KANSAS GEOLOGICAL SURVEY
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The Dakota Aquifer System in Kansas

P. Allen Macfarlane

Introduction

In the last decade, the need to identify alternative water sources for the western and central parts of Kansas has sparked interest in the Dakota aquifer and highlighted the need for improved understanding of its flow system and water quality. The Dakota aquifer system consists of sandstone bodies deposited about 100 million years ago during the Cretaceous Period. These formations are found at the surface and in the subsurface in most of the western two-thirds of Kansas. Kansans, and others in the Great Plains region, have used the Dakota as a source of water for more than a century. However, until recently, not much was known about how water moves through the Dakota aquifer or the water's source. In 1988 the Kansas Geological Survey began a comprehensive program of research on this aquifer system. This publication summarizes some of the information derived from this research. Terms printed in **boldface** type are defined in the Glossary at the end of this publication.

Groundwater from the Dakota aquifer is used for domestic, municipal, industrial, and agricultural purposes, primarily where the aquifer is near the surface in southwestern and central Kansas. In southwestern Kansas, the Dakota is used in conjunction with the overlying High Plains aquifer (the Ogallala and associated shallow aquifers) as a source of water for irrigation. In central Kansas, the Dakota provides a good source of water for irrigation, stock watering, municipal supply, and industry. In west-central Kansas, the aquifer is a primary source of water for livestock and domestic use. Some attempts have been made to use Dakota groundwater of marginal chemical quality for public supply, either by blending with fresher waters from shallow aquifers or by employing advanced treatment technologies. Both methods have increased the supply of water for municipal purposes.

Aquifers and Aquitards

In a practical sense, an **aquifer** is an underground rock formation that is **permeable** and yields amounts of water to wells at usable rates. An **aquitard** does not yield appreciable amounts of water to wells because it is much less permeable. Groundwater flow through an aquitard is much slower than through an aquifer. Typical Kansas aquifers are composed of sand, gravel, or sandstone; aquitards are usually composed of shale. Aquifers and aquitards are not necessarily contained within a single geologic unit; they may consist of only a portion of a unit or include several units.

The Dakota Aquifer

The Dakota aquifer system extends across much of the central North American continent from approximately the Arctic Circle in Canada to northeastern New Mexico and the Oklahoma panhandle and from the Rocky Mountains to western Iowa and Minnesota. The aquifer underlies approximately 40,000 square miles (103,600 square km) of the western two-thirds of Kansas (fig. 1).

The Dakota aquifer system consists of sandstone bodies in the Cheyenne Sandstone, Kiowa Formation, and

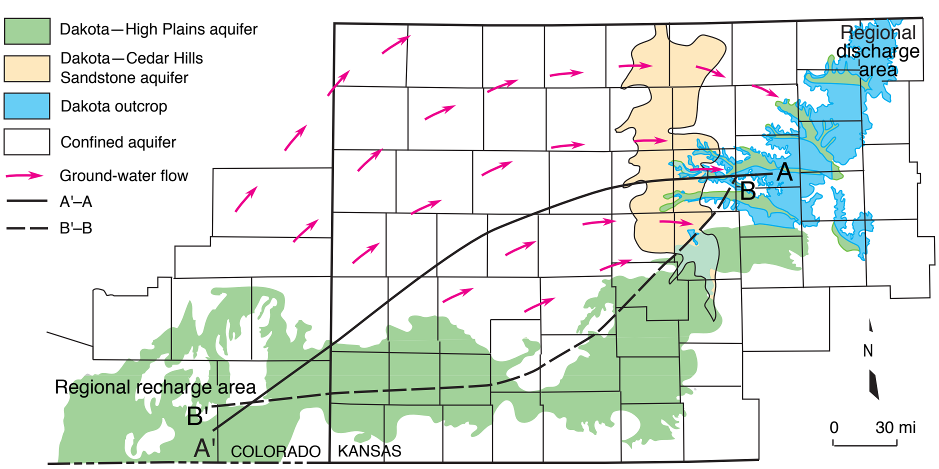

Figure 1. Map showing the confined and unconfined regions of the Dakota aquifer in Kansas and regions of hydraulic connection with other aquifer systems. Arrows indicate the directions of groundwater flow through the confined Dakota aquifer from the regional recharge to the discharge area. The lines A'–A and B'–B show the trace of the cross sections in figs. 3 and 5, respectively.

