GROUNDWATER

Volume 1 Elements of an Arkansas State Groundwater Quality Protection Strategy

State of Arkansas
Department of Pollution Control and Ecology

STATE OF ARKANSAS

DEPARTMENT OF POLLUTION CONTROL AND ECOLOGY

FISCAL YEAR 1981 - TASK A - NONPOINT SOURCE

GROUNDWATER

Elements Of An Arkansas State Groundwater Quality Protection Strategy

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*Activities 4, 6, 9, 10, 11 are ADPC&E supporting documents and are not subject to specific public hearing comments. All contracted supporting documents are available under separate cover at the ADPC&E office in Little Rock, Arkansas, for public review.

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Elements of an Arkansas State Groundwater Quality Protection Strategy

I. INTRODUCTION

Groundwater contamination within Arkansas was not addressed in the initial 208 State Water Quality Management Plan. Since the initial plan was written and submitted, a growing awareness of the importance of protecting and managing our state's groundwater resources has surfaced.

In response to that awareness, the Department of Pollution Control and Ecology included a plan for the development of a groundwater quality management strategy in its 208 Continuing Planning Process for Nonpoint Sources in November of 1980 and the plan was funded in fiscal year 1981. The various parts of the plan were assembled between 1981 and August of 1985 when the final draft of the strategy was written.

During that period, attention to groundwater has increased as its use as a source of drinking water and irrigation grew both in Arkansas and in the nation as a whole. Questions of quality and availability were raised and publicly debated. Nationally, the depletion of the Ogallala aquifer in the high plains states caused growing concern and produced an immediate threat to Arkansas as Texas looked longingly at the seeming abundance of water across the border. Quality issues were raised by the publicity given to Superfund sites that contaminated groundwater both here and elsewhere.

Such concerns caused EPA to issue its own groundwater related projects that became available to the states under Section 106 of the Clean Water Act in fiscal year 1985.

The Arkansas strategy is to some extent the product of these forces. It incorporates aspects of the EPA protection strategy and has blended elements of other groundwater related programs such as Superfund into its framework. It also utilized the help and data of other agencies with an interest in groundwater (these agencies were represented on the Groundwater Quality Protection Strategy Technical Steering Committee whose members are listed on the adjoining page).

Hence, the final product is the result of a number of different agencies, both state and federal, consultants, and contractors. The staff of the Water Division coordinated the work of all of these people and ultimately put together the final product.

The strategy is designed to be open-ended, subject to change as situations warrant adaptations. Such flexibility is especially important with groundwater since our understanding and concerns are changing rapidly. The strategy then is not meant to be the final word but the beginning of a protective approach.

Strategy Objective and Activities

As stated in the Arkansas Department of Pollution Control and Ecology's (ADPC&E) Water Quality Management Workplan, the objective of our groundwater strategy is:

> To formulate and recommend a management strategy to protect the quality of Arkansas' groundwater resources. Under this objective the following activities were involved.

ACTIVITIES

1. Establish a committee comprised of representatives of state and federal agencies having responsibility for, or interests in, groundwater.
2. Compile a summary of available groundwater data and information for the state.
3. Summarize groundwater quality criteria/guidelines by use.
4. Summarize known and projected groundwater pollution problems.
5. Classify, by quality, Arkansas' groundwater resources.
6. Recommend a comprehensive interagency data acquisition and management system.
7. Summarize the existing groundwater monitoring network and recommend improvements.
8. Analyze existing legislation; make recommendations regarding needed legislation.
9. Compile and develop criteria for the determination of the relative groundwater pollution potential of selected sources of contamination.
10. Delineate and rank areas of the state according to the degree of safeguards required for groundwater protection.
11. Provide cooperative groundwater training with state and federal agencies.
12. Recommend optional management strategies to control groundwater pollution.

PRODUCT

A feasibility report addressing Activities 2, 3, 5, 7, 8 and 12 presenting the steps necessary to protect Arkansas' groundwater quality. Activities 4, 6, 9, 10 and 11 will be within reports produced under separate cover.

Groundwater and Aquifers: Definitions

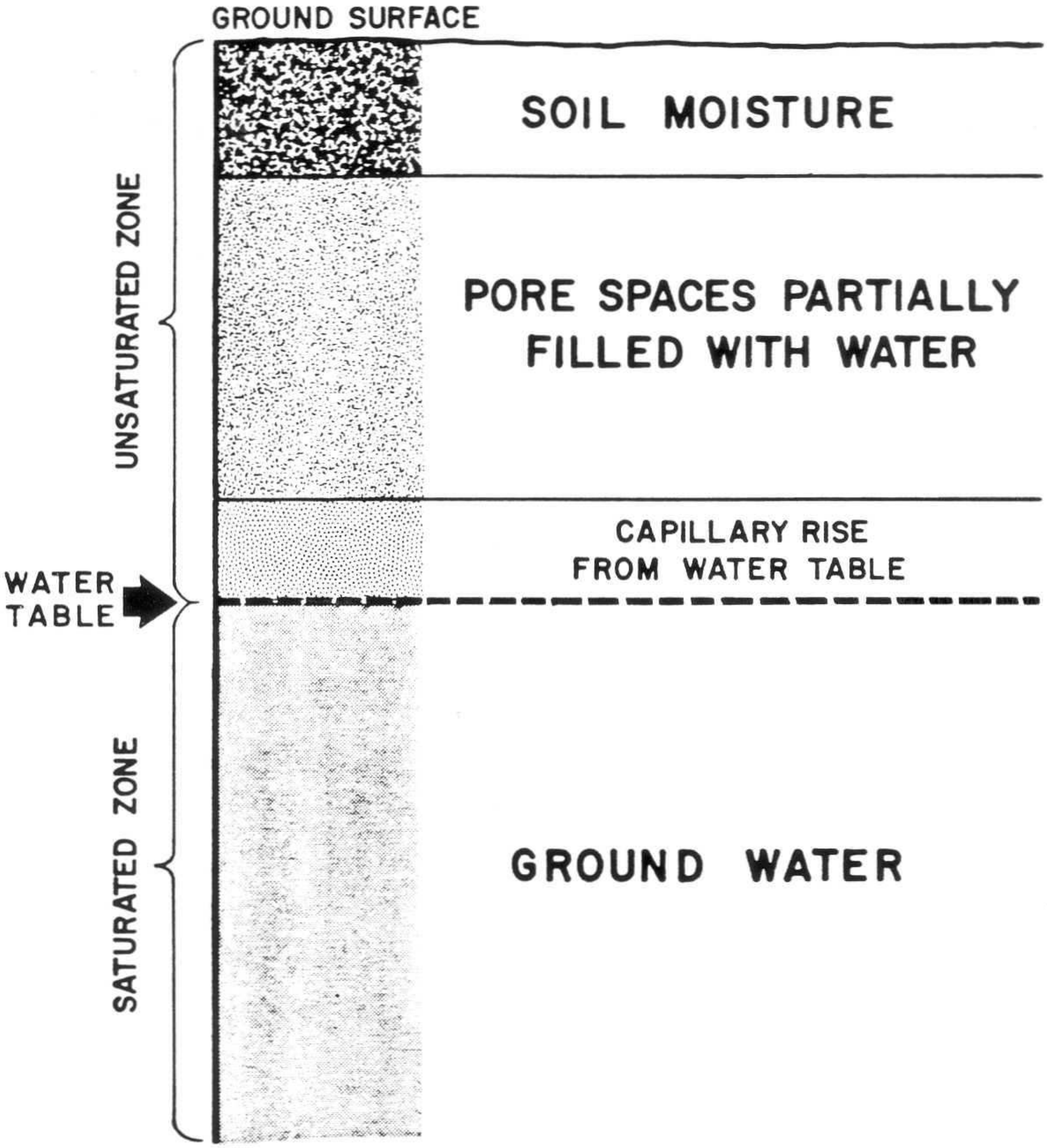
The term groundwater is usually reserved for the subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated.

All water beneath the surface is referred to as subsurface water. The equivalent term for water on the land surface is surface water. Subsurface water occurs in two different zones. One zone, which occurs immediately below the land surface in most areas, contains both water and air and is referred to as the unsaturated zone. The unsaturated zone is almost invariably underlain by a zone in which all interconnected openings are full of water. This zone is referred to as the saturated zone.

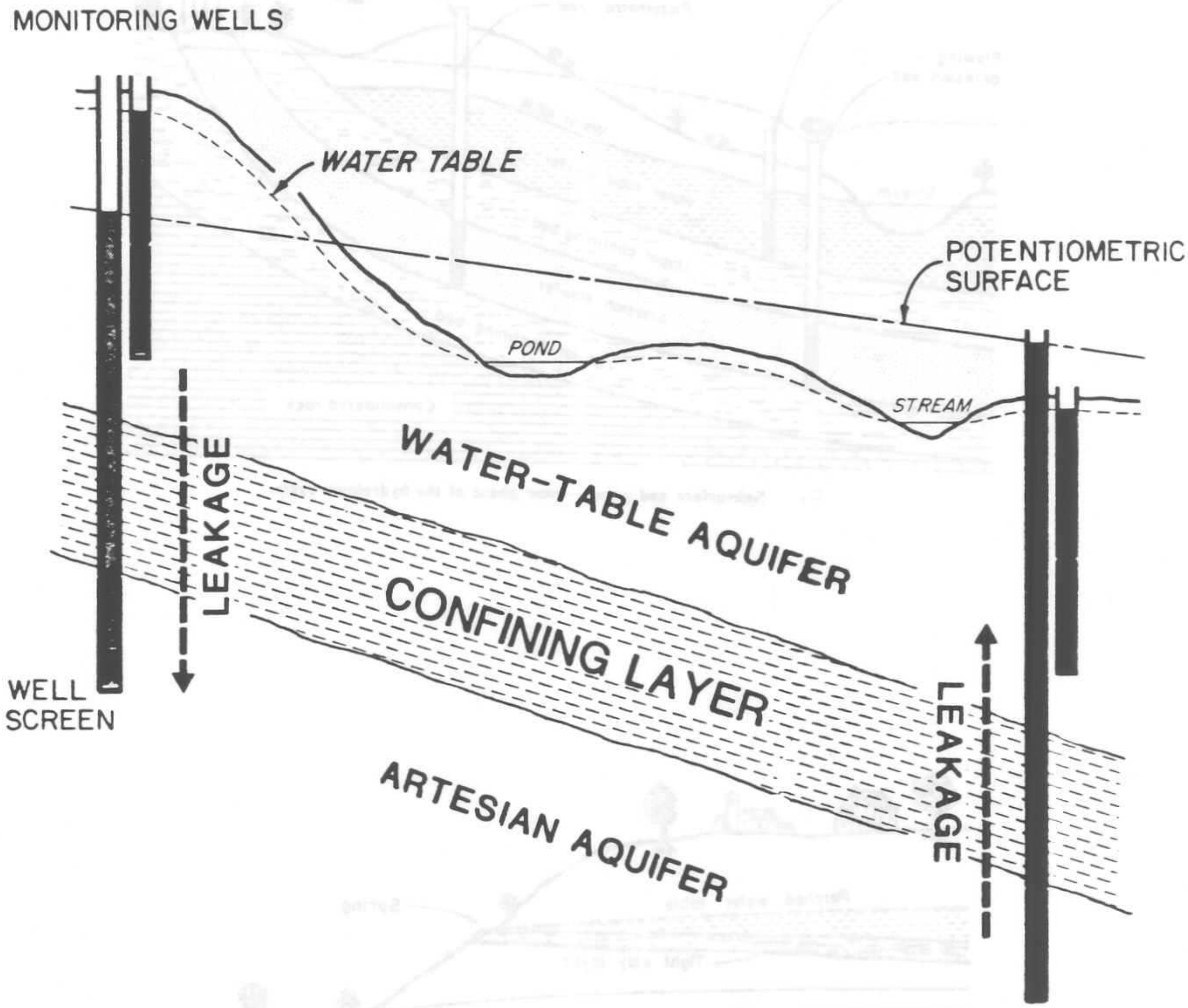
Water in the saturated zone is the only subsurface water that is available to supply wells and springs and is the only water to which the name groundwater is correctly applied. Recharge of the saturated zone occurs by percolation of water from the land surface through the unsaturated zone. The unsaturated zone may be derived usefully into three parts (or subzones); (1) the soil zone, (2) the intermediate zone, and (3) the capillary fringe (see diagram a).

The upper part - which differs in thickness from only inches thick to a depth of several feet - is referred to as the soil zone. The soil zone is the zone that supports plant growth. It is crisscrossed by living roots, by holes left by decayed roots of earlier vegetation, and by animal and worm burrows. This zone tends to have a higher porosity and permeability than the underlying material. The soil zone is underlain by the intermediate zone, its size is dependent upon the thickness of the soil zone and the depth of the capillary fringe.

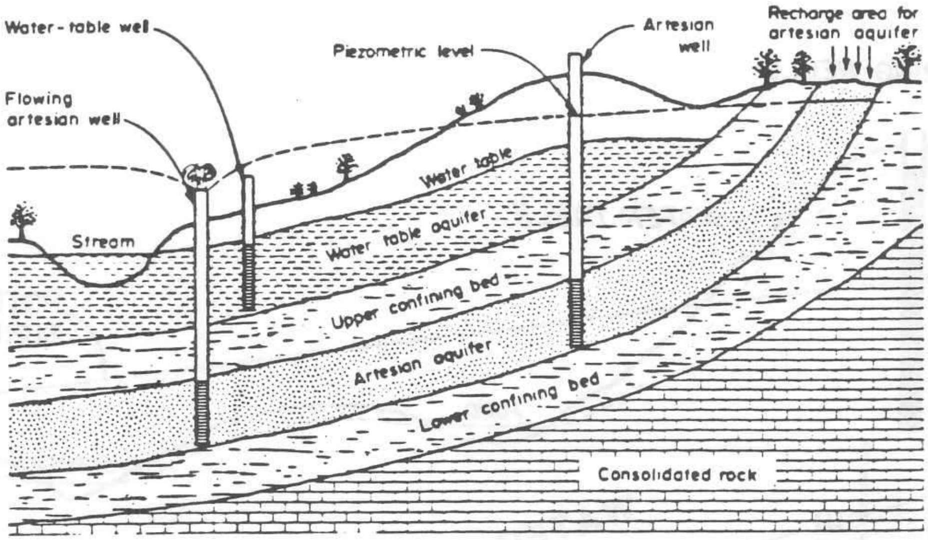
Moving to the lowest part of the unsaturated zone, the boundary between it and the saturated zone is occupied by the capillary fringe. The capillary fringe results from the attraction between water and rocks. As a result of this attraction, water clings as a film on the surface of rock particles and rises up small-diameter pores against the pull of gravity. Water in the capillary fringe and in the overlying part of the unsaturated zone is under a negative hydraulic pressure - that is, it is under a pressure less than atmospheric. The water table is the level in the saturated zone at which the hydraulic pressure is equal to atmospheric pressure (see diagram b).



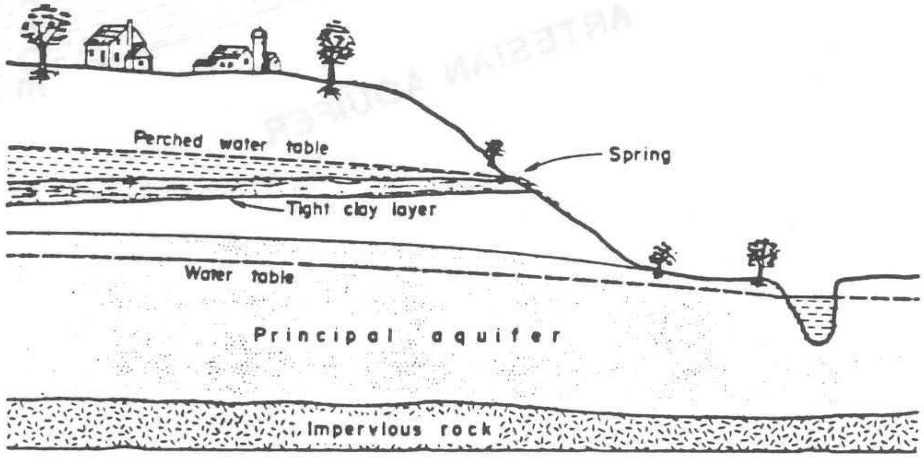
a. Relationship between unsaturated and saturated zones (after Edward E. Johnson, Inc., 1966).



b. **Relationships within the hydrologic system.**



c. **Subsurface and ground-water phase of the hydrologic cycle.**



d. **Perched water table occurs above impervious stratum and above the main water table.**

The "uppermost" aquifer encountered below the surface is usually referred to as an "unconfined" or alluvial aquifer if it is associated with a stream or river sometimes referred to as the "principal aquifer" (see diagram d). Aquifers have been defined in different ways but the applicable definition for the purpose of this study is from the Federal Register, 40 CFR 146-146.03:

> "Aquifer" - geological formation, group of formations, or part of a formation that is capable of yielding a significant amount of water to a well or spring (same as 40 CFR Part 122.3 definitions).

Each Federal program has adapted this basic definition to suit its purposes, as for example the following definitions from the Safe Drinking Water Act.

> "Underground Sources of Drinking Water" (USDW) - an aquifer or its portion (1)(i) which supplies any public water supply system or (ii) which contains a sufficient quantity of groundwater to supply a public water system; and (A) currently supplies drinking water for human consumption; or (B) contains fewer than 10,000 mg/l total dissolved solids; and (2) which is not an exempted aquifer.

> "Public Water System" - means a system for the provision to the public of piped water for human consumption, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals.

> "Confined (or artesian) aquifer" - Groundwater which is under pressure significantly greater than atmospheric, and its upper limit is the bottom of a bed of distinctly lower hydraulic conductivity than that of the material in which the confined water occurs (see diagram c).

A more complete list of definitions is included in the appendix at the end.

Arkansas Physiography

On the basis of the land surface and differences in the underlying rocks, Arkansas is divided into two areas of nearly equal size. The northwestern half is part of a physiographic division known as the Interior Highlands, and the southeastern half is part of the Gulf Coastal Plain. (Includes the Mississippi Embayment.) These areas are shown in Figure 1.

The land surface in the Interior Highlands is hilly to mountainous. The Interior Highlands is divided into the

Ozark Mountains, Arkansas River Valley and the Ouachita Mountains. The altitude ranges from about 250 to 2,800 feet above sea level, averaging about 1,400 feet. The valley of the Arkansas River crosses the Highlands in a general southeasterly direction.

The bedrock in the Interior Highlands consists of interbedded shale, sandstone, and limestone. The rocks are relatively old geologically, and they have been compacted and cemented. North of the Arkansas River in the Ozark Mountains the formations generally are nearly flat lying and show little faulting or folding. South of the river in the Ouachita Mountains they have been extensively folded, faulted, and jointed.

The differences in topography between the Interior Highlands and the Gulf Coastal Plain are caused in a large part by differences of earth materials underlying the areas. The geologic formations also control, to a large extent, the occurrence and availability of groundwater in the two regions. Figure 1, also shows the approximate productive areas of the most important water-bearing deposits in Arkansas.

Nearly everywhere in the Interior Highlands region, wells will yield a few gallons of water per minute, and good water is available for domestic use. However, in most of the region wells will not yield as much as 50 gallons per minute except in northwestern Arkansas there are several formations which, at places where conditions are favorable, may yield between 50 to 500 gallons per minute to wells. At present only very general statements can be made about these formations, either because at present they are tapped by only a few wells or because information about wells is not available. The formations are in ascending order (oldest to youngest) the Gasconade Dolomite, the Roubidoux Formation, the Cotter Dolomite, the St. Peter Sandstone, the Boone formation, the Batesville Sandstone, and the Hale Formation.

The Gasconade and Roubidoux Formations are tapped by several wells in northwestern Arkansas. The maximum reported yield of any well is 450 gpm. These wells range in depth from 1,000 to more than 2,000 feet. These formations do not crop out in Arkansas, but they underlie a large area in north-central and northwestern Arkansas. They are relatively undeveloped but may be the most important potential source of groundwater in the area where they occur.

