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Salt Contamination of Groundwater in South-Central Kansas

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Introduction

The natural contamination of fresh groundwater by saltwater is an important water-quality issue in many areas of Kansas. This saltwater comes from naturally occurring salt minerals in the subsurface. Proper management of groundwater reduces, and frequently avoids, intrusion of saltwater into freshwater supplies. This circular provides water users and public officials with a basic explanation of how saltwater enters water supplies and outlines methods that might diminish or prevent natural salt contamination of freshwater aquifers. South-central Kansas, the focus of this publication, contains unconsolidated (uncemented) sand and gravel aquifers of the Great Bend Prairie, the Equus Beds, and the Arkansas River valley. Many of the same explanations and methods apply in other parts of Kansas where natural salt contamination is a problem.

Areas of south-central Kansas where salt contamination of freshwater aquifers might occur are illustrated in fig. 1. South-central Kansas is shown in detail because of the high occurrence of salt-contamination problems in this region. "Natural" sources of saltwater contamination of freshwater aquifers are the focus of this circular. Locations of "unnatural" salt contamination also have been included in fig. 1.

Salt

When talking about "salt," most people think of table salt or rock salt — sodium chloride — but the term is often used to mean almost any dissolved minerals or inorganic constituents found in water. The salt content of water, also referred to as salinity or total dissolved solids (TDS), is an important water-quality factor. Excessive salt content can

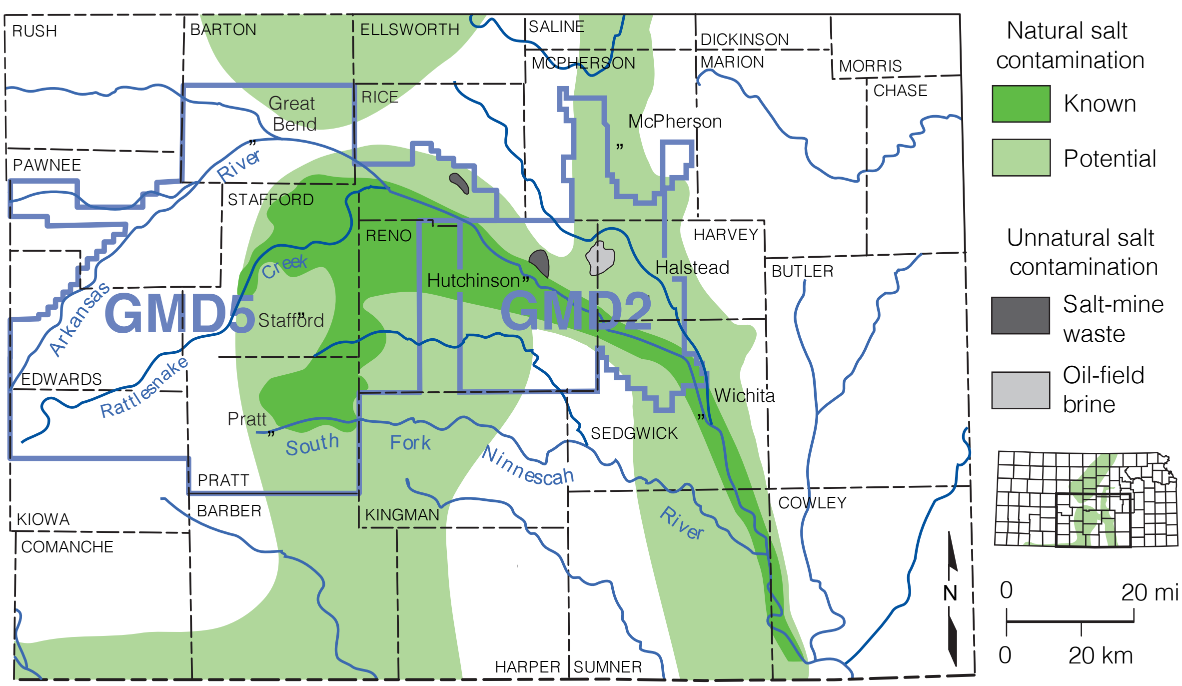

Figure 1. Areas with known or potential saltwater contamination in south-central Kansas. Areas identified as "known" natural salt contamination have saltwater within the freshwater aquifer. In the areas labeled "potential" natural salt contamination, subsurface bedrock formations containing salt or saltwater are in contact with the overlying freshwater aquifers. Groundwater Management District boundaries (GMD) 2 and 5 are shown in blue.

make water unpleasant, harmful to plants and animals, or uneconomic to use. In addition, high-salinity water contributes to the deterioration of domestic plumbing and water heaters and municipal and industrial water-works equipment. Table 1 illustrates how salinity limits the use of water for domestic and agricultural uses.

