Framework for the Kentucky Ground-Water Monitoring Network: A Report of the Interagency Technical Advisory Committee

Dr. Lyle V.A. Sendlein, Director
Kentucky Water Resources Research Institute

April 1996

Framework for the Kentucky Ground-Water Monitoring Network: A Report of the Interagency Technical Advisory Committee

Executive Summary

Introduction

This report describes an activity that was conducted by the Kentucky Water Resources Research Institute (KWRRI) at the request of the Kentucky Geological Survey (KGS). As a result of a recommendation of the Ground Water Consensus Committee convened by Secretary Phillip Shepherd, Kentucky Natural Resources and Environmental Protection Cabinet, draft legislation was developed for the creation of a ground water monitoring network. This legislation did not get enacted in the 1994 session of the Legislature but has been submitted to the 1996 Legislature.

In this bill, an interagency technical advisory committee is defined as a body of individuals who are very familiar with ground-water data collection and utilization by state agencies. Because the need for such an activity is increasing, the Director of the KWRRI invited the agencies listed in the proposed legislation to participate in the formation of an *ad hoc* Interagency Technical Advisory Committee. This report describes the work of this committee

Major Goals for a Ground Water Monitoring Network

I. Provide baseline data on ambient ground-water resources
II. Characterize ground-water resources
III. Disseminate information collected and created by the network

The condition of ***ambient* ground water** as used in this document refers to the existing condition of ground water in Kentucky at a given time. The network will avoid monitoring ground water that is affected by a point source of contamination. It is a primary objective of the network to determine the condition of ambient ground water used in each major area of Kentucky and document long-term changes in quality and quantity.

Baseline data on ground-water resources used and collected by the network should:
(1) Provide an adequate spatial coverage of usable data in each major area of the State, and
(2) Provide a measure of long-term trends in ground-water quality and quantity.

The network will coordinate with other data-collection efforts in the State to build and appropriate information base on ambient ground-water resources.

Electronic data transfer to agencies and among agencies should be facilitated by the network as it prevents useful data from languishing in only paper form.

The Network Design Subcommittee attempted to propose an "acceptable" or "adequate" level of data to be gathered for baseline information. Virtually all members of the subcommittee, as scientists and engineers, would prefer a greater amount of data than is proposed in this framework for determining the ambient quality of ground water and variations over time. General State funding constraints kept the discussions focused on a reasonable and limited network design.

April 1996

Basic outline of data-collection tasks:

I. Use of existing data. Sources will include appropriate data currently being collected by other programs, and appropriate historical data that is computerized. If funding is available, data entry of the most valuable information in paper records is a goal.

II. A Temporal Network established through network monitoring strategy will be periodically re-sampled to evaluate changes in ground-water resources over time. Most of these proposed 641 sampling points will be springs and existing wells, and a minority of sites will be new monitoring wells.

III. Annual, one-time sampling of 120 additional wells and springs (one per county) that fit network criteria.

IV. Identify areas in each region where information on ground-water resources is lacking and, if possible, develop study areas to determine physical controls on ground-water quality and quantity that affect users.

The Network Design Subcommittee established seven different areas as the basis for development of tailored monitoring strategies. These areas correspond to six physiographic areas and a River Alluvium category. The spatial distribution of sampling points will be sufficient to characterize ground water based on numerous subdivisions of the State including major watersheds, ADD districts, major aquifers, and others.

Proposals for each area include the number of wells and springs to be monitored as part of the Temporal Network. The total number of monitoring points to be sampled on a repeated basis is 641 for the entire State.

The network should have resources to collect 800 ground-water samples per year. This amount of sampling will require three sampling teams. One sampling team should be based in western Kentucky.

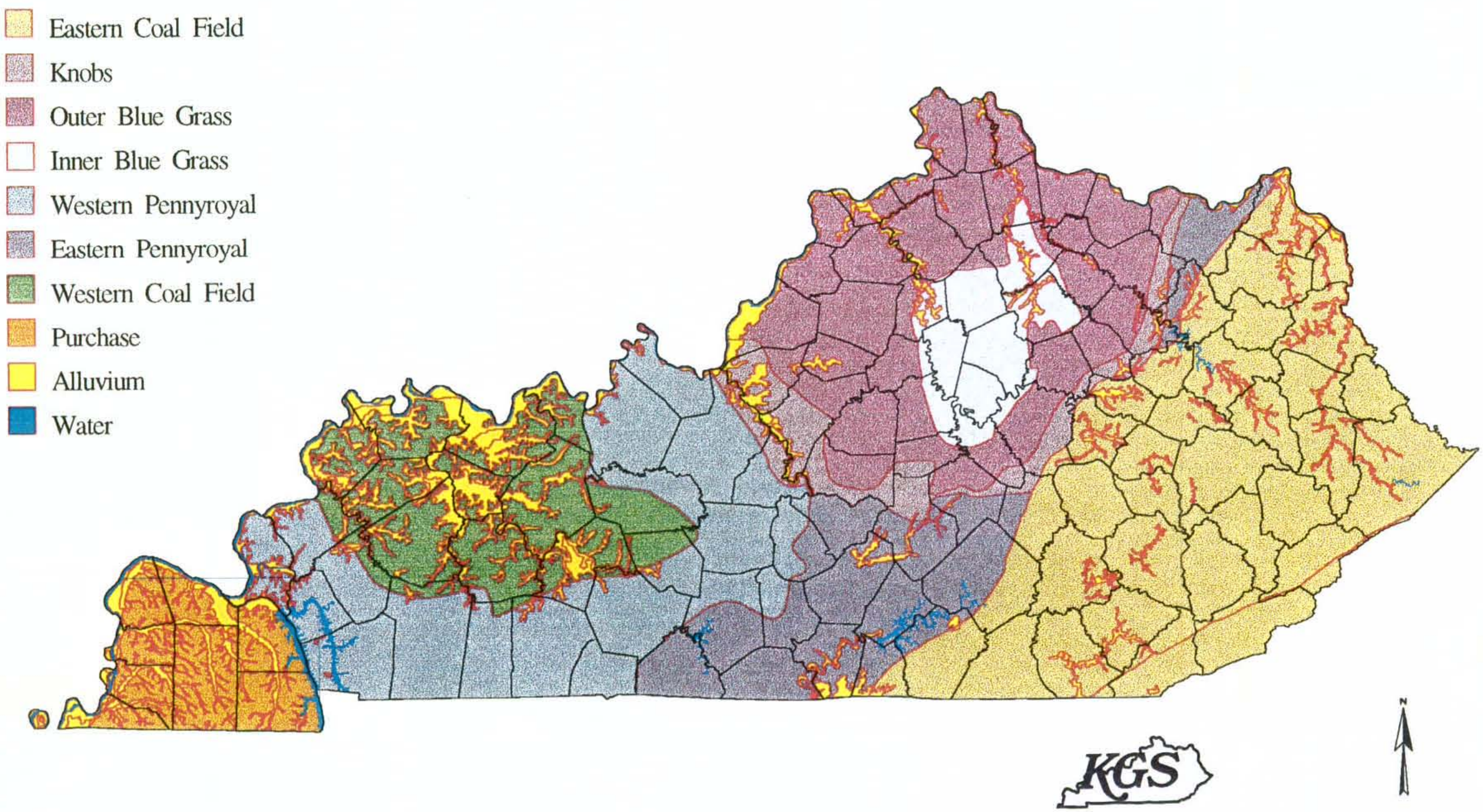
The list of laboratory analyses includes the many natural constituents that affect the potability of water, common pesticides, and other common organic chemicals.

The sampling frequency will be different for different monitoring points. It is advantageous to have a sample from each season of the year from each ground-water source for an evaluation of seasonal variation in quality and quantity. It will take a number of years to collect a sample from all four seasons at all of the proposed Temporal monitoring points. Water sources with very little seasonal variation in water quality will be sampled less frequently than other sites.

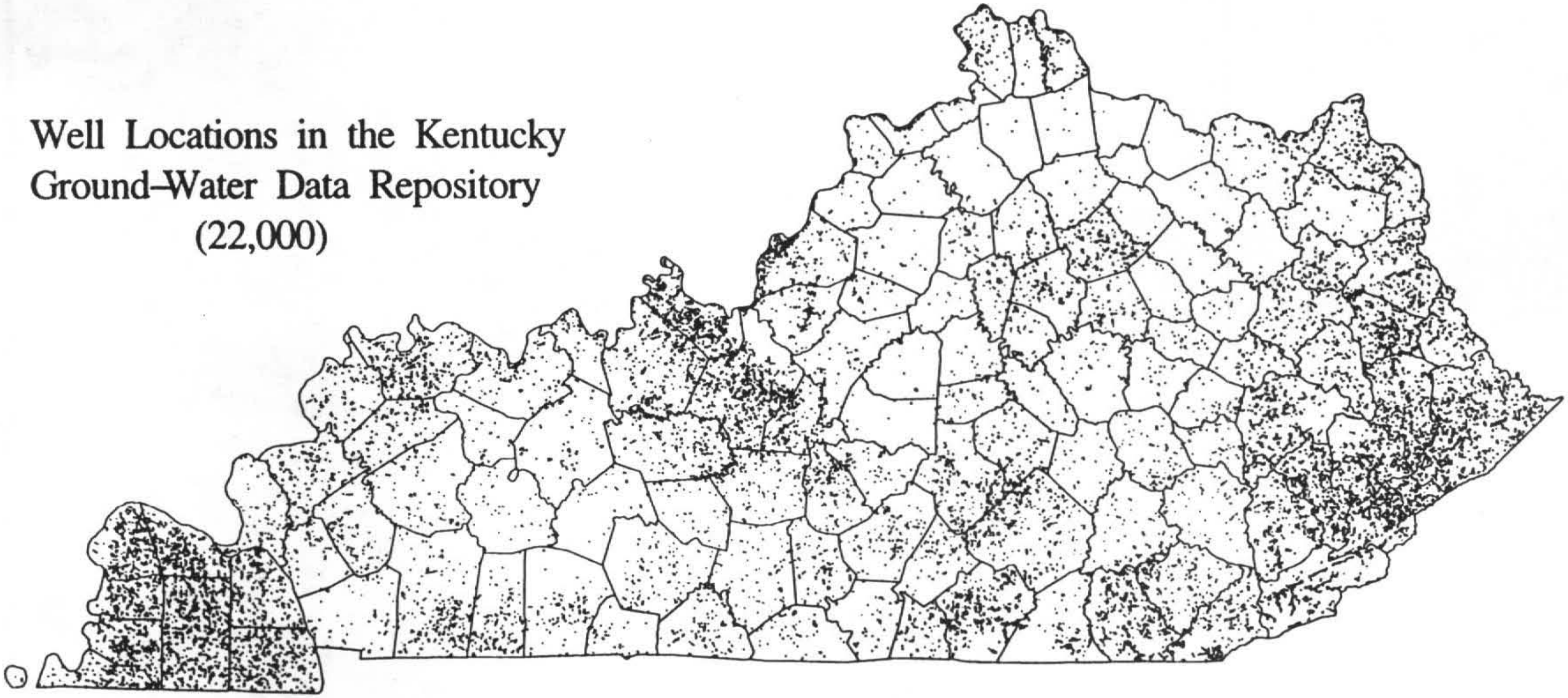
The level of actual funding for the network will require an evaluation of network design by the Technical Advisory Committee and the Kentucky Geological Survey.

The following state maps are for reference. They show the physiographic regions of Kentucky and documented water-well locations.

Regions of Kentucky



Well Locations in the Kentucky
Ground-Water Data Repository
(22,000)



Framework for the Kentucky Ground-Water Monitoring Network: A Report of the Interagency Technical Advisory Committee

Dr. Lyle V.A. Sendlein, Director
Kentucky Water Resources Research Institute

April 1996

TABLE OF CONTENTS

PREFACE

Interagency Technical Advisory Committee

At the request of the Director of the Kentucky Geological Survey (KGS), the Kentucky Water Resources Research Institute convened a group of individuals representing all of the governmental agencies that collect ground-water information. The agencies selected were those included in proposed legislation that was not enacted in the last session. The language of the proposed legislation called for the creation of an Interagency Technical Advisory Committee to be chaired by the Director of the Kentucky Water Resources Research Institute. Realizing that the need is even greater for the coordination of the collection and storage of ground-water information than a year ago, the leadership of the agencies identified in that legislation agreed to be part of the Interagency Technical Advisory Committee.

The agencies that participated in this committee activity and the designated person from each agency are presented below:

University of Kentucky Water Resources Research Institute
- **Lyle V. A. Sendlein**
- **Jim Kipp**

Kentucky Geological Survey
- **Philip Conrad**
- **James Dinger**

Kentucky Department for Environmental Protection
- **Division of Water**
  - **Jack Wilson**
- **Division of Waste Management**
  - **Mike Welch**

Kentucky Department for Surface Mining Reclamation and Enforcement
- **Dick Rohlf**

University of Kentucky College of Agriculture
- **Bill Thom**

U. S. Geological Survey
- **Chuck Taylor**

Kentucky Division of Conservation
- **Steve Coleman**

Kentucky Society of Professional Engineers
- **Mike Welch**

Kentucky Professional Geologists
  - **Don Haney**

Kentucky Rural Water Association
- **Joe Burns**

Kentucky Department of Agriculture
- **Division of Pesticides**
  - **Ernest Collins**

Kentucky Cabinet for Human Resources, Division of Environmental Sanitation and Community Safety
  - **Sam Burnette**

Kentucky Protection and Regulation Cabinet Department of Mines and Minerals
- **Rick Bender**

Kentucky Ground-Water Association
- **Michael Murray**

Individual Participants

As the Committee began its work, it became apparent that other individuals needed to be a part of the activity. Each participating agency provided the individuals that were most intimately involved with the collection and storage of ground-water information. The time and ideas contributed to this effort are greatly appreciated. These individuals are listed below:

Chuck Taylor, USGS	David Wunsch, KGS
Mike Unthank, USGS	Jim Currens, KGS
Tom Mesko, USGS	Dan Carey, KGS
Jack Wilson, DOW	Alex Fogle, KGS
Peter Goodman, DOW	Steve Coleman, DOC
David Leo, DOW	Brents Dickinson, KSPE
Jim Webb, DOW	Ernest Collins, DA
Bill Yarnell, DOW	Joe Burns, KRWA
Joe Ray, DOW	Lyle Sendlein, KWRRI
Kay Harker, KNREPC	Jim Kipp, KWRRI
Zita Hardin, KNREPC	Dick Rohlf, DSMRE
Brian Baker, DWM	Dave Johnson, DSMRE
Tammy Hecker, DWM	Pam Carew, DSMRE
Don Haney, KGS	Rick Bender, DMM
John Kiefer, KGS	Michael Murray, KGWA
Jim Cobb, KGS	Mike Welch, DWM
Jim Dinger, KGS	Sam Burnette, CHR
Phil Conrad, KGS	J.R. Hamm, DSMRE
Bart Davidson, KGS	Bill Thom, UKCAgr.