The Cotter Dolomite and Boone Formation are the surface rock over a large area in north-central and northwestern Arkansas, respectively. They are the source of water for numerous springs. There is a wide range in the yields of wells

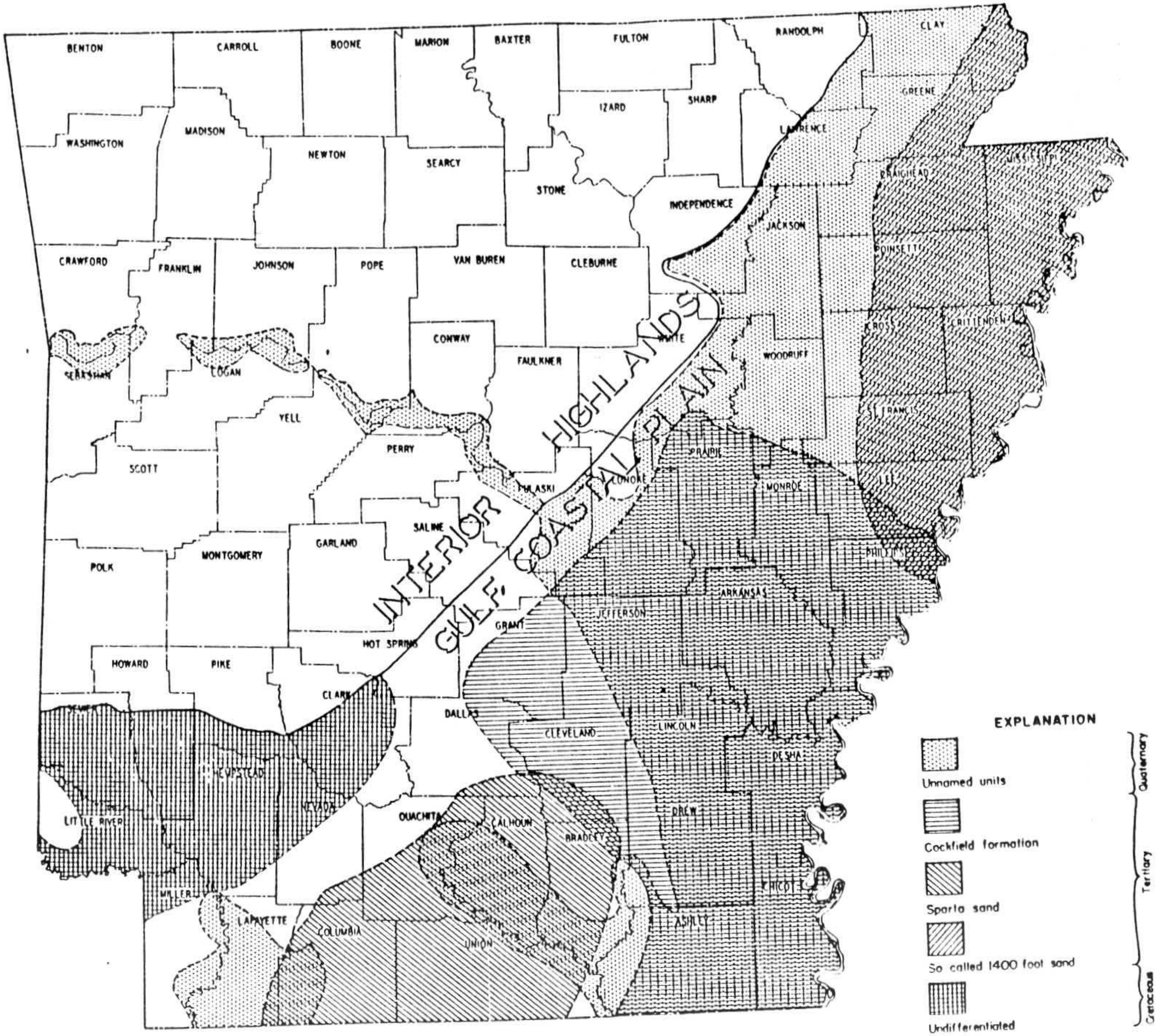


Figure 1. Approximate productive areas of the most important water-bearing deposits in Arkansas.

tapping these formations, depending on the local thickness of the formation, the height of the locality above streams, and particularly the number and effective size of fractures and solution channels penetrated by the well. A mantle of chert debris formed by the weathering of these formation is important in much of the area; because it tends to check and hold the runoff from precipitation, and wells obtain water directly from the mantle or from the fractures and solution channels which it feeds.

The St. Peter Sandstone, the Batesville Sandstone, and the Hale Formation crop out in irregular, relatively narrow, east-trending bands. They yield water to wells at places where they have been fractured and where they have not been cemented or where the calcareous cement has been leached out, leaving a porous sandstone.

The deposits of alluvium in the valley of the Arkansas River are a potentially important source of groundwater. At present this source has not been extensively used. Existing records show that at some place wells can be developed with yields of 500 gallons per minute or more. Elsewhere in the alluivum, the maximum yields are considerably less. The quality of the water from the alluvium is generally suitable for most uses. However, there may be a considerable difference in the quality of the water from place to place.

Nearly all the Gulf Coastal Plain region is underlain by one or more deposits that will yield fairly large amounts of good-quality water to wells.

Formations of the Cretaceous Age are outcropped in south Arkansas in a general east-trending band. They dip in a general southerly direction. Some of these formations will yield good water in sufficient quantity for domestic and small industrial or municipal supplies. The yields of all of the known wells are less than 500 gallons per minute. The water is of acceptable quality in and near the outcrop areas of the water-bearing formations, but a few miles down dip to the south it is mineralized and is unsuitable for most uses.

In northeastern Arkansas there is an important water-bearing deposit of Tertiary Age, which is known locally at Memphis, Tennessee, as the "1,400-foot" sand. The sand occurs at a depth of about 1,000 feet in northeastern Arkansas and reaches a depth of 1,900 feet in the east-central part of the State. Water from the sand is of good quality, and it is used extensively for municipal supplies in northeastern Arkansas. The 1,400-foot sand extends into western Tennessee, and it is tapped by numerous wells in the vicinity of Memphis.

The water is under artesian pressure and originally it flowed from the wells. As the number of wells tapping the sand was increased and there was an increase in the amount of water used, the artesian pressure declined so that it is now necessary to use pumps to get water from most of the wells.

The Sparta Sand underlies a large area in southern Arkansas. It is the most important source of groundwater in south-central Arkansas, where it is used extensively for industrial and municipal supplies and in the oil fields. Important centers of pumping are in the vicinity of El Dorado and Magnolia. The Sparta Sand is present, at a greater depth, in southeastern Arkansas, but the water tends to be mineralized and is not suitable for most uses.

The Sparta Sand extends into northern Louisiana and western Mississippi. A large amount of water is taken from it in these states, particularly in northern Louisiana.

The Cockfield Formation underlies a large area in east-central and southeastern Arkansas. The formation is an important source of water or industrial use in the vicinity of Pine Bluff and for municipal supplies in most of the area in which it occurs. Water from the Cockfield Formation is pumped for irrigation from about 20 or 30 wells in east-central Arkansas, chiefly in the Grand Prairie region.

Deposits of Quarternary age occur in a large part of the Gulf Coastal Plain in eastern Arkansas and in the valleys of the Saline, Ouachita, Red, and Arkansas Rivers. They are relatively young and are everywhere exposed at the surface. They are generally less than 200 feet thick. The upper part consists of silt and clay and is relatively impermeable, and the lower part consists of sand and gravel and generally yields water to wells.

These deposits are by far the most important sources of groundwater in Arkansas with respect to both presently developed supplies and undeveloped reserves. The largest use of water from these deposits is for the irrigation of rice and other crops.

Bibliography and Summary
of Available Groundwater Data
and Information

Activity #2

The best source of a quick review of the quantity and quality of groundwater in the state is in the ADPC&E publication, Nonpoint Source Pollution Assessment Summaries, 1979, for each of the five major river basins in the state. This can be supplemented with the groundwater section of ADPC&E's, Arkansas Water Inventory Report, 1982, which also summarizes recent reports issued by the Soil and Water Commission, the Unites Geological Commission and the ADPC&E. The State Water Plan of 1975, produced by the Arkansas Soil and Water Commission contains much information on municipal water supplies. It is currently being updated and the new plan will have an expanded and improved groundwater section.

For groundwater quality, the best source is the Chemical Data, 1982, released by the Arkansas Health Department about every ten years. It includes chemical analysis of samples submitted by public water supplies every three years. Similar chemical analyses are done by the University of Arkansas Cooperative Extension Service for farmers who turn in irrigation well samples to their county agents. A computer printout of these analyses is available from the UA Extension Office. Further chemical data from the sampling stations of the USGS is presented in their, Water Resources Data, 1981. These analyses are also placed in the federal computer system, STORET, and printouts are available from ADPC&E. Water quantity data is published by the USGS on a yearly basis. Well levels from their statewide monitoring network are given along with figures on consumption for each county and each significant aquifer.

There are relatively old but valuable groundwater use and quality data scattered throughout the numerous reports published by the USGS and Geological Commission. The Arkansas Water Resources Research Center also publishes studies dealing with all aspects of groundwater - most of which deal with the Ozark region. Lists of the reports of all three of the above agencies are available.

A summary of some of the major potential threats to groundwater is the Surface Impoundments Assessment published by the Arkansas Soil and Water Commission in 1979 under contract from the ADPC&E. Metroplan, a council of local governments, mainly Pulaski and Saline Counties, made use of this report to study local groundwater conditions in their area and issued a more site-specific examination which involved water quality samples from 12 local wells.

The Underground Injection Control program of ADPC&E has sponsored several studies relating to groundwater, including a summary of the major aquifers underlying eastern and southern Arkansas and the quality of the groundwater in each. A series of maps of these aquifers including areas of high and low concentrations of total dissolved solids, potentiometric surfaces and outcrop areas were produced. A complete list of these studies and their major conclusions is published in ADPC&E, Underground Injection Control, Primacy Application class I, III, IV and V.

Several regional reports of the USGS and Environmental Protection Agency include Arkansas (c.f. Summary Appraisals of the Nation's Groundwater Resources - Arkansas - White - Red Region, USGS #813-H, 1976, EPA, Groundwater Pollution in the South Central States, 1973).

Also, the regional Southwest and Texas, Water Works Journal frequently has articles related to Arkansas (see Arkansas Special Issue, April, 1983).

Most of the items mentioned above are available to the public. These and many more are included in the Groundwater Library of the National Water Well Association which will under take bibliographic research for a fee.

The most recent bibliography available has been published by Geraghty and Miller - Fritz van den Leeden, Groundwater Bibliography, Syosset, N.Y., 1983.

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GROUNDWATER QUALITY AND USE BY RIVER BASIN

INTRODUCTION

Arkansas is endowed with an abundance of fresh underground water. This water, commonly referred to as groundwater, is stored in and yielded by waterbearing formations called aquifers in every part of the state. These aquifers occur from near the land surface to depths of several thousand feet below the land surface. The combined rate of water yield to wells from all fresh water aquifers in Arkansas in 1981 was 4,300 billion gallons per day. Of this yield, about 93% was for agricultural use, 2% for industrial use 2% for municipal use, 2% for rural domestic use and 1% for thermoelectric energy. These aquifers, in their areas of outcrop also discharge water to major streams of the state at one time of the year or another. Awareness of the importance of groundwater to the state has grown along with its increased use. From 1975 to 1981 groundwater use increased from 2.6 to 4.3 billion gallons per day, a 60 percent increase (Hall and Holland, Water Use in Arkansas, USGS Report #84-4070).

Groundwater problems in Arkansas are localized and include contamination, poor natural quality, overdraft, and low yields. Contaminations of shallow domestic wells by human and animal wastes is the most prominent problem as evidenced by high nitrate concentrations. Some surficial aquifers appear to have been contaminated by industrial wastes which include both heavy metals and organic chemicals. Contamination of fresh groundwater by saline water has occurred in several places due to large-scale pumping. The most prominent include the Sparta Sand Aquifer in Independence, White, Monroe, Lincoln, Desha and Chicot Counties, and in areas adjacent to the Arkansas River. Continued, large-scale pumping has the potential to increase these areas of contamination. In some areas the occurrence of saline water appears to be of natural origin and not the result of human activity. Some saltwater contamination in south Arkansas is due to oil and gas exploration, production and disposal practices.

Groundwater levels are declining in large areas of the State where pumping rates exceed recharge rates. Groundwater levels in the Sparta Sand aquifer have declined as much as 320 feet in the vicinity of El Dorado, as much as 225 feet in the vicinity of Magnolia, and as much as 60 feet in the vicinity of Stuttgart. Water levels in the alluvial aquifer have declined in western Craighead, Cross, Poinsett Counties and in eastern Jackson and Woodruff Counties. The greatest decline in the alluival aquifer has been in Poinsett County where water levels at one point are almost 120 feet below land surface - a decline of some 70 feet since the early 1900's when it was first used as an irrigation source (Bryant and Others, Groundwater Problems in Arkansas, USGS Report #85-4010).

Low yields of groundwater in the Interior Highlands prohibit large-scale groundwater development. Over most of the Highlands, yields to wells are less than 25 gallons per minute (GPM). Exceptions to the low yields are the Arkansas River alluvium which yields 300 to 750 gallons per minute and the Roubidoux and Gunter Sandstone aquifers in northwest Arkansas which yield as much as 450 and 500 GPM, respectively.

Potential groundwater problems are found statewide. A large number of waste impoundments, landfills, and open dumps pose potential threats to groundwater, especially those located in moderate to high aquifer recharge zones. Contamination from waste impoundments and dumps has occurred and the potential for more to happen is a probability. Hazardous substances transported by pipe lines, vehicles, and trains as well as storage tanks containing hazardous substances are sources of potential contamination. Groundwater use, major aquifers, availability of groundwater and known contaminants are listed in the following tables. For purposes of convenience and consistency the tables are organized by the same river basin segment used in other reports issued by the department.

Because of the wide variation in the quality of the groundwater within each segment, no general statement about the quality in the segment was possible. The tables do indicate which aquifers are being used and how much water is available which is a general guide to finding water of sufficient quality and quantity for most purposes. Specific quality determinations, however, would have to be determined on a site-specific basis.

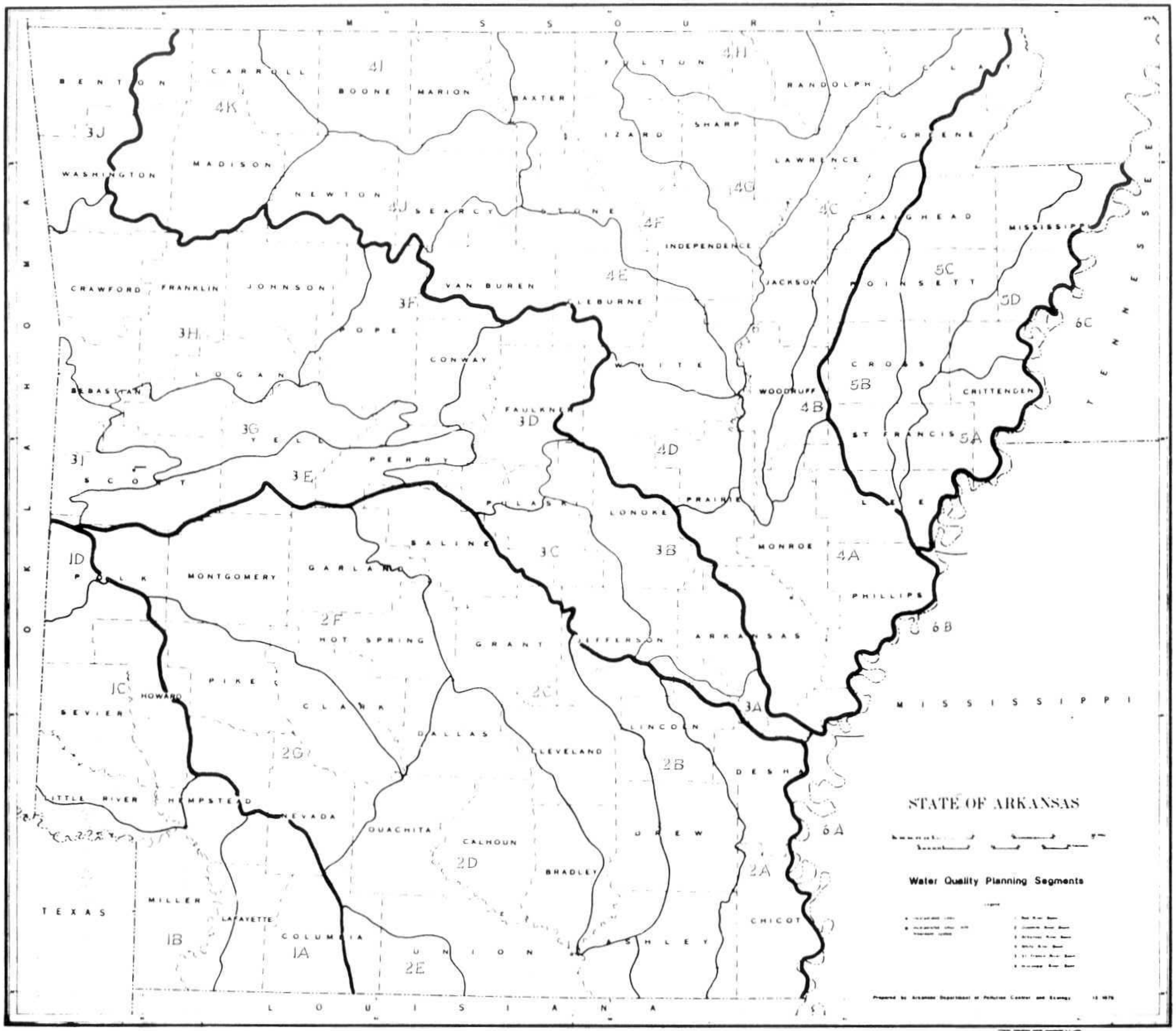


Figure 2. Water Quality Planning Segments

Table 1, Groundwater Problems, Use, and Availability by Planning Segment.

Basin Segment	Population Using Groundwater as Drinking Water	Major Aquifers	Availability	*Reported Problems in at Least One Well Above SDWA Limits
1A	100%	Carrizo, Wilcox, Tokio, Cane River, Sparta,	50 - 500 GPM in NW >500 in So.	High Chlorides, Iron. Sodium
1B	33%	See Above	50-500 GPM	High Chlorides
1C	60%	Paleozoic Rocks Nacatoch, Tokio, Trinity, Quarternary	<50 in NE 50-500 in So.	High Salt, Acidity, Iron, Barium, Manganese
1D	64%	Paleozoic Rocks	<50 GPM	Iron, Manganese
2A	100%	Sparta, Cockfield, Quarternary	>500 GPM	High Iron, Chlorides, Sodium
2B	100%	See Above	>500 GPM	See Above
2C	80%	See Above	50 - 500	See Above
2D	100% (except Ouachita Co. 40%)	See Above Add Carrizo Sand	50 - 500	See Above-Add High Sulphates, EDB, Mercury, Arsenic, Barium, Lead, Selenium, Nitrates, Chromium
2E	100%	Sparta Sand, Cockfield	>500	High Chlorides, Oil Production Residuals
2F	38%	Same as 2A add Ozan, Midway Group, Paleozoic Rocks	Low yields <50 GPM	High Nitrate, Iron, Chlorides, Penta-Chlorophenol Fluorides

*Problems listed have been reported in at least one well in the segment. They are not representative of the segment as a whole.

Basin Segment	Population Using Groundwater as Drinking Water	Major Aquifers	Availability	*Reported Problems in at Least One Well Above SDWA Limits
2G	82%	See Above	See Above 50-100 GPM in the So. Part	See Above
3A	100%	Quaternary Age Jackson Group, Cockfield, Sparta Sand	>500 GPM Dropping Water Levels	Salinity
3B	90%	See Above, also Atoka and Wilcox	See Above	Salinity, Cadmium, Chlorophenols, Benzene
3C	63%	Same as 3A, also Wilcox	50- 500 GPM	High Iron, Lead, Chromium, Dissolved Solids, Chlorides, Natural Radioactivity
3D	42%	Paleozoic Rocks Quartenary, Memphis,	<50 GPM Drought Susceptibility	
3E	45%	Paleozoic Rocks	<50 GPM	Acidity, Salinity, Nitrates
3F	75%	Paleozoic Rocks	<50 GPM	Salinity, Iron
3G	73%	Paleozoic Rocks	<50 GPM	Salinity, Acidity
3H	48%	Quaternary, Paleozoic and Arkansas River Alluvium	50-500 GPM	Salinity, Alkalinity, Acid Mine Drainage
3I	20%	Quaternary, Paleozoic	< 50 GPM	See Above
3J	36%	Gasconade, Roubidoux, Gunter	50-500 GPM	Nitrates

*Problems listed have been reported in at least one well in the segment. They are not representative of the segment as a whole.

Basin Segment	Population Using Groundwater as Drinking Water	Major Aquifers	Availability	*Reported Problems in at Least One Well Above SDWA Limits
4A	100%	Quaternary, Sparta	Declining well levels <500 GPM	Increasing Salinity. Iron, Alkalinity
4B	88%	Wilcox, Memphis Quaternary	50 to 500 GPM Declining Levels	High Dissolved Solids
4C	88%	See Above, add Nacatoch	50 to 500 GPM Declining Levels	See Above
4D	67%	See above add Atoka		Barium, Selenium, Cadmium, Lead, Nitrates
4E	45%	Quarternary, Paleozoic Rocks	<50 GPM	Salinity, Iron, Flourides
4F	63%	See Above	50 to 500 GPM	See Above
4G	74%	See Above	50 to 500 GPM	See Above
4H	87%	Paleozoic, Nacatoch, Wilcox, Quarternary	50 to 500 GPM	Iron, Manganese, Hardness
4I	99%	Roubidoux, Gasconade, Cotter	50 to 500 GPM	Salinity
4J	94%	See Above	<50 GPM Supplies Limited	
4K	54%	See Above	50 to 500 GMP	Nitrates in Shallow Wells

*Problems listed have been reported in at least one well in the segment. They are not representative of the segment as a whole.