Sources of Saltwater Contamination

Possible sources of excess salinity in groundwater include 1) recharge by irrigation water, 2) contamination of surface water or soil by wastewater, road salt, and other sources, 3) contamination by oil-field brine and salt-mine waste, and 4) naturally occurring sources of salt.

Recharge by irrigation water and contaminated surface-water typically causes modest salinity increases in groundwater, while contamination by oil-field brines and salt mining can be highly concentrated. Salt contamination associated with oil or mining activities is typically localized.

Natural sources of salt contamination of freshwater aquifers, the emphasis of this publication, include salt- and saltwater-bearing bedrock formations.

Groundwater Behavior and Saltwater Contamination

Groundwater in Kansas does not flow in rivers or streams as water does on the surface. Instead, under natural conditions, groundwater flows slowly — usually a few inches or feet per day — through small openings, or pores, in the aquifer. The mostly horizontal flow is modified by vertical movement — downward in areas of recharge created by precipitation, and upward with discharge to creeks, rivers, wetlands, or wells (fig 2). Where recharge is high and freshwater moves downward, aquifers may be flushed of their salt content. By contrast, surface discharge can create circulation patterns that cause saltwater to move upward. This is why many of the salt-contamination areas shown in fig. 1 are associated with streams, rivers, and marshes.

Saltwater is found in deep bedrock formations almost everywhere, while freshwater is usually found only near the earth's surface. In most places, freshwater aquifers are separated from saltwater-containing aquifers by barriers called confining beds. Confining beds are clay or bedrock layers that slow or prevent the vertical movement of water between aquifers. Where the confining bed is absent or penetrated by natural features such as faults or fractures, or by human-made features such as improperly abandoned wells, saltwater may leak upward and contaminate the freshwater aquifer. Within an unconsolidated aquifer, thick and extensive clay layers can function as confining beds. Where saltwater has moved above a clay layer, the clay can serve as a perching horizon, maintaining the saltwater higher than would otherwise be expected (fig. 2). Unlike large regional layers of confining bedrock, these clay layers are variable and unpredictable in their size and distribution.

Table 1. Water-quality threshold indicators for domestic and agricultural uses. Chloride concentration (Cl) is the primary indicator of salinity; corresponding TDS values are approximations for sodium chloride type groundwater.

TDS (mg/L) (ppm)	**Cl** (mg/L) (ppm)		**Water Use Limits**
		>3000	Unsuitable for most domestic/ agricultural purposes
5700	3000	>2200	Poor water for livestock
3900	2000		
		>1500	Poor water for poultry
2100	1000		
		>500	Generally unsuitable for irrigation
1200	500		
		>350	May adversely affect many crops
		140–350	Moderately tolerant plants usually show slight to substantial injury
700	250	**250**	**DRINKING WATER STANDARD**
		70–140	Sensitive plants usually show slight to moderate injury
		<70	Generally safe for most purposes

Because saltwater is denser than freshwater, it remains near the bottom of aquifers and flows downgradient unless it is drawn upward by natural discharge or pumping. In some areas, the aquifer may contain substantial amounts of saltwater near its base, but the freshwater in the uppermost part of the aquifer may not be affected.

In south-central Kansas, bedrock formations containing saltwater and salt layers are in contact with the overlying freshwater aquifer. In these areas, confining beds can be thin, discontinuous, or absent (fig. 2), and freshwater aquifers are potentially vulnerable to natural salt contamination.

Predicting Saltwater Contamination

Many factors affect the nature, development, and predictability of natural salt contamination. Understanding the hydrology and geology of aquifers is important. Uncertainties in water use and management are caused by variations in the distribution of natural features (clay layers, faults, fractures, salt- and saltwater-bearing formations, groundwater flow patterns) and human-induced problems (improperly abandoned wells, boreholes).

Groundwater Management Districts 2 and 5 have established groundwater-quality monitoring networks and

