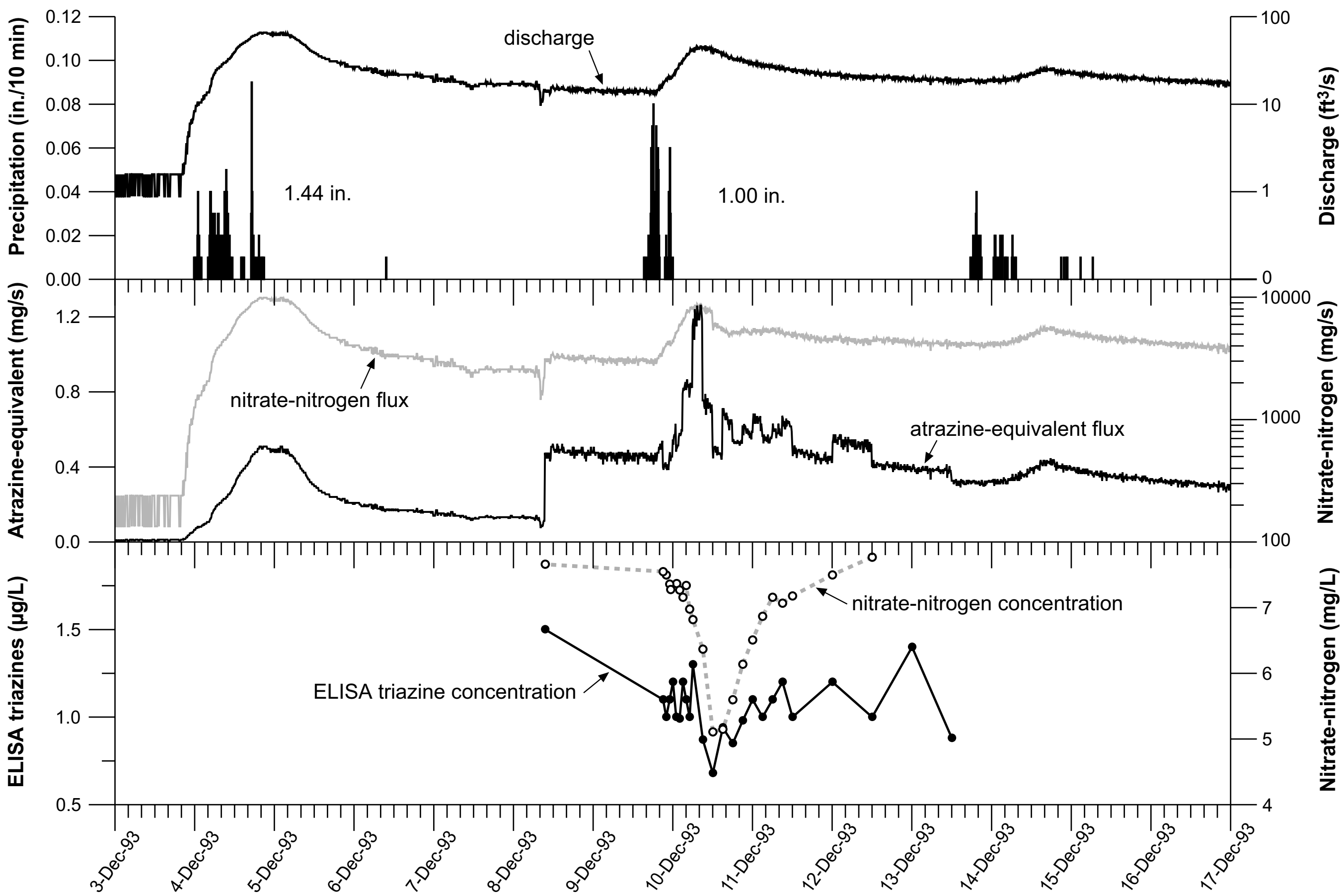


Figure 21. Discharge hydrograph and chemographs showing elevated atrazine-equivalent triazine flux during an early-winter high-flow event at Pleasant Grove Spring.

lected at 23:45 on April 29, 1994, during an event that began with only 0.70 in. (1.7 cm) of rain at Pleasant Grove Spring, although more rain may have fallen in the basin headwaters. Farm fields that are plowed are highly vulnerable to soil loss between the time they are tilled and before crops have grown sufficiently to provide cover. Although most fields in the Pleasant Grove Spring Basin are no-till or minimum tillage, a number of fields are plowed by conventional methods. The months between March and June consistently have the highest suspended sediment concentrations. The April 29 event is also an excellent example of the dilution of nitrate concentrations and the enhancement of pesticide concentrations by the arrival of runoff at the spring.

Conclusions

The Pleasant Grove Spring ground-water basin was determined by ground-water dye tracing to cover approximately 10,054 acres (4,069 hc). Roughly 70 percent of the basin is crop land, and 22 percent is pasture. About 3,300 acres (1,335 hc) of corn is grown in a 2-year rotation with wheat and soybeans. Significant numbers of beef cattle, dairy cattle, and swine are raised. Nonagricultural activities in the basin are minimal.

The Pleasant Grove Spring ground-water basin has mature karst topography and is characterized by sinkholes, sinking streams, springs, and karst windows. Upper Pleasant Grove Creek loses flow underground to Pleasant Grove Spring during base-flow conditions, but it does not go outside the basin. The Canyon karst window represents a major ground-water sub-basin. Conversely, Leslie Page karst window is a perched and isolated interior sub-basin. A potentiometric ground-water surface map (Plate 2) and dye traces indicate that the basin can be divided into two ground-water flow regimes: slow (diffuse) and fast (conduit). Flow rates in the fast-flow regime are measured in days, whereas flow rates in the slow-flow regime are measured in weeks. The slow-flow regime slowly releases from storage constituents that are dissolved in ground water.

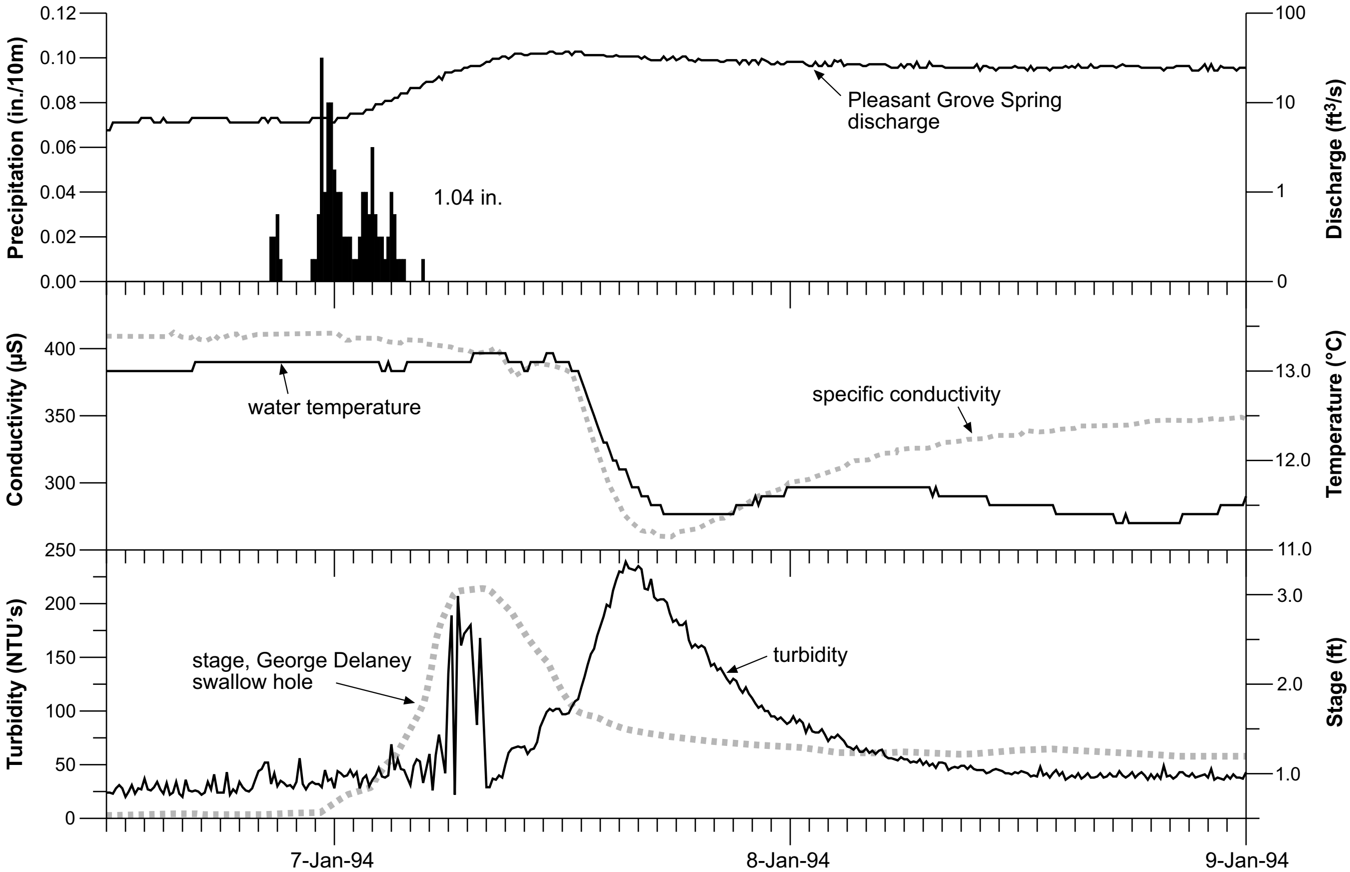


Figure 22. Stage hydrograph for George Delaney swallow hole and discharge hydrograph and chemographs for Pleasant Grove Spring, illustrating flow travel time from George Delaney swallow hole.

Analysis of water samples collected during the first year of study was used to identify contaminants of potential concern. Results suggest that nonpoint-source pollution from agriculture is ubiquitous in the ground water of the Pleasant Grove Spring karst ground-water basin. Contaminants of concern are triazine herbicides and bacteria. Nutrients such as nitrate and orthophosphate are also present in higher than natural concentrations, but generally do not exceed drinking-water standards. Nitrate-nitrogen concentrations throughout the study period in the basin vary narrowly from a minimum of 0.02 mg/L (lower detection limit) to a maximum of 10.8 mg/L, and average 5.26 mg/L. Nitrate-nitrogen concentrations in forested areas are as low as 0.61 mg/L (Boyer and Pasquarell, 1994). Sediment is an episodic environmental pollutant. Volatile organic compounds were absent from two samples collected at Leslie Page karst window and two samples from Pleasant Grove Spring. Heavy-metal concentrations in the basin are below maximum contaminant levels for drinking-water.

Concentrations of some pesticides exceed drinking-water standards at Pleasant Grove Spring during storms in the planting season. Triazine concentrations as high as 44 µg/L have been measured. Carbofuran, metolachlor, and alachlor are found in concentrations substantially above detection limits only during the planting season. Maximum concentrations detected were 7.4, 9.6, and 6.1 µg/L, respectively. Low triazine concentrations (0.5 to 1.5 µg/L) persist in the ground water through the remainder of the year.

The annual mass flux of atrazine-equivalent triazines and nitrate-nitrogen was estimated for Pleasant Grove Spring. Atrazine-equivalent losses in 1992–93 were 0.033 lb/acre (0.037 kg/hc) or 1.65 percent of atrazine applied, resulting in a flow-weighted average of 4.91 µg/L. Atrazine-equivalent loss in 1993–94 was at a flow-weighted average of 0.97 µg/L (1.0 percent of applied atrazine). Mass flux of other pesticides was substantially less. Nitrate-nitrogen losses for 1992–93 were 15.86 lb/acre (17.7 kg/hc) or 11.5 percent of nitrate-nitrogen applied to crops in the basin. Losses of nitrate-nitrogen were 64.7 lb/acre (72.5 kg/hc) or 47.2 percent of nitrate-ni-

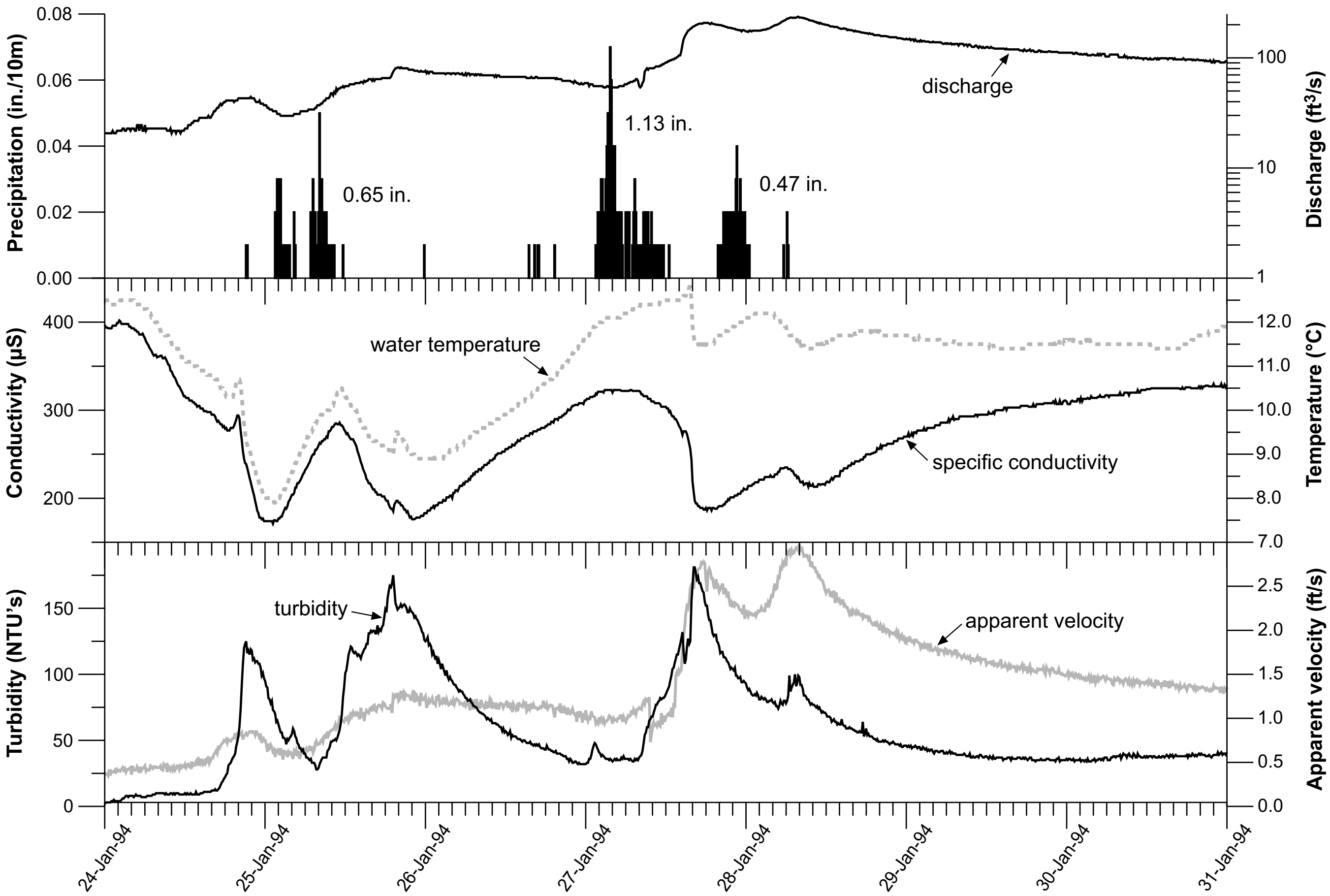


Figure 23. Chemographs and discharge hydrograph for Pleasant Grove Spring, illustrating the discordance of the occurrence of turbidity relative to velocity increases.

trogen applied in 1993–94. The smaller atrazine-equivalent loss and greater nitrate-nitrogen loss may be caused by changes in application rates or by wetter weather conditions in 1993–94 than 1992–93.

The annual mass flux of nitrate-nitrogen at Pleasant Grove Spring is apparently low, in comparison to the Big Spring Basin in Iowa (Hallberg and others, 1984) and considering the significant application of nitrate-nitrogen in the watershed. The cause of the low flux is not understood, but at least three hypotheses are possible. Harvest may export large amounts of nitrogen from the basin. If this is the case, farmers are managing nitrogen use well and maximizing crop uptake. Crop residue left on the fields may be responsible for the slight increase in nitrate observed during the wet winter and early spring months prior to rapid plant growth. A second hypothesis is that the apparently iron-rich soils may be sorbing, then later releasing, nitrogen (Thomas, 1972). The third hypothesis is that the nitrate is remaining stored, in solution, in ground water in the slow-flow zone of the aquifer. This hypothesis is strongly supported by the concentration trends of other water-quality parameters. Whatever the mechanism, it is strongly moderating nitrate concentrations, which show only modest changes over the course of a year.

Average bacteria counts in the Pleasant Grove Spring Basin are always above drinking-water standards, and occasionally are above water-supply limits, suggesting that ground water in the basin is unsafe for human consumption without sanitization. Bacteria counts at Pleasant Grove Spring of samples collected during both phase I and phase II averaged 550 col/100 ml fecal coliform and 2,550 col/100 ml fecal streptococci. Basinwide, samples averaged 465 col/100 ml fecal coliform and 1,891 col/100 ml fecal streptococci; maximum counts were 14,000 and 24,000 col/100 ml, respectively. Unfortunately, *Enterococcus* speciation analysis and sampling for optical brightener failed to identify the source of the bacteria. Fecal coliform and fecal streptococci counts shift between ratios indicating animal and human sources, depending on flow. Bacteria levels were lower after a facility to handle animal waste was installed on Upper Pleasant Grove Creek. High strepto-

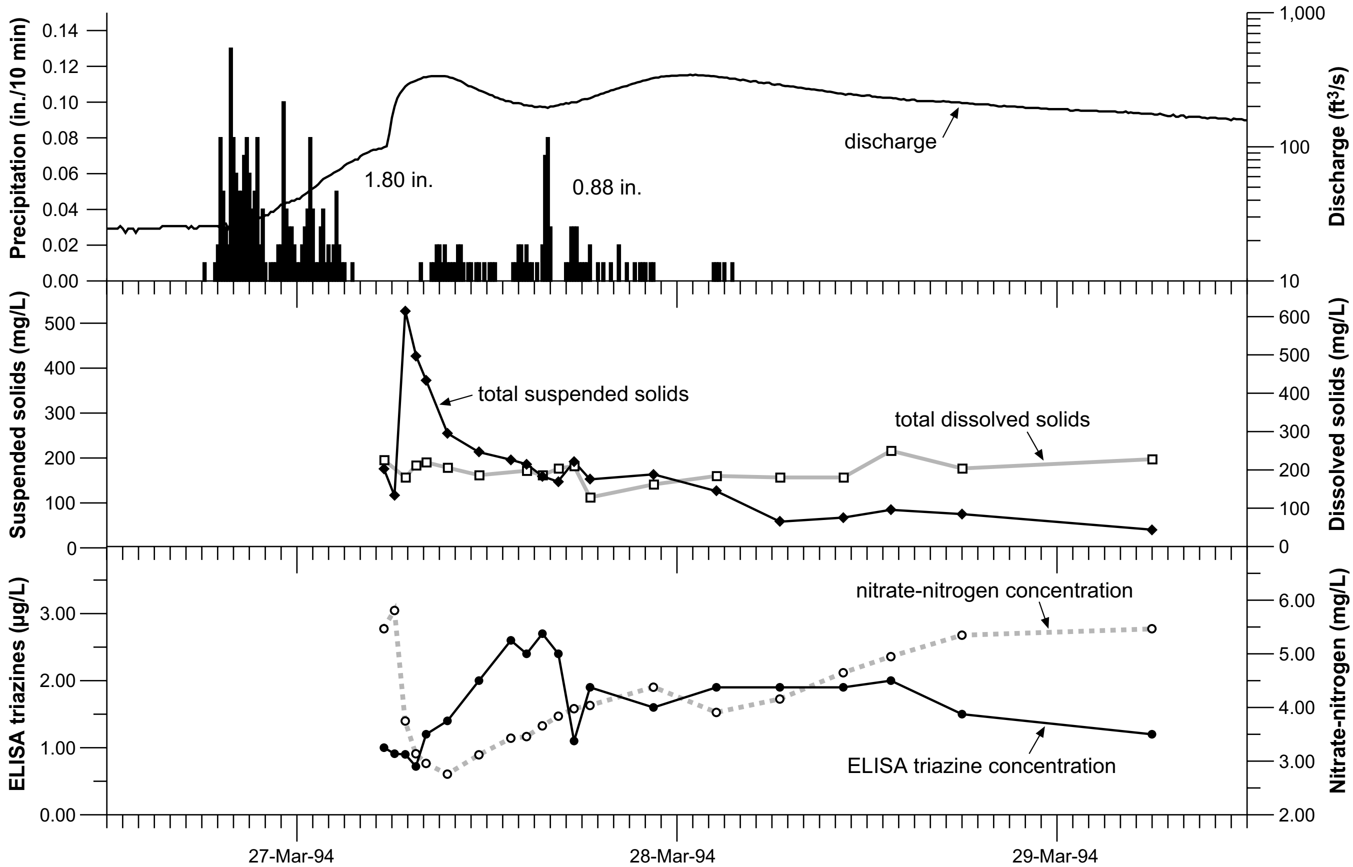


Figure 24. Discharge hydrograph and chemographs for the March 1994 high-flow event at Pleasant Grove Spring showing the discordance of triazine concentration (determined by ELISA) and both dissolved and suspended solids.

cocci counts followed by high coliform counts suggest animal waste is mobilized early in a high-flow event, followed by mobilization of human waste later in the event.

Monitored high-flow events reveal the complex interrelationship of chemical application, tillage, and weather to contaminant transport. Peaks in atrazine-equivalent triazine flux are clearly associated with waters originating as field runoff, which enters the ground at swallow holes. The travel time for pesticides in runoff from the headwaters of the basin to Pleasant Grove Spring is less than a day. This is supported by other water-quality parameters associated with the higher pesticide concentration such as temperature changes, reduced conductivity, and increased turbidity. Analysis of filtered and unfiltered sample splits shows no apparent difference in concentration of pesticides, however. Also, the late arrival of higher nitrate concentrations and the stabilization of triazine concentrations to pre-event levels support the model of a diffuse-flow zone storing chemicals and moderating water-quality changes.

Summary

This report covers field work conducted between August 1990 and October 1994. During phase I, the area and hydrology of the Pleasant Grove Spring karst ground-water basin were delineated, land use in the basin was mapped, and contaminants were identified. During phase II, monitoring sites were instrumented and pre-BMP monitoring began. The monitoring included collection of data during storms. Also, wells were inventoried and water levels were measured in wells in order to construct a potentiometric map. BMP implementation is now under way.

Pollutants in concentrations of environmental and human health concern occur in ground water in the Pleasant Grove Spring karst drainage basin. Most of these pollutants stem directly from, or are closely associated with, use in agriculture. Although concentrations

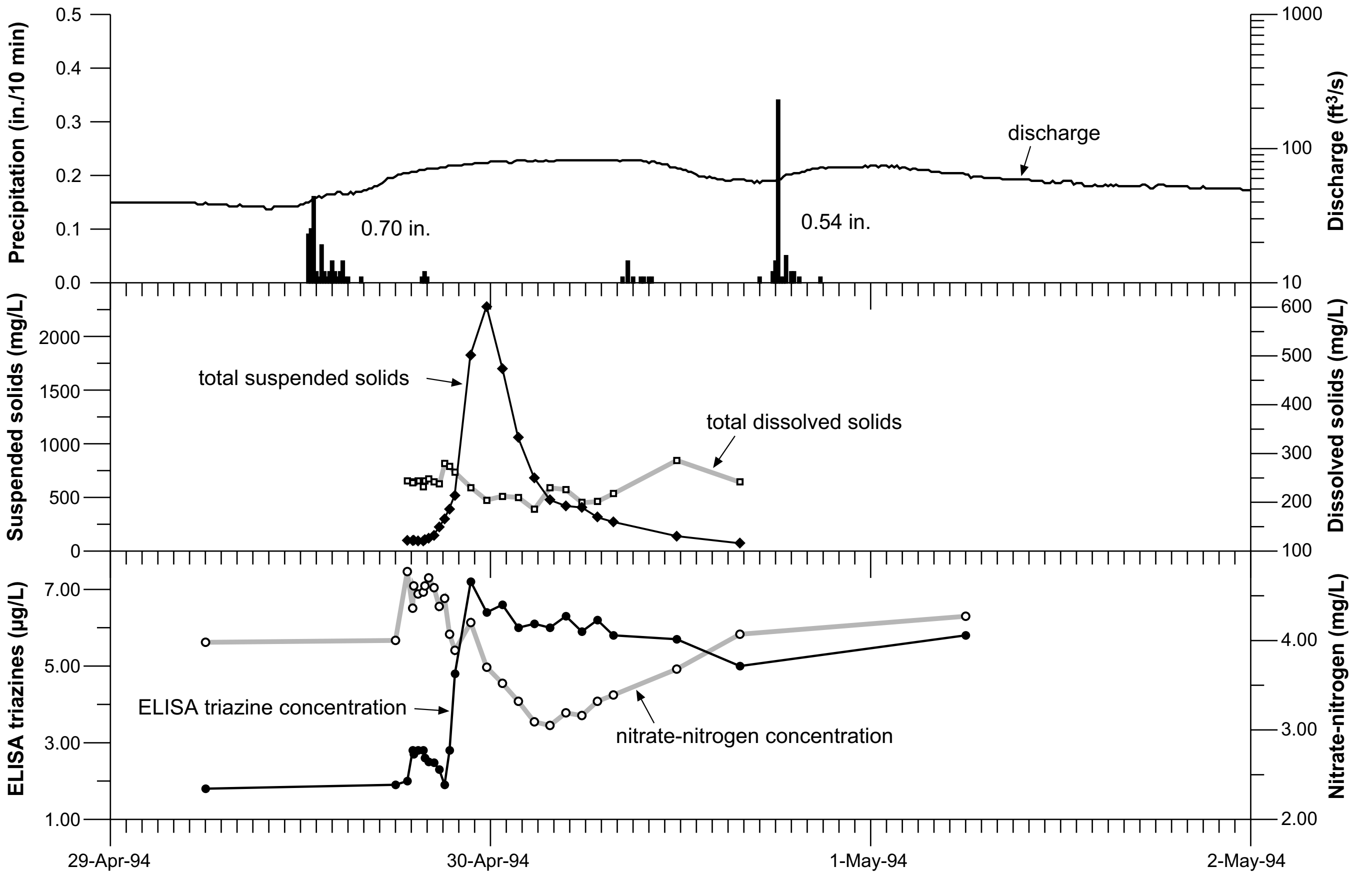


Figure 25. Discharge hydrograph and chemographs for the April 29, 1994, high-flow event at Pleasant Grove Spring.

of atrazine above drinking-water limits generally occur only after significant rainfall immediately following the planting season (when many pesticides are applied), and are associated with ground water originating as direct run-in, the peak atrazine concentrations are of environmental concern. Nitrate losses, though not an ecological problem, suggest significant economic loss to farmers. Bacteria counts improved after a facility to handle animal waste was installed, but remain a concern for drinking-water. Sediment is a major pollutant, but remains unquantified.

The hydrogeology of the basin is a significant controlling influence on the temporal variation of contaminant concentrations. The fast-flow conduit region is characterized by intermediate concentrations of nitrate and pesticides during low flow but substantially higher concentrations of triazines and lower concentrations of nitrate during high flow. The diffuse (slow) flow regime, which is estimated to represent slightly less than half of the basin, drains into the area dominated by conduit flow. The diffuse-flow region has persistently higher concentrations of nitrate but lower, less variable concentrations of triazines. The diffuse, slow-flow area is acting as a reservoir of agricultural chemicals, maintaining a background level of triazines and nitrate during low flow in the conduit-flow regime. Triazine concentrations are significantly higher during high flow, while nitrate concentrations are diluted.

Both municipal and domestic water supplies derived from ground water can be adversely affected. BMP implementation in the basin should focus on controlling animal waste, controlling crop field runoff with associated sediment and pesticide loss, and using more efficient methods of applying nutrients. A strong education program on ground-water protection is highly recommended.

References Cited

Aley, Tom, and Fletcher, M.W., 1976, The water tracer's cookbook: Missouri Speleology, v. 16, no. 6, 36 p.

Alhajjar, B.J., 1990, Indicators of chemical pollution from septic systems: Ground Water, v. 28, no. 4, p. 559–568.

Ashton, K., 1966, The analysis of flow data from karst drainage systems: Transactions of the Cave Research Group of Great Britain, v. 7, p. 161–203.

Atkinson, T.C., 1973, Experiments in tracing underground waters in limestone: Journal of Hydrology, v. 19, p. 323–349.

Baker, J.L., 1980, Agricultural areas as nonpoint sources of pollution, *in* Overcash, M.R., and Davidson, J.M., eds., Environmental impact of nonpoint source pollution: Ann Arbor, Mich., Ann Arbor Science Publishers, p. 275–303.

Baker, J.L., Johnson, H.P., Borcherding, M.A., and Payne, W.R., 1978, Nutrient and pesticide movement from field to stream—A field study, *in* Best management practices for agriculture and silviculture: Ann Arbor, Mich., Ann Arbor Science Publishers, p. 213–245.

Boyer, D.G., and Pasquarell, G.C., 1994, Agricultural land use impacts on karst ground water quality, *in* Effects of human-induced changes on hydrologic systems: American Water Resources Association, p. 791–799.

Brown, C.J., 1985, Effects of ground water recharge on nitrate-N concentrations in a conduit flow–dominated carbonate aquifer in the Sinking Valley groundwater basin, south-central Kentucky: Richmond, Eastern Kentucky University, master's thesis, 145 p.

Brown, R.F., and Lambert, T.W., 1962, Availability of ground water in Allen, Barren, Edmonson, Green, Hart, Logan, Metcalfe, Monroe, Simpson, and Warren Counties, Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA-32, 3 plates, scale 1:125,000.

Buchanan, T.J., and Somers, W.P., 1976, Discharge measurements at gaging stations, *in* Techniques of water-resources investigations of the United States Geological Survey: U.S. Geological Survey, Applications of Hydraulics, book 3, chapter A8, 65 p.

Canter, L.W., 1987, Nitrates and pesticides in ground water—An analysis of a computer-based literature search, *in* Fairchild, D.M., ed., Ground-water quality and agricultural practices: Chelsea, Mich., Lewis Publishers, p. 153–174.

Canter, L.W., and Knox, R.C., 1985, Septic tank system effects on ground water quality: Chelsea, Mich., Lewis Publishers, 336 p.

Cohen, S.Z., Eiden, C., and Lorber, M.N., 1986, Monitoring ground water for pesticides, *in* Garner, W.Y., Honeycutt, R.C., and Nigg, H.N., eds., Evaluation of pesticides in ground water: American Chemical Society Symposium Series 315, p. 170–196.

Crawford, N.C., 1986, Karst hydrologic problems associated with urban development—Ground-water contamination, hazardous fumes, sinkhole flooding, and sinkhole collapse in the Bowling Green area, Kentucky, *in* Environmental problems in karst terranes and their solutions: National Water Well Association, Eastern Kentucky University, Friends of the Karst, Kentucky Division of Water, National Park Service, and Western Kentucky University, Field Trip B, 85 p.

Cupp, J.D., 1994, Geomorphic analysis as a predictive tool in determining ground-water flow patterns in the Mississippian Plateau Region of Kentucky: Lexington, University of Kentucky, master's thesis, 98 p.

Currens, J.C., 1993, Characterization and quantification of nonpoint-source pollutant loads in the Pleasant Grove Spring Basin, Logan County, Kentucky—A conduit-flow-dominated karst aquifer underlying an intensive-use agricultural region: Kentucky Geological Survey, Open-File Report OF-93-07, 78 p.

Dao, T.H., Lavy, T.L., and Sorensen, R.C., 1979, Atrazine degradation and residue distribution in soil: Soil Science Society of America Journal, v. 43, p. 1129–1133.

Davis, S.N., Campbell, D.J., Bentley, H.W., and Flynn, T.J., 1985, Ground-water tracers: U.S. Environmental Protection Agency–Office of Research and Development and National Water Well Association, 200 p.

Devilbiss, T.S., 1981, An investigation into the movement of an agricultural pesticide within the groundwater system of a karst swallet: Richmond, Eastern Kentucky University, master's thesis, 99 p.

Dye, J.W., Barton, A.J., and Froedge, R.D., 1975, Soil survey of Logan County, Kentucky: U.S. Department of Agriculture–Soil Conservation Service, in cooperation with the Kentucky Agricultural Experiment Station–National Cooperative Soil Survey, 78 p.

Felton, G.K., 1991, Agricultural chemicals at the outlet of a shallow carbonate aquifer: American Society of

Agricultural Engineers, 1991 International Summer Meeting, Albuquerque, N. Mex., paper 91-2109, 26 p.

Hall, J.K., Pawlus, M., and Higgins, E.R., 1972, Losses of atrazine in runoff water and soil sediment: Journal of Environmental Quality, v. 1, no. 2, p. 172–176.

Hallberg, G.R., Hoyer, B.E., Bettis, E.A., III, and Libra, R.D., 1983, Hydrogeology, water quality, and land management in the Big Spring Basin, Clayton County, Iowa: Iowa Geological Survey, Open-File Report 83-3, 191 p.

Hallberg, G.R., Libra, R.D., Bettis, E.A., III, and Hoyer, B.E., 1984, Hydrogeologic and water quality investigations in the Big Spring Basin, Clayton County, Iowa: Iowa Geological Survey, Open-File Report 84-4, 231 p.

Hampson, S.K., 1994, The impact of agricultural practices on epikarstic ground-water quality in the Inner Bluegrass Region in Kentucky: Lexington, University of Kentucky, master's thesis, 311 p.

Haszler, G.R., 1993, Water quality assessment in agricultural areas of Kentucky; surface- and ground-water report, October 1992–September 1993: University of Kentucky, Committee on Water Quality Assessment, 188 p.

Johnston, W.R., Ittihadieh, F.T., Craig, K.R., and Pillsbury, A.F., 1967, Insecticides in tile drainage effluent: Water Resources Research, v. 3, no. 2, p. 525–537.

Jones, W.K., 1984, Dye tracer tests in karst areas: The NSS Bulletin, Journal of Caves and Karst Studies, v. 46, no. 2, p. 3–9.

Keagy, D.M., Dinger, J.S., Fogle, A.W., and Sendlein, L.V.A., 1994a, Interim report on the effect of pesticides, nitrate, and bacteria on ground-water quality in a karst terrain in the Inner Blue Grass Region, Woodford County, Kentucky: Kentucky Geological Survey, Open-File Report OF-93-04, 46 p.

