

Kansas Water Plan

Planning Setting: Kansas Hydrologic, Climatic and Demographic Characteristics

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The physical Kansas that we experience today is the result of geologic and climatic factors interacting over eons of time. The resultant soils, topography and drainage pattern, along with the climate have helped influence where people live, work and play and the types of activities that they pursue.

Kansas, with a total area of 82,277 square miles, lies at the center of the contiguous United States and some 700 miles south of the geographic center of North America which is located in North Dakota. The land surface of Kansas slopes gently from west to east with extreme elevations ranging from 4,039 feet at Mt. Sunflower in Wallace County down to 679 feet at the point where the Verdigris River leaves the state in Montgomery County. The approximate mean elevation of the state is 2,000 feet.

Generalized bedrock formations or unconsolidated surface deposits are shown in Figure 1. These were formed by sediments deposited in ancient seas or by material deposited by wind, river currents or glaciers. The physical and chemical properties of these rock formations are critical to their suitability as aquifers and also influence surface water quality.

Figure 2 illustrates the general land cover and land use pattern across Kansas in 2005.

Kansas water resources are ground water dominated in the western half of the state and surface water dominated in the eastern half. Climate is a significant factor in this variability, with semi-arid conditions, low precipitation (typically 16 to 22 inches annually) and limited surface water in western Kansas. There are [aquifers](#) in eastern Kansas; however they are generally much more limited in extent and yield than the aquifers in western Kansas.

Surface Water Availability

Kansas has several major rivers and aquifers, but few natural lakes. Many reservoirs, large and small, have been constructed to control flooding and store water for beneficial use. Major rivers within Kansas include the Arkansas, the Kansas and the Neosho. The state's largest river, the Missouri, forms the northeast border.

Characteristics - The surface drainage pattern of Kansas reflects the general west to east slope of the land and the erosion characteristics of the bedrock formations. The entire state ultimately drains to the Gulf of Mexico by way of the Mississippi River as illustrated in Figure 3. In general, the northern half of the state is drained by the Missouri River and its tributaries, while the southern half is part of the Arkansas River drainage.

Twelve major river basins are commonly recognized in Kansas for general planning purposes, including preparation of the *Kansas Water Plan*. These basins are shown in Figure 4. The Upper Republican, Solomon, Smoky Hill-Saline, Kansas-Lower Republican, Marais des Cygnes and Missouri basins are all part of the greater Missouri River basin, while the Cimarron, Upper Arkansas, Lower Arkansas, Walnut, Verdigris and Neosho basins are part of the greater Arkansas River basin.

Streamflow volume in eastern Kansas is much greater than it is in the west due to greater total precipitation and the fact that runoff rates increase greatly from west to east across the state. This is reflected in the summary streamflow statistics shown in Table 1.⁽²⁾ Also worthy of note is the much greater annual volume of discharge generally experienced in streams located in the Missouri basin as compared with streams in the Arkansas basin.

Wide seasonal and year-to-year variations in flow are experienced in Kansas streams. For example, while the 1918-2007 annual mean flow in the Kansas River at De Soto is 7,295 cubic feet per second (cfs), monthly

mean flow varies from 2,840 cfs in January to 14,800 cfs in June. Annual mean flow has varied from 1,326 cfs in 1956 to 30,570 cfs in 1993.⁽²⁾

The year 1956 was the worst of the 1952-1957 drought period, which is considered the “drought-of-record” in Kansas. Four great floods, including that of 1993, have occurred on the Kansas River since the beginning of European settlement. The other great flood years were 1844, 1903 and 1951. The [Flood Damage Mitigation and Small Dam Safety](#) Management Section provides additional information about flooding.

Loss of Flow in Perennial Streams - Surface water and ground water are parts of a complex hydrologic system, and a change in one can impact the other. Areas in Kansas that have been intensely developed for ground water use have experienced water level declines. A consequence of these water level declines in some areas has been a decrease in baseflow in hydraulically connected streams. As a result, the flow in some western Kansas streams has become intermittent rather than perennial over time as depicted in Figure 5, causing a loss of water available to riparian vegetation and wetlands, and a detrimental impact to aquatic ecosystems.