Basin Segment	Population Using Groundwater as Drinking Water	Major Aquifers	Availability	*Reported Problems in at Least One Well Above SDWA Limits
5A	100%	Quarternary, Wilcox, 1,400 ft. Sand	>500 GPM	Hardness, Iron, Sodium
5B	90%	See Above, Add Memphis and Cockfield	>500 GPM	Salinity, Nitrates
5C	100%	Quarternary, Wilcox, Nacatoch	>500 GPM	Salinity, Hardness, Iron
5D	100%	Quarternary, Wilcox	>500 Declining Levels	See Above

*Problems listed have been reported in at least one well in the segment. They are not representative of the segment as a whole.

Groundwater Resources

ACTIVITIES 3 and 5

Introduction - Quality Criteria

Quality criteria for groundwater are primarily related to drinking water which is the most important use to which groundwater is put. The recommended standards for drinking water are set by the Safe Drinking Water Act and are adopted by most states. Arkansas is no exception. The Arkansas Department of Health uses the National Primary Drinking Water Standards in setting the standard to which public water supplies must adhere. These criteria are set forth in Table #2.

Irrigated agriculture is by far the largest consumer of groundwater in Arkansas. About 90% of all groundwater use is for irrigation. Table #3 lists the EPA recommended limits for pollutants in water used for irrigation. These criteria are only guidelines and it is up to the individual farmer to aquaint himself with the criteria and use them as he sees fit. The University Cooperative Extension System will test the farmer's irrigation well for a fee, with arrangements made through the county agent.

Industrial use of groundwater was estimated at 2.2% in 1981. Industrial users are usually tied to municipal water supplies although some have their own wells. Some have specific quality needs, as, for example, those industries that use boilers need to have water with a sodium level of less than 200 milligrams per liter o r excessive frothing will take place. Other limits are suggested in the EPA Water Quality Criteria handbook, but since the industrial users are so varied in their needs, it is impossible to adapt a table that will be of use to any but a relatively small number of industrial uses. Table #4 is an example of the kind of criteria that apply to a few industries.

Classification of Groundwater - Principles and Goals

The classification of groundwater in the ten or so states that have a system in place usually revolves around drinking water standards. Sources of drinking water are given a priority rating in the classification of groundwater. The basic idea of the classification process is to identify aquifers or aquifer segments that are either being used as public drinking water supplies or are potential sources of drinking water. Beyond this, the state may choose to identify and classify groundwater according to either use or quality, the two being closely related since quality in most cases will determine use. Usually the designated use is "the highest and best use of the groundwater resources".

A parallel and equally valid conservation principal is that high quality water should be used only when a lower grade cannot be tolerated by the user. The principle leads in two directions; one towards the reuse of wastewater for nonpotable purposes,and the other towards the identification of aquifer segments that may be unsuitable for drinking water but is perfectly acceptable for other purposes. It may determine that the only use of an aquifer that yields poor quality water may be as a repository for the injection of hazardous waste.

The objective of groundwater classification, then, is to provide a systematic approach to the implementation of a statewide groundwater quality protection strategy by formally designating the use of and water quality goal for, the groundwater resource. The resource can then be protected through appropriate land management. It may also be used as the basis for the implementation of best management practices.

Table 2 —Primary drinking water standards

[From U.S. Environmental Protection Agency, 1977]

Selected constituent	Maximum contaminant level (milligrams per liter)
Arsenic	0.05
Barium	1.00
Cadmium	0:010
Chromium	0.05
Lead	0.05
Mercury	0.002
Selenium	0.01
Silver	0.05
Fluoride	1.4 - 2.4 depending on average temperature
Nitrate as N[1]	10.00 mg/L
Coliform bacteria	a) For standard samples (100 ml) the arithmetic means of all samples examined in a compliance period shall not exceed one colony. b) When less than 20 samples per month are examined, not more than one sample shall have a coliform count in excess of 4 per 100 ml.
Turbidity	1 turbidity unit
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.10
Toxaphene	0.005
2,4 - D	0.10
2,4,5-TP (Silvex)	0.01
TTHM (total trihalomethanes)	0.10
Combined Radium - 226 and radium - 228	5 pCi/1*
Gross Alpha Particle Activity (including radium-226, excluding radon and uranium)	15 pCi/1
Beta Particle and Photon Radioactivity from manmade radionuclides	Average annual conc. shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 millirem/year
Tritium (total body)	20,000 pCi/l
Strontium-90 (bone marrow)	8 pCi/l

*pCi/l = piocuries/liter

[1] The maximum contaminant level for nitrate applies to community and noncommunity water systems. Other inorganic chemicals apply only to community water systems.

TABLE #3 RECOMMENDED LIMITS FOR POLLUTANTS IN WATER USED FOR IRRIGATION*

TRACE HEAVY METALS

Constituent	Long-Term Use (mg/l)	Short-Term Use (mg/l)	Remarks
Aluminum	5.0	20.0	Can cause non-productivity in acid soils, but soils at pH 5.5 to 8.0 will precipitate the ion and eliminate toxicity
Arsenic	0.10	2.0	Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to less than 0.05 mg/l for rice.
Beryllium	0.10	0.5	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans.
Boron	0.75	2.0	Essential to plant growth, with optiumum yields for many obtained at a few-tenths mg/l in nutrient solutions. Toxic to many sensitive plants (e.g., citrus plants) at 1 mg/l.
Chromium	0.1	1.0	Not generally recognized as essential growth element. Conservative limits recommended due to lack of knowledge on toxicity to plants.
Cobalt	0.50	5.0	Toxic To tomatoe plants at 0.1 mg/l in nutrient solution. Trends to be inactivated by neutral and alkaline soils.
Copper	0.2	5.0	Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solution.
Fluoride	1.0	15.0	Inactivated by neutral and alkaline soils.
Iron	5.0	20.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of essential phosphorus and molybedendum.
Lead	5.0	10.0	Can inhibit plant cell growth at very high concentrations.

*From EPA-600/8-80-036, Guidelines for Water Reuse

TABLE #3 RECOMMENDED LIMITS FOR POLLUTANTS IN WATER USED FOR IRRIGATION*
TRACE HEAVY METALS

Constituent	Long-Term Use (mg/1)	Short-Term Use (mg/1)	Remarks
Lithium	2.5	2.5	Tolerated by most crops at up to 5 mg/1; mobile in soil. Toxic to citrus at low doses -recommended limit is 0.075 mg/1.
Manganese	0.2	10.0	Toxic to a number of crops at a few tenths to a few mg/1 in acid soils.
Molybdenum	0.01	0.05	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high levels of available molybdenum.
Nickel	0.2	2.0	Toxic to a number of plants at 0.5 to 1.0 mg/1; reduced toxicity at neutral or alkaline pH.
Selenium	0.02	0.02	Toxic to plants at low concentrations and to livestock if forage is grown in soils with low levels of added selenium.
Tin, Tungsten	-	-	Effectively excluded by plants; specific tolerance levels unknown.
Vanadium	0.1	1.0	Toxic to many plants at relatively low concentrations.
Zinc	2.0	10.0	Toxic to many plants at widely varying concentrations; reduced toxicity at increased pH (6 or above) and in fine-textured or organic soils.

Constituent	Recommended Limit	Remarks
pH	4.5-9.0	Most effects of pH on plant growth are indirect (e.g., pH effects on heavy metals; toxicity described above).
Fecal Coliform	1,000/100 ml	Irrigation waters at or below this limit should pose no hazard to animals or man from their use or from consumption of raw crops irrigated with the waters.

Constituent	Recommended Limit	Remarks
TDS	500-5,000 mg/1	Below 500 mg/1, no detrimental effects are usually noticed. Between 500 and 1,000 mg/1, TDS in irrigation water can affect many crops, and careful management practices should be followed. Above 2,000 mg/1, water can be used regularly only for tolerant plants on permeable soils.

For water used continuously on all soils.
For water used for a period of up to 20 years on fine-textured neutral or alkaline soils.
*From EPA 600/8-80-036, Guidelines for Water Reuse.

TABLE 4

Water quality requirements—mg/L

Characteristics	Boiler Feedwater <933 kPa (<150 psig)	Boiler Feedwater <10 241 kPa (<1500 psig)	Cooling Water, Once-Through Circulation: Fresh	Cooling Water, Once-Through Circulation: Brackish	Cooling Water, Makeup for Recirculation: Fresh	Cooling Water, Makeup for Recirculation: Brackish	Process Water by Industry: Textile	Lumber	Pulp and Paper	Chemical Products	Petroleum and Coal Products	Primary Metal	Food Canning	Bottled and Canned Soft Drinks	Tanning
Silica (SiO_2)	~30	0.01	50	25	50	25			50	50	60		50		
Aluminum (Al)	5	0.01			0.1										
Iron (Fe)	1	0.01			0.5		0.1		0.3	0.1	1.0		0.2	0.3	50
Manganese (Mn)	0.3				0.5		0.01		0.1	0.1			0.2	0.05	0.2
Copper (Cu)	0.5	0.01					0.05								
Calcium (Ca)		*	200	520	50	420			20	70	75		100		60
Magnesium (Mg)		*							12	20	30				
Sodium and potassium (Na+K)											230				
Ammonia (NH_3)	0.1	0.7									40				
Bicarbonate (HCO_3)	170	*	600		25					130	480				
Sulfate (SO_4)			680	2 700	200	2 700				100	600		250	500	250
Chloride (Cl)			600		500				200	500	300	500	250	500	250
Fluoride (F)			600	19 000	500	19 000				5	1.2		1	1.7	
Nitrate (NO_3)											10		10		
Phosphate (PO_4)															
Dissolved solids	700	0.5	1000	35 000	500	35 000	100		100	1000	1000	1500	500		
Suspended solids	10	0	5000	2 500	100	100	5	<3-mm diameter	10	5	10	3000	10		
Hardness ($CaCO_3$)	20	0.07	850	6 250	130	6 250	25		475	250	350	1000	250		150
Alkalinity ($CaCO_3$)	140	0	500	115	20	115				125	500	200	250	85	
Acidity ($CaCO_3$)												75			
pH	8-10	8.8-9.2	5-8.3				6-8	5-9	4.6-9.4	5.5-9	6-9	5-9	6.5-8.5		6-8
Color—units							5		10	20	25		5	10	5
Organics															
MBAS					1							30			
CCl_4					1										
COD	5	0	75	75	75	75									
Dissolved oxygen	<0.007	<0.0007													
Temperature—°C (°F)	48 (120)	48 (120)	37 (100)	48 (120)		37 (100)	48 (120)		37 (100)			37 (100)			
Turbidity—tu	10	0.05	5000	100											

*Determined by treatment of other constituents

These guidelines apply to either ground or surface waters, treated or untreated, from, Journal AWWA, July, 1983, p. 353.

Groundwater Quality Classification - Definitions

What follows is based on the classification system described in EPA's Groundwater Strategy. The main emphasis in the classification system is on the protection of drinking water. An underground source of drinking water (USDW) has been defined as an aquifer or its portion:

1. (i) which supplies any public water system; or
   (ii) which contains a sufficient quantity of groundwater to supply a public water system; and
      (a) currently supplies drinking water for human consumption; or
      (b) contains fewer than 10,000 mg/l TDS; and
2. Which is not an exempted aquifer.

An aquifer or portion thereof which would otherwise meet the definition of USDW may be exempted from protection by the Director of the Arkansas Department of Pollution Control and Ecology after public notice and opportunity for public hearing upon final approval by the Administrator of EPA. An aquifer or portion thereof may be exempted if it does not currently serve as a source of drinking water (as specified in 40 CFR Part 146.04).

Groundwater Classification

Class I - Special Groundwaters - those aquifers or portions thereof that are a source of the base flow or water levels for an ecologically sensitive system that, if polluted, would destroy a unique habitat, or serves as an irreplaceable source of drinking water for at least 3,000 people.

Criteria

1. Dissolved oxygen	As naturally occurs.
2. Oil and grease	None other than of natural origin.
3. Color and turbidity	None other than of natural origin.
4. Coliform bacteria per 100 ml	Not to exceed a monthly arithmetic mean of 1 or, more than 4 in any individual sample collected.
5. Taste and odor	None other than of natural origin.

Class II - All other groundwater that is used as an existing or is a potential USDW, e.g., any groundwater with total dissolved solids less than 10,000 mg/l. These aquifers are to be protected according to the criteria suggested above but would not be given the extra protection afforded to special aquifers in terms of landfill siting criteria and other possible polluting activities.

Class III - Groundwater that is not now or is not considered possible USDW sources - groundwater with total dissolved solids of greater than 10,000 mg/l, or those aquifers or portions thereof that are exempted for consideration as USDW's for other reasons.

Explanation

While some aquifers and geographic areas fall clearly into one classification or another, the task of determining whether the groundwater in a specific location fits the criteria for Class I, II, or III will ultimately have to be made on a site-specific basis as part of the permitting process.

In the following list, an attempt has been made to group some of the most-used aquifers in the state into the classifications that seem most appropriate for them. Class I groundwater, the breakoff point for groundwater that served an irreplaceable source of drinking water for a significant number of people was established as 3,000 persons. Also, all limestone aquifers that outcropped in the interior highlands were considered sufficiently sensitive ecologically to warrant Class I classification.

The quantity and quality of the water in an aquifer varies considerably within different portions of the same aquifer. The Midway Group, for example, yields a significant amount of water only in a small area in Saline County. Otherwise, the Midway is unproductive. Also, some confined aquifers in Arkansas eventually become too mineralized downdip from their outcrop areas to be considered USDW's and at that point become Class III aquifers. A Class I aquifer may shift into Class II at the point where the mineralization process exceeds 1,000 mg/l but is less than 10,000 mg/l TDS. The classification of an aquifer is valid only for the portion under examination. The major aquifers of the coastal plain have been mapped so that the areas where their water becomes usable is known. Most of the aquifers of the interior highlands have not yet been mapped. The aquifers listed on the following page are classified according to their highest and best use.

Since Arkansas falls naturally into two major geologic regions, the coastal plain and the interior highlands, the classification system is divided accordingly. And, as the aquifers of the coastal plain are far more productive and are therefore used much more extensively than those of the interior highlands, much more is known about them. Hence, we are able to classify them with greater specificity, and the tables which follow reflect that. Many of the formations of the Interior Highlands are used only for domestic purposes with an occasional small public or community well. Therefore, rather than list all of these formations we have grouped then under the category of "Surficial Paleozoic Rocks" and have identified only the major or especially sensitive formations by name.

CLASSIFICATION OF MAJOR AQUIFERS

INTERIOR HIGHLANDS

Class I

Quarternary Deposits
Big Fork Chert
Arkansas Novaculite
Roubidoux Formation
Gunter Sandstone Member
Paleozoic Age limestone and dolomite formations (e.g., Boone, Pitkin, Fernvale, Cotter, and Jefferson City Formations).

Class II

Surficial Paleozoic Rocks (e.g., Hale, Atoka, Batesville, St. Peter, Prairie Grove, Powell, Everton, Savahanna Hartshorne, Jackfork, Stanley, and McAlester Formations).

COASTAL PLAIN

Class I

Quarternary Deposits
*Cockfield Formation
*Sparta Sand
Cane River Formation
*Carrizo Sand
Wilcox Group
Nacatoch Sand
Trinity Group
*These three constitute the Memphis Sand in NE Arkansas

Class II

Jackson Group
Cook Mountain Formation
Midway
Other limestone, marl, and sandstone formation of Cretaceous Age

Class III

All remaining formations and those portions of all aquifers that are below the fresh and saltwater interface (defined as >10,000 mg/l TDS)..

Ecologically Sensitive Groundwater Supported (ESGS) Areas - Class I

The following ESGS areas have been identified by the Arkansas Natural Heritage Commission as habitats for endangered species:

1. The Cave Springs Cave - Ozark cavefish habitate and gray bat habitat.
2. Logan Cave - Ozark cavefish and gray bat habitat.
3. Civil War Cave - Ozark cavefish habitat.
4. Hell Creek Cave - Cambarus zophonastes habitat.
5. Castle Cave - southern cavefish habitat.
6. Marble Falls Cave - Ozark big-eared bat habitat.
7. Blanchard Springs Caverns - outstanding cave cosystem and grey bat habitat.
8. Gap Creek - high-quality upland headwater stream.
9. Mammoth Spring - largest spring in Arkansas and habitat for the Ozark hellbender.
10. Queen Wilhelmina State Park Spring Seeps - habitat for Stygobromus montanus.
11. Hot Springs National Park - thermal springs.
12. William Tate Spring Run - habitat for the Arkansas darter and least darter.

Other ESGS areas, such as wetlands and streams that provide habitat to threatened or endangered species whose base flow is provided by a hydrologic connection to adjacent groundwaters may be specifically listed as entitled to Class I protection as soon as enough information is available.

The major aquifers are classified accoring to use on the following page. Maps of some of the aquifers of the Gulf Coastal Plain highlighting their ares of usability are also included.

Table 5. Aquifer Classification by Use

Groundwater Use Classification	Beneficial Uses									
	Public Supply	Irrigation	Domestic	Livestock	Fish & Minnow Farm	Wildlife Impoundment	Electric Energy	Self Supplied Industry	(Highly Vulnerable	Special Aquifers)
Mississippi Alluvium and Terrace Deposits	X	X	X	X	X			X		X
Arkansas Alluvium and Terrace Deposits		X	X				X			
Ouachita Alluvium and Terrace Deposits		X	X							
Jackson Group Undifferentiated			X							
Cockfield Formation - Claiborne Group	X	X	X	X				X		X
Sparta Sand	X	X	X	X				X		X
Memphis Aquifer	X	X	X							
Atoka			X							
Carrizo Sand			X					X		
Wilcox Group Undifferentiated	X		X							
Clayton Formation - Midway Group	X									
Boone Formation	X									
Nacatoch Sand	X							X		
Ozan Formation	X									
Tokio Formation	X									
Paleozoic Rock Undifferentiated	X	X	X							X
Roubidoux	X									X
Gasconade	X									X
Gunter Member	X									X
Cane River	X	X								
Trinity Group	X									
Cotter Dolomite	X									
Everton	X									
Potosi - Eminence	X									X

