KANSAS GEOLOGICAL SURVEY
Public Information Circular 1 • February 1995

# A User's Guide to Well-Spacing Requirements for the Dakota Aquifer in Kansas

**P. Allen Macfarlane,** Geohydrology Section, Kansas Geological Survey
**and Robert S. Sawin,** Public Outreach, Kansas Geological Survey

## Introduction

This publication provides current and potential users of water from the Dakota aquifer in Kansas with a summary of the 1994 well-spacing requirements adopted by the Chief Engineer of the Division of Water Resources, Kansas Department of Agriculture, and explains the basis for these new requirements.

The Kansas Geological Survey provides information on the Dakota aquifer to Kansans interested in developing water supplies or in learning more about the aquifer. The Survey also advises state and local agencies on issues related to the Dakota aquifer and other water resources in the state. The Dakota Aquifer Program is a long-term project being conducted by the Kansas Geological Survey to assess the water-resource potential and planning needs of the Dakota aquifer.

Further information on the topics covered in this pamphlet can be found in the publication Kansas Ground Water (Kansas Geological Survey, Educational Series 10), compiled by Rex Buchanan and Robert Buddemeier. Additional information on the Dakota aquifer can be obtained by contacting the Geohydrology Section at the Kansas Geological Survey.

## Characteristics of the Dakota Aquifer

The Dakota aquifer underlies most of the western two-thirds of Kansas (figure 1). The geologic units that collectively form the Dakota aquifer belong to the Dakota Formation, the Kiowa Formation, and the Cheyenne Sandstone (figure 2). Not all of these units are present throughout the aquifer's extent. The combined thickness of these units may be more than 700 feet (210 m) in west-central parts of the state. Not all of the units that constitute the Dakota aquifer contain aquifer-grade material (usually sandstone) that can yield water to wells. The amount of sandstone in the Dakota aquifer varies from less than 70 feet (21m) to more than 350 feet (107m) of the total thickness. Variations in thickness can change over very

