A moderate positive correlation between orthophosphate-P concentration and percentage of agricultural land was observed (Spearman rank coefficient (r_s) = 0.51, $p < 0.0001$). Overall, the relationship between orthophosphate-P concentration and percentage of row crop land use ($r_s = 0.57$, $p < 0.0001$) was stronger than that between orthophosphate-P concentration and percentage of pasture land ($r_s = 0.49$, $p < 0.0001$). A moderate inverse relationship between orthophosphate-P concentration and percentage of forested land was also observed ($r_s = -0.67$, $p < 0.0001$).

Moderate positive correlations were observed between orthophosphate-P concentration and percentage of residential land use ($r_s = 0.66$, $p < 0.0001$) and between orthophosphate-P concentration and percentage of commercial land use ($r_s = 0.71$, $p < 0.0001$). Regionally, correlations between both orthophosphate-P concentration and percentage of residential land use and between orthophosphate-P concentration and percentage of commercial land use were moderate ($r_s = 0.61$, $p < 0.0001$) in the Bluegrass region, but no significant correlation was observed between orthophosphate-P concentration and percentage of residential or commercial land in the East Kentucky Coal Field, Mississippian Plateau or Ohio River Alluvium regions. 351 of 565 samples were taken in the Bluegrass region; 349 were taken at sites with less than 50% residential land use. All 33 sites had less than 30% commercial land use. In summary, orthophosphate-P occurrence in groundwater in BMU 1 may be elevated from nonpoint sources.

Total phosphorus is the sum of organic and inorganic forms of phosphorus. Total phosphorus in reference reach springs was usually nondetect, using an MDL of 0.05 mg/L.

Phosphorus was analyzed in 426 samples and found in 325, or 76.3% (Table 17). Median values were less than 0.05 mg/L in the Eastern Coal Field and the Mississippian Plateau, and 0.032 mg/L in the Ohio River Alluvium (Table 18). The highest median was 0.23 mg/L in the Bluegrass and the highest value (0.938 mg/L) also occurred in that physiographic province. Map distribution of total phosphorus is shown in Figure 57. Reference springs had a median

BMU 1 Median
Total Phosphorus Data

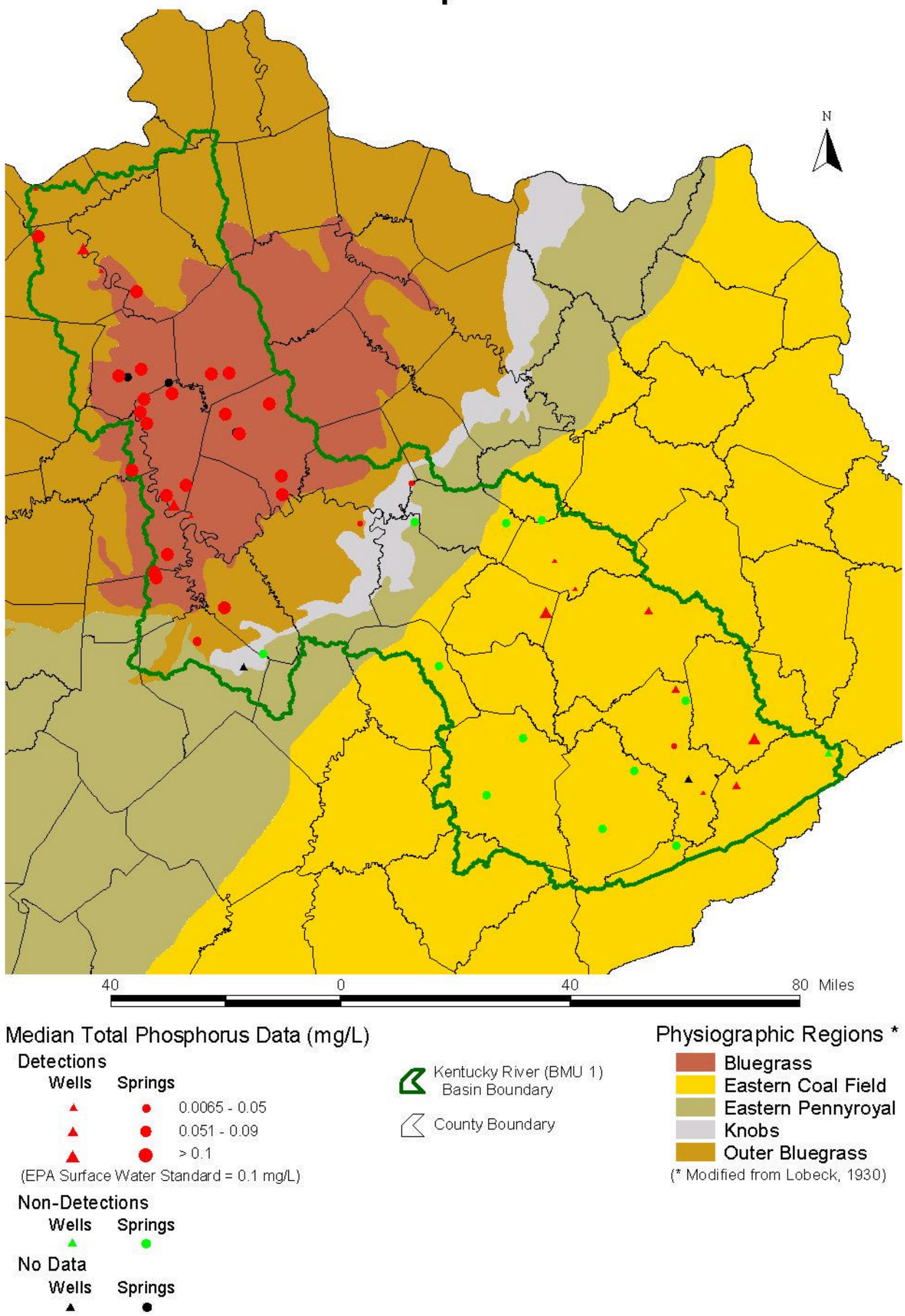


Figure 57. Total Phosphorus Map

phosphorus value of 0.019 mg/L (Table 5), suggesting that values elevated above that level may reflect nonpoint source pollution.

In summary, phosphorus may have impacted groundwater in the study area, but a definitive interpretation is difficult, given this parameter occurs naturally, especially in the phosphatic limestones of the Bluegrass.

Volatile Organic Compounds (Benzene, Toluene, Ethylbenzene, Xylenes, MTBE)

Summaries and descriptive statistics for the volatile organic compounds included in this report are shown in Tables 19 and 20.

The volatile organic compounds most often detected in groundwater are the BTEX compounds: **b**enzene, **t**oluene, **e**thylbenzene and **x**ylenes. Also of concern is **m**ethyl-**t**ertiary-**b**utyl-**e**ther, or MTBE. Because these compounds are among the most commonly found hazardous components of gasoline (Irwin and others, 1997) and because of potential acute and long-term impacts to aquatic life and human health, they are included in this report. Although BTEX compounds also occur naturally, their occurrence in groundwater is usually indicative of point source contamination, most often leaking underground storage tanks.

In urban areas, nonpoint sources of BTEX and MTBE include leaks from automobile gas tanks. Some researchers are concerned with possible air-borne deposition of BTEX and MTBE from the incomplete combustion of fossil fuels. An additional potential source is from pesticides that may contain volatile organic compounds, including BTEX, used as carriers for the active ingredient. These volatile organic compounds are important to evaluate because of various detrimental effects to human health and the environment.