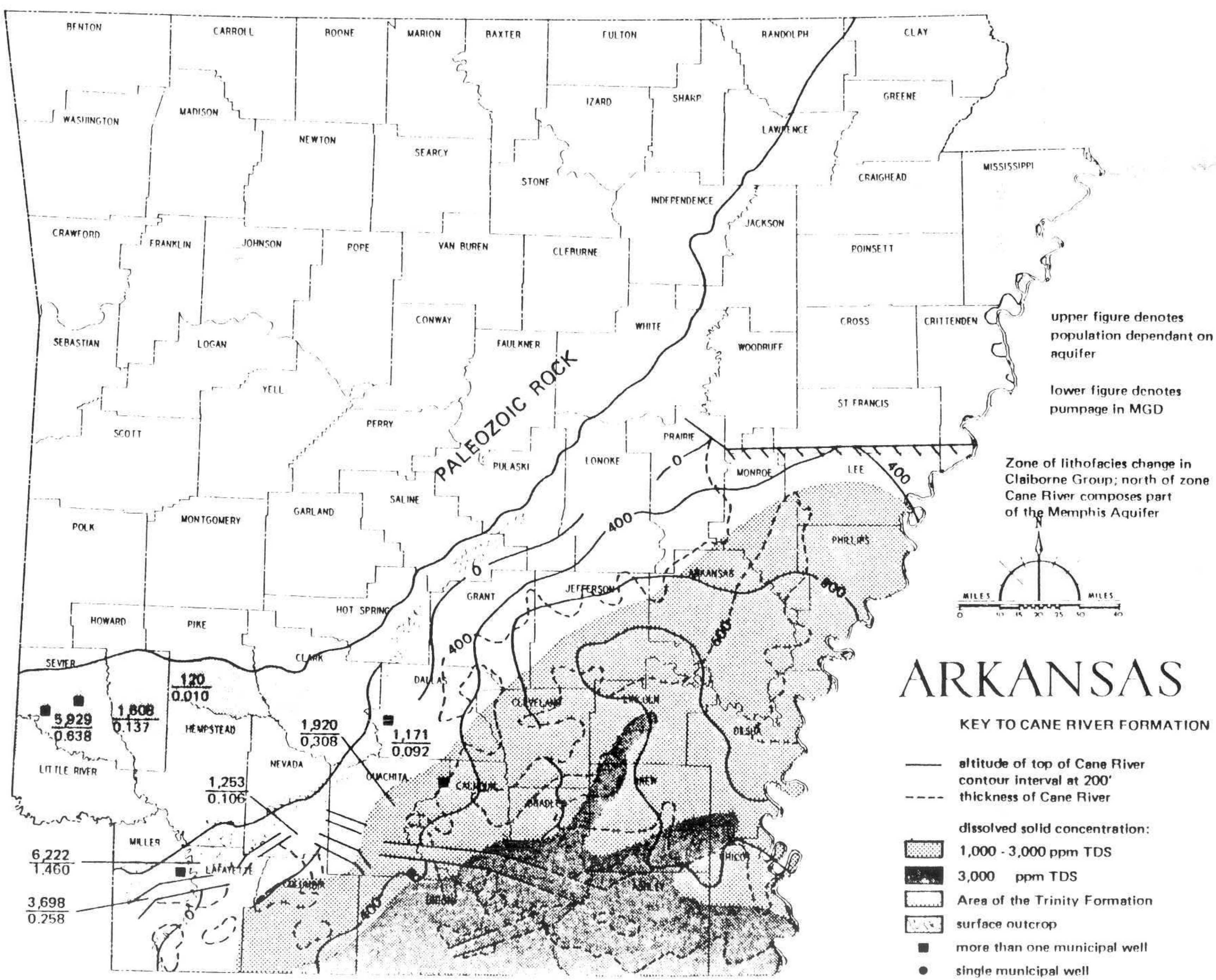


Figure 4. Cane River Formation

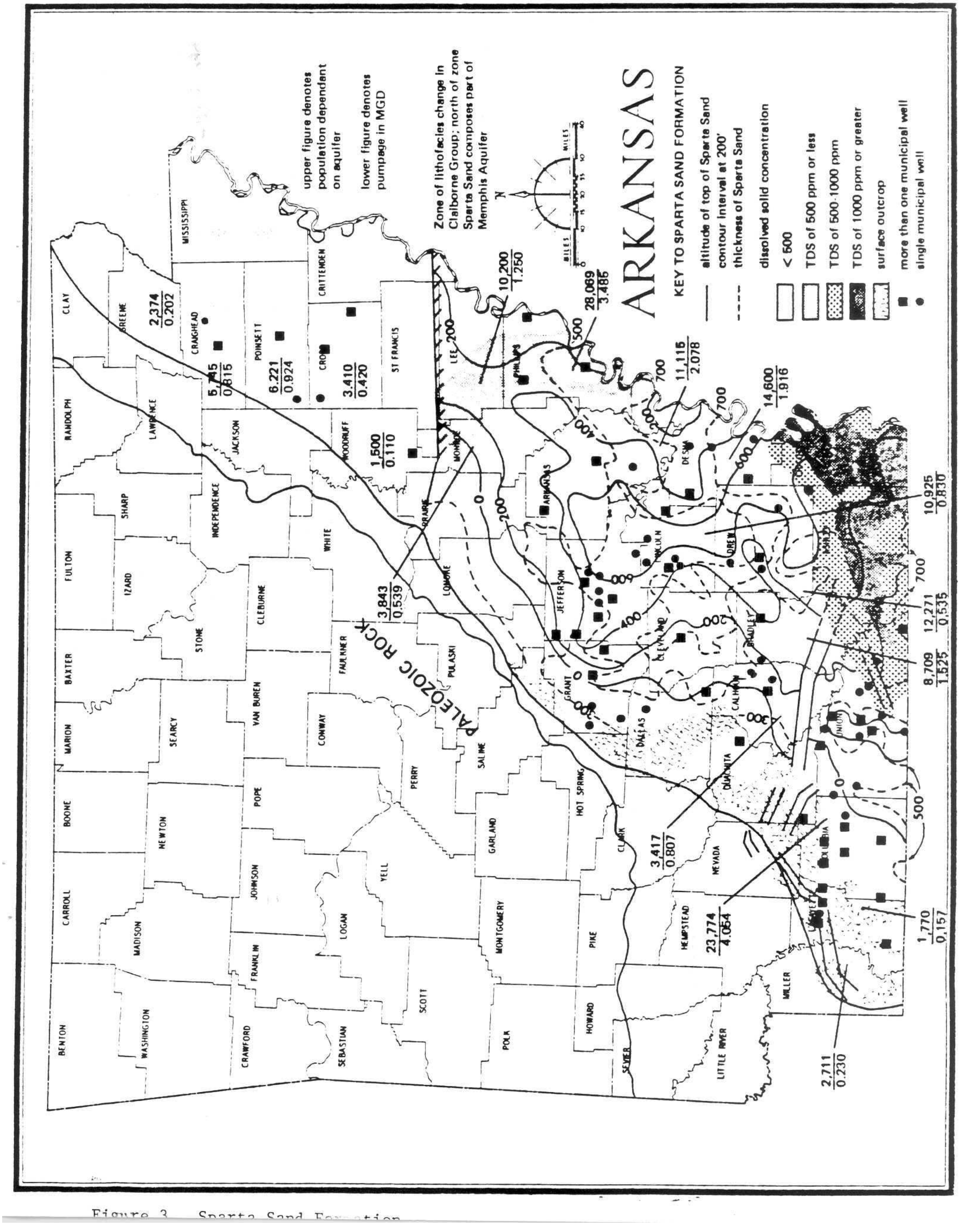


Figure 3 Sparta Sand Formation

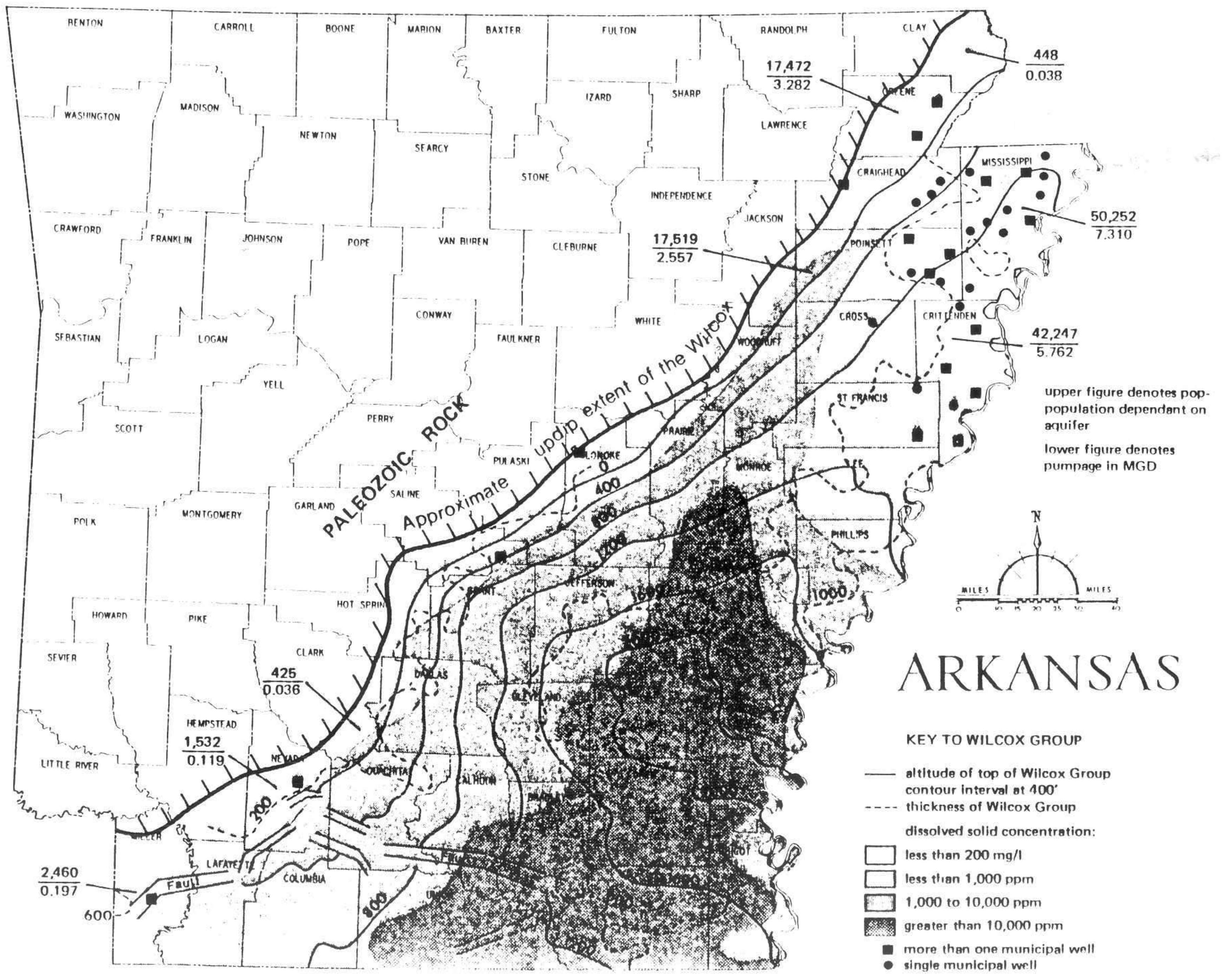


Figure 6, Wilcox Group

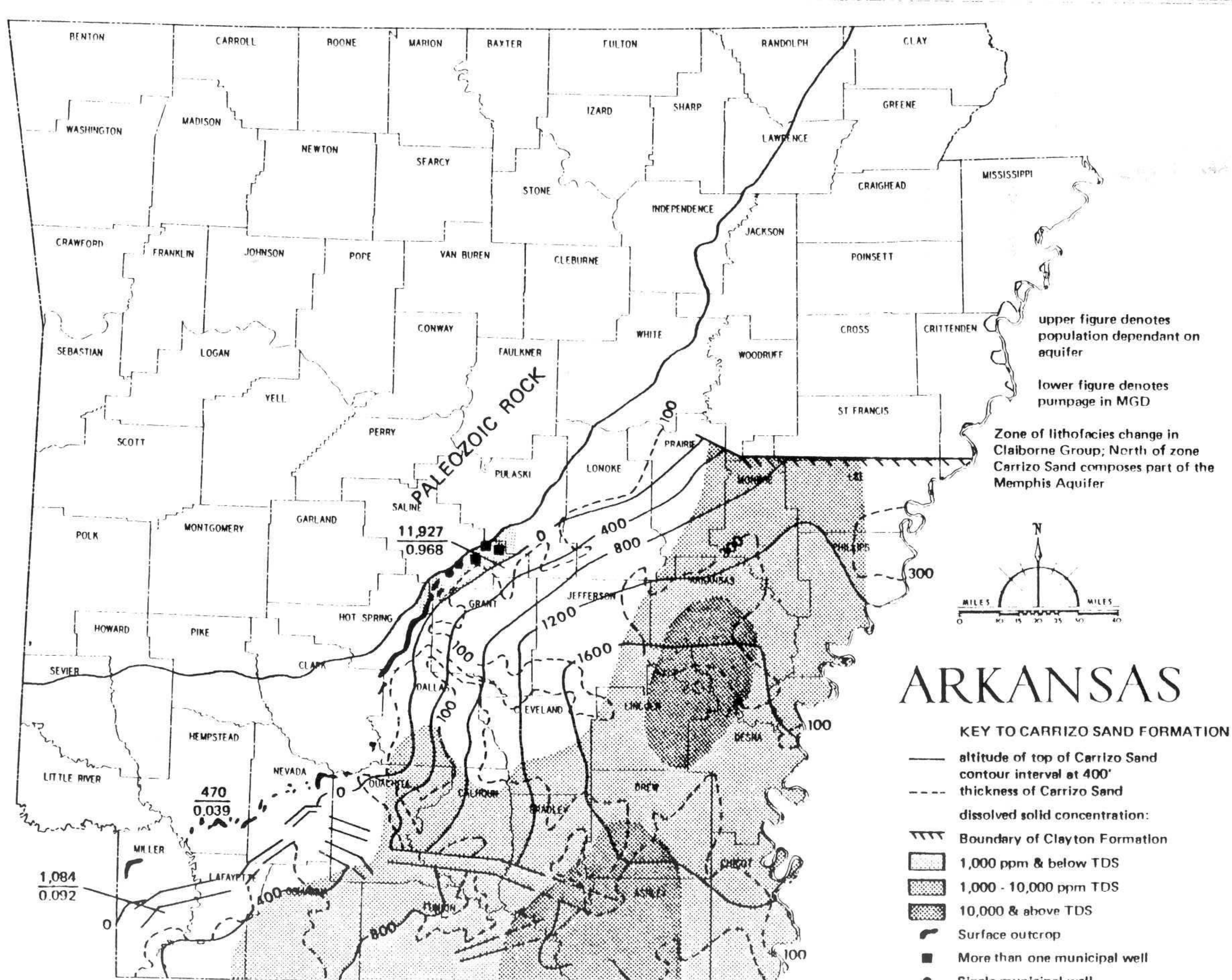


Figure 5. Carrizo Sand Formation

IV. GROUNDWATER PROBLEMS IN ARKANSAS

The importance of groundwater to America and to Arkansas has only recently come to the attention of the general public. The plight of the Ogallala aquifer in the nation's high plains brought the first media attention to the subject. The aquifer was drying up and since the economic life of many of the people in the high plains area was dependent on that water, concerns were expressed about how and why this was happening and what other states were similarly threatened. Arkansas was only indirectly affected as a border state that might be called upon to deliver water to Texas if the plans could be worked out and the costs were not prohibitive.

Meanwhile, the drought of 1980 brought the attention of Arkansans to problems closer at hand. Our citizens learned that wells could run dry and cause considerable trouble and expense to communities and individual farmers who ran out of water. Water that had been taken for granted in a state blessed with an abundant supply, suddenly, or, so it seemed, was caught short.

And, not only was the supply in question, the quality was uncertain as well. Boiling orders went out to several Arkansas communities during the drought and the number of farmers turning in water samples that were high in salt from their irrigation wells began to concern state officials.

About the same time, Arkansans began to learn about hazardous waste and the effect it might have on their water. A fishing ban was placed on Bayou Meto; dioxin had been found in the fish. Arkansas, the natural state, was finding out that it was not immune to the unnatural effects of modern industry.

Groundwater is important to the people of Arkansas, 43% of whom are dependent on groundwater for their drinking water. Small communities in the state are especially dependent on groundwater; 75% of all public water supplies use groundwater. The cities of Pine Bluff, Jonesboro and El Dorado are some of the larger communities that get their water from groundwater.

Irrigated agriculture is by far the state's largest user of groundwater, consuming over 90% of the over 4 billion gallons per day that were used in the drought year of 1980. The rice industry accounted for over 80% of that use, and it is the availability of that water which accounts for the fact that

Arkansas is number one in the nation in rice production. Agricultural irrigation is also responsible for the dropping water tables and potential shortages that threaten the farmers of the Grand Prairie.

Other industries, such as paper mills and chicken processors are large water users. One paper mill, for example, will consume as much water as a city of a million people. Oil refineries and food and mineral processors of all types are also major consumers.

All of these water consumers have water criteria that must be applied in determining whether the health of the people, the growth of the crops, or the operation of machinery will be affected. Like people, the health of plants and some machines is, to some extent, determined by the quality of the water.

These are some of the reasons why groundwater problems are receiving increased attention from both Federal and State regulatory agencies and from water users. Although Arkansas is blessed with an abundance of good quality groundwater, problems are fairly widespread in the State. Most groundwater problems in Arkansas can be grouped into four categories: pollution, overdraft, insufficient supplies and poor natural quality.

The recent expansion of Arkansas' urban population and its industrial and agricultural productivity has put additional strains on its water supply and increased the potential for ever-greater contamination problems. As water use has grown, water quality problems have been made worse. This is especially evident in areas where saltwater intrusion has been a problem.

For example, extensive pumping in Monroe, Lincoln, Desha, Miller and Lafayette counties has already caused area of saltwater intrusion into the fresh groundwater to increase in size and concentration. Water levels have dropped dramatically under the cities of Pine Bluff, El Dorado and Magnolia and saltwater problems threaten the latter two.

The threats to groundwater in southern and eastern Arkansas are especially significant as these are areas of almost total dependency on groundwater for drinking supplies and irrigation. Oil production and agricultural activities have made many of the streams in the delta and southern coastal plain unfit for most uses.

Indeed, for a large part of the southern and eastern sections of the state there is only one source of drinking water, the Sparta Sand aquifer in the south central part of the state and the Cockfield in the east. The uppermost or alluvial aquifers in these areas are, for the most part, unfit for drinking without extensive treatment, and the lower aquifers are too salty. Recently, both the Sparta and Cockfield have shown trends toward increasing salinization.

Fortunately, the northwestern part of the state where the consolidated rock formations yield far less water than the sand formation of the delta, there are more abundant and relatively purer surface water supplies. In both areas, northwest and southeast, there is some exchange between surface and groundwaters. Stream flow in the dry summer season in both areas consists to varying degrees of seepage from aquifers into the stream bed. In the flood season, or, when the rivers and streams are high, the groundwater is recharged from the surface water. Contaminants may be passed from one to the other in the process. Since the surface water throughout the state has been increasing in dissolved solids, this trend can be expected to eventually affect the groundwater.

Acid rain is a suspected contributor to this process of increasing dissolved solids in the state's ground and surface water. Water that is more acidic will dissolve more minerals than less acidic water as it percolates through the soil into the aquifer below.

While no studies of the effects of acid rain on groundwater in Arkansas have been made, studies from Sweden show that there is a potential for damage to the quality of groundwater from acid rain. (Odin, Sweden, 1968, and Hultburg and Wenblad, Sweden, 1980).

Perhaps the most revealing fact about the arrival of Arkansas as an industrial state is the increasing amount of hazardous waste being generated in Arkansas. In 1982 we generated slightly over 59,000 tons in the state. By 1983 that figure had jumped to 127,000 tons (ADPC&E Files).. The figures do not reflect the true magnitude of our problem for those who generate less than 2,200 lbs. (regulation changes reduced this figure to 220 in August of 1985) of hazardous waste per month are not required to report their tonage to the state, although some do voluntarily. The only exception to this is a special category of "acutely hazardous waste" such as, the pesticide parathion. Mandantory reports are required whenever more than one kilogram per month is generated. There is a possibility that some unreported waste may go illegally into dumps and landfills or end up dumped on roads and fields without regard to the potential damage to water, human, and animal life.

What happens to a pollutant entering groundwater is not always understood. Some pollutants tend to be adsorbed by rock materials, especially by clay and organic material. Some pollutants are changed by oxidation and bacterial action in soil zones and the end product may be less hazardous. It used to be assumed that all organic materials were adsorbed by soils, other organic material, and rocks, and would not enter an aquifer. Recent studies however, have shown that some soluble organics enter aquifers without undergoing changes (Roberts and Others, "The Movement of Organic Chemicals in Groundwater",Journal AWWA, 1982).

Keeping abreast of these new chemicals is a full-time job. There are about a thousand new ones created each year. Some of these have caused enormous problems for those who protect our water supplies. Among these, the so-called trihalomethanes have received much public attention, especially since they were found in the drinking water of the City of New Orleans. The trihalomethanes are formed by the combination of organic chemicals in the water with chlorine used to purify the water to produce the suspected carcinogens. Other organic chemicals, however, like the nemacide, ethylenedibromide (EDB), dioxin, benzenes and phenols have been found in groundwater in Arkansas in wells near industrial sites.

Of the wastes that are considered hazardous, the largest quantities generated in Arkansas are spent solvents including the nation's most common groundwater pollutant, trichloroethylene (TCE). Over one million pounds of these spent solvents were generated in Arkansas in 1983. These solvents, especially those like TCE that are known as volatile organic chemicals (VOCs) have caused considerable problems in other states.

Most of the waste generated in the State of Arkansas is not officially listed as hazardous, even though it may do a great deal of damage. Brine, for example, which is pumped up with oil from deep below the earth's surface, while not on the RCRA hazardous waste list has an extremely high salt content that can be devastating to fish and vegetation and can make water unfit for irrigation or drinking.

Thousands of acres of south Arkansas have been rendered useless by brine spills and many of the creeks and streams run high in chlorides from brine runoff and the continuing seepage from past spills. Groundwater also has been affected in Miller, Lafayette and Union counties. Underground injection of brine back to the deep formations from whence it came has relieved the problem somewhat on the surface but has introduced a new potential problem of contamination from below the pressure is built up in the lower formations due to these injections. The same theoretical problems exists with the use of injection wells for the disposal of industrial waste. Also, there are additional dangers from leaking and abandoned wells that could serve as conduits for waste or leak directly into freshwater formations.

The concentration of the oil industry and related chemical industries in south Arkansas has given that section of the state more potential problems than any other. According to EPA records, some forty sites in south Arkansas contain hazardous waste. There are about 1,200 saltwater disposal wells, 6 industrial waste wells, and 55 spent brine injection wells. Union County alone generated 602,043 tons of hazardous waste in 1984, some twenty times more than the second largest generator, Lonoke County.

The high recharge potential of the land surface combined with the large number of abandoned oil and water wells adds to the possibility for groundwater pollution in the area. A portion of the recharge areas for both the Sparta Sand and the Cockfield aquifers, two of the major sources of drinking water for both this area and northern Louisiana, are in the areas described, the Cockfield outcropping in Union County and the Sparta further to the west. Many of the communities and rural dwellers are 100% dependent on these aquifers for their drinking water.

Monitoring wells around some of the more hazardous sites indicate that some of these chemicals have already penatrated the Cockfield. Chlorides above SDWA standards have been found in both the Cockfield and the Sparta. Sodium levels have also been trending upwards in municipalities using these aquifers. (See the table and map on sodium on the following pages. See also, Chesney, Clay, "Surface Impoundment Assesment, State of Arkansas, 1979).

In 1978-79, an attempt was made to locate and assess the potential for contamination of all of the major liquid-waste holding impoundments in Arkansas. The study, known formally as the pits, ponds and lagoons study, located some 7,640 agricultural, municipal, mining, industrial and oil-related impoundments, and assessed 518 of these according to the severity of the threat to the groundwater in the vicinity of the impoundment. Those with a rating of 15 or above have been plotted on the summary map in the USGS problems study on which this summary is based.