Dakota Formation in Kansas (fig. 2). The sandstone bodies are encapsulated in shales that are a part of these geologic units. The shales, however, are not considered part of the aquifer. Not all of these geologic formations are present throughout the aquifer's extent. The combined thickness of these geologic units ranges up to more than 700 feet (213 m) in parts of west-central Kansas.

In western and parts of central Kansas, the Dakota aquifer system is separated into upper and lower aquifers by an aquitard within the Kiowa Formation. The upper Dakota aquifer consists of the sandstones in the Dakota Formation. The lower Dakota aquifer consists of sandstones in the lower part of the Kiowa Formation and Cheyenne Sandstone. Over much of central Kansas, this aquitard in the Kiowa is not present, and the upper and lower aquifer units cannot be distinguished.

The total thickness of sandstone in the Dakota aquifer ranges from less than 5% to more than 50% of the combined thickness of the Dakota and Kiowa Formations and the Cheyenne Sandstone and varies dramatically even over distances of less than a few miles. Variations in the thickness of the sandstone are related to the way in which the sands were deposited. In Kansas, the sands were deposited in ancient rivers, deltas, and beaches along the eastern side of an inland seaway. The discontinuous sandstone bodies are lens shaped, rather than flat and continuous. Typically, the best sandstone aquifers are up to 100 feet (30 m) thick, 1.5 miles (2.4 km) wide, and 20 miles (32 km) or more long. Outcrops of these thick, alluvial sandstone bodies form the bluffs and canyons along the north shore of Kanopolis Reservoir in Ellsworth County and along the Saline River valley in the vicinity and upstream of Wilson Reservoir in Russell County.

Well Yields from the Dakota Aquifer

Reported well yields in the Dakota aquifer of Kansas range widely and are generally the highest in central and southwestern Kansas. Well yields of up to 1,000 gallons per minute (63.1 L/sec) have been reported from Hodgeman and Ford counties. Well yield depends on the design and condition of the well, the pumping equipment, and the aquifer's ability to produce water. The most important factors governing the ability of the Dakota aquifer to produce water are the thickness of the sandstone and its permeability. In general, the greater the thickness of sandstone adjacent to the well screen, the greater the yield because more of the aquifer is available to the well. The more permeable the sandstone, the greater the yield. Limited laboratory and field tests indicate that the sandstones of the Dakota aquifer are generally more permeable in central Kansas than they are farther to the west.

Other Aquifer and Aquitard Units that Influence the Dakota Aquifer

Over most of its extent in Kansas, the Dakota is overlain by a relatively impermeable sequence of younger shale and chalk units that form the Upper Cretaceous aquitard (fig. 3). Outcrops of some of the units that form this aquitard can be seen, for example, in roadcuts in Russell and Ellis counties where I-70 crosses the

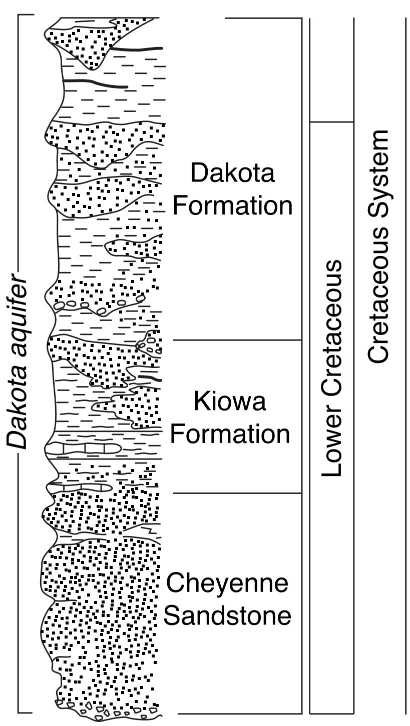

Figure 2. Geologic units of the Dakota Aquifer.