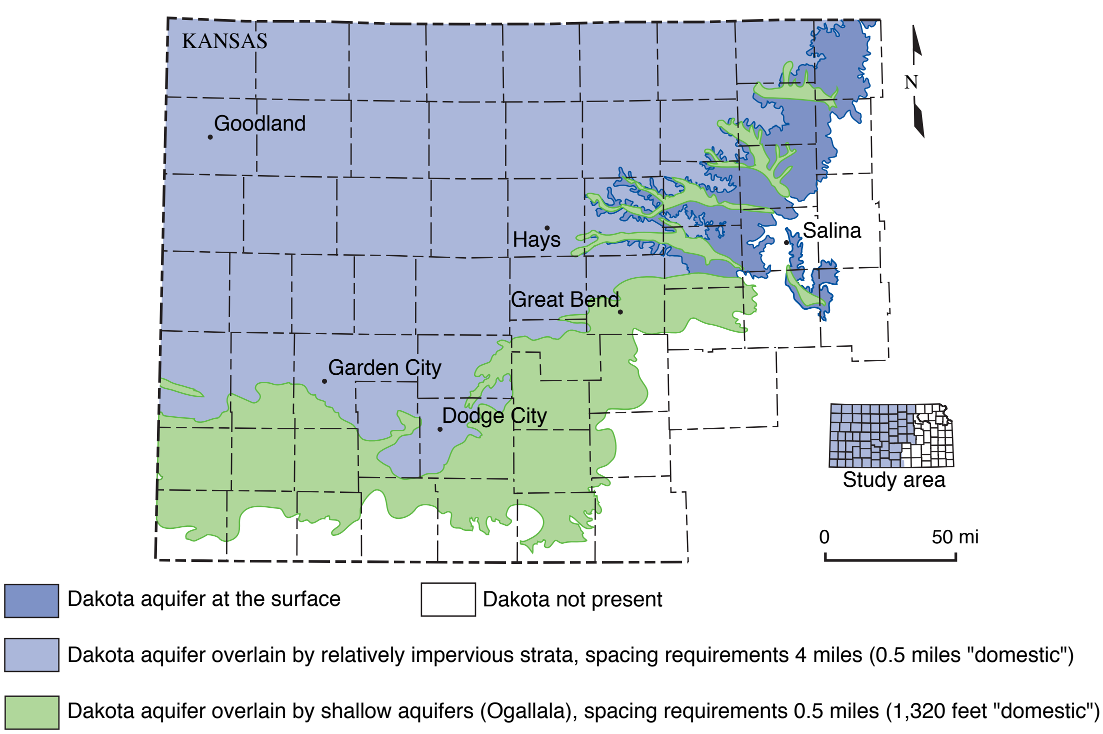


*Figure 1. The Dakota aquifer in Kansas.*

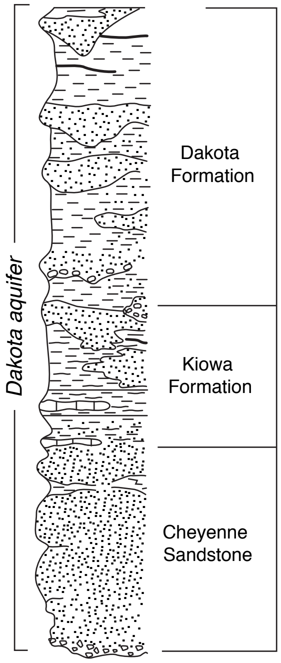


*Figure 2. Geologic units of the Dakota aquifer.*

short lateral distances. Statewide, the average amount of sandstone is about one-third of the entire thickness. The sandstones occur as irregular, discontinuous bodies within relatively impervious (incapable of transmitting fluids) shaly strata and generally occur in several more or less distinct zones within the geologic units (figure 2).

These irregular sandstone bodies were deposited during the early part of the Cretaceous Period of geologic history (approximately 90–100 million years ago) in river valleys and along ancient shorelines. Seas eventually covered most of what is now Kansas, and the exposed land surfaces laid to the east. The river-deposited sandstone bodies occur in the lower two-thirds of the Dakota Formation and the Cheyenne Sandstone. They are ribbonlike in shape (figure 3A) and are up to 20 miles (32 km) in length, 1.5 miles (2.4 km) wide, and can be over 100 feet (30 m) thick. With some exceptions, these sandstone bodies are oriented in an east-west direction, parallel to the drainage direction. The shoreline sandstone bodies occur in the upper Dakota Formation and the Kiowa Formation. They are usually thin and sheetlike (figure 3B), typically up to 50 feet (15 m) thick and covering several square miles. The long axes of these sandstone bodies tend to be oriented in a north-south direction, parallel to the orientation of the ancient shorelines. In central Kansas, river-deposited sandstones dominate the upper part of the Dakota aquifer, but in western Kansas near the Kansas-Colorado border, shoreline sandstones are more dominant in the upper part of the aquifer. Both river-deposited and shoreline sandstones occur in the lower part of the Dakota aquifer throughout its extent.

## Sources of Freshwater Recharge for the Dakota Aquifer

Figure 1 illustrates the areal extent of the Dakota aquifer in Kansas. At its eastern extent in central Kansas, the Dakota is a shallow aquifer that is at or near the surface. In this area, precipitation enters the aquifer directly, adding recharge (replenishment of the aquifer with water, usually a direct or indirect result of precipitation). In parts of southwestern and south-central Kansas, the Dakota aquifer is directly beneath the water-saturated Ogallala aquifer (figure 4A). Research shows that both aquifers behaved largely as a single system prior to water-well development. Near the Kansas-Colorado border in areas unaffected by pumping, the Dakota aquifer recharges the Ogallala aquifer, but farther to the east, the Ogallala recharges the Dakota. In northwestern Kansas, the Dakota aquifer is overlain by a sequence of relatively impervious shales and chalks that are up to 2,000 feet (600 m) thick in the northwest corner of the state. Recharge from precipitation in this part of the aquifer is negligible, except where this impervious layer is very thin near its eastern and southern extents (figure 4B).