Why a Ground-Water Monitoring Network?

The idea of a ground-water monitoring network is not new. Various state agencies have been trying to get funding to develop an adequate monitoring program to learn more about the ground water of the Commonwealth. A significant portion of the population relies on ground water for drinking water, and there is agricultural and industrial use of this resource as well. The information on ground water from private wells is currently from individual study sites and other clusters of data with little information for large areas of Kentucky. However, the collection of ground-water data has increased in recent years due to regulatory requirements, and it is apparent that a lot of the information being collected is not easily accessed. It is clear that some form of infrastructure is needed to facilitate the collection, storage and dissemination of ground-water information.

Ground-water data acquired from different programs and placed in a central data base can be used to characterize the occurrence and quality of the ground water. Natural variations in the occurrence and quality of the ground water make it difficult to characterize and assess the quality of the resource with current information. Systematic collection of ground-water data will greatly assist in identifying natural variations in quality and quantity of ground water that are of concern to users, assessing resource allocation, setting wellhead protection boundaries, and evaluating and improving the quality and quantity of data collected through all programs that can support ground-water data management systems.

The Secretary of the Natural Resources and Environmental Protection Cabinet convened a Groundwater Consensus Committee in 1993 to assist in the drafting of groundwater protection regulations for the Commonwealth. The committee consisted of representatives from State, Federal, local, business and industrial, and public interests. During the deliberations of this committee, it became apparent that not enough ground-water information was available to best utilize the resource or to make good management decisions to protect it. As part of the Committees work, a subcommittee was established to explore ways that ground water information could be collected and stored for future management use. This subcommittee developed a draft bill for consideration by the legislature. This bill has been modified and is currently being presented for consideration by the next session of the legislature. A copy of that bill is attached as Appendix I.

INTRODUCTION

Interagency Technical Advisory Committee

The Interagency Technical Advisory Committee began meeting on June 8, 1995. Two subcommittees were established for the major planning activities. During 1995, there were a total of eight meetings of the Committee and the Network Design and Data Format Subcommittees. The main goal of the Interagency Technical Advisory Committee was to produce a report with recommendations on establishing a statewide ground-water network.

Major Goals For A Ground Water Monitoring Network

I. Provide baseline data on ambient ground-water resources
II. Characterize ambient ground-water resources
III. Disseminate information collected and created by the network

Mission Statement for the Network

Provide baseline data on ground-water resources with an emphasis on currently-used, ambient ground water, or ground-water that has the potential for future development, or a direct impact on the quality of surface-water supplies through ground-water discharge. Ambient here refers to the existing condition of ground-water in Kentucky at a given time. The network, by design, will avoid monitoring ground water affected by point sources of contamination. Appropriate data from all sampling efforts will be used, and additional data that are needed for characterization will be collected by the network. It is a primary objective of the network to determine the condition of ambient ground water used in each major area of Kentucky and document long-term changes in quality and quantity.

Characterize ground-water resources such that various aspects of the quality and quantity of the resource are evaluated, including spatial and temporal variability, the quality of resources that are used, and long-term changes.

Disseminate information collected and created by the network by various means. Summary information will be available via the Internet, paper publications, and other appropriate avenues of distribution. Summaries for different areas of the State will include defining subsurface zones with good and poor ambient water quality with respect to home, industrial, and agricultural uses. Variations in ground-water quality over time will also be defined for various settings. Such characterizations will be created using knowledge of the subsurface systems that control variations in quality and quantity, and changes over time. Much of this information will be reduced to simple maps and diagrams that can be read by non-scientists. Also, data collected by the Network will be stored in the Kentucky Ground-Water Data Repository, and will be available to anyone.

Coordination of Monitoring Organizations

The Network will be far more effective if all monitoring organizations in the State participate in data collection and storage in the Kentucky Ground-Water Data Repository. The coordination of monitoring organizations will greatly reduce redundant efforts, expedite the use of data from various sources, and assure the usefulness of network information for multiple purposes. The Interagency Technical Advisory Committee should guide and assist the network in data transfer between various organizations and inclusion in the Repository, and in establishing mutually beneficial data-collection activities in the State. This may include coordinating with other water monitoring efforts to conserve human and fiscal resources, while maintaining the integrity of information on ambient ground water.

DATA-FORMAT SUBCOMMITTEE ACTIVITIES AND RECOMMENDATIONS

Data-Format Objectives

The long-term goal of the Data-Format Subcommittee is to facilitate efficient inter-agency transfer of electronic groundwater information, and to promote submission of these data electronically to the Kentucky Ground-Water Data Repository. The purposes of electronic data handling are to: (1) reduce the need for labor-intensive and costly re-typing of data from paper copies, (2) reduce the unavoidable errors from re-typing columns of data, and (3) increase the amount of data that is used electronically for various purposes due to greater efficiency. Although every agency that collects groundwater information will have some data fields that are unique to the needs of that agency, the Data-Format Subcommittee also recommends the use of a standardized format for primary data fields used by the agencies, such as latitude/longitude, surface elevation, etc.

A primary department agency that collects ground water information, the Department for Environmental Protection, is already planning to develop better electronic data-handling capabilities, including the submission of data to appropriate agencies in an electronic format when possible.

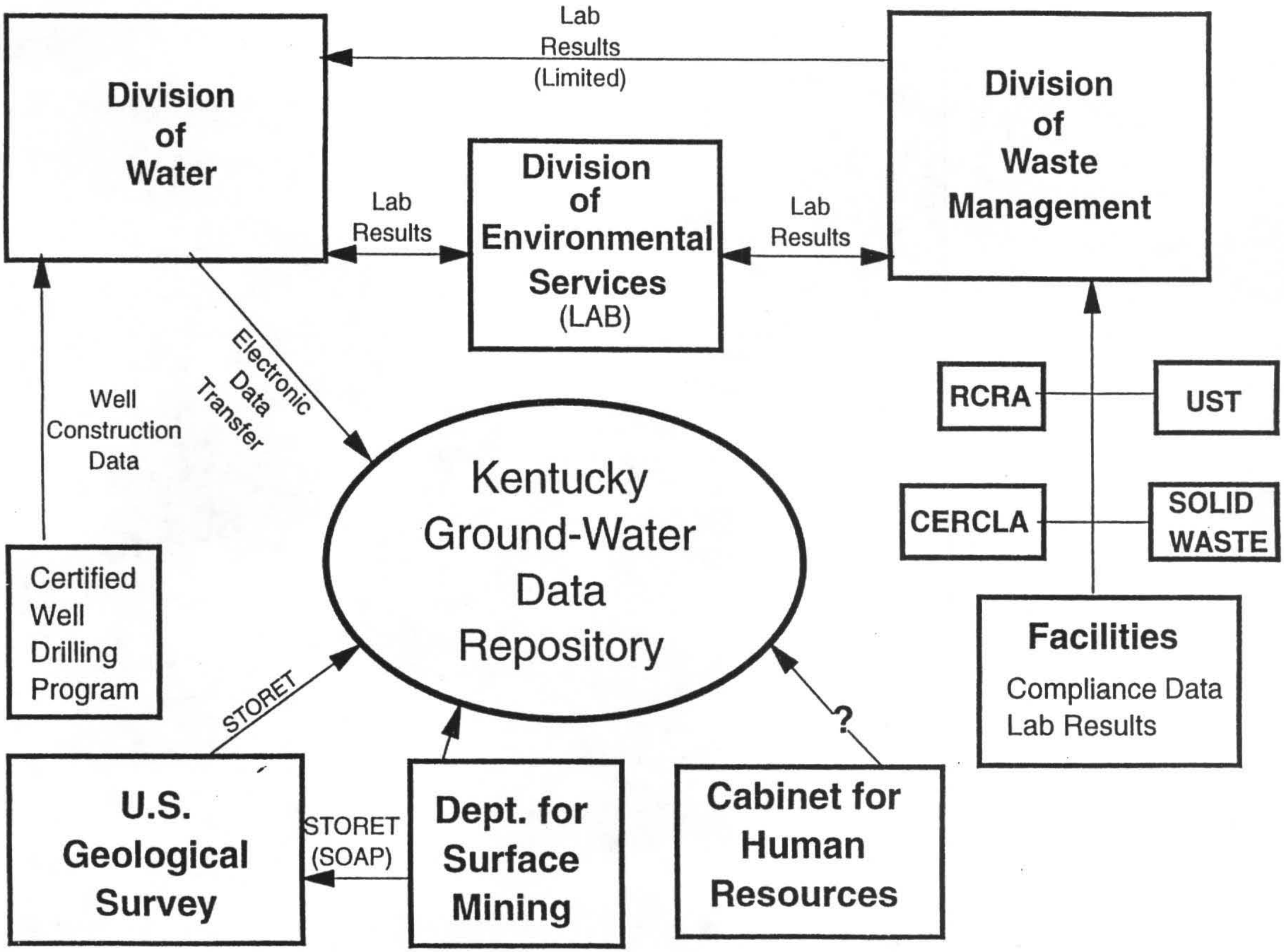
Current Status of Data Handling

Several of the cooperating agencies have already developed their own data bases and have provided varying amounts of electronic data to the Repository. Additional data are currently needed from some of these agencies to keep records up to date. The flow chart on the following page shows the contributors as of December 1995.

The first and only meeting of the Data-Format Subcommittee took place on July 6, 1995. It was generally agreed that the agencies capable of transferring data electronically were already using reasonably compatible data formats. Those agencies in the process of developing a computer system were given a copy of the Repository data exchange format, which specifies a generalized format for major parameters. A copy of the Repository Data Exchange Format is available from the Kentucky Ground-Water Data Repository. Forms for submission of data to the Division of Waste Management (Appendix II) are closely related to the Repository data format.

Summary tables of the types of data collected by agencies involved in the Interagency Task Force are shown below. Tables I and II illustrate the sources of computerized and non-computerized data sources.

It is noted that the apparent wealth of data listed below is limited in its usefulness for many ground-water concerns. For instance, wells and springs for which there is an iron analysis often do not have analyses for other elements and compounds of interest, such as nitrate, barium, or fluoride. In addition, some sites have been sampled dozens of times, and such wells or springs are enumerated dozens of times in the total number of analyses from each source. Some sampling points are therefore counted more than one time giving an impression of a greater number of sources than have actually been sampled. For these reasons the distribution of ground-water sources with analyses of interest is very poor, with sparse information in many parts of the Commonwealth.



Inter-Agency Ground-Water Data Transmission Flow Chart

Table I
Computerized Data Sources

Kentucky Ground-Water Data Repository (KGS)
- -39,000 water well records from various sources, including Division of Water.
- -450 springs
- -300 dye traces
- -16,000 water quality analyses, primarily from STORET data.

Kentucky Division of Water (DOW)
- -32,000 water well records (water wells from 1985, monitoring wells from 1991) based on well completion forms from the Certified Well Driller Program.
- -Water quality analyses on wells sampled by DOW inspectors or field personnel
- -Dye trace maps (not computerized)
- -Nonpoint source water-quality data

Kentucky Division of Conservation
- -Rural water testing data for approximately 5,000 wells across Kentucky. First two rounds of quality data were transferred to the repository.

Kentucky Department of Surface Mining and Reclamation Enforcement
- -Water quality data from 4,000 pre-mining wells from 1983-1990. Paper records only since 1990.
- -Small Operators Assistance Program (SOAP) continues to provide quality data to STORET data base (EPA).

Table II
Non-Computerized Data Sources

Kentucky Division of Waste Management
- -Has developed standardized forms with consistent data fields, based on the KGS data exchange format.
- -Have begun phased approach, involving standard forms for data submission (paper records). Will move toward electronic transfer of data in ASCII format.
- -Water quality data from 4 programs: CERCLA (Superfund), RCRA, UST and Solid Waste. Monitoring wells are recorded with DOW through certified well driller program, and thereby go into repository. Quality data is in hard copy only.
- -RCRA has 40 facilities, about 250 quality samples.

Kentucky Division of Pesticides
- -Currently monitoring 50 wells. These have been sampled once, and may be sampled quarterly. Results are hard copy only.
- -Most of the well-head data is on-line with the repository.

Kentucky Cabinet for Human Resources
- -3,000 to 4,000 water samples analyzed per year for bacteria.
- - Hard copy only.

U.S. Geological Survey
- -Some water-level data from wells collected. Some data available on compact disk (Water Data

reports).

Kentucky Division of Oil and Gas
-Hard copy of oil and gas wells goes to KGS Data Center; some records contain shows of water and depth to brine.