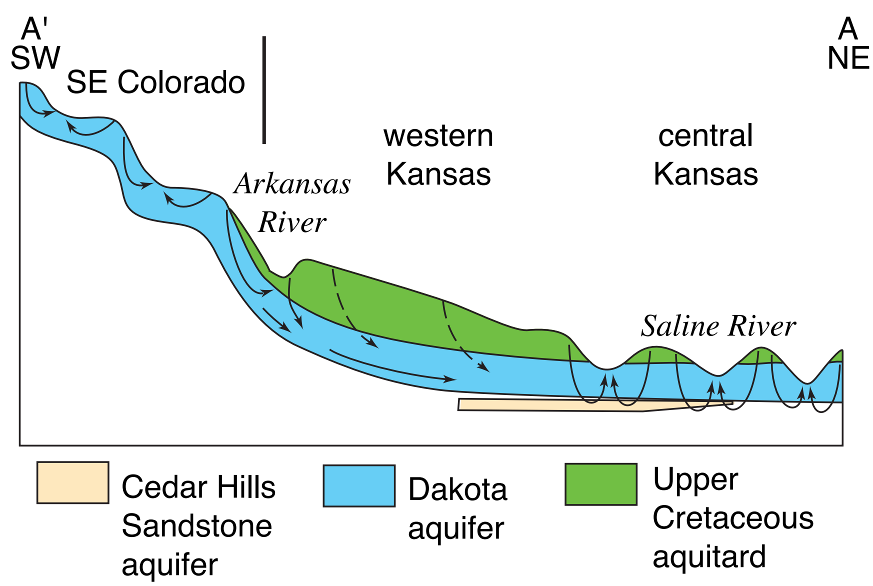

Figure 3. Cross section showing groundwater flow patterns in the confined Dakota aquifer and the overlying Upper Cretaceous aquitard from southeastern Colorado to central Kansas. Note the thick aquitard above the confined Dakota in western Kansas. The negligible amount of recharge entering the Dakota from the aquitard is indicated by the dashed arrows. Trace of cross section shown in fig. 1.

Blue Hills region. The aquitard increases in thickness toward the northwest corner of the state, where it is more than 2,000 feet (610 m) thick. Where this aquitard is present, the Dakota is a **confined aquifer**. Water levels in wells screened in a confined aquifer are higher than the top of the aquifer (fig. 4A). This occurs because groundwater throughout the confined aquifer is under fluid pressure.

Elsewhere, the Dakota aquifer is unconfined. The water level in a well screened in an **unconfined aquifer** is approximately equal to the elevation of the water table. Where the Dakota aquifer is at or near the surface, such as in north-central Kansas (fig. 1), the water table defines the top of the aquifer (fig. 4B). However, in some places the Dakota is in contact with an overlying unconfined aquifer, such as the High Plains aquifer in southwestern and south-central Kansas (figs. 1, 5). Water levels in the Dakota aquifer in these parts of the state are approximately at the same elevation as the water table in the overlying aquifer because both aquifers are **hydraulically connected** and behave as a single system.

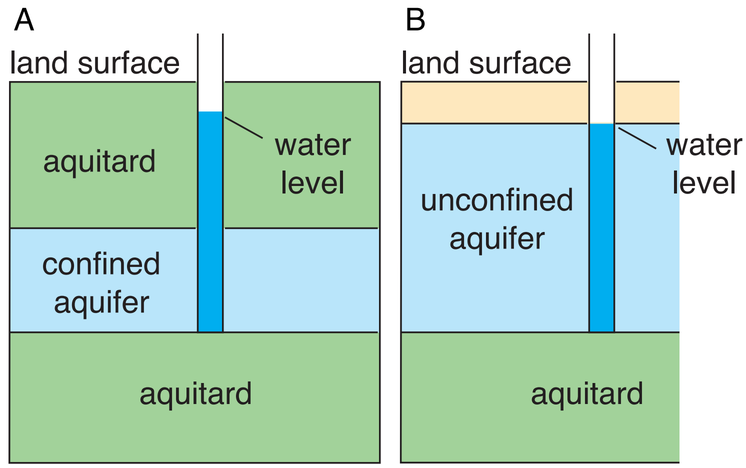

Figure 4. Water levels in wells screened in confined (A) and unconfined (B) aquifers.