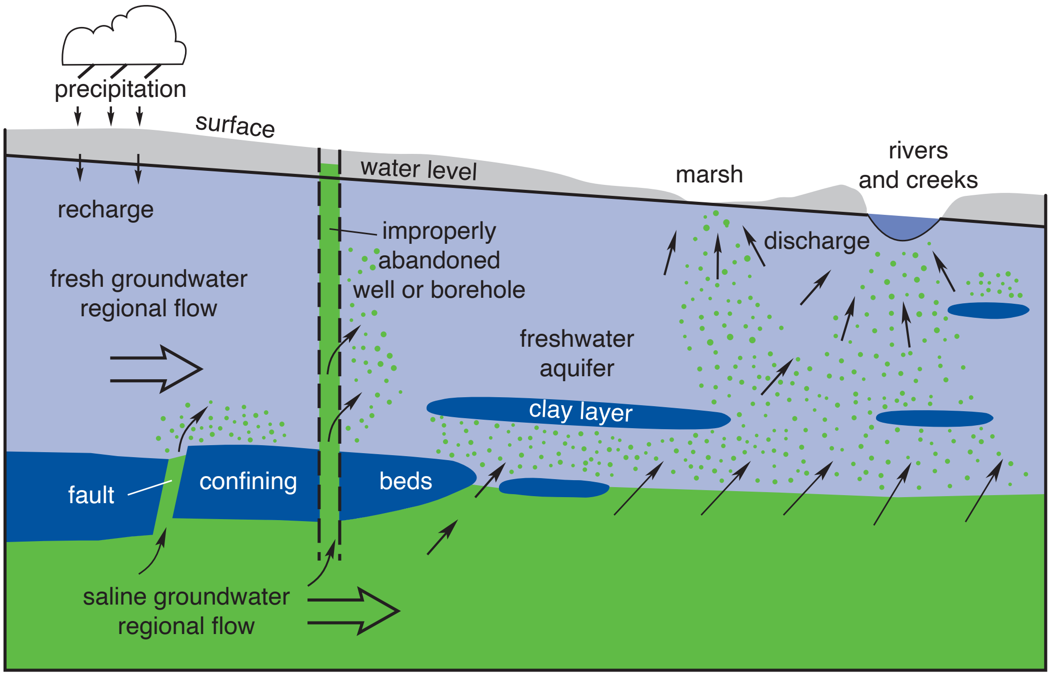

Figure 2. Schematic illustration of factors influencing movement of saltwater from a bedrock aquifer to the overlying freshwater aquifer and surface-water discharge areas.

databases to provide basic information to groundwater users. Additional information is available from other local, state, and federal agencies.

Pumping Wells in Areas Vulnerable to Saltwater Contamination

Pumping a well too hard can cause upconing of saltwater into the freshwater aquifer. Figure 3A illustrates a situation in which saltwater at the base of the freshwater aquifer does not rise much above the level of a partially confining clay layer. High-capacity wells in fig. 3B, however, create groundwater flow that pulls saltwater up through openings in the confining bed. Eventually, saltwater moves along the top of the clay layer and enters the well.

High-capacity irrigation or municipal-supply wells have zones of influence that may extend more than a mile from the well. These wells can dramatically alter water-table elevations and groundwater-flow directions. Because groundwater moves relatively slowly, it may take several years for an underground source of salt contamination to be diverted to the well or nearby wells. Once an area is contaminated, remediation by human modification is difficult, and natural processes are slow.

Severe drought can lead to salt-contamination problems not observed during normal or excess precipitation. During periods of little or no recharge, groundwater continues to discharge naturally from freshwater aquifers, decreasing the thickness of the freshwater zone overlying the saltwater. Regional pumping is likely to be greater during droughts and can further decrease the thickness of the freshwater aquifer. Thus, upconing of saltwater can be more severe during extended droughts.

Precautions and Procedures

How can groundwater be used with reasonable safety in potentially vulnerable areas, especially in view of the uncertainties involved in predicting salt contamination? There is no easy answer, but users can take steps to