Recommendations

It is recommended that the Data Format Subcommittee meet at least once every 6 months to discuss the progress in electronic data handling of State agencies in addition to future goals in data transmission.

NETWORK DESIGN SUBCOMMITTEE ACTIVITIES AND RECOMMENDATIONS

The Subcommittee met many times to discuss the concept of a monitoring network and to develop strategies necessary to establish and execute such a network. Many philosophical discussions ensued with the development of an overall strategy, or framework, placed in the following context.

The monitoring network will fill in gaps of information between site-specific studies and other sampling programs in two ways:

(1) Providing an adequate spatial coverage of usable data in the State, and
(2) Providing a measure of long-term trends in ground-water quality and quantity.

Data used and collected by the network should have an adequate coverage to define important spatial variations in water quality in given areas across the State. Consideration was given to different areas that could be used to define sampling strategies. Areas that were considered included physiographic regions, watersheds, ADD districts, and other such divisions. Subsurface flow systems control ground- water quality and its availability for use. It was decided that physiographic regions best reflected the anticipated ground-water systems. It was also noted the strategies for monitoring in this document are probably not adequate to determine the affect of discharging ground-water on the quality of surface-water resources.

To define ground-water flow systems, it necessary to account for the relative flow rate or speed and residence time of water in the aquifer system. The categories listed below are different sides of the same coin. In well-developed karst regions it is often more instructive to speak in terms of flow rate or speed of ground-water movement. In all other hydrogeologic settings, it is often advantageous to consider the residence time because the flow rate may be very slow. These terms are shown below to illustrate their relationships.

Short-residence time	Quick flow
Moderate-residence time	Moderate-speed flow
Long-residence time	Slow flow

As a practical move, very poor quality and little-used resources will be monitored less than currently-used resources or resources with the potential for future use.

Components of Data Used by the Network

I. Use of existing data. Sources will include appropriate data currently being collected by all programs, and appropriate historical data that is computerized. Data entry to electronic files of the most-valuable information in paper records is a goal.

II. A Temporal Network established through network monitoring strategy will be periodically re-sampled to evaluate temporal changes in ground-water resources across the State. Most of these sampling points will be springs and existing wells, and a minority will be new monitoring wells.

III. One-Time sampling of 120 additional private wells and springs annually that fit network criteria.

IV. Identify areas in each region where information on ground-water resources is lacking and, if possible, develop focused or intense study areas to determine physical controls on ground-water quality and quantity that affect users.

General Considerations for Network Monitoring

Areal Distribution

Data used and collected by the network should have an adequate areal coverage to define important spatial variations in water quality in given areas across the State. Areas of the State that should have ground-water resources characterized include: physiographic regions, major watersheds, ADD districts, and major aquifers.

Strategies developed for evaluating the condition of ambient ground water in the State have been based on physiographic regions of the State. The unique physical and chemical characteristics of the surface and subsurface in each region were acknowledged as having a profound effect on the natural quality and quantity of ground-water resources, and on the potential for its contamination.

Ground-Water Systems

In each area of the State, parts of the overall ground-water system flows at different rates and have different residence times. These different flow systems can be correlated with: (1) differences in natural ground-water quality, (2) potential for contamination of ground water, and (3) the fate of any contaminants. Existing information on each area will be used to select ground-water sampling points that are likely to be part of distinct ground-water flow systems.

Distinguishing which flow system is tapped by each source will often be possible after a period of sampling. Long-residence time/slow-flow systems in general will be monitored less frequently than short-residence time/quick-flow systems, and therefore a greater portion of network resources will be used for monitoring short-residence time/quick flow and moderate-residence time/moderate-speed flow systems.

Geographical Information System (GIS)

GIS tools will enable the network to efficiently convert data into valuable information. GIS will be used to define ranges and trends in water quality for regions, subregions, major watersheds, aquifers, well-depth ranges, age of wells, major land uses, types of flow systems in the area, and other subsets of data.

GIS should be used extensively to select new monitoring points that match the criteria of the network. The site-selection process will be continual for One-Time sampling; for selecting and integrating data from all organizations; and for evaluating replacement sites for temporally sampled wells/springs that are no longer available.

Outside Expertise and Training

The roles of the network are diverse and dynamic so the needs of the network for outside expertise will continually change. There should be provision for contracting with outside experts and organizations for focused assistance. This assistance might include chemical evaluation of iron in the Kentucky's groundwater, a workshop on sampling methods, evaluating the effect of river water entering the sand and gravel aquifer near the Ohio River, or an advanced statistical review of water-quality data from karst springs. These specific types of assistance and input will prevent the network from getting tunnel vision in collection and evaluation of baseline data. It will also help the network get the best information available to users and potential users of ground-water resources.

Temporal Network

A large portion of baseline data collected by the network should be usable for characterization of ground-water resources, including evaluation of changes in quality and quantity over time. **It is proposed that 680 samples be part of a Temporal Network of wells and springs that will periodically be re-sampled.**

Selected wells and springs sampled by the cooperating organizations will be important candidates for inclusion in the Temporal Network. It is anticipated that most of the appropriate wells and springs in temporary sampling programs will eventually be monitored directly by the network sampling program as the original monitoring organization finishes its own sampling. In some cases, the original monitoring organization may be willing to enter a long-term agreement with the network to continue limited monitoring of selected monitoring points.

Over-representation of a subarea is a potential drawback of proposed monitoring strategies which do not include a mechanism for areal distribution of sampling points (i.e., given number of sites per county in an area). Where ground water is used in such areas, the Temporal Network should fulfill the intended strategy, and maintain an adequate spatial variability of springs and/or wells. This will allow flexibility in both conceptual and statistical use of the data for physiographic areas, major watersheds, and other such subdivisions of the data.

To adequately monitor some ground-water resources that are not sampled by cooperating monitoring organizations, it is likely that the installation of some new monitoring wells will be required. This may be the case where physical controls on ground-water quality and quantity are complex and where existing wells do not fit the criteria of the network. Monitoring wells will also be required in cases where areas or problems have been identified for detailed study (Intense Study Areas).

One-Time Sampling

It is proposed that 120 wells and springs in Kentucky be sampled on a one-time basis each year to improve the spatial coverage of the network beyond monitoring points in the continuing Temporal Network and data currently collected by all cooperating organizations. These will be collected from one location per county per year. These sampling points should meet the criteria established by the network. Most sites are likely to be chosen using database information and GIS tools, and backup (redundant) sites will be selected to assure that inability to sample specific wells or springs is not a deterrent.

Intense Study Areas

Cooperating agencies may identify problem areas for detailed study where there is a dearth of knowledge on ground-water resources. Some settings may be nominated for further study. Depending on the funding source, cooperating organizations or the network program will conduct these studies.

The following table lists past and ongoing studies that were considered by the authors of the regional monitoring strategies which follow. They are examples of past and present intense study areas that provide or indicate conceptual models of ground-water quality, flow, and/or quantity. The studies were each conducted differently, but are a useful basis for further characterization of ground-water resources of Kentucky. Some important questions remain, and over time further study areas will be developed for a variety of purposes. The broader network data discussed above will provide information on ground water between these intense locations of study, and also determine long-term trends in water quality.

PAST AND ONGOING STUDY AREAS IN KENTUCKY THAT PROVIDE OR INDICATE CONCEPTUAL MODELS OF GROUND-WATER QUALITY AND GROUND-WATER FLOW/QUANTITY

Name of Study	Quality or Quantity	Organization	Time Frame	Best Contact
Eastern Kentucky Coal Field				
Star Fire (Breathitt, Perry, Knox Counties)	QL, QN	KGS	Ongoing	David Wunsch
Deep Mine Subsidence (Leslie Co.)	QL, QN	KGS	Ongoing	Shelley Minns
Robinson Forest (Breathitt Co.)	QN	KGS	Ongoing	David Wunsch
Western Kentucky Coal Field				
Union & Webster Co., Deep Mine		KGS, KWRRI	Past	Dinger, Fickle
Henderson Co. NPS 271 farm	QL, QN	KGS, KWRRI	Future	Keagy
Hopkins Co. NPS 271 farm	QL, QN	KGS,KWRRI	Past	Conrad
Daviess Co. NPS 271 farm	QL, QN	KGS,KWRRI	Past	Conrad
Summary-Regional, W. KY. C.F.	QL, QN	USGS	Past	Taylor
Inner Bluegrass				
Woodford County Farm NPS 271 (UK)	QL, QN	KGS,KWRRI	Ongoing	Keagy
Garret s Spring NPS/Sinking Creek	QL, QN	UK Agr Eng/KGS,KWRRI	Past	Felton/Currens
		UK Dept Geol	Past	
Report: "..the Inner Bluegrass", Thrailkill	QL, QN	UK Dept Geol	Past	
Dissertation: Scanlon, 1985	QL			
Outer Bluegrass				
Thrailkill ("..the Inner Bluegrass")	QL, QN	UK Dept Geol	Past	
Percy Daugherty Spec. Pub. 12 (Series 11)			Past	
Bourbon County farm NPS 271	QL, QN	KGS, KWRRI	Past	Keagy
Alluvium				
Simulations of GW flow in Owensboro, KY	QN	USGS	Ongoing	Unthank
Simulations of GW flow in Carrolton, KY	QN	USGS	Ongoing	Unthank
City of Louiville, Alluvial Aquifer Quality	QL, QN	USGS	Future	Unthank
Jackson Purchase				
Agricult. area, 271 NPS (Hickman Co.)	QL, QN	KGS	Past	Conrad
Bandana Nitrate Study	QL	DOW	Past	Webb
Northern Marshall County	QL, QN	DOW	Ongoing	Webb, Yarnell
Eastern Pennyroyal				
Water Works 319 NPS		DOW	Present	Webb, Moody, Ray
Seven Springs 319 NPS	QL, QN	DOW	Past	Leo
Western Pennyroyal				
Pleasant Grove Spr. NPS	QL, QN	KGS	Ongoing	Currens
Mammoth Cave NP Springs	QL, QN	Nat l Park Service	Ongoing	Meiman
Ft. Campbell, GW flow, quality, isotopes	QL, QN	USGS	Present	Taylor
Elizabethtown, GW flow and quality, Mull	QL, QN	USGS	Past	
Elizabethtown, Lambert		USGS	Past	
Geohydrology & Water Quality, Meade Co.	QL, QN	USGS	Past	Taylor
Water Well Education & Testing Program	QL	Ky Div of Cons, Ky Farm Bureau, Ky Dept of Agr, KGS, UK Coll. Agr., & Rural Sociology	Ongoing	Coleman (Div of Cons) Carey (KGS)

Sampling

Sampling Teams

Collection of approximately 800 samples per year is a reasonable goal. This will require the use of three network sampling teams in the State, each of which will sample/measure ground-water resources in approximately one-third of the State. It is suggested that one of the sampling teams be based in western Kentucky for more efficient sampling in that area.

Methods used must be the same for all sampling teams to provide the standardized information needed. The sampling teams will record site information and will use the same field procedures. Samples and computerized field information will be transferred in a timely manner. Sampling teams will also properly maintain equipment, assist in selecting monitoring sites, and assist in checking the accuracy of data. The Kentucky Geological Survey will coordinate and provide oversight of the sampling teams to assure consistency and appropriateness of procedures, continued fulfillment of monitoring strategies, and timeliness of sample and data transfer.

Criteria for Selection of Wells and Springs

Mandatory Criteria

1. Cooperative owner, with State well/spring form completed (copy of form in Appendix III)
2. Future accessibility for sampling granted (except one-time sampling)
3. History of the site is known or can be determined
4. There is no known contamination from a point source
5. The sampling point is accessible by vehicle
6. Wells: Depth of well and cased interval known
7. Wells: Casing is sealed to at least 1985 State well-construction standard
8. Wells: dedicated pump, or can be efficiently sampled by one person
9. Wells and piped spring supplies: have a pre-treatment tap if treated

Highly Desirable Criteria

10. Springs: Physical access to flowing water should not require the use of waders, boats, building bridges, or other time-consuming efforts
11. Wells: Open interval taps only one aquifer or water-producing zone
12. Wells: Water level in well can be measured

Other Desirable Criteria

13. Site ownership by local, state or federal agency
14. Prior water-quality data available
15. Wells: Lithological and geophysical logs available
16. Wells: Hydrogeologic info. available (water levels, pump tests. etc)

Sampling Frequency

It is a goal to sample quarterly or at least have seasonal samples (which may be from different years) on record for each monitoring point, so that the seasonal variability of the resource can be evaluated. Initial sampling frequency will have to be less than quarterly for most sites to sample the 641 sites proposed for the Temporal Network. Sampling twice annually or every 5th quarter may establish that some sources have very low seasonal variability in quality and quantity. In such cases, more frequent sampling may not be warranted.

It is expected that the most common sampling frequencies will be:

biweekly--26 samples per year
quarterly--one sample from each season in year
every fifth quarter--one sample from each season in 5 years
every 2.5 years--one sample from each of 2 seasons in 5 years
every 5 years--one season is consistently sampled every 5 years

Water Analyses

A list of recommended field and laboratory analyses follows. The list includes ICAP analysis of metals by the Kentucky Geological Survey Water Laboratory. Although some of the metals in the ICAP analysis list are not of great significance to water supplies, they are part of a one-price suite of metals that are analyzed together by the apparatus. Several of the metal analyses in this suite are of great significance to the potability of ground water in Kentucky. These latter metals, and potassium, will be analyzed using AA (atomic absorption) to take advantage of lower detection limit. Analyzing metals by both these methods is the most cost-efficient way to provide data on metal concentrations in Kentucky ground water. Due to the higher cost, only one-tenth of the samples collected will be analyzed by AA.

