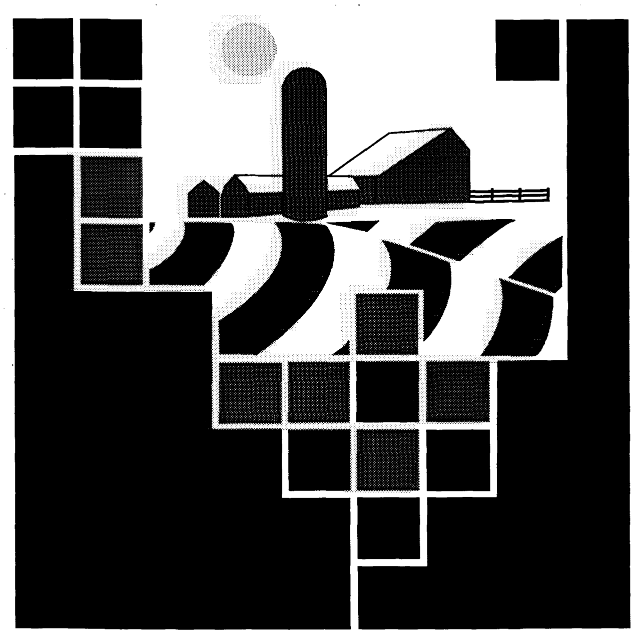
GROUNDWATER QUALITY OBSERVATIONS from the BLUEGRASS WATERSHED AUDUBON COUNTY, IOWA

Technical Information Series 20



Iowa Department of Natural Resources
Larry J. Wilson, Director
April 1991

GROUNDWATER QUALITY OBSERVATIONS from the BLUEGRASS WATERSHED AUDUBON COUNTY, IOWA

Technical Information Series 20

A Report of The Integrated Farm Management Demonstration Project

Prepared by

Lynette S. Seigley and George R. Hallberg

Energy and Geological Resources Division
Geological Survey Bureau

This project has been supported, in part, by the
Integrated Farm Management Demonstration Project
of the Agricultural Energy Management Fund, State of Iowa,
through the Iowa Department of Agriculture and Land Stewardship
with funds provided through the Iowa Groundwater Protection Act, and
through analytical services of the University Hygienic Laboratory

April 1991

Iowa Department of Natural Resources
Larry J. Wilson, Director

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PREFACE

The Bluegrass Watershed Project encompasses a 1,024-acre watershed in north-central Audubon County and is part of the statewide Integrated Farm Management Demonstration Project (IFMDP). The IFMDP is sponsored by the Iowa Department of Agriculture and Land Stewardship and supported by funds allocated through the 1987 Iowa Groundwater Protection Act. The Bluegrass Watershed Project has two primary components: on-farm demonstration and education programs conducted by the Iowa State University Cooperative Extension Service (CES); and water-quality monitoring conducted by the Iowa Department of Natural Resources, Geological Survey Bureau (IDNR).

The on-farm demonstration projects help local farmers implement efficient farm-management practices. These practices include conservation tillage, weed management, integrated pest management, and nutrient management (including comparative fertilizer and manure-management demonstrations). The project's focus is on reducing nutrient, chemical, and energy inputs through more efficient usage, thereby enhancing profitability and reducing potential environmental effects. Eleven farms have been involved in the demonstration portion of the project.

This study reports on the initial monitoring of the watershed in 1987, 1988, and 1989. It provides background data for longer term monitoring which has been expanded to additional sites.

ABSTRACT

The Bluegrass Watershed encompasses 1,024 acres of agricultural land in north-central Audubon County, Iowa. Groundwater from active and inactive private wells, tile lines and surface water from Bluegrass Creek have been monitored for bacteria, nitrate, and pesticides since May 1987 to determine water quality in and around the watershed. The majority of the rural population in this part of Iowa use shallow (20 to 40 feet deep), large-diameter (three to four feet) "seepage" wells located in the surficial geologic deposits (loess, glacial till, and alluvium). The groundwater yielded by these wells is susceptible to contamination from land-applied chemicals. Sites were sampled on a monthly basis. In addition, the sites were sampled after rainfalls of over one inch to determine what immediate changes in water quality occur during these recharge events.

Most of the sampling results described are from 1988 and 1989, the driest consecutive two-year period in Iowa climatic records. The drought conditions confound interpretation of changes in water quality that may result from changes in farm management in the watershed; further monitoring will clarify these relationships.

Bacteria samples were primarily collected from active wells; coliform bacteria were detected in 90% of the samples from active wells. Total coliform bacteria typically occur in samples from such water-table wells.

Yearly mean nitrate concentrations for active wells, tile lines, and surface water showed a statistically significant decline from 1987 to 1989. Mean annual nitrate concentration decreased from 48.3 to 37.8 mg/L (as NO_3) in active wells, 28.8 to 11.5 mg/L in inactive wells, 65.3 to 50.9 mg/L in tile lines, and 60.0 to 40.8 mg/L in surface water. Statistical analysis of rainfall (event) and normal monthly sampling (non-event) for each site category showed no significant difference in nitrate concentration. One active well (W-1) showed the most significant change in nitrate concentration, declining from over 70 mg/L to <1 mg/L since May 1987. This decline is related to a change in land management; the land surrounding the well was taken out of row-crop production in 1987 and placed in the Conservation Reserve Program (CRP).

Three hundred and fifty-three samples were analyzed for pesticides (herbicides and insecticides). No insecticides were detected. Forty-one percent (145/353) of the herbicide samples had detections of one or more herbicides at concentrations of 0.1 ug/L or greater. Atrazine was detected in 90% of the 145 positive samples, cyanazine in 54%, alachlor in 28%, metolachlor in 24%, trifluralin in 4%, and pendimethalin in 3%. Herbicide concentrations ranged from 0.1 to 28.0 ug/L. In general, herbicide concentrations were greater for rainfall samples than normal monthly samples. Eighty-four percent of all herbicide detections occurred during the months of May to September with the highest concentrations of individual herbicides occurring during the months of May, June, or July.

The nitrate concentrations in the wells appear related to the geologic materials in which the wells are located, whereas, herbicide occurrence appears to be related primarily to the type of well (active versus inactive).

INTRODUCTION

The Iowa Department of Natural Resources (IDNR) has been monitoring water quality in a small agricultural watershed to determine the effect of farm management changes on groundwater quality. The Bluegrass Watershed is a 1,024-acre watershed located in portions of sections 21, 22, 27, 28, 33, and 34, T81N, R35W, in north-central Audubon County (Figure 1). The water quality of seven private wells, 12 tile lines and the Bluegrass Creek (at one site) has been monitored since 1987 (Figure 2). These sites have been sampled monthly for nitrate and periodically for pesticides. Several private wells have also been sampled monthly for total coliform bacteria.

The private water-supply wells in this part of the state are generally shallow, large-diameter "seepage" wells which, because of their shallow depth and location, make them inherently susceptible to contamination from land-surface activities. Previous water-quality data from Audubon County have shown unsafe bacteria levels and high nitrate concentrations.

Sites were sampled on a monthly basis. Because previous studies have shown that water quality may change rapidly during periods of groundwater recharge (primarily rainfall events when infiltrating water flows through the soil, Everts et al., 1989; Kanwar et al., 1985; Hallberg et al., 1984; Kross et al., 1990), sites were also sampled after rainfall events of at least one inch to monitor possible changes.

This report summarizes initial observations from the monitoring in the Bluegrass Watershed during these drought years. Longer term monitoring, under more normal rainfall conditions, will help answer questions about nitrate and pesticide movement in the shallow groundwater system in western Iowa and farm management effects on the groundwater quality.

Geologic Setting

The Bluegrass Watershed is located in the Southern Iowa Drift Plain (Prior, 1976), an area characterized by an integrated stream network and rolling topography. Upland divide areas are underlain by 20 to 25 feet (6.1 to 7.6 m) of Wisconsinan-age Peoria Loess overlying a Yarmouth-Sangamon paleosol (buried soil)

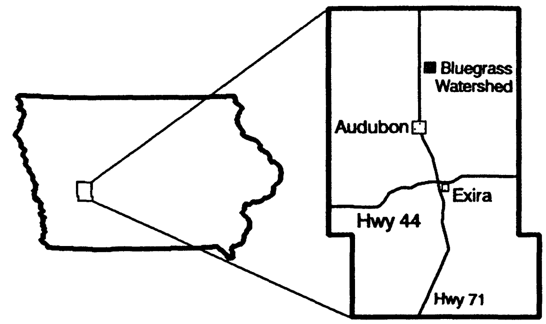


Figure 1. Location map of the Bluegrass Watershed, Audubon County, Iowa.

developed, in part, in the underlying pre-Illinoian-age till. Eolian sand, ranging in thickness from one to eight feet (0.3 to 2.4 m), occurs in the lower part of the loess in parts of the watershed, and is interbedded with the loess in others. The paleosol developed in the pre-Illinoian till represents a stratum of greatly reduced permeability. Downward movement of groundwater or percolating soil water is limited at this horizon, and groundwater flow is predominantly lateral towards Bluegrass Creek and its tributary drainages. This lateral groundwater movement supplies baseflow to Bluegrass Creek.

Drainageways are underlain by silty alluvial fills of the Camp Creek, Roberts Creek and Gunder members of the Holocene-age DeForest Formation (these have been described in other parts of the state by Bettis and Littke, 1987, and in western Iowa by Bettis, 1990). In the Bluegrass Watershed, the Camp Creek Member is yellowish-brown, oxidized, silty, stratified alluvium. It varies from two to seven feet (0.6 to 2.1 m) in thickness, and is thickest next to Bluegrass Creek. The Roberts Creek Member is gray to greenish-gray to black, stratified, organic-rich silty alluvium adjacent to the modern creek channel. Thickness of the Roberts Creek Member varies from 12 to more than 20 feet (3.7 to 6.1 m). The Gunder Member is brown to grayish-brown, oxidized, silty to loamy alluvium, present beneath a low terrace along Bluegrass Creek (E.A. Bettis, III, IDNR, personal communication). Unlike the Roberts Creek Member, it has low organic matter content. Thickness of the Gunder Member ranges from 14 to 16 feet (3.4-4.9 m).

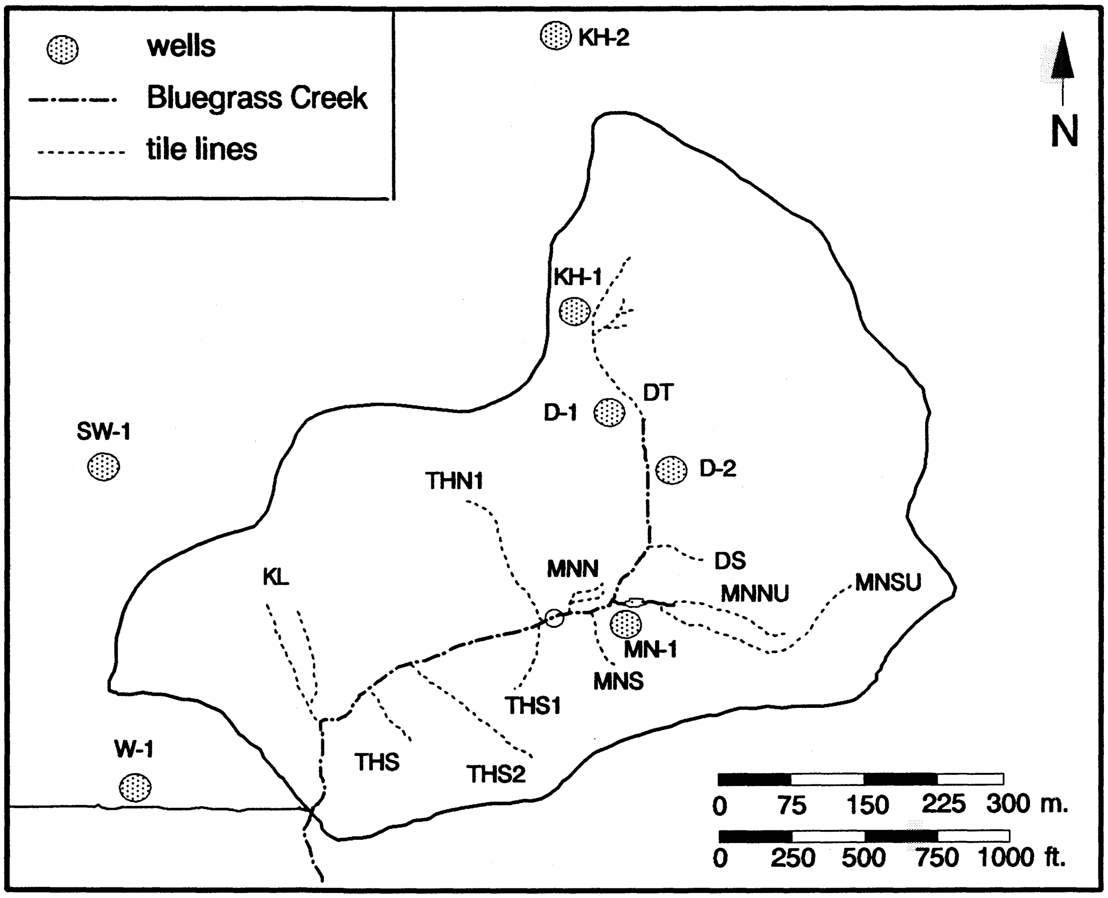


Figure 2. Location of private wells and tile lines in and adjacent to the Bluegrass Watershed. The open circle is where surface water was sampled.

The till sequence beneath the upland loess and stream alluvium in Audubon County varies in thickness from 0 to 370 feet (0 to 112.8 m), but in the Bluegrass Watershed is typically about 300 feet (91.5 m) thick. It varies from yellow, oxidized, leached till in the upper portion to unoxidized and unleached at depth. Multiple tills occur within the sequence.

Bedrock in the area is Cretaceous Dakota Sandstone, an important aquifer in portions of western Iowa. Well-log information for Audubon County indicates the Dakota Sandstone varies in thickness from 25 to 90 feet (7.6 to 27.4 m), and lies 35 to 300 feet (10.7 to 91.5 m) beneath the surface. In the Bluegrass Watershed area, the top of the Dakota Sandstone is approximately 300 feet (91.5 m) below the land surface and is not typically used for domestic/farm wells because natural water quality is generally poor in areas where it is buried this deeply (Runkle, 1985; Munter et al., 1983; Burkart, 1982).

Well Construction

Most of the rural population use shallow, large-diameter "seepage" wells, generally 20 to 40 feet (6.1 to 12.2 m) deep, and three feet (0.9 m) in diameter. These wells generally are located in the middle of row-cropped fields, commonly 1/4 to 1/2 mile (0.4 to 0.8 km) from the houses they supply. The wells are far removed from home septic systems, manure storage, cattle yards, and hydrants where pesticides are mixed. The wells are located in areas of groundwater discharge or where groundwater flow converges (in upland drainageways, in low areas on upland positions, or in alluvium along creeks and rivers); these settings maximize sustained seepage to the wells. The wells are typically bored to the loess/paleosol-till contact, and the large perimeter area is designed to provide increased seepage from the surrounding low-permeability sediments, and the large volume provides a storage reservoir.

Often the wells are constructed of stacked concrete curbing with each section 2.5 to 3.0 feet (0.8 to 0.9 m) high; some older wells have brick curbing. Typically a submersible pump or suction pump at the well provides water to a pressure/storage tank in the well or at the house. From the pressure tank a water line may distribute water to the house and then to outdoor hydrants around the farm.

These wells are typical for this part of the state because the bedrock aquifers are deeply buried and have relatively poor quality water (high total-dissolved solids, including sulfates). Their shallow depth and location make these wells inherently susceptible to contamination from modern land-surface activities.

Previous Water-Quality Data from Audubon County

Previous water-quality data from Audubon County has shown unsafe total coliform bacteria levels and high nitrate concentration. From 1980 to 1985, 331 total bacteria and 269 total nitrate samples from private wells were submitted to the University Hygienic Laboratory (UHL). Annually, 45% to 69% of the samples tested positive for total coliform bacteria, and 28% to 50% exceeded the U.S. Environmental Protection Agency (U.S. EPA) drinking-water standard for nitrate (45 milligrams per liter, mg/L, as NO_3).

A voluntary, county-wide testing of rural wells in Audubon County in September 1988 showed that more than 75% of 228 samples were positive for total coliform bacteria and 26% of 231 samples had nitrate concentrations >45 mg/L.

