Groundwater Recharge in Kansas

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Introduction

Recharge is generally defined as the movement of water from the land surface into an aquifer. Recharge can be either natural, from precipitation that falls on the earth's surface and works its way underground, or it can be artificial, from human activities that deliberately or inadvertently replenish an aquifer. Knowledge of recharge is necessary to effectively manage groundwater resources and protect them from pollution, and to determine how fast an aquifer will be depleted when pumping and natural outflow exceed recharge.

This public information circular describes the factors that influence recharge, research on recharge rates in Kansas, the consensus about recharge rates across the state, the importance of recharge in water management, and artificial-recharge projects in Kansas. Recharge is an especially important issue in western Kansas, where high-volume pumping from the Ogallala portion of the High Plains aquifer (fig. 1) and low recharge rates raise concerns about groundwater depletion. Therefore, much of this circular focuses on recharge and related issues in western Kansas, although the principles outlined here apply to all areas.

Recharge Defined

Recharge is the movement of water into an aquifer (a geologic formation that holds water in its pore space in economic quantities). While the primary source of natural recharge is precipitation, other sources of recharge to an aquifer are seepage from streams and lakes or movement of water from one aquifer into another. Recharge also can be human induced; examples of artificial recharge include irrigation return-flow (water that moves from irrigated fields or canals back into an aquifer) and water from water mains, septic tanks, sewers, or drainage ditches. In general, however, artificial recharge refers to the deliberate use of water to replenish an aquifer.

Recharge is usually measured in inches of water per year, the same way that precipitation is measured. However, a given amount of recharge may result in a larger increase in the elevation of a water table. For example, one inch of recharge might increase the water level in an aquifer by five or six inches. That is because only about 10 to 25 percent of an aquifer is pore space that is connected; the rest is the solid material, such as

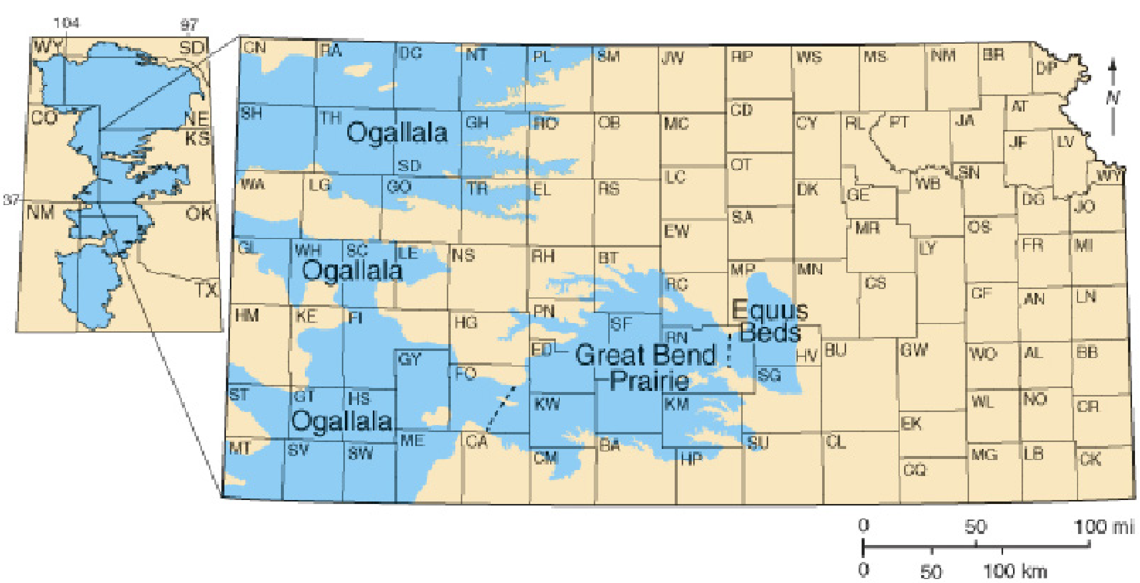

Figure 1. Extent of the High Plains aquifer in Kansas.

sand and gravel, that makes up the aquifer. In an aquifer that consists of 17 percent interconnected pore space, the movement of 1 foot of water into the aquifer would result in a water-level increase of about 6 feet.