The type of sweep for organic chemicals indicated in the following list will be determined by the Interagency Technical Advisory Committee. Due to the cost of such analyses, only a subset of the sampled wells and springs will be analyzed for these constituents each year. It is proposed that the 120 "One-Time" samples be analyzed for organic constituents, and that 200 different sampling points of the Temporal Network be analyzed for organic constituents each year. Samples from the Temporal Network sampling points should be analyzed for the organic sweep at least once, and every 5 years if possible. The expected attrition rate of sampling sites for the Temporal Network is 50% every 5 years. This attrition rate affects the number of network sampling points that should be targeted for organic chemical analyses in order to evaluate each sampling point at least once.

Field Measurements

Springs: flow rate
Wells: depth to water
pH
Conductance
Temperature
D.O.
Salinity
Turbidity
Odor

Laboratory Analyses

Nutrients
Nitrate/Nitrate-N
Nitrite-N
Ammonia-N
TOC
Orthophosphate

Major Ions
Bicarbonate
Carbonate
Chloride
Sulfate
Sodium
Potassium
Magnesium
Calcium

Other Inorganics
Acidity
Alkalinity
Fluoride
Bromide

Radiometrics
Tritium -- very judicious use
Gross alpha radiation

Pesticides
Analyses by ELISA

Analyses by GC
Potential confirmation of
GC analyses by mass spec.
Other Organics
Sweep for organic chemicals
Metals by ICAP
(total and dissolved)
Aluminum
Antimony
Arsenic
Barium
Beryllium
Boron
Cadmium
Calcium
Chromium
Cobalt copper
Gold
Iron
Lead
Lithium
Magnesium
Manganese
Nickel
Phosphorus
Potassium
Selenium
Silicon
Silver
Sodium
Strontium
Sulfur
Thallium
Tin
Vanadium
Zinc

Elements by AA
(lower detection limit)
Antimony
Arsenic
Cadmium
Lead
Potassium
Selenium
Thallium
Silica

Dissemination of Information

Information for the Public

Dissemination of information collected and interpreted by the network will take place by various means. Summary information will be available via the Internet, paper publications and other appropriate avenues of distribution. Summaries for different areas of the State will include defining subsurface zones with good and poor ambient water quality with respect to home, industrial, and agricultural uses. Variations in ground-water quality over time will also be defined for various settings.

Such characterizations will be created using knowledge of the subsurface systems that control variations in quality and quantity, and changes over time. Much of the summary information will be reduced to maps and diagrams that can be read by non-scientists, and will be of interest to users or potential users of a private ground-water supplies. It is a charge of the Kentucky Geological Survey to use network information to create such publications. Other organizations may also be involved and fully credited in the creation and distribution of network documents.

Data Availability and Use

Data will be housed in the Kentucky Ground-Water Data Repository. The Repository provides data on ground water by request in a number of formats. A data-checking procedure will be established to qualify the data before release to the Repository. This procedure will be finite to allow timely release of network data.

PROPOSED MONITORING STRATEGIES

The following pages contain a monitoring strategy for each of seven areas of the State written by individual committee members. The areas discussed are in the following order:

Eastern Kentucky Coal Field
Western Kentucky Coal Field
Inner Bluegrass and Pennyroyal Karst
Outer Bluegrass
Knobs Region
Jackson Purchase
River Alluvium

Eastern Kentucky Coal Field
David Wunsch

Ground-Water Resources

Over 300,000 people use ground-water supplies in the Eastern Kentucky Coal Field. Approximately 280,000 people are served by private wells (U.S. Census, 1990), and the remaining users are in homes, schools, and businesses served by public utilities that supply ground water (Ky. Division of Water data, 1994).

Flow System and Geochemistry

Several studies completed in the recent past have greatly enhanced our knowledge of ground-water movement and geochemistry in the Coal Field (Kipp and other, 1983; Wunsch, 1992; Minns, 1993). The study by Wunsch (1992) and subsequent research in Robinson Forest provide insight to the hydrochemical facies that are to be expected in various regions of the ground-water flow system. In this regard, the expense of drilling new monitoring wells to create an Intensive Study Area (ISA) may not be necessary, thus, the resources could be used in other capacities or in other provinces that are not well defined.

Based on the hydrochemical model presented by Wunsch (1992), several hydrochemical facies are associated with the flow systems in Eastern Kentucky Coal Field. In general, a Na-HCO3 facies is related to old, isolated water usually encountered in the interior of the ridges or upland areas where granular flow dominates. This zone is usually characterized by having an alkaline pH ($7< pH<9.5$) and high (greater than 1.0 mg/L) fluoride concentration. Ground water in the shallow fracture zones are commonly a mixed-cation (e.g., Ca, Mg and Na) waters with the predominant anion being bicarbonate or sulfate. Na-Cl water types, with Na-Cl concentrations high enough to be classified as brackish, are often encountered in the valley bottoms beneath adjacent to third order or higher streams. The ground water usually has a near neutral pH, but may contain high (>1.0 mg/L) levels of barium and hydrogen sulfide. Water from shallow or dug wells tends to be very soft with a variable chemistry.

Physical Setting

The Coal Field consists of relatively flat lying, maturely dissected Early, Middle, and Upper Pennsylvanian age rocks. The Breathitt and the Lee Formations, make up the majority of the rocks that form the Coal Field. Upper Pennsylvanian rocks of the Conemaugh Formation crop out in the northeast corner of the Coal Field near the intersection of the borders of Ohio, West Virginia, and Kentucky. Each of these three formations consist of repeating sequences of sandstone, shale, coal, underclay, and to a lesser extent, limestones. Topographic relief ranges from a low of 300 feet in the northeast near the Ohio River to a maximum of near 3,500 feet in the southern part of the Coal Field in the vicinity of the Pine Mountain overthrust.

The Eastern Kentucky Coal Field Province is comprised of 39 counties. Based on aerial distribution, only four counties are predominantly underlain by the Conemaugh Formation. The Lee Formation is the primary formation exposed in 13 counties that form the western boundary of the Coal Field. The remaining 22 counties are primarily underlain by the Breathitt Formation.

Proposed Network Monitoring Strategy

Ideally, having at least one monitoring well in each 7.5 minute quadrangle would provide a uniform and well-distributed ground-water monitoring network. However, with state budgetary constraints, it seems highly unlikely that funds would be available for a network undertaking of this magnitude. An expedient and reasonable alternative exists and that is to have several wells in *each county* in the Coal Field Province. This would provide a reasonable "grid" system for an equitably distributed monitoring network. The region map near the beginning of this report shows the counties included in the Eastern Coal Field Province as listed by the KGS Ground Water Data Repository. It can be seen that each county is comparable in area. Therefore, representation by county would allow for good spatial representation.

It is suggested that for the initial set up of the network, *3 wells* be located in each county. One well should be located in the interior upland area. This will probably be a deep well (>150 feet) representing the water stored in the granular aquifers, and should exist on the ridge slope or in an upland area away from third order or higher drainage. The second well should represent the shallow fracture system (well depth up to 150 feet) in or adjacent to the valley bottom; and the third well should be a shallow well (<50 feet), which would represent water from the shallow fractured bedrock, or from regolith and alluvium. This may include dug wells. Monitoring parts of the flow system purely on depth does not guarantee that the well will in actuality be representative of the desired flow zone (i.e., a well 120 feet deep may not intersect a fracture to receive any water from the shallow fracture system). However, on a statistical basis, the majority of the wells situated within the prescribed depthfield *are likely* to be representative of the desired zone.

This monitoring scenario would utilize 117 wells for the entire Coal Field, with 12 wells in the Conemaugh, 39 in the Lee, and 66 representing the Breathitt Formation. This is a reasonable and attainable number for the initial phases of the ground-water monitoring network.

Wells used for public supply (schools, etc.) in each county should be included as often as possible, because: (1) they tend to be used regularly, so the water is continuously flushed and probably representative of the aquifer, (2) access is more likely for water quality sampling and perhaps water-level measurements, (3) these wells will most likely have better-than-average well construction information, and (4) these wells serve the public.

Domestic wells used for the network should be chosen on the quality of well construction characteristics and continued access. This monitoring scheme will allow for the characterization of ground water for each of the major rock formations that underlie the Eastern Kentucky Coal Field based on the flow system identified for these rocks. Based on models of ground-water quality, this is a more efficient method of determining spatial and temporal changes in ground-water quality and its availability to citizens than pooling information from all types of ground-water resources.

Monitoring Summary

Monitored wells: 3 in each of 39 counties

1. interior upland well	39
2. shallow fracture system well	39
3. shallow/dug wells	39
	117

Total: 117 wells

References

Kipp, James A., Lawrence, F.N.,and Dinger, James S., 1983, conceptual model of ground-water flow in the Eastern Kentucky Coal Field: Symposium for Surface Mining, Hydrology, and Reclamation, 1983, University of Kentucky, Lexington, Kentucky, p. 543-548.

Minns, S. A, 1993, Conceptual model of local and regional ground-water flow in the Eastern Kentucky Coal Field: Kentucky Geological Survey Thesis Series 6, Series IX, 194 p.

Wunsch, David R., 1992, Ground-water geochemistry and its relationship to the flow system at an unmined site in the Eastern Kentucky Coal Field. Doctoral Dissertation, University of Kentucky, 239 p.

Western Kentucky Coal Field

David Wunsch

Ground-Water Resources

Over 37,000 people use ground water in the Western Kentucky Coal Field and adjacent alluvial supplies. Approximately 27,000 people are served by private wells (U.S. Census, 1990), and 10,000 other people in homes, schools, and businesses are served by public utilities that supply ground water (Ky. Division of Water data, 1994). Sandstone or a combination of rock units in the Pennsylvanian bedrock are the most common aquifers in the Coal Field. The Anvil Rock Sandstone is the broadest single-unit aquifer. It is commonly used in western counties of the region.

Flow System and Geochemistry

Few recent studies have been completed concerning the ground-water movement and geochemistry in the Western Kentucky Coal Field. Fickel (1990) and several USGS reports describe the ground-water resources of the area, but little or no complex hydrochemical studies have been performed. This suggests that drilling new monitoring wells to create an Intensive Study Area (ISA) may be necessary to accurately define the flow system and related hydrochemical facies.

A study by Wunsch (1982) in the coal bearing rocks in eastern Ohio may provide insight. The Ohio coal belt consists of flat lying Pennsylvanian rocks with subtle topography that is similar to the Western Kentucky Coal Field. Na-HCO3 is the dominant water type found in deep (150-300 foot-deep) bedrock wells. These wells also produce high fluoride and have a high pH. Mixed cation water types are commonly encountered at shallower depths.

Physical Setting

The Western Kentucky Coal Field consists of relatively flat lying, Early, Middle, and Upper Pennsylvanian age rocks. Four major formations, the Sturgis, Carbondale, Tradewater, and Caseyville, make up the majority of the rocks that form the topography of the Coal Field. Upper Pennsylvanian rocks of the Sturgis and Carbondale Formation crop out in the center of the basin that forms the Coal Field, with the progressively older rocks of the Tradewater and Caseyville Formations found around the periphery. Each of these formations consists of repeating sequences of sandstone, shale, coal, underclay, and to a lesser extent, limestones. Topographic relief is relatively low. The lowest elevation is approximately 400 feet, and is found near the Ohio river. The maximum elevation is approximately 700 feet and is found in the central area of the basin. The Coal Field includes a sizable area that is overlain by recent alluvium consisting of fluvial deposits, outwash, and loess. The Western Kentucky Coal Field is structurally more complex than the Eastern Kentucky Coal Field, with two major east-west trending fault zones (Rough Creek and the Pennyrile) traversing the basin. The extensive faulting typically allows for the deep recharge of relatively fresh ground water. Deep sandstone lenses are considered good aquifers in some areas.

Distribution of Geologic Formations

Twenty counties encompass the Western Kentucky Coal Field. Based on areal distribution, the nine counties found along the periphery of the Coal Field are partially underlain by Pennsylvanian rocks and partially by carbonates. The remaining 11 counties are primarily underlain by the Middle and Upper Pennsylvanian aged Sturgis and Carbondale Formations. These 11 counties also contain the majority of the alluvial sediments.

Proposed Network Monitoring Strategy

Ideally, having at least one monitoring well in each 7.5 minute quadrangle would provide a uniform and well-distributed ground-water monitoring network. However, with state budgetary constraints, it seems highly unlikely that funds would be available for a network undertaking of this magnitude. An expedient and reasonable alternative exists, and that is to have several wells in *each county* in the Western Kentucky Coal Field Province. This would provide a reasonable "grid" system for an equitably distributed monitoring network. Figure 1 shows the counties included in the Western Coal Field Province as listed by the KGS Ground Water Data Repository. It can be seen that each county is comparable in area. Therefore, representation by county would allow for good spatial representation.

It is suggested that for the initial set up of the network, *3 wells* be located in each county. One well should be a deep well (>150 feet) representing the water stored in the deep granular aquifers. The second well should be placed at a shallower depth (< 150 feet) to monitor the effects of a perceived shallow fracture zone. The third well should be a shallow well (<50 feet), which would represent water from the alluvial deposits. Monitoring parts of the flow system purely on depth does not guarantee that the well will in actuality be representative of the desired flow zone. However, on a statistical basis, the majority of the wells situated within the prescribed depth field *are likely* to be representative of the desired zone. Additional emphasis on well location is suggested in counties that are traversed by either of the major fault zones. In this way, the effects of the faulting on recharge and water chemistry may be evaluated. Additional wells may be located in these counties along the fault zones if funding permits. The Coal Field would also be suitable for two intense study areas beyond the county-basis monitoring strategy: One should be in the structurally uncomplicated upland area and one in the proximity of a fault zone.