Reservoirs - In an attempt to reduce the uncertainty produced by the state’s variability in climate and associated surface water supplies, Kansans have built numerous ponds and reservoirs. As of 2005, nearly 6,000 small dams in the state were regulated by the Kansas Department of Agriculture-Division of Water Resources. More than 1,500 of these dams have been constructed by organized watershed districts. Based on information on 4,000 of these regulated dams, their average age is now approximately 40 years.

The federal government has constructed 24 major reservoirs in Kansas.⁽¹⁾ The primary authorized use for reservoirs built by the U.S. Army Corps of Engineers at the time of their construction was flood control. Irrigation water supply was a primary use for those reservoirs constructed by the U.S. Bureau of Reclamation (Bureau), along with flood control. Other authorized uses, which vary by reservoir include municipal and industrial water supply, water quality, recreation and navigation support. The [Public Water Supply](#) Management Section provides additional information about the use of these reservoirs for municipal and industrial water supply.

Ground Water Availability

Figure 6 illustrates the general availability of ground water across Kansas in terms of typical well yield. The greater yields present in much of western and south central Kansas contrast with lesser yields in the east except for alluvial aquifers adjacent to the Kansas River.

The water resources of Kansas, including ground water, are becoming fully allocated. As demands increase and treatment technology improves, brackish ground water sources are being evaluated to meet a portion of the growing demand in areas where fresh water supplies are limited.

Kansas has seven primary freshwater aquifer sources as shown in Figure 7. The most developed sources are in unconsolidated sediments: the High Plains aquifer, the alluvial aquifers, and, to a lesser extent, the Glacial Drift aquifers. There are also several bedrock aquifers: the Dakota, the Ozark, the Osage and Flint Hills, along with a few more minor aquifers. A description of the basic characteristics of each primary aquifer follows.⁽⁴⁾

Alluvial Aquifers - Alluvial aquifers occur in the sand, gravel, silts and clays deposited by the major rivers and many of the smaller streams in Kansas. The thickness of the deposits varies considerably, with the deepest deposits up to 300 feet occurring in the major river valleys. The water in these aquifers tends to be shallow (10–30 feet), recharges relatively quickly, and is often directly connected to the stream. In parts of eastern Kansas, the alluvial aquifers are the only significant source of ground water. In the Arkansas, Republican, Kansas and Pawnee river valleys, alluvial wells often yield 500 gallons per minute (GPM).

The water in the alluvial aquifers generally flows towards or sub-parallel to the streams. High stream flows can enhance aquifer recharge from the rivers. During periods of low streamflow, water flows out of the alluvial aquifers and back into the streams; this contribution to streamflow is referred to as baseflow.

Baseflow helps maintain streamflow even when there is little precipitation and surface runoff. However, heavy withdrawals from an alluvial aquifer can lower the water table to the point where it no longer replenishes the stream. This has occurred in a number of streams in western and central Kansas including the Solomon, Smoky Hill, Arkansas, Pawnee and Walnut rivers.

Water quality in alluvial aquifers is generally acceptable for most purposes. Saltwater from Permian deposits has seeped into the Solomon and Smoky Hill River alluvial aquifers in Saline and Dickinson counties. Salinity problems have also occurred in parts of the Cimarron River valley of southwest Kansas, in the Ninnescah River in south central Kansas, and in portions of the Arkansas River valley. The Dakota aquifer also discharges saline water in Russell County and the Solomon River in Mitchell and Ottawa counties.

Glacial Drift Aquifers - Northeast Kansas was covered by continental glaciers roughly 750,000 years ago. The landforms and deposits left by the glaciers are common features in an area north of the Kansas River and east of Tuttle Creek Reservoir, extending to the Missouri River. Glacial deposits consist of a poorly sorted mix of sand, gravel and clay. In some cases these deposits have filled in ancient valleys that are now prolific water bearing sources. The buried valleys may be several miles wide, and 200 to 400 feet deep. Buried alluvial aquifers are not widespread nor are they well mapped. As a result, water in these aquifers can be difficult to locate.