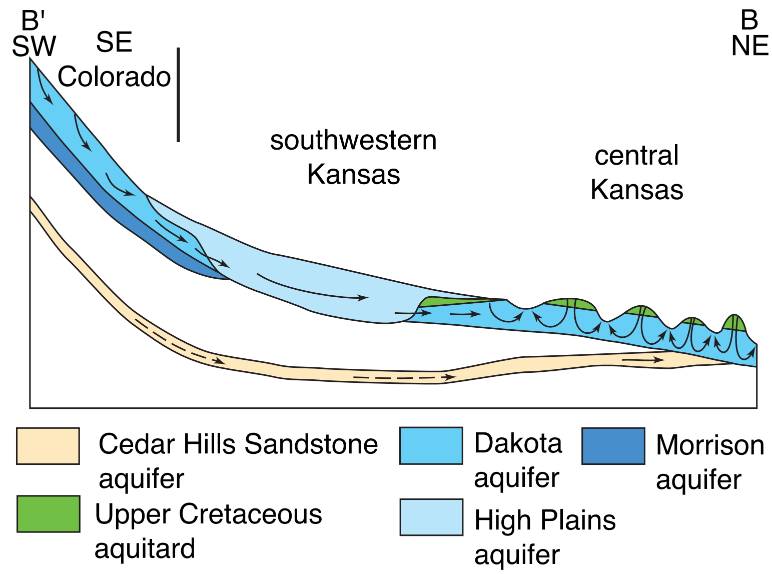

Figure 5. Cross section showing groundwater flow patterns in the mostly unconfined Dakota aquifer, High Plains aquifer, and Cedar Hills Sandstone aquifer from southeastern Colorado to central Kansas. Note the groundwater flow pattern between the Dakota and High Plains aquifers in southwestern Kansas. The negligible flow of groundwater in the Cedar Hills Sandstone in the southwestern part of the cross section is indicated by the dashed arrows. Trace of cross section shown in fig. 1.

The Confined Dakota Aquifer

The **recharge area** for the confined Dakota aquifer in Kansas is in southeastern Colorado (figs. 1, 3). The cross section shown in fig. 3 is along one flow path from the regional recharge area to the **discharge area** of the confined Dakota aquifer. Much of the northeastward flow in the Dakota from the regional recharge area is intercepted by the Arkansas River near the Kansas-Colorado border. As a result, only a small portion of the recharge entering the aquifer in the regional recharge area actually flows into the confined Dakota aquifer in western Kansas. Research indicates that where the Upper Cretaceous aquitard is thickest, freshwater recharge from overlying sources to the Dakota is negligible. Groundwater exits from the confined Dakota aquifer in the regional discharge area in central Kansas where the eastward-flowing rivers have cut down through the Upper Cretaceous aquitard and into the Dakota aquifer.

Groundwater flow rates in the confined Dakota are very low compared to those in the High Plains aquifer or stream-aquifer systems. Consequently, depending on the flow path, groundwater takes from tens of thousands of years to millions of years to travel from the regional recharge to the discharge area. Over the millions of years that this flow system has been operating, freshwater recharge has flushed the **salinity** (the total concentration of the dissolved constituents in the water) from a large part of the upper Dakota aquifer in Kansas and southeastern Colorado (fig. 6).

Elsewhere, such as in northwest and north-central Kansas, recharge has not been as effective at removing saline water from the Dakota. The