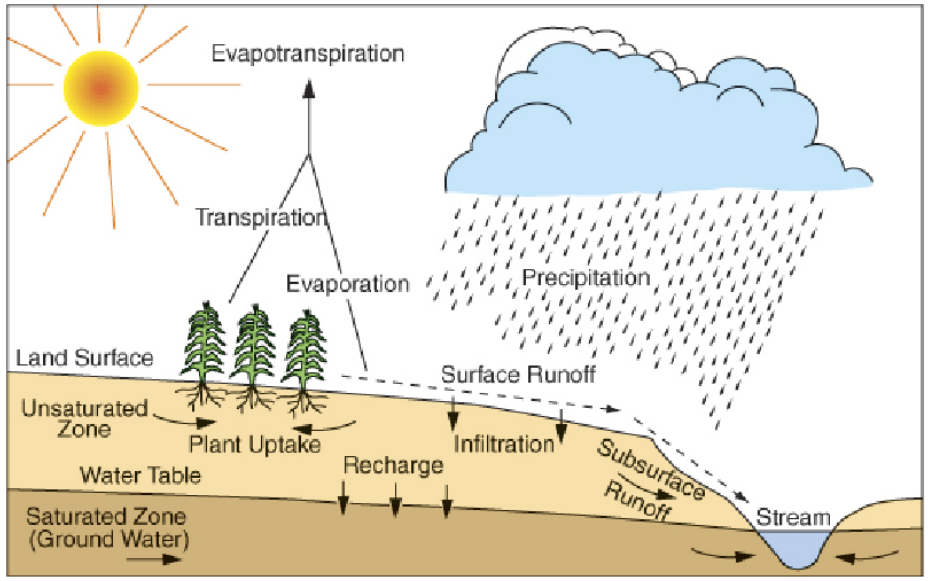

Figure 2. Groundwater recharge in the hydrologic cycle.

Factors Influencing Recharge

Climate: The amount of precipitation that falls on the earth's surface plays a major role in the amount of recharge (fig. 2). However, precipitation is not the only climatic factor affecting recharge. The timing and seasonal distribution of precipitation are also important. A certain amount of moisture build-up in the soil is necessary for groundwater recharge. Thus, early spring rains, when soils are at their wettest following snowmelt, are usually the most effective in recharging the aquifer. In addition to snowmelt, frequent rainfall, with relatively small evaporation and plant transpiration losses, builds up soil-moisture levels and thus enhances the recharge process. In the summer, short-duration, heavy rains or thunderstorms do not usually contribute to recharge. When the weather is hot and windy, plants need more water to grow and survive, causing them to remove water from the soil before it has a chance to replenish the aquifer. That hot and windy condition makes it more likely that water will evaporate before it has a chance to percolate deep into the soil. Because average annual precipitation is low in western Kansas (as little as 15 inches per year in some places) and much higher in eastern Kansas (more than 40 inches), recharge is generally considerably higher in eastern Kansas than in western Kansas.

Soils and Geology: To recharge an aquifer, water has to move through the root zone and down into the water table. Some types of soils, such as the sandier soils of central Kansas, allow water to move more quickly through the soil profile than other soils, such as those that are high in clay. The geologic make-up of an area also affects recharge. Water may reach the aquifer more quickly through fractures than through the interconnected space of porous materials.

Vegetation and Land Use: Types of vegetation and land-use practices also influence recharge. Mature plants have a greater ability to extract moisture from the soil than younger plants. Of the crops that are generally grown in Kansas, alfalfa (because it has deep roots and is harvested several times a year) extracts the most moisture from the soil, thus lessening recharge. Prairie grasses generally take up less moisture than alfalfa but more than other crops. Wheat, because its roots are shallow, takes up the least amount of water. One study in south-central Kansas (Sophocleous and McAllister, 1990) estimated that recharge was about 0.15 inches per year in areas planted to alfalfa, compared to 5.1 inches per year for wheat (average annual precipitation during the 1982–1983 study period was 21.62 inches).