Water-bearing zones can be as shallow as 5 to 50 feet in buried alluvial aquifers, but often exceed 100 feet. Well yields range from 10 to 500 gallons per minute (GPM). The water quality from shallow wells is generally good, although in some wells the nitrate concentrations exceed the safe drinking water level of 10 milligrams per liter (mg/L). The deeper wells often have more mineralized water, with total dissolved solids exceeding 500 mg/L.

High Plains Aquifer - The High Plains aquifer⁽⁷⁾ underlies the western and south central portions of Kansas. It is one of the world's largest aquifers, and underlies portions of eight states, from South Dakota to Texas and New Mexico. About 27% of the irrigated cropland in the United States overlies the High Plains aquifer. In Kansas, the aquifer consists of the hydraulically interconnected Ogallala aquifer in the west, the shallower and geologically younger Great Bend Prairie and the Equus Beds aquifers in south central Kansas, and associated alluvial and sand dune aquifers. Figure 8 shows the average saturated thickness of the High Plains aquifer in Kansas.

The Ogallala portion of the High Plains aquifer is the primary source of water in western Kansas for all uses, and is heavily developed, primarily for irrigation. Most of the Ogallala-High Plains aquifer is closed to or restricted from additional development. The aquifer is threatened by continued over-use and, in localized areas, deteriorating water quality.

The Ogallala-High Plains aquifer is up to several hundred feet thick in places, with the thickest deposits in southwestern Kansas. The saturated thickness is also highly variable, with some locations having more than 300 feet of water. Recharge from precipitation to the Ogallala may be as high as 1 inch per year, but may vary depending on local precipitation, soil type, land use, vegetation, and other factors. Ground water flow in general is in a west-northwest to east-southeast direction.

The Great Bend Prairie aquifer in south central Kansas is similar in composition to the Ogallala. It ranges in thickness from 350 feet in portions of Kiowa and Edwards counties, to thin deposits in Kingman and Reno counties. Recharge to the Great Bend Prairie may be up to three inches per year.

The Equus Beds, to the east, is an alluvial deposit of an ancestral river that flowed into the Arkansas River. The deposits filled an abandoned river channel in Harvey and McPherson counties, as well as areas of subsidence from salt dissolution. The deposits range up to 270 feet in thickness, with water depths typically fairly shallow, from 5 or 10 feet to 60 or 70 feet below ground surface. In the Equus Beds recharge may be up to four inches per year.

The water quality is generally good for most purposes, except in areas where salt has seeped in, either from natural sources or oil field brine disposal. The aquifer is a primary source of water for the Wichita metropolitan area. Protection from contamination is a high concern, due to the aquifer's shallow, vulnerable location.

Dakota Aquifer - The Dakota aquifer occurs within the sandstones of the Dakota Formation, as well as the Kiowa Formation and Cheyenne Sandstone. The Dakota aquifer system consists of upper and lower units, separated in western and central Kansas by the shale units of the Kiowa.⁽⁵⁾ This shale aquitard ranges up to 300 feet in parts of west central and southwestern Kansas. The shale aquitard is not present in much of central Kansas, and in those regions there may be direct hydraulic connection between the upper and lower Dakota aquifer.

In much of western Kansas, the aquifer is confined by younger Cretaceous bedrock units that overlie the aquifer. In central and a few areas of southwestern Kansas, the Dakota crops out at the surface and the aquifer is unconfined. In much of southwest Kansas, the Dakota underlies and is hydraulically connected to the High Plains aquifer.