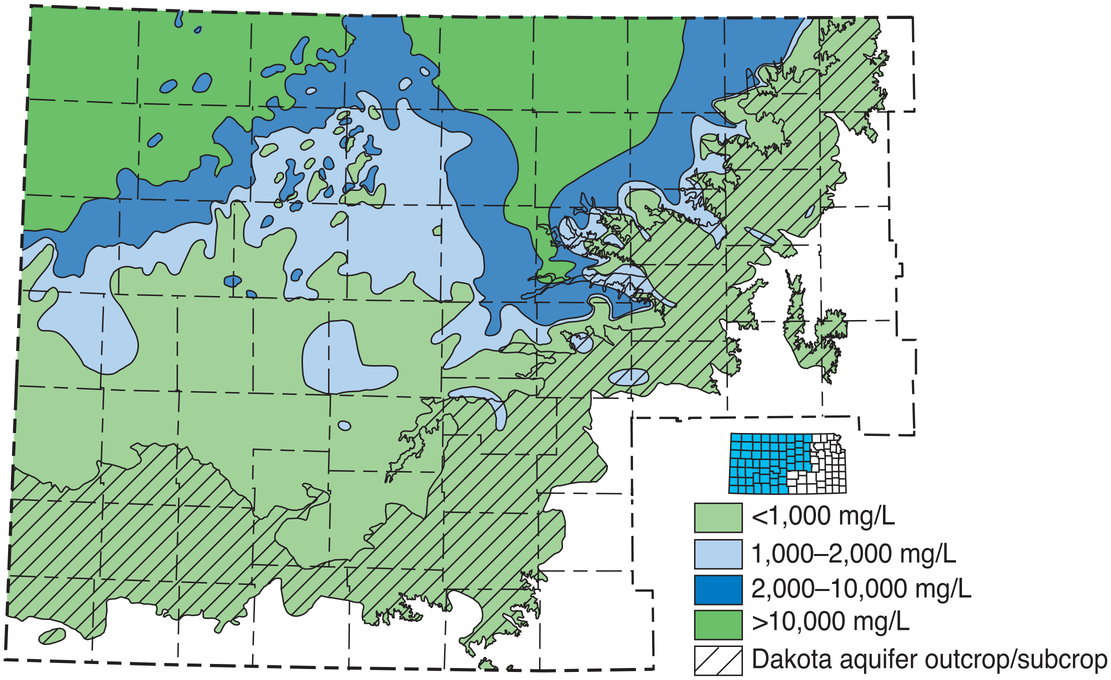

Figure 6. Distribution of total dissolved solids (TDS) concentrations in groundwaters in the upper Dakota aquifer in western and central Kansas. Water containing less than 1,000 mg/L TDS is defined as fresh. Water with 1,000–2,000 mg/L TDS is usable for many purposes but is less desirable than freshwater. A concentration of 10,000 mg/L TDS is defined in the state regulations of the Kansas Corporation Commission as the upper limit of usable water; above 10,000 mg/L, a water is classified as unusable or mineralized.

northwest corner of the state is very far away from the regional recharge area and freshwater recharge from the Upper Cretaceous aquitard is negligible. In north-central Kansas, an additional source of recharge to the confined lower Dakota comes from the underlying Cedar Hills Sandstone where both aquifers are in contact (figs. 1 and 6). The Cedar Hills Sandstone contains saltwater from the dissolution of naturally occurring salt and other readily soluble minerals. In much of north-central and northwest Kansas, groundwater salinity exceeds 10,000 mg/L (milligrams per liter) and is far too salty for most uses. Because groundwater salinity generally increases with depth in the upper and lower Dakota aquifers throughout their extent in Kansas, the best quality water is usually found at the top of the Dakota aquifer.

The Unconfined Dakota Aquifer

The unconfined Dakota in central Kansas is locally recharged by infiltrating precipitation, averaging about 0.2–0.3 inches/year (0.5–0.8 cm/yr). Groundwater moves faster in the unconfined Dakota and is returned to the surface locally through freshwater and saltwater springs, seeps, and marshes. Salt marshes are common in some of the river valleys of north-central Kansas, such as the Jamestown salt marsh in northwestern Cloud and southwestern Republic counties. The discharge of saltwater from the Dakota diminishes surface-water quality during periods of low flow in some of the river systems that cross this part of the state, such as the Saline River.

The unconfined Dakota aquifer is also recharged by water from southeastern Colorado (fig. 5). In southwestern Kansas, the Dakota aquifer, sandstone aquifers in the Morrison, and the High Plains aquifer behave as a single, hydraulically connected system. Groundwater from the Dakota and aquifers in the underlying Morrison moves into the High Plains aquifer near the Kansas-Colorado border. In Gray and northern Meade counties, groundwater flow is from the High Plains to the Dakota aquifer.

Summary

Groundwater availability and levels of salinity in the Dakota aquifer are highly variable because of the different sources of fresh and saltwater recharge to the aquifer and the flow of groundwater through the aquifer system. In general, the Dakota is a good source of freshwater where the aquifer is encountered at shallow depths in southwestern, west-central, and central Kansas. In these areas, the aquifer is closer to sources of freshwater recharge and most of the salinity has been removed by the flow of groundwater acting over millions of years.