BTEX and MTBE are moderately persistent in the environment, particularly groundwater, for two primary reasons. First, the water solubility of the BTEX constituents range from moderate to high; from 161 mg/L for ethylbenzene to 1730 mg/L for benzene. In

Table 19. Volatile Organic Compounds Summary

BMU1: VOCs SUMMARY[1]		BENZENE	TOLUENE	ETHYLBENZENE	XYLENE	MTBE [2]
NUMBER OF SAMPLES	TOTAL:	209	209	209	209	198
BY REGION:	BLUEGRASS (INNER & OUTER):	147	147	147	147	137
	EASTERN COAL FIELD:	37	37	37	37	37
	MISSISSIPPIAN PLATEAU:	22	22	22	22	21
	OHIO RIVER ALLUVIUM:	3	3	3	3	3
NUMBER OF DETECTIONS	TOTAL:	4	4	0	6	12
	% DETECTS (vs SAMPLES):	1.9%	1.9%	0.0%	2.9%	6.1%
BY REGION:	BLUEGRASS (INNER & OUTER):	4	4	0	6	12
	EASTERN COAL FIELD:	0	0	0	0	0
	MISSISSIPPIAN PLATEAU:	0	0	0	0	0
	OHIO RIVER ALLUVIUM:	0	0	0	0	0
NUMBER OF DETECTIONS ABOVE STANDARD	TOTAL:	0	0	0	0	1
	% DETECTIONS > STANDARD (of SAMPLES w/DETECTIONS):	0.0%	0.0%	0.0%	0.0%	8.3%
	% SAMPLES > STANDARD (of TOTAL SAMPLES):	0.0%	0.0%	0.0%	0.0%	0.5%
BY REGION:	BLUEGRASS (INNER & OUTER):	0	0	0	0	1
	EASTERN COAL FIELD:	0	0	0	0	0
	MISSISSIPPIAN PLATEAU:	0	0	0	0	0
	OHIO RIVER ALLUVIUM:	0	0	0	0	0
NUMBER OF SITES[3]	TOTAL:	34	34	34	34	31
BY REGION:	BLUEGRASS (INNER & OUTER):	20	20	20	20	17
	EASTERN COAL FIELD:	10	10	10	10	10
	MISSISSIPPIAN PLATEAU:	3	3	3	3	3
	OHIO RIVER ALLUVIUM:	1	1	1	1	1
NUMBER OF SITES WITH DETECTIONS	TOTAL:	2	2	0	1	1
	% SITES W/DETECTIONS:	5.9%	5.9%	0.0%	2.9%	3.2%
BY REGION:	BLUEGRASS (INNER & OUTER):	2	2	0	1	1
	EASTERN COAL FIELD:	0	0	0	0	0
	MISSISSIPPIAN PLATEAU:	0	0	0	0	0
	OHIO RIVER ALLUVIUM:	0	0	0	0	0
NUMBER OF SITES WITH DETECTIONS ABOVE STANDARD	TOTAL:	0	0	0	0	1
	%SITES w/DETECTIONS>STANDARD (of SITES w/DETECTIONS):	0.0%	0.0%	0.0%	0.0%	100.0%
	%SITES w/DETECTIONS>STANDARD (of TOTAL SITES):	0.0%	0.0%	0.0%	0.0%	3.2%
BY REGION:	BLUEGRASS (INNER & OUTER):	0	0	0	0	1
	EASTERN COAL FIELD:	0	0	0	0	0
	MISSISSIPPIAN PLATEAU:	0	0	0	0	0
	OHIO RIVER ALLUVIUM:	0	0	0	0	0

	MCL (mg/L)
BENZENE	0.005
TOLUENE	1.000
ETHYLBENZENE	0.700
XYLENE	10.000
MTBE	0.050

[1]VOCs were not included in all analyses:
209 out of 565 samples (at 34 out of 57 sites) show VOC values in this report.

[2]Only 198 MTBE values out of 565 samples:
366 analyses: samples prior to 1999 were not analyzed for MTBE
1 analysis: analysis by different lab did not include MTBE

Table 20. Volatile Organic Compounds Descriptive Statistics

BMU 1: VOCs DESCRIPTIVE STATISTICS	START DATE	END DATE	MAX	MEDIAN	MIN	MODE
	BENZENE (mg/L)					
TOTAL:	**10/16/96**	**06/11/03**	**0.00147**	**< 0.0005**	**0.00038**	**< 0.0005**
BLUEGRASS (INNER & OUTER):	10/16/96	06/11/03	0.00147	< 0.0005	0.00038	< 0.0005
EASTERN COAL FIELD:	04/13/99	05/28/03	< 0.0005	< 0.0005	< 0.0005	< 0.0005
MISSISSIPPIAN PLATEAU:	12/03/96	06/11/03	< 0.0005	< 0.0005	< 0.0005	< 0.0005
OHIO RIVER ALLUVIUM:	04/21/99	03/07/00	< 0.0005	< 0.0005	< 0.0005	< 0.0005
	TOLUENE (mg/L)					
TOTAL:	**10/16/96**	**06/11/03**	**0.00336**	**< 0.0005**	**0.00038**	**< 0.0005**
BLUEGRASS (INNER & OUTER):	10/16/96	06/11/03	0.00147	< 0.0005	0.00038	< 0.0005
EASTERN COAL FIELD:	04/13/99	05/28/03	< 0.0005	< 0.0005	< 0.0005	< 0.0005
MISSISSIPPIAN PLATEAU:	12/03/96	06/11/03	< 0.0005	< 0.0005	< 0.0005	< 0.0005
OHIO RIVER ALLUVIUM:	04/21/99	03/07/00	< 0.0005	< 0.0005	< 0.0005	< 0.0005
	ETHYLBENZENE (mg/L)					
TOTAL:	**10/16/96**	**06/11/03**	**< 0.0005**	**< 0.0005**	**< 0.0005**	**< 0.0005**
BLUEGRASS (INNER & OUTER):	10/16/96	06/11/03	< 0.0005	< 0.0005	< 0.0005	< 0.0005
EASTERN COAL FIELD:	04/13/99	05/28/03	< 0.0005	< 0.0005	< 0.0005	< 0.0005
MISSISSIPPIAN PLATEAU:	12/03/96	06/11/03	< 0.0005	< 0.0005	< 0.0005	< 0.0005
OHIO RIVER ALLUVIUM:	04/21/99	03/07/00	< 0.0005	< 0.0005	< 0.0005	< 0.0005
	XYLENES (mg/L)					
TOTAL:	**10/16/96**	**06/11/03**	**0.0119**	**< 0.0005**	**< 0.0005**	**< 0.0005**
BLUEGRASS (INNER & OUTER):	10/16/96	06/11/03	0.0119	< 0.0005	< 0.0005	< 0.0005
EASTERN COAL FIELD:	04/13/99	05/28/03	< 0.0005	< 0.0005	< 0.0005	< 0.0005
MISSISSIPPIAN PLATEAU:	12/03/96	06/11/03	< 0.0005	< 0.0005	< 0.0005	< 0.0005
OHIO RIVER ALLUVIUM:	04/21/99	03/07/00	< 0.0005	< 0.0005	< 0.0005	< 0.0005
	MTBE (mg/L)					
TOTAL:	**04/13/99**	**06/11/03**	**0.0501**	**< 0.001**	**0.000433**	**< 0.001**
BLUEGRASS (INNER & OUTER):	04/13/99	06/11/03	0.0501	< 0.001	0.000433	< 0.001
EASTERN COAL FIELD:	04/13/99	05/28/03	< 0.02	< 0.001	< 0.001	< 0.001
MISSISSIPPIAN PLATEAU:	04/12/00	06/11/03	< 0.001	< 0.001	< 0.001	< 0.001
OHIO RIVER ALLUVIUM:	04/21/99	03/07/00	< 0.02	< 0.02	< 0.001	< 0.02

comparison, MTBE is very soluble, with values from 43,000 mg/L to 54,300 mg/L. Because of this solubility, MTBE in contaminant plumes moves at virtually the same rate as the water itself, whereas BTEX plumes move at somewhat slower rates. Second, because these compounds (except for benzene) have relatively low vapor pressure and Henry's law constants, they tend to remain in solution, rather than being volatilized. Because of these and other, physical and chemical characteristics, clean up of contaminated groundwater is difficult.