This monitoring scenario would necessitate the utilization of 60 wells for the entire Coal Field. This is a reasonable and attainable number for the initial phases of the ground water monitoring network. Wells used for public supply (schools, etc.) in each county should be included as often as possible, because: (1) they tend to be used regularly, so the water is continuously flushed and probably representative of the aquifer, (2) access is more likely for water quality sampling and perhaps water level measurements, and (3) these wells will most likely have better than average well construction information, and (4) these wells serve the public. Domestic wells used for the network should be chosen on the quality of well construction characteristics and continued access. This monitoring scheme will allow for the characterization of ground water for each of the major rock formations that underlie the Western Kentucky Coal Field based on the flow system identified for these rocks.

Monitoring Summary

Monitored wells: 3 in each of 20 counties

1. interior upland well	20
2. shallow fracture system well	20
3. shallow/dug wells	20
	60

If possible, two intense study areas could be developed beyond the county-based monitoring strategy.

Total: 60 wells

References

Fickel, T. D, 1990, A hydrogeologic investigation of the Anvil Rock Sandstone in parts of Union, County, Kentucky: The impact of underground coal mining on the ground-water system: Master's Thesis, University of Kentucky, Lexington, Kentucky, 168 p.

Wunsch, D. R., 1982, Fluoride distribution and relation to chemical character of ground water in northeast Ohio, Master Thesis, University of Akron, Akron, Ohio, 101 p.

Inner Blue Grass and Pennyroyal Karst

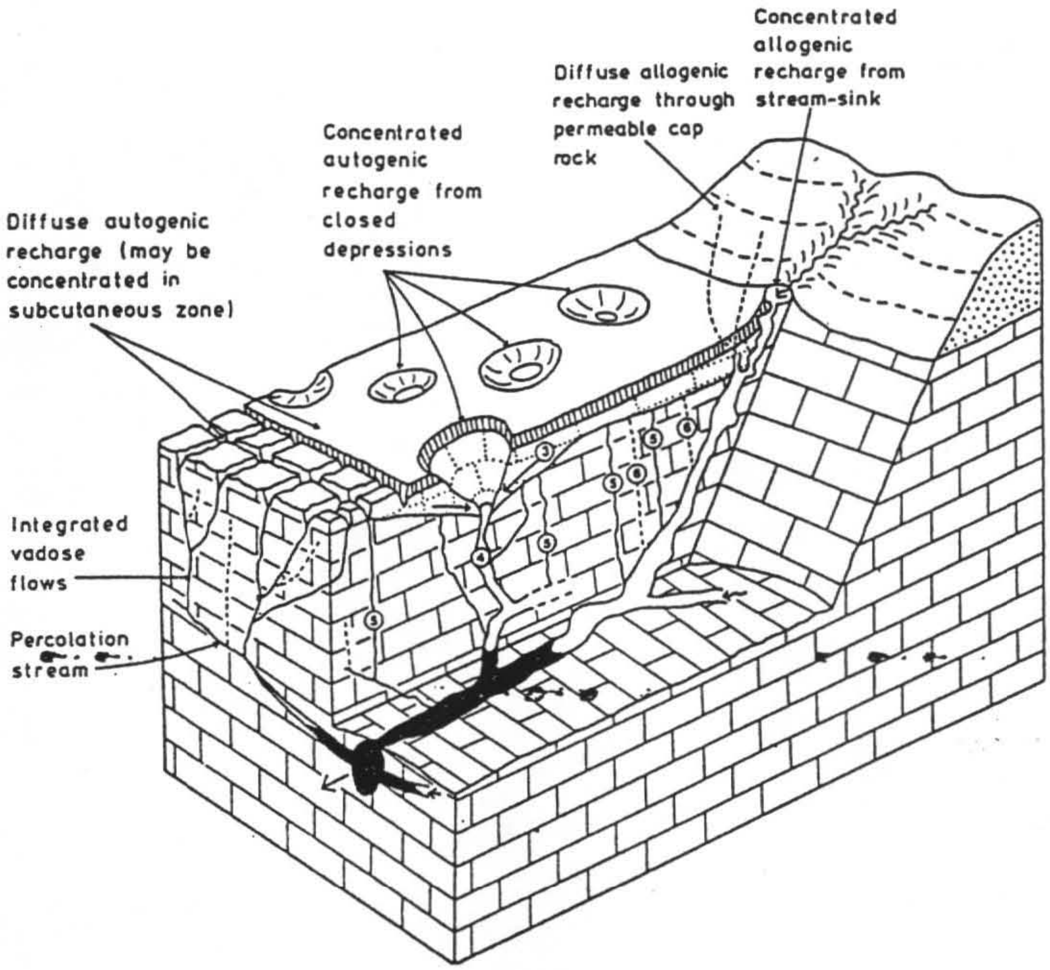
Chuck Taylor, David Leo, Jim Currens, Jim Webb, and Joe Ray

Ground-Water Resources

Karst ground-water flow systems in the both Inner Bluegrass and Pennyroyal Karst Regions are characterized by the presence of three distinct yet hydraulically-integrated flow regimes: Conduit-dominated flow, diffuse-(fracture-)dominated flow, and epikarstic (or subcutaneous) flow (see following block diagram). Therefore, karst aquifer systems possess hydrologic characteristics that require special considerations for effective ground-water monitoring and sampling. Appropriate hydrogeologic and/or hydrochemical conceptual models are described by Thrailkill (1985) and Scanlon (1989) for the Inner Bluegrass Karst, and by various writers in the monograph by White and White (1985) for the Pennyroyal (Mississippian) Karst.

Proposed Network Monitoring Strategy

Springs are the natural outlets for ground water and integrate flows from each of the three flow regimes in a karst aquifer system. Because of this, and the impracticability of locating and drilling into subsurface conduits, springs are preferred sites for monitoring ground water in karst aquifers (Quinlan and Ewers, 1985). Monitoring wells are needed, however, for sampling ground water in the diffuse and epikarstic flow regimes. Therefore, this strategy for implementing a ground-water monitoring network



From Gunn, 1985.

relies on the combined use of springs and wells as sampling sites. Public (municipal) water-supply springs are priority sampling sites, because the quality of ground water is of the utmost importance to human health and well-being.

Approximately 372 spring locations are identified in the Kentucky Department for Environmental Protection ground-water data base, however, this inventory is incomplete and lacks much basic hydrologic and geologic information (for example, the base flow discharge of each spring). Therefore, a
principal goal of the statewide ground-water monitoring network is to identify additional springs and collect basic hydrologic data needed to sufficiently characterize these ground-water resources.

Criteria for Selection of Network Sampling Sites

One useful method for classifying springs is by base-flow discharge. Springs listed in the KDOW data base for which discharge measurements or estimates are available can be arbitrarily divided into three general classes:

Class	Reported Discharge (in ft^3/sec.)	No. of Springs
1	> 10	11
2	1 - 10	61
3	< 1	300

Depending on the funding and logistical support available, two sets of criteria (designated as "acceptable" and "minimal") are presented below as recommended alternate strategies for a network design. The number and locations of public water-supply springs (approx. 30) and the number of springs per discharge class (listed previously) are used to establish selection of sampling sites listed under each of the two criteria sets. The two criteria sets are as follows:

Acceptable Criteria Set

(1) All water-supply springs (approx. 30).

(2) 160 additional springs (43% of KDOW spring inventory) selected proportionally by discharge class: 10 Class 1 springs, 50 Class 2 springs, and 100 Class 3 springs[1].

(3) 1 pair of nested monitoring wells constructed in the epikarst and diffuse flow regimes in the upstream part of each water-supply spring basin sampled (approx. 60 wells in total).

(4) 100 additional bedrock wells distributed randomly and/or in locations (counties) where no spring sites are available[2].

Minimal Criteria Set

(1) 10 water-supply springs: Royal Spring, Boils of Rockcastle River, Pirtle Spring, White Mills Spring, Rio Spring, Waterworks Spring, Auburn Spring, Hunter Spring, Cadiz Spring, and Merriwether Spring.

(2) 16 additional springs (about 5% of KDOW spring inventory) selected proportionally by discharge class: 1 Class 1 spring, 5 Class 2 springs, and 10 Class 3 springs[1].

(3) 1 bedrock monitoring well constructed in the upstream part of each water-supply spring basin (10 wells in total).

(4) 10 additional bedrock monitoring wells distributed randomly in counties where no spring sampling site is available[2].

[1] The indicated number of spring sampling sites to be selected per discharge class is based on the range and distribution of spring discharges indicated in the KDOW ground-water data base.

[2] Existing wells selected so as to provide broadest areal coverage of both Inner Bluegrass and Pennyroyal karst regions.

The acceptable criteria set would provide the most statistically valid network design by including all water-supply springs and a representative sample set of springs from each of the three spring classes. The acceptable criteria set would also provide for representative sampling of each the three karst flow regimes (conduit, diffuse, and epikarst flow). The minimal" criteria set would provide a much more limited network design that restricts the number of water-supply springs sampled and excludes sampling of the epikarst flow regime (a potentially important limitation, because the epikarst regime is generally that part of a karst aquifer system first affected by contamination or degradation).

Sampling Frequency

Sampling frequencies recommended here correspond to the acceptable and minimal sampling-point criteria presented above.

Acceptable Frequency Set

(1) Quarterly sampling of all water-supply springs and wells in network.

(2) Bi-weekly sampling of 6 Class 1 or 2 springs selected randomly from each physiographic region (12) springs in total) for a period of one year. New spring sites would be selected for sampling every year.

(3) Continuous sampling: data collected from intensive study projects only.

Minimal Frequency Set

(1) Bi-weekly sampling of 5 randomly selected water-supply springs for a period of one year. The remaining 5 water-supply springs would be selected for sampling the next year, and the two sets of springs would be rotated each year.

(2) Quarterly sampling of all wells and other springs in the network.

Recommended Sampling Constituents

The following chemical constituents and field parameters are recommended. We anticipate that, with the possible exception of bacteria and indicator pesticides, most of these will constitute the sample parameter list used for the overall (statewide) ground-water network. Bacteria and indicator pesticides are necessary parameters for karst waters because of the relatively direct and rapid infiltration of surface runoff into the aquifer systems by way of sinkholes and sinking streams.

a) Major ions (dissolved): Fe, Mn, Na, K, Ca, Mg, SO4, Cl, Fl, HCO3
b) Field parameters: pH, Specific cond., temp, TDS, DO (wells only)
c) Trace metals: Ba, Sr
d) Nutrients: nitrate, total P
e) Bacteria: total coliform, fecal strep/coliform
f) "Indicator" pesticides: triazines, alachlor, and metolachlor

Monitoring Summary

Municipal springs priority (~30, perhaps less)
1 pair nested wells with each municipal spring
10 springs >10 cfs
50 springs 1 - 10 cfs
100 springs <1 cfs
100 additional bedrock wells

Total: 350 sampling points

References

Quinlan, J. F., and Ewers, R. O., 1985. Ground water flow in limestone terranes: Strategy, rationale, and procedures for reliable, efficient monitoring of ground-water quality in karst areas. Fifth National Symposium and Exposition on Aquifer Restoration and

Ground Water Monitoring, Columbus, Ohio, Proceedings. National Water Well Association. p.197-234.
Scanlon, B. R., 1989. Physical controls on hydrochemical variability in the Inner Bluegrass karst region of central Kentucky. Ground Water, v.27, no.5, p.639-646.
Thrailkill, J., 1985. The Inner Bluegrass Karst Region. in Dougherty, P. H., Caves and Karst of Kentucky. Kentucky Geological Survey Special Publication 12, Series 11, p.63-77.
White, W. B., and E. L. White, 1989. Karst Hydrology Concepts from the Mammoth Cave Area. Van Reinhold. New York. 346p.

Outer Bluegrass

Jim Currens

Ground-Water Resources

Little is known of the water resources of the Outer Bluegrass upon which a rational, monitoring-network design can be based. Palmquist and Hall (1961) summarized the ground-water supply potential of wells for the entire Bluegrass region in two short paragraphs. They concluded that roughly two-thirds of producing wells produced adequate supplies for a "modern" household, and about half of the holes drilled were dry. Hydrogeologic atlases for the region are also similarly vague, however Hall and Palmquist (1960) indicate that wells yielding up to 500 gpd are sometimes successful in valley bottoms.

There are relatively few wells in the Outer Bluegrass, and scattered springs occur only along the narrow outcrop of relatively thin carbonate formations. These limitations, and the need to know the permeability of shale units where landfills might be sited, suggests that the use of springs and existing wells as monitoring sites may be less advantageous in the Outer Bluegrass than in other regions.

Physical Setting

The upper Ordovician, Silurian and Devonian formations of the Outer Blue Grass are largely composed of relatively impermeable siltstones and shales with minor carbonate units in the upper part of the section. In recent years, the geology of the Outer Bluegrass have made the region attractive for the construction of designed landfills in recent years. Because of the shortage of available landfill space in the karst areas of Kentucky this trend is likely to continue.

Proposed Network Monitoring Strategy

The recommended strategy is to devote the majority of resources to drilling monitoring well nests consisting of a well/piezometer nest completed in the weathered zone, the deepest likely producing zone at the site, and an intermediate depth (preferable also in a producing zone). If inflow into one or more of the wells warrants a pumping test, a piezometer should be installed a short distance from the well nest. Packer testing should be conducted in conjunction with or as a substitute for the offset piezometer. Four such nests should be constructed. One nest each in the northern, southern, eastern, and western Outer Bluegrass. The siting of the well nests must be chosen carefully as in a site-specific study. Should a hydrolithologic unit in the Outer Bluegrass be suspected of being a potential aquifer, testing of the aquifer should take precedence over demonstration of the impermeability of a shale unit. However, at a minimum, one nest should be completed in shale.

