CONTEMPORARY GROUND WATER QUALITY

STATE OF ARKANSAS

(1994 - 1996)

ARKANSAS DEPARTMENT OF ENVIRONMENTAL QUALITY

JUNE 1996
WQ96-06-1

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PREFACE

Section 106 (e) of the Clean Water Act requests that each State monitor the quality of its ground water resources and report the status to Congress every two years in its State 305 (b) report. The 305 (b) report summarizes both the surface-water and ground-water quality of the State for the two-year period. This document, with minor revisions, represents "Part IV - Ground Water Assessment" from that report.

The ambient monitoring program established by the Arkansas Department of Pollution Control and Ecology (ADPC&E) is designed to gather background ground water-quality from various aquifers in the State. This monitoring program also helps evaluate the effectiveness of the Department's pollution control program. The EPA has encouraged States to assess ground water quality for selected aquifers or hydrogeologic settings within the State or portions of aquifers or hydrogeologic settings that reflect State priority considerations. The assessment of ground water quality within specific aquifers or hydrogeologic units will provide a more meaningful interpretation of ground water quality within the State. This is intended as a "stand alone" document on the quality of ground water in the State of Arkansas for the 1994-1996 reporting period. It may provide useful information for those who are not familiar with the aquifers of the State or of the special concerns of the water quality within those aquifers. An attempt is made to provide information on the status of ground water research within the State and of various programs that have been implemented to protect the quality of the ground water.

GROUND WATER QUALITY

OVERVIEW

Ground water continues to be one of Arkansas' most important natural resources. Between 1975 and 1980 ground water use increased from 2,596 to 4,056 million gallons per day, a 56 percent increase (Holland and Ludwig, 1981). The rate of increase slowed somewhat between 1980 and 1990 when ground water use rose from 4,056 million gallons per day to 4,708 million gallons per day, a 16 percent increase (Holland, 1993). Part of the reason for the lower rate of increase of ground water usage can be attributed to reliance on surface water by a greater segment of the populace for public supply and for commercial purposes. Nevertheless, ground water accounts for 1,580 million gallons more per day in total withdrawals than surface water (Holland, 1993). Ground water accounts for a little over 60 percent of the total withdrawals and 47.21 percent of the total used for drinking water. This considerable reliance on ground water stresses the need for increased water quality monitoring and associated research.

Ground-water quality is monitored by several state agencies and the United States Geological Survey both on an ambient basis and for specific investigations. Monitoring programs established to provide early detection of a pollutant entering a fresh water aquifer can be an effective way to preserve the quality of the ground water by initiating steps to eliminate or prevent further water quality degradation. However, there are too few monitoring sites located statewide to effectively monitor the quality of ground water before it becomes too late to protect public and private systems.

The Arkansas Department of Pollution Control and Ecology has established an ambient ground-water quality monitoring program at various statewide locations which provides background ground-water quality data from various aquifers. At the same time, it evaluates water quality in areas of specific interest such as in and around communities located in agricultural and industrial areas or in the extremely complex karst region of northern Arkansas, which is especially vulnerable to contamination. This monitoring program has recently been expanded to increase the areal extent and the number of sampling sites for each area. New areas are also under consideration for implementation into the program. The Department has also participated in or funded ground-water quality investigations with other state and federal agencies. The ambient ground-water quality monitoring was designed to help in water-quality planning and development of ground-water standards as part of the Arkansas Ground Water Protection Program. This program is funded entirely with Clean Water Act, Section 106 funds and resides within the Water Quality Planning Branch of the Water Division of the Department.

The Program has produced documents such as "Groundwater - Volume 1 Elements of an Arkansas State Groundwater Protection Strategy" (1985) and " A Profile of the Arkansas State Groundwater Quality Protection Program" (1991) as precursors to the "Comprehensive State Ground Water Protection Program" (CSGWPP), which is being developed by a statewide committee chaired by the Arkansas Soil and Water Conservation Commission (AS&WCC). The main goals for FY96 are to continue to implement program changes developed during FY94 and FY95, especially in the area of statewide ambient monitoring. Program personnel will continue to work with other departments and other state agencies in a more comprehensive approach to ground water protection.

Ground-water protection programs are in varying stages of development by the State. The Wellhead Protection Program (WHPP), under the authority of the Arkansas Department of Health (ADH), is making steady progress in its implementation statewide. Accomplishments since program start-up in 1991 include development of WHP programs for about 100 public water systems, delineations of wellhead protection areas for more than 300 wells, outreach and technical aid programs, and WHP road signs designed by the Arkansas State Highway and Transportation Department (Cordova, written communication). The AS&WCC has utilized funds from Section 106 of the Clean Water Act to identify areas of the State which may be vulnerable to contamination from nonpoint source pollution, especially through the use of pesticides. Oher activities by the AS&WCC include development of a State Ground-Water Protection Priority Map and Ground-Water Quality Data Base (Smith, et al, 1995).

Although the overall quality of ground water in Arkansas appears to be good, widespread problems do occur and their presence has been addressed by a number of recent studies conducted by state agencies, educational institutions, the United States Geological Survey, and by independent scientific investigations. Specific investigations have targeted pesticides and nitrates as indicators of contamination in fresh-water aquifers. Other studies have taken a look at saline intrusion or brine contamination, an increasing problem in southern and eastern Arkansas. Contamination of ground water by microbial organisms normally found only in surface water is currently being investigated. Microbial contamination may be caused by poor well construction or by hydrogeological conditions permitting easy movement of the contaminant into the aquifer. A number of public water systems have had problems with elevated levels of radionuclides, in northern Arkansas. Widespread problems have also been reported to be related to waste products generated by cattle, poultry and swine operations, particularly in northwest Arkansas. Problems common to other states include leaks from underground storage tanks, landfills, hazardous waste sites, sewage treatment lagoons, septic tanks, and surface impoundments related to the oil and gas industry. There are over 7,640 impoundments related to agricultural, oil and gas, municipal and mining activities. Over 6,000 of these impoundments are associated with oil and gas operations in west central and southern Arkansas (Chesney, 1979).

Ground Water Occurrence

Physiographically, the state of Arkansas can be divided into two provinces by a diagonal line running from the northeast to the southwest, each segment representing approximately one-half of the state. The segment northwest of this diagonal line is called the Interior Highlands Province, or the Paleozoic outcrop area of the state. This province can further be divided into the Ozark, Boston Mountains, Arkansas Valley, and Ouachita Mountains Regions (Figure 1). Mesozoic and Cenozoic sediments outcrop south and east of this line, lap upon the Paleozoic rocks and unconformably overlie them. These rocks lie within the Gulf Coastal Plain Province. The rocks representing the Cenozoic (Tertiary and Quaternary) are more extensive at the surface than the Mesozoic rocks which crop out in the southwest portion of the state (Landes, 1970). The rock types and their weathered products associated with each of these regions are a major factor in controlling the occurrence of ground water.

The majority of the ground water supplies in the Gulf Coastal Plain are obtained from six aquifers. These are in the Quaternary deposits (alluvium), Cockfield Formation, Sparta Sand, Wilcox Group, Nacatoch Sand, and the Tokio Formation (Bryant et al, 1985). These aquifers are part of a thick sequence of semiconsolidated sediments consisting of sands, shales and clays, with sand representing the larger fraction (Table 1). The yields for these aquifers range from 300 to 2,000 gallons per minute for the formations excluding the Quaternary alluvial aquifer, which ranges from 1,000 to 2,000 gallons per minute (Bryant et al, 1985).

The Interior Highlands are underlain by consolidated rocks consisting of sands, shales and carbonates of Paleozoic age. Most of the ground water in this province occurs in fractures and joints in the consolidated rocks, and in solution cavities in the carbonate rocks (limestones and dolomites). Two of the most important aquifers in northern Arkansas are the Roubidoux Formation and the Gunter Sandstone (Van Buren Formation). Yields for the combined intervals range up to 500 gallons per minute (Bryant et al, 1985). Other formations that contribute ground water range in age from the Pennsylvanian through the Cambrian and are chiefly carbonate (Table 2). Paleozoic strata in the Arkansas Valley and Ouachita Region of the Interior Highland Province produce water from fractures in sandstone and shale (Table 3). Yield is commonly in the range of 10 to 25 gallons per minute (Bryant et al, 1985).

Use Of Ground Water

Table 4 is a compilation of withdrawals of ground water from the major aquifers within the state. This table shows the rather dramatic contrast in withdrawals from the Quaternary alluvial aquifer of the Gulf Coastal Plain and all the other aquifers of the state combined.

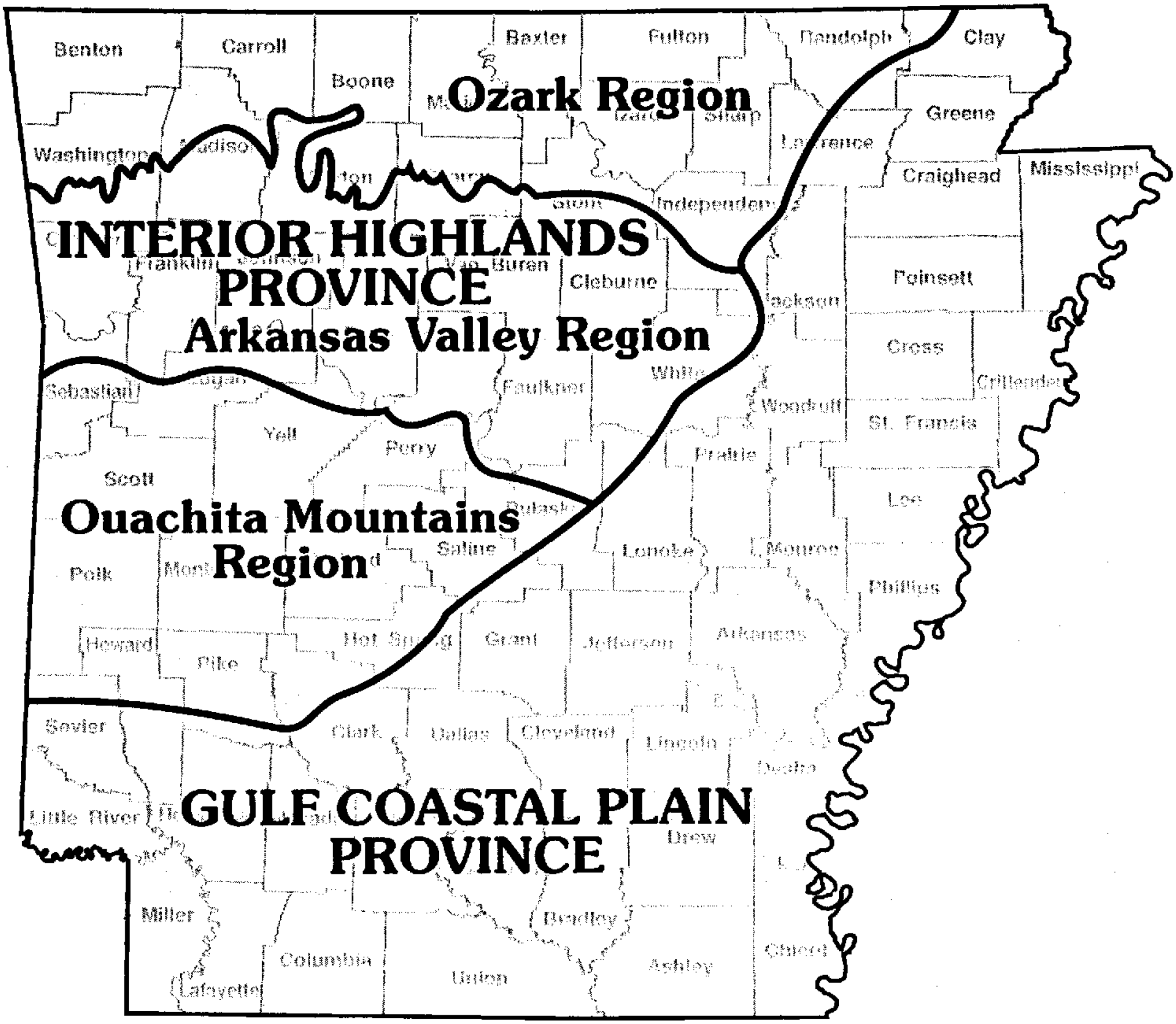

Figure 1. Physiographic Provinces of Arkansas (from Landes, 1970)

Table 1. Generalized Stratigraphic Column Of The Gulf Coastal Plain Of Southern And Eastern Arkansas (Modified from Terry and Others, 1986)

ERA	SYSTEM	SERIES	GROUP	FORMATION
Cenozoic	Quaternary	Holocene & Pleistocene		Alluvium & Terrace Deposits *
	Tertiary	Eocene	Jackson	Undifferentiated
			Claiborne	Cockfield Formation *
				Cook Mountain Formation
				Sparta and Memphis Sand *
				Cane River Formation
				Carrizo Sand
			Wilcox	Undifferentiated *
		Paleocene	Midway	Undifferentiated
Mesozoic	Cretaceous	Upper Cretaceous		Arkadelphia Marl
				Nacatoch Sand *
				Tokio Formation *
				Undifferentiated
Paleozoic	Undifferentiated	Undifferentiated		Undifferentiated

(* denotes major aquifers)

Table 2. Generalized Stratigraphic Units In Northern Arkansas And Geohydrologic Units.