Topography: For the most part, areas of relatively steep topography have lower rates of recharge. Water runs off steeper slopes more quickly with less infiltration into the ground and thus produces less recharge than flatter areas where water has more time to soak into the ground.

Depth to Groundwater: In general, the deeper the aquifer, the less the recharge. When water has a greater distance to travel before reaching the water table, it is more likely to be captured by plant roots, absorbed by the soil, or blocked from the aquifer by a layer of clay or some other rock material. Thus, in parts of western Kansas, where the Ogallala portion of the High Plains aquifer is several hundred feet deep, water has greater travel times and recharge is low. By comparison, in parts of central Kansas, the water table is less than 20 feet deep and water moves from the surface to the aquifer much more quickly.

All the above-mentioned factors that control recharge can be mapped as separate overlays using Geographic Information Systems (GIS) technologies and combined to classify regions of higher and lower recharge. This was done, for example, in the Big Bend Groundwater Management District No. 5 in south-central Kansas, where maps of (1) average annual precipitation, (2) available water capacity of the soil (amount of water a soil can store in a form available for use by plants), (3) depth to water table, and (4) average springtime rainfall rate were combined to identify areas of high and low recharge as shown in fig. 3 (Sophocleous, 1992).

Recharge Research

Knowledge of recharge and its relationship with land use is essential for integrated water-resources management. Because many factors influence recharge, and because these factors vary greatly from place to place across the state, recharge is difficult to determine in any one location and difficult to estimate for large areas. Nonetheless, an estimate of recharge is needed to assess the impact of withdrawing groundwater from an aquifer and to reliably estimate the long-term behavior of an aquifer under various management schemes. Reliable estimates of recharge and recharge mechanisms are also needed to assess the risk of groundwater contamination and to evaluate artificial recharge potential. If water and contaminants (such as nitrates and pesticides) move rapidly through fractures and other preferential pathways, for example, the contaminant is likely to reach the water table at relatively high concentrations soon after application at the soil surface. However, if contaminants move through the soil, then the much slower travel time allows for contaminants to disperse, dilute, and break down, thus influencing the final concentration that reaches the groundwater.

Many recharge estimates are based on mathematical models. Because these models rely on generalizations about the factors that influence recharge, the results of these models are sensitive to the amount of recharge and how it varies from place to place and over time. One study by the U.S. Geological Survey (Hansen, 1991) was based on water-budget modeling and has been used by the Division of Water Resources (DWR) of the Kansas Department of Agriculture in making decisions on requests for new water rights. The study estimated recharge rates as high as 8 inches per year in southeastern Kansas, about 3 inches per year in central Kansas, and less than an inch per year over about the western third of the state (fig. 4).