Benzene is found naturally in the environment in organic matter, including coal and petroleum and is released into the environment during combustion. This compound is found in products manufactured from crude oil, including gasoline, diesel and other fuels, plastics, detergents and pesticides. Benzene has an MCL of 0.005 mg/L, is a known carcinogen, and has been associated with various nervous system disorders, anemia and immune system depression (US EPA, 2000).

Toluene is a clear liquid that occurs naturally in crude oil, as well as in products made from refined crude, such as gasoline and diesel fuel. Toluene also occurs naturally in coal and is common in manufactured products including paint, paint thinner, and fingernail polish. Although toluene is not considered carcinogenic in humans (US EPA, 2000), it has been linked with several detrimental physical and neurological effects, including diminished coordination and the loss of sleep. Toluene has an MCL of 1.0 mg/L.

Ethylbenzene is another component of crude oil and is a constituent of refined petroleum products, including gasoline. In addition, this colorless liquid is used to manufacture styrene. According to the US EPA (2000), limited studies of ethylbenzene have shown no carcinogenic effects in humans; however, animal studies have shown detrimental health effects to the central nervous system. The MCL for ethylbenzene is 0.7 mg/L.

Xylenes are any one of a group of organic compounds typically found in crude oil, as well as in refined petroleum products such as gasoline. Xylenes are clear and sweet-smelling. They are used as solvents and in the manufacture of plastics, polyester and film. Xylenes have an MCL of 10 mg/L. They are not carcinogenic in humans, although data are limited. In humans, exposure to excessive amounts is associated with disorders of the central nervous system, kidneys and liver (US EPA, 2000).

BTEX compounds were analyzed for in 209 samples at 147 sites. Benzene and toluene were each detected four times, or 1.9%; xylenes were found in six samples (2.9%); and ethylbenzene was not detected (Table 20). As shown in Figure 58, benzene, toluene and xylenes