(modified from Leidy and Morris, 1990)

ERA	SYSTEM	FORMATION	UNIT / SYSTEM
Paleozoic	Pennsylvanian	Atoka Sandstone Bloyd Shale Hale Formation	Western Interior Plains Confining System
	Mississippian	Pitkin Limestone Fayetteville Shale Batesville Sandstone Moorefield Formation	
		Boone Formation St. Joe Limestone Member	Springfield Plateau Aquifer
		Chattanooga Shale	Ozark Confining Unit
	Devonian	Clifty Limestone Penters Chert	Ozark Aquifer
	Silurian	Lafferty Limestone St. Clair Limestone Brassfield Limestone	
	Ordovician	Cason Shale Fernvale Limestone Kimmswick Limestone Plattin Limestone Joachim Dolomite St. Peter Sandstone Everton Formation Smithville Formation Powell Dolomite Cotter Dolomite Jefferson City Dolomite Roubidoux Formation Gasconade Dolomite Van Buren Formation Gunter Sandstone Member	
	Cambrian	Eminence Dolomite Potosi Dolomite	

Table 3. Generalized Stratigraphic Column Of The Arkansas River Valley And Ouachita Mountain Region (from Haley and Others, 1993)

ERA	SYSTEM	SERIES	FORMATION
Cenozoic	Quaternary	Holocene & Pleistocene	Alluvium & Terrace Deposits
Paleozoic	Pennsylvanian	Des Moinesian	Boggy Formation
			Savanna Formation
			McAlester Formation
			Hartshorne Sandstone
		Atokan	Atoka Formation
		Morrowan	Johns Valley Shale
	Mississippian & Devonian		Jackfork Sandstone
			Stanley Shale Arkansas Novaculite
	Silurian		Missouri Mountain Shale Blaylock Sandstone
	Ordovician		Polk Creek Shale Big Fork Chert Womble Shale Blakely Sandstone Mazarn Shale Crystal Mountain Sandstone Collier Shale

Table 4. WITHDRAWALS OF GROUND WATER FROM AQUIFERS IN ARKANSAS, 1990 (in million gallons per day)

(modified from Holland, T.W. (1993). Use of Water in Arkansas, 1990)

AQUIFER	WITHDRAWAL(MGD)
Quaternary Alluvium	4375.77
Cockfield Formation	8.09
Sparta/Memphis Sand	222.50
Cane River Formation	2.20
Wilcox Group	30.85
Clayton Formation	0.02
Nacatoch Sand	3.14
Tokio Formation	2.29
Trinity Group	.23
Paleozoic (Undifferentiated)	63.06
Total	4708.15

This aquifer is the principal source of water for irrigation, but is also important as a source of water for public and domestic use. Due to large scale pumping of this aquifer, several areas within the state have become vulnerable to saltwater contamination. The second most important aquifer, in terms of withdrawal, is the Sparta/Memphis aquifer, which is located in the same province as the alluvial aquifer. This aquifer, particularly in southern Arkansas, also has had saltwater contamination related to large scale pumping. The chief source of ground water in the Paleozoic strata of northern Arkansas comes from the Roubidoux Formation and the Gunter Sandstone (Van Buren Formation). These aquifers, combined with the other Paleozoic aquifers of northern Arkansas, the Arkansas Valley and the Ouachita Region, rank third in terms of withdrawal. Table 5 reflects the significance of ground water, in terms of usage, compared to surface water.

Ground Water Protection Programs

Surface Mining and Reclamation Division

In 1979, the Arkansas State 72nd General Assembly passed Act 134, as amended by Act 647 of 1979, the Arkansas Surface Coal Mining and Reclamation Act. These Acts authorized the Arkansas Pollution Control and Ecology Commission to promulgate regulations pertaining to surface-coal mining and reclamation consistent with, but no more restrictive than, the federal regulations issued by the Secretary of the Interior pursuant to Public Law 95-87.

On July 25, 1980, the Commission adopted the Arkansas Surface Coal Mining and Reclamation Code (Regulation Number 20). Regulation Number 20 contains standards to insure protection of ground water during surface coal-mining and reclamation operations. Regulation 20 requires that a quarterly monitoring report be submitted to the Department to verify that groundwater quality is not being adversely affected. Currently, there are eight coal-mining operations in Arkansas operating a total of 19 monitor wells.

Regulated Storage Tank Division

Regulation No. 12, 1989, protects ground water from leaking underground storage tanks. The portion of the regulation addressing leak detection and response was adopted directly from Title 40, Code of Federal Regulations. Currently, there are over 16,000 storage tanks registered with the Department. Several different leak detection methods may be employed; including ground water and/or vapor monitoring, automatic tank gauging, secondary containment with interstitial monitoring, and statistical inventory reconciliation.

Currently, there is no effective way of maintaining a data base of the number of facilities using ground-water monitoring wells for leak detection. Also many monitoring wells are used for site investigations at sites where a leak has been confirmed and, therefore, serve only as temporary structures for investigative and remediation purposes. However, it is estimated that there are over 10,000 monitoring wells in the state for leak-detection purposes.

Table 5. TOTAL WITHDRAWALS IN TERMS OF USEAGE (MGAL/D)
(modified from Holland, T.W. (1993). Use of Water in Arkansas, 1990)

	Ground Water	Surface Water	% Ground Water
Public Supply	118.95	189.57	38.60
Domestic	50.61	0.00	100.00
Commercial	14.31	207.30	6.50
Industrial	98.92	78.43	55.80
Mining	1.82	0.66	73.30
Livestock	124.96	64.44	66.00
Irrigation	4,296.15	949.28	82.00
Thermo-electric	2.43	1,638.22	< 1.00

Solid Waste Division

Department Regulation 22 was promulgated in 1984 pursuant to the Arkansas Solid Waste Management Act, Act 237 of 1971. Regulation 22, which was known as the Arkansas Solid Waste Management Code, required all new landfills to have a recompacted clay liner, leachate collection and monitoring wells. As a nationally recognized leader in the permitting of solid waste landfills, the Solid Waste Division was asked to provide a staff member to serve on the National Committee to develop the RCRA Subtitle D regulations. Later, those regulations were incorporated by reference into Regulation 22.

In 1995 Regulation 22 was rewritten to incorporate the RCRA Subtitle D into the body of the regulations and include more stringent requirements. The more stringent requirements include QA/QC requirements for landfill construction, leak detection requirements, and an additional composite liner for sites located in the Boone-St. Joe outcrop areas of the state.

Hazardous Waste Division Ground Water Protection Overview

The Hazardous Waste Division enforces ground-water protection through basically two major authorities. ADPC&E Regulation 23 Hazardous Waste Management (RCRA) is the primary authority for facilities which treat, store, or dispose of hazardous waste in defined, regulated units. Additionally, a facility seeking a permit for the treatment, storage or disposal of hazardous waste is to required institute corrective action for all releases of hazardous waste or constituents from any solid waste management unit at the facility, regardless of the time at which wastes were placed in such unit.

The Arkansas Remedial Action Trust Fund Act (RATF), Act 479 of 1985 provides additional authority for corrective action and clean-up of hazardous waste releases at RCRA sites as well as abandoned hazardous substance sites. RATF authority is primarily done through consent administrative orders (CAO), but can be used to abate immediate, imminent hazards with the trust fund.

The RCRA program provides a very good framework for the protection of ground water from contamination with required minimum technological requirements (MTR's) for the design of units which treat, store, or dispose of hazardous waste. Mandatory ground-water monitoring requirements assure that a release to the ground water will be detected rapidly, utilizing statistical analysis of data compared to background and/or waste-related constituents. The RCRA program requires corrective action when hazardous waste constituents, as defined, are released into the ground water.

Water Division

Ground-water protection authority within the Water Division is provided within Act 472, Arkansas Water and Air Pollution Control Act. The Act states that no waste shall be placed in a manner which can potentially pollute the "Waters of the State." Because the definition of "Waters of the State" includes subsurface water, the Department is responsible for protecting ground water from sources which are not specifically regulated by other federal and state programs (i.e., solid waste, hazardous waste, etc.).

In the absence of statewide ground-water standards, the Water Division uses the federal primary drinking water standards as action levels for the prevention and cleanup of ground-water contamination. Most of the contamination cases regulated by the Water Division are in regard to releases from waste storage lagoons, above-ground storage tanks, and a myriad of other sources.

Arkansas' Wellhead Protection Program

The Wellhead Protection (WHPP) program was authorized by the 1986 Amendments to the Safe Drinking Water Act. The Arkansas Department of Health in July, 1986, was designated by the Governor to be the lead agency in carrying out the WHP program. The program is the first formal attempt by the federal government in its environmental protection role to prevent contamination from taking place in public water-supply wells; in contrast to costly clean-up or remediation programs. The program includes several minimum requirements including: 1) de-lineating a Wellhead Protection Area for each well or wellfield, 2) identifying all potential man-made sources of contaminants injurious to public health within each WHP area, and 3) developing outreach activities for increasing public awareness.

Since program start-up, study and experience have shown that presently four methods of delineation of wellhead protection areas are usable in Arkansas: 1) arbitrary fixed radius, 2) volumetric, 3) mathematical flow equation, and 4) hydrogeologic mapping and hydrologic budget combined. Some methods are most applicable to aquifers of the Coastal Plain and others to aquifers of the Interior Highlands. Accomplishments since program start-up in 1991 include development of programs for about 100 public water systems, delineations of wellhead protection areas for more than 300 wells, outreach and technical aid programs, and WHP road signs designed by the Arkansas State Highway and Transportation Department (Cordova, written communication).

GROUND WATER QUALITY MONITORING

Table 6 lists the approximate number of ground water-quality data available for the state. The Department of Health, Department of Pollution Control and Ecology, and the United States Geological Survey monitor ground water sources on a regular basis. Other investigations by state agencies or institutions are usually conducted on a one-time basis only.

The Department of Pollution Control and Ecology monitors the water quality of 154 wells and 11 springs once every three years. This monitoring is part of the on-going, ambient-monitoring program initiated in 1986 to gather background ground water-quality data from various aquifers in the state. The nine monitoring areas have specific lists of sampling constituents, which are based on the types of contaminants likely to be found in their respective areas. The monitoring wells located at industrial or landfill sites regulated by RCRA or CERCLA are monitored at least yearly, but only for indicator parameters required by the regulations.

The Department of Health, as primacy agency for the SDWA, monitors public water supply wells every three years ($\pm$ 920 wells). The Total Coliform Rule requires sampling on a monthly basis with the number of samples dependent on the size of population served. Nitrate monitoring is conducted on a yearly basis unless a sample greater than or equal to 50

TABLE 6 GROUND WATER QUALITY DATA AVAILABILITY			
Agency	Number of wells/springs		Computer
Pollution Control	±670	(RCRA)	(Storet)
	154/11	(Water)	(Storet)
	19	(Mining)	IBM
	±260	(CERCLA)	Paper Only
	±200	(Solid Waste)	Mac
	*	(RST)	Paper Only
Health Department	±920	(Community)	Wang
	±500	(Non-Community)	
USGS	4,100	(Research Wells)	(Watstore)
	25	(Master Wells)	
UA - Extension	>2,900	(Wells)	IBM
	<100	(Springs)	
US DOE (NURE)	1,369	(Wells)	IBM
UA & AR Tech	±455	(Wells)	IBM
	±85	(Springs)	

* See section on Regulated Storage Tank Division under " Ground Water Protection Programs".

percent of the MCL triggers the need for increased sampling. Raw-water sampling has been implemented in order to detect microbial contaminants for selected ground water wells found to be at risk from contaminated surface water (Surface Water Treatment Rule). This sampling (microscopic particulate analysis) is performed in conjunction with weekly, raw-water bacteriological testing, turbidity, temperature and pH determinations.