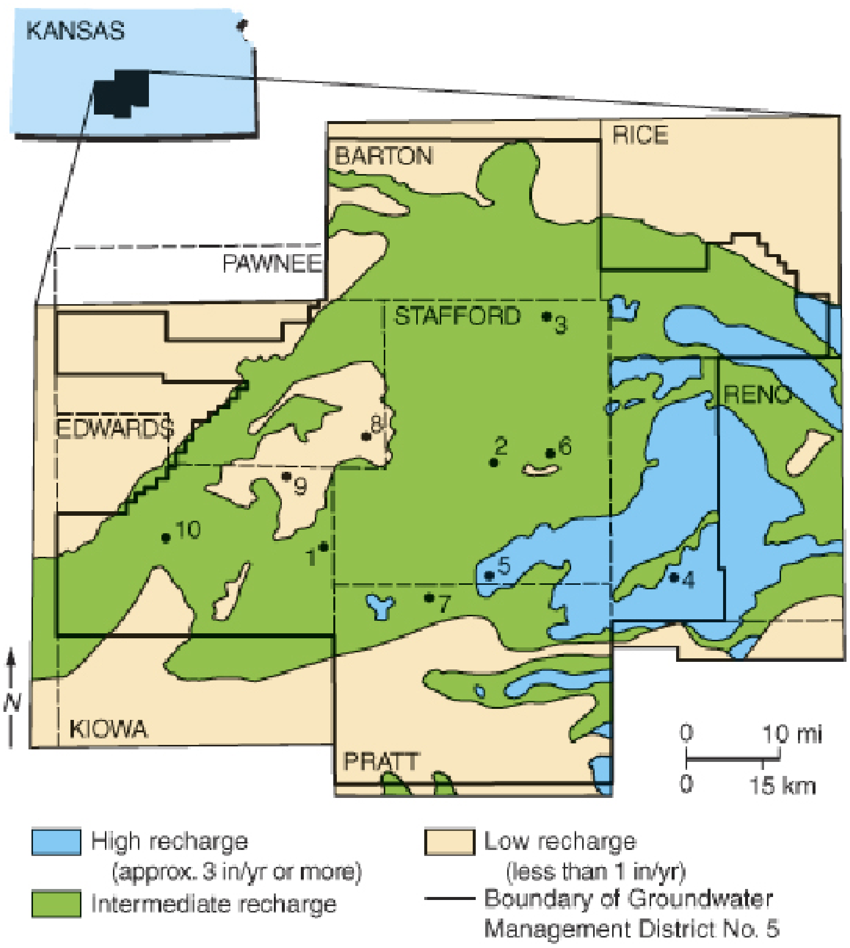

Figure 3. Recharge zonation for the Great Bend Prairie region of central Kansas. Numbers indicate monitoring sites (adapted from Sophocleous, 1992).

The U.S. and Kansas geological surveys have developed models for smaller areas of the state. Some of those models estimate that recharge is greater under irrigated cropland than under non-irrigated cropland. That's primarily because the wetter soil profile allows precipitation to move through the soil more quickly and thus recharge the aquifer. Researchers studied recharge in Finney County, in southwestern Kansas, and compared recharge during the years before large-scale irrigation (generally termed pre-development) with recharge after the onset of irrigation in the 1950s and 1960s (Meyer et al., 1970). That study indicated that predevelopment recharge was very low: less than half an inch per year. Recharge after development was estimated at approximately 2.7 inches per year, although factors other than increased irrigation (such as changing from grassland to cropland and significantly above-average precipitation over the 1940–1951 period) also were responsible.

Studies that estimate recharge in the field are few. It is expensive to drill wells and install instrumentation

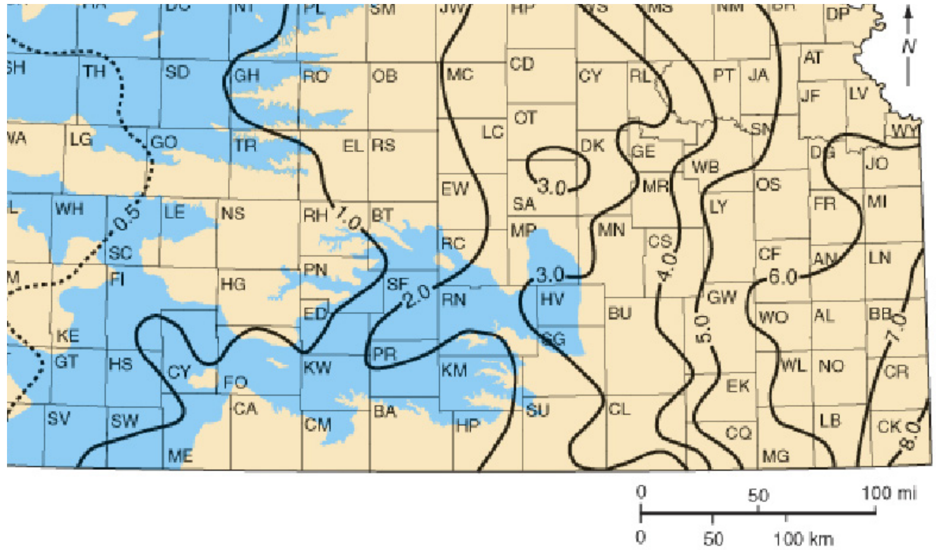

Figure 4. Mean annual potential natural recharge (in inches per year) is shown by one-inch contours (except in western Kansas where a half-inch interval was used to show more detail). The extent of the High Plains aquifer in Kansas is outlined in blue (adapted from Hansen, 1991).