In addition, the report details several cases of contamination stemming from these impoundment. The majority of these stem from brine spills and seepage in south Arkansas. Most of these brine pits did not have liners and some were intentionally dug so as to allow the brine to seep into the ground so that the pit could be used more frequently.

While liquid waste impoundments are one of Arkansas' most obvious potential sources of contamination, most communities in the state are more directly concerned with solid waste problems. Many of the larger communities have relatively safe permitted landfills that are supervised by trained personnel. However, there are still over 300 open dumps in the state and many of these could be leaching all manner of contaminants into the groundwater. Many of these dumps are being closed by the state, but in some areas, especially those with no convenient permitted landfills and no organized waste removal programs, the practice of open dumping continues.

Arkansas geology is such that its groundwater is less vulnerable to contamination in some places than in others. Hard clay is considered a good barrier for most contamination and is sometimes used as a liner for landfills. Sandy soils are most permeable and will allow water to percolate downward to recharge aquifers. Limestone may be turned into solution by water and direct channels into the groundwater may be created. The same factors that will allow water to recharge aquifers will also allow some contaminants to enter aquifers.

Hence, in northwest Arkansas, where the karst topography has allowed the formation of sink holes and disappearing streams, nitrates have been found in many shallow wells. Also, the sand soils of south Arkansas has allowed brines and other contaminants to percolate down into the groundwater.

On the other hand, the clay caps that keep out many contaminants also may prevent sufficient recharge of the aquifer to meet the needs of those who use it. This is the case in many of the rice-growing areas of central and eastern Arkansas, the hard, clay pan which holds the water on the rice fields also serves to prevent the aquifer below the clay to recharge itself. The result has been that farmers have to drill even deeper and more expensive wells to reach the water below their fields. The clay cap over the aquifer is beneficial in retarding the entry of pollutants, but is also a hinderance to the extent that it prevents the recharging of the aquifer.

This summary and the accompanying, more-detailed report by USGS has illustrated known problems and potential problems. More information is needed about the condition of the groundwater in several areas of the state to allow a better assessment of how serious those problems are. Homeowners in rural areas with their own wells are most in need of quality control. Many of these wells draw water from the uppermost aquifer which is the one most likely to be contaminated and these wells are not tested on a regular basis. We also have little knowledge about the quality of water used in irrigation. Samples from irrigation wells need to be taken and analyzed for potential contaminants that could enter nearby drinking wells or could be taken up by plants which are eaten by humans.

There are neglected aquifers in the state that could possibly serve as water supplies, especially in northwestern Arkansas. These need to be sampled, mapped and analyzed so that they can be utilized, if needed. Act 1051 of 1985 has provided for such assessments to be made as part of the state water plan being produced by the ASWCC.

New chemicals are introduced at a faster rate than they can be analyzed for potential health effects. The Environmental Protection Agency has been trying for three years to expand the number of organic chemicals to be included in drinking water standards. So far, only six pesticides and the four major trihalomethanes have made the list. Nine more organic chemicals are included in revisions to the Safe Drinking Water Act that have passed both houses of Congress. There is no was of predicting how many more new chemicals may be added to the Arkansas environment in the meantime. The state could, however, begin testing for chemicals according to its own understanding of the potential dangers to its water without waiting for EPA. These are only some of the more obvious steps that could be taken.

Whatever action is taken, hopefully it will be based on a forthright, realistic evaluation of the problems that are threatening our water supplies. This report is meant to bring those problems to the attention of all of the state's consumers of water.

Sodium Trends in South Arkansas

As the following table illustrates, some towns in Arkansas have been experiencing increasing levels of sodium in their drinking water. The exact cause of such increases is unknown. There does, however, seem to be some relationship to increased pumpage which has the effect of drawing saltier water into the cone of depression established by the pumping of the well. Other possibilities include, downward migration from surface impoundments, leaking injection wells and upward migration through faults, cracks and abandoned wells. The data listed below has been taken directly from the wells whenever possible. Sometimes, however, only composite samples from the tap were available. Also, occasionally, data from new wells were given under the same number as the old wells, and the numbering of wells was not always consistent. Hence, there are weaknesses in the data that are inherent in the record, and therefore, what follows is meant to be only an indication of trends and not a precise scientific study. Where multiple wells were used, an average reading was estimated (see maps, Figures 6 & 7).

The following towns draw their water from the Cockfield Formation.

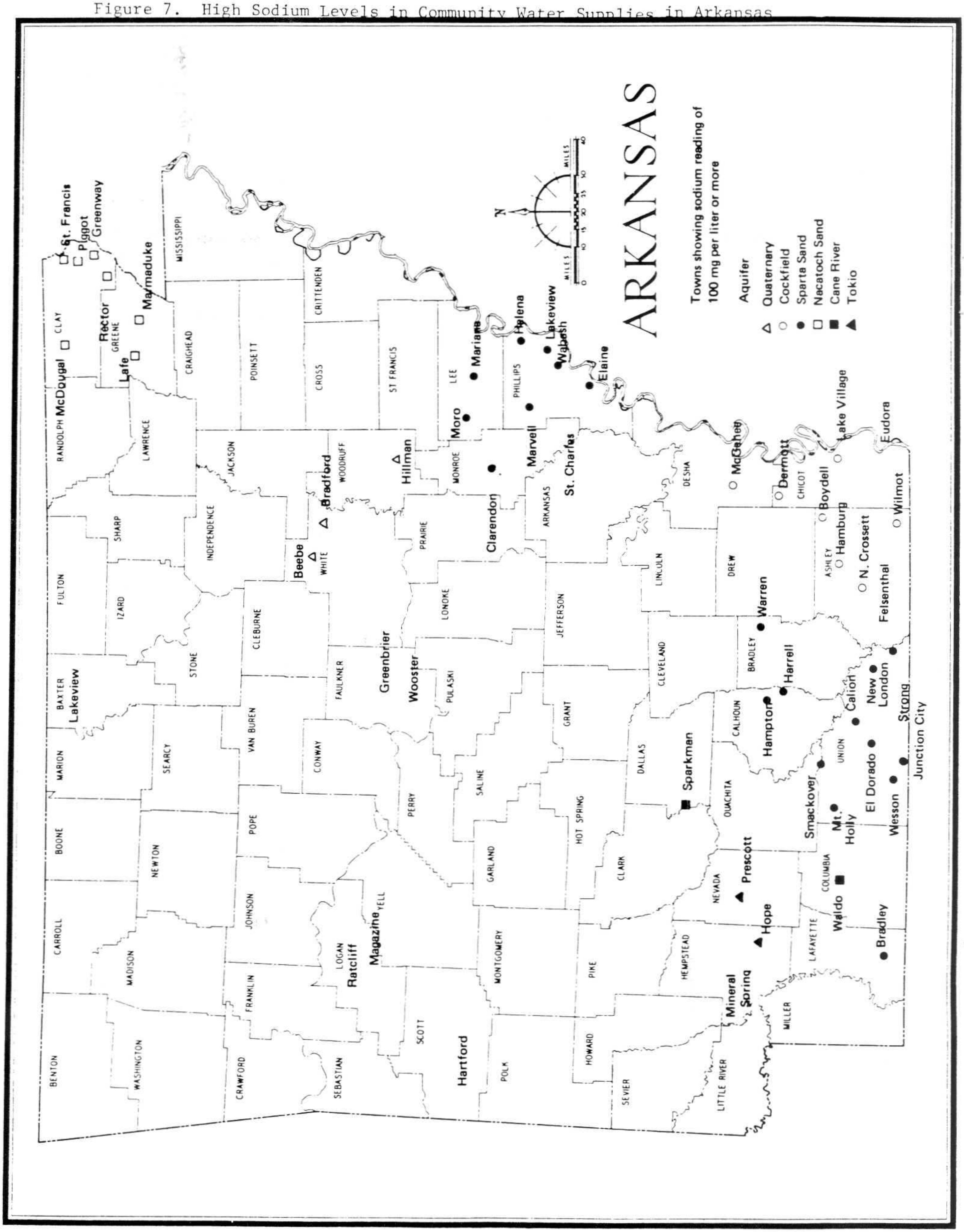
Town	Year	Sodium mg/1**	Town	Year	Sodium mg/1
Elaine	1971	285	Lake Village	1978	105
	1975	285		1981	130
	1982	290		1984	160
Eudora	1971	52	Wilmot	1975	120
	1975	96		1978	215
	1980	190		1983	220

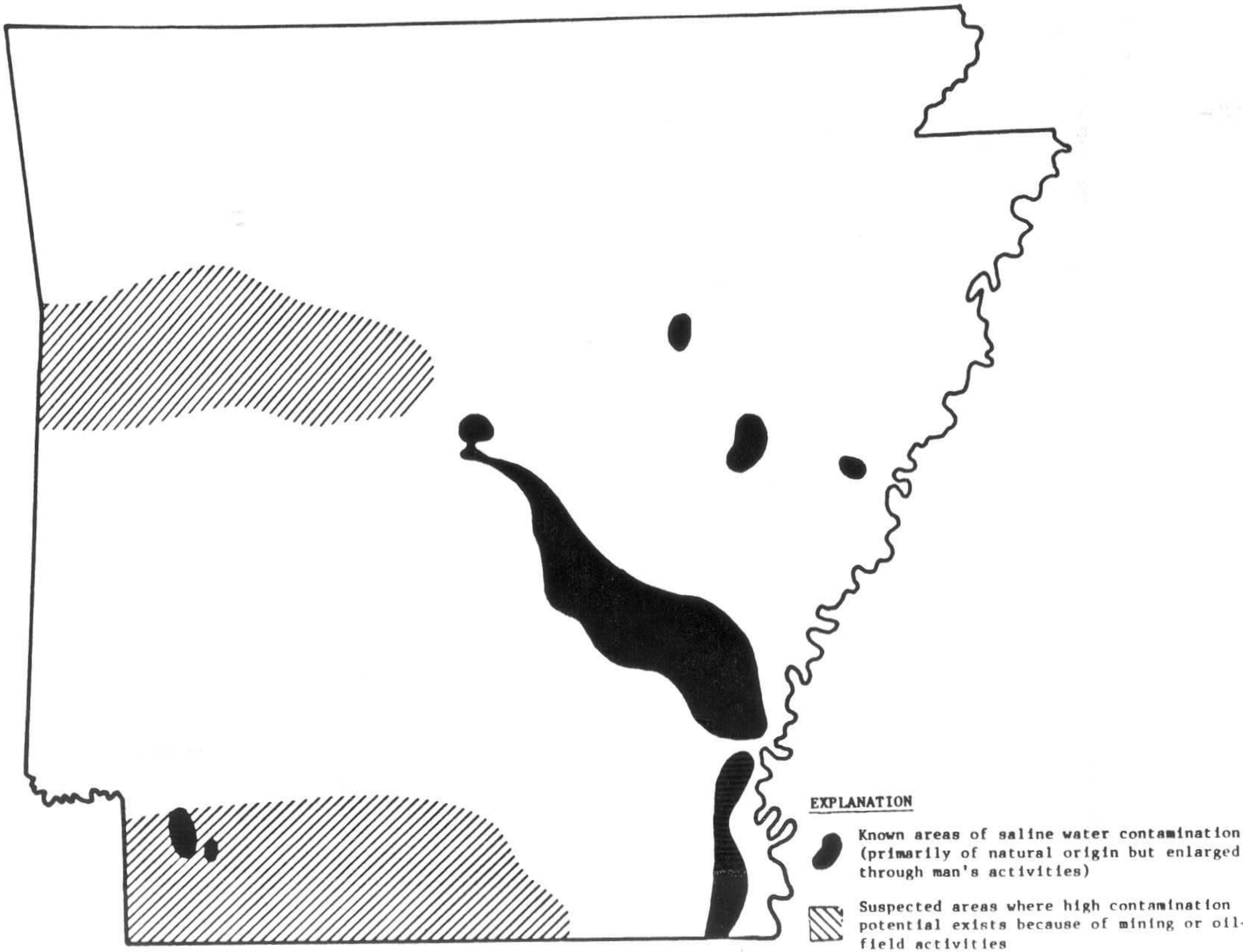
The following town draw their water from the Sparta Sand Formation.

Bradley	1972	225	Huttig	1975	135
	1977	286		1982	260
	1980	250		1985	185
Felsenthal	1976	153	Sparkman	1977	157
	1982	300		1981	300
	1985	220		1984	258
El Dorado-Well #12					
	1971	132			
	1981	140			

**The readings from sodium are in milligrams per liter (mg/1). There is no Federal standard for sodium although the Federal government advises that people on a salt restricted diet do not consume water with over 20 mg/1. The State of Arkansas issues a salt warning at 100 mg/1.

Figure 7. High Sodium Levels in Community Water Supplies in Arkansas





NOTE: Areas of suspected contamination from animal feeding operations, septic tanks, open dumps, landfills, pits, ponds and lagoons are not included on this map for lack of sufficient room. Contamination from these sources is usually of the uppermost or water table aquifer and may leave lower confined aquifers untouched. Also not included on the map above are shallow domestic wells contaminated mostly by nitrates and chlorides. Some of the data for such wells are in the USGS, Groundwater data files Watstore.

Figure 8, Saline Water Contamination.

GROUNDWATER MONITORING NETWORK - RECOMMENDATIONS

Activity 7

In the introduction to the groundwater strategy narrative, we introduced several definitions for the term aquifer and gave a rough explanation of how aquifers developed. In that section we distinguished between "confined" aquifers, those that are confined between two relatively impermeable layers, and the uppermost or "unconfined" aquifer whose upper level becomes the water table. Unconfined aquifers, because they are nearest the surface, are the most susceptable to contamination from surface activity. For the same reason, they are the most easily monitored. We can, for example, measure the concentration of leachates from landfills and other sources through the use of electronic conductivity measurements without digging monitoring wells. Most discussions, seminars and strategies for monitoring deal with the unconfined aquifer. Our approach will be to deal with the unconfined aquifer first and proceed downward, through the intervening layers, with each successive aquifer.

The emphasis at each level will be on protection and prevention. As the "Manual of Laws, Regulations and Institutions for Control of Groundwater Pollution" (prepared for EPA by the National Water Well Association, June, 1976) says:

> A polluted stream may be "cleaned up" by vigorous enforcement of laws enacted <u>after</u> the problem is recognized. A groundwater source, on the other hand, in effect may be permanently spoiled if pollution is not <u>prevented</u>. (II-1, underlining added)

Control measures and a groundwater protection program in general must be "prevention-oriented" if the program is to be cost-effective and substantially deal with the problem of groundwater quality degradation. This prevention-orientation also suggests the need for a strong, carefully-conceived monitoring system in order that groundwater pollution occurrences may be detected early so that protective measures can be taken. This need for early detection creates further difficulties, however. The EPA Manual states:

> A state agency can monitor the streams of the state to determine where surface water pollution is occurring and can place limits on discharges into these streams. A similarly direct monitoring and limitation of groundwater pollution is not possible. Groundwater pollution can occur almost anyplace, it can occur much more secretly, and measurement of its impact on groundwater is usually impossible within the time in which action must be taken to avoid permanent damage.

Thus, since it is extremely difficult to develop a monitoring system to detect groundwater pollution when it occurs (and, perhaps, even more hazardous to depend upon such a system), any potentially successfuly protection strategy will most likely be based upon the principle that"... the most effective method of groundwater quality control is protection from pollution." (p.I-55)

Although technical difficulties and an inadequate understanding of groundwater pollution processes and phenomna have plagued past efforts to develop a sound prevention strategy, the administrative design of such prevention measures is now much more viable due to a plethora of recent research. We now understand that designing a monitoring system fo r the diversity of the pollution sources requires a different set of approaches for each activity. Non-point agricultural sources, urban runoff and timber harvesting all have to be approached differently from such point source sites as; industrial waste impoundments, municipal landfills, and brine pits. The latter can be readily monitored once the terrain is surveyed, the groundwater flow charted, and well sites selected, The problem lies with the large number of such sites and the limited funds available for monitoring. Fortunately, industries are becoming more aware of the potential costs involved in a suit for damages resulting from groundwater contamination and are, hence, more likely to do some of their own monitoring.

But only a few of the largest industries have done any systematic monitoring (the SIA study of 130 industrial sites found only 9.7% had monitoring wells). Municipalities are less likely than industry to have monitoring wells (only 1.4% according to the SIA study). Agricultural sites had no monitoring wells at all.

Hazardous waste treatment and disposal sites are monitored more closely than anything else (17 RCRA sites are required to have groundwater monitoring. In addition, one permitted facility, the Pine Bluff Arsenal, is also required to have groundwater monitoring for two of its units; a landfill and a surface impoundment). The methodology of groundwater monitoring is quite clearly spelled out in the EPA Groundwater Monitoring Guidance manual (OMB No. 200-0423; 1/31/84). In this manual, owners of such facilities are told precisely what to monitor for, how to dig the necessary wells, how to obtain the necessary hydrological information to determine where to dig and the number of wells needed. Sampling methods, record keeping, and methods of determining the extent of contamination are all laid out.

While directed at Interim Status Facilities under RCRA, the manual contains information that could be of use to all industries that have reason to believe that their activities could have some effect on the quality of groundwater in their vicinity. Also, the monitoring principles could be easily adapted to municipal, agricultural, or any other large producer of waste products that is concerned with maintaining the quality of the groundwater.

Monitoring by itself can be of value through the information it provides and, hence, the protection of the public that can be a by-product of that information. However, since prevention of pollution is the agreed upon goal of most strategies, given the difficulties and expense of cleanup, then, monitoring by itself is not enough. A complete system may have to model the "cradel to grave" protection designed by EPA for hazardous waste, the main elements of which are as follows:

1. Siting criteria design.
2. A system of permits.
3. Compliance and enforcement mechanisms.
4. Emergency and remedial capability.
5. Local land use.

To be effective, such a system would involve monitoring (i.e., supervision and regulation) at every stage.

1. Siting Criteria

Under Activity 9 and 10 a series of reports were produced by the Wright-Pierce Firm of Topsham, Maine covering the siting of landfills, surface impoundments, and land application systems in the State of Arkansas. These guidelines, along with State and Federal regulations, are currently used in the permitting of hazardous waste sites in the state. To help in the site selection process, a series of maps were produced by Wright-Pierce which provide some guidance in finding appropriate geographic areas where these facilities could be sited safely according to the geologic structure of the underlying soils. The maps could also serve as guides for the siting of a wide range of other activities that could impact the groundwater.

2. Permits

Once a facility is in place, the main concern of a pollution control agency is the waste produced. The permitting process dovetails nicely into a system where the potential pollutant is easily detected and measured. The permit is granted with the expectation that effluent limitations will not be violated, monitoring devices are installed and the permit may be withdrawn if the standards are violated.

With groundwater contamination, the whole business becomes more complex. The effluent is not easily detected or monitored. Awareness of contamination may never happen unless someone's well is affected and the source is determined. Then, too, the problem may not be a dramatic confrontation with a plume of highly toxic waste, but a gradual increase in nitrate or sodium levels that ultimately affect only a small percentage of the population that is sensitive to higher levels.

Monitoring in the first case is covered adequately in the EPA Groundwater Monitoring Manual mentioned earlier. Wells are drilled around a suspected source and the area is sampled on a regular basis. In the second, the source may easily be in practices that are implicit in the agricultural activity of the people, nitrates, for example that are spread on the ground as part of the fertilization process may work their way downward into the drinking water. Those affected are not in a position to exert a great deal of political pressure and have only a marginal economic status. Their wells are not monitored at all, except for occasional surveys done by government or university personnel.

In the first case there is a clear and sueable violator and the permitting process described above is directly transferable. In the second, however, the entire community may be responsible to the extent that they are involved in agricultural activities and the entire community has to cooperate to protect the aquifer. For example, the states of Massachusetts and Vermont have suggested plans which involve entire communities in developing protection strategies for their water. Most of these strategies involve zoning laws which restrict the use and number of septic tanks, limit the application of fertilizers on some land and at certain times of the year, and restrict the number and location of feedlots. This approach to groundwater protection is specifically applicable to rural northwest and northcentral Arkansas where high nitrate levels have been detected in rural wells. This shifts the permitting and regulating burden to the local level.

Community protection of its water resources makes sense for all Arkansas communities. It is much easier to monitor and regulate surface activity than it is to clean up groundwater contamination after it has occured, whether it is a point-source discharge or a generalized, non-point contamination.

3. Compliance and Enforcement

If protection is the goal, enforcement is the problem in groundwater protection. While detection can be both difficult and expensive for point source discharges into the groundwater, at least once the problem is detected, responsibility can be ascribed. For non-point contamination, the fixing of responsibility can be impossible and, indeed, it may rest with the whole community. Hence, compliance and enforcement proceedings when they have been enacted at all, have been directed at point source contamination.

Voluntary compliance with advocated Best Management Practices have been the only lever by which non-point pollutors have been approached. Farmers and timber companies have responded to BMP requests according to their financial ability and their interest in the environment. So far, these programs have only indirectly been concerned with groundwater, and, since they have been all voluntary, there has been no enforcement. But, were compliance to be undertaken, the logic of having the local communities enact and enforce protection ordinances against non-point pollutors has much to recommend it. The local citizenry are, after all, the ones who are to drink the water they are protecting.