The United States Geological Survey (USGS) has 25 master wells scattered throughout the state which are sampled regularly every five years. The other wells utilized by the USGS are sampled for specific projects and not at a regular frequency.

Most of the other wells or springs listed in Table 6 are sampled for particular projects such as the on-going nitrate study conducted by the Cooperative Extension Service and various research projects by the Arkansas Water Resources Center (AWRC), which focuses much of its research on the effects of agricultural pesticides and nutrients on ground and surface water.

Arkansas Ambient Ground Water Monitoring Program

The Arkansas Department of Pollution Control and Ecology initiated this program in 1986 in order to gather background, ground-water quality data from various aquifers in the state. Samples have been collected every three years for general water-quality indicators, metals, petroleum hydrocarbons, and pesticides. Some of the areas have been sampled and analyzed for the third time since inception of the program. The nine currently-active monitoring areas (Figure 2) are described in more detail in the following sections:

1) Ouachita County - a recharge area of the Sparta sand aquifer.
2) Lonoke, Lonoke County - an agricultural community in the Mississippi Delta.
3) Pine Bluff, Jefferson County - a community system in the Arkansas River Valley.
4) Omaha, Boone County - a karst area in northern Arkansas.
5) El Dorado, Union County - an industrialized urban center in the oil producing area of Arkansas.
6) Jonesboro, Craighead County - second largest city on ground water in the state and located in the middle of an agricultural region in the Arkansas Delta.
7) Brinkley, Monroe County - an agricultural community affected by saltwater intrusion of uncertain origin.
8) Chicot County - an area of extensive saltwater contamination in southeastern Arkansas.
9) Buffalo River Watershed, Newton County - an area potentially impacted by confined animal operations.

In addition to the nine areas listed above, two new areas are currently being considered for implementation into the monitoring program. One of these is located in the region surrounding the town of Hardy in Fulton, Izard, Randolph, and Sharp Counties which lie within the Interior Highlands province. The other is located in an area that encompasses a portion of the Athens Plateau region of the Interior Highlands province and extends into the Gulf Coastal Plain province of southwestern Arkansas (Figure 2).

All available wells (i.e. domestic, commercial, public, irrigation, etc.) were inventoried and considered for possible use as part of a monitoring network in each area. Some wells have had to be replaced due to abandonment or inaccessibility. Lists of sampling constituents were based on the types of contaminants likely to be found in each of the respective areas. Selected water- quality parameters are included in the tables following a brief summary of each of the monitoring areas. Reports describing each of these areas with complete chemical analyses are available from the Department.

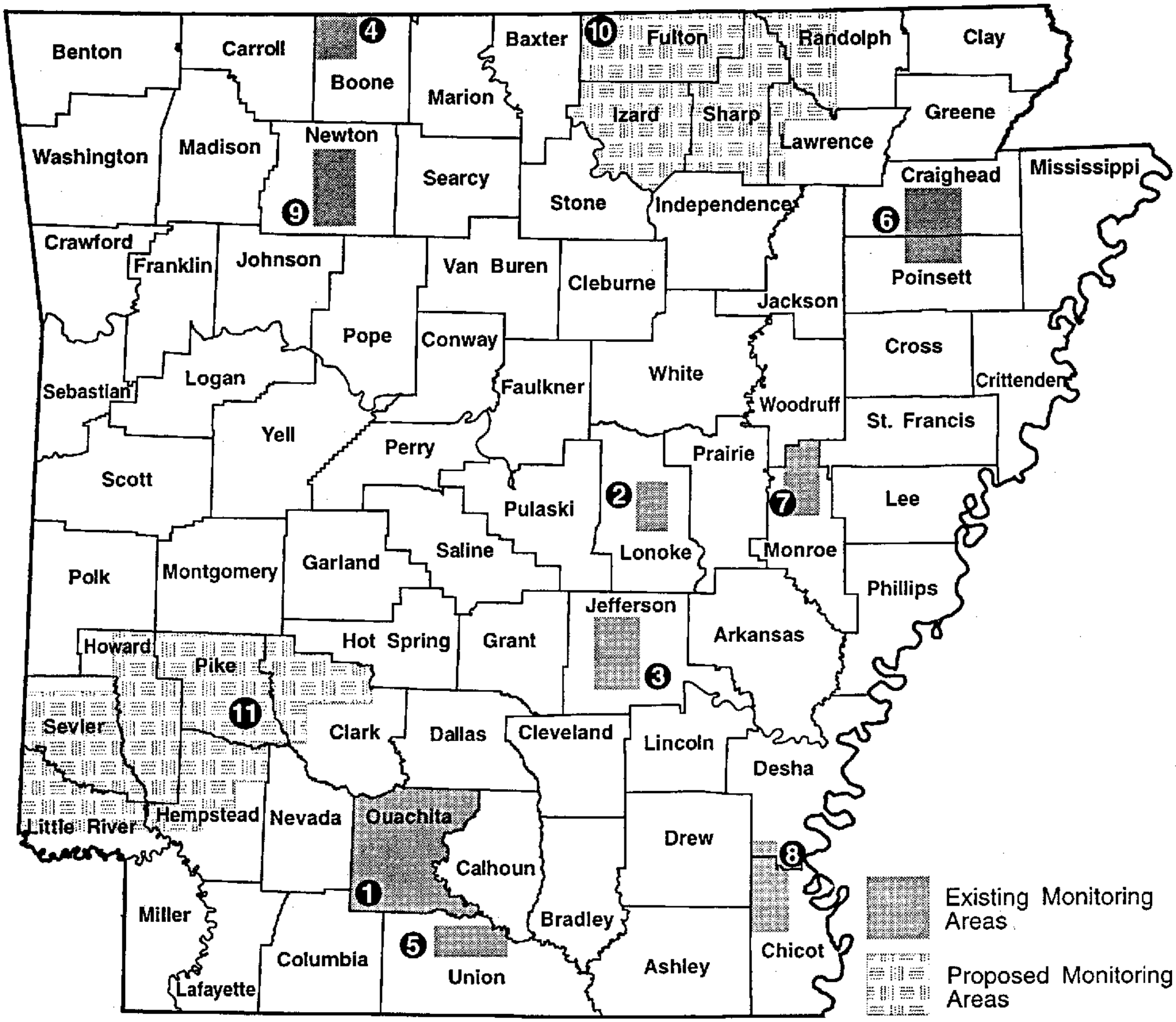

Figure 2. Arkansas Ambient Ground Water Monitoring Program

Existing monitoring areas include Ouachita (1), Lonoke (2), Pine Bluff (3), Omaha (4), El Dorado (5), Jonesboro (6), Brinkley (7), Chicot (8), and Buffalo River Watershed (9). Expansion areas will include Hardy (10) and Athens Plateau/Coastal Plain (11).

Ouachita

The Ouachita monitoring program, located in Ouachita County, southern Arkansas, encompasses approximately 350 square miles. This area is in the Gulf Coastal Plain physiographic province, and is characterized by heavily timbered flatlands and low hills. The surface geology consists of rocks of Eocene, Pleistocene, and Recent age (Albin, 1964).

This area was selected because it is a recharge area of one of the state's most important aquifers, the Sparta Sand. The objective of the monitoring program is to provide data about baseline water quality in the recharge area and to determine the extent of contamination from existing pollution sources in Ouachita County. This would include operations related to the timber industry and various oil and gas-related activities, particularly in the southwestern portion of the area. Sampling categories of chemical constituents included the following: total alkalinity, chloride, total hardness, nutrients, sulfate, total and fecal coliform, and total organic carbon.

The Sparta Sand, which crops out over much of Ouachita County, consists mainly of gray, very fine to medium sand and brown and gray sandy clay. The Sparta sand thickness is about 300 feet in the outcrop area. Yield for wells screened in the Sparta average about 300 gallons per minute (Albin, 1964). The depth of the Sparta Sand ranges from the surface to approximately 300 feet. The wells used in this study ranged from 51 feet to 370 feet deep.

Table 7 lists the descriptive statistics for selected water-quality parameters for twenty-six Sparta wells sampled during the first three sampling periods conducted in 1986, 1989, and 1992. Data used in this table reflects the most recent sampling period which is generally, but not always, from the third sampling. The fourth sampling will be undertaken during the second quarter of 1996.

There was no serious contamination detected in the twenty-six Sparta wells sampled. Elevated nitrate levels were observed in one of the wells (3.33 mg/L). This well had levels of 1.60 mg/L and 1.64 mg/L from the previous two samplings, respectively. The highest chloride value observed was 72 mg/L from a well which produced water from 285 to 300 feet. The chloride concentrations throughout the area showed no correlation with well depth.

Lonoke

The Lonoke monitoring program area encompasses approximately 90 square miles surrounding the town of Lonoke in central Lonoke County. Physiographically, the area is located in the Gulf Coastal Plain province. According to Counts (1957), "this region consists of broad and nearly level interstream divide areas and flood plain cut from a few feet to about 25 feet below them. The bottom lands of the flood plains are characterized by numerous swamps, bayous, lakes, and abandoned stream channels." Quaternary alluvial deposits cover much of the area and may obtain a thickness in excess of 150 feet.

Table 7. DESCRIPTIVE STATISTICS - SELECTED WATER QUALITY PARAMETERS - 26 SPARTA WELLS - OUACHITA COUNTY, ARKANSAS

PARAMETER	TOTAL WELLS	MEAN	MEDIAN	STANDARD DEVIATION	RANGE
Alkalinity Total (mg/l)	26	50.46	21.50	44.28	5.00 - 151.00
Cl Total (mg/l)	26	10.15	5.00	14.90	2.00 - 72.00
Coliform Fecal /100 ml	23	2.35	.500	5.52	1.0K - 28.00
NH3-N Total (mg/l)	26	.143	.067	.189	.05K - .740
NO3-N Total (mg/l)	26	.198	.040	.632	.01K - 3.33
Phos.-T. Ortho (mg/l)	26	.090	.060	.075	.03K - .280
SO4 Total (mg/l)	26	13.58	10.00	14.65	1.0K - 63.00
TOC (mg/l)	26	3.86	3.35	3.06	.500 - 14.00

This area was selected because it represents an agricultural community in the Mississippi Delta where pesticide and fertilizer use increase the potential for ground water contamination. The objective of the monitoring program is to determine if agricultural practices in the Lonoke, Arkansas area have resulted in contamination of the alluvial aquifer by pesticide residues and nitrates associated with fertilizer application. Sources of pollution, in addition to pesticides and fertilizer, include a RCRA site, a landfill, and an unknown number of septic tanks. Sampling categories of chemical constituents included the following: major and trace inorganic constituents, nutrients, total organic carbon, total alkalinity, and selected pesticides. The Quaternary alluvial deposits unconformably overlie rocks of Tertiary age. The alluvial deposits consists of gray to light-brown sand and sand and gravel, reddish-brown fine sand, and gray, yellow, and red silt and clay. These alluvial deposits are a very significant source of ground water used for irrigation, public water supply, and domestic purposes. Well yields commonly are in the range of 400 to 1,700 gallons per minute for wells developed at depths of about 60 feet to over 150 feet (Counts, 1957). Only one well was sampled from the Sparta aquifer in this investigation. The Sparta aquifer is less than

300 feet thick and subcrops the alluvial aquifer throughout much of the study area. The Sparta consists of fine to medium sand with some interbedded clay. The yield from this aquifer is commonly in excess of 1,000 gallons per minute (Leidy and Morris, 1990).

Table 8 summarizes the results of the third sampling conducted in August, 1994. Nine wells, eight from the alluvial aquifer and one from the Sparta Sand, were sampled. There was no evidence of ground water contamination in any of the wells by pesticides or from any other source. High iron and manganese concentrations, common in shallow alluvial aquifers, were detected in most wells. All the wells exceeded the secondary maximum contaminant level (SMCL) established by EPA for iron (300 μg/L). Seven of the alluvial wells exceeded the SMCL for manganese (50 μg/L). A more thorough review of the program area and a complete chemical analyses is included in the, "Report On The Third Sampling Of The El Dorado, Pine Bluff, and Lonoke Prototypes" (Van Schaik and Kresse, 1994).

Pine Bluff

The Pine Bluff monitoring program is located within the city of Pine Bluff in south-central Jefferson County. It lies within the Gulf Coastal Plain physiographic province. The area is dominated by the flood plain of the Arkansas River which lies immediately to the northeast of the city. The surface geology consists of clay, silt, sand, and gravel of Quaternary Age. The confining clays and silts of the Jackson Group crop out to the west of the city.