Total coliform bacteria are not a health hazard, but their presence suggests that disease-causing organisms may be able to enter the drinking water supply. Total coliform bacteria are ubiquitous in soils, surface water, and shallow groundwater. Cisterns are commonly associated with unsafe coliform bacteria counts (Hallberg et al., 1983). Approximately 25% of the samples from the county-wide sampling were from wells using cisterns for water storage, and approximately 90% of these samples tested positive for total coliform. The high percent detection of total coliform bacteria is not unusual. The Iowa State-Wide Rural Well-Water Survey (Kross et al., 1990) showed a significant correspondence between areas in western Iowa (including Audubon County) dominated by shallow, water-table wells and the number of wells indicating the presence of total coliforms. From 71% to 78% of these wells had total coliform bacteria present; only 5%, however, were positive for fecal coliform bacteria.

Previous studies in Iowa have shown that nitrate concentrations are generally lower in water from deeper wells (Hallberg and Hoyer, 1982; Detroy et al., 1988; Kross et al., 1990; Thompson, 1990). The samples from the county-wide testing showed the same trend. The mean nitrate concentrations for the well depth categories were 59 mg/L (0 to 19 feet; 0 to 5.8 m), 36 mg/L (20 to 39 feet; 6.1 to 11.9 m), 21 mg/L (40 to 99 feet; 12.2 to 30.2 m), 3 mg/L (100 to 200 feet; 30.5 to 61.0 m), and <1 mg/L (wells >200 feet; >61.0 m). Of the wells sampled, more than 65% were less than 40 feet (12.2 m) deep and more than 82% were less than 100 feet (30.5 m) deep.

BLUEGRASS WATERSHED MONITORING

Water sampling in Bluegrass Watershed to monitor changes in water quality began in May 1987. All of the water-quality results are tabulated in the Appendix. Sites were sampled for bacteria, nitrate and pesticides. Bacteria and nitrate are two primary tests used to determine whether the quality of drinking water may be a health concern. Because some private wells were not pumped on a regular basis, the private wells were separated into two categories: active and inactive wells. Four private wells were classified as active wells because they were regularly pumped for household and/or livestock water supplies. Two of these sites were also connected to rural-water supply systems, either for back-up, or for household use. At the other two sites the wells are the only water source.

Three other wells were considered inactive wells. They were not pumped on a regular basis,

Table 1. Precipitation totals by year for the Audubon 1SSE weather station.

Year	Precipitation (inches)	Rainfall (millimeters)	Departure from normal
1980	22.00	559	-10.75
1981	28.63	727	-4.12
1982	40.37	1025	+7.62
1983	34.59	879	+1.84
1984	43.26	1099	+10.51
1985	26.31	668	-6.44
1986	45.95	1167	+13.20
1987	35.74	908	+2.99
1988	19.31	490	-13.44
1989	31.72	806	-1.03
1990	33.68	876	+1.74

but kept as potential back-up water supplies or were no longer in use, but had not yet been plugged and sealed. One well was occasionally used to water cattle. These inactive wells were too large to pump or bail effectively when monthly samples were collected, and therefore, relatively stagnant water was sampled. Samples from these wells may not be representative of groundwater conditions; inactive wells are not pumped, and consequently do not remove the water they hold in storage and do not allow "new" groundwater into the well.

Precipitation

Precipitation records illustrate below normal precipitation during the sampling period (Table 1). The weather station, Audubon 1SSE, is located six miles south of the Bluegrass Watershed (Climatological Data Iowa, 1980-1987; Iowa Climate Review, 1988-1990). Mean annual precipitation is 32.75 inches (831.9 mm) based on the record from 1951 to 1980. Figure 3 shows the monthly precipitation from January 1987 through December 1989 and the departure from normal monthly precipitation for the same time period. Precipitation was below normal for most of 1988 and part of 1989; this was the driest consecutive two-year period on record for Iowa.

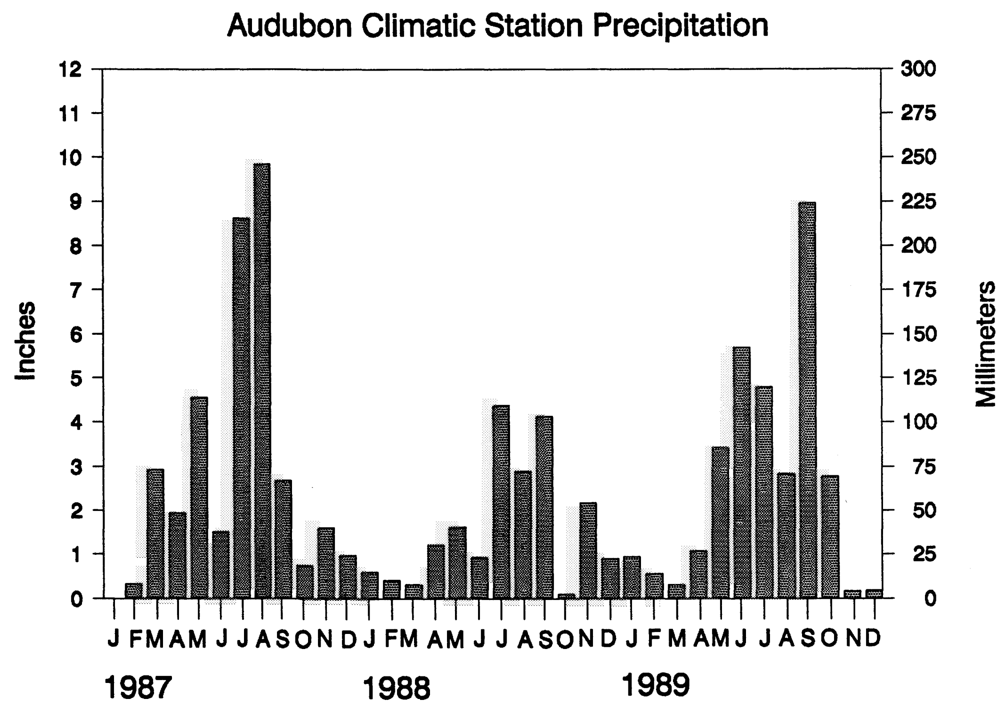
Precipitation in 1987 was 2.99 inches (75.9 mm) above the mean annual precipitation, but 1988 and 1989 were 13.44 inches (341.4 mm) and 1.03 inches (26.2 mm) below the mean, respectively. However, annual rainfall for 1989 approached the annual mean only because September rainfall was 8.96 inches (227.6 mm), 5.3 inches (134.6 mm) above the normal September precipitation. Most other months in 1989 were below normal (Figure 3). The drought resulted in several dry tile lines and a decline in water levels in wells.

Discharge from the East Nishnabotna River and water levels in a sand-and-gravel (alluvial aquifer) well along the river, monitored by the U.S. Geological Survey (USGS), reflect the regional nature of the drought conditions during 1988 and 1989 (O'Connell et al., 1989). During 1986 to 1989, the water level in the well declined almost six feet. The closest USGS surface-water gaging station is on the East Nishnabotna River near Atlantic. Most of the drainage basin above Atlantic is in Audubon County, and Bluegrass Creek is a tributary, joining the river south of Audubon. Average annual discharge for the East Nishnabotna River at Atlantic is 223 cubic feet per second (CFS). For 1987 the mean annual discharge was 263 CFS, but for 1988 and 1989 discharge was substantially below normal; in 1988 mean discharge was 70 CFS and for 1989 it was 135 CFS (Melcher et al., 1988, 1989; O'Connell et al., 1989; O'Connell et al., in press).

Water-Quality Sampling and Analyses

Four of the private wells were sampled for bacteria and nitrate. The other sites (inactive wells, tile lines, surface water) were sampled monthly for nitrate. During 1987 and 1988, samples for pesticide analyses were not collected at all sites each month. During 1989 the sampling for pesticides was more frequent. Samples for nitrate and pesticides were also collected shortly after four rainfall events: June 8, 1988; June 23, 1989; June 27, 1989; and September 4-5, 1989.

Water-quality samples were analyzed by the University Hygienic Laboratory (UHL) in Iowa City, an EPA certified laboratory. Total coliform bacteria was determined using the Most Probable Number (MPN) method and reported as safe (for zero coliforms) or unsafe (if coliforms are present). Nitrate results, reported as NO_3, are in milligrams/liter (mg/L); one mg/L is equal to one part per million (ppm). The drinking water standard for nitrate, as set by U.S. EPA, is 45



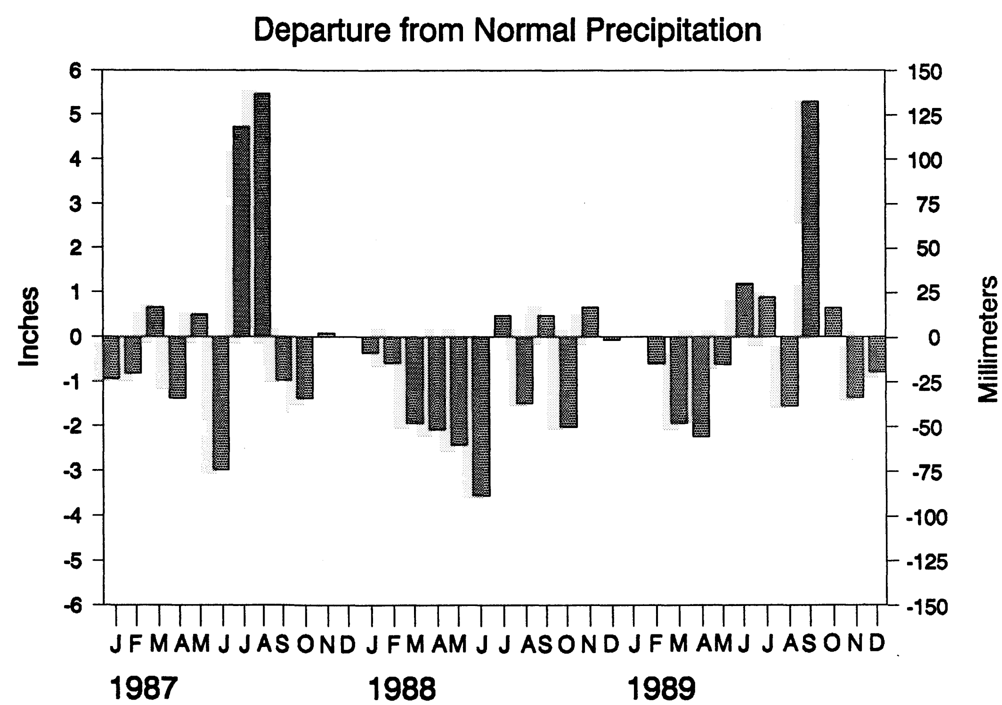


Figure 3. Total precipitation and departure from normal precipitation for the Audubon 1SSE weather station from 1987 to 1989.

Table 2. Pesticides analyzed in the Bluegrass Watershed samples.

INSECTICIDES		HERBICIDES	
Chemical name	Typical product name	Chemical name	Typical product name
chlorpyrifos	Lorsban	* alachlor	Lasso
diazinon	Many product names	* atrazine	Aatrex
dimethoate	Cygon	butylate	Sutan
ethoprop	Mocap	* cyanazine	Bladex
fonofos	Dyfonate	* metolachlor	Dual
malathion	Many product names	metribuzin	Sencor
parathion	Many product names	* pendimethalin	Prowl
phorate	Thimet	propachlor	Ramrod
terbufos	Counter	* trifluralin	Treflan

* Detected in water samples from the Bluegrass Watershed.

mg/L. Nitrate was analyzed by cadmium reduction using a Technicon auto-analyzer system, and included nitrate plus nitrite. Analyses below the quantitation limit for nitrate were reported as <1 mg/L. For statistical analysis, values below the quantitation limit were given a value of 0.5 mg/L. Non-parametric statistical analyses were done using the Kruskal-Wallis test.

Presently 18 pesticides are included in the multi-residue analysis scan by UHL. The pesticides were analyzed by gas chromatography (after U.S. EPA, 1980) with dual-flame photometric and/or nitrogen-phosphorus detectors. The quantitation limit (smallest concentration the lab confidently quantifies for reporting) for the 18 pesticides was 0.1 micrograms per liter (ug/L), which is one part per billion (ppb). All detections were confirmed and quantified on two columns with periodic confirmations with electron-capture detectors and GC-mass spectrometry. Table 2 lists the common chemical names and typical product names for the 18 pesticides analyzed. The lab routinely runs internal calibration standards for the listed pesticides, as well as other spikes, duplicates, and blanks for quality assurance and quality control. Hallberg and others (1990) provide a more detailed review of this method.

Associated with the 18 pesticides are Health Advisory Levels, Risk Specific Doses and/or Maximum Contaminant Levels. The U.S. EPA has established Lifetime Health Advisory Levels (HALs) (U.S. EPA, 1987). Health advisories are established for non-carcinogenic chemicals. Consumption of water at or below the HALs over an average human lifetime is not expected to cause adverse non-cancer health effects. Health advisories are non-regulatory and, therefore, not legally enforceable. They serve as advisory guidelines and, in their calculation, contain a margin of safety.

For "known" or "probable" human carcinogens, a cancer risk estimate is done. This estimate is referred to as Risk Specific Dose (RSD) and is calculated at a 10^{-6} Cancer Risk. The RSD represents the concentration of a chemical in drinking water which if consumed for a lifetime would result in an excess lifetime cancer risk of one in one million. This assumes that all of the exposure to the chemical is from the drinking water source and a 150 pound (70 kilogram) adult consumes approximately two liters per day of the contaminated water for 70 years (U.S. EPA, 1990). A Maximum Contaminant Level (MCL) is determined and may also be proposed for public drinking water supplies. An MCL is a legally enforceable standard for public water supplies. An MCL considers water treatment and economic factors, not just the health risk assessment.

Description of Monitoring Sites

Seven private wells, 12 tile lines, and one surface water site were sampled in and around the watershed to monitor water quality (Figure 2). Four private wells were active wells and three

Table 3. Summary of total coliform bacteria from active wells.

By year	1987	1988	1989	Total
Number of safe (MPN-0)	1 (5%)	0 (0%)	12 (21%)	13 (10%)
Number of unsafe (MPN>0)	21 (95%)	47 (100%)	45 (79%)	113 (90%)

By month for all years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of safe	3	0	4	1	1	2	1	0	0	0	0	0
Number of unsafe	9	3	12	7	10	18	7	7	18	8	12	3

inactive. The tile lines were generally three to five feet (0.9 to 1.5 m) below the ground surface and constructed of either slotted polyvinyl chloride pipe or clay tile. Sampling depended on climatic conditions. During the drought, many tile lines were dry for several consecutive months and, during the winter, water in the tile lines was frequently frozen or the tile lines were buried in snow.

The surface water samples from Bluegrass Creek were collected near the bridge crossing in the middle of the watershed. The samples were collected either from the bridge itself or from the stream bank. At this location, seven tile lines discharged upstream of the sampling site and five tile lines discharged downstream.

RESULTS OF TOTAL COLIFORM BACTERIA MONITORING

Bacteria samples were collected monthly from active wells and periodically from inactive wells (see Appendix). Only an MPN value of 0 is reported as "safe" related to total coliform bacteria. Tile lines and surface water were not analyzed because total coliforms are ubiquitous in surface water and shallow groundwater (tile water) and would always contain high MPN values.

Total coliform bacteria are a recurring problem in these shallow, active private wells. Ninety percent of the samples had total coliform bacteria present (Table 3). The number of unsafe bacteria samples were high, whether comparing bacteria detections by year or by month (Table 3).

The repeated occurrence of total coliform bacteria in these wells is typical for shallow wells. Wells completed at or near the water table often show high values for total coliform bacteria (Thompson, 1984; Kross et al., 1990). Kross and others (1990) concluded that total coliform bacteria results from water-table wells are ambiguous at best. Total coliform are not a health hazard themselves; they occur naturally in the near surface soil-water environment. The only clear implication of positive results for total coliform bacteria is that shallow groundwater or surface water has entered the water system (if the sample has been properly handled).

RESULTS OF NITRATE MONITORING

Many factors may potentially affect nitrate occurrence and concentration: site type (category), geomorphic position and geologic materials, landuse, well construction, precipitation, and time of sampling (routine monthly versus rainstorm-related sampling). Each site category, except for the inactive wells, indicated a statistically significant difference (90% confidence interval) in nitrate occurrence and concentration from 1987 to 1989 (Table 4 and Figure 4). For each category, nitrate concentrations declined from 1987 to 1989, as did the percentage of samples exceeding the

Table 4. Nitrate concentrations for wells, tile lines, and surface water; as NO_3 in mg/L.