4. Emergency Response

Despite the best precautions, spills and other emergencies will occur, and, hence, some provision for responding to emergencies and providing for remedial action needs to be taken.

ADPC&E shares responsibility for responding to emergencies involving hazardous substances with the Health Department. Generally, this has meant that the Health Department treats those who have been exposed and has the responsibility of appraising the danger to public water sources from a hazardous waste emergency, notifying the public and monitoring the source, if necessary. ADPC&E monitors the cleaning up of the hazardous substance, or preventing it from spreading. Some attention has been paid to the idea that hazardous waste spills on the surface can percolate into the groundwater but the major concern has been with surface cleanup and containment. Decisions as to the potential impact on groundwater needs to be made for each spill and the recommended monitoring and/or groundwater restoration clearly defined. This is especially important for aquifer recharge areas.

5. Local Land Use

Monitoring in its broadest sense involves a whole range of activities on the surface since most surface activity involves, in some way, the quality of the water beneath the surface. So, too, is the case with surface water. Most surface water ultimately interfaces with groundwater, sometimes directly as in the case of losing streams that become part of the aquifer that it merges with or indirectly as when secondary streams enter major rivers which recharge alluvial aquifers. Monitoring of the surface water is, in that sense, a way of monitoring what goes into the ground.

The very nature of unconfined aquifers, thus, makes it imperative that a total environmental approach to preventing contamination be attained. Community involvement and public participation must be a key component. Some understanding of how vulnerable groundwater is and what steps need to be taken to protect it needs to be imparted to the public at large if sufficient cooperation is to be forthcoming.

To that end, the State of Massachusetts has put together a handbook called, "Groundwater Quality and Protection: A Guide for Local Officials" that in simple and forthright terms with ample use of illustrations describes the basic hydrology of unconfined aquifers and the measures that need to be taken to protect the water from contamination. It includes examples of zoning laws related to groundwater and lists towns that have enacted them. It also provides guidance through the maze of state and federal agencies that can aid local communities in protecting their groundwater.

A guide by itself, however, is of little use unless local communities are interested in protecting the quality of their water. The State of Vermont has addressed the problem of apathetic local communities by promoting the surface monitoring of what it calls "aquifer protection zones". These zones are in that area which roughly corresponds to the wells' area "radius of influence" or that area from which the well draws its water. In a way, it is a community extension of the old farm idea that you do not build your privy too close to your well.

Within that protection zone, no potential pollution source is allowed and septic tanks are limited to one per acre. The area can also be zoned for recreation, forestry or agricultural use. Only 19% of the groundwater systems statewide have attained this level of protection. Vermont's goal is to encourage as many municipal water suppliers as possible to attain this level of protection.

The goal in most states then has been focused on protecting drinking water drawn from the uppermost or unconfined aquifer. Many cities in Arkansas, however, have already been forced to drill deeper wells into confined, lower-level aquifers. In Arkansas, the Sparta Sand is the most important source of domestic water for much of the southern and eastern part of the state. Contamination of the alluvial or unconfined Quaternary aquifer is the usual cause of deeper drilling.

For these deeper, confined aquifers, monitoring can only be done by using deep wells as electronic resistivity tests will work only for an unconfined aquifer close to the surface. Thus far, there has been very little monitoring done as the expense of digging water quality monitoring wells for the lower aquifers has proved too great. Hence, we only find out about the problem with these aquifers after they have been contaminated.

Since the aquifers are far below the surface, and they are confined by relatively impermeable barriers, contamination from the surface usually will only impact directly on these aquifers in their recharge areas. However, contamination can reach the lower aquifer if the layers between the aquifers are pierced by unplugged, abandoned, or improperly constructed oil or irrigation wells, or by faults or cracks.

Similarly, contamination from saltwater or brine from the lower aquifer can be drawn upwards as pressure is lowered by excessive pumping of the upper aquifers. The combined affects of municipal, agricultural and industrial pumping out of the Quarternary and Sparta Sand aquifers have already caused concern about drinking water quality in some areas. Monitoring for trends toward higher sodium or TDS concentrations is one essential way to determine if pumping has exceeded safe yields - that maximum that can be pumped without causing excessive drawdowns in the wells which would in turn cause deterioration in water quality. Underground injection into the lower aquifer can cause cones of impression, increasing pressure and the possibility of upward movement. El Dorado is an area where there exists both an extensive cone of depression caused from public water supply withdrawals and cones of impression caused by injection wells in the area.

Connate water, seawater left behind and trapped in rock formations by changes in the earth's geology, can also penetrate fresh water layers through faults. The rate at which this happens can be affected by pumping. Such seems to be the case around Bald Knob in White County. Since intrusion by connate waters seems to occur along the dividing line between the Ozark Highlands and the Mississippi alluvium, it might be possible to monitor for it. At any rate, once detected in the freshwater aquifer, the connate plume should be monitored, its source tracked, and the possibility of grout injection, or other methods of halting its spread, should be implemented.

How to detect and track contamination in the lower aquifers before it appears in drinking or irrigation water wells, given the immensity of the expense involved in digging monitor wells, is the biggest problem in groundwater monitoring. USGS now has only twenty-six water quality monitoring wells. While the number of wells needed to monitor groundwater quality need not be as great as the number monitoring on the surface, twenty-six wells is far from sufficient. There are over 500 wells which are used as public drinking water sources and have chemical data sampled from them by the Health Department. This source is the best supply of quality data on the groundwater of Arkansas. Since, by the time contamination is detected it may be too late to protect the public, or save the aquifer as a drinking water source, some more effective method needs to be devised. A network of strategically placed monitoring wells upflow from municipal wells might help. Such wells could also serve to help guide communities in the drilling of new wells.

The most important aspect of groundwater monitoring, then, involves preventing potential surface pollutants from entering the groundwater, especially in recharge areas, and, secondly, preventing the intrusion of brine or seawater from polluted lower aquifers. To do that, a monitoring network which both looks at surface activity and water quality on a periodic basis needs to be established and maintained.

Because of the diversity of the activities involved, a measure of cooperation in sharing data, taking responsibility and enforcing required regulations.

would seem to be imperative. State and local agencies need to cooperate and share information along with federal agencies. Municipal water well monitoring data from the Health Department needs to be integrated with USGS data from their monitoring wells. Data from RCRA sites, University Cooperative Extension tests, and from private laboratories, all can add to the needed data base.

The greatest need in the development of a monitoring system is in the area of water quality. With the exception of the Health Department's monitoring of public drinking water supply system, water quality has not been the predominate concern of most of the monitoring that has gone on. USGS, for example, devotes most of its time to the measurement of water levels from over 400 monitor wells scattered about the state. The resulting potentiometric maps are of great use to farmers who wish to know the best place to drill a well. Farmers concerned with the quality of irrigation wells can turn to the University Extension System that will test their well for a small fee. While the information accumulated in the process can be of value, it cannot substitute for a systematic monitoring system.

A vital step in setting up a statewide systematic monitoring system would probably involve the introduction of some basic agreement on minimum standards for quality control and a basic set of parameters that all would test for. Similar standards for well construction, sampling frequency, number of sampling points, etc., would be needed. Consistent policies for the collecting and reporting of results would also seem necessary. Such a system would generate a large number of valuable pieces of information that would need storing in the manner recommended in Activity 6.

It is hard to estimate the expense of such a system. While greater quality control and an increase in the amount of sampling being done would certainly increase expenses, some advantages and savings should accrue from the centralization and standardization of the data collection process. David Miller of the consulting firm of Geraghty and Miller has estimated that monitoring systems can cost anywhere from $100,000 to $1,000,000 dollars depending on the needs and wishes of the state, the extent of industrialization, and the status of groundwater as an issue in the public mind.

Groundwater Specific Monitoring Proposal

In order to determine the extent to which groundwater quality criteria are being violated, extensive monitoring will be necessary. Presently, the majority of the groundwater monitoring in the state is being done by the Health Department which monitors public drinking supplies. Some irrigation wells are tested by the University of Arkansas Cooperative Extension Office on a demand basis. USGS monitors five of twenty-six wells on a yearly basis. About twenty industrial sites have groundwater monitoring systems set up according to RCRA requirements. Some twenty landfills are similarly equipped. The most dependable data on water quality is that generated by USGS, followed by that of the Health Department.

The result is that there are many gaps in the collection of groundwater quality data. These are:

1. Unmonitored geographic areas
2. Unmonitored aquifers
3. Unmonitored domestic and irrigation wells
4. Unmonitored contaminants
5. Unmonitored contamination sources

1. Unmonitored Geographic Areas

   To fill these gaps, monitoring wells would have to be drilled into those areas where there are no municipal wells. This would be especially important in such areas that are also recharge areas for aquifers that serve as drinking water sources and/or are up gradient from public water supplies.

2. Unmonitored Aquifers

   There are also neglected aquifers which could be but are not currently in use as drinking water supplies. Aquifers used only for domestic water supplies tend to be neglected. But, in an era of water scarcity, even aquifers that are not as productive as the major water supply sources, should not be overlooked. They and their users need monitoring and protection from contamination.

3. Unmonitored Domestic and Irrigation Wells

   If they are willing to pay the costs, farmers and domestic well users may have their drinking water and irrigation wells analyzed. Most do not unless there is some reason to believe that contamination exists. By then, it may be too late. Concern about well levels has resulted in a number of monitoring and safe withdrawal schemes in farm areas. Increasing salinization has also provoked studies. So far, no solutions for either problem have reached the implementation stage. It would seem that one natural solution to the problem would be to have the wells that are sampled for water levels be sampled for water quality, or at least those that are in or near critical areas. Drinking wells could be sampled at the same time.

Sampling for domestic wells not linked to irrigation farming would have to be tested according to the aquifer protection strategy in the area in which the well was located.

4. Unmonitored Contaminants

Contamination may now go unnoticed because no one looks for it. The most dramatic illustration is with the many new organic chemicals that have been developed since World War II. Of special concern has been the so-called "volatile organic chemicals (VOCs)". One of these VOCs, trichloroethylene, has been of particular concern. Widely used as an industrial and dry cleaning solvent, TCE has caused major contamination in a variety of cities. According to ADPC&E records, 294,094 lbs. of TCE was generated in Arkansas in 1982. Some 3 million lbs. of halogenated solvents including sludges and still bottoms were manifested as being transported in the state.

According to Federal drinking water standards, Arkansas must scan municipal wells for trihalomethanes, but is not required to look specifically for TCE. TCE and other VOCs may be added to the Federal standards in the near future.

New pesticides are also not included, although the older now banned pesticides, such as DDT, are. Some toxic pesticides in use in Arkansas like Aldicarb have never been monitored in the state. Because nitrates are not harmful to most crops, the UA Cooperative Extension Service does not monitor farm samples brought to it for this parameter, even though high nitrates can contaminate domestic wells.

In addition to specific potential contaminants that go unmonitored, there are some major unmonitored potential sources of groundwater contamination. These are surface impoundments and underground storage tanks.

5. Unmonitored Contamination Sources

There are some 7,000 surface impoundments in the state, most of which contain brine brought up with oil pumping operations. Although state regulations now require linings under these pits and that they be used mainly as backup for underground injection wells, many still remain from the unregulated period and are not lined.

No one knows how many underground storage tanks there are in Arkansas. Most farms, and many factories have their own gas tanks and chemical tanks, in addition to the thousands of service stations that cover the state. Leaks from such tanks have threatened water supplies in several Arkansas towns.

Large storage tanks and major impoundments could be monitored in sensitive areas by the state in the same manner that RCRA industrial sites and landfills are monitored. However, most of them would have to become the responsibility of local governments as part of their local water supply protection programs to be developed with the aid of the state.

The Underground Injection Control Program (UIC) is relatively new. The inspection, permitting, and program coordination has just been worked out. Thus far, the program calls for the periodic inspection of the mechanical integrity of the injection wells, the recording of the volume and content of what is injected and the pressures maintained in the course of injection. Not all categories of wells have been inspected.

Monitoring needs in this program are currently under review by the Federal government and new groundwater monitoring requirements may be established.

Similar problems can be found in the RCRA monitoring program. Only a small percentage of sites have a groundwater monitoring system. Expansion of this program to cover only the bigger and potentially hazardous sites would cost much money.

Mines, both abandoned and active also do not maintain adequate groundwater monitoring.

COSTS

The costs of such a program are almost impossible to estimate. As it is now, the costs are being born by several agencies most of which are mentioned above.

Specific Recommendations - (Listed in order of priority.)

1. That monitoring systems be developed for cities using groundwater for public water supply. That this system involve the placement of monitoring wells updip from the wells currently in use so that contamination may be detected before the public supply is affected. That the cities be selected according to need and number of people served.

2. That area-wide protection systems be established on a basis of need and use similar to that devised by the State of Idaho, (cf., A Proposed Groundwater Quality Monitoring Network for Idaho, USGS Open-File Report, 79-1477).

3. For smaller communities and rural domestic users, it is recommended that the department set up an aquifer protection program that would involve public officials and citizens in a program to help them protect their own underground water supplies. This would involve the development of a hand book for public officials, training courses, and other educational materials to aid in making communities more aware of the need to involve themselves in groundwater protection. State personnel would be trained as teachers and advisors.

4. That special attention be given by the state and the federal government in protecting recharge areas of aquifers that are extensively used for public drinking water sources, in this state and neighboring states. This may require a special permitting and licensing arrangement for such critically important recharge areas. Activities which might result in damage to the water might be managed differently. Landfills, storage tanks, and industries using or generating hazardous materials would be given careful scrutiny before being permitted to operate. Since land use and zoning legislation may be required in especially sensitive areas, local and county governments would need to be involved in the overall planning for the protection of such areas.

5. That all surface impoundments assessed with a hazardous rating above 15 and on sites not already monitored under RCRA or Superfund, be monitored for groundwater contamination.

6. That a groundwater monitoring handbook for local officials on groundwater protection be developed.

ELEMENTS OF AN ARKANSAS STATE GROUNDWATER STRATEGY
Activity 8

1. Groundwater in Federal and State Law

No comprehensive federal groundwater law exists comparable to the legislation covering surface water or ocean pollution. This may reflect a federal view that groundwater quality problems are susceptible to local or state resolution and do not affect "interstate commerce" as directly as do surface waters. Federal measures for the control of groundwater pollution are scattered through several different laws that are not primarily concerned with groundwater. These are:

Clean Water Act of 1977 - congressionally delegated authority to the U.S. Environmental Protection Agency over surface water and groundwater; however, the scope of EPA authority over groundwater pollution has been ambiguous - partly because of the phrasing of Section 309 which refers to "navigable waters" - limiting its applicability to groundwater;

Safe Drinking Water Act of 1974 - protects groundwater through its Underground Injection Control Program; sets limits on some substances that may occur in public water supplies;

Section 1424(e) The Gonzales Amendment

Provides state agencies with a legal mechanism to protect the recharge zones of special or "sole source" aquifers. In such areas, federally - assisted projects which are found to endanger the quality of the water as set forth in the maximum contaminant levels set by the Safe Drinking Water Act, could have their funding halted by EPA.

Once designated as a "sole source" aquifer, then section 3004 and 4002 of the Resource Recovery and Conservation Act (1976) comes into play which allows state agencies to prohibit facilities in the recharge areas, require a leachate monitoring system, design specification for landfills, surface impoundments, basin and land farms. Thus giving the state legal support in restricting severely or prohibiting waste facilities within the recharge zone;

Resource Conservation and Recovery Act of 1976 (RCRA) - through which the EPA recently promulgated approximately 2,000 pages of regulations involving the classification, handling, testing, and disposal of hazardous substances. It sets standards for the construction and monitoring of RCRA sites, including the digging of monitoring wells;

Toxic Substances Control Act of 1976 (TSCA) - which overlaps with RCRA in some respects, also deals with toxic substances, particularly polychlorinated biphenyls (PCBs); and

Surface Mining Control and Reclamation Act of 1977 - which deals with the release and disposal of mine water.

National Environmental Policy Act - forces consideration of the effects of federal action on groundwater in the writing of environmental impact statements. The federal reservation of water rights doctrine has been expanded to include groundwaters (1 Harv. Env. L. Rev. 173). In Cappaert v. United States (426 U. S. 128, 1976), the U. S. Supreme Court held that "since the implied reservation-of-water doctrine is based on the necessity of water for the purpose of the federal reservation....the United States can protect its water from subsequent diversity, whether the diversion is of surface or groundwater." The court cited no cases to support this holding, relying instead on two National Water Commission publications and simple logic.

In August of 1984, EPA released its long awaited groundwater protection stragegy. Consistent with its past pronouncements on groundwater, EPA's current stragegy lays the burden in protection on the states. It calls upon them to build their groundwater programs using existing appropriations. New funds are to be used mainly for "information gathering and planning," with implementation reserved for those states who have completed their basic planning.

To assist the states, EPA established an office of groundwater to coordinate programs. New regulations concerning the formerly unregulated underground storage tanks and surface impoundments will be promulgated along with further specifications for the protection and cleanup of aquifers.

The EPA strategy suggests that aquifers will be protected according to their "highest and best use", according to three classifications:

1. Special aquifers -- those that are vulnerable to surface contamination, i.e. karst formations, sand and gravel aquifers. Those that are defined as ecologically vital, irreplaceable, or essential to the public.

2. Drinking water sources - currently used or potential sources.

3. All other aquifers.

This system was utilized in the classification established in Activity 5.

Special aquifers should receive special attention; i.e., Superfund sites over special aquifers will be cleaned up first, more stringent regulations for the storage, and disposal of chemicals will be applied over special aquifers, and special casing will be needed for disposal wells that are drilled through them. Further rules for land applications of nutrients and for new facilities over these aquifers will be applied.

Drinking water sources will have the same protections now in place. If a contaminant enters an aquifer used as a source of drinking water, it will be cleaned up with the best available technology, or, if that is not possible, the contaminant plume will be managed and confined.

Aquifers too salty or otherwise deteriorated to be used as drinking water sources will be managed so that as little contamination as possible escapes from them into cleaner aquifers that are or could be used as drinking water.

EPA's has promised to develop a strategy for groundwater monitoring to be released in the near future.

EPA also promised that landfills, surface impoundments, and leaking storage tanks would be given special attention through programs designed to study the threat to groundwater presented by these sources of contamination. The first study which is to deal with leaking underground storage tanks is already underway
under the direction of the Office of Pesticides and Toxic Substances (OPTS).

Most of the actions to be taken by EPA involve the further use of existing regulations listed above, such as; FIFRA, the Federal Insecticide, Fungicide, and Rodenticide Act, which will be used to control pesticides that may leach into the groundwater, TSCA, the Toxic Substances Control Act, which will be used to regulate new chemicals.

2. Groundwater in State Law

The power of the state governments to take measures necessary to protect groundwater through zoning laws and eminent domain jurisdiction have been consistently upheld by the Federal Courts. In a Florida case involving the right of the state to impose minimum lot sizes to limit the number of houses built over a vital recharge area, the court held that "the inclusion of ecological considerations as a legitimate objective of zoning ordinances....is long overdue" and held "that preservation of the ecological balance....is a valid exercise of public power...."

The courts have also held eminent domain rights of the state and municipalities over riparian rights of individuals when environmental protection is at issue. States and individuals have had increasing success in holding polluters responsible for damage done to groundwater. Examples of the above cases are too numerous to list here but an excellent summary prepared by Geraghty and Miller is on file at ADPC&E.

Two other cases have enormous implications for Arkansas in its relationship with water scarce states on its borders. In disputes between Texas and New Mexico and between Nebraska and Utah, groundwater was defined as subject to the provisions of the interstate commerce provisions of Federal law and therefore not subject to state laws banning the export of water. But, in neither case have environmental questions been at issue.

Hence, the general thrust of the courts has been to allow the states to protect their environment and to seek equity from polluters but not to treat water differently from other resources shipped out of state.

Groundwaters are generally subject to the same treatment as that given to watercourses and it follows that the Arkansas positions, with respect to groundwaters, conforms to the riparian doctrine. Therefore, groundwaters also come within the framework of the reasonable use theory as applied to watercourses. Disputes over water have generally been decided according to a reasonable use test which allows each owner to use the water for his own purposes having due regard for the effect of that use upon other riparian owners and on the public in general.

The following criteria test the "reasonableness" of a given use:

1. The purpose of the use must be lawful and beneficial to the user and suitable to the stream involved;

2. The social utility of a proposed or existing use should be considered;

3. Use of the water must be made on riparian land (used by the riparian owner on land adjacent to the stream or lake);

4. The quantity of water diverted to the exclusive use of the riparian user must be viewed in light of the total flow;

5. The use must not pollute the water so as to significantly harm lower riparian users;

6. The manner of flow must not be appreciably altered.

Specifically, the Arkansas Supreme Court has declared the following general rules and principles with regard to the reasonable use of water which is subject to riparian rights:

a. The right to use water for strictly domestic purposes -- such as for household use -- is superior to many other uses of water -- such as for fishing, recreation and irrigation.

b. Other than the use mentioned above, all other lawful uses of water are equal. (Some recognized lawful uses are fishing, recreation and irrigation.)

c. When one lawful use of water is destroyed by another lawful use, the latter use must yield or it may be enjoined.

d. When one lawful use of water interferes with or detracts from another use, than a question arises as to whether, under all the facts and circumstances of that particular case, the interfering use shall be declared unreasonable and, as such, enjoined, or whether a reasonable and equitable adjustment should be made having due regard to the reasonable rights of each. Where different lawful and reasonable uses are inherently mutually exclusive, the prior in time will prevail and the latter must cease.