This area was selected because Pine Bluff is the largest community within the state using ground water to meet all its needs. The most widely used aquifer to meet community and industrial purposes is the Sparta Sand. One objective of the monitoring program is to monitor water quality within the cone of depression developed within the Sparta aquifer caused by the large-scale drawdown by public and commercial wells. The chief sources of contaminants entering the Sparta aquifer within the cone of depression would include a wide range of industrial, municipal, and domestic pollutants. The industrial discharges include a wide variety of wastes generated by electroplating operations, paper mills, timber products, railways, and chemical or biochemical weapon manufacturing. Sampling categories of chemical constituents included the following: total alkalinity, major and minor inorganic constituents, metals, nutrients, chloride, sulfate, total organic carbon, and selected pesticides.

Results of the third sampling period conducted during June, 1994, is summarized in Tables 9 and 10. The twelve wells sampled included three alluvial wells, one Cockfield well, and eight Sparta wells. There was little indication of contamination in the wells sampled with the exception of one of the alluvial wells which had a relatively high arsenic concentration (37 μg/L). This well had an arsenic level of 44 μg/L reported during the first sampling, but below detection limits during the second sampling. These elevated levels are still below the maximum contaminant level (MCL) established by the EPA (50 μg/L). The chloride concentration for this well was also somewhat elevated (196 mg/L).

Table 8. DESCRIPTIVE STATISTICS - SELECTED WATER QUALITY PARAMETERS - 8 ALLUVIAL WELLS - LONOKE, ARKANSAS

PARAMETER	TOTAL WELLS	MEAN	MEDIAN	STANDARD DEVIATION	RANGE
Alkalinity Total (mg/l)	8	196.50	204.00	83.76	72.00 - 306.00
Ba Total Rec. (μg/l)	8	.222	.160	.119	.090 - .430
Ca Total Rec. (mg/l)	8	53.33	49.10	32.80	10.10 - 108.00
Cl Total (mg/l)	8	16.54	13.95	8.94	5.05 - 37.60
Fe Total Rec. (μg/l)	8	6153.8	3315.0	5593.2	2400.0 - 18800.0
Hardness Total (mg/l)	8	225.70	201.50	143.95	46.20 - 472.00
K Total Rec. (mg/l)	8	1.19	1.25	.302	.730 - 1.60
Mg Total Rec. (mg/l)	8	11.66	11.85	5.19	3.10 - 20.00
Mn Total Rec. (μg/l)	8	506.68	434.50	298.36	8.40 - 950.00
Na Total Rec. (mg/l)	8	17.28	15.65	6.00	9.20 - 30.60
NH3-N Total (mg/l)	8	.149	.058	.149	.05K - .378
NO3-N Total (mg/l)	8	.035	.034	.006	.024 - .045
SO4 Total (mg/l)	8	46.78	22.60	59.60	4.40 - 190.00
TDS (mg/l)	8	309.88	279.50	152.81	110.00 - 590.00

Table 9. DESCRIPTIVE STATISTICS - SELECTED WATER QUALITY PARAMETERS - 3 ALLUVIAL WELLS - PINE BLUFF, ARKANSAS

PARAMETER	TOTAL WELLS	MEAN	MEDIAN	STANDARD DEVIATION	RANGE
Alkalinity Total (mg/l)	3	160.00	115.00	94.90	73.00 - 292.00
Ba Total Rec. (µg/l)	3	324.33	375.00	165.59	101.00 - 497.00
Ca Total Rec. (mg/l)	3	62.63	44.00	53.93	7.90 - 136.00
Cl Total (mg/l)	3	104.20	103.00	74.47	13.60 - 196.00
Fe Total Rec. (µg/l)	3	16133.3	16400.0	3026.9	12300.0 - 19700.0
Hardness Total (mg/l)	3	302.33	273.00	102.55	194.00 - 440.00
Mn Total Rec. (µg/l)	3	956.00	1100.0	513.17	268.00 - 1500.0
Na Total Rec. (mg/l)	3	58.43	58.00	36.21	14.30 - 103.00
NO3-N Total (mg/l)	3	.396	.034	.519	.025 - 1.13
SO4 Total (mg/l)	3	17.70	19.70	8.93	5.90 - 27.50
TDS (mg/l)	3	564.67	557.00	145.85	390.00 - 747.00

Two wells were sampled for the first time becauseof their proximity to the center of the cone of depression within the Sparta aquifer (Status Report - Arkansas Prototype Monitoring Program, April, 1994). There were no elevated Na or Cl concentrations in these wells such as evidenced in El Dorado near the center of the cone of depression within the Sparta aquifer. A more thorough review of this program area accompanied by complete chemical analyses is included in the document entitled "Report On The Third Sampling Of The El Dorado, Pine Bluff, and Lonoke Prototypes" (Van Schaik and Kresse, 1994).

Table 10. DESCRIPTIVE STATISTICS - SELECTED WATER QUALITY PARAMETERS - 8 SPARTA WELLS - PINE BLUFF, ARKANSAS

PARAMETER	TOTAL WELLS	MEAN	MEDIAN	STANDARD DEVIATION	RANGE
Alkalinity Total (mg/l)	8	66.75	67.00	7.53	56.00 - 77.00
Ba Total Rec. (µg/l)	8	115.88	122.50	14.05	92.00 - 128.00
Ca Total Rec. (mg/l)	8	7.01	7.20	1.51	4.00 - 9.80
Cl Total (mg/l)	8	3.29	3.10	.729	2.22 - 4.20
Fe Total Rec. (µg/l)	8	7938.1	2650.0	10650.0	1700.0 - 33400.0
Hardness Total (mg/l)	8	23.63	24.60	5.94	13.20 - 33.00
Mn Total Rec. (µg/l)	8	73.10	61.00	44.41	33.80 - 187.00
Na Total Rec. (mg/l)	8	16.35	16.10	3.94	11.00 - 21.90
NH3-N Total (mg/l)	4	.258	.278	.113	.082 - .392
NO3-N Total (mg/l)	8	.028	.025	.012	.02K - .054
SO4 Total (mg/l)	8	6.95	4.70	6.34	1.90 - 22.90
TDS (mg/l)	8	84.50	90.50	27.67	16.00 - 108.00

Omaha

The Omaha monitoring program occupies an area of about 160 square miles aroun the town of Omaha in the northwestern part of Boone County. This area lies within the Interior Highlands physiographic province. The landscape exhibits moderate relief with elevations ranging from 700 feet above sea level in the northeastern portion of the area to 1,600 feet near the center of the area (Leidy and Morris, 1990). The surface geology consists of the cherty limestones of the Boone Formation occupying the central portion of the area with the Cotter Dolomite exposed to the northwest and northeast in the major stream tributaries.

This area was selected because it is in an area of increased animal production and near a wood treatment, Superfund site contaminated with wood preservatives. The objective of this monitoring program is to examine the feasibility of monitoring ground water in carbonate terrains, which are subject to the processes of karstification, and to describe and compare the ambient quality of the ground water in the Boone Formation and Cotter Dolomite. The chief sources of pollution are service stations, septic tanks, poultry and livestock farms, and the abandoned wood treatment plant. Sampling constituents included the following: total alkalinity, bicarbonate, major and trace inorganic constituents, nutrients, total organic carbon, VOCS, and semivolatiles.

Samples were taken from springs in the Boone Formation and Cotter Dolomite, and from wells that penetrated the Cotter Dolomite as these two formations are the major aquifers in the area. Water in the Boone Formation is generally unconfined in the area with springs issuing from solution-enlarged fractures. The flow rates may range from 1.5 to 1,400 gallons per minute. The wells drilled into the Cotter Dolomite may have contributions from overlying formations (i.e. Powell and Everton Formations and even Boone, where present). Domestic wells, in most cases, have only a small vertical section cased through the overburden, thereby leaving the rest of the hole open. Wells drilled into the Cotter Dolomite may yield 5 to 10 gallons per minute (Leidy and Morris, 1990).

The Boone Formation consists of fine- to coarsely-crystalline bedded limestone with abundant quantities of gray chert in the form of nodules or as massive beds. The lower portion of the Boone Formation consists of a medium- to coarsely-crystalline limestone (St. Joe Limestone). Dissolution occurs along bedding planes and fracture traces creating a network of solution channels which may enlarge to form caves or collapse structures. The thickness of the Boone Formation in the Omaha monitoring area ranges from 0 to 200 feet (Imes, 1990). The Cotter Dolomite, which may be as much as 500 feet thick, consists of a massive, medium-grained, gray rock or a fine-grained earthy, white to buff rock (Caplan, 1960). It may also contain minor amounts of shale, chert, and sandstone (Croneis, 1930).

The third sampling of this monitoring area was completed in February, 1996. In addition to the ten springs issuing from the Boone Formation (one in the Cotter Dolomite), fourteen wells were sampled including one well in the Boone Formation, twelve wells in the Cotter Dolomite, and one well from the Roubidoux - Gunter interval (public water supply).

Descriptive statistics of selected water-quality parameters for the various springs and wells sampled during the third sampling period are listed in Tables 11 and 12. Nitrate concentrations of the ten springs issuing from the Boone Formation ranged from 0.034 to 8.5 mg/L with a median of 1.85 mg/L. This compares to a range of 0.02K to 1.14 mg/L for the 12 wells that penetrated the Cotter Dolomite. The median concentration for those wells was 0.265 mg/L. The presence of pentachlorophenol (1447 μg/L) in Cricket Spring indicates that there is still an impact from wood preservatives. The spring is located within a quarter mile of a Superfund site which was formerly a wood treatment plant. The concentration reported at the time of a USGS water quality study in 1987 was 1200 μg/L (Leidy and Morris, 1990). The concentration reported during the first sampling period by the Department (1989) was 3023 μg/L. Concentrations of iron, manganese, and lead were generally low with one well and one spring exceeding the SMCL for iron and two springs exceeding the SMCL for manganese. Because both spring samples were slightly turbid, and the samples were unfiltered, the elevated concentrations may reflect dissolution of suspended material by the addition of nitric acid. Lead concentrations for the twelve Cotter Dolomite wells had a range of 2.0K to 7.9 μg/L with a median concentration of 1.0 μg/L. A thorough report on this monitoring program with complete chemical analyses will be completed in the second quarter of 1996.

El Dorado

The El Dorado monitoring program is located in and immediately surrounding the city of El Dorado. This city is approximately seventeen miles north of the Louisiana border in Union County and lies within the Gulf Coastal Plain physiographic province. The landscape is mostly sandy and gently rolling terrain with a vegetative cover of pine forests and pastures (Leidy and Taylor, 1992). The surface geology consists of clays and lignitic sands of the Cockfield Formation (Claiborne Group).

The area was originally chosen because it lies within the Bayou D'Loutre drainage basin which could potentially be affected by municipal and industrial discharges. Most of the wells sampled during the first two periods were located in the shallow Cockfield aquifer - the one most likely to be impacted by surface contamination. Another reason for the selection of this area was due to the development of a cone of depression causing a localized reversal in ground water flow in the deeper El Dorado aquifer. This situation created a problem with saltwater contamination, where the source of the saltwater is theorized by Broom and others (1984) to be from a graben located just to the south and east of the cone of depression (and the city). The first two sampling periods utilized only two deep wells in the El Dorado aquifer - both located near the cone of depression. The third sampling period included an additional four wells in the El Dorado aquifer, located to the north, east, and south of the two original wells.