	Mean nitrate concentration (mg/L)	Median nitrate concentration (mg/L)	Range of nitrate concentration mg/L	Number of samples	% Samples > 45 mg/L
ACTIVE WELLS					
May 1987 - Dec. 1987	48.3	31.0	4 - 137	26	58%
Jan. 1988 - Dec. 1988	42.6	24.0	<1 - 125	48	27%
Jan. 1989 - Dec. 1989	37.8	14.0	<1 - 146	62	23%
INACTIVE WELLS					
May 1987 - Dec. 1987	28.8	35.5	<1 - 60	14	7%
Jan. 1988 - Dec. 1988	14.8	10.0	<1 - 40	37	0%
Jan. 1989 - Dec. 1989	11.5	4.0	<1 - 59	45	4%
TILE LINES					
May 1987 - Dec. 1987	65.3	64.0	28 - 96	47	87%
Jan. 1988 - Dec. 1988	56.8	56.5	3 - 110	92	72%
Jan. 1989 - Dec. 1989	50.9	48.0	3 - 94	116	58%
SURFACE WATER					
May 1987 - Dec. 1987	60.0	54.0	52 - 84	7	100%
Jan. 1988 - Dec. 1988	50.0	51.0	33 - 72	12	75%
Jan. 1989 - Dec. 1989	40.8	45.0	24 - 57	15	47%

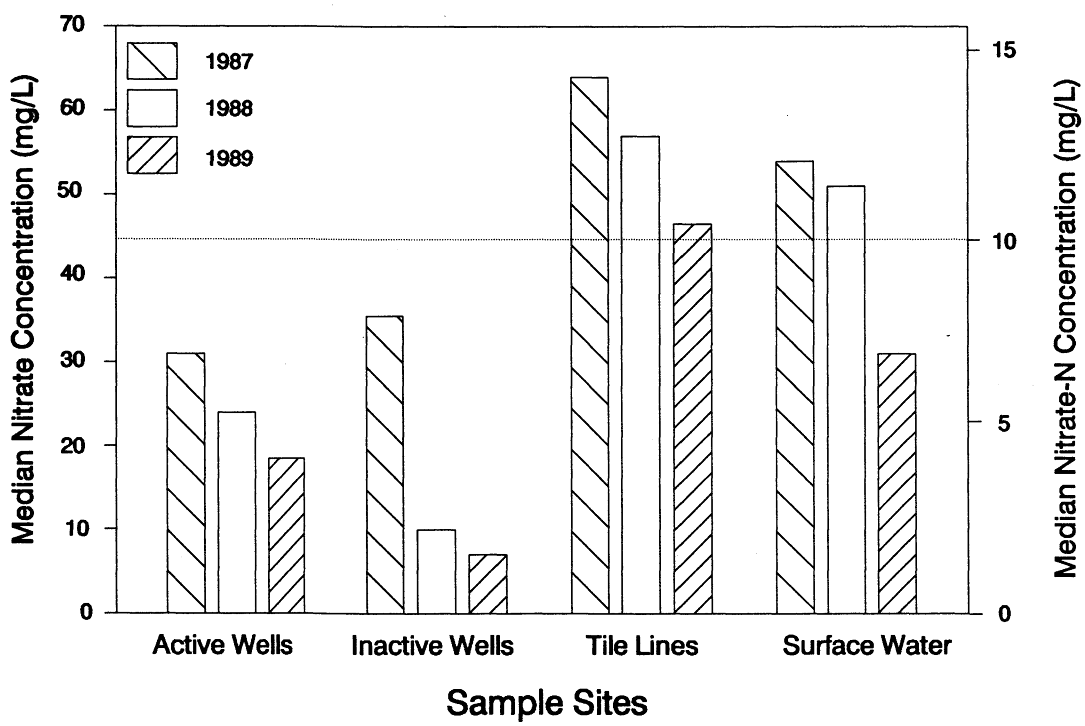


Figure 4. Median nitrate concentrations by year for active wells, inactive wells, tile lines and the surface water site. The data include rainfall-event and routine monthly samples. Dashed line represents the maximum contaminant level for public drinking water supplies.

Table 5. Nitrate concentration of rainfall-event versus routine monthly samples for wells, tile lines, and surface water; as NO_3 in mg/L.

	Mean nitrate concentration (mg/L)	Median nitrate concentration (mg/L)	Range of nitrate concentration (mg/L)	Number of samples
ACTIVE WELLS				
Event	44.4	26.0	<1 - 146	20
Non-Event	41.9	23.0	<1 - 145	116
INACTIVE WELLS				
Event	16.8	11.0	<1 - 56	13
Non-Event	15.1	10.0	<1 - 60	83
TILE LINES				
Event	54.8	49.0	25 - 106	51
Non-Event	56.9	59.0	3 - 110	199
SURFACE WATER				
Event	46.6	46.0	28 - 72	5
Non-Event	48.2	50.0	24 - 84	29

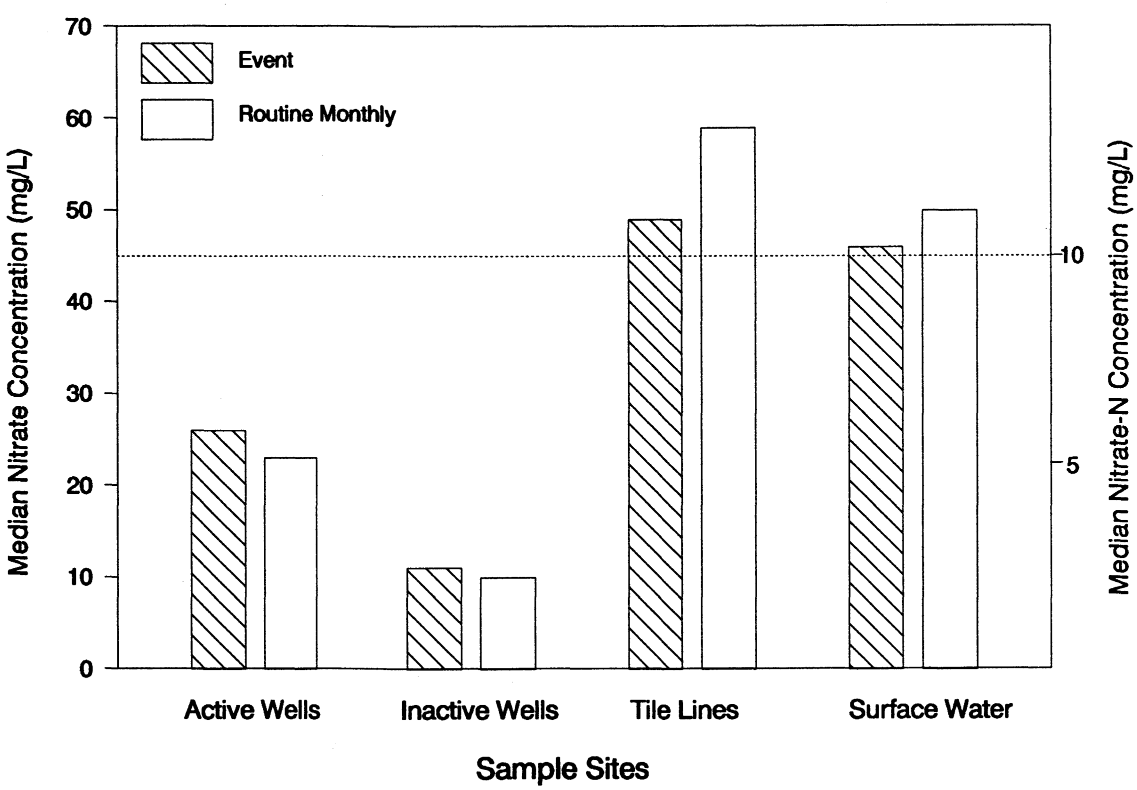


Figure 5. Median nitrate concentration for rainfall-event and routine monthly sampling for active wells, inactive wells, tile lines and the surface water site. Dashed line represents the maximum contaminant level for public drinking water supplies.

public drinking-water standard of 45 mg/L. There was no statistically significant difference between samples routinely taken monthly and those after rainfalls (Table 5 and Figure 5). Well construction, and improvements in well construction during the monitoring period, had no effect on nitrate concentrations. In addition to differences among categories, there was significant variation within categories, which are discussed below.

Nitrate Data from Active Wells

Nitrate concentrations differed significantly among the four wells (Figure 6) and do not appear to be affected by faulty well construction; instead, the primary factors appear to be the geomorphic position and geologic materials the wells are situated in, and the land management around the wells.

Well MN-1 had the lowest nitrate concentrations of the four active wells. It is constructed of concrete curbing with a secure cover and is mounded a few feet above the surrounding area. Nitrate concentrations varied from <1 to 16 mg/L with the highest concentration in May 1987. There were no seasonal changes in nitrate or any increase associated with rainfall. The well is located in the alluvial plain adjacent to Bluegrass Creek, an area that has been a grass buffer strip since sampling began. The well is most likely situated in Roberts Creek alluvium where conditions may favor denitrification (the bacterial reduction of nitrate to nitrogen gas), which, in combination with landuse, may result in the relatively low nitrate concentrations.

Well W-1 has shown the most significant decline in nitrate concentration since sampling began (Figure 6). The well is mounded a few feet above the surrounding surface and has a secure concrete cover. It is situated along a small tributary to Bluegrass Creek and, based on soil coring done in the watershed, is probably finished in locally derived alluvium. The yearly mean nitrate concentration declined from 68 mg/L in 1987 to 10 mg/L in 1989. Denitrification may be important in this well because of its probable location in organic-rich Roberts Creek alluvium. However, a change in land management appears to be the most direct cause. The area surrounding the well was taken out of row-crop production in 1987 and placed in the Conservation Reserve Program (CRP). Preliminary 1990 data from W-1 showed a continued decline in nitrate concentrations, with nine of twelve samples from 1990 reporting nitrate concentrations less than 10 mg/L. While there is uncertainty about whether the decrease in nitrate is related to the drought, changes in landuse, denitrification, or a combination of these factors, the return to above normal rainfall for 1990 and the continued decline in nitrate concentrations suggest that the change in landuse has been a direct cause.

The nitrate concentrations in well SW-1 varied between 12 and 40 mg/L (Figure 6); higher nitrate concentrations occurred during the summer and lower concentrations during the winter. The well, constructed of small brick curbing, has a concrete well cover level with the ground surface, and is situated along a first-order drainageway in local upland alluvium. No soil coring was done in the immediate area of this well so it is uncertain if geologic materials affect nitrate concentrations at this site. The field adjacent to SW-1 was in corn in 1987 and soybeans in 1988 and 1989.

Only well KH-2 had nitrate concentrations consistently above 45 mg/L. The high nitrate does not appear related to well construction. Well construction for KH-2 is similar to W-1; the well is mounded and has a secure concrete cover. It is situated near the head of a drainageway and is probably completed in loess at the contact with the underlying paleosol. The field adjacent to the well was in soybeans in 1987, corn in 1988, and a filter strip was placed around the well in 1989 and the remainder of the field was in soybeans. It is uncertain if the filter strip and changing crop patterns had a significant effect on the nitrate concentrations at KH-2; elevated nitrate concentrations (>100 mg/L) also occur in two monitoring wells located in similar landscape position and materials to KH-2. The high nitrate concentrations in these monitoring wells appear the result of normal rainfall and infiltration through the soil and movement of available nitrate nitrogen downward into the groundwater. Preliminary 1990 data for KH-2 (not presented in this report) show a decline of 20 mg/L in mean nitrate concentration.

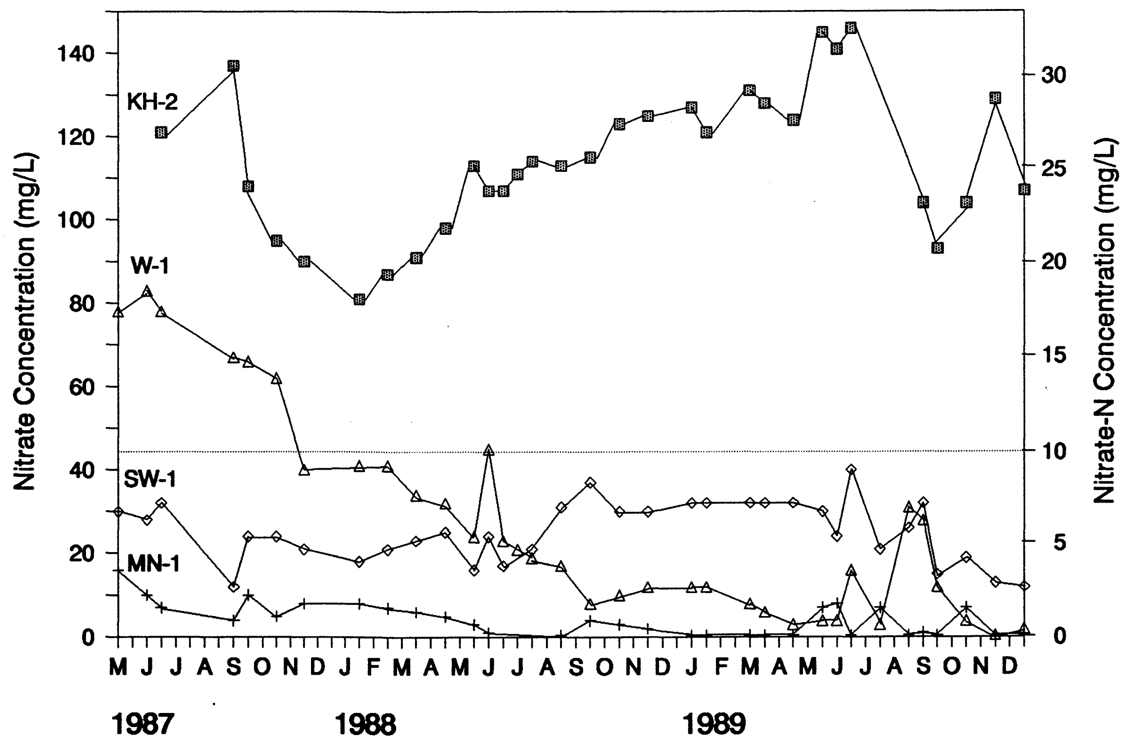


Figure 6. Nitrate concentrations for the four active wells from May 1987 to December 1989 (includes rainfall-event and routine monthly samples). Dashed line represents the maximum contaminant level for public drinking water supplies.

Nitrate Data from Inactive Wells

Inactive wells had the lowest nitrate concentrations of the four site categories. Well construction did not appear to have affected nitrate concentration. Variations seem to be related primarily to geomorphic position and geologic materials; all three may have been affected by surrounding land management.

Wells D-1 and D-2 were located at opposite ends of a pasture that was downslope, and likely down flow, of surrounding row-cropped fields. The pasture is on the alluvial plain of Bluegrass Creek; D-1 is in a poorly drained and intermittently wet area, and D-2 is in a better drained area that is normally dry. Both areas have been in pasture since at least 1987. Both wells are constructed of concrete curbing with concrete covers. The curbing extends two feet (0.6 m) above ground surface on D-1 and for D-2 the curbing is flush with the ground surface. D-2 originally had a deteriorating wooden cover but was replaced with a concrete cover in the summer of 1989.

Groundwater from D-2 had the lowest nitrate concentration of the three inactive wells, generally <15 mg/L (Figure 7). Nitrate concentrations in D-1 have shown a steady decline from the upper 30s in 1987 to concentrations of <1 mg/L in 1989. Preliminary 1990 data for D-1 reported all nitrate concentrations <10 mg/L. Based on soil cores, both wells are in Roberts Creek alluvium. The low nitrate concentrations may result from: 1) location of wells in unfertilized pastures, 2) denitrification as groundwater moves laterally through the Roberts Creek, and/or 3) denitrification within the wells or at the well-soil interface because the wells are used infrequently.