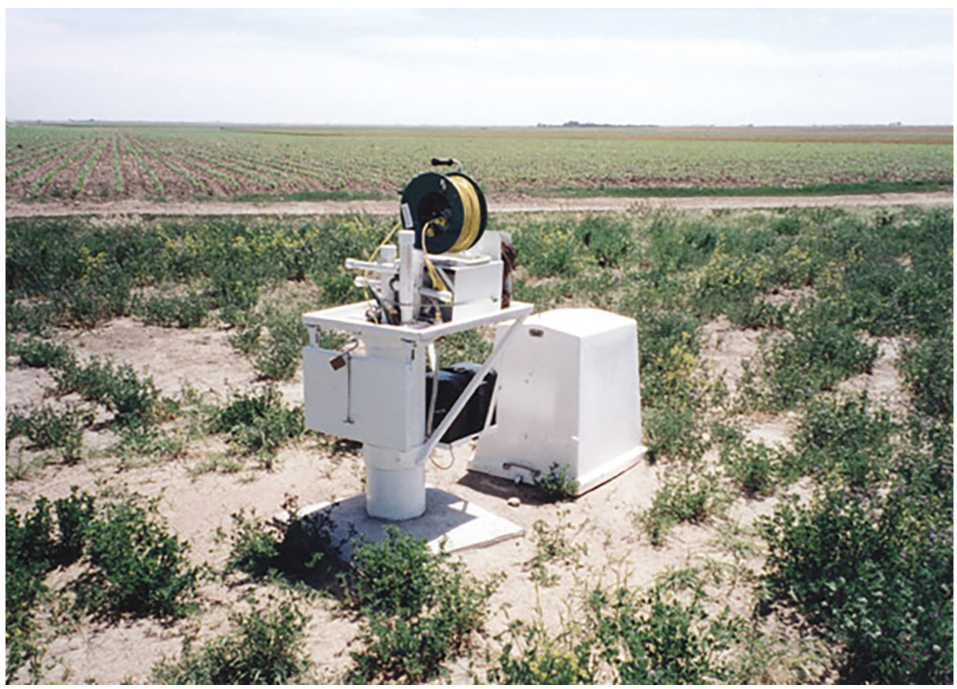

Figure 5. Recharge-monitoring site, southwest Kansas (Sophocleous et al., 2002).

to measure the movement of water underground. Recently, the Kansas and U.S. geological surveys developed recharge-estimation sites in southern Finney County and in the Cimarron National Grassland in Morton County (fig. 5). Those studies indicated that recharge was close to 0.1 inch per year, and was considerably less in grassland areas than under irrigated land (Sophocleous et al., 2002). In general, annual recharge was estimated at less than one percent of annual precipitation. Irrigation development is now so widespread that irrigation seems to contribute more than precipitation to recharge in that region, although this recharge is at the expense of groundwater that was previously stored in the aquifer. Clearly, more irrigation to increase recharge is not the solution to declining water levels.

In an earlier, multi-year (1985–1992) study by the Kansas Geological Survey, in cooperation with the Big Bend Groundwater Management District in the Great Bend Prairie region of the High Plains aquifer, recharge was estimated to be about 10 percent of the annual precipitation, though in some years no recharge occurred at some locations (Sophocleous, 1992). Thus, it is clear that the time period and the size of the study area significantly affect estimations of recharge.