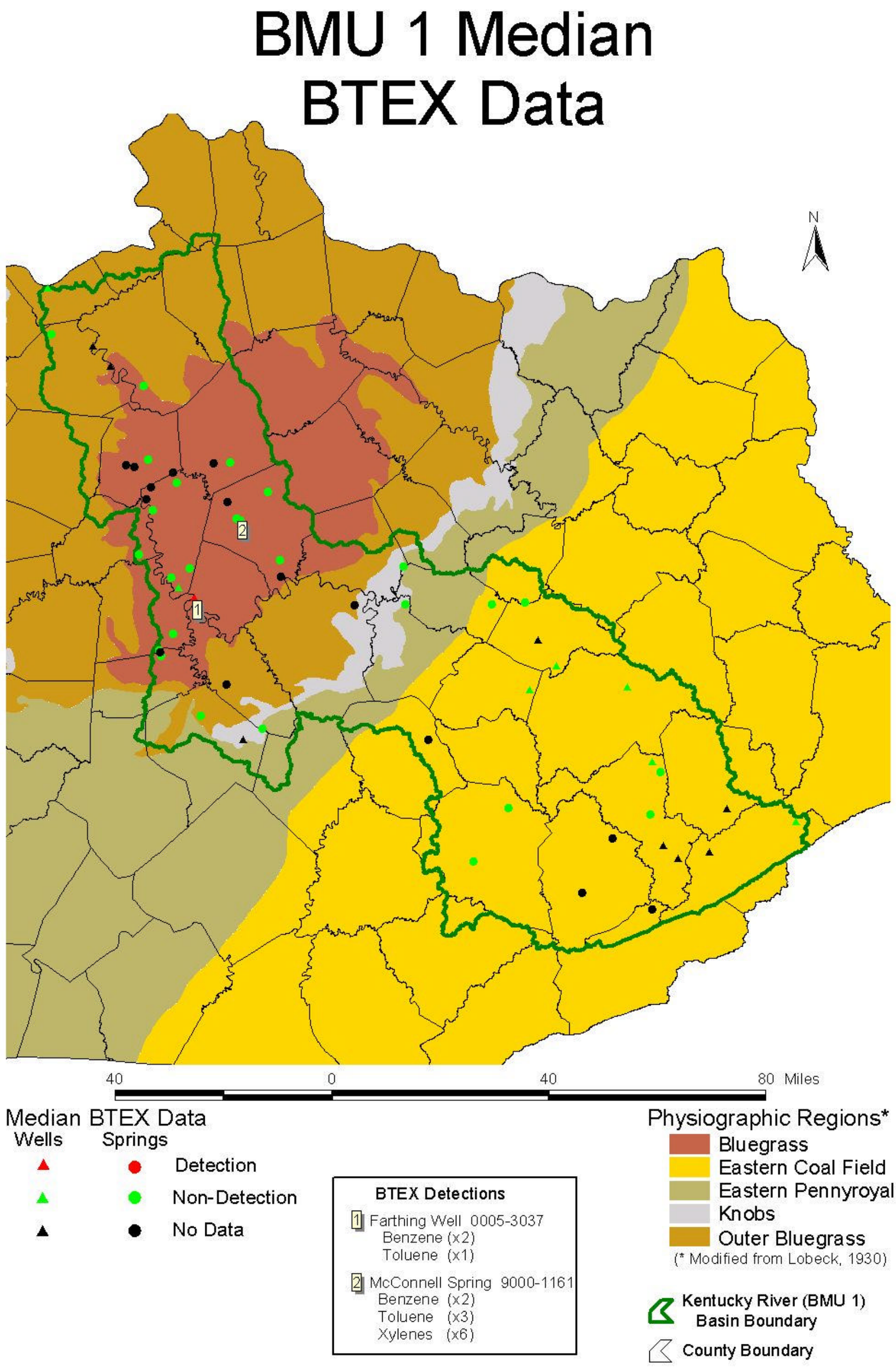


Figure 58. BTEX Map

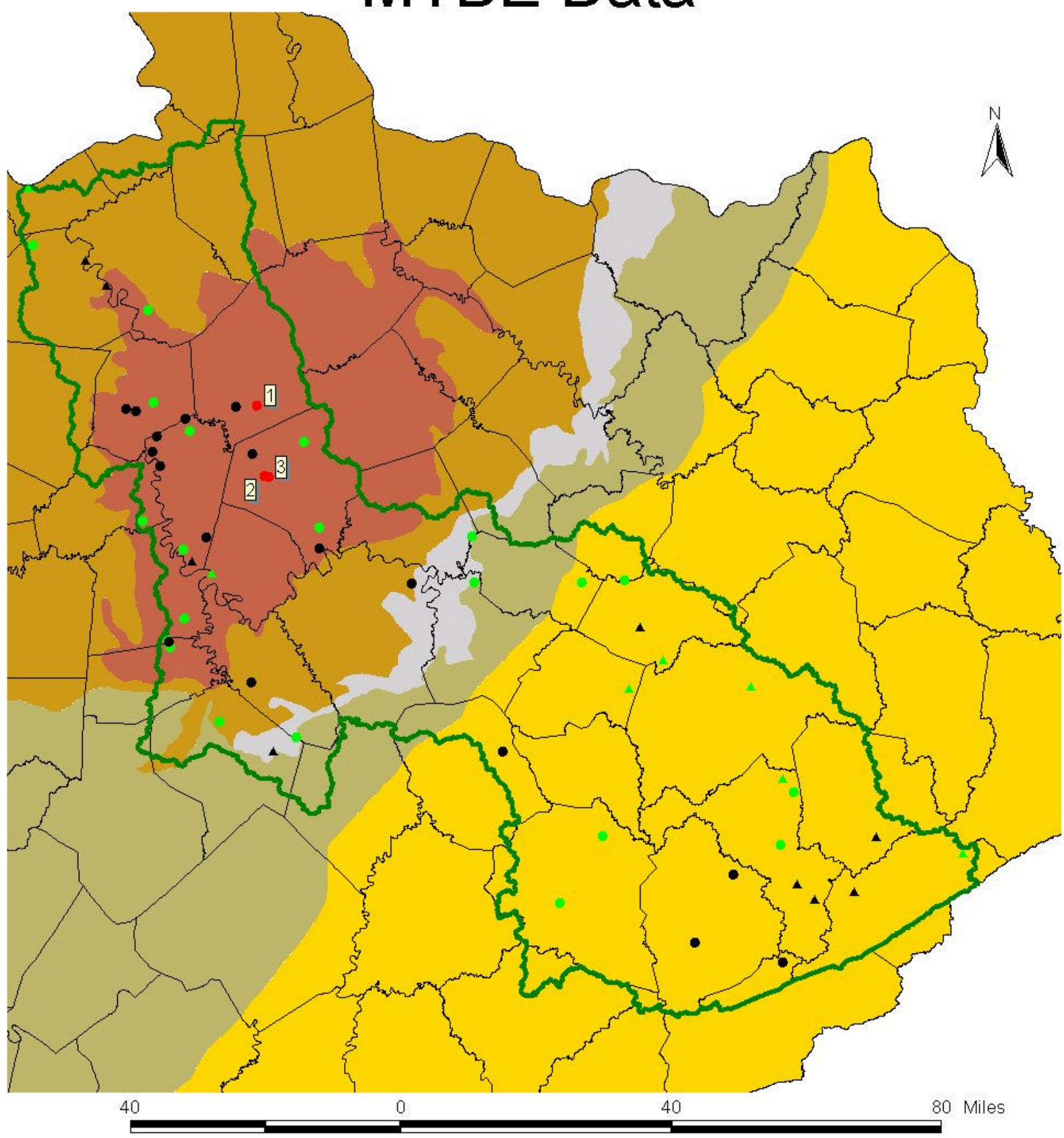
were detected at the Farthing well and McConnell Spring. The source at the Farthing well is unknown, but the detections at McConnell Spring are probably the result of nonpoint source pollution from urban runoff.

Methyl-tertiary-butyl-ether, or MTBE, is a manufactured compound and does not occur naturally. It is used as an oxygenate added to gasoline in order to promote more complete combustion, increase octane and to reduce emissions of carbon monoxide and ozone. MTBE is very mobile in groundwater and has contaminated numerous aquifers throughout the United States. This compound has no MCL; however, the proposed risk-based DEP standard is 0.05 mg/L. According to the US EPA (1997), no studies have documented human health effects from the consumption of MTBE-contaminated water. However, animal studies have shown some carcinogenic and non-carcinogenic effects.

MTBE was analyzed in 198 samples and detected 12 times, or 6.1% (Tables 19 & 20). As shown in Figure 59, MTBE was detected four times in Royal Spring, seven times at McConnell Spring, and once at Prestons Cave Spring, which is a resurgence of McConnell. The occurrence of MTBE in BMU 1 is the result of nonpoint source pollution from urban runoff.

BTEX and MTBE are not widespread nonpoint source pollutants of concern, but they do impact groundwater in some urban springs. The occurrence of these pollutants should continue to be monitored.

BMU 1 Median MTBE Data



Median MTBE Data

Wells	Springs	
	●	Detections
▲	●	Non-Detections
▲	●	No Data

(DEP Risk Based Standard = 0.05 mg/L)

Kentucky River (BMU 1) Basin Boundary

County Boundary

Physiographic Regions*

- Bluegrass
- Eastern Coal Field
- Eastern Pennyroyal
- Knobs
- Outer Bluegrass

(* Modified from Lobeck, 1930)

Specific Detections (mg/L)

1 Royal Spring 9000-0055		
	7-Mar-2001	0.00458
	12-Dec-2001	0.000994
	24-Apr-2002	0.000957
	2-Oct-2002	0.00541
2 Prestons Cave 9000-0103		
	10-Oct-2000	0.00116
3 McConnell Spring 9000-1161		
	13-Apr-1999	0.00501
	13-Oct-1999	0.0501
	11-Jan-2000	0.00998
	12-Apr-2000	0.00422
	25-Apr-2000	0.00597
	31-May-2000	0.00509
	7-Mar-2001	0.000433

Figure 59. MTBE Map

SUMMARY and CONCLUSIONS

The purpose of this project was to collect data and evaluate ambient groundwater quality in BMU 1 and assess nonpoint source impacts to groundwater. Samples collected specifically for this grant were analyzed along with additional data collected in BMU 1 for other projects, including the Statewide Ambient Groundwater Monitoring Program and through an MOA with the Kentucky Division of Pesticides. Almost 600 analyses from 57 sites were reviewed for this report. Although limited in scope, this study adds valuable data to the existing body of groundwater knowledge for the state in general and BMU 1 in particular. The results should prove useful to environmental regulators, resource planners, researchers and private citizens.

Thirty analytes indicative of naturally occurring groundwater chemistry and potential nonpoint source impacts were review. In general, ambient groundwater quality in BMU 1 is good; however, nonpoint sources have impacted, and continue to threaten, the resource in some areas. The table below summarizes these impacts.

A “Definite” impact is defined as an occurrence or detection of an anthropogenic parameter, such as a pesticide or volatile organic compound. Whether such impacts are detrimental would require receptor studies outside the scope of this inquiry. Definite nonpoint source impacts to groundwater in BMU 1 were documented for the following parameters: atrazine (and atrazine desethyl), metolachlor, alachlor and simazine.

A “Possible” impact is a category for those parameters that occur both naturally as well as from anthropogenic sources. These impacts are difficult to assess and at this time, only tentative conclusions can be made. Possible nonpoint source impacts to groundwater were found for several nutrients (nitrate-N, ammonia-N, total phosphorus, orthophosphate-P), pH, lead, total dissolved solids and total suspended solids. The latter two parameters in particular are difficult to assess because they measure numerous elements and compounds, rather than discrete ones.