Well KH-1 has had the most variable nitrate concentrations of the inactive wells, fluctuating from <1 to 60 mg/L (Figure 7). It is constructed of concrete curbing with less than two feet (0.6 m) above the ground surface. The well cover is wooden. KH-1 is located halfway up a first-order drainageway, tributary to Bluegrass Creek, and is

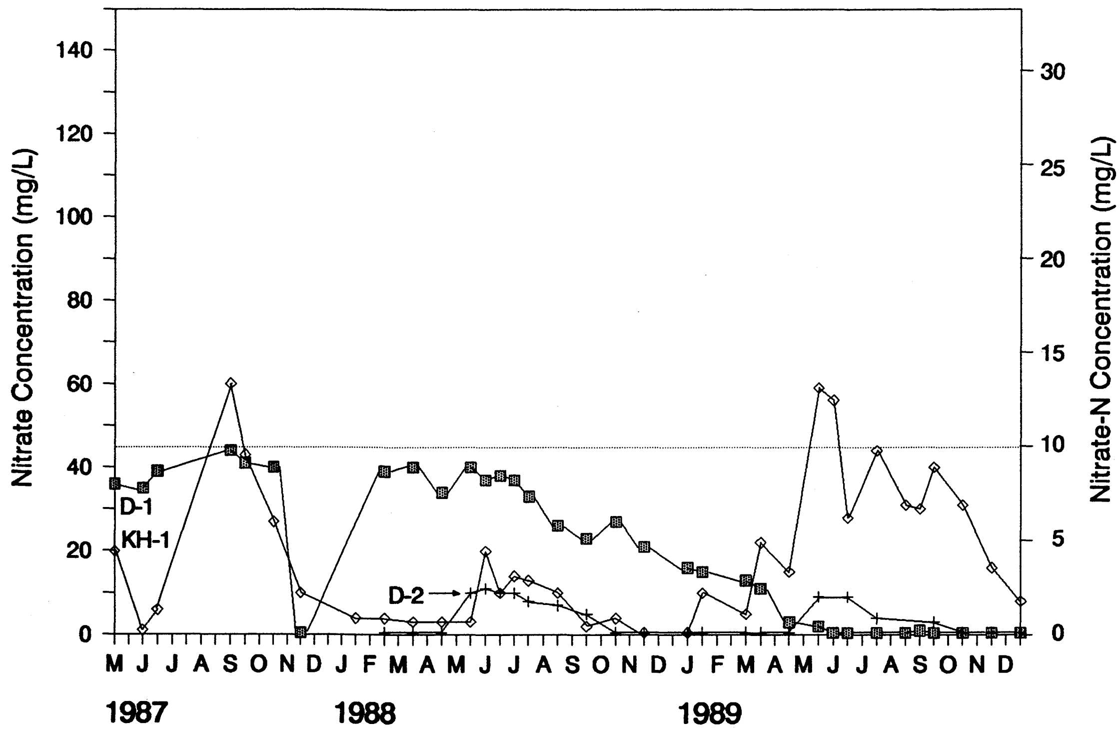


Figure 7. Nitrate concentrations for the three inactive wells from May 1987 to December 1989 (includes rainfall-event and routine monthly samples). Dashed line represents the maximum contaminant level for public drinking water supplies.

completed in interlayered silts and sands. The variable nitrate appears related to the geology and farm management around the well. Preliminary data from another monitoring well in interlayered silts and sands showed similar nitrate concentrations. The field surrounding KH-1 was in corn in 1987, soybeans in 1988, and corn in 1989. During both 1988 and 1989 a strip of land adjacent to the well was taken out of row-crop production and placed in annual set-aside acres. The nitrate concentrations for KH-1 were higher during 1987 and 1989, years when corn was planted in the field upslope of the well. Lower nitrate concentrations occurred during 1988 when the field was in soybeans. No nitrogen fertilizer was applied on the soybeans so the application of nitrogen fertilizer on corn may explain the increase in nitrate concentrations during 1987 and 1989. In addition to the variation between years, nitrate concentrations in KH-1 showed seasonal variation also. In general, the lowest nitrate concentrations occurred during the winter months with seasonal increases during the summer months. For KH-1, nitrate concentrations varied with the depth in the well. The samples had nitrate of 31, 18, and 16 mg/L, respectively, from top to bottom.

As found for the active wells, well construction does not appear to affect the nitrate concentrations in the inactive wells. The nitrate concentrations varied with the geomorphic position and the geologic materials in which the wells are situated, and the surrounding crop history. Conditions suitable for denitrification occur at D-1 and D-2.

Nitrate Data from Tile Lines

The tile line category had the highest annual mean and median nitrate concentrations (Table 4 and Figure 4). Geologic materials were not of importance since the tile lines drain materials similar to those in which the wells are completed: alluvium along the drainageways where the tiles outlet and loess upslope. As a group, tile lines

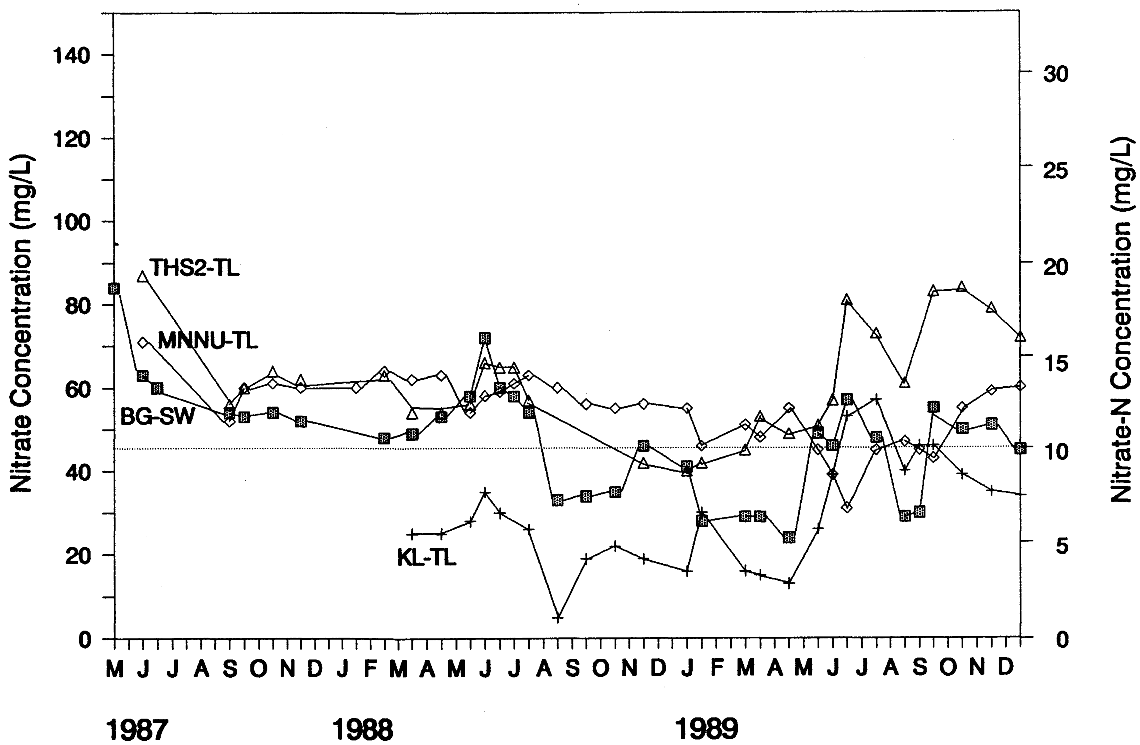


Figure 8. Nitrate concentrations for the surface water site and three tile lines from May 1987 to December 1989 (includes rainfall-event and routine monthly samples). Dashed line represents the maximum contaminant level for public drinking water supplies.

showed no statistically significant difference between routine monthly samples and rainfall-event samples (Table 5 and Figure 5).

Tile lines in the watershed primarily drain fields in corn-soybean rotations; a few acres are in set-aside, alfalfa, oats, or sod. Data are presented for KL-TL, MNNU-TL, and THS2-TL, the three tile lines that flowed most consistently during the monitoring period.

Nitrate concentrations from tile line KL-TL have increased from a mean concentration of 24.3 mg/L in 1988 to 33.7 mg/L in 1989 (sampling did not begin until March 1988 on this tile line). Overall, nitrate concentrations varied from 5 to 57 mg/L and fluctuated seasonally; nitrate concentrations increased during the late spring and summer months and declined over the late fall and winter months (Figure 8). KL-TL is the farthest west tile line sampled in the watershed (Figure 2). Of all the tile lines monitored, it flowed the most consistently and had the greatest discharge. The tile line drains a field that was in a corn-soybean-soybean rotation from 1987 to 1989. The mean nitrate concentration showed an increase from 1988 to 1989 even though soybeans were planted both years with no addition of nitrogen fertilizer. The increase in nitrate concentrations in 1989 may result from nitrogen stored in the soil during previous year(s) that was mobilized by late spring and early summer rains. The residual nitrate may be related to carryover from corn years because of the drought and/or unused nitrate from fixation with soybeans following soybeans in the crop sequence.

Two anomalous nitrate concentrations occurred: in August 1988 when the nitrate concentrations declined to 5 mg/L, the lowest concentration recorded, and the other in January 1989 when there was an unusual increase in nitrate concentration. It is uncertain what caused the August 1988 decline, although it may be drought related. The January 1989 increase occurred during unseasonably mild temperatures (average high for January 1989 was 40.5 °F), causing an early melt of snow cover and allowing recharge from infiltration.

Tile line MNNU-TL showed a decline in annual mean nitrate concentration from 61 mg/L in 1987 to 48 mg/L in 1989 (Figure 8). The decline from 1988 to 1989 was statistically significant. Overall, nitrate concentrations varied from 31 to 71 mg/L and showed no seasonal variation. The tile line drains an area in the southeast portion of the watershed (Figure 2). Tile line MNNU-TL drained a field in a corn-soybean-corn rotation during the 1987 to 1989 period. There were too few samples in 1987 to determine if the 1987 to 1988 decline was significant, but the 1988 to 1989 decline was statistically significant. An increase in nitrate concentrations might have been expected in 1989 with the change to corn. There is an increase in nitrate concentrations toward the end of 1989. Preliminary 1990 data (near normal precipitation for the year - Table 1) show a statistically significant increase in nitrate concentrations even though the field was in soybeans. This suggests that the drought was probably a factor in the movement of nitrate to the tile line, and that the response to cropping factors was delayed in time.

Mean nitrate concentrations from tile line THS2-TL declined from 65.8 mg/L in 1987 to 58.5 mg/L in 1988 and increased to 61.4 mg/L in 1989 (Figure 8). Overall, nitrate concentrations varied from 40 to 87 mg/L. The tile line differs from the other two tile lines in that the field it drains was partially in corn and soybeans for 1987 and 1988, and entirely in corn for 1989. Too few samples were collected in 1987 to determine if the 1987 to 1988 decline was significant, but the increase from 1988 to 1989 was not statistically significant

Nitrate Data from the Surface Water Site

Bluegrass Creek had the greatest percent of samples with nitrate concentrations >45 mg/L. The elevated nitrate concentrations in surface water are expected because much of the flow is from groundwater (outflow from tile lines and groundwater baseflow). The annual mean nitrate concentration declined from 60 to 50 to 40.8 mg/L from 1987 to 1989 (Table 4 and Figure 8). The variation in nitrate concentrations in Bluegrass Creek is difficult to determine at this time, although it is probably drought related. With constant nitrogen management, nitrate concentrations in shallow groundwater typically vary with recharge from rainfall infiltration (Baker et al., 1975). With limited recharge from infiltration through the soil during the drought of 1988-89, nitrate concentrations would be expected to decline (Hallberg, 1989; Hallberg et al., 1984, 1986). Also, with more prolonged low-flows, greater in-stream losses by denitrification or consumption would also be expected. Thus, it is difficult to directly assess the effect of changing land-use practices on the decline in nitrate concentrations. Comparison of rainfall-event samples and normal monthly samples from the surface water site showed no significant difference (Table 5 and Figure 5). The slightly lower nitrate concentration may be caused by nitrate dilution from runoff during rainfall events.

Summary of the Nitrate Data

In summary, the nitrate data for the 1987-89 period suggest that three important factors control nitrate concentrations in the shallow groundwater and surface water within the watershed: 1) landuse and the resulting nitrogen management; 2) the amount of infiltration recharge; and 3) denitrification of groundwater in the organic-rich alluvium of the Roberts Creek Member.

A more significant difference in nitrate concentration between rainfall-event and normal monthly samples might be expected since infiltrating water should leach nitrate from the soil matrix. However, the timing of the sampling varied anywhere from a few hours to a day after the rain. Iowa studies have shown that the most significant increases in nitrate concentration from infiltration recharge occur from a few hours to a few days after the rainfall (Hallberg et al., 1984, 1985, 1986; Kanwar, 1981). Consequently the peak nitrate concentrations may have been missed.

Also, all of the events sampled were during an extended dry period in 1988 and 1989. Infiltration may have followed macropores (particularly shrinkage cracks) developed within the soil column, bypassing the soil matrix where NO_3-N is stored.

RESULTS OF PESTICIDE MONITORING

From May 1987 to December 1989, 353 samples were analyzed for pesticides (Table 6). The number of samples analyzed increased from 1987 to 1989 because of a more frequent sampling for pesticides during 1989.

No insecticides were detected, but 145 of the 353 samples (41%) had herbicide detections. Sixty of the samples (41%) detected only one herbicide; the remaining 85 samples (59%) detected more than one herbicide. All of the detected herbicides are used in the watershed. Atrazine was most commonly detected (90% of the 145 samples). The other detected herbicides include cyanazine (54% of the samples with detections), alachlor (28%), metolachlor (24%), trifluralin (4%), and pendimethalin (3%). Concentrations of these herbicides ranged from 0.1 to 28.0 ug/L (ppb).

The same factors that potentially affect nitrate concentrations (site type, geomorphic position and geologic materials, precipitation, etc.) were evaluated to determine their effect on pesticide concentrations. Table 7 lists herbicide detections by site category and the month(s) when herbicides were detected; also included in Table 7 is the maximum concentration and the month of occurrence for each herbicide. The maximum concentrations all occurred during May, June, or July. Seventy-three percent of the maximum concentrations were associated with a rainfall-event sample. Eighty-four percent of the herbicide detections occurred during May to September. The high percentage of herbicide detections from May to September is expected because pesticide application occurs primarily from April to June which, when combined with timely rainfall, can result in herbicide infiltration to the groundwater.

Table 8 compares herbicide detections for routine monthly samples versus rainfall-event samples. Of the 353 herbicide samples collected, 72 (20%) were associated with a rainfall event. For the event samples, 49 (68%) had detections of one or more herbicides, whereas, 96 (34%) of the normal monthly samples had herbicides detected.

Table 9 shows the number of herbicide samples and percent herbicide detections by year for each site category. There is a high percentage of herbicide detections for inactive wells. The active wells, tile lines and surface water show an increase in percent detections from 1987 to 1989. As previously indicated, the frequency of sampling for pesticide samples during 1987 and 1988 was variable (pesticide samples not collected all months from all sites) and prevents analysis of any trends that may appear in the data in Table 9. Herbicide sampling occurred only during five months of 1987 and samples were not collected during all of the months when pesticides might be expected. During 1989, pesticide samples were collected from additional sites on a more consistent basis.

During the study period, the percentage of herbicide detections appears to increase (Table 9) while nitrate concentrations generally declined (Table 4). These opposing trends may have resulted from the dry conditions during 1988 and 1989. Much of the water movement through the soil zone may have been by macropore flow, allowing water to bypass the soil matrix. Much of the nitrate is contained within the matrix, as is much of the soil's potential for adsorbing herbicides. Therefore, flow through macropores bypasses the bulk of the leachable nitrate while allowing herbicide transport to the water table.

Herbicide Data from Active Wells

Figure 9 shows the number of herbicide detections by month for active wells. Herbicides were detected from June through November in the active wells (Table 7). The same herbicides were detected in routine monthly samples except for alachlor and trifluralin in rainfall-related samples. The maximum concentrations of alachlor, atrazine, cyanazine, metolachlor, pendimethalin and trifluralin were associated with rainfall events (Table 8). Herbicide concentrations generally declined rapidly after rainfall events; regular monthly samples following the rainfall sample often showed either much lower concentrations of detected herbicides or no detections.

Also indicated in Table 6 are the percent herbicide detections greater than the U.S. EPA Lifetime Health Advisory Levels (HALs) (U.S. EPA, 1987) and the Risk Specific Dose. Only water from the active wells is used for human consumption, and of these wells, alachlor,

Table 6. Summary of herbicide detections; Bluegrass Watershed, 1987-1989.

Herbicide	Number of samples (N)	Number of detections (%)	Range of detected concentrations (ug/L)	Mean of detections	U.S. EPA HALs	% herbicide detections > U.S. EPA HALs
ACTIVE WELLS						
alachlor	73	3 (4%)	0.12 - 5.40	1.90	0.4[1]	33%
atrazine	73	14 (19%)	0.10 - 16.0	1.99	3.0	14%
cyanazine	73	8 (11%)	0.11 - 24.0	3.23	10.0	13%
metolachlor	73	5 (7%)	0.10 - 0.66	0.30	100.0	0%
pendimethalin	73	2 (3%)	0.15 - 0.47	0.31	*[2]	
trifluralin	73	1 (1%)	1.10 - 1.10	1.10	5.0	0%
INACTIVE WELLS						
alachlor	72	26 (36%)	0.20 - 5.20	1.76	0.4[1]	69%
atrazine	72	53 (74%)	0.11 - 17.0	3.71	3.0	43%
cyanazine	72	45 (63%)	0.13 - 28.0	3.99	10.0	13%
metolachlor	72	8 (11%)	0.11 - 0.65	0.26	100.0	0%
pendimethalin	72	1 (1%)	1.10 - 1.10	1.10	*[2]	
trifluralin	72	4 (6%)	0.21 - 0.88	0.53	5.0	0%
TILE LINES						
alachlor	186	8 (4%)	0.11 - 0.32	0.24	0.4[1]	0%
atrazine	186	54 (29%)	0.10 - 7.40	0.49	3.0	2%
cyanazine	186	19 (10%)	0.10 - 0.91	0.21	10.0	0%
metolachlor	186	18 (10%)	0.11 - 6.50	0.69	100.0	0%
trifluralin	186	1 (1%)	0.18 - 0.18	0.18	5.0	0%
SURFACE WATER						
alachlor	22	3 (14%)	0.19 - 1.30	0.86	0.4[1]	67%
atrazine	22	9 (41%)	0.17 - 4.20	1.15	3.0	22%
cyanazine	22	7 (32%)	0.15 - 2.70	0.63	10.0	0%
metolachlor	22	4 (18%)	0.10 - 4.60	1.35	100.0	0%
pendimethalin	22	2 (9%)	0.14 - 0.30	0.22	*[2]	

[1] The value of 0.4 ug/L is the Risk Specific Dose. The proposed MCL for alachlor is 2.0 ug/L.

