certain pollutants, or mitigate damages to polluted groundwater. Of the 16 federal laws providing various degrees of protection, three have major impacts on groundwater quality. They are the Safe Drinking Water Act (SDWA), the Resources Conservation and Recovery Act (RCRA), and the Comprehensive Environmental Response Compensation and Liability Act (CERCLA).

The SDWA sets out quality standards for drinking water, controls the underground injection of wastes, and protects aquifers that are sole drinking water sources. The RCRA regulates hazardous waste storage, disposal, and requires a systematic monitoring program to insure chemical wastes do not leak or leach into groundwaters. It also provides for state programs to regulate municipal solid waste facilities. The CERCLA (Superfund) funds the cleanup of hazardous waste sites.

Inconsistencies in federal groundwater protection laws sometimes lead to conflicts, duplication, deficiencies in protection efforts, and differing degrees of protection. For example, there are differences in the way federal laws define the resource to be protected. Some federal programs indicate that aquifers closest to the surface are to be protected. Other programs specifically protect underground sources of drinking water. Still others have impacts on groundwater, but do not specifically provide for its protection.

Current Oklahoma Groundwater Protection Activities

The Oklahoma Water Resources Board (OWRB) conducts an ongoing, systematic program to acquire data on the chemical characteristics of the groundwaters (and surface waters) of Oklahoma. The purposes of such investigations are to determine beneficial uses, assess the effects of waste discharge, and develop quality standards of groundwater. The 1982 OWRB Oklahoma Water Quality Standards were the first in the state to address groundwater by designating beneficial uses for 21 groundwater basins.

In May of 1983, the OWRB initiated an annual groundwater sampling program. Its purposes are to define the chemical characteristics of water in 21 major basins and evaluate the data as an aid to generating water quality criteria to protect the beneficial uses of those groundwater resources. OWRB sampled, at random, 506 pumping wells representing the major groundwater basins throughout the state. One well per four townships was sampled, except in the Panhandle underlain by the Ogallala Aquifer, where one well was sampled per township. Samples were analyzed for metals, chemical quality, and nutrients. Water temperature, pH, and specific conductivity were measured on site, and field observations were recorded at each site.

The OWRB groundwater sampling program has continued since 1983. Wells were sampled and water analyzed in 1984, 1985, and 1986. Each year criteria for selecting wells to be sampled have become more restrictive. The number of wells sampled has declined (205 in 1986), but the reliability of data accumulated has improved.

Conclusions

Clearly, there are many aspects of groundwater quality and groundwater pollution that are not well understood. It is important that research is continued to build information about the current and potential future states of our groundwater resources. As such information becomes available, other, more policy related issues, will surface, such as:

- Should individual states be responsible for establishing groundwater protection goals and policies, or should there be a national goal to give groundwater protection efforts more focus and direction?
- What should be specific groundwater protection goals? Should groundwater be protected at its existing quality or at different levels, depending on its existing quality, expected use, and site conditions?
- What management strategies and specific groundwater protection activities should be promoted and enforced, respectively, to best accomplish various groundwater protection goals?

For Oklahoma and the nation, groundwater is a vital resource now and in the future. Groundwater quality and groundwater protection issues will be addressed by public decision makers at local, state, and national levels. These decision makers need objective information to base strategies to address existing and potential groundwater quality problems, and they need input from constituents so they can consider this information in the perspective of the general needs and concerns of society now and in the future.

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Groundwater: A Resource for the Future

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http://osufacts.okstate.edu

Groundwater is one of Oklahoma's priceless natural resources and is found throughout the state in 21 major basins and 150 smaller basins. It is estimated that the major groundwater basins in Oklahoma store 320 million acre-feet of fresh water, about one-half of which is recoverable. Groundwater in Oklahoma supplies 61 percent of the total water reported used and 80 percent of the state's irrigation needs. Oklahoma groundwater also supplies municipal water to more than 300 Oklahoma cities and towns. Groundwater is equally important to the rest of the nation as it is to Oklahoma. Agriculture is very dependent upon groundwater. Almost two-thirds of the country's total groundwater use is for irrigation. America's households are also very dependent upon groundwater, the drinking water supply of about 50 percent of the nation's population. In rural areas nationwide, about 95 percent of all households depend on groundwater.

Nearly one-half of all of Oklahoma's groundwater is found in formations in western Oklahoma, including the Arbuckle Group, Dog Creek Shale and Blaine Gypsum, Rush Spring Sandstone, Elk City Sandstone, Ogallala Formation, and in alluvium and terrace deposits (Figure 1). Wells in these formations yield as much as 2,000 gallons per minute, but average about 300 gallons per minute.

Central Oklahoma contains perhaps one-third of the state's groundwater resources, which are stored in the Arbuckle Group, Vamoosa Formation, Oscar Formation, Garber-Wellington Formation, and alluvium and terrace deposits along stream beds (Figure 1). Wells in these aquifers have average yields of about 200 gallons per minute, a generous supply for rural homes, some communities, and industries.