Any resources remaining should be directed toward water quality monitoring at the monitoring wells and existing sites. I suggest that a total of 32 sites should be selected. This assumes that only a few of the monitoring wells will produce sufficient water for analysis. The apportionment of the sites between springs and wells will be dictated by field conditions, because existing sites are scarce. However, where a spring is monitored a well should be monitored in the same ground-water basin. Any wells or springs identified as high capacity should receive priority because of their significance as a water source.

Monitoring Summary

Monitoring 20 springs and existing wells
If possible, also construct 4 new nests of 3 wells for water & packer testing.

Total: 32 sampling points

Knobs Region
Jim Kipp

Ground-Water Resources

"At depths greater than 50-200 feet below local stream level, all ground water is of the sodium chloride type and too mineralized for domestic use. The depth to saline water is largely dependent upon the amount of shale in the bedrock, for the shale restricts the zone of relatively rapid circulation to shallow depths." (page 1, Hendrickson and Krieger, 1964)

Fresh water wells in the valleys will probably be fairly shallow (due to saline water near surface) and related to fractures and the near-surface weathered zone in the shales. Large, active regional flow systems probably are not very likely in the relatively tight shales in this region. Wells and springs are both used for water supplies, and springs may be more common in the western portion of the Knobs. Where an acceptable ground-water source is used, it is an important water resource.

Physical Setting

Background Information on the physical setting can be found in USGS Water Supply Paper 1700, Hendrickson and Krieger, 1964:

> "The Knobs is a narrow belt of hills, generally less than 10 miles wide, around the east, south, and west of the Outer Blue Grass. It is transitional on the east with the Eastern Coal Field Region and on the south and west with the Mississippian Plateau Region. The rocks underlying the Knobs are chiefly shale but include some sandstone and limestone. On the west the Knobs, as defined in this report, is underlain by rocks of Devonian and Mississippian age; on the east it is underlain by rocks ranging from Late Ordovician to Pennsylvanian in age. Typically the topography is conical hills separated by broad, relatively flat stream valleys. The conical hills generally are capped by resistant sandstone and limestone; the hill slopes and broad valleys are underlain by easily eroded shale. Runoff generally is rapid. Springs are small, and most go dry in dry weather.
>
> A typical land-surface profile across the Knobs would show a transition from the rolling hills of the Outer Blue Grass, through the typical Knobs topography of conical hills with broad, flat lowlands, to the high plateaus developed on Mississippian limestone to the west and south and Pennsylvanian sandstone to the east." (pages 7-8)
>
> "More than 90 percent of the Blue Grass area is underlain by rocks of Ordovician age. .....the proportion of shale increases upward from rocks of the High Bridge group through the Eden group. The Maysville group consists of limestone and shale in approximately equal amounts. The Richmond group, which overlies the Maysville, is predominantly shale and shaly limestone, but the proportion of shale in the Richmond is not as great as in the Eden.
>
> Rocks of Silurian age rest unconformably on Ordovician rocks on the flanks of the Jessamine dome in the western, southern, and eastern parts of the Blue Grass region. On the west side of

the dome, the Silurian rocks consist chiefly of limestone and some shale. On the east side of the dome, shale predominates in the Silurian, and only minor amounts of limestone are present.

Rocks of Devonian age rest unconformably on rocks of Silurian and Ordovician age on the western, southern, and eastern flanks of the region. On both sides of the Jessamine dome, the Devonian consists of a lower limestone unit overlain by a unit of black shale.

Rocks of Mississippian age that cap the Knobs around the outer edge of the Blue Grass region except on the north consist chiefly of shale, siltstone, and sandstone, but include some limestone. Rocks of Pennsylvanian age also cap some of the Knobs on the east side of the region, but they are of little hydrologic importance in the region." (pages 9-10).

Proposed Network Monitoring Strategy

1. As a transition zone between the Outer Bluegrass and the Eastern Kentucky Coal Field and the Mississippian Plateaus, monitoring strategy in the Knobs may reflect a combination of strategies from the adjacent regions, as appropriate for actual conditions.

2. Any existing public water supply wells or springs in the region should have priority as initial sampling sites. Other known existing high-capacity supplies should also be considered for sampling. Perhaps 12 wells would be sufficient for establishing the general quality of the resource and monitoring long-term changes.

3. A focused study of an individual knob (rising as much as 750 feet above the surrounding lowlands) using wells and springs might provide a better understanding of the flow system in the hills. However, flow in an individual knob would not represent part of a continuous widespread regional flow system.

4. Wells (existing or newly drilled for this monitoring effort) may be relatively low capacity and, depending on the sampling protocol, difficult to sample (little available drawdown).

5. As a narrow band (generally less than 10 miles wide), it probably can not be justified to attempt to document trends or changes across the Knobs belt. A good geographic distribution (3 or 4 locations around the Knobs arc) would be useful, however. The Knobs are part of several counties, but only 3 counties have half or more of their area in this physiographic region.

Monitoring Summary

12 monitored wells and springs, including any high-capacity supplies used in the region
To the extent that information in typical flow on a small scale is needed, monitoring wells could be installed in a typical knob to determine patterns of ground-water quality and occurrence.

Jackson Purchase
Bill Yarnell

Ground-Water Resources

Approximately 150,000 residents of the Jackson Purchase Region use ground-water supplies. Over 40,000 of these residents are served by private water wells (U.S. Census, 1990), and almost 110,000 are served by water utilities that supply ground-water to homes, schools and businesses (Ky. Division of Water data, 1994).

Formations of unconsolidated sand, silt, gravel and clay rest unconformably on carbonate bedrock. The primary ground-water producers in this region are the carbonate bedrock, the unconsolidated sediments of the McNairy Formation and the Claiborne Group. The Porters Creek Clay separates the McNairy Formation from the Claiborne Group and functions primarily as an aquitard. Wells in the Jackson Purchase Region can yield as much as 1,000 gallons per minute (Department for Environmental Protection, Consolidated Groundwater Database).

Physical Setting

The Jackson Purchase Region is the far western part of Kentucky and includes Fulton, Hickman, Carlisle, Ballard, McCracken, Graves, Marshall and Calloway counties. The Region is bounded by the Mississippi River, Ohio River, Tennessee River and Kentucky Lake. The area is characterized by low rolling hills and is dissected by a dendritic drainage pattern of creeks, streams and bayous.

The Jackson Purchase Region is the northern most part of the Mississippi embayment and is distinctly different from the rest of Kentucky. Paleozoic carbonate bedrock is overlain by unconsolidated sediments of late Cretaceous to Eocene in age. The unconsolidated sediments include the McNairy Formation, the Porters Creek Clay and the Claiborne Group, which here includes the Jackson Formation. The unconsolidated sediments are the product of marine, fluvio-marine and lacustrine depositional environments and include gravel, sand, silt and clay.

Proposed Network Monitoring Strategy

Groundwater in the Jackson Purchase Region is primarily produced from one of three major aquifers, the Paleozoic carbonate bedrock, the McNairy Formation and the Claiborne Group (Davis, and others, 1973). The McNairy Formation and the Claiborne Group are separated by the Porters Creek Clay. The Porters Creek Clay functions as an aquitard in the Region.

A groundwater monitoring plan should include distributed sample sites in each of the major water bearing units. Most counties in the Jackson Purchase have wells that penetrate the unconsolidated sediments of the Mississippi embayment into the Paleozoic bedrock. The unconsolidated sediments commonly produce water from a perched zone, a water-table zone and in some areas from a confined zone, especially the McNairy Formation below the Porters Creek Clay.

McNairy Formation and Paleozoic bedrock wells should be sampled in Ballard, McCracken, Marshall and Calloway counties. Sample sites in the McNairy Formation should be chosen from existing wells to represent perched, water table and confined conditions. Ballard, Carlisle, Hickman and Fulton counties rely on the Claiborne Group for groundwater from the unconsolidated sediments. Sample sites in these counties should be selected from existing wells to represent perched and water table conditions. Graves county is much larger than the other counties in the Jackson Purchase Region. Wells in Graves county receive water from perched zones and water table condition in the Claiborne Group. The McNairy Formation is also penetrated by wells in Graves county and exists under confined conditions.

County	Perched Zone	McNairy	Claiborne	Paleozoic	Spring	County
Ballard	1 (McNairy)	1	1	1		4
McCracken	1 (McNairy)	1		1		3
Marshall	1 (McNairy)	1		1		3
Calloway	1(McNairy)	1		1		3
Carlisle	1 (Claiborne)		1	1		3
Hickman	1 (Claiborne)		1	1	1	4
Fulton	1 (Claiborne)		1	1		3
Graves	2 (Claiborne)	1 (confined)	2	1		6
Totals	**9**	**5**	**6**	**8**	**1**	29

Monitoring Summary

3 wells in most counties
McNairy Formation, Claiborne Group wells, and 1 spring = 12
Perched-water wells = 9
Bedrock wells = 8

Total sampling points = 29

Reference

Davis, R.W., Lambert, T.W., and Hansen Jr., A.J., 1973, Subsurface Geology and Ground-Water Resources of the Hackson Purchase Region, Kentucky, U.S. Geological Survey Water-Supply Paper 1987, 66 p.

Major River Valley Alluvium

Chuck Taylor, Mike Unthank, and Philip Conrad

Well water from moderately thick and thin alluvium near several rivers in the State will be sampled as part of the other monitoring strategies defined in previous pages of this document. This monitoring strategy focuses on the thickest river alluvium in Kentucky, including that of the Ohio and Mississippi Rivers which are heavily used as a source of water. The strategy also considers the thick alluvium used near the Green, Kentucky and Big Sandy Rivers.

Ground-Water Resources

The unconsolidated sediments in many river channels and floodplains in Kentucky form important aquifers used for many domestic, industrial, and municipal water supplies. The greatest yields to wells in the State are obtained from alluvium near the Ohio and Mississippi Rivers, where sediments are thick, laterally extensive, and store large quantities of ground water. The Ohio River alluvium constitutes an extensive much-used aquifer, particularly near the cities of Carrollton, Louisville, Owensboro, and Paducah. Ground water from this source has its greatest use in and near the cities of Carrollton, Louisville, Owensboro, and Paducah, and is used as an aquifer elsewhere along the Ohio

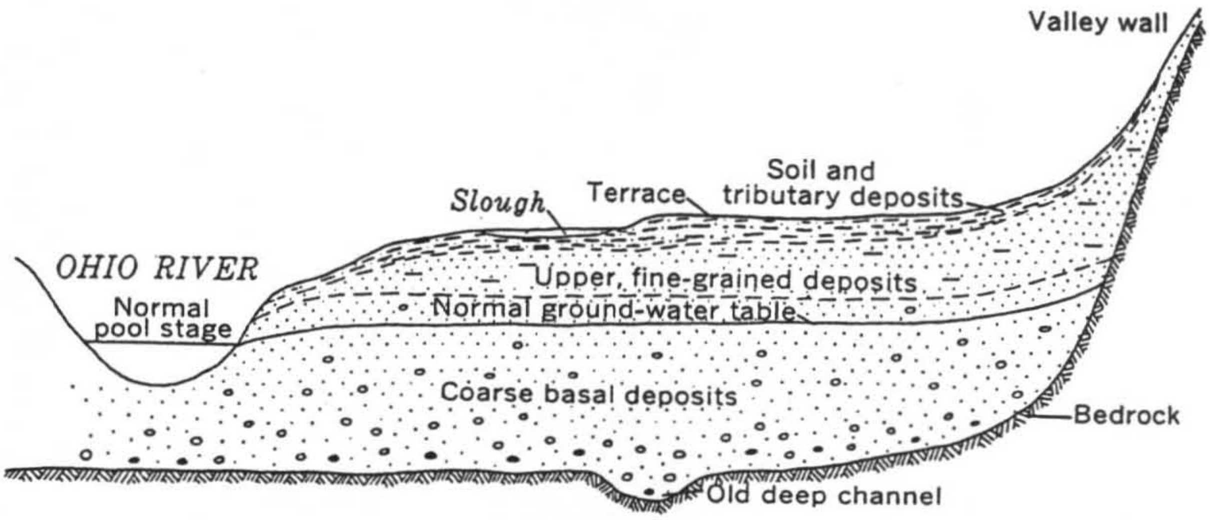
River. Sandy alluvial sediments are less extensive and less used as a water source along the Green, Big Sandy, Kentucky, and other Rivers.

The unconsolidated sediments in river channels and their floodplains contain ground water that is either flowing to the river from ground-water resources, or river water that is flowing out into aquifers. The quality and volume of ground water that is flowing to the river affects surface-water volume and quality. Water flowing from the river to recharge ground water affects ground-water volume and quality.

Physical Setting

Ohio River alluvium generally consists of two major components: an upper layer consisting of finer-grained sediments (mostly silt, clay, and fine sand), and a lower layer consisting of coarser sediments (mostly sand, gravel, and cobbles) (see cross section). The principal aquifer is the lower coarse-grained alluvium. This is also true of Green River alluvium in the Western Kentucky Coal Field, and alluvium in some other drainages of the State. There is little alluvium in some reaches of many rivers, especially in headwaters regions and where river gorges are incised into bedrock.

Water levels and flow directions in alluvial aquifer systems are greatly influenced by river stage, and locally, by water withdrawal (Faust and Lyverse, 1987). Previous studies describing the geology and hydrology typical of the Ohio River alluvium were done by Rorabaugh (1956) and Gallaher and Price (1966).



From Galaher and Price, 1966.

Proposed Monitoring Strategy

A greater proportion of this proposed strategy is focused on monitoring changes in alluvial aquifers of the Ohio and Mississippi Rivers than in alluvium of other rivers in the State. Thinner alluvium will be sampled as part of the other regional monitoring strategies in this document, and through approximately 15 wells proposed in the following pages.