Table IV-11. DESCRIPTIVE STATISTICS - SELECTED WATER QUALITY PARAMETERS - 10 SPRINGS - BOONE FORMATION - OMAHA, ARKANSAS

PARAMETER	TOTAL SPRINGS	MEAN	MEDIAN	STANDARD DEVIATION	RANGE
Alkalinity Total (mg/l)	10	153.50	174.50	60.39	61.00-250.00
Ca Total Rec. (mg/l)	10	62.83	70.45	20.82	25.60 - 89.00
Cl Total (mg/l)	10	9.98	8.45	3.35	6.60 - 16.65
Cu Total Rec. (µg/l)	10	1.37	1.00	.832	2.0K - 3.71
Fe Total Rec. (µg/l)	10	188.96	4.75	496.91	1.8K - 1670.0
Hardness Total (mg/l)	10	164.70	184.00	51.10	69.00 - 229.00
K Total Rec. (mg/l)	10	1.04	.960	.332	.545 - 1.70
Mg Total Rec. (mg/l)	10	1.91	1.60	.624	1.25 - 3.20
Mn Total Rec. (µg/l)	10	150.83	1.00	420.57	2.0K - 1410.0
Na Total Rec. (mg/l)	10	3.92	3.25	1.22	2.60 - 6.00
NH3-N Total (mg/l)	10	.045	.038	.024	.05K - .104
NO3-N Total (mg/l)	10	2.85	1.85	2.73	.034 - 8.46
SO4 Total (mg/l)	10	7.26	7.55	3.26	1.70 - 12.40
TDS (mg/l)	10	199.45	215.50	45.27	105.5 - 251.50
Zn Total Rec. (µg/l)	10	2.32	2.35	1.58	2.0K - 6.47

Table IV-12. DESCRIPTIVE STATISTICS - SELECTED WATER QUALITY PARAMETERS - 12 COTTER DOLOMITE WELLS - OMAHA, ARKANSAS

PARAMETER	TOTAL WELLS	MEAN	MEDIAN	STANDARD DEVIATION	RANGE
Alkalinity Total (mg/l)	12	225.42	232.50	48.62	138.00 - 288.00
Ca Total Rec. (mg/l)	12	60.00	54.75	20.88	36.60 - 111.00
Cl Total (mg/l)	12	3.56	3.24	1.69	1.50 - 7.55
Cu Total Rec. (μg/l)	12	14.47	8.08	16.36	2.05 - 64.90
Fe Total Rec. (μg/l)	12	169.15	22.85	435.26	.900 - 1600.0
Hardness Total (mg/l)	12	239.67	251.00	49.73	175.00 - 314.00
K Total Rec. (mg/l)	12	1.68	1.31	.897	.668 - 3.36
Mg Total Rec. (mg/l)	12	21.81	20.10	7.80	4.19 - 33.20
Mn Total Rec. (μg/l)	12	3.16	1.00	4.43	2.0K - 15.80
Na Total Rec. (mg/l)	12	4.04	1.84	3.42	.909 - 11.07
NH3-N Total (mg/l)	12	.049	.025	.048	.05K - .200
NO3-N Total (mg/l)	12	.321	.265	.300	.02K - 1.14
SO4 Total (mg/l)	12	25.84	19.45	12.38	14.10 - 56.10
TDS (mg/l)	12	252.88	265.25	53.39	179.50 - 332.00
Zn Total Rec. (μg/l)	12	639.88	500.00	629.03	13.40 - 2050.0

The eighteen sites sampled during the third period included nine Cockfield wells, three Greensand (Upper Sparta) wells, and six El Dorado (Lower Sparta) wells. Results of the third period are listed in Tables 13, 14, and 15. There was no evidence of saltwater contamination in the shallow Cockfield aquifer or in the Greensand aquifer. In addition to the common water quality constituents and metals listed in the tables, VOCS and pesticides were run on all wells screened in the Cockfield aquifer. The primary and secondary maximum contaminant levels for drinking water were not exceeded in any sampled wells.

There does appear to be a gradual increase in Na, Cl, and total dissolved solids (TDS) in the El Dorado aquifer in a southward direction. This does not support or refute the theory presented by Broom and others (1984), but does suggest that there is a regional increase in Na, Cl, and TDS downdip. There were no deep wells located in the graben or at the mouth of the graben to validate the theory. A report by Payne (1968) states that there is a regional change in the ground water chemistry of the Sparta Sand from a bicarbonate water province toward a chloride water province to the southeast of El Dorado (near Strong, Arkansas). This would add credibility to the idea that the chloride concentration as well as the TDS should naturally increase to the southeast. Future sampling will include additional wells to the south of the current sites used in this study. A more thorough review of the program area accompanied by complete chemical analyses is included in the document entitled "Report On The Third Sampling Of The El Dorado, Pine Bluff, and Lonoke Prototypes" (Van Schaik and Kresse, 1994).

Jonesboro

The Jonesboro monitoring program is located in close proximity to the city of Jonesboro in south-central Craighead County and extends into north-central Poinsett County. The project area lies within the Gulf Coastal Plain physiographic province. The city of Jonesboro lies on Crowley's Ridge, an erosional remnant of unconsolidated Eocene clay, silt, sand, and lignite capped by Pliocene sand and gravel and middle to late Pleistocene loess (Guccione et. al., 1986). Local relief can be as much as 200 feet within the metropolitan area.

This area was originally selected because of the relatively large population utilizing ground water and the lack of an extensive confining layer separating the alluvial aquifer from the underlying Memphis aquifer; thereby increasing the susceptibility of the deeper aquifer to contamination moving through the shallow aquifer. Communication between these two aquifers was suggested by Broom and Lyford (1982) as they noted that water-level decline in the Memphis aquifer was almost entirely in response to irrigation well discharge from the alluvial aquifer. The Memphis aquifer (Sparta equivalent) is the source for the four public water supply fields that supply Jonesboro with drinking water.

Table 13. DESCRIPTIVE STATISTICS - SELECTED WATER QUALITY PARAMETERS - 9 COCKFIELD WELLS - EL DORADO, ARKANSAS

PARAMETER	TOTAL WELLS	MEAN	MEDIAN	STANDARD DEVIATION	RANGE
Alkalinity Total (mg/l)	9	35.33	35.00	13.95	7.00 - 52.00
Ba Total Rec. (µg/l)	9	47.44	52.00	24.47	10K - 77.00
Ca Total Rec. (mg/l)	9	4.24	2.70	3.06	.1K - 8.70
Cl Total (mg/l)	9	19.33	8.49	25.61	2.40 - 82.30
Fe Total Rec. (µg/l)	9	801.11	50.00	2016.5	100K - 6500.0
Hardness Total (mg/l)	9	39.81	39.60	25.88	5.0K - 96.00
Mn Total Rec. (µg/l)	8	5.00	5.00	0.00	0.00
Na Total Rec. (mg/l)	9	25.93	12.00	28.09	3.40 - 98.00
NH3-N Total (mg/l)	9	.047	.025	.037	.05K - .137
NO3-N Total (mg/l)	9	.242	.148	.291	.024 - .974
Phos.-T Ortho (mg/l)	9	.070	.015	.069	.03K - .192
SO4 Total (mg/l)	9	13.41	5.90	15.57	2.60 - 54.80
TDS (mg/l)	9	142.11	110.00	82.83	36.00 - 298.00

Table 14. DESCRIPTIVE STATISTICS - SELECTED WATER QUALITY PARAMETERS - 3 GREENSAND (SPARTA) WELLS - EL DORADO, ARKANSAS

PARAMETER	TOTAL WELLS	MEAN	MEDIAN	STANDARD DEVIATION	RANGE
Alkalinity Total (mg/l)	3	156.33	149.00	11.09	148.00 - 172.00
Ba Total Rec. (µg/l)	3	77.00	77.00	24.49	47.00 - 107.00
Ca Total Rec. (mg/l)	3	4.63	5.60	2.11	1.70 - 6.60
Cl Total (mg/l)	3	2.51	2.70	.264	2.14 - 2.70
Fe Total Rec. (µg/l)	3	50.00	50.00	0.00	0.00
Hardness Total (mg/l)	3	36.30	30.90	10.06	27.60 - 50.40
Mn Total Rec. (µg/l)	3	5.00	5.00	0.00	0.00
Na Total Rec. (mg/l)	3	51.00	51.00	.816	50.00 - 52.00
NH3-N Total (mg/l)	3	.654	.660	.172	.440 - .862
NO3-N Total (mg/l)	3	.030	.027	.004	.027 - .035
Phos.-T Ortho (mg/l)	3	.095	.086	.055	.032 - .167
SO4 Total (mg/l)	3	3.27	3.70	1.46	1.30 - 4.80
TDS (mg/l)	3	176.33	170.00	8.96	170.00 - 189.00

Table 15. DESCRIPTIVE STATISTICS - SELECTED WATER QUALITY PARAMETERS - 6 EL DORADO (SPARTA) WELLS - EL DORADO, ARKANSAS

PARAMETER	TOTAL WELLS	MEAN	MEDIAN	STANDARD DEVIATION	RANGE
Alkalinity Total (mg/l)	6	198.17	195.50	7.69	189.00 - 210.00
Ba Total Rec. (μg/l)	6	6.33	5.00	2.98	10K - 13.00
Ca Total Rec. (mg/l)	6	.917	.650	.897	.1K - 2.10
Cl Total (mg/l)	6	55.88	51.65	29.62	22.50 - 104.00
Fe Total Rec. (μg/l)	6	50.00	50.00	0.00	0.00
Hardness Total (mg/l)	6	3.93	2.50	3.21	5.0K - 11.10
Mn Total Rec. (μg/l)	6	5.00	5.00	0.00	0.00
Na Total Rec. (mg/l)	6	117.67	99.50	32.69	92.00 - 184.00
NH3-N Total (mg/l)	6	.448	.464	.050	.361 - .502
NO3-N Total (mg/l)	6	.024	.026	.007	.02K - .031
Phos.-T Ortho (mg/l)	6	.202	.195	.028	.161 - .242
SO4 Total (mg/l)	6	11.18	4.80	11.90	1.30 - 34.10
TDS (mg/l)	6	325.33	309.00	65.64	254.00 - 417.00

Sampling categories included major and trace inorganics, nutrients, total organic carbon, VOCs, and selected pesticides. Eighteen wells were sampled during June, 1995, including fourteen wells in the alluvial aquifer and four wells in the Memphis aquifer (public water supply). Descriptive statistics of selected water quality parameters for the eighteen wells are listed in Tables 16 and 17. Elevated nitrate concentrations in the alluvial aquifer were observed in two wells (11.3 and 1.9 mg/L) and in one Memphis aquifer well (1.69 mg/L). The SMCL established by the EPA for iron (300 ug/L) was exceeded in eight alluvial wells. The SMCL for manganese (50 μg/L) was exceeded in nine of the alluvial wells. One alluvial well, with a TDS concentration of 703 mg/L, exceeded the SMCL (500 mg/L).

A pesticide scan for the more common pesticides used in rice and soybean production was run for all wells screened in the alluvial aquifer. Two of the fourteen alluvial wells (14.3 %) had traces of p-p'-DDE (a metabolite of DDT). The two wells had concentrations of 0.01730 and 0.00745 μg/L, respectively. All alluvial wells were analyzed for VOCS with no detections. A more thorough review of the program area accompanied by complete chemical analyses is included in the document entitled "Report On The Third Sampling Of The Jonesboro Prototype" (Van Schaik and Kresse, 1995).

Brinkley

The Brinkley monitoring program area encompasses approximately 56 square miles surrounding the town of Brinkley in northern Monroe County. This area lies within the Gulf Coastal Plain physiographic province. The country is mostly farmland used for rice, cotton, and soybean production. The surface geology consists of the clay, silt, sand and gravel of Quaternary alluvial and terrace deposits which range in thickness from 100 to 160 feet (Morris and Bush, 1986).

This area was originally selected because it represents a community in eastern Arkansas where 100 percent of the population uses ground water to meet community needs and previous studies have shown it to be the site of a large area of contaminated ground water in what was formerly fresh water aquifers. Sampling categories of chemical constituents include both major and trace inorganic constituents, nutrients, total organic carbon, VOCS, and selected pesticides. The chief source of pollution is contamination of the alluvial aquifer by saltwater intrusion. Other potential sources of pollution are pesticides and nitrates originating from agricultural practices.