Keagy, D.M., Dinger, J.S., Hampson, S.K., and Sendlein, L.V.A., 1994b, Interim report on the effect of fractures on the quantity of ground water and the occurrence of pesticides and nutrients in the epikarst of the Inner Blue Grass Region, Bourbon County, Kentucky: Kentucky Geological Survey, Open-File Report OF-93-05, 31 p.

Kentucky Agricultural Statistics Service, 1993, Kentucky agricultural statistics, 1992: Louisville, Kentucky Agricultural Statistics Service, 143 p.

Kentucky Division of Water, 1988, 1988 Kentucky report to Congress on water quality: Kentucky Natural Resources and Environmental Protection Cabinet, 150 p.

Libra, R.D., 1987, Impacts of agricultural chemicals on ground-water quality in Iowa, *in* Fairchild, D.M., ed., Ground-water quality and agricultural practices: Chelsea, Mich., Lewis Publishers, p. 185–215.

Libra, R.D., Hallberg, G.R., Hoyer, B.E., and Johnson, L.G., 1986, The Big Spring Basin Study, Iowa, *in* Agricultural impacts on ground water, a conference: National Water Well Association, p. 253–273.

Lichtenstein, E.P., 1958, Movement of insecticides in soils under leaching and non-leaching conditions: Journal of Economic Entomology, v. 51, no. 3, p. 380–383.

Magette, W.L., Weismiller, R.A., Angle, J.S., and Brinsfield, R.B., 1988, Nitrate standard for ground water beneath agricultural production areas: American Society of Agricultural Engineers paper 88-2642, 16 p.

Martin, J.R., and Green, J.D., 1992, Chemical control of weeds in Kentucky farm crops—1992: University of Kentucky College of Agriculture–Cooperative Extension Service, 87 p.

Meiman, J., 1985, Investigation of flood pulse movement through a maturely karstified aquifer at Mammoth Cave National Park: Richmond, Eastern Kentucky University, master's thesis, 343 p.

Meiman, J., 1991, The effects of recharge basin land-use practices on water quality at Mammoth Cave National Park, Kentucky, *in* Proceedings of the Third Conference on Hydrogeology, Ecology, Monitoring, and Management of Ground Water in Karst Terrains, December 4–6, 1991, Nashville, Tenn.: U.S. Environmental Protection Agency and the Association of Ground Water Scientists and Engineers, p. 697–714.

Miller, R.C., 1968, Geologic map of the Russellville quadrangle, Logan County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-714, scale 1:24,000.

Mull, D.S., Smoot, J.L., and Liebermann, T.D., 1988, Dye-tracing techniques used to determine ground-water flow in a carbonate aquifer system near Elizabethtown, Kentucky: U.S. Geological Survey Water-Resources Investigations Report 87-4174, 95 p.

Mylroie, J.E., 1984, Oakville Cave, *in* Western Kentucky speleological survey, annual report 1984: Murray

State University–College of Environmental Sciences, scale 1:462.

Nitzkin, J.L., and Henry, M.H., 1971, Infectious hepatitis in Logan County, Kentucky; a probable common source outbreak: Journal of the Kentucky Medical Association, p. 349–353.

Ogden, A.E., 1988, Distinguishing flow regimes of springs in carbonate rock terrains, *in* Lehr, J.H., ed., Proceedings, Association of Ground Water Scientists and Engineers, Ground Water Geochemistry Conference, February 16–18, 1988: National Water Well Association, p. 53–73.

Ohmicron, Corp., 1991, Atrazine RaPID assay [technical bulletin accompanying test kit]: Newtown, Pa., Ohmicron Corp., 2 p.

Palmer, A.N., 1981, A geological guide to Mammoth Cave National Park: Teaneck, N.J., Zephyrus Press, 196 p.

Quinlan, J.F., ed., 1987, Qualitative water-tracing with dyes in karst terrains—Practical karst hydrogeology, with emphasis on groundwater monitoring: National Water Well Association, 26 p.

Quinlan, J.F., and Alexander, E.C., Jr., 1987, How often should samples be taken at relevant locations for reliable monitoring of pollutants from an agricultural, waste disposal, or spill site in a karst terrain, *in* Proceedings of the Second Multidisciplinary Conference on Sinkholes and the Environmental Impacts of Karst, Orlando, Fla., February 9–11, 1987: Boston, A.A. Balkema, p. 277–286.

Rainey, H.C., III, 1965, Geologic map of the Dennis quadrangle, Logan County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-450, scale 1:24,000.

Sampson, W.F., 1995, Biological survey of Pleasant Grove Spring, Logan County, Kentucky, for "Characterization and Quantification of Nonpoint-Source Pollutant Loads in a Karst Aquifer Underlying an Agricultural Region": Kentucky Division of Water–Water Quality Branch, 10 p.

Sharpley, A.N., and Syers, J.K., 1979, Phosphorus inputs into a stream draining an agricultural watershed: Water, Air, and Soil Pollution, v. 11, p. 417–428.

Shawe, F.R., 1966a, Geologic map of the Adairville quadrangle, Kentucky-Tennessee: U.S. Geological Survey Geologic Quadrangle Map GQ-569, scale 1:24,000.

Shawe, F.R., 1966b, Geologic map of the Dot quadrangle, Kentucky-Tennessee: U.S. Geological Survey Geologic Quadrangle Map GQ-568, scale 1:24,000.

Smart, P.L., 1984, A review of the toxicity of twelve fluorescent dyes used for water tracing: The NSS Bulletin, Journal of Caves and Karst Studies, v. 46, no. 2, p. 21–33.

Smith, M.C., Bottcher, A.B., Campbell, K.L., and Thomas, D.L., 1988, Measurement of pesticide transport to shallow groundwater: American Society of Agricultural Engineers paper 88-2640, 42 p.

Steele, K.F., and Smith, C.R., 1994, Hydrochemistry and water quality of two primary carbonate aquifers, Ozark Plateaus Province, *in* Effects of human-induced changes on hydrologic systems: American Water Resources Association, p. 1147–1156.

Thomas, G.W., 1972, The relation between soil characteristics, water movement, and nitrate contamination of ground water: University of Kentucky–Kentucky Water Resources Research Institute, Research Report 140, 31 p.

Thomas, G.W., and Phillips, R.E., 1979, Consequences of water movement in macropores: Journal of Environmental Quality, v. 8, no. 2, p. 149–152.

Thrailkill, John, Byrd, P.E., Sullivan, S.B., Spangler, L.E., Taylor, C.J., Nelson, G.K., and Pogue, K.R., 1983, Studies in dye-tracing techniques and karst hydrogeology: University of Kentucky–Kentucky Water Resources Research Institute, Research Report 140, 89 p.

Thurman, E.M., Meyer, M., Pomes, M., Perry, C.A., and Schwab, A.P., 1990, Enzyme-linked immunosorbent assay compared with gas chromatography / mass spectrometry for the determination of triazine herbicides in water: Analytical Chemistry, v. 62, no. 18, p. 2043–2048.

Tucker, N.L., 1982, Nonpoint agricultural pollution in a karst aquifer: Lost River groundwater basin, Warren County, Kentucky: Bowling Green, Western Kentucky University, master's thesis, 91 p.

U.S. Environmental Protection Agency, 1983, Handbook for sampling and sample preservation of water and waste water: U.S. Environmental Protection Agency, EPA-600 / 4-82 / 029, 402 p.

U.S. Environmental Protection Agency, 1989, Method 407. Determination of nitrogen- and phosphorus-containing pesticides in water by gas chromatography with a nitrogen-phosphorus detector, revision

2.0, *in* Methods for the determination of organic compounds in drinking water: U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Office of Research and Development, EPA / 600 / 4-88 / 039, p. 143–146.

U.S. Geological Survey, 1982, U.S. Geological Survey national handbook of recommended methods for water-data acquisition; chapter 5, chemical and physical quality of water and sediment: U.S. Geological Survey, p. 5-1–5-194.

Van Couvering, J.A., 1962, Characteristics of large springs in Kentucky: Kentucky Geological Survey, ser. 10, Information Circular 8, 37 p.

Verduin, J., 1970, Significance of phosphorus in water supplies, *in* Willrich, T.L., and Smith, G.E., ed., Agricultural practices and water quality: Ames, Iowa State University Press, p. 63–71.

Wartenberg, D., 1988, Groundwater contamination by Temik aldicarb pesticide; the first eight months: Water Resources Research, v. 24, no. 2, p. 185–194.

White, A.W., Barnett, A.P., Wright, B.G., and Holladay, J.H., 1967, Atrazine losses from fallow land caused by runoff and erosion: Environmental Science and Technology, v. 1, no. 9, p. 740–744.

White, W.B., 1988, Geomorphology and hydrology of karst terrains: Oxford, Oxford University Press, 464 p.

Appendix A:
Discharge Observations of Springs and Streams in the Pleasant Grove Spring Drainage Basin

Pleasant Grove Spring

Date	*Time (CST)*	*Conditions*	*Stage (ft)*	*Discharge (ft^3/s)*
Aug/02/1990	11:00			1.30
Feb/28/1991	9:10			51.20
Apr/09/1991	14:45			47.50
Apr/09/1991	15:28			44.93
Apr/11/1991	13:40			44.76
Apr/11/1991	14:38			41.93
Apr/11/1991	12:20			41.70
May/01/1991	10:17			19.70
May/22/1991	12:23			37.70
Jun/26/1991	11:24			22.40
Jul/25/1991	11:20			5.55
Aug/29/1991	13:40			2.53
Sep/24/1991	10:46			1.85
Oct/22/1991	8:50			1.50
Dec/17/1991	8:06	falling	2.42	59.40
Jan/29/1992	10:50	stable	1.85	11.98
Feb/26/1992	11:50	stable	1.96	14.92
Mar/25/1992	13:55	stable	2.00	32.65
Apr/29/1992	11:10	falling	1.89	7.42
May/27/1992	11:45	stable	1.80	1.90
Jun/03/1992	15:20	rising	1.93	11.64
Jun/04/1992	14:10	falling	2.36	48.66
Jun/18/1992	8:20	falling	1.88	12.76
Jul/22/1992	17:00	rising	1.74	7.52
Jul/23/1992	13:50	falling	1.74	5.93
Aug/26/1992	11:10	falling	1.66	2.96
Oct/06/1992	15:40	falling	1.64	2.63
Nov/06/1992	9:00	falling	1.68	2.46
Dec/02/1992	9:50	falling	1.76	2.82
Jan/07/1993	16:00	stable	2.06	24.15
Jan/08/1993	12:20	falling	2.06	22.33
Feb/04/1993	11:40	falling	1.90	12.41
Mar/03/1993	10:10	falling	2.50	55.47
Apr/07/1993	9:10	falling	2.17	29.36
May/04/1993	13:10	falling	4.24	188.34
May/05/1993	10:10	falling	3.08	88.64
May/05/1993	12:10	falling	3.04	111.30
Aug/04/1993	10:00	stable	1.66	3.04
Sep/09/1993	7:50	falling	1.62	1.84
Oct/06/1993	7:00	falling	1.61	1.74
Nov/09/1993	11:40	falling	1.64	1.36
Mar/28/1994	15:22	falling	4.42	128.94
Apr/11/1994	13:52	stable	7.45	463.38
Apr/11/1994	18:17	falling	7.13	434.88
Apr/11/1994	14:24	falling	7.30	457.53
Apr/12/1994	9:00	falling	5.52	237.35
Aug/03/1994	9:20	stable	1.68	3.67

Spring Valley karst window

Date	*Time (CST)*	*Conditions*	*Stage (ft)*	*Discharge (ft^3/s)*
Aug/02/1990	10:21			2.39
Feb/28/1991	10:51			58.90
Apr/09/1991	10:24			32.40
Apr/11/1991	10:46			45.50
Jun/26/1991	12:00			20.08
Jul/25/1991	10:30			5.23
Aug/29/1991	12:40			2.80
Sep/24/1991	9:24			2.36
Oct/22/1991	9:30			4.50
Jan/29/1992	10:00			11.82
Feb/26/1992	11:00			15.44
Mar/25/1992	11:10			29.77
Apr/29/1992	9:36			7.40
May/27/1992	10:15			2.32
Jul/23/1992	12:50			5.80
May/20/1993	9:10	falling	1.18	16.19
Jun/02/1993	12:20	stable	1.10	12.87
Jun/17/1993	8:50	falling	0.83	6.77
Jun/30/1993	11:10	falling	0.79	5.05
Sep/07/1993	14:20	stable	0.72	1.80
Nov/08/1993	16:20	stable	1.08	1.28
Dec/07/1993	16:44	falling	1.54	21.95

The Canyon karst window

Date	*Time (CST)*	*Conditions*	*Stage (ft)*	*Discharge (ft^3/s)*
Aug/02/1990	9:13			0.11
May/01/1991	9:31			0.13
May/22/1991	9:56			8.70
Jun/26/1991	8:58			0.13
Jul/25/1991	9:35			0.14
Aug/29/1991	11:55			0.02
Sep/24/1991	8:40			0.01
Jan/29/1992	8:35			0.09
Feb/26/1992	9:32			0.14
Apr/29/1992	8:40			0.10
May/29/1992	11:05			0.02

Shackelford Spring

Date	*Time (CST)*	*Conditions*	*Stage (ft)*	*Discharge (ft^3/s)*
Feb/28/1991	12:59			0.48
May/01/1991	8:05			0.57
Jul/25/1991	8:20			0.54
Aug/29/1991	11:13			0.29
Sep/24/1991	7:48			0.12
Dec/17/1991	12:35			0.96
Jan/28/1992	14:21			0.33
Feb/26/1992	8:47			0.78
Mar/25/1992	9:02			0.58
Apr/29/1992	7:43			0.16

Thad Flowers blue hole

Date	*Time (CST)*	*Conditions*	*Stage (ft)*	*Discharge (ft^3/s)*
Feb/28/1991	12:12			0.55
May/01/1991	8:13			0.02
May/22/1991	7:17			0.20
Dec/17/1991	13:35			0.87
Mar/25/1992	7:45			0.50

George Delaney swallow hole

Date	*Time (CST)*	*Conditions*	*Stage (ft)*	*Discharge (ft^3/s)*
May/22/1991	11:25			8.75
Jun/26/1991	9:45			3.15
Jul/25/1991	9:55			0.01
Dec/17/1991	10:15			18.30
Jan/29/1992	9:17			1.64
Feb/26/1992	10:20			3.18
Mar/25/1992	10:03			10.46
May/20/1993	8:00	falling	1.46	2.29
Jun/03/1993	8:50	stable	0.71	1.36
Jun/03/1993	9:02	stable	0.71	1.26
Jun/17/1993	8:20	falling	0.14	0.00
Jun/17/1993	8:15	falling	0.14	0.00
Dec/07/1993	12:03	falling	1.07	6.15
Jan/11/1994	15:45	falling	1.16	10.81
Mar/03/1994	8:26	falling	2.50	12.29
Jun/02/1994	11:28	stable	0.68	0.60

Leslie Page karst window

Date	*Time (CST)*	*Conditions*	*Stage (ft)*	*Discharge (ft^3/s)*
May/05/1993	9:20		0.78	0.48
May/20/1993	11:10	falling	0.62	0.01
Jun/02/1993	10:10		0.63	0.02
Jun/17/1993	9:50	falling	0.61	0.04
Jun/30/1993	10:00	falling	0.59	0.00
Sep/07/1993	14:40		0.50	0.25
Oct/05/1993	12:40	falling	0.50	0.00
Dec/07/1993	16:07	falling	0.62	0.07
Dec/07/1993	16:07	falling	0.62	
Jan/11/1994	14:06	stable	0.72	0.08
Feb/02/1994	9:45	falling	0.76	0.41
Feb/22/1994	13:34	rising	0.86	0.32

Upper Pleasant Grove Creek

Date	*Time (CST)*	*Conditions*	*Stage (ft)*	*Discharge (ft^3/s)*
Jun/17/1993	7:40	falling	0.40	1.31
Jun/30/1993	9:00		0.40	0.37
Sep/07/1993	15:16	stable	0.18	0.00
Dec/07/1993	15:00	falling	1.14	9.57
Feb/22/1994	15:27	rising	2.50	61.91

Appendix B:
Analytical Methods, Sample Containers, Preservatives, and Holding Times Used for Samples Collected in the Pleasant Grove Spring Basin During Phases I and II

Analytical methods for water samples are listed in Table B-1. Comprehensive (C) samples include every analyte on the list except bacteria and field pH, temperature, total alkalinity, and conductivity. Analytes included in base flow (B) and event (E) sampling are indicated under the heading "Analysis Suite." Bacteria, volatile organics, and optical brightener analyses are topical (T) and may be collected by themselves or in conjunction with another analysis suite.

Pesticide concentrations were determined by two methods: gas chromatograph (GC) with either a nitrogen-phosphorus detector (method 507) or electron-capture (method 508), and enzyme-linked immunosorbent assay (ELISA) or immunoassay. All samples collected before April 1992, and some samples collected after that date, were analyzed for pesticides by gas chromatograph. Beginning in April 1992 all samples were also analyzed by ELISA for triazine herbicides (collectively, atrazine, simazine, and cyanazine), alachlor, metolachlor, 2,4-D, and carbofuran. Because there were no results above detection limit for 2,4-D during the first year, analysis for 2,4-D was discontinued. Pesticide results after April 1992 reported in this document are ELISA unless otherwise noted.

The GC method provides a more accurate analysis, but is expensive and therefore used less often. For a few exceptions the reported GC analyses of some pesticides may have a slightly lower detection limit than those listed here. The pesticides determined by gas chromatograph and their detections in micrograms per liter are listed in Table B-2.

The Kentucky Geological Survey water-quality laboratory used Ohmicron "RaPID Assay" ELISA kits for all immunoassay analyses. The following description of the ELISA analytical method is excerpted from Ohmicron Corp. literature (1991) that accompanies each kit and is generally applicable to all Ohmicron kits:

> The sample to be tested is added, along with an enzyme conjugate, to a disposable test tube, followed by paramagnetic particles with antibodies specific to triazines attached. Both the atrazine (which may be in the sample) and the enzyme labeled atrazine (the enzyme conjugate) compete for antibody binding sites on the magnetic particles. At the end of an incubation period, a magnetic field is applied to hold the paramagnetic particles (with atrazine and labeled atrazine analog bound to the antibodies on the particles, in proportion to their original concentration) in the tube and allow the unbound reagents to be decanted. After decanting the particles are washed and the enzyme substrate and the chromogen are added. The enzyme-labeled atrazine analog bound to the atrazine antibody catalyzes the conversion of the substrate/chromogen mixture to a colored product. After incubation the reaction is stopped with acid. Since the labeled atrazine was in competition with the unlabeled atrazine for the antibody sites, the color developed is inversely proportional to the concentration of atrazine in the sample.

The intensity of the color change is quantified on a spectrophotometer and the concentration reported in micrograms per liter.

While GC analysis detects specific target pesticides individually, ELISA analysis detects a target pesticide and a few additional chemically related compounds. The ELISA triazine analysis is designed to be most sensitive to atrazine, which it measures above a detection limit of 0.046 µg/L, though it also detects simazine (above 0.34 µg/L) and cyanazine (above 1.0 µg/L), according to the manufacturer's literature. The method also detects some degradation products of the pesticides. The ELISA triazine results are therefore the total of triazine herbicides and degradation products in the sample. The other ELISA analyses similarly react to a small group of compounds, but are most sensitive to the targeted pesticide. Detection limits by ELISA analysis, as used by the Kentucky Geological Survey water-quality laboratory, are as follows (units are µg/L): triazines, 0.06 (standard deviation [SD] 0.08); metolachlor, 0.06 (SD 0.3); 2,4-D, 0.90 (SD 0.16).

Table B-1. Analytical methods, sample containers, preservatives, and maximum holding times.

Metals, Total

Analyte	*Container*	*Preservative*	*Holding Time*	*Analytical Procedure*	*MDL* (mg/L)*	*Analysis Suite*
Arsenic	Polyethylene	HNO_3, ice	6 months	EPA 200.7a	0.050	C
Barium					0.0007	C
Calcium					0.023	C, E
Chromium					0.008	C
Copper					0.007	C
Iron					0.006	C
Lead					0.071	C
Magnesium					0.030	C, E
Manganese					0.002	C
Nickel					0.049	C
Phosphorus					0.121	C
Potassium					1.210	C
Silicon					0.034	C
Sodium					0.018	C
Strontium					0.001	C
Sulfur					0.030	C
Zinc					0.004	C

Metals, Dissolved

Analyte	*Container*	*Preservative*	*Holding Time*	*Analytical Procedure*	*MDL* (mg/L)*	*Analysis Suite*
Arsenic	Polyethylene	HNO_3, ice	6 months	EPA 200.7a	0.050	C
Barium					0.0007	C
Calcium					0.023	C
Chromium					0.008	C
Copper					0.007	C
Iron					0.006	C
Lead					0.071	C
Magnesium					0.030	C
Manganese					0.002	C
Nickel					0.049	C
Phosphorus					0.121	C
Potassium					1.21	C
Silicon					0.034	C
Sodium					0.018	C
Strontium					0.001	C
Sulfur					0.030	C
Zinc					0.004	C

*As of July 1993

Table B-1. Continued.

Nutrients

Analyte	*Container*	*Preservative*	*Holding Time*	*Analytical Procedure*	*MDL* (mg/L)*	*Analysis Suite*
Phosphorus-Total	Polyethylene	H_2SO_4, ice	14 days	Calculated	0.121	C
Orthophosphate				EPA 365	0.009	C
Nitrate-Nitrogen				EPA 300.0	0.02	C, B, E
Ammonia-Nitrogen			48 hours	EPA 350.3	0.07	C
Kjeldahl-Nitrogen				EPA 351.4	0.03	C
Nitrite-Nitrogen				EPA 354.1	0.002	C

Inorganics–Nonmetals

Analyte	*Container*	*Preservative*	*Holding Time*	*Analytical Procedure*	*MDL* (mg/L)*	*Analysis Suite*
Bicarbonate	Polyethylene	Ice only	28 days	Calculated	3.0	C
Chloride				EPA 300.0	1.0	C
Conductance				EPA 120.1	–	C
Fluoride				EPA 340.2	0.020	C
pH				EPA 150.1	–	C
Sulfate				EPA 300.0	5.0	C
Total hardness				Calculated	1.0	C, E
Suspended solids				EPA 160.1	3.0	C, E
Dissolved solids				EPA 160.1	10.0	C, E

Pesticides–Gas chromatograph

Analyte	*Container*	*Preservative*	*Holding Time*	*Analytical Procedure*	*MDL* (µg/L)*	*Analysis Suite*
Butylate	Amber glass	Ice only	7 days	EPA 507 & 508	0.40	C
Trifluralin					0.01	
Atrazine					0.30	
Metribuzin					0.01	
Alachlor					0.03	
Linuron					0.10	
Metolachlor					0.05	
Pendimethalin					0.02	
Simazine					0.30	
Malathion					0.05	
Chlorpyrifos					0.007	
Endosulfan I					0.02	
Endosulfan II					0.02	
Permethrin					0.10	
Diazinon					0.10	
Chlorothalonil					0.01	
Cyanazine					0.50	

*As of July 1993

Table B-1. Continued.

Pesticides–Enzyme-linked immunosorbent assay

Analyte	*Container*	*Preservative*	*Holding Time*	*Analytical Procedure*	*MDL (µg/L)*	*Analysis Suite*
Alachlor	Amber glass	Ice only	7 days	KGS water-quality lab	0.06	C, B, E
Metolachlor					0.05	
Triazine					0.06	
Carbofuran					0.07	
2,4-D					0.90	C

Bacteria

Analyte	*Container*	*Preservative*	*Holding Time*	*Analytical Procedure*	*MDL (count)*	*Analysis Suite*
Total coli	Nalgene	Ice only	6 hours	SM 17 9222B	1	T
Fecal coli				SM 17 9222D	1	
Fecal strep				SM 17 9230B	1	

Appendix C:
Analyses of Precipitation and Miscellaneous Quality-Assurance and Quality-Control Samples

Precipitation Samples

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Nitrate (as N) (mg/L)*	*Deployment Duration*
RAIN0001	Jun/4/1992	12:35	< 0.06		< 0.07	< 0.06		1:45 hrs.
RAIN0002	Jul/7/1992	13:43	< 0.06	< 0.08	< 0.07	0.18		21 days
RAIN0003	May/19/1992	8:55	0.68		< 0.07	0.81		17 hrs.
RAIN0004	Jun/1/1993	16:43	0.93	0.55	< 0.07	0.35		12 days
RAIN0005	Jul/1/1993	8:05	< 0.06		< 0.07	0.2	0.28	30 days
RAIN0006	Mar/28/1994	11:40	< 0.07		< 0.08	< 0.08	0.271	21:30 hrs.
RAIN0007	Jun/2/1994	11:56	< 0.07		< 0.08	< 0.08	0.926	1:15 hrs.

Miscellaneous Samples

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Nitrate (as N) (mg/L)*
CAWW0001	Apr/28/1994	7:36	1.4		< 0.08	0.33	2.76
CAWW0002	Apr/28/1994	7:36	1.1	< 0.1	< 0.08	0.17	2.69
LDWW0001	Jun/26/1991	7:23	2.01				6.0
MHWW0001	Jun/24/1993	9:00	3.2		< 0.06	0.28	3.14
MMWW0001	Jul/15/1993	10:50	< 0.06		< 0.07	< 0.06	0.77

Quality-Assurance/Quality-Control Samples

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Nitrate (as N) (mg/L)*
LPDP0090	May/12/1994	10:40	1.3		< 0.08	0.44	5.29
PGDP0306	Dec/8/1993	9:30	1.2		< 0.07	< 0.06	7.45
PGDP0342	Feb/2/1994	12:10	< 0.07				7.32
PGDP0344	Mar/1/1994	11:00	0.72		< 0.08	< 0.08	6.94
PGDP0346	Mar/28/1994	15:57	2.1		< 0.08	0.28	4.97
PGDP0385	Apr/7/1994	14:00	1.9				6.17
PGDP0392	Apr/13/1994	6:15	2.2		< 0.08	0.24	5.58
PGDP0412	Apr/27/1994	10:00	1.8		< 0.08	0.42	3.95
PGDP0463	Jun/1/1994	12:00	1.0		< 0.08	< 0.08	4.2
PGDP0532	Jul/7/1994	7:10	1.1				
PGDP0539	Aug/16/1994	10:00	0.72			< 0.08	4.31
PGEB0215	May/4/1993	13:55		< 0.23			
PGEB0159	Mar/5/1993	10:00		< 0.018			
PGEB0065	Oct/6/1993	12:50		< 0.16			
PGEB0343	Feb/22/1994	11:20	< 0.07	< 0.19	< 0.08	< 0.08	< 0.1
PGEB2901	Mar/2/1994	10:00	< 0.07				< 0.1
PGEB3701	Mar/2/1994	10:00	< 0.07				< 0.1
LPEB3702	Mar/2/1994	14:00	< 0.07				< 0.1
PGEB0364	Mar/28/1994	13:00	< 0.07		< 0.08	< 0.08	< 0.1
PGEB0412	Apr/27/1994	10:00	< 0.06		< 0.08	< 0.08	< 0.1
PGEB0532	Jul/7/1994	7:10	< 0.07				< 0.1
FIBK0002	Apr/29/1992	7:33	< 0.06	< 0.021	< 0.07	< 0.04	
FIBK0306	Dec/8/1993	9:30	< 0.06		< 0.07	< 0.06	< 0.1
FIBK0342	Feb/02/1994	12:10	< 0.07				< 0.1

Sample Number Explanations

RAIN—Precipitation sample
CAWW—City of Adairville Water Works, Russell Law Oper.
MHWW—Water well; see ID number 17174, Appendix E
MMWW—Water well; see ID number 17155, Appendix E
LDWW—Water well; see ID number 11385, Appendix E
LPDP—Duplicate of Leslie Page karst window sample
PGDP—Duplicates of Pleasant Grove Spring samples
PGEB—Equipment blank collected at Pleasant Grove Spring
LPEB—Equipment blank collected at Leslie Page karst window
FIBK—Field blank

APPENDIX D:
SUMMARY OF GROUND-WATER DYE TRACES IN THE PLEASANT GROVE SPRING BASIN STUDY AREA

Adairville Quadrangle

Spring Name: Unknown (probably Masons Spring)

ID Number	*Formation/Member*	*Spring Type*	*Receiving Water Body*	*River Basin*	*Latitude*	*Longitude*	*Elevation*
13793	St. Louis	Gravity	Little Whippoorwill Ck.	LCR	364325.0	865058.0	530.0
Comments: Detected in Little Whippoorwill Creek at Kentucky Highway 663 bridge, approximately 1.5 mi downstream of Masons Spring, the largest spring known between Hobsons Spring and Kentucky Highway 663.							
Researcher	*Injection Point Name*	*Dye Used*	*Dye Injection*	*Bug Recovery*	*Latitude*	*Longitude*	*Elevation*
JCC DK	Tadpole estavelle	Fluorescein	Jun/13/1991	Jun/19/1991	364455.0	865157.0	585.0

Dennis Quadrangle

Spring Name: Hobsons

ID Number	*Formation/Member*	*Spring Type*	*Receiving Water Body*	*River Basin*	*Latitude*	*Longitude*	*Elevation*
13161	St. Louis	Rise pool	Little Whippoorwill Ck.	LCR	364507.0	865123.0	570.0
Comments: About 2,000 ft northeast of intersection U.S. Highway 431 and Kentucky Highway 739.							
Researcher	*Injection Point Name*	*Dye Used*	*Dye Injection*	*Bug Recovery*	*Latitude*	*Longitude*	*Elevation*
JCC CDG	McCaleb karst window	Tinopal CBS-X	Apr/24/1991	Apr/30/1991	364705.0	865145.0	595.0
JCC DG	Scales karst window	Rhodamine WT	Feb/20/1991	Mar/27/1991	364608.0	865130.0	585.0
JCC DK	Greenbriar Cave	Rhodamine WT	Jun/13/1991	Jun/19/1991	364758.0	865111.0	620.0
JCC DK	Crawdad estavelle	Tinopal CBS-X	Jul/11/1991	Aug/21/1991	364719.0	865231.0	615.0
JCC DK	Scales estavelle	Fluorescein	Jul/11/1991	Jul/18/1991	364612.0	865158.0	585.0
DG RM	Unnamed sinkhole	Rhodamine WT	Sep/09/1992	Sep/23/1992	364838.0	865231.5	655.0

Dot Quadrangle

Spring Name: Pleasant Grove

ID Number	*Formation/Member*	*Spring Type*	*Receiving Water Body*	*River Basin*	*Latitude*	*Longitude*	*Elevation*
10795	St. Louis	Rise pool	Pleasant Grove Creek	LCR	364244.0	865419.0	510.0
Comments: Also called Dripping Spring. Perennial discharge from a bedrock cave at 1 to 200 ft^3/s.							
Researcher	*Injection Point Name*	*Dye Used*	*Dye Injection*	*Bug Recovery*	*Latitude*	*Longitude*	*Elevation*
JCC DK	The Canyon	Direct Yellow 96	Apr/18/1991	Apr/23/1991	364451.0	865358.0	550.0
JCC DK	Delaney swallow hole	Rhodamine WT	Apr/18/1991	Apr/23/1991	364425.0	865512.0	540.0
JCC DG	Kemper karst window	Direct Yellow 96	Mar/21/1991	Mar/27/1991	364322.0	865330.0	550.0
JCC DG	Dotson karst window	Fluorescein	Mar/21/1991	Mar/27/1991	364349.0	865441.0	535.0
JCC DK	Harper well	Tinopal CBS-X	Jun/13/1991	Jun/19/1991	364554.0	865333.0	580.0
JCC JA	U. Pleasant Gr. Ck. (UPGC)	Rhodamine WT	Jan/16/1992	Jan/23/1992	364535.0	865450.0	575.0
JCC	Poison Ivy karst window	Fluorescein	Jun/04/1992	Jun/10/1992	364348.0	865242.0	580.0
DG	Harper karst window	Rhodamine WT	Apr/21/1992	May/14/1992	364512.0	865402.5	595.0
JCC EF	Piper estavelle, UPGC	Rhodamine WT	Nov/25/1992	Dec/16/1992	364535.0	865450.0	575.0
JCC DG	Headwaters, UPGC	Rhodamine WT	Jan/21/1993	Feb/03/1993	364713.0	865508.0	595.0
JCC DG	Bob Miller sinkhole	Fluorescein	Jan/20/1993	Jan/28/1993	364435.0	865245.0	585.0
JCC EF	Johnson swallow hole	Rhodamine WT	Mar/24/1993	Apr/01/1993	364305.0	865444.0	520.0
JCC	Wheatfield estavelle	Fluorescein	Apr/22/1993	May/05/1993	364435.0	865337.0	580.0
JCC	Gooch sinkhole	Rhodamine WT	Jan/27/1994	Feb/02/1994	364537.0	865238.0	610.0
JCC	Marvin Dotson sinkhole	Fluorescein	Mar/27/1994	Mar/29/1994	364332.0	865420.0	565.0

Spring Name: Dotson Spring

ID Number	*Formation/Member*	*Spring Type*	*Receiving Water Body*	*River Basin*	*Latitude*	*Longitude*	*Elevation*
13686	St. Louis	Rise pool	Pleasant Grove Creek	LCR	364218.0	865438.0	505.0
Comments: On east bank of Pleasant Grove Creek, west of Stovall Road, and approximately 0.75 mi downstream of Pleasant Grove Spring.							
Researcher	*Injection Point Name*	*Dye Used*	*Dye Injection*	*Bug Recovery*	*Latitude*	*Longitude*	*Elevation*
JCC	Timmie karst window	Direct Yellow 96	Feb/19/1992	Feb/25/1992	364219.0	865418.0	505.0
JCC DG	Travis sinkhole	Fluorescein	Dec/02/1992	Dec/16/1992	364244.0	865234.0	560.0

Spring Name: Campbell blue hole

ID Number	*Formation/Member*	*Spring Type*	*Receiving Water Body*	*River Basin*	*Latitude*	*Longitude*	*Elevation*
13800	St. Louis	Rise pool	Pleasant Grove Creek	LCR	364202.0	865507.0	495.0
Comments: Located 1,000 ft east of Kentucky Highway 96 and 100 ft west of Pleasant Grove Creek.							
Researcher	*Injection Point Name*	*Dye Used*	*Dye Injection*	*Bug Recovery*	*Latitude*	*Longitude*	*Elevation*
JCC DK	Richarson karst window	Direct Yellow 96	Jun/13/1991	Jun/19/1991	364207.0	865558.0	535.0
JCC JA	Trailer karst window	Direct Yellow 96	Jan/16/1992	Jan/23/1992	364217.0	865514.0	540.0

Spring Name: Claude Blick

ID Number	*Formation/Member*	*Spring Type*	*Receiving Water Body*	*River Basin*	*Latitude*	*Longitude*	*Elevation*
13802	St. Louis	Gravity	Whippoorwill Creek	LCR	364253.0	865735.0	495.0
Comments: Located 200 ft west of Kentucky Highway 1041, on east bank of Whippoorwill Creek.							
Researcher	*Injection Point Name*	*Dye Used*	*Dye Injection*	*Bug Recovery*	*Latitude*	*Longitude*	*Elevation*
JCC DK	Roaring well Cave	Rhodamine WT	Jul/11/1991	Jul/18/1991	364258.0	865629.0	540.0

Spring Name: Unknown (probably unnamed spring on Pleasant Grove (Creek)

ID Number	*Formation/Member*	*Spring Type*	*Receiving Water Body*	*River Basin*	*Latitude*	*Longitude*	*Elevation*
13161	St. Louis	Gravity	Pleasant Grove Creek	LCR	364217.0	865450.0	505.0
Comments: Detected in Pleasant Grove Creek at Mortimer Road bridge, approximately 1/8 mile downstream of an unnamed spring on the west bank of Pleasant Grove Creek, less than 100 feet west of an abandoned house. The spring is the largest known on the west bank between Pleasant Grove Spring and Mortimer Road.							
Researcher	*Injection Point Name*	*Dye Used*	*Dye Injection*	*Bug Recovery*	*Latitude*	*Longitude*	*Elevation*
JCC EF	Rodgers sinkhole	Fluorescein	Mar/24/1993	Apr/01/1993	364255.0	865509.0	550.0

Russellville Quadrangle

Spring Name: Steve Blick

ID Number	*Formation/Member*	*Spring Type*	*Receiving Water Body*	*River Basin*	*Latitude*	*Longitude*	*Elevation*
13805	Ste. Genevieve	Gravity	Whippoorwill Creek	LCR	364508.0	865859.0	530
Comments: Located on east bank of Whippoorwill Creek, northwest of intersection of Kentucky Highway 1309, and Kentucky Highway 775, and about 400 ft. west of Kentucky Highway 1309.							
Researcher	*Injection Point Name*	*Dye Used*	*Dye Injection*	*Bug Recovery*	*Latitude*	*Longitude*	*Elevation*
JCC EF	King Cave	Rhodamine WT	Mar/04/1993	Mar/23/1993	364436.0	865715.0	565

Spring Name: Dawson

ID Number	Formation/Member	Spring Type	Receiving Water Body	River Basin	Latitude	Longitude	Elevation
13806	Ste. Genevieve	Gravity	Whippoorwill Creek	LCR	364614.0	865814.0	550
Comments: Located approximately 2,000 ft. west of Kentucky Highway 1041 on east bank of Whippoorwill Creek.							
Researcher	*Injection Point Name*	*Dye Used*	*Dye Injection*	*Bug Recovery*	*Latitude*	*Longitude*	*Elevation*
JCC DK	Hickory Hill Karst W.	Fluorescein	Apr/18/1991	Apr/23/1991	364528.0	865610.0	575
JCC DK	Drinking Cup Cave	Direct Yellow 96	Jul/11/1991	Jul/18/1991	364630.0	865647.0	585
JCC DH	Miles karst window	Tinopal CBS-X	Mar/26/1992	Apr/01/1992	364606.0	865602.0	590
DG	Shackelford sinkhole	Tinopal CBS-X	Apr/21/1992	Apr/30/1992	364619.0	865500.0	585

Spring Name: Spring View

ID Number	Formation/Member	Spring Type	Receiving Water Body	River Basin	Latitude	Longitude	Elevation
13809	Ste. Genevieve	Rise Pool	Dry Fork of Whippoorwill Ck.	LCR	364746.0	865830.0	565
Comments: Located 400 ft south of U.S. Highway 79, and flows into Dry Fork.							
Researcher	*Injection Point Name*	*Dye Used*	*Dye Injection*	*Bug Recovery*	*Latitude*	*Longitude*	*Elevation*
JCC JA	Toon Swallow Hole	Direct Yellow 96	Jan/16/1992	Jan/23/1992	364758.0	865658.0	585
JCC JA	Wilkins karst window	Fluorescein	Jan/16/1992	Jan/23/1992	364814.0	865415.0	615
JCC	Golf Course swallow hole	Rhodamine WT	Feb/19/1992	Feb/25/1992	364855.0	865305.0	645
JCC	Sansom estavelle	Tinopal CBS-X	Feb/19/1992	Feb/25/1992	364827.0	865325.0	635

Spring Name: Thad Flowers blue hole

ID Number	Formation/Member	Spring Type	Receiving Water Body	River Basin	Latitude	Longitude	Elevation
13950	Ste. Genevieve	Rise Pool	Upper Pleasant Grove Creek	LCR	364635.0	865348.0	600
Comments: An estevelle located 2,000 ft east of Kentucky Highway 96 in a grove of trees.							
Researcher	*Injection Point Name*	*Dye Used*	*Dye Injection*	*Bug Recovery*	*Latitude*	*Longitude*	*Elevation*
JCC	Hindman sinkhole	Fluorescein	Feb/16/1993	Mar/03/1993	364653.0	865343.0	610

Appendix E:
Inventory of Water Wells in the Pleasant Grove Spring Basin

Static Water Levels Measured Between June 1 and September 13, 1993

Well ID Number	*Latitude*	*Longitude*	*Total Depth (ft)*	*Elevation (ft)*	*Static Water Level (ft)*
11385	364628	865746	100.0	590	
11485	364220	865435	37.0	530	
11486	364225	865432	92.2	530	23.5
11487	364225	865257	135.0	580	60.0
11488	364230	865250	165.0	580	70.0
11489	364313	865330	17.7	560	17.7
11490	364315	865325		570	
11491	364318	865350	76.6	580	61.8
11492	364328	865405	96.9	575	59.6
11493	364340	865445	91.5	585	71.5
11495	364222	865409		540	
11496	364407	865432		575	
11497	364433	865520		580	
11498	364428	865430	80.0	590	60.0
11499	364452	865408	95.5	600	72.5
11500	364430	865238	46.2	620	22.2
17127	364458	865353	35.0	610	25.0
17128	364445	865317	65.7	600	49.2
17129	364458	865402		590	
17151	364515	865315		600	
17152	364450	865250	100.1	605	54.3
17153	364502	865236	98.0	620	80.0
17154	364452	865232		620	
17155	364500	865238	94.5	620	45.0
17156	364508	865240	31.1	620	26.1
17157	364432	865425		610	
17158	364440	865228	84.2	620	60.0
17159	364456	865228		620	
17160	364448	865235	33.7	615	31.8
17161	364330	865230		620	
17162	364328	865215		600	
17163	364305	865200		610	
17164	364318	865335		600	
17165	364455	865328	63.0	590	30.0
17166	364450	865420		612	
17167	364525	865425		610	
17168	364520	865320	75.0	610	55.0
17169	364250	864450	65.0	560	60.0
17170	364320	865340	69.5	560	36.7
17171	364553	865345		640	
17172	364553	865315	66.0	630	55.0
17173	364535	865255		640	
17174	364530	865250	65.0	620	
17175	364603	865410	64.6	605	23.0
17176	364608	865410		590	8.5
17177	364720	865455	73.8	605	8.5
17178	364630	865400	37.5	610	24.6
17179	364718	865425	104.6	640	29.6

Static Water Levels (Continued)

17180	364715	865423	29.2	620	9.2
17181	364740	865345	135.0	650	
17182	364715	865345		645	
17183	364700	865445		600	
17184	364738	865340		650	
17185	364738	865338		650	
17186	364800	865400		640	
17187	364740	865305		650	
17188	364756	865228	87.1	640	22.2
17189	364638	865258	90.0	640	50.0
17190	364508	865220	42.3	620	33.3
17191	364402	865228	64.0	600	30.0
17192	364510	865225		610	
17193	364456	865215		600	
17194	364455	865215	44.0	620	
17195	364550	865154		610	
17196	364615	865103		600	
17197	364730	865222		625	
17198	364722	865238	87.8	630	31.0
17199	364548	865156		630	
17200	364450	865138		600	
17201	364404	865128	121.3	590	52.5
17202	364447	865127	36.0	587	30.4
17203	364412	865131		595	
17204	364250	865605		600	60.0
17205	364250	865415		550	
17206	364307	865504		570	
17207	364314	865440	90.0	560	
17208	364308	865442		540	
17209	364326	865435	85.0	580	75.0
17210	364402	865504	75.0	560	49.0
17211	364330	865549	60.0	590	40.0
17212	364402	865639	70.0	598	50.0
17213	364407	865640	57.6	570	27.3
17214	364526	865547	80.0	610	70.0
17215	364550	865558		600	
17216	364740	865510		620	
17217	364650	865202		640	
17218	364806	865415		640	
17219	364803	865409	90.8	635	12.5
17220	364719	865404	76.3	630	26.3
17221	364508	865143	79.3	620	46.0
17222	364432	865202		620	
17223	364510	865245		620	
17224	364426	865557		590	
17225	364352	865434		600	
17226	364549	865407	140.0	620	2.0
17227	364643	865427	35.7	610	29.0
17228	364635	865424		600	
17229	364309	865450	48.3	550	41.8

Static Water Levels (Continued)

17230	364552	865322		630	
17231	364617	865457		615	
17232	364616	865502		615	
17233	364615	865457		615	
17234	364514	865144		620	
17235	364420	865639		575	
17236	364306	865553		610	
17237	364830	865548	22.4	610	11.3
17238	364427	865630	85.3	580	50.0
17239	364827	865551		640	
17240	364827	865553		630	46.0
17241	364830	865550	45.8	630	33.9
17242	364814	865324		640	39.2

Appendix F:
Field Water-Quality Measurements and Descriptive Statistics for the Pleasant Grove Spring Drainage Basin

Pleasant Grove Spring, August 1990–September 1991

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
PGSP0001	Aug/02/1990	11:15	6.49	493	14.6
PGSP0002	Feb/28/1991	9:55	5.90	349	12.2
PGSP0003	May/01/1991	10:10	6.50	418	14.4
PGSP0004	May/22/1991	11:30	6.38	390	15.2
PGSP0005	Jun/26/1991	9:42	6.19	326	15.3
PGSP0006	Jul/25/1991	10:15	6.54	423	15.1
PGSP0007	Aug/29/1991	12:30	6.10	356	15.1
PGSP0008	Sep/24/1991	9:30	6.60	422	14.6
		Average*	6.34	397	14.6
		Maximum	6.60	493	15.3
		Minimum	5.90	326	12.2
		Stand. Dev.	0.25	53.5	1.0
		Coef. Var.	0.04	0.1	0.1
Total of 8 observations					

Spring Valley karst window, August 1990–September 1991

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
SVKW0001	Aug/02/1990	10:00	6.32	478	14.3
SVKW0002	Feb/28/1991	11:00	6.75	349	12.0
SVKW0003	May/22/1991	12:17	6.42	384	14.9
SVKW0004	Jun/26/1991	11:00	6.50	331	15.2
SVKW0005	Jul/25/1991	9:30	6.60	424	14.8
SVKW0006	Aug/29/1991	11:35	6.35	349	14.7
SVKW0007	Sep/24/1991	8:40	6.60	411	14.4
		Average*	6.51	389	14.3
		Maximum	6.75	478	15.2
		Minimum	6.32	331	12.0
		Stand. Dev.	0.15	52.0	1.1
		Coef. Var.	0.02	0.1	0.1
Total of 7 observations					

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

The Canyon karst window, August 1990–September 1991

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
TCKW0001	Aug/02/1990	9:00	5.97	370	14.1
TCKW0002	May/01/1991	8:45	6.30	408	13.6
TCKW0003	May/22/1991	9:30	6.40	386	14.4
TCKW0004	Jun/26/1991	7:45	6.52	349	14.4
TCKW0005	Jul/25/1991	8:24	6.30	405	14.4
TCKW0006	Aug/29/1991	10:45	6.38	335	14.5
TCKW0007	Sep/24/1991	7:40	6.42	400	14.4
		Average*	6.33	379	14.3
		Maximum	6.52	408	14.5
		Minimum	5.97	335	13.6
		Stand. Dev.	0.17	28.6	0.3
		Coef. Var.	0.03	0.1	
Total of 7 observations					

Shackelford Spring, August 1990–September 1991

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
SKSP0001	Aug/02/1990	7:10	6.10	486	15.9
SKSP0002	Feb/28/1991	13:25	6.83	384	12.7
SKSP0003	May/01/1991	7:05	6.70	411	12.8
SKSP0004	May/22/1991	7:45	6.46	418	13.6
SKSP0005	Jul/25/1991	7:20	6.58	428	16.1
SKSP0006	Aug/29/1991	10:00	6.54	348	17.3
SKSP0007	Sep/24/1991	6:40	6.20	394	17.7
		Average*	6.49	410	15.2
		Maximum	6.83	486	17.7
		Minimum	6.10	348	12.7
		Stand. Dev.	0.26	42.7	2.1
		Coef. Var.	0.04	0.1	0.1
Total of 7 observations					

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Thad Flowers blue hole, August 1990–September 1991

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
TFBH0001	Feb/28/1991	12:05	6.80	356	13.8
TFBH0002	May/01/1991	7:45	6.64	399	13.2
TFBH0003	May/22/1991	6:50	6.06	397	13.0
TFBH0004	Jun/26/1991	7:15	6.35	386	19.8
TFBH0005	Jul/25/1991	11:10	6.92	506	22.6
TFBH0006	Aug/29/1991	9:25	6.01	110	23.0
		Average*	6.46	359	17.6
		Maximum	6.92	506	23.0
		Minimum	6.01	110	13.0
		Stand. Dev.	0.38	132.2	4.8
		Coef. Var.	0.06	0.4	0.3
Total of 6 observations					

George Delaney swallow hole, August 1990–September 1991

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
GDSW0001	May/22/1991	10:30	7.00	432	16.8
GDSW0002	Jun/26/1991	8:50	6.70	372	17.3
GDSW0003	Jul/25/1991	8:55	7.19	438	20.2
		Average*	6.96	414	18.1
		Maximum	7.19	438	20.2
		Minimum	6.70	372	16.8
Total of 3 observations					

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
PGSP0009	Oct/22/1991	8:50	6.55	483	14.4
PGSP0010	Dec/17/1991	8:06	6.14	438	12.6
PGSP0011	Jan/29/1992	11:00	6.56	557	13.2
PGSP0012	Feb/26/1992	12:15	6.12	505	13.4
PGSP0013	Mar/25/1992	13:20	7.04	334	13.4
PGSP0014	Apr/01/1992	16:16	6.96	295	13.9
PGSP0015	Apr/09/1992	15:28	6.96	304	14.5
PGSP0021	Apr/29/1992	9:40	7.23		15.7
PGSP0026	May/27/1992	10:45	7.12	325	14.5
PGSP0027	Jun/03/1992	15:45	7.19	412	14.3
PGSP0052	Jun/04/1992	17:15	7.09	316	14.7
PGSP0053	Jun/10/1992	13:20	7.21	400	14.7
PGSP0054	Jun/18/1992	9:30	7.07	352	14.9
PGSP0062	Aug/26/1992	11:30	7.04	365	15.3
		Average*	6.88	391	14.5
		Maximum	7.73	557	15.7
		Minimum	6.12	295	12.6
		Stand. Dev.	0.38	83.6	0.9
		Coef. Var.	0.06	0.2	0.10
Total of 14 observations					

Spring Valley karst window, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
SVKW0008	Oct/22/1991	8:00	6.33	483	14.2
SVKW0009	Jan/29/1992	10:00	6.09	555	13.3
SVKW0010	Feb/26/1992	11:00	6.76	505	13.3
SVKW0011	Mar/25/1992	10:55	6.93	351	13.3
SVKW0013	Apr/29/1992	8:40	7.10		16.0
SVKW0014	May/27/1992	9:15	7.16	300	18.1
		Average*	6.73	439	14.7
		Maximum	7.16	555	18.1
		Minimum	6.09	300	13.3
		Stand. Dev.	0.43	108.2	2.0
		Coef. Var.	0.06	0.2	0.1
Total of 6 observations					

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

The Canyon karst window, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
TCKW0008	Dec/17/1991	11:30	6.36	462	13.2
TCKW0009	Jan/29/1992	8:30	6.01	559	14.0
TCKW0010	Feb/26/1992	9:45	6.56	508	14.1
TCKW0011	Mar/25/1992	12:00	6.99	356	14.1
TCKW0013	Apr/29/1992	7:40	7.04		14.6
TCKW0014	May/27/1992	10:05	6.92	310	17.6
		Average*	6.65	439	14.6
		Maximum	7.04	559	17.6
		Minimum	6.01	310	13.2
		Stand. Dev.	0.41	103.9	1.5
		Coef. Var.	0.06	0.2	0.1
Total of 6 observations					

Shackelford Spring, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
SKSP0008	Oct/22/1991	6:34	6.24	473	17.3
SKSP0009	Dec/17/1991	12:00	6.15	492	14.5
SKSP0010	Jan/29/1992	14:30	6.37	534	13.0
SKSP0011	Feb/26/1992	8:40	5.37	465	12.0
SKSP0012	Mar/25/1992	8:40	7.10	413	12.4
SKSP0013	Apr/29/1992	6:43	7.25		12.6
SKSP0014	May/27/1992	11:50	7.16	280	16.5
		Average*	6.52	443	14.0
		Maximum	7.25	534	17.3
		Minimum	5.37	280	12.0
		Stand. Dev.	0.69	88.9	2.1
		Coef. Var.	0.11	0.2	0.2
Total of 7 observations					

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Thad Flowers blue hole, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
TFBH0007	Dec/17/1991	13:30	6.24	446	14.4
TFBH0008	Jan/29/1992	7:50	6.81	440	6.5
TFBH0009	Feb/26/1992	7:30	6.86	342	7.5
TFBH0010	Mar/25/1992	7:20	7.30	337	13.0
		Average*	6.80	391	10.4
		Maximum	7.30	446	14.4
		Minimum	6.24	337	6.5
		Stand. Dev.	0.43	59.8	3.9
		Coef. Var.	0.06	0.2	0.4
Total of 4 observations					

George Delaney swallow hole, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
GDSW0004	Dec/17/1991	10:00	6.83	408	9.8
GDSW0005	Jan/29/1992	9:10	6.91	469	7.9
GDSW0006	Feb/26/1992	10:20	7.42	415	7.8
GDSW0007	Mar/25/1992	9:45	7.71	389	10.7
		Average*	7.22	420	9.1
		Maximum	7.71	469	10.7
		Minimum	6.83	389	7.8
		Stand. Dev.	0.42	34.3	1.4
		Coef. Var.	0.06	0.1	0.2
Total of 4 observations					

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
PGSP0065	Oct/06/1992	12:50	7.14	382	16.1
PGSP0067	Nov/06/1992	9:00	6.93	643	14.3
PGSP0070	Dec/03/1992	9:07	7.43	709	14.1
PGSP0071	Jan/08/1993	10:19	6.62	481	13.0
PGSP0108	Feb/04/1993	10:00	7.40	536	13.0
PGSP0159	Mar/05/1993	10:00	7.20	250	12.2
PGSP0211	Apr/07/1993	8:22	7.18	468	14.1
PGSP0215	May/04/1993	13:55	6.87	226	14.7
PGSP0255	May/20/1993	9:42	7.23	744	14.5
PGSP0264	Jun/02/1993	14:30	7.26	420	14.7
PGSP0299	Aug/04/1993	9:00	7.16	642	14.6
PGSP0302	Sep/09/1993	7:30	7.24	484	14.8
		Average*	7.14	499	14.2
		Maximum	7.43	744	16.1
		Minimum	6.62	226	12.2
		Stand. Dev.	0.23	166.4	1.0
		Coef. Var.	0.03	0.3	0.1
Total of 12 observations					

Spring Valley karst window, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
SVKW0015	May/20/1993	9:20	7.20	565	14.7
SVKW0017	Jun/02/1993	12:55	7.25	337	14.6
		Average*	7.23	451	14.7
Total of 2 observations					

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

George Delaney swallow hole, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
GDSW0009	May/20/1993	8:14	7.00	533	14.5
GDSW010A	Jun/03/1993	8:45	7.78	431	16.2
		Average*	7.39	482	15.4
Total of 2 observations					

Leslie Page karst window, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
LPKW0009	May/20/1993	11:10	7.60	157	13.9
LPKW010A	Jun/02/1993	16:50	7.40	208	14.7
LPKW0014	Jun/30/1993	9:45	7.65	229	15.9
		Average*	7.56	180	14.6
		Maximum	7.65	229	15.9
		Minimum	7.40	125	13.9
Total of 3 observations					

Upper Pleasant Grove Creek, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
UPGC0002	Jun/30/1993	9:10	7.65	387	21.4
UPGC0003	Aug/03/1993	15:33	8.52	414	28.2
		Average*	8.09	401	24.8
Total of 2 observations					

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
PGSP0303	Oct/06/1993	7:30	7.13	421	14.4
PGSP0304	Nov/09/1993	10:45	7.36	347	14.0
PGSP0334	Jan/12/1994	11:40	7.11	390	12.1
PGSP0342	Feb/02/1994	12:10	7.13	237	11.8
PGSP0343	Feb/22/1994	11:20	7.00	202	13.0
PGSP0344	Mar/01/1994	11:00	7.45	136	12.7
PGSP0364	Mar/28/1994	13:00	7.01	200	12.3
PGSP	Apr/20/1994	11:15	7.10	173	14.4
PGSP0410	Apr/26/1994	6:00	7.21	374	15.0
PGSP0412	Apr/27/1994	10:00	7.25	356	15.6
PGSP0413	Apr/28/1994	6:00	7.23	352	15.8
PGSP0449	May/12/1994	9:00	7.19	392	14.5
PGSP	May/17/1994	13:57	7.13	417	16.5
PGSP0463	Jun/01/1994	12:00	7.23	423	14.3
PGSP0529	Jul/06/1994	10:30		350	
PGSP0538	Aug/03/1994	8:30	6.93	360	14.5
		Average*	7.16	321	14.1
		Maximum	7.45	423	16.5
		Minimum	6.93	136	11.8
		Stand. Dev.	0.13	96.4	1.4
		Coef. Var.	0.02	0.3	0.1
Total of 16 observations					

George Delaney swallow hole, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
GDSW0013	Mar/28/1994	10:40		190	10.1
GDSW0015	Apr/20/1994	12:10	7.80	191	16.1
GDSW0016	Apr/26/1994	15:30	8.14	376	19.3
GDSW0017	May/12/1994	9:50	7.90	408	15.0
GDSW0018	May/17/1994	13:28	7.92	426	18.0
GDSW0019	Jun/01/1994	7:36	7.65	406	16.1
GDSW0021	Jul/06/1994	9:45		400	
		Average*	7.88	342	15.8
		Maximum	8.14	426	19.3
		Minimum	7.65	190	10.1
		Stand. Dev.	0.18	104.8	3.2
		Coef. Var.	0.02	0.3	0.2
Total of 7 observations					

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Leslie Page karst window, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
LPKW0019	Oct/05/1993	13:20	7.70	167	15.1
LPKW0020	Nov/09/1993	9:35	7.75	121	12.5
LPKW0022	Jan/11/1994	14:23	6.70	124	14.1
LPKW0023	Feb/02/1994	9:55	6.92	20	12.5
LPKW0024	Feb/22/1994	13:30	6.21	40	14.0
LPKW0080	Apr/27/1994	8:31	6.94	219	14.0
LPKW0090	May/12/1994	10:40	6.53	176	14.0
LPKW	May/17/1994	12:48	7.05	198	16.5
LPKW0104	Jun/01/1994	8:30	6.62	241	13.8
LPKW0106	Jun/27/1994	23:50		230	
LPKW0109	Aug/02/1994	14:20	6.41	209	14.9
		Average*	6.88	159	14.1
		Maximum	7.75	241	16.5
		Minimum	6.21	20	12.5
		Stand. Dev.	0.51	74.8	1.2
		Coef. Var.	0.07	0.5	0.1
Total of 11 observations					

Upper Pleasant Grove Creek, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
UPGC0006	Feb/22/1994	15:16	7.50	162	11.0
UPGC0007	Mar/28/1994	11:05		185	11.5
UPGC0009	Apr/20/1994	12:25	7.88	175	19.5
UPGC0010	Apr/27/1994	7:10	7.63	380	15.8
UPGC0011	May/12/1994	10:10	7.84	408	17.0
UPGC0012	May/17/1994	12:13	8.03	416	22.0
UPGC0013	Jun/01/1994	7:07	7.77	437	15.1
UPGC0015	Jul/06/1994	7:30		365	
		Average*	7.78	316	16.0
		Maximum	8.03	437	22.0
		Minimum	7.50	162	11.0
		Stand. Dev.	0.19	119.7	4.0
		Coef. Var.	0.02	0.4	0.2
Total of 8 observations					

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Miller School House water well, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Field pH*	*Field Specific Conductance (at 25°C) (µS)*	*Water Temperature (°C)*
MSHW0001	Apr/26/1994	14:00	7.43	615	15.5
Total of 1 observation					

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

APPENDIX G:
WATER SAMPLE ANALYSES AND DESCRIPTIVE STATISTICS FOR THE PLEASANT GROVE SPRING DRAINAGE BASIN

Pleasant Grove Spring, August 1990–September 1991

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
PGSP0001	Aug/02/1990	11:15	4.10				
PGSP0002	Feb/28/1991	9:55	4.50	< 0.01	0.080	< 0.030	< 0.010
PGSP0003	May/01/1991	10:10	4.80	0.011	0.080	< 0.030	0.020
PGSP0004	May/22/1991	11:30	4.30	0.036	0.040	< 0.030	0.048
PGSP0005	Jun/26/1991	9:42	4.20	0.006	0.030	< 0.030	0.048
PGSP0006	Jul/25/1991	10:15	4.20	0.003	0.030	< 0.030	0.050
PGSP0007	Aug/29/1991	12:30	3.82	0.003	0.020	< 0.030	0.040
PGSP0008	Sep/24/1991	9:30	3.57				0.048
		Average*	4.19	0.012	0.047		0.038
		Maximum	4.80	0.036	0.080	< 0.030	0.050
		Minimum	3.57	0.003	0.020		< 0.010
		Stand. Dev.	0.38	0.011	0.027		0.016
		Coef. Var.	0.09	0.917	0.570		0.427
Number of analyses: 8							

Spring Valley karst window, August 1990–September 1991

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
SVKW0001	Aug/02/1990	10:00	4.10				
SVKW0002	Feb/28/1991	11:00	4.70	< 0.01	0.120	< 0.030	< 0.010
SVKW0003	May/22/1991	12:17	4.50	0.031	0.030	< 0.030	0.053
SVKW0004	Jun/26/1991	11:00	4.20	0.005	0.050	< 0.030	0.046
SVKW0005	Jul/25/1991	9:30	4.20	0.006	0.030	< 0.030	0.066
SVKW0006	Aug/29/1991	11:35	3.80	0.003	0.010	< 0.030	0.045
SVKW0007	Sep/24/1991	8:40	3.57				0.043
		Average*	4.15	0.011	0.048		0.044
		Maximum	4.70	0.031	0.120	< 0.030	0.066
		Minimum	3.57	0.003	0.010		< 0.010
		Stand. Dev.	0.39	0.010	0.043		0.019
		Coef. Var.	0.09	0.932	0.889		0.424
Number of analyses 7							

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

The Canyon karst window, August 1990–September 1991

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
TCKW0001	Aug/02/1990	9:00	3.90				
TCKW0002	May/01/1991	8:45	3.50	0.005	0.010	< 0.030	0.029
TCKW0003	May/22/1991	9:30	2.70	0.008	0.040	< 0.030	0.049
TCKW0004	Jun/26/1991	7:45	3.70	0.003	0.030	< 0.030	0.032
TCKW0005	Jul/25/1991	8:24	3.90	0.004	0.030	< 0.030	0.046
TCKW0006	Aug/29/1991	10:45	3.62	0.004	0.030	< 0.030	0.042
TCKW0007	Sep/24/1991	7:40	3.46				0.046
		Average*	3.54	0.005	0.028		0.041
		Maximum	3.90	0.008	0.040	< 0.030	0.049
		Minimum	2.70	0.003	0.010		0.049
		Stand. Dev.	0.41	0.002	0.011		0.008
		Coef. Var.	0.12	0.344	0.391		0.203
Number of analyses 7							

Shackelford Spring, August 1990–September 1991

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
SKSP0001	Aug/02/1990	7:10	7.10				
SKSP0002	Feb/28/1991	13:25	7.00	< 0.01	0.090	< 0.030	< 0.010
SKSP0003	May/01/1991	7:05	7.60	0.004	0.090	< 0.030	0.024
SKSP0004	May/22/1991	7:45	7.40	0.006	0.040	< 0.030	0.038
SKSP0005	Jul/25/1991	7:20	8.20	0.002	0.060	< 0.030	0.055
SKSP0006	Aug/29/1991	10:00	7.04	0.003	0.010	< 0.030	0.058
SKSP0007	Sep/24/1991	6:40	6.43				0.057
		Average*	7.25	0.005	0.058		0.040
		Maximum	8.20	0.006	0.090	< 0.030	0.058
		Minimum	6.43	0.002	0.010		< 0.010
		Stand. Dev.	0.56	0.003	0.034		0.020
		Coef. Var.	0.08	0.566	0.590		0.496
Number of analyses 7							

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Thad Flowers blue hole, August 1990–September 1991

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
TFBH0001	Feb/28/1991	12:05	6.40		0.050	< 0.030	< 0.010
TFBH0002	May/01/1991	7:45	7.00	0.013	0.050	< 0.030	0.008
TFBH0003	May/22/1991	6:50	6.80	0.010	0.070	0.300	0.024
TFBH0004	Jun/26/1991	7:15	4.60	0.426	0.300	< 0.030	0.049
TFBH0005	Jul/25/1991	11:10	0.02	0.007	4.460	0.090	0.062
TFBH0006	Aug/29/1991	9:25	1.04	0.208	1.020	< 0.030	0.477
		Average*	4.31	0.133	0.992	0.085	0.105
		Maximum	7.00	0.426	4.460	0.300	0.477
		Minimum	0.02	0.007	0.050	< 0.030	< 0.010
		Stand. Dev.	3.06	0.165	1.740		0.184
		Coef. Var.	0.71	1.244	1.754		1.748
Number of analyses 6							

George Delaney swallow hole, August 1990–September 1991

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
GDSW0001	May/22/1991	10:30	6.70	0.058	0.050	< 0.030	0.040
GDSW0002	Jun/26/1991	8:50	5.70	0.034	0.050	< 0.030	0.033
GDSW0003	Jul/25/1991	8:55	4.30	0.171	0.120	< 0.030	0.074
		Average*	5.57	0.088	0.073		0.049
		Maximum	6.70	0.171	0.120	< 0.030	0.074
		Minimum	4.30	0.034	0.050		0.033
Number of analyses 3							

Pleasant Grove Spring, August 1990–September 1991

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
PGSP0001	7.16	468	219	278	5	0.106
PGSP0002	7.02	363	150	194	26	0.688
PGSP0003	7.15	397	174	256	9	0.128
PGSP0004	7.08	365	160	254	33	0.772
PGSP0005	6.98	357	154	230	18	1.230
PGSP0006	6.71	440	200	238	8	0.213
PGSP0007	6.48	481	224	310	3	0.058
PGSP0008	6.93	489	232	308	4	0.046
Average*	6.94	420	189.13	259	13.25	0.405
Maximum	7.16	489	232	310	33	1.230
Minimum	6.48	357	150	194	3	0.046
Stand. Dev.	0.23	56.0	33.61	39.5	11.21	0.439
Coef. Var	0.03	0.1	0.18	0.2	0.85	1.083
Number of analyses 8						

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Spring Valley karst window, August 1990–September 1991

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
SVKW0001	7.12	466	218	283	4	0.134
SVKW0002	7.08	362	150	194	32	0.778
SVKW0003	7.18	369	162	252	40	1.100
SVKW0004	7.10	359	156	232	16	0.788
SVKW0005	6.73	441	199	250	8	0.279
SVKW0006	6.55	479	222	306	5	0.384
SVKW0007	6.93	489	231	284	5	0.194
Average*	6.96	424	191.14	257	15.71	0.522
Maximum	7.18	489	231	306	40	1.100
Minimum	6.55	359	150	194	4	0.134
Stand. Dev.	0.23	58.3	34.40	37.6	14.61	0.367
Coef. Var.	0.03	0.1	0.18	0.1	0.93	0.702
Number of analyses 7						

The Canyon karst window, August 1990–September 1991

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
TCKW0001	7.11	450	212	276	16	0.558
TCKW0002	7.00	395	179	222	34	0.424
TCKW0003	6.99	367	168	214	94	2.650
TCKW0004	7.00	387	174	250	23	0.692
TCKW0005	6.71	427	194	238	24	0.600
TCKW0006	6.62	458	213	296	26	0.750
TCKW0007	7.03	467	221	276	56	2.430
Average*	6.92	422	194.43	253	39.00	1.158
Maximum	7.11	467	221	296	94	2.650
Minimum	6.62	367	168	214	16	0.424
Stand. Dev.	0.18	39.0	21.27	30.6	27.44	0.952
Coef. Var.	0.03	0.1	0.11	0.1	0.70	0.822
Number of analyses 7						

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Shackelford Spring, August 1990–September 1991

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
SKSP0001	7.20	443	212	299	4	0.147
SKSP0002	6.98	392	150	212	8	0.118
SKSP0003	7.09	407	163	264	6	0.123
SKSP0004	7.16	406	162	316	40	0.012
SKSP0005	6.88	433	168	296	7	0.303
SKSP0006	6.66	444	178	298	5	1.040
SKSP0007	7.08	444	184	270	27	0.388
Average*	7.01	424	173.86	279	13.86	0.304
Maximum	7.20	444	212	316	40	1.040
Minimum	6.66	392	150	212	4	0.012
Stand. Dev.	0.19	21.9	20.15	34.7	13.99	0.348
Coef. Var.	0.03	0.1	0.12	0.1	1.01	1.143
Number of analyses 7						

Thad Flowers blue hole, August 1990–September 1991

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
TFBH0001	6.92	360	129	202	3	0.014
TFBH0002	7.15	390	154	268	3	0.028
TFBH0003	7.02	382	150	304	4	0.126
TFBH0004	7.04	372	151	260	6	0.123
TFBH0005	7.12	437	203	232	8	1.010
TFBH0006	6.33	121	37	164	420	
Average*	6.93	344	137.33	238	74.00	0.260
Maximum	7.15	437	203	304	420	1.010
Minimum	6.33	121	37	164	3	0.014
Stand. Dev.	0.30	112.2	54.91	50.1	169.52	0.422
Coef. Var.	0.04	0.3	0.40	0.2	2.29	1.623
Number of analyses 6						

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

George Delaney swallow hole, August 1990–September 1991

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
GDSW0001	7.60	385	154	308	16	0.146
GDSW0002	7.02	381	157	244	14	0.375
GDSW0003	7.48	411	177	268	36	1.390
Average*	7.37	392	162.67	273	22.00	0.637
Maximum	7.60	411	177	308	36	1.390
Minimum	7.02	381	154	244	14	0.146
Number of analyses 3						

Pleasant Grove Spring, August 1990–September 1991

Sample Number	*Total Calcium (mg/L as Ca)*	*Total Magnesium (mg/L as Mg)*	*Total Sodium (mg/L as Na)*	*Total Potassium (mg/L as K)*	*Bicarbonate (mg/L as HCO_3^-)*	*Total Sulfate (mg/L as SO_4^{-2})*	*Dissolved Chloride (mg/L as Cl)*
PGSP0001	78.10	7.59	2.18	1.32	267	5.48	5.01
PGSP0002	62.90	5.57	2.08	1.66	183	5.00	6.13
PGSP0003	68.20	6.15	2.21	1.12	212	10.90	5.86
PGSP0004	65.60	5.93	2.11	1.26	195	5.62	5.18
PGSP0005	64.30	5.98	1.89	1.91	188	5.00	5.00
PGSP0006	76.60	7.40	2.18	1.17	244	5.40	5.28
PGSP0007	88.00	8.46	2.26	1.15	273	7.53	4.65
PGSP0008	85.90	8.37	2.17	1.22	283	5.82	4.33
Average*	73.70	6.93	2.14	1.35	230.63	6.34	5.18
Maximum	88.00	8.46	2.26	1.91	283	10.90	6.13
Minimum	62.90	5.57	1.89	1.12	183	5.00	4.33
Stand. Dev.	9.87	1.16	0.11	0.28	40.96	2.01	0.59
Coef. Var.	0.13	0.17	0.05	0.21	0.18	0.32	0.11
Number of analyses 8							

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Spring Valley karst window, August 1990–September 1991

Sample Number	*Total Calcium (mg/L as Ca)*	*Total Magnesium (mg/L as Mg)*	*Total Sodium (mg/L as Na)*	*Total Potassium (mg/L as K)*	*Bicarbonate (mg/L as HCO_3^-)*	*Total Sulfate (mg/L as SO_4^{-2})*	*Dissolved Chloride (mg/L as Cl)*
SVKW0001	80.10	7.99	2.25	1.32	266	5.50	4.88
SVKW0002	63.50	5.68	2.10	1.43	183	5.00	5.94
SVKW0003	66.70	6.07	2.14	1.07	198	5.46	5.34
SVKW0004	64.40	6.05	1.95	1.51	190	5.00	5.12
SVKW0005	77.40	7.54	2.17	1.27	243	5.06	5.17
SVKW0006	85.70	8.50	2.20	1.11	271	5.00	4.62
SVKW0007	84.00	8.44	2.15	1.38	282	5.84	4.15
Average*	74.54	7.18	2.14	1.30	233.29	5.27	5.03
Maximum	85.70	8.50	2.25	1.51	282	5.84	5.94
Minimum	63.50	5.68	1.95	1.07	183	5.00	4.15
Stand. Dev.	9.48	1.22	0.10	0.16	42.05	0.34	0.57
Coef. Var.	0.13	0.17	0.04	0.12	0.18	0.06	0.11
Number of analyses 7							

The Canyon karst window, August 1990–September 1991

Sample Number	*Total Calcium (mg/L as Ca)*	*Total Magnesium (mg/L as Mg)*	*Total Sodium (mg/L as Na)*	*Total Potassium (mg/L as K)*	*Bicarbonate (mg/L as HCO_3^-)*	*Total Sulfate (mg/L as SO_4^{-2})*	*Dissolved Chloride (mg/L as Cl)*
TCKW0001	78.70	7.49	2.19	1.32	258	0.00	4.26
TCKW0002	70.70	6.06	1.98	1.15	218	9.06	4.82
TCKW0003	67.50	6.51	1.95	1.46	205	5.94	4.38
TCKW0004	73.40	6.18	1.99	1.28	212	5.00	4.77
TCKW0005	75.60	7.16	2.11	1.15	236	5.00	4.80
TCKW0006	85.00	8.17	2.24	1.31	260	5.00	4.42
TCKW0007	81.40	8.23	2.28	1.10	269	5.25	4.05
Average*	76.04	7.11	2.11	1.25	236.86	5.04	4.50
Maximum	85.00	8.23	2.28	1.46	269	9.06	4.82
Minimum	67.50	6.06	1.95	1.10	205	0.00	4.05
Stand. Dev.	6.12	0.90	0.13	0.13	25.84	2.66	0.30
Coef. Var.	0.08	0.13	0.06	0.10	0.11	0.53	0.07
Number of analyses 7							

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Shackelford Spring, August 1990–September 1991

Sample Number	*Total Calcium (mg/L as Ca)*	*Total Magnesium (mg/L as Mg)*	*Total Sodium (mg/L as Na)*	*Total Potassium (mg/L as K)*	*Bicarbonate (mg/L as HCO_3^-)*	*Total Sulfate (mg/L as SO_4^{-2})*	*Dissolved Chloride (mg/L as Cl)*
SKSP0001	74.30	5.59	3.17	1.32	258	6.59	9.60
SKSP0002	69.10	5.45	2.66	1.30	182	5.69	7.74
SKSP0003	71.30	5.54	2.87	1.10	199	10.60	8.60
SKSP0004	72.40	5.65	2.88	0.93	198	7.11	8.67
SKSP0005	75.80	5.81	3.23	1.05	205	6.04	9.45
SKSP0006	77.70	5.99	3.08	1.07	217	12.60	9.53
SKSP0007	76.30	6.00	2.96	1.18	224	8.76	9.52
Average*	73.84	5.72	2.98	1.14	211.86	8.20	9.02
Maximum	77.70	6.00	3.23	1.32	258	12.60	9.60
Minimum	69.10	5.45	2.66	0.93	182	5.69	7.74
Stand. Dev.	3.05	0.22	0.20	0.14	24.49	2.59	0.70
Coef. Var.	0.04	0.04	0.07	0.12	0.12	0.32	0.08
Number of analyses 7							

Thad Flowers blue hole, August 1990–September 1991

Sample Number	*Total Calcium (mg/L as Ca)*	*Total Magnesium (mg/L as Mg)*	*Total Sodium (mg/L as Na)*	*Total Potassium (mg/L as K)*	*Bicarbonate (mg/L as HCO_3^-)*	*Total Sulfate (mg/L as SO_4^{-2})*	*Dissolved Chloride (mg/L as Cl)*
TFBH0001	62.10	4.51	2.91	0.76	157	8.48	10.40
TFBH0002	67.20	4.73	3.19	0.66	188	15.30	10.80
TFBH0003	64.60	4.58	3.17	0.93	183	7.05	10.30
TFBH0004	68.80	4.77	3.10	1.60	184	7.14	9.52
TFBH0005	72.10	5.21	3.08	3.01	248	6.20	10.40
TFBH0006	1.00	1.00	1.00	1.00	45	14.40	2.00
Average*	66.96	4.76	3.09	1.39	167.50	9.76	8.90
Maximum	72.10	5.21	3.19	3.01	248	15.30	10.80
Minimum	62.10	4.51	2.91	0.66	45	6.20	2.00
Stand. Dev.	3.84	0.27	0.11	0.98	67.13	4.02	3.41
Coef. Var.	0.06	0.06	0.04	0.70	0.40	0.41	0.38
Number of analyses 6							

George Delaney swallow hole, August 1990–September 1991

Sample Number	*Total Calcium (mg/L as Ca)*	*Total Magnesium (mg/L as Mg)*	*Total Sodium (mg/L as Na)*	*Total Potassium (mg/L as K)*	*Bicarbonate (mg/L as HCO_3^-)*	*Total Sulfate (mg/L as SO_4^{-2})*	*Dissolved Chloride (mg/L as Cl)*
GDSW0001	68.20	5.36	3.04	0.93	188	6.48	8.45
GDSW0002	71.60	5.82	2.75	1.26	191	6.31	7.81
GDSW0003	71.50	6.45	2.75	1.81	216	6.01	8.04
Average*	70.43	5.88	2.85	1.33	198.33	6.27	8.10
Maximum	71.60	6.45	3.04	1.81	216	6.48	8.45
Minimum	68.20	5.36	2.75	0.93	188	6.01	7.81
Number of analyses 3							

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_{2-})*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
PGSP0009	Oct/22/1991	8:50	3.69				0.037
PGSP0010	Dec/17/1991	8:06	5.25				0.049
PGSP0011	Jan/29/1992	11:00	4.77				0.030
PGSP0012	Feb/26/1992	12:15	4.54				0.034
PGSP0013	Mar/25/1992	13:20	5.00				0.027
PGSP0014	Apr/01/1992	16:16	5.00				
PGSP0015	Apr/09/1992	15:28	4.75				
PGSP0016	Apr/16/1992	10:30	4.66				
PGSP0017	Apr/20/1992	18:55	4.66				
PGSP0018	Apr/21/1992	8:30	4.50				
PGSP0019	Apr/21/1992	17:55	4.54				
PGSP0020	Apr/22/1992	7:37	4.59				
PGSP0021	Apr/29/1992	9:40	4.38				0.034
PGSP0022	May/07/1992	12:30	4.32				
PGSP0023	May/14/1992	8:30	4.30				
PGSP0024	May/20/1992	7:35	5.79				
PGSP0025	May/20/1992	14:30					
PGSP0026	May/27/1992	10:45	5.18				0.035
PGSP0027	Jun/03/1992	15:45	5.83				0.049
PGSP0028	Jun/04/1992	2:58	4.76				
PGSP0029	Jun/04/1992	3:18	4.71				
PGSP0030	Jun/04/1992	3:38	4.75				
PGSP0031	Jun/04/1992	3:58	4.77				
PGSP0032	Jun/04/1992	4:18	4.64				
PGSP0033	Jun/04/1992	4:38	4.24				
PGSP0034	Jun/04/1992	4:58	3.38				
PGSP0035	Jun/04/1992	5:18	3.72				
PGSP0036	Jun/04/1992	5:38	3.87				
PGSP0037	Jun/04/1992	5:58	3.96				
PGSP0038	Jun/04/1992	6:58	3.38				
PGSP0039	Jun/04/1992	7:58	3.80				
PGSP0040	Jun/04/1992	8:58	4.22				
PGSP0041	Jun/04/1992	9:58	4.42				
PGSP0042	Jun/04/1992	10:58	4.44				
PGSP0043	Jun/04/1992	11:58	4.67				
PGSP0044	Jun/04/1992	12:58	5.02				
PGSP0045	Jun/04/1992	13:58	5.10				
PGSP0046	Jun/04/1992	14:58	5.11				
PGSP0047	Jun/04/1992	15:58	4.80				
PGSP0052	Jun/04/1992	17:15					
PGSP0048	Jun/04/1992	19:55	5.09				
PGSP0049	Jun/04/1992	23:55	5.25				
PGSP0050	Jun/05/1992	3:55	5.37				
PGSP0051	Jun/05/1992	7:55	5.52				
PGSP0053	Jun/10/1992	13:20	5.03				
PGSP0054	Jun/18/1992	9:30	4.59				0.050
PGSP0055	Jun/24/1992	13:35	4.84				
PGSP0056	Jul/01/1992	15:00	4.84				

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_{2-})*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
PGSP0057	Jul/08/1992	11:15	4.66				
PGSP0058	Jul/13/1992	15:00	4.66				
PGSP0059	Jul/23/1992	15:45	4.70				
PGSP0060	Jul/30/1992	6:55	6.62				
PGSP0061	Aug/13/1992	14:15	4.61				
PGSP0062	Aug/26/1992	11:30	6.22				0.039
PGSP0063	Sep/09/1992	11:42	4.48				
PGSP0064	Sep/23/1992	14:25	4.00				
		Average*	4.70				0.038
		Maximum	6.62				0.050
		Minimum	3.38				0.027
		Stand. Dev.	0.62				0.008
		Coef. Var.	0.13				0.215
Total of 56 analyses for Pleasant Grove Spring							

Spring Valley karst window, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_{2-})*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
SVKW0008	Oct/22/1991	8:00	3.44				0.043
SVKW0009	Jan/29/1992	10:00	4.79				0.027
SVKW0010	Feb/26/1992	11:00	4.72				0.030
SVKW0011	Mar/25/1992	10:55	5.13				0.027
SVKW0012	Apr/01/1992	15:15	5.02				
SVKW0013	Apr/29/1992	8:40	4.52				0.039
SVKW0014	May/27/1992	9:15	5.40				0.033
		Average*	4.72				0.033
		Maximum	5.40				0.043
		Minimum	3.44				0.027
		Stand. Dev.	0.63				0.007
		Coef. Var.	0.13				0.199
Total of 7 analyses for Spring Valley karst window							

The Canyon karst window, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_{2-})*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
TCKW0008	Dec/17/1991	11:30	4.00				0.040
TCKW0009	Jan/29/1992	8:30	4.09				0.031
TCKW0010	Feb/26/1992	9:45	3.80				0.026
TCKW0011	Mar/25/1992	12:00	3.98				0.032
TCKW0012	Apr/01/1992	14:45	3.89				
TCKW0013	Apr/29/1992	7:40	3.98				0.032
TCKW0014	May/27/1992	10:05	5.02				0.030
		Average*	4.11				0.032
		Maximum	5.02				0.040
		Minimum	3.80				0.026
		Stand. Dev.	0.41				0.005
		Coef. Var.	0.10				0.144
Total of 7 analyses for The Canyon karst window							

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Shackelford Spring, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_{2-})*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
SKSP0008	Oct/22/1991	6:34	6.52				0.035
SKSP0009	Dec/17/1991	12:00	7.44				0.042
SKSP0010	Jan/29/1992	14:30	7.41				0.028
SKSP0011	Feb/26/1992	8:40	7.57				0.028
SKSP0012	Mar/25/1992	8:40	7.10				0.028
SKSP0013	Apr/29/1992	6:43	7.19				0.027
SKSP0014	May/27/1992	11:50	8.50				0.033
		Average*	7.39				0.032
		Maximum	8.50				0.042
		Minimum	6.52				0.027
		Stand. Dev.	0.60				0.006
		Coef. Var.	0.08				0.174
Total of 7 analyses for Shackelford Spring							

Thad Flowers blue hole, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_{2-})*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
TFBH0007	Dec/17/1991	13:30	8.46				0.035
TFBH0008	Jan/29/1992	7:50	7.23				0.026
TFBH0009	Feb/26/1992	7:30	3.10				0.016
TFBH0010	Mar/25/1992	7:20	7.03				0.018
		Average*	6.45				0.024
		Maximum	8.46				0.035
		Minimum	3.10				0.016
		Stand. Dev.	2.33				0.009
		Coef. Var.	0.36				0.364
Total of 4 analyses for Thad Flowers blue hole							

George Delaney swallow hole, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_{2-})*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
GDSW0004	Dec/17/1991	10:00	7.15				0.051
GDSW0005	Jan/29/1992	9:10	6.69				0.018
GDSW0006	Feb/26/1992	10:20	6.80				0.072
GDSW0007	Mar/25/1992	9:45	6.94				0.018
GDSW0008	Apr/01/1992	15:45	6.80				
		Average*	6.88				0.040
		Maximum	7.15				0.072
		Minimum	6.69				0.018
		Stand. Dev.	0.18				0.027
		Coef. Var.	0.03				0.668
Total of 5 analyses for George Delaney swallow hole							

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1991–September 1992

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
PGSP0009	6.90	490	238	274	3	0.061
PGSP0010	7.00	384	165	218	37	1.350
PGSP0011	7.30	427	190	218	4	0.071
PGSP0012	7.12	429	196	280	6	0.406
PGSP0013	6.63	393	175	254	9	0.178
PGSP0021	6.30	425	196	246	3	0.075
PGSP0026	7.22	434	201	286	3	0.224
PGSP0027	7.09	418	189	270	4	0.358
PGSP0028				268	8	
PGSP0029				304	35	
PGSP0030				322	34	
PGSP0031				290	114	
PGSP0032				300	186	
PGSP0033				242	370	
PGSP0034				190	667	
PGSP0035				242	311	
PGSP0036				254	249	
PGSP0037				268	289	
PGSP0038				248	597	
PGSP0039				326	294	
PGSP0040				328	302	
PGSP0041				322	196	
PGSP0042				294	122	
PGSP0043				260	116	
PGSP0044				272	101	
PGSP0045				260	128	
PGSP0046				262	113	
PGSP0047				234	115	
PGSP0048				224	99	
PGSP0049				208	62	
PGSP0050				216	45	
PGSP0051				232	35	
PGSP0054	6.74	414	186	262	3	0.257
PGSP0057				274	11	
PGSP0058				250	4	
PGSP0062	7.01	476	225	280	3	0.018
Average*	6.93	429	196.10	263	129.94	0.300
Maximum	7.30	490	238	328	667	1.350
Minimum	6.30	384	165	190	3	0.018
Stand. Dev.	0.30	32.7	21.65	34.3	163.72	0.391
Coef. Var.	0.04	0.1	0.11	0.1	1.26	1.306
Total of 36 analyses for Pleasant Grove Spring						

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Spring Valley karst window, October 1991–September 1992

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
SVKW0008	6.75	492	237	272	3	0.067
SVKW0009	7.29	427	190	230	5	0.119
SVKW0010	7.13	430	195	286	6	0.283
SVKW0011	6.55	395	175	256	12	0.241
SVKW0013	6.15	431	197	242	6	0.093
SVKW0014	7.19	433	202	280	3	0.207
Average*	6.84	435	199.33	261	5.83	0.168
Maximum	7.29	492	237	286	12	0.283
Minimum	6.15	395	175	230	3	0.067
Stand. Dev.	0.44	31.5	20.64	22.2	3.31	0.088
Coef. Var.	0.06	0.1	0.10	0.1	0.57	0.520
Total of 6 analyses for Spring Valley karst window						

The Canyon karst window, October 1991–September 1992

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
TCKW0008	6.87	389	177	226	20	0.993
TCKW0009	7.12	425	194	236	22	0.680
TCKW0010	6.98	431	205	260	16	0.489
TCKW0011	6.56	392	184	252	36	0.964
TCKW0013	5.99	424	200	256	17	0.445
TCKW0014	7.07	427	202	268	8	0.630
Average*	6.77	415	193.67	250	19.83	0.700
Maximum	7.12	431	205	268	36	0.933
Minimum	5.99	389	177	226	8	0.445
Stand. Dev.	0.43	18.9	11.04	15.7	9.26	0.233
Coef. Var.	0.06		0.06	0.1	0.47	0.332
Total of 6 analyses for The Canyon karst window						

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Shackelford Spring, October 1991–September 1992

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
SKSP0008	6.75	450	190	256	4	0.272
SKSP0009	7.06	423	170	244	14	0.365
SKSP0010	7.27	429	171	238	5	0.184
SKSP0011	7.11	428	171	316	6	0.184
SKSP0012	6.57	413	170	298	4	0.126
SKSP0013	6.09	418	169	268	4	0.204
SKSP0014	7.29	427	173	288	6	0.167
Average*	6.88	427	173.43	273	6.14	0.215
Maximum	7.29	450	190	316	14	0.365
Minimum	6.09	413	169	238	4	0.126
Stand. Dev.	0.44	11.7	7.41	29.1	3.58	0.080
Coef. Var.	0.06		0.04	0.1	0.58	0.371
Total of 7 analyses for Shackelford Spring						

Thad Flowers blue hole, October 1991–September 1992

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
TFBH0007	7.09	365	133	202	18	0.367
TFBH0008	7.71	402	152	218	20	0.494
TFBH0009	7.63	365	152	226	34	0.616
TFBH0010	6.50	362	137	250	4	0.047
Average*	7.23	374	143.50	224	19.00	0.381
Maximum	7.71	402	152	250	34	0.616
Minimum	6.50	362	133	202	4	0.047
Stand. Dev.	0.56	19.1	9.95	20.0	12.27	0.245
Coef. Var.	0.08	0.1	0.07	0.1	0.65	0.642
Total of 4 analyses for Thad Flowers blue hole						

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

George Delaney swallow hole, October 1991–September 1992

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
GDSW0004	7.46	386	149	216	12	0.395
GDSW0005	7.68	418	168	218	8	0.168
GDSW0006	7.62	408	164	305	22	0.420
GDSW0007	7.00	389	156	274	14	0.230
Average*	7.44	400	159.25	253	14.00	0.303
Maximum	7.68	418	168	305	22	0.420
Minimum	7.00	386	149	216	8	0.168
Stand. Dev.	0.31	15.3	8.46	43.7	5.89	0.123
Coef. Var.	0.04		0.05	0.2	0.42	0.407
Total of 4 analyses for George Delaney swallow hole						

Pleasant Grove Spring, October 1991–September 1992

Sample Number	*Total Calcium (mg/L as Ca)*	*Total Magnesium (mg/L as Mg)*	*Total Sodium (mg/L as Na)*	*Total Potassium (mg/L as K)*	*Bicarbonate (mg/L as HCO_3^-)*	*Total Sulfate (mg/L as SO_4^{-2})*	*Dissolved Chloride (mg/L as Cl)*
PGSP0009	88.90	8.85	2.24	0.93	290	6.24	4.13
PGSP0010	76.90	6.58	2.46	1.77	201	5.60	5.83
PGSP0011	76.30	6.96	2.33	0.92	232	5.53	10.30
PGSP0012	79.00	7.21	2.48	1.62	239	6.02	6.22
PGSP0013	70.70	6.17	2.40	1.20	213	5.26	6.41
PGSP0021	78.90	7.38	2.37	1.42	239	5.18	4.87
PGSP0026	79.90	7.66	2.32	1.31	245	5.66	5.26
PGSP0027	75.70	6.99	2.21	1.23	230	5.14	5.29
PGSP0054	69.90	6.55	2.18	0.72	227	5.26	4.56
PGSP0062	83.40	8.23	3.10	0.72	274	5.54	5.91
Average*	77.96	7.26	2.41	1.18	239.00	5.54	5.88
Maximum	88.90	8.85	3.10	1.77	290	6.24	10.30
Minimum	69.90	6.17	2.18	0.72	201	5.14	4.13
Stand. Dev.	5.59	0.81	0.26	0.36	26.36	0.36	1.72
Coef. Var.	0.07	0.11	0.11	0.30	0.11	0.07	0.29
Total of 10 analyses for Pleasant Grove Spring							

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Spring Valley karst window, October 1991–September 1992

Sample Number	Total Calcium (mg/L as Ca)	Total Magnesium (mg/L as Mg)	Total Sodium (mg/L as Na)	Total Potassium (mg/L as K)	Bicarbonate (mg/L as HCO_3^-)	Total Sulfate (mg/L as SO_4^{-2})	Dissolved Chloride (mg/L as Cl)
SVKW0008	89.30	9.11	2.26	0.94	289	6.54	4.92
SVKW0009	75.10	6.97	2.31	1.14	232	5.18	6.22
SVKW0010	78.40	7.21	2.48	1.33	238	6.27	6.53
SVKW0011	70.60	6.22	2.44	0.96	213	5.34	6.66
SVKW0013	78.10	7.41	2.31	1.11	240	5.24	5.04
SVKW0014	80.30	7.83	2.35	1.24	246	5.68	5.38
Average*	78.63	7.46	2.36	1.12	243.00	5.71	5.79
Maximum	89.30	9.11	2.48	1.33	289	6.54	6.66
Minimum	70.60	6.22	2.26	0.94	213	5.18	4.92
Stand. Dev.	6.23	0.97	0.08	0.15	25.22	0.57	0.77
Coef. Var.	0.08	0.13	0.04	0.14	0.10	0.10	0.13
Total of 6 analyses for Spring Valley karst window							

The Canyon karst window, October 1991–September 1992

Sample Number	Total Calcium (mg/L as Ca)	Total Magnesium (mg/L as Mg)	Total Sodium (mg/L as Na)	Total Potassium (mg/L as K)	Bicarbonate (mg/L as HCO_3^-)	Total Sulfate (mg/L as SO_4^{-2})	Dissolved Chloride (mg/L as Cl)
TCKW0008	73.60	6.17	1.94	1.37	216	5.26	4.34
TCKW0009	77.00	6.81	2.15	1.15	236	5.00	5.11
TCKW0010	79.70	6.92	2.18	1.51	250	5.07	4.11
TCKW0011	71.40	6.18	2.02	1.42	224	5.00	4.82
TCKW0013	80.10	7.26	2.29	1.17	244	5.00	4.25
TCKW0014	78.20	7.14	2.16	1.48	246	5.00	4.36
Average*	76.67	6.75	2.12	1.35	236.00	5.06	4.50
Maximum	80.10	7.26	2.29	1.51	250	5.26	5.11
Minimum	71.40	6.17	1.94	1.15	216	5.00	4.11
Stand. Dev.	3.48	0.47	0.12	0.16	13.45	0.10	0.38
Coef. Var.	0.05	0.07	0.06	0.11	0.06	0.02	0.09
Total of 6 analyses for The Canyon karst window							

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Shackelford Spring, October 1991–September 1992

Sample Number	*Total Calcium (mg/L as Ca)*	*Total Magnesium (mg/L as Mg)*	*Total Sodium (mg/L as Na)*	*Total Potassium (mg/L as K)*	*Bicarbonate (mg/L as HCO_3^-)*	*Total Sulfate (mg/L as SO_4^{-2})*	*Dissolved Chloride (mg/L as Cl)*
SKSP0008	78.00	6.02	3.04	0.93	232	7.40	9.29
SKSP0009	75.90	5.90	2.85	1.39	207	6.80	8.05
SKSP0010	76.60	5.85	3.02	1.18	208	6.44	9.72
SKSP0011	77.00	5.90	3.14	1.35	208	7.47	9.96
SKSP0012	75.80	5.85	2.95	1.20	207	6.47	8.81
SKSP0013	76.10	5.81	3.03	1.15	206	6.33	8.80
SKSP0014	75.20	5.84	3.20	1.04	211	7.32	10.00
Average*	76.37	5.88	3.03	1.18	211.29	6.89	9.23
Maximum	78.00	6.02	3.20	1.39	232	7.47	10.00
Minimum	75.20	5.81	2.85	0.93	206	6.33	8.05
Stand. Dev.	0.92	0.07	0.12	0.16	9.27	0.50	0.72
Coef. Var.	0.01	0.01	0.04	0.14	0.04	0.07	0.08
Total of 7 analyses for Shackelford Spring							

Thad Flowers blue hole, October 1991–September 1992

Sample Number	*Total Calcium (mg/L as Ca)*	*Total Magnesium (mg/L as Mg)*	*Total Sodium (mg/L as Na)*	*Total Potassium (mg/L as K)*	*Bicarbonate (mg/L as HCO_3^-)*	*Total Sulfate (mg/L as SO_4^{-2})*	*Dissolved Chloride (mg/L as Cl)*
TFBH0007	65.60	4.63	2.84	0.93	162	5.51	11.00
TFBH0008	71.50	5.03	3.20	0.95	185	6.83	12.80
TFBH0009	67.00	5.25	3.20	1.35	185	8.98	12.80
TFBH0010	63.30	4.60	3.01	0.72	167	7.87	11.00
Average*	66.85	4.88	3.06	0.99	174.75	7.30	11.90
Maximum	71.50	5.25	3.20	1.35	185	8.98	12.80
Minimum	63.30	4.60	2.84	0.72	162	5.51	11.00
Stand. Dev.	3.45	0.32	0.17	0.26	12.01	1.48	1.04
Coef. Var.	0.05	0.06	0.06	0.27	0.07	0.20	0.09
Total of 4 analyses for Thad Flowers blue hole							

George Delaney swallow hole, October 1991–September 1992

Sample Number	*Total Calcium (mg/L as Ca)*	*Total Magnesium (mg/L as Mg)*	*Total Sodium (mg/L as Na)*	*Total Potassium (mg/L as K)*	*Bicarbonate (mg/L as HCO_3^-)*	*Total Sulfate (mg/L as SO_4^{-2})*	*Dissolved Chloride (mg/L as Cl)*
GDSW0004	66.50	5.21	2.94	1.68	182	7.51	9.76
GDSW0005	71.50	6.04	3.18	1.06	205	6.72	10.10
GDSW0006	71.60	5.67	3.63	2.19	200	8.61	10.20
GDSW0007	68.90	5.38	3.18	0.88	190	6.82	9.82
Average*	69.63	5.58	3.23	1.45	194.25	7.42	9.97
Maximum	71.60	6.04	3.63	2.19	205	8.61	10.20
Minimum	66.50	5.21	2.94	0.88	182	6.72	9.76
Stand. Dev.	2.43	0.36	0.29	0.60	10.28	0.87	0.21
Coef. Var.	0.03	0.07	0.09	0.41	0.05	0.12	0.02
Total of 4 analyses for George Delaney swallow hole							

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
PGSP0065	Oct/06/1992	12:50	4.29				0.033
PGSP0066	Oct/22/1992	10:14	4.00				
PGSP0067	Nov/06/1992	9:00	3.84				0.044
PGSP0068	Nov/20/1992	11:54	3.96				
PGSP0070	Dec/03/1992	9:07	4.02				0.083
PGSP0071	Jan/08/1993	10:19	5.18				0.045
PGSP0072	Jan/13/1993	8:00	5.29				
PGSP0073	Jan/13/1993	9:00	5.56				
PGSP0074	Jan/13/1993	10:00	5.51				
PGSP0075	Jan/13/1993	11:00	5.49				
PGSP0076	Jan/13/1993	12:00	5.44				
PGSP0077	Jan/13/1993	13:00	5.38				
PGSP0078	Jan/13/1993	14:00	5.47				
PGSP0079	Jan/13/1993	15:00	5.40				
PGSP0080	Jan/13/1993	16:00	5.42				
PGSP0081	Jan/13/1993	17:00	5.40				
PGSP0082	Jan/21/1993	10:15	5.33				
PGSP0083	Jan/28/1993	15:06	5.54				
PGSP0084	Jan/28/1993	15:40	5.33				
PGSP0089	Jan/28/1993	20:40	5.40				
PGSP0095	Jan/29/1993	2:40	5.45				
PGSP0101	Jan/29/1993	8:40	5.40				
PGSP0107	Jan/29/1993	14:40	5.38				
PGSP0108	Feb/04/1993	10:00	5.24				0.045
PGSP0109	Feb/16/1993	6:10	4.97				
PGSP0110	Feb/16/1993	6:30	5.02				
PGSP0111	Feb/16/1993	6:50	4.93				
PGSP0112	Feb/16/1993	7:10	4.95				
PGSP0113	Feb/16/1993	7:30	4.95				
PGSP0114	Feb/16/1993	7:50	4.93				
PGSP0115	Feb/16/1993	8:10	5.11				
PGSP0116	Feb/16/1993	8:30	5.04				
PGSP0117	Feb/16/1993	8:50	4.93				
PGSP0118	Feb/16/1993	9:10	5.02				
PGSP0119	Feb/16/1993	10:10	4.84				
PGSP0120	Feb/16/1993	11:10	4.97				
PGSP0121	Feb/16/1993	12:10	4.84				
PGSP0122	Feb/16/1993	13:10	5.02				
PGSP0123	Feb/16/1993	14:10	4.88				
PGSP0124	Feb/16/1993	15:10	4.97				
PGSP0125	Feb/16/1993	16:10	5.00				
PGSP0126	Feb/16/1993	17:10	5.00				
PGSP0127	Feb/16/1993	18:10	5.06				
PGSP0128	Feb/16/1993	19:10	5.00				
PGSP0129	Feb/16/1993	23:10	4.90				
PGSP0130	Feb/17/1993	3:10	4.68				
PGSP0131	Feb/17/1993	7:10	4.88				
PGSP0132	Feb/17/1993	11:10	5.06				
PGSP0133	Feb/17/1993	16:30	5.29				
PGSP0134	Feb/18/1993	8:00	5.42				
PGSP0135	Feb/21/1993	10:13	5.15				
PGSP0136	Feb/21/1993	10:33	5.02				
PGSP0137	Feb/21/1993	10:53	5.13				
PGSP0138	Feb/21/1993	11:13	5.11				

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
PGSP0139	Feb/21/1993	11:33	4.97				
PGSP0140	Feb/21/1993	11:53	4.95				
PGSP0141	Feb/21/1993	12:13	5.00				
PGSP0142	Feb/21/1993	12:33	5.02				
PGSP0143	Feb/21/1993	12:53	4.93				
PGSP0144	Feb/21/1993	13:13	4.88				
PGSP0145	Feb/21/1993	14:13	4.93				
PGSP0146	Feb/21/1993	15:13	5.02				
PGSP0147	Feb/21/1993	16:13	5.18				
PGSP0148	Feb/21/1993	17:13	5.11				
PGSP0149	Feb/21/1993	18:13	5.11				
PGSP0150	Feb/21/1993	19:13	5.20				
PGSP0151	Feb/21/1993	20:13	5.24				
PGSP0152	Feb/21/1993	21:13	5.24				
PGSP0153	Feb/21/1993	22:13	5.00				
PGSP0154	Feb/21/1993	23:13	5.20				
PGSP0155	Feb/22/1993	3:13	5.20				
PGSP0156	Feb/22/1993	7:13	5.20				
PGSP0157	Feb/22/1993	11:13	5.13				
PGSP0158	Feb/22/1993	15:13	5.29				
PGSP0159	Mar/03/1993	9:00	4.66				0.078
PGSP0160	Mar/18/1993	10:20	5.45				
PGSP0161	Mar/22/1993	20:15	5.22				
PGSP0172	Mar/23/1993	1:15	5.15				
PGSP0176	Mar/23/1993	5:15	5.09				
PGSP0180	Mar/23/1993	9:15	5.00				
PGSP0181	Mar/23/1993	13:15	4.45				
PGSP0182	Mar/23/1993	17:15	4.48				
PGSP0183	Mar/23/1993	21:15	4.86				
PGSP0184	Mar/24/1993	1:15	4.90				
PGSP0185	Mar/25/1993	11:00	5.33				
PGSP0186	Mar/26/1993	2:28	5.20				
PGSP0187	Mar/26/1993	2:48	5.09				
PGSP0188	Mar/26/1993	3:08	5.02				
PGSP0189	Mar/26/1993	3:28	5.13				
PGSP0190	Mar/26/1993	3:48	5.13				
PGSP0191	Mar/26/1993	4:08	5.13				
PGSP0192	Mar/26/1993	4:28	4.75				
PGSP0193	Mar/26/1993	4:48	5.06				
PGSP0194	Mar/26/1993	5:08	5.04				
PGSP0195	Mar/26/1993	5:28	5.04				
PGSP0196	Mar/26/1993	6:28	5.06				
PGSP0197	Mar/26/1993	7:28	5.24				
PGSP0198	Mar/26/1993	8:28	5.18				
PGSP0199	Mar/26/1993	9:28	5.24				
PGSP0200	Mar/26/1993	10:28	5.18				
PGSP0201	Mar/26/1993	11:28	4.77				
PGSP0202	Mar/26/1993	12:28	4.48				
PGSP0203	Mar/26/1993	13:28	4.38				
PGSP0204	Mar/26/1993	14:28	4.43				
PGSP0205	Mar/26/1993	15:28	4.50				
PGSP0206	Mar/26/1993	19:28	4.52				
PGSP0207	Mar/26/1993	23:28	4.84				
PGSP0208	Mar/27/1993	3:28	5.09				
PGSP0209	Mar/27/1993	7:28	5.09				

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
PGSP0210	Apr/01/1993	16:54	5.15				
PGSP0211	Apr/07/1993	8:22	5.09				0.033
PGSP0212	Apr/21/1993	15:10	5.04				
PGSP0213	May/03/1993	17:39	4.70				
PGSP0214	May/03/1993	18:39	4.81				
PGSP0215	May/04/1993	13:55	4.25				0.310
PGSP0216	May/04/1993	14:50	4.84				
PGSP0217	May/04/1993	15:50	5.06				
PGSP0218	May/04/1993	16:50	5.06				
PGSP0219	May/04/1993	17:50	5.20				
PGSP0220	May/04/1993	18:50	5.29				
PGSP0221	May/04/1993	19:50	5.27				
PGSP0222	May/04/1993	20:50	5.31				
PGSP0223	May/04/1993	21:50	5.38				
PGSP0224	May/04/1993	22:50	5.38				
PGSP0225	May/05/1993	1:50	5.56				
PGSP0226	May/05/1993	4:50	5.79				
PGSP0227	May/05/1993	7:50	5.97				
PGSP0228	May/05/1993	10:50	6.08				
PGSP0229	May/05/1993	13:50	5.81				
PGSP0230	May/05/1993	16:50	5.94				
PGSP0231	May/05/1993	19:50	5.74				
PGSP0232	May/05/1993	22:50	5.74				
PGSP0233	May/06/1993	1:50	5.94				
PGSP0234	May/06/1993	9:15	5.62				
PGSP0235	May/18/1993	3:22	4.88				
PGSP0241	May/18/1993	9:22	4.95				
PGSP0251	May/19/1993	9:22	5.06				
PGSP0255	May/20/1993	9:42	4.90				
PGSP0256	May/21/1993	2:15	5.11				
PGSP0257	May/22/1993	2:15	4.97				
PGSP0258	May/23/1993	2:15	4.84				
PGSP0259	May/24/1993	2:15	4.84				
PGSP0260	May/26/1993	12:42	5.00				
PGSP0261	May/29/1993	18:50	4.56				
PGSP0262	Jun/01/1993	16:29	5.20				
PGSP0263	Jun/02/1993	4:29	5.44				
PGSP0264	Jun/02/1993	14:30					0.040
PGSP0265	Jun/08/1993	17:14	4.83				
PGSP0266	Jun/16/1993	6:05	4.88				
PGSP0267	Jun/24/1993	9:23	4.83				
PGSP0268	Jun/24/1993	19:52	4.47				
PGSP0269	Jun/24/1993	20:52	4.56				
PGSP0270	Jun/24/1993	21:52	4.41				
PGSP0271	Jun/24/1993	22:52	4.55				
PGSP0272	Jun/24/1993	23:52	4.60				
PGSP0273	Jun/25/1993	0:52	4.57				
PGSP0274	Jun/25/1993	1:52	4.56				
PGSP0275	Jun/25/1993	2:52	4.56				
PGSP0276	Jun/25/1993	3:52	4.53				
PGSP0277	Jun/25/1993	4:52	4.54				
PGSP0278	Jun/25/1993	7:52	4.65				
PGSP0279	Jun/25/1993	10:52	4.64				
PGSP0280	Jun/25/1993	13:52	4.55				
PGSP0281	Jun/25/1993	16:52	4.59				

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
PGSP0282	Jun/25/1993	19:52	4.69				
PGSP0283	Jun/25/1993	22:52	4.80				
PGSP0284	Jun/26/1993	1:52	4.49				
PGSP0285	Jun/26/1993	4:52	4.05				
PGSP0286	Jun/26/1993	7:52	3.61				
PGSP0287	Jun/26/1993	10:52	3.51				
PGSP0288	Jun/26/1993	22:52	3.83				
PGSP0289	Jun/27/1993	10:52	4.22				
PGSP0290	Jun/27/1993	22:52	4.42				
PGSP0291	Jun/28/1993	10:52	4.47				
PGSP0292	Jun/29/1993	11:00	4.43				0.152
PGSP0293	Jul/02/1993	16:04	3.54				
PGSP0294	Jul/03/1993	13:04	4.14				
PGSP0295	Jul/15/1993	12:08	4.44				
PGSP0296	Jul/16/1993	11:30					
PGSP0297	Jul/22/1993	11:20					
PGSP0298	Jul/29/1993	9:46	5.42				
PGSP0299	Aug/04/1993	9:00	6.33				0.041
PGSP0300	Aug/14/1993	15:53	5.49				
PGSP0301	Aug/24/1993	12:18	5.13				
PGSP0302	Sep/09/1993	7:30	5.65				0.030
		Average*	4.98				0.078
		Maximum	6.33				0.310
		Minimum	3.51				0.300
		Stand. Dev.	0.46				0.081
		Coef. Var.	0.09				1.038
Number of analyses: 185							

Spring Valley karst window, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
SVKW0015	May/20/1993	9:20	5.01				
SVKW0016	May/26/1993	12:10	5.11				
		Average*	5.06				
Number of analyses: 2							

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

George Delaney swallow hole, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
GDSW0009	May/20/1993	8:14	6.98				
GDSW0010	May/26/1993	11:50	6.66				
GDSW0011	Jun/17/1993	8:20	5.56				
		Average*	6.40				
		Maximum	6.98				
		Minimum	5.56				
Number of analyses: 3							

Leslie Page karst window, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
LPKW0001	Apr/10/1993	18:00	5.15				
LPKW0002	Apr/11/1993	6:00	5.31				
LPKW0003	Apr/11/1993	18:00	4.88				
LPKW0004	Apr/12/1993	6:00	5.08				
LPKW0005	Apr/12/1993	18:00	4.97				
LPKW0006	Apr/13/1993	6:00	5.11				
LPKW0007	May/05/1993	8:17	4.38				
LPKW0009	May/20/1993	11:10	4.86				
LPKW0010	May/26/1993	11:30	4.88				
LPKW010A	Jun/02/1993	16:50					
LPKW0011	Jun/08/1993	8:34	4.90				
LPKW0012	Jun/17/1993	9:50	4.72				
LPKW0013	Jun/24/1993	10:00	4.72				
LPKW0014	Jun/30/1993	9:45	4.49				
LPKW0015	Jul/15/1993	11:22	4.22				
LPKW0017	Jul/29/1993	10:32	5.24				
		Average*	4.86				
		Maximum	5.31				
		Minimum	4.22				
		Stand. Dev.	0.31				
		Coef. Var.	0.06				
Number of analyses: 16							

Upper Pleasant Grove Creek, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
UPGC0001	Jun/17/1993	7:25	8.00				
UPGC0002	Jun/30/1993	9:10	6.33				
UPGC0003	Aug/03/1993	15:33	8.00				
		Average*	7.44				
		Maximum	8.00				
		Minimum	6.33				
Number of analyses: 3							

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1992–September 1993

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
PGSP0065	7.26	478	235	248	3	0.111
PGSP0067	7.64	547	241	258	3	0.007
PGSP0070	7.25	488	241	300	3	0.006
PGSP0071	7.16	432	198	212	8	0.279
PGSP0084				258	8	
PGSP0089				224	7	
PGSP0095				248	6	
PGSP0101				260	5	
PGSP0107				254	7	
PGSP0108	7.07	464	198	254	4	0.122
PGSP0109				256	4	
PGSP0110				264	6	
PGSP0111				260	7	
PGSP0112				286	8	
PGSP0113				266	7	
PGSP0114				262	9	
PGSP0115				260	10	
PGSP0116				258	12	
PGSP0117				242	12	
PGSP0118				244	16	
PGSP0119				248	18	
PGSP0120				256	22	
PGSP0121				256	22	
PGSP0122				252	22	
PGSP0123				274	18	
PGSP0124				266	11	
PGSP0125				288	22	
PGSP0126				266	21	
PGSP0127				268	22	
PGSP0128				274	18	
PGSP0129				232	25	
PGSP0130				238	21	
PGSP0131				214	18	
PGSP0132				230	14	
PGSP0133				238	11	
PGSP0134				246	8	
PGSP0135				248	46	
PGSP0136				270	42	
PGSP0137				250	55	
PGSP0138				260	64	
PGSP0139				258	82	
PGSP0140				262	76	
PGSP0141				226	67	
PGSP0142				228	72	
PGSP0143				234	87	

Pleasant Grove Spring, October 1992–September 1993

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
PGSP0144				216	82	
PGSP0145				236	53	
PGSP0146				242	68	
PGSP0147				262	87	
PGSP0148				258	96	
PGSP0149				236	132	
PGSP0150				246	176	
PGSP0151				252	232	
PGSP0152				230	240	
PGSP0153				546	239	
PGSP0154				548	226	
PGSP0155				542	162	
PGSP0156				548	116	
PGSP0157				564	83	
PGSP0158				554	66	
PGSP0159	7.38	406	141	222	63	2.930
PGSP0161				250	5	
PGSP0172				268	48	
PGSP0176				242	36	
PGSP0180				240	53	
PGSP0181				236	64	
PGSP0182				228	42	
PGSP0183				230	29	
PGSP0184				226	29	
PGSP0185				244	10	
PGSP0186				242	38	
PGSP0187				258	41	
PGSP0188				248	40	
PGSP0189				238	40	
PGSP0190				242	45	
PGSP0191				246	47	
PGSP0192				238	48	
PGSP0193				250	51	
PGSP0194				268	53	
PGSP0195				258	62	
PGSP0196				272	89	
PGSP0197				270	104	
PGSP0198				278	135	
PGSP0199				208	167	
PGSP0200				212	212	
PGSP0201				212	211	
PGSP0202				210	191	
PGSP0203				220	174	
PGSP0204				210	150	
PGSP0205				154	130	

Pleasant Grove Spring, October 1992–September 1993

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
PGSP0206				162	90	
PGSP0207				178	72	
PGSP0208				176	63	
PGSP0209				180	56	
PGSP0210				180	34	
PGSP0211	7.63	395	149	248	6	0.123
PGSP0213				272	14	
PGSP0214				214	98	
PGSP0215	7.23	241	98	176	201	7.170
PGSP0216				200	202	
PGSP0217				206	162	
PGSP0218				528	184	
PGSP0219				400	164	
PGSP0220				498	170	
PGSP0221				466	156	
PGSP0222				468	164	
PGSP0223				274	146	
PGSP0224				194	160	
PGSP0225				192	134	
PGSP0226				214	120	
PGSP0227				218	108	
PGSP0228				232	100	
PGSP0229				216	160	
PGSP0230				298	94	
PGSP0231				302	86	
PGSP0232				292	86	
PGSP0233				310	70	
PGSP0234				304	76	
PGSP0264	7.25	424	195	270	11	0.117
PGSP0268				238	14	
PGSP0269				240	12	
PGSP0270				228	21	
PGSP0271				262	10	
PGSP0272				262	8	
PGSP0273				242	10	
PGSP0274				246	12	
PGSP0275				236	15	
PGSP0276				214	16	
PGSP0277				220	22	
PGSP0278				224	17	
PGSP0279				244	27	
PGSP0280				226	13	
PGSP0281				286	16	
PGSP0282				204	56	
PGSP0283				272	28	

Pleasant Grove Spring, October 1992–September 1993

Sample Number	Laboratory pH	Laboratory Specific Conductance (at 25°C) (µS)	Total Alkalinity (mg/L as CaCO3)	Dissolved Solids Residue on Evaporation (mg/L 180°C)	Suspended Solids Residue on Evaporation (mg/L 180°C)	Total Iron (mg/L as Fe)
PGSP0284				370	61	
PGSP0285				348	69	
PGSP0286				266	80	
PGSP0287				258	74	
PGSP0288				294	27	
PGSP0289				298	8	
PGSP0290				316	14	
PGSP0291				336	8	
PGSP0292	7.00	438	214	258	10	0.166
PGSP0299	7.15	405	232	276	3	
Average*	7.27	429	194.73	267	64.36	1.103
Maximum	7.64	547	241	564	240	7.170
Minimum	7.00	241	98	154	3	0.006
Stand. Dev.	0.21	76.6	46.93	79.5	62.77	2.309
Coef. Var.	0.03	0.2	0.24	0.3	0.98	2.093
Number of analyses: 145						

Pleasant Grove Spring, October 1992–September 1993

Sample Number	Total Calcium (mg/L as Ca)	Total Magnesium (mg/L as Mg)	Total Sodium (mg/L as Na)	Total Potassium (mg/L as K)	Bicarbonate (mg/L as HCO_3^-)	Total Sulfate (mg/L as SO_4^{-2})	Dissolved Chloride (mg/L as Cl)
PGSP0065	85.00	8.48	2.39	1.28	286	5.85	6.15
PGSP0067	85.20	8.49	2.38	1.28	294	5.89	5.46
PGSP0070	87.40	8.80	2.46	1.28	294	5.65	5.67
PGSP0071	76.20	6.82	2.79	2.06	241	5.78	6.50
PGSP0108	79.40	7.24	2.67	1.28	241	5.26	6.19
PGSP0159	55.30	5.02	0.21	2.59	172	6.61	6.23
PGSP0211	68.50	6.04	2.50	1.28	182	5.36	6.86
PGSP0215	41.20	4.38	1.42	5.08	119	6.34	5.33
PGSP0299					283	5.37	6.09
PGSP0302	89.40	9.09	2.42	1.21	294	5.43	5.76
Average*	74.18	7.15	2.14	1.93	235.56	5.75	6.02
Maximum	89.40	9.09	2.79	5.08	294	6.61	6.86
Minimum	41.20	4.38	0.21	1.21	119	5.26	5.33
Stand. Dev.	16.40	1.72	0.82	1.28	64.28	0.44	0.47
Coef. Var.	0.22	0.24	0.38	0.66	0.27	0.08	0.08
Number of analyses: 10							

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1993–September 1994

Sample Number	Date	Time (CST)	Total Nitrate-Nitrogen (mg/L as N)	Total Nitrite (mg/L as NO_2^-)	Ammonia (mg/L as NH_3)	Total Kjeldahl Nitrogen (mg/L as N)	Orthophosphate (mg/L as PO_4^{-3})
PGSP0303	Oct/06/1993	7:30	5.40				0.032
PGSP0304	Nov/09/1993	10:45	5.01				0.035
PGSP0305	Nov/18/1993	12:37	5.33				
PGSP0306	Dec/08/1993	9:30	7.66				
PGSP0307	Dec/09/1993	21:04	7.55				
PGSP0308	Dec/09/1993	22:04	7.50				
PGSP0309	Dec/09/1993	23:04	7.36				
PGSP0310	Dec/10/1993	0:04	7.30				
PGSP0311	Dec/10/1993	1:04	7.36				
PGSP0312	Dec/10/1993	2:04	7.27				
PGSP0313	Dec/10/1993	3:04	7.16				
PGSP0314	Dec/10/1993	4:04	7.34				
PGSP0315	Dec/10/1993	5:04	6.98				
PGSP0316	Dec/10/1993	6:04	6.82				
PGSP0317	Dec/10/1993	9:04	6.37				
PGSP0318	Dec/10/1993	12:04	5.11				
PGSP0319	Dec/10/1993	15:04	5.15				
PGSP0320	Dec/10/1993	18:04	5.60				
PGSP0321	Dec/10/1993	21:04	6.14				
PGSP0322	Dec/11/1993	0:04	6.51				
PGSP0323	Dec/11/1993	3:04	6.87				
PGSP0324	Dec/11/1993	6:04	7.16				
PGSP0325	Dec/11/1993	9:04	7.07				
PGSP0326	Dec/11/1993	12:04	7.18				
PGSP0327	Dec/12/1993	0:04	7.50				
PGSP0328	Dec/12/1993	12:04	7.77				
PGSP0329	Dec/13/1993	0:04	7.55				
PGSP0330	Dec/13/1993	12:04	7.82				
PGSP0332	Dec/29/1993	12:55	7.07				
PGSP0333	Jan/02/1994	3:55	6.84				
PGSP0334	Jan/12/1994	11:40	7.16				
PGSP0335	Jan/24/1994	17:24	4.90				
PGSP0336	Jan/24/1994	20:24	4.65				
PGSP0337	Jan/25/1994	8:24	4.88				
PGSP0338	Jan/25/1994	20:24	3.75				
PGSP0339	Jan/26/1994	8:24	5.04				
PGSP0340	Jan/26/1994	20:24	6.42				
PGSP0341	Jan/27/1994	8:50	6.66				
PGSP0342	Feb/02/1994	12:10	7.34				
PGSP0343	Feb/22/1994	11:20	7.05				0.053
PGSP0344	Mar/01/1994	11:00	7.05				
PGSP0345	Mar/09/1994	9:00	3.82				
PGSP0346	Mar/15/1994	15:57	6.82				
PGSP0347	Mar/27/1994	5:30	5.47				
PGSP0348	Mar/27/1994	6:10	5.81				
PGSP0349	Mar/27/1994	6:50	3.75				
PGSP0350	Mar/27/1994	7:30	3.14				
PGSP0351	Mar/27/1994	8:10	2.96				
PGSP0352	Mar/27/1994	9:30	2.76				
PGSP0353	Mar/27/1994	11:30	3.12				
PGSP0354	Mar/27/1994	13:30	3.43				
PGSP0355	Mar/27/1994	14:30	3.46				
PGSP0356	Mar/27/1994	15:30	3.66				
PGSP0357	Mar/27/1994	16:30	3.84				

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
PGSP0358	Mar/27/1994	17:30	3.98				
PGSP0359	Mar/27/1994	18:30	4.04				
PGSP0360	Mar/27/1994	22:30	4.38				
PGSP0361	Mar/28/1994	2:30	3.91				
PGSP0362	Mar/28/1994	6:30	4.16				
PGSP0363	Mar/28/1994	10:30	4.65				
PGSP0364	Mar/28/1994	13:00	4.95				0.138
PGSP0365	Mar/28/1994	18:00	5.35				
PGSP0366	Mar/29/1994	6:00	5.47				
PGSP0367	Mar/29/1994	18:00	5.74				
PGSP0368	Mar/30/1994	6:00	5.90				
PGSP0369	Mar/30/1994	18:00	6.23				
PGSP0370	Mar/31/1994	6:00	6.23				
PGSP0371	Mar/31/1994	18:00	5.81				
PGSP0372	Apr/01/1994	6:00	6.30				
PGSP0373	Apr/01/1994	18:00	5.58				
PGSP0374	Apr/02/1994	6:00	6.12				
PGSP0375	Apr/02/1994	18:00	6.28				
PGSP0376	Apr/03/1994	6:00	6.23				
PGSP0377	Apr/03/1994	18:00	6.30				
PGSP0378	Apr/04/1994	6:00	5.99				
PGSP0379	Apr/04/1994	18:00	6.35				
PGSP0380	Apr/05/1994	6:00	6.23				
PGSP0381	Apr/05/1994	18:00	6.28				
PGSP0382	Apr/06/1994	6:00	5.58				
PGSP0383	Apr/06/1994	18:00	5.87				
PGSP0384	Apr/07/1994	6:00	6.12				
PGSP0385	Apr/07/1994	14:00	6.14				
PGSP0387	Apr/11/1994	14:13	2.37				
PGSP0388	Apr/11/1994	17:57	3.14				
PGSP0389	Apr/12/1994	7:30	5.38				
PGSP0391	Apr/12/1994	15:30	5.67				
PGSP0392	Apr/13/1994	6:15	5.65				
PGSP0393	Apr/13/1994	18:00	6.10				
PGSP0394	Apr/14/1994	6:00	6.17				
PGSP0395	Apr/14/1994	18:00	6.28				
PGSP0396	Apr/15/1994	6:00	6.23				
PGSP0397	Apr/15/1994	18:00	4.99				
PGSP0398	Apr/16/1994	6:00	5.08				
PGSP0399	Apr/16/1994	18:00	5.78				
PGSP0400	Apr/17/1994	6:00	6.05				
PGSP0401	Apr/17/1994	18:00	6.26				
PGSP0402	Apr/18/1994	6:00	6.12				
PGSP0403	Apr/18/1994	18:00	6.10				
PGSP0404	Apr/19/1994	6:00	6.08				
PGSP404A	Apr/20/1994	6:00	4.27				
PGSP0405	Apr/21/1994	6:00	4.77				
PGSP0406	Apr/22/1994	6:00	4.43				
PGSP0407	Apr/23/1994	6:00	4.34				
PGSP0408	Apr/24/1994	6:00	4.04				
PGSP0409	Apr/25/1994	6:00	4.25				
PGSP0410	Apr/26/1994	6:00	4.02				
PGSP0411	Apr/27/1994	6:00	4.09				
PGSP0412	Apr/27/1994	10:00	4.11				0.509

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
PGSP0413	Apr/28/1994	6:00	3.91				
PGSP0414	Apr/29/1994	6:00	3.98				
PGSP0415	Apr/29/1994	18:00	4.00				
PGSP0416	Apr/29/1994	18:45	4.77				
PGSP0417	Apr/29/1994	19:05	4.36				
PGSP0418	Apr/29/1994	19:09	4.61				
PGSP0419	Apr/29/1994	19:25	4.52				
PGSP0420	Apr/29/1994	19:45	4.54				
PGSP0421	Apr/29/1994	19:51	4.61				
PGSP0422	Apr/29/1994	20:05	4.70				
PGSP0423	Apr/29/1994	20:25	4.59				
PGSP0424	Apr/29/1994	20:45	4.38				
PGSP0425	Apr/29/1994	21:05	4.47				
PGSP0426	Apr/29/1994	21:25	4.07				
PGSP0427	Apr/29/1994	21:45	3.89				
PGSP0428	Apr/29/1994	22:45	4.20				
PGSP0429	Apr/29/1994	23:45	3.70				
PGSP0430	Apr/30/1994	0:45	3.52				
PGSP0431	Apr/30/1994	1:45	3.32				
PGSP0432	Apr/30/1994	2:45	3.09				
PGSP0433	Apr/30/1994	3:45	3.05				
PGSP0434	Apr/30/1994	4:45	3.19				
PGSP0435	Apr/30/1994	5:45	3.16				
PGSP0436	Apr/30/1994	6:45	3.32				
PGSP0437	Apr/30/1994	7:45	3.39				
PGSP0438	Apr/30/1994	11:45	3.68				
PGSP0439	Apr/30/1994	15:45	4.07				
PGSP0440	May/01/1994	6:00	4.27				
PGSP0441	May/02/1994	6:00	4.61				
PGSP0442	May/03/1994	6:00	4.09				
PGSP0443	May/04/1994	6:00	4.38				
PGSP0444	May/04/1994	18:00	4.34				
PGSP0445	May/05/1994	6:00	4.34				
PGSP0446	May/07/1994	6:00	4.22				
PGSP0447	May/09/1994	6:00	4.47				
PGSP0448	May/11/1994	6:00	4.36				
PGSP0449	May/12/1994	9:00	4.36				
PGSP0450	May/13/1994	6:00	4.20				
PGSP0451	May/14/1994	6:00	4.22				
PGSP0452	May/15/1994	6:00	3.98				
PGSP0453	May/15/1994	18:00	4.29				
PGSP0454	May/16/1994	6:00	4.04				
PGSP0455	May/17/1994	6:00	4.22				
PGSP0456	May/18/1994	6:00	4.41				
PGSP0457	May/20/1994	6:00	4.45				
PGSP0458	May/22/1994	6:00	4.34				
PGSP0459	May/24/1994	6:00	4.29				
PGSP0460	May/26/1994	6:00	4.29				
PGSP0461	May/28/1994	6:00	3.95				
PGSP0462	May/30/1994	6:00	4.25				
PGSP0463	Jun/01/1994	12:00	4.20				
PGSP0464	Jun/03/1994	6:00	4.22				
PGSP0465	Jun/05/1994	6:00	3.84				
PGSP0466	Jun/07/1994	6:00	4.22				

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
PGSP0467	Jun/09/1994	6:00	4.43				
PGSP0468	Jun/10/1994	6:00	4.59				
PGSP0469	Jun/10/1994	11:01	4.74				
PGSP0470	Jun/10/1994	11:21	4.70				
PGSP0471	Jun/10/1994	11:41	4.72				
PGSP0472	Jun/10/1994	12:01	4.65				
PGSP0473	Jun/10/1994	12:21	4.65				
PGSP0474	Jun/10/1994	12:41	4.72				
PGSP0475	Jun/10/1994	13:01	4.65				
PGSP0476	Jun/10/1994	13:21	4.74				
PGSP0477	Jun/10/1994	13:41	4.63				
PGSP0478	Jun/10/1994	14:01	4.70				
PGSP0479	Jun/10/1994	15:01	4.36				
PGSP0480	Jun/10/1994	16:01	4.74				
PGSP0481	Jun/10/1994	17:01	4.65				
PGSP0482	Jun/10/1994	18:01	4.70				
PGSP0483	Jun/10/1994	19:01	4.61				
PGSP0484	Jun/10/1994	20:01	4.63				
PGSP0485	Jun/10/1994	21:01	4.68				
PGSP0486	Jun/10/1994	22:01	4.65				
PGSP0487	Jun/10/1994	23:01	4.61				
PGSP0488	Jun/11/1994	0:01	4.61				
PGSP0489	Jun/11/1994	4:01	4.61				
PGSP0490	Jun/11/1994	6:00	4.13				
PGSP0491	Jun/11/1994	8:01	4.56				
PGSP0492	Jun/11/1994	12:01	4.50				
PGSP0493	Jun/11/1994	16:01	4.52				
PGSP0494	Jun/14/1994	6:00	4.52				
PGSP0495	Jun/16/1994	6:00	4.11				
PGSP0496	Jun/17/1994	6:00	4.18				
PGSP0497	Jun/17/1994	21:13	4.59				
PGSP0498	Jun/17/1994	21:33	4.63				
PGSP0499	Jun/17/1994	21:53	4.65				
PGSP0500	Jun/17/1994	22:13	4.63				
PGSP0501	Jun/17/1994	22:33	4.59				
PGSP0502	Jun/17/1994	22:53	4.65				
PGSP0503	Jun/17/1994	23:13					
PGSP0504	Jun/17/1994	23:33	4.72				
PGSP0505	Jun/17/1994	23:53	4.81				
PGSP0506	Jun/18/1994	0:13	4.70				
PGSP0507	Jun/18/1994	1:13	4.79				
PGSP0508	Jun/18/1994	2:13	4.25				
PGSP0509	Jun/18/1994	3:13	3.23				
PGSP0510	Jun/18/1994	4:13	3.23				
PGSP0511	Jun/18/1994	5:13	3.37				
PGSP0512	Jun/18/1994	6:13	3.39				
PGSP0513	Jun/18/1994	7:13	3.50				
PGSP0514	Jun/18/1994	8:13	3.57				
PGSP0515	Jun/18/1994	9:13	3.52				
PGSP0516	Jun/18/1994	10:13	3.59				
PGSP0517	Jun/18/1994	14:13	3.50				
PGSP0518	Jun/18/1994	18:13	3.48				
PGSP0519	Jun/18/1994	22:13	3.66				
PGSP0520	Jun/19/1994	2:13	3.75				

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
PGSP0521	Jun/20/1994	6:00	4.22				
PGSP0522	Jun/22/1994	6:00	4.07				
PGSP0523	Jun/24/1994	6:00	4.09				
PGSP0524	Jun/26/1994	6:00	4.16				
PGSP0525	Jun/29/1994	6:00	4.16				
PGSP0526	Jul/01/1994	6:00	4.27				
PGSP0527	Jul/03/1994	6:00	4.22				
PGSP0528	Jul/05/1994	6:00	4.22				
PGSP0529	Jul/06/1994	10:30	4.41				
PGSP0530	Jul/07/1994	6:00	4.16				
PGSP0531	Jul/07/1994	6:30	3.95				
PGSP0532	Jul/07/1994	7:10	3.68				
PGSP0533	Jul/07/1994	11:30	2.67				
PGSP0534	Jul/13/1994	6:00	4.22				
PGSP0535	Jul/20/1994	6:00	4.45				
PGSP0537	Jul/25/1994	18:38	4.29				
PGSP0538	Aug/03/1994	8:30	4.27				
PGSP0539	Aug/16/1994	10:00	4.16				
PGSP0540	Sep/08/1994	8:15	3.86				
PGSP0541	Sep/19/1994	13:50	3.82				
		Average*	4.86				0.153
		Maximum	7.82				0.509
		Minimum	2.37				0.035
		Stand. Dev.	1.20				0.203
		Coef. Var.	0.25				1.326
Total of 236 analyses for Pleasant Grove Spring							

George Delaney swallow hole, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
GDSW0012	Dec/07/1993	11:40	10.40				
GDSW0013	Mar/28/1994	10:40	5.69				
GDSW0014	Apr/07/1994	15:00	7.77				
GDSW0015	Apr/20/1994	12:10	7.79				
GDSW0016	Apr/26/1994	15:30	5.35				
GDSW0017	May/12/1994	9:50	5.72				
GDSW0018	May/17/1994	13:28	5.60				
GDSW0019	Jun/01/1994	7:36	5.42				
GDSW0020	Jun/15/1994	0:20	4.70				
GDSW0021	Jul/06/1994	9:45	4.88				
		Average*	6.33				
		Maximum	10.40				
		Minimum	4.70				
		Stand. Dev.	1.78				
		Coef. Var.	0.28				
Total of 10 analyses for George Delaney swallow hole							

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Leslie Page karst window, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
LPKW0020	Nov/09/1993	9:35	5.42				
LPKW0021	Dec/07/1993	16:53	5.90				
LPKW0022	Jan/11/1994	14:23	6.37				
LPKW0023	Feb/02/1994	9:55	7.34				
LPKW0024	Feb/22/1994	13:30	7.43				0.035
LPKW0026	Mar/10/1994	19:23	8.79				
LPKW0027	Mar/10/1994	19:43	8.22				
LPKW0028	Mar/10/1994	20:03	8.09				
LPKW0029	Mar/10/1994	20:23	8.20				
LPKW0030	Mar/10/1994	20:43	8.22				
LPKW0031	Mar/10/1994	21:03	8.09				
LPKW0032	Mar/10/1994	21:23	8.79				
LPKW0033	Mar/10/1994	21:43	7.88				
LPKW0034	Mar/10/1994	22:03	7.86				
LPKW0035	Mar/10/1994	22:23	7.88				
LPKW0036	Mar/10/1994	23:23	7.86				
LPKW0037	Mar/11/1994	0:23	8.49				
LPKW0038	Mar/11/1994	1:23	7.91				
LPKW0039	Mar/11/1994	2:23	8.02				
LPKW0040	Mar/11/1994	3:23	7.95				
LPKW0041	Mar/11/1994	4:23	8.65				
LPKW0042	Mar/11/1994	5:23	8.02				
LPKW0043	Mar/11/1994	6:23	8.02				
LPKW0044	Mar/11/1994	7:23	8.18				
LPKW0045	Mar/11/1994	8:23	8.65				
LPKW0046	Mar/11/1994	12:23	8.63				
LPKW0047	Mar/11/1994	16:23	8.61				
LPKW0048	Mar/11/1994	20:23	8.72				
LPKW0049	Mar/12/1994	0:23	8.67				
LPKW0050	Mar/15/1994	17:10	7.70				
LPKW0051	Mar/27/1994	15:50	7.32				
LPKW0052	Mar/28/1994	9:10	7.79				
LPKW0053	Mar/28/1994	9:30	6.75				
LPKW0054	Mar/28/1994	9:50	7.68				
LPKW0055	Mar/28/1994	10:10	7.86				
LPKW0056	Mar/28/1994	10:30	7.61				
LPKW0057	Mar/28/1994	10:50	7.86				
LPKW0058	Mar/28/1994	11:10	7.77				
LPKW0059	Mar/28/1994	11:30	7.55				
LPKW0060	Mar/28/1994	11:50	7.59				
LPKW0061	Mar/28/1994	12:10	7.73				
LPKW0062	Mar/28/1994	12:30	7.73				
LPKW0063	Mar/28/1994	13:30	7.59				
LPKW0064	Mar/28/1994	14:30	7.88				
LPKW0065	Mar/28/1994	15:30	7.93				
LPKW0066	Mar/28/1994	16:30	7.75				
LPKW0067	Mar/28/1994	17:30	7.79				
LPKW0068	Mar/28/1994	18:30	7.86				
LPKW0069	Mar/28/1994	19:30	7.68				
LPKW0070	Mar/28/1994	20:30	7.73				
LPKW0071	Mar/28/1994	21:30	7.77				
LPKW0072	Mar/28/1994	22:30	7.79				
LPKW0073	Mar/29/1994	2:30	7.86				
LPKW0074	Mar/29/1994	6:30	7.84				

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Leslie Page karst window, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
LPKW0075	Mar/29/1994	10:30	7.88				
LPKW0076	Mar/29/1994	14:30	7.59				
LPKW0077	Apr/07/1994	10:55	6.94				
LPKW0078	Apr/12/1994	8:06	8.38				
LPKW0079	Apr/20/1994	8:15	7.52				
LPKW0080	Apr/27/1994	8:31	4.54				
LPKW0081	May/02/1994	12:23	5.20				
LPKW0082	May/03/1994	6:00	5.04				
LPKW0083	May/04/1994	6:00	5.01				
LPKW0088	May/09/1994	6:00	5.35				
LPKW0089	May/11/1994	6:00	5.33				
LPKW0090	May/12/1994	10:40	5.31				
LPKW0091	May/13/1994	6:00	5.42				
LPKW0092	May/14/1994	6:00	5.33				
LPKW0093	May/15/1994	6:00	5.31				
LPKW0094	May/16/1994	6:00	5.24				
LPKW0095	May/17/1994	6:00	5.33				
LPKW0096	May/18/1994	6:00	5.26				
LPKW0097	May/20/1994	6:00	5.15				
LPKW0098	May/22/1994	6:00	5.15				
LPKW0099	May/24/1994	6:00	5.15				
LPKW0100	May/25/1994	10:45	5.04				
LPKW0101	May/27/1994	10:45	5.13				
LPKW0102	May/29/1994	10:45	5.01				
LPKW0103	May/31/1994	10:45	4.92				
LPKW0104	Jun/01/1994	8:30	4.72				
LPKW0105	Jun/15/1994	11:35	4.92				
LPKW0106	Jun/27/1994	23:50	4.77				
LPKW0107	Jun/28/1994	7:50	4.54				
LPKW0108	Jun/29/1994	7:50	4.61				
LPKW0109	Aug/02/1994	14:20	4.31				
LPKW0110	Sep/07/1994	12:50	4.18				
		Average*	6.90				
		Maximum	8.79				
		Minimum	4.18				
		Stand. Dev.	1.50				
		Coef. Var.	0.22				
Total of 86 analyses for Leslie Page karst window							

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Upper Pleasant Grove Creek, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
UPGC0004	Nov/18/1993	11:31	8.43				
UPGC0005	Dec/07/1993	15:10	10.80				
UPGC0006	Feb/22/1994	15:16	7.30				
UPGC0007	Mar/28/1994	11:05	5.60				
UPGC0008	Apr/07/1994	10:25	8.04				
UPGC0009	Apr/20/1994	12:25	7.77				
UPGC0010	Apr/27/1994	7:10	5.62				
UPGC0011	May/12/1994	10:10	6.01				
UPGC0012	May/17/1994	12:13	5.65				
UPGC0013	Jun/01/1994	7:07	6.96				
UPGC0014	Jun/15/1994	11:00	7.39				
UPGC0015	Jul/06/1994	7:30	6.73				
		Average*	7.19				
		Maximum	10.80				
		Minimum	5.60				
		Stand. Dev.	1.50				
		Coef. Var.	0.21				
Total of 12 analyses for Upper Pleasant Grove Creek							

Miller School House water well, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total Nitrate-Nitrogen (mg/L as N)*	*Total Nitrite (mg/L as NO_2^-)*	*Ammonia (mg/L as NH_3)*	*Total Kjeldahl Nitrogen (mg/L as N)*	*Orthophosphate (mg/L as PO_4^{-3})*
MSHW0001	Apr/26/1994	14:00	1.45				0.766
Total of 1 analysis for Miller School House water well							

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1993–September 1994

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
PGSP0303	6.82	503		296	5	0.048
PGSP0304	7.36	508		302	4	0.006
PGSP0307				276	7	
PGSP0312				278	17	
PGSP0317				278	205	
PGSP0326				258	14	
PGSP0328				256	8	
PGSP0330				260	3	
PGSP0335				144	44	
PGSP0336				178	143	
PGSP0337				156	51	
PGSP0338				152	293	
PGSP0339				174	123	
PGSP0340				206	98	
PGSP0341				218	65	
PGSP0343	6.75	352		222	44	0.857
PGSP0345				140	140	
PGSP0346				196	196	
PGSP0347				226	176	
PGSP0349				180	527	
PGSP0350				212	427	
PGSP0351				220	373	
PGSP0352				206	255	
PGSP0353				186	214	
PGSP0355				198	186	
PGSP0356				186	159	
PGSP0357				204	147	
PGSP0358				210	192	
PGSP0359				128	153	
PGSP0360				162	163	
PGSP0361				184	127	
PGSP0362				180	59	
PGSP0363				180	67	
PGSP0364				250	85	
PGSP0365				204	75	2.360
PGSP0366				228	40	
PGSP0367				216	52	
PGSP0368				228	46	
PGSP0369				228	38	
PGSP0370				222	33	
PGSP0371				230	32	
PGSP0372				228	29	
PGSP0373				332	28	
PGSP0374				238	36	
PGSP0375				244	29	
PGSP0376				224	27	

Pleasant Grove Spring, October 1993–September 1994

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
PGSP0377				248	33	
PGSP0378				238	24	
PGSP0379				186	23	
PGSP0380				182	24	
PGSP0381				188	24	
PGSP0382				166	37	
PGSP0383				174	31	
PGSP0384				180	19	
PGSP0387				162		
PGSP0388				178		
PGSP0389				202		
PGSP0391				200		
PGSP0392				206		
PGSP0393				232	139	
PGSP0394				238	93	
PGSP0395				234	67	
PGSP0396				212	90	
PGSP0397				202	290	
PGSP0398				222	81	
PGSP0399				220	44	
PGSP0400				218	52	
PGSP0401				250	47	
PGSP0402				236	46	
PGSP0403				242	49	
PGSP0404				234	45	
PGSP0412	7.20	356		216	4	0.419
PGSP0416				244	99	
PGSP0417				240	98	
PGSP0418				242	101	
PGSP0419				244	94	
PGSP0420				232	94	
PGSP0421				244	107	
PGSP0422				248	120	
PGSP0423				242	146	
PGSP0424				238	224	
PGSP0425				280	299	
PGSP0426				274	391	
PGSP0427				262	518	
PGSP0428				230	1827	
PGSP0429				204	2278	
PGSP0430				212	1700	
PGSP0431				210	1061	
PGSP0432				186	682	
PGSP0433				230	478	
PGSP0434				226	421	
PGSP0435				200	407	

Pleasant Grove Spring, October 1993–September 1994

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
PGSP0436				202	318	
PGSP0437				218	272	
PGSP0438				286	138	
PGSP0439				242	74	
PGSP0443				254	33	
PGSP0445					28	
PGSP0448					20	
PGSP0469				236	28	
PGSP0470				226	15	
PGSP0471				240	15	
PGSP0472				128	11	
PGSP0473				210	11	
PGSP0474				242	10	
PGSP0475				234	10	
PGSP0476				242	9	
PGSP0477				248	10	
PGSP0478				232	13	
PGSP0479				246	15	
PGSP0480				242	14	
PGSP0481				262	11	
PGSP0482				250	13	
PGSP0483				262	12	
PGSP0484				284	6	
PGSP0485				270	20	
PGSP0486				268	6	
PGSP0487				240	16	
PGSP0488				256	24	
PGSP0491				272	13	
PGSP0492				276	11	
PGSP0493				280	22	
PGSP0497				210	45	
PGSP0498				218	30	
PGSP0499				222	29	
PGSP0500				216	56	
PGSP0501				406	97	
PGSP0502				228	123	
PGSP0503				236	165	
PGSP0504				234	15	
PGSP0505				250	3	
PGSP0506				264	226	
PGSP0507				254	373	
PGSP0508				178	706	
PGSP0509				134	951	
PGSP0510				132	764	
PGSP0511				130	621	

Pleasant Grove Spring, October 1993–September 1994

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
PGSP0512				142	540	
PGSP0513				150	364	
PGSP0514				142	321	
PGSP0515				146	271	
PGSP0516				150	210	
PGSP0517				164	123	
PGSP0518				178	91	
PGSP0519				176	71	
PGSP0520				200	67	
Average*	7.03	430		222	179.32	0.738
Maximum	7.36	508		406	2,278	2.360
Minimum	6.75	352		128	3	0.006
Stand. Dev.	0.29	87.5		57.7	326.43	0.969
Coef. Var.	0.04	0.2		0.3	1.82	1.314
Total of 146 analyses for Pleasant Grove Spring						

Leslie Page karst window, October 1993–September 1994

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
LPKW0024	6.17	171		104	34	0.842
LPKW0026				62	4	
LPKW0027				88		
LPKW0028				58		
LPKW0029				66		
LPKW0030				60		
LPKW0031				48		
LPKW0032				74	3	
LPKW0033				46		
LPKW0034				48		
LPKW0035				50		
LPKW0036				44		
LPKW0037				100	3	
LPKW0038				32		
LPKW0040				38		
LPKW0041				108	3	
LPKW0042				34		
LPKW0043				38		
LPKW0044				32		
LPKW0045				102	3	
LPKW0046				96	3	
LPKW0047				100	3	

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Leslie Page karst window, October 1993–September 1994

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
LPKW0048				118	3	
LPKW0049				84	3	
LPKW0050				108		
LPKW0053				66		
LPKW0054				90		
LPKW0055				96		
LPKW0056				78		
LPKW0057				88		
LPKW0058				98		
LPKW0059				102		
LPKW0060				102		
LPKW0061				114		
LPKW0062				114		
LPKW0063				108		
LPKW0064				108		
LPKW0065				118		
LPKW0066				114		
LPKW0067				120		
LPKW0068				114		
LPKW0069				56		
LPKW0070				88		
LPKW0071				102		
LPKW0072				76		
LPKW0073				108		
LPKW0074				116		
LPKW0075				116		
LPKW0076				114		
LPKW0078				126		
Average*	6.17	171		85	6.20	
Maximum	6.17	171		126	34	
Minimum	6.17	171		32	3	
Stand. Dev.				28.5	9.77	
Coef. Var.				0.3	1.58	
Total of 50 analyses for Leslie Page karst window						

Miller School House water well, October 1993–September 1994

Sample Number	*Laboratory pH*	*Laboratory Specific Conductance (at 25°C) (µS)*	*Total Alkalinity (mg/L as CaCO3)*	*Dissolved Solids Residue on Evaporation (mg/L 180°C)*	*Suspended Solids Residue on Evaporation (mg/L 180°C)*	*Total Iron (mg/L as Fe)*
MSHW0001	7.51	590		350	8	0.237
Total of 1 analysis for Miller School House water well						

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1993–September 1994

Sample Number	*Total Calcium (mg/L as Ca)*	*Total Magnesium (mg/L as Mg)*	*Total Sodium (mg/L as Na)*	*Total Potassium (mg/L as K)*	*Bicarbonate (mg/L as HCO_3^-)*	*Total Sulfate (mg/L as SO_4^{-2})*	*Dissolved Chloride (mg/L as Cl)*
PGSP0303	90.20	9.22	2.37	1.21	307	5.76	4.90
PGSP0304	92.10	9.52	2.43	1.25	308	6.24	4.98
PGSP0343	59.20	5.19	2.33	1.76	178	6.30	6.84
PGSP0364	42.60	4.26	1.71	2.65	128	5.80	5.10
PGSP0412	60.40	5.56	2.05	1.30	190	5.10	5.30
Average*	68.90	6.75	2.18	1.63	222.20	5.84	5.42
Maximum	92.10	9.52	2.43	2.65	308	6.30	6.84
Minimum	42.60	4.26	1.71	1.21	128	5.10	4.90
Stand. Dev.	21.51	2.44	0.30	0.61	81.27	0.48	0.81
Coef. Var.	0.31	0.36	0.14	0.37	0.37	0.08	0.15
Number of analyses 5							

Leslie Page karst window, October 1993–September 1994

Sample Number	*Total Calcium (mg/L as Ca)*	*Total Magnesium (mg/L as Mg)*	*Total Sodium (mg/L as Na)*	*Total Potassium (mg/L as K)*	*Bicarbonate (mg/L as HCO_3^-)*	*Total Sulfate (mg/L as SO_4^{-2})*	*Dissolved Chloride (mg/L as Cl)*
LPKW0024	23.90	2.85	2.45	1.30	63	12.90	8.32
Number of analyses 1							

Miller School House water well, October 1993–September 1994

Sample Number	*Total Calcium (mg/L as Ca)*	*Total Magnesium (mg/L as Mg)*	*Total Sodium (mg/L as Na)*	*Total Potassium (mg/L as K)*	*Bicarbonate (mg/L as HCO_3^-)*	*Total Sulfate (mg/L as SO_4^{-2})*	*Dissolved Chloride (mg/L as Cl)*
MSHW0001	54.80	32.00	14.60	1.21	348	26.20	5.30
Number of analyses 1							

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Appendix H:
Water Sample Analyses and Descriptive Statistics for Samples Collected from Pleasant Grove Spring and Shackelford Spring and Used to Develop Figure 10

Pleasant Grove Spring

Sample Number †	*Total Calcium (mg/L as Ca)*	*Total Magnesium (mg/L as Mg)*	*Total Sodium (mg/L as Na)*	*Total Potassium (mg/L as K)*	*Bicarbonate (mg/L as HCO_3)*	*Total Sulfate (mg/L as SO_4)*	*Dissolved Chloride (mg/L as Cl)*
PGSP0003	68.20	6.15	2.21	1.12	212	10.90	5.86
PGSP0004	65.60	5.93	2.11	1.26	195	5.62	5.18
PGSP0006	76.60	7.40	2.18	1.17	244	5.40	5.28
PGSP0007	88.00	8.46	2.26	1.15	273	7.53	4.65
PGSP0008	85.90	8.37	2.17	1.22	283	5.82	4.33
PGSP0009	88.90	8.85	2.24	0.93	290	6.24	4.13
PGSP0010	76.90	6.58	2.46	1.77	201	5.60	5.83
PGSP0011	76.30	6.96	2.33	0.92	232	5.53	10.30
PGSP0012	79.00	7.21	2.48	1.62	239	6.02	6.22
PGSP0013	70.70	6.17	2.40	1.20	213	5.26	6.41
PGSP0021	78.90	7.38	2.37	1.42	239	5.18	4.87
PGSP0026	79.90	7.66	2.32	1.31	245	5.66	5.26
Average*	77.91	7.26	2.29	1.26	238.83	6.23	5.69
Maximum	88.90	8.85	2.48	1.77	290	10.90	10.30
Minimum	65.60	5.93	2.11	0.92	195	5.18	4.13
Stand. Dev.	7.36	0.96	0.12	0.25	31.02	1.60	1.62
Coef. Var.	0.09	0.13	0.05	0.20	0.13	0.26	0.28
Number of analyses 12							

Shackelford Spring

Sample Number†	*Total Calcium (mg/L as Ca)*	*Total Magnesium (mg/L as Mg)*	*Total Sodium (mg/L as Na)*	*Total Potassium (mg/L as K)*	*Bicarbonate (mg/L as HCO_3)*	*Total Sulfate (mg/L as SO_4)*	*Dissolved Chloride (mg/L as Cl)*
SKSP0003	71.30	5.54	2.87	1.10	199	10.60	8.60
SKSP0004	72.40	5.65	2.88	0.93	198	7.11	8.67
SKSP0005	75.80	5.81	3.23	1.05	205	6.04	9.45
SKSP0006	77.70	5.99	3.08	1.07	217	12.60	9.53
SKSP0007	76.30	6.00	2.96	1.18	224	8.76	9.52
SKSP0008	78.00	6.02	3.04	0.93	232	7.40	9.29
SKSP0009	75.90	5.90	2.85	1.39	207	6.80	8.05
SKSP0010	76.60	5.85	3.02	1.18	208	6.44	9.72
SKSP0011	77.00	5.90	3.14	1.35	208	7.47	9.96
SKSP0012	75.80	5.85	2.95	1.20	207	6.47	8.81
SKSP0013	76.10	5.81	3.03	1.15	206	6.33	8.80
SKSP0014	75.20	5.84	3.20	1.04	211	7.32	10.00
Average*	75.68	5.85	3.02	1.13	210.17	7.78	9.20
Maximum	78.00	6.02	3.23	1.39	232	12.60	10.00
Minimum	71.30	5.54	2.85	0.93	198	6.04	8.05
Stand. Dev.	1.97	0.14	0.13	0.14	9.82	1.97	0.61
Coef. Var.	0.03	0.02	0.04	0.13	0.05	0.25	0.07
Number of analyses 12							

†See Appendix G for collection dates and additional data.
*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Appendix I:
Pesticide Analysis for Water Samples from the Pleasant Grove Spring Drainage Basin

Pleasant Grove Spring, October 1990–September 1991

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
PGSP0003	May/01/1991	11:10		0.390	< 0.320				< 0.035	0.031
PGSP0004	May/22/1991	11:30		1.300	< 0.350				< 0.048	0.170
PGSP0005	Jun/26/1991	9:42		1.400	< 0.250				0.087	0.100
PGSP0006	Jul/25/1991	10:15		0.470	< 0.250				< 0.036	< 0.020
PGSP0007	Aug/29/1991	12:30		0.340	< 0.250				< 0.036	0.031
PGSP0008	Sep/24/1991	9:30		0.230	< 0.250				< 0.036	0.030
			Average*	0.688						0.064
			Maximum	1.400	< 0.350				0.087	0.170
			Minimum	0.230					< 0.035	0.020
			Stand. Dev.	0.519						0.060
			Coef. Var.	0.755						0.937
			No. Analyses	6	6				6	6

Spring Valley karst window, October 1990–September 1991

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
SVKW0004	Jun/26/1991	11:00		1.400	< 0.250				0.081	0.090
SVKW0006	Aug/29/1991	11:35		0.370	< 0.250				< 0.036	0.020
SVKW0007	Sep/24/1991	8:40		0.270	< 0.250				< 0.036	0.027
			Average*	0.680						0.046
			Maximum	1.400	< 0.250				0.081	0.090
			Minimum	0.270					< 0.036	0.020
			No. Analyses	3					3	3

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

The Canyon karst window, October 1990–September 1991

Sample Number	Date	Time (CST)	Total ELISA Triazines (µg/L)	Total GC Atrazine (µg/L)	Total GC Simazine (µg/L)	Total GC Cyanazine (µg/L)	Total ELISA Carbofuran (µg/L)	Total ELISA Metolachlor (µg/L)	Total GC Metolachlor (µg/L)	Total GC Alachlor (µg/L)
TCKW0002	May/01/1991	8:45		0.750	< 0.320				< 0.035	< 0.022
TCKW0003	May/22/1991	9:30		1.000	< 0.350				< 0.048	< 0.022
TCKW0004	Jun/26/1991	7:45		1.100	< 0.250				< 0.036	< 0.020
TCKW0005	Jul/25/1991	8:24		0.390	< 0.250				< 0.036	< 0.020
TCKW0006	Aug/29/1991	10:45		0.360	< 0.250				< 0.036	< 0.020
TCKW0007	Sep/24/1991	7:40		0.230	< 0.250				< 0.036	< 0.020
			Average*	0.638						
			Maximum	1.100	< 0.350				< 0.048	< 0.022
			Minimum	0.230						
			Stand. Dev.	0.364						
			Coef. Var.	0.570						
			No. Analyses	6	6				6	6

Shackelford Spring, October 1990–September 1991

Sample Number	Date	Time (CST)	Total ELISA Triazines (µg/L)	Total GC Atrazine (µg/L)	Total GC Simazine (µg/L)	Total GC Cyanazine (µg/L)	Total ELISA Carbofuran (µg/L)	Total ELISA Metolachlor (µg/L)	Total GC Metolachlor (µg/L)	Total GC Alachlor (µg/L)
SKSP0003	May/01/1991	7:05		0.720	< 0.320				< 0.035	< 0.022
SKSP0005	Jul/25/1991	7:20		0.530	< 0.250				< 0.036	< 0.020
SKSP0006	Aug/29/1991	10:00		0.380	< 0.250				< 0.036	< 0.020
SKSP0007	Sep/24/1991	6:40		0.310	< 0.250				< 0.036	< 0.020
			Average*	0.485						
			Maximum	0.720	< 0.320				< 0.036	< 0.022
			Minimum	0.310						
			Stand. Dev.	0.182						
			Coef. Var.	0.374						
			No. Analyses	4	4				4	4

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Thad Flowers blue hole, October 1990–September 1991

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
TFBH0002	May/01/1991	7:45		0.570	< 0.320				< 0.035	0.025
TFBH0003	May/22/1991	6:50		0.550	< 0.350				< 0.048	< 0.022
TFBH0004	Jun/26/1991	7:15		0.590	< 0.250				0.110	0.180
TFBH0005	Jul/25/1991	11:10		1.200	0.570				0.053	< 0.020
TFBH0006	Aug/29/1991	9:25		< 0.160	< 0.250				< 0.036	< 0.020
			Average*	0.614						
			Maximum	1.200	0.570				0.110	0.180
			Minimum	0.160	< 0.250				< 0.035	< 0.020
			Stand. Dev.	0.373						
			Coef. Var.	0.607						
			No. Analyses	5	5				5	5

George Delaney swallow hole, October 1990–September 1991

Date	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
May/22/1991	10:30		1.300	< 0.350				< 0.048	0.039
Jun/26/1991	8:50		1.000	< 0.250				< 0.036	< 0.020
Jul/25/1991	8:55		0.480	< 0.250				< 0.036	< 0.020
		Average*	0.927						
		Maximum	1.300	< 0.350				< 0.048	0.039
		Minimum	0.480						< 0.020
		No. Analyses	3	3				3	3

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
PGSP0009	Oct/22/1991	8:50		0.280	< 0.250				< 0.036	0.024
PGSP0010	Dec/17/1991	8:06		0.100	< 0.250				< 0.040	< 0.018
PGSP0011	Jan/29/1992	11:00		0.290	0.590				< 0.040	< 0.018
PGSP0012	Feb/26/1992	12:15		0.250	1.100		< 0.070		< 0.040	< 0.018
PGSP0013	Mar/25/1992	13:20		0.450	< 0.250				< 0.040	< 0.018
PGSP0014	Apr/01/1992	16:16	0.61				< 0.070	< 0.060		
PGSP0015	Apr/09/1992	15:28	0.74				< 0.070	< 0.060		
PGSP0016	Apr/16/1992	10:30	0.63				< 0.070	< 0.060		
PGSP0017	Apr/20/1992	18:55	0.58				< 0.070	< 0.060		
PGSP0018	Apr/21/1992	8:30	0.58				< 0.070	< 0.060		
PGSP0019	Apr/21/1992	17:55	1.10				0.130	< 0.060		
PGSP0020	Apr/22/1992	7:37	0.77				0.110	0.094		
PGSP0021	Apr/29/1992	9:40	0.57	0.270	< 0.250		< 0.070		0.250	< 0.018
PGSP0022	May/07/1992	12:30	0.58				0.100		< 0.060	< 0.060
PGSP0023	May/14/1992	8:30	0.49				< 0.070	< 0.060		
PGSP0024	May/20/1992	7:35	4.00				0.570	1.800		
PGSP0025	May/20/1992	14:30	5.60				0.560	1.200		
PGSP0026	May/27/1992	10:45	1.40	1.200	< 0.250		< 0.070	0.081	0.540	0.018
PGSP0027	Jun/03/1992	15:45	1.50	0.940	< 0.250		0.081	< 0.060	0.380	< 0.018
PGSP0028	Jun/04/1992	2:58	1.40				0.077	< 0.060		
PGSP0029	Jun/04/1992	3:18	1.20				0.120	< 0.060		
PGSP0030	Jun/04/1992	3:38	1.20				0.160	< 0.060		
PGSP0031	Jun/04/1992	3:58	1.20				0.200	< 0.060		
PGSP0032	Jun/04/1992	4:18	1.40				0.120	< 0.060		
PGSP0033	Jun/04/1992	4:38	2.20				0.160	1.100		
PGSP0034	Jun/04/1992	4:58	2.80				0.110	2.300		
PGSP0035	Jun/04/1992	5:18	2.30				< 0.070	1.200		
PGSP0036	Jun/04/1992	5:38	2.10				< 0.070	0.600		
PGSP0037	Jun/04/1992	5:58	2.60				< 0.070	0.370		
PGSP0038	Jun/04/1992	6:58	3.70				0.210	0.760		
PGSP0039	Jun/04/1992	7:58	2.20				0.280	0.580		
PGSP0040	Jun/04/1992	8:58	2.90				0.390	0.600		
PGSP0041	Jun/04/1992	9:58	2.20				0.470	0.180		
PGSP0042	Jun/04/1992	10:58	1.90				1.000	0.380		
PGSP0043	Jun/04/1992	11:58	2.00				1.600	0.270		
PGSP0044	Jun/04/1992	12:58	2.90				1.100	0.390		
PGSP0045	Jun/04/1992	13:58	2.70				0.300	0.220		

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
PGSP0046	Jun/04/1992	14:58	2.30				0.340	0.170		
PGSP0047	Jun/04/1992	15:58	2.50				0.200	0.200		
PGSP0052	Jun/04/1992	17:15	3.00	2.600	0.300		0.310	0.150	0.520	0.073
PGSP0048	Jun/04/1992	19:58	3.40				0.260	0.300		
PGSP0049	Jun/04/1992	23:58	4.00				0.270	0.350		
PGSP0050	Jun/05/1992	3:58	4.20				0.480	0.440		
PGSP0051	Jun/05/1992	7:58	3.00				0.300	0.350		
PGSP0053	Jun/10/1992	13:20	1.10				0.086	< 0.060		
PGSP0054	Jun/18/1992	9:30	1.10	1.000	< 0.250		0.370	< 0.060	0.330	0.035
PGSP0055	Jun/24/1992	13:35					0.120	< 0.060		
PGSP0056	Jul/01/1992	15:00	0.88				< 0.070	< 0.060		
PGSP0057	Jul/08/1992	11:15	0.88				< 0.070	< 0.060		
PGSP0058	Jul/13/1992	15:00	0.99				< 0.070	< 0.060		
PGSP0059	Jul/23/1992	15:45	0.82				< 0.070	0.081		
PGSP0060	Jul/30/1992	6:55	0.81				< 0.070	< 0.060		
PGSP0061	Aug/13/1992	14:15	0.76				< 0.070	< 0.060		
PGSP0062	Aug/26/1992	11:30	0.55	0.370	< 0.083	< 0.100	< 0.070	< 0.060	< 0.040	< 0.018
PGSP0063	Sep/09/1992	11:42	0.57				< 0.070	< 0.060		
PGSP0064	Sep/23/1992	14:25	0.61				< 0.070	0.200		
		Average*	1.772	0.705	0.348		0.232	0.321	0.193	0.028
		Maximum	5.60	2.600	1.100		1.600	2.300	0.540	0.073
		Minimum	0.49	0.100	< 0.083		< 0.070	< 0.060	< 0.036	< 0.018
		Stand. Dev.	1.199	0.726	0.276		0.292	0.469	0.201	0.019
		Coef. Var.	0.677	1.030	0.795		1.261	1.459	1.041	0.674
		No. Analyses	51	11	11	1	52	49	12	12

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Spring Valley karst window, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
SVKW0008	Oct/22/1991	8:00		0.280	< 0.250				< 0.036	0.021
SVKW0009	Jan/29/1992	10:00		< 0.210	< 0.250				< 0.040	< 0.018
SVKW0010	Feb/26/1992	11:00		0.360	4.500		< 0.070		< 0.040	< 0.018
SVKW0011	Mar/25/1992	10:55		0.320	< 0.250				< 0.040	0.041
SVKW0012	Apr/01/1992	15:15	0.88				< 0.070	< 0.060		
SVKW0013	Apr/29/1992	8:40	0.59	0.250	< 0.250		< 0.070	< 0.060	0.110	< 0.018
SVKW0014	May/27/1992	9:15	1.40	1.200	< 0.250		< 0.070	0.070	0.400	< 0.018
		Average*	0.957	0.437	0.958					
		Maximum	1.40	1.200	4.500		< 0.070	0.070	0.400	0.041
		Minimum	0.59	< 0.210	< 0.250			< 0.060	< 0.036	< 0.018
		Stand. Dev.	0.410	0.378	1.735					
		Coef. Var.	0.429	0.865	1.810					
		No. Analyses	3	6	6		4	3	6	6

The Canyon karst window, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
TCKW0008	Dec/17/1991	11:30		0.300	< 0.250				< 0.040	< 0.018
TCKW0009	Jan/29/1992	8:30		0.310	< 0.250				< 0.040	< 0.018
TCKW0010	Feb/26/1992	9:45		0.280	2.200		< 0.070		< 0.040	< 0.018
TCKW0011	Mar/25/1992	12:00		0.440	< 0.250				< 0.040	< 0.018
TCKW0012	Apr/01/1992	14:45	0.96				< 0.070		< 0.060	
TCKW0013	Apr/29/1992	7:40	0.65	< 0.340	< 0.250		< 0.070		0.220	< 0.018
TCKW0014	May/27/1992	10:05	1.10	0.930	< 0.250		< 0.070	0.110	0.410	< 0.018
		Average*	0.903	0.433						
		Maximum	1.10	0.930	2.200		< 0.070		0.410	< 0.018
		Minimum	0.65	0.280	< 0.250				< 0.040	
		Stand. Dev.	0.230	0.250						
		Coef. Var.	0.255	0.576						
		No. Analyses	3	6	6		4	1	7	6

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Shackelford Spring, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
SKSP0008	Oct/22/1991	6:34		0.290	< 0.250				< 0.036	< 0.020
SKSP0009	Dec/17/1991	12:00		0.480	< 0.250				< 0.040	< 0.018
SKSP0010	Jan/28/1992	14:30		0.300	< 0.250				< 0.040	< 0.018
SKSP0011	Feb/26/1992	8:40		0.310	< 0.250		< 0.070		< 0.040	< 0.018
SKSP0012	Mar/25/1992	15:15		< 0.210	< 0.250				< 0.040	< 0.018
SKSP0013	Apr/29/1992	6:43	0.51	0.250	< 0.250		< 0.070		< 0.040	< 0.018
SKSP0014	May/27/1992	11:50	1.10	0.830	< 0.250		< 0.070	< 0.060	0.120	< 0.018
		Average*	0.805	0.381						
		Maximum	1.10	0.830	< 0.250		< 0.070		0.120	< 0.020
		Minimum	0.51	0.210					< 0.036	
		Stand. Dev.		0.215						
		Coef. Var.		0.564						
		No. Analyses	2	7	7		3	1	7	7

Thad Flowers blue hole, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
TFBH0007	Dec/17/1991	13:30		0.300	< 0.250				< 0.040	< 0.018
TFBH0008	Jan/28/1992	7:50		< 0.210	< 0.250				< 0.040	< 0.018
TFBH0009	Feb/26/1992	7:30		0.560	< 0.250		0.09		< 0.040	< 0.018
TFBH0010	Mar/25/1992	7:20		0.260	< 0.250				< 0.040	< 0.018
			Average*	0.333						
			Maximum	0.560	< 0.250				< 0.040	< 0.018
			Minimum	< 0.210						
			Stand. Dev.							
			Coef. Var.							
			No. Analyses	4	4		1		4	4

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

George Delaney swallow hole, October 1991–September 1992

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
GDSW0004	Dec/17/1991	10:00		0.230	< 0.250				< 0.040	0.071
GDSW0005	Jan/29/1992	9:10		< 0.210	0.420				< 0.040	< 0.018
GDSW0006	Feb/26/1992	10:20		0.460	1.000		< 0.070		< 0.040	< 0.018
GDSW0007	Mar/25/1992	9:45		< 0.210	< 0.250				< 0.040	0.043
GDSW0008	Apr/01/1992	15:45	0.48				< 0.070	< 0.060		
		Average*								
		Maximum		0.460	1.000		< 0.070		< 0.040	0.071
		Minimum		< 0.210	< 0.250					< 0.018
		No. Analyses	1	4	4		2	1	4	4

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
PGSP0065	Oct/06/1992	12:50	0.76		< 0.160	< 0.150	< 0.070	< 0.060	< 0.035	< 0.018
PGSP0066	Oct/22/1992	10:14	0.41				< 0.070	< 0.060		
PGSP0067	Nov/06/1992	9:00	0.53	0.270	< 0.160	< 0.150	< 0.070	< 0.060	< 0.035	< 0.018
PGSP0068	Nov/20/1992	11:54	0.62				< 0.070	< 0.060		
PGSP0070	Dec/03/1992	9:07	0.76	0.330	< 0.160	< 0.150	< 0.070	< 0.060	< 0.035	< 0.018
PGSP0071	Jan/08/1993	10:19	0.74	0.340	< 0.160	< 0.200	< 0.070	< 0.060	< 0.035	< 0.018
PGSP0072	Jan/13/1993	8:00	0.59				< 0.070	< 0.060		
PGSP0073	Jan/13/1993	9:00	0.57				< 0.070	< 0.060		
PGSP0074	Jan/13/1993	10:00	0.62				< 0.070	< 0.060		
PGSP0075	Jan/13/1993	11:00	0.66				< 0.070	< 0.060		
PGSP0076	Jan/13/1993	12:00	0.62				< 0.070	< 0.060		
PGSP0077	Jan/13/1993	13:00	0.64				< 0.070	0.730		
PGSP0078	Jan/13/1993	14:00	0.62				< 0.070	< 0.060		< 0.060
PGSP0079	Jan/13/1993	15:00	0.59				< 0.070	0.066		
PGSP0080	Jan/13/1993	16:00	0.54				< 0.070	< 0.060		
PGSP0081	Jan/13/1993	17:00	0.63				< 0.070	< 0.060		
PGSP0082	Jan/21/1993	10:15	0.52				< 0.070	< 0.060		
PGSP0083	Jan/28/1993	15:06	0.58				< 0.070	< 0.060		
PGSP0084	Jan/28/1993	15:40	0.62				< 0.070	< 0.060		
PGSP0089	Jan/28/1993	20:40	0.60				< 0.070	< 0.060		
PGSP0095	Jan/29/1993	2:40	0.64				< 0.070	< 0.060		
PGSP0101	Jan/29/1993	8:40	0.60				< 0.070	< 0.060		
PGSP0107	Jan/29/1993	14:40	0.67				< 0.070	< 0.060		
PGSP0108	Feb/04/1993	10:00	< 0.06	0.290	< 0.160	< 0.200	< 0.070	< 0.060	< 0.035	< 0.018
PGSP0109	Feb/16/1993	6:10	0.64				< 0.070	< 0.060		
PGSP0110	Feb/16/1993	6:30	0.63				< 0.070	< 0.060		
PGSP0111	Feb/16/1993	6:50	0.70				< 0.070	< 0.060		
PGSP0112	Feb/16/1993	7:10	0.65				< 0.070	< 0.060		
PGSP0113	Feb/16/1993	7:30	0.74				< 0.070	< 0.060		
PGSP0114	Feb/16/1993	7:50	0.64				< 0.070	< 0.060		
PGSP0115	Feb/16/1993	8:10	0.73				< 0.070	< 0.060		
PGSP0116	Feb/16/1993	8:30	0.79				< 0.070	< 0.060		
PGSP0117	Feb/16/1993	8:50	0.67				< 0.070	< 0.060		
PGSP0118	Feb/16/1993	9:10	0.67				< 0.070	< 0.060		
PGSP0119	Feb/16/1993	10:10	0.67				< 0.070	< 0.060		

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
PGSP0120	Feb/16/1993	11:10	0.72				< 0.070	< 0.060		
PGSP0121	Feb/16/1993	12:10	0.72				< 0.070	< 0.060		
PGSP0122	Feb/16/1993	13:10	0.72				< 0.070	< 0.060		
PGSP0123	Feb/16/1993	14:10	0.74				< 0.070	0.074		
PGSP0124	Feb/16/1993	15:10	0.72				< 0.070	0.065		
PGSP0125	Feb/16/1993	16:10	0.76	0.290	< 0.160	< 0.200	< 0.070	0.066	< 0.035	
PGSP0126	Feb/16/1993	17:10	0.75				< 0.070	0.083		
PGSP0127	Feb/16/1993	18:10	0.69				< 0.070	0.060		
PGSP0128	Feb/16/1993	19:10	0.72				< 0.070	0.060		
PGSP0129	Feb/16/1993	23:10	0.68				< 0.070	0.062		
PGSP0130	Feb/17/1993	3:10	0.66				< 0.070	< 0.060		
PGSP0131	Feb/17/1993	7:10	0.70				< 0.070	0.066		
PGSP0132	Feb/17/1993	11:10	0.71				< 0.070	< 0.060		
PGSP0133	Feb/17/1993	16:30	0.79				< 0.070	0.061		
PGSP0134	Feb/18/1993	8:00	0.83				< 0.070	< 0.060		
PGSP0135	Feb/21/1993	10:13	0.54				< 0.070	< 0.060		
PGSP0136	Feb/21/1993	10:33	0.58				< 0.070	< 0.060		
PGSP0137	Feb/21/1993	10:53	0.60				< 0.070	< 0.060		
PGSP0138	Feb/21/1993	11:13	0.54				< 0.070	< 0.060		
PGSP0139	Feb/21/1993	11:33	0.58				< 0.070	< 0.060		
PGSP0140	Feb/21/1993	11:53	0.59				< 0.070	< 0.060		
PGSP0141	Feb/21/1993	12:13	0.53				< 0.070	< 0.060		
PGSP0142	Feb/21/1993	12:33	0.60				< 0.070	< 0.060		
PGSP0143	Feb/21/1993	12:53	0.60				< 0.070	< 0.060		
PGSP0144	Feb/21/1993	13:13	0.59				< 0.070	< 0.060		
PGSP0145	Feb/21/1993	14:13	0.57				< 0.070	< 0.060		
PGSP0146	Feb/21/1993	15:13	0.58				< 0.070	< 0.060		
PGSP0147	Feb/21/1993	16:13	0.55				< 0.070	< 0.060		
PGSP0148	Feb/21/1993	17:13	0.55				< 0.070	< 0.060		
PGSP0149	Feb/21/1993	18:13	0.58				< 0.070	< 0.060		
PGSP0150	Feb/21/1993	19:13	0.49				< 0.070	< 0.060		
PGSP0151	Feb/21/1993	20:13	0.52				< 0.070	< 0.060		
PGSP0152	Feb/21/1993	21:13	0.51				< 0.070	< 0.060		
PGSP0153	Feb/21/1993	22:13	0.53				< 0.070	< 0.060		

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
PGSP0154	Feb/21/1993	23:13	0.69				< 0.070	< 0.060		
PGSP0155	Feb/22/1993	3:13	0.55				< 0.070	< 0.060		
PGSP0156	Feb/22/1993	7:13	0.51				< 0.070	< 0.060		
PGSP0157	Feb/22/1993	11:13	0.56				< 0.070	< 0.060		
PGSP0158	Feb/22/1993	15:13	0.60				< 0.070	< 0.060		
PGSP0159	Mar/03/1993	9:00	0.55	0.260	< 0.360	< 0.240	< 0.070	< 0.060	< 0.031	< 0.018
PGSP0160	Mar/18/1993	10:20	0.51				< 0.070	< 0.060		
PGSP0161	Mar/22/1993	20:15	0.59				< 0.070	< 0.060		
PGSP0172	Mar/23/1993	1:15	0.58				< 0.070	< 0.060		
PGSP0176	Mar/23/1993	5:15	0.60				< 0.070	0.069		
PGSP0180	Mar/23/1993	9:15	0.63				< 0.070	< 0.060		
PGSP0181	Mar/23/1993	13:15	0.56				< 0.070	0.075		
PGSP0182	Mar/23/1993	17:15	0.44				< 0.070	< 0.060		
PGSP0183	Mar/23/1993	21:15	1.80				< 0.070	0.067		
PGSP0184	Mar/24/1993	1:15	2.60				< 0.070	< 0.060		
PGSP0185	Mar/25/1993	11:00	1.20				< 0.070	< 0.060		
PGSP0186	Mar/26/1993	2:28	0.98				< 0.070	< 0.060		
PGSP0187	Mar/26/1993	2:48	0.94				< 0.070	< 0.060		
PGSP0188	Mar/26/1993	3:08	0.90				< 0.070	< 0.060		
PGSP0189	Mar/26/1993	3:28	1.00				< 0.070	< 0.060		
PGSP0190	Mar/26/1993	3:48	0.88				< 0.070	< 0.060		
PGSP0191	Mar/26/1993	4:08	1.00				< 0.070	< 0.060		
PGSP0192	Mar/26/1993	4:28	0.81				< 0.070	< 0.060		
PGSP0193	Mar/26/1993	4:48	0.97				< 0.070	< 0.060		
PGSP0194	Mar/26/1993	5:08	0.85				< 0.070	< 0.060		
PGSP0195	Mar/26/1993	5:28	1.00				< 0.070	< 0.060		
PGSP0196	Mar/26/1993	6:28	0.86				< 0.070	< 0.060		
PGSP0197	Mar/26/1993	7:28	0.82				< 0.070	< 0.060		
PGSP0198	Mar/26/1993	8:28	0.90				< 0.070	< 0.060		
PGSP0199	Mar/26/1993	9:28	0.82				< 0.070	< 0.060		
PGSP0200	Mar/26/1993	10:28	0.77				< 0.070	< 0.060		
PGSP0201	Mar/26/1993	11:28	0.76				< 0.070	< 0.060		
PGSP0202	Mar/26/1993	12:28	0.79				< 0.070	< 0.060		
PGSP0203	Mar/26/1993	13:28	0.84				< 0.070	< 0.060		

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
PGSP0204	Mar/26/1993	14:28	0.81				< 0.070	< 0.060		
PGSP0205	Mar/26/1993	15:28	0.87				< 0.070	< 0.060		
PGSP0206	Mar/26/1993	19:28	1.10				< 0.070	< 0.060		
PGSP0207	Mar/26/1993	23:28	1.20				< 0.070	< 0.060		
PGSP0208	Mar/27/1993	3:28	1.20				< 0.070	< 0.060		
PGSP0209	Mar/27/1993	7:28	1.10				< 0.070	< 0.060		
PGSP0210	Apr/01/1993	16:54	0.90				< 0.070	< 0.060		
PGSP0211	Apr/07/1993	8:22	0.53	0.430	< 0.360	< 0.240	< 0.070	< 0.060	< 0.031	< 0.018
PGSP0212	Apr/21/1993	15:10	1.10				< 0.070	< 0.060		
PGSP0213	May/03/1993	17:39	1.20				< 0.070	< 0.060		
PGSP0214	May/03/1993	18:39	30.0				< 0.070	9.300		
PGSP0215	May/04/1993	13:50	41.0	28.000	< 0.260	4.400	0.740	8.200	5.100	6.100
PGSP0216	May/04/1993	14:50	44.0				0.830	9.600		
PGSP0217	May/04/1993	15:50	42.0				0.870	9.300		
PGSP0218	May/04/1993	16:50	39.0				0.950	8.100		
PGSP0219	May/04/1993	17:50	42.0				0.900	7.800		
PGSP0220	May/04/1993	18:50	39.0				0.890	7.900		
PGSP0221	May/04/1993	19:50	38.0				0.760	7.400		
PGSP0222	May/04/1993	20:50	38.0				0.700	7.800		
PGSP0223	May/04/1993	21:50	40.0				0.790	7.100		
PGSP0224	May/04/1993	22:50	43.0				0.710	6.900		
PGSP0225	May/05/1993	1:50	40.0				0.640	7.200		
PGSP0226	May/05/1993	4:50	29.0				0.500	7.100		
PGSP0227	May/05/1993	7:50	31.0				0.500	7.000		
PGSP0228	May/05/1993	10:50	30.0				0.430	5.900		
PGSP0229	May/05/1993	13:50	28.0				0.400	5.000		
PGSP0230	May/05/1993	16:50	28.0				0.350	4.600		
PGSP0231	May/05/1993	19:50	27.0				0.340	4.500		
PGSP0232	May/05/1993	22:50	24.0				0.300	4.300		
PGSP0233	May/06/1993	1:50	24.0				0.300	3.300		
PGSP0234	May/06/1993	9:15	23.0				0.240	2.600		
PGSP0235	May/18/1993	3:22	3.30				< 0.070	0.910		
PGSP0241	May/18/1993	9:22	3.00				< 0.070	0.690		
PGSP0251	May/19/1993	9:22	2.80				< 0.070	0.730		

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
PGSP0255	May/20/1993	9:42	2.80				< 0.070	0.770		
PGSP0256	May/21/1993	2:15	2.40				< 0.070	0.320		
PGSP0257	May/22/1993	2:15	2.30				< 0.070	0.280		
PGSP0258	May/23/1993	2:15	2.40				< 0.070	0.250		
PGSP0259	May/24/1993	2:15	1.90				< 0.070	0.260		
PGSP0260	May/26/1993	12:42	2.10				< 0.070	0.200		
PGSP0261	May/29/1993	18:50	2.00				< 0.070	0.160		
PGSP0262	Jun/01/1993	16:29	3.60				0.660	1.000		
PGSP0263	Jun/02/1993	4:29	3.60				0.600	0.780		
PGSP0264	Jun/02/1993	14:30	3.40	2.300	< 0.260		0.550	0.700	0.370	0.080
PGSP0265	Jun/08/1993	17:14	2.00				0.100	0.260		
PGSP0266	Jun/16/1993	6:05	2.00				< 0.070	0.130		
PGSP0267	Jun/24/1993	9:23	1.60				< 0.070	0.080		
PGSP0268	Jun/24/1993	19:52	1.90				< 0.070	0.180		
PGSP0269	Jun/24/1993	20:52	2.10				< 0.070	< 0.060		
PGSP0270	Jun/24/1993	21:52	1.70				< 0.070	0.061		
PGSP0271	Jun/24/1993	22:52	1.50				< 0.070	0.130		
PGSP0272	Jun/24/1993	23:52	1.80				< 0.070	0.160		
PGSP0273	Jun/25/1993	0:52	1.80				< 0.070	0.150		
PGSP0274	Jun/25/1993	1:52	1.70				< 0.070	0.110		
PGSP0275	Jun/25/1993	2:52	1.90				< 0.070	0.180		
PGSP0276	Jun/25/1993	3:52	1.80				< 0.070	0.210		
PGSP0277	Jun/25/1993	4:52	1.80				< 0.070	0.110		
PGSP0278	Jun/25/1993	7:52	1.40				< 0.070	0.110		
PGSP0279	Jun/25/1993	10:52	1.50				< 0.070	0.140		
PGSP0280	Jun/25/1993	13:52	1.60				< 0.070	0.150		
PGSP0281	Jun/25/1993	16:52	1.60				< 0.070	0.089		
PGSP0282	Jun/25/1993	19:52	1.40				< 0.070	0.170		
PGSP0283	Jun/25/1993	22:52	1.50				< 0.070	0.120		
PGSP0284	Jun/26/1993	1:52	1.40				< 0.070	0.430		
PGSP0285	Jun/26/1993	4:52	1.60				< 0.070	1.300		
PGSP0286	Jun/26/1993	7:52	0.82				< 0.070	1.300		
PGSP0287	Jun/26/1993	10:52	1.80				0.083	1.200		
PGSP0288	Jun/26/1993	22:52	1.90				0.077	0.840		

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
PGSP0289	Jun/27/1993	10:52	1.80				< 0.070	0.320		
PGSP0290	Jun/27/1993	22:52	0.96				< 0.070	0.180		
PGSP0291	Jun/28/1993	10:52	1.50				< 0.070	0.130		
PGSP0292	Jun/29/1993	11:00	1.80	0.910	< 0.260	< 0.240	< 0.070	0.160	0.088	< 0.018
PGSP0293	Jul/02/1993	16:04	1.50				< 0.070	0.180		
PGSP0294	Jul/03/1993	13:04	1.40				< 0.070	0.100		
PGSP0295	Jul/15/1993	12:08	1.20				< 0.070	0.060		
PGSP0296	Jul/16/1993	11:29	1.40				< 0.070	0.670		
PGSP0297	Jul/22/1993	11:17	1.20				< 0.070	0.660		
PGSP0298	Jul/29/1993	9:46	1.30				< 0.070	0.060		
PGSP0299	Aug/04/1993	9:00	1.10	0.660	< 0.260	< 0.240	< 0.070	0.067	0.081	< 0.018
PGSP0300	Aug/14/1993	15:53	1.00				< 0.070	< 0.060		
PGSP0301	Aug/24/1993	12:18	0.97				< 0.070	0.060		
PGSP0302	Sep/09/1993	7:30	0.80	0.400	< 0.260		< 0.070	< 0.060	0.033	< 0.018
		Average*	4.837	2.873	0.231	0.583	0.137	0.891	0.457	0.459
		Maximum	44.00	28.000	0.360	4.400	0.950	9.600	5.100	6.1
		Minimum	< 0.06	0.260	< 0.160	< 0.150	< 0.070	< 0.060	< 0.031	< 0.018
		Stand. Dev.	10.829	7.934	0.073	1.267	1.930	2.181	1.398	1.624
		Coef. Var.	2.239	2.761	0.314	2.174	1.408	2.448	3.058	3.541
		No. Analyses	184	11	13	10	183	184	12	14

Spring Valley karst window, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
SVKW0015	May/20/1993	9:20	2.80				< 0.070	0.840		
SVKW0016	May/26/1993	12:10	2.00				< 0.070	0.180		
SVKW0017	Jun/02/1993	12:55	2.90				0.540	0.650		
		Average*	2.567					0.557		
		Maximum	2.90				0.540	0.840		
		Minimum	2.00				< 0.070	0.180		
		No. Analyses	3				3	3		

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

George Delaney swallow hole, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
GDSW0009	May/20/1993	8:14	2.600				< 0.070	1.000		
GDSW0010	May/26/1993	11:50	1.900				< 0.070	< 0.060		
GDSW010A	Jun/03/1993	8:45	3.100					0.390		
GDSW0011	Jun/17/1993	8:20	2.100				< 0.070	< 0.060		
		Average*	2.425							
		Maximum	3.100				< 0.070	1.000		
		Minimum	1.900					< 0.060		
		No. Analyses	4				3	4		

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Leslie Page karst window, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
LPKW0001	Apr/10/1993	18:00	0.25				< 0.070	< 0.060		
LPKW0002	Apr/11/1993	6:00	0.36				< 0.070	< 0.060		
LPKW0003	Apr/11/1993	18:00	0.25				< 0.070	< 0.060		
LPKW0004	Apr/12/1993	6:00	0.34				< 0.070	< 0.060		
LPKW0005	Apr/12/1993	18:00	0.29				< 0.070	< 0.060		
LPKW0006	Apr/13/1993	6:00	0.34				< 0.070	< 0.060		
LPKW0007	May/05/1993	8:17	2.00				< 0.070	< 0.060		
LPKW0009	May/20/1993	11:10	1.10				< 0.070	< 0.060		
LPKW0010	May/26/1993	11:30	0.40				< 0.070	< 0.060		
LPKW010A	Jun/02/1993	16:50	0.64				< 0.070	< 0.060		
LPKW0011	Jun/08/1993	8:34	0.45				< 0.070	< 0.060		
LPKW0012	Jun/17/1993	9:50	0.37				< 0.070	< 0.060		
LPKW0013	Jun/24/1993	10:00	0.44				< 0.070	< 0.060		
LPKW0014	Jun/30/1993	9:45	0.47				< 0.070	0.082		
LPKW0015	Jul/15/1993	11:22	0.28				< 0.070	< 0.060		
LPKW0016	Jul/22/1993	10:19	0.30				< 0.070	0.490		
LPKW0017	Jul/29/1993	10:32	0.41				< 0.070	< 0.060		
		Average*	0.511					0.087		
		Maximum	2.00				< 0.070	0.490		
		Minimum	0.25					< 0.060		
		Stand. Dev.	0.433					0.104		
		Coef. Var.	0.847					1.202		
		No. Analyses	17				17	17		

Upper Pleasant Grove Creek, October 1992–September 1993

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
UPGC0001	Jun/17/1993	7:25	2.10			< 0.070	0.370			
UPGC0002	Jun/30/1993	9:10	2.20			0.086	0.470			
UPGC0003	Aug/03/1993	15:33	1.70			< 0.070	0.075			
		Average*	2.000				0.305			
		Maximum	2.20			0.086	0.470			
		Minimum	1.70			< 0.070	0.075			
		No. Analyses	3			3	3			

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
PGSP0303	Oct/06/1993	7:30	0.63	0.420	< 0.260		< 0.070	< 0.060	0.031	< 0.018
PGSP0304	Nov/09/1993	10:45	0.63	0.420	< 0.260		< 0.070	< 0.031	< 0.031	
PGSP0305	Nov/18/1993	12:37	0.51				< 0.070	0.080		
PGSP0306	Dec/08/1993	9:30	1.50				< 0.070	< 0.060		
PGSP0307	Dec/09/1993	21:04	1.10				< 0.070	< 0.060		0.067
PGSP0308	Dec/09/1993	22:04	1.00							
PGSP0309	Dec/09/1993	23:04	1.10							
PGSP0310	Dec/10/1993	0:04	1.20							
PGSP0311	Dec/10/1993	1:04	1.00							
PGSP0312	Dec/10/1993	2:04	0.99				< 0.070	< 0.060		
PGSP0313	Dec/10/1993	3:04	1.20							
PGSP0314	Dec/10/1993	4:04	1.10							
PGSP0315	Dec/10/1993	5:04	1.00							
PGSP0316	Dec/10/1993	6:04	1.30							
PGSP0317	Dec/10/1993	9:04	0.87				< 0.070	0.064		
PGSP0318	Dec/10/1993	12:04	0.68							
PGSP0319	Dec/10/1993	15:04	0.94							
PGSP0320	Dec/10/1993	18:04	0.85							
PGSP0321	Dec/10/1993	21:04	0.98							
PGSP0322	Dec/11/1993	0:04	1.10							
PGSP0323	Dec/11/1993	3:04	1.00							
PGSP0324	Dec/11/1993	6:04	1.10							
PGSP0325	Dec/11/1993	9:04	1.20							
PGSP0326	Dec/11/1993	12:04	1.00				< 0.070	< 0.060		
PGSP0327	Dec/12/1993	0:04	1.20							
PGSP0328	Dec/12/1993	12:04	1.00				< 0.070	< 0.060		
PGSP0329	Dec/13/1993	0:04	1.40							
PGSP0330	Dec/13/1993	12:04	0.88				< 0.070	< 0.060		
PGSP0332	Dec/29/1993	12:55	0.87				< 0.080	< 0.080		
PGSP0333	Jan/02/1994	3:55	0.83				< 0.080	< 0.080		
PGSP0334	Jan/12/1994	11:40	0.94				< 0.080	< 0.080		
PGSP0335	Jan/24/1994	17:24	0.57				< 0.080	< 0.080		
PGSP0336	Jan/24/1994	20:24	0.49				< 0.080	< 0.080		
PGSP0337	Jan/25/1994	8:24	0.62				< 0.080	< 0.080		
PGSP0338	Jan/25/1994	20:24	0.50				< 0.080	< 0.080		

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
PGSP0339	Jan/26/1994	8:24	0.53				< 0.080	< 0.080		
PGSP0340	Jan/26/1994	20:24	0.76				< 0.080	< 0.080		
PGSP0341	Jan/27/1994	8:50	0.87				< 0.080	< 0.080		
PGSP0342	Feb/02/1994	12:10	< 0.07				< 0.080	< 0.080		
PGSP0343	Feb/22/1994	11:20	0.72	0.320	< 0.350		< 0.080	< 0.080	< 0.023	< 0.017
PGSP0344	Mar/01/1994	11:00	0.69				< 0.080	< 0.080		
PGSP0345	Mar/09/1994	9:00	1.30				< 0.080	0.280		
PGSP0346	Mar/15/1994	15:57	1.50				< 0.080	0.350		
PGSP0347	Mar/27/1994	5:30	1.00				< 0.080	0.170		
PGSP0348	Mar/27/1994	6:10	0.91				< 0.080	0.140		
PGSP0349	Mar/27/1994	6:50	0.90				< 0.080	0.087		
PGSP0350	Mar/27/1994	7:30	0.72				< 0.080	< 0.080		
PGSP0351	Mar/27/1994	8:10	1.20				< 0.080	< 0.080		
PGSP0352	Mar/27/1994	9:30	1.40				< 0.080	< 0.080		
PGSP0353	Mar/27/1994	11:30	2.00				< 0.080	< 0.080		
PGSP0354	Mar/27/1994	13:30	2.60				< 0.080	0.099		
PGSP0355	Mar/27/1994	14:30	2.40				< 0.080	0.100		
PGSP0356	Mar/27/1994	15:30	2.70				< 0.080	0.150		
PGSP0357	Mar/27/1994	16:30	2.40				< 0.080	0.100		
PGSP0358	Mar/27/1994	17:30	1.10				< 0.080	0.110		
PGSP0359	Mar/27/1994	18:30	1.90				< 0.080	0.210		
PGSP0360	Mar/27/1994	22:30	1.60				< 0.080	0.130		
PGSP0361	Mar/28/1994	2:30	1.90				< 0.080	0.170		
PGSP0362	Mar/28/1994	6:30	1.90				< 0.080	0.140		
PGSP0363	Mar/28/1994	10:30	1.90				< 0.080	0.120		
PGSP0364	Mar/28/1994	13:00	2.00	1.150	< 0.100	< 0.500	< 0.080	< 0.250		
PGSP0365	Mar/28/1994	18:00	1.50				< 0.080	0.170		
PGSP0366	Mar/29/1994	6:00	1.20				< 0.080	0.190		
PGSP0367	Mar/29/1994	18:00	1.30				< 0.080	0.170		
PGSP0368	Mar/30/1994	6:00	1.20				< 0.080	0.140		
PGSP0369	Mar/30/1994	18:00	1.20				< 0.080	0.160		
PGSP0370	Mar/31/1994	6:00	1.20				< 0.080	0.160		
PGSP0371	Mar/31/1994	18:00	1.10				< 0.080	0.160		
PGSP0372	Apr/01/1994	6:00	1.10				< 0.080	0.110		

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
PGSP0373	Apr/01/1994	18:00	1.30				< 0.080	0.110		
PGSP0374	Apr/02/1994	6:00	1.30				< 0.080	0.160		
PGSP0375	Apr/02/1994	18:00	1.30				< 0.080	0.140		
PGSP0376	Apr/03/1994	6:00	1.30				< 0.080	0.140		
PGSP0377	Apr/03/1994	18:00	1.20				< 0.080	0.130		
PGSP0378	Apr/04/1994	6:00	1.20				< 0.080	0.140		
PGSP0379	Apr/04/1994	18:00	1.10				< 0.080	0.130		
PGSP0380	Apr/05/1994	6:00	1.20				< 0.080	0.110		
PGSP0381	Apr/05/1994	18:00	1.20				< 0.080	0.150		
PGSP0382	Apr/06/1994	6:00	0.93				< 0.080	0.120		
PGSP0383	Apr/06/1994	18:00	1.90				< 0.080	0.200		
PGSP0384	Apr/07/1994	6:00	2.40				< 0.080	0.230		
PGSP0385	Apr/07/1994	14:00	2.10				< 0.080	0.300		
PGSP0387	Apr/11/1994	14:13	3.10				< 0.080	< 0.080		
PGSP0388	Apr/11/1994	17:57	3.00				< 0.080	0.980		
PGSP0389	Apr/12/1994	7:30	2.90				< 0.080	0.320		
PGSP0391	Apr/12/1994	15:30	2.50				< 0.080	0.200		
PGSP0392	Apr/13/1994	6:15	2.60				< 0.080	0.260		
PGSP0393	Apr/13/1994	18:00	2.20				< 0.080	0.130		
PGSP0394	Apr/14/1994	6:00	1.90				< 0.080	0.130		
PGSP0395	Apr/14/1994	18:00	1.80				< 0.080	0.180		
PGSP0396	Apr/15/1994	6:00	1.70				< 0.080	0.180		
PGSP0397	Apr/15/1994	18:00	1.60				0.170	0.120		
PGSP0398	Apr/16/1994	6:00	2.50				< 0.080	0.350		
PGSP0399	Apr/16/1994	18:00	2.00				< 0.080	0.230		
PGSP0400	Apr/17/1994	6:00	0.76				< 0.080	0.200		
PGSP0401	Apr/17/1994	18:00	1.80				< 0.080	0.160		
PGSP0402	Apr/18/1994	6:00	1.70				< 0.080	0.160		
PGSP0403	Apr/18/1994	18:00	1.70				< 0.080	0.140		
PGSP0404	Apr/19/1994	6:00	1.60				< 0.080	0.160		
PGSP404A	Apr/20/1994	6:00	1.80				< 0.080	0.340		
PGSP0405	Apr/21/1994	6:00	1.80				< 0.080	0.240		
PGSP0406	Apr/22/1994	6:00	1.90				< 0.080	0.300		
PGSP0407	Apr/23/1994	6:00	1.70				< 0.080	0.290		

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
PGSP0408	Apr/24/1994	6:00	1.80				< 0.080	0.320		
PGSP0409	Apr/25/1994	6:00	1.80				< 0.080	0.340		
PGSP0410	Apr/26/1994	6:00	1.80				< 0.080	0.560		
PGSP0411	Apr/27/1994	6:00	1.90				< 0.080	0.200		
PGSP0412	Apr/27/1994	10:00	1.90	< 0.100	< 0.100		< 0.080	0.320	< 0.250	< 0.100
PGSP0413	Apr/28/1994	6:00	1.90				< 0.080	0.290		
PGSP0414	Apr/29/1994	6:00	1.80				< 0.080	0.280		
PGSP0415	Apr/29/1994	18:00	1.90				< 0.080	0.250		
PGSP0416	Apr/29/1994	18:45	2.00				0.180	0.430		
PGSP0417	Apr/29/1994	19:05	2.80				0.092	0.430		
PGSP0418	Apr/29/1994	19:09	2.70				< 0.080	0.360		
PGSP0419	Apr/29/1994	19:25	2.80				0.130	0.430		
PGSP0420	Apr/29/1994	19:45	2.80				< 0.080	0.450		
PGSP0421	Apr/29/1994	19:51	2.60				< 0.080	0.340		
PGSP0422	Apr/29/1994	20:05	2.50				< 0.080	0.350		
PGSP0423	Apr/29/1994	20:25	2.48				< 0.080	0.400		
PGSP0424	Apr/29/1994	20:45	2.30				< 0.080	0.470		
PGSP0425	Apr/29/1994	21:05	1.90				< 0.080	0.500		
PGSP0426	Apr/29/1994	21:25	2.80				< 0.080	0.330		
PGSP0427	Apr/29/1994	21:45	4.80				< 0.080	0.370		
PGSP0428	Apr/29/1994	22:45	7.20				1.400	1.000		
PGSP0429	Apr/29/1994	23:45	6.40				5.700	1.700		
PGSP0430	Apr/30/1994	0:45	6.60				7.400	1.800		
PGSP0431	Apr/30/1994	1:45	6.00				5.700	1.700		
PGSP0432	Apr/30/1994	2:45	6.10				3.800	2.700		
PGSP0433	Apr/30/1994	3:45	6.00				3.800	3.800		
PGSP0434	Apr/30/1994	4:45	6.30				4.900	4.300		
PGSP0435	Apr/30/1994	5:45	5.90				5.200	4.500		
PGSP0436	Apr/30/1994	6:45	6.20				5.800	4.200		
PGSP0437	Apr/30/1994	7:45	5.80				4.700	3.600		
PGSP0438	Apr/30/1994	11:45	5.70				3.000	2.300		
PGSP0439	Apr/30/1994	15:45	5.00				1.100	1.400		
PGSP0440	May/01/1994	6:00	5.80				0.220	2.100		
PGSP0441	May/02/1994	6:00	4.08				< 0.080	1.200		

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1993–September 1994

Sample Number	Date	Time (CST)	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
PGSP0442	May/03/1994	6:00	2.60				0.087	0.390		
PGSP0443	May/04/1994	6:00	3.70				0.530	0.600		
PGSP0444	May/04/1994	18:00	3.30				0.530	0.680		
PGSP0445	May/05/1994	6:00	2.40				0.230	0.410		
PGSP0446	May/07/1994	6:00	1.90				< 0.080	0.200		
PGSP0447	May/09/1994	6:00	2.20				0.140	0.270		
PGSP0448	May/11/1994	6:00	1.80				0.096	0.190		
PGSP0449	May/12/1994	9:00	1.50				0.089	0.180		
PGSP0450	May/13/1994	6:00	1.40				< 0.080	0.240		
PGSP0451	May/14/1994	6:00	1.50				< 0.080	0.230		
PGSP0452	May/15/1994	6:00	1.60				< 0.080	0.200		
PGSP0453	May/15/1994	18:00	1.50				< 0.080	0.210		
PGSP0454	May/16/1994	6:00	3.50				< 0.080	0.360		
PGSP0455	May/17/1994	6:00	2.50				< 0.080	0.400		
PGSP0456	May/18/1994	6:00	1.70				< 0.080	0.120		
PGSP0457	May/20/1994	6:00	1.40				< 0.080	< 0.080		
PGSP0458	May/22/1994	6:00	1.20				< 0.080	< 0.080		
PGSP0459	May/24/1994	6:00	1.20				< 0.080	< 0.080		
PGSP0460	May/26/1994	6:00	1.20				< 0.080	< 0.080		
PGSP0461	May/28/1994	6:00	1.20				< 0.080	< 0.080		
PGSP0462	May/30/1994	6:00	1.10				< 0.080	< 0.080		
PGSP0463	Jun/01/1994	12:00	1.00				< 0.080	< 0.080		
PGSP0464	Jun/03/1994	6:00	1.00					< 0.080		
PGSP0465	Jun/05/1994	6:00	0.99					< 0.080		
PGSP0466	Jun/07/1994	6:00	1.10					< 0.080		
PGSP0467	Jun/09/1994	6:00	1.20					0.130		
PGSP0468	Jun/10/1994	6:00	1.20					0.100		
PGSP0469	Jun/10/1994	11:01	1.40					0.150		
PGSP0470	Jun/10/1994	11:21	1.30					0.150		
PGSP0471	Jun/10/1994	11:41	1.30					0.160		
PGSP0472	Jun/10/1994	12:01	1.30					0.120		
PGSP0473	Jun/10/1994	12:21	1.30					0.150		
PGSP0474	Jun/10/1994	12:41	1.20					0.170		
PGSP0475	Jun/10/1994	13:01	1.30					0.130		

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
PGSP0476	Jun/10/1994	13:21	1.30					0.170		
PGSP0477	Jun/10/1994	13:41	1.30					0.140		
PGSP0478	Jun/10/1994	14:01	1.40					0.140		
PGSP0479	Jun/10/1994	15:01	1.40					0.150		
PGSP0480	Jun/10/1994	16:01	1.30					< 0.080		
PGSP0481	Jun/10/1994	17:01	1.30					0.097		
PGSP0482	Jun/10/1994	18:01	1.40					< 0.080		
PGSP0483	Jun/10/1994	19:01	1.20					< 0.080		
PGSP0484	Jun/10/1994	20:01	1.20					< 0.080		
PGSP0485	Jun/10/1994	21:01	1.30					< 0.080		
PGSP0486	Jun/10/1994	22:01	1.30					< 0.080		
PGSP0487	Jun/10/1994	23:01	1.30					< 0.080		
PGSP0488	Jun/11/1994	0:01	1.20					< 0.080		
PGSP0489	Jun/11/1994	4:01	1.20					< 0.080		
PGSP0490	Jun/11/1994	6:00	1.10					< 0.080		
PGSP0491	Jun/11/1994	8:01	1.30					< 0.080		
PGSP0492	Jun/11/1994	12:01	1.30					< 0.080		
PGSP0493	Jun/11/1994	16:01	1.10					< 0.080		
PGSP0494	Jun/14/1994	6:00	1.10					< 0.080		
PGSP0495	Jun/16/1994	6:00	0.99					< 0.080		
PGSP0496	Jun/17/1994	6:00	1.10					< 0.080		
PGSP0497	Jun/17/1994	21:13	1.10					< 0.080		
PGSP0498	Jun/17/1994	21:33	1.10					< 0.080		
PGSP0499	Jun/17/1994	21:53	1.10					< 0.080		
PGSP0500	Jun/17/1994	22:13	1.10					< 0.080		
PGSP0501	Jun/17/1994	22:33	1.10					< 0.080		
PGSP0502	Jun/17/1994	22:53	1.10					< 0.080		
PGSP0503	Jun/17/1994	23:13								
PGSP0504	Jun/17/1994	23:33	1.00					< 0.080		
PGSP0505	Jun/17/1994	23:53	1.10					< 0.080		
PGSP0506	Jun/18/1994	0:13	1.00					< 0.080		
PGSP0507	Jun/18/1994	1:13	1.00					< 0.080		
PGSP0508	Jun/18/1994	2:13	2.80					0.440		
PGSP0509	Jun/18/1994	3:13	3.50					0.720		

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (μg/L)*	*Total GC Atrazine (μg/L)*	*Total GC Simazine (μg/L)*	*Total GC Cyanazine (μg/L)*	*Total ELISA Carbofuran (μg/L)*	*Total ELISA Metolachlor (μg/L)*	*Total GC Metolachlor (μg/L)*	*Total GC Alachlor (μg/L)*
PGSP0510	Jun/18/1994	4:13	4.00					1.200		
PGSP0511	Jun/18/1994	5:13	3.80					1.500		
PGSP0512	Jun/18/1994	6:13	3.80					1.100		
PGSP0513	Jun/18/1994	7:13	4.10					1.600		
PGSP0514	Jun/18/1994	8:13	4.00					1.800		
PGSP0515	Jun/18/1994	9:13	3.90					1.800		
PGSP0516	Jun/18/1994	10:13	4.20					1.800		
PGSP0517	Jun/18/1994	14:13	3.80					1.500		
PGSP0518	Jun/18/1994	18:13	4.30					1.400		
PGSP0519	Jun/18/1994	22:13	3.60					1.300		
PGSP0520	Jun/19/1994	2:13	3.40					1.100		
PGSP0521	Jun/20/1994	6:00	1.40					0.160		
PGSP0522	Jun/22/1994	6:00	1.30					< 0.080		
PGSP0523	Jun/24/1994	6:00	1.10					< 0.080		
PGSP0524	Jun/26/1994	6:00	1.10					< 0.080		
PGSP0525	Jun/29/1994	6:00	1.10					0.110		
PGSP0526	Jul/01/1994	6:00	1.00					0.110		
PGSP0527	Jul/03/1994	6:00	0.98					< 0.080		
PGSP0528	Jul/05/1994	6:00	0.88					< 0.080		
PGSP0529	Jul/06/1994	10:30	0.98					< 0.080		
PGSP0530	Jul/07/1994	6:00	1.00					0.098		
PGSP0531	Jul/07/1994	6:30	1.00					0.180		
PGSP0532	Jul/07/1994	7:10	1.10					0.270		
PGSP0533	Jul/07/1994	11:30	1.30					3.100		
PGSP0534	Jul/13/1994	6:00	1.10					0.210		
PGSP0535	Jul/20/1994	6:00	1.00					< 0.080		
PGSP0537	Jul/25/1994	8:40	1.00					< 0.080		
PGSP0538	Aug/03/1994	8:30	0.80					< 0.080		

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Pleasant Grove Spring, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
PGSP0539	Aug/16/1994	10:00	0.63					< 0.080		
PGSP0540	Sep/08/1994	8:15	0.60					< 0.080		
PGSP0541	Sep/19/1994	13:50	0.64					< 0.080		
		Average*	1.844	0.482	0.214		0.458	0.409		0.044
		Maximum	7.20	1.150	0.350		7.400	4.500	< 0.250	0.1
		Minimum	< 0.07	< 0.100	< 0.100		< 0.070	< 0.060		0.017
		Stand. Dev.	1.333	0.396	0.110		1.313	0.749		0.038
		Coef. Var.	0.723	0.821	0.516		2.864	1.831		0.861
		No. Analyses	236	5	5	1	140	217	4	5