Parameters with “No” significant impacts to groundwater in BMU 1 were: 1) either not detected, 2) detected in a very limited number of samples or at very low values, such as mercury,

Table 1. Nonpoint Source Impacts to Groundwater in BMU 1

	PARAMETER	NO NPS INFLUENCE ON GROUNDWATER QUALITY	POSSIBLE NPS INFLUENCE ON GROUNDWATER QUALITY	DEFINITE NPS INFLUENCE ON GROUNDWATER QUALITY
Bulk Water Quality Parameters	Conductivity	•		
	Hardness (Ca/Mg)	•		
	pH	•		
Anions	Chloride	•		
	Fluoride	•		
	Sulfate	•		
Metals	Arsenic	•		
	Barium	•		
	Iron	•		
	Lead		•	
	Manganese	•		
	Mercury	•		
Nutrients	Ammonia-N		•	
	Nitrate-N		•	
	Nitrite-N	•		
	Orthophosphate-P		•	
	Total phosphorous		•	
Pesticides	Alachlor			•
	Atrazine (incl. desethyl)			•
	Cyanazine	•		
	Metolachlor			•
	Simazine			•
Residues	Total Dissolved Solids		•	
	Total Suspended Solids		•	
Volatile Organic Compounds	Benzene			•
	Ethylbenzene	•		
	Toluene			•
	Xylenes			•
	MTBE			•

or 3) detected at levels thought to occur naturally. This study found no impacts to groundwater for the following: conductivity, hardness, chloride, fluoride, sulfate, arsenic, barium, iron, manganese, mercury, nitrite, and cyanazine.

Several biases inherent in any sampling program are a concern in the design, implementation and analysis of results. Most importantly, personnel and funding limit both the geographical distribution of sites, as well as the sampling schedule and frequency. For this study, only one site per approximately 123 square miles could be sampled. Temporal variations, which are important in all groundwater systems, but especially in quick-flow karst systems, may not be

adequately addressed through quarterly sampling for one year. Although these problems may preclude definitive conclusions regarding groundwater quality, this project and others like it, contribute vital data that add to our incremental understanding of this resource.

The authors recommend that additional groundwater studies continue, including expansion of the statewide ambient monitoring program and more focused nonpoint source projects, in order to characterize, protect and manage this resource. In particular, future studies should increase the density of sampling sites and the frequency of monitoring, especially in karst terrane.

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APPENDIX A Financial & Administrative Closeout

The Groundwater Branch has committed to the following outputs:

- Identification of suitable groundwater monitoring sites in the Kentucky River basin
- Collection of samples from 30 sites quarterly for one year and delivering these samples to the laboratory for analysis for several parameters, including major inorganic ions, nutrients, pesticides, metals, volatile organic compounds and residues
- Data analysis, including data collected within the basin for other projects
- Production of a report summarizing all relevant groundwater data for this BMU
- Delivering hard-copies of the basin report to the River Basin Teams, local conservation districts, Natural Resource Conservation Service, Agricultural Water Quality Authority, Agricultural Extension offices, and interested stakeholders
- Posting the report on the Division of Water's internet site

Budget Summary

Budget Categories	**Section 319(h)**	**Non-Federal Match**	**Total**	**Final Expenditures**
Personnel	$30,000	$20,000	$50,000	$50,000
Supplies				
Equipment				
Travel				
Contractual				
Operating Costs				
Other				
TOTAL	**$30,000**	**$20,000**	**$50,000**	**$50,000**

There was no equipment purchased for this project and there were no special grant conditions placed on this project.

APPENDIX B Quality Assurance / Quality Control for Water Monitoring

1. Title Section

A. Project Name

Expanded Groundwater Monitoring for Nonpoint Source Pollution Assessment in the Kentucky River Basin

B. QA/QC Plan Preparers

James S. Webb, Geologist - Registered
David P. Leo, Geologist Supervisor - Registered

Kentucky Division of Water, Groundwater Branch
14 Reilly Road
Frankfort, Kentucky 40601

(502) 564-3410

C. Date

April, 1997

D. Project Description

The Kentucky Division of Water currently conducts quarterly nonpoint source groundwater monitoring at approximately 70 sites across the state. This project means to expand that monitoring effort in the Kentucky River Basin (Kentucky Basin Management Unit Two) by increasing the number of monitoring sites and focusing additional efforts of the existing monitoring network in this watershed. This project is intended to work in coordination with other members of the River Basin Team who are conducting surface water and biological sampling.

The goal of this project is to identify the impacts of nonpoint source pollution on the groundwater in the Kentucky River Basin. The objective of this study is to identify aquifers that have been impacted by nonpoint source pollution. Problems in these areas will be identified in order that future nonpoint source resources may be properly focused regarding nonpoint source pollution prevention and pollution abatement.

2. Project Organization and Responsibility

A. Key Personnel

James Webb, Geologist-Registered, Technical Services Section of the Kentucky Division of Water Groundwater Branch will coordinate this project. David P. Leo, Geologist Supervisor - Registered, Technical Services Section, and Peter T. Goodmann, Manager, Groundwater Branch, will provide additional project oversight. James Webb, and Kevin Francis, Hazard Regional Office, will

perform field reconnaissance to select sites and will be responsible for sample collection and delivery. The Kentucky Department for Environmental Protection's Division of Environmental Services laboratory will be responsible for sample analysis. All data generated will be delivered to the Kentucky DEP Consolidated Groundwater Database and will be forwarded to the Kentucky Geological Survey's Groundwater Data Repository.

B. Laboratory

Division of Environmental Services
100 Sower Boulevard
Frankfort, Kentucky 40601

(502) 564-6120

C. Participating Agencies

The Groundwater Branch will coordinate with the Division of Water's Watershed Initiative, the Kentucky River Basin Team, and the Division of Water's Water Quality Branch.

3. Watershed Information

A. Stream Names

Groundwater in the Kentucky River and its tributaries is the focus of this study. Numerous groundwater monitoring sites in these areas have been identified.

B. Major River Basin

The entire Kentucky River basin is included in this study. This includes the lower and central subbasins of the main stem, as well as the North, South, and Middle Forks of the Kentucky River, and tributaries. (Note that the central subbasin of the main stem of the Kentucky River is labeled as the "Upper Kentucky River" by the USGS.)

USGS Hydrologic Unit Number

Lower Kentucky River	05100205
Upper Kentucky River	05100204
North Fork Kentucky River	05100201
South Fork Kentucky River	05100203
Middle Fork Kentucky River	05100202

C. Stream Order

This project encompasses the entire Kentucky River basin, including the North, South, and Middle Forks.

D. Counties in Which Study Area is Located

Lower Kentucky River Subbasin:

Anderson, Boone, Boyle, Carroll, Clark, Fayette, Franklin, Gallatin, Garrard, Grant, Henry, Jessamine, Lincoln, Madison, Mercer, Owen Rockcastle, Scott, Shelby, Woodford

Central (Upper) Kentucky River Subbasin:

Clark, Estill, Jackson, Lee, Madison, Menifee, Montgomery, Owsley, Powell, Wolfe

North Fork Kentucky River:

Breathitt, Knott, Lee, Letcher, Perry, Wolfe

South Fork Kentucky River:

Bell, Clay, Jackson, Knox, Lee, Leslie, Owsley

Middle Fork Kentucky River:

Breathitt, Harlan, Lee, Leslie, Perry

4. Monitoring Objectives

Determine impacts of nonpoint source pollution on groundwater resources in selected areas of the Kentucky River basin

Provide guidance for the nonpoint source program to focus future resources relating to nonpoint source pollution of groundwater.

Support other programs, such as Wellhead Protection program, Groundwater Protection Plan program, Agriculture Water Quality Authority, etc.

Provide additional data useful for the long-term management of the resource.

5. Study Area Description

The Kentucky River rises in the Eastern Kentucky Coal Field Region, which is generally underlain by Pennsylvanian shale, sandstone, coal, and siltstone. The middle reaches of the Kentucky River traverse through the Outer Bluegrass Region and the Inner Bluegrass Region, which is characterized by gently rolling topography and is underlain by Ordovician limestone with some interbedded shale and moderately developed karst hydrology. Between the Eastern Coal Field and the Bluegrass, the Kentucky River also passes through a narrow sections of the Mississippian Plateau and the Knobs Physiographic Regions.