An investigation by Morris and Bush (1986) mapped saltwater contamination using water quality data from 217 wells in the alluvial aquifer. The study found that approximately 56 square miles of the alluvial aquifer had been contaminated by saltwater. Saltwater contamination has been a problem since first being recognized in the 1940's. Their investigation considered three possible sources of contamination as follows: 1) accumulation of dissolved solids from a zone of stagnation within the aquifer; 2) irrigation practices which allow the accumulation of salts through evaporation; and 3) saltwater intrusion from below

Table 16. DESCRIPTIVE STATISTICS - SELECTED WATER QUALITY PARAMETERS - 14 ALLUVIAL WELLS - JONESBORO, ARKANSAS

PARAMETER	TOTAL WELLS	MEAN	MEDIAN	STANDARD DEVIATION	RANGE
B Total Rec. (µg/l)	14	4.32	2.85	4.26	3.4K - 18.10
Ba Total Rec. (µg/l)	14	110.67	83.25	79.64	30.60 - 292.50
Ca Total Rec. (mg/l)	14	66.68	59.15	42.04	13.50 - 155.00
Cl Total (mg/l)	14	17.97	14.40	12.27	5.90 - 47.00
Fe Total Rec. (µg/l)	14	2027.8	2045.0	2239.5	8.40 - 8060.0
Hardness Total (mg/l)	14	238.29	230.00	142.15	55.00 - 562.00
K Total Rec. (mg/l)	14	.770	.770	.240	.460 - 1.30
Mg Total Rec. (mg/l)	14	17.46	16.00	9.77	5.30 - 42.50
Mn Total Rec. (µg/l)	14	264.66	249.50	257.73	2.0K - 777.00
Na Total Rec. (mg/l)	14	19.68	15.00	9.65	10.40 - 45.81
NH3-N Total (mg/l)	14	.087	.058	.068	.05K - .293
NO3-N Total (mg/l)	14	.989	.010	2.90	.02K - 11.30
SO4 Total (mg/l)	14	41.89	30.50	40.13	3.90 - 152.00
TDS (mg/l)	14	328.93	348.00	164.25	123.00 - 703.00

Table 17. DESCRIPTIVE STATISTICS - SELECTED WATER QUALITY PARAMETERS - 4 MEMPHIS WELLS - JONESBORO, ARKANSAS

PARAMETER	TOTAL WELLS	MEAN	MEDIAN	STANDARD DEVIATION	RANGE
B Total Rec. (μg/l)	4	1.70	1.70	0.00	0.00
Ba Total Rec. (μg/l)	4	26.40	25.60	5.28	20.70 - 33.70
Ca Total Rec. (mg/l)	4	13.23	12.55	3.30	9.50 - 18.30
Cl Total (mg/l)	4	9.30	9.60	1.24	7.50 - 10.50
Fe Total Rec. (μg/l)	4	84.58	40.75	95.06	11.80 - 245.00
Hardness Total (mg/l)	4	55.50	52.00	14.52	40.00 - 78.00
K Total Rec. (mg/l)	4	.565	.560	.065	.500 - .640
Mg Total Rec. (mg/l)	4	5.45	5.00	1.56	4.30 - 7.90
Mn Total Rec. (μg/l)	4	4.35	4.10	2.65	2.0K -8.20
Na Total Rec. (mg/l)	4	11.75	12.10	1.87	9.10 - 13.70
NH3-N Total (mg/l)	4	.084	.074	.187	.071 - .116
NO3-N Total (mg/l)	4	.777	.539	.542	.341 - 1.69
SO4 Total (mg/l)	4	9.78	5.70	8.23	3.90 - 23.80
TDS (mg/l)	4	211.50	130.00	161.08	97.00 - 489.00

caused by pumping the upper aquifers. Chemical data collected for the report showed that the chemical composition of the alluvial aquifer was similar to that of the Sparta aquifer in contaminated areas, thereby suggesting that the most likely source of contamination was the upward movement into the alluvial aquifer from the underlying Sparta through the thinned or absent Jackson confining unit.

Likewise, the Sparta aquifer was contaminated by the deeper Nacatoch aquifer possibly by upward movement of ground water along faults which subsequently have become sealed over time. The present monitoring program represents both an effort to monitor changes in ground water quality in the alluvial aquifer over time and to determine if the areal extent of the contamination is expanding.

Table 18 lists the descriptive statistics of selected water quality parameters for the twenty-seven alluvial wells sampled during the third sampling event conducted in August, 1995. Ground water quality is quite variable due to the presence of definable saltwater contamination in much of the study area. Twenty-five wells exceeded the SMCL for iron (300 μg/L) and manganese (50 μg/L). Twenty wells exceeded the SMCL for TDS (500 mg/L). Six wells exceeded the SMCL for chloride (250 mg/L). Chloride concenrations ranged from 4.8 to 581 mg/L with a median concentration of 81.2 mg/L. A pesticide scan for the more common pesticides used in rice and soybean production was run for all wells screened in the alluvial aquifer. Trace amounts of pesticides were detected in three of the twenty-seven wells (11.1 %). The three pesticides detected were Molinate (0.04898 μg/L), Methyl-Parathion (0.01395 μg/L), and Metribuzin (0.00744 μg/L).

A comparison of chloride concentrations from selected wells over a period of twenty years indicated some increases as well as decreases. This investigation suggests that the areas that were considered the most contaminated by high salinity are still the most contaminated. Irrigation waters from the twenty-seven wells were classified in terms of salinity hazard and sodium hazard utilizing the sodium-adsorption-ratio (SAR) and specific conductivity. The sodium hazard for the wells used in the present study ranged from low to high with most of the wells falling within the low sodium hazard category (21 of 27 wells). The salinity hazard ranged from low to very high with high hazard being the most prevalent (17 of 27 wells).

Results of the most recent sampling indicate that the area of contamination is basically of the same configuration as cited in the USGS report. The number of wells utilized for this monitoring program may be slightly increased in the future. It may be useful to monitor wells considerably further from the area of contamination, such as those located in the vicinity of the city water supply wells. A more thorough review of the program area accompanied by complete chemical analyses is included in the document entitled "Report On The Third Sampling Of The Brinkley Prototype" (Van Schaik and Kresse, 1996).

Table 18. DESCRIPTIVE STATISTICS - SELECTED WATER QUALITY PARAMETERS - 27 ALLUVIAL WELLS - BRINKLEY, ARKANSAS

PARAMETER	TOTAL WELLS	MEAN	MEDIAN	STANDARD DEVIATION	RANGE
Alkalinity Total (mg/l)	27	359.37	399.00	107.52	62.00 - 469.00
B Total Rec. (μg/l)	27	197.60	70.30	306.78	3.4K - 1336.0
Ca Total Rec. (mg/l)	27	108.91	113.00	62.24	.100 - 239.00
Cl Total (mg/l)	27	149.07	81.20	163.54	4.80 - 581.00
Fe Total Rec. (μg/l)	27	3323.11	3090.00	2196.04	2.0K - 8190.0
Hardness Total (mg/l)	26	390.38	411.50	203.80	33.00 - 762.00
K Total Rec. (mg/l)	27	2.32	1.90	1.43	.02K - 6.50
Mg Total Rec. (mg/l)	27	25.29	28.70	14.93	.006K - 47.90
Mn Total Rec. (μg/l)	27	429.55	412.00	263.00	2.0K - 1030.0
Na Total Rec. (mg/l)	27	108.83	67.30	107.63	8.70 - 445.50
NH3-N Total (mg/l)	27	.710	.662	.404	.116 - 1.70
NO3-N Total (mg/l)	27	.020	.010	.049	.02K - .270
SO4 Total (mg/l)	27	40.50	15.10	47.47	2.30 - 189.00
TDS (mg/l)	27	663.48	652.00	319.89	134.00 - 1332.0

Chicot

The Chicot monitoring area is located in southwestern Chicot County just northwest of the town of Eudora in extreme southeastern Arkansas. The area, which lies within the Gulf Coastal Plain physiographic province, is characterized by relatively flat terrain and is typified by sluggish, meandering streams, and includes such features as oxbow lakes, natural levees, and irrigation ditches (Fitzpatrick, 1985). The surface geology consists of clay, silt, sand, and gravel of Quaternary Age.

This monitoring program is a continuance of a program established by the Department to monitor ground water in an area of extensive saltwater contamination that also covers parts of Ashley, Desha, Drew, and Lincoln Counties. The Soil Conservation Service (Natural Resources Conservation Service), in 1989, had originally proposed the establishment of surface water impoundments to help reduce the use of ground water and, at the same time, improve the water quality in the Quaternary alluvial aquifer, and protect the long-term productivity of prime farmland in the area. The Department was to establish baseline water quality before the surface impoundments were built and then sample the ground water at three-year intervals thereafter to determine the effects of reduced ground water pumping on water quality. This program was never established due to the lack of funding. However, the Department decided to maintain a ground-water monitoring program in the area to evaluate trends in ground water quality. A ground-water quality monitoring network was established in late 1990 with sampling to be maintained at three-year intervals on all wells. The most recent sampling was conducted in October, 1993. Three wells from this group were also sampled in November, 1992.

The chief sources of saltwater contamination are thought to be 1) accumulation of dissolved solids from past intrusion from the Arkansas River; 2) irrigation practices which allow the accumulation of salts through evaporation; 3) saltwater intrusion from below caused by pumping the upper aquifers, especially where the Jackson confining unit is thin or absent; and 4) movement through abandoned oil and gas test holes (Fitzpatrick, 1985).

Descriptive statistics of selected water quality parameters for the nine wells sampled during the second sampling event are listed in Table 19. Chloride concentrations ranged from 168 to 1100 mg/L with a median of 840 mg/L. The SMCL for iron was exceeded in the five alluvial wells that were analyzed for that element. One of those five wells also had a manganese concentration in excess of the SMCL. None of the wells had nitrate concentrations above the detection limit. This program will be expanded during the fourth quarter of 1996 to include additional wells in the Quaternary alluvium along with wells producing from the Cockfield and Sparta aquifers.

Table 19. DESCRIPTIVE STATISTICS - SELECTED WATER QUALITY PARAMETERS - 9 ALLUVIAL WELLS - CHICOT COUNTY, ARKANSAS

PARAMETER	TOTAL WELLS	MEAN	MEDIAN	STANDARD DEVIATION	RANGE
Cl Total (mg/l)	9	732.56	840.00	299.98	168.00 - 1100.0
Fe Total Rec. (µg/l)	5	4780.0	400.00	5558.2	200.00 - 12900.0
Mn Total Rec. (µg/l)	5	277.05	.200	541.56	.05K - 1360
NH3-N Total (mg/l)	9	.703	.774	.233	.227 - .976
NO3-N Total (mg/l)	9	.010	.010	0.00	0.00
Phos.-T Ortho (mg/l)	7	.108	.015	.117	.03K - .323
SO4 Total (mg/l)	9	158.56	172.00	122.98	1.0K - 315.00
TDS (mg/l)	7	1863.6	2066.0	695.65	580.00 - 2656.0

Buffalo River Watershed

The Buffalo River Watershed program area lies within the Ozark Region of the Interior Highlands physiographic province. The surface geology of the main tributaries of the Buffalo River, including the Buffalo River Valley, is composed mainly of the cherty limestones of the Boone Formation of Mississippian age, although the Everton Formation and St. Peter sandstone of Ordovician age are exposed in the eastern portion of the area. The rocks of the Boone Formation (including the lower St. Joe limestone member) make up the Springfield Plateau aquifer. The outcropping Everton and St. Peter sandstone and older formations including the Powell, Cotter, Roubidoux, and Gunter member of the Gasconade Formation which do not outcrop in the immediate area, comprise the rocks that make up the Ozark aquifer. Younger strata exposed in the Boston Mountains are composed chiefly of interbedded sandstones, limestones, and shales of the Hale, Bloyd, and Atoka Formations of Pennsylvanian age. These rocks comprise a portion of the Western Interior Plains Confining

System, but locally are water-bearing and are a source of domestic and public water supply (i.e. Deer and Lurton-Pelsor Water Associations). The program area presently includes the Little Buffalo, Big Creek, and Cave Creek sub-basins of the Buffalo River watershed.

Northwest Arkansas has the greatest percentage of broiler houses, hog farms, and dairies of any other area of the state. In conjunction with having some of the highest animal production rates in the United States, northwest Arkansas is also listed as one of the most vulnerable areas of the state to potential ground water pollution. Because of this situation, the Department is currently conducting a study to assess both surface and ground water impacts from 6 hog farms in the Buffalo River Basin. The Buffalo River was chosen because of its importance to the state and the pristine condition of the river. The Buffalo National River was established by Congress in 1972 "for the purpose of conserving and interpreting an area containing unique scenic and scientific features, and preserving as a free-flowing stream an important segment of the Buffalo River." The Department also has designated the Buffalo River as an Outstanding State Resource Water and Natural and Scenic Waterway with extraordinary recreation and aesthetic values; the highest ranking given to a stream in the state.

Both the Ozark and Springfield Plateau aquifers, which serve as sources of domestic water supply for residents in this area, are listed as Class I aquifers in the Arkansas State Groundwater Quality Protection Strategy (1985). The Park Service Water Quality Report (Mott, 1991) found that springs have consistently higher nitrate concentrations as compared to surface water, which suggests that base flow from ground water may contribute more nitrates on a continual basis than surface water runoff.

To assess ground-water quality conditions at the farm sites, a minimum of three monitoring wells were installed up and down gradient of farm waste lagoons. The monitoring wells were dominantly completed in the weathered, unconfined portion of the aquifer system; although nested wells were installed in both the upper, perched zone and the deeper, confined system (fractured shale bedrock) at one site. Ground-water samples were to be retrieved on a monthly basis for the first six months and on a quarterly basis, thereafter. The Department is currently considering conducting a domestic well-water quality survey in the Buffalo River watershed, which will provide additional information on general water quality in the area. A project report is due sometime in early 1998.