Ohio River alluvium is a major aquifer in Kentucky, and 12 existing public water-supply wells are candidates for network monitoring sites (see following table). An adequate geographic distribution of sampling points using the Ohio River alluvial aquifer would be achieved by monitoring 1 well from each of the 12 public suppliers. The wells listed in the following table withdraw water from the lower coarse-grained Ohio River alluvium, however, the water table is generally within the upper fine-grained alluvium. Therefore, 1 additional well should be added at each of the selected locations to sample ground water quality nearer the water table in the fine-grained alluvium. This brings the total number of wells in the Ohio River alluvium to 24. Two additional wells are proposed to extend the geographic coverage of this part of the monitoring network to alluvium along the Mississippi River. This raises the total to 26.

A study of the water-quality of the Ohio River alluvium in the Louisville area is planned to begin in 1996 as part of a cooperative investigation between the city of Louisville and the U. S. Geological Survey. Selected monitoring wells used for this investigation can also serve the needs of this monitoring network. Data from this study will be stored at the Kentucky Ground-Water Data Repository.

Ground water in alluvium of smaller rivers should also be monitored in typical locations where it is used as a water source. Fifteen (15) locations can be chosen. These will likely be located in the following river basins: Green, Kentucky, Licking, Salt and Big Sandy, based on current knowledge of where alluvium is most likely to be used near small and moderate-size rivers. Alluvium in these basins can be thin and discontinuous. These 15 sites should not be redundant with alluvial wells monitored as part of other regional proposals, and if possible, located close to existing surface-water monitoring stations. This latter placement will allow surface-water and ground-water records to be compared to assess the affect of ground-water quality on surface-water quality, and vice versa. This information is important because a large portion of the perennial flow of surface streams consists of ground water that has discharged from bedrock and alluvium, and the relationship is poorly understood in many areas. This small number of wells will not be adequate to determine actual effect of ground water on surface water in Kentucky, however, conclusions may be drawn if augmented with data from other ground- and surface-water monitoring programs.

Monitoring Frequency

Because of the amount of published and unpublished water-quality data collected from water-supply wells in the Ohio River alluvium, quarterly sampling of wells in the alluvial aquifer network is recommended for coarse-grained alluvium. A minimum frequency of twice per year during low and high river stage is recommended if quarterly sampling is not possible. The frequency of monitoring water in fine-grained deposits should be assessed after a set of samples from the four seasons has been collected. Synoptic water-level measurements of the wells and nearby river or major stream should be conducted during each sampling visit if possible. At a minimum, biannual synoptic measurements that includes one high-flow and low-flow period should be used to collect water-level and water-quality data. Coordination of sampling with surface-water monitoring programs is advised. Periodic collection of synoptic surface-water samples by this network should also be considered where coordination with other programs is not possible.

Locations of Public Water-Supply Wells in the Ohio River Alluvial Aquifer

1. Cloverport Municipal Water Plant-- Breckinridge Co.
2. Carrolton Municipal Water Works-- Carroll Co.
3. Owensboro Municipal Utilities-- Daviess Co.
4. Warsaw Municipal Water Works-- Gallatin Co.
5. South Shore Water Works, Worthington, Wurtland-- Greenup Co.
6. Hardin County No. 1, West Point-- Hardin Co.
7. Henry County Water District No. 2-- Trimble Co.
8. Louisville Water Company-- Jefferson Co.
9. TVA Shawnee Steam Plant-- McCracken Co.
10. Western Lewis County - Rectorville Water and Gas-- Mason Co.

11. Brandenburg Water Works-- Meade Co.
12. Goshen Utilities, Oldham County Water District-- Oldham Co.

Monitoring Summary

12	public ground-water supplies in Ohio River alluvium
12	supplies and monitoring wells in finer grained unit above
2	well-water supplies in Mississippi River alluvium
15	in alluvium of other rivers in Kentucky
41	total wells for both sampling and water-level monitoring

References Cited

Gallaher, J.T.,Price, W E., Jr., 1966.Hydrology the alluvial deposits in the Ohio River valley in Kentucky. U. S. Geological Survey Water-Supply Paper 1818, 80p.

Rorabaugh, M. I., 1956. Ground-water resources of the southwestern part of the Louisville area, Kentucky. U. S. Geological Survey Water-Supply Paper 1360-b, 169p.

Faust, R. J., and Lyverse, M. A., 1987. Ground-water levels in the alluvial aquifer at Louisville, Kentucky, 1982-87. U. S. Geological Survey Water Resources Investigation Report 87-4197, 18p.

SUMMARY AND RECOMMENDATIONS

This report outlines a proposed program for coordinating the ground water data collection for the State. Major recommendations are the following:

1. All of the ground-water data currently available and planned to be collected in the future should be recorded in a standardized format that will allow for electronic storage in the Kentucky Ground Water Repository. A systematic approach should be developed to capture much of the ground water data that is currently present only in paper form.

2. An annual periodic sampling and analysis of 641 sampling points should be installed for the State. These locations have been described in the regional summaries presented above and represent a total State coverage.

3. In addition to the periodic resampling and analysis locations one-time sampling of 120 locations.

4. Areas that require a more intense study site to adequately define the distribution of ground-water quality and quantity and controls on the usability of water resources should be identified by the network and may be monitored by the network as an Intense Study Area.

Appendix I

Proposed Legislation

AN ACT relating to a groundwater monitoring network.

Be it enacted by the General Assembly of the Commonwealth of Kentucky:

SECTION 1. A NEW SECTION OF KRS CHAPTER 151 IS CREATED TO READ AS FOLLOWS:

It is a finding of the General Assembly that groundwater makes up over ninety-five percent (95%) of the fresh-water resources in Kentucky. Groundwater accounts for over thirty percent (30%) of the public and domestic water supplies in the Commonwealth, and up to ninety percent (90%) of all rural domestic supplies, and is the major source of water to streams during drought conditions. It is imperative that a system for characterizing and monitoring groundwater be developed, so that information acquired through existing programs will allow Kentucky to build an adequate and reliable database through identifying and characterizing the groundwater resource. Groundwater systems can be modeled, and plans formulated, for recognizing and dealing with degradation if it occurs. The information from the monitoring network can be used to address resource allocation concerns, set boundaries on wellhead protection areas, evaluate and improve the quality and quantity of data collected through all programs, and support a groundwater data management system.

SECTION 2. A NEW SECTION OF KRS CHAPTER 151 IS CREATED TO READ AS FOLLOWS:

As used in Sections 1 to 4 of this Act, unless the context requires otherwise:

(1) "Committee" means the Interagency Technical Advisory Committee on Groundwater as created in Section 4 of this Act;

(2) "KGS" means the Kentucky Geological Survey;

(3) "Groundwater system" means a body of groundwater that is separated from other bodies of groundwater by flow direction or water chemistry;

(4) "Monitoring network" means a series of wells that will be tested on a periodic basis for water level and water chemistry; and

(5) "Groundwater resource" means groundwater that is currently being used or is capable of being used.

SECTION 3. A NEW SECTION OF KRS CHAPTER 151 IS CREATED TO READ AS FOLLOWS:

(1) The KGS shall establish a long-term groundwater monitoring network for the purpose of characterizing the quality, quantity, and distribution of Kentucky's groundwater resources.

(2) The monitoring network shall include:

(a) The development of protocols needed for standardization of the data being collected by regulatory programs;

(b) The utilization of newly drilled domestic water wells as part of the network; and

(c) The statewide installation of monitoring wells in areas of demonstrated need.

This information shall be collected on a statewide basis and provide long-term data collection to determine the quality, quantity, and occurrence of groundwater throughout the Commonwealth, in order to assist in the protection of those resources by the proper regulatory agencies. The KGS shall utilize collected data to support research efforts that develop models for groundwater systems, and to determine and monitor trends of groundwater movement, water quality, and quantity.

(3) The KGS shall enter data from the network into a groundwater database which is readily available to the public, government agencies, industry, and other entities that request access. Analyzed data shall be made available in the form of maps, charts, bulletins, and reports.

(4) *The KGS shall solicit input from state and local agencies, industry, agriculture, universities, and the public, to determine priority areas to be covered by the network as it is developed.*

(5) *Within forty-five (45) days of the end of the state fiscal year, the KGS shall annually provide to the Governor and the General Assembly a summary of the groundwater monitoring network data collection and analysis activities.*

SECTION 4. A NEW SECTION OF KRS CHAPTER 151 IS CREATED TO READ AS FOLLOWS:

(1) *There is hereby established an Interagency Technical Advisory Committee on Groundwater, to assist the KGS in the development, coordination, and implementation of a groundwater monitoring network for the Commonwealth. The committee shall consist of one (1) representative from each of the following agencies, to be appointed by that agency:*

(a) *Division of Water of the Kentucky Department for Environmental Protection;*

(b) *Division of Waste Management of the Kentucky Department for Environmental Protection;*

(c) *Division of Conservation of the Kentucky Department for Natural Resources;*

(d) *Division of Forestry of the Kentucky Department for Natural Resources;*

(e) *Cabinet for Human Resources, Division of Environmental Sanitation and Community Safety;*

(f) *Department of Mines and Minerals;*

(g) *Kentucky Geological Survey;*

(h) *U.S. Geological Survey;*

(i) *Department for Surface Mining Reclamation and Enforcement;*

(j) *Department for Natural Resources;*

(k) *University of Kentucky Water Resources Research Institute;*

(l) *Department of Agriculture;*

(m) *University of Kentucky College of Agriculture; and*

(n) *Kentucky Water Well Association.*

(2) *The committee shall have one (1) nonvoting legislative liaison, to be appointed by the Legislative Research Commission. The chair of the committee shall be the director of the University of Kentucky Water Resources Research Institute. The duties and responsibilities of the committee shall include:*

(a) *Developing a plan for the overall characterization of the state's groundwater, including distribution, water quantity, and water quality;*

(b) *Reviewing the data entry process to ensure that all data collected are placed into the Kentucky groundwater repository;*

(c) *Establishing a long-term groundwater monitoring plan for the Commonwealth;*

(d) *Making recommendations for prioritization of the state's groundwater research needs;*

(e) *Reviewing and evaluating annually groundwater data collection and analysis; and*

(f) *Making recommendations regarding the Commonwealth's needs for groundwater research.*

Appendix II

Current Analysis Submittal Forms

Division of Waste Management
Hazardous Waste Branch
14 Reilly Road
Frankfort, KY 40601
(502)564-6716

FINDS/UNIT: ________________/___
LAB ID: ______________
For Official Use Only

GROUNDWATER SAMPLE ANALYSIS

AKGWA NUMBER [1], Facility Well/Spring Number			
Facility's Local Well or Spring Number (e.g. MW-1, MW-2, etc.)			
Sample Sequence # (For Official Use Only)			
If sample is a Blank, specify Type (Field, Trip, Method, or Equipment)			
Sample Date and Time (Month/Day/Year hour:minutes)			
Duplicate ('Y' or 'N') [2]			
Split ('Y' or 'N') [3]			
Facility Sample ID Number (if applicable)			
Laboratory Sample ID Number (if applicable)			
Date of Analysis (Month/Day/Year)			
Gradient with respect to Monitored Unit (UP, DOWN, SIDE, UNKNOWN)			

CAS RN [4]		CONSTITUENT	T D [5]	UNIT OF MEASURE	METHOD	DETECTED VALUE OR PQL [6]	FLAGS	DETECTED VALUE OR PQL	FLAGS	DETECTED VALUE OR PQL	FLAGS
83-32-9	0	Acenaphthene									
208-96-8	0	Acenaphthylene									
67-64-1	0	Acetone									
98-86-2	0	Acetophenone									
75-05-8	1	Acetonitrile; Methyl cyanide									
53-96-3	2	2-Acetylaminofluorane; 2-AAF									

[1] AKGWA = KDEP official well registration program number. AKGWA # is 0000-0000 for any type of blank.
[2] Duplicate = 'Y' indicates that the sample is a duplicate of another sample in this report.
[3] Split = 'Y' indicates the sample has been split and analyzed by separate laboratories.
[4] Chemical Abstracts Service Registry Number
[5] 'T' = Total, 'D' = Dissolved
[6] '<' indicates a non-detect.
Value then shown is Practical Quantitation Limit. (please use '<', not 'ND').

STANDARD FLAGS:
J = Estimated value
B = Analyte found in blank
A = Average value
N = Presumptive ID
D = Concentration from analysis of a secondary dilution factor

FINDS/UNIT: ____________________/___
LAB ID: ____________________
For Official Use Only

GROUNDWATER SAMPLE ANALYSIS - (Cont.)

AKGWA NUMBER , Facility Well/Spring Number			
Facility's Local Well or Spring Number (e.g. MW-1, MW-2, etc.)			

CAS RN [4]		CONSTITUENT	T D [5]	UNIT OF MEASURE	METHOD	DETECTED VALUE OR PQL [6]	FLAGS	DETECTED VALUE OR PQL	FLAGS	DETECTED VALUE OR PQL	FLAGS
107-02-8	3	Acrolein									
107-13-1	0	Acrylonitrile									
309-00-2	0	Aldrin									
107-05-1	0	Allyl chloride									
92-67-1	0	4-Aminobiphenyl									
62-53-3	0	Aniline									
120-12-7	0	Anthracene									
7440-36-0	0	Antimony									
140-57-8	1	Aramite									
7440-38-2	0	Arsenic									
7440-39-3	0	Barium									
71-43-2	0	Benzene									
56-55-3	1	Benzo[a]anthracene; Benzanthracene									
205-99-2	1	Benzo[b]fluoranthene									

↓ ANALYTE LIST CONTINUES

[4]Chemical Abstracts Service Registry Number
[5]'T' = Total, 'D' = Dissolved
[6]'<' indicates a non-detect. Value then shown is Practical Quantitation Limit. (please use '<', not 'ND').