6. Monitoring Program/Technical Design

A. Monitoring Approaches

Monitoring will begin in April 1997. Duplicate samples will be collected for at least 10% of all samples in order to check reproducibility and provide QA/QC.

Field reconnaissance will be conducted prior to groundwater sampling to assess the suitability and accessibility of each site. The appropriate Well Inspection or Spring Inventory records will be completed. Site locations will be plotted on 7.5-minute topographic maps, and identified by a site name and unique identification number (AKGWA number) for incorporation into the Department for Environmental Protection's Consolidated Groundwater Data Base and the Kentucky Geological Survey's Groundwater Data Repository.

B. Monitoring Station Location Strategy

All monitoring station locations will be in addition to other stations currently sampled in the basin. All monitoring sites will be karst groundwater basin springs or karst windows, fracture springs, contact springs or water wells.

C. Sample Frequency and Duration

Monitoring will begin in April 1997 and samples will be collected quarterly through April 1998.

D. Sample Parameters, Containers, Preservation, and Handling

Consistent with other monitoring efforts, samples will be collected at each spring or well and analyzed for some or all of the following: major inorganic ions; nutrients; total organic carbon; pesticides, including the most commonly used herbicides, insecticides, and fungicides; dissolved and total metals; and residues. The list of parameters can be found on the attached Chain-of-Custody Form. The analytical methods, containers, volumes collected, preservation, and sample transport will be consistent with the Division of Water's Standard Operating Procedures for Nonpoint Source Surface Water Quality Monitoring Projects, prepared by the Water Quality Branch (August, 2002).

Major inorganic ions are used to establish background groundwater chemistry and also used to measure impacts from nonpoint source pollutants such as abandoned mine lands and abandoned oil and gas production operations by measuring pH, alkalinity, chloride, sulfate, and fluoride. Nutrients and total organic carbon are used to measure impacts from agricultural operations (ammonia, nitrate, nitrite, total Kjeldahl nitrogen or TKN, and orthophosphate) and/or improper sewage disposal (nitrates, ammonia). Where sewage is suspected as a nonpoint source pollutant, unbleached cotton "bugs" may be used to detect optical brighteners (whitening agents used in laundry products and commonly found in sewage). Pesticides are measured to determine both rural agriculture and urban domestic- and commercial-use impacts on ground water. Metals are used to establish the rock-groundwater chemistry, establish local and regional backgrounds for metals, and determine nonpoint source impacts from abandoned coal mine operations.

Bacteria are **not** a proposed sampling parameter because of logistic considerations. Sampling at numerous sites occurs over a one or two-day period, commonly in remote regions. Because of the short holding time for bacteria (6 hours for fecal coliform, 24 hours for total coliform) we are unable to sample efficiently and regularly collect bacteria samples and comply with the required holding times. Where bacteria are suspected to be a nonpoint source pollutant, bacteria samples may be collected or other sampling events may be scheduled. In addition, unbleached cotton "bugs" may be used to detect optical brighteners, common in domestic sewage, originating from laundry products.

All samples will be analyzed by the Division of Environmental Services laboratory according to the appropriate EPA water method.

7. Chain-of-Custody Procedures

Sample containers will be labeled with the site name and well or spring identification number, sample collection date and time, analysis requested, preservation method, and collector's initials. Sampling personnel will complete a Chain-of-Custody Record, developed in conjunction with the DES laboratory, for each sample. The DES laboratory will be responsible for following approved laboratory QA/QC procedures, conducting analyses within the designated holding times, following EPA-approved analytical techniques, and reporting analytical results to the Groundwater Branch. A sample Chain-of-Custody Form is attached.

8. Quality Assurance/Quality Control Procedures

A. Decontamination Protocols

All sampling supplies that come in contact with the sample will be new, disposable equipment, or will be decontaminated prior to and after each use, using the following protocols.

Sample Collection and Filtration Equipment

Whenever possible, sample collection is conducted using the sample container, except for dissolved metals, which are filtered on site. Sample collection equipment, such as bailers and buckets, will consist of Teflon. Pesticide samples will be collected using the sample container or a stainless steel bailer or bucket, in order to avoid the problem of pesticide adsorption to the sampling device (as is considered to occur with Teflon instruments). Any reusable equipment will be decontaminated by rinsing with a 10% hydrochloric acid (HCL) solution, triple rinsed with deionized water, and triple rinsed with water from the source to be sampled prior to collecting a sample. After sampling is complete, excess sample will be disposed of, and the equipment will again be rinsed with the 10% HCL solution and triple rinsed with deionized water.

New 0.45 micron filters will be used at each sampling site. Any tubing that contacts the sample will also be new. Any reusable filter apparatus will be decontaminated in the same manner as sample collection equipment. Any intermediary collection vessel will be triple rinsed with filtrate prior to use.

Field Meters

Field meter probes will be rinsed with deionized water before and after each use.

B. Equipment Calibration

Field meters will be calibrated in accordance with the manufacturers instructions.

C. Sample Collection and Preservation/Contamination Prevention

Water samples will be fresh groundwater collected prior to any type of water treatment. Samples not requiring field filtration will be collected directly in the sampling container. Samples requiring field filtration will be collected in a Teflon bucket decontaminated in accordance with decontamination protocols for sample collection and filtration equipment, filtered, and transferred to the appropriate container. Pesticide samples will be collected using the sample container or a stainless steel bailer or bucket, wherever necessary.

Sample containers will be obtained from approved vendors, and will be new or laboratory-decontaminated in accordance with Division of Environmental Services accepted procedures. Sample containerization, preservation, and holding time requirements are outlined in the Division of Water's Standard Operating Procedures for Nonpoint Source Surface Water Quality Monitoring Projects, prepared by the Water Quality Branch (August, 2002). Necessary preservatives will be added in the field; preservatives for dissolved constituents will be added after field filtration. Samples will be stored in coolers packed with ice for transport to the Division of Environmental Services laboratory.

Sample containers will be labeled with the site name and identification number, sample collection date and time, analysis requested, preservation method, and collector's initials. Sampling personnel will complete a Chain-of-Custody Record) for each sample. The Division of Environmental Services laboratory will be responsible for following approved laboratory QA/QC procedures, conducting analyses within the designated holding times, following EPA-approved analytical techniques, and reporting analytical results to the Groundwater Branch. Wells will be purged properly prior to sampling.

Samples will be collected as close to the spring resurgence as possible. If inhospitable terrain prohibits spring access, a decontaminated Teflon bucket attached to a new polypropylene rope may be lowered to the spring to collect the sample. Samples for pesticide analysis will be collected using a stainless steel bucket.

Duplicates and Blanks

Duplicate samples will be collected for at least 10% of all samples in order to check reproducibility and provide QA/QC control. At least one duplicate sample will be submitted with each batch of samples, regardless of the number of samples in the batch. Blanks of deionized water will be submitted at least once per quarter. Blanks will be collected, filtered, and preserved in the same manner as a sample.

Field Measurements

Conductivity, temperature, and pH will be measured in the field at each site using portable automatic temperature compensating meters, and recorded in a field log book. Meters will be calibrated according to the manufacturer's specifications, using standard buffer solutions. Meter probes will be decontaminated according to decontamination protocols for field meters and stored according to the manufacturer's recommendations.