Based on recharge studies in the state, the consensus is that estimated average annual recharge to the area underlain by the Ogallala portion of the High Plains aquifer is on the order of less than 0.3 inch per year (Sophocleous, 2003). Much work remains to be done in studying recharge rates in Kansas. Interest is growing in the role of localized features on recharge, such as playas (broad, shallow depressions in western Kansas that fill with water during wet times and dry up during dry times). Although quantification of natural recharge is a difficult task, for most practical purposes it is sufficient to make approximate estimates and then refine these estimates through monitoring and analysis of aquifer responses to pumping.

Recharge and Water Management

In studying hydrologic systems, scientists generally construct a water budget. This is somewhat similar to a household budget, but instead of measuring income and expenses, a water budget measures water coming into a system and water going out of a system. In a system that is in balance, the amount of water entering the system, either through precipitation or movement underground, roughly equals the amount of water leaving the system, either for use by plants or via springs, seeps, creeks, or streams.

When recharge is low and additional uses are introduced, such as heavy pumping, water-level declines are almost certain to occur. Pumping more water than is entering the system is similar to spending more money than is in a checking account and is called an "overdraft." When water is removed from underground at the rate of feet per year, as it is in parts of western Kansas, and recharge is less than 0.3 inches per year, recharge is almost negligible in terms of overall water use.

To extend the life of aquifers in semi-arid parts of Kansas, reliance on recharge can only be a small part of the answer. Reduction of demand will play a larger role, through water-conservation measures, increasing irrigation efficiency, improving crop productivity, recycling and re-use, learning more about groundwater and irrigation through research, making information available through education, and establishing water-sharing networks. Many of these actions are underway in Kansas, and information is available from local groundwater management districts, the Kansas Geological Survey, the U.S. Geological Survey, the Division of Water Resources of the Kansas Department of Agriculture, the Kansas Water Office, the Ogallala Aquifer Institute, and Kansas State University's Extension Service, among others. Additional information on recharge is available in the literature (for example, see Lerner et al., 1990; Alley et al., 2002; Sophocleous, 2003; and an entire "Ground-water Recharge" recent theme issue in *Hydrogeology Journal*, v. 10, no. 1, February 2002).

Artificial Recharge

One possible solution to declining water levels is to artificially increase the amount of water moving into an aquifer. Artificial recharge requires an additional source of water to put into the ground, which is generally a problem in areas such as western Kansas that are already short of water. That was the major reason for discontinuing several small-scale recharge projects (including the use of playas to recharge underlying aquifers) attempted in the late 1970s and early 1980s in Kansas. Moving water from areas where water is plentiful, such as eastern Kansas, to water-short areas in western Kansas has been proposed over the years, but the high cost of transferring water over great distances (several hundred miles) and increased elevations (from about 1,000 feet in eastern Kansas to nearly 4,000 feet in the west) makes it uneconomical.

A more successful artificial-recharge project has been carried out in the Equus Beds Groundwater Management District in south-central Kansas. Water is taken from the Little Arkansas River during times of high flow and from wells in the aquifer immediately surrounding the Little Arkansas. That water is then pumped a few miles and transferred to wells, ponds, and other structures where it is put into the Equus Beds portion of the High Plains aquifer, an important source of drinking water for the city of Wichita and other cities and a source of water for irrigation and domestic use in central Kansas (fig. 6). Filtering and other treatments are used to make sure that the water put into the aquifer is of high quality. This artificial-recharge project also keeps the water table high enough to prevent a salt plume (originating from the briny Arkansas River) from migrating into the Wichita well field. While the project is still in its initial stages, it seems to have been successful in artificially moving water from a surface source (the Little Arkansas River) into the Equus Beds portion of the High Plains aquifer. (For more information visit the website http://ks.water.usgs.gov/Kansas/equus/.) In areas where surface water is relatively plentiful and in proximity to heavily used aquifers, such recharge projects may be feasible.

Figure 6. Recharge basin where water from the Little Arkansas River is recharging the Equus Beds portion of the High Plains aquifer.

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