Oklahoma Comprehensive Water Plan

OCWP

Lower Arkansas Watershed Planning Region Report

Version 1.1

Oklahoma Water Resources Board

The objective of the Oklahoma Comprehensive Water Plan is to ensure a dependable water supply for all Oklahomans through integrated and coordinated water resources planning by providing the information necessary for water providers, policy-makers, and end users to make informed decisions concerning the use and management of Oklahoma's water resources.

This study, managed and executed by the Oklahoma Water Resources Board under its authority to update the Oklahoma Comprehensive Water Plan, was funded jointly through monies generously provided by the Oklahoma State Legislature and the federal government through cooperative agreements with the U.S. Army Corps of Engineers and Bureau of Reclamation.

Oklahoma Comprehensive Water Plan

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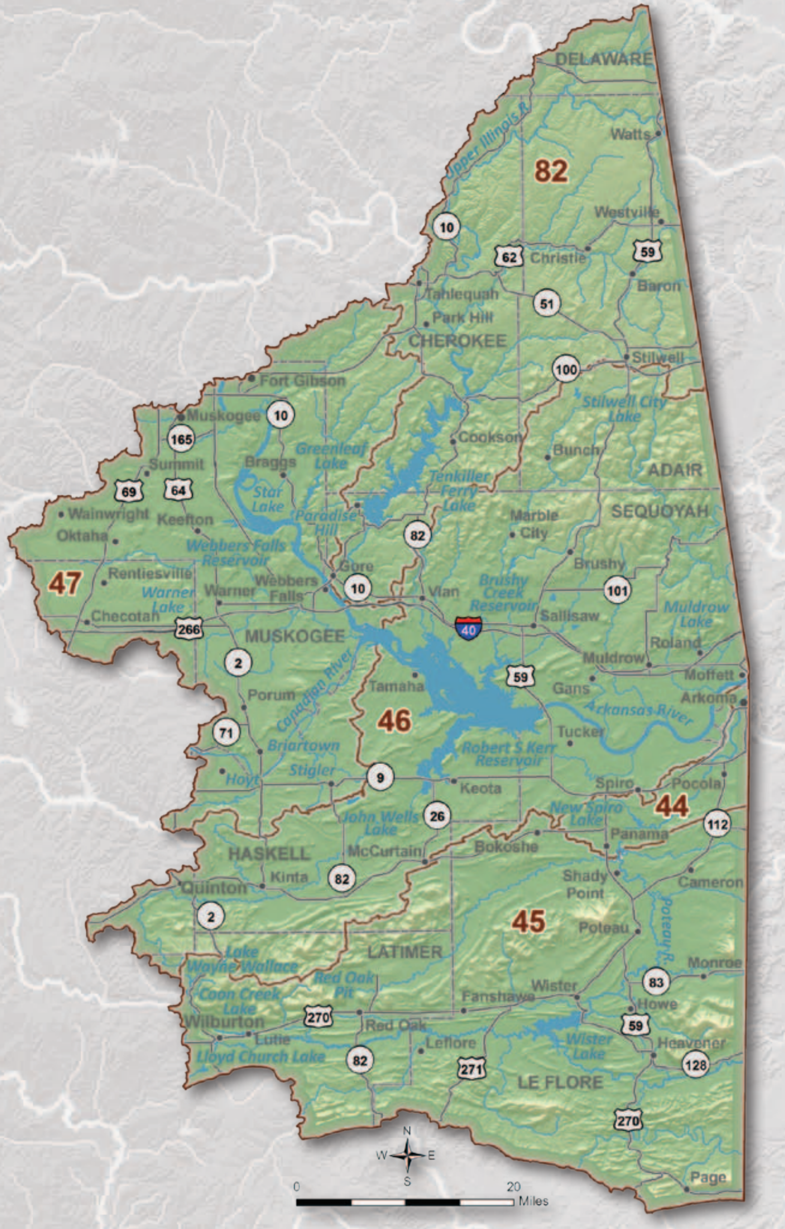
The online version of this 2012 OCWP Watershed Planning Region Report (Version 1.1) includes figures that have been updated since distribution of the original printed version. Revisions herein primarily pertain to the seasonality (i.e., the percent of total annual demand distributed by month) of Crop Irrigation demand. While the annual water demand remains unchanged, the timing and magnitude of projected gaps and depletions have been modified in some basins. The online version may also include other additional or updated data and information since the original version was printed.