CHAIN OF CUSTODY RECORD
NATURAL RESOURCES AND ENVIRONMENTAL PROTECTION CABINET
DIVISION OF WATER - GROUNDWATER BRANCH - Monitoring Network - Billing Code: WPC0400Z

Site Identification	Collection Date/Time	Field Measurements
Location: County: AKGWA #:	Date: _____ Time: _____	pH: _____ Conductivity: _____ µmhos Temp: _____ °C Spring flow: _____

Sampler ID: _____

Division for Environmental Services Samples			
Analysis Requested	**Container Size, Type**	**Preservation Method**	**Parameters**
	1000 ml Plastic Cubitainer	Cool to 4°C	**Bulk Parameters** By **ICP:** Chloride, Fluoride, Nitrate-N, Nitrite-N, Sulfate, Ortho-P **plus** Alkalinity, Conductivity, pH, TSS, TDS
	1000 ml Plastic Cubitainer	H_2SO_4 Cool to 4°C	**Nutrients** NH_3 / TKN / TOC/Total Phosphorous
	1000 ml Plastic Boston Round	Filtered HNO_3 Cool to 4°C	**Dissolved Metals** Aluminum, Barium, Calcium, Iron, Magnesium, Manganese, Nickel, Potassium, Silver, Sodium, Zinc
	1000 ml Plastic Boston Round	HNO_3 Cool to 4°C	**Total Metals** By **ICP**: Aluminum, Barium, Calcium, Iron, Magnesium, Manganese, Nickel, Potassium, Silver, Sodium, Zinc By **Graphite Furnace**: Arsenic, Cadmium, Chromium, Copper, Lead, Selenium By **Cold Vapor Extraction**: Mercury
	1000 ml Amber Glass	Cool to 4°C	**N/P Pesticides** Organochlorine Pesticides/PCBs Methods 507/508
	1000 ml Amber Glass	Cool to 4°C	**Herbicides** Method 555
	Three 40 ml Glass	HCl Cool to 4°C	**VOCs** (Trip Blank Required)

COMMENTS:

Signatures:

Relinquished by: _____ Relinquished by: _____

Received by: _____ Received by: _____

Date: _____ Time: _____ Date: _____ Time: _____

Relinquished by: _____ Relinquished by: _____

Received by: _____ Received by: _____

Date: _____ Time: _____ Date: _____ Time: _____

Sample #: _____ Report #: _____

Revised 5/26/04

APPENDIX C Groundwater Sites Monitored in BMU 1

COUNTY	SITE NUMBER	SITE NAME	PHYSIOGRAPHIC REGION	7.5 QUADRANGLE	TYPE	LATITUDE	LONGITUDE
Carroll	00004033	Carrollton Well	Ohio River Alluvium	Carrollton	PWS Well	38.68040556	85.17739444
Perry	00007178	Viper Elem Well	E KY Coal Field	Hazard S	PWS Well	37.16194444	83.13194444
Letcher	00028100	Fleming/Neon Well	E KY Coal Field	Jenkins W	PWS Well	37.2174003	82.6854692
Wolfe	00029638	Bethany Well	E KY Coal Field	Landsaw	PWS Well	37.6498811	83.4738028
Lincoln	00039352	Wm Whitley Well	Miss Plateau	Crab Orchard	Unused Well	37.4683333	84.53
Owen	00040553	Glenwood Hall Well	Bluegrass	Worthville	PWS Well	38.52438889	85.02344444
Letcher	00044576	Mountain Heritage Well	E KY Coal Field	Blackey	PWS Well	37.14097222	82.97777778
Wolfe	00044679	Campton Double-Kwik	E KY Coal Field	Campton	PWS Well	37.72152778	83.53416667
Perry	00044688	Homeplace Well	E KY Coal Field	Noble	PWS Well	37.38805556	83.16111111
Perry	00046635	Whiskey Store Well	E KY Coal Field	Vicco	PWS Well	37.12805556	83.08583333
Knott	00046639	Baker Well	E KY Coal Field	Hindman	Private Well	37.2569442	82.9166667
Breathitt	00047174	Rousseau School Well	E KY Coal Field	Guage	PWS Well	37.5886019	83.2388969
Lee	00048656	Samples Well	E KY Coal Field	Tallega	Private Well	37.58916667	83.56694444
Henry	00048657	Cox Well	Bluegrass	Gratz	Unused Well	38.47138889	84.96666667
Mercer	00053037	Farthing Well	Bluegrass	Wilmore	Private Well	37.8508333	84.6897222
Woodford	00054122	Hack Well	Bluegrass	Keene	Private Well	37.8777567	84.7413889
Scott	90000055	Royal Spring	Bluegrass	Georgetown	PWS Spring	38.20888889	84.56166667
Fayette	90000077	Silver Spring	Bluegrass	Lexington W	Unused Spring	38.1039786	84.5746872
Fayette	90000103	Prestons Cave Spring	Bluegrass	Lexington W	Unused Spring	38.05694444	84.54194444
Lincoln	90000120	St Asaph Spring	Bluegrass	Stanford	Unused Spring	37.53138889	84.67361111
Fayette	90000552	Russell Cave Spring	Bluegrass	Centerville	Unused Spring	38.12861111	84.43444444
Boyle	90000583	Rankin Spring	Bluegrass	Danville	Private Spring	37.69361111	84.80222222
Woodford	90001053	Moores Spring	Bluegrass	Salvisa	Unreg Public Spring	37.90138889	84.76527778
Woodford	90001103	Shanes Spring	Bluegrass	Frankfort E	Unused Spring	38.1877611	84.7580167
Henry	90001132	Barker Spring	Bluegrass	Campbellsburg	Unused Spring	38.55583333	85.16666667
Jackson	90001133	Turkey Foot Spring	E KY Coal Field	Mckee	Unreg Public Spring	37.45972222	83.91111111
Powell	90001134	Nada Spring	Miss Plateau	Slade	Unreg Public Spring	37.81638889	83.68777778
Estill	90001135	Spout Spring	Miss Plateau	Clay City	Unreg Public Spring	37.82277778	83.97916667
Anderson	90001139	McCalls Spring	Bluegrass	Salvisa	Unused Spring	37.96447222	84.87388889
Franklin	90001143	Cedar Cove Spring	Bluegrass	Frankfort E	Unused Spring	38.21888889	84.84166667
Garrard	90001144	Dripping Springs	Bluegrass	Brodhead	Unreg Public Spring	37.49638889	84.46666667
Franklin	90001152	Sanchez Spring	Bluegrass	Frankfort W	Unused Spring	38.19861111	84.88805556
Menifee	90001154	Trail Spring	E KY Coal Field	Pomeroyton	Unused Spring	37.82027778	83.57361111
Clay	90001155	Aunt Sophs Spring	E KY Coal Field	Oneida	Unreg Public Spring	37.27277778	83.64777778
Clay	90001156	Mustang Spring	E KY Coal Field	Manchester	Unreg Public Spring	37.13194444	83.76805556
Woodford	90001157	Watts Ferry Spring	Bluegrass	Tyrone	Unreg Public Spring	38.11194444	84.84638889
Madison	90001159	Corren Spring	Bluegrass	Union City	Unused Spring	37.8225	84.15
Owen	90001160	Ford Spring	Bluegrass	Monterey	Unused Spring	38.41666667	84.85416667
Fayette	90001161	McConnell Spring	Bluegrass	Lexington W	Unused Spring	38.05416667	84.53
Powell	90001178	Sizemore Spring	Miss Plateau	Levee	Unused Spring	37.92194444	83.98388889
Scott	90001194	Slacks Spring	Bluegrass	Georgetown	Unused Spring	38.20638889	84.61777778
Woodford	90001200	Spring St Blue Hole	Bluegrass	Midway	Irrigation Spring	38.15722222	84.74305556
Fayette	90001201	Boggs Spring	Bluegrass	Coletown	Unused Spring	37.94611111	84.39722222
Mercer	90001208	Burgin Spring	Bluegrass	Harrodsburg	Unused Spring	37.75277778	84.76333333
Franklin	90001236	Double Springs	Bluegrass	Frankfort W	Unused Spring	38.2047219	84.9152778
Garrard	90001381	Jackman Cave Spring	Bluegrass	Lancaster	Unused Spring	37.61555556	84.58555556
Fayette	90001949	Lauras Spring	Bluegrass	Coletown	Private Spring	37.90083333	84.3975
Mercer	90002197	Gwinn Spring	Bluegrass	Danville	Livestock Spring	37.70777778	84.80777778
Boyle	90002199	Blacksmith Spring	Bluegrass	Danville	Unused Spring	37.70444444	84.80694444
Woodford	90002424	Labrador Spring	Bluegrass	Keene	Unused Spring	37.92722222	84.70333333
Woodford	90002425	Old Taylor Spring	Bluegrass	Frankfort E	Unused Spring	38.14527778	84.83305556
Woodford	90002427	Clifton Spring	Bluegrass	Tyrone	Unused Spring	38.0825	84.82583333
Leslie	90002445	Tower Mnt. Spring	E KY Coal Field	Hoskinston	Private Spring	37.04	83.40694444
Perry	90002448	Dads Spring	E KY Coal Field	Hazard N	Unused Spring	37.3574778	83.1333622
Perry	90002449	Lothair Spring	E KY Coal Field	Hazard S	Private Spring	37.24555556	83.17333333
Harlan	90002451	Hemlock Spring	E KY Coal Field	Nolansburg	Unused Spring	36.9925	83.175
Leslie	90002452	Wooton Spring	E KY Coal Field	Hyden E	Private Spring	37.18333333	83.3