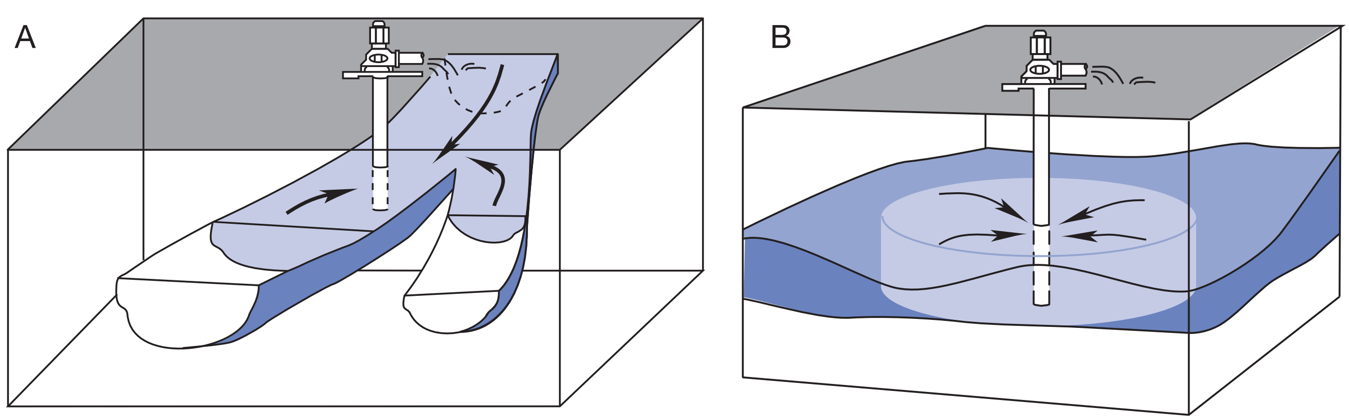


*Figure 3. Irregular sandstone bodies. A) River-deposited sandstones, B) shoreline sandstones. Arrows represent flow toward the well. Lighter shading represents the volume affected by pumping a single well.*

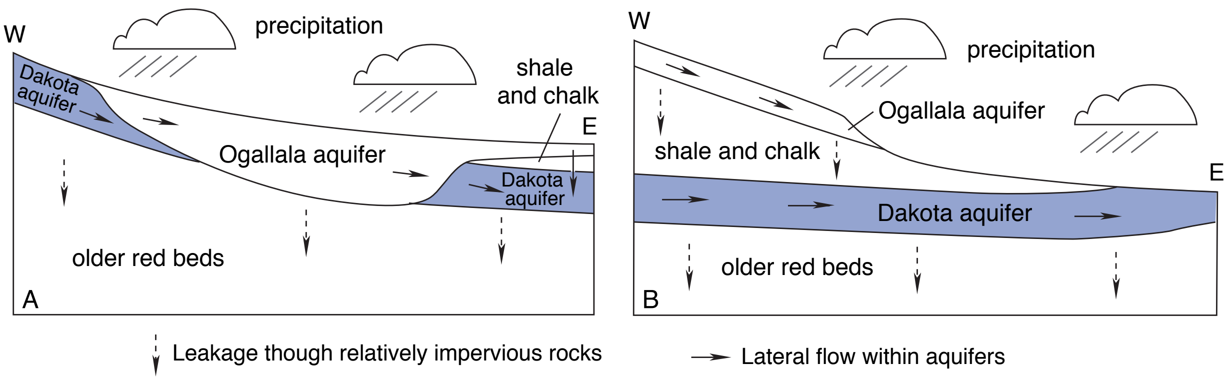


*Figure 4. Groundwater flow. Diagrams not to scale.*

## New Well-Spacing Requirements for the Dakota Aquifer in Kansas

In 1994, the Division of Water Resources of the Kansas Department of Agriculture, the state agency that regulates water-well development, modified the existing well-spacing requirements for the Dakota aquifer based on research results from the Dakota Aquifer Program. Well-spacing requirements are based on the aquifer's recharge capabilities and flow rates.