The Dakota aquifer is used for municipal, industrial and irrigation uses in central and western Kansas. Ground water flow in the Dakota aquifer is from recharge areas in southwestern Kansas and southeastern Colorado northeastward towards discharge areas in central Kansas and Nebraska. Well yields range widely, but typically average between 50 and 100 gpm. In central Kansas, the Dakota overlies salt-bearing Permian deposits and is recharged, in part, by the saltwater, making the aquifer unusable. Some deeper portions of the Dakota aquifer become saline with total dissolved solids that exceed 10,000 mg/L.

There is growing interest in the Dakota aquifer as a water source. Unlike the High Plains aquifer, it is still open to new appropriations in many areas. However, it is deeper, so more expensive to pump, has more variable water quality, and wells typically have lower yields than do those utilizing the High Plains aquifer.

Flint Hills Aquifer - In the Flint Hills of eastern Kansas there are aquifers of limited extent in the Permian age limestones of the Chase and Council Grove Groups. These provide water for farmsteads and small communities. Well yields range from 10 to 100 gpm, typically, although some individual wells and springs discharge at considerably higher rates. The town of Florence in Marion County gets its water from a local spring. The quality of water from these aquifers is suitable for most purposes, although the sulfate concentrations can exceed 250 mg/L locally.⁽⁴⁾

Osage Cuestas Aquifer System - Several of the sandstones and limestones of the Pennsylvanian age Douglas Group bear water utilized by small towns, rural water districts and domestic wells in eastern Kansas. The primary aquifer occurs in the Tonganoxie and Ireland sandstones. These deposits are in ancient river valleys that were cut into older bedrock. Recharge to the aquifers comes primarily from precipitation where the rock units crop-out or occurs in the shallow subsurface. These aquifers provide water to rural populations that do not have access to streams or reservoirs. Typical well yields are 5 to 50 gpm or less. The aquifers are typically unconfined. Some of the wells produce water with fluoride concentrations that exceed 1.4 mg/L. Water quality deteriorates to the west, where it becomes more saline. Lateral movement of the saline waters is a problem where well fields are close and are pumped too intensely.

Ozark Aquifer - The Ozark Plateau aquifer system is located in the southeastern corner of Kansas. It consists of two aquifer units separated by an impervious aquitard. The upper aquifer unit is the Springfield Plateau aquifer, the lower unit is the Ozark aquifer. In areas of southeast Kansas, where the Ozark aquifer is used as a water source, it is referred to as the Roubidoux. Elsewhere in Kansas, where not used as a drinking water source, it is often referred to as the Arbuckle.⁽⁴⁾

The Ozark aquifer is a confined aquifer, occurring in fractures and solution cavities within rock units consisting of soluble dolomite. It is a heterogeneous and high yielding aquifer, in which water levels are very responsive to withdrawals. Well yields typically range from 150 to more than 2,000 gpm. Recharge comes from precipitation falling on the Ozark region in southern Missouri, where the Cambro-Ordovician rocks crop-out at the surface.

The aquifer is an important source of water for the tri-state region of Missouri, Kansas and Oklahoma. Over the past two decades, water users in Cherokee and Crawford counties in Kansas have reported significant water level declines in wells, in some cases 50 to 100 feet in just a few years, as a result of increased withdrawals.

Declines in the Ozark aquifer can induce recharge from the overlying Springfield aquifer, the Arbuckle portion of the aquifer to the west or sources deeper within the Ozark, which could result in declines in water quality. The Springfield aquifer contains numerous mining and industrial contaminants, which could leak downward into the Ozark aquifer. Also, as water levels continue to decline in the freshwater part of the Ozark aquifer, brines from the Arbuckle could migrate eastward. The poor quality water, with high dissolved solids, chloride concentrations, and hardness, could cause treatment problems for some public water supplies and industries.

Water Use

Kansans divert approximately four million acre-feet of water annually for their use. Statewide, irrigation is the largest water user, accounting for 80-85 percent of all water diverted in most years. Municipal use is the second largest water use category. Figure 9 shows 2006 Kansas water use by category. About 90 percent of the water used is pumped from ground water sources.⁽¹¹⁾

Figure 10 shows county [water use](#) by type and relative amount across Kansas in 2006. The large amount of water use in many western and south central counties, particularly for irrigation, stands out as does the very modest overall use of water in many non-metropolitan eastern and north central counties. Ground water is the major source of supply in western Kansas, while surface water supplies predominate in the east.