Table C-1 Groundwater Sites Monitored in BMU1

SITE NUMBER	SITE NAME	SAMPLE EVENTS PER SITE	1 QTR 1995	2 QTR 1995	3 QTR 1995	4 QTR 1995	1 QTR 1996	2 QTR 1996	3 QTR 1996	4 QTR 1996	1 QTR 1997	2 QTR 1997	3 QTR 1997	4 QTR 1997	1 QTR 1998	2 QTR 1998	3 QTR 1998	4 QTR 1998	1 QTR 1999	2 QTR 1999	3 QTR 1999	4 QTR 1999	1 QTR 2000	2 QTR 2000	3 QTR 2000	4 QTR 2000	1 QTR 2001	2 QTR 2001	3 QTR 2001	4 QTR 2001	1 QTR 2002	2 QTR 2002	3 QTR 2002	4 QTR 2002	1 QTR 2003	2 QTR 2003
00004033	Carrollton Well	**4**																		1	1	1	1													
00007178	Viper Elem Well	**7**		1		1	1	1	1	1		1																								
00028100	Fleming/Neon Well	**18**		1			1	1	1			1	1	1	1	1			1	1				1	1		1				1	1		1		1
00029638	Bethany Well	**4**																1	1	1					1											
00039352	Wm Whitley Well	**5**		1	1	1	1	1																												
00040553	Glenwood Hall Well	**5**															1	1	1	1	1															
00044576	Mountain Heritage Well	**2**											1	1																						
00044679	Campton Double-Kwik	**5**											1				1	1	1	1																
00044688	Homeplace Well	**7**											1	1			1	1	1	2																
00046635	Whiskey Store Well	**3**																1	1	1																
00046639	Baker Well	**4**															1	1	1	1																
00047174	Rousseau School Well	**6**											1				1	1	1	1	1															
00048656	Samples Well	**1**																		1																
00048657	Cox Well	**4**															1	1	1	1																
00053037	Farthing Well	**2**																						1	1											
00054122	Hack Well	**1**																						1												
90000055	Royal Spring	**36**		1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	2	1	1	1	3	1		1	1	1	1		1	2	1	1	1
90000077	Silver Spring	**3**					1												1	1																
90000103	Prestons Cave Spring	**2**											1													1										
90000120	St Asaph Spring	**19**											1	1	1		1	1		1		1	1	1	1		1	1	1	1		1	1	1	1	1
90000552	Russell Cave Spring	**28**		1	1	1	1	1		1	1	2	1	1		1			1	1		1	1	3			1	1	1	1		1	1	1	1	1
90000583	Rankin Spring	**2**																			1		1													
90001053	Moores Spring	**1**																					1													
90001103	Shanes Spring	**1**							1																											
90001132	Barker Spring	**22**		1		1	1	2		2	1	1	1	1	1	1			1								1	1	1		1	1		1	1	1
90001133	Turkey Foot Spring	**15**		1	1	1	1	1	1	1	1	1	1	1	1	1	1		1																	
90001134	Nada Spring	**33**		1	1	1	1	1	1	1	1	1	2	1	1	1		1	2	1	1	1		2	2		1	1	1	1		1	1	1	1	1
90001135	Spout Spring	**28**		1	1	1	1	1	1	1	1	1	2		1	1		1		1	1	1		1	1		1	1	1	1		1	1	1	1	1
90001139	McCalls Spring	**32**		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		2		2	1	2	1		1	1	1	1		1	1	1	1	1
90001143	Cedar Cove Spring	**32**			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	2	1		1	1	1	1		1	1	1	1	1
90001144	Dripping Springs	**24**			1	1	1	1	1	1	1	1	1	1	1				1			1	1	1			1	1	1	1		1	1	1	1	1
90001152	Sanchez Spring	**1**											1																							
90001154	Trail Spring	**9**															1	1	1	1	1	1		2	1											
90001155	Aunt Sophs Spring	**7**															1	1	1	2		1		1												
90001156	Mustang Spring	**17**															1	1	1	2		1		1	1		1		2		1	1	1	1	1	1
90001157	Watts Ferry Spring	**6**															1	1	2	1			1													
90001159	Corren Spring	**3**															1	1		1																
90001160	Ford Spring	**7**															1	1	1	1	1		1	1												
90001161	McConnell Spring	**33**		1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	2		1	1	3			1	1	1	1		1	1	1	1	1
90001178	Sizemore Spring	**8**								1		1	1	1	1	1		1						1												
90001194	Slacks Spring	**5**															1		2	1			1													
90001200	Spring St Blue Hole	**26**								1	1	1	2	1	1	3	2		1	2	1		1	4	1			3	1							
90001201	Boggs Spring	**26**										1	2	1	1	3	2	1	1	3	1		1	4	1			3	1							
90001208	Burgin Spring	**8**											1	1	1		1	1		1			1	1												
90001236	Double Springs	**1**															1																			
90001381	Jackman Cave Spring	**3**															1	1		1																
90001949	Lauras Spring	**5**													1		1	1	1	1																
90002197	Gwinn Spring	**1**																					1													
90002199	Blacksmith Spring	**1**																					1													
90002424	Labrador Spring	**4**															1	1	1	1																
90002425	Old Taylor Spring	**3**															1	1	1																	
90002427	Clifton Spring	**4**																1	2	1																
90002445	Tower Mnt. Spring	**3**															1	1		1																
90002448	Dads Spring	**15**															1	1	1	2				1	1		1		2			1	1	1	1	1
90002449	Lothair Spring	**5**															1	1	1	1				1												
90002451	Hemlock Spring	**4**															1	1	1	1																
90002452	Wooton Spring	**4**															1	2	1																	
57	**TOTALS**	**565**	0	11	10	12	14	14	11	14	11	18	26	17	16	17	34	35	38	49	12	14	18	38	15	1	13	16	16	9	3	13	12	13	12	13

Table C-2 Number of Groundwater Samples per Site in BMU1