- Where the Dakota aquifer is at the surface or beneath the Ogallala aquifer (generally areas of rapid recharge), the new-well spacing is 0.5 mile (0.8 km) for all wells other than domestic, and 1,320 feet (396 m) for domestic wells.
- The new-well spacing where the Dakota aquifer is overlain by impervious rock units (generally very slow recharge) is 4 miles (6.4 km) for all wells other than domestic, and 0.5 mile (0.8 km) for domestic wells.

## What Happens When the Pump Is Turned On?

When the pump is turned on, the water level drops in the well and in the aquifer adjacent to the well being produced. The drawdown is the decline of water level observed in wells screened in the aquifer being pumped. The amount of drawdown is at a maximum at the pumping well and diminishes to zero some distance away. The region affected by drawdown from pumping is called the cone of depression (figure 5). The size of the cone of depression and the drawdown will increase until there is a balance between the pumping rate and the flow into the well from the surrounding aquifer. Once the pump is turned off, the cone of depression diminishes in size and water levels will recover to near pre-pumping levels as flow continues to move into that portion of the aquifer affected by drawdown.

The size of the cone of depression and the amount of drawdown depend on the pumping rate and the ability of the aquifer's material to transmit water to the pumping well. The aquifer's ability to transmit water to the well is directly related to its permeability (the capacity of a porous material for transmitting a fluid) and total thickness. Aquifer materials that are more permeable and have greater thicknesses allow larger volumes of water to flow toward the pumping well.

## What Happens in the Dakota Aquifer When the Pump Is Turned On?

Sandstones of the Dakota aquifer in the western part of the state consist of cemented, fine to very fine sand grains. In general, this aquifer material is 50–100 times less permeable to the flow of water than the uncemented, coarser sands and gravels in shallower aquifers such as the Ogallala. These permeability differences indicate that a pumping well in the Dakota aquifer will produce a significantly greater amount of drawdown than would a well in the shallower Ogallala aquifers being pumped at the same rate. In some parts of central Kansas, the permeability of the thicker river-deposited sandstones of the Dakota aquifer may approach the permeability of these shallower aquifers.

Sandstone aquifers in the Dakota are also much smaller in extent and thickness than the Ogallala aquifer. The Dakota aquifer can be thought of as a complex natural plumbing system consisting of sandstone bodies, some of which are connected to each other and which transmit water for considerable distances. If all the sandstone bodies in a local area are connected, then water flows from all these bodies toward the well (figure 3A).

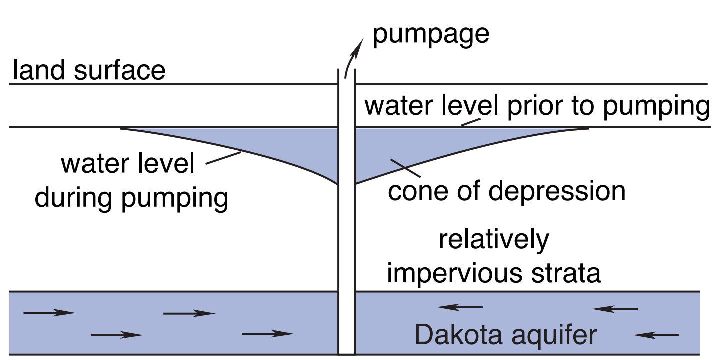


*Figure 5. Cone of depression resulting from drawdown from pumping.*

The shape of the cone of depression depends on the shape of the sandstone bodies that are connected to the well. Depending on the rate and duration of pumping, the cone of depression of a river-deposited sandstone can extend along the length of the sandstone body for several miles and may extend into other sandstone bodies (figure 3A). This exaggeration of the cone of depression along the sandstone body occurs because the relatively impervious shaly rock surrounding it contributes no water to the pumping well. The result is a cone of depression with a linear or irregular shape. In the sheetlike shoreline sandstone bodies, the shape of the cone of depression is usually more circular (figure 3B).