3. <u>Case Law</u>

A leading case which deals with questions of groundwater use, <u>Jones V.</u>

OZ-Ark-Val Poultry Company, 228 Ark. 76,306 S.W. 2d 111, 1957, was a case of conflict between the industrial use of groundwater and domestic wells. The Court held that industry interference with the groundwater was unreasonable and an injunction was issued to prevent excessive pumping by the industrial users. The Court applied the "reasonable use doctrine" to resolve the conflict. The Court recognized that under our law, the domestic purposes of groundwater purposes prevail. The Court further stated that, where two or more tracts of separately-owned land join with a common underground reservoir, each owner has common and correlative right to the use of the water on his land if the common supply is sufficient. However, if the supply is limited and one use interferes with another use, then each person is limited to a reasonable share in order not to hamper the use of the other party.

The Arkansas Supreme Court has not rigidly defined reasonable use. The Court has ruled "that we are not necessarily adopting all the interpretations given it by the decisions of other states, and that our own interpretation will be developed in the future as occasions arise. Harris vs. Brooks, 225 Ark. 436, 283 S.W. 2d 129 (1955). Clearly, the definition of reasonable use is evolving as the court addresses more complex water problems. The court recently reversed a previous ruling requiring riparian owners to use water on riparian lands and demonstrated a willingness to adapt to changing needs. In Lingo vs. the City of Jacksonville, 258 Ark. 63, 522 S.W. 2d 403, 1975, the court ruled that the city of Jacksonville could legally buy land, drill wells, remove the water to a distant point and sell it to its customers. The Arkansas high court has consistently tried to guarantee maximum beneficial use of the State's water resources. The court concludes:

> "In all our consideration of the reasonable use theory, as we have attempted to explain it, we have accepted the view that the benefits accruing to society in general from a maximum utilization of our water resources should not be denied merely because of the difficulties which may arise in its application." Harris vs. Brooks, 225 Ark. 436, 283 S.W. 2d 129, 1966.

Domestic use is preferred over other uses of ground and surface water. In times of scarcity, surface water use is allowed in the following order: (1) sustaining life, (2) maintaining health and (3) increasing wealth. The correlative rights rule (giving overlying owners a proportionate or prorated share) governs groundwater use during times of scarcity.

The courts decide which uses are reasonable or unreasonable on a case by case basis as conflicts arise. The Arkansas high court has modified the common law on several occasions in order to allow maximum beneficial use of the state's water resources and seems willing to make further changes as needed.

To summarize, Arkansas water law is based on a riparian/reasonable use rule for both surface and groundwater (whether percolating or flowing). Riparian owners are allowed to make reasonable beneficial use of the water "with due regard to the rights of others similarly situated".

Legislation and Regulations

A. Arkansas Department of Pollution Control and Ecology.

1. Act 472 of 1949 as amended; Arkansas Water and Air Pollution Control Act

   Under the authority of Act 472 of 1949, the ADPC&E has broad powers of regulation and enforcement over "waters of the state", both "surface and underground". Hence, it follows that all the kinds of monitoring, classifying and regulating that have been done for surface water, can be done for groundwaters (given, of course, the physical limitation imposed by geology).

2. Regulation #1, ADPC&E November 1, 1958 and Order 1-58, October 13, 1958 and Order 1-59, June 29, 1959.
   For the Prevention of Pollution by Saltwater and Other Field Wastes Produced by Oil and Gas Wells.

   This attempted to prevent brine from the oil fields from polluting the "waters of the state". Provided for underground injection wherever possible and outlawed holding ponds over porous or gravel soils. Supplemented by SDWA's UIC Program.

3. Regulation #2, ADPC&E as amended, November, 1984
   Arkansas Water Quality Standards

   Deals primarily with surface water. However, the courts have ruled that where there is a significant hydrological connection between ground and surface waters, existing surface water standards apply to the groundwater. Also, since many Arkansas streams are composed of seepage from groundwater during periods of low flow, the standards are currently being applied to what is primarily groundwater.

4. Regulation #3, Underground Injection Control Code, March 1982.

   Adopts, by reference, most of the Federal regulations dealing with the construction and control of injection wells.

5. Surface Mining Act, Act 134 of 1979 as amended by Act 647 of 1979.

   The program, in regard to groundwater, consists of a permit system which would allow for the assessment of the effect a mining activity might have on the groundwater resources, either quality or quantity.

6. The Arkansas Open Cut Land Reclamation Act, Act 336 of 1977, as amended by Act 824.

   Regulates reclamation of land disturbed by open cut mining; requires a permit for open cut mining.

7. Arkansas Solid Waste Management Act, Act 237 of 1971

Requires proper and permitted disposal of solid waste; requires all municipalities to develop solid waste management plans; authorizes county courts to provide solid waste management systems.

B. Arkansas Soil and Water Conservation Commission

1. Act 217 of 1969 authorized the Commission to develop the Arkansas State Water Plan that would serve as the state water policy for the development of water and related land resources in the state of Arkansas. All reports, studies and related planning activities were required to take the State Water Plan into consideration. In 1975, the first State Water Plan was published. In 1980, work on revising the 1975 plan began.

2. Act 1051 of 1985 outlined many variables that needed to be quantified or delineated and included in the State Water Plan, expected to be released by mid 1986. Some requirements of the Act were: (a) current and projected needs of public water supplies, industry and agriculture, (b) define and quantify the safe yield of all streams, reservoirs and aquifers, (c) quantify requirements of fish and wildlife, navigation, riparian rights and minimum stream flows. In addition, the act authorized interbasin transfer and non riparian use contingent upon guideline development by the Commission and required all groundwater users to report the quantity of groundwater withdrawn on an annual basis. The Commission will now collect and compile of groundwater use data in addition to surface water use data and surface water allocation that was authorized by Act 180 of 1969.

3. Act 417 of 1985 will provide incentives for construction of surface reservoirs in the form of a state tax credit not to exceed 50% of the total construction cost or $30,000 over a 10 year period. Any applicant that converts to surface water from groundwater sources may receive a tax credit equal to 10% of the total conversion cost. Persons seeking eligibility for the tax breaks must apply to Arkansas Soil and Water Conservation Commission for evaluation and acceptance.

C. Arkansas Geological Commission - Act 16 of 1963, charges the Commission with the collection and dissemination of data regarding water and other natural resources. This Act also specifically states that the Commission will engage in cooperative agreements with the U.S. Geological Survey to perform investigations concerning water resources, which includes quantitative and qualitative analysis of groundwater.

D. Arkansas Oil and Gas Commission - Act 105 of 1939.

This program consists of a permitting system for the underground injection of any industrial waste into existing aquifers. The permits are considered on a case by case basis in regard to means and level of injection, quality of water injected, use of groundwater in area, etc. An informal agreement exists between this Commission and the Department of Pollution Control and Ecology which indicates the Commission will deal with all impacts from the well head down and the Department of Pollution Control and Ecology will deal with problems related to surface water pollution (this in carrying out of the Department Reg. #1). The Department of Pollution Control and Ecology will, in instances of hazardous waste inspections, work with potential subsurface impacts.

E. Arkansas Health Department - Act 402 of 1977.

The program pertains primarily to the permit of waste treatment systems for individual dwellings, with limitations being the quantity of wastewater treated. Permits are considered on a case by case basis, with the exception being that certain requirements are particularly applied to certain areas of the State to protect groundwater sources specifically. The Department has authority to prevent and/or stop groundwater contamination sources by declaring them "public health nuisances." The Department is also authorized by Act 71 of 1973 to control septic tank pumpers and the disposal of said sludge. Septic tank installers are also permitted by the Health Department. The Department not only considers septic tanks but any accepted method of waste treatment. Numerous alternatives are available and considered by the Health Department whenever physical conditions and economic justifications warrant.

F. University of Arkansas - Act 737 of 1977, calls for septic tank research funds to be appropriated for research to be conducted on septic tanks design at the University's Agricultural Experiment Farms. This work is ongoing and is currently funded as a line item in the University's budget.

G. Water Well Construction Committee - Act 641 of 1969 as amended by Act 783 of 1985 gave the Committee the authority to issue water well drillers contractors licenses, registration and rig permits. The Committee insures that proper construction and abandonment standards are followed and investigates complaints against drillers. The Committee maintains files on completion reports submitted by drillers. Act 822 of 1985 extended authority of the Committee to include wells drilled for the purpose of obtaining or exchanging thermal energy for use in groundwater source air conditioning and heat pump systems.

Recommendations

Sufficient authority exists under the current statutes to regulate groundwater quality to at least the extent to which surface water is now being regulated. Additional funding may be required if an expanded groundwater program is to develop.

Most states maintain both a structural and theoretical separation between the parts of government that deal with quality issues and those that deal with quantity. Arkansas is no different in this respect. Legislative measures directed towards the water supply problem have been closely associated with the Arkansas Soil and Water Conservation Commission. Quality issues have been given under Act 472 to the ADPC&E. Despite this legal situation the two issues are joined in nature, as has been amply demonstrated in the problems section of this document, and, hence cooperation between the two agencies has been necessary.

For example, the groundwater strategy has been coordinated with all agencies involved with groundwater through the Technical Steering Committee developed through Activity #1. Other areas of overlapping concern and jurisdiction have been worked out through informal meetings where cooperation has been stressed and duplication avoided. MOU's detailing the functions of each agency in areas where quantity and quality issues are involved may be necessary.

In addition to the recommendations made above, the following are courses that could be considered.

1. The establishment of a tax on groundwater users to pay for hydrologic and other studies that may be necessary to protect groundwater.

2. The introduction of state supported PALS (Protective Alert Levels) levels below the maximum contaminant levels established by EPA which could be used as a basis to trigger an alterting mechanism what would allow the state to take measures before contaminant levels become dangerous.

3. Many interagency agreements and MOU's are needed to coordinate the use of groundwater data and to establish monitoring responsibilities. Inter-agency cooperation could result in considerable savings to the taxpayers to the extent such cooperation resulted in the more efficient use of labor, space and equipment.

4. The establishment of a water conservation and protection curriculum in the schools.

MANAGING GROUNDWATER AT THE LOCAL LEVEL

TASK 8 and 12

As has been emphasized throughout this report, prevention of groundwater contamination is the wisest policy in most cases. Whenever local communities have had to try to clean up contaminated wells, they have found the operation to be difficult and very expensive. Hence, many have chosen to focus on preventative measures available through existing local authorities. Currently, local governments have the authority to protect their groundwaters through:

1. Zoning
2. General Bylaws or Ordinances
3. Subdivision Regulations
4. Board of Health Regulations
5. Wetlands Bylaws
6. Local Input into State and Federal Programs

The table below compares the procedural requirements and is followed by a discussion of each.

	Statutory Authority	Who Adopts	Required Vote
Zoning	Amendment 55 (Arkansas Legislative Code #173801)	County Quorum Court City Council Town Council	Majority vote 2/3rds vote of all members city/town council.
Local By-law		County Quorumm Court City/Town Council	Majority vote of all members city/town council and majority vote of town meeting unless otherwise provided by ordinance, by-laws or chapter.
Subdivision Rules and Regulations	Arkansas Legislative Code #173801	County Planning City/Town Council	Majority vote of entire membership.

<u>Zoning</u>

Deriving from the police power vested by the state's consititution, zoning has long been used as a means for communities to manage growth, Towns may enact zoning restrictions protecting local groundwaters for the following purposes: to conserve health, to prevent overcrowding of land, to facilitate the adequate provision of water, and for various other environmentally-related goals provided their is no conflict with Federal and State authorities.

Since zoning is a means of regulating land use, any regulation placed upon land may be looked upon by the landowner as a "taking" of one of his property rights. In such challenges, the courts look at the positive value of the community at large versus the loss of the particular use of the land to the individual. When an ordinance goes beyond the scope of just limiting uses and into the deprivation of property without just compensation, the court would rule in favor of a landowner. However, a bylaw which has gone through the democratic voting process will generally be upheld unless the party bringing suite can establish the burden of proof necessary against the bylaw.

Zoning to protect ground and surface waters has been more common in the dry, arid western states until recently when years of lower rainfall coupled with groundwater contamination has limited community water supply and towns have begun passing bylaws.

Elsewhere the most prevalent zoning approach prevents contaminants from getting into water supplies by regulating activities and land uses which might generate contaminants in the area that feeds or recharges the underground water supply. The other approach permits all uses as long as they meet specified performance standards, e.g., discharges do not exceed specified water quality standards.

The system is similar to a stream feeding into a lake. There is no way to keep the lake free from contaminants if someone continues to discharge contaminants into the stream. Thus, the "aquifer recharge" area is one of the most critical areas to protect as it is the source of an aquifer's water.

Recommendation for Zoning Ordinances

Groundwater or aquifer protection zones/districts should be added to the zoning ordinances of cities and towns. These bylaws are usually some type of "protection district", either Aquifer Recharge, Groundwater, Water Supply, Water Resource, Watershed, etc.. Occasionally, groundwater concerns are incorporated into wetland overlay districts. Commonly, these zoning ordinances are prepared as "overlay districts", areas superimposed on the existing zoning map with provision that the rules of the underlying district continue except where overlaying district is more stringent.

Most zoning ordinances regulate uses and activities, and several also rely heavily on performance standards. Some towns only list prohibited uses, with the remaining uses subject to zoning in the underlying district. Others only list permitted uses with specific requirements attached to those uses. Most of the others also include a special permit, either for listed uses or in order to receive an exemption from the prohibited uses or added requirements.

There is little consensus on which local board should be responsible for plan review and approval, special permits and enforcement, or, even whether it should
be at the town or county level. Town and county agencies used include the Board of Health, Building Inspectors, Conservation Commission, Fire Chief and, most frequently, the Planning Board. Some towns require a site plan to be submitted with the permit application, and also require a listing of hazardous and toxic materials and their use, septic system approval and certification of underground storage tanks.

Aside from solid waste disposal, towns differ on whether a use should be prohibited or allowed with a special permit. The types of zones protected also vary from a radius around a municipal well to an entire watershed feeding a reservoir or a well field. This difference in the breadth of area protected could account for the choice of a special permit requirement rather than a prohibited use. Generally, the most narrowly defined protection zones (i.e., those immediately surrounding the well zone) are more strictly regulated than the broader watershed protection zones. Furthermore, towns with more than one zone will often prohibit a use in the aquifer zone but issue a special permit in another zone. Similarly, uses requiring a special permit in the aquifer zone may be allowed in another zone.

For those towns issuing special permits for certain uses or as exemptions, criteria for granting special permits generally address the quality and quantity of the water resources. The concerns are both to perpetuate the recharge, thereby maintaining the groundwater yield, and to prevent degradation of the water quality. Some use drinking water standards and others use the current water quality as the measure.

Thus, while there are many different approaches that local governments can use in adopting zoning bylaws, there is much consensus. Most use overlay districts and supplementary written descriptions to identify the area. There is general agreement that hazardous and toxic materials, petroleum products, waste disposal, septic systems, excavation, construction of impervious surfaces and, in certain communities, agricultural uses are potential sources of groundwater contamination and need to be regulated within these districts. The variation in bylaws is most evident in the specifics: whether or not to allow uses which <u>generate</u> hazardous wastes (as opposed to manufacture, storage, use, etc.); how much and what type of discharges to allow in septic systems; what depth above high groundwater level to allow sand and gravel extraction and which town agency should administer and/or enforce the regulations.

A second zoning approach used by a number of towns has been to institute large lot zoning of water supply protection and other conservation purposes. Several of these zoning ordinances have been tested in court. A bylaw allowing only two-acre lots was upheld on the grounds of protection of public health because each lot had to have a well and septic system. The relationship between the bylaw and water supply was clear. In another case in the court would not allow 2.5 acre zoning because the town wanted to keep the land in its natural state. To use large lot zoning for groundwater protection, the relationship between the bylaw and the protection of health, safety and general welfare must be clear.

Thus, both good technical information on groundwater location and flow direction in the town and a clear relationship between the bylaw provision and water supply are essential to a strong bylaw which will hold up if tested in court.

<u>Specific Recommendations for Arkansas Local Governments</u>

Since potential sources of contamination are too many and varied for any state agency to handle by itself, local participation aimed at protecting local sources of groundwater to be used for drinking, irrigation, industrial and municipal uses is essential to the success of any groundwater protection strategy.

This has even more significance in communities located over special aquifers that once contaminated are irreplacable, or, are essential to the community that has no alternative source of surface water. This situation exists in most of the communities of southern and eastern Arkansas. They are 100% dependent on groundwater for drinking water and 85% dependent on it as a source of irrigation. No uncontaminated sources of surface water are available. The state agency needs to contact these communities and involve them in the protection of their water. We intend to begin with the education process to convince people that what is proposed is in their best interests. If they are involved in the planning they will know the reasons for groundwater protection activity.

To do the job right, the state needs the funds to implement the coordinating activities that will be necessary if the strategy is to succeed. Local geologic situations will have to be studied. Monitoring sites, special protection zones, and water needs assessments will have to be made. All this technical data will have to be translated into language that the citizenery can understand.

Local governments are the only units qualified to invoke and enforce building codes in aquifer recharge areas, to limit paving to avoid interfering with the recharge process, and generally look after the area's natural vegetation.

While the State Board of Health generally supervises septic tanks in the state, there is room for local initiative in the management of septic tank cleaning and maintainance programs.

But, in order to do any of the above, local governments have to be convinced that the expenditure of time and monies is necessary. Then, once convinced that groundwater protection is a good and necessary activity, technical help in setting up ordinances and programs, in doing geological surveys, and generally explaining the hows and whys of groundwater protection, has to be made available on an ongoing basis.

Budget

1. Public Relations II..........................
2. Planner III..................................
3. Geologist....................................
4. One Secretary................................

Proposal

Request funds to develop and publish a manual on "Groundwater Quality: Protecting Local Supplies" to act as a guide for local officials. Funds would be needed to research, write and publish the manual. It would then be used by the team previously described whose function would be to convince local officials of the need to protect their water supply and offer guidance as how that could best be done.

Researcher/writer...............................
Printing Costs..................................
Lay out/photography.............................

OPTIONAL MANAGEMENT STRATEGIES

Task 12

Under Task 8 concerning state and federal legislation it was found that ADPC&E has sufficient authority under existing statutes to install practically any program to protect groundwater that it can get funding for. The Federal government has funded several source-specific programs, such as RCRA, the UIC program, and Superfund, all of which have had some bearing on groundwater protection. Any state strategy that is recommended must take these programs into consideration and build upon them.

Within that general framework, numerous approaches have been tried. New Jersey emphasizes the permitting of discharges into the groundwater. Connecticut has a well-defined groundwater classification system. Arizona emphasizes groundwater use management. Vermont established aquifer protection zones around every municipal well. No one approach seems to work any better than another. Each state seems to have to work out its own approach based on its own particular needs, problems, and goals.

However, certain guiding concepts have emerged that seem to encompass the framework for a successful groundwater protection strategy. These are:

> What happens on the land surface may determine groundwater quality. Most sources of groundwater pollution, including those caused by overdraft are not controlled by Federal and State regulatory programs.
>
> Traditional approaches to groundwater protection have involved management of individual pollution sources through permitting and enforcement programs. This fails to recognize the broad range of "nonpoint" sources causing groundwater pollution and the irreversibility of contamination once it occurs.
>
> Current trend is toward preventive programs aimed at protection of critical recharge areas through controls over land use and human activities.
>
> Recognition of different aquifer uses and the fact that not all aquifers are of equal value are key policies underlying realistic groundwater protection programs. Anti-degradation policies can be a stumbling block.
>
> Protection involves regulation of groundwater as a resource at state and local levels. This requires changing rules of water rights (e.g., groundwater is a "water of the state," not the overlying property owner's).
>
> Groundwater protection requires coordinated management of surface and groundwater resources.
>
> Controlled degradation and plume management may be more cost effective than statewide enforcement of strict groundwater standards. Recognition of existing degraded areas justifies more stringent controls in high-quality, high-yield or sole-source aquifers.

Some problems are regional in scope and will therefore require interstate cooperation for resolution as some aquifers underly several states. Recharge areas, also, do not respect state boundaries. Regional and Federal cooperation is needed to address these areas.

A strategy that is designed to deal with the broad range of non-point pollution sources must enlist the support of a wide range of businessmen, industrialists, farmers, consumers and politicians who must be aware of which aquifer needs protecting, how to protect it, and what their role in its protection is.