The aquifer is suitable for most uses throughout its extent in Kansas except for areas of high salinity in the northwest and north-central parts of the state. The major limitations on its use depend on the cost of producing the water, aquifer thickness, and the necessity of additional treatment to remove salinity.

The cost of producing water from the Dakota is directly related to factors that include the energy and other costs associated with well installation and pumping. These factors are significant in determining whether taking water from the Dakota is economical, particularly where the depth to the top of the Dakota exceeds 1,000 feet (305 m) near the northwest corner of the state.

Well yields in the Dakota are generally not as great as in the High Plains aquifer. As a result, the Dakota should not be considered a replacement source of water for the High Plains aquifer. Nevertheless, if it is managed properly, the Dakota will be an important source of water for Kansans in the future.

Additional Information

Additional information on the Dakota aquifer can be obtained by contacting the Geohydrology Section at the Kansas Geological Survey (785-864-3965; 785-864-7728, FAX).

Further information on the topics covered in this pamphlet can be found in the following publications.

Buchanan, R. C., and Buddemeier, R. W., compilers, 1993, Kansas Ground Water: Kansas Geological Survey, Educational Series 10.

Macfarlane, P. A., 1995, The Effect of River Valleys and the Upper Cretaceous Aquitard on Regional flow in the Dakota aquifer in the Central Great Plains of Kansas and Southeastern Colorado; in, Current Research on Kansas Geology, Kansas Geological Survey, Bulletin 238.

Macfarlane, P. A., and Sawin, R. S., 1996, A User's Guide to Well-spacing Requirements for the Dakota Aquifer in Kansas: Kansas Geological Survey, Public Information Circular 1.

U.S. Bureau of Mines, 1995, Minerals Yearbook, Area Reports — Domestic 1993-94, v. 2: Washington, D.C., U.S. Government Printing Office, p. 97-101.

Glossary

Aquifer: A part of a geologic formation, or one or more geologic formations, that is porous and permeable enough to transmit water at a rate sufficient to feed a spring or for economic extraction by a well. An aquifer transmits more water than an aquitard.

Aquitard: A part of a geologic formation, or one or more geologic formations, that is of much lower permeability than an aquifer and will not transmit water at a rate sufficient to feed a spring or for economic extraction by a well.

Confined aquifer: An aquifer that is bounded above and below by aquitard units; water levels in wells screened in a confined aquifer are higher than the top of the aquifer.

Discharge area: An area where groundwater is lost naturally from an aquifer through springs, seeps, or hydraulic connection to other aquifers. The water leaving the aquifer is referred to as discharge.

Hydraulically connected: A condition in which groundwater moves easily between aquifers that are in direct contact. An indication of this condition is that the water levels in both aquifers are approximately equal.

Permeability: A measure of the ease with which water will move through an aquifer or an aquitard. A geologic unit is **permeable** if groundwater moves easily through it.

Recharge area: A geographic area where water enters (**recharges**) an aquifer. Recharge areas usually coincide with topographically elevated regions where aquifer units crop out at the surface. In these areas, infiltrated precipitation is the primary source of recharge. The recharge area may also coincide with the area of hydraulic connection where one aquifer receives flow from another adjacent aquifer.

Salinity: The sum of the dissolved materials in water expressed in milligrams/liter (mg/L). The upper limit for freshwater is 1,000 mg/L; natural seawater has a salinity of approximately 35,000 mg/L.

Unconfined aquifer: An aquifer that is not bounded above by an aquitard; water levels in wells screened in an unconfined aquifer coincide with the elevation of the water table.

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The Kansas Geological Survey (KGS) is a research and service division of the University of Kansas that investigates and provides information about the state's natural resources. KGS scientists pursue research related to surface and subsurface geology, energy resources, groundwater, and environmental hazards. They develop innovative tools and techniques, monitor earthquakes and groundwater levels, investigate water-quality concerns, and map the state's surface geology.

The KGS has no regulatory authority and does not take positions on natural resource issues. The main headquarters of the KGS is in Lawrence in the West District of the University of Kansas, and the Kansas Geologic Sample Repository of the KGS is in Wichita.

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Kansas Geological Survey
The University of Kansas
1930 Constant Avenue
Lawrence, KS 66047-3724
785-864-3965
http://www.kgs.ku.edu