STANDARD FLAGS:
J = Estimated value
B = Analyte found in blank
A = Average value
N = Presumptive ID
D = Concentration from analysis of a secondary dilution factor

Appendix III

Kentucky Well Inspection Form

KENTUCKY WELL INSPECTION FORM

(1) AKGWA NUMBER ☐☐☐☐ – ☐☐☐☐

Attach Well Record Label Here (if applicable)

Note: Water well labels begin with "0", monitoring well labels begin with "8".

(2) OWNER/FACILITY INFORMATION

Well Owner's Name: ____________ Last ____________ First ____________ MI

Mailing Address: ____________

City: ____________ State: ______ Zip: ______

Well Address (if different) ____________

City: ____________ State: ______ Zip: ______

Phone: ( ) ____________

(3) WELL RECORD LABEL LOCATION:

( ) well casing ( ) pressure tank ( ) water pipe
( ) well cap ( ) electric box ( ) not labeled
( ) pump ( ) other ______

(4) WELL LOCATION

USGS Quadrangle Name ______ County ______

Latitude ______ Longitude ______

(5) PHYSIOGRAPHIC OR HYDROLOGIC REGION

( ) Blue Grass ( ) Ohio River Alluvium
( ) E. Coal Field ( ) W. Coal Field
( ) Miss. Plateau ( ) Jackson Purchase

(6) DRILLER INFORMATION

Who Constructed Well? ____________ ( ) unknown

Address: ____________

City: ____________ State: ______ Zip: ______

Date Well Completed: ___/___/___ ( ) unknown
Month Day Year

(7) GENERAL

Type of Construction:
( ) drilled/augered
( ) excavate & backfill
( ) hand dug/blasted

Depth of Well: ______ ft.
( ) measured
( ) reported
( ) unknown

Static Water Level, ft. below surface: ______
( ) measured
( ) reported
( ) not measured
( ) can't be measured

Well Yield: ______
( ) gpm ( ) gph ( ) gpd
( ) measured
( ) estimated
( ) unknown

(8) SURFACE ANNULAR MATERIAL:

( ) clay ( ) drill cuttings
( ) cement ( ) unknown
( ) open ( ) sand ( ) gravel
( ) concrete pad

(9) WELLHEAD

Is Well Located in a Pit?
( ) yes ( ) no ( ) unknown

Wellhead (casing top):
( ) well cap ( ) sanitary seal
( ) flush mount ( ) locking cap
( ) open ( ) unknown

Casing Above Ground Level?
( ) yes ( ) no ( ) unknown
______ inches above ground.

Discharge Pipe Below Surface?
( ) yes ( ) no ( ) unknown

Pitless Adapter Used?
( ) yes ( ) no ( ) unknown

(10) PUMP DETAILS

Date Installed: ___/___/___
( ) unknown Month Day Year

Pump Type:
( ) submersible ( ) bailer
( ) turbine ( ) jet ( ) hand pump
( ) none ( ) other ( ) unknown

Intake Level: ______ ft. below surface

Electric Connection:
( ) 2 wire ( ) 3 wire ( ) unknown

(11) WELL CONSTRUCTION DETAILS

Feet Below Surface From	To	Casing Inside Dia. (in.)	Casing Type	Casing Wall Thickness (in.)

(12) SKETCH MAP OF VICINITY

(13) WELL USE (check all that apply)

( ) domestic ( ) livestock ( ) not used
( ) public ( ) irrigation ( ) abandoned
( ) industrial ( ) monitoring
( ) other ______

PWSID# ______

Water Withdrawal Permit # ______

(14) WELL SERVICE

Number of People Served: ______

Number of Service Connections: ______

Any Quantity Problems? ( ) yes ( ) no
Any Quality Problems? ( ) yes ( ) no
If "yes", describe in COMMENTS section, below.

(15) COMPLIANCE TO STANDARDS

Construction in Compliance with KY Standards?
( ) yes ( ) no ( ) unknown ( ) pre-law
If "no", describe in COMMENTS section, below.

(16) RELATIVE LOCATION

( ) upgradient ( ) sidegradient ( ) unknown
( ) downgradient ( ) varying ( ) N/A

(17) INSPECTION INFORMATION

Date of Inspection: ___/___/___
Month Day Year

Water Quality Sample Taken: ( ) yes ( ) no

Reason for Inspection:
( ) general survey
( ) specific complaint investigation
( ) spill or incident response
( ) contamination site investigation
( ) enforcement
( ) general water quality analysis
( ) ambient groundwater monitoring
( ) other ______

Program Name and Facility ID#: ______

Alternate Well ID#: ______

(18) ELEVATION

______ ft. AMSL

From ( ) ground surface
( ) top of casing

By ( ) map
( ) survey
( ) report
( ) GPS

(19) TREATMENT SYSTEM

( ) none
( ) water softener
( ) ultraviolet
( ) chlorination
( ) aeration
( ) charcoal filter
( ) sand filter
( ) iron treatment
( ) fluoridation
( ) other

Treatment Bypass Available? ( ) yes ( ) no

(20) OPTIONAL USE

Will Owner Allow State Access?
( ) yes ( ) no ( ) unknown

Extent of Monitoring Allowed:
( ) collect sample
( ) measure SWL
( ) pump well
( ) complete access
( ) notification required
( ) other (describe below)

Monitoring Feasibility: ______

(21) COMMENTS: ______

(22) INSPECTOR IDENTIFICATION

Name: ____________ Last ____________ First ____ MI ____ Inspector ID#

Agency: ( ) DOW ( ) DWM ( ) CHR ( ) KGS ( ) other ______

Signature of Inspector: ____________ Date: ______

Distribution: White copy to DOW, pink copy to Inspecting Agency, yellow copy to Owner.

Printed with State Funds.

DEP 4051
Revised 3/1/1993

Appendix IV

Scenario of Sampling Frequency
and
Possible Monitoring Frequencies

Scenario of Sampling Frequency

The following table shows a scenario, or exercise, of a potential sampling regimen using just two sampling frequencies for the Temporal sites. The number of samples collected over a 10 year period is shown. The premise of this scenario is quarterly collection of samples from each Temporal site for two consecutive years, after which each of those sites would shift to sampling every fifth quarter. The table lists the number of **samples** and the number of **sites** that can be monitored each year for a 10-year period. The differentiation between **samples** and **sites** in the table is important.

The assumptions are: (1) 800 samples can be collected per year, (2) 120 samples are dedicated to one-time sampling each year, (3) 680 samples are dedicated to temporal sampling each year, (4) the sampling frequency will be quarterly for Temporal sites in the first two years, (5) after two years, each site that has been sampled quarterly is shifted to a sampling frequency of every 5th quarter for the remainder of the 10 years in the exercise.

The 10-year table shows that after 6 years, 442 sites have been sampled quarterly, and 720 sites have been sampled once for a total of 1,162 sampled sites. It has been proposed in the regional monitoring strategies that a total of 641 sampling points be part of the Temporal Network. All of these sites would have been sampled at least once by year 11. This exercise shows that, in reality, the sampling of most sites will have to be less frequent than shown in the table if each of the 600+ sites in the Temporal Network is to be sampled at least once in the first few years of monitoring by the network.

Possible Monitoring Frequencies

Note: Since the following table was created in October, 1995, the number of sites in the Jackson Purchase region has differed by two and the number in the River Alluvium increased by three, giving a total of 641 sites proposed for the Temporal Network at this time. The numbers in the table have not been changed at this time because it still offers an example and the number of sampling sites for each region may continue to change.

The following table of "Sampling Sites and Proposed Freqencies" shows three different potential sampling frequencies for the 641 proposed sites. These are: greatest frequency, interim frequency, and minimum frequency. The second column shows the number of proposed sampling points for each region.

For each of the sampling frequencies, the total samples that would have to be analyzed is shown at the bottom of each of the three sample columns. This bottom number assumes that in addition to the temporal samples listed in the table, there will be 120 one-time samples collected annually. And that an additional 15 percent of all samples will be required as quality-control samples that also will be analyzed by the laboratories. To sustain sampling of all sites in the network at the interim rate, about 846 samples would have to be collected annually for the network--46 by other organizations, and 800 by the network. In reality, a mix of the various sampling frequencies, and sampling by other organizations would need to be used to monitor all of the sites of the Temporal Network.

Exercise where temporal samples are collected only quarterly or every 5th quarter

All temporal sites sampled quarterly for 2 years, followed by 5th quarter sampling. First year, 170 sites sampled quarterly.

		Year 1	Year 1	Year 1	Year 2	Year 2	Year 2	Year 3	Year 3	Year 3	Year 4	Year 4	Year 4	Year 5	Year 5	Year 5
Sampling Frequency	Samples per year per site	Samples Collected	Sites Sampled in Year	Sites in Frequency	Samples Collected	Sites Sampled in Year	Sites in Frequency	Samples Collected	Sites Sampled in Year	Sites in Frequency	Samples Collected	Sites Sampled in Year	Sites in Frequency	Samples Collected	Sites Sampled in Year	Sites in Frequency
Quarterly	4	680	170	170	680	170	170	544	136	136	544	136	136	408	102	102
Every 5th quarter	0.8		0	0		0	0	136	136	170	136	136	170	272	272	340
One-time sampling		120	120		120	120		120	120		120	120		120	120	
Total all samples		800			800			800			800			800		
Cumulative all samples		800			1600			2400			3200			4000		
Cumulative "temporal" sites				170			170			306			306			442
Cumulative "one-time" sites				120			240			360			480			600
Cumulative all sites				290			410			666			786			1042

		Year 6	Year 6	Year 6	Year 7	Year 7	Year 7	Year 8	Year 8	Year 8	Year 9	Year 9	Year 9	Year 10	Year 10	Year 10
Sampling Frequency	Samples per year per site	Samples Collected	Sites Sampled in Year	Sites in Frequency	Samples Collected	Sites Sampled in Year	Sites in Frequency	Samples Collected	Sites Sampled in Year	Sites in Frequency	Samples Collected	Sites Sampled in Year	Sites in Frequency	Samples Collected	Sites Sampled in Year	Sites in Frequency
Quarterly	4	408	102	102	326	82	82	326	82	82	262	66	66	262	66	66
Every 5th quarter	0.8	272	272	340	354	354	443	354	354	443	418	418	523	418	418	523
One-time sampling		120	120		120	120		120	120		120	120		120	120	120
Total all samples		800			800			800			800			800		
Cumulative all samples		4800			5600			6400			7200			8000		
Cumulative "temporal" sites				442			523			523			588			588
Cumulative "one-time" sites				720			840			960			1080			1200
Cumulative all sites				1162			1363			1483			1668			1788

P.C. 10/23/95

Sampling Sites and Proposed Sampling Frequencies

Frequencies: Greatest, Interim, Minimum

10/23/95

	Sampling Points	Proposed Greatest Frequency	Greatest Frequency Annual *Samples*	Possible Interim Sampling Frequency	Interim Frequency Annual *Samples*	Proposed Minimum Sampling Frequency	Minimum Frequency Annual *Samples*
Eastern Ky. Coal Field							
interior upland well x 39 counties	39	Q	156	5th Q if changes	31	5 yrs.	8
shallow fracture system x 39 counties	39	Q	156	5th Q if changes	31	2.5 yrs	16
shallow/dug wells x 39 counties	39	Q	156	5th Q if changes	31	2.5 yrs	16
	117		468		94		39
Outer Bluegrass							
4 mon.-well nests of 3 wells	12	Q	48	5th Q if changes	10	2.5 years	5
Existing wells, some springs	20	Q	80	5th Q if changes	16	2.5 years	8
	32		128		26		13
Knobs							
Public-supply wells	?	Q	?	5th Q if changes	?	2.5 years	?
Other existing wells	12	Q	48	5th Q if changes	10	2.5 years	5
	12		48		10		5
Inner Bluegrass and Pennyroyal							
Mun. springs	30	Q	120	Q	120	Q	120
Class 1 springs >10 cfs	10	Q	40	Q	40	Q	40
Class 2 springs 1-10 cfs	50	Q	200	5th Q if changes	40	5th Q	40
Class 3 springs <1 cfs	100	Q	400	5th Q if changes	80	2.5 years	40
Subset of 12 springs @ 26/yr.		26/yr=12x22 extra/yr.	264	monthly	96	bimonthly	48
Monit. wells (30 pairs)	60	Q	240	5th Q if changes	48	2.5 years	24
Wells, 100 additional	100	Q	400	5th Q if changes	80	2.5 years	40
	350		1664		504		352
Western Ky. Coal Field							
deeper granular aQ well x 20 counties	20	Q	80	5th Q if changes	16	5 years	16
<150' well, fracture zone x 20 counties	20	Q	80	5th Q if changes	16	2.5 years	8
<50' well x 20 counties	20	Q	80	5th Q if changes	16	2.5 years	8
	60		240		48		32
Jackson Purchase							
Bedrock wells	5	Q	20	5th Q if changes	4	2.5 years	2
McNairy wells, unconfined & confined	11	Q	44	5th Q if changes	9	5th Q -- crops out, 2.5 if confined	7
Eocene, wells and 1 spring	15	Q	60	5th Q if changes	12	2.5 yrs to 5th Q	9
	31		124		25		9
River Alluvium							
Ohio & Mississippi R. Alluvium, municipal	14	Q	56	5th Q if changes	11	2.5 years	6
wells in fine-grained deposits	12	Q	48	5th Q if changes	10	2.5 years	5
Other river alluvium (new to proposal)	12	Q	48	5th Q if changes	10	2.5 years	5
	38		152		30		15
Total from above =	640 plus one-time sites	Total from above =	2824 plus 120 1-time 424 QAQC		736 plus 120 1-time 110 QAQC		465 plus 120 1-time 70 QAQC
		Annual samples in theory=	**3368**		**966**		**655**