[2] No US EPA Lifetime Health Advisory Level available for pendimethalin.

Table 7. Herbicide detections by site category by month and maximum concentration.

Herbicide(s) detected	Month(s) of detections	Month maximum conc. (maximum concentration - ug/L)
ACTIVE WELLS		
alachlor	Jun	Jun (5.40)
atrazine	Jun, Jul, Aug, Sep, Oct, Nov	Jun (16.0)
cyanazine	Jun, Jul, Sep, Oct	Jun (24.0)
metolachlor	Jun, Sep	Jun (0.66)
pendimethalin	Jun, Aug	Jun (0.47)
trifluralin	Jun	Jun (1.10)
INACTIVE WELLS		
alachlor	Jan, Mar through Nov	Jun (5.20)
atrazine	all months	Jul (17.0)
cyanazine	all months	Jul (28.0)
metolachlor	Mar, Apr, Jun	Jun (0.65)
pendimethalin	Jun	Jun (1.10)
trifluralin	Jun, Jul	Jun (0.88)
TILE LINES		
alachlor	May, Jun	May (0.32)
atrazine	Jan, Mar, May through Dec	Jun (7.40)
cyanazine	May, Jun, Sep, Oct	Jun (0.91)
metolachlor	Mar, Jun, Sep	Jun (6.50)
trifluralin	Jun	Jun (0.18)
SURFACE WATER		
alachlor	May, Jun	May (1.30)
atrazine	Mar, Jun, Jul, Aug, Sep	Jun (4.20)
cyanazine	May, Jun, Jul, Sep	Jun (2.70)
metolachlor	Mar, Jun, Sep	Jun (4.60)
pendimethalin	May, Jun	Jun (0.30)

Table 8. Herbicide detections - routine monthly versus rainfall-event samples.

Herbicide	Number of samples	Number of detections (%)	Range of detected concentrations (ug/L)	Number of samples	Number of detections (%)	Range of detected concentrations (ug/L)
	Routine monthly samples			Event samples		
ACTIVE WELLS						
alachlor	57	0 (0%)		16	3 (19%)	0.12 - 5.40
atrazine	57	6 (10%)	0.10 - 0.26	16	7 (44%)	0.12 - 16.0
cyanazine	57	3 (5%)	0.13 - 0.18	16	5 (31%)	0.11 - 24.0
metolachlor	57	1 (2%)	0.15 - 0.15	16	4 (25%)	0.10 - 0.66
pendimethalin	57	1 (2%)	0.15 - 0.15	16	1 (6%)	0.47 - 0.47
trifluralin	57	0 (0%)		16	1 (6%)	1.10 - 1.10
INACTIVE WELLS						
alachlor	62	19 (31%)	0.20 - 5.10	10	7 (70%)	0.21 - 5.20
atrazine	62	46 (74%)	0.11 - 17.0	10	7 (70%)	0.23 - 13.0
cyanazine	62	38 (61%)	0.14 - 28.0	10	7 (70%)	0.13 - 26.0
metolachlor	62	4 (6%)	0.11 - 0.39	10	4 (40%)	0.14 - 0.65
pendimethalin	62	0 (0%)		10	1 (10%)	1.10 - 1.10
trifluralin	62	3 (5%)	0.35 - 0.88	10	1 (10%)	0.21 - 0.21
TILE LINES						
alachlor	141	1 (1%)	0.32 - 0.32	45	7 (16%)	0.11 - 0.18
atrazine	141	30 (21%)	0.10 - 1.00	45	24 (53%)	0.13 - 7.40
cyanazine	141	3 (2%)	0.10 - 0.29	45	16 (36%)	0.10 - 0.91
metolachlor	141	1 (1%)	0.19 - 0.19	45	17 (38%)	0.11 - 6.50
trifluralin	141	0 (0%)		45	1 (2%)	0.18 - 0.18
SURFACE WATER						
alachlor	17	1 (6%)	1.30 - 1.30	5	2 (40%)	0.19 - 1.10
atrazine	17	4 (24%)	0.18 - 0.25	5	5 (100%)	0.17 - 4.20
cyanazine	17	2 (12%)	0.21 - 0.65	5	5 (100%)	0.15 - 2.70
metolachlor	17	1 (6%)	0.24 - 0.24	5	3 (60%)	0.10 - 4.60
pendimethalin	17	1 (6%)	0.14 - 0.14	5	1 (20%)	0.30 - 0.30

Table 9. Percent herbicide detections by year by site category.

Year	Total number of samples	Percent detections	Year	Number of samples	Percent detections
ACTIVE WELLS			TILE LINES		
1987	13	8 %	1987	29	24 %
1988	11	27 %	1988	45	36 %
1989	49	29 %	1989	112	36 %
INACTIVE WELLS			SURFACE WATER		
1987	8	63 %	1987	4	0 %
1988	21	81 %	1988	4	50 %
1989	43	74 %	1989	14	50 %

atrazine and cyanazine were detected at concentrations above the HALs. All of the detections above the HALs were associated with a rainfall-event sample. Of the herbicides detected in Bluegrass Watershed, there are no MCLs for atrazine, cyanazine, metolachlor, pendimethalin, or trifluralin. However, an MCL has been proposed for alachlor at 2.0 ug/L. Only one sample from an active well reported an alachlor concentration greater than the proposed MCL. This sample was associated with a rainfall event.

Herbicide Data from Inactive Wells

Samples from the inactive wells showed a high percentage of detections of herbicides throughout the year (Figure 9). The same herbicides were detected as in the active wells, and maximum concentrations were comparable (Table 7). Alachlor, atrazine, and cyanazine were detected during most of the year, and metolachlor, pendimethalin and trifluralin were detected only in the spring and/or early summer (Table 7).

Half the maximum herbicide concentrations from inactive wells were associated with routine monthly samples and half were associated with rainfall-event samples. Although maximum herbicide concentrations are comparable between the active and inactive wells, herbicide concentrations remained high following rainfall events and continued to be detected for several months.

This suggests several possibilities about groundwater and solute flux in the watershed. First, during significant rainfall periods, infiltrating recharge waters contain relatively high concentrations of herbicides, which are delivered to the water table, and thus the wells. These high concentrations apparently do not persist long, at least within portions of the shallow groundwater system, as indicated by the rapid decline in herbicide concentrations of the active wells. The active wells are routinely pumped and presumably yield samples more indicative of conditions at the time of sampling. The contrasting behavior in the inactive wells suggests various alternatives. The inactive wells may retain the water delivered during recharge events, and maintain the relatively high herbicide concentrations, suggesting that there is limited groundwater flow into and out of these wells under non-pumping conditions. Alternatively, the inactive wells may exhibit herbicide residues longer because of their position in the flow system. Two of the inactive wells are located in pastures, along the bottomland of Bluegrass Creek, that rarely, if ever, receive pesticide application. Overland flow of the creek was not observed during the study period, and the recharge water for these wells must have come from upgradient flow. All of the surrounding, upgradient ground is in row crop receiving herbicides. Hence, the prolonged high herbicide concentrations may be related to the time of travel through the groundwater system from upland areas, to the discharge regions in the alluvium along Bluegrass Creek. This will be reviewed in future reports using data from the monitoring wells that have been installed. In addition, although nitrate concentrations are affected by the geologic units in which these wells are situated (showing reduced NO_3, likely

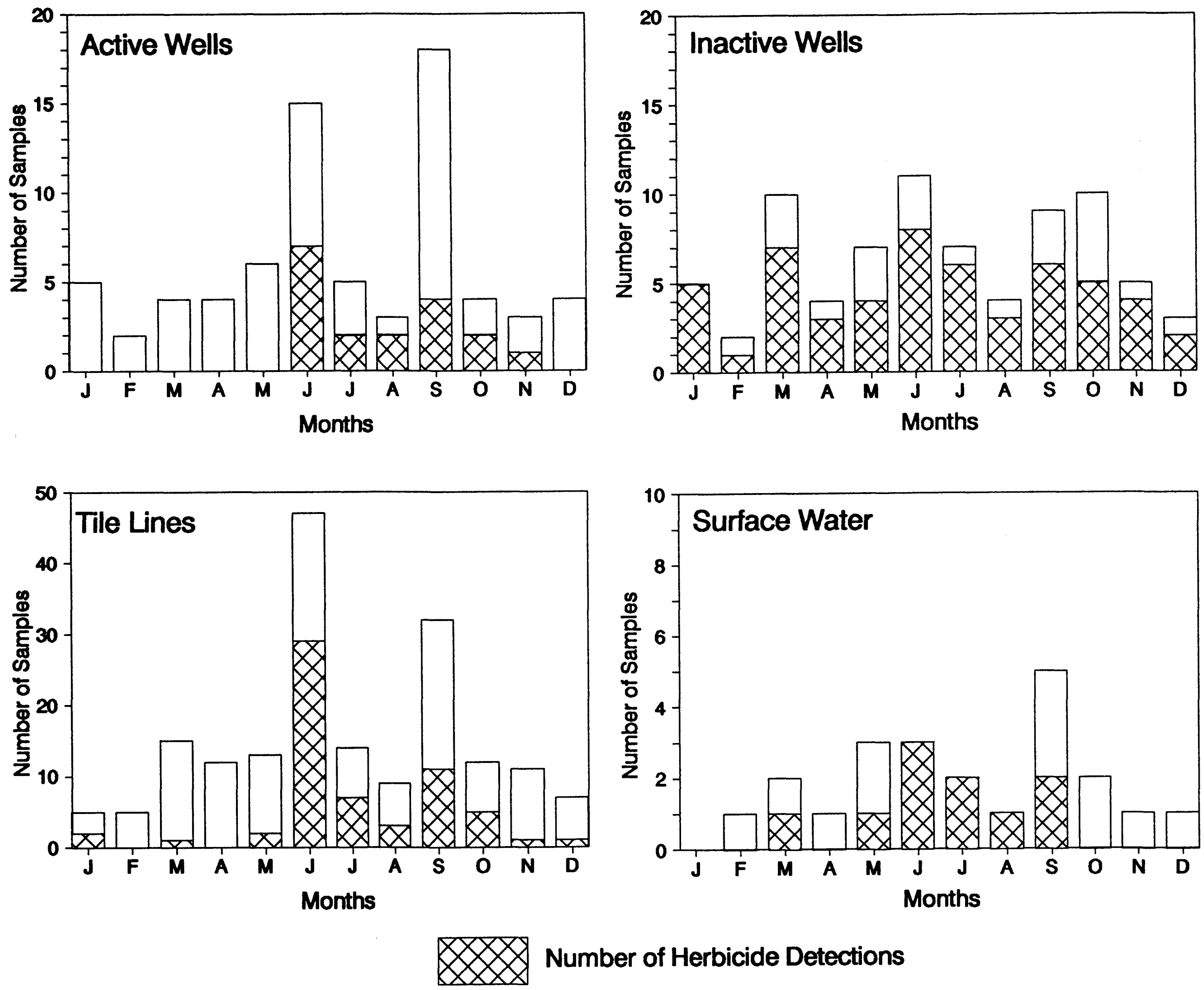


Figure 9. Number of herbicide detections by month for active wells, inactive wells, tile lines and the surface water site from May 1987 to December 1989.

from denitrification), herbicide concentrations do not appear to be similarly influenced.

Herbicide Data from Tile Lines

Pesticide occurrence in groundwater collected from tile lines was strongly related to the time of the year and to rainfall events (Tables 7 and 8). The maximum herbicide concentrations occurred in May and June (Table 7). Four of the maximum concentrations were associated with rainfall events and one with normal monthly samples. The same herbicides were detected in both rainfall-event and routine monthly samples, except for the single detection of trifluralin from a rainfall-related sample (Table 8). Herbicide detections were greater during the summer and early fall months (Figure 9). Only atrazine was detected throughout most of the year in tile lines, whereas, the other herbicides were detected from March through October (Table 7).

Herbicide Data from the Surface Water Site

Herbicides were detected in surface water from Bluegrass Creek during the March through September period (Table 7 and Figure 9). The same herbicides were detected in rainfall-event and routine monthly samples. Four of the five maximum herbicide concentrations were from rainfall-events samples (Table 8). The same herbicides were detected as in the tile lines, except for the two occurrences of pendimethalin from the surface water and one occurrence of trifluralin from a tile line. It is not surprising that surface water from Bluegrass Creek had similar herbicide detections as the tile-line water since the tile lines supply water to and drain the fields that, during heavy rains, provide runoff to Bluegrass Creek (Table 6).

Summary of the Pesticide Data

In summary, the herbicide data from 1987 to 1989 from all site categories indicate the following: 1) the occurrence of herbicides in the shallow groundwater and surface water occurs primarily from late spring to early fall and is related to the timing of herbicide application and rainfall; 2) maximum concentrations in the active and inactive wells are comparable, but concentrations rapidly decline in active wells after rainfall events while in inactive wells they do not; 3) herbicide concentrations above HALs occurred in the active wells only during rainfall-event samples; and 4) herbicide concentrations in general were greater for rainfall-event samples than normal monthly samples for the active wells, tile lines, and surface-water site.

The highest herbicide concentrations were detected in samples from the active and inactive wells. Additional monitoring is needed to assess why this occurs. Shallow wells in the watershed tap the water table, and many are located in fields where the herbicides are applied. Because of the drought, runoff was limited, which may have contributed to the higher herbicide concentrations in the wells than in the surface water. Also, runoff typically only lasts a short time and the sampling may have missed the maximum concentrations in the surface water.

CONCLUSIONS

Water-quality monitoring in the Bluegrass Watershed was undertaken to study the effects of changes in landuse and farming practices on groundwater quality in a small agricultural watershed in western Iowa. Most of the data are from 1988 and 1989, the two driest consecutive years on record for Iowa. Drought conditions during this period complicate interpretation of the results. A summary of observations and interpretations, to date, is outlined below. The data provide an important baseline for comparison to continued water-quality data collected from the watershed.

1) Total coliform bacteria were detected in 90% of the samples from active wells. This is typical of shallow wells that tap the water table.

2) Since sampling began in May 1987, all four site categories (active and inactive wells, tile lines, and surface water) have shown a decrease in mean and median annual nitrate concentrations. The decreases were statistically significant for all site categories except for the inactive wells. These changes may be related to the drought, but at this time are difficult to determine.

3) There was no statistically significant difference between the mean and median nitrate concentration for rainfall-event versus normal monthly samples for the site categories.

4) Active well W-1 showed the most significant decline in nitrate concentration since sampling began, decreasing from a yearly mean concentration of 68 mg/L in 1987 to 10 mg/L in 1989. This decline is interpreted to be related to the conversion of land surrounding the well from row-crop to the Conservation Reserve Program in 1987.

5) Low nitrate concentrations in several of the wells (D-1, D-2, MN-1) may be caused by the wells being situated in organic-rich Roberts Creek alluvium, thus enhancing denitrification.

6) Active well KH-2, has consistently shown nitrate concentrations greater than the Maximum Contaminant Level. The cause of the high nitrate appears related to routine leaching of nitrate to the water table from surrounding areas of row crop. The well is situated in loess, an organic-poor sediment, where denitrification is probably limited.

7) One hundred and forty-five of the 353 samples (41%) analyzed for pesticides had detections of one or more herbicides. No insecticides were detected. Of the 145 positive herbicide detections, 60 (41%) were detections of a single herbicide and 85 (59%) were detections of two or more.

8) The most commonly detected herbicide

was atrazine (in 90% of samples with detections). Cyanazine (54%), alachlor (28%), metolachlor (24%), trifluralin (4%), and pendimethalin (3%) were also detected. The highest concentration of any herbicide was 28.0 ug/L of cyanazine, from an inactive well.

9) Maximum herbicide concentrations were comparable between active and inactive wells. For the active wells, all of the maximum concentrations were associated with rainfall events and the concentrations declined significantly or were no longer detected in the month following. Herbicide concentrations remained elevated in inactive wells the month following an event sample. This suggests that the high concentrations apparently do not persist long within the shallow groundwater system.