## Effect of Pumping Multiple Wells on the Dakota Aquifer

If multiple wells in the Dakota aquifer are withdrawing water from the same sandstone body, their cones of depression will probably overlap and coalesce (figure 6). This is because of the relatively small size of the sandstone bodies. If multiple wells operate simultaneously for some time, the aquifer may not be able to adequately replace the withdrawn water with recharge, resulting in water-level declines.

## Rationale for Well-Spacing Requirements

The water resources of Kansas are managed by the Division of Water Resources using the concept of safe yield. Safe yield is the long-term sustainable yield of the source of supply, including hydraulically connected surface water and groundwater. Thus, the total amount of water pumped from an aquifer should be less than the net recharge so as not to deplete the aquifer. The purpose of well-spacing requirements is to ensure that additional wells using the Dakota aquifer as a source of supply do not impair the supply of water to existing wells.

Impairment can also result from over-development of the entire aquifer. The Dakota aquifer is susceptible to over-development unless the spacing between wells is adequate to avoid overlap in their respective cones of depression. If wells are too close together, they may cause permanent water-level declines and eventual depletion of the aquifer. This is most likely where the Dakota aquifer is overlain by thick, relatively impervious strata. Results from the Dakota Aquifer Program show that there is no significant local freshwater recharge to this part of the aquifer. Consequently, water must come from other parts of the aquifer not affected by pumping. This represents a net loss of water from the aquifer and may cause water-level declines. In areas where the Dakota aquifer is at the surface or is overlain by shallow aquifers, local recharge to the Dakota aquifer from precipitation or from the overlying aquifer is sufficient to justify a denser well spacing.

A denser well spacing for domestic wells is appropriate because they typically operate at low pumping rates and for relatively short periods of time, causing less impact on the aquifer than nondomestic wells pumping at higher rates and for longer periods of time.

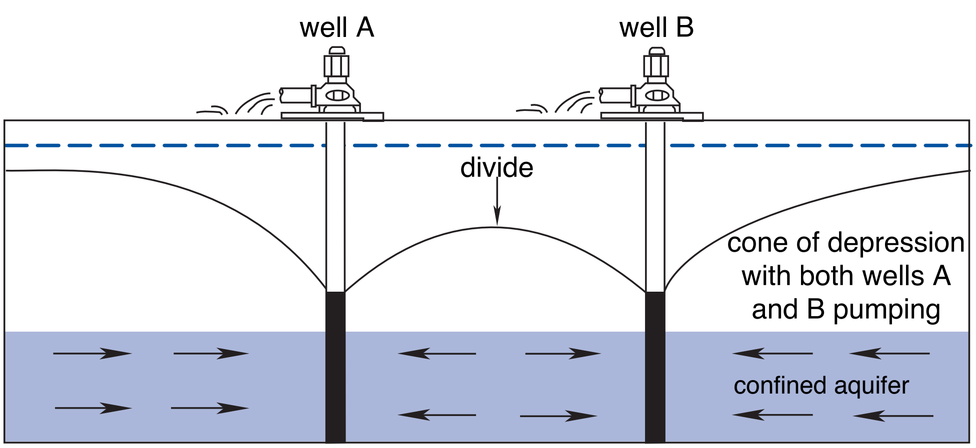


*Figure 6. When two nearby wells are pumping, they create a cone of depression, which overlaps. Note the flow moving in both directions between the pumping wells.*


KANSAS GEOLOGICAL SURVEY
The University of Kansas

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.

Public Information Circular 1
February 1995

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