Eastern Oklahoma is underlain by three major basins: the Roubidoux, Antlers Sand, and allovium deposits (Figure 1). Average yields from these basins are about 100 gallons per minute.

Groundwater Quality

It is important to understand groundwater's natural characteristics in order to understand groundwater quality problems. Groundwater is part of the earth's hydrologic cycle, the movement of water through the atmosphere, oceans, surface channels, and underground aquifers. In this cycle, contamination from one medium can spread and pollute others over time.

Groundwater generally moves very slowly, typically a few feet to a few tens of feet per year. Contaminants enter aquifers, flow and disperse in plumes, usually moving in the direction of and at the speed of groundwater flow. Little if any dispersion and dilution occurs. As a result, concentrations of contaminants in groundwater are sometimes quite high, usually several times greater than found in surface waters. Also, groundwater can be heavily contaminated in one place and pristine only a few feet away.

Fortunately, the slow movement of groundwater tends to localize contamination. Unfortunately, it also makes detection and monitoring of contaminants extremely difficult and expensive. For example, many test wells may be needed to locate and assess the rate and direction of travel of a contaminant plume.

Unlike air and surface water, groundwater cannot easily cleanse itself. Pollutants may be physically, chemically, or biologically altered as water percolates from the surface recharge zone down through various soils to an aquifer. However, the majority of pollutants remain in their unaltered state. Little, if any, additional cleansing takes place after contaminants reach a cool, dark aquifer. Once contaminated, groundwater can remain so for thousands of years.

The location and nature of aquifers can make them vulnerable to contamination. Shallow aquifers overlain by sandy or porous soils are particularly vulnerable. Such soils permit rapid percolation of water from the recharge zone, thus providing limited natural cleansing or retention of contaminants in the soil. Aquifers also exist in irregular, porous limestone formations. In these aquifers, groundwater may travel uncharacteristically fast through fractures and channels. Because water flows swiftly and unpredictably down through these channels, large areas of aquifers may be contaminated in a short period of time.

Some aquifers or systems of aquifers are critically important to man because they are sole sources of municipal, industrial, or irrigation water. Other aquifers are important because they recharge environrnentally sensitive areas such as wetlands and estuaries. Contamination of these areas can disturb vital ecological systems.

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MAJOR GROUND WATER BASINS IN OKLAHOMA

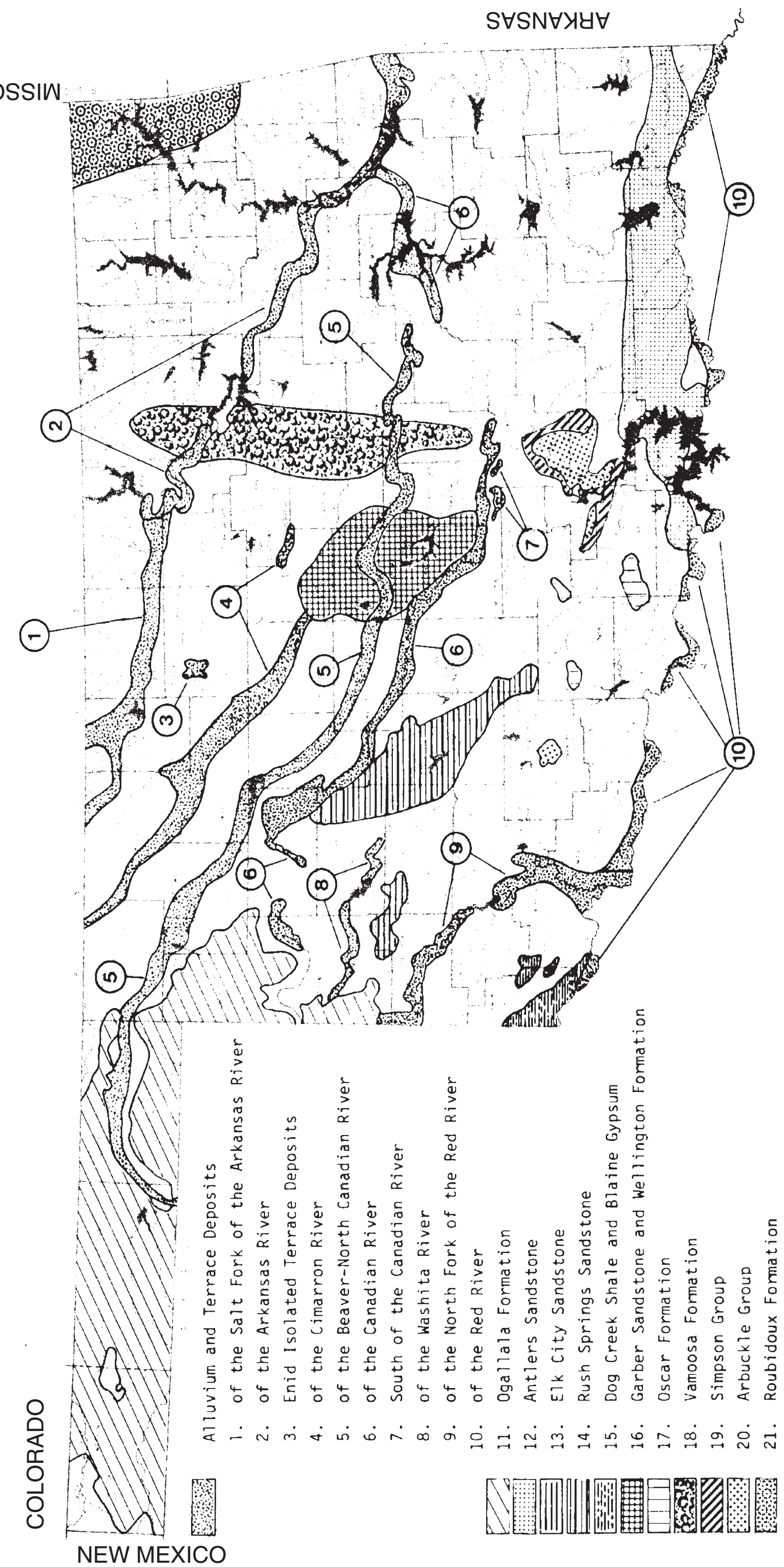

Figure 1. Groundwater Formations in Oklahoma.
Source: Data — U.S. Geological Survey and Oklahoma Water Resources Board
Mapping — Oklahoma Water Resources Board

Agricultural chemicals can pollute groundwater, but little is currently known about the extent of such pollution. The U.S. Environmental Protection Agency is currently sponsoring studies in about one-half of the states to quantify the degree of existing agricultural chemical pollution and to identify the culprit chemicals. Such a study is being conducted in Oklahoma.

The quality of Oklahoma's groundwater resources seems to be good at this time; however, some problems are in evidence (Table 1). Waters of the Dog Creek Shale and Blaine Gypsum demonstrate sulfate levels exceeding water quality standards for municipal supply, yet are appropriate for irrigation. Brine infiltration is a problem in the Vamoosa Formation and increased oil and gas exploration activity could pose similar problems in other groundwater basins. Abandoned, improperly plugged oil and gas wells, chemical waste and brine disposal wells, poorly designed sanitary landfills, nitrates from irrigation infiltration, and abandoned water wells are currently creating local pollution problems in Oklahoma and offer potential for substantial pollution of the state's groundwaters.

Current Federal Groundwater Protection Activities

Because awareness of groundwater quality problems lagged behind concern for other environmental resources, laws applied to groundwater protection are spotty, at best. Most of them were written to protect resources other than groundwater from specific sources of pollution. In the absence of specific legislation, existing laws were "stretched" to include groundwater. To compound the problem, federal, state, local, and private responsibilities in groundwater protection have not been clearly defined.

Existing federal laws are intended to protect the integrity of groundwater used as public or private drinking water supply, control contamination from specific sources and

Table 1. Yield and Quality Information for Oklahoma's Groundwater Basins.

		Quality by Use[A]		
Western Basins	**Approximate Average** Yield (Gallons per Minute)	**Agriculture**	**Industry**	Human **Consumption**
Arbuckle Group	25-500	S	P.S.[F]	P.S.[F]
Dog Creek Shale and Blain Gypsum	10-20,000	S	P.S.[G]	N.S.
Rush Springs Sandstone	400	S	S	S
Elk City Sandstone	60-200	S	S	S
Ogallala Formation	700	S	S	S[H]
Alluvium and Terrace Deposits	100-300	S	S	S[H]
Central Basins				
Arbuckle Group	200-500[B]	S	S	S[H]
Simpson Group	100-200	S	S	S
Vamoosa Formation	10-500[C]	S	S	S[I]
Oscar Formation	150-180	S	S	S
Garber-Wellington Formation	50-450	S	S	S[J]
Alluvium and Terrace Deposits	100-500	S	S	S[K]
Eastern Basins				
Roubidoux	200[D]	S[L]	S[L]	S[L]
Antlers Sand	100-150	S	S	N.S.
Alluvium and Terrace Deposits	20-1,000[E]	S	S	S[H]

A. S = Suitable
P.S. = Possibly suitable
N.S. = Not Suitable
B. Deep tests have produced yields in excess of 2,500 gallons per minute.
C. The best wells, with maximum production of as much as 500 gallons per minute, are in the Seminole area. Otherwise, yields generally decline from south to north, with 250 gallons per minute yields in the south and 10-20 gallons per minute in the north.
D. Some wells produce as much as 1,000 gallons per minute.
E. Yields are lower in the north and higher in the south.
F. Water should be checked for excessive concentrations of fluorides.
G. Only in certain locations.
H. Water is hard.
I. Water is hard and brine infiltration has occurred in some areas.
J. Water is locally high in sulfate, chloride, or other mineral constituents.
K. Water quality is generally good in the south and poorer in the north.
L. Except in far west when sodium chloride renders water unusable.