Oklahoma Comprehensive Water Plan

Lower Arkansas Watershed Planning Region



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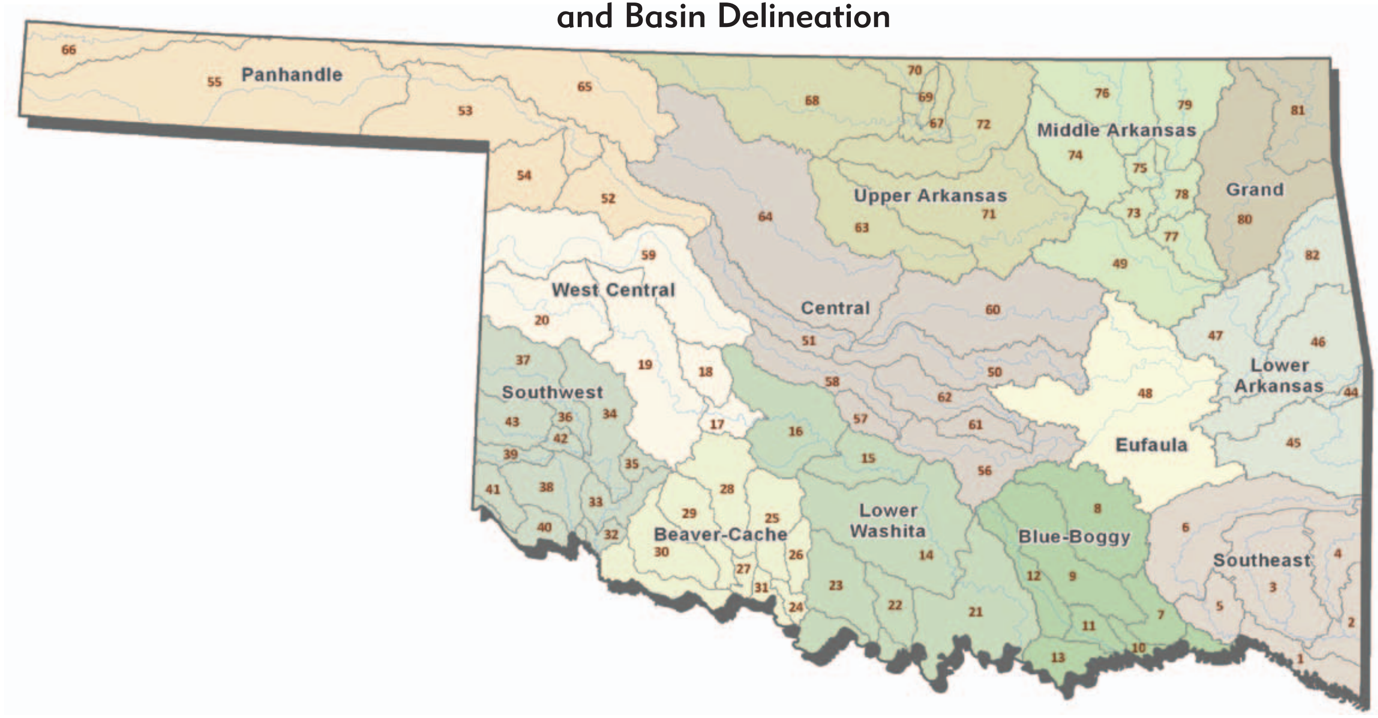


Introduction

The Oklahoma Comprehensive Water Plan (OCWP) was originally developed in 1980 and last updated in 1995. With the specific objective of establishing a reliable supply of water for state users throughout at least the next 50 years, the current update represents the most ambitious and intensive water planning effort ever undertaken by the state. The *2012 OCWP Update* is guided by two ultimate goals:

1. Provide safe and dependable water supply for all Oklahomans while improving the economy and protecting the environment.
2. Provide information so that water providers, policy makers, and water users can make informed decisions concerning the use and management of Oklahoma's water resources.

In accordance with the goals, the *2012 OCWP Update* has been developed under an innovative parallel-path approach: inclusive and dynamic public participation to build sound water policy complemented by detailed technical evaluations.

Also unique to this update are studies conducted according to specific geographic boundaries (watersheds) rