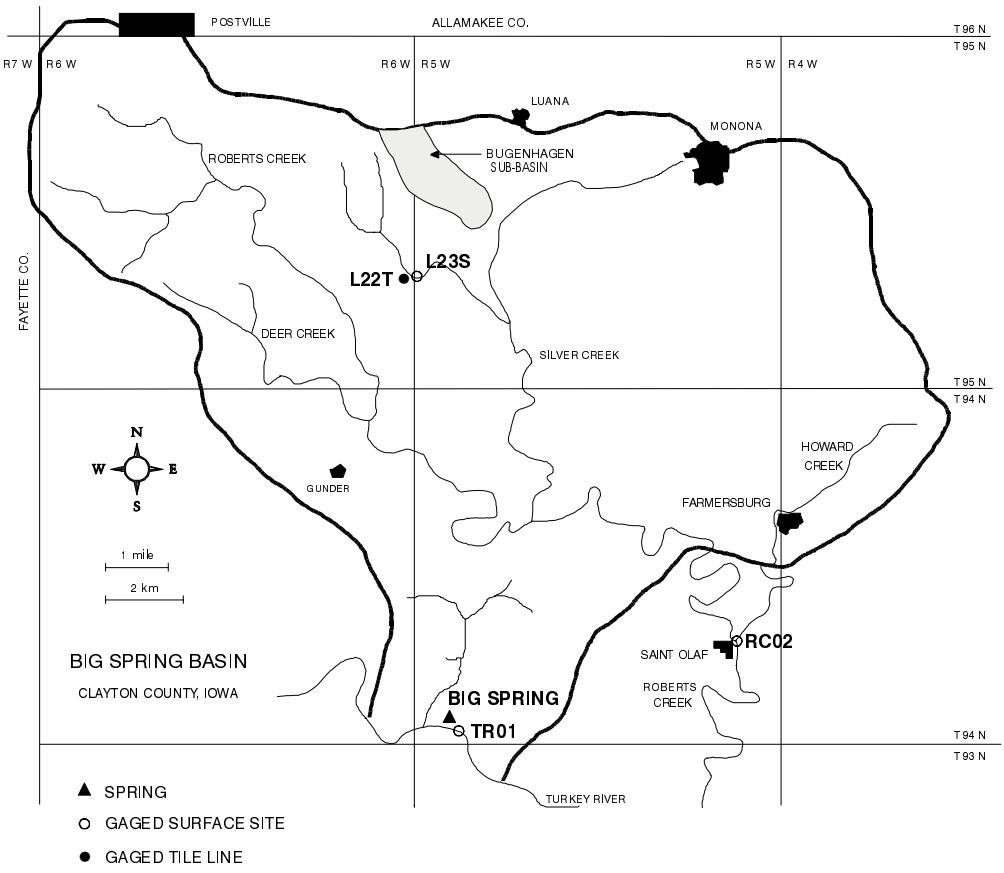
GROUNDWATER and SURFACE WATER MONITORING in the BIG SPRING BASIN 1996 - 1999: A Summary Review

Geological Survey Bureau
Technical Information Series 44



Iowa Department of Natural Resources
Lyle W. Asell, Interim Director
December 2000

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A Report of the Big Spring Basin Demonstration Project

Prepared by

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December 2000

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIX A

LIST OF APPENDIX B

LIST OF APPENDIX C

GROUNDWATER and SURFACE WATER MONITORING in the BIG SPRING BASIN 1996-1999: A Summary Review

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ABSTRACT

The Big Spring basin is a 103 mi^2 (267 km^2) groundwater basin located in Clayton County, northeast Iowa. Precipitation, groundwater and surface-water discharges, and the concentrations and loads of various agricultural contaminants have been monitored within and around the basin since 1981. This report summarizes the monitoring results at Big Spring, Turkey River, Silver Creek, and tile line outlet L22T during WYs 1996 through 1999, and Roberts Creek during WYs 1993 through 1999.

Previous monitoring results have shown a time lag between annual precipitation and annual groundwater discharge from Big Spring. This was confirmed by the discharge and precipitation data obtained during WYs 1996 through 1999. After receiving below normal annual precipitation during WYs 1994 and 1995, the Big Spring basin had 30.59 inches of rainfall in WY 1996, which was 1.31 inches greater than WY 1995 and 2.38 inches below the long-term average. The groundwater discharge at Big Spring decreased from 30,013 ac-ft in WY 1995 to 28,143 ac-ft in WY 1996. In WY 1997, precipitation within the Big Spring basin totaled 38.29 inches, which was 5.32 inches above the long-term average. However, annual groundwater discharge at Big Spring continually decreased to 22,943 ac-ft, the smallest annual discharge at Big Spring since WY 1991. The relatively wet conditions continued in WYs 1998 and 1999. Annual precipitation totaled 41.21 inches in WY 1998, which was 8.24 inches greater than the long-term precipitation average. Correspondingly, groundwater discharge increased to 35,713 ac-ft for this water year. During WY 1999, annual precipitation within the Big Spring basin was 39.99 inches. Although this precipitation was 1.22 inches lower than that in WY 1998, annual groundwater discharge at Big Spring increased to 37,133 ac-ft. The non-linear relationship between annual precipitation and groundwater discharge from Big Spring results from variations in discharge-controlling factors, including precipitation intensity, timing and distribution patterns, antecedent soil moisture, groundwater storage, and evapotranspiration rates.

Water quality, especially the annual fw mean concentrations and loads of nitrate-N, can be affected by variations in discharge. Annual fw mean nitrate-N concentrations and loads showed trends similar to groundwater discharge during most of the monitoring period. However, the annual fw mean nitrate concentration for Big Spring increased from 45.3 mg/L (10.1 mg/L as NO_3-N) in WY 1995 to 46.4 mg/L (10.3 mg/L as NO_3-N) in WY 1996, while annual groundwater discharge decreased from 30,013 ac-ft to 28,143 ac-ft. The nitrate-N contamination and load increased significantly along with annual groundwater

discharge in WY 1998. In WY 1999, the nitrate-N concentration and load decreased slightly as annual groundwater discharge increased. These divergences may be related to regional antecedent conditions, such as the amount of groundwater flux during the previous water year.

Unlike nitrate, atrazine trends did not coincide with changes of annual groundwater discharge. Annual atrazine concentrations and loads from Big Spring varied significantly from WY 1995 through WY 1999, but remained relatively low compared with WYs 1990 and 1991. In WY 1997, the annual atrazine load decreased to 10.5 pounds, which was the third-smallest annual load since WY 1982. In WY 1998, the annual fw mean atrazine concentration at Big Spring decreased to 0.12 μg/L, which was the lowest level recorded during the monitoring period. In addition, increasing numbers of non-detections of atrazine occurred at Big Spring and other monitoring sites during recent years. These may be the result of reductions in atrazine application, landuse improvements, and the replacement of atrazine by new pesticides, such as acetochlor, within the Big Spring basin. Reduced sampling frequency may also be affecting the accuracy of atrazine fw mean concentration and load calculations.

INTRODUCTION

The 103 mi^2 (267 km^2) Big Spring groundwater basin is located in Clayton County, northeast Iowa (Fig. 1). It is a karst-carbonate aquifer area within the Paleozoic Plateau landform region (Hallberg et al., 1984b; Prior, 1991). The bedrock in this area is Ordovician and Silurian strata, primarily limestone and dolomite. The main aquifer used in the basin is the Ordovician Galena Group (Galena aquifer), with an average thickness of 220 ft (67m) in the study area. Sinkholes are widely distributed in the Big Spring basin, particularly in the eastern portion, and drain about 11% of the basin (Hallberg et al., 1983). The Galena aquifer is recharged by both infiltration through the thin mantle of glacial deposits and surface runoff captured by sinkholes in some areas. Because of the direct interaction between surface runoff and infiltration, the introduction of contaminants from the land surface into the groundwater is of great concern in the karst region.

Landuse within the basin is essentially agricultural. Forty to fifty percent of the basin is annually cropped to corn, typically in rotation with alfalfa. Small- to moderate-sized hog and dairy operations are common. There are no significant industrial or urban contamination sources, such as large livestock feedlots, factories, or landfills. Therefore, agricultural activities are the main factor impacting groundwater quality within the basin. The principal contaminants of concern for public health are nitrates, pesticides, bacteria, and turbidity around the study area (Hallberg et al., 1983).

The landuse, hydrology, and water quality of the Big Spring basin have been extensively studied by the Iowa Department of Natural Resources, Geological Survey Bureau (GSB). The Big Spring basin hydrologic and water quality monitoring project started in Water Year 1982 (WY; A water year is a 12-month period, from October 1 through September 30, designated by the calendar year in which it ends.). To monitor water quality of the basin, a network of sites, including groundwater, surface water, tile lines and springs, was established by the GSB and cooperating agencies. In addition to monitoring, the Big Spring basin has been the

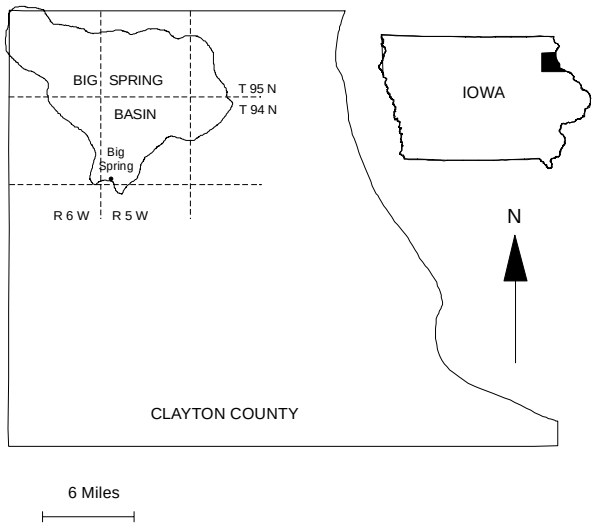

Figure 1. Location of the Big Spring basin in northeastern Iowa.

site of extensive education and demonstration activities that were designed to improve the environmental and economic performance of agriculture. These activities were conducted under the auspices of the Big Spring Basin Demonstration Project (1986-1992) and continued as part of the Northeast Iowa Demonstration Project (1992-1999), under the direction of Iowa State University Extension.

The design and facilities of the Big Spring monitoring project and the summary review for 1982 were described by Hallberg and others (1983). Monitoring summary reviews of Big Spring and the Turkey River were reported by Hallberg and others (1984a, 1989), Libra and others (1991), Rowden and others (1993a, 1995b), and Liu and others (1997). Summary review of surface water monitoring in the Big Spring basin was reported by Rowden and others (1995a, 1998). Other water quality reviews for the basin were presented by Hallberg and others (1984b, 1985, 1987). The design and implementation of monitoring sites for the Big Spring project were described by Littke and Hallberg (1991) and Libra and others (1992). Groundwater monitoring wells in the Big Spring basin and related data were described by Rowden and Libra (1990). Big Spring hydrologic monitoring

data were also presented by Kalkhoff (1989), Kalkhoff and Kuzniar (1991, 1994), Kalkhoff and others (1992). Other publications related to the study of the Big Spring basin include Libra and others (1986, 1987), Nations (1990), Goolsby and others (1990), Capel (1990), Nations and Hallberg (1992), Kolpin and Kalkhoff (1993), Rowden and others (1993b), Seigley and others (1993), Hallberg and others (1993), Rowden (1995), Kalkhoff and Schaap (1996), Rowden and Libra (1996), and Liu and others (1998, 1999).

This report is a continuing summary review of the hydrologic and water quality monitoring results from the Big Spring project, with focus on climatic conditions, groundwater and surface water discharge, and the distribution and concentrations of agricultural chemicals, particularly nitrate and common herbicides. It will summarize the monitoring results from Big Spring, tile line site L22T, and surface water sites Turkey River (TR01), Roberts Creek (RC02), and Silver Creek (L23S). This report covers WYs 1996 through 1999 for Big Spring, TR01, and L22T; WYs 1993 through 1999 for RC02; and WYs 1996 through 1998 for L23S. Analytical methods and processes are the same as in previous reports, which were reviewed in Hallberg and others (1989).

HYDROLOGIC AND WATER QUALITY MONITORING

Monitoring Site Description

Since 1981, over fifty groundwater and surface water sites have been routinely monitored for water quality within the Big Spring basin. Locations of the five sites involved in this report are shown in Figure 2. Detailed information on these sites can be found in Hallberg and others (1983), Littke and Hallberg (1991), and Rowden and others (1995a, 1998).

Big Spring, the largest spring in the state, is located near the base of the Galena aquifer. Over 85% of the groundwater that exits the Big Spring basin is discharged through Big Spring to the Turkey River. Groundwater discharge at Big Spring varies with local climatic conditions and precipitation or snowmelt. The long-term discharge record shows a range from 10.7 cubic feet per second (cfs) to 490 cfs, with a long-term average of 48 cfs. The discharge from Big Spring is used to rear trout at a state-owned fish hatchery. Water levels at Big Spring are recorded continuously by two Stevens A-35 water level recorders within the hatchery water distribution system, and the recorders are adjusted to measured water levels by GSB staff weekly. A GSB computer program calculates daily discharge from Big Spring, using stage-discharge relationships established by the United States Geological Survey (USGS). Weekly sampling for water quality has continued at this site since 1981.

Tile line site L22T is located on the south bank of Silver Creek about 65 ft (20 m) west of county road W70, southwest of Luana. The 5-inch tile is about 6 feet deep in alluvium soils with no surface intakes. Monitoring at L22T started on October 1, 1986 and ended on September 30, 1999. Discharge at this site was recorded by an ISCO flow meter and/or a Stevens drum recorder, which continually monitored the shallow groundwater discharge from approximately 85 acres (Rowden et al., 1998). During the monitoring period, groundwater discharge at L22T varied from 0.001 cfs to 0.957 cfs, with two days without flow in January, 1990. The long-term discharge average for L22T is 0.103 cfs. Sampling at L22T was weekly, along with event sampling during earlier monitoring years.

Surface water site L23S is located by the bridge on country road W70, about 60 ft (18 m) east of the tile line site L22T. Discharge at L23S was monitored by a USGS gaging station. This station continually monitored the 4.39 mi^2 (11.37 km^2) watershed of the west branch of Silver Creek from May 13, 1986 through September 30, 1998. Except for forty-three days without flow in late 1989 and early 1990, discharge at L23S ranged between 0.01 and 431 cfs, with an average of 3.2 cfs for the monitoring period. Surface water at L23S was sampled weekly or monthly for different contaminants during the monitoring period.

Surface water site RC02 is located at St. Olaf, on the southern perimeter of the Big Spring basin. Roberts Creek drains a 70.7 mi^2 (183 km^2) area

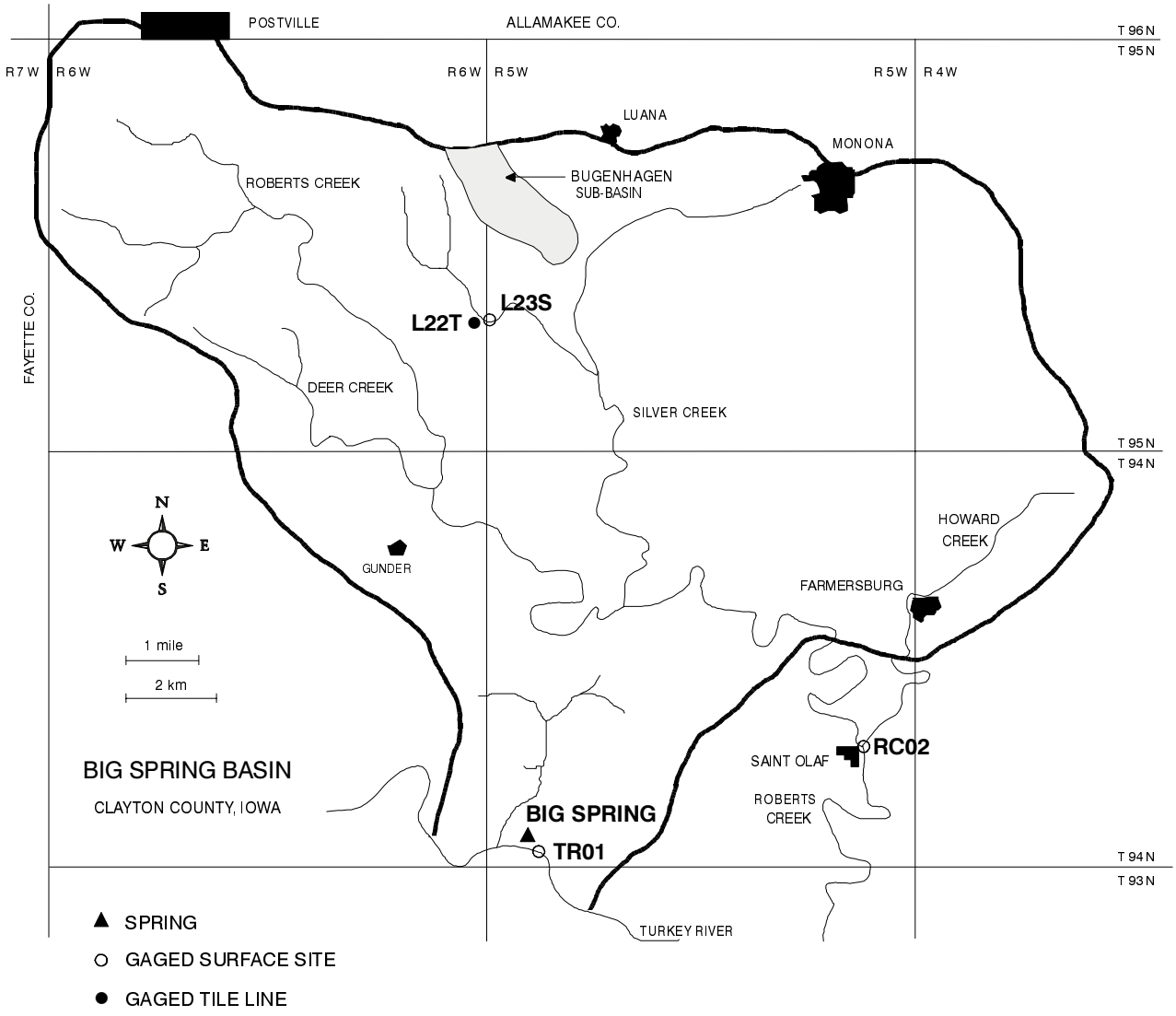

Figure 2. Map of the Big Spring basin showing the locations of monitoring sites.

above RC02. About 75-80% of the surface water exits the Big Spring basin by Roberts Creek. Discharge at RC02 has been monitored and recorded by a standard USGS gaging station since March 25, 1986. During the monitoring period, Roberts Creek was dry for 112 days in 1989, 1990, and 1992. The greatest discharge at RC02 was 7,090 cfs, recorded on June 15, 1991. The long-term discharge average at this site is 32.1 cfs. Sampling has been weekly at RC02.

Discharge for TR01 on the Turkey River is monitored and recorded by a USGS gaging station near Garber, about 15 miles (24 km) downstream from Big Spring. The Turkey River is a high baseflow stream, deriving a significant part of its discharge from influent groundwater. As defined, the Turkey River basin above Garber contains 1,545 mi^2 (4,002 km^2). Data from the Turkey River provide a regional perspective for the hydrologic and water quality monitoring at Big Spring. Between October 1, 1981 and September 30, 1999, discharge from the Turkey River has

Table 1. Annual precipitation, departure from normal, and discharge/precipitation ratio for the Big Spring basin for WYs 1982 through 1999.

Water Year	Annual Precipitation		Departure from Normal	Discharge as
	(mm)	(inches)	(inches)	% of Precipitation
1982	852	33.56	0.59	20.0%
1983	1131	44.53	11.56	21.0%
1984	833	32.81	-0.16	18.0%
1985	910	35.84	2.87	13.0%
1986	939	36.96	3.99	15.0%
1987	812	31.98	-0.99	14.0%
1988	583	22.94	-10.03	20.5%
1989	618	24.32	-8.65	9.0%
1990	962	37.87	4.90	8.0%
1991	1201	47.28	14.31	16.0%
1992	908	35.74	2.77	19.0%
1993	1180	46.47	13.50	23.0%
1994	773	30.42	-2.55	18.7%
1995	744	29.28	-3.69	18.7%
1996	777	30.59	-2.38	16.7%
1997	973	38.29	5.32	10.9%
1998	1047	41.21	8.24	15.8%
1999	1016	39.99	7.02	16.9%

ranged from 56 cfs on December 22, 1989 to 43,400 cfs on May 17, 1999, with an average of 1,299 cfs. Samples for water-quality analyses for TR01 were collected weekly or monthly near the Big Spring fish hatchery.

All water-quality analyses have been performed by the University Hygienic Laboratory (UHL), University of Iowa. The chemical compounds analyzed for include nitrogen nutrients and common pesticides/herbicides, such as acetochlor, alachlor (Lasso), atrazine, butylate (Sutan), cyanazine (Bladex), metolachlor (Dual), metribuzin (Sencor), trifluralin (Treflan) and two metabolites of atrazine: desethyl atrazine and desisopropyl atrazine. Discharge data for the Turkey River, Silver Creek and Roberts Creek were supplied by the Water Resources Division of the U.S. Geological Survey, Iowa District (May et al., 1997, 1998, 1999; Nalley et al., 2000).

Precipitation

Daily precipitation for the Big Spring basin for WYs 1996 through 1999 was calculated based on data from the National Atmospheric Deposition Program (NADP) station at the Big Spring hatchery and the stations of the Iowa Department of Agriculture and Land Stewardship, State Climatology Office (IDALS, SCO) located in Elkader, Fayette, and Postville. Daily minimum/maximum temperature data were from the Elkader weather station. The mean annual precipitation of the Big Spring basin for the period 1951-1980, 32.97 inches, is defined in this report as normal precipitation. Precipitation for the larger Turkey River drainage basin is estimated using averages for the state's northeast climatic division (IDALS, SCO).

Table 1 summarizes annual precipitation and

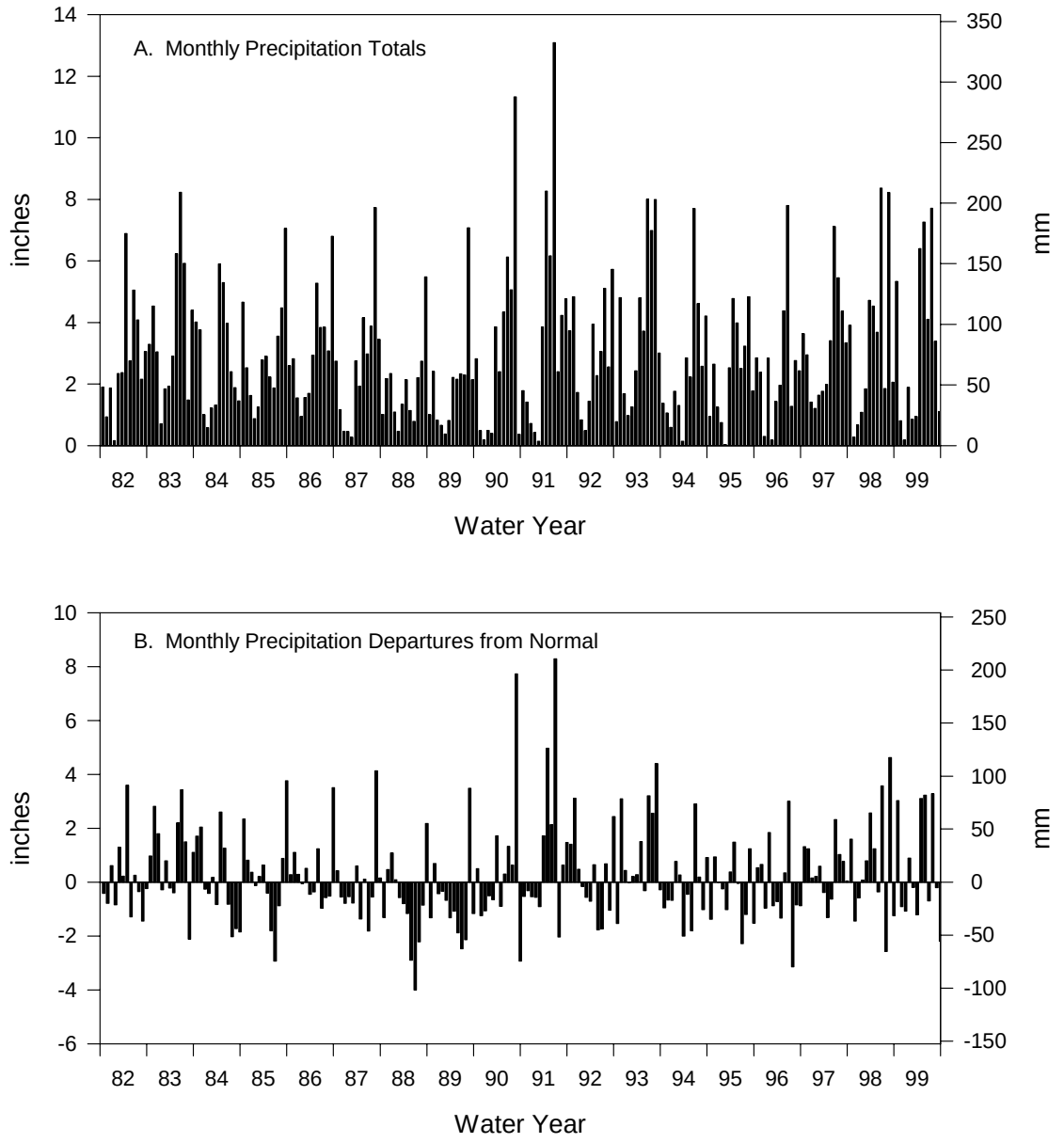

Figure 3. A) Monthly precipitation totals and B) departures from normal for the Big Spring basin, WYs 1982-1999 (Data from the Iowa Dept. of Ag. and Land Stewardship, State Climatologist Office).

departures from normal within the Big Spring basin for WYs 1982 through 1999. Monthly precipitation and departures from normal for this period are illustrated in Figure 3. The 18-year period of record in the Big Spring basin has been characterized by significant climatic variability. Annual precipitation has varied from 22.94 inches (WY 1988) to 47.28 inches (WY 1991). The two driest consecutive years in Iowa's recorded history, WYs 1988 and 1989, had annual precipitation totals of 22.94 and 24.32 inches, respectively. These were 10.03 and 8.65 inches below normal, or 70% and 74% of the long-term average precipitation. These dry years were followed by

Table 2. Monthly precipitation and departure from normal for the Big Spring basin, WYs 1996-1999.

Water Year 1996	Basin precip (inches)	Departure from normal (inches)	% of normal	Water Year 1997	Basin precip (inches)	Departure from normal (inches)	% of normal
Oct-95	2.85	0.53	123%	Oct-96	3.63	1.31	156%
Nov-95	2.38	0.66	138%	Nov-96	2.95	1.23	172%
Dec-95	0.30	-0.96	24%	Dec-96	1.41	0.15	112%
Jan-96	2.84	1.84	284%	Jan-97	1.21	0.21	121%
Feb-96	0.18	-0.87	17%	Feb-97	1.64	0.59	156%
Mar-96	1.43	-0.72	67%	Mar-97	1.77	-0.38	82%
Apr-96	1.96	-1.34	59%	Apr-97	1.99	-1.31	60%
May-96	4.38	0.34	108%	May-97	3.41	-0.63	84%
Jun-96	7.80	3.00	163%	Jun-97	7.12	2.32	148%
Jul-96	1.28	-3.15	29%	Jul-97	5.45	1.02	123%
Aug-96	2.76	-0.84	77%	Aug-97	4.37	0.77	121%
Sep-96	2.43	-0.87	74%	Sep-97	3.34	0.04	101%
TOTAL	30.59	-2.38	93%	TOTAL	38.29	5.32	116%

Water Year 1998	Basin precip (inches)	Departure from normal (inches)	% of normal	Water Year 1999	Basin precip (inches)	Departure from normal (inches)	% of normal
Oct-97	3.91	1.59	169%	Oct-98	5.34	3.02	230%
Nov-97	0.28	-1.44	16%	Nov-98	0.81	-0.91	47%
Dec-97	0.67	-0.59	53%	Dec-98	0.18	-1.08	14%
Jan-98	1.08	0.08	108%	Jan-99	1.89	0.89	189%
Feb-98	1.84	0.79	175%	Feb-99	0.86	-0.19	82%
Mar-98	4.72	2.57	220%	Mar-99	0.94	-1.21	44%
Apr-98	4.53	1.23	137%	Apr-99	6.40	3.10	194%
May-98	3.68	-0.36	91%	May-99	7.26	3.22	180%
Jun-98	8.37	3.57	174%	Jun-99	4.10	-0.70	85%
Jul-98	1.85	-2.58	42%	Jul-99	7.71	3.28	174%
Aug-98	8.22	4.62	228%	Aug-99	3.39	-0.21	94%
Sep-98	2.06	-1.24	62%	Sep-99	1.11	-2.19	34%
TOTAL	41.21	8.24	125%	TOTAL	39.99	7.02	121%

two wet years. In WY 1990, the annual precipitation, 37.87 inches, was 4.90 inches above normal, or 115% of the long-term average precipitation. Water Year 1991 was the wettest year since the Big Spring project's inception. The annual precipitation, 47.28 inches, was 14.31 inches above normal, and 143% of the long-term average. The annual precipitation for WY 1992, 35.74 inches, was close to the long-term average precipitation (32.97 inches). Water Year 1993 was another wet year following WY 1991. The annual precipitation, 46.47 inches, was 13.50 inches above normal, or 141% of the long-term average. In WY 1993, most rainfall events occurred during the June through August period, and major flooding occurred throughout much of Iowa, including the

Big Spring basin. Water Years 1994 and 1995 were relatively dry. The annual precipitation for WY 1994, 30.42 inches, was 2.55 inches below normal, or 92% of the long-term average. For WY 1995, the annual precipitation, 29.28 inches, was 3.69 inches below normal, or 89% of the long-term average. The annual precipitation for WY 1995 was the third lowest since the Big Spring project started in WY 1982. The relatively dry conditions continued in WY 1996. The annual precipitation for this water year was 30.59 inches, which was 2.38 inches below normal, or 93% of the long-term average. From WY 1997 through WY 1999, annual precipitation in the Big Spring basin was again above average. The annual precipitation was 38.29 inches for WY 1997, 41.21 inches for WY 1998, and 39.99 inches for WY 1999. These totals were 5.32 inches, 8.24 inches, and 7.02 inches above normal, or 116%, 125%, and 121% of the long-term average, respectively.

Table 2 shows the monthly precipitation and departure from normal for WYs 1996 through 1999 for the Big Spring basin. During WY 1996, the precipitation totals for October, November, January, and June were considerably greater than normal. The wettest month of the water year was June, with 7.80 inches of precipitation. This was 3.0 inches above normal, or 163% of the long-term average for the month. June has typically been the wettest month in the Big Spring basin. Previous studies have indicated that the March through June period is typically marked by low evapotranspiration and wet conditions, and is important for groundwater recharge in the Big Spring area (Hallberg et al., 1983, 1984a, 1989; Libra et al., 1991; Rowden et al., 1993a, 1995b). The growing season during WY 1996 was dry. The total precipitation for March through September was 22.04 inches, or 3.58 inches below normal. The driest month of WY 1996 was February, with 0.18 inches of precipitation, or 17% of the long-term average for the month. During WY 1997, all monthly precipitation totals were greater than normal except March through May. Like WY 1996, June had the greatest monthly precipitation during the water year, at 7.12 inches. This was 2.23 inches above normal, or 148% of the long-term average precipitation for the month. The driest month of WY 1997 was April, with 1.99 inches of precipitation, or 60% of normal. The relatively wet conditions continued in the Big Spring basin during WYs 1998 and 1999. For WY 1998, precipitation in October, February, March, April, June, and August was significantly above normal. The wettest month was June, with 8.37 inches of rainfall. From March through June, the total precipitation was 21.3 inches, which was 7.01 inches above normal for this period. The driest month of this water year was November, with 0.28 inches of precipitation, which was 16% of normal. In WY 1999, months with above normal precipitation included October, January, April, May, and July. The wettest month was July, with 7.71 inches of rainfall, which was 3.28 inches above normal. The March through June period had 18.7 inches of precipitation, which was 4.41 inches above normal. The driest month was December, with 0.18 inches of precipitation, or 14% of the normal for the month. After three years of greater than normal annual precipitation, especially the wet March through June groundwater recharge periods, discharge in the study area became more responsive to precipitation events.

Water Years 1993 through 1995

Data from monitoring site RC02 for WYs 1993 through 1995 are discussed below. Data for Big Spring and TR01 for this period were summarized by Rowden et al. (1995a & b), and Liu et al. (1997). Data from L22T and L23S for this period were discussed by Rowden et al. (1998).

Discharge Monitoring

Tables 3 through 5 and Figure 4C summarize the discharge data from RC02 during WYs 1993 through 1995. The discharge at RC02 for WY 1993 was 61,970 acre-feet (ac-ft), which was the greatest annual discharge recorded during the monitoring period. Mean daily discharge at RC02 varied between 7.4 cfs on February 24, 1993 and 1,490 cfs on March 31, 1993, with an annual average rate of 85.6 cfs. The discharge was

Table 3. Annual summary of water and chemical discharges from RC02 for WY 1993 (Discharge data are from the U.S. Geological Survey, Water Resources Division, IA Dist.).

DISCHARGE	
Total	
acre-feet	61,970
millions cf	2,699
millions cm	76.4
Average	
cfs	85.6
cms	2.4
mg/d	55.3
gpm	38,417
PRECIPITATION AND DISCHARGE	
Precipitation	46.5 inches (1,180 mm)
Discharge	16.4 inches (417 mm)
Discharge as % of precipitation	35%

NITRATE DISCHARGE		
Concentration - mg/L	**As NO_3**	**As NO_3-N**
Flow-weighted mean	33.2	7.4
Mean of analyses	40.8	9.1
	NO_3-N output	**Total N output**
lbs - N	1,241,639	1,698,214
kg - N	563,102	770,165
lbs - N/acre	27.4	37.5

ATRAZINE DISCHARGE	
Concentration - µg/L	
Flow-weighted mean	0.90
Mean of analyses	0.73
Total output	
lbs	152
kg	69.0

equivalent to 35% of the annual precipitation. In March, minor rainfall and snowmelt generated the largest runoff event of WY 1993. The monthly discharge totaled 12,200 ac-ft for March, which was the greatest monthly discharge during the water year. The month with lowest discharge was February, at 641 ac-ft.

Discharge at RC02 significantly decreased in WY 1994. The annual discharge for the water year was 12,710 ac-ft, which was 20.5% of the discharge for WY 1993. The discharge was equivalent to 11.1% of the annual precipitation for WY 1994. Mean daily discharge at RC02 varied between 6.0 cfs and 320 cfs, with a daily average rate of 17.6 cfs. The wettest month during WY 1994 was March, with 2,920 ac-ft of discharge. Following March, Roberts Creek showed mainly declining flow through the end of the water year. The lowest monthly discharge, 495 ac-ft, occurred in September.

Relatively dry conditions continued in WY 1995. The annual discharge at RC02 was14, 720 ac-ft, accounted for 13.3% of annual precipitation. Mean daily discharge varied between 2.6 cfs and 163 cfs, with an average rate of 20.3 cfs. Relatively higher discharges occurred in March through May. April had the greatest monthly discharge, 4,640 ac-ft, and September had the lowest, 197 ac-ft.

Nitrate Monitoring

Tables 3 through 5, appendix tables A-1 through A-3, and Figure 4B summarize the nitrate monitoring results for RC02 for WYs 1993 through 1995. During WY 1993, samples for both nitrate and full nitrogen series (N-series; including nitrate-N, ammonia-N, and organic-N) analyses were collected weekly from RC02. During WY 1994, weekly analyses for nitrogen nutrients have been changed from full N-series to partial N-series (nitrate-N plus ammonia-N) and weekly nitrate analyses were discontinued. Thus, the annual total nitrogen output from RC02 only included organic-N for part of WY 1994, and did not include organic-N for WY 1995.

During WY 1993, fifty-two water samples from RC02 were analyzed for nitrate and full N-series.

All of the samples contained detectable nitrate, concentrations ranged from 9.0 mg/L (2.0 mg/L as NO_3-N) to 83.0 mg/L (18.4 mg/L as NO_3-N). Nitrate-N concentrations ranged from 1.8 mg/L (8.1 mg/L as NO_3) to 18.0 mg/L (81.0 mg/L as NO_3). Forty-nine samples, or 94%, contained detectable organic-N, and twenty-six samples, or 50%, contained detectable ammonia-N. The greatest concentration was 7.6 mg/L for organic-N, and 7.4 mg/L for ammonia-N. Both maximums were detected from a sample collected on March 9. During WY 1993, about 1.7 million pounds of nitrogen was discharged by Roberts Creek. Of this total, more than 1.2 million pounds, or 73%, were in the form of nitrate-N. This is equivalent to 27.4 pounds of nitrate-N per acre (lbs-N/acre) for the watershed. The flow-weighted (fw) mean nitrate concentration (mean concentration per unit volume of discharge) for the water year was 33.2 mg/L (7.4 mg/L as NO_3-N). The fw mean concentration was 1.7 mg/L for organic-N, and 1.0 mg/L for ammonia-N. Table A-1 summarizes the nitrate discharge from RC02 during WY 1993 on a monthly basis. The greatest monthly fw mean nitrate concentration, 47.9 mg/L (10.6 mg/L as NO_3-N), occurred in January. The lowest monthly fw mean nitrate concentration, 19.1 mg/L (4.2 mg/L as NO_3-N), occurred in March. The total monthly nitrate-N output ranged from 16 thousand pounds in February to 250 thousand pounds in July. July accounted for 20% of the annual nitrate-N discharged by the creek during WY 1993.

In WY 1994, fifty-two samples from RC02 were analyzed for nitrate-N and ammonia-N. All samples contained detectable nitrate-N, and thirty-five samples, or 67%, contained detectable ammonia-N. The concentrations of nitrate ranged between 10.8 mg/L (2.4 mg/L as NO_3-N) and 42.8 mg/L (9.5 mg/L as NO_3-N). The greatest concentration analyzed for ammonia-N was 2.4 mg/L occurred on September 27. Three samples collected in October were analyzed for nitrate, and eight samples collected from October through December were analyzed for organic-N. All these samples contained detectable nitrate, with concentrations ranged between 36 and 39 mg/L

Table 4. Annual summary of water and chemical discharges from RC02 for WY 1994 (Discharge data are from the U.S. Geological Survey, Water Resources Division, IA Dist.).

DISCHARGE

Total

acre-feet	12,710
millions cf	554
millions cm	15.67

Average

cfs	17.6
cms	0.50
mg/d	11.37
gpm	7,899

PRECIPITATION AND DISCHARGE

Precipitation	30.42 inches (773 mm)
Discharge	3.37 inches (86 mm)
Discharge as % of precipitation	11.1%

NITRATE DISCHARGE

Concentration - mg/L	**As NO_3**	**As NO_3-N**
Flow-weighted mean	26.6	5.9
Mean of analyses	37.7	8.4

	NO_3-N output	**Total N output**
lbs - N	204,163	237,245
kg - N	92,591	107,594
lbs - N/acre	4.51	5.24

ATRAZINE DISCHARGE

Concentration - µg/L

Flow-weighted mean	0.43
Mean of analyses	0.46

Total output

lbs	15.0
kg	6.80

Table 5. Annual summary of water and chemical discharges from RC02 for WY 1995 (Discharge data are from the U.S. Geological Survey, Water Resources Division, IA Dist.).

DISCHARGE	
Total	
acre-feet	14,720
millions cf	641
millions cm	18.2
Average	
cfs	20.3
cms	0.57
mg/d	13.1
gpm	9,111
PRECIPITATION AND DISCHARGE	
Precipitation	29.28 inches (744 mm)
Discharge	3.90 inches (99 mm)
Discharge as % of precipitation	13.3%

NITRATE DISCHARGE		
Concentration - mg/L	**As NO_3**	**As NO_3-N**
Flow-weighted mean	28.1	6.3
Mean of analyses	24.6	5.5
	NO_3-N output	**Total N output**
lbs - N	250,438	265,502*
kg - N	113,577	120,409*
lbs - N/acre	5.5	5.9*

ATRAZINE DISCHARGE	
Concentration - µg/L	
Flow-weighted mean	0.23
Mean of analyses	0.16
Total output	
lbs	9.4
kg	4.3

* Total NO - plus Ammonia-N.

(8.0 and 8.7 mg/L as NO_3-N), and organic-N, with concentrations ranged from 0.4 to 1.5 mg/L. In WY 1994, 237 thousand pounds of nitrogen were discharged by Roberts Creek. Among them, 204 thousand pounds, or 86%, were in the form of nitrate-N. This is equivalent to 4.5 lbs-N/acre for the sub-basin. The fw mean nitrate concentration for WY 1994 was 26.6 mg/L (5.9 mg/L as NO_3-N). The annual fw mean ammonia-N concentration was 0.8 mg/L. Monthly nitrate-N discharge data for Roberts Creek during WY 1994 is shown in Table A-2. The monthly fw mean nitrate concentration varied from 14.0 mg/L (3.1 mg/L as NO_3-N) in September to 40.8 mg/L (9.1 mg/L as NO_3-N) in January. October had the greatest monthly nitrate-N output, 34.9 thousand pounds, while September had the lowest monthly nitrate-N output, 4.2 thousand pounds. Water Year 1994 had the lowest annual nitrate-N load and fw mean concentration since WY 1991.

Fifty-two weekly samples were collected from RC02 and analyzed for partial N-series during WY 1995. Of them, fifty-one samples, or 98%, contained detectable nitrate-N. The greatest nitrate concentration, 58.5 mg/L (13.0 mg/L as NO_3-N), was detected in a sample collected on May 30. Twenty-nine samples, or 56%, contained detectable ammonia-N. The greatest concentration for ammonia-N was 2.2 mg/L, which was detected in a sample collected on February 21. In WY 1995, total about 266 thousand pounds of nitrate-N and ammonia-N were discharged by Roberts Creek. Of this total, more than 250 thousand pounds, or 94%, were in the form of nitrate-N. This amount is equivalent to 5.5 lbs-N/acre for the sub-basin. The annual fw mean nitrate concentration was 28.1 mg/L (6.3 mg/L as NO_3-N), and the annual fw mean ammonia-N concentration was 0.4 mg/L for WY 1995. Table A-3 summarizes the nitrate and nitrate-N discharged from RC02 during WY 1995 on a monthly basis. The greatest monthly fw mean nitrate concentration, 39.4 mg/L (8.7 mg/L as NO_3-N), occurred in June. The lowest monthly fw mean nitrate concentration, 16.0 mg/L (3.6 mg/L as NO_3-N), occurred in September. The total monthly nitrate-N output ranged from 1.9 thousand pounds in September to 85.9 thousand

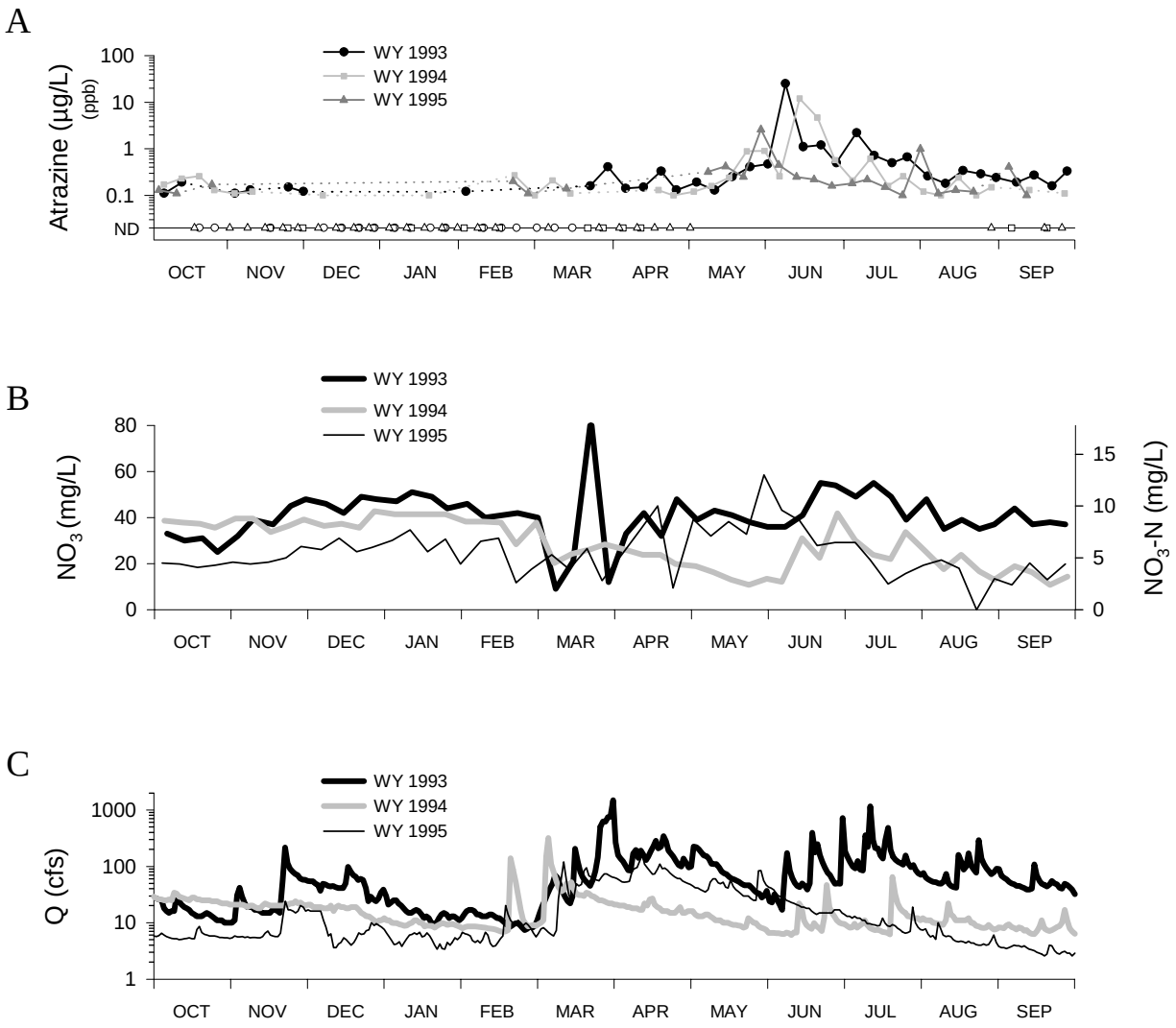

Figure 4. A) Atrazine, B) nitrate concentrations and C) discharge hydrographs for RC02 for WYs 1993 through 1995 (discharge data are from the U.S. Geological Survey, W.R.D., IA Dist.)

pounds in April. April accounted for 34% of annual nitrate-N discharged by the creek during WY 1995.

Pesticide Monitoring

Tables 3 through 5, appendix tables B-1 through B-3 and Figure 4A summarize the results of pesticide monitoring at RC02 during WYs 1993 through 1995. Fifty-two weekly samples were collected from RC02, and analyzed for common pesticides during WY 1993. Atrazine was the most frequently detected compound. Thirty-five of the total samples, or 67%, contained detectable atrazine (the typical detection limit for pesticides is 0.10 µg/L). All samples collected after mid-March were above the detection limit. The greatest atrazine concentration, 25 µg/L, was detected in a sample collected on June 8. In WY 1993, a total of 152 pounds of atrazine were discharged by Roberts Creek, this was the second greatest annual atrazine load since WY 1986. The annual fw

mean atrazine concentration at RC02 for WY 1993 was 0.90 µg/L. Table B-1 summarizes atrazine monitoring results at RC02 on a monthly basis for WY 1993. During the water year, the greatest monthly fw mean atrazine concentration, 3.01 µg/L, occurred in June, and the largest monthly atrazine load, 67.6 pounds, occurred in July. All samples collected in December and January were below the detection limit. January had the lowest monthly fw mean atrazine concentration, 0.01 µg/L, and the lowest monthly atrazine load, 0.02 pounds.

Other pesticides analyzed for RC02 include alachlor, butylate, cyanazine, metolachlor, metribuzin, trifluralin, and fonofos. Among the fifty-two samples, nine samples, or 17%, contained detectable alachlor, with the greatest concentration at 17.0 µg/L. Six samples, or 11.5%, contained detectable cyanazine, with the greatest concentration at 5.2 µg/L. Thirteen samples, or 25%, contained detectable metolachlor, with the greatest concentration at 6.0 µg/L. All the maximum concentrations were detected in a sample collected on June 8. No samples contained detectable concentrations of butylate, metribuzin, trifluralin, and fonofos during WY 1993. Analysis for the atrazine metabolites desethyl atrazine and desisopropyl atrazine started on January 5, 1993. A total of thirty-nine samples from RC02 were analyzed for the metabolites. Four samples, or 10%, contained detectable desisopropyl atrazine, with the largest concentration at 0.26 µg/L. Nineteen samples, or 49%, contained detectable desethyl atrazine, with the greatest concentration at 1.2 µg/L.

During WY 1994, fifty-two weekly samples for pesticide/herbicide analyses were collected from RC02. Of these, thirty-four samples, or 65%, contained detectable atrazine. Atrazine was more frequently detected after mid-April. The greatest atrazine concentration, 12.0 µg/L, was sampled on June 14. In WY 1994, a total of 15.0 pounds of atrazine were discharged by Roberts Creek, which was 2.3% of the atrazine discharged in WY 1991. The annual fw mean atrazine concentration for WY 1994 was 0.43 µg/L. Monthly atrazine concentrations and loads for RC02 during WY 1994 are shown in Table B-2. During the water year, June had the greatest monthly fw mean atrazine concentration, 3.98 µg/L, and the largest monthly atrazine load, 7.0 pounds. The atrazine load in June accounted for 47% of the annual atrazine output. December and January had the lowest monthly fw mean atrazine concentrations, 0.03 µg/L, and January had the lowest monthly atrazine load, 0.04 pounds.

Among the fifty-two samples collected in WY 1994, seven samples, or 13%, contained detectable alachlor; five samples, or 9.6%, contained detectable cyanazine; nine samples, or 17%, contained detectable metolachlor; three samples, or 5.8%, contained detectable desisopropyl atrazine; and forty-one samples, or 79%, contained detectable desethyl atrazine. The greatest concentrations detected were 2.8 µg/L for alachlor, 1.2 µg/L for cyanazine, 4.8 µg/L for metolachlor, 0.28 µg/L for desisopropyl atrazine, and 1.0 µg/L for desethyl atrazine. All maximum concentrations were detected in a sample collected on June 14. Butylate, metribuzin, trifluralin, and fonofos were not detected at RC02 in WY 1994. Acetochlor was added to the list of analyses in August, 1994, but no detections were reported during the water year. Analysis for fonofos ended in late October.

Fifty-one weekly samples were collected from RC02 for common pesticide/herbicide analyses in WY 1995. Twenty-four of them, or 47%, contained detectable atrazine. The greatest atrazine concentration was 2.6 µg/L from a sample collected on May 30. The total atrazine output for WY 1995 was 9.4 pounds, at an annual fw mean concentration of 0.23 µg/L. This was the second lowest annual atrazine load and the lowest annual fw mean concentration measured at RC02 since monitoring started in WY 1986. The lowest annual atrazine output, 6.7 pounds, measured in WY 1988 (Rowden et al., 1995a). Table B-3 summarizes atrazine monitoring results at RC02 on a monthly basis for WY 1995. During the water year, all samples collected in November, December, January, and April were below the atrazine detection limit (<0.1 µg/L). No atrazine was discharged during December, January, and April. The greatest monthly fw mean atrazine

concentration, 0.73 µg/L, and the largest monthly atrazine load, 5.5 pounds, occurred in May.

Among the fifty-one samples collected at RC02 during WY 1995, four samples, or 7.8%, contained detectable acetochlor and cyanazine; five samples, or 9.8%, contained detectable alachlor; six samples, or 12%, contained detectable metolachlor; and twenty-five samples, or 49%, contained detectable desethyl atrazine. The greatest detected concentrations were 0.59 µg/L for acetochlor, 1.3 µg/L for alachlor, 0.66 µg/L for cyanazine, 1.2 µg/L for metolachlor, and 0.35 µg/L for desethyl atrazine. The sample with the greatest alachlor concentration was collected on August 1. All other maximum concentrations were detected in a sample collected on May 30. Butylate, metribuzin, trifluralin, and desisopropyl atrazine were not detected at RC02 during WY 1995.

Water Year 1996

Discharge Monitoring

During WY 1996, the annual precipitation for the Big Spring basin was 30.59 inches, which was 2.38 inches below the normal. This was the third consecutive water year with precipitation lower than the long-term average (see Table 1). The groundwater discharge at Big Spring totaled 28,143 ac-ft for the water year, which was about 89% of the WYs 1982-1999 average. The annual discharge was equivalent to 16.7% of the annual precipitation (Table 6). Figure 5 shows the discharge hydrograph (A) and water temperature (B) for Big Spring, along with daily precipitation for the Big Spring basin (C) and daily maximum/minimum air temperatures recorded at the Elkader weather observation station (D) for WY 1996. During this water year, the mean daily groundwater discharge from Big Spring varied between 22.5 cfs and 295 cfs, at an average rate of 38.8 cfs. Most rainfall during the water year occurred in May and June. Much greater than normal precipitation caused significant runoff and infiltration, and resulted in increased groundwater discharges at Big Spring during June and early July. Table 7 summarizes the groundwater

Table 6. Annual summary of groundwater and chemical discharges from the Big Spring basin to the Turkey River for WY 1996.

DISCHARGE	
Total	
acre-feet	28,143
millions cf	1,224
millions cm	34.7
Average	
cfs	38.8
cms	1.10
mg/d	25.06
gpm	17,399
PRECIPITATION AND DISCHARGE	
Precipitation	30.59 inches (777 mm)
Discharge	5.12 inches (130 mm)
Discharge as % of precipitation	16.7%

NITRATE DISCHARGE		
Concentration - mg/L	**As NO_3**	**As NO_3-N**
Flow-weighted mean	46.4	10.3
Mean of analyses	45.6	10.1
	NO_3-N output	**Total N output**
lbs - N	789,277	795,338*
kg - N	357,949	360,697*
lbs - N/acre	11.97	12.07*

ATRAZINE DISCHARGE	
Concentration - µg/L	
Flow-weighted mean	0.27
Mean of analyses	0.15
Total output	
lbs	20.45
kg	9.28

* Total NO - plus Ammonia-N.

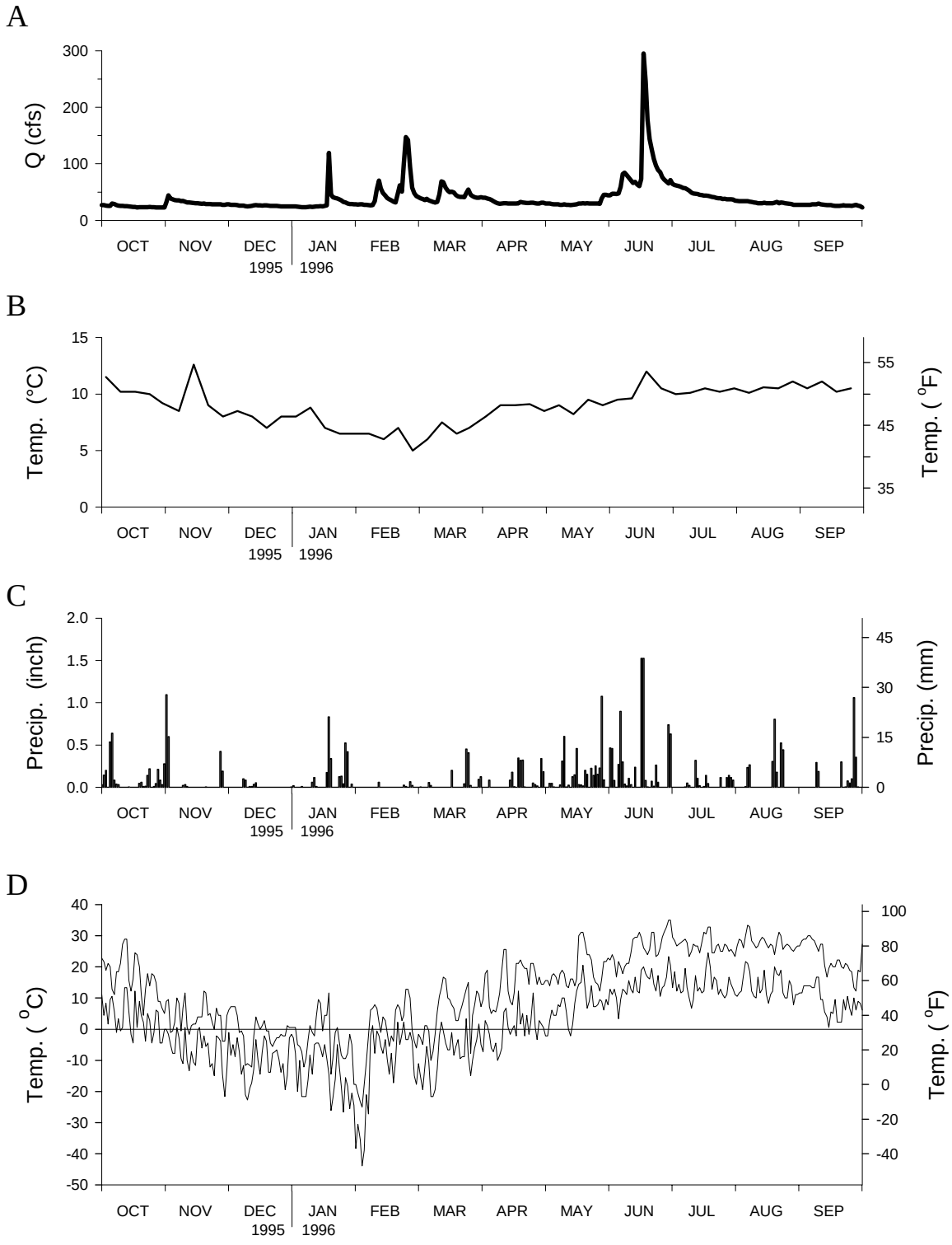

Figure 5. A) Groundwater discharge, B) groundwater temperature and C) daily precipitation for the Big Spring basin; and D) maximum/minimum temperatures for Elkader, IA (Iowa Dept. of Ag. and Land Stewardship, State Climatologist Office), for WY 1996.

Table 7. Monthly summary of groundwater discharge from the Big Spring basin for WY 1996.

	1995 Oct	Nov	Dec	1996 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
TOTAL MONTHLY DISCHARGE												
Acre-feet	1,513	1,875	1,589	1,940	2,960	2,704	1,899	1,885	5,427	2,858	1,898	1,596
Cubic feet (millions)	66	82	69	85	129	118	83	82	237	125	83	70
Gallons (millions)	493	611	518	632	965	881	619	614	1,769	931	619	520
Cubic meters (millions)	1.9	2.3	2.0	2.4	3.6	3.3	2.3	2.3	6.7	3.5	2.3	2.0
AVERAGE DISCHARGE												
cfs	25	32	26	32	51	44	32	31	91	46	31	27
cms	0.7	0.9	0.7	0.9	1.5	1.2	0.9	0.9	2.6	1.3	0.9	0.8
mg/d	16	20	17	20	33	28	21	20	59	30	20	17
MAXIMUM												
cfs	30	44	28	119	147	69	40	45	295	64	34	29
cms	0.8	1.3	0.8	3.4	4.2	1.9	1.1	1.3	8.3	1.8	1.0	0.8
MINIMUM												
cfs	23	27	24	23	27	32	29	27	44	35	27	23
cms	0.6	0.8	0.7	0.7	0.8	0.9	0.8	0.8	1.2	1.0	0.8	0.6

discharge on a monthly basis for Big Spring during WY 1996. The greatest monthly discharge, 5,427 ac-ft, occurred in June at an average rate of 91 cfs. The lowest monthly discharge, 1,513 ac-ft, was generated in October, at an average rate of 25 cfs. During WY 1996, all monthly discharge totals were less than 2,000 ac-ft except for February, March, June, and July, when runoff was generated by snowmelt and/or intense rainfall.

The annual discharge for WY 1996 for the Turkey River at Garber was 581,900 ac-ft, at an average rate of 801 cfs (Table 8). Surface-water discharge accounted for 24.2% of the annual precipitation in the northeast Iowa region, and was equal to 81.7% of the long-term (WYs 1913-1996) average annual discharge for the river. The hydrograph for the Turkey River at Garber for WY 1996 was similar to the hydrograph for Big Spring (Fig. 6B), except that the Turkey River had more obvious discharge peaks generated by rainfall accompanied with snowmelt during late March. For the Turkey River, the greatest mean daily discharge rate, 8,610 cfs, occurred on June 18, and the lowest daily discharge rate, 160 cfs, was measured on February 3 (May et al., 1997). The largest monthly discharge during WY 1996, 174,700 ac-ft, occurred in June, while the lowest, 16,920 ac-ft, occurred in September. December and January also had monthly discharges of less than 20,000 ac-ft (May et al., 1997).

The monitoring summary for Roberts Creek (RC02) in WY 1996 is shown on Table 9. The

Table 8. Annual summary of water and chemical discharges from the Turkey River at Garber for WY 1996 (Discharge data are from the U.S. Geological Survey, Water Resources Division, IA Dist.).

DISCHARGE

Total

acre-feet	581,900
millions cf	25,348
millions cm	717

Average

cfs	801
cms	22.7
mg/d	518
gpm	359,489

PRECIPITATION AND DISCHARGE

Precipitation	29.24 inches (743 mm)
Discharge	7.06 inches (179 mm)
Discharge as % of precipitation	24.2%

NITRATE DISCHARGE

Concentration - mg/L	As NO_3	As NO_3-N
Flow-weighted mean	31.0	6.9
Mean of analyses	28.9	6.4

NO_3-N output

lbs - N	10,920,049
kg - N	4,952,403
lbs - N/acre	11.0

ATRAZINE DISCHARGE

Concentration - µg/L

Flow-weighted mean	0.40
Mean of analyses	0.20

Total output

lbs	637
kg	289

annual discharge at RC02 totaled 10,720 ac-ft, at an average rate of 14.8 cfs, which was about 56% of the long-term (WYs 1986-1996) mean discharge. Surface-water discharge for WY 1996 accounted for 9.3% of the annual precipitation. The hydrograph for RC02 in WY 1996 is shown on Figure 7C. Significant discharge peaks occurred in November, March, and June. The daily discharge rate ranged from 1.5 cfs on September 24 to 372 cfs on June 17. On a monthly basis, September had the lowest discharge (142 ac-ft), and June had the greatest (4,470 ac-ft).

Table 10 summarizes the monitoring results from Silver Creek (L23S) in WY 1996. The annual discharge at L23S was 1,360 ac-ft, at an average rate of 1.87 cfs. Both of them are the lowest since WY 1991. Discharge accounted for 18.9% of precipitation. Significant runoff in the sub-basin occurred in January through March and again in June (Fig. 7C). Daily mean discharge at L23S varied between 0.26 cfs on December 28 and 55 cfs on June 17. The month with the lowest total discharge, 34 ac-ft, was October, while June had the greatest, at 511 ac-ft.

The annual monitoring results from tile line site L22T are summarized in Table 11 and Figure 7. The annual discharge at L22T totaled 49.5 ac-ft, at an average rate of 0.068 cfs for WY 1996. The discharge accounted for 22.8% of precipitation. The shallow groundwater hydrograph for L22T is shown on Figure 7C. During the water year, most discharge peaks occurred in January through March, and in June. The mean daily discharge ranged between 0.032 cfs from September 16 through 25 and 0.52 cfs on June 17. On a monthly basis, September had the lowest discharge, 1.99 ac-ft, and the lowest discharge rate, 0.033 cfs. June had the greatest monthly discharge at 10.13 ac-ft and discharge rate at 0.17 cfs.

Nitrate Monitoring

During WY 1996, fifty-two samples were collected from Big Spring for partial N-series analyses. The annual nitrogen discharge results are summarized on Table 6. More than 795 thousand pounds of nitrate- and ammonia-N were

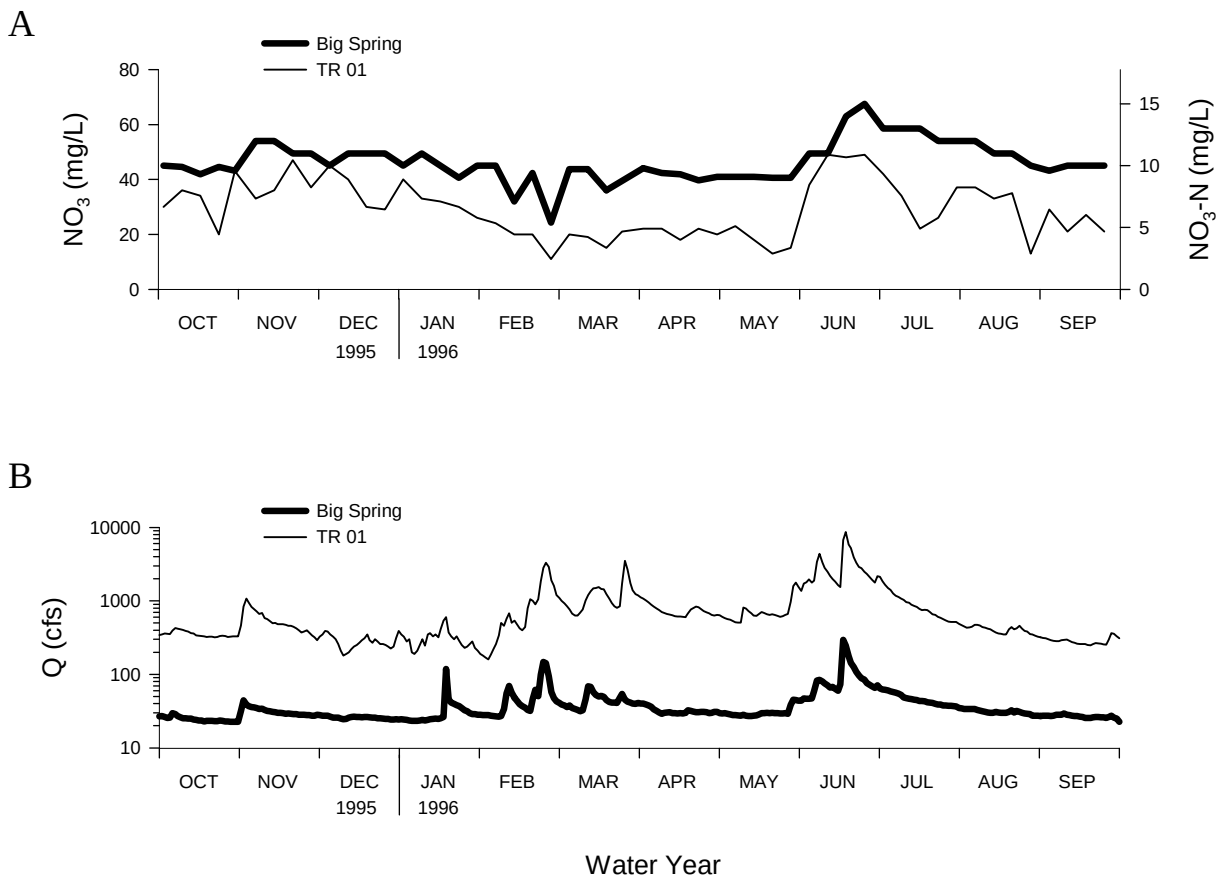

Figure 6. A) Nitrate concentrations and B) discharge hydrographs for Big Spring (bold lines) and the Turkey River at Garber (lighter lines) for WY 1996 (Turkey River discharge data are from the U.S. Geological Survey, W.R.D., IA Dist.).

discharged by groundwater from the Big Spring basin during this water year. Of this total, 789 thousand pounds, or 99%, were in the form of nitrate-N. This amount is equivalent to about 12 lbs-N/acre for the basin. The fw mean nitrate concentration for the water year was 46.4 mg/L (10.3 mg/L as NO_3-N), which was slightly greater than the fw mean nitrate concentration for WY 1995. The annual nitrate-N load and the lbs-N/acre for WY 1996 were the lowest since WY 1991.

The variations in nitrate concentration during the water year are illustrated on Figure 8B. The WY 1996 was characterized by relatively stable nitrate concentrations, accompanied with fluctuations following groundwater discharge events. The lowest nitrate concentration from Big Spring during this water year, 24 mg/L (5.4 mg/L as NO_3-N), occurred on February 27, following the second greatest discharge event of the year which occurred from February 23 through February 26. The greatest nitrate concentration, 68 mg/L (15.0 mg/L as NO_3-N), was measured on June 25, about one week following the largest groundwater discharge event of the water year. Among the fifty-two samples collected during the water year, twenty-two samples, or 42%, contained nitrate concentrations below the 45 mg/L (10.0 mg/L as NO_3-N) drinking water standard for nitrate.

Table A-4 summarizes the nitrate discharge from Big Spring during WY 1996 on a monthly basis. The greatest monthly fw mean nitrate

concentration, 57 mg/L (12.7 mg/L as NO_3-N), occurred in July. June had the greatest monthly nitrate-N output, 180 thousand pounds. The lowest monthly fw mean nitrate concentration, 33 mg/L (7.3 mg/L as NO_3-N), occurred in February, while the lowest monthly nitrate-N output, 40 thousand pounds, occurred in October. June, the wettest month of the water year, accounted for 19.3% of the annual groundwater discharge, and 22.8% of the annual nitrate-N load. The monthly fw mean nitrate concentration was below the 45 mg/L (10.0 mg/L as NO_3-N) drinking water standard for nitrate in October, and January through May during WY 1996.

Among the fifty-two samples collected from Big Spring, thirteen samples, or 25%, contained detectable concentrations for ammonia-N (>0.1 mg/L) in WY 1996, at an annual fw mean ammonia-N concentration of 0.08 mg/L. Samples with relatively high ammonia-N concentrations were collected in late January through late February. The greatest ammonia-N concentration, 0.8 mg/L, was sampled on February 13.

For the Turkey River, fifty-two weekly samples for nitrate analysis were collected, while N-series sampling was discontinued in WY 1996. The Turkey River during WY 1996 discharged a total of 10.9 million pounds of nitrate-N. This is equivalent to 11.0 lbs-N/acre for the Turkey River basin above Garber. During WYs 1984-1996, the annual nitrate-N discharged by the Turkey River has varied between 1.6 million pounds in WY 1989 (Libra et al., 1991) and 32.4 million pounds in WY 1993 (Rowden et al., 1995b). The annual nitrate-N load for WY 1996 was the second lowest since WY 1990. The annual mean of analysis for nitrate was 28.9 mg/L (6.4 mg/L as NO_3-N), and the annual fw mean nitrate concentration was 31.0 mg/L (6.9 mg/L as NO_3-N). The annual fw mean nitrate concentration of this water year was the third greatest since WY 1984. This probably resulted from the relatively minor runoff and increased proportion of infiltration recharge constituting the discharge.

Figure 6 shows the nitrate concentrations (6A) and hydrographs (6B) for the Turkey River and Big Spring. The lowest nitrate concentration from

Table 9. Annual summary of water and chemical discharges from RC02 for WY 1996 (Discharge data are from the U.S. Geological Survey, Water Resources Division, IA Dist.).

DISCHARGE	
Total	
acre-feet	10,720
millions cf	467.0
millions cm	13.22
Average	
cfs	14.8
cms	0.419
mg/d	9.57
gpm	6,642
PRECIPITATION AND DISCHARGE	
Precipitation	30.59 inches (777 mm)
Discharge	2.84 inches (72 mm)
Discharge as % of precipitation	9.3%

NITRATE DISCHARGE		
Concentration - mg/L	**As NO_3**	**As NO_3-N**
Flow-weighted mean	35.0	7.8
Mean of analyses	26.6	5.9
	NO_3-N output	**Total N output**
lbs - N	227,277	239,930*
kg - N	103,073	108,812*
lbs - N/acre	5.02	5.30*

ATRAZINE DISCHARGE	
Concentration - µg/L	
Flow-weighted mean	1.79
Mean of analyses	0.42
Total output	
lbs	52.2
kg	23.7

* Total NO - plus Ammonia-N.

the Turkey River during this water year, 11 mg/L (2.4 mg/L as NO_3-N), occurred on February 27. The greatest nitrate concentration, 49 mg/L (10.9 mg/L as NO_3-N), occurred on June 11 and 25.

Monthly nitrate concentrations and loads from the Turkey River for WY 1996 are shown in Table A-5. The fw mean nitrate concentrations remained well below the 45 mg/L (10 mg/L as NO_3-N) drinking water standard for all months except June, when the monthly fw mean nitrate concentration was 45.4 mg/L (10.1 mg/L as NO_3-N). The lowest monthly fw mean nitrate concentration, 16.1 mg/L (3.6 mg/L as NO_3-N), occurred in February. The greatest monthly nitrate-N load, 4.8 million pounds, occurred in June, and the lowest monthly nitrate-N load, 249 thousand pounds, occurred in September. June accounted for 30% of the annual surface-water discharge and 44% of the annual nitrate-N output, while September accounted for 2.9% of the annual surface-water discharge and 2.3% of the annual nitrate-N output.

In WY 1996, fifty-two weekly samples were collected from RC02 and analyzed for partial N-series. Fifty-one samples, or 98%, contained detectable nitrate. The greatest nitrate concentration of this water year, 72 mg/L (16 mg/L as NO_3-N), was sampled on June 18. In WY 1996, Roberts Creek discharged 240 thousand pounds of nitrogen. Of this total, 227 thousand pounds, or 95%, were in the form of nitrate-N. This is equivalent to 5.0 lbs-N/acre within the watershed. The fw mean nitrate concentration for WY 1996 was 35 mg/L (7.8 mg/L as NO_3-N). On a monthly basis, the fw mean nitrate concentration varied from 11.0 mg/L (2.4 mg/L as NO_3-N) in September to 48.8 mg/L (10.9 mg/L as NO_3-N) in June (Table A-6). June had the greatest monthly nitrate-N output at 132 thousand pounds, while September had the lowest monthly nitrate-N output at 950 pounds.

Twenty-six samples, or 50% of the total, from RC02 contained detectable concentrations of ammonia-N. The sample with the greatest concentration of ammonia-N, 3.1 mg/L, was collected on February 13. The total ammonia-N discharged by Roberts Creek in WY 1996 was

Table 10. Annual summary of water and chemical discharges from L23S for WY 1996 (Discharge data are from the U.S. Geological Survey, Water Resources Division, IA Dist.).

DISCHARGE

Total

acre-feet	1,360
millions cf	59.24
millions cm	1.68

Average

cfs	1.87
cms	0.053
mg/d	1.21
gpm	839

PRECIPITATION AND DISCHARGE

Precipitation	30.59 inches (777 mm)
Discharge	5.80 inches (147 mm)
Discharge as % of precipitation	18.9%

NITRATE DISCHARGE

Concentration - mg/L	As NO_3	As NO_3-N
Flow-weighted mean	48.8	10.8
Mean of analyses	42.6	9.5

	NO_3-N output	Total N output
lbs - N	40,083	41,590*
kg - N	18,178	18,862*
lbs - N/acre	14.2	14.8*

ATRAZINE DISCHARGE

Concentration - µg/L

Flow-weighted mean	0.89
Mean of analyses	0.25

Total output

lbs	3.27
kg	1.48

* Total NO - plus Ammonia-N.

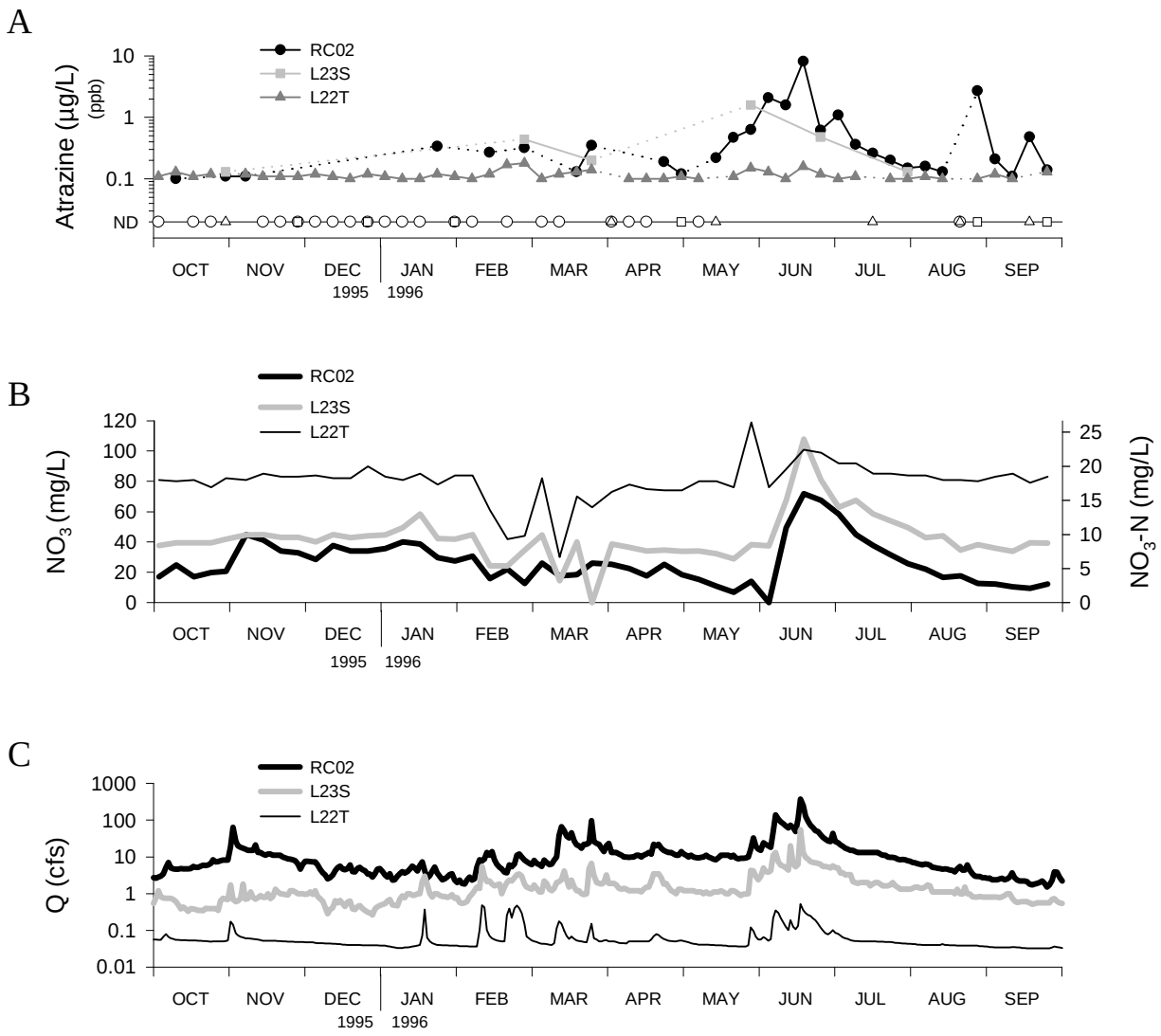

Figure 7. A) Atrazine, B) nitrate distributions and C) discharge hydrographs for RC02, L23S and L22T for WY 1996 (RC02 and L23S discharge data are from the U.S. Geological Survey, W.R.D., IA Dist.).

12.7 thousand pounds, at an annual fw mean concentration of 0.43 mg/L.

Fifty-two weekly samples were collected from L23S and analyzed for partial N-series during WY 1996. Fifty-one samples, or 98%, contained detectable nitrate. The greatest nitrate concentration, 108 mg/L (24 mg/L as NO_3-N), sampled on June 18. In WY 1996, Silver Creek discharged about 41.6 thousand pounds of nitrate-N and ammonia-N. Of this total, 40 thousand pounds, or 96%, were in the form of nitrate-N. This is equivalent to 14.2 lbs-N/acre for the sub-basin. The annual fw mean nitrate concentration was 48.8 mg/L (10.8 mg/L as NO_3-N). Table A-7 summarizes the nitrate and nitrate-N discharges on a monthly basis. The greatest monthly fw mean nitrate concentration, 64.7 mg/L (14.4 mg/L as NO_3-N), occurred in June. The lowest, 26.8 mg/L (5.9 mg/L as NO_3-N), occurred in March. The monthly nitrate-N output ranged from 795

pounds in October to 20 thousand pounds in June. June accounted for about 38% of the annual surface-water discharge, and 50% of the annual nitrate-N load during WY 1996.

Of the fifty-two samples collected from L23S during WY 1996, thirty-one, or 60%, contained detectable concentrations of ammonia-N. The sample with the greatest concentration of ammonia-N, 4.0 mg/L, was collected on February 20. The total ammonia-N discharged by Silver Creek in WY 1996 was 1,507 pounds, at an annual fw mean concentration of 0.41 mg/L.

Compared with other sites in the Big Spring basin, nitrate concentrations were significant greater at tile line site L22T (see Fig. 7B). In WY 1996, fifty-two samples from L22T were analyzed for nitrate. All of the samples contained detectable nitrate, and forty-nine, or 94%, were above the 45 mg/L drinking water standard for nitrate. Nitrate concentrations ranged between 30 mg/L (6.7 mg/L as NO_3-N) on March 12 and 119 mg/L (26.4 mg/L as NO_3-N) on May 28. During WY 1996, 2,241 pounds of nitrate-N were discharged from L22T, which is equivalent to 26.4 lbs-N/acre within the drainage area. This was the lowest annual nitrate load for L22T since WY 1991. The annual fw mean nitrate concentration for WY 1996 was 74.9 mg/L (16.6 mg/L as NO_3-N). This was the lowest fw mean nitrate concentration since WY 1990. The monthly nitrate-N discharge data for WY 1996 are shown in Table A-8. The monthly fw mean nitrate concentration varied from 46.5 mg/L (10.3 mg/L as NO_3-N) in February to 89.8 mg/L (20.0 mg/L as NO_3-N) in June. June also had the greatest monthly nitrate-N output, 550 pounds, while September had the lowest, 99 pounds. Both ammonia-N and organic-N were not analyzed for L22T during WY 1996.

Pesticide Monitoring

Figures 8A, 9, and 10A, Table 6 and appendix Table B-4 summarize the results of pesticide monitoring at Big Spring for WY 1996. Fifty-two samples from Big Spring were analyzed for pesticides during the water year. Among the analytes, atrazine was the most frequently detected

Table 11. Annual summary of shallow groundwater and chemical discharges from L22T for WY 1996.

DISCHARGE

Total

acre-feet	49.5
millions cf	2.15
millions cm	0.061

Average

cfs	0.068
cms	0.002
mg/d	0.044
gpm	30.52

PRECIPITATION AND DISCHARGE

Precipitation	30.59 inches (777 mm)
Discharge	6.99 inches (178 mm)
Discharge as % of precipitation	22.8%

NITRATE DISCHARGE

Concentration - mg/L	As NO_3	As NO_3-N
Flow-weighted mean	74.9	16.6
Mean of analyses	79.7	17.7

NO_3-N output

lbs - N	2,241
kg - N	1,016
lbs - N/acre	26.4

ATRAZINE DISCHARGE

Concentration - µg/L

Flow-weighted mean	0.13
Mean of analyses	0.10

Total output

lbs	0.018
g	8.17

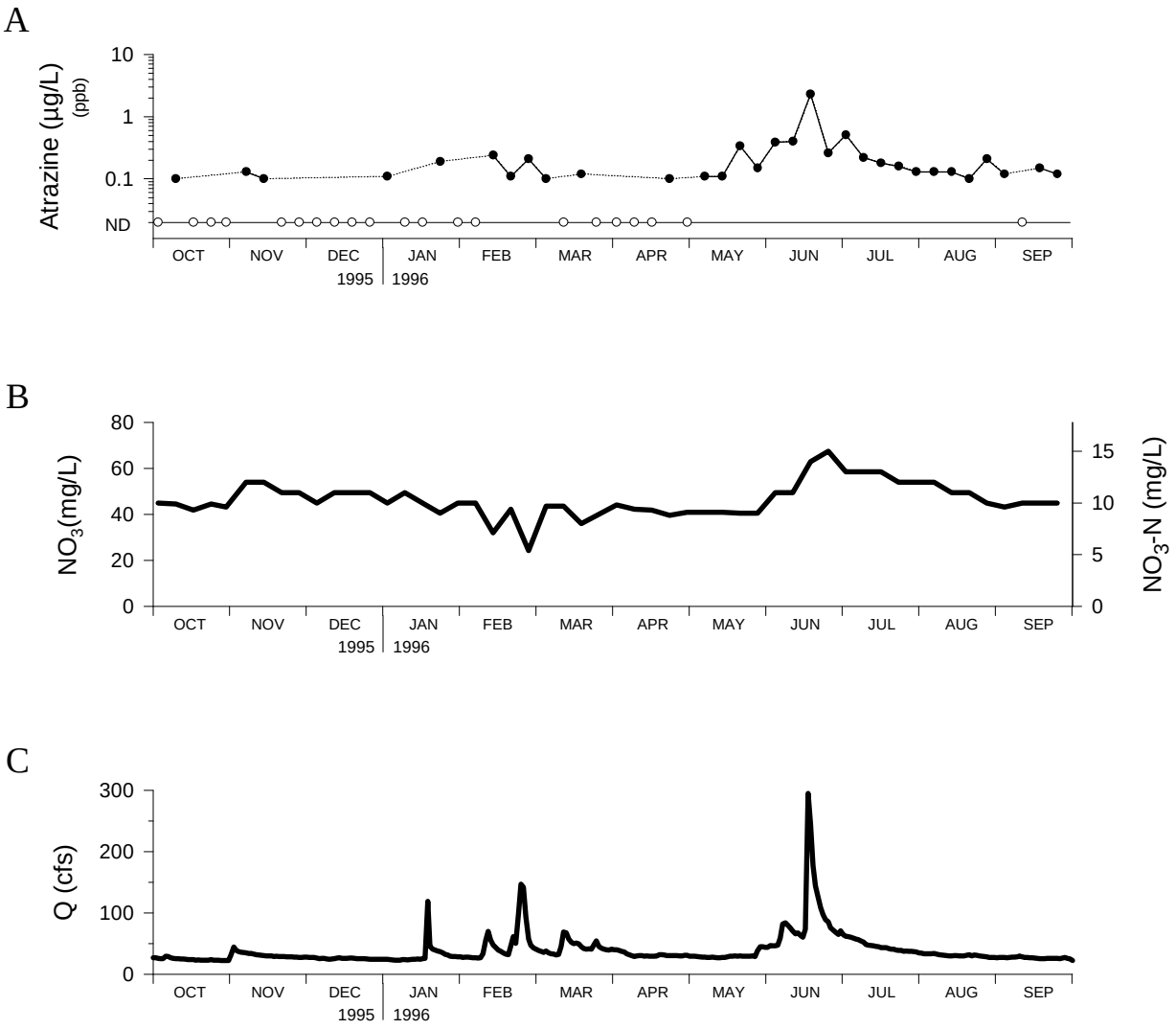

Figure 8. A) Atrazine and B) nitrate concentrations; and C) groundwater discharge at Big Spring for WY 1996.

compound. In WY 1996, a total of 20.5 pounds of atrazine were discharged from Big Spring groundwater at annual fw mean concentration of 0.27 µg/L. Both the annual atrazine load and fw mean concentration for WY 1996 were significantly greater than for WY 1995, which had the lowest annual fw mean concentration for atrazine, 0.12 µg/L, and the second lowest annual atrazine load, 9.8 pounds, since WY 1982 (Liu et al., 1997). During WY 1996, atrazine was not detected consistently until May. The greatest atrazine concentration of the water year, 2.30 µg/L, was sampled on June 18 during the largest groundwater discharge peak of the water year (Fig. 8).

Table B-4 summarizes mean atrazine concentrations and loads at Big Spring on a monthly basis for WY 1996. During the water year, the greatest monthly fw mean atrazine concentration, 0.80 µg/L, and the largest monthly atrazine load, 11.8 pounds, occurred in June, the month with the greatest groundwater discharge. All four samples analyzed for atrazine in December were below the detection limit (<0.10 µg/L). December had the lowest monthly fw mean atrazine concentration,

0.01 µg/L. That is the lowest monthly fw mean atrazine concentration at Big Spring since WY 1984. The previous low, 0.04 µg/L, occurred in April of WY 1994 (Liu et al., 1997). The lowest monthly atrazine load since WY 1984, 0.03 pounds, also occurred in December. The previous lowest monthly atrazine load, 0.20 pounds, was recorded in August of WY 1988 and December of WY 1989 (Libra et al., 1991).

Figure 9 shows the concentrations for atrazine, cyanazine, alachlor, and metolachlor on a logarithmic scale. Concentration bars ending at the "ND" line indicate a non-detection. Of the fifty-two samples collected from Big Spring during WY 1996, thirty-one, or 60%, contained detectable levels of atrazine; one sample (2%), contained detectable levels of cyanazine and alachlor; and three samples (6%) contained detectable levels of metolachlor. The greatest concentration was 0.35 µg/L for cyanazine, 0.16 µg/L for alachlor, and 1.40 µg/L for metolachlor. All the maximums occurred on June 18.

Figure 10A shows the trends for atrazine and the atrazine metabolites desethyl atrazine and desisopropyl atrazine. Among the fifty-two samples collected from Big Spring in WY 1996, thirty-two samples, or 62%, contained detectable desethyl atrazine. The concentration trend for desethyl atrazine was similar to atrazine. The greatest concentration, 0.54 µg/L, was also sampled on June 18. Desisopropyl atrazine was not detected in Big Spring groundwater during the water year.

Other pesticides analyzed for in Big Spring groundwater during WY 1996 include acetochlor, butylate, metribuzin, and trifluralin. Two of the fifty-two samples (4%) contained detectable acetochlor, with the greatest concentration 0.53 µg/L on June 18. Butylate, metribuzin, and trifluralin were not detected during the water year at Big Spring.

The pesticide data for the Turkey River during WY 1996 are summarized in Figure 10B, Table 8 and appendix Table B-5. During the water year, twelve monthly samples from the Turkey River were analyzed for pesticides. The river discharged a total of 637 pounds of atrazine, at annual fw mean concentration of 0.40 µg/L. This was the

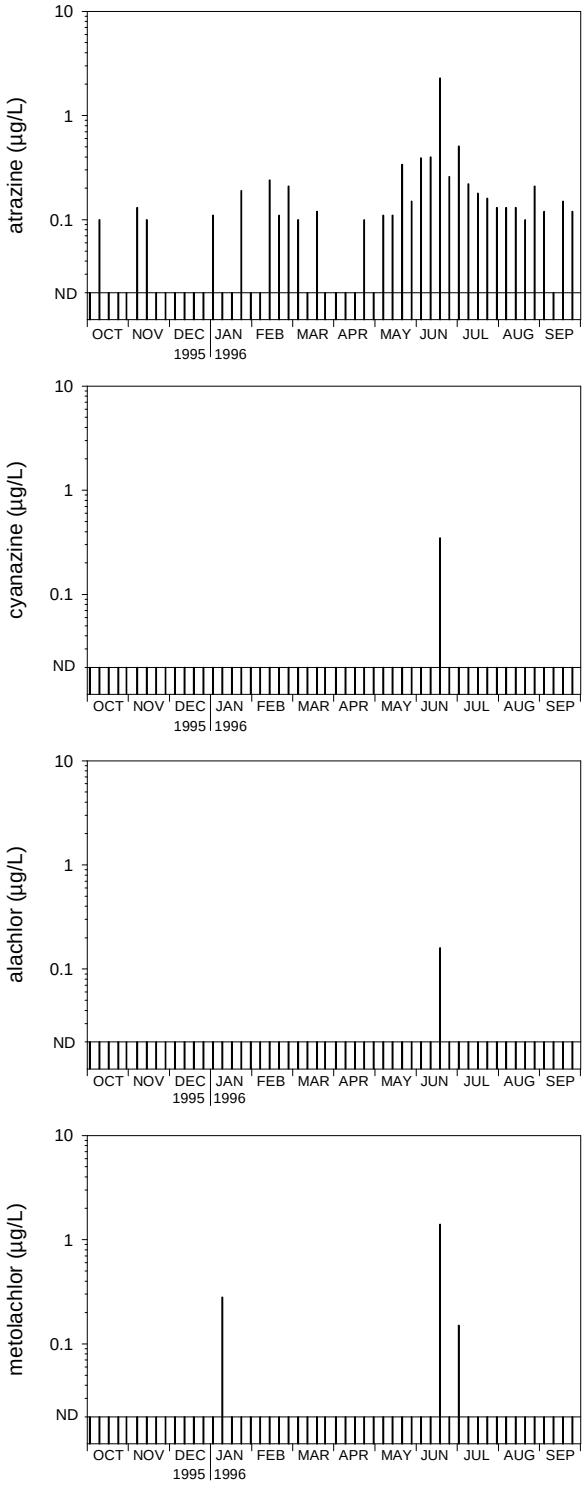

Figure 9. Bar graphs of pesticide concentrations at Big Spring for WY 1996. ND represents not detected.

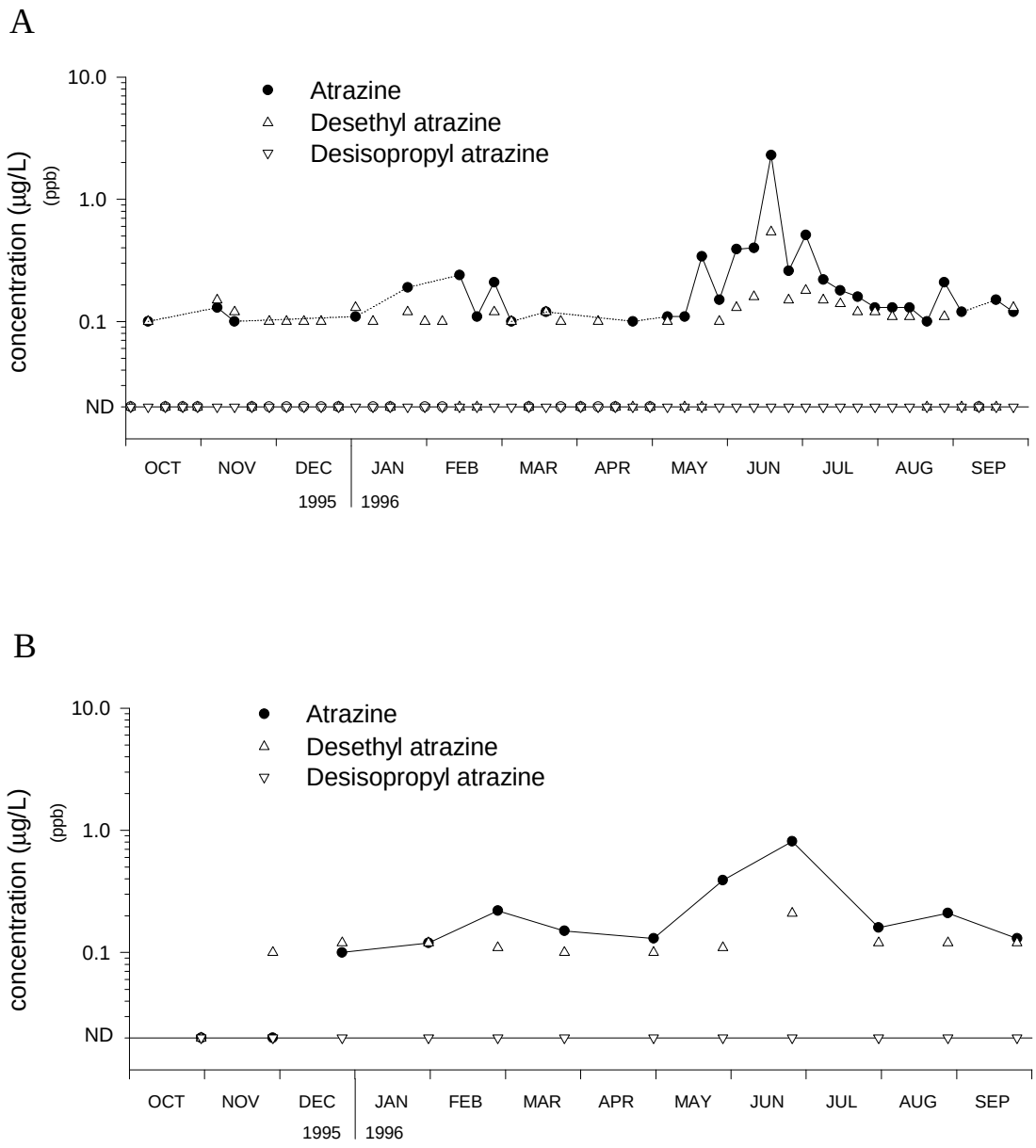

Figure 10. A) Atrazine, desethyl atrazine and desisopropyl atrazine concentrations for Big Spring and B) the Turkey River at Garber for WY 1996. ND represents not detected.

third-lowest annual atrazine load and fw mean atrazine concentration observed at the Turkey River during the WY 1986-1996 period. The annual mean of analyses for atrazine observed for the water year was 0.20 µg/L. This was the lowest recorded since WY 1986, when atrazine monitoring started at TR01. The lowest previous annual mean of analyses concentration for atrazine at TR01 was 0.27 µg/L recorded in WY 1992 (Rowden et al., 1995b).

Table B-5 summarizes the mean atrazine concentrations and loads on a monthly basis for the Turkey River for WY 1996. The greatest monthly fw mean atrazine concentration, 0.92 µg/

L, and atrazine load, 438 pounds, occurred in June. June accounted for 69% of the annual atrazine load and 30% of the annual surface water discharge. The lowest monthly fw mean atrazine concentration for the Turkey River during the water year, 0.04 µg/L, and the lowest monthly atrazine load, 2.0 pounds, occurred in December. The fw mean atrazine concentration for December (0.04 µg/L) was the second lowest monthly fw mean concentration for the Turkey River since WY 1986. The lowest, 0.02 µg/L, was recorded in November, 1987 (Libra et al., 1991). Another month with a fw mean atrazine concentration of 0.04 µg/L occurred in December, 1988 (Libra et al., 1991).

The trends for atrazine and its metabolites desethyl atrazine and desisopropyl atrazine are shown in Figure 10B. Of the twelve monthly samples collected from the Turkey River during WY 1996, ten samples, or 83%, contained detectable levels of atrazine. The samples collected in October and November were below detection. Eleven samples, or 92%, contained detectable concentrations of desethyl atrazine. The greatest desethyl atrazine concentration, 0.21 µg/L, sampled on June 25. None of the samples contained detectable desisopropyl atrazine.

Other pesticides detected in the Turkey River during WY 1996 were acetochlor and metolachlor. Of the twelve samples, one contained detectable acetochlor at 0.19 µg/L. This sample was collected on May 28. Four samples, or 33%, contained detectable metolachlor. The sample with the greatest metolachlor concentration, 1.0 µg/L, was collected on February 27. Alachlor, butylate, cyanazine, metribuzin, and trifluralin were not detected. Because pesticide sampling for the Turkey River was on a monthly schedule, it is probable that significant concentration peaks were missed.

Table 9, appendix Table B-6 and Figure 7A summarize the results of pesticide monitoring at RC02 during WY 1996. Fifty-two weekly samples were collected and analyzed for common pesticides during the water year. Twenty-nine of the samples (56%) contained detectable atrazine. The greatest concentration, 8.2 µg/L, occurred on June 18. In WY 1996, Roberts Creek discharged a total of 52.2 pounds of atrazine, at an annual fw mean concentration of 1.79 µg/L. Table B-6 summarizes atrazine monitoring results at RC02 on a monthly basis for WY 1996. During the water year, the greatest monthly fw mean atrazine concentration, 4.0 µg/L, and atrazine load, 48.6 pounds, occurred in June. All samples collected in December were below the atrazine detection limit (<0.1 µg/L). June accounted for 93% of the annual atrazine load and 42% of the annual surface water discharge. Fifteen samples (29%) contained detectable desethyl atrazine, with the largest concentration at 1.40 µg/L. One sample contained detectable desisopropyl atrazine at concentration of 0.17 µg/L.

Other pesticides detected at RC02 include acetochlor, alachlor, cyanazine, and metolachlor. Six samples (12%) contained detectable acetochlor, with the greatest concentration at 0.65 µg/L. Five samples (10%) contained detectable alachlor, with the greatest concentration at 0.43 µg/L. Four samples (8%) contained detectable cyanazine, with the greatest concentration at 0.73 µg/L. Eight samples (15%) contained detectable metolachlor, with the greatest concentration at 2.1 µg/L. All the maximum concentrations occurred on June 18. No samples from RC02 contained detectable concentrations of butylate, metribuzin, or trifluralin during WY 1996.

The pesticide monitoring data for L23S in WY 1996 are summarized in Table 10, appendix Table B-7 and Figure 7A. During the water year, twelve monthly samples were collected from L23S. Six contained detectable atrazine. The greatest concentration, 1.60 µg/L, occurred on May 28. In WY 1996, a total of 3.27 pounds of atrazine were discharged by Silver Creek. The annual fw mean atrazine concentration for WY 1996 was 0.89 µg/L. Monthly atrazine concentrations and loads for WY 1996 are shown in Table B-7. During the water year, June had the greatest monthly fw mean atrazine concentration, 2.09 µg/L, and load, 2.9 pounds. The atrazine load for June accounted for 90% of the annual atrazine output, while surface water discharge for the month accounted for 38% of the annual discharge. December and September

had the lowest monthly fw mean atrazine concentration, 0.02 µg/L, and atrazine load, 0.03 ounces. The samples collected in November, December, January, April, August, and September did not contain detectable atrazine.

Among the twelve samples collected in WY 1996, one sample collected on May 28 contained detectable acetochlor at 1.2 µg/L, cyanazine at 0.96 µg/L, and metolachlor at 1.5 µg/L. Five samples (42%) contained detectable desethyl atrazine. The sample with the greatest desethyl atrazine concentration, 0.23 µg/L, was also collected on May 28. Alachlor, butylate, metribuzin, trifluralin, and desisopropyl atrazine were not detected at L23S during WY 1996.

Table 11, appendix Table B-8 and Figure 7A summarize the results of pesticide monitoring at L22T during WY 1996. Fifty-one samples were collected weekly from L22T in WY 1996. Forty-six (88%) contained detectable atrazine. The greatest concentration of atrazine, 0.18 µg/L, occurred on February 27. Total atrazine output in WY 1996 was 0.018 pounds, at an annual fw mean concentration of 0.13 µg/L. Table B-8 summarizes atrazine monitoring results at L22T on a monthly basis for WY 1996. The greatest monthly fw mean atrazine concentration, 0.20 µg/L, and atrazine load, 0.08 ounces, occurred in February. August had the lowest monthly fw mean atrazine concentration at 0.08 µg/L. Only minor loads occurred in December, April, May, and July through September.

Among the fifty-two samples collected from L22T, forty-seven samples, or 90%, contained detectable desethyl atrazine. A sample collected on September 24 had the greatest concentration at 0.22 µg/L. No other pesticides were detected at L22T during WY 1996.

Water Year 1997

Discharge Monitoring

Tables 12 and 13 and Figure 11 summarize the groundwater discharge and climatic data for Big Spring during WY 1997. Following three years of lower than normal precipitation, annual precipitation

Table 12. Annual summary of groundwater and chemical discharges from the Big Spring basin to the Turkey River for WY 1997.

DISCHARGE

Total

acre-feet	22,943
millions cf	998
millions cm	28.3

Average

cfs	31.7
cms	0.90
mg/d	20.48
gpm	14,223

PRECIPITATION AND DISCHARGE

Precipitation	38.29inches (973 mm)
Discharge	4.18 inches (106 mm)
Discharge as % of precipitation	10.9%

NITRATE DISCHARGE

Concentration - mg/L	As NO_3	As NO_3-N
Flow-weighted mean	43.5	9.7
Mean of analyses	43.5	9.7

	NO_3-N output	Total N output
lbs - N	602,655	609,652*
kg - N	273,313	276,486*
lbs - N/acre	9.14	9.25*

ATRAZINE DISCHARGE

Concentration - µg/L

Flow-weighted mean	0.17
Mean of analyses	0.10

Total output

lbs	10.45
kg	4.74

* Total NO - plus Ammonia-N.

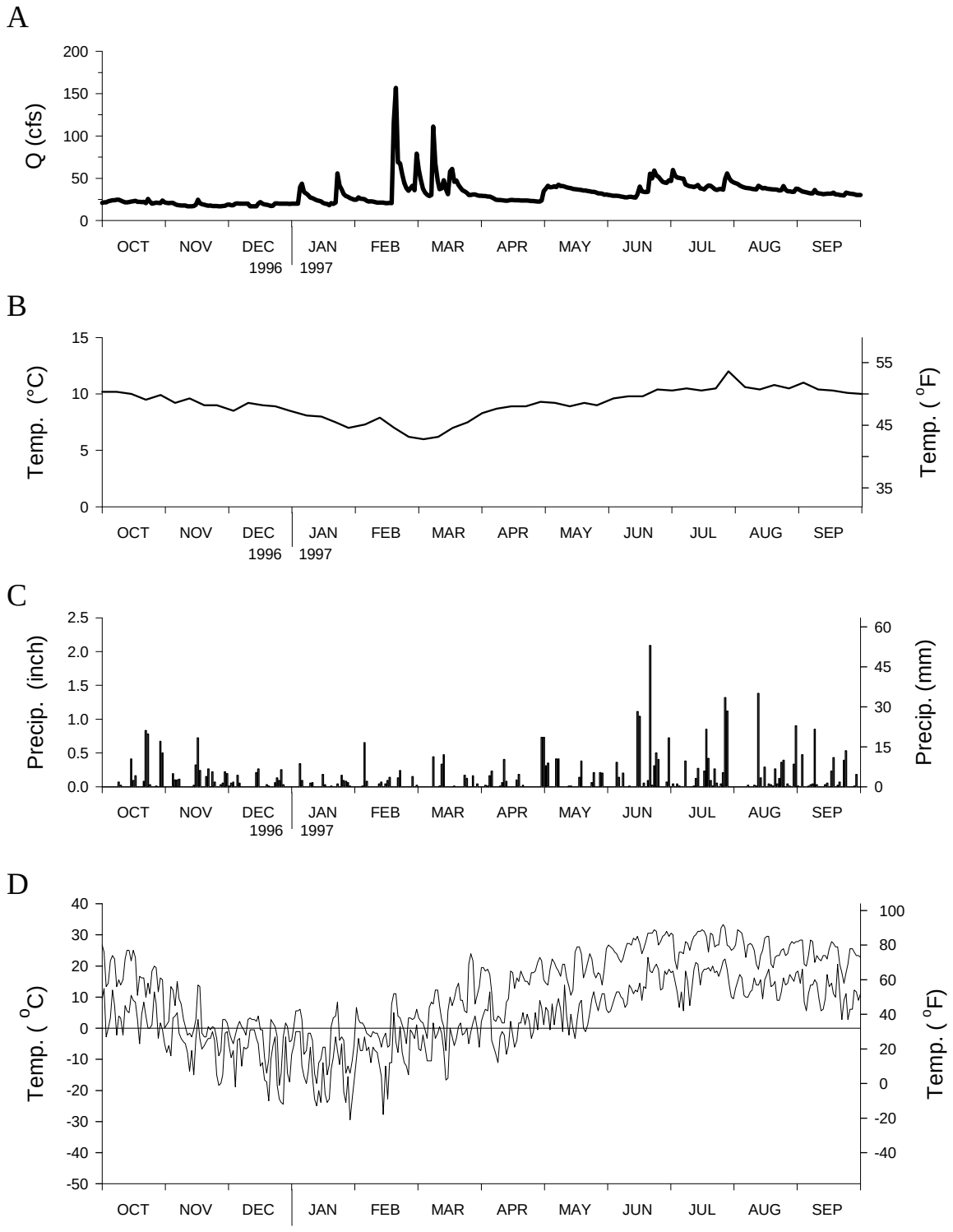

Figure 11. A) Groundwater discharge, B) groundwater temperature and C) daily precipitation for the Big Spring basin; and D) maximum/minimum temperatures for Elkader, IA (Iowa Dept. of Ag. and Land Stewardship, State Climatology Office), for WY 1997.

Table 13. Monthly summary of groundwater discharge from the Big Spring basin for WY 1997.

	1996 Oct	Nov	Dec	1997 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
TOTAL MONTHLY DISCHARGE												
Acre-feet	1,371	1,099	1,181	1,674	2,142	2,652	1,471	2,250	2,192	2,680	2,328	1,902
Cubic feet (millions)	60	48	51	73	93	116	64	98	96	117	101	83
Gallons (millions)	447	358	385	546	698	864	479	733	714	873	759	620
Cubic meters (millions)	1.7	1.4	1.5	2.1	2.6	3.3	1.8	2.8	2.7	3.3	2.9	2.3
AVERAGE DISCHARGE												
cfs	22	18	19	27	39	43	25	37	37	44	38	32
cms	0.6	0.5	0.5	0.8	1.1	1.2	0.7	1.0	1.0	1.2	1.1	0.9
mg/d	14	12	12	18	25	28	16	24	24	28	24	21
MAXIMUM												
cfs	25	25	22	56	157	111	29	42	59	60	44	36
cms	0.7	0.7	0.6	1.6	4.4	3.1	0.8	1.2	1.7	1.7	1.2	1.0
MINIMUM												
cfs	20	17	17	18	20	29	22	31	27	36	34	30
cms	0.6	0.5	0.5	0.5	0.6	0.8	0.6	0.9	0.8	1.0	1.0	0.8

in the Big Spring basin increased to 38.29 inches (973 mm) in WY 1997. This was 5.32 inches greater than the long-term average for the basin, and was the fourth greatest annual precipitation since monitoring began in WY 1982. The increase in precipitation, however, did not increase the annual groundwater discharge at Big Spring. The annual discharge at Big Spring was 22,943 ac-ft, at an average daily discharge rate of 31.7 cfs. This was the third lowest annual discharge at Big Spring since WY 1982, and was only 39% of the greatest annual discharge, 58,186 ac-ft, recorded in WY 1993 (Rowden et al., 1995b). The groundwater discharge was equivalent to 10.9% of precipitation during WY 1997. It was also the third lowest discharge/precipitation rate since monitoring began in WY 1982.

Figure 11 shows the discharge hydrograph (A) and groundwater temperature (B) for Big Spring, along with daily precipitation in the basin (C) and daily maximum/minimum air temperature (D) recorded at the Elkader weather station for WY 1997. During the first 3 months, the mean daily discharge from Big Spring remained below 25 cfs except on October 23. The lowest daily discharge rate of the water year, 16.8 cfs, occurred for four days during this period. Significant discharge peaks in January through March were generated mainly by snowmelt. The greatest daily discharge rate of the water year, 156.6 cfs, was recorded on February 19. Several daily rainfalls exceeding 1 inch occurred in June through August. However,

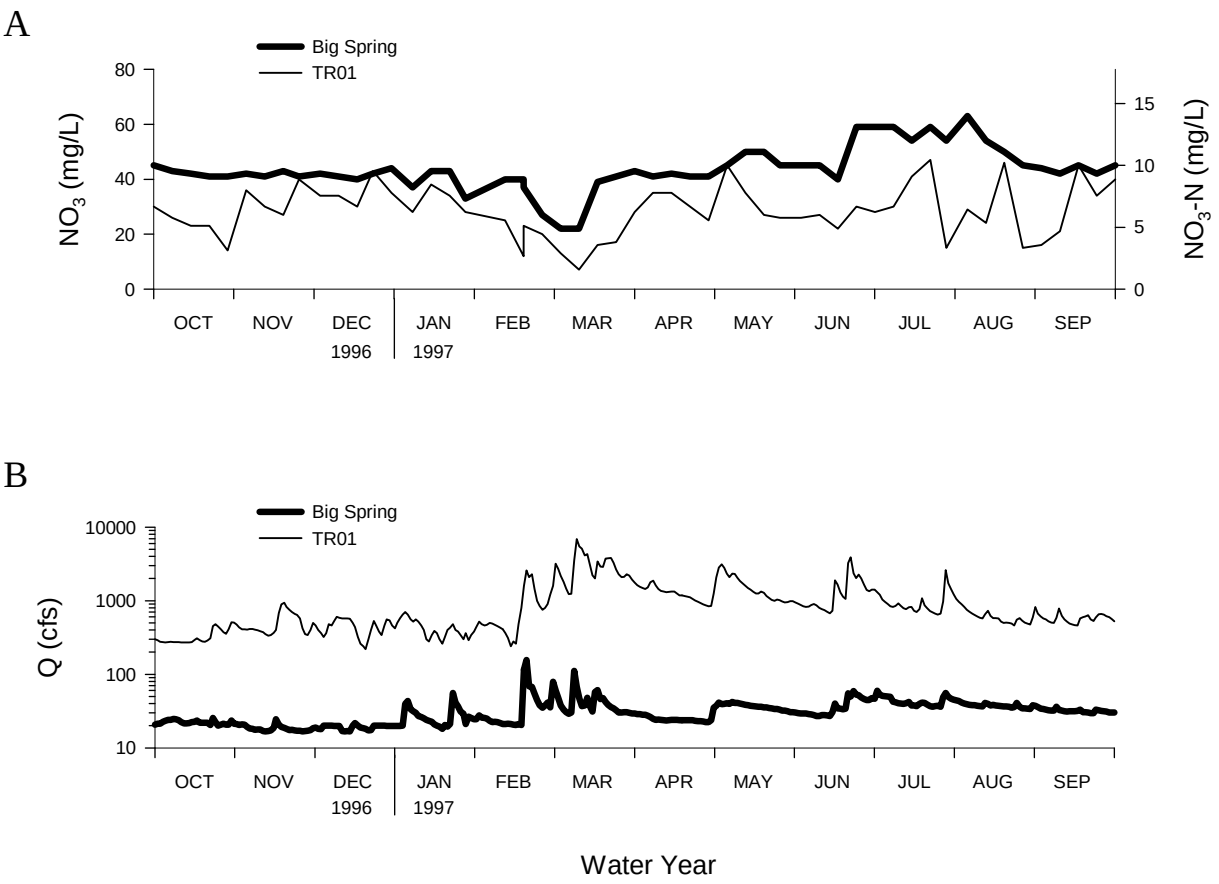

Figure 12. A) Nitrate concentrations and B) discharge hydrographs for Big Spring (bold lines) and the Turkey River at Garber (lighter lines) for WY 1997 (Turkey River discharge data are from the U.S. Geological Survey, W.R.D., IA Dist.).

they did not cause significant runoff in the area. The greatest daily precipitation, 2.09 inches, occurred on June 21. The average groundwater discharge rate was 55.4 cfs on that day, and increased to 59.0 cfs on June 23.

Table 13 summarizes the groundwater discharge data from Big Spring on a monthly basis. The greatest monthly discharge, 2,680 ac-ft, occurred in July, at an average daily discharge rate of 44 cfs. This was only 32% of the largest monthly discharge from Big Spring, 8,436 ac-ft, recorded in July of WY 1993 (Rowden et al., 1995b). The lowest monthly discharge of the water year, 1,099 ac-ft, occurred in November, at an average daily discharge rate of 18 cfs. The wettest month of the water year, June, had 2,192 ac-ft of discharge, accounted for 18.6% of the annual precipitation and 9.6% of the annual discharge.

The lighter line in Figure 12B shows the hydrograph for the Turkey River on a logarithmic scale. Compared with Big Spring, the discharge from the Turkey River was more responsive to precipitation events. The annual surface water discharge from the Turkey River at Garber was 718,900 ac-ft, at an average daily discharge rate of 993 cfs (Table 14). This amount was 101% of the long-term mean annual discharge for the Turkey River. The precipitation for northeast Iowa was 34.45 inches (900 mm) in WY 1997. Discharge for the Turkey River was equivalent to 24.6% of precipitation. On a monthly basis, March had the greatest discharge, 181,700 ac-ft, at a mean daily

Table 14. Annual summary of water and chemical discharges from the Turkey River at Garber for WY 1997 (Discharge data are from the U.S. Geological Survey, Water Resources Division, IA Dist.).

DISCHARGE

Total

acre-feet	718,900
millions cf	31,315
millions cm	886.4

Average

cfs	993
cms	28.1
mg/d	642
gpm	445,658

PRECIPITATION AND DISCHARGE

Precipitation	35.45 inches (900 mm)
Discharge	8.73 inches (222 mm)
Discharge as % of precipitation	24.6%

NITRATE DISCHARGE

Concentration - mg/L	**As NO_3**	**As NO_3-N**
Flow-weighted mean	25.8	5.7
Mean of analyses	29.3	6.5

	NO_3-N output	**Total N output**
lbs - N	11,202,240	11,847,455*
kg - N	5,080,381	5,372,996*
lbs - N/acre	11.3	12.0*

ATRAZINE DISCHARGE

Concentration - µg/L

Flow-weighted mean	0.30
Mean of analyses	0.24

Total output

lbs	579
kg	263

* Total NO - plus Ammonia-N.

discharge rate of 2,955 cfs. The lowest monthly discharge, 20,070 ac-ft, occurred in October, at an average daily discharge rate of 326 cfs. The maximum daily discharge, 6,850 cfs, was generated by snowmelt on March 10. The minimum daily discharge, 220 cfs, occurred on December 20 (May et al., 1998).

Table 15 summarizes the monitoring results at RC02 during WY 1997. The annual discharge at RC02 totaled 18,660 ac-ft, at an average discharge rate of 25.8 cfs. Discharge accounted for 12.9% of the annual precipitation. The hydrograph for RC02 in WY 1997 is shown on Figure 13C using a logarithmic scale. Significant discharge peaks occurred in February and March due to snowmelt. The daily discharge rate ranged from 1.5 cfs on October 9 to 900 cfs on February 18. Although WY 1997 was relatively wet, the first four months of the water year were relatively dry, and had a total discharge of less than 1,000 ac-ft at RC02. On a monthly basis, October had the lowest discharge with 169 ac-ft, while March had the greatest discharge with 5,140 ac-ft.

Table 16 summarizes the monitoring results from L23S during WY 1997. The annual discharge at L23S totaled 2,170 ac-ft, at an average rate of 3.0 cfs. The discharge accounted for 24.2% of the annual precipitation. Like Roberts Creek, significant runoff in the sub-basin occurred in February and March (Fig. 13C). Mean daily discharge at L23S varied between 0.28 cfs on December 20 and 243 cfs on February 18. The month with the lowest total discharge, 35 ac-ft, was December, while February had the greatest monthly discharge, 689 ac-ft.

The annual monitoring results from tile line site L22T for WY 1997 are summarized in Table 17 and Figure 13. The annual discharge at L22T totaled 45.1 ac-ft, at an average discharge rate of 0.062 cfs. These amounts were not only smaller than those in WY 1996, but were also the lowest since WY 1991. The discharge accounted for 16.6% of precipitation. This was also the lowest discharge/precipitation ratio for L22T since WY 1991. The shallow groundwater hydrograph for L22T is shown on Figure 13C. The lowest mean daily discharge of the water year, 0.032 cfs,

Table 15. Annual summary of water and chemical discharges from RC02 for WY 1997 (Discharge data are from the U.S. Geological Survey, Water Resources Division, IA Dist.).

DISCHARGE

Total

acre-feet	18,660
millions cf	812.8
millions cm	23.01

Average

cfs	25.8
cms	0.731
mg/d	16.67
gpm	11,579

PRECIPITATION AND DISCHARGE

Precipitation	38.29 inches (973 mm)
Discharge	4.95 inches (126 mm)
Discharge as % of precipitation	12.9%

NITRATE DISCHARGE

Concentration - mg/L	**As NO_3**	**As NO_3-N**
Flow-weighted mean	23.1	5.1
Mean of analyses	26.8	6.0

	NO_3-N output	**Total N output**
lbs - N	261,155	307,550*
kg - N	118,438	139,478*
lbs - N/acre	5.77	6.80*

ATRAZINE DISCHARGE

Concentration - µg/L

Flow-weighted mean	0.65
Mean of analyses	0.49

Total output

lbs	32.8
kg	14.9

* Total NO - plus Ammonia-N.

occurred on January 19, 20, 27 through 30, and February 3. The greatest discharge rate, 0.596 cfs, occurred on February 18. On a monthly basis, September had the lowest discharge at 2.41 ac-ft. The greatest monthly discharge, 8.11 ac-ft, occurred in March.

Nitrate Monitoring

Groundwater samples for partial N-series analyses were collected weekly from Big Spring in WY 1997. The nitrate monitoring results at Big Spring for the water year are summarized in Tables 12, appendix Table A-9 and Figure 14B. During WY 1997, fifty-four samples were collected from Big Spring. A total of 610 thousand pounds of nitrate- and ammonia-N were discharged by groundwater at Big Spring. Of this total, 603 thousand pounds, or 99%, were in the form of nitrate-N. This is equivalent to 9.1 lbs-N/acre within the basin. The annual fw mean nitrate concentration for the water year was 43.5 mg/L (9.7 mg/L as NO_3-N). Three distinct periods are apparent in the nitrate data (Figure 14B). From the beginning of the water year through late April, nitrate concentrations were relatively low. All of the samples collected during this period had nitrate concentrations below 45 mg/L (10.0 mg/L as NO_3-N). The lowest nitrate concentration of the water year, 22 mg/L (4.8 mg/L as NO_3-N), was sampled on March 11. From early May through mid-August, nitrate concentrations at Big Spring were relatively high, with virtually all exceeding 45 mg/L (10.0 mg/L as NO_3-N). The greatest nitrate concentration of the water year, 63 mg/L (14.0 mg/L as NO_3-N), was sampled on August 5. In the following period, nitrate concentrations gradually decreased, and around 45 mg/L (10.0 mg/L as NO_3-N) by end of the water year. Among the fifty-four samples collected at Big Spring during the water year, thirty-six samples, or 67%, had nitrate concentrations below the 45 mg/L (10.0 mg/L as NO_3-N) drinking water standard for nitrate.

Table A-9 summarizes the nitrate discharged from Big Spring during WY 1997 on a monthly basis. Monthly fw mean nitrate concentrations

Table 16. Annual summary of water and chemical discharges from L23S for WY 1997 (Discharge data are from the U.S. Geological Survey, Water Resources Division, IA Dist.).

DISCHARGE

Total

acre-feet	2,170
millions cf	94.53
millions cm	2.68

Average

cfs	3.0
cms	0.085
mg/d	1.94
gpm	1,246

PRECIPITATION AND DISCHARGE

Precipitation	38.29 inches (973 mm)
Discharge	9.27 inches (235 mm)
Discharge as % of precipitation	24.2%

NITRATE DISCHARGE

Concentration - mg/L	As NO_3	As NO_3-N
Flow-weighted mean	25.9	5.7
Mean of analyses	40.5	9.0

	NO_3-N output	Total N output
lbs - N	33,995	43,740*
kg - N	15,417	19,837*
lbs - N/acre	12.1	15.6*

ATRAZINE DISCHARGE

Concentration - µg/L

Flow-weighted mean	0.35
Mean of analyses	0.08

Total output

lbs	2.08
g	945.4

* Total NO - plus Ammonia-N.

were below the 45 mg/L (10.0 mg/L as NO_3-N) for all months except May through August. The greatest monthly fw mean nitrate concentration, 57 mg/L (12.7 mg/L as NO_3-N), and nitrate-N output, 93 thousand pounds, occurred in July. The lowest monthly fw mean nitrate concentration, 30 mg/L (6.7 mg/L as NO_3-N), occurred in February, while the lowest monthly nitrate-N output, 28 thousand pounds, occurred in November. June, the wettest month of the water year, accounted for 18.6% of the annual groundwater discharge, and 10.6% of the annual nitrate-N load.

Twelve of the fifty-four samples (22%) collected from Big Spring contained detectable concentrations of ammonia-N. Relatively high concentrations occurred between mid-February and late March. The greatest ammonia-N concentration, 0.7 mg/L, was sampled on March 11. The total ammonia-N discharged by Big Spring in WY 1997 was 6,998 pounds, at an annual fw mean concentration of 0.11 mg/L.

Figure 12A, Table 14 and appendix Table A-10 summarize nitrate concentrations and loads for the Turkey River during WY 1997. During this water year, fifty-four weekly samples were analyzed for nitrate and twelve monthly samples were analyzed for partial-N series. A total of 11.8 million pounds of nitrate- and ammonia-N were discharged by the Turkey River in WY 1997. Of this total, 11.2 million pounds, or 95%, were in the form of nitrate-N. This was equivalent to 11.3 lbs-N/acre for the Turkey River basin above Garber. The annual mean of analysis for nitrate was 29.3 mg/L (6.5 mg/L as NO_3-N), and the annual fw mean nitrate concentration for the Turkey River was 25.8 mg/L (5.7 mg/L as NO_3-N) in WY 1997.

Figure 12 shows a comparison of nitrate concentration and discharge for Big Spring and the Turkey River. Several snowmelt events occurred in the basin during February and March. These events significantly reduced nitrate concentrations to below 20 mg/L (4.4 mg/L as NO_3-N) for most samples collected from the Turkey River during this period. The lowest nitrate concentration of the water year, 7 mg/L (1.6 mg/L as NO_3-N), was sampled on March 11, one day

after the greatest daily discharge during WY 1997. Nitrate concentrations then fluctuated between 15 mg/L (3.3 mg/L as NO_3-N) and 47 mg/L (10.4 mg/L as NO_3-N) through end of the water year. The greatest nitrate concentration during the water year, 47 mg/L (10.4 mg/L as NO_3-N), occurred on July 22.

Table A-10 shows nitrate concentrations and loads for the Turkey River on a monthly basis. Monthly fw mean nitrate concentrations remained well below the 45 mg/L (10 mg/L as NO_3-N) drinking water standard for nitrate during the water year. The lowest monthly fw mean, 14 mg/L (3.1 mg/L as NO_3-N), occurred in March. The month with the greatest fw mean nitrate concentration, 37 mg/L (8.2 mg/L as NO_3-N), was December. May had the greatest monthly nitrate-N load, 2.05 million pounds, and October had the lowest, 251 thousand pounds.

Among the 12 samples collected from TR01 for partial-N series, six samples (50%) contained detectable ammonia-N (concentration >0.1 mg/L). These detections occurred in January through March and June through August. The greatest ammonia-N concentration, 0.6 mg/L, occurred on February 25. The total ammonia-N discharged by the Turkey River in WY 1997 was 645 thousand pounds, at an annual fw mean concentration of 0.33 mg/L.

Nutrient monitoring results from RC02 in WY 1997 are shown in Table 15, appendix Table A-11 and Figure 13B. During the water year, fifty-three weekly samples were collected from RC02 for partial N-series analyses. All samples contained detectable nitrate, and concentrations varied between 8.6 mg/L (1.9 mg/L as NO_3-N) on October 8 and 58.5 mg/L (13.0 mg/L as NO_3-N) on July 15. In WY 1997, Roberts Creek discharged a total of 308 thousand pounds of nitrogen. Among them, 261 thousand pounds, or 85%, were in the form of nitrate-N. This is equivalent to 5.8 lbs-N/acre for the sub-basin. The fw mean nitrate concentration for WY 1997 was 23.1 mg/L (5.1 mg/L as NO_3-N). This was the second lowest annual fw mean nitrate concentration at RC02 since WY 1986. The lowest, 9.1 mg/L (2.0 mg/L as NO_3-N), occurred in WY 1989 (Rowden et al.,

Table 17. Annual summary of shallow groundwater and chemical discharges from L22T for WY 1997.

DISCHARGE

Total

acre-feet	45.1
millions cf	1.96
millions cm	0.056

Average

cfs	0.062
cms	0.002
mg/d	0.040
gpm	27.826

PRECIPITATION AND DISCHARGE

Precipitation	38.29	inches (973 mm)
Discharge	6.37	inches (162 mm)
Discharge as % of precipitation	16.6%	

NITRATE DISCHARGE

Concentration - mg/L	As NO_3	As NO_3-N
Flow-weighted mean	57.5	12.8
Mean of analyses	68.4	15.2

NO_3-N output

lbs - N	1,566
kg - N	710
lbs - N/acre	18.42

ATRAZINE DISCHARGE

Concentration - µg/L

Flow-weighted mean	0.02
Mean of analyses	0.02

Total output

lbs	0.003
g	1.15

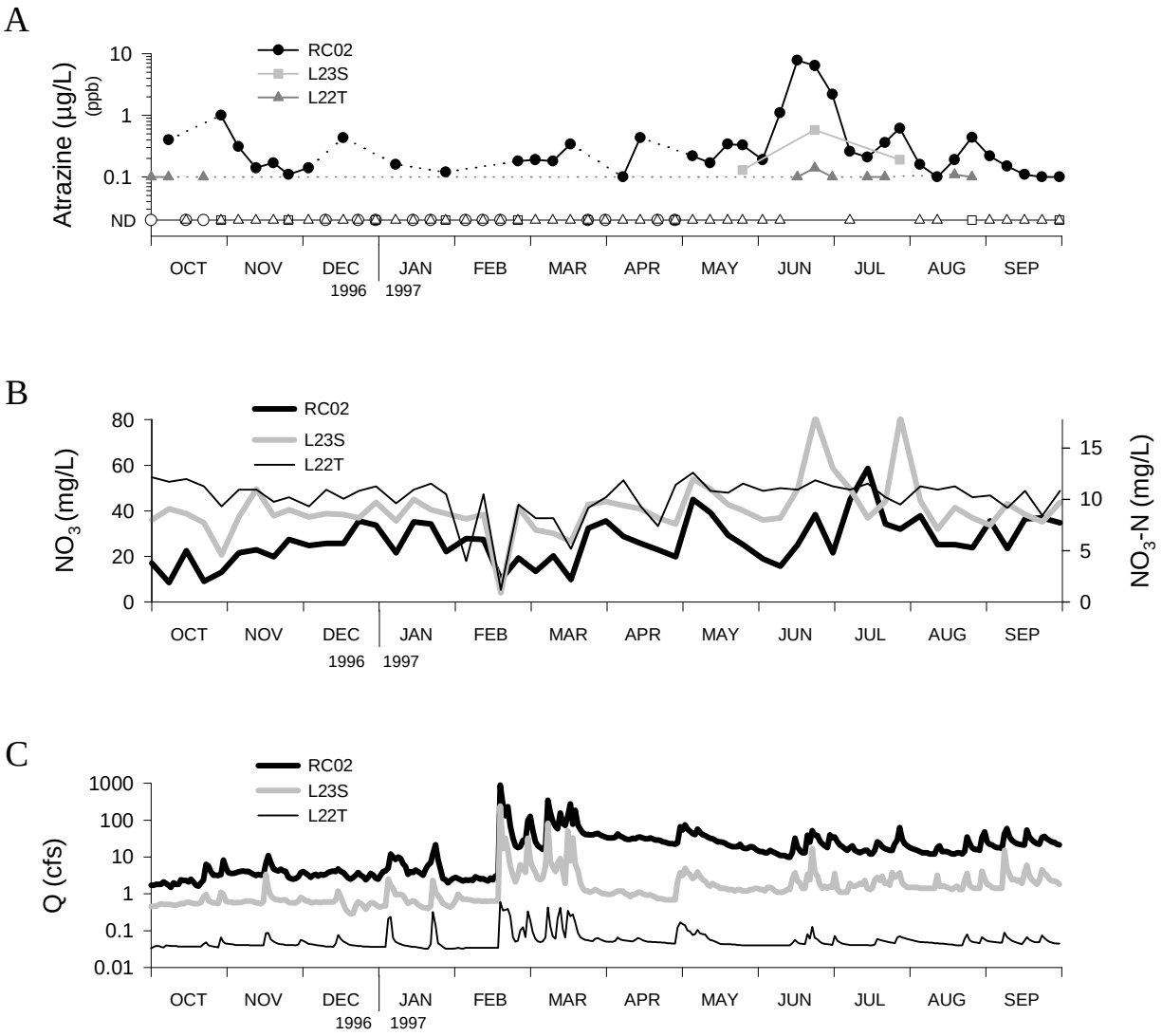

Figure 13. A) Atrazine, B) nitrate distributions and C) discharge hydrographs for RC02, L23S and L22T for WY 1997 (RC02 and L23S discharge data are from the U.S. Geological Survey, W.R.D., IA Dist.).

1995). On a monthly basis (Table A-11), fw mean nitrate concentration at RC02 varied from 13.4 mg/L (3.0 mg/L as NO_3-N) in October to 36.6 mg/L (8.1 mg/L as NO_3-N) in July. March had the greatest monthly nitrate-N output, 54 thousand pounds, while October had the lowest at 1,400 pounds.

Among the fifty-three samples collected from RC02 during WY 1997, thirty-two, or 60%, contained detectable ammonia-N. The greatest ammonia-N concentration, 2.9 mg/L, occurred on February 18. The total ammonia-N discharged by Roberts Creek in WY 1997 was 46.4 thousand pounds, at an annual fw mean concentration of 0.91 mg/L. This was the greatest annual fw mean ammonia-N concentration at RC02 during the monitoring period.

Fifty-three weekly samples were collected from L23S and analyzed for partial N-series during WY 1997. All samples contained detectable nitrate,

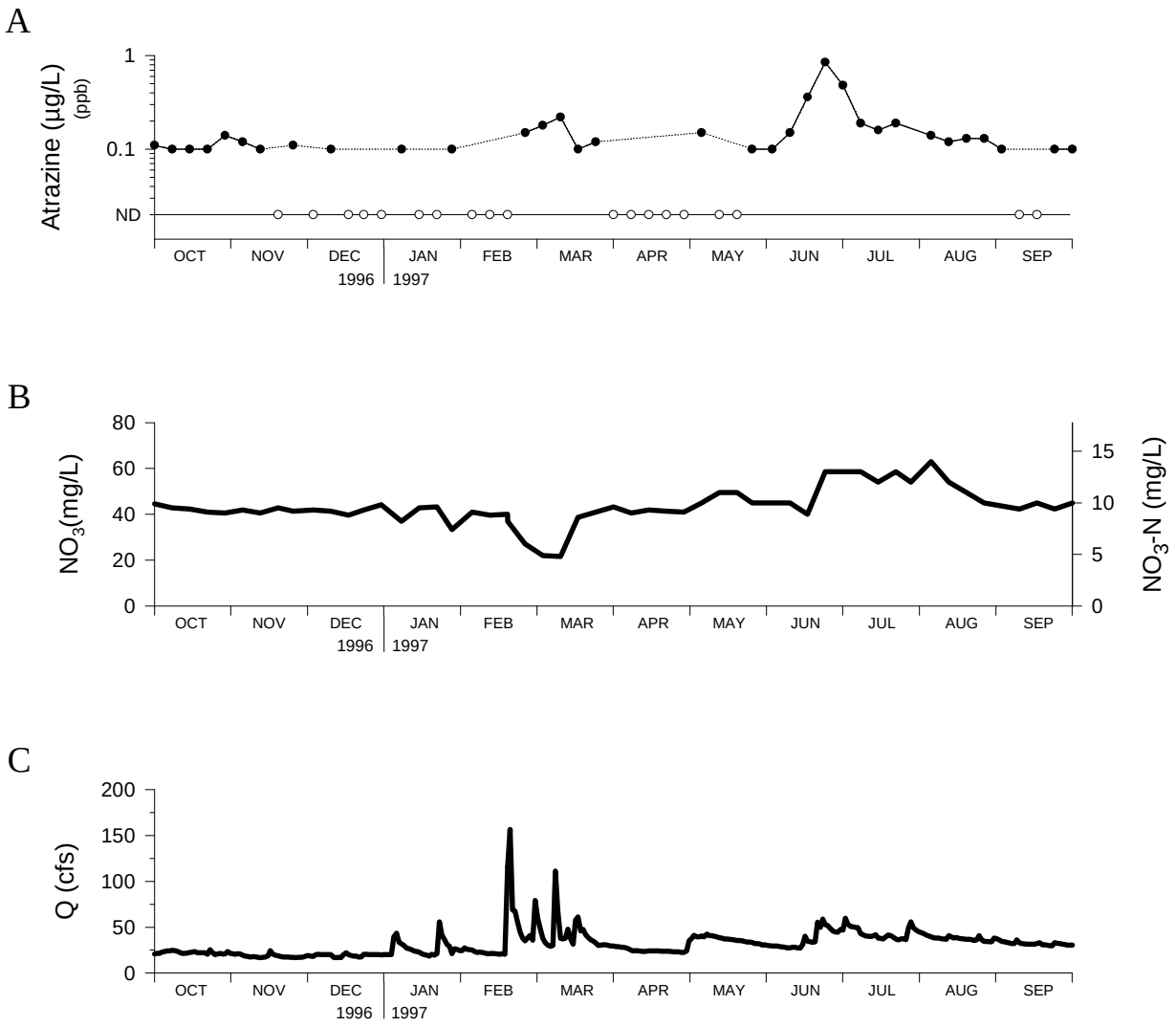

Figure 14. A) Atrazine and B) nitrate concentrations; and C) groundwater discharge at Big Spring for WY 1997.

with concentrations ranging between 4.1 mg/L (0.9 mg/L as NO_3-N) on February 18 and 81 mg/L (18.0 mg/L as NO_3-N) on June 24 and July 28 (Fig. 13B). The annual data for L23S for WY 1997 is shown on Table 16. During the water year, Silver Creek discharged about 43 thousand pounds of nitrate-N and ammonia-N. Of this total, 34 thousand pounds, or 78%, were in the form of nitrate-N. This is equivalent to 12.1 lbs-N/acre within the sub-basin. The annual fw mean nitrate concentration was 25.9 mg/L (5.7 mg/L as NO_3-N). This was the third lowest annual concentration since monitoring started in WY 1986. The lower annual concentrations were recorded in WY 1989 at 9.0 mg/L (2.0 mg/L as NO_3-N) and in WY 1990 at 25.4 mg/L (5.6 mg/L as NO_3-N) (Rowden et al., 1995a). Appendix Table A-12 summarizes the nitrate and nitrate-N loads from L23S on a monthly basis. The greatest monthly fw mean nitrate concentration, 48.4 mg/L (10.8 mg/L as NO_3-N), occurred in June. The lowest monthly fw mean nitrate concentration, 10.8 mg/L (2.4

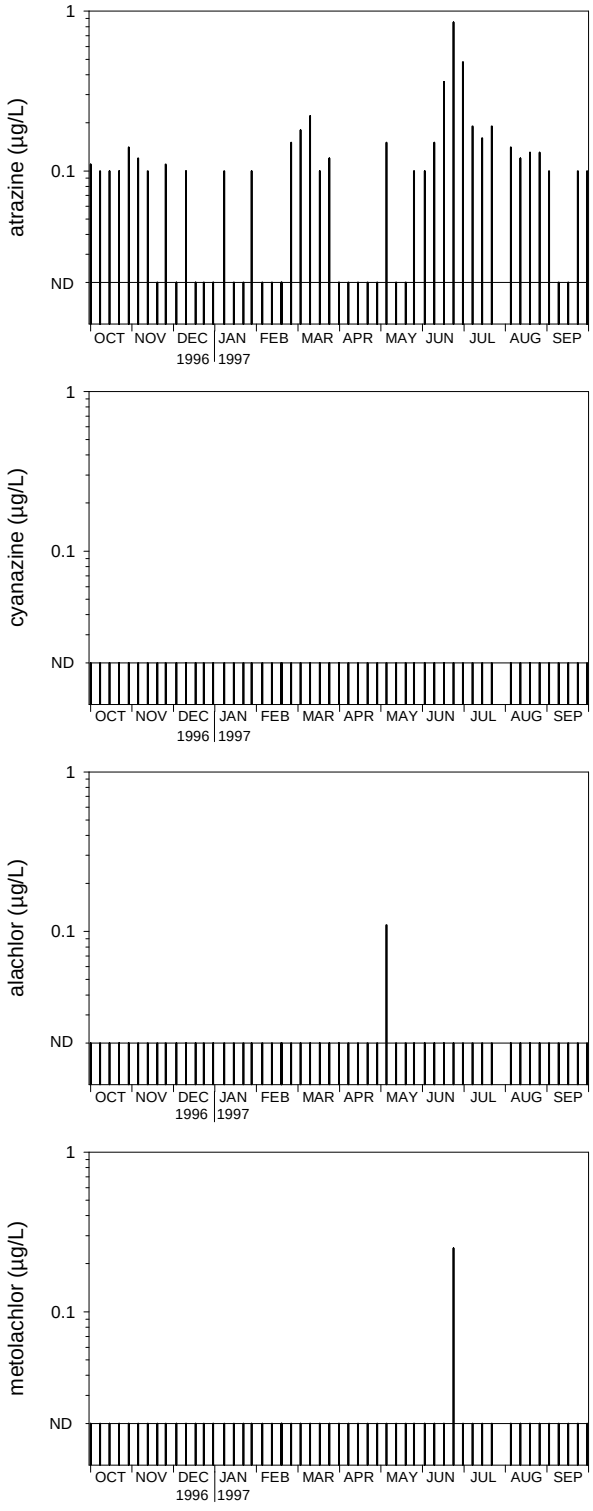

Figure 15. Bar graphs of pesticide concentrations at Big Spring for WY 1997. ND represents not detected.

mg/L as NO_3-N), occurred in February. The total monthly nitrate-N output ranged from 788 pounds in October to 7,452 pounds in March.

Among the fifty-three samples collected from L23S during WY 1997, thirty-two (60%) contained detectable ammonia-N. The greatest ammonia-N concentration, 8.8 mg/L, occurred on October 29. The total ammonia-N discharged by Silver Creek in WY 1997 was 9,745 pounds, at an annual fw mean concentration of 1.65 mg/L. This was the second greatest annual fw mean ammonia-N concentration at L23S during the monitoring period. The greatest, 2.4 mg/L, recorded in WY 1989 (Rowden et al., 1995a).

In WY 1997, fifty-three samples from L22T were analyzed for nitrate. All samples contained detectable nitrate, and fifty, or 94%, were above the 45 mg/L (10.0 mg/L as NO_3-N) standard for nitrate. The lowest nitrate concentration, 8.0 mg/L (1.8 mg/L as NO_3-N), was sampled on February 18, the day with greatest groundwater discharge of the water year (Figure 13). The greatest nitrate concentration, 85 mg/L (18.9 mg/L as NO_3-N), was sampled on May 6. During WY 1997, a total of 1,566 pounds of nitrate-N were discharged by L22T, which was equivalent to 18.4 lbs-N/acre within the drainage area. This was the lowest annual nitrate-N load for L22T since WY 1991. The annual fw mean nitrate concentration for WY 1997 was 57.5 mg/L (12.8 mg/L as NO_3-N), which was the lowest annual fw mean concentration since the monitoring started in WY 1987. The monthly nitrate-N discharge data for WY 1997 is shown in appendix Table A-13. February had the lowest monthly fw mean nitrate concentration at 34.1 mg/L (7.6 mg/L as NO_3-N), and October had the greatest at 77.6 mg/L (17.2 mg/L as NO_3-N). The monthly nitrate-N discharge at L22T ranged from 109 pounds in December to 178 pounds in March.

Pesticide Monitoring

Pesticide monitoring results from Big Spring for WY 1997 are summarized in Table 12, appendix Table B-9 and figures 14A, 15 and 16A. Fifty-three samples were analyzed for pesticides, and

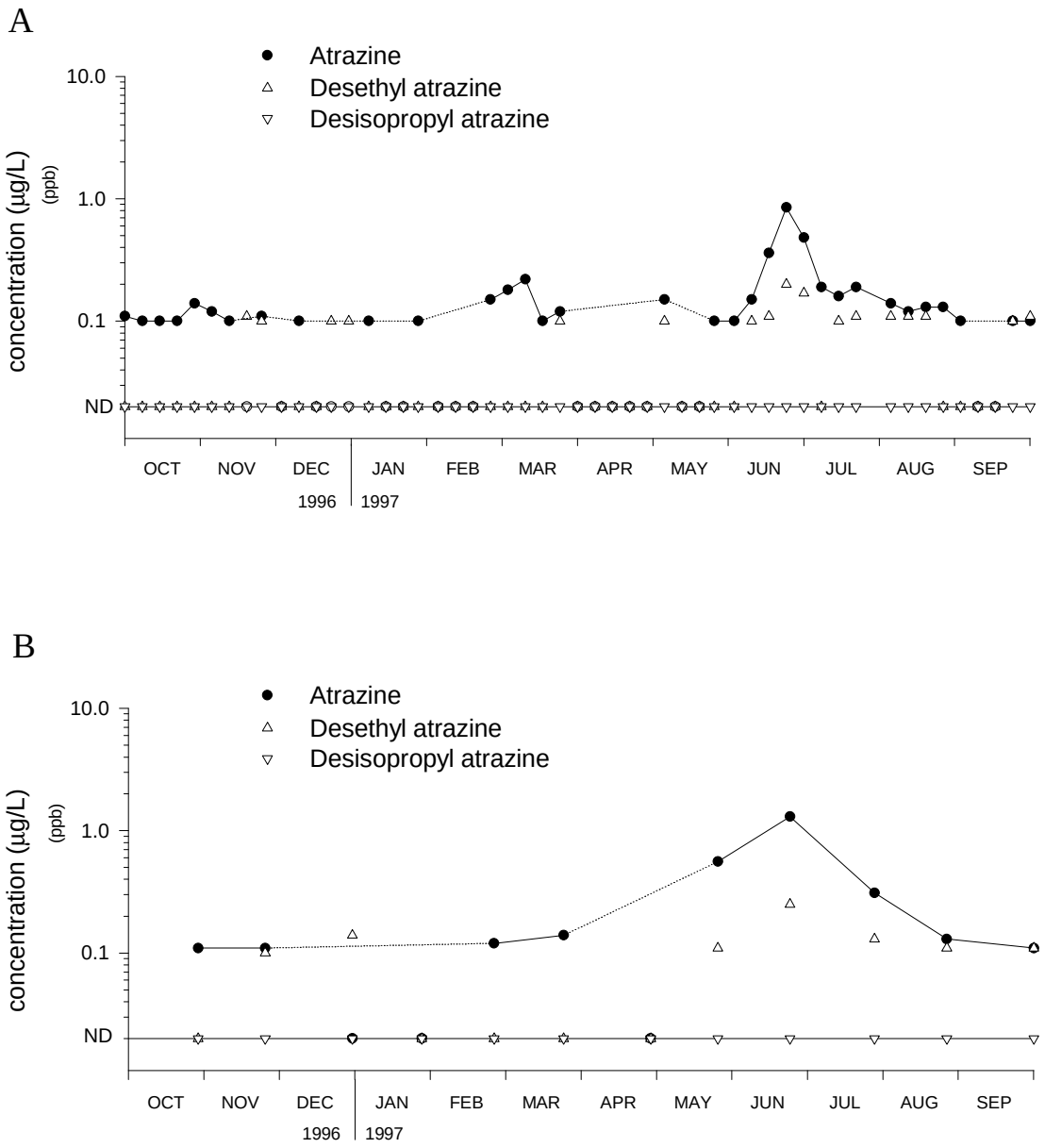

Figure 16. A) Atrazine, desethyl atrazine and desisopropyl atrazine concentrations for Big Spring and B) the Turkey River at Garber for WY 1997. ND represents not detected.

thirty-three (62%) contained detectable concentration of atrazine. Most non-detections for atrazine occurred in late November through mid-February and April to mid-May (Fig. 14A). The greatest atrazine concentration of the water year, 0.85 µg/L, occurred on June 24. An estimated 10.5 pounds of atrazine were discharged through Big Spring during the water year. This was the third lowest annual atrazine load from Big Spring since WY 1982. The annual fw mean atrazine concentration for WY 1997 was 0.17 µg/L. This was the third lowest annual fw mean atrazine

concentration since monitoring began in WY 1982.

Table B-9 summarizes atrazine concentrations and loads at Big Spring on a monthly basis for WY 1997. During the water year, the greatest monthly fw mean atrazine concentration, 0.39 µg/L, and the atrazine load, 2.33 pounds, occurred in June. Since all five samples collected in April were below the detection limit for atrazine (<0.1 µg/L), the monthly fw mean concentration, mean concentration of analyses, and load for atrazine could not be calculated for the month. The lowest computed monthly fw mean atrazine concentration, 0.03 µg/L, and monthly atrazine load, 0.10 pounds, occurred in December. These were the second lowest monthly fw mean atrazine concentration and load at Big Spring since WY 1984.

Figure 15 summarizes the concentrations for atrazine, cyanazine, alachlor, and metolachlor on a logarithmic scale for Big Spring in WY 1997. Among the fifty-three samples collected from Big Spring during WY 1997, one contained detectable alachlor and metolachlor. None of the samples contained detectable cyanazine. The sample that contained alachlor, at 0.11 µg/L, was collected on May 6. Metolachlor, at 0.25 µg/L, was detected in a sample collected on June 24.

Figure 16A shows the trends for atrazine and the atrazine metabolites desethyl atrazine and desisopropyl atrazine from Big Spring groundwater in WY 1997. Of the fifty-three samples, seventeen (32%) contained detectable desethyl atrazine. Most of the detections occurred from June through August. The greatest desethyl atrazine concentration during the water year, 0.20 µg/L, occurred on June 24. Desisopropyl atrazine was not detected in Big Spring groundwater during the water year.

Other pesticides analyzed for in Big Spring groundwater during WY 1997 include acetochlor, butylate, metribuzin, and trifluralin. Of the fifty-three samples, three (6%) collected from mid-June through early July contained detectable acetochlor. The greatest acetochlor concentration, 0.20 µg/L, occurred on July 1. None of the samples collected from Big Spring in WY 1997 contained detectable butylate, metribuzin, or trifluralin.

Figure 16B, Table 14 and appendix Table B-10 summarize the atrazine data for the Turkey River. During WY 1997, twelve monthly samples from TR01 were analyzed for pesticides. A total of 579 pounds of atrazine were discharged by the river in WY 1997. This was the third lowest annual atrazine load from the river since WY 1986. The annual fw mean atrazine concentration was 0.30 µg/L for WY 1997. This was the second lowest annual fw mean atrazine concentration observed at the Turkey River since WY 1986.

Table B-10 summarizes atrazine concentrations and loads on a monthly basis for the Turkey River in WY 1997. The greatest monthly fw mean atrazine concentration, 0.82 µg/L, and load, 182 pounds, occurred in June. The lowest monthly fw mean atrazine concentration (0.02 µg/L) and load (1.7 pounds) occurred in January. The fw mean atrazine concentration for January was also the lowest since WY 1986. The mean of atrazine analyses for December, January and April of the water year could not be calculated since all samples collected during these months were below the detection limit.

The distribution trends of atrazine and its metabolites desethyl atrazine and desisopropyl atrazine for the Turkey River during WY 1997 are shown in Figure 16B. Nine of the twelve samples, or 75%, contained detectable levels of atrazine. Atrazine concentrations peaked in May through July. The greatest atrazine concentration, 1.30 µg/L, occurred on June 24. The rest of the samples with detectable atrazine had concentrations near 0.10 µg/L. Seven of the samples, or 58%, contained detectable concentrations of desethyl atrazine. The sample with the greatest desethyl atrazine concentration, 0.25 µg/L, was also collected on June 24. None of the samples from the Turkey River contained detectable desisopropyl atrazine in WY 1997.

Other pesticides detected in Turkey River surface water during WY 1997 include acetochlor, cyanazine and metolachlor. Three of the samples, or 25%, contained detectable acetochlor and metolachlor. The greatest acetochlor concentration, 0.63 µg/L, was sampled on May 26, and the greatest concentration of metolachlor,

0.20 µg/L, was sampled on June 24. The sample collected on June 24 also contained detectable cyanazine at concentration of 0.19 µg/L. All samples from the Turkey River were below the detection limits for alachlor, butylate, metribuzin, and trifluralin during WY 1997.

Table 15, appendix Table B-11 and Figure 13A summarize the results of pesticide monitoring at RC02 during WY 1997. Fifty-three weekly samples were analyzed from RC02 for common pesticides during the water year. Thirty-eight (72%) contained detectable atrazine. The greatest concentration for atrazine, 7.8 µg/L, occurred on June 17. During this water year, Roberts Creek discharged a total of 32.8 pounds of atrazine, at annual fw mean concentration of 0.65 µg/L. Table B-11 summarizes atrazine monitoring results at RC02 on a monthly basis. The greatest monthly fw mean atrazine concentration (4.0 µg/L) and load (13 pounds) occurred in June. June accounted for 40% of the annual atrazine load and 6.4% of the annual surface water discharge. The lowest monthly fw mean atrazine concentration, 0.09 µg/L, occurred in April, and the lowest monthly atrazine load, 0.08 pounds, occurred in December. For the atrazine metabolites, twenty of the samples, or 38%, contained detectable desethyl atrazine, with the largest concentration at 0.93 µg/L. Three samples, or 5.7%, contained detectable desisopropyl atrazine, with the greatest concentration at 0.26 µg/L. The greatest desethyl and desisopropyl atrazine concentrations were sampled on June 24.

Other pesticides detected at RC02 in WY 1997 include acetochlor, alachlor, cyanazine, and metolachlor. Seven samples (13%) contained detectable acetochlor, with the greatest concentration at 1.60 µg/L. Five samples (9.4%) contained detectable alachlor, at a maximum concentration of 0.66 µg/L. Three samples (6%) contained detectable cyanazine, with the greatest concentration at 0.48 µg/L. Eight samples, or 15%, contained detectable metolachlor, with the greatest concentration at 4.0 µg/L. The greatest concentration of acetochlor was sampled on June 17. All other maximum concentrations occurred on June 24. No samples contained detectable concentrations of butylate, metribuzin, or trifluralin at RC02 in WY 1997.

The pesticide monitoring data for L23S during WY 1997 are summarized in Table 16, appendix Table B-12 and Figure 13A. During the water year, twelve monthly samples from L23S were analyzed for common pesticides. Three samples (25%) contained detectable atrazine, and two (17%) contained detectable desethyl atrazine. The greatest concentration of atrazine, 0.58 µg/L, and desethyl atrazine, 0.36 µg/L, occurred on June 24. In WY 1997, Silver Creek discharged a total of 2.08 pounds of atrazine. The annual fw mean atrazine concentration for WY 1997 was 0.35 µg/L. Monthly atrazine concentrations and loads for WY 1997 are shown in Table B-12. During the water year, February had the greatest monthly fw mean atrazine concentration, 0.78 µg/L, and load, 1.5 pounds. The atrazine load for February accounted for 72% of the annual atrazine output, while discharge for the month accounted for 32% of the annual discharge. December had the lowest monthly fw mean atrazine concentration, 0.01 µg/L, and load, 0.01ounce. The samples collected in October through April, August and September did not contain detectable atrazine.

Metolachlor was the only other pesticide detected at L23S in WY 1997, and was detected in three samples (25%) collected in May through July. The greatest concentration, 0.37 µg/l, occurred on June 24.

Table 17, appendix Table B-13 and Figure 13A summarize the results of pesticide monitoring at L22T during WY 1997. Fifty-two weekly samples were collected from L22T in WY 1997. Ten (19%) contained detectable atrazine. The greatest concentration of atrazine, 0.14 µg/L, occurred on June 24. Total atrazine output at L22T in WY 1997 was 0.003 pounds, with a fw mean concentration of 0.02 µg/L. Table B-13 summarizes atrazine monitoring results at L22T on a monthly basis for WY 1997. The greatest monthly fw mean atrazine concentration, 0.10 µg/L, occurred in July. Atrazine was not detected in any samples collected in November through May and September. The months with atrazine detections had monthly atrazine loads of 0.01

Table 18. Annual summary of groundwater and chemical discharges from the Big Spring basin to the Turkey River for WY 1998.

DISCHARGE

Total

acre-feet	35,713
millions cf	1,554
millions cm	44.0

Average

cfs	49.3
cms	1.40
mg/d	31.9
gpm	22,139

PRECIPITATION AND DISCHARGE

Precipitation	41.21 inches (1,047 mm)
Discharge	6.50 inches (165 mm)
Discharge as % of precipitation	15.8%

NITRATE DISCHARGE

Concentration - mg/L	As NO_3	As NO_3-N
Flow-weighted mean	56.2	12.5
Mean of analyses	55.3	12.3

	NO_3-N output	Total N output
lbs - N	1,212,455	1,217,496*
kg - N	549,866	552,152*
lbs - N/acre	18.39	18.47*

ATRAZINE DISCHARGE

Concentration - µg/L

Flow-weighted mean	0.12
Mean of analyses	0.09

Total output

lbs	11.58
kg	5.25

* Total NO - plus Ammonia-N.

ounces or less. Because atrazine was infrequently detected throughout the water year, the annual atrazine output, as well as the annual fw mean atrazine concentration, for WY 1997 was the lowest recorded since monitoring started at L22T in WY 1987.

Of the fifty-two samples collected from L22T, thirty-nine (75%) contained detectable desethyl atrazine. The greatest concentration of desethyl atrazine, 0.15 µg/L, occurred on June 24, August 12, and August 26. One sample collected on December 30 contained desisopropyl atrazine at 0.14 µg/L. No other pesticides were detected at L22T during WY 1997.

Water Year 1998

Discharge Monitoring

Tables 18 and 19, and Figure 17 summarize the groundwater discharge and climatic information for Big Spring during WY 1998. Following WY 1997, WY 1998 was another wet year. Annual precipitation in the Big Spring basin totaled 41.21 inches (1,047 mm), which was 8.24 inches greater than the long-term average for the basin, and was the third greatest annual precipitation since monitoring began in WY 1982. The annual groundwater discharge at Big Spring was 35,713 ac-ft, at an average rate of 49.3 cfs. The groundwater discharge was equivalent to 15.8% of the precipitation during the water year.

Discharge at Big Spring was relatively low during the first 5 months of the water year, with rates generally less than 30 cfs (Fig. 17). The lowest daily discharge rate of the water year, 20 cfs, occurred on December 28 and 29. Discharge rates significantly increased after late February, generated by snowmelt and precipitation. The greatest mean daily discharge rate of the water year, 408 cfs, recorded on April 1. Other discharge peaks occurred in June due to intense precipitation. Significant precipitation also occurred in early August, but did not generate significant discharge peaks at Big Spring because of high evapotranspiration rates during the period.

Table 19 summarizes the groundwater discharge

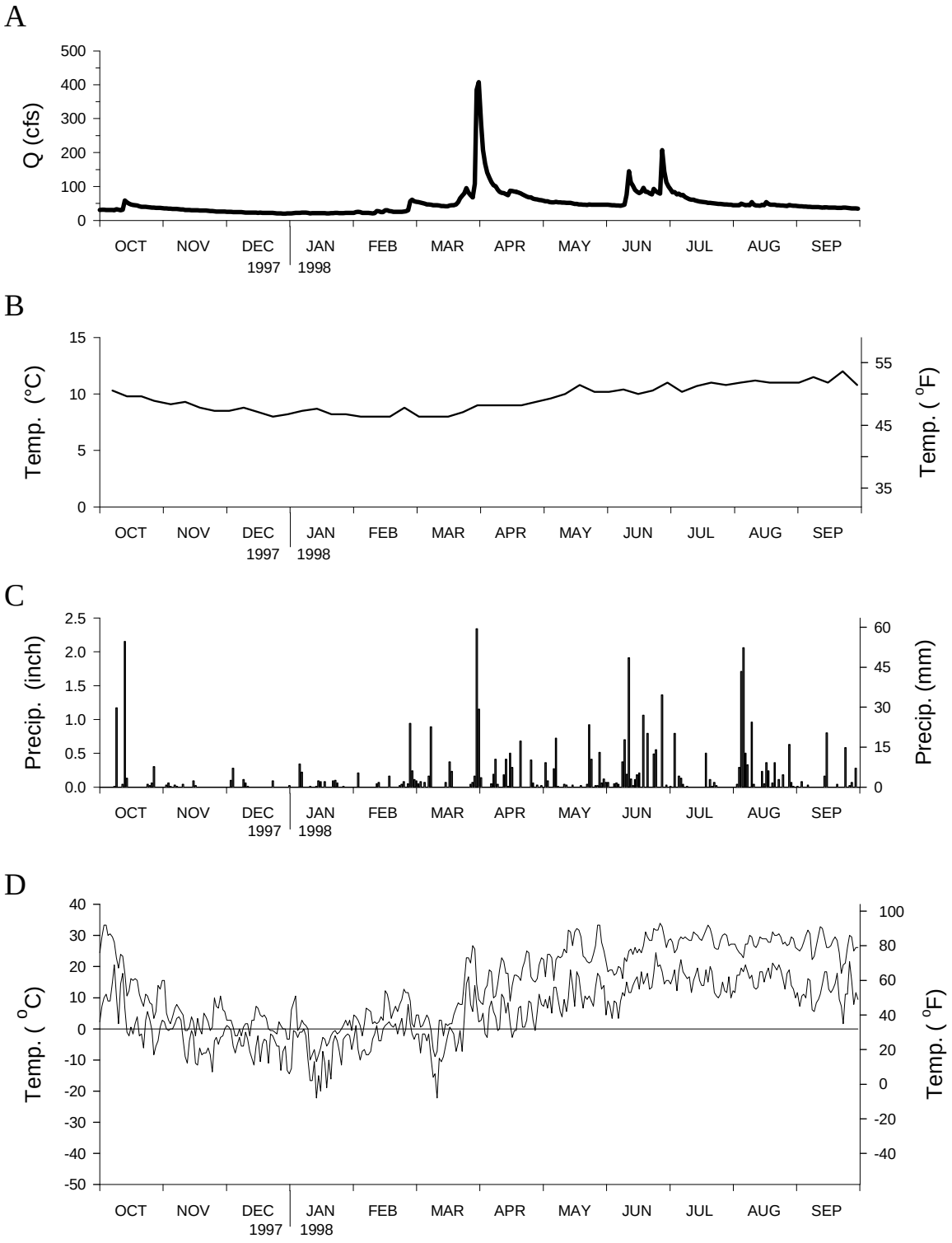

Figure 17. A) Groundwater discharge, B) groundwater temperature and C) daily precipitation for the Big Spring basin; and D) maximum/minimum temperatures for Elkader, IA (Iowa Dept. of Ag. and Land Stewardship, State Climatology Office), for WY 1998.

Table 19. Monthly summary of groundwater discharge from the Big Spring basin for WY 1998.

	1997 Oct	Nov	Dec	1998 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
TOTAL MONTHLY DISCHARGE												
Acre-feet	2,325	1,796	1,380	1,325	1,519	4,106	6,455	3,097	4,853	3,772	2,801	2,284
Cubic feet (millions)	101	78	60	58	66	179	281	135	212	164	122	100
Gallons (millions)	758	585	450	432	495	1,338	2,104	1,009	1,581	1,229	913	744
Cubic meters (millions)	2.9	2.2	1.7	1.6	1.9	5.1	8.0	3.8	6.0	4.7	3.5	2.8
AVERAGE DISCHARGE												
cfs	38	30	22	22	27	67	108	50	82	61	46	38
cms	1.1	0.9	0.6	0.6	0.8	1.9	3.1	1.4	2.3	1.7	1.3	1.1
mg/d	24	20	15	14	18	43	70	33	53	40	29	25
MAXIMUM												
cfs	59	36	25	23	61	385	408	59	207	100	54	43
cms	1.7	1.0	0.7	0.7	1.7	10.9	11.5	1.7	5.9	2.8	1.5	1.2
MINIMUM												
cfs	30	26	20	21	21	41	61	45	43	46	43	35
cms	0.8	0.7	0.6	0.6	0.6	1.2	1.7	1.3	1.2	1.3	1.2	1.0

data from Big Spring on a monthly basis. The greatest monthly discharge totaled 6,455 ac-ft in April, at an average daily discharge rate of 108 cfs. April accounted for 11.0% of the annual precipitation and 18.1% of the annual discharge. The lowest monthly discharge of the water year, 1,325 ac-ft, occurred in January. Both December and January had the lowest monthly average discharge rate, 22 cfs. The wettest month of the water year, June, had 4,853 ac-ft of discharge, and accounted for 20.3% of the annual precipitation and 13.6% of the annual discharge.

The monitoring results for the Turkey River during WY 1998 are summarized in Table 20, and the hydrograph is shown by the lighter line in Figure 18B using a logarithmic scale. The annual surface water discharge from the Turkey River at Garber was 1,208,000 ac-ft, at an average rate of 1,669 cfs. This amount is 168% of the long-term mean annual discharge for the Turkey River. The annual precipitation for northeast Iowa was 41.21 inches (1,047 mm) in WY 1998. The surface water discharge from the Turkey River was equivalent to 35.6% of the annual precipitation. The greatest daily discharge rate from the Turkey River at Garber during the water year, 15,100 cfs, occurred on April 1. The minimum daily discharge rate, 300 cfs, occurred on December 21, 22, and 30. On a monthly basis, April had the greatest discharge, 257,200 ac-ft, at a mean rate of 4,322 cfs. The lowest, 24,690 ac-ft, occurred in December, at an average rate of 402 cfs (May et al., 1999).

Table 21 summarizes the monitoring results at

RC02 during WY 1998. The annual discharge at RC02 totaled 31,540 ac-ft. Daily discharge rates ranged from 3.2 cfs on September 8 to 1,030 cfs on March 31, with an average rate of 43.6 cfs. These were the third greatest annual discharge and average rate recorded at RC02 since monitoring started in WY 1986. The annual discharge accounted for 20.3% of the annual precipitation. The hydrograph for RC02 during WY 1998 is shown on Figure 19C using a logarithmic scale. Discharge peaks with greater than 100 cfs discharge rates occurred in October, February, March, April, June and July. September had the lowest monthly discharge at 364 ac-ft, while April had the greatest monthly discharge at 7,920 ac-ft (May et al., 1999).

Table 22 summarizes the monitoring results from L23S during WY 1998. The annual discharge totaled 3,480 ac-ft, with an average rate of 4.81 cfs. The discharge accounted for 35.1% of the annual precipitation. The hydrograph for L23S is shown on Figure 19C. Discharge peaks with greater than 10 cfs discharge rates occurred in October, February, March, April, June, and July. Daily discharge rates at L23S varied between 0.45 cfs on January 13 and 83 cfs on June 28. January had the lowest monthly discharge at 58 ac-ft, while June had the greatest, 738 ac-ft.

The annual monitoring results from L22T are summarized in Table 23 and Figure 19. Annual discharge at L22T totaled 91.0 ac-ft, with an average rate of 0.126 cfs. These were the third greatest amounts recorded at L22T since WY 1987. The discharge accounted for 31.2% of precipitation of the Big Spring basin. The hydrograph for L22T is shown on Figure 19C. The lowest daily discharge rate, 0.036 cfs, occurred on October 7, and the greatest, 0.885 cfs, occurred on April 1. On a monthly basis, January had the lowest discharge, 2.91 ac-ft, and discharge rate, 0.047 cfs. The greatest monthly discharge, 18.35 ac-ft, and discharge rate, 0.31 cfs, occurred in April.

Nitrate Monitoring

Fifty-two weekly samples for partial N-series

Table 20. Annual summary of water and chemical discharges from the Turkey River at Garber for WY 1998 (Discharge data are from the U.S. Geological Survey, Water Resources Division, IA Dist.).

DISCHARGE	
Total	
acre-feet	1,208,000
millions cf	52,620
millions cm	1,489.5
Average	
cfs	1,669
cms	47.3
mg/d	1,079
gpm	749,047
PRECIPITATION AND DISCHARGE	
Precipitation	41.21 inches (1,047 mm)
Discharge	14.66 inches (372 mm)
Discharge as % of precipitation	35.6%

NITRATE DISCHARGE		
Concentration - mg/L	**As NO_3**	**As NO_3-N**
Flow-weighted mean	34.8	7.7
Mean of analyses	33.5	7.5

	NO_3-N output	**Total N output**
lbs - N	25,432,510	25,680,040*
kg - N	11,534,018	11,646,277*
lbs - N/acre	25.7	26.0*

ATRAZINE DISCHARGE	
Concentration - µg/L	
Flow-weighted mean	0.64
Mean of analyses	0.63
Total output	
lbs	2,109
kg	956.6

* Total NO - plus Ammonia-N.

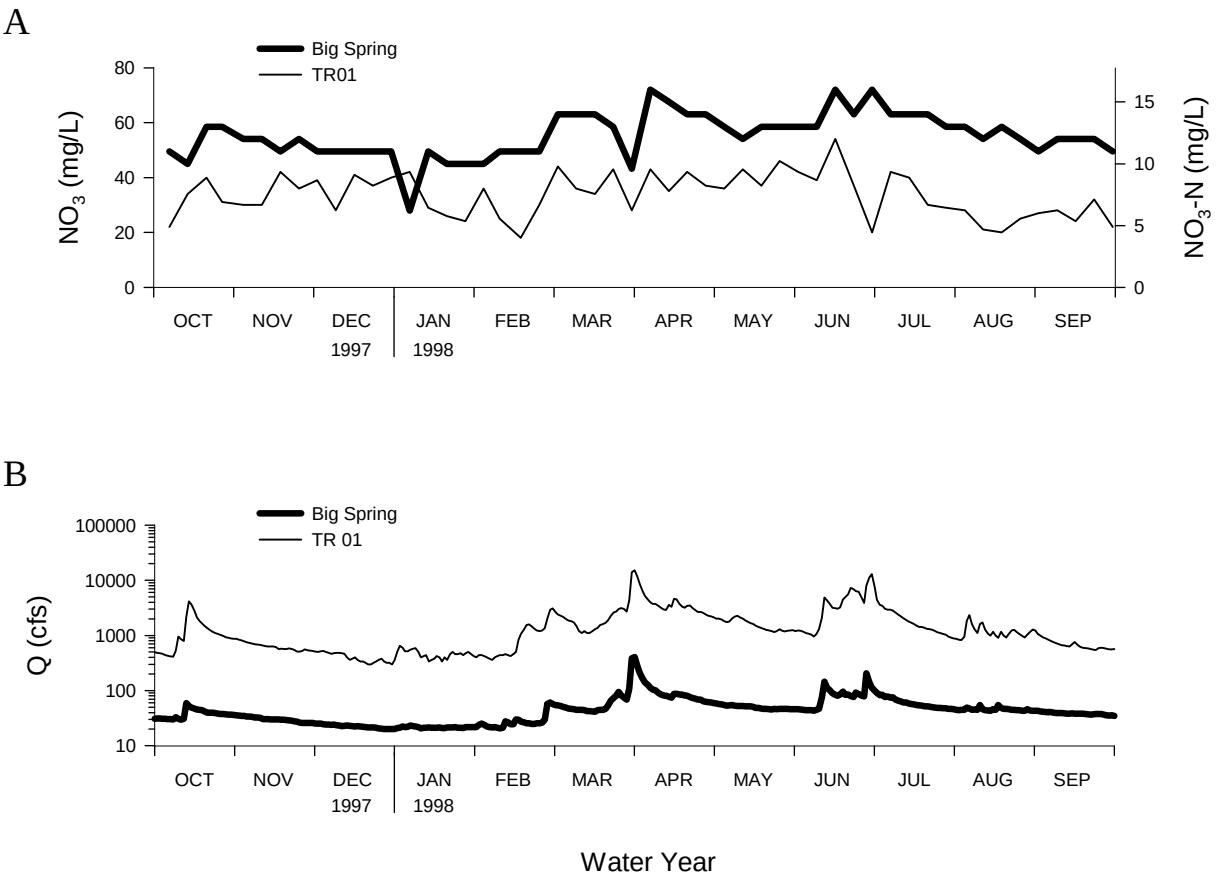

Figure 18. A) Nitrate concentrations and B) discharge hydrographs for Big Spring (bold lines) and the Turkey River at Garber (lighter lines) for WY 1998 (Turkey River discharge data are from the U.S. Geological Survey, W.R.D., IA Dist.).

analyses were collected from Big Spring in WY 1998. The nitrate monitoring results at Big Spring for the water year are summarized in Table 18, appendix Table A-14 and Figure 20B. Nitrate concentrations were relatively high at Big Spring throughout the water year, and the concentration trends coincided well with groundwater discharge patterns (Fig. 20B & C). During WY 1998, a total of 1.22 million pounds of nitrate- and ammonia-N were discharged by groundwater at Big Spring. Of this total, 1.21 million pounds, or 99.6%, were in the form of nitrate-N. This is equivalent to 18.4 lbs-N/acre within the basin. The annual fw mean nitrate concentration for the water year was 56.2 mg/L (12.5 mg/L as NO_3-N). These were the fourth greatest annual load and the second highest annual fw mean concentration for nitrate-N since monitoring started in WY 1982. Among the fifty-two samples, fifty had the nitrate concentration greater than 45 mg/L (10.0 mg/L as NO_3-N). The greatest nitrate concentration of the water year, 72 mg/L (16.0 mg/L as NO_3-N), occurred on April 7, June 16, and June 30, just following significant groundwater discharge events. The lowest nitrate concentration of the water year, 28 mg/L (6.2 mg/L as NO_3-N), occurred on January 6 during base flow.

Table A-14 summarizes the nitrate concentration and load at Big Spring during WY 1998 on a monthly basis. All monthly fw mean nitrate concentrations were above the 45 mg/L (10.0 mg/L as NO_3-N) drinking water standard

for nitrate. The greatest monthly fw mean nitrate concentration, 63 mg/L (14.0 mg/L as NO_3-N), occurred in July. The greatest monthly nitrate-N load, 235 thousand pounds, occurred in April. The lowest monthly fw mean nitrate concentration, 45.3 mg/L (10.1 mg/L as NO_3-N), and the lowest nitrate-N output, 36 thousand pounds, occurred in January.

Ammonia-N was not frequently detected at Big Spring during WY 1998. Only two of the fifty-two samples (3.8%) collected in late March and late April contained detectable ammonia-N (>0.1 mg/L). Both samples contained an ammonia-N concentration of 0.40 mg/L. The annual ammonia-N load at Big Spring was 5,041 pounds, at an annual fw mean concentration of 0.05 mg/L.

Figure 18A, Table 20 and appendix Table A-15 summarize nitrate concentrations and loads for the Turkey River during WY 1998. Fifty-two weekly samples were analyzed for nitrate and twelve monthly samples were analyzed for partial-N series. A total of 25.7 million pounds of nitrate- and ammonia-N were discharged by the Turkey River in WY 1998. Of this total, 25.4 million pounds, or 99%, were in the form of nitrate-N. This was equivalent to 25.7 lbs-N/acre for the Turkey River basin above Garber. This amount was more than double of that for WY 1997, and was the fourth greatest annual nitrate-N output from the Turkey River since WY 1986. The annual fw mean nitrate concentration for the Turkey River was 34.8 mg/L (7.7 mg/L as NO_3-N) in WY 1998. This was the third greatest annual fw mean nitrate concentration since WY 1986.

Figure 18 shows a comparison of nitrate concentrations and discharges at Big Spring and the Turkey River. Nitrate concentrations ranged between 18.0 mg/L (4.0 mg/L as NO_3-N) on February 17 and 54.0 mg/L (12.0 mg/L as NO_3-N) on June 16 for the Turkey River during WY 1998. Table A-15 shows nitrate concentrations and loads for the Turkey River on a monthly basis. All monthly fw mean nitrate concentrations remained well below the 45 mg/L (10.0 mg/L as NO_3-N) drinking water standard for nitrate during the water year. The lowest monthly fw mean

Table 21. Annual summary of water and chemical discharges from RC02 for WY 1998 (Discharge data are from the U.S. Geological Survey, Water Resources Division, IA Dist.).

DISCHARGE

Total

acre-feet	31,540
millions cf	1374
millions cm	38.9

Average

cfs	43.6
cms	1.23
mg/d	28.2
gpm	19,568

PRECIPITATION AND DISCHARGE

Precipitation	41.21 inches (1,047 mm)
Discharge	8.36 inches (213 mm)
Discharge as % of precipitation	20.3%

NITRATE DISCHARGE

Concentration - mg/L	As NO_3	As NO_3-N
Flow-weighted mean	45.6	10.1
Mean of analyses	42.3	9.4

	NO_3-N output	Total N output
lbs - N	869,147	904,238*
kg - N	394,171	410,085*
lbs - N/acre	19.2	20.0*

ATRAZINE DISCHARGE

Concentration - µg/L

Flow-weighted mean	0.20
Mean of analyses	0.16

Total output

lbs	17.5
kg	7.96

* Total NO - plus Ammonia-N.

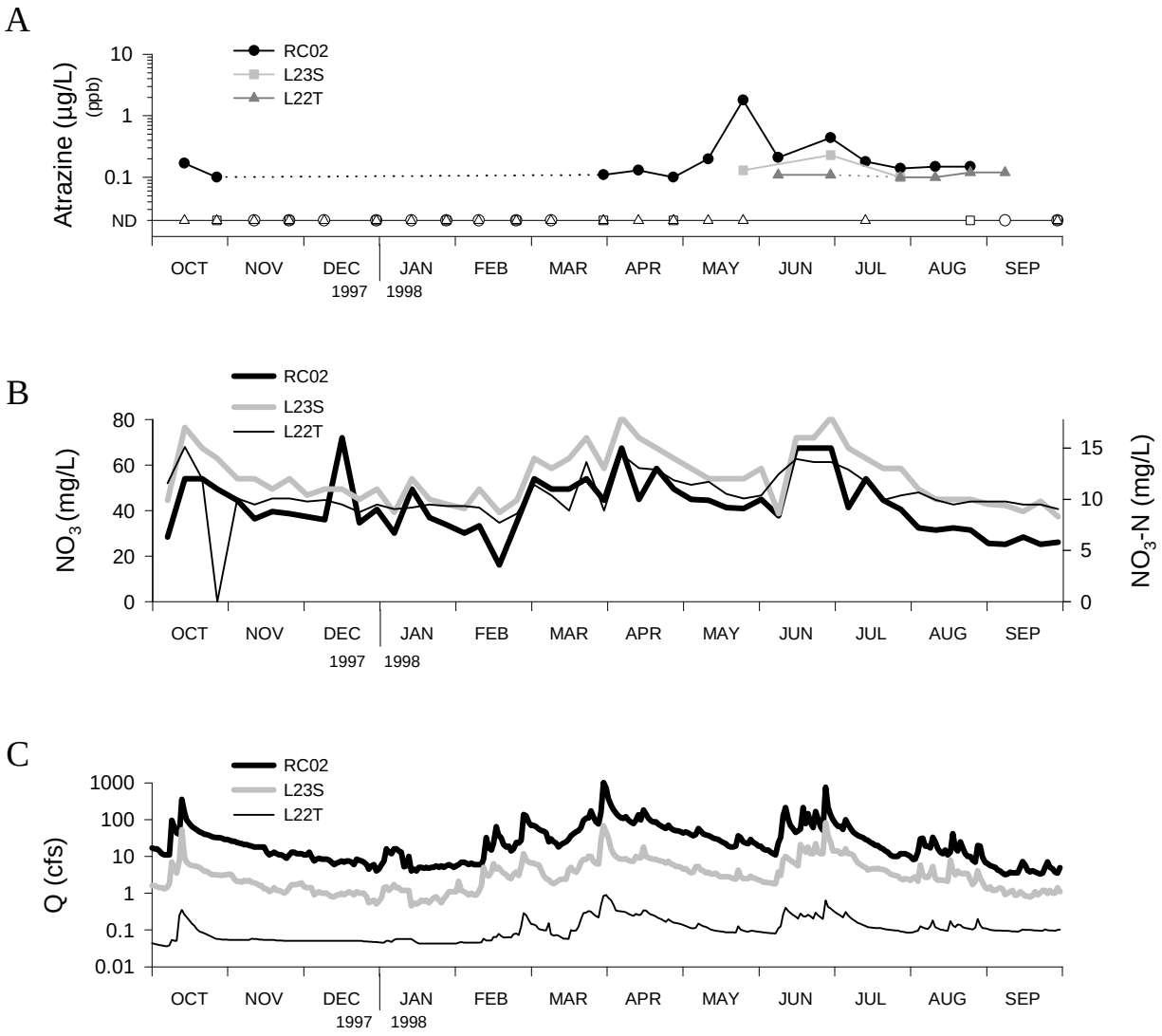

Figure 19. A) Atrazine, B) nitrate distributions and C) discharge hydrographs for RC02, L23S and L22T for WY 1998 (RC02 and L23S discharge data are from the U.S. Geological Survey, W.R.D., IA Dist.).

nitrate concentration, 22.8 mg/L (5.1 mg/L as NO_3-N), occurred in August. The month with the greatest fw mean nitrate concentration, 39.9 mg/L (8.9 mg/L as NO_3-N), was May. April had the greatest monthly nitrate-N load, 5.8 million pounds, and December had the lowest, at 533 thousand pounds.

Among the twelve samples collected from the Turkey River for partial-N series analyses, four samples, or 33%, contained detectable ammonia-N (concentration >0.1 mg/L). The greatest ammonia-N concentration, 0.2 mg/L, occurred on March 31. The annual ammonia-N load from the Turkey River was 247.5 thousand pounds, with fw mean concentration of 0.08 mg/L during WY 1998.

Table 21, appendix Table A-16 and Figure 19B show the nitrate monitoring results at RC02 during WY 1998. During the water year, fifty-two weekly samples were collected from RC02 for partial N-series analyses. All the samples contained detectable nitrate, with concentrations varying

Table 22. Annual summary of water and chemical discharges from L23S for WY 1998 (Discharge data are from the U.S. Geological Survey, Water Resources Division, IA Dist.).

DISCHARGE

Total

acre-feet	3,480
millions cf	151.6
millions cm	4.29

Average

cfs	4.81
cms	0.136
mg/d	3.11
gpm	2,159

PRECIPITATION AND DISCHARGE

Precipitation	41.21 inches (1,047 mm)
Discharge	14.86 inches (378 mm)
Discharge as % of precipitation	35.1%

NITRATE DISCHARGE

Concentration - mg/L	**As NO_3**	**As NO_3-N**
Flow-weighted mean	56.2	12.5
Mean of analyses	54.6	12.1

	NO_3-N output	**Total N output**
lbs - N	118,351	118,980*
kg - N	53,674	53,959*
lbs - N/acre	42.1	42.4*

ATRAZINE DISCHARGE

Concentration - µg/L

Flow-weighted mean	0.11
Mean of analyses	0.04

Total output

lbs	1.05
g	475.9

* Total NO - plus Ammonia-N.

between 16.2 mg/L (3.6 mg/L as NO_3-N) on February 17 and 72.0 mg/L (16.0 mg/L as NO_3-N) on December 16. In WY 1998, Roberts Creek discharged a total of 904.2 thousand pounds of nitrogen. Of this total, 869.1 thousand pounds, or 96%, were in the form of nitrate-N. This is equivalent to 19.2 lbs-N/acre within the sub-basin. The annual fw mean nitrate concentration for WY 1998 was 45.6 mg/L (10.1 mg/L as NO_3-N). The annual nitrate-N load for WY 1998 was the third greatest, and the annual fw mean nitrate concentration was the second greatest since WY 1986. On a monthly basis (Table A-16), the fw mean nitrate concentration varied from 19.2 mg/L (4.3 mg/L as NO_3-N) in February to 54.5 mg/L (12.1 mg/L as NO_3-N) in April. April also had the greatest monthly nitrate-N output, 261 thousand pounds, while September had the lowest monthly output at 4,100 pounds.

Fifty-one samples from Roberts Creek were analyzed for ammonia-N during WY 1998. Fourteen, or 27%, contained detectable ammonia-N. The sample with the greatest concentration of ammonia-N, 1.6 mg/L, was collected on June 9. The total ammonia-N discharged by Roberts Creek in WY 1998 was 35.1 thousand pounds, with an annual fw mean concentration of 0.41 mg/L.

Fifty-two weekly samples were collected from L23S and analyzed for partial N-series during WY 1998. All samples contained detectable nitrate, with concentrations ranging between 37.4 mg/L (8.3 mg/L as NO_3-N) on September 29 and 81.0 mg/L (18.0 mg/L as NO_3-N) on April 7 and June 30. In WY 1998, total about 119 thousand pounds of nitrate-N and ammonia-N were discharged by Silver Creek. Of this, 118.4 thousand pounds (99%) were in the form of nitrate-N. This was equivalent to 42.1 lb-N/acre within the sub-basin. This was the third greatest annual nitrate-N load for L23S since monitoring began in WY 1986. Greater annual nitrate-N loads were recorded in WYs 1992 and 1993 (Rowden et al., 1995a). The annual fw mean nitrate concentration for L23S was 56.2 mg/L (12.5 mg/L as NO_3-N) for WY 1998 (Table 22). That was the greatest annual fw mean nitrate concentration measured at L23S since WY 1986. Table A-17 summarizes the nitrate

Table 23. Annual summary of shallow groundwater and chemical discharges from L22T for WY 1998.

DISCHARGE	
Total	
acre-feet	91.0
millions cf	3.96
millions cm	0.112
Average	
cfs	0.126
cms	0.004
mg/d	0.081
gpm	56.5
PRECIPITATION AND DISCHARGE	
Precipitation	41.21 inches (1,047 mm)
Discharge	12.85 inches (326 mm)
Discharge as % of precipitation	31.2%
NITRATE DISCHARGE	
Concentration - mg/L	**As NO_3** / **As NO_3-N**
Flow-weighted mean	75.6 / 16.8
Mean of analyses	70.5 / 15.7
NO_3-N output	
lbs - N	4,154
kg - N	1,884
lbs - N/acre	48.9
ATRAZINE DISCHARGE	
Concentration - µg/L	
Flow-weighted mean	0.05
Mean of analyses	0.03
Total output	
lbs	0.012
g	5.34

and nitrate-N loads and concentrations at L23S on a monthly basis. The greatest fw mean nitrate concentration, 69.8 mg/L (15.5 mg/L as NO_3-N), occurred in July, and the lowest, 36.2 mg/L (8.0 mg/L as NO_3-N), occurred in February. The monthly nitrate-N output ranged from 1,460 pounds in January to 26,158 pounds in April.

Eight of the fifty-two samples from L23S, or 15%, contained detectable ammonia-N. The greatest concentration, 0.5 mg/L, was detected in a sample collected on February 17. The annual ammonia-N load for Silver Creek was 629 pounds, at an annual fw mean concentration of 0.07 mg/L for WY 1998.

In WY 1998, fifty-two samples from L22T were analyzed for nitrate. Fifty-one of the samples contained detectable nitrate, and were above the 45 mg/L standard for nitrate. The only non-detection for nitrate was collected on October 27. The greatest nitrate concentration, 102 mg/L (22.7 mg/L as NO_3-N), occurred on October 14. During WY 1998, a total of 4,154 pounds of nitrate-N were discharged by L22T. This was equivalent to 48.9 lbs-N/acre within the drainage area. The annual fw mean nitrate concentration for WY 1998 was 75.6 mg/L (16.8 mg/L as NO_3-N). The monthly nitrate-N discharge data for L22T for WY 1998 is shown in Table A-18. February had the lowest monthly fw mean nitrate concentration at 56.9 mg/L (12.6 mg/L as NO_3-N), and June had the greatest at 86.5 mg/L (19.2 mg/L as NO_3-N). The monthly nitrate-N output ranged from 110 pounds in January to 911 pounds in April.

Pesticide Monitoring

Pesticide monitoring results from Big Spring for WY 1998 are summarized in Table 18, appendix Table B-14 and figures 20A, 21 and 22A. Twenty-four samples from Big Spring were collected in the second and last week of each month for pesticide analyses. Twelve, or 50%, contained detectable atrazine; most of the detections occurred between April and early September (Figs. 20A & 21). The greatest atrazine concentration, 0.44 µg/L, occurred on May 26. In WY 1998, 11.6 pounds of atrazine were discharged through Big Spring.

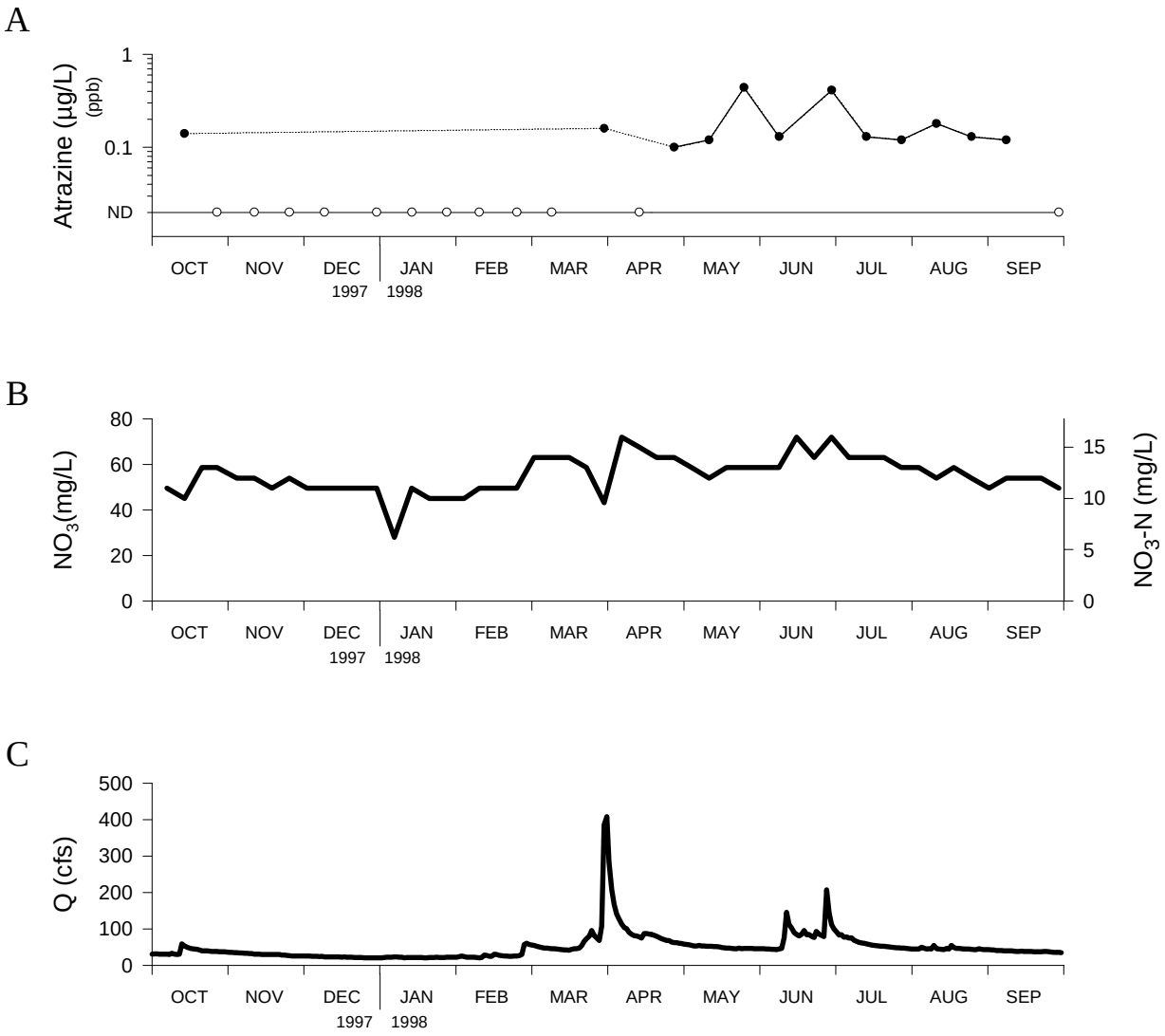

Figure 20. A) Atrazine and B) nitrate concentrations; and C) groundwater discharge for Big Spring for WY 1998.

The annual fw mean atrazine concentration for WY 1998 was 0.12 µg/L, the lowest annual fw mean atrazine concentration observed at Big Spring since monitoring started in WY 1982. Another 0.12 µg/L annual fw mean concentration for atrazine occurred in WY 1995 (Liu et al., 1997). Table B-14 summarizes atrazine concentrations and loads at Big Spring on a monthly basis for WY 1998. During the water year, the greatest monthly fw mean atrazine concentration, 0.24 µg/L, and load, 3.17 pounds, occurred in June. June accounted for 27% of the annual atrazine output from Big Spring. Since all samples collected in November through February were below the detection limit for atrazine (<0.1 µg/L), a mean of analyses for these months cold not be computed. Flow-weighted mean atrazine concentrations and loads also could not be calculated for November through January. The lowest computed monthly fw mean atrazine concentration, 0.02 µg/L, and load, 0.06 pounds, occurred in February.

Figure 22A shows the trends for atrazine and

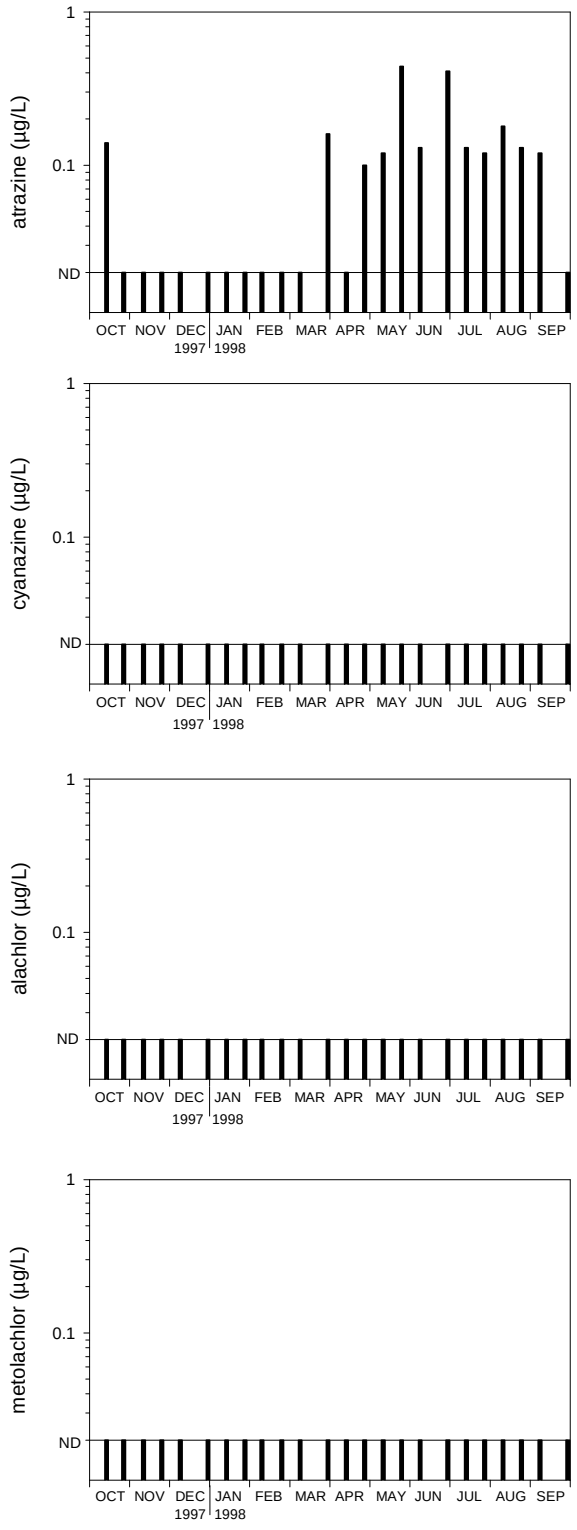

Figure 21. Bar graphs of pesticide concentrations at Big Spring for WY 1998. ND represents not detected.

the atrazine metabolites desethyl atrazine and desisopropyl atrazine from Big Spring groundwater in WY 1998. Of the twenty-four samples, fourteen (58%) contained detectable desethyl atrazine. The detection pattern for desethyl atrazine was very similar to atrazine. The greatest desethyl atrazine concentration, 0.28 µg/L, occurred on June 30. Desisopropyl atrazine was not detected at Big Spring during the water year. Acetochlor was detected once, at a concentration of 0.21 µg/L, on May 26. None of the samples collected from Big Spring in WY 1998 contained detectable concentrations of alachlor, butylate, cyanazine, metolachlor, metribuzin, and trifluralin.

Figure 22B, Table 20 and appendix Table B-15 summarize the atrazine monitoring results for the Turkey River. During WY 1998, eleven samples from TR01 were analyzed for pesticides. An estimated 2,109 pounds of atrazine were discharged by the river in WY 1998, with annual fw mean atrazine concentration at 0.64 µg/L.

Table B-15 summarizes atrazine concentrations and loads on a monthly basis for TR01 in WY 1998. The fw mean atrazine concentrations were less than 1.0 µg/L for all months except May and June. The greatest monthly fw mean atrazine concentration, 2.01 µg/L, occurred in May, while the greatest monthly atrazine load, 1,236 pounds, occurred in June. June accounted for 59% of the total annual atrazine load at TR01. The computed lowest monthly fw mean atrazine concentration, 0.03 µg/L, and load, 2.7 pounds, for the water year were recorded in January. The monthly mean of atrazine analyses for October through April and September could not be calculated since all samples collected during these months were below the detection limit. No samples were collected in December.

The distribution trends for atrazine and its metabolites desethyl atrazine and desisopropyl atrazine for the Turkey River during WY 1998 are shown in Figure 22B. Of the eleven samples, four (36%) collected during May through August contained detectable levels of atrazine. The greatest atrazine concentration, 4.10 µg/L, occurred on May 26. Five of the eleven samples, or 45%, contained detectable desethyl atrazine.

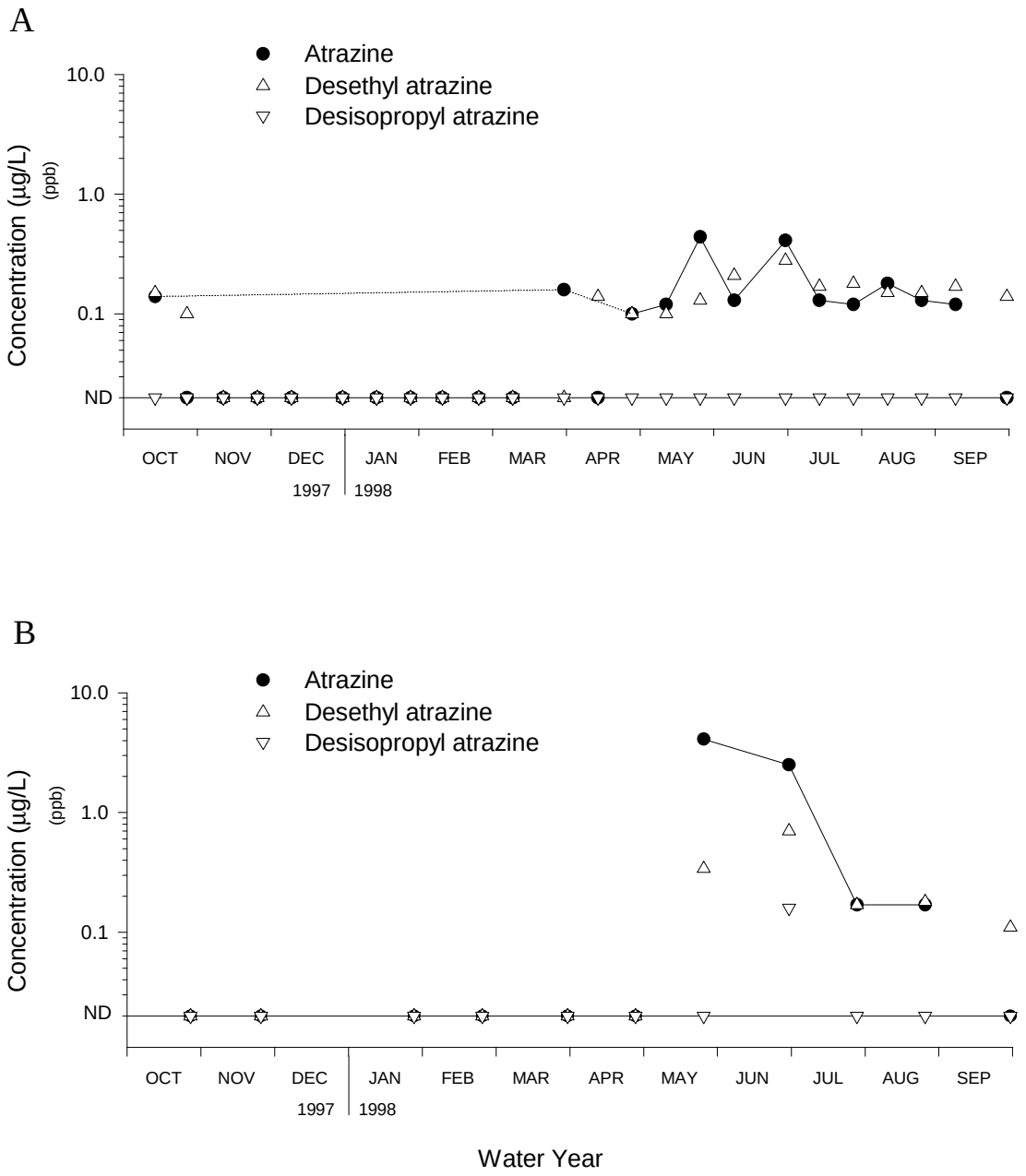

Figure 22. A) Atrazine, desethyl atrazine and desisopropyl atrazine concentrations for Big Spring and B) the Turkey River at Garber for WY 1998. ND represents not detected.

The sample with the greatest desethyl atrazine concentration, 0.70 µg/L, was collected on June 30. One of the samples, or 9%, contained detectable desisopropyl atrazine at a concentration of 0.16 µg/L.

Other pesticides detected in Turkey River surface water during WY 1998 include alachlor in one sample (9%), acetochlor and cyanazine in two samples (18%), and metolachlor in three samples (27%). Maximum concentrations were 0.33 µg/L

for alachlor, 3.40 µg/L for acetochlor, 0.64 µg/L for cyanazine, and 0.63 µg/L for metolachlor. All maximums occurred on May 26. Butylate, metribuzin, and trifluralin were not detected at TR01 during WY 1998.

Table 21, appendix Table B-16 and Figure 19A summarize the results of pesticide monitoring at RC02 during WY 1998. Twenty-four samples were collected in the second and last week of each month from RC02 for common pesticide analyses. Thirteen of them (54%), collected in October and from late March through August, contained detectable atrazine (>0.10 µg/L). The greatest concentration, 1.80 µg/L, occurred on May 26. In WY 1998, Roberts Creek discharged a total of 17.5 pounds of atrazine, at a fw mean concentration of 0.20 µg/L. This was the lowest annual fw mean atrazine concentration and the fifth lowest annual atrazine load at RC02 since WY 1986. Table B-16 summarizes atrazine monitoring results at RC02 on a monthly basis for WY 1998. During the water year, the greatest monthly fw mean atrazine concentration, 0.55 µg/L, and load, 8.9 pounds, occurred in June. June accounted for 51% of the annual atrazine load and 19% of the annual discharge. The lowest monthly fw mean atrazine concentration, 0.02 µg/L, and load, 0.01 pounds, occurred in September. All samples collected in November through February and September were below the detection limit for atrazine. Therefore, fw mean atrazine concentration and load for November, December, and January could not be calculated. For the metabolites of atrazine, fifteen of the twenty-four samples (63%) contained detectable desethyl atrazine, with the greatest concentration at 0.35 µg/L on June 30. No sample contained detectable desisopropyl atrazine during the water year.

Acetochlor was detected in two samples and alachlor in one sample at RC02. The greatest concentrations, 1.80 µg/L for acetochlor and 0.89 µg/L for alachlor, occurred on May 26. Butylate, cyanazine, metolachlor, metribuzin, and trifluralin were not detected during WY 1998.

The pesticide monitoring data for L23S for WY 1998 are summarized in Table 22, appendix Table B-17 and Figure 19A. During the water year, twelve monthly samples were collected from L23S for common pesticide analyses. Three (25%) contained detectable atrazine, and five (42%) contained detectable desethyl atrazine. The greatest concentrations of atrazine, 0.23 µg/L, and desethyl atrazine, 0.30 µg/L, occurred on June 30. In WY 1998, Silver Creek discharged a total of 1.05 pounds of atrazine. The annual fw mean atrazine concentration for WY 1998 was 0.11 µg/L. This was the second lowest annual fw mean atrazine concentration since monitoring started at L23S in WY 1986. Monthly atrazine concentrations and loads for L23S during WY 1998 are shown in Table B-17. Atrazine was detected only during the May through July period. June had the greatest fw mean atrazine concentration, 0.19 µg/L, and load, 6.3 ounces. August had the lowest monthly fw mean atrazine concentration, 0.03 µg/L, and January had the lowest computed monthly atrazine load, 0.13 ounces. Monthly fw mean atrazine concentrations and loads were not calculated for November, December, and September for the water year, since atrazine was not detected and could not be estimated for these months. No other pesticides were detected at L23S in WY 1998.

Table 23, appendix Table B-18 and Figure 19A summarize the results of pesticide monitoring at L22T during WY 1998. Twenty-four samples were collected during the second and last week of each month from L22T for common pesticide analyses. Six samples (25%) contained detectable atrazine. The greatest concentration for atrazine, 0.12 µg/L, occurred on August 25 and September 8. Total atrazine output in WY 1998 was 0.012 pounds, with an annual fw mean concentration of 0.05 µg/L. These were the second lowest annual fw mean atrazine concentration and load at L22T since monitoring started in WY 1987. The lowest annual fw mean atrazine concentration, 0.02 µg/L, and load, 0.003 pounds, were recorded in WY 1997 (this report). Table B-18 summarizes atrazine monitoring results at L22T on a monthly basis for WY 1998. The greatest monthly fw mean atrazine concentration, 0.12 µg/L, occurred in August, and the greatest monthly atrazine load, 0.07 ounces, occurred in June. None of the samples collected

Table 24. Annual summary of groundwater and chemical discharges from the Big Spring basin to the Turkey River for WY 1999.

DISCHARGE

Total

acre-feet	37,133
millions cf	1,615
millions cm	45.8

Average

cfs	51.3
cms	1.45
mg/d	33.1
gpm	23,019

PRECIPITATION AND DISCHARGE

Precipitation	39.99	inches (1,016 mm)
Discharge	6.76	inches (172 mm)
Discharge as % of precipitation	16.9%	

NITRATE DISCHARGE

Concentration - mg/L	**As NO_3**	**As NO_3-N**
Flow-weighted mean	53.0	11.8
Mean of analyses	51.9	11.5

NO_3-N output

lbs - N	1,189,548
kg - N	539,478
lbs - N/acre	18.0

ATRAZINE DISCHARGE

Concentration - µg/L

Flow-weighted mean	0.24
Mean of analyses	0.12

Total output

lbs	23.80
kg	10.79

in October through May contained detectable atrazine. Due to a lack of detections, monthly fw mean atrazine concentrations and loads for November through January, March, and May were not calculated.

Of the twenty-four samples collected from L22T, sixteen samples, or 67%, contained detectable desethyl atrazine. The greatest concentration of desethyl atrazine, 0.29 µg/L, was sampled on September 8. No other pesticides were detected from L22T during WY 1998.

Water Year 1999

Discharge Monitoring

Tables 24 and 25 and Figure 23 summarize the groundwater discharge and climatic information for Big Spring during WY 1999. Like WYs 1997 and 1998, WY 1999 was a wet year. Annual precipitation in the Big Spring basin totaled 39.99 inches (1,016 mm), which was 7.02 inches greater than the long-term average for the basin. The annual groundwater discharge at Big Spring was 37,133 ac-ft, at an average rate of 51.3 cfs. The groundwater discharge was equivalent to 16.9% of the annual precipitation. Figure 23 shows groundwater discharge and water temperature at Big Spring along with daily precipitation and air temperature in the basin. Discharge rates were relatively low during the first four months of the water year. The lowest rate of the water year, 25.5 cfs, occurred on January 25. Significant discharge peaks occurred in April and May. The greatest daily discharge rate of the water year, 490 cfs, was recorded on May 17 following intense rainfall. This was also the greatest daily discharge rate recorded at Big Spring since monitoring started in WY 1981. Significant precipitation also occurred in June, July and August, but did not generate significant discharge peaks at Big Spring because of high evapotranspiration rates during the period.

Table 25 summarizes the groundwater discharge data from Big Spring on a monthly basis. The greatest monthly discharge totaled 7,337 ac-ft in May, at an average rate of 119 cfs. This was the fourth greatest monthly groundwater discharge

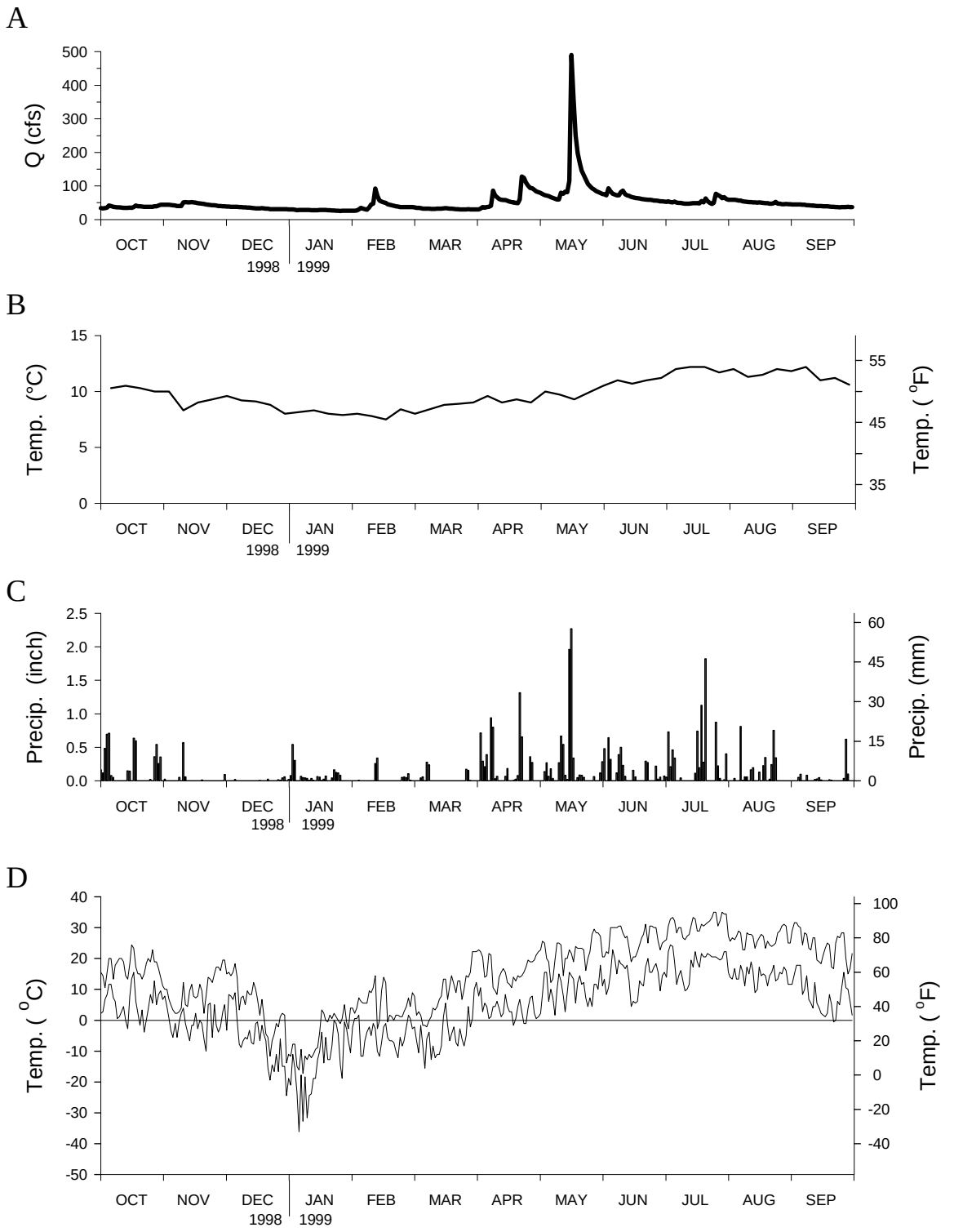

Figure 23. A) Groundwater discharge, B) groundwater temperature and C) daily precipitation for the Big Spring basin; and D) maximum/minimum temperatures for Elkader, IA (Iowa Dept. of Ag. and Land Stewardship, State Climatology Office), for WY 1999.

Table 25. Monthly summary of groundwater discharge from the Big Spring basin for WY 1999.

	1998 Oct	Nov	Dec	1999 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
TOTAL MONTHLY DISCHARGE												
Acre-feet	2,313	2,662	2,086	1,698	2,344	1,972	3,827	7,337	4,039	3,319	3,145	2,392
Cubic feet (millions)	101	116	91	74	102	86	167	320	176	145	137	104
Gallons (millions)	754	868	680	553	764	643	1,247	2,391	1,316	1,082	1,025	780
Cubic meters (millions)	2.9	3.3	2.6	2.1	2.9	2.4	4.7	9.0	5.0	4.1	3.9	2.9
AVERAGE DISCHARGE												
cfs	38	45	34	28	42	32	64	119	68	54	51	40
cms	1.1	1.3	1.0	0.8	1.2	0.9	1.8	3.4	1.9	1.5	1.4	1.1
mg/d	24	29	22	18	27	21	42	77	44	35	33	26
MAXIMUM												
cfs	44	52	39	30	92	36	128	490	93	77	59	45
cms	1.2	1.5	1.1	0.9	2.6	1.0	3.6	13.9	2.6	2.2	1.7	1.3
MINIMUM												
cfs	34	39	30	26	26	30	30	59	54	47	45	36
cms	0.9	1.1	0.9	0.7	0.7	0.8	0.9	1.7	1.5	1.3	1.3	1.0

recorded at Big Spring. Greater monthly discharges were recorded in July, 1993 at 8,436 ac-ft, June, 1991 at 8,415 ac-ft, and April, 1993 at 7,991 ac-ft (Rowden et al., 1993a, 1995b). May accounted for 18.2% of the annual precipitation and 19.8% of the annual discharge. The lowest monthly discharge of the water year, 1,698 ac-ft, and average discharge rate, 28 cfs, occurred in January. The wettest month of the water year, July, had 3,319 ac-ft of discharge, which accounted for 19.3% of the annual precipitation and 8.9% of the annual discharge.

The monitoring results from TR01 in WY 1999 are summarized in Table 26 and Figure 24B. The annual surface water discharge from the Turkey River at Garber was 1,399,000 ac-ft, at an average daily discharge rate of 1,932 cfs. This amount was 192% of the long-term annual discharge mean for the Turkey River, and was the second greatest annual discharge and average discharge rate since the monitoring started in WY1986. The greatest annual discharge for the Turkey River, 2,103,000 ac-ft, was recorded in WY 1993 (Rowden et al., 1995b). The annual precipitation for northeast Iowa was 42.64 inches (1,083 mm) in WY 1999. The surface water discharge from the Turkey River was equivalent to 39.8% of the annual precipitation. On a monthly basis, May had the greatest discharge, 318,300 ac-ft, at a mean rate of 5,176 cfs. The lowest monthly discharge, 20,510 ac-ft, occurred in December, at an average rate of 334 cfs. The greatest daily discharge rate from the Turkey River at Garber, 43,400 cfs, occurred on May 17. This was also the greatest daily

Table 26. Annual summary of water and chemical discharges from the Turkey River at Garber for WY 1999 (Discharge data are from the U.S. Geological Survey, Water Resources Division, IA Dist.).

DISCHARGE

Total

acre-feet	1,399,000
millions cf	60,940
millions cm	1,725

Average

cfs	1,932
cms	54.7
mg/d	1,249
gpm	867,082

PRECIPITATION AND DISCHARGE

Precipitation	42.64 inches (1,083 mm)
Discharge	16.98 inches (431 mm)
Discharge as % of precipitation	39.8%

NITRATE DISCHARGE

Concentration - mg/L	As NO_3	As NO_3-N
Flow-weighted mean	33.9	7.5
Mean of analyses	34.5	7.7

NO_3-N output

lbs - N	28,683,494
kg - N	13,008,387
lbs - N/acre	29.0

ATRAZINE DISCHARGE

Concentration - µg/L

Flow-weighted mean	0.53
Mean of analyses	0.17

Total output

lbs	2,025
kg	918

discharge rate for the Turkey River since WY 1913. The minimum daily discharge rate during WY 1999, 250 cfs, was recorded on January 5 and 13 (Nalley et al., 2000). Comparing the hydrographs of Big Spring and the Turkey River (Fig. 24B), discharge of the Turkey River was more responsive to precipitation events in July and August.

Table 27 and Figure 25 summarize the monitoring results at RC02 during WY 1999. The annual discharge at RC02 totaled 27,680 ac-ft, at an average discharge rate of 38.2 cfs. The discharge for the water year was 133% of the long-term average annual discharge at RC02. Surface water discharge for WY 1999 accounted for 18.4% of the annual precipitation. The hydrograph for RC02 during WY 1999 is shown on Figure 25C using a logarithmic scale. Many discharge events occurred throughout the water year. Significant peaks with discharge rates greater than 100 cfs occurred in February, and April through August. The daily discharge rate ranged from 2.6 cfs on December 22 to 1,800 cfs on May 17. On a monthly basis, January had the lowest monthly discharge, 254 ac-ft, at an average discharge rate at 4.14 cfs, while May had the greatest monthly discharge of 10,080 ac-ft, at an average discharge rate of 164 cfs (Nalley et al., 2000).

Discharge monitoring at L23S on Silver Creek was terminated at the end of WY 1998.

The annual monitoring results from L22T are summarized in Table 28 and Figure 25. The annual discharge at L22T totaled 106.6 ac-ft, with an average discharge rate of 0.147 cfs for WY 1999. These were the second greatest annual discharge and discharge rate recorded at L22T since WY 1987. The greatest annual discharge, 188.7 ac-ft, and discharge rate, 0.261 ac-ft, were recorded in WY 1993 (Rowden et al., 1998). The annual discharge accounted for 37.6% of the annual precipitation within the Big Spring basin. The daily discharge rate during the water year ranged between 0.067 cfs on January 13 through 31 and 0.65 cfs on February 11 and May 17. On a monthly basis, January had the lowest discharge, 4.18 ac-ft, at an average rate of 0.068 cfs. The

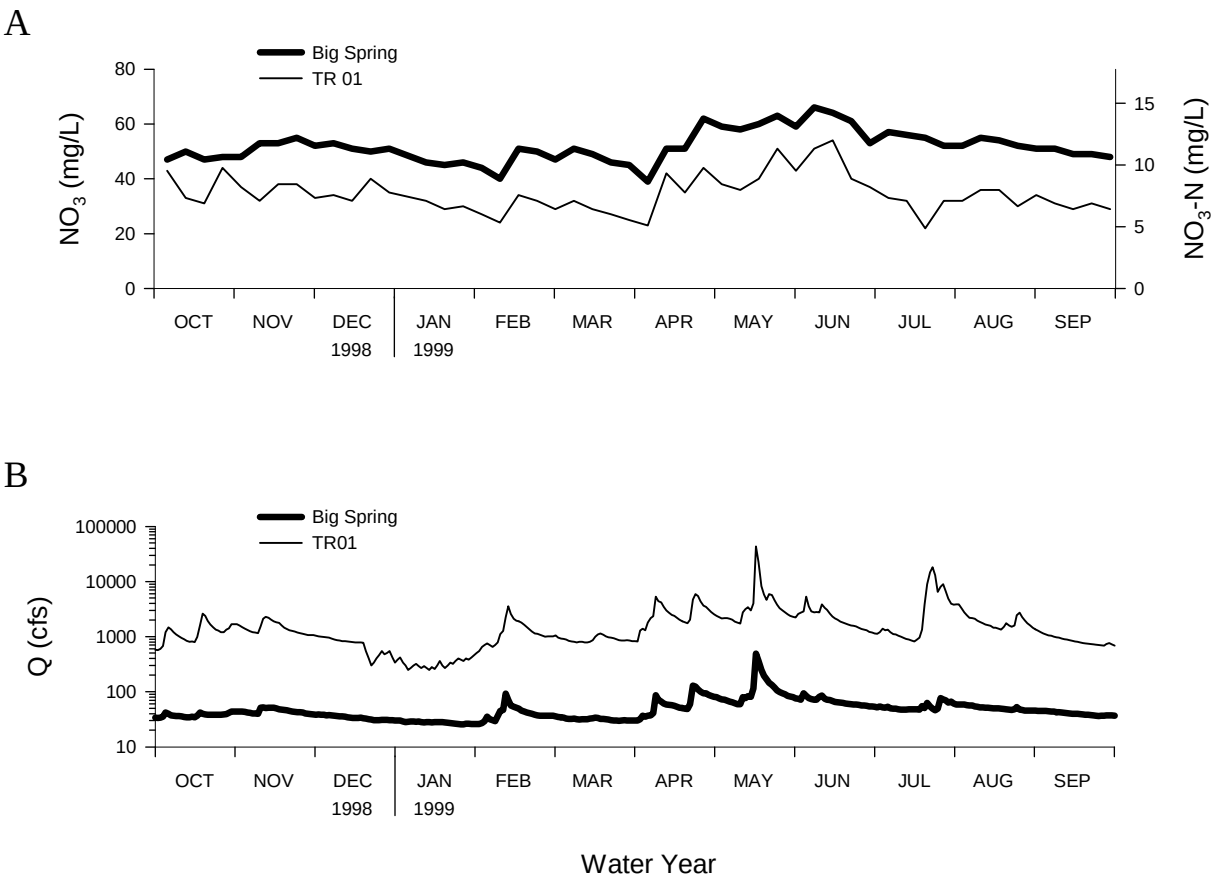

Figure 24. A) Nitrate concentrations and B) discharge hydrographs for Big Spring (bold lines) and the Turkey River at Garber (lighter lines) for WY 1999 (Turkey River discharge data are from the U.S. Geological Survey, W.R.D., IA Dist.).

greatest monthly discharge, 19.26 ac-ft, and rate, 0.313 cfs, occurred in May.

Nitrate Monitoring

Fifty-one weekly groundwater samples for nitrate analysis were collected from Big Spring during WY 1999. Results are summarized in Table 24, appendix Table A-19 and Figure 26B. Nitrate concentrations were relatively high at Big Spring throughout the water year (Fig. 26B), with forty-eight samples having nitrate concentrations greater than 45 mg/L (10.0 mg/L as NO_3-N). During WY 1999, a total of 1.2 million pounds of nitrate-N were discharged by groundwater at Big Spring. This was equivalent to 18.0 lbs-N/acre within the basin. The annual fw mean nitrate concentration for the water year was 53 mg/L (11.8 mg/L as NO_3-N). The greatest nitrate concentration, 66 mg/L (14.7 mg/L as NO_3-N), occurred on June 8. The lowest, 39 mg/L (8.7 mg/L as NO_3-N), occurred on April 6. Table A-19 summarizes the nitrate concentrations and loads at Big Spring on a monthly basis. All monthly fw mean nitrate concentrations were above the 45 mg/L (10.0 mg/L as NO_3-N) drinking water standard for nitrate. The greatest monthly fw mean nitrate concentration, 61 mg/L (13.6 mg/L as NO_3-N), occurred in June. The greatest monthly nitrate-N load, 254 thousand pounds which accounted for 21% of the annual nitrate-N output, occurred in May. February had the lowest monthly

fw mean nitrate concentration, 46 mg/L (10.1 mg/L as NO_3-N), while January had the lowest monthly nitrate-N output, 48 thousand pounds.

Figure 24A, Table 26 and appendix Table A-20 summarize nitrate concentrations and loads for the Turkey River during WY 1999. Fifty-one samples were analyzed for nitrate during the water year. Nitrate concentrations ranged between 22 mg/L (4.9 mg/L as NO_3-N) on July 20 and 54 mg/L (12.0 mg/L as NO_3-N) on June 15. A total of 28.7 million pounds of nitrate-N were discharged by the Turkey River in WY 1999, which was equivalent to 29.0 lbs-N/acre for the Turkey River basin above Garber. The annual fw mean nitrate concentration was 34 mg/L (7.5 mg/L as NO_3-N). These were the third greatest annual nitrate-N output and the fourth greatest annual fw mean nitrate concentration for the Turkey River since WY 1986.

Table A-20 shows nitrate concentrations and loads for the Turkey River on a monthly basis. All monthly fw mean nitrate concentrations were below the 45 mg/L (10 mg/L as NO_3-N) drinking water standard for nitrate during the water year. The lowest monthly concentration, 25 mg/L (5.5 mg/L as NO_3-N), occurred in July. June had the greatest fw mean nitrate concentration at 44.6 mg/L (9.9 mg/L as NO_3-N). May had the greatest nitrate-N load, 7.4 million pounds, and January had the lowest, 390 thousand pounds.

Nitrate monitoring results at RC02 during WY 1999 are summarized in tables 27 and A-21 and Figure 25B. Fifty-one weekly samples were collected from RC02 for nitrate analysis. Concentrations varied between 18 mg/L (4.0 mg/L as NO_3-N) on August 24 and 71 mg/L (15.8 mg/L as NO_3-N) on May 25. In WY 1999, a total of 628.7 thousand pounds of nitrate-N were discharged by Roberts Creek. This was equivalent to 13.9 lbs-N/acre within the sub-basin. The annual fw mean nitrate concentration for WY 1999 was 37.6 mg/L (8.3 mg/L as NO_3-N). On a monthly basis, the fw mean nitrate concentration varied from 25 mg/L (5.6 mg/L as NO_3-N) in October to 49.7 mg/L (11.0 mg/L as NO_3-N) in June. May had the greatest monthly nitrate-N output at 259 thousand pounds, while January had

Table 27. Annual summary of water and chemical discharges from RC02 for WY 1999 (Discharge data are from the U.S. Geological Survey, Water Resources Division, IA Dist.).

DISCHARGE

Total

acre-feet	27,680
millions cf	1,206
millions cm	34.1

Average

cfs	38.2
cms	1.08
mg/d	24.7
gpm	17,144

PRECIPITATION AND DISCHARGE

Precipitation	39.99 inches (1,016 mm)
Discharge	7.34 inches (186 mm)
Discharge as % of precipitation	18.4%

NITRATE DISCHARGE

Concentration - mg/L	As NO_3	As NO_3-N
Flow-weighted mean	37.6	8.3
Mean of analyses	37.1	8.2

NO_3-N output

lbs - N	628,710
kg - N	285,129
lbs - N/acre	13.9

ATRAZINE DISCHARGE

Concentration - µg/L

Flow-weighted mean	0.65
Mean of analyses	0.18

Total output

lbs	49.3
kg	22.3

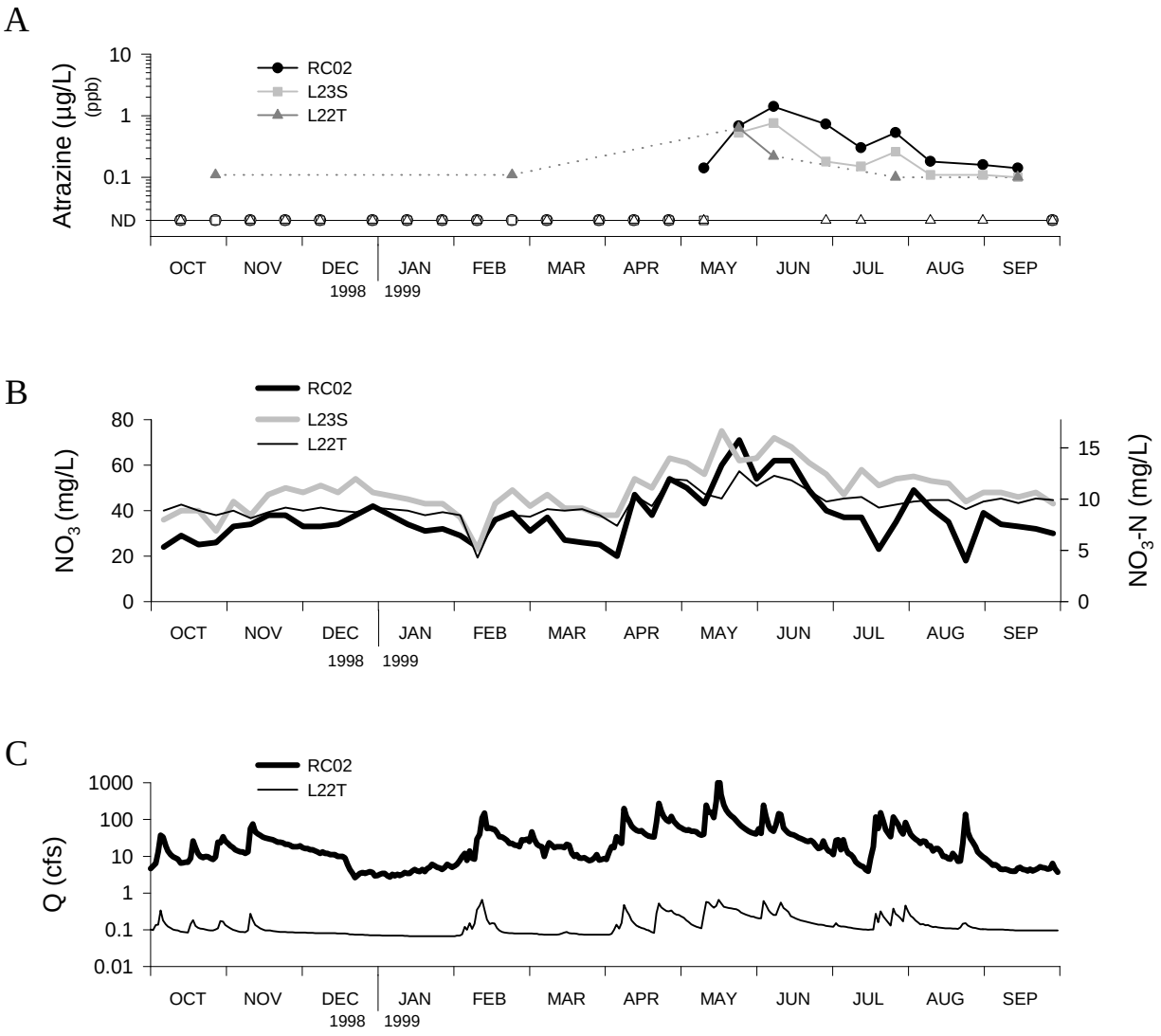

Figure 25. A) Atrazine, B) nitrate distributions and C) discharge hydrographs for RC02, L23S and L22T for WY 1999 (RC02 and L23S discharge data are from the U.S. Geological Survey, W.R.D., IA Dist.).

the lowest monthly nitrate-N output, 5.0 thousand pounds.

Fifty-one samples were collected weekly from L23S and analyzed for nitrate during WY 1999. All samples contained detectable nitrate, with concentrations ranging between 23 mg/L (5.1 mg/L as NO_3-N) on February 9 and 75 mg/L (16.7 mg/L as NO_3-N) on May 18. Since discharge monitoring at L23S was terminated at the end of WY 1998, fw mean nitrate concentrations and loads were not calculated for the water year. Monthly means of nitrate analyses are shown in Table 29, and ranged from 37 mg/L (8.2 mg/L as NO_3-N) in October to 64 mg/L (14.1 mg/L as NO_3-N) in May and June.

In WY 1999, fifty-one samples from tile line site L22T were analyzed for nitrate. Fifty samples had concentrations above the 45 mg/L (10.0 mg/L as NO_3-N) standard for nitrate. The greatest nitrate concentration, 86 mg/L (19.1 mg/L as NO_3-

Table 28. Annual summary of shallow groundwater and chemical discharges from L22T for WY 1999.

DISCHARGE	
Total	
acre-feet	106.6
millions cf	4.64
millions cm	0.131
Average	
cfs	0.147
cms	0.004
mg/d	0.095
gpm	66.0
PRECIPITATION AND DISCHARGE	
Precipitation	39.99 inches (1,016 mm)
Discharge	15.05 inches (382 mm)
Discharge as % of precipitation	37.6%

NITRATE DISCHARGE		
Concentration - mg/L	**As NO_3**	**As NO_3-N**
Flow-weighted mean	63.6	14.1
Mean of analyses	62.6	13.9
NO_3-N output		
lbs - N	4,094	
kg - N	1,857	
lbs - N/acre	48.2	

ATRAZINE DISCHARGE	
Concentration - µg/L	
Flow-weighted mean	0.15
Mean of analyses	0.05
Total output	
lbs	0.042
g	19.24

N), occurred on May 25, and the lowest nitrate concentration, 29 mg/L (6.4 mg/L as NO_3-N), occurred on February 9. During WY 1999, a total of 4,094 pounds of nitrate-N were discharged from L22T, which was equivalent to 48.2 lbs-N/acre within the drainage area. The annual fw mean nitrate concentration for WY 1999 was 63.6 mg/L (14.1 mg/L as NO_3-N). The monthly nitrate-N data for WY 1999 is shown in Table A-22. February had the lowest monthly fw mean nitrate concentration at 40 mg/L (8.9 mg/L as NO_3-N), while May and June had the greatest concentrations at 73 mg/L (16.1 mg/L as NO_3-N). The monthly nitrate-N output at L22T ranged from 151 pounds in January to 844 pounds in May.

Pesticide Monitoring

Pesticide monitoring results at Big Spring for WY 1999 are summarized in Table 24, appendix Table B-19 and figures 26A, 27 and 28A. Twenty-four samples were collected from Big Spring for pesticide analyses during the second and last week of each month. In WY 1999, a total of 23.8 pounds of atrazine were discharged through Big Spring. The annual fw mean atrazine concentration for WY 1999 was 0.24 µg/L, and the annual mean of analyses for atrazine was 0.12 µg/L.

Table B-19 summarizes atrazine concentrations and loads at Big Spring on a monthly basis. During the water year, the greatest monthly fw mean atrazine concentration, 0.68 µg/L, occurred in June. The largest monthly atrazine load, 10.4 pounds, occurred in May. May accounted for 44% of the annual atrazine output and 20% of the annual groundwater discharge from Big Spring. Since all samples collected from November through April were below the detection limit for atrazine (<0.1 µg/L), a mean of analyses was not computed for these months. Flow-weighted mean atrazine concentrations and loads were also not calculated for December, January, and March since all estimates of atrazine concentrations were below detection limits during the 3 months. The lowest computed monthly fw mean atrazine concentration, 0.02 µg/L, and load, 0.14 pounds, occurred in

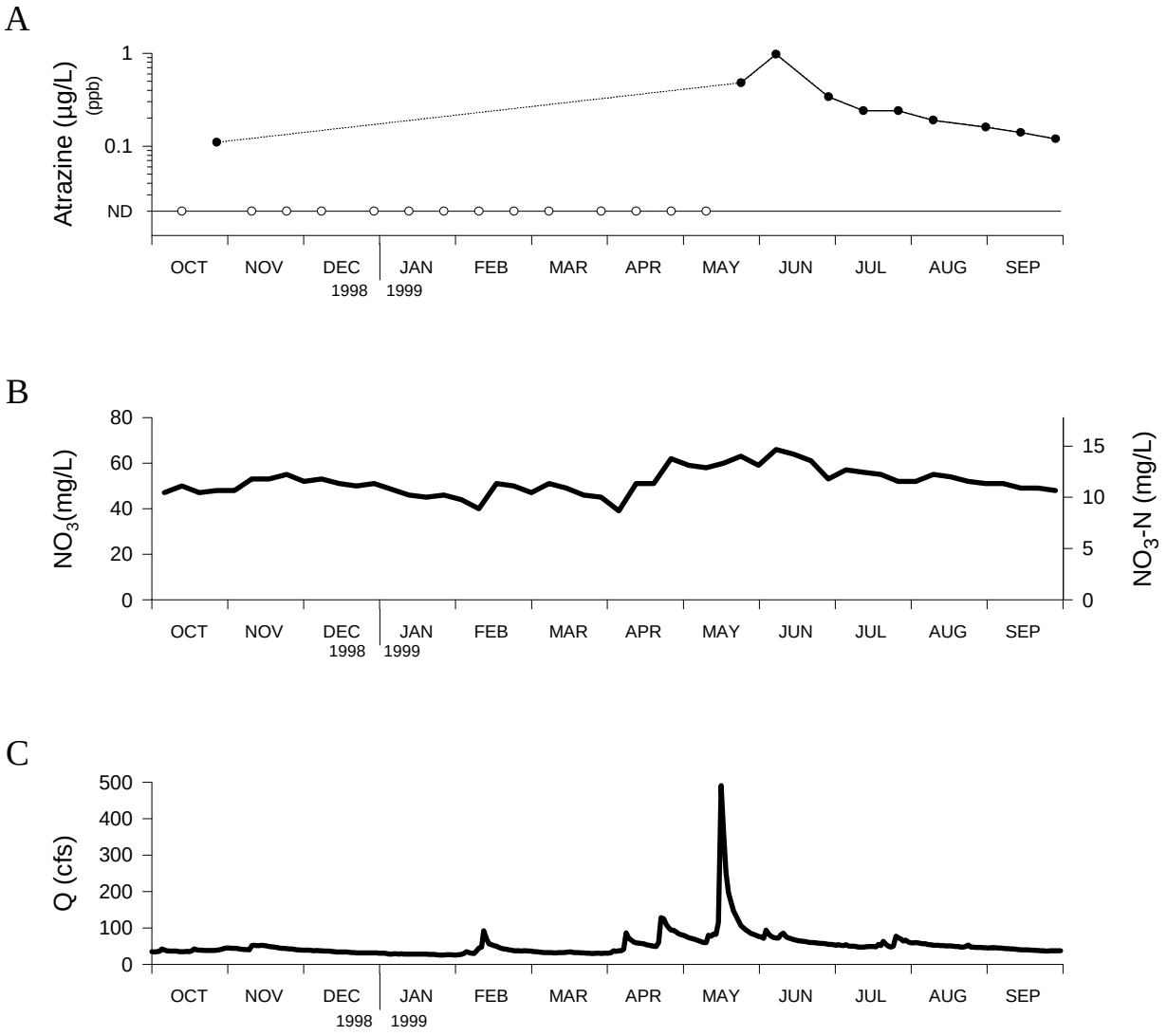

Figure 26. A) Atrazine and B) nitrate concentrations; and C) groundwater discharge for Big Spring for WY 1999.

November.

Figure 28A shows trends for atrazine and atrazine metabolites desethyl atrazine and desisopropyl atrazine from Big Spring groundwater in WY 1999. Of the twenty-four samples, ten (42%) contained detectable atrazine, with most detections occurred in late May through September (Figs. 26A & 27). The greatest atrazine concentration, 0.97 µg/L, occurred on June 8. Twenty samples, or 83%, contained detectable desethyl atrazine. The greatest desethyl atrazine concentration, 0.22 µg/L, occurred on July 27. Desisopropyl atrazine was not detected at Big Spring during the water year. Among the twenty-four samples, four samples (17%) contained detectable acetochlor, with a maximum concentration of 0.47 µg/L occurring on June 8. Alachlor, butylate, cyanazine, metolachlor, metribuzin, and trifluralin were not detected at Big Spring during the water year.

Figure 28B, Table 26 and appendix Table B-20 summarize the atrazine monitoring results for the

Turkey River. During WY 1999, twenty-four samples were collected from TR01 for pesticide analyses. The river in WY 1999 discharged a total of 2,025 pounds of atrazine. The annual fw mean atrazine concentration was 0.53 µg/L for WY 1999. Both the annual atrazine load and fw mean concentration were slightly lower than those in WY 1998. Table B-20 summarizes atrazine concentrations and loads on a monthly basis for TR01. The fw mean atrazine concentrations were less than 1.0 µg/L for all months except May, which had the highest concentration, 1.43 µg/L, and load, 1,235 pounds. May accounted for 61% of the annual atrazine load and 23% of the annual surface-water discharge at TR01. All samples collected in November, and January through April, were below the detection limit for atrazine (<0.1 µg/L). Therefore means of atrazine analyses were not computed for these months. Flow-weighted mean atrazine concentrations and loads were also not calculated for January and March since all estimates for atrazine concentrations were below detection limits for the 2 months. The lowest computed monthly fw mean atrazine concentration, 0.03 µg/L, occurred in November and December, and the lowest monthly atrazine load, 3.2 pounds, occurred in December.

The concentration trends for atrazine and its metabolites desethyl atrazine and desisopropyl atrazine for the Turkey River during WY 1999 are shown in Figure 28B. Of the twenty-four samples, eleven (46%) contained detectable levels of atrazine. The greatest atrazine concentration, 1.3 µg/L, occurred on May 25. Twenty of the samples, or 83%, contained detectable concentrations of desethyl atrazine. The greatest desethyl atrazine concentration, 0.33 µg/L, was sampled on July 27. Desisopropyl atrazine was not detected at TR01 during WY 1999. Other pesticides detected at the Turkey River in WY 1999 include acetochlor, cyanazine and metolachlor. Acetochlor was detected in two samples, or 8% of the total. The greatest concentration, 0.52 µg/L, occurred on May 25. Cyanazine and metolachlor were detected in one sample collected on May 25. The concentrations were 0.22 µg/L for cyanazine and 0.17 µg/L for metolachlor. Alachlor, butylate,

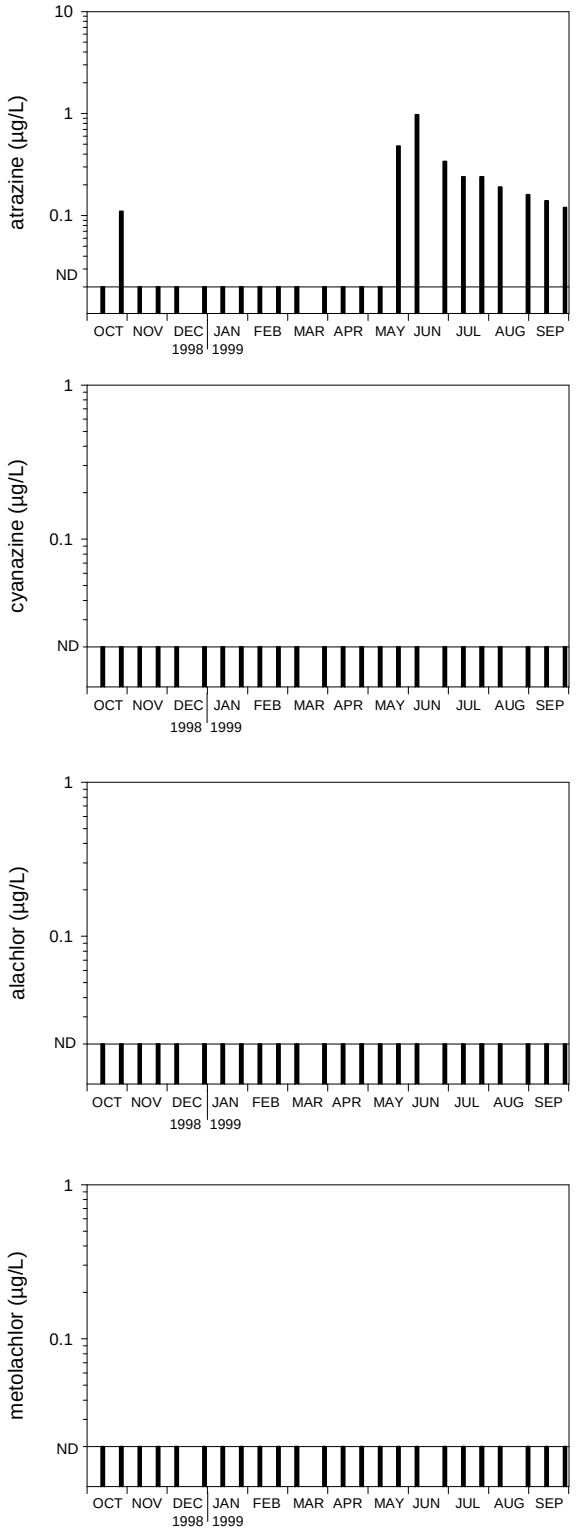

Figure 27. Bar graphs of pesticide concentrations for Big Spring for WY 1999. ND represents not detected.

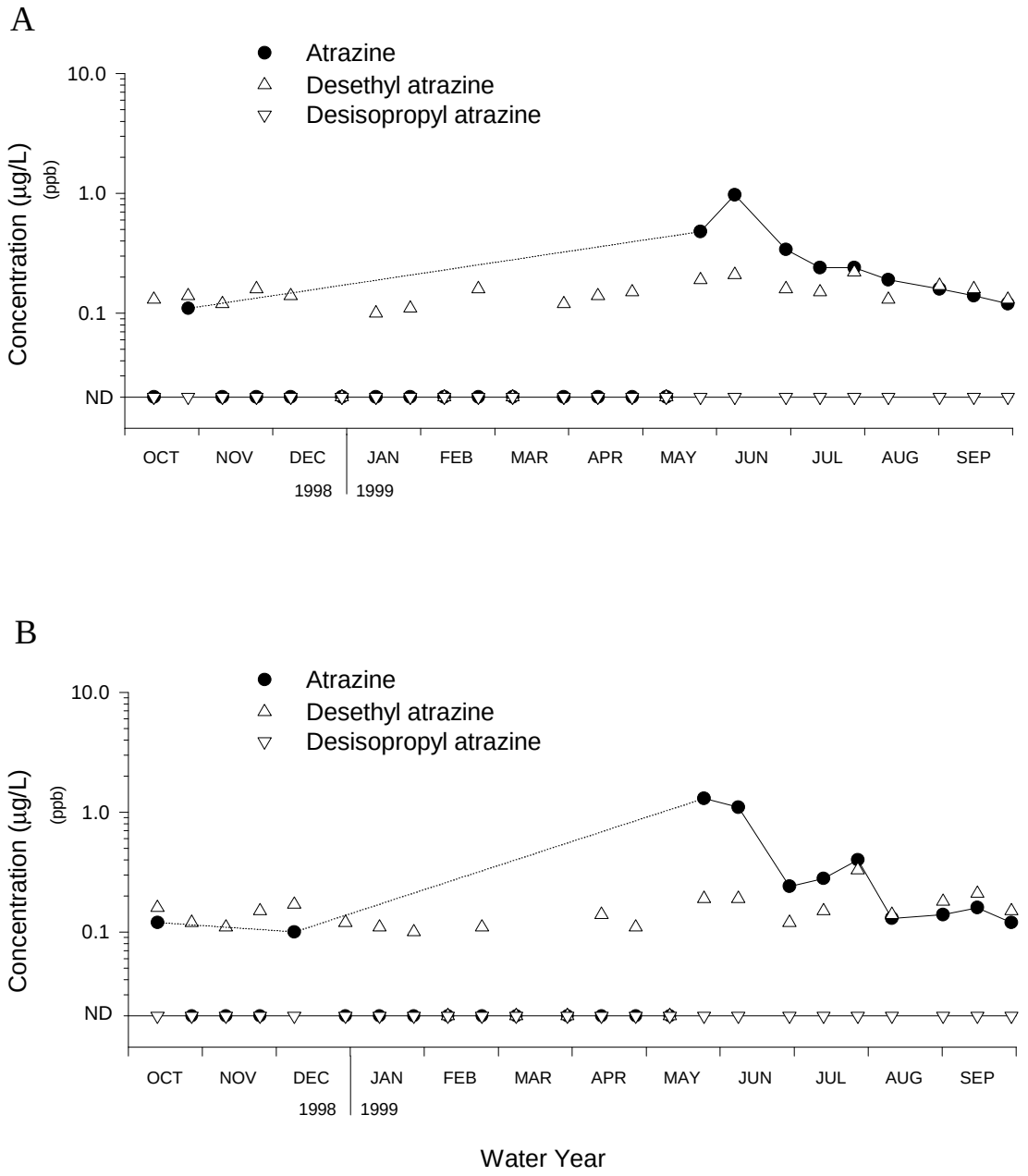

Figure 28. A) Atrazine, desethyl atrazine and desisopropyl atrazine concentrations for Big Spring and B) the Turkey River at Garber for WY 1999. ND represents not detected.

metribuzin, and trifluralin were not detected at TR01 during WY 1999.

Table 27, appendix Table B-21 and Figure 25A summarize the pesticide monitoring results at RC02 during WY 1999. Twenty-four samples for common pesticide analyses were collected during the second and last week of each month from RC02. Nine (38%) samples from the May through September period contained detectable atrazine. The greatest concentration, 1.40 µg/L, occurred

Table 29. Monthly summary of mean concentrations of atrazine and nitrate-N analyses from L23S for WY 1999.

	1998 Oct	Nov	Dec	1999 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Mean of atrazine analyses, in µg/L	*	*	*	*	*	*	*	0.27	0.47	0.21	0.11	0.05
Mean of NO_3 analyses, in mg/L;	37	45	50	44	38	42	51	64	64	53	50	46
as NO_3-N	8.2	9.9	11.1	9.7	8.4	9.3	11.4	14.1	14.2	11.7	11.2	10.3

* All samples below detection limits.

on June 8. In WY 1999, a total of 49.3 pounds of atrazine were discharged by Roberts Creek, at annual fw mean concentration of 0.65 µg/L. This annual atrazine load was almost three times that of the annual load in WY 1998, and was the fourth greatest annual atrazine load at RC02 since WY 1986. Table B-21 summarizes the atrazine monitoring results at RC02 on a monthly basis for WY 1999. During the water year, the greatest monthly fw mean atrazine concentration, 1.31 µg/L, occurred in June. The largest monthly atrazine load, 30.9 pounds, occurred in May. May accounted for 63% of the annual atrazine load and 36% of the annual surface water discharge. All samples collected during October through April were below the detection limit for atrazine (Fig. 25A). Therefore, the means of atrazine analyses for these months were not computed. The greatest monthly mean of atrazine analyses, 1.07 µg/L, occurred in June. Flow-weighted mean atrazine concentrations and loads were also not calculated for December and January since all estimates for atrazine concentrations were below detection limits during the two months. The lowest computed monthly fw mean atrazine concentration, 0.01 µg/L, and load, 0.04 pounds, occurred in November and March.

Fourteen samples, or 58%, contained detectable desethyl atrazine, with the largest concentration at 0.36 µg/L occurring on July 27. Desisopropyl atrazine was not detected at RC02 during the water year. Five samples (21%) contained detectable acetochlor. All detections occurred during the May through July period. The greatest concentration, 0.51 µg/L, occurred on June 8. No other pesticides were detected at RC02 during WY 1999.

Twenty-four samples were collected from L23S for common pesticide analyses during WY 1999. Eight samples, or 33%, collected during May through September, contained detectable nitrate. Ten samples (42%) contained detectable desethyl atrazine, and two (8%) contained detectable acetochlor. The greatest concentrations detected were 0.76 µg/L for atrazine, 0.26 µg/L for desethyl atrazine, and 0.33 µg/L for acetochlor. The maximum concentrations were sampled on June 8 for atrazine and acetochlor, and on July 27 for desethyl atrazine. No other pesticides were detected at L23S during WY 1999. Monthly means of atrazine analyses are shown in Table 29, ranged from 0.05 µg/L in September to 0.47 µg/L in June. Atrazine was not detected at L23S during October through April. Since surface water discharge monitoring at L23S was discontinued at the end of WY 1998, annual and monthly fw mean atrazine concentrations and loads were not calculated for WY 1999.

Table 28, appendix Table B-22 and Figure 25A summarize the results of pesticide monitoring at

L22T during WY 1999. Twenty-four samples were collected during the second and last week of each month for pesticide analysis. Six samples (25%) contained detectable atrazine. The greatest atrazine concentration, 0.63 µg/L, occurred on May 25. The total atrazine output in WY 1999 was 0.042 pounds, which was the third greatest since monitoring started in WY 1987. Larger annual atrazine load at L22T occurred in WYs 1991 (0.063 pounds) and 1993 (0.053 pounds). The annual fw mean atrazine concentration for WY 1999 was 0.15 µg/L, which was three times that of WY 1998. Table B-22 summarizes atrazine monitoring results at L22T on a monthly basis for WY 1999. The greatest monthly fw mean atrazine concentration, 0.41 µg/L, and load, 0.34 ounces, occurred in May. None of the samples collected during November, December, January, March, April, and August contained detectable atrazine. Since estimates for atrazine concentrations were below detection limits, monthly fw mean atrazine concentrations and loads were not calculated for December and January. The lowest computed fw mean atrazine concentration, 0.01 µg/L, and load, 0.002 ounces, occurred in November.

Of the twenty-four samples collected at L22T, nineteen samples, or 79%, contained detectable desethyl atrazine. The greatest desethyl atrazine concentration, 0.22 µg/L, occurred on September 14. One sample, from May 25, contained detectable acetochlor, at a concentration of 0.11 µg/L. No other pesticides were detected at L22T during WY 1999.

DISCUSSION

Discharge and water quality monitoring results during the respective monitoring periods are summarized in Figure 29 for Big Spring and Figure 30 for TR01, RC02, L23S, and L22T. Related numeral data for WYs 1986 through 1999 are summarized in Table 30. Within a given basin, groundwater discharge and water quality can be affected by many factors. The regression analysis for Big Spring, as well as previous studies, have shown that antecedent conditions exert a significant influence upon groundwater discharge and the

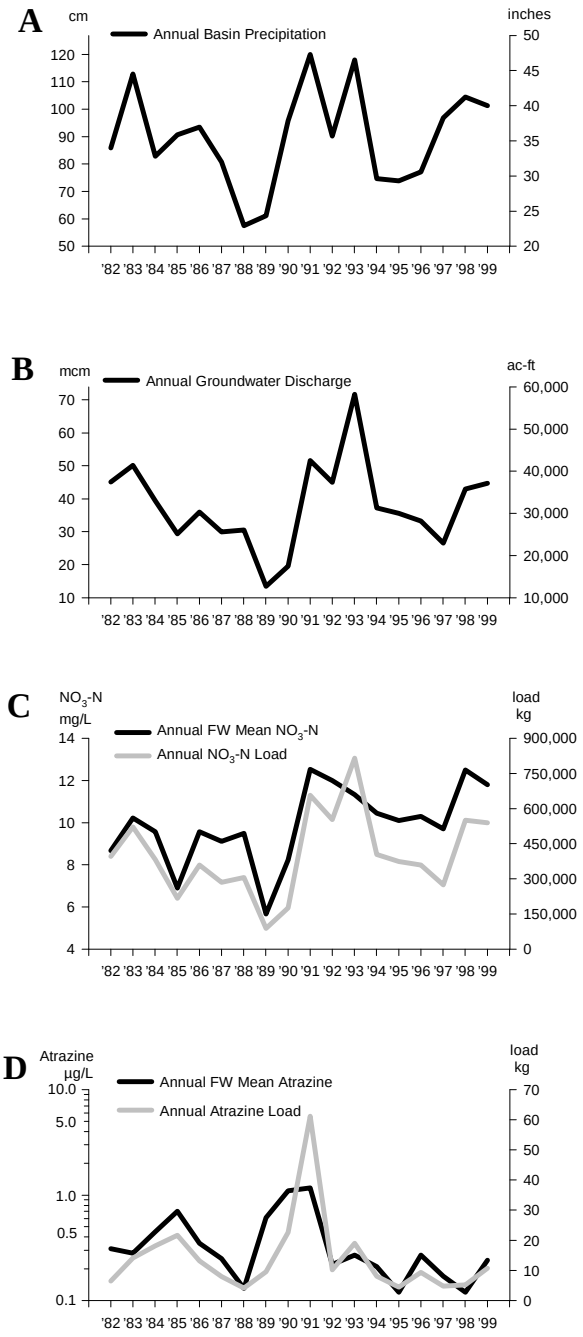

Figure 29. Summary of annual A) basin precipitation, B) groundwater discharge, C) flow-weighted mean NO_3-N concentrations and loads, and D) flow-weighted mean atrazine concentrations and loads from Big Spring groundwater for WYs 1982 through 1999.

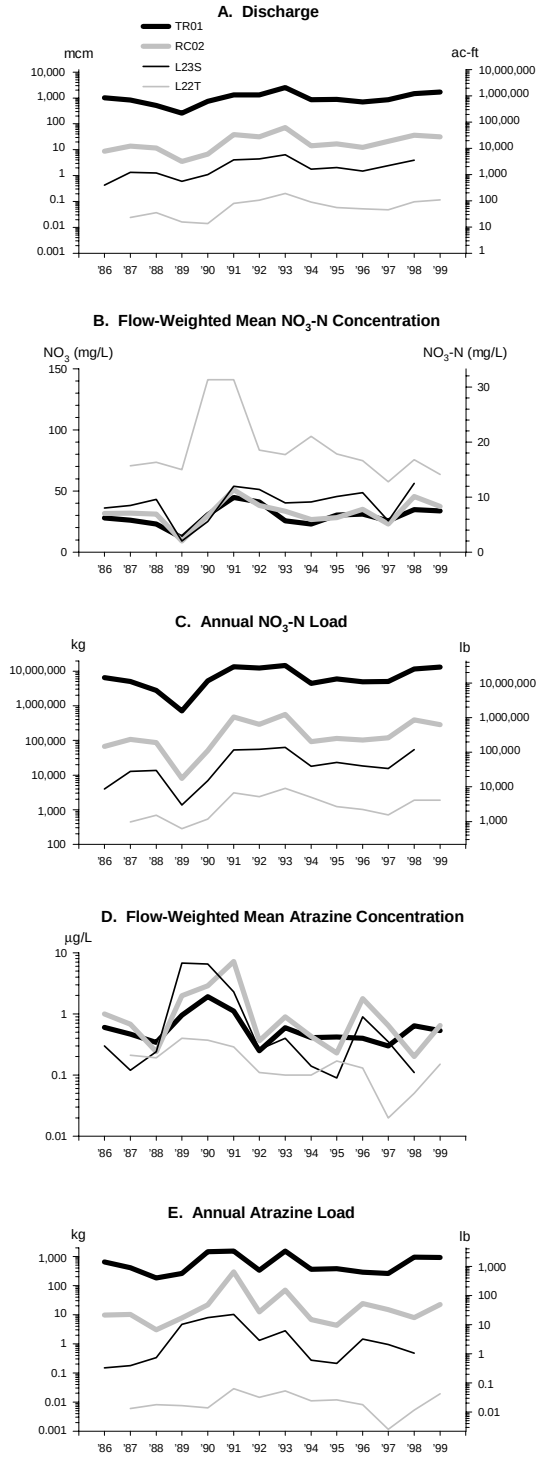

Figure 30. Summary of annual A) discharge, B) flow-weighted mean NO_3-N concentrations and C) loads, and D) flow-weighted mean atrazine concentrations and E) loads for TR01, RC02, L23S and L22T for WYs 1986 through 1999.

transport of contaminants within the basin's hydrologic system. Monitoring results during WYs 1996-1999 particularly illustrate the effects.

Water years 1994-1996 were relatively dry in the Big Spring basin. The annual precipitation was 30.42 inches for WY 1994, 29.28 inches for WY 1995, and 30.59 inches for WY 1996. These totals were 2.55 inches, 3.69 inches and 2.38 inches below the long-term average precipitation, respectively (Table 1). During WY 1996, the annual precipitation in the basin was 1.31 inches greater than WY 1995, but the annual groundwater discharge at Big Spring was 1,870 ac-ft less than the annual discharge for WY 1995. The discharge/ precipitation ratio decreased from 18.7% in WYs 1994 and 1995 to 16.7% in WY 1996. Following lower than normal annual precipitation for three consecutive years, WY 1997 was relatively wet, with annual precipitation of 38.29 inches. This amount was 5.32 inches above the long-term average, and was the fourth greatest annual precipitation within the basin since monitoring began in WY 1982. The groundwater discharge from Big Spring, however, did not increase but decreased significantly from 28,143 ac-ft in WY 1996 to 22,943 ac-ft in WY 1997 (Fig. 29A & B). In other words, WY 1997 received 116% of the normal annual precipitation, but the annual groundwater discharge from Big Spring declined to 72% of the annual average. The discharge as a percentage of precipitation correspondingly decreased from 16.7% in WY 1996 to 10.9% in WY 1997. This was the third lowest discharge/ precipitation ratio recorded in the basin since WY 1982 (Table 1). Throughout the monitoring period, annual groundwater discharge at Big Spring has often not coincided with annual precipitation. The regression analysis shows that the coefficient of determination (r^2) for discharge versus precipitation is 0.46 (Fig. 31). If water years with extremely high or low precipitation are removed from the analysis, the coefficient of determination decreases to 0.002, indicating almost no correlation between annual precipitation and groundwater discharge at Big Spring.

Several factors, including precipitation intensity and timing, distribution patterns, soil moisture,

Table 30. Water year summary for tile line site L22T, Silver Creek (L23S), Roberts Creek (RC02), Turkey River (TR01), and Big Spring (BSP) for WYs 1986 through 1999.

	Water Year													
	86*	87	88	89	90	91	92	93	94	95	96	97	98	99
							Discharge (in.)							
L22T		3.2	4.9	2.2	2.0	11.2	14.6	26.6	12.6	7.9	7.0	6.4	12.9	15.1
L23S	1.7	5.2	4.9	2.4	4.2	15.4	17.0	24.4	6.8	8.0	5.8	9.3	14.9	**
RC02	2.1	3.2	2.7	0.8	1.6	8.9	7.4	16.4	3.4	3.9	2.8	5.0	8.4	7.3
TR01	11.2	8.5	5.3	2.7	7.7	13.4	13.4	25.5	8.7	8.9	7.1	8.7	14.7	17.0
BSP+	5.5	4.6	4.7	2.3	3.2	7.7	6.8	10.6	5.7	5.5	5.1	4.2	6.5	7.0
							Flow weighted mean NO_3 concentration (mg/L)							
L22T		71	73	67	141	141	83	80	95	80	75	58	76	64
L23S	36	38	43	9	25	54	52	40	41	46	49	26	56	**
RC02	31	32	31	9	30	51	38	33	27	28	35	23	46	38
TR01	28	26	23	12	31	44	41	26	23	30	31	26	35	34
BSP+	43	41	43	25	37	56	54	51	47	45	46	44	56	53
							NO_3-N load (lbs/acre)							
L22T		11.4	18.1	7.3	13.8	79.2	61.3	107.1	59.7	31.8	26.4	18.4	48.9	48.2
L23S	3.1	9.7	10.6	1.1	5.4	41.7	44.0	49.5	14.0	18.4	14.2	12.1	42.1	**
RC02	3.3	5.2	4.2	0.4	2.5	22.8	14.2	27.4	4.5	5.5	5.0	5.8	19.2	13.9
TR01	14.5	11.2	6.1	1.6	11.8	29.9	27.6	32.8	10.0	13.4	11.0	11.3	25.7	29.0
BSP+	12.0	9.5	10.2	3.0	5.9	21.9	18.5	27.2	13.5	12.5	12.0	9.1	18.4	18.1
							Flow weighted mean atrazine concentration (µg/L)							
L22T		0.21	0.19	0.40	0.37	0.29	0.11	0.10	0.10	0.17	0.13	0.02	0.05	0.15
L23S	0.30	0.12	0.24	6.75	6.52	2.30	0.26	0.40	0.14	0.09	0.89	0.35	0.11	**
RC02	1.00	0.68	0.24	1.98	2.89	7.20	0.36	0.90	0.43	0.23	1.79	0.65	0.20	0.65
TR01	0.60	0.47	0.34	0.95	1.90	1.11	0.25	0.59	0.41	0.42	0.40	0.30	0.64	0.53
BSP+	0.35	0.25	0.13	0.61	1.06	1.17	0.22	0.27	0.21	0.12	0.27	0.17	0.12	0.24
							Atrazine load (lbs)							
L22T		0.013	0.018	0.017	0.014	0.063	0.032	0.053	0.024	0.026	0.018	0.003	0.012	0.042
L23S	0.30	0.40	0.80	10.1	17.4	22.5	2.90	6.20	0.59	0.47	3.27	2.08	1.05	**
RC02	21.1	22.5	6.70	17.1	48.8	655	27.2	152	15.0	9.40	52.2	32.8	17.5	49.3
TR01	1,407	891	407	571	3,259	3,325	739	3,386	806	841	637	579	2,109	2,025
BSP+	29.0	17.6	9.20	21.2	50.0	135	22.5	42.0	17.8	9.80	20.5	10.5	11.6	23.8

+ Big Spring.

* Not available for L22T; partial water year for L23S and RC02.

** Not available for this water year because of the omission of discharge data.

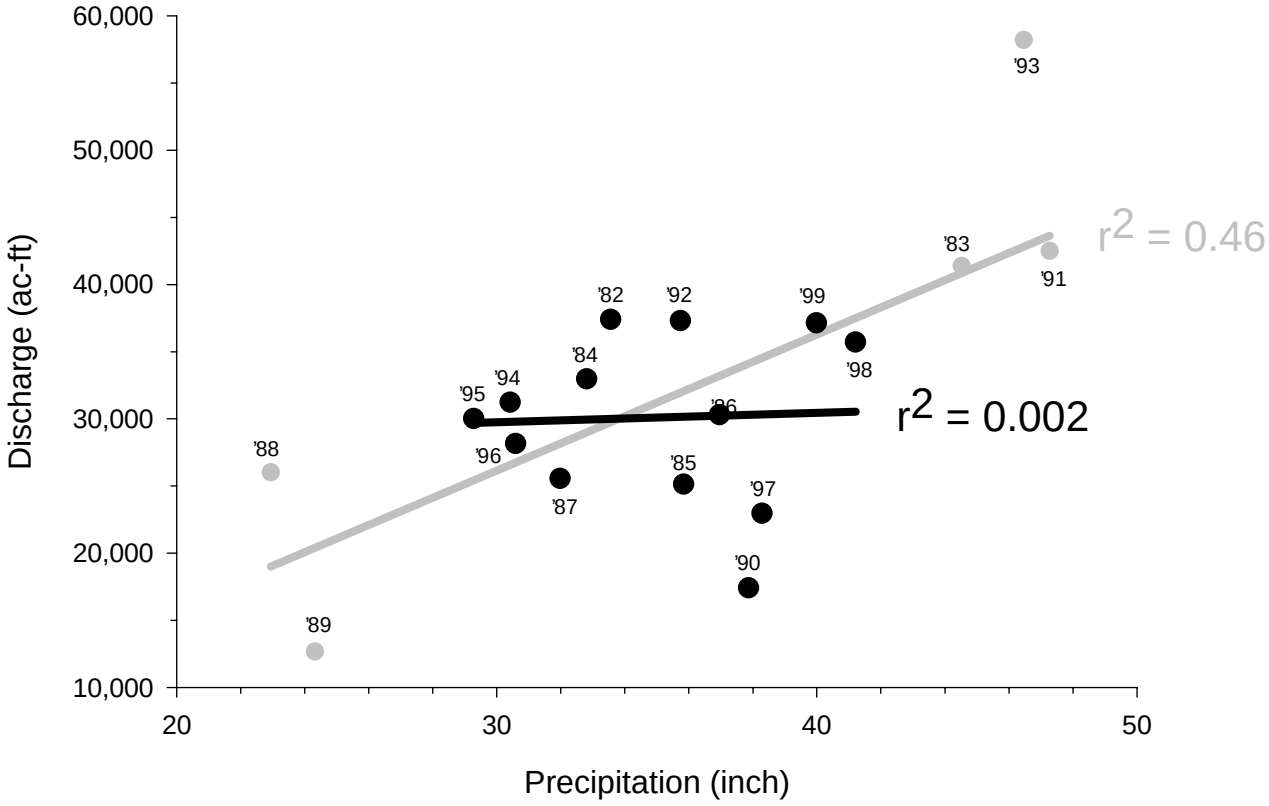

Figure 31. Regression of annual precipitation versus groundwater discharge for Big Spring. The coefficient of determination (r^2) for the completed data is 0.46, for the selected water years is 0.002.

groundwater storage, and antecedent conditions, may be responsible for the non-linear discharge/ precipitation relationship. In WY 1997, precipitation was quite evenly distributed throughout the year, and most significant rainfall occurred during the growing season. During May through September, precipitation in the Big Spring basin was 23.69 inches, which was 3.52 inches greater than normal. Because of high evapotranspiration rates during this period, most rainfall events did not generate significant runoff in the basin. However, the most important factor affecting the discharge/ precipitation ratio in WY 1997 was probably the dry antecedent conditions in the Big Spring basin. Following three years of below normal precipitation, much of the rainfall in WY 1997 probably infiltrated into the soil, and recharged the less transmissive portions of the basin's hydrologic system that had been depleted during WYs 1994-1996.

Another example of the effects of antecedent conditions occurred in WY 1999. Following two years with above normal precipitation, WY 1999 was another wet year. By the end of May, the total precipitation in the Big Spring area was 23.68 inches, or 6.84 inches greater than normal for this period of the water year. The continued above normal rainfall saturated the soil within the basin, and made groundwater discharge at Big Spring more respective to runoff. During May 16 and 17, the Big Spring basin had a two-day precipitation total of 4.23 inches. Although this was not an extreme amount of precipitation, the groundwater discharge rate at Big Spring increased to 490 cfs on May 17, which was the greatest discharge rate recorded at Big Spring since monitoring started in 1981. On the same day, the surface water

discharge rate of the Turkey River increased to 43,400 cfs, which was the greatest daily discharge rate since WY 1913 (Nalley et al., 2000).

Water quality can be affected by variations in discharge. Based on the long-term monitoring results, this is especially true with the annual fw mean nitrate-N concentrations and loads of both groundwater at Big Spring and surface water of different streams within the basin (Figs. 29C, 30B & C). However, the annual discharge at Big Spring decreased from 30,013 ac-ft in WY 1995 to 28,143 ac-ft in WY 1996, while the annual fw mean nitrate concentration increased from 45.3 mg/L (10.1 mg/L as NO_3-N) to 46.4 mg/L (10.3 mg/L as NO_3-N). Water Year 1996 was the first year of monitoring that the annual fw mean nitrate concentration increased as the annual groundwater discharge decreased, even though the increase was small. The increase may have resulted from a lack of significant groundwater flux during late WY 1995. The lack of recharge may have left nitrate in the soil, which was later leached into the groundwater system during WY 1996. Conversely, the annual fw mean nitrate concentration decreased from 56 mg/L in WY 1998 to 53 mg/L in WY 1999, while the annual groundwater discharge at Big Spring increased from 35,713 ac-ft in WY 1998 to 37,133 ac-ft in WY 1999. Before WY 1999, this situation only occurred in WY 1993, when the fw mean nitrate concentration decreased from 54 mg/L (12.0 mg/L as NO_3-N) to 51 mg/L (11.3 mg/L as NO_3-N) as the annual discharge increased from 37,278 ac-ft to 58,186 ac-ft (Rowden et al., 1995b). Correspondingly, the annual nitrate-N load also decreased from 1,212,455 pounds in WY 1998 to 1,189,548 pounds in WY 1999. Water Year 1999 was the first year of monitoring that the annual nitrate-N load decreased as the groundwater discharge increased. The declining nitrate concentration and load in WY 1999 may suggest that nitrate had been leached from the soil during the relatively wet WYs 1997 and 1998, leaving less available for transport to the hydrologic system during WY 1999.

The declines may also have resulted from improvements in nitrogen management within the basin. Although there are different sources of nitrogen within the Big Spring basin, the greatest nitrogen input is from fertilizer applied to corn. From 1981 to 1993, the average rates for fertilizer used on corn within the basin were reduced from 174 to 115 pounds per acre, lowering nitrogen loading by 34% with no apparent yield losses (Rowden et al., 1995b, 1998).

Atrazine is the most frequently detected pesticide in the Big Spring basin hydrologic system. Atrazine concentrations from Big Spring varied significantly during the WY 1996-1999 period, although concentrations remained at relatively low levels compared with levels during WYs 1990 and 1991 (Fig. 29D). Unlike nitrate, variations in annual atrazine loads and fw mean concentrations do not coincide with changes in annual groundwater discharge. The annual atrazine load at Big Spring increased from 9.8 pounds in WY 1995 to 20.5 pounds in WY 1996, and the annual fw mean atrazine concentration correspondingly increased from the lowest value recorded, 0.12 µg/L, to 0.27 µg/L. In WY 1997, the fw mean atrazine concentration and load decreased to 0.17 µg/L and 10.5 pounds, which were the third lowest recorded since WY 1982. In WY 1998, the annual fw mean atrazine concentration continued decreasing to 0.12 µg/L. Although the average annual atrazine concentration and load increased in WY 1999, they remained at relatively low levels compared with most monitored years. During recent years, the number of non-detections of atrazine for Big Spring and other monitoring sites has increased (see Appendix B), significantly reducing the annual atrazine discharge from the Big Spring basin.

The reduced atrazine concentrations and loads during recent years may result from a number of factors. Extensive educational programs aimed at reducing the input of agricultural chemicals may play an important role in the continued reduction of atrazine concentrations and loads within the Big Spring basin. Although it is difficult to obtain accurate estimates of atrazine use within the basin, farm surveys have shown that atrazine application rates have been reduced from about 2 pounds per acre in the early 1980's to less than 1.5 pounds per

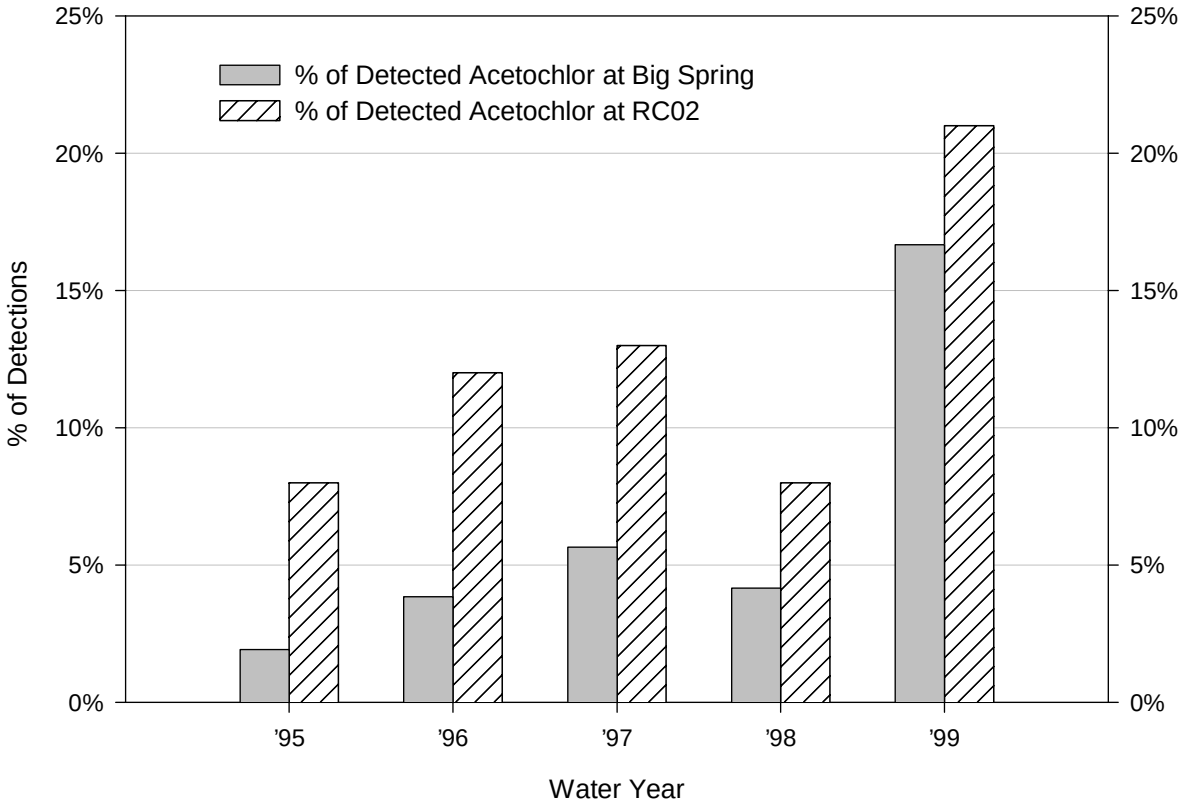

Figure 32. Percentage of acetochlor detections for Big Spring and RC02 from WY 1995 through WY 1999.

acre by 1990 (Rowden et al., 1995b, 1998). Reductions of atrazine concentrations and loads may also result from the replacement of atrazine by other herbicides. Acetochlor, for example, is a relatively new herbicide that is now commonly used in the basin. Acetochlor was added to the list of pesticide analyses for the Big Spring project in August 1994, and no samples with detectable acetochlor in that water year. In WY 1995, 2% of the samples analyzed from Big Spring contained detectable acetochlor (>0.1 µg/L). The percentage of detection for acetochlor was 4% in WY 1996, 6% in WY 1997, 4% in WY 1998, and 17% in WY 1999 (Fig. 32). Acetochlor was also detected at other sites within the Big Spring basin at increasing frequencies and concentrations. For example, 8% of samples collected at RC02 in WY 1995 contained detectable acetochlor. The percentage of detections was 12% in WY 1996, 13% in WY 1997, 8% in WY 1998, and rose to 21% in WY 1999.

Sampling time and frequency also affect the computation of concentrations and loads of agricultural compounds. Generally, a greater sampling frequency increases the accuracy of estimates for the computation of fw mean atrazine concentrations and loads. Based on previous studies, high atrazine concentrations usually accompany significant runoff events, while concentration peaks for nitrate-nitrogen usually occur within a few days after the discharge peak. Because peak runoff is temporary, chemical concentrations change as discharge recedes. Therefore, accurate computation of nitrate and in particular atrazine concentrations, as well as accurate annual loads, are dependent on both scheduled routine sampling and specific event sampling. In WYs 1996 through 1999, only routine samples were collected. This probably reduced

the annual averages of the fw mean concentrations and loads of those analyzed agricultural contaminants. Since WY 1998, the sampling schedule for pesticide analyses was changed from weekly to monthly or twice monthly. It is probable that some significant changes in contaminant concentrations were missed during the intervals between the prolonged sample collections and that these changes affect the accuracy of the data for these water years.

The degradation of atrazine has also been considered as a factor affecting atrazine concentrations and loads (Kolpin and Kalkhoff, 1993; Rowden et al., 1995, 1998; Liu et al., 1997). Research indicates that biotic degradation of atrazine initially produces either desethyl atrazine or desisopropyl atrazine. The data from this study show that detections of desethyl atrazine are much more frequent than desisopropyl atrazine in the Big Spring basin. During WYs 1996-1999, 577 samples were collected from the five monitored sites within the basin for pesticide analyses. Of these, 51%, contained detectable atrazine, 58% contained detectable desethyl atrazine, and only 6 samples, or 1%, contained detectable desisopropyl atrazine. These results strongly support research that suggests desethyl atrazine be the more stable initial degradation product (Adams and Thurman, 1991). At the five monitoring sites within the Big Spring basin, desethyl atrazine occurred year round, and has shown trends similar to atrazine in both groundwater and surface water. This supports the suggestion that abiotic processes may also be a likely cause of atrazine degradation (Kolpin and Kalkhoff, 1993).

OVERVIEW OF MONITORING RESULTS FOR WYs 1982 THROUGH 1999

Annual precipitation in the Big Spring basin has varied from 22.9 inches in WY 1988 to 47.3 inches in WY 1991. The long-term average is 32.97 inches. Groundwater discharge rates at Big Spring have varied between 10.7 cfs on December 26, 1989 and 490 cfs on May 17, 1999, with a long-term average of 48 cfs. The annual groundwater discharge at Big Spring has fluctuated from 12,672 ac-ft in WY 1989 to 58,186 ac-ft in WY 1993. The long-term average annual discharge is 31,773 ac-ft. The groundwater discharge as percentage of precipitation has ranged from 8.0% in WY 1990 to 23.0% in WY 1993, with a long-term average of 16.3%. As mentioned above, annual groundwater discharge at Big Spring often does not correlate well with annual precipitation. Figure 33 shows the annual precipitation and groundwater discharge departures from the long-term average. During the monitoring period, significant discordance between annual precipitation and groundwater discharge occurred in WYs 1985, 1990, and 1997, when annual precipitation totals were significantly greater than the long-term average while annual groundwater discharges were far below the long-term average. Research indicates that these discrepancies resulted from antecedent soil moisture conditions within the basin, and variance in the intensity, timing, and distribution patterns of precipitation (Liu et al., 1999).

For the Turkey River basin above Garber, annual precipitation has varied between 23.3 inches in WY 1988 and 50.6 inches in WY 1993 during the WY 1982-1999 period. Daily discharge rates at Garber have ranged from 56 cfs on December 22, 1989 to 43,400 cfs on May 17, 1999, with an average of 1,299 cfs. The annual discharge totals varied from 220,700 ac-ft in WY 1989 to 2,103,000 ac-ft in WY 1993. Surface water discharge monitoring at RC02 started on March 25, 1986. During the monitoring period, there was no flow for a total of 112 days in 1989, 1990, and 1992. The greatest mean daily discharge rate, 7,090 cfs, was recorded on June 15, 1991. At RC02, the long-term average daily discharge rate is about 32 cfs, and the annual discharge totals has ranged from 3,160 ac-ft in WY 1989 to 61,970 ac-ft in WY 1993. Discharge monitoring at L23S started on May 13, 1986 and ended on September 30, 1998. During this period, the creek was dry for 43 days in 1989 and 1990. The greatest daily discharge rate, 431 cfs, occurred on May 15, 1991. The average discharge rate for the monitoring period was 3.2 cfs, and the annual discharge totals varied between 552 ac-ft in WY

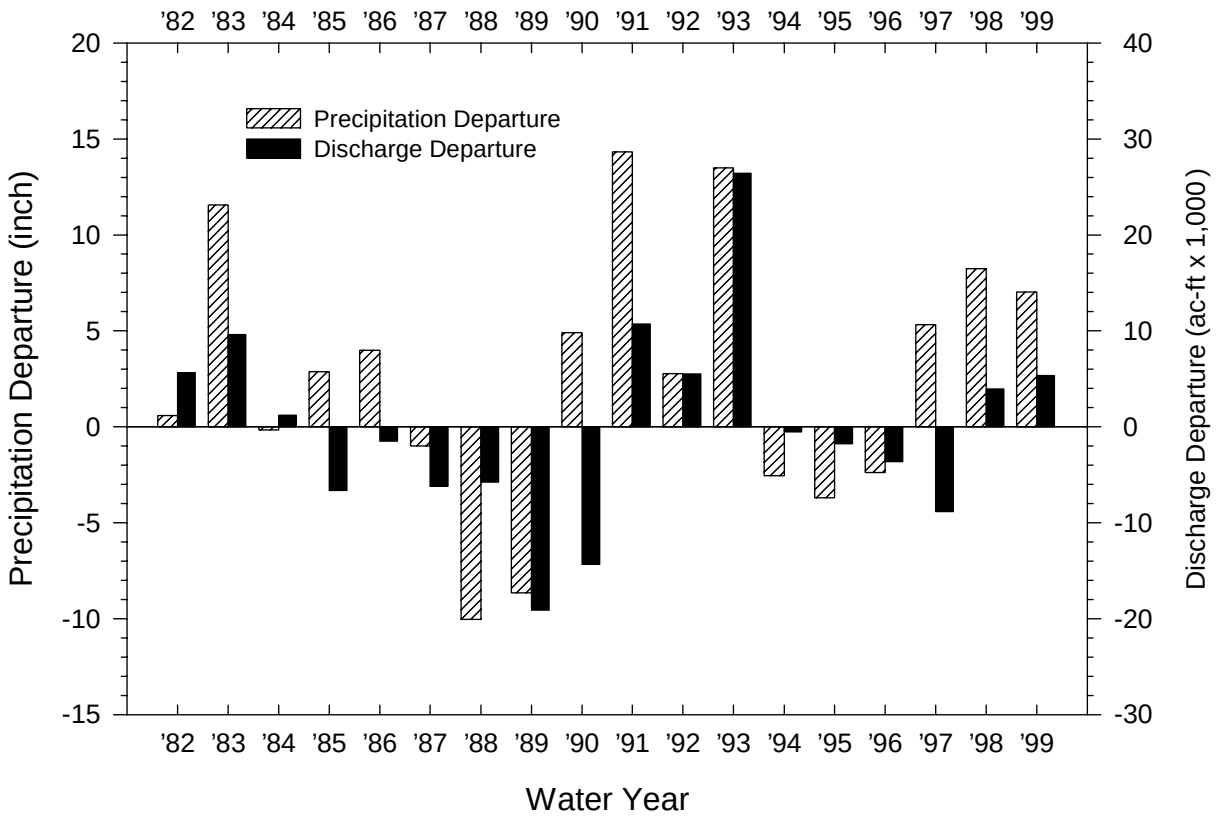

Figure 33. Annual precipitation and Big Spring groundwater discharge departures from long-term average for WYs 1982 through 1999.

1989 to 5,720 ac-ft in WY 1993. Shallow groundwater monitoring at tile line site L22T was from October 1, 1986 through September 30, 1999. During this period, there was no discharge at L22T for two days (January 1 and 20, 1990). The greatest daily discharge rate, 0.96 cfs, occurred on six days in 1991 and 1992. The long-term average discharge rate was about 0.10 cfs. The annual discharge totals varied from 13.8 ac-ft in WY 1990 to 188.7 ac-ft in WY 1993.

The annual fw mean nitrate concentrations and total nitrogen loads during the monitoring period are illustrated in figures 29C, 30B and 30C, and in appended tables C-1 through C-5. The long-term monitoring results show that annual nitrate-N loads correspond well with changes in annual groundwater discharge during the monitoring period. The annual fw mean nitrate concentrations coincided with annual groundwater and surface water discharge changes during most of the monitoring period. At Big Spring, the annual fw mean nitrate concentration has varied between 25 mg/L (5.7 mg/L as NO_3-N) in WY 1989 and 56 mg/L (12.5 mg/L as NO_3-N) in WYs 1991 and 1998. The annual nitrate-N load has fluctuated significantly between 194,928 pounds in WY 1989 and 1.8 million pounds in WY 1993, and averaged around 888,000 pounds. Ammonia-N was analyzed for at Big Spring from WY 1986 through WY 1998. The annual fw mean concentrations ranged from <0.1 mg/L in WYs 1995, 1996 and 1998 to 0.6 mg/L in WY 1989. Organic-N was analyzed for at Big Spring between WYs 1986 and 1994, with an annual fw mean concentration range of 0.1 mg/L in WY 1994 to 0.9 mg/L in WY 1991.

For TR01, the annual fw mean nitrate

concentration has varied from 12 mg/L (2.6 mg/L as NO_3-N) in WY 1989 to 44 mg/L (9.9 mg/L as NO_3-N) in WY 1991. The annual nitrate-N load has fluctuated between 1.58 million pounds in WY 1989 and 32.4 million pounds in WY 1993, and averaged around 15.9 million pounds during the WYs 1984-1999 period. Ammonia-N was analyzed for at TR01 from WY 1987 through WY 1994, then in WYs 1997 and 1998. The annual fw mean concentrations ranged between 0.08 mg/L in WY 1998 and 1.39 mg/L in WY 1989. Organic-N was analyzed for at TR01 between WYs 1987 and 1993, annual fw mean concentrations ranged from 0.65 mg/L in WY 1992 to 2.40 mg/L in WY 1989.

Nitrogen nutrients were monitored at RC02 from mid WY 1986 through WY 1999. The annual fw mean nitrate concentration has varied from 9.1 mg/L (2.0 mg/L as NO_3-N) in WY 1989 to 51 mg/L (11.3 mg/L as NO_3-N) in WY 1991. The annual nitrate-N load has ranged between 17,393 pounds in WY 1989 and 1.2 million pounds in WY 1993, and averaged around 432,800 pounds. Ammonia-N was analyzed for at RC02 from WY 1986 through WY 1998. The annual fw mean concentrations ranged from 0.1 mg/L in WYs 1986, 1987, 1988, 1991 and 1992 to 1.0 mg/L in WY 1993. Organic-N was analyzed for at RC02 between WYs 1986 and 1994. Annual fw mean concentrations of organic-N ranged from 0.2 mg/L in WYs 1987 and 1994 to 1.7 mg/L in WY 1993.

At L23S, nitrogen nutrient concentrations were monitored from WY 1986 through WY 1999. Annual fw mean concentrations and loads for nitrate-N and ammonia-N are only available through WY 1998 because discharge monitoring ended in WY 1998. The annual fw mean nitrate concentrations at L23S varied between 9.0 mg/L (2.0 mg/L as NO_3-N) in WY 1989 and 56 mg/L (12.5 mg/L as NO_3-N) in WY 1998. The annual nitrate-N load has fluctuated between 2,998 pounds in WY 1989 and 138,951 pounds in WY 1993, and averaged about 57,400 pounds. The annual fw mean concentrations for ammonia-N ranged from 0.1 mg/L in WYs 1986 through 1988, 1991 through 1993, and 1998, to 2.4 mg/L in WY 1989. Organic-N was analyzed at L23S between WYs 1986 and 1993, with annual fw mean concentrations ranging from 0.1 mg/L in WY 1989 to 2.9 mg/L in WY 1990.

Nitrogen nutrients were analyzed for at L22T from WY 1987 through WY 1999. Nitrate concentrations were usually high at L22T. The annual fw mean nitrate concentrations have varied from 58 mg/L (12.8 mg/L as NO_3-N) in WY 1997 to 141 mg/L (31.3 mg/L as NO_3-N) in WYs 1990 and 1991. The annual nitrate-N load has ranged between 622 pounds in WY 1989 and 9,103 pounds in WY 1993. The long-term average load is around 3,476 pounds. Ammonia-N and organic-N were analyzed for at L22T from WY 1987 through WY 1994. The annual fw mean ammonia-N concentration ranged from less than 0.1 mg/L in WYs 1990 and 1991 to 0.2 mg/L in WY 1993. Annual fw mean concentrations of organic-N ranged from less than 0.1 mg/L in WY 1994 to 0.7 mg/L in WY 1988.

Figures 29D, 30D & E and Table 30, appended tables C1 through C5 summarize the atrazine distribution trends, annual loads and fw mean concentrations at the five monitoring sites in Big Spring basin during monitoring periods. As mentioned above, atrazine concentrations and loads did not show a linear relationship with groundwater and surface water discharge, but did show decreases since WY 1991. At Big Spring, the annual fw mean atrazine concentrations have varied from 0.12 µg/L in WYs 1995 and 1998 to 1.17 µg/L in WY 1991, and annual atrazine loads have ranged from 9.2 pounds in WY 1988 to 135 pounds in WY 1991. The long-term annual atrazine load averaged 30.8 pounds. For TR01, annual fw mean atrazine concentrations varied between 0.25 µg/L in WY 1992 and 1.90 µg/L in WY 1990, while annual atrazine loads have ranged from 407 pounds in WY 1988 to 3,386 pounds in WY 1993. The long-term average was 1,499 pounds. Annual fw mean atrazine concentrations at RC02 varied from 0.20 µg/L in WY 1998 to 7.20 µg/L in WY 1991, and annual atrazine outputs ranged from 6.7 pounds in WY 1988 to 655 pounds in WY 1991. The average annual atrazine load at RC02 was 80.5 pounds for the monitoring period. For L23S, annual fw mean atrazine concentrations varied

between 0.09 µg/L in WY 1995 and 6.75 µg/L in WY 1989. Annual atrazine loads at L23S have ranged from 0.4 pounds in WY 1987 to 22.5 pounds in WY 1991. The long-term average annual atrazine load at L23S was 5.64 pounds. For tile line L22T, the lowest annual fw mean atrazine concentration, 0.02 µg/L, and load, 0.003 pounds, occurred in WY 1997. Water Year 1989 had the greatest annual fw mean atrazine concentration at 0.40 µg/L, while WY 1991 had the greatest annual atrazine load at 0.063 pounds. The long-term average annual atrazine load at L22T was 0.024 pounds.

Appendix tables C-6 through C-10 show the percentages of detections and maximum concentrations for common pesticides in groundwater and surface water at the monitoring sites. Of the analyzed pesticides, atrazine and one of its metabolites, desethyl atrazine, were the most frequently detected, followed by cyanazine, alachlor, and metolachlor. Metribuzin was rarely detected at Big Spring, L23S, and L22T, at less than 1% of total analyses. Metribuzin was not detected at TR01 and RC02. The insecticide fonofos was only rarely detected at Big Spring and RC02. Trifluralin was only detected once at RC02 in WY 1990. Acetochlor was added to the analysis list in August of 1994. Since then, it has been detected at an increasing rate in the Big Spring basin. Overall, however, the annual percentage of detections for most agricultural chemicals have been declining during the last few years. The occurrence of atrazine has significantly declined at all monitoring sites during recent years, while desethyl atrazine has not. This may be related to atrazine degradation mechanisms, but the details remain unknown.

SUMMARY

Groundwater and surface-water discharge and water quality within the Big Spring basin have been monitored since WY 1982. Results from the monitoring project provide a long-term view of water quality trends in the basin, as well as a large amount of data concerning agricultural contamination of water resources. Although some questions remain to be solved in the future, the 18-year monitoring record has largely improved our understanding of nonpoint source contamination.

The monitoring data have shown that the discharge of Big Spring is not linearly related to precipitation, but controlled by the amount, timing, and intensity of precipitation and snowmelt. Climatic variations, along with antecedent conditions, also exert a significant control on the transport, concentrations, and loads of agricultural-related contaminants.

Water quality within a watershed depends on many factors, including geological setting, climatic features, recharge/discharge rates, chemical transport and degradation mechanics, and application rates of agricultural chemicals. The results from the Big Spring monitoring project indicate that nitrate contamination is closely related to average water flux through the Big Spring hydrologic system on an annual basis. However, annual atrazine concentrations and loads do not show this relationship. In the Big Spring basin, atrazine concentrations and loads have significantly decreased since WY 1991. Along with other factors, changes in atrazine applications within the basin may play an important role in these reductions.

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The development of monitoring sites within the Big Spring basin has been a cooperative effort. The USGS, Water Resources Division in Iowa City designed, constructed and maintained the stream gaging stations and also cooperated in water-quality monitoring. Tile monitoring sites and a surface-water flume site were designed and constructed by Dr. James Baker, Department of Agricultural Engineering, ISU, Agriculture and Home Economics Experiment Station. Other cooperating agencies included the departments of Agronomy and Botany, ISU, and the University of Iowa Hygienic Laboratory.

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APPENDIX A

Monthly summaries of nitrate-N discharge for Big Spring, Turkey River, Silver Creek and tile line site L22T for WYs 1996 through 1999 and Roberts Creek for WYs 1993 through 1999

Table A-1. Monthly summary of nitrate-N discharged from the Roberts Creek (RC02) for WY 1993.

	1992 Oct	Nov	Dec	1993 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	30.5	35.6	44.6	47.9	41.3	19.1	32.6	41.1	34.2	35.0	39.2	39.6
as NO_3-N	6.8	7.9	9.9	10.6	9.2	4.2	7.2	9.1	7.6	7.8	8.7	8.8
Mean of NO_3 analyses,												
in mg/L;	29.8	40.2	46.3	47.8	42.3	33.0	38.8	40.3	44.4	48.0	41.2	39.0
as NO_3-N	6.6	8.9	10.3	10.6	9.4	7.3	8.6	8.9	9.9	10.7	9.2	8.7
Total monthly NO_3-N output,												
thousands lbs	18.2	55.4	77.7	27.1	16.0	141	196	135	128	250	127	69.5
Total monthly NO_3-N output,												
thousands kg	8.2	25.1	35.2	12.3	7.3	63.8	89.0	61.3	58.0	114	57.7	31.5

Table A-2. Monthly summary of nitrate-N discharged from the Roberts Creek (RC02) for WY 1994.

	1993 Oct	Nov	Dec	1994 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	36.3	36.9	38.1	40.8	25.3	19.5	24.1	15.0	19.7	25.8	19.2	14.0
as NO_3-N	8.1	8.2	8.5	9.1	5.6	4.3	5.3	3.3	4.4	5.7	4.3	3.1
Mean of NO_3 analyses,												
in mg/L;	37.4	37.7	38.0	41.4	35.7	27.4	23.4	14.5	26.9	27.5	19.3	15.1
as NO_3-N	8.3	8.4	8.5	9.2	7.9	6.1	5.2	3.2	6.0	6.1	4.3	3.4
Total monthly NO_3-N output,												
thousands lbs	34.9	27.3	23.6	14.3	15.7	34.5	16.0	6.1	7.7	12.3	7.5	4.2
Total monthly NO_3-N output,												
thousands kg	15.8	12.4	10.7	6.5	7.1	15.6	7.3	2.8	3.5	5.6	3.4	1.9

Nitrate was only analyzed for the first month in this water year. The means of analyses for nitrate are calculated from NO_3-N.

Table A-3. Monthly summary of nitrate-N discharged from the Roberts Creek (RC02) for WY 1995.

	1994 Oct	Nov	Dec	1995 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	19.3	22.2	27.4	28.1	20.0	18.0	30.6	36.2	39.4	20.6	18.0	16.0
as NO_3-N	4.3	4.9	6.1	6.2	4.4	4.0	6.8	8.1	8.7	4.6	4.0	3.6
Mean of NO_3 analyses,												
in mg/L;	19.5	22.2	27.3	28.1	22.5	20.1	28.4	40.1	34.8	19.5	14.5	16.0
as NO_3-N	4.3	4.9	6.1	6.2	5.0	4.5	6.3	8.9	7.7	4.3	3.2	3.6
Total monthly NO_3-N output,												
thousands lbs	4.1	7.7	8.6	5.3	5.0	29.8	85.9	60.0	30.8	7.7	3.5	1.9
Total monthly NO_3-N output,												
thousands kg	1.9	3.5	3.9	2.4	2.3	13.5	39.0	27.2	14.0	3.5	1.6	0.86

Nitrate was not analyzed in this water year. The means of analyses for nitrate are calculated from NO_3-N.

Table A-4. Monthly summary of nitrate-N discharged in groundwater from the Big Spring basin to the Turkey River for WY 1996.

	1995 Oct	Nov	Dec	1996 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	43.4	50.4	48.5	42.4	32.8	38.6	41.8	41.4	55.0	57.2	49.7	44.6
as NO_3-N	9.6	11.2	10.8	9.4	7.3	8.6	9.3	9.2	12.2	12.7	11.0	9.9
Mean of NO_3 analyses,												
in mg/L;	43.8	51.8	48.4	45.0	35.9	41.1	41.8	40.7	57.4	56.7	49.5	44.6
as NO_3-N	9.7	11.5	10.8	10.0	8.0	9.1	9.3	9.1	12.8	12.6	11.0	9.9
Total monthly NO_3-N output,												
thousands lbs	39.6	57.2	46.6	49.7	58.7	63.1	48.0	47.2	180	98.8	57.0	43.1
Total monthly NO_3-N output,												
thousands kg	17.9	25.9	21.1	22.6	26.6	28.6	21.8	21.4	81.8	44.8	25.8	19.5

Table A-5. Monthly summary of nitrate-N discharged from the Turkey River (TR01) for WY 1996.

	1995 Oct	Nov	Dec	1996 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	33.4	37.1	34.0	32.0	16.1	18.8	20.8	17.4	45.4	32.8	30.4	24.3
as NO_3-N	7.4	8.3	7.6	7.1	3.6	4.2	4.6	3.9	10.1	7.3	6.8	5.4
Mean of NO_3 analyses,												
in mg/L;	32.6	38.3	36.0	32.2	18.8	18.8	20.8	17.3	46.0	32.2	29.5	24.5
as NO_3-N	7.2	8.5	8.0	7.2	4.2	4.2	4.6	3.8	10.2	7.2	6.6	5.4
Total monthly NO_3-N output,												
thousands lbs	437	723	356	361	518	858	563	480	4,796	1,121	457	249
Total monthly NO_3-N output,												
thousands kg	198	328	161	164	235	389	255	218	2,175	509	207	113

Table A-6. Monthly summary of nitrate-N discharged from the Roberts Creek (RC02) for WY 1996.

	1995 Oct	Nov	Dec	1996 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	19.3	34.1	33.3	35.2	17.7	21.1	21.5	11.8	48.8	43.7	17.8	11.0
as NO_3-N	4.3	7.6	7.4	7.8	3.9	4.7	4.8	2.6	10.9	9.7	3.9	2.4
Mean of NO_3 analyses,												
in mg/L;	19.9	38.4	33.6	34.3	20.3	22.1	21.8	11.7	47.3	39.7	17.2	11.0
as NO_3-N	4.4	8.5	7.5	7.6	4.5	4.9	4.8	2.6	10.5	8.8	3.8	2.5
Total monthly NO_3-N output,												
thousands lbs	4.0	17.7	5.9	4.8	4.0	18.3	10.2	5.0	132	21.3	3.1	0.95
Total monthly NO_3-N output,												
thousands kg	1.8	8.0	2.7	2.2	1.8	8.3	4.6	2.3	59.9	9.6	1.4	0.43

Nitrate was not analyzed in this water year. The means of analysis for nitrate are calculated from NO_3-N.

Table A-7. Monthly summary of nitrate-N discharged from the Silver Creek (L23S) for WY 1996.

	1995 Oct	Nov	Dec	1996 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	39.2	41.5	42.7	46.0	27.5	26.8	35.5	34.6	64.7	60.5	40.7	37.1
as NO_3-N	8.7	9.2	9.5	10.2	6.1	5.9	7.9	7.7	14.4	13.5	9.1	8.2
Mean of NO_3 analyses,												
in mg/L;	39.7	44.0	43.0	47.3	32.1	24.9	35.6	33.4	73.5	58.5	40.0	37.1
as NO_3-N	8.8	9.8	9.6	10.5	7.1	5.5	7.9	7.4	16.3	13.0	8.9	8.3
Total monthly NO_3-N output,												
lbs	795	1,426	893	1,613	1,775	2,046	2,156	1,784	19,999	4,975	1,725	896
Total monthly NO_3-N output,												
kg	360	647	405	732	805	928	978	809	9,070	2,256	783	406

Nitrate was not analyzed in this water year. The means of analysis for nitrate are calculated from NO_3-N.

Table A-8. Monthly summary of nitrate-N discharged from the tile line site L22T for WY 1996.

	1995 Oct	Nov	Dec	1996 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	80.1	79.7	83.9	72.9	46.5	63.1	74.9	83.8	89.8	87.9	81.8	82.4
as NO_3-N	17.8	17.7	18.7	16.2	10.3	14.0	16.6	18.6	20.0	19.5	18.2	18.3
Mean of NO_3 analyses,												
in mg/L;	80.0	83.0	84.5	82.2	57.8	61.3	74.8	88.8	91.0	87.6	81.5	82.5
as NO_3-N	17.8	18.4	18.8	18.3	12.8	13.6	16.6	19.7	20.2	19.5	18.1	18.3
Total monthly NO_3-N output,												
lbs	163	178	131	137	250	155	143	143	550	172	119	99.3
Total monthly NO_3-N output,												
kg	73.8	80.7	59.6	62.0	114	70.5	64.8	64.9	249	77.9	54.0	45.1

Table A-9. Monthly summary of nitrate-N discharged in groundwater from the Big Spring basin to the Turkey River for WY 1997.

	1996 Oct	Nov	Dec	1997 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	42.3	41.4	41.6	37.6	30.1	31.5	41.6	46.4	48.6	57.2	53.4	43.9
as NO_3-N	9.4	9.2	9.2	8.4	6.7	7.0	9.3	10.3	10.8	12.7	11.9	9.8
Mean of NO_3 analyses,												
in mg/L;	42.2	41.6	41.8	39.0	36.9	30.8	41.6	47.3	47.1	56.7	52.9	43.7
as NO_3-N	9.4	9.3	9.3	8.7	8.2	6.9	9.2	10.5	10.5	12.6	11.8	9.7
Total monthly NO_3-N output,												
thousands lbs	35.1	27.5	29.7	38.0	39.0	50.5	37.0	63.2	64.5	92.6	75.1	50.4
Total monthly NO_3-N output,												
thousands kg	15.9	12.5	13.5	17.3	17.7	22.9	16.8	28.7	29.2	42.0	34.1	22.9

Table A-10. Monthly summary of nitrate-N discharged from the Turkey River (TR01) for WY 1997.

	1996 Oct	Nov	Dec	1997 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	20.7	31.9	37.0	31.7	17.5	14.1	32.6	34.8	25.4	31.7	26.6	30.9
as NO_3-N	4.6	7.1	8.2	7.0	3.9	3.1	7.3	7.7	5.7	7.0	5.9	6.9
Mean of NO_3 analyses,												
in mg/L;	23.2	33.3	35.2	32.0	31.0	13.3	30.6	33.3	26.3	32.2	28.5	31.2
as NO_3-N	5.2	7.4	7.8	7.1	6.9	2.9	6.8	7.4	5.8	7.2	6.3	6.9
Total monthly NO_3-N output,												
thousands lbs	251	572	607	501	482	1,555	1,509	2,046	1,249	1,165	625	641
Total monthly NO_3-N output,												
thousands kg	114	260	275	227	219	705	684	928	566	528	283	291

Table A-11. Monthly summary of nitrate-N discharged from the Roberts Creek (RC02) for WY 1997.

	1996 Oct	Nov	Dec	1997 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	13.4	21.0	28.7	25.6	13.6	17.4	26.9	29.5	27.2	36.6	27.8	33.2
as NO_3-N	3.0	4.7	6.4	5.7	3.0	3.9	6.0	6.6	6.0	8.1	6.2	7.4
Mean of NO_3 analyses,												
in mg/L;	14.0	23.0	29.1	28.2	21.2	19.0	26.6	34.7	24.5	38.3	28.0	33.4
as NO_3-N	3.1	5.1	6.5	6.3	4.7	4.2	5.9	7.7	5.5	8.5	6.2	7.4
Total monthly NO_3-N output,												
thousands lbs	1.4	3.1	3.6	5.6	28.9	54.0	29.5	36.2	19.6	28.5	17.7	33.0
Total monthly NO_3-N output,												
thousands kg	0.62	1.4	1.6	2.5	13.1	24.5	13.4	16.4	8.9	12.9	8.0	15.0

Nitrate was not analyzed in this water year. The means of analysis for nitrate are calculated from NO_3-N.

Table A-12. Monthly summary of nitrate-N discharged from the Silver Creek (L23S) for WY 1997.

	1996 Oct	Nov	Dec	1997 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	35.7	37.9	38.4	34.1	10.8	20.8	40.0	40.8	43.6	48.4	39.2	38.9
as NO_3-N	7.9	8.4	8.5	7.6	2.4	4.6	8.9	9.1	9.7	10.8	8.7	8.6
Mean of NO_3 analyses,												
in mg/L;	34.2	41.3	39.0	40.0	30.1	32.8	39.7	46.6	50.9	54.0	38.7	38.8
as NO_3-N	7.6	9.2	8.7	8.9	6.7	7.3	8.8	10.4	11.3	12.0	8.6	8.6
Total monthly NO_3-N output,												
lbs	788	1,018	806	1,008	4,511	7,452	1,381	3,135	3,589	3,635	2,528	4,144
Total monthly NO_3-N output,												
kg	357	462	366	457	2,046	3,380	626	1,422	1,628	1,649	1,146	1,879

Nitrate was not analyzed in this water year. The means of analysis for nitrate are calculated from NO_3-N.

Table A-13. Monthly summary of nitrate-N discharged from the tile line site L22T for WY 1997.

	1996 Oct	Nov	Dec	1997 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	77.6	69.1	69.2	58.2	34.1	36.2	64.0	63.1	71.8	70.6	72.2	66.7
as NO_3-N	17.2	15.3	15.4	12.9	7.6	8.0	14.2	14.0	16.0	15.7	16.0	14.8
Mean of NO_3 analyses,												
in mg/L;	76.2	70.8	70.8	72.0	42.5	51.8	67.8	77.0	75.5	72.2	73.8	67.0
as NO_3-N	16.9	15.7	15.7	16.0	9.4	11.5	15.1	17.1	16.8	16.0	16.4	14.9
Total monthly NO_3-N output,												
lbs	113	114	109	135	122	178	124	156	125	129	132	128
Total monthly NO_3-N output,												
kg	51.3	51.6	49.2	61.3	55.5	80.5	56.3	70.5	56.9	58.7	60.1	58.0

Table A-14. Monthly summary of nitrate-N discharged in groundwater from the Big Spring basin to the Turkey River for WY 1998.

	1997 Oct	Nov	Dec	1998 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	51.4	52.4	50.0	45.3	45.6	55.4	60.3	57.6	59.1	63.0	55.5	52.1
as NO_3-N	11.4	11.6	11.1	10.1	10.1	12.3	13.4	12.8	13.1	14.0	12.3	11.6
Mean of NO_3 analyses,												
in mg/L;	52.9	52.9	49.5	41.9	48.4	58.1	66.4	57.4	64.8	61.9	56.3	52.2
as NO_3-N	11.8	11.8	11.0	9.3	10.8	12.9	14.8	12.8	14.4	13.8	12.5	11.6
Total monthly NO_3-N output,												
thousands lbs	72.3	56.9	41.7	36.3	41.9	138	235	108	173	144	94.0	72.0
Total monthly NO_3-N output,												
thousands kg	32.8	25.8	18.9	16.5	19.0	62.4	107	48.9	78.7	65.1	42.7	32.6

Nitrate was not analyzed in this water year. The means of analyses for nitrate are calculated from NO_3-N.

Table A-15. Monthly summary of nitrate-N discharged from the Turkey River (TR01) for WY 1998.

	1997 Oct	Nov	Dec	1998 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	34.3	34.0	35.7	39.5	25.7	35.2	37.0	39.9	36.5	35.3	22.8	26.7
as NO_3-N	7.6	7.6	7.9	8.8	5.7	7.8	8.2	8.9	8.1	7.8	5.1	5.9
Mean of NO_3 analyses,												
in mg/L;	31.8	34.5	37.0	30.3	27.3	37.0	39.3	40.5	38.4	35.3	23.5	26.6
as NO_3-N	7.1	7.7	8.2	6.7	6.1	8.2	8.7	9.0	8.5	7.8	5.2	5.9
Total monthly NO_3-N output,												
thousands lbs	1,574	775	533	679	787	3,192	5,753	2,397	5,325	2,753	1,007	656
Total monthly NO_3-N output,												
thousands kg	714	352	242	308	357	1,448	2,609	1,087	2,415	1,249	457	297

Table A-16. Monthly summary of nitrate-N discharged from the Roberts Creek (RC02) for WY 1998.

	1997 Oct	Nov	Dec	1998 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	39.5	41.2	44.8	34.5	19.2	48.0	54.5	43.4	43.9	53.0	30.9	26.1
as NO_3-N	8.8	9.2	10.0	7.7	4.3	10.7	12.1	9.6	9.8	11.8	6.9	5.8
Mean of NO_3 analyses,												
in mg/L;	46.5	39.8	44.1	37.6	28.7	50.3	55.1	43.0	57.1	45.1	32.0	26.1
as NO_3-N	10.3	8.9	9.8	8.4	6.4	11.2	12.3	9.6	12.7	10.0	7.1	5.8
Total monthly NO_3-N output,												
thousands lbs	77.5	24.5	12.6	9.5	16.5	167	261	52.0	157	68.5	18.9	4.1
Total monthly NO_3-N output,												
thousands kg	35.1	11.1	5.7	4.3	7.5	75.7	118	23.6	71.2	31.1	8.6	1.9

Nitrate was not analyzed in this water year. The means of analyses for nitrate are calculated from NO_3-N.

Table A-17. Monthly summary of nitrate-N discharged from the Silver Creek (L23S) for WY 1998.

	1997 Oct	Nov	Dec	1998 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	47.0	53.1	47.9	41.4	36.2	61.3	67.4	55.3	51.5	69.8	44.4	41.3
as NO_3-N	10.5	11.8	10.6	9.2	8.0	13.6	15.0	12.3	11.5	15.5	9.9	9.2
Mean of NO_3 analyses,												
in mg/L;	62.9	52.9	48.1	45.2	43.6	63.0	70.9	55.1	64.4	61.9	46.1	41.2
as NO_3-N	14.0	11.8	10.7	10.1	9.7	14.0	15.8	12.3	14.3	13.8	10.3	9.2
Total monthly NO_3-N output,												
lbs	9,565	3,346	1,707	1,460	4,088	17,691	26,158	7,039	23,004	17,569	5,092	1,633
Total monthly NO_3-N output,												
kg	4,338	1,517	774	662	1,854	8,023	11,863	3,192	10,433	7,968	2,309	741

Nitrate was not analyzed in this water year. The means of analyses for nitrate are calculated from NO_3-N.

Table A-18. Monthly summary of nitrate-N discharged from the tile line site L22T for WY 1998.

	1997 Oct	Nov	Dec	1998 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	80.3	67.7	64.0	62.7	56.9	72.3	82.1	74.0	86.5	81.2	66.8	64.7
as NO_3-N	17.9	15.0	14.2	13.9	12.6	16.1	18.3	16.4	19.2	18.0	14.8	14.4
Mean of NO_3 analyses,												
in mg/L;	65.3	67.0	64.0	62.5	58.8	71.8	88.0	73.8	86.4	75.8	67.3	64.2
as NO_3-N	14.5	14.9	14.2	13.9	13.1	16.0	19.6	16.4	19.2	16.8	14.9	14.3
Total monthly NO_3-N output,												
lbs	281	129	118	110	142	482	911	292	700	468	294	226
Total monthly NO_3-N output,												
kg	128	58.5	53.4	50.1	64.6	219	413	133	317	212	133	102

Table A-19. Monthly summary of nitrate-N discharged in groundwater from the Big Spring basin to the Turkey River for WY 1999.

	1998 Oct	Nov	Dec	1999 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	48.9	52.7	51.5	46.9	45.6	48.6	49.2	57.4	61.3	54.8	53.2	49.6
as NO_3-N	10.9	11.7	11.5	10.4	10.1	10.8	10.9	12.8	13.6	12.2	11.8	11.0
Mean of NO_3 analyses,												
in mg/L;	48.0	52.3	51.4	45.7	46.3	47.6	50.8	60.0	60.6	55.0	52.8	49.3
as NO_3-N	10.7	11.6	11.4	10.1	10.3	10.6	11.3	13.3	13.5	12.2	11.7	10.9
Total monthly NO_3-N output,												
thousands lbs	68.3	84.7	65.0	48.2	64.7	57.9	114	254	150	110	101	71.8
Total monthly NO_3-N output,												
thousands kg	31.0	38.4	29.5	21.8	29.3	26.3	51.6	115	67.9	49.8	45.9	32.5

Table A-20. Monthly summary of nitrate-N discharged from the Turkey River (TR01) for WY 1999.

	1998 Oct	Nov	Dec	1999 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	36.3	35.7	34.0	31.5	28.8	28.8	32.7	38.6	44.6	24.8	33.7	30.6
as NO_3-N	8.1	7.9	7.6	7.0	6.4	6.4	7.3	8.6	9.9	5.5	7.5	6.8
Mean of NO_3 analyses,												
in mg/L;	37.8	36.3	34.8	30.3	29.3	28.4	36.0	41.3	45.0	29.8	33.6	30.0
as NO_3-N	8.4	8.1	7.7	6.7	6.5	6.3	8.0	9.2	10.0	6.6	7.5	6.7
Total monthly NO_3-N output,												
thousands lbs	1,687	1,885	894	390	1,284	966	3,340	7,432	3,712	3,622	2,517	955
Total monthly NO_3-N output,												
thousands kg	765	855	406	177	582	438	1,515	3,370	1,683	1,642	1,142	433

Table A-21. Monthly summary of nitrate-N discharged from the Roberts Creek (RC02) for WY 1999.

	1998 Oct	Nov	Dec	1999 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	25.0	35.3	34.2	32.5	29.3	29.2	31.7	42.4	49.7	30.7	35.0	34.0
as NO_3-N	5.6	7.8	7.6	7.2	6.5	6.5	7.1	9.4	11.0	6.8	7.8	7.6
Mean of NO_3 analyses,												
in mg/L;	26.0	35.8	36.0	32.3	32.0	29.2	39.8	56.0	53.4	33.0	36.4	32.3
as NO_3-N	5.8	7.9	8.0	7.2	7.1	6.5	8.8	12.4	11.9	7.3	8.1	7.2
Total monthly NO_3-N output,												
thousands lbs	13.0	32.9	11.2	5.0	33.5	17.7	80.6	259	94.4	45.0	30.8	6.1
Total monthly NO_3-N output,												
thousands kg	5.9	14.9	5.1	2.3	15.2	8.0	36.6	117	42.8	20.4	14.0	2.8

Table A-22. Monthly summary of nitrate-N discharged from the tile line site L22T for WY 1999.

	1998 Oct	Nov	Dec	1999 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean NO_3 concentration,												
in mg/L;	59.0	59.3	60.8	59.6	40.0	59.7	60.4	72.5	72.6	64.3	65.4	67.1
as NO_3-N	13.1	13.2	13.5	13.2	8.9	13.3	13.4	16.1	16.1	14.3	14.5	14.9
Mean of NO_3 analyses,												
in mg/L;	60.3	59.0	60.6	58.7	49.5	59.0	66.0	76.3	75.6	65.8	65.4	53.6
as NO_3-N	13.4	13.1	13.5	13.0	11.0	13.1	14.7	16.9	16.8	14.6	14.5	11.9
Total monthly NO_3-N output,												
lbs	274	222	176	151	206	170	441	844	647	402	329	231
Total monthly NO_3-N output,												
kg	124	101	80	68	94	77	200	383	294	182	149	105

APPENDIX B

Monthly summaries of atrazine discharge for Big Spring, Turkey River, Silver Creek and tile line site L22T for WYs 1996 through 1999 and Roberts Creek for WYs 1993 through 1999

Table B-1. Monthly summary of atrazine discharged from the Roberts Creek (RC02) for WY 1993.

	1992 Oct	Nov	Dec	1993 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow weighted mean atrazine concentration, in µg/L	0.09	0.26	0.03	0.01	0.03	0.49	0.22	0.20	3.0	2.1	0.30	0.21
Mean of atrazine analyses, in µg/L	0.08	0.10	*	*	0.03	0.17	0.19	0.25	5.7	1.0	0.26	0.24
Total monthly atrazine output, lbs	0.25	1.8	0.25	0.02	0.05	16.3	6.0	3.0	50.6	67.6	4.4	1.7
Total monthly atrazine output, kg	0.11	0.83	0.11	0.01	0.02	7.4	2.7	1.4	23.0	30.7	2.0	0.77

* All samples below detection limit.

Table B-2. Monthly summary of atrazine discharged from the Roberts Creek (RC02) for WY 1994.

	1993 Oct	Nov	Dec	1994 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.21	0.06	0.03	0.03	0.22	0.23	0.06	0.37	4.0	1.5	0.16	0.09
Mean of atrazine analyses, in µg/L	0.20	0.05	0.03	0.03	0.07	0.08	0.06	0.46	4.4	0.31	0.14	0.06
Total monthly atrazine output, lbs	0.91	0.19	0.07	0.04	0.61	1.8	0.19	0.68	7.0	3.1	0.29	0.12
Total monthly atrazine output, kg	0.41	0.09	0.03	0.02	0.28	0.81	0.09	0.31	3.2	1.4	0.13	0.05

Table B-3. Monthly summary of atrazine discharged from the Roberts Creek (RC02) for WY 1995.

	1994 Oct	Nov	Dec	1995 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.12	*	*	*	0.12	0.10	*	0.73	0.61	0.31	0.21	0.13
Mean of atrazine analyses, in µg/L	0.10	*	*	*	0.08	0.05	*	0.72	0.27	0.16	0.27	0.13
Total monthly atrazine output, lbs	0.12	0.01	*	*	0.14	0.73	*	5.5	2.1	0.53	0.19	0.07
Total monthly atrazine output, kg	0.05	0.003	*	*	0.06	0.33	*	2.5	0.97	0.24	0.09	0.03

* All samples below detection limit.

Table B-4. Monthly summary of atrazine discharged in groundwater from the Big Spring basin to the Turkey River for WY 1996.

	1995 Oct	Nov	Dec	1996 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.03	0.08	0.01	0.16	0.32	0.06	0.03	0.18	0.80	0.24	0.14	0.11
Mean of atrazine analyses, in µg/L	0.02	0.06	*	0.06	0.14	0.06	0.02	0.18	0.84	0.24	0.14	0.10
Total monthly atrazine output, lbs	0.13	0.39	0.03	0.84	2.6	0.47	0.14	0.92	11.8	1.9	0.72	0.50
Total monthly atrazine output, kg	0.06	0.18	0.01	0.38	1.2	0.21	0.06	0.42	5.4	0.86	0.33	0.22

* All samples below detection limit.

Table B-5. Monthly summary of atrazine discharged from the Turkey River (TR01) for WY 1996.

	1995 Oct	Nov	Dec	1996 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.06	0.12	0.04	0.12	0.23	0.15	0.12	0.25	0.92	0.32	0.19	0.15
Mean of atrazine analyses, in µg/L	*	*	0.10	0.12	0.22	0.15	0.13	0.39	0.81	0.16	0.21	0.13
Total monthly atrazine output, lbs	3.4	10.1	2.0	6.0	33.1	31.2	14.3	31.4	438	48.6	12.5	7.0
Total monthly atrazine output, kg	1.5	4.6	0.92	2.7	15.0	14.1	6.5	14.3	199	22.0	5.7	3.2

* All samples below detection limit.

Table B-6. Monthly summary of atrazine discharged from the Roberts Creek (RC02) for WY 1996.

	1995 Oct	Nov	Dec	1996 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.06	0.09	*	0.05	0.21	0.17	0.07	0.43	4.0	0.48	0.54	0.22
Mean of atrazine analyses, in µg/L	0.04	0.03	*	0.07	0.15	0.12	0.06	0.33	3.1	0.41	0.75	0.24
Total monthly atrazine output, lbs	0.05	0.21	*	0.03	0.21	0.65	0.15	0.81	48.6	1.1	0.43	0.09
Total monthly atrazine output, kg	0.02	0.10	*	0.01	0.10	0.29	0.07	0.37	22.0	0.48	0.19	0.04

* All samples below detection limit.

Table B-7. Monthly summary of atrazine discharged from the Silver Creek (L23S) for WY 1996.

	1995 Oct	Nov	Dec	1996 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.07	0.08	0.02	0.07	0.27	0.12	0.07	0.43	2.1	0.19	0.10	0.02
Mean of atrazine analyses, in µg/L	0.13	*	*	*	0.44	0.20	*	1.6	0.48	0.13	*	*
Total monthly atrazine output, ounces	0.10	0.19	0.03	0.19	1.2	0.68	0.29	1.6	46.6	1.1	0.30	0.03
Total monthly atrazine output, grams	2.8	5.4	0.80	5.3	35.0	19.3	8.1	45.5	1,322	31.7	8.5	0.83

* All samples below detection limit.

Table B-8. Monthly summary of atrazine discharged from the tile line site L22T for WY 1996.

	1995 Oct	Nov	Dec	1996 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.11	0.12	0.11	0.15	0.20	0.12	0.10	0.11	0.15	0.09	0.08	0.10
Mean of atrazine analyses, in µg/L	0.09	0.11	0.11	0.11	0.14	0.12	0.08	0.09	0.13	0.08	0.08	0.09
Total monthly atrazine output, ounces	0.02	0.02	0.01	0.02	0.08	0.02	0.01	0.01	0.06	0.01	0.01	0.01
Total monthly atrazine output, grams	0.45	0.54	0.35	0.56	2.3	0.61	0.38	0.37	1.8	0.34	0.25	0.24

Table B-9. Monthly summary of atrazine discharged in groundwater from the Big Spring basin to the Turkey River for WY 1997.

	1996 Oct	Nov	Dec	1997 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.11	0.10	0.03	0.09	0.32	0.23	*	0.08	0.39	0.24	0.13	0.07
Mean of atrazine analyses, in µg/L	0.11	0.08	0.02	0.05	0.03	0.16	*	0.06	0.37	0.26	0.13	0.06
Total monthly atrazine output, lbs	0.42	0.29	0.10	0.40	1.9	1.6	*	0.48	2.3	1.7	0.82	0.38
Total monthly atrazine output, kg	0.19	0.13	0.04	0.18	0.84	0.74	*	0.22	1.1	0.79	0.37	0.17

* All samples below detection limit.

Table B-10. Monthly summary of atrazine discharged from the Turkey River (TR01) for WY 1997.

	1996 Oct	Nov	Dec	1997 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.10	0.11	0.06	0.02	0.12	0.29	0.08	0.56	0.82	0.16	0.15	0.12
Mean of atrazine analyses, in µg/L	0.11	0.11	*	*	0.12	0.14	*	0.56	1.3	0.31	0.13	0.11
Total monthly atrazine output, lbs	5.7	9.2	4.3	1.7	14.4	145	16.2	148	182	26.2	15.4	11.1
Total monthly atrazine output, kg	2.6	4.2	1.9	0.8	6.5	65.7	7.4	67.3	82.5	11.9	7.0	5.1

* All samples below detection limit.

Table B-11. Monthly summary of atrazine discharged from the Roberts Creek (RC02) for WY 1997.

	1996 Oct	Nov	Dec	1997 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.68	0.23	0.14	0.16	0.69	0.51	0.09	0.27	4.0	0.59	0.24	0.13
Mean of atrazine analyses, in µg/L	0.28	0.18	0.11	0.07	0.05	0.18	0.11	0.27	3.9	0.73	0.22	0.14
Total monthly atrazine output, lbs	0.31	0.15	0.08	0.16	6.7	7.1	0.47	1.5	13.0	2.1	0.70	0.58
Total monthly atrazine output, kg	0.14	0.07	0.03	0.07	3.0	3.2	0.21	0.69	5.9	0.94	0.32	0.27

Table B-12. Monthly summary of atrazine discharged from the Silver Creek (L23S) for WY 1997.

	1996 Oct	Nov	Dec	1997 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.05	0.03	0.01	0.02	0.78	0.13	0.05	0.16	0.51	0.21	0.11	0.07
Mean of atrazine analyses, in µg/L	*	*	*	*	*	*	*	0.13	0.58	0.19	*	*
Total monthly atrazine output, ounces	0.09	0.06	0.01	0.05	23.5	3.4	0.12	0.87	3.1	1.1	0.51	0.51
Total monthly atrazine output, grams	2.5	1.6	0.3	1.4	667	96.8	3.3	24.6	86.6	31.9	14.6	14.5

* All samples below detection limit.

Table B-13. Monthly summary of atrazine discharged from the tile line site L22T for WY 1997.

	1996 Oct	Nov	Dec	1997 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.06	0.02	*	*	*	*	*	*	0.08	0.10	0.06	0.01
Mean of atrazine analyses, in µg/L	0.06	*	*	*	*	*	*	*	0.06	0.08	0.05	*
Total monthly atrazine output, ounces	0.01	0.003	*	*	*	*	*	*	0.01	0.01	0.01	0.001
Total monthly atrazine output, grams	0.17	0.08	*	*	*	*	*	*	0.28	0.36	0.24	0.03

* All samples below detection limit.

Table B-14. Monthly summary of atrazine discharged in groundwater from the Big Spring basin to the Turkey River for WY 1998.

	1997 Oct	Nov	Dec	1998 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.09	*	*	*	0.02	0.08	0.11	0.17	0.24	0.16	0.15	0.11
Mean of atrazine analyses, in µg/L	0.07	*	*	*	*	0.08	0.05	0.28	0.27	0.13	0.16	0.06
Total monthly atrazine output, lbs	0.57	*	*	*	0.06	0.91	2.0	1.5	3.2	1.6	1.1	0.68
Total monthly atrazine output, kg	0.26	*	*	*	0.03	0.41	0.91	0.66	1.4	0.73	0.51	0.31

* All samples below detection limit.

Table B-15. Monthly summary of atrazine discharged from the Turkey River (TR01) for WY 1998.

	1997 Oct	Nov	Dec	1998 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.09	*	**	0.03	0.06	0.04	0.09	2.0	1.9	0.49	0.18	0.12
Mean of atrazine analyses, in µg/L	*	*	**	*	*	*	*	4.1	2.5	0.17	0.17	*
Total monthly atrazine output, lbs	17.7	*	**	2.7	8.0	18.3	60.4	544	1,236	173	35.8	13.5
Total monthly atrazine output, kg	8.0	*	**	1.2	3.6	8.3	27.4	247	561	78.4	16.2	6.1

* All samples below detection limit. ** No samples taken.

Table B-16. Monthly summary of atrazine discharged from the Roberts Creek (RC02) for WY 1998.

	1997 Oct	Nov	Dec	1998 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.13	*	*	*	0.06	0.07	0.11	0.34	0.55	0.25	0.15	0.02
Mean of atrazine analyses, in µg/L	0.14	*	*	*	*	0.06	0.12	1.0	0.33	0.16	0.15	*
Total monthly atrazine output, lbs	1.1	*	*	*	0.24	1.2	2.4	1.8	8.9	1.5	0.42	0.01
Total monthly atrazine output, kg	0.52	*	*	*	0.11	0.53	1.1	0.83	4.0	0.66	0.19	0.005

* All samples below detection limit.

Table B-17. Monthly summary of atrazine discharged from the Silver Creek (L23S) for WY 1998.

	1997 Oct	Nov	Dec	1998 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.11	*	*	0.05	0.07	0.09	0.10	0.10	0.19	0.13	0.03	*
Mean of atrazine analyses, in µg/L	*	*	*	*	*	*	*	0.13	0.23	0.10	*	*
Total monthly atrazine output, ounces	1.6	*	*	0.13	0.60	1.8	2.9	0.89	6.3	2.3	0.29	*
Total monthly atrazine output, grams	45.4	*	*	3.6	17.0	51.4	82.0	25.2	177	65.7	8.1	*

* All samples below detection limit.

Table B-18. Monthly summary of atrazine discharged from the tile line site L22T for WY 1998.

	1997 Oct	Nov	Dec	1998 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.01	*	*	*	0.03	*	0.02	*	0.11	0.07	0.12	0.10
Mean of atrazine analyses, in µg/L	*	*	*	*	*	*	*	*	0.11	0.05	0.11	0.06
Total monthly atrazine output, ounces	0.003	*	*	*	0.01	*	0.02	*	0.07	0.03	0.04	0.03
Total monthly atrazine output, grams	0.09	*	*	*	0.18	*	0.56	*	1.9	0.85	1.1	0.71

* All samples below detection limit.

Table B-19. Monthly summary of atrazine discharged in groundwater from the Big Spring basin to the Turkey River for WY 1999.

	1998 Oct	Nov	Dec	1999 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.07	0.02	*	*	0.03	*	0.04	0.52	0.68	0.25	0.18	0.14
Mean of atrazine analyses, in µg/L	0.06	*	*	*	*	*	*	0.24	0.66	0.24	0.18	0.13
Total monthly atrazine output, lbs	0.41	0.14	*	*	0.22	*	0.40	10.4	7.5	2.2	1.6	0.91
Total monthly atrazine output, kg	0.19	0.06	*	*	0.10	*	0.18	4.7	3.4	1.0	0.71	0.41

* All samples below detection limit.

Table B-20. Monthly summary of atrazine discharged from the Turkey River (TR01) for WY 1999.

	1998 Oct	Nov	Dec	1999 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.11	0.03	0.03	*	0.05	*	0.05	1.4	0.85	0.51	0.16	0.13
Mean of atrazine analyses, in µg/L	0.06	*	0.05	*	*	*	*	0.65	0.67	0.34	0.14	0.14
Total monthly atrazine output, lbs	22.3	6.4	3.2	*	10.9	*	21.2	1,235	318	335	53.8	18.8
Total monthly atrazine output, kg	10.1	2.9	1.4	*	5.0	*	9.6	560	144	152	24.4	8.5

* All samples below detection limit.

Table B-21. Monthly summary of atrazine discharged from the Roberts Creek (RC02) for WY 1999.

	1998 Oct	Nov	Dec	1999 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.03	0.01	*	*	0.05	0.01	0.08	1.1	1.3	0.72	0.23	0.11
Mean of atrazine analyses, in µg/L	*	*	*	*	*	*	*	0.41	1.1	0.42	0.17	0.07
Total monthly atrazine output, lbs	0.07	0.04	*	*	0.28	0.04	0.97	30.9	11.2	4.7	0.91	0.09
Total monthly atrazine output, kg	0.03	0.02	*	*	0.13	0.02	0.44	14.0	5.1	2.1	0.41	0.04

* All samples below detection limit.

Table B-22. Monthly summary of atrazine discharged from the tile line site L22T for WY 1999.

	1998 Oct	Nov	Dec	1999 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flow-weighted mean atrazine concentration, in µg/L	0.07	0.01	*	*	0.08	0.02	0.07	0.41	0.24	0.10	0.07	0.06
Mean of atrazine analyses, in µg/L	0.06	*	*	*	0.06	*	*	0.32	0.11	0.05	*	0.03
Total monthly atrazine output, ounces	0.03	0.002	*	*	0.03	0.004	0.03	0.34	0.15	0.05	0.02	0.02
Total monthly atrazine output, grams	0.71	0.06	*	*	0.89	0.10	0.98	9.8	4.3	1.3	0.68	0.43

* All samples below detection limit.

APPENDIX C

Water year summaries and summaries of annual % of detections and maximum concentrations of common pesticides for Big Spring, Turkey River, Roberts Creek, Silver Creek and tile line site L22T

Table C-1. Water year summary of groundwater, nitrogen, and atrazine discharges from the Big Spring basin to the Turkey River for WYs 1982 through 1999.

	Water Year																	
	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
Precipitation:																		
water inches	34.0	44.5	32.8	35.8	37.0	32.0	22.9	24.3	37.9	47.3	35.7	46.5	30.4	29.3	30.6	38.3	41.2	40.0
Groundwater discharge (Q) to the Turkey River:																		
mean Q, cfs	51.4	56.9	45.3	35.2	42.0	35.4	35.8	17.6	24.1	58.7	51.4	80.4	43.2	41.5	38.8	31.7	49.3	51.3
total Q, inches	6.8	7.5	5.9	4.6	5.5	4.6	4.7	2.3	3.2	7.7	6.8	10.6	5.7	5.5	5.1	4.2	6.5	6.8
acre-feet, 1000s	37.4	41.4	32.7	25.1	30.3	25.5	26.0	12.7	17.5	42.5	37.3	58.2	31.3	30.0	28.1	22.9	35.7	37.1
Nitrogen discharged with groundwater:																		
flow-wtd mean concentration, mg/L																		
as nitrate (NO_3)	39	46	43	31	43	41	43	25	37	56	54	51	47	45	46	44	56	53
as nitrate-N (NO_3-N)	8.8	10.3	9.7	7.0	9.7	9.1	9.5	5.7	8.2	12.5	12.0	11.4	10.4	10.1	10.3	9.7	12.5	11.8
ammonia-N*	*	*	*	*	0.1	0.1	0.1	0.6	0.1	0.1	0.1	0.2	0.2	<0.1	<0.1	0.1	<0.1	***
organic-N*	*	*	*	*	0.5	0.2	0.3	0.8	0.6	0.9	0.3	0.6	0.1	**	**	**	**	**
nitrogen load:																		
(nitrate-N + nitrite-N)																		
1,000s lbs-N	873.0	1,150	843.4	476.8	790.5	628.6	672.0	194.9	388.5	1,446	1,220	1,796	888.5	822.6	789.3	602.7	1,212	1,190
lbs-N/acre	13.2	17.4	12.8	7.2	12.0	9.5	10.2	3.0	5.9	21.9	18.5	27.2	13.5	12.5	12.0	9.1	18.4	18.0
(for total basin area)																		
Atrazine discharged with groundwater:																		
flow-wtd mean concentration,																		
atrazine, µg/L	0.31	0.28	0.45	0.70	0.35	0.25	0.13	0.61	1.06	1.17	0.22	0.27	0.21	0.12	0.27	0.17	0.12	0.24
atrazine load;																		
lbs - atrazine	14.2	31.2	40.0	47.6	29.0	17.6	9.2	21.2	50.0	135.0	22.5	42.0	17.8	9.8	20.5	10.5	11.6	23.8

* Prior to WY 1986 ammonia-N and organic-N were not analyzed frequently enough to calculate annual flow-weighted means.

** Since WY 1995, organic-N has been omitted from analysis list.

*** Since WY 1999, ammonia-N has been omitted from analysis list.

Table C-2. Water year summary of surface water, nitrogen, and atrazine discharges from the Turkey River (TR01) for WYs 1986 through 1999.

	Water Year													
	86	87	88	89	90	91	92	93	94	95	96	97	98	99
Precipitation:														
water inches*	40.7	32.0	23.3	25.0	38.3	36.9	35.8	50.6	31.2	30.1	29.2	35.5	41.2	42.6
Surface-water discharge (Q):														
mean Q, cfs	1,185	971	601	305	873	1,524	1,517	2,905	993	1,007	801	993	1,669	1,932
total Q, inches	10.4	8.5	5.3	2.7	7.7	13.4	13.4	25.5	8.7	8.9	7.1	8.7	14.7	17.0
acre-feet (thousands)	858	699	436	221	632	1,103	1,101	2,103	719	729	582	719	1,208	1,399
Nitrogen discharged with surface water: flow-wtd mean concentration, mg/L														
as nitrate (NO_3)	28.0	26.0	23.0	11.9	30.5	44.4	41.0	25.6	22.8	30.1	31.0	25.8	34.8	33.9
as nitrate-N (NO_3-N)	6.2	5.8	5.1	2.6	6.8	9.9	9.1	5.7	5.1	6.7	6.9	5.7	7.7	7.5
ammonia-N	n/a	0.18	0.14	1.39	0.78	0.46	0.15	0.50	0.35	n/a	n/a	0.33	0.08	n/a
organic-N	n/a	0.88	0.76	2.40	2.18	1.09	0.65	1.57	n/a	n/a	n/a	n/a	n/a	n/a
nitrogen load: (nitrate-N + nitrite-N)														
lbs-N (thousands)	14,306	11,120	6,053	1,580	11,650	29,592	27,244	32,448	9,903	13,253	10,920	11,202	25,433	28,683
lbs-N/acre (for total basin area)	14.5	11.2	6.1	1.6	11.8	29.9	27.6	32.8	10.0	13.4	11.0	11.3	25.7	29.0
Atrazine discharged with surface water: flow-wtd mean concentration,														
atrazine, µg/L	0.60	0.47	0.34	0.95	1.90	1.11	0.25	0.59	0.41	0.42	0.40	0.30	0.64	0.53
atrazine load;														
lbs - atrazine	1,407	891	407	571	3,259	3,325	739	3,386	803	841	637	579	2,109	2,025

* Data from IDALS,SCO for the state's northeast climatic division.

Table C-3. Water year summary of surface water, nitrogen, and atrazine discharges from the Roberts Creek (RC02) for WYs 1986 through 1999.

	Water Year													
	86*	87	88	89	90	91	92	93	94	95	96	97	98	99
Precipitation:														
water inches	25.8	32.0	22.9	24.3	37.9	47.3	35.7	46.5	30.4	29.3	30.6	38.3	41.2	40.0
Surface-water discharge (Q):														
mean Q, cfs	20.3	16.9	14.1	4.4	8.3	46.2	38.4	85.6	17.6	20.3	14.8	25.8	43.6	38.2
total Q, inches	2.1	3.2	2.7	0.8	1.6	8.9	7.4	16.4	3.4	3.9	2.8	5.0	8.4	7.3
acre-feet	7,771	12,220	10,193	3,160	6,030	33,443	27,890	61,970	12,710	14,720	10,720	18,660	31,540	27,680
Nitrogen discharged with surface water:														
flow-wtd mean concentration, mg/L														
as nitrate (NO_3)	31	32	31	9.1	30	51	38	33	27	28	35	23	46	38
as nitrate-N (NO_3-N)	7.0	7.1	6.9	2.0	6.6	11.3	8.5	7.4	5.9	6.3	7.8	5.1	10.1	8.3
ammonia-N	0.1	0.1	0.1	0.3	0.4	0.1	0.1	1.0	0.8	0.4	0.4	0.9	0.4	n/a
organic-N	0.5	0.2	0.3	1.1	1.2	1.1	0.3	1.7	0.2	n/a	n/a	n/a	n/a	n/a
nitrogen load: (nitrate-N + nitrite-N)														
lbs-N (thousands)	147	236	191	17	111	1,032	643	1,242	204	250	227	261	869	629
lbs-N/acre (for sub-basin area)	3.3	5.2	4.2	0.4	2.5	22.8	14.2	27.4	4.5	5.5	5.0	5.8	19.2	13.9
Atrazine discharged with surface water:														
flow-wtd mean concentration, atrazine, µg/L	1.00	0.68	0.24	1.98	2.89	7.20	0.36	0.90	0.43	0.23	1.79	0.65	0.20	0.65
atrazine load; lbs - atrazine	21.1	22.5	6.7	17.1	48.8	655	27.2	152	15.0	9.4	52.2	32.8	17.5	49.3

* Partial water year.

Table C-4. Water year summary of surface water, nitrogen, and atrazine discharges from the Silver Creek (L23S) for WYs 1986 through 1999.

	Water Year													
	86*	87	88	89	90	91	92	93	94	95	96	97	98	99
Precipitation:														
water inches	22.4	32.0	22.9	24.3	37.9	47.3	35.7	46.5	30.4	29.3	30.6	38.3	41.2	40.0
Surface-water discharge (Q):														
mean Q, cfs	1.3	1.7	1.6	0.8	1.4	4.9	5.5	7.9	2.2	2.6	1.9	3.0	4.8	**
total Q, inches	1.7	5.2	4.9	2.4	4.2	15.4	17.0	24.4	6.8	8.0	5.8	9.3	14.9	**
acre-feet	398	1,220	1,150	552	982	3,594	3,980	5,720	1,590	1,870	1,360	2,170	3,480	**
Nitrogen discharged with surface water: flow-wtd mean concentration, mg/L														
as nitrate (NO_3)	36	38	43	9	25	54	52	40	41	46	49	26	56	**
as nitrate-N (NO_3-N)	8.0	8.5	9.6	2.0	5.6	12.0	11.4	8.9	9.1	10.1	10.8	5.7	12.5	**
ammonia-N	0.1	0.1	0.1	2.4	1.2	0.1	0.1	0.1	1.0	0.4	0.4	1.7	0.1	**
organic-N	0.2	0.5	0.3	0.1	2.9	1.3	0.3	1.8	n/a	n/a	n/a	n/a	n/a	**
nitrogen load: (nitrate-N + nitrite-N)														
lbs-N	8,687	27,177	29,885	2,998	15,034	117,164	123,530	138,951	39,358	51,621	40,083	33,995	118,351	**
lbs-N/acre (for sub-basin area)	3.1	9.7	10.6	1.1	5.4	41.7	44.0	49.5	14.0	18.4	14.2	12.1	42.1	**
Atrazine discharged with surface water: flow-wtd mean concentration,														
atrazine, µg/L	0.30	0.12	0.24	6.75	6.52	2.30	0.26	0.40	0.14	0.09	0.89	0.35	0.11	**
atrazine load;														
lbs - atrazine	0.33	0.40	0.76	10.10	17.40	22.50	2.90	6.20	0.59	0.47	3.27	2.08	1.05	**

* Partial water year.

** Not available for this water year because of the omission of discharge data.

Table C-5. Water year summary of shallow groundwater, nitrogen, and atrazine discharges from the tile line site L22T for WYs 1987 through 1999.

	Water Year												
	87	88	89	90	91	92	93	94	95	96	97	98	99
Precipitation:													
water inches	32.0	22.9	24.3	37.9	47.3	35.7	46.5	30.4	29.3	30.6	38.3	41.2	40.0
Shallow groundwater discharge (Q):													
mean Q, cfs	0.032	0.048	0.021	0.019	0.109	0.143	0.261	0.123	0.077	0.068	0.062	0.126	0.147
total Q, inches	3.2	4.9	2.2	2.0	11.2	14.6	26.6	12.6	7.9	7.0	6.4	12.9	15.1
acre-feet	22.8	34.9	15.3	13.8	79.2	103.5	188.7	88.9	55.7	49.5	45.1	91.0	106.6
Nitrogen discharged with groundwater:													
flow-wtd mean concentration, mg/L													
as nitrate (NO_3)	71	73	67	141	141	83	80	95	80	75	58	76	64
as nitrate-N (NO_3-N)	15.7	16.2	15.0	31.3	31.3	18.5	17.7	21.0	17.8	16.7	12.8	16.8	14.1
ammonia-N	0.1	0.1	0.1	<0.1	<0.1	0.1	0.2	0.1	n/a	n/a	n/a	n/a	n/a
organic-N	0.2	0.7	0.2	0.3	0.3	0.2	0.4	<0.1	n/a	n/a	n/a	n/a	n/a
nitrogen load:													
(nitrate-N + nitrite-N)													
lbs-N	970	1,539	622	1,171	6,735	5,213	9,103	5,074	2,700	2,241	1,566	4,154	4,094
lbs-N/acre	11.4	18.1	7.3	13.8	79.2	61.3	107.1	59.7	31.8	26.4	18.4	48.9	48.2
(for sub-basin area)													
Atrazine discharged with groundwater:													
flow-wtd mean concentration,													
atrazine, µg/L	0.21	0.19	0.40	0.37	0.29	0.11	0.10	0.10	0.17	0.13	0.02	0.05	0.15
atrazine load;													
lbs - atrazine	0.013	0.018	0.017	0.014	0.063	0.032	0.053	0.024	0.026	0.018	0.003	0.012	0.042

Table C-6. Summary of annual % of detections and maximum concentrations for common pesticides in groundwater at Big Spring for WYs 1982 through 1999.

	Water Year																	
	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	
Pesticide common chemical name	% detections maximum concentrations, µg/L																		% detections (total record)
Herbicides																			
atrazine	100%	100%	100%	100%	99%	100%	75%	88%	100%	100%	100%	94%	94%	75%	60%	62%	50%	42%	86%
	2.50	5.10	10.00	6.10	1.40	0.65	0.42	3.30	8.20	16.00	1.00	2.50	1.30	1.30	2.30	0.85	0.44	0.97	
acetochlor	na	na	na	na	na	na	na	na	na	na	na	na	nd	2%	4%	6%	4%	17%	6%
	na	na	na	na	na	na	na	na	na	na	na	na	nd	0.60	0.53	0.20	0.21	0.47	
alachlor	16%	28%	23%	14%	7%	2%	nd	18%	18%	18%	3%	4%	4%	4%	2%	2%	nd	nd	9%
	0.15	0.63	4.00	5.00	0.65	0.10	nd	0.22	0.91	5.50	0.56	1.50	2.10	0.25	0.16	0.11	nd	nd	
butylate	na	na	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0%
	na	na	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	
cyanazine	32%	26%	21%	15%	3%	5%	3%	31%	35%	13%	5%	8%	2%	4%	2%	nd	nd	nd	11%
	0.70	1.20	1.70	4.60	0.12	0.12	1.00	3.00	0.94	2.60	0.51	1.90	0.14	0.12	0.35	nd	nd	nd	
metolachlor	na	4%	17%	4%	4%	nd	nd	6%	8%	4%	2%	6%	10%	6%	6%	2%	nd	nd	4%
	na	0.62	4.50	4.60	0.62	nd	nd	0.21	0.61	2.20	0.17	0.86	2.30	0.38	1.40	0.25	nd	nd	
metribuzin	na	na	na	1%	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	<1%
	na	na	na	3.60	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	
trifluralin	na	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0%
	na	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	
Atrazine metabolities																			
desethyl atrazine	na	na	na	na	na	na	na	na	na	na	na	96%	98%	88%	62%	32%	58%	83%	74%
	na	na	na	na	na	na	na	na	na	na	na	0.46	0.32	0.18	0.54	0.20	0.28	0.22	
desisopropyl atrazine	na	na	na	na	na	na	na	na	na	na	na	na	nd	nd	nd	nd	nd	nd	
	na	na	na	na	na	na	na	na	na	na	na	na	nd	nd	nd	nd	nd	nd	
Insecticides																			
fonofos	na	1%	8%	nd	nd	nd	nd	nd	nd	nd	nd	nd	na	na	na	na	na	na	<1%
	na	0.11	0.35	nd	nd	nd	nd	nd	nd	nd	nd	nd	na	na	na	na	na	na	

na- not analyzed; nd- not detected.

Table C-7. Summary of annual % of detections and maximum concentrations for common pesticides from the Turkey River (TR01) for WYs 1982 through 1999.

	Water Year																		
	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	
Pesticide																			
common chemical	% detections																		% detections
name	maximum concentrations, µg/L																		(since WY '86)
Herbicides																			
atrazine	na	100%*	na	100%	100%	100%	87%	92%	100%	100%	100%	100%	100%	100%	83%	75%	36%	46%	86%
	na	1.60	na	6.50	1.20	5.20	4.40	4.60	20.00	2.90	0.66	1.10	1.20	2.40	0.81	1.30	4.10	1.30	
acetochlor	na	na	na	na	na	na	na	na	na	na	na	na	nd	17%	8%	25%	18%	8%	14%
	na	na	na	na	na	na	na	na	na	na	na	na	nd	1.30	0.19	0.63	3.40	0.52	
alachlor	na	na	na	100%*	8%	15%	7%	33%	30%	13%	nd	17%	17%	17%	nd	nd	9%	nd	12%
	na	na	na	4.10	0.24	0.66	3.50	2.30	13.00	1.90	nd	0.10	0.39	0.41	nd	nd	0.33	nd	
butylate	na	na	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0%
	na	na	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	
cyanazine	na	na	na	100%**	8%	23%	15%	42%	40%	13%	3%	8%	17%	17%	nd	8%	18%	4%	16%
	na	na	na	1.90	0.11	2.80	2.90	1.80	6.80	0.51	0.21	0.18	0.23	1.00	nd	0.19	0.64	0.22	
metolachlor	na	na	na	100%*	13%	8%	nd	42%	35%	20%	nd	25%	33%	25%	33%	25%	28%	4%	20%
	na	na	na	1.90	0.18	0.38	nd	2.30	2.90	1.20	nd	0.19	0.52	0.67	1.00	0.20	0.63	0.17	
metribuzin	na	na	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0%
	na	na	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	
trifluralin	na	na	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0%
	na	na	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	
Atrazine metabolities																			
desethyl atrazine	na	na	na	na	na	na	na	na	na	na	na	44%	100%	100%	92%	58%	45%	83%	75%
	na	na	na	na	na	na	na	na	na	na	na	0.32	0.54	0.30	0.21	0.25	0.70	0.33	
desisopropyl atrazine	na	na	na	na	na	na	na	na	na	na	na	nd	nd	nd	nd	nd	9%	nd	1%
	na	na	na	na	na	na	na	na	na	na	na	nd	nd	nd	nd	nd	0.16	nd	
Insecticides																			
fonofos	na	na	na	na	nd	nd	nd	nd	nd	nd	nd	nd	na	na	na	na	na	na	0%
	na	na	na	na	nd	nd	nd	nd	nd	nd	nd	nd	na	na	na	na	na	na	

na- not analyzed; nd- not detected; * total analyzed 3 samples; ** total analyzed 4 samples.

Table C-8. Summary of annual % of detections and maximum concentrations for common pesticides from the Roberts Creek (RC02) for WYs 1982 through 1999.

	Water Year																		
	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	
Pesticide																			
common chemical									% detections										% detections
name									maximum concentrations, µg/L										(since WY '86)
Herbicides																			
atrazine	na	na	na	100%	100%	91%	89%	95%	100%	91%	95%	67%	65%	47%	56%	72%	54%	38%	78%
	na	na	na	1.20	1.70	10.00	1.80	4.40	30.00	20.00	8.10	25.00	12.00	2.60	8.20	7.80	1.80	1.40	
acetochlor	na	na	na	na	na	na	na	na	na	na	na	na	nd	8%	12%	13%	8%	21%	11%
	na	na	na	na	na	na	na	na	na	na	na	na	nd	0.59	0.65	1.60	1.80	0.51	
alachlor	na	na	na	50%	20%	24%	5%	27%	45%	23%	21%	17%	13%	10%	10%	9%	4%	nd	18%
	na	na	na	0.12	0.31	4.80	1.90	0.69	8.20	8.80	3.40	17.00	2.80	1.30	0.43	0.66	0.89	nd	
butylate	na	na	na	na	nd	nd	nd	nd	1%	nd	nd	nd	nd	nd	nd	nd	nd	nd	<1%
	na	na	na	na	nd	nd	nd	nd	1.30	nd	nd	nd	nd	nd	nd	nd	nd	nd	
cyanazine	na	na	na	50%	10%	36%	16%	41%	54%	17%	18%	12%	10%	8%	8%	6%	nd	nd	20%
	na	na	na	0.21	0.14	3.00	1.00	0.74	8.50	3.00	4.40	5.20	1.20	0.66	0.73	0.48	nd	nd	
metolachlor	na	na	na	na	nd	6%	2%	25%	36%	16%	16%	25%	17%	12%	13%	15%	nd	nd	16%
	na	na	na	na	nd	0.72	0.20	0.83	7.40	6.70	4.80	6.00	4.80	1.20	2.10	4.00	nd	nd	
metribuzin	na	na	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0%
	na	na	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	
trifluralin	na	na	na	nd	nd	nd	nd	nd	1%	nd	nd	nd	nd	nd	nd	nd	nd	nd	<1%
	na	na	na	nd	nd	nd	nd	nd	0.10	nd	nd	nd	nd	nd	nd	nd	nd	nd	
Atrazine metabolities																			
desethyl atrazine	na	na	na	na	na	na	na	na	na	na	na	49%	79%	49%	29%	38%	63%	58%	51%
	na	na	na	na	na	na	na	na	na	na	na	1.20	1.00	0.35	1.40	0.93	0.35	0.36	
desisopropyl atrazine	na	na	na	na	na	na	na	na	na	na	na	10%	6%	nd	2%	6%	nd	nd	3%
	na	na	na	na	na	na	na	na	na	na	na	0.26	0.28	nd	0.17	0.26	nd	nd	
Insecticides																			
fonofos	na	na	na	nd	nd	nd	2%	nd	nd	nd	nd	nd	nd	na	na	na	na	na	<1%
	na	na	na	nd	nd	nd	0.10	nd	nd	nd	nd	nd	nd	na	na	na	na	na	

na- not analyzed; nd- not detected.

Table C-9. Summary of annual % of detections and maximum concentrations for common pesticides from the Silver Creek (L23S) for WYs 1982 through 1999.

	Water Year																		
	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	
Pesticide common chemical name	% detections maximum concentrations, µg/L																		% detections (since WY '86)
Herbicides																			
atrazine	100%	100%	100%*	100%	88%	71%	40%	63%	94%	83%	100%	62%	33%	18%	50%	25%	25%	33%	60%
	0.82	0.93	0.60	2.40	0.60	0.68	8.40	68.00	16.00	1.80	1.20	0.48	0.16	0.73	1.60	0.58	0.23	0.76	
acetochlor	na	na	na	na	na	na	na	na	na	na	na	na	nd	9%	8%	nd	nd	8%	5%
	na	na	na	na	na	na	na	na	na	na	na	na	nd	0.38	1.20	nd	nd	0.33	
alachlor	100%*	na	nd	25%	38%	5%	7%	13%	13%	13%	10%	15%	nd	nd	nd	nd	nd	nd	8%
	0.15	na	nd	0.20	0.31	0.12	4.50	38.00	1.40	0.32	0.13	0.81	nd	nd	nd	nd	nd	nd	
butylate	na	na	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0%
	na	na	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	
cyanazine	na	100%*	nd	25%	nd	19%	7%	44%	13%	13%	10%	nd	nd	nd	8%	nd	nd	nd	10%
	na	0.10	nd	0.35	nd	0.19	1.90	22.00	0.57	0.74	0.28	nd	nd	nd	0.96	nd	nd	nd	
metolachlor	na	na	na	na	13%	nd	7%	13%	10%	10%	5%	8%	8%	9%	8%	25%	nd	nd	7%
	na	na	nd	na	0.60	nd	0.21	4.20	1.90	0.56	0.50	0.22	0.15	0.22	1.50	0.37	nd	nd	
metribuzin	na	na	na	na	nd	nd	nd	6%	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	<1%
	na	na	na	na	nd	nd	nd	0.13	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	
trifluralin	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0%
	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	
Atrazine metabolities																			
desethyl atrazine	na	na	na	na	na	na	na	na	na	na	na	30%	83%	36%	42%	17%	42%	42%	42%
	na	na	na	na	na	na	na	na	na	na	na	0.22	0.19	0.20	0.23	0.36	0.30	0.26	
desisopropyl atrazine	na	na	na	na	na	na	na	na	na	na	na	10%	nd	nd	nd	nd	nd	nd	1%
	na	na	na	na	na	na	na	na	na	na	na	0.12	nd	nd	nd	nd	nd	nd	
Insecticides																			
fonofos	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	na	na	na	na	na	na	0%
	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	na	na	na	na	na	na	

na- not analyzed; nd- not detected; * only one analysis.

Table C-10. Summary of annual % of detections and maximum concentrations for common pesticides from the tile line site L22T for WYs 1982 through 1999.

	Water Year																		
	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	
Pesticide common chemical name	% detections maximum concentrations, µg/L																		% detections (since WY '86)
Herbicides																			
atrazine	100%	100%	100%	75%	100%	94%	75%	100%	95%	87%	79%	60%	76%	72%	88%	19%	25%	25%	75%
	1.40	1.20	0.35	2.70	0.69	3.40	1.80	8.50	8.20	1.40	0.40	0.73	1.98	0.90	0.18	0.14	0.12	0.63	
acetochlor	na	na	na	na	na	na	na	na	na	na	na	na	nd	nd	nd	nd	nd	4%	<1%
	na	na	na	na	na	na	na	na	na	na	na	na	nd	nd	nd	nd	nd	0.11	
alachlor	100%*	100%*	nd	8%	18%	2%	5%	7%	nd	8%	10%	2%	nd	nd	nd	nd	nd	nd	3%
	0.16	0.12	nd	4.20	0.13	0.48	2.00	0.70	nd	2.30	2.00	0.10	nd	nd	nd	nd	nd	nd	
butylate	na	na	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0%
	na	na	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	
cyanazine	na	100%*	nd	8%	nd	4%	3%	7%	4%	2%	nd	7%	nd	nd	nd	nd	nd	nd	2%
	na	0.11	nd	5.30	nd	0.25	0.72	0.71	0.24	0.19	nd	1.60	nd	nd	nd	nd	nd	nd	
metolachlor	na	na	nd	100%	nd	nd	nd	2%	nd	nd	nd	7%	nd	nd	nd	nd	nd	nd	1%
	na	na	nd	5.70	nd	nd	nd	0.24	nd	nd	nd	0.35	nd	nd	nd	nd	nd	nd	
metribuzin	na	na	na	100%*	nd	nd	nd	2%	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	<1%
	na	na	na	1.90	nd	nd	nd	0.21	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	
trifluralin	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0%
	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	
Atrazine metabolities																			
desethyl atrazine	na	na	na	na	na	na	na	na	na	na	na	49%	91%	98%	90%	75%	67%	79%	80%
	na	na	na	na	na	na	na	na	na	na	na	0.41	0.30	0.27	0.22	0.15	0.29	0.22	
desisopropyl atrazine	na	na	na	na	na	na	na	na	na	na	na	14%	nd	2%	nd	2%	nd	nd	3%
	na	na	na	na	na	na	na	na	na	na	na	0.38	nd	0.10	nd	0.14	nd	nd	
Insecticides																			
fonofos	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	na	na	na	na	na	0%
	na	na	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	na	na	na	na	na	

na- not analyzed; nd- not detected; * only one analysis.

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