All non-domestic Kansas water users must submit an annual water use report to the Kansas Department of Agriculture-Division of Water Resources (DWR). The DWR collaborates with the Kansas Water Office and the U.S. Geological Survey in publishing municipal and irrigation water use reports each year.⁽¹²⁾

Climate

Owing to its location, Kansas has a continental climate characterized by large variations in temperature, both seasonally and from day-to-day, and by concentration of precipitation during the growing season.

The oceans are the primary source of atmospheric moisture. In the case of moisture from the Pacific Ocean carried inland on prevailing westerly winds, much is lost as snow and rain over the Rocky Mountains and other western mountain ranges. Thus, western Kansas is in a so-called "rain shadow" downwind from the Rockies.

During summer, a semi-permanent area of high pressure, the Bermuda High, develops in the western Atlantic Ocean. The clockwise circulation around the Bermuda High brings warm, moist air northward from the Gulf of Mexico into the central United States. Here, this moist airmass often interacts with cold fronts associated with storms steered by the jet stream, bringing rain and thunderstorms to Kansas. During the winter there is a much greater frequency of dry continental air masses originating over northern Canada, which results in much less precipitation during that season.

Figure 11 illustrates the main influences upon the state's climate.

Wide seasonal temperature variations are characteristic of Kansas. Far from the tempering influence of the ocean and without any mountain barrier to the north, Kansas is subject to occasional outbreaks of Arctic air during winter and hot, dry air masses from the desert southwest during summer.

Extreme temperatures recorded in the state have ranged from 121^oF at Alton and Fredonia in July 1936 down to -40^oF at Lebanon in February 1905. Total precipitation in a given year has ranged from 6.62 inches at Colby in 1910 to 71.99 inches at Hiawatha in 1973.⁽¹⁸⁾

Climate Normals - Normal values for precipitation, temperature and other variables are based upon a 30-year period of record, as recommended by the World Meteorological Organization. In the United States, these normals are established by the National Climatic Data Center,⁽²⁰⁾ an agency within the National Oceanic and Atmospheric Administration (NOAA). NOAA is also the parent agency for the National Weather Service.

The current climate normals are based upon the period 1971 through 2000. These normals are adjusted every 10 years. The next normal period will be 1981-2010. Normals may be established for individual weather

stations, multi-county areas (climate divisions) within a state or for the state as a whole. In the case of individual stations, daily normals for maximum, minimum and average temperature and total precipitation are determined. Normal threshold dates for occurrences such as frost dates may also be determined. Monthly average temperature and total precipitation normals are established for individual stations, climate divisions and the state.

Figure 12 shows the multi-county climate divisions within Kansas. Figures 13, 14 and 15 show statewide patterns of normal annual total precipitation, normal annual temperature and the normal number of days between the last frost of spring and the first frost of autumn. Tables 3 and 4 following the maps provide current normal monthly total precipitation and average temperatures for each climate division.

Climate Variability and Drought - In describing the difference between weather and climate an old adage states "climate is what you expect and weather is what you get." Both weather and climate exhibit a great deal of variability in Kansas. This may be the case over several days, from year-to-year, or over a multi-year period. Precipitation variability is common throughout the year while temperatures tend to vary most during the winter.

Perhaps the most striking example of this variability is the periodic recurrence of drought conditions in Kansas. Drought differs from other natural disasters in that its onset is generally slow, but it may persist for a long period of time. Drought impacts are cumulative, first affecting soil moisture and agriculture, but ultimately affecting ground water levels, streamflow and reservoir storage if the drought is severe and persistent.⁽¹⁹⁾

Drought is commonly monitored through the use of indicators or indices and not by precipitation alone.⁽²¹⁾ A common index used in the United States is the Palmer Drought Severity Index (PDSI). The PDSI is a soil moisture algorithm developed in the 1960s. It is based on the supply and demand concept of the water balance equation and is commonly calculated by climate division. The PDSI varies roughly between +/- 6.00 with values of 1.00 or above indicating wet conditions and values of -1.00 or below indicating drought of varying intensity.