In that sense, the role of local governments seems vital to a successful groundwater strategy for it is at the local level that the citizen is faced directly with threats to his drinking and irrigation water. Hence, local programs need to be encouraged to do the following:

> Local governments may wield greatest power in protection programs. Local authority extends to any land use or activity that can be seen to threaten public health, safety, and welfare by impairment of groundwater quality.
>
> Land-use zoning may require minimum residential lot sizes of 1 to 4 acres to protect groundwater from nitrate released by septic systems and lawn fertilizers in humid regions.
>
> "Overlay" zoning may be used to impose performance, standards, prohibitions of certain activities and water quality impact analyses on development in recharge areas without changing underlying zoned uses.
>
> Zoning affects only future uses of land. County and local ordinances and health regulations have no grandfather clauses, and control existing uses.
>
> Local ordinances actually in place in other states require registration of storage facilities for all quantities of toxic and hazardous materials, testing and replacement of underground gasoline storage tanks, and bans on consumer products containing toxic and hazardous materials.
>
> Efforts to accommodate industrial development without jeopardizing groundwater quality lead to direct involvement of local authorities in plant management and housekeeping practices. Local requirements typically exceed State and Federal programs in scope and stringency.

It was toward the end of interagency coordination and cooperation within the general goal of protection of groundwater resources that the groundwater strategy steering committee was created. Each agency has their own perspective on groundwater problems and their own data files which relate to that perspective. The Health Department has a wealth of chemical data on the quality of municipal water supplies and a set of standards that each supplier is required to maintain. The University Cooperative Extension tests farm irrigation wells and has a wealth of chemical data from samples submitted through county agents. USGS has its own network of wells that it monitors for quality and quantity and has its own network of wells that it monitors for quality and quantity and stores its data into its own WATSTORE computer and into EPA's STORET system. The need to pull these reports together to give as comprehensive a view of underground water quality was the motivation for Activity #6 which developed a data management strategy.

There are also other areas where cooperation provided not only better perspectives on problems but more defined and coherent mechanisms for dealing with problems. Thus, for example, the State Water Plan now being drawn up by the Soil and Water Commission has a groundwater component that will be coordinated with the groundwater strategy. Soil and Water's traditional concern with water use overlaps with and affects ADPC&E and the Health Department's concerns with quality. Legislative plans for developing a state Water Code incorporated all three perspectives, and Activity #4, which called for an assessment of the state's groundwater contamination problems, contracted by USGS, also involved the cooperation of all these agencies.

Other states are also moving towards such cooperation and coordination. New Jersey, for example, has developed an Integrated Groundwater Monitoring strategy, that will coordinate scattered monitoring programs to both assess groundwater quality and track compliance in their permitting program. New York has developed a cooperative problem prevention strategy for groundwater management to be jointly sponsored and coordinated by the New York Department of Environmental Conservation and the New York State Department of Health.

Some states have experimented with the consolidation of power and responsibility for specific functions within one agency. New Mexico has placed its groundwater protection policy in the New Mexico Environmental Improvement Division while the State Engineer's Office has authority over water rights, both ground and surface water, water development, and protection of the state's waters from over-use or contamination. Activities of the two offices are coordinated through the New Mexico Water Quality Control Commission. Colorado has a similar system except the responsibility of administering water rights is shared with seven district water judges throughout the state. In Kansas, water planning is centralized in the newly created Kansas Water Office. Texas had placed its data collection, planning and surface water allocation authorities in its Department of Water Resources, but has recently decentralized some of these functions.

Whatever direction Arkansas chooses, it is certain that some contingency planning needs to be done in advance. Other states can offer some guidance in such planning. Indeed, such planning may soon begin.

Act 1003 of the 1985 session was passed to authorize the Joint Interim Committee on Agriculture and Economic Development to conduct a study on the management, regulation and use of surface and groundwater. The Joint Interim Committee Agriculture and Economic Development has voted to conduct a study to determine the various state and local agencies and commissions having authority or responsibility for managing and regulating surface and groundwater and the various uses of water, both quality and quantity. The Committee may determine the extent of the authority and responsibility of each of those agencies and commissions, and identify the amount of State funds spent for these purposes. The Committee may also determine the feasibility of reallocating and controlling the authority and responsibility for administering, managing and regulating all surface and groundwater (both quality and quantity) and the beneficial uses of water, and other related environmental pollution control activities in the State in order to avoid overlapping and conflicting water uses of various agencies regarding administration, management, regulation, enforcement, and use of water. In addition the Committee may make a determination of the desirability of creating a separate coordinating agency to manage and regulate water and the use of water for all purposes, both quality and quantity, and related pollution control activities.

The existing State and local agencies and commissions having authority with respect to the administration, management, regulation, enforcement, and use of water in the State shall cooperate on a pro rata basis with and assist the Committee when requested to do so by the Committee and shall provide staff assistance and appropriate data to the Committee to the extent that the budget of the various agencies permit.

We know that the same aquifer can be used for different purposes. The Quaternary and the Sparta, both for example, are used by farmers, self-supplied industry, domestic and municipal water systems. If the priority is to be the maintenance of these aquifers as sources of drinking water, then some method of regulating uses for other purposes has to be determined. If the drilling of oil wells and irrigation wells through aquifers used as drinking water supplies threatens the quality of the water, some means of regulating drilling has to be effected.

As it exists now, a farmer can drill a well anywhere he wants on his own land and use as much water as he can afford to pump provided he drills the well according to the specifications outlined by the Arkansas Water Well Construction Code and no one takes him to court. A similar situation exists regarding the drilling of oil wells. The welfare of the aquifer affected by the drilling and the effects of pumping on it are not even considered by the Water Well Commission and are of only recent concern to the Oil and Gas Commission.

No one yet has taken a serious look at what the effects of all that drilling has been. We do have a few studies of the effects of overpumping of irrigation waters and some recommendations as to how to arrive at "safe yields" for some aquifers. We do not have any mechanism for enforcing either the limitation of drilling or the distribution of shares of "safe yield" components (the federally-funded Underground Injection Control program, however, does regulate all types of injection wells).

A sensible aquifer management strategy would, then, have to look at all real and potential threats to its integrity in the classification it has received. Hence, the recharge area of a Class I aquifer needs special protection from surface pollution, whether from urban, agricultural or industrial waste. Pumping must be limited to a "safe yield" that does not exceed the aquifer recharge rate. Monitoring of the aquifer, particularly, in those places where contamination is likely, needs to be done on a regular basis (Task 7 addressed this problem in particular and made specific recommendations regarding it).

Data from monitoring sites need to be collected and organized so that trends can be spotted and analyzed before the problems become too severe to deal with economically. Prevention of pollution is universally recognized as the most effective method of quality control (Task 6 was designed to address the problem of data acquisition and management and make specific recommendations regarding it).

The question this section addresses is that of managing the monitoring and data collection systems that are recommended and coordinating the results generated by each. For example, if the problem areas that are assessed and monitored indicate a priority problem is emerging, how is it to be handled?

In the introduction we set forth four basic management strategies, each with an ascending order of activity and expenditure. The first, or baseline strategy, called for a continuing series of activity at the current level with no new public policies. This would assume that groundwater quality monitoring would continue at its present level, that no new legislation to regulate withdrawals would be passed and that expenditures for permitting, inspecting, planning and all other groundwater related activities would continue at about the present level. The expected result of such a "baseline" strategy would be that present level of degradation could be expected to continue. That is, we could expect to see continue increases in the level of nitrates in the uppermost aquifer and continued increased in the levels of sodium in all of the aquifers used for municipal supplies in southern and eastern Arkansas. At some point, the result would probably entail major health problems in both area.

There are some problems, such as, the anomalously high levels of chlorides in areas around Brinkley in Monroe and Lee counties, in Chicot, Desha, Independence and Lawrence counties that, since we are not sure of the cause of these outbreaks, are unpredictable. Hopefully, USGS studies of these areas currently under way will allow us to predict what will happen with these.

A baseline approach to water use in places like the Grand Prairie is far easier to conceptulaize. Studies are under way that will allow us to predict fairly accurately how far water levels will drop given a certain level of withdrawal for municipal and agricultural use. Right now we can be reasonably certain that water levels will continue to drop given current levels of use although by unpredictable amounts depending on precipitation rates and government policies.

Contamination levels due to industrial contamination is also hard to predict given the current level of protection. Information even from the most publicized contamination sources is sparce and unreliable. Groundwater monitoring has, so far, been limited to hazardous waste sites covered by RCRA and some permitted municipal landfills. Without an adequate information base it is impossible to predict the effects of continuing at the present level of protection. From the areas that have been studied, however, it is a safe assumption that without further protection, contamination from industrial sources will continue to grow.

Management Strategy #1

This strategy calls for the use of voluntary action to improve water quality through research, education programs and incentives to consider alternative practices not under current use in the baseline condition. These would include the following:

1. Increased advocacy of "Best Management Practices", especially in vulnerable groundwater recharge areas.

2. More research into actual and potential problems.

3. Increased public education.

4. Encouragement of conservation and recycling projects.

Management Strategy #2

This strategy adds supply augmentation to the voluntary efforts of #1. These would include the following:

1. Diverting surface water to shortage prone areas.

2. Storing rainwater and floodwater in surface impoundments.

3. Groundwater recharge efforts using municipal wastewater or other readily-available treated water.

4. Desalination of otherwise drinkable water.

5. Vegetation control to reduce evapotranspiration, balanced with revegetation to control erosion.

Most of the above have been considered and rejected as too expensive in the earlier, more water-excess days. Only when shortages and declining quality are matters of national concern would they become economically-feasible alternatives.

Management Strategy #3

This strategy introduces some mandatory programs of a regulatory nature in addition to the voluntary efforts described in Strategy #1 and the augmentation efforts of Strategy #2. For groundwater, a minimum program would probably include the following:

1. State, county, local zoning laws to protect recharge areas.

2. Limits to the allowable nitrate loading of sensitive areas.

3. Limits to the allowable salt loading of sensitive areas.

4. Limits to the allowable population in critical areas.

5. Expansion of required industrial and municipal monitoring.

6. Limiting of discharges into the groundwater similar to that which now applies to surface waters.

7. The limitation of withdrawals from aquifers with declining water levels.

These are all efforts at conserving the quantity and quality of the state's groundwater. However, these efforts may not be enough and efforts at adding to the supply of water might have to be made.

Costs

As mentioned on p. 63 in relationship to groundwater monitoring, costs for groundwater protection are impossible to predict. There is no way to know in advance how extensive the problems we have are or how much of an effort is needed to maintain adequate protection. Our recommendation is to begin with a monitoring system and assess costs as more data becomes available.

Specific Recommendations

In addition to the general management alternative framework laid out above, a number of specific recommendations arose from the process of conducting the activities conducted as part of the strategy development process. These are listed below in the order in which the activities are listed in the FY81 workplan.

Activity 1. The Groundwater Steering Committee.

This committee proved to be an invaluable tool for fostering communication between the representatives of the various agencies that participated on the committee. The committee should continue to meet to resolve strategy implementation problems as they arise.

Activity 2. Groundwater Data Summary and Bibliography.

The data summary for this activity became a part of the biannual 305(b) Water Quality Inventory. This should be updated for each new report. The bibliography should be updated on a regular basis and kept on the Water Division computer file.

Activity 3. Groundwater Quality Criteria.

As in Activity 2, these criteria need to be evaluated and updated periodically. It should be done on an ongoing basis as new information appears. These should be placed on the Water Division computer as soon as they are made available. These criteria are based on maximum levels for specified uses and are the basis for the aquifer classification system recommended in Activity 5.

Activity 4. Groundwater Problem Summary.

This summary will be the basis for the report included in each 305(b) inventory and will be updated accordingly. It also should be made into a pamphlet for distribution to the general public, complete with photos from the groundwater slide show.

Activity 5. Groundwater Classification.

This classification would need revision as new chemical information about the aquifers becomes available. MOU's with USGS and the Geological Commission need to be formalized as to how these aquifers will be mapped and updated accordingly.

Activity 6. Data Management System.

This study recommended that STORET be the main storage system for the state's groundwater data. It also recommended that a users group be established to coordinate data storage activities (the groundwater steering committee seemed the logical basis for that group). The report also recommended hiring an experienced systems analyst and a program analyst to implement their recommendations. The purchase of new computer equipment was also recommended.

Activity 7. <u>Monitoring System Recommendations.</u>

Changes in this survey would also be included in the 305(b) Report. Recommended approaches to monitoring are as follows:

a. That a monitoring system for public supply wells be set up that would alert the public to potential contamination before the water supply became unusable.

b. That area-wide monitoring systems be set up according to need similar to that set up in the State of Idaho. High need areas in Arkansas would include Lonoke and Union counties and those domestic water users near oil and gas drilling sites, or animal waste sites in a karst topography.

c. That the ADPC&E establish a local monitoring project that would aid communities in the state that wish to protect their own groundwater supplies.

d. That special consideration be given to monitoring in recharge areas of major aquifers.

e. That surface impoundments with a hazardous rating above 15 be monitored.

f. That a handbook for local officials on groundwater quality monitoring be published and distributed.

g. That MOU's be developed with all agencies involved in the collecting and use of groundwater data.

Activity 8. <u>Recommended Leglisation</u>

Federal legislation and administrative procedures are changing rapidly. In the course of one year, three different versions of the EPA National Groundwater Strategy were released. Revisions to the Clean Water Act which would affect groundwater were in both the House and Senate committees.

There has been a good deal of activity at the state level also. Although a comprehensive state Water Code failed to pass the state legislature, two related Acts did. These were:

Act 417 of 1985-will provide incentives for offstream storage and conversion from groundwater to surface water sources.

Act 1051 of 1985-authorized interbasin transfer and non-riparian use of such water primarily to supplement those basins with a water deficit or where increasing dependence on groundwater or surface water has or will exceed the safe yield of the systems.

Generally, both ADPC&E and the ASWCC support policies which are directed towards: (A) Research - Conservation - Education, (B) Alternate Supplies and (C) Quality Control and Regulation. Towards these ends both organizations feel that water management districts should be authorized and established in critical use areas. Critical use areas would be defined as areas where the safe yield of an aquifer, stream, river or river basin is currently or projected to be exceeded. The district would allocate surface and groundwater in the area by issuing water rights, consulting and advising all users as to the availability of water resources and the most practical methods of water diversion, development, conservation, storage, well spacings, new well installation, utilization and maintenance of water quality. Authority of the district would be vested in a board of directors consisting of a composite of local people in proportion to the categories of water use in the area. Technical assistance would be provided by the ASWCC but local people would have input in the decision making process concerning water management in view of the current problems within their critical use area.

Continued cooperation between state agencies should assure the development of a groundwater strategy that would ultimately result in an adequate supply of high quality water to meet the needs of the people of Arkansas. All state and federal agencies involved in the water resources will have to use every approach currently available to accomplish this common goal.

Additional specific legislative recommendations are as follows:

a. The establishment of a tax on groundwater users to pay for hydrological studies that may be necessary to protect water supplies.

b. Legislation requiring the introduction of Protective Alert Levels (PALs). These would be standards below EPA Maximum Allowable Concentrations which would be used to trigger an alert mechanism that would allow the state to take measures to protect the water from further contamination before the situation became dangerous.

c. Establish a curriculum for the understanding of the principles of water conservation and protection within the state's schools and universities.

d. Legislation establishing incentives for local governments who establish groundwater protection ordinances, for the introduction of groundwater conservation practices, and for the reduction or curtailment of potentially threatening land uses.

Definitions of Selected Groundwater Terms

The following definitions are presented for clarification and consistency of use. Many groundwater terms can be confusing or their use can be misleading. This list should not be considered complete in any way; however, it does provide the definitions of those terms that a community is most likely to come in contact with as it begins to understand its groundwater reserves. The majority of these definitions come from the U.S. Geological Survey Water-Supply Paper 1988.

Terms

Aquifer:	A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.
Artesian:	(1) See: groundwater, confined; (2) a second meaning, as used by well drillers, refers to any well terminating in bedrock.
Capillary Fringe:	The zone immediately above the water table in which all or some of the interstics are filled with water that is under less than atmospheric pressure and that is continuous with the water below the water table.
Cone of Depression:	(Or drawdown cone): a roughly conical concavity (or dimple in the potentiometric surface around a pumping well.
Confining Bed:	A body of "impermeable" material stratigraphically adjacent to one or more aquifers. Synonyms: aquitard; aquiclude; and aquifuge.
Diffusion:	The process by which dissolved substances move from a region of higher to one of lower concentration.
Dispersion:	The act of spreading or distributing a dissolved substance from a fixed or constant source; or the process by which a dissolved substance spreads out from a constant or fixed source.
Groundwater, Confined:	Groundwater which is under pressure significantly greater than atmospheric, and its upper limit is the bottom of a bed of distinctly lower hydraulic conductivity than that of the material in which the confined water occurs.
Groundwater, Perched:	Unconfined groundwater separated from an underlying body of groundwater by an unsaturated zone. Its water table is a perched water table.

Groundwater, Unconfined: Water in an aquifer that has a water table.

Groundwater Divide: A vertical, imaginary, impermeable boundary which in an ideal, symmetrical groundwater system coincides exactly with the topographic highs which represent surface water divides from which water flows in opposite directions.

Head, Static Head: The height above a standard datum of the surface of a column of water (or other liquid) that can be supported by the static pressure at a given point. Head, when used alone, is understood to mean static head. The head is proportional to the fluid potential; therefore, the head is a measure of the potential.

Homogeneity: The quality or state of having uniform structure or composition; in hydrology, this term describes an ideal fluid.

Hydraulic Conductivity, K: If a porous medium is istropic and the fluid is homogeneous, the hydraulic conductivity of the medium is the volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow. It can have any units of length per time suitable to the problem involved.

Hydraulic Gradient: The change in static head per unit of distance in a given direction. If not specified, the direction generally is understood to be that of the maximum rate of decrease in head.

Hydrologic Cycle: The continuous circulation of water between the ocean, atmosphere and land.

Infiltration: The entry into the soil of water made available at the ground surface, together with the associated flow away from the ground surface within the unsaturated zone.

Isotropy: That condition in which all significant properties are independent of direction.

Intrinsic Permeability: A measure of the relative ease with which a porous medium can transmit a liquid under a potential gradient. It is a property of the medium alone and is independent of the nature of the liquid and the force field causing movement.

Leachate: The liquid derived from the leaching of buried refuse in sanitary landfills and dumps by percolating water derived from rain or snowmelt. It frequently contains large number of inorganic contaminants, high values for total dissolved solids, and may contain many organic contaminants.

Perched Water Table: The occurrence of a discontinous saturated zone with an unsaturated zone above and below. This condition is commonly caused by layered geologic materials with differing permeabilities.

Percolate: Water moving by gravity through pore spaces unsatured geologic material.

Permeability: The capacity of a porous medium for transmitting water.

Piezometer: A nonpumping well, generally of small diamter, which is used to measure the elevation of the water table or potentiometric surface. A piezometer generally has a short well screen through which water can enter.

Plume: A relatively discrete body of contaminated groundwater originating from a specified source(s) and influenced in its movement by such factors as the local groundwater flow pattern, specific gravity and solubility of the contaminant, the subsurface geology within the zone of saturation, and the influence of pumping wells.

Porosity: The ratio of the volume of small openings in soil or rock to its total volume; it is usually expressed as a percentage.

Potentiometric Surface: A surface which represents the static head. In an aquifer it is defined by the levels to which water will rise in tightly cased wells. The water table is a particular potentiometric surface.

Recharge: The entry into the saturated zone of water made available at the water table surface, together with the associated flow away from the water table within the saturated zone.

Recharge Area: That portion of a drainage basin in which the net saturated flow of groundwater is directed away from the water table.

Recharge, Artificial: The addition of water to the groundwater by activities of man at a recharge rate greater than normal.

Runoff: (1) That portion of precipitation which does not return to the atmosphere through evapotranspiration nor infiltrate the soil to recharge groundwater, but leaves the hydrologic system as streamflow; also (2), that portion of percipitation delivered to streams as overland flow to tributary channels.

Saltwater Intrusion: (Seawater intrusion): The migration of saltwater into freshwater aquifers under the influence of groundwater development (pumping).

Saturated Zone: The subsurface zone occurring below the water table where the soil pores are filled with water, and the moisture content equals the porosity.

Safe Yield: The amount of water that can be withdrawn annually from a groundwater basin without producing an undesirable result. Undesirable results include depletion of groundwater reserves, intrusion of low quality water, contravention of water rights, and others, such as depletion of streamflow and land subsidence.

Specific Capacity: The discharge from a pumping well (the pumping rate) divided by the drawdown in the well; it is a measure of the productivity of a well.

Specific Retention: The ratio of (1) the volume of water which the rock or soil, after being saturated, will retain against the pull of gravity to (2) the volume of rock or salt.

Specific Yield: The ratio of (1) volume of water which the rock or soil, after being saturated, will yield by gravity to (2) the volume of the rock or soil.

Storage Coefficient: The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. In an unconfined aquifer, the storage coefficient is equal to the specific yield.

Unconfined Aquifer: An aquifer having a water table.

Unsaturated Zone: The subsurface zone occurring above the water table and the capillary fringe where the soil pores are only partially filled with water, and the moisture content is less than the porosity.

Vertical Flow Potential: The vertical component of the hydraulic head in a three-dimensional groundwater system. The installation of two or more piezometers next to one another, each open to a different elevation, are needed to determine the vertical component of groundwater flow.

Water Table: The surface on which the fluid pressure in the pores of a porous medium is exactly atmospheric. It is the level at which water stands in a shallow well open along its length and penetrating the surficial deposits just deeply enough to encounter standing water in the bottom.

Watershed: The area of contribution to a surface water body. It is defined by topographic high points.