George Delaney swallow hole, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
GDSW0012	Dec/07/1993	11:40	1.10				< 0.070	< 0.060		
GDSW0013	Mar/28/1994	10:40	0.48				< 0.080	< 0.080		
GDSW0014	Apr/07/1994	15:00	2.10				< 0.080	0.140		
GDSW0015	Apr/20/1994	12:10	0.90				< 0.080	< 0.080		
GDSW0016	Apr/26/1994	15:30	1.20				< 0.080	< 0.080		
GDSW0017	May/12/1994	9:50	1.30				< 0.080	< 0.080		
GDSW0018	May/17/1994	13:28	1.30				< 0.080	< 0.080		
GDSW0019	Jun/01/1994	7:36	1.10				< 0.080	< 0.080		
GDSW0020	Jun/15/1994	0:20	1.20					< 0.080		
GDSW0021	Jul/06/1994	9:45	1.10					< 0.080		
		Average*	1.178							
		Maximum	2.10				< 0.080	0.140		
		Minimum	0.48					< 0.060		
		No. Analyses	10				8	10		

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Leslie Page karst window, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
LPKW0019	Oct/05/1993	13:20	0.12				< 0.070	< 0.060		
LPKW0020	Nov/09/1993	9:35	0.15					< 0.060		
LPKW0021	Dec/07/1993	16:53	0.39				< 0.070	< 0.060		
LPKW0022	Jan/11/1994	14:23	0.34				< 0.080	< 0.080		
LPKW0023	Feb/02/1994	9:55	0.07				< 0.080	< 0.080		
LPKW0024	Feb/22/1994	13:30	0.57	0.220	< 0.350		< 0.080	< 0.080	< 0.023	< 0.017
LPKW0026	Mar/10/1994	19:23	3.00				< 0.080	1.900		
LPKW0027	Mar/10/1994	19:43	3.10				< 0.080	1.500		
LPKW0028	Mar/10/1994	20:03	3.00				< 0.080	2.100		
LPKW0029	Mar/10/1994	20:23	2.90				< 0.080	2.100		
LPKW0030	Mar/10/1994	20:43	2.90				< 0.080	2.000		
LPKW0031	Mar/10/1994	21:03	3.00				< 0.080	2.000		
LPKW0032	Mar/10/1994	21:23	2.80				< 0.080	1.700		
LPKW0033	Mar/10/1994	21:43	2.80				< 0.080	2.000		
LPKW0034	Mar/10/1994	22:03	2.60				< 0.080	1.900		
LPKW0035	Mar/10/1994	22:23	2.60				< 0.080	1.800		
LPKW0036	Mar/10/1994	23:23	2.30				< 0.080	1.400		
LPKW0037	Mar/11/1994	0:23	2.40				< 0.080	1.400		
LPKW0038	Mar/11/1994	1:23	3.50				< 0.080	2.800		
LPKW0039	Mar/11/1994	2:23	3.30				< 0.080	2.500		
LPKW0040	Mar/11/1994	3:23	3.40				< 0.080	2.300		
LPKW0041	Mar/11/1994	4:23	3.30				< 0.080	2.500		
LPKW0042	Mar/11/1994	5:23	3.20				< 0.080	2.600		
LPKW0043	Mar/11/1994	6:23	3.50				< 0.080	2.500		
LPKW0044	Mar/11/1994	7:23	3.60				< 0.080	2.600		
LPKW0045	Mar/11/1994	8:23	3.20				< 0.080	2.500		
LPKW0046	Mar/11/1994	12:23	3.50				< 0.080	2.500		
LPKW0047	Mar/11/1994	16:23	3.20				< 0.080	2.300		
LPKW0048	Mar/11/1994	20:23	3.40				< 0.080	2.300		
LPKW0049	Mar/12/1994	0:23	3.10				< 0.080	2.200		
LPKW0050	Mar/15/1994	17:10	1.60				< 0.080	0.650		
LPKW0051	Mar/27/1994	15:50	3.30				< 0.080	2.100		
LPKW0052	Mar/28/1994	9:10	2.70				< 0.080	2.000		
LPKW0053	Mar/28/1994	9:30	2.70				< 0.080	1.100		

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Leslie Page karst window, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
LPKW0054	Mar/28/1994	9:50	2.80				< 0.080	1.200		
LPKW0055	Mar/28/1994	10:10	2.70				< 0.080	1.200		
LPKW0056	Mar/28/1994	10:30	2.60				< 0.080	1.100		
LPKW0057	Mar/28/1994	10:50	3.20				< 0.080	1.100		
LPKW0058	Mar/28/1994	11:10	2.80				< 0.080	1.100		
LPKW0059	Mar/28/1994	11:30	3.10				< 0.080	1.100		
LPKW0060	Mar/28/1994	11:50	2.40				< 0.080	1.100		
LPKW0061	Mar/28/1994	12:10	2.50				0.290	1.300		
LPKW0062	Mar/28/1994	12:30	2.50				< 0.080	1.100		
LPKW0063	Mar/28/1994	13:30	2.60				< 0.080	1.100		
LPKW0064	Mar/28/1994	14:30	2.40				< 0.080	1.200		
LPKW0065	Mar/28/1994	15:30	2.40				< 0.080	1.000		
LPKW0066	Mar/28/1994	16:30	2.50				< 0.080	1.100		
LPKW0067	Mar/28/1994	17:30	2.40				< 0.080	1.000		
LPKW0068	Mar/28/1994	18:30	2.30				< 0.080	0.920		
LPKW0069	Mar/28/1994	19:30	2.50				< 0.080	0.970		
LPKW0070	Mar/28/1994	20:30	2.10				< 0.080	0.840		
LPKW0071	Mar/28/1994	21:30	2.30				< 0.080	0.990		
LPKW0072	Mar/28/1994	22:30	2.40				< 0.080	0.880		
LPKW0073	Mar/29/1994	2:30	2.00				< 0.080	0.780		
LPKW0074	Mar/29/1994	6:30	1.90				< 0.080	0.720		
LPKW0075	Mar/29/1994	10:30	1.80				< 0.080	1.100		
LPKW0076	Mar/29/1994	14:30	1.70				< 0.080	0.920		
LPKW0077	Apr/07/1994	10:55	1.60				< 0.080	0.390		
LPKW0078	Apr/12/1994	8:06	3.40				< 0.080	1.300		
LPKW0079	Apr/20/1994	8:15	1.80				< 0.080	0.410		
LPKW0080	Apr/27/1994	8:31	1.60				< 0.080	0.380		
LPKW0081	May/02/1994	12:23	2.00				< 0.080	0.660		
LPKW0082	May/03/1994	6:00	1.60				< 0.080	0.340		
LPKW0083	May/04/1994	6:00	1.80				< 0.080	0.360		
LKPW0083	May/04/1994	6:00	1.80				< 0.080	0.360		
LPKW0088	May/09/1994	6:00	1.30				< 0.080	0.410		
LPKW0089	May/11/1994	6:00	1.20				< 0.080	0.390		
LPKW0090	May/12/1994	10:40	1.10				< 0.080	0.430		

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Leslie Page karst window, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
LPKW0091	May/13/1994	6:00	1.30				< 0.080	0.390		
LPKW0092	May/14/1994	6:00	1.30				< 0.080	0.490		
LKPW0092	May/14/1994	6:00	1.30				< 0.080	0.490		
LPKW0093	May/15/1994	6:00	1.30				< 0.080	0.160		
LPKW0094	May/16/1994	6:00	1.10				< 0.080	0.410		
LPKW0095	May/17/1994	6:00	1.60				< 0.080	0.450		
LPKW0096	May/18/1994	6:00	1.50				< 0.080	0.310		
LPKW0097	May/20/1994	6:00	1.20				< 0.080	0.190		
LPKW0098	May/22/1994	6:00	1.20				< 0.080	0.170		
LPKW0099	May/24/1994	6:00	1.20				< 0.080	< 0.080		
LPKW0100	May/25/1994	10:45	1.20				< 0.080	0.250		
LPKW0101	May/27/1994	10:45	1.20				< 0.080	0.210		
LPKW0102	May/29/1994	10:45	1.10				< 0.080	0.200		
LPKW0103	May/31/1994	10:45	1.10				< 0.080	0.190		
LPKW0104	Jun/01/1994	8:30	1.20				< 0.080	0.210		
LPKW0105	Jun/15/1994	11:35	1.10					0.120		
LPKW0106	Jun/27/1994	23:50	0.91					0.320		
LPKW0107	Jun/28/1994	7:50	0.91					0.310		
LPKW0108	Jun/29/1994	7:50	0.90					0.280		
LPKW0109	Aug/02/1994	14:20	0.75					0.110		
LPKW0110	Sep/07/1994	12:50	0.52					0.140		
		Average*	2.091					1.048		
		Maximum	3.60				0.290	2.800		
		Minimum	0.07				< 0.070	< 0.060		
		Stand. Dev.	0.939					0.812		
		Coef. Var.	0.449					0.774		
		No. Analyses	89	1	1		83	89	1	1

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Upper Pleasant Grove Creek, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
UPGC0004	Nov/18/1993	11:31	1.10				< 0.070	< 0.060		
UPGC0005	Dec/07/1993	15:10	0.64				< 0.070	< 0.060		
UPGC0006	Feb/22/1994	15:16	0.77				< 0.080	< 0.080		
UPGC0007	Mar/28/1994	11:05	0.50				< 0.080	< 0.080		
UPGC0008	Apr/07/1994	10:25	1.90				< 0.080	0.270		
UPGC0009	Apr/20/1994	12:25	1.00				< 0.080	< 0.080		
UPGC0010	Apr/27/1994	7:10	1.10				< 0.080	< 0.080		
UPGC0011	May/12/1994	10:10	1.40				< 0.080	< 0.080		
UPGC0012	May/17/1994	12:13	1.50				< 0.080	< 0.080		
UPGC0013	Jun/01/1994	7:07	1.00				< 0.080	< 0.080		
UPGC0014	Jun/15/1994	11:00	1.20					< 0.080		
UPGC0015	Jul/06/1994	7:30	1.20					< 0.080		
		Average*	1.109							
		Maximum	1.90				< 0.080	0.270		
		Minimum	0.50					< 0.060		
		Stand. Dev.	0.383							
		Coef. Var.	0.345							
		No. Analyses	12				10	12		

Miller School House water well, October 1993–September 1994

Sample Number	*Date*	*Time (CST)*	*Total ELISA Triazines (µg/L)*	*Total GC Atrazine (µg/L)*	*Total GC Simazine (µg/L)*	*Total GC Cyanazine (µg/L)*	*Total ELISA Carbofuran (µg/L)*	*Total ELISA Metolachlor (µg/L)*	*Total GC Metolachlor (µg/L)*	*Total GC Alachlor (µg/L)*
MSHW0001	Apr/26/1994	14:00	0.070	< 0.100	< 0.100		< 0.080	< 0.080	< 0.250	< 0.100
		No. Analyses	1	1	1		1	1	1	1

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin. No data means an analysis was not performed.

Appendix J:
Bacteria Analyses and Descriptive Statistics for the Pleasant Grove Spring Drainage Basin

Pleasant Grove Spring, prior to June 1992

Sample Number	*Date*	*Fecal Coliform (col/100 ml)*	*Fecal Streptococci (col/100 ml)*	*Fecal Coliform-Fecal Strep Ratio*
PGSP0001	Aug/02/1990	518	9,000	0.06
PGSP0002	Feb/28/1991	22	70	0.31
PGSP0003	May/01/1991	136	70	1.94
PGSP0004	May/22/1991	236	1,300	0.18
PGSP0005	Jun/26/1991	418	16,000	0.03
PGSP0006	Jul/25/1991	118	110	1.07
PGSP0008	Sep/24/1991	3,400	540	6.30
PGSP0009	Oct/22/1991	49	49	1.00
PGSP0011	Jan/29/1992	18	130	0.14
PGSP0012	Feb/26/1992	2,727	16,000	0.17
PGSP0013	Mar/25/1992	90	230	0.39
PGSP0021	Apr/29/1992	108	920	0.12
PGSP0026	May/27/1992	180	350	0.51
	Average*	617	3,444	0.94
	Maximum	3,400	16,000	6.30
	Minimum	18	49	0.03
	Stand. Dev.	1,104	6,068	1.70
	Coef. Var	1.8	1.8	1.8
Total of 13 analyses				

Spring Valley karst window, prior to June 1992

Sample Number	*Date*	*Fecal Coliform (col/100 ml)*	*Fecal Streptococci (col/100 ml)*	*Fecal Coliform-Fecal Strep Ratio*
SVKW0001	Aug/02/1990	23	300	0.08
SVKW0002	Feb/28/1991	33	50	0.66
SVKW0003	May/22/1991	345	920	0.38
SVKW0004	Jun/26/1991	264	5,400	0.05
SVKW0005	Jul/25/1991	100	49	2.04
SVKW0007	Sep/24/1991	700	2,400	0.29
SVKW0008	Oct/22/1991	22	130	0.17
SVKW0009	Jan/29/1992	18	220	0.08
SVKW0010	Feb/26/1992	1,364	16,000	0.09
SVKW0011	Mar/25/1992	90	330	0.27
SVKW0013	Apr/29/1992	81	540	0.15
SVKW0014	May/27/1992	297	170	1.75
	Average*	278	2,209	0.50
	Maximum	1,364	16,000	2.04
	Minimum	18	49	0.05
	Stand. Dev.	396	4,610	0.68
	Coef. Var.	1.4	2.1	1.4
Total of 12 analyses				

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin.

The Canyon karst window, prior to June 1992

Sample Number	*Date*	*Fecal Coliform (col/100 ml)*	*Fecal Streptococci (col/100 ml)*	*Fecal Coliform-Fecal Strep Ratio*
TCKW0001	Aug/02/1990	33	110	0.30
TCKW0002	May/01/1991	11	49	0.22
TCKW0003	May/22/1991	155	350	0.44
TCKW0004	Jun/26/1991	91	3,500	0.03
TCKW0005	Jul/25/1991	9	94	0.10
TCKW0007	Sep/24/1991	300	130	2.31
TCKW0009	Jan/29/1992	9	49	0.18
TCKW0010	Feb/26/1992	18	350	0.05
TCKW0011	Mar/25/1992	198	22	9.00
TCKW0013	Apr/29/1992	27	23	1.17
TCKW0014	May/27/1992	63	130	0.48
	Average*	83	437	1.30
	Maximum	300	3,500	9.00
	Minimum	9	22	0.03
	Stand. Dev.	96	1,022	2.64
	Coef. Var.	1.2	2.3	2.0
Total of 11 analyses				

Shackelford Spring, prior to June 1992

Sample Number	*Date*	*Fecal Coliform (col/100 ml)*	*Fecal Streptococci (col/100 ml)*	*Fecal Coliform-Fecal Strep Ratio*
SKSP0001	Aug/02/1990	8	20	0.40
SKSP0002	Feb/28/1991	4	14	0.29
SKSP0003	May/01/1991	58	23	2.52
SKSP0004	May/22/1991	100	2,400	0.04
SKSP0005	Jul/25/1991	4	49	0.08
SKSP0007	Sep/24/1991	82	240	0.34
SKSP0008	Oct/22/1991	49	49	1.00
SKSP0010	Jan/29/1992	9	14	0.64
SKSP0011	Feb/26/1992	54	130	0.42
SKSP0012	Mar/25/1992	63	94	0.67
SKSP0013	Apr/29/1992	10	5	2.00
SKSP0014	May/27/1992	81	240	0.34
	Average*	44	273	0.73
	Maximum	100	2,400	2.52
	Minimum	4	5	0.04
	Stand. Dev.	35	675	0.77
	Coef. Var.	0.8	2.5	1.1
Total of 12 analyses				

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin.

Thad Flowers blue hole, prior to June 1992

Sample Number	*Date*	*Fecal Coliform (col/100 ml)*	*Fecal Streptococci (col/100 ml)*	*Fecal Coliform-Fecal Strep Ratio*
TFBH0001	Feb/28/1991	3	7	0.43
TFBH0002	May/01/1991	14	7	2.00
TFBH0003	May/22/1991	7	540	0.01
TFBH0004	Jun/26/1991	55	2,400	0.02
TFBH0005	Jul/25/1991	573	3,500	0.16
TFBH0008	Jan/29/1992	54	1,700	0.03
TFBH0009	Feb/26/1992	90	1,600	0.06
TFBH0010	Mar/25/1992	18	46	0.39
	Average*	102	1,225	0.39
	Maximum	573	3,500	2.00
	Minimum	3	7	0.01
	Stand. Dev.	193	1,296	0.67
	Coef. Var.	1.9	1.1	1.7
Total of 8 analyses				

George Delaney swallow hole, prior to June 1992

Sample Number	*Date*	*Fecal Coliform (col/100 ml)*	*Fecal Streptococci (col/100 ml)*	*Fecal Coliform-Fecal Strep Ratio*
GDSW0001	May/22/1991	391	3,500	0.11
GDSW0002	Jun/26/1991	345	5,400	0.06
GDSW0003	Jul/25/1991	1,800	3,500	0.51
GDSW0005	Jan/29/1992	126	920	0.14
GDSW0006	Feb/26/1992	14,000	24,000	0.58
GDSW0007	Mar/25/1992	540	490	1.10
	Average*	2,867	6,302	0.42
	Maximum	14,000	24,000	1.10
	Minimum	126	490	0.06
	Stand. Dev.	5,486	8,860	0.40
	Coef. Var.	1.9	1.4	1.0
Total of 6 analyses				

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin.

Pleasant Grove Spring, after October 1993

Sample Number	*Date*	*Fecal Coliform (col/100 ml)*	*Fecal Streptococci (col/100 ml)*	*Fecal Coliform-Fecal Strep Ratio*
PGSP0344	Mar/01/1994	85	171	0.497
PGSP0366	Mar/29/1994	800	4,000	0.200
PGSP0392	Apr/13/1994	1,273	1,441	0.883
PGSP0412	Apr/27/1994	297	153	1.941
PGSP0449	May/12/1994	180	90	2.000
PGSP0463	Jun/01/1994	327	155	2.110
PGSP0529	Jul/06/1994	10	216	0.046
	Average*	425	889	1.100
	Maximum	1,273	4,000	2.110
	Minimum	10	90	0.050
	Stand. Dev.	453	1,453	0.900
	Coef. Var.	1.1	1.6	0.8
Total of 7 Analyses				

The Canyon karst window, after October 1993

Sample Number	*Date*	*Fecal Coliform (col/100 ml)*	*Fecal Streptococci (col/100 ml)*	*Fecal Coliform-Fecal Strep Ratio*
TCKW0015	Jun/01/1994	11	36	0.306
TCKW0016	Jul/06/1994	10	1,455	0.007
	Average*	11	746	0.16
Total of 2 Analyses				

George Delaney swallow hole, after October 1993

Sample Number	*Date*	*Fecal Coliform (col/100 ml)*	*Fecal Streptococci (col/100 ml)*	*Fecal Coliform-Fecal Strep Ratio*
GDSW0019	Jun/01/1994	1,100	1,400	0.786
GDSW0021	Jul/06/1994	1,273	5,364	0.237
	Average*	1,187	3,382	0.51
Total of 2 Analyses				

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin.

Leslie Page karst window, after October 1993

Sample Number	*Date*	*Fecal Coliform (col/100 ml)*	*Fecal Streptococci (col/100 ml)*	*Fecal Coliform-Fecal Strep Ratio*
LPKW0025	Mar/01/1994	7	9	0.778
LPKW0080	Apr/27/1994	45	3,636	0.012
LPKW0090	May/12/1994	10	10	1.000
LPKW0104	Jun/01/1994	1	218	0.005
LPKW0106	Jul/06/1994	10	2,182	0.005
	Average*	15	1,211	0.36
	Maximum	45	1,211	0.36
	Minimum	1	9	0.00
	Stand. Dev.	0.17	1,635	0.49
	Coef. Var.	1.2	1.4	1.4
Total of 5 Analyses				

*These statistics are presented as a descriptive summary of the table. The effects of aliasing and variable sampling intervals may significantly affect the validity of averages presented as representative of ground-water quality in the basin.

REPORT of INVESTIGATIONS 1
Series XII, 1999
PLATE 1

KENTUCKY GEOLOGICAL SURVEY
James C. Cobb, State Geologist and Director
UNIVERSITY OF KENTUCKY, Lexington

Water-Well Locations and Potentiometric Surface with Hypothesized Flow Routes

Pleasant Grove Spring Karst Ground-Water Drainage Basin, Logan County, Kentucky

EXPLANATION

- Spring
- Swallow hole
- Hand-dug well
- Drilled well
- Estavelle
- 17128 / 551′ — AKGWA* number / Elevation of water surface (ft)
- Slow-flow sub-basin
- Permanent stream course
- Intermittent stream course
- Hypothesized ground-water flow (route and direction; dashed where intermittent)
- 510′ — Projected potentiometric surface contour line (feet above mean sea level)
- Ground-water basin boundary

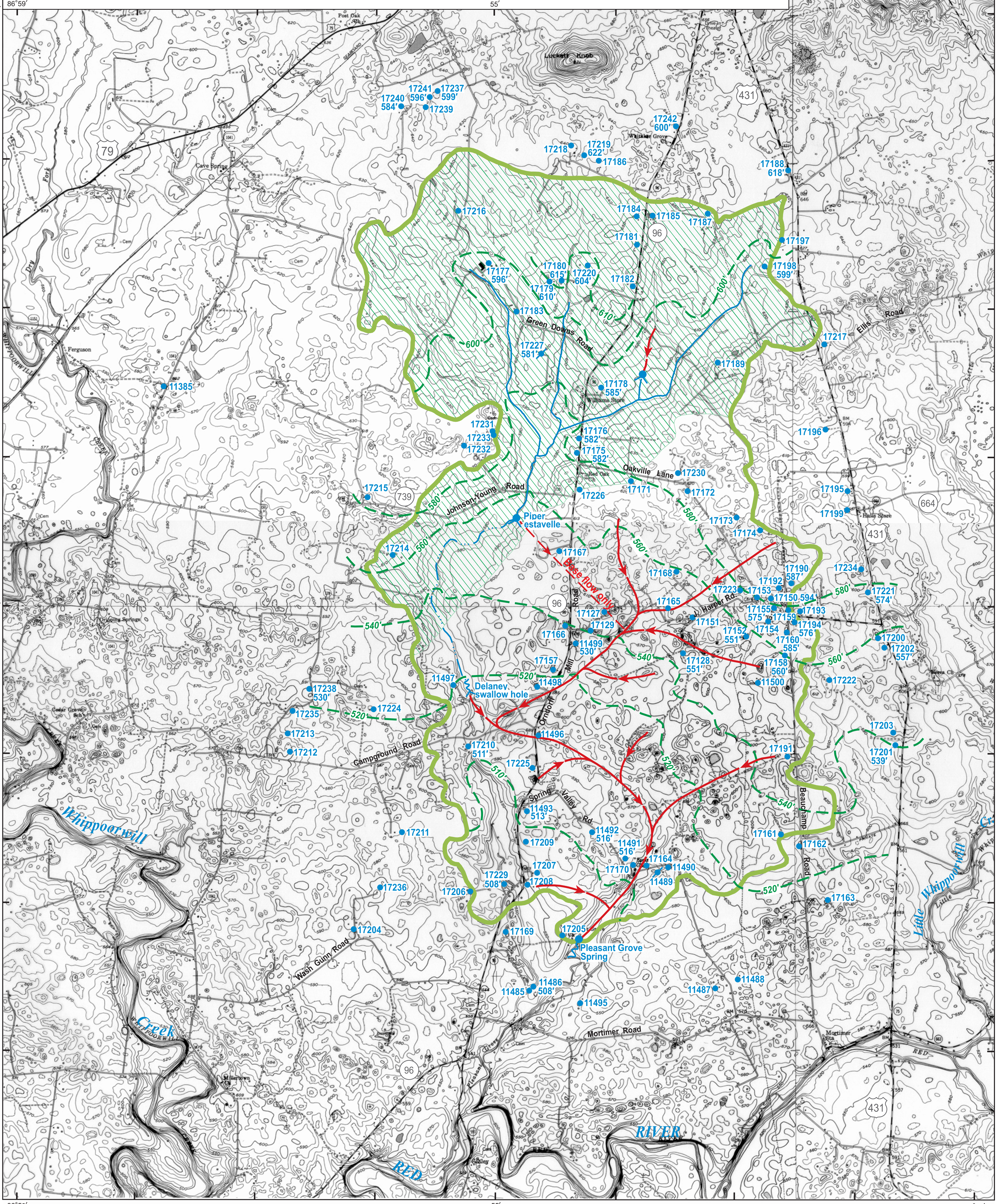
*Kentucky Division of Water well-identification number

SCALE 1:48,000

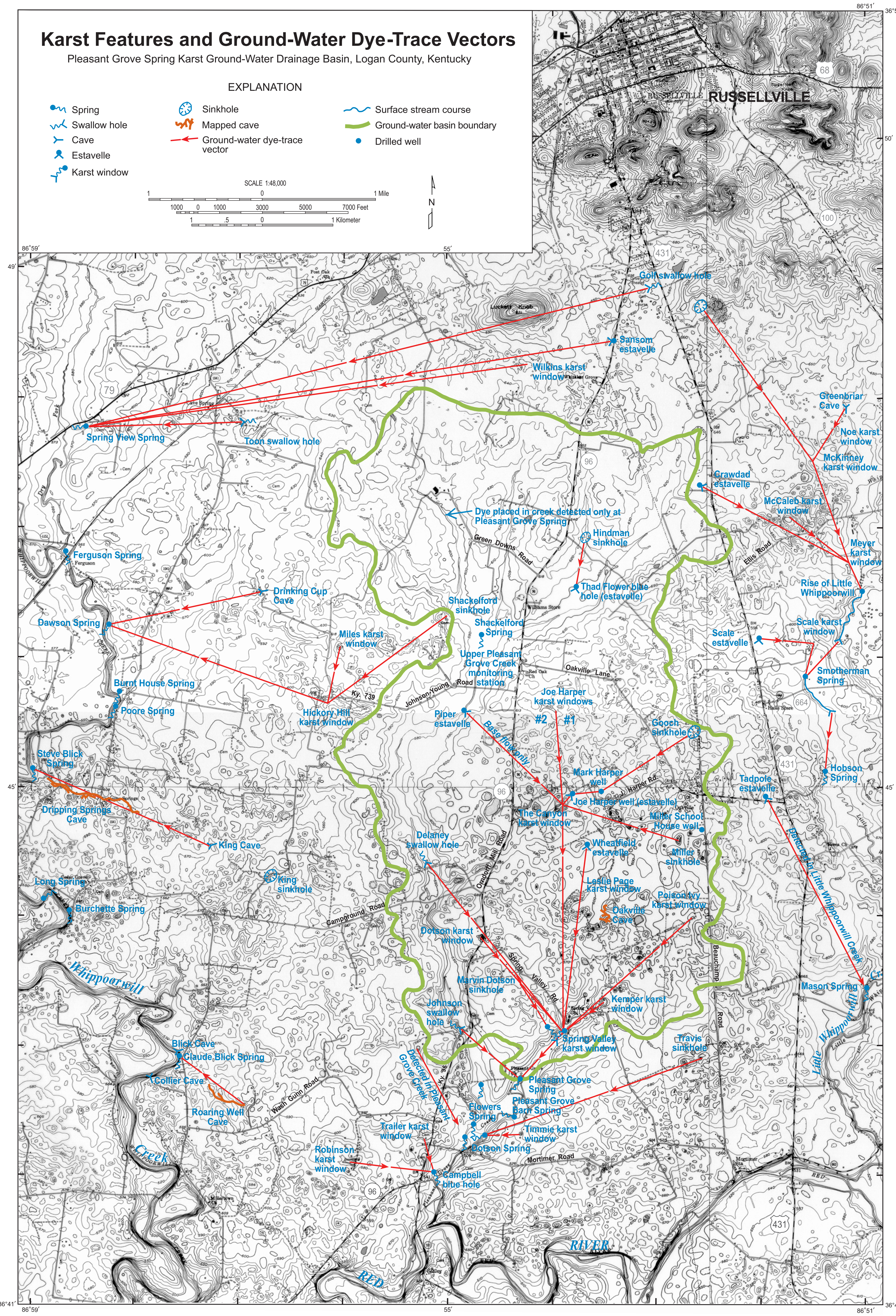
1 Mile — 0 — 1; 1000 — 0 — 1000 — 3000 — 5000 — 7000 Feet; 1 — .5 — 0 — 1 Kilometer

N

Water-level observations made between June 2, 1993, and September 13, 1993



KENTUCKY GEOLOGICAL SURVEY
James C. Cobb, State Geologist and Director
UNIVERSITY OF KENTUCKY, Lexington



Selected Water Resources Publications Available from the Kentucky Geological Survey

KGS Information Circular 5 (ser. 11): Quality of surface water in Bell County, Kentucky, by R.B. Cook, Jr., and R.E. Mallette, 1981, 11 p. **$3.00**

KGS Information Circular 37 (ser. 11): Water quality in the Kentucky River Basin, by D.I. Carey, 1992, 56 p. **$4.00**

KGS Information Circular 44 (ser. 11): Quality of private ground-water supplies in Kentucky, by D.I. Carey and others, 1993, 155 p. **$10.00**

KGS Information Circular 46 (ser. 11): Impact of riparian grass filter strips on surface-water quality, by A.W. Fogle and others, 1994, 14 p. **$3.00**

KGS Information Circular 52 (ser. 11): Ground water in the Kentucky River Basin, by D.I. Carey and others, 1994, 67 p. **$9.95**

KGS Information Circular 60 (ser. 11): Ground-water quality in Kentucky: Nitrate-nitrogen, by P.G. Conrad and others, 1999, 4 p. **$1.50**

KGS Map and Chart Series 10 (ser. 11): Mapped karst ground-water basins in the Lexington 30 x 60 minute quadrangle, by J.C. Currens and J.A. Ray, 1996, scale 1:100,000 **$5.00**

KGS Map and Chart Series 16 (ser. 11): Mapped karst ground-water basins in the Harrodsburg 30 x 60 minute quadrangle, by J.C. Currens and J.A. Ray, 1998, scale 1:100,000 **$5.00**

KGS Map and Chart Series 17 (ser. 11): Mapped karst ground-water basins in the Campbellsville 30 x 60 minute quadrangle, by J.A. Ray and J.C. Currens, 1998, scale 1:100,000 **$5.00**

KGS Map and Chart Series 18 (ser. 11): Mapped karst ground-water basins in the Somerset 30 x 60 minute quadrangle, by J.C. Currens and J.A. Ray, 1998, scale 1:100,000 **$5.00**

KGS Map and Chart Series 19 (ser. 11): Mapped karst ground-water basins in the Beaver Dam 30 x 60 minute quadrangle, by J.A. Ray and J.C. Currens, 1998, scale 1:100,000 **$5.00**

KGS Report of Investigations 7 (ser. 11): Flooding of Sinking Creek karst area in Jessamine and Woodford Counties, Kentucky, by J.C. Currens and C.D.R. Graham, 1993, 33 p. **$4.00**

KGS Report of Investigations 9 (ser. 11): Effects of longwall mining on hydrogeology, Leslie County, Kentucky; part 1: Premining conditions, by S.A. Minns and others, 1995, 37 p. **$7.50**

KGS Report of Investigations 10 (ser. 11): Hydrogeology, hydrogeochemistry, and spoil settlement at a large mine-spoil area in eastern Kentucky: Star Fire tract, by D.R. Wunsch and others, 1996, 49 p. **$12.00**

KGS Report of Investigations 11 (ser. 11): Hydrogeology and ground-water monitoring of coal-ash disposal sites in a karst terrane near Burnside, south-central Kentucky, by S.M. Hutcheson and others, 1997, 21 p. **$7.50**

KGS Report of Investigations 12 (ser. 11): Fresh-water aquifer in the Knox Group (Cambrian–Ordovician) of central Kentucky, by J.A. Kipp, 1997, 15 p. **$7.50**

KGS Report of Investigations 13 (ser. 11): Impact of topographic data resolution on hydrologic and nonpoint-source pollution modeling in a karst terrane, by A.W. Fogle, 1998, 22 p. **$5.00**

KGS Reprint 29 (ser. 11): Ordinance for the control of urban development in sinkhole areas in the Blue Grass karst region, Lexington, Kentucky, by J.S. Dinger and J.R. Rebmann, 1991, 14 p. **$2.50**

KGS Reprint 30 (ser. 11): Stress-relief fracture control of ground-water movement in the Appalachian Plateaus, by J.A. Kipp and J.S. Dinger, 1991, 11 p. **$2.50**

KGS Reprint 31 (ser. 11): High barium concentrations in ground water in eastern Kentucky, by D.R. Wunsch, 1991, 14 p. **$2.50**

KGS Special Publication 1 (ser. 11): Bibliography of karst geology in Kentucky, by J.C. Currens and P. McGrain, 1979, 59 p. **$5.00**

KGS Special Publication 12 (ser. 11): Caves and karst of Kentucky, ed. by P.H. Dougherty, 1985, 196 p. **$12.50**

KGS Thesis Series 5 (ser. 11): Ground-water geochemistry and its relationship to the flow system at an unmined site in the Eastern Kentucky Coal Field, by D.R. Wunsch, 1993, 128 p. **$10.00**

KGS Thesis Series 6 (ser. 11): Conceptual model of local and regional ground-water flow in the Eastern Kentucky Coal Field, by S.A. Minns, 1993, 194 p. **$10.00**

U.S. Geological Survey Open-File Report 80-685: A compilation of ground water quality data for Kentucky, by R.J. Faust, G.R. Banfield, and G.R. Willingers, 1980, 963 p. **$12.00**

U.S. Geological Survey Hydrologic Atlases. **Consult KGS "List of Publications" for specific locations and prices**

U.S. Geological Survey Water-Supply Paper 2202: Chloroform contamination in part of the alluvial aquifer, southwest Louisville, Kentucky, by R.W. Davis and E.W. Matthews, 1994, 25 p. **$4.00**

U.S. Geological Survey Water-Supply Paper 2254: Groundwater sensitivity regions of Kentucky, study and interpretation of the chemical characteristics of natural water, by J.D. Hem, 1994, 263 p., 3 plates **$15.00**

Kentucky Department for Environmental Protection, Division of Water, Groundwater Branch, map: Groundwater sensitivity regions of Kentucky, 1994, scale 1:500,000 **$7.00**

For information on obtaining copies of this publication and other Kentucky Geological Survey maps and publications, call:
Publication Sales Office
(606) 257-3896
View the KGS World Wide Web site at www.uky.edu/kgs