Nitrate Investigations

Cooperative Extension Service Program

The University of Arkansas Cooperative Extension Service is presently conducting a water sampling and testing program focusing on nitrates. A Status Report was issued in November, 1993, summarizing the results of the program (Teague et.al., 1993). Since this has been an on-going program, and no new report has been issued, a summary of the 1993 report is presented, and is followed by a current update at the end of this discussion.

Through October 1992, 3196 water samples had been analyzed for NO_3+NO_2. The results from this sampling program represented 2441 wells or springs from twenty-two counties. Included in this total are 1754 wells for which depths were reported.

The analyses were separated into high (NO_3 > 44 mg/L), medium (14 mg/L < NO_3 < 44 mg/L), or low (NO_3 < 14 mg/L) nitrate sources. Approximately 44 mg/L NO_3 is equivalent to 10 mg/L NO_3-N, exceeding EPA's drinking water MCL. After the results were analyzed, 1997 (81.8%) were in the low range, 341 (13.6%) in the medium range, and 113 (4.6%) in the high range. These eight counties reported higher than 4.6% in the high range: Benton, Cleburne, Columbia, Howard, Independence, Sevier, Union, and Washington (Table 20).

The 1754 wells which had depths reported through October, 1992 were mostly less than 100 feet in depth. Of the 84 high-nitrate wells, 8 (11%) are greater than 200 feet deep; 19 (23%) are between 100 and 200 feet deep; and 57 (66%) are less than 100 feet deep.

Fifty-one high range sources were selected for more extensive evaluations. Site evaluations documented the source type, well or spring, and characterized them as either a shallow dug, bored, or shallow drilled well, and whether the source was downslope of human waste or animal confinement facilities. At 19 sites, septic tanks and/or filter fields were found within 200 feet of the wellhead usually on level slopes or upslope. At 16 sites, either an operational or abondanded poultry house or pad was found less than 100 feet from the wellhead. Vulnerability to NO_3 contamination is generally influenced by soil type, depth to ground water, bedrock geology, and/or proximity to the source (i.e. human waste or animal confinement facilities).

Cooperative Extension Service - Nitrate Investigation Update

Between 1989 and 1996, approximately 3850 individual water sources (wells and springs) were tested for NO_3-N. Some of these sources were tested more than once, bringing the total number of tested samples to about 4800; approximately 2900 are wells. Based on the highest observed sample concentration for each tested source, the median concentration of NO_3-N for wells was approximately 0.2 mg/L and the corresponding median for all tested sources is the same. Overall, less than 4% of the water sources have tested higher than 10.0 mg/L, and almost 18% have tested higher than 3.0 mg/L. The corresponding percentages for wells are roughly the same as for all water sources (Teague, written communication).

Table 20. Number of Different Water Sources In the Low-, Medium-, and High-Concentration Ranges for Twenty-two Arkansas Counties Sampled, 1989-1992

(Teague and others, 1993)

County	Nitrate Levels *						County Total	
	Low		Medium		High			
	No.	%	No.	%	No.	%	No.	% of All Sources
Benton	149	60.3	82	33.2	16	6.5	247	10.1
Calhoun	13	68.4	6	31.6	0	0.0	19	0.8
Cleburne	94	75.2	16	12.8	15	12.0	125	5.1
Cleveland	19	100.0	0	0.0	0	0.0	19	0.8
Columbia	155	75.2	27	13.1	24	11.7	206	8.4
Conway	159	94.0	7	4.1	3	1.8	169	6.9
Cross	38	86.4	6	13.6	0	0.0	44	1.8
Dallas	47	82.5	10	17.5	0	0.0	57	2.3
Faulkner	133	96.4	4	2.9	1	0.7	138	5.7
Howard	87	78.4	17	15.3	7	6.3	111	4.5
Independence	181	85.0	22	10.3	10	4.7	213	8.7
Little River	19	90.5	2	9.5	0	0.0	21	0.9
Lonoke	35	100.0	0	0.0	0	0.0	35	1.4
Mississippi	85	90.4	8	8.5	1	1.0	94	3.9
Phillips	98	100.0	0	0.0	0	0.0	98	4.0
Polk	84	95.5	4	4.5	0	0.0	88	3.6
Scott	85	93.4	3	3.3	3	3.3	91	3.7
Sevier	98	73.7	25	18.8	10	7.5	133	5.4
Union	128	85.9	12	8.1	9	6.0	149	6.1
Washington	133	62.1	71	33.2	10	4.7	214	8.8
Woodruff	11	100.0	0	0.0	0	0.0	11	0.5
Yell	146	91.8	9	5.7	4	2.5	159	6.5
	1997	81.8	331	13.6	113	4.6	2441	100.0

* Low - 0-15 mg/l NO3; Medium - 15-44 mg/l NO3; High - > 44 mg/l

Pesticides

Arkansas Pesticide Monitoring

The Arkansas Water Resources Center (AWRC) sampled twenty wells in Pulaski and Lonoke Counties in what was thought to be vulnerable ground water areas during June, 1995. This sampling, which is part of a contamination prevention program funded by the State Plant Board (SPB), assists the AS&WCC in the development of their ground water vulnerability study. Pesticides were detected in one well in Pulaski County out of 20 sampled in the two-county area (5%). The four pesticides detected in the well were Aciflouren (27 μg/L), Bentazon (135 μg/L), Fluometuron (24 μg/L), and Metribuzin (4 μg/L). The well will be resampled in the near future to verify results (Smith et al, 1995). To date, 13 out of a total of 138 wells analyzed for pesticides in what is thought to be vulnerable areas, have had detections (9.4%) (Steele, written communication). Table 21 lists the wells that had pesticide detections during the period 1992-1995.

Microbial

Surface Water Treatment Rule - Ground Water Under The Influence

The only state agency presently conducting investigations with regard to ground water contaminated by microscopic organisms normally found in surface water is the Arkansas Department of Health (ADH), the primacy agency for the SDWA. The ADH was required to evaluate all community ground water sources by June 29, 1994. All non-community ground water sources must be evaluated by June 29, 1999 to determine if the sources are ground water under the direct influence of surface water (GWUDI) and therefore subject to the Surface Water Treatment Rule (SWTR).

Surface-water contamination of ground water is a public health hazard. Surface water carries disease-causing protozoa and other organisms resistant to the chlorination used to disinfect most public wells. The ADH is responsible for implementing federal and state laws and regulations, and determining if public drinking water supply wells have GWUDI of surface water.

The ADH has developed an objective method to determine if a well is GWUDI. The method first uses water-quality information to detect indicators of contamination and then identifies the possible pathways of contamination.

Three primary types of water-quality information are used: (1) microscopic particulate analysis, a test that identifies surface-water bio-indicators such as algae, diatoms, rotifers, Giardia cysts, and chlorophyll containing plant debris; (2) weekly raw-water bacteriological tests to determine if a high percentage of the samples have Coliform bacteria; and (3) weekly turbidity, temperature, pH, and other data that can infer contamination. In selected cases

Table 21. WELLS DETECTED WITH PESTICIDES BY THE AWRC FOR THE PERIOD 1992-1995 (Steele, written communication)

Well	County Location	Well Use	Collection Date	Pesticides Detected	Concentration (μg/l)
DREW -1	Drew	Drinking	4/22/93	Metolachlor †	0.7
POIN #1	Poinsett	Irrigation	12/6/93, 3/29/94	Bentazon ○	0.2, <K
MISS #4	Mississippi	Garden	11/2/93	Bentazon †	2.5
MISS #5	Mississippi	Green House	11/2/93, 3/28/94	Bentazon ○	0.3, <K
CH #4	Craighead	Mixing	11/22/93, 3/29/94	Fluometuron ○	0.5, <K
WOOD #7	Woodruff	Domestic	5/23/94, 6/29/94 7/27/94, 5/15/95	Bentazon *	55, 66, 78, 21
WOOD #9	Woodruff	Mixing	5/24/94, 6/29/94 5/15/95	Acifluorfen * Bentazon * Fluometuron *	1.7, 8.6, 6.8 25, 88, 37 0.9, 0.8, 0.4
WOOD #11	Woodruff	Garden	7/26/94, 2/20/95	Metolachlor *	13, 11.5
WOOD #25	Woodruff	Domestic	9/15/94, 2/20/95	Bentazon *	4.4, 1.9
WOOD #26	Woodruff	Domestic	9/15/94, 2/20/95	Bentazon *	1.5, 0.9
WOOD #29	Woodruff	Domestic	9/29/94, 2/20/95	Metribuzin *	0.35, 0.4
WOOD 34(PB)	Woodruff	Farm Stead	2/20/95, 5/15/95	Alachlor † Bentazon † Acifluorfen †	1.5, ⊗ 1.5, ⊗ 0.5, ⊗
PUL #14	Pulaski	Drinking	6/19/95	Acifluorfen ¶ Bentazon ¶ Fluometuron ¶ Metribuzin ¶	27 135 24 4.0

* Verified by at least one other sample collected at a later time (at least one month); † Not verified; ¶ Waiting for verification;
○ No pesticide detected in a later sampling (several months later); <K Below detection limits; ⊗ Analytical results not received.

these data can be correlated with precipitation, river stage, and other environmental data to identify the sources of contamination. All three of these information categories must be carefully evaluated, because each have different significance, reliability, and possible sampling errors.

The pathways are identified by evaluating the well's conformance to established construction standards for the surface and subsurface characteristics of the well site. Two primary types of deficiencies that provide possible pathways for surface water contamination are: (1) unsuitable below ground construction, particularly shallow casings and grout in areas without a confining layer or in aquifers with high fracture porosity or solution cavities; and (2) well sites with poor drainage, a high soil infiltration rate, highly permeable outcrops and other characteristics. These pathways can be identified or inferred by site investigations and review of well logs, published reports and other materials.

Arkansas has more than 1,700 public drinking-water supply wells. During the three years since the GWUDI program began, more than 900 wells have been determined not GWUDI using the ADH objective method. Evaluation of the remaining wells will be completed by 1999. For many of the wells evaluated the ADH has recommended simple, above-ground construction repairs or site maintenance procedures that effectively closed the pathways of surface water contamination (Jones and Godfrey, 1995).

Other Studies

Water Quality In Selected Springs, Benton County

The USGS Fayetteville Office with the support of the Department is currently monitoring four springs in Northwest Arkansas. The project is one of many studies, past and present, supported by the Department to assess baseline ground-water quality and evaluate impacts from various land-use sources in Northwest Arkansas. The enlargement of secondary fractures by dissolution of limestone within the Boone-St. Joe Formations acts to transmit large volumes of water at velocities upwards to meters per second in some locations. Springs serve as natural discharge points for water within the Boone-St. Joe aquifer. Many studies have shown that the water quality of the springs can be highly variable as a result of rapid recharge through surface karst features and the high-velocity flow systems associated with the enlarged fractures; therefore, the timing of sample collection is critical for answering questions related to resource assessment and water-quality degradation.

In order to assess the variability of the physical and water-quality parameters associated with springs, the USGS installed continuous sampling devices at four ground-water basins in Benton County; Stroud Spring, Cave Spring, Big Spring and Logan Spring. In the basins which are believed to be fault-bounded, flow and water-quality attributes can vary by more than two orders of magnitude; whereas, in the non-faulted basins, hydrogeologic variability is much less pronounced. Data have been collected for a period of over one year on a continuous basis. Continuous sampling parameters include dissolved oxygen, temperature, specific conductance, pH, and stage. Water-quality parameters, including major cations and anions, and metals and fecal coliform, have been collected as random-grab samples to assess water quality at various stages within all of the basins. Water-quality analyses to date reveal that all parameters except fecal coliform are below federal maximum contaminant levels. A continuous sampling event is planned in the near future to assess the water quality variability before, during and after a major storm event.

In addition to documenting system variability and helping formulate sampling rationale, preliminary data from continuous monitors and discrete hydrologic event sampling is providing valuable information on budget contributions from these complex springs. Basins characterized by regional faults are hydrologically less well integrated, and preferred pathways and conduit flow seem to dominate. Information from this and other studies in the area will ultimately be used to develop a conceptual model of flow within the Springfield Plateau; an area characterized by localized areas of immature to mature developed karst terrains. Such a model, together with field mapping and water quality data, assists state agencies and private industry by providing a tool for making decisions concerning land use and siting criteria, which will protect ground water for present and future beneficial uses.