Figure 16 shows the trend in the PDSI in the Southwest Kansas Climate Division between 1895 and 2007. The temporal variability of moisture conditions is evident with the drought periods in the 1930s and 1950s clearly indicated.⁽²⁰⁾

Implications of Climate Change - Climate change or "global warming" has been a contentious issue in recent years. The degree to which human activity has been responsible for change is particularly controversial. Also, there is disagreement on how best to respond to climate change. Proposals to reduce greenhouse gas emissions to the atmosphere have received the most attention, but adaptation is another strategy being considered.

On March 21, 2008, Kansas Governor Kathleen Sebelius issued Executive Order 08-03 establishing the Kansas Energy and Environmental Policy Advisory Group (KEEP). The KEEP was directed to examine issues related to climate change and energy in Kansas and to make recommendations to the Governor for reducing greenhouse gas emissions in the state. A preliminary report is due in January 2009 with a final report to be submitted to the Governor on or before the first day of the 2010 legislative session.

Models used to predict the future impacts of climate change tend to provide very broad projections that are difficult to reduce to a local scale. Attempts have been made to model the effects of climate change at a regional scale in the United States, particularly in the Colorado River basin. Model results at this scale are not available for the Great Plains or the Midwest.

Due diligence in protecting water resources and adapting to future climate variability may be important to maintaining and improving the quality of life and the state's economy.

Population and Demographic Change

Kansas has experienced significant demographic changes since the end of World War II. As identified by Krider and Clifford,⁽²³⁾ these changes include 1) the concentration of population growth in the state's urban

counties, 2) the aging of the population, and 3) rapid growth in minority populations.

Population growth in Kansas has lagged behind the national average in recent decades. During the 1980s, the population of Kansas increased by 4.8%, compared to a national increase of 9.8%. During the 1990s, population growth in Kansas, 8.5%, was four percent below the national figure.⁽²⁶⁾ Table 5 shows the total population of Kansas by decade since 1950 compared with that of regional states.

Worthy of note is that Kansas had a greater population than Colorado as recently as 1970. Colorado's population now exceeds that of Kansas by more than 2 million people. Also of interest is the mega-state status of Texas, the second most populous state in the Union following California. With 23.9 million people, the total population of Texas is nearly that of the other seven regional states combined (24.7 million).

The most significant Kansas population trend has been the rapid movement of people from rural to urban areas.⁽²³⁾ Between 1950 and 2000, 44 Kansas counties experienced a population decline of 25 percent or more. Thirty-two counties grew during this time period. Growing counties were centered in the Kansas City and Wichita metropolitan areas, southwest Kansas and counties serving as regional commercial and medical hubs. Other growing counties benefitted from hosting a state university or military base, or in being served by an interstate highway.

As a result of this population shift, the state's population is increasingly being concentrated in its largest counties. By 2007, Johnson County had surpassed Sedgwick County as the state's most populous. The 10 largest counties in 2007 had a total population of 1,766,684. This was some 63% of the state total. In 1950, the 10 largest counties accounted for only 43% of the state's total population. Figure 17 illustrates the estimated 2007 population, by county, across Kansas.

Population Projections - In the 1990s, the Kansas Water Office made county and river basin population estimates and projections out to the year 2040. These projections were endorsed by the Kansas Department of Administration-Division of the Budget as the official Kansas projections.⁽²²⁾ These are available at [Kansas Population 1990-2040](#). Water demands associated with these projections were made by county and by public water system.

More recently, some adjustments to county population projections based on 2000 U.S. Census figures have been made as part of the analyses supporting the Kansas Water Authority's Reservoir Sustainability Initiative.

Resources

Surface Water Availability

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Population and Demographic Change

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