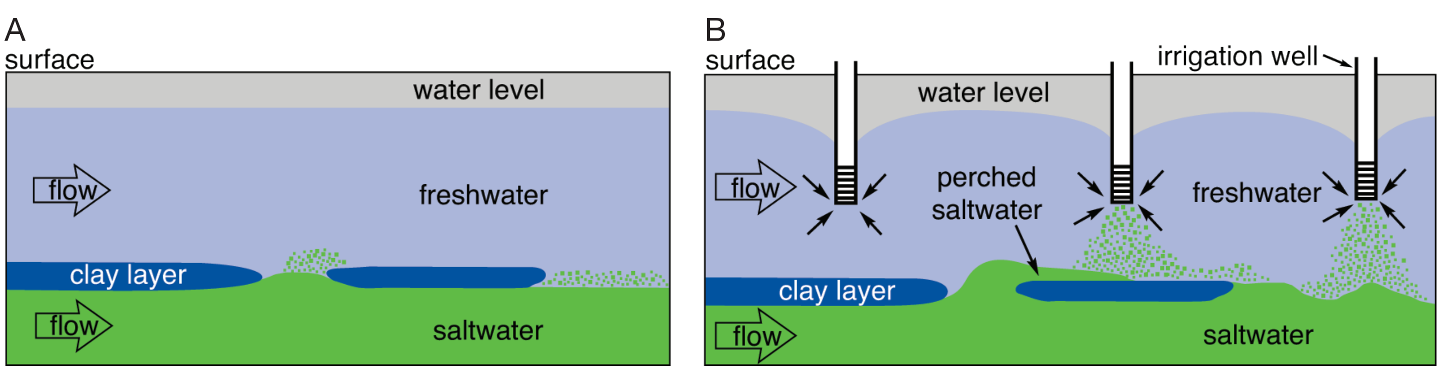

Figure 3. (A) The undisturbed aquifer contains saltwater at its base, but saltwater does not rise much above the level of the discontinuous clay layer. (B) During pumping, saltwater moves toward the discharge points, and upconing beneath the pumping wells occurs.

minimize or avoid saltwater problems. Domestic or stock wells are unlikely to have a major impact on water quality, but it is a different story for irrigators and other high-volume users. As has been discussed, high-volume wells can create their own problems. A number of common-sense precautions can be followed:

1. **Assess Well Location and Surrounding Area —** Check with locally knowledgeable people or agencies for saltwater problems in the vicinity of the proposed well. If problems are present, determine whether the source of salt contamination was identified. Investigate a larger area (a few miles) surrounding the proposed well, especially in the upgradient direction. Learn and comply with any local or state requirements or recommendations.
2. **Install the Well Carefully —** Wells that penetrate a confining bed, encounter saltwater, or are not properly plugged can be major contributors to unnecessary salt contamination. Drilling operations should log wells carefully, monitor water quality, and complete or plug holes according to state requirements for proper well construction and plugging procedures.
3. **Design for Minimum Water-Quality Impact —** Screen wells as shallow as practical and pump slowly to minimize upconing. In areas of known salt contamination of the deeper aquifer, safe pumping may require multiple smaller wells rather than a single large well (see fig. 4). If only one well is used, pumping at lower rates for longer periods of time could be advantageous.
4. **Irrigate Conservatively —** Using less water not only preserves the quantity of the resource, it also protects its quality and can prolong the useful life of the well.
5. **Test Water Quality and Keep Records —** Test for salinity at the beginning and end of each season, and more frequently if a saltwater problem is suspected. If water quality deteriorates, early detection allows time to modify operating or crop patterns and minimize loss.

If saltwater problems are related to drought, climatic conditions should be a factor in water-use planning.

For information and assistance with saltwater-contamination problems, contact the local Groundwater Management District (GMD2 316/835-2224; GMD5 316/234-5352), the Division of Water Resources (316/234-5311), the Kansas Department of Health and Environment (785/296-1500), the Kansas Ground Water Association (316/548-2669), or the Kansas Geological Survey (785/864-3965). The problems, and the appropriate solutions, depend on the source of the salt contamination. The best defense, however, is to avoid problems in the first place by planning new wells carefully and operating existing wells prudently.

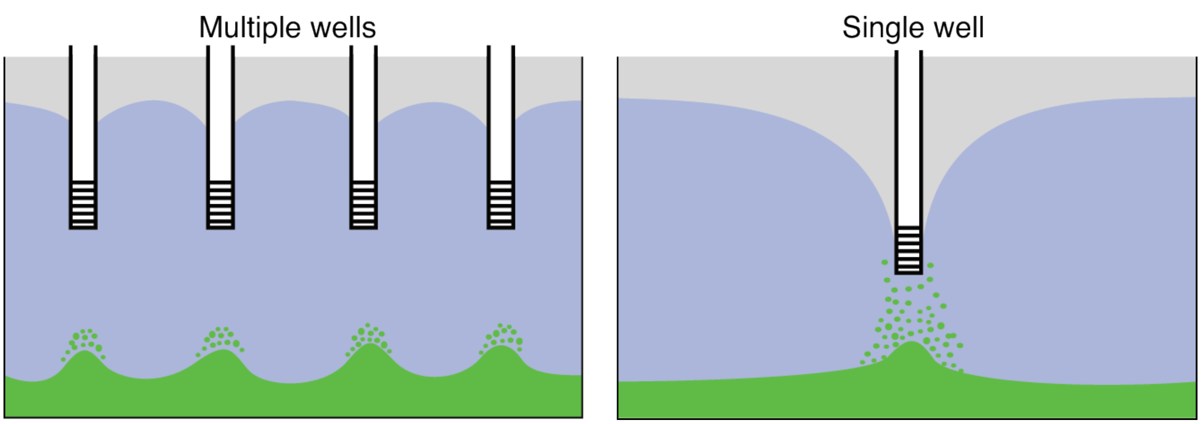

Figure 4. Dispersed, low-volume pumping produces less serious salt contamination than does concentrated withdrawal.

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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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