USGS NAWQA Programs

The USGS began implementation of the National Water Quality Assessment (NAWQA) Program in 1991 to describe the status and trends in the quality of the Nation's ground and surface water resources. The Ozark Plateaus region was among the first 20 NAWQA study units selected for the study. The Ozark Plateaus Study Unit encompasses approximately 48,000 square miles in northern Arkansas, southeastern Kansas, southern Missouri, and northeastern Oklahoma (Pugh and Adamski, 1993).

This study unit is located in an area that has been extensively karstified. Ground water flow can be quite complex and contaminant transport can occur very rapidly. Water quality analyses will address sources of nitrate and bacteriological contamination, such as those generated by poultry and livestock operations, septic tanks, sewage lagoons, and wastewater treatment plants. Water quality degradation has occurred in mining districts where mine drainage is a problem. Other sources of contamination have been found associated with elevated radionuclides in public water supply wells, pesticides, and organic releases into fresh water aquifers.

Intensive field data were collected from 1993-1995 on the ground water, surface water, and aquatic biological communities within the study unit. Beginning in 1996, these data will be analyzed and numerous topical reports describing the water quality will be published. Low intensity phase sampling also begins in 1996 and continues through the year 2000. Samples at selected locations during this low intensity phase will aid in describing water quality trends. The Ozark Plateaus study unit will begin its second round of high intensity sampling in 2001 (Freiwald, written communication).

The USGS began assessment activities in 1994 for the Mississippi Embayment Study Unit whcih covers approximately 48,500 square miles and includes parts of Arkansas, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee. More than seventy-five percent of the land use in the study area consists of cropland with interspersed pasture, forest, and woodland. Major water quality issues that will be addressed will include potential nonpoint sources of pollution such as irrigated and nonirrigated agriculture, grazing, and recreation. Potential point sources of pollution are agriculture, aquaculture, municipal wastewater treatment facilities, and landfills. The area, underlain by the Mississippi River alluvium is a large producer of cotton, soybeans, and rice. Aquacultue (i.e. catfish farming) is also an important activity (Mallory, 1994).

In 1994-95, existing water quality data were gathered, examined, and the sampling plan for the study's high intensity phase was formulated. In 1996, the study unit will begin implementation of the three year high intensity phase with field data collection of ground water, surface-water, and aquatic biological community samples. In 1999, the study unit will enter into the low intensity phase consisting of limited selective sampling and report writing.

The Arkansas portion of the study unit will have 8 to 10 public water supply wells sampled in 1996. This will be followed by 8 to 10 irrigation wells in 1997, and 8 to 10 irrigation wells in 1998. Sampling constituents will include major inorganics, nutrients, VOCS, pesticides, radon, stable isotopes, and dissolved oxygen (Gonthier, personal communication).

Major Sources Of Contamination

It is difficult to specify what source of contamination poses the most serious threat to human health and/or the environment within the State of Arkansas. What is considered a source of concern in a very localized part of the State is not a concern elsewhere. As can be seen from Table 22 showing SDWA MCL violations for public water supply systems in the State (ADH - Arkansas Drinking Water Update), most violations are related to bacteriological, inorganic, and radionuclide problems. Bacteriological problems may be related to temporary interruptions of disinfection or mechanical problems such as water line breaks, thus are not related to ground water quality. Inorganic violations are usually related to high fluoride concentrations which is a localized problem. Problems associated with elevated levels of radionuclides detected in several public water supply systems (chiefly in northern Arkansas) may also be localized, but this concern has yet to be fully addressed by scientific investigations. Naturally occurring radioactivity (radium-226 and -228) in ground water in excess of the MCL has been detected in the Ozark aquifer where it is confined, notably in Newton and Searcy Counties (Adamski and others, 1995).

Table 23 list major sources of ground water contamination and contaminants. The sheer quantity of nitrate investigations show that it is a statewide problem mostly related to poultry, swine, and livestock operations, as well as septic systems, sewage lagoons, and wastewater treatment plants, etc. The extent of pesticide contamination is still not well documented as some studies have randomly selected sampling sites without considering the physical and

Table 22. SDWA MCL VIOLATIONS FOR GROUND WATER SYSTEMS (10/94 - 9/95)

(ARKANSAS DRINKING WATER UPDATE - ARKANSAS DEPARTMENT OF HEALTH)

	Bacti MCL	Turbid-ity MCL	Organic MCL	Inorg. MCL	Radchem MCL	THM MCL
10/94	2	0	0	1-(F)	6-(Ra)	0
11/94	1	0	0	1-(F)	6-(Ra)	0
12/94	3	0	0	1-(F)	6-(Ra)	0
1/95	0	0	0	1-(F)	6-(Ra)	0
2/95	0	0	0	1-(F)	6-(Ra)	0
3/95	1	0	0	1-(F)	6-(Ra)	0
4/95	3	0	0	0-(F)	0-(Ra)	0
5/95	4	0	0	1-(F)	0-(Ra)	0
6/95	3	0	0	0-(F)	6-(Ra)	0
7/95	3	0	0	1-(F)	3-(Ra)	0
8/95	2	0	0	1-(F)	3-(Ra)	0
9/95	3	0	0	1-(F)	3-(Ra)	0
TOTAL	25	0	0	10	51	0

Radchem = Radiochemical; THM = Trihalomethane
(F) = Flouride MCL; (Ra) = Radiochemical MCL

chemical nature of the soil and confining layers which could serve as a barrier to contamination from the surface. The physical and chemical nature of the pesticide also has to be taken into account in order to fully evaluate the ability of the chemical to be transported into the fresh water aquifer. A joint agency program directed at pesticide contamination in areas that are thought to be particularly vulnerable has found pesticides in 9.4 percent of the wells over a three year period (1992-1995). An earlier investigation conducted over a two year period found that 33 percent of the wells sampled in an area of heavy pesticide use were contaminated with one or more pesticides (Hays and Morris, 1992). Saltwater intrusion is a localized but very serious problem related to heavy drawdown, irrigation practices, or the area hydrogeology. Brine contamination is also a localized problem related to improperly lined surface impoundments, corroded casing of injection wells, or from earlier improper disposal to the land surface or streams. The Surface Water Treatment Rule (SWTR) has focused attention on microbial contamination in our public water systems. Recent documented waterborne disease outbreaks have been a cause of national concern. Most contamination problems related to organic chemicals (i.e. petrochemicals) may be very serious, but are generally localized in extent. The intent of the on-going ambient water quality monitoring program (ADPC&E) is to document changes in the quality of ground water over time, to determine if known areas of contamination are expanding (i.e. areas of saltwater intrusion), and to assist in water quality planning.

The USEPA 1996 305(b) guidelines encourage each state to list the 10 highest priority sources of ground water contamination. The factors considered when selecting the 10 highest priority sources of ground water contamination in Table 23 are listed in order of importance next to each source. However, the contaminant sources are not ranked. The following factors are listed below:

(A) Human health and/or environmental risk (toxicity)
(B) Size of the population at risk
(C) Location of the sources relative to drinking water sources
(D) Number and/or size of contaminant sources
(E) Hydrogeologic sensitivity
(F) State findings, other findings
(G) Other criteria

The following is a list of contaminants considered to be associated with each of the sources that was checked:

(A) Inorganic pesticides
(B) Organic pesticides
(C) Halogenated solvents
(D) Petroleum compounds
(E) Nitrate
(F) Flouride *
(G) Salinity/brine
(H) Metals
(I) Radionuclides *
(J) Bacteria
(K) Protozoa
(L) Viruses
(M) Other (please add or describe in the narrative)

* Elevated levels of flouride and radionuclides identified in MCL violations are considered to be naturally occurring contaminants and are not associated with any of the sources identified in Table 23.

Table 23. MAJOR SOURCES OF GROUND WATER CONTAMINATION

Contaminant Source	Ten Highest Priority Sources (✓)	Factors Considered	Contaminants
Agricultural Activities			
Agricultural Chemical Facil.			
Animal Feedlots	✓	D,E,A	E
Drainage Wells			
Fertilizer Applications	✓	D,E,A	E
Irrigation Practices			
Pesticide Applications	✓	D,E,A	A,B
Storage & Treatment Activities			
Land Application			
Material Stockpiles			
Storage Tanks Above Ground			
Storage Tanks Underground	✓	D,E,A,B	C,D
Surface Impoundments	✓	D,E,A	G,H,E
Waste Piles			
Waste Tailings			
Disposal Activities			
Deep Injection Wells			
Landfills	✓	D,E,A,C	C,D,J,L,H
Septic Systems	✓	D,E,A,B,C	E,J,K,L
Shallow Injection Wells			
Other			
Hazardous Waste Generators			
Hazardous Waste Sites	✓	A,E,B,C	C,D,H
Industrial Facilities			
Material Transfer Operations			
Mining and Mine Drainage			
Pipelines and Sewer Lines			
Salt Storage and Road Salting			
Salt Water Intrusion	✓	E,C,A	G
Spills	✓	A,E,C	C,D
Transportation of Materials			
Urban Runoff			

Table 24 lists the present status of the State Ground Water Protection Programs. As can be seen, most of the programs are fully established or are in the process of implementation. One progressive step that the Water Division (ADPC&E) has taken toward early detection at facilities with potential sources of ground-water contamination is to include ground-water monitoring requirements for certain facilities within NPDES and State Programs (no discharge) permits. This procedure assists in assessing the impact from sludge application, manure spreading, earthen lagoons, and other sources of potential ground-water contamination. Currently, the State Programs Branch has begun the permitting of commercial soil treatment facilities for treatment of petroleum contaminated soils. Ground Water Protection Program personnel are active in reviewing these permits in order to insure that ground water will be protected beneath these facilities.

In addition to these steps, a Quality Management (QM) Team was also developed on a Department-wide basis to assess ground-water protection within each Division and the Department as a whole. The results of the QM process was the formulation of a method for coordinating ground water activities within the Department, development of a protocol for case management of potential ground water contamination events, and development of a draft set of ground water regulations for the State. The regulations are currently being developed by the QM Team and will be forwarded to the Administration for review upon completion.

Table IV-24. SUMMARY OF STATE GROUND WATER PROTECTION PROGRAMS

Programs or Activities	Check (✓)	Implementation Status	Responsible State Agency
Act. SARA Title III Program	✓	Fully Established	ADPC&E
Ambient GW Monitoring	✓	Fully Established	ADPC&E
Aquifer Vulnerability Assess.	✓	Continuing Efforts	AS&WCC
Aquifer Mapping	✓	Continuing Efforts	Multi-Agency
Aquifer Characterization	✓	Continuing Efforts	Multi-Agency
Comp. Data Mgmt. System	✓	Under Development	AS&WCC
EPA Endorsed CSGWPP	✓	Pending	AS&WCC
Ground Water Discharge Pmt.	NA	NA	ADPC&E
Ground Water - BMP's	✓	Continuing Efforts	Multi-Agency
Ground Water Legislation			
Ground Water Classification	✓	Continuing Efforts	ADPC&E, AS&WCC
Ground Water Quality Stds.	✓	Under Development	ADPC&E
Interagency Coord. - GW	✓	Continuing Efforts	AS&WCC
Nonpoint Source Controls	✓	Continuing Efforts	AS&WCC, ADPC&E
Pesticide State Mgmt. Plan	✓	Fully Established	SPB
Pollution Prevention Program	✓	Continuing Efforts	ADPC&E, AS&WCC, ADH, SPB, CES, NRCS
RCRA Primacy	✓	Fully Established	ADPC&E
State Superfund	✓	Fully Established	ADPC&E
State RCRA Program - More Strict Than RCRA Primacy	NA	NA	ADPC&E
State Septic Tank Regulations	✓	Fully Established	ADH
UST Installation Requirements	✓	Fully Established	ADPC&E
UST Remediation Fund	✓	Fully Established	ADPC&E
UST Permit Program	✓	Fully Established	ADPC&E
UIC Program	✓	Fully Established	ADPC&E
Vulnerability Assessment For Drinking Water/Wellhead Protection	✓	Continuing Efforts	ADH
Well Abandonment Regs.	✓	Fully Established	AWWCC
EPA-Approved WHPP	✓	Fully Established	ADH
Well Installation Regulations	✓	Fully Established	ADH

ADPC&E: Arkansas Department of Pollution Control and Ecology; AS&WCC: Arkansas Soil and Water Conservation Commission; ADH: Arkansas Department of Health; SPB: Arkansas State Plant Board; NRCS: Natural Resources Conservation Service; CES: University of Arkansas Cooperative Extension Service; AWWCC: Arkansas Water Well Construction Commission - (Under authority of AS&WCC).

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