10) Most of the herbicide detections (84%) occurred during the months of May to September.

11) Of the 353 herbicide samples collected, 72 (20%) were associated with a rainfall-event and 281 (80%) were from normal monthly collections. Of the rainfall-event samples, 68% had detections of one or more herbicides. In comparison, 34% of the normal monthly samples had herbicide detections. In general, the herbicide concentrations were higher for rainfall event samples than for normal monthly samples.

12) Only surface water from Bluegrass Creek had the same herbicides detected in both the rainfall-event and normal monthly samples.

13) Although nitrate concentrations were related to the geologic units in which the wells were situated, herbicide occurrence was not.

ACKNOWLEDGEMENTS

This project has been partially supported by the Integrated Farm Management Demonstration Project of the Agricultural Energy Management Fund, State of Iowa, through the Iowa Department of Agriculture and Land Stewardship, and by analytical services of the University of Iowa Hygienic Laboratory.

The authors gratefully acknowledge the field assistance of Deb Quade, Maureen Holub, Brenda Nations, Carol Thompson, John Littke, and Roger Bruner. Art Bettis drilled the soil cores and helped determine the Quaternary stratigraphy in the watershed. Cristina Plocher reviewed the water-quality database. Tim Kemmis, Bob Libra, and Carol Thompson provided editorial review.

Thanks are extended to Paul Walther, Audubon County Agriculturist - Iowa State University Cooperative Extension Service, for assisting with water sampling during some of the rainfall events and for providing needed information throughout the project.

Finally, we would like to thank the farmers in the watershed for allowing access to their property for soil coring and installation of monitoring wells, for allowing monitoring of their private wells and tile lines, and for providing farm management histories.

REFERENCES

Baker, J.L., Campbell, K.L., Johnson, H.P., and Hanway, J.J., 1975, Nitrate, phosphorus, and sulfate in subsurface drainage water: Journal of Environmental Quality, v. 4, p. 406-412.

Bettis, E.A., III, 1990, Holocene alluvial stratigraphy of western Iowa, in Bettis, E.A., III (ed.), Holocene Alluvial Stratigraphy and Selected Aspects of the Quaternary History of Western Iowa: Guidebook of Midwest Friends of the Pleistocene 37th Field Conference, p. 1-17.

Bettis, E.A., III, and Littke, J.P., 1987, Holocene alluvial stratigraphy and landscape development in Soap Creek Watershed, Appanoose, Davis, Monroe, and Wapello counties, Iowa: Iowa Department of Natural Resources, Geological Survey Open-File Report 87-2, 170 p.

Burkart, M.R., 1982, Availability and quality of water from the Dakota aquifer, northwest Iowa: U.S. Geological Survey Open-File Report 82-264, 83 p.

Climatological Data Iowa, 1980-1987, National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.

Detroy, M.G., Hunt, P.K.B., and Holub, M.A., 1988, Ground-water-quality-monitoring program in Iowa: nitrate and pesticides in shallow aquifers: U.S. Geological Survey Water-Resources Investigations Report 88-4123, 31 p.

Everts, C.J., Kanwar, R.S., Alexander, E.C., Jr., and Alexander, S.C., 1989, Comparison of tracer mobilities under laboratory and field conditions: Journal of Environmental Quality, v. 18, p. 491-498.

Hallberg, G.R., 1989, Nitrogen management and ground water protection, in Follett, R.F., ed., Developments in Agricultural and Managed-Forest Ecology 21: Nitrogen Management and Ground Water Protection: New York, Elsevier, p. 35-74.

Hallberg, G.R., and Hoyer, B.E., 1982, Sinkholes, hydrogeology, and groundwater quality in northeast Iowa: Iowa Geological Survey Open-File Report 82-3, 120 p.

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

Hallberg, G.R., Libra, R.D., Bettis, E.A., III, and Hoyer, B.E., 1984, Hydrologic and water-quality investigations in the Big Spring basin, Clayton County, Iowa: 1983 water-year: Iowa Geological Survey Open-File Report 84-4, 231 p.

Hallberg, G.R., Libra, R.D., and Hoyer, B.E., 1985, Nonpoint source contamination of groundwater in karst-carbonate aquifers in Iowa, in Perspectives on Nonpoint Source Pollution: Washington, D.C., U.S. Environmental Protection Agency, EPA 440/5 85-001, p. 109-114.

Hallberg, G.R., Baker, J.L., and Randall, G.W., 1986, Utility of tile-line effluent studies to evaluate the impact of agricultural practices on groundwater, in Agricultural Impacts on Groundwater: Worthington, Ohio, National Water Well Association, p. 298-328.

Hallberg, G.R., Kross, B.C., Libra, R.D., Burmeister, L.F., Weih, L.M.B., Lynch, C.F., Bruner, D.R., Lewis, M.Q., Cherryholmes, K.L., Johnson, J.K., and Culp, M.A., 1990, The Iowa state-wide rural well-water survey design report: a systematic sampling of domestic drinking water quality: Iowa Department of Natural Resources Technical Information Series 17, 135 p.

Iowa Climate Review, 1988-1990, State Climatology Office, Iowa Department of Agriculture and Land Stewardship, Des Moines, Iowa.

Kanwar, R.S., 1981, Hydrologic simulation of nitrate losses with tile drainage water:

Unpublished Ph.D. Dissertation, Department of Agricultural Engineering, Iowa State University, Ames, Iowa, 266 p.

Kanwar, R.S., Baker, J.L., and Laflen, J.M., 1985, Nitrate movement through the soil profile in relation to tillage system and fertilizer application method: Transactions of the American Society of Agricultural Engineers, v. 28, no. 6, p. 1802-1807.

Kross, B. C., Hallberg, G.R., Bruner, D.R., Libra, R.D., Rex, K.D., Weih, L.M.B., Vermace, M.E., Burmeister, L.F., Hall, N.H., Cherryholmes, K.L., Johnson, J.K., Selim, M.I., Nations, B.K., Seigley, L.S., Quade, D.J., Dudler, A.G., Sesker, K.D., Culp, M.A., Lynch, C.F., Nicholson, H.F., and Hughes, J.P., 1990, The Iowa state-wide rural well-water survey water-quality data: initial analysis: Iowa Department of Natural Resources Technical Information Series 19, 142 p.

Melcher, N.B., Baebenroth, R.W., Detroy, M.G., Karsten, R.A., and Matthes, W.J., 1988, Water resources data Iowa, water year 1987: U.S. Geological Survey Water-Data Report IA-87-1, 345 p.

Melcher, N.B., Detroy, M.G., Karsten, R.A., and Matthes, W.J., 1989, Water resources data Iowa, water year 1988: U.S. Geological Survey Water-Data Report IA-88-1, 377 p.

Munter, J.A., Ludvigson, G.A., and Bunker, B.J., 1983, Hydrogeology and stratigraphy of the Dakota Formation in northwest Iowa: Iowa Geological Survey Water-Supply Bulletin 13, 55 p.

O'Connell, D.J., Liszewski, M.J., Lambert, R.B., and Matthes, W.J., 1989, Water resources data Iowa, water year 1989: U.S. Geological Survey Water-Data Report IA-89-1, 399 p.

O'Connell, D.J., Liszewski, M.J., Lambert, R.B., and Matthes, W.J., in press, Water resources data Iowa, water year 1990: U.S. Geological Survey Water-Data Report.

Prior, J.C., 1976, A regional guide to Iowa landforms: Iowa Geological Survey Educational Series 3, 71 p.

Runkle, D.L., 1985, Hydrology of the alluvial, buried channel, basal Pleistocene and Dakota aquifers in west-central Iowa: U.S. Geological Survey Water Resources Investigations Report, 85-4239, 111 p.

Thompson, C.A., 1984, Hydrogeology and water quality of the upper Des Moines River alluvial aquifer: Iowa Geological Survey Open File Report 84-5, 170 p.

Thompson, C.A., 1990, Nitrate and pesticide distribution in the West Fork Des Moines River alluvial aquifer: Iowa Department of Natural Resources Technical Information Series 18, 43 p.

U.S. Environmental Protection Agency, 1980, Manual of analytical methods for the analysis of pesticides in humans and environmental samples: U.S. Environmental Protection Agency, Washington, D.C., EPA-600/8-80-038.

U.S. Environmental Protection Agency, 1987, Health advisories for 50 pesticides: U.S. Environmental Protection Agency, Office of Drinking Water, Washington, D.C.

U.S. Environmental Protection Agency, 1990, National Pesticide Survey: Survey Analytes: U.S. Environmental Protection Agency, Washington, D.C.

APPENDIX.

Water-Quality Data from the Bluegrass Watershed

Site	Date	Nitrate	Bacteria	PESTICIDES - HERBICIDES								
				alachlor	atrazine	butylate	cyanazine	metolachlor	metribuzin	pendimethalin	propachlor	trifluralin
		(mg/L)	(MPN)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
INACTIVE WELLS												
D-1	13-May-87	36.00	2.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	16-Jun-87	35.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	26-Jun-87	39.00										
D-1	03-Sep-87	44.00										
D-1	30-Sep-87	41.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	26-Oct-87	40.00	16+									
D-1	30-Nov-87	<1	16+									
D-1	29-Feb-88	39.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	28-Mar-88	40.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	25-Apr-88	34.00	16									
D-1	31-May-88	40.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	08-Jun-88	37.00	16+	2.10	3.50	<0.1	0.31	0.18	<0.1	<0.1	<0.1	0.21
D-1	28-Jun-88	38.00	16+									
D-1	11-Jul-88	37.00		<0.1	0.47	<0.1	0.23	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	25-Jul-88	33.00	16+									
D-1	30-Aug-88	26.00										
D-1	25-Sep-88	23.00		<0.1	0.36	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	23-Oct-88	27.00										
D-1	28-Nov-88	21.00										
D-1	03-Jan-89	16.00		<0.1	0.14	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	31-Jan-89	15.00	16+	<0.1	0.17	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	06-Mar-89	13.00	9.2	<0.1	0.11	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	13-Mar-89	13.00	9.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	28-Mar-89	11.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	25-Apr-89	3.00	16	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	31-May-89	2.00		<0.1	<0.1	<0.1	<0.1	<0.3	<0.1	<0.1	<0.1	<0.1
D-1	23-Jun-89	<1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	27-Jun-89	<1		0.21	0.23	<0.1	0.13	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	25-Jul-89	<1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	28-Aug-89	<1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	04-Sep-89	<1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Site	Date	Nitrate	Bacteria	PESTICIDES - HERBICIDES alachlor	atrazine	butylate	cyanazine	metolachlor	metribuzin	pendimethalin	propachlor	trifluralin
		(mg/L)	(MPN)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
D-1	26-Sep-89	<1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	30-Oct-89	<1		<0.1	<0.1	<0.1	0.14	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	27-Nov-89	<1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-1	27-Dec-89	<1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
D-2	29-Feb-88	<1	16+									
D-2	28-Mar-88	<1										
D-2	25-Apr-88	<1										
D-2	31-May-88	10.00										
D-2	08-Jun-88	11.00		5.20	0.97	<0.1	26.00	0.65	<0.1	1.10	<0.1	<0.1
D-2	28-Jun-88	10.00										
D-2	11-Jul-88	10.00		2.70	0.76	<0.1	28.00	<0.1	<0.1	<0.1	<0.1	<0.1
D-2	25-Jul-88	8.00										
D-2	30-Aug-88	7.00										
D-2	25-Sep-88	5.00										
D-2	23-Oct-88	<1										
D-2	28-Nov-88	<1										
D-2	03-Jan-89	<1										
D-2	31-Jan-89	<1	9.2									
D-2	06-Mar-89	<1	2.2									
D-2	13-Mar-89	<1	2.2	0.33	0.93	<0.1	13.00	0.39	<0.1	<0.1	<0.1	<0.1
D-2	28-Mar-89	<1	0	0.34	0.99	<0.1	11.00	0.24	<0.1	<0.1	<0.1	<0.1
D-2	25-Apr-89	<1		0.20	0.85	<0.1	15.00	0.17	<0.1	<0.1	<0.1	<0.1
D-2	31-May-89	9.00		<0.3	0.64	<0.1	10.00	<0.1	<0.1	<0.1	<0.1	<0.1
D-2	27-Jun-89	9.00		0.25	0.36	<0.1	3.10	0.19	<0.1	<0.1	<0.1	<0.1
D-2	25-Jul-89	4.00		<0.1	0.47	<0.1	6.70	<0.1	<0.1	<0.1	<0.1	<0.1
D-2	28-Aug-89			<0.1	0.32	<0.1	5.10	<0.1	<0.1	<0.1	<0.1	<0.1
D-2	26-Sep-89	3.00		<0.1	0.36	<0.1	5.50	<0.1	<0.1	<0.4	<0.1	<0.1
D-2	30-Oct-89	<1		<0.1	0.22	<0.1	1.30	<0.1	<0.1	<0.1	<0.1	<0.1
D-2	27-Nov-89	<1		<0.1	0.29	<0.1	1.90	<0.1	<0.1	<0.1	<0.1	<0.1
D-2	27-Dec-89	<1		<0.1	0.26	<0.1	3.70	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	13-May-87	20.00		<0.1	0.44	<0.1	0.19	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	16-Jun-87	1.00	16+	<0.1	0.58	<0.1	1.90	<0.1	<0.1	<0.1	<0.1	<0.1

				PESTICIDES - HERBICIDES								
Site	Date	Nitrate (mg/L)	Bacteria (MPN)	alachlor (ug/L)	atrazine (ug/L)	butylate (ug/L)	cyanazine (ug/L)	metolachlor (ug/L)	metribuzin (ug/L)	pendimethalin (ug/L)	propachlor (ug/L)	trifluralin (ug/L)
KH-1	26-Jun-87	6.00										
KH-1	03-Sep-87	60.00										
KH-1	30-Sep-87	43.00	16+	<0.1	0.30	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	26-Oct-87	27.00	16+	<0.1	0.33	<0.1	0.82	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	30-Nov-87	10.00	16+	<0.1	0.23	<0.1	0.60	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	25-Jan-88	4.00	16+	<0.1	0.35	<0.1	0.95	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	29-Feb-88	4.00	16+	<0.1	0.27	<0.1	1.10	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	28-Mar-88	3.00	16	<0.1	0.41	<0.1	1.10	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	25-Apr-88	3.00		<0.1	0.34	<0.1	1.10	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	31-May-88	3.00		<0.1	0.47	<0.1	1.20	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	08-Jun-88	20.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	28-Jun-88	10.00		5.10	9.30	<0.1	12.00	<0.1	<0.1	<0.1	<0.1	0.88
KH-1	11-Jul-88	14.00		3.80	8.50	<0.1	<0.5	<0.1	<0.1	<0.1	<0.1	0.69
KH-1	25-Jul-88	13.00		3.60	8.70	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.35
KH-1	30-Aug-88	10.00		1.90	9.30	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	25-Sep-88	2.00		2.20	9.80	<0.1	1.20	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	23-Oct-88	4.00		1.70	13.00	<0.1	1.60	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	28-Nov-88	<1		1.20	11.00	<0.1	1.30	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	03-Jan-89	<1		0.72	11.00	<0.1	0.64	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	31-Jan-89	10.00	16+	0.50	9.00	<0.1	0.82	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	06-Mar-89	5.00	16+	0.32	7.70	<0.1	0.94	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	13-Mar-89	16.00	16+	<0.1	1.20	<0.1	<0.1	0.11	<0.1	<0.1	<0.1	<0.1
KH-1	28-Mar-89	22.00	16+	<0.1	3.90	<0.1	0.37	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	25-Apr-89	15.00		<0.1	3.80	<0.1	0.38	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	31-May-89	59.00		2.20	5.00	<0.1	1.20	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	23-Jun-89	56.00		1.90	6.10	<0.1	1.10	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	27-Jun-89	28.00		4.00	13.00	<0.1	2.90	0.14	<0.1	<0.1	<0.1	<0.1
KH-1	25-Jul-89	44.00		3.30	17.00	<0.1	4.40	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	28-Aug-89	31.00		0.96	5.70	<0.1	1.80	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	04-Sep-89	30.00		0.53	3.30	<0.1	1.10	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	26-Sep-89	40.00		<0.3	5.00	<0.1	1.50	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	30-Oct-89	31.00		<0.5	3.60	<0.1	1.90	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	27-Nov-89	16.00		0.35	8.30	<0.1	1.90	<0.1	<0.1	<0.1	<0.1	<0.1
KH-1	27-Dec-89	8.00		0.22	7.20	<0.1	2.30	<0.1	<0.1	<0.1	<0.1	<0.1

Site	Date	Nitrate	Bacteria	PESTICIDES - HERBICIDES alachlor	atrazine	butylate	cyanazine	metolachlor	metribuzin	pendimethalin	propachlor	trifluralin
		(mg/L)	(MPN)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
ACTIVE WELLS												
KH-2	26-Jun-87	121.00	0									
KH-2	03-Sep-87	137.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KH-2	30-Sep-87	108.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KH-2	26-Oct-87	95.00	16+									
KH-2	30-Nov-87	90.00	16+									
KH-2	25-Jan-88	81.00	5.1									
KH-2	29-Feb-88	87.00	9.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KH-2	28-Mar-88	91.00	16+									
KH-2	25-Apr-88	98.00	5.1									
KH-2	31-May-88	113.00	2.2									
KH-2	08-Jun-88	107.00	2.2	5.40	8.40	<0.1	0.99	<0.1	<0.1	<0.1	<0.1	1.10
KH-2	28-Jun-88	107.00	16+									
KH-2	11-Jul-88	111.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KH-2	25-Jul-88	114.00	16+									
KH-2	30-Aug-88	113.00	16+									
KH-2	25-Sep-88	115.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KH-2	23-Oct-88	123.00	16+									
KH-2	28-Nov-88	125.00	16									
KH-2	03-Jan-89	127.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KH-2	31-Jan-89	121.00	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KH-2	06-Mar-89	131.00	9.2									
KH-2	13-Mar-89	129.00	16	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KH-2	28-Mar-89	128.00	0									
KH-2	25-Apr-89	124.00	16	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KH-2	31-May-89	145.00	16+	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KH-2	23-Jun-89	141.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KH-2	27-Jun-89	146.00	9.2	<0.1	0.12	<0.1	0.11	<0.1	<0.1	<0.1	<0.1	<0.1
KH-2	04-Sep-89	104.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KH-2	26-Sep-89	93.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KH-2	30-Oct-89	104.00		<0.1	0.21	<0.1	0.15	<0.1	<0.1	<0.1	<0.1	<0.1

Site	Date	Nitrate	Bacteria	PESTICIDES - HERBICIDES								
				alachlor	atrazine	butylate	cyanazine	metolachlor	metribuzin	pendimethalin	propachlor	trifluralin
		(mg/L)	(MPN)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
KH-2	27-Nov-89	129.00	2.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KH-2	27-Dec-89	107.00	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MN-1	13-May-87	16.00	9.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MN-1	16-Jun-87	10.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MN-1	26-Jun-87	7.00	16+									
MN-1	03-Sep-87	4.00	16+									
MN-1	30-Sep-87	10.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MN-1	26-Oct-87	5.00	16+									
MN-1	30-Nov-87	8.00	16+									
MN-1	25-Jan-88	8.00	9.2									
MN-1	29-Feb-88	7.00										
MN-1	28-Mar-88	6.00	16+									
MN-1	25-Apr-88	5.00	16									
MN-1	31-May-88	3.00	16+									
MN-1	08-Jun-88	1.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MN-1	28-Jun-88		16+									
MN-1	30-Aug-88	<1	16+									
MN-1	25-Sep-88	4.00	16	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MN-1	23-Oct-88	3.00	16									
MN-1	28-Nov-88	2.00	16									
MN-1	03-Jan-89	<1	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MN-1	31-Jan-89	<1	2.2									
MN-1	06-Mar-89	<1	0									
MN-1	13-Mar-89	<1	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MN-1	28-Mar-89	<1	16									
MN-1	25-Apr-89	<1	2.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MN-1	31-May-89	7.00	0									
MN-1	23-Jun-89	8.00	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MN-1	27-Jun-89	<1	16+	<0.1	<0.1	<0.1	0.11	<0.1	<0.1	<0.1	<0.1	<0.1
MN-1	25-Jul-89	7.00	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MN-1	28-Aug-89	<1	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MN-1	04-Sep-89	1.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MN-1	26-Sep-89	<1	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Site	Date	Nitrate	Bacteria	PESTICIDES - HERBICIDES								
				alachlor	atrazine	butylate	cyanazine	metolachlor	metribuzin	pendimethalin	propachlor	trifluralin
		(mg/L)	(MPN)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
MN-1	30-Oct-89	7.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MN-1	27-Nov-89	<1	5.1									
MN-1	27-Dec-89	<1	9.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW-1	13-May-87	30.00	5.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW-1	16-Jun-87	28.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW-1	26-Jun-87	32.00										
SW-1	03-Sep-87	12.00		<0.1	<0.1	<0.1	<0.1	0.15	<0.1	<0.1	<0.1	<0.1
SW-1	29-Sep-87	24.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW-1	26-Oct-87	24.00	16+									
SW-1	30-Nov-87	21.00	16+									
SW-1	25-Jan-88	18.00	16+									
SW-1	29-Feb-88	21.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW-1	28-Mar-88	23.00	16+									
SW-1	25-Apr-88	25.00	16+									
SW-1	31-May-88	16.00	16									
SW-1	08-Jun-88	24.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW-1	28-Jun-88	17.00	16+									
SW-1	25-Jul-88	21.00	16+									
SW-1	30-Aug-88	31.00	16+									
SW-1	25-Sep-88	37.00	16+									
SW-1	23-Oct-88	30.00	5.1									
SW-1	28-Nov-88	30.00	16+									
SW-1	03-Jan-89	32.00	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW-1	31-Jan-89	32.00	16+									
SW-1	06-Mar-89	32.00	0									
SW-1	13-Mar-89	31.00	5.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW-1	28-Mar-89	32.00	0									
SW-1	25-Apr-89	32.00	2.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW-1	31-May-89	30.00	16	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW-1	23-Jun-89	24.00	16+	<0.1	0.41	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
SW-1	27-Jun-89	40.00	16+	0.12	0.86	<0.1	<0.1	0.40	<0.1	<0.1	<0.1	<0.1
SW-1	25-Jul-89	21.00	16	<0.1	0.26	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW-1	28-Aug-89	26.00	16+	<0.1	0.26	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Site	Date	Nitrate	Bacteria	PESTICIDES - HERBICIDES								
				alachlor	atrazine	butylate	cyanazine	metolachlor	metribuzin	pendimethalin	propachlor	trifluralin
		(mg/L)	(MPN)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
SW-1	04-Sep-89	32.00	16+	<0.1	0.63	<0.1	<0.1	0.10	<0.1	<0.1	<0.1	<0.1
SW-1	26-Sep-89	15.00	16+	<0.1	0.16	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW-1	30-Oct-89	19.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW-1	27-Nov-89	13.00	16+	<0.1	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SW-1	27-Dec-89	12.00	16	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
W-1	13-May-87	78.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
W-1	16-Jun-87	83.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
W-1	26-Jun-87	78.00										
W-1	03-Sep-87	67.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
W-1	29-Sep-87	66.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
W-1	26-Oct-87	62.00	16+									
W-1	30-Nov-87	40.00	16+									
W-1	25-Jan-88	41.00	16+									
W-1	29-Feb-88	41.00	16+									
W-1	28-Mar-88	34.00	16+									
W-1	25-Apr-88	32.00	16+									
W-1	31-May-88	24.00	16+									
W-1	08-Jun-88	45.00	16+	<0.1	16.00	<0.1	24.00	0.66	<0.1	<0.1	<0.1	<0.1
W-1	28-Jun-88	23.00	16+									
W-1	11-Jul-88	21.00		<0.1	<0.1	<0.1	0.18	<0.1	<0.1	<0.1	<0.1	<0.1
W-1	25-Jul-88	19.00	16+									
W-1	30-Aug-88	17.00	16+									
W-1	25-Sep-88	8.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
W-1	23-Oct-88	10.00	16+									
W-1	28-Nov-88	12.00	16+									
W-1	03-Jan-89	12.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
W-1	31-Jan-89	12.00	16+									
W-1	06-Mar-89	8.00	5.1									
W-1	13-Mar-89	9.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
W-1	28-Mar-89	6.00	9.2									
W-1	25-Apr-89	3.00	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
W-1	31-May-89	4.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
W-1	23-Jun-89	4.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Site	Date	Nitrate	Bacteria	PESTICIDES - HERBICIDES								
				alachlor	atrazine	butylate	cyanazine	metolachlor	metribuzin	pendimethalin	propachlor	trifluralin
		(mg/L)	(MPN)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
W-1	27-Jun-89	16.00	16+	0.18	0.20	<0.1	0.15	0.20	<0.1	0.47	<0.1	<0.1
W-1	25-Jul-89	3.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
W-1	28-Aug-89	31.00	16+	<0.1	0.13	<0.1	<0.1	<0.1	<0.1	0.15	<0.1	<0.1
W-1	04-Sep-89	28.00	16+	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
W-1	26-Sep-89	12.00	16+	<0.1	<0.1	<0.1	0.13	<0.1	<0.1	<0.1	<0.1	<0.1
W-1	30-Oct-89	4.00		<0.1	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
W-1	27-Nov-89	<1	9.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
W-1	27-Dec-89	2.00	2.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
TILE LINES												
DT-TL	13-May-87	70.00										
DT-TL	16-Jun-87	76.00										
DT-TL	03-Sep-87	67.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
DT-TL	30-Sep-87	60.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
DT-TL	26-Oct-87	59.00										
DT-TL	30-Nov-87	63.00										
DT-TL	29-Feb-88	71.00										
DT-TL	28-Mar-88	65.00										
DT-TL	25-Apr-88	72.00										
DT-TL	31-May-88	79.00										
DT-TL	08-Jun-88	106.00										
DT-TL	28-Jun-88	86.00										
DT-TL	25-Jul-88	70.00										
DT-TL	30-Aug-88	53.00										
DT-TL	25-Sep-88	43.00										
DT-TL	23-Oct-88	46.00										
DT-TL	28-Nov-88	52.00										
DT-TL	28-Mar-89	48.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
DT-TL	25-Apr-89	53.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
DT-TL	31-May-89	64.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
DT-TL	23-Jun-89	64.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
DT-TL	27-Jun-89	83.00		0.15	0.14	<0.1	0.11	0.15	<0.1	<0.1	<0.1	<0.1

Site	Date	Nitrate	Bacteria	PESTICIDES - HERBICIDES								
				alachlor	atrazine	butylate	cyanazine	metolachlor	metribuzin	pendimethalin	propachlor	trifluralin
		(mg/L)	(MPN)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
DT-TL	25-Jul-89	63.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
DT-TL	28-Aug-89	48.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
DT-TL	26-Sep-89	61.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
DT-TL	30-Oct-89	56.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
DT-TL	27-Nov-89	57.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
DT-TL	27-Dec-89	60.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	16-Jun-87	71.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	26-Jun-87			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	03-Sep-87	52.00										
MNNU-TL	29-Sep-87	60.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	26-Oct-87	61.00										
MNNU-TL	30-Nov-87	60.00										
MNNU-TL	25-Jan-88	60.00										
MNNU-TL	29-Feb-88	64.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	28-Mar-88	62.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	25-Apr-88	63.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	31-May-88	54.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	08-Jun-88	58.00		<0.1	1.20	<0.1	0.45	1.40	<0.1	<0.1	<0.1	<0.1
MNNU-TL	08-Jun-88	58.00		<0.1	0.27	<0.1	0.11	0.20	<0.1	<0.1	<0.1	<0.1
MNNU-TL	28-Jun-88	59.00										
MNNU-TL	11-Jul-88	61.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	25-Jul-88	63.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	30-Aug-88	60.00										
MNNU-TL	25-Sep-88	56.00										
MNNU-TL	23-Oct-88	55.00										
MNNU-TL	28-Nov-88	56.00										
MNNU-TL	03-Jan-89	55.00										
MNNU-TL	31-Jan-89	46.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	06-Mar-89	51.00										
MNNU-TL	13-Mar-89	37.00		<0.1	0.28	<0.1	<0.1	0.19	<0.1	<0.1	<0.1	<0.1
MNNU-TL	28-Mar-89	48.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	25-Apr-89	55.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	31-May-89	45.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

				PESTICIDES - HERBICIDES								
Site	Date	Nitrate (mg/L)	Bacteria (MPN)	alachlor (ug/L)	atrazine (ug/L)	butylate (ug/L)	cyanazine (ug/L)	metolachlor (ug/L)	metribuzin (ug/L)	pendimethalin (ug/L)	propachlor (ug/L)	trifluralin (ug/L)
MNNU-TL	23-Jun-89	39.00		<0.1	1.30	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	27-Jun-89	31.00		0.14	1.00	<0.1	0.10	0.14	<0.1	<0.1	<0.1	<0.1
MNNU-TL	25-Jul-89	45.00		<0.1	1.00	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	28-Aug-89	47.00		<0.1	0.51	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	04-Sep-89	45.00		<0.1	0.70	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	26-Sep-89	43.00		<0.1	0.34	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	30-Oct-89	55.00		<0.1	0.18	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	27-Nov-89	59.00		<0.1	0.17	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNNU-TL	27-Dec-89	60.00		<0.1	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNN-TL	13-May-87	90.00										
MNN-TL	16-Jun-87	96.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNN-TL	26-Jun-87	96.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNN-TL	03-Sep-87	83.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNN-TL	29-Sep-87	82.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNN-TL	26-Oct-87	90.00										
MNN-TL	30-Nov-87	88.00										
MNN-TL	29-Feb-88	95.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNN-TL	28-Mar-88	89.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNN-TL	25-Apr-88	93.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNN-TL	31-May-88	92.00										
MNN-TL	08-Jun-88	89.00		<0.1	<0.1	<0.1	0.49	0.21	<0.1	<0.1	<0.1	<0.1
MNN-TL	08-Jun-88	88.00										
MNN-TL	28-Jun-88	102.00										
*MNN-TL	11-Jul-88											
*MNN-TL	25-Jul-88											
*MNN-TL	30-Aug-88											
*MNN-TL	25-Sep-88											
*MNN-TL	23-Oct-88											
*MNN-TL	28-Nov-88											
*MNN-TL	03-Jan-89											
*MNN-TL	31-Jan-89											
*MNN-TL	06-Mar-89											
*MNN-TL	13-Mar-89											

Site	Date	Nitrate	Bacteria	PESTICIDES - HERBICIDES								
				alachlor	atrazine	butylate	cyanazine	metolachlor	metribuzin	pendimethalin	propachlor	trifluralin
		(mg/L)	(MPN)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
*MNN-TL	28-Mar-89											
*MNN-TL	25-Apr-89											
*MNN-TL	31-May-89											
*MNN-TL	23-Jun-89											
MNN-TL	27-Jun-89	94.00		<0.1	<0.1	<0.1	<0.1	0.11	<0.1	<0.1	<0.1	<0.1
*MNN-TL	25-Jul-89											
MNN-TL	28-Aug-89	65.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNN-TL	04-Sep-89	63.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNN-TL	26-Sep-89	79.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNN-TL	30-Oct-89	80.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNN-TL	27-Nov-89	89.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
*MNN-TL	27-Dec-89											
MNSU-TL	13-May-87	37.00										
MNSU-TL	16-Jun-87	37.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNSU-TL	26-Jun-87			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNSU-TL	03-Sep-87	31.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNSU-TL	29-Sep-87	31.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNSU-TL	26-Oct-87	30.00										
MNSU-TL	30-Nov-87	28.00										
MNSU-TL	25-Jan-88	28.00										
MNSU-TL	29-Feb-88	27.00										
MNSU-TL	28-Mar-88	25.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNSU-TL	25-Apr-88	26.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
*MNSU-TL	31-May-88											
MNSU-TL	08-Jun-88	45.00		<0.1	0.15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNSU-TL	08-Jun-88	43.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
*MNSU-TL	28-Jun-88											
*MNSU-TL	11-Jul-88											
*MNSU-TL	25-Jul-88											
*MNSU-TL	30-Aug-88											
*MNSU-TL	25-Sep-88											
*MNSU-TL	23-Oct-88											
*MNSU-TL	28-Nov-88											

Site	Date	Nitrate (mg/L)	Bacteria (MPN)	PESTICIDES - HERBICIDES alachlor (ug/L)	atrazine (ug/L)	butylate (ug/L)	cyanazine (ug/L)	metolachlor (ug/L)	metribuzin (ug/L)	pendimethalin (ug/L)	propachlor (ug/L)	trifluralin (ug/L)
*MNSU-TL	03-Jan-89											
MNSU-TL	31-Jan-89	32.00		<0.1	0.47	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
*MNSU-TL	06-Mar-89											
*MNSU-TL	13-Mar-89											
*MNSU-TL	28-Mar-89											
*MNSU-TL	25-Apr-89											
*MNSU-TL	31-May-89											
MNSU-TL	23-Jun-89	36.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNSU-TL	27-Jun-89	44.00		0.11	<0.1	<0.1	0.14	0.14	<0.1	<0.1	<0.1	<0.1
*MNSU-TL	25-Jul-89											
*MNSU-TL	28-Aug-89											
MNSU-TL	04-Sep-89	28.00		<0.1	<0.1	<0.1	<0.1	0.29	<0.1	<0.1	<0.1	<0.1
MNSU-TL	26-Sep-89	34.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
*MNSU-TL	30-Oct-89											
*MNSU-TL	27-Nov-89											
*MNSU-TL	27-Dec-89											
MNSU2-TL	08-Jun-88	29.00										
MNSU2-TL	27-Jun-89	3.00		<0.1	2.20	<0.1	0.91	1.60	<0.1	<0.1	<0.1	0.18
MNSU2-TL	28-Aug-89	5.00		<0.1	0.13	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
*MNSU2-TL	26-Sep-89											
MNSU2-TL	30-Oct-89	16.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNSU2-TL	27-Nov-89	31.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
*MNSU2-TL	27-Dec-89											
MNS-TL	13-May-87	78.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNS-TL	16-Jun-87	80.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNS-TL	26-Jun-87	77.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNS-TL	03-Sep-87	57.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNS-TL	29-Sep-87	61.00										
MNS-TL	26-Oct-87	64.00										
MNS-TL	30-Nov-87	58.00										
MNS-TL	29-Feb-88	51.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNS-TL	28-Mar-88	48.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Site	Date	Nitrate (mg/L)	Bacteria (MPN)	PESTICIDES - HERBICIDES alachlor (ug/L)	atrazine (ug/L)	butylate (ug/L)	cyanazine (ug/L)	metolachlor (ug/L)	metribuzin (ug/L)	pendimethalin (ug/L)	propachlor (ug/L)	trifluralin (ug/L)
MNS-TL	25-Apr-88	47.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNS-TL	31-May-88	54.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNS-TL	08-Jun-88	55.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNS-TL	08-Jun-88	52.00		<0.1	0.14	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNS-TL	28-Jun-88	50.00										
MNS-TL	11-Jul-88	54.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
*MNS-TL	25-Jul-88											
*MNS-TL	30-Aug-88											
*MNS-TL	25-Sep-88											
*MNS-TL	23-Oct-88											
*MNS-TL	28-Nov-88											
*MNS-TL	03-Jan-89											
MNS-TL	31-Jan-89	32.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
*MNS-TL	06-Mar-89											
*MNS-TL	13-Mar-89											
MNS-TL	28-Mar-89	41.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNS-TL	25-Apr-89	60.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNS-TL	31-May-89	36.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNS-TL	23-Jun-89	36.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNS-TL	27-Jun-89	46.00		<0.1	0.18	<0.1	0.10	0.13	<0.1	<0.1	<0.1	<0.1
MNS-TL	25-Jul-89	45.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNS-TL	28-Aug-89	37.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNS-TL	26-Sep-89	55.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNS-TL	30-Oct-89	62.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNS-TL	27-Nov-89	67.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MNS-TL	27-Dec-89	61.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THN1-TL	29-Feb-88	7.00										
THN1-TL	28-Mar-88	13.00										
*THN1-TL	25-Apr-88											
*THN1-TL	31-May-88											
THN1-TL	08-Jun-88	31.00		<0.1	<0.1	<0.1	0.16	<0.1	<0.1	<0.1	<0.1	<0.1
THN1-TL	08-Jun-88	29.00										
THN1-TL	28-Jun-88	3.00										

Site	Date	Nitrate (mg/L)	Bacteria (MPN)	PESTICIDES - HERBICIDES								
				alachlor (ug/L)	atrazine (ug/L)	butylate (ug/L)	cyanazine (ug/L)	metolachlor (ug/L)	metribuzin (ug/L)	pendimethalin (ug/L)	propachlor (ug/L)	trifluralin (ug/L)
THN1-TL	11-Jul-88	8.00										
*THN1-TL	25-Jul-88											
*THN1-TL	30-Aug-88											
*THN1-TL	25-Sep-88											
*THN1-TL	23-Oct-88											
*THN1-TL	28-Nov-88											
*THN1-TL	03-Jan-89											
*THN1-TL	31-Jan-89											
*THN1-TL	06-Mar-89											
*THN1-TL	13-Mar-89											
*THN1-TL	28-Mar-89											
*THN1-TL	25-Apr-89											
THN1-TL	31-May-89	23.00		<0.1	<0.1	<0.1	<0.1	<0.3	<0.1	<0.1	<0.1	<0.1
THN1-TL	23-Jun-89	25.00		<0.1	1.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THN1-TL	27-Jun-89	49.00		<0.1	0.16	<0.1	0.11	0.14	<0.1	<0.1	<0.1	<0.1
*THN1-TL	25-Jul-89											
*THN1-TL	28-Aug-89											
THN1-TL	04-Sep-89	37.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THN1-TL	26-Sep-89	47.00		<0.1	<0.1	<0.1	0.12	<0.1	<0.1	<0.1	<0.1	<0.1
THN1-TL	30-Oct-89	39.00		<0.1	<0.1	<0.1	0.10	<0.1	<0.1	<0.1	<0.1	<0.1
THN1-TL	27-Nov-89	32.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
*THN1-TL	27-Dec-89											
THS1-TL	16-Jun-87	71.00		<0.1	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS1-TL	03-Sep-87	72.00		<0.1	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS1-TL	29-Sep-87	68.00		<0.1	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS1-TL	26-Oct-87	73.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS1-TL	30-Nov-87	78.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS1-TL	29-Feb-88	93.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS1-TL	28-Mar-88	92.00										
THS1-TL	25-Apr-88	104.00										
THS1-TL	31-May-88	106.00										
THS1-TL	08-Jun-88	83.00		<0.1	1.10	<0.1	<0.1	0.43	<0.1	<0.1	<0.1	<0.1
THS1-TL	08-Jun-88	83.00		<0.1	0.99	<0.1	<0.1	0.42	<0.1	<0.1	<0.1	<0.1

Site	Date	Nitrate (mg/L)	Bacteria (MPN)	PESTICIDES - HERBICIDES alachlor (ug/L)	atrazine (ug/L)	butylate (ug/L)	cyanazine (ug/L)	metolachlor (ug/L)	metribuzin (ug/L)	pendimethalin (ug/L)	propachlor (ug/L)	trifluralin (ug/L)
THS1-TL	28-Jun-88	103.00										
THS1-TL	11-Jul-88	105.00		<0.1	0.12	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS1-TL	25-Jul-88	110.00										
*THS1-TL	30-Aug-88											
*THS1-TL	25-Sep-88											
*THS1-TL	23-Oct-88											
*THS1-TL	28-Nov-88											
*THS1-TL	03-Jan-89											
*THS1-TL	31-Jan-89											
*THS1-TL	06-Mar-89											
*THS1-TL	13-Mar-89											
*THS1-TL	28-Mar-89											
*THS1-TL	25-Apr-89											
*THS1-TL	31-May-89											
THS1-TL	23-Jun-89	81.00		<0.1	0.15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS1-TL	27-Jun-89	82.00		0.12	0.27	<0.1	0.13	<0.1	<0.1	<0.1	<0.1	<0.1
THS1-TL	25-Jul-89	88.00		<0.1	0.24	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS1-TL	28-Aug-89	83.00		<0.1	0.13	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS1-TL	04-Sep-89	70.00		<0.1	0.34	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS1-TL	26-Sep-89	75.00		<0.1	0.21	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS1-TL	30-Oct-89	69.00		<0.1	0.14	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS1-TL	27-Nov-89	75.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS1-TL	27-Dec-89	87.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	16-Jun-87	87.00										
THS2-TL	03-Sep-87	56.00										
THS2-TL	29-Sep-87	60.00		<0.1	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	26-Oct-87	64.00		<0.1	0.13	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	30-Nov-87	62.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	29-Feb-88	63.00										
THS2-TL	28-Mar-88	54.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	25-Apr-88	54.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	31-May-88	56.00		<0.1	0.12	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	08-Jun-88	66.00		<0.1	0.55	<0.1	<0.1	0.12	<0.1	<0.1	<0.1	<0.1

Site	Date	Nitrate (mg/L)	Bacteria (MPN)	PESTICIDES - HERBICIDES alachlor (ug/L)	atrazine (ug/L)	butylate (ug/L)	cyanazine (ug/L)	metolachlor (ug/L)	metribuzin (ug/L)	pendimethalin (ug/L)	propachlor (ug/L)	trifluralin (ug/L)
THS2-TL	08-Jun-88	63.00		<0.1	0.30	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	28-Jun-88	65.00		<0.1	0.12	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	11-Jul-88	65.00		<0.1	0.14	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	25-Jul-88	57.00										
*THS2-TL	30-Aug-88											
*THS2-TL	25-Sep-88											
*THS2-TL	23-Oct-88											
THS2-TL	28-Nov-88	42.00										
THS2-TL	03-Jan-89	40.00										
THS2-TL	31-Jan-89	42.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
*THS2-TL	06-Mar-89											
THS2-TL	13-Mar-89	45.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	28-Mar-89	43.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	25-Apr-89	49.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	31-May-89	51.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	23-Jun-89	57.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	27-Jun-89	81.00		0.17	0.13	<0.1	0.14	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	25-Jul-89	73.00		<0.1	0.12	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	28-Aug-89	61.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	26-Sep-89	83.00		<0.1	0.11	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	30-Oct-89	84.00		<0.1	0.12	<0.1	0.12	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	27-Nov-89	79.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS2-TL	27-Dec-89	72.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS-TL	13-May-87	73.00										
THS-TL	16-Jun-87	77.00										
THS-TL	26-Jun-87			<0.1	0.13	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS-TL	03-Sep-87	65.00		<0.1	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS-TL	29-Sep-87	62.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS-TL	26-Oct-87	56.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS-TL	30-Nov-87	51.00										
THS-TL	29-Feb-88	59.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS-TL	28-Mar-88	54.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS-TL	25-Apr-88	60.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Site	Date	Nitrate	Bacteria	PESTICIDES - HERBICIDES								
				alachlor	atrazine	butylate	cyanazine	metolachlor	metribuzin	pendimethalin	propachlor	trifluralin
		(mg/L)	(MPN)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
THS-TL	31-May-88	59.00										
THS-TL	08-Jun-88	73.00		<0.1	7.40	<0.1	<0.1	6.50	<0.1	<0.1	<0.1	<0.1
THS-TL	08-Jun-88	65.00										
THS-TL	28-Jun-88	64.00										
THS-TL	11-Jul-88	64.00		<0.1	0.17	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS-TL	25-Jul-88	56.00										
*THS-TL	30-Aug-88											
*THS-TL	25-Sep-88											
*THS-TL	23-Oct-88											
*THS-TL	28-Nov-88											
*THS-TL	03-Jan-89											
*THS-TL	31-Jan-89											
*THS-TL	06-Mar-89											
*THS-TL	13-Mar-89											
*THS-TL	28-Mar-89											
*THS-TL	25-Apr-89											
THS-TL	31-May-89	35.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS-TL	23-Jun-89	63.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS-TL	27-Jun-89	89.00		0.18	0.23	<0.1	0.10	0.11	<0.1	<0.1	<0.1	<0.1
THS-TL	25-Jul-89	72.00		<0.1	0.11	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS-TL	28-Aug-89	59.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS-TL	04-Sep-89	47.00		<0.1	0.20	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
THS-TL	26-Sep-89	64.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS-TL	30-Oct-89	64.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS-TL	27-Nov-89	62.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
THS-TL	27-Dec-89	61.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KL-TL	28-Mar-88	25.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KL-TL	25-Apr-88	25.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KL-TL	31-May-88	28.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KL-TL	08-Jun-88	35.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KL-TL	08-Jun-88	32.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KL-TL	28-Jun-88	30.00										
KL-TL	25-Jul-88	26.00										

Site	Date	Nitrate (mg/L)	Bacteria (MPN)	PESTICIDES - HERBICIDES alachlor (ug/L)	atrazine (ug/L)	butylate (ug/L)	cyanazine (ug/L)	metolachlor (ug/L)	metribuzin (ug/L)	pendimethalin (ug/L)	propachlor (ug/L)	trifluralin (ug/L)
KL-TL	30-Aug-88	5.00										
KL-TL	25-Sep-88	19.00										
KL-TL	23-Oct-88	22.00										
KL-TL	28-Nov-88	19.00										
KL-TL	03-Jan-89	16.00										
KL-TL	31-Jan-89	30.00		<0.1	0.15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
%KL-TL	06-Mar-89											
KL-TL	13-Mar-89	16.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KL-TL	28-Mar-89	15.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KL-TL	25-Apr-89	13.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KL-TL	31-May-89	26.00		<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KL-TL	23-Jun-89	39.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KL-TL	27-Jun-89	53.00		<0.1	0.13	<0.1	0.10	0.12	<0.1	<0.1	<0.1	<0.1
KL-TL	25-Jul-89	57.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KL-TL	28-Aug-89	40.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KL-TL	04-Sep-89	46.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KL-TL	26-Sep-89	46.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KL-TL	30-Oct-89	39.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KL-TL	27-Nov-89	35.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
KL-TL	27-Dec-89	34.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
DS-TL	31-May-89	31.00		0.32	<0.1	<0.1	0.29	<0.1	<0.1	<0.1	<0.1	<0.1
DS-TL	23-Jun-89	45.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
DS-TL	27-Jun-89	59.00		0.12	<0.1	<0.1	0.15	<0.1	<0.1	<0.1	<0.1	<0.1
DS-TL	25-Jul-89	32.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
*DS-TL	28-Aug-89											
DS-TL	04-Sep-89	34.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
DS-TL	26-Sep-89	33.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
DS-TL	30-Oct-89	30.00										
*DS-TL	27-Nov-89											
*DS-TL	27-Dec-89											

Site	Date	Nitrate (mg/L)	Bacteria (MPN)	PESTICIDES - HERBICIDES alachlor (ug/L)	atrazine (ug/L)	butylate (ug/L)	cyanazine (ug/L)	metolachlor (ug/L)	metribuzin (ug/L)	pendimethalin (ug/L)	propachlor (ug/L)	trifluralin (ug/L)
SURFACE WATER												
BG-SW	13-May-87	84.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BG-SW	16-Jun-87	63.00										
BG-SW	26-Jun-87	60.00										
BG-SW	03-Sep-87	54.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BG-SW	29-Sep-87	53.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BG-SW	26-Oct-87	54.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BG-SW	30-Nov-87	52.00										
BG-SW	29-Feb-88	48.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BG-SW	28-Mar-88	49.00										
BG-SW	25-Apr-88	53.00										
BG-SW	31-May-88	58.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BG-SW	08-Jun-88	72.00		1.10	3.60	<0.1	2.70	4.60	<0.1	0.30	<0.1	<0.1
BG-SW	28-Jun-88	60.00										
BG-SW	11-Jul-88	58.00		<0.1	0.25	<0.1	0.21	<0.1	<0.1	<0.1	<0.1	<0.1
BG-SW	25-Jul-88	54.00										
BG-SW	30-Aug-88	33.00										
BG-SW	25-Sep-88	34.00										
BG-SW	23-Oct-88	35.00										
BG-SW	28-Nov-88	46.00										
BG-SW	03-Jan-89	41.00										
BG-SW	31-Jan-89	28.00										
%BG-SW	06-Mar-89											
BG-SW	13-Mar-89	29.00		<0.1	0.18	<0.1	<0.1	0.24	<0.1	<0.1	<0.1	<0.1
BG-SW	28-Mar-89	29.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BG-SW	25-Apr-89	24.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BG-SW	31-May-89	49.00		1.30	<0.1	<0.1	0.65	<0.1	<0.1	0.14	<0.1	<0.1
BG-SW	23-Jun-89	46.00		<0.1	4.20	<0.1	0.15	<0.1	<0.1	<0.1	<0.1	<0.1
BG-SW	27-Jun-89	57.00		0.19	1.30	<0.1	0.27	0.44	<0.2	<0.1	<0.1	<0.1
BG-SW	25-Jul-89	48.00		<0.1	0.19	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BG-SW	28-Aug-89	29.00		<0.1	0.22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BG-SW	04-Sep-89	30.00		<0.1	0.17	<0.1	0.25	<0.1	<0.1	<0.1	<0.1	<0.1

Site	Date	Nitrate (mg/L)	Bacteria (MPN)	PESTICIDES - HERBICIDES alachlor (ug/L)	atrazine (ug/L)	butylate (ug/L)	cyanazine (ug/L)	metolachlor (ug/L)	metribuzin (ug/L)	pendimethalin (ug/L)	propachlor (ug/L)	trifluralin (ug/L)
BG-SW	05-Sep-89	31.00		<0.1	0.22	<0.1	0.18	0.10	<0.1	<0.1	<0.1	<0.1
BG-SW	26-Sep-89	55.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BG-SW	30-Oct-89	50.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BG-SW	27-Nov-89	51.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BG-SW	27-Dec-89	45.00		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

NOTE: * Denotes dry tile lines.

% Denotes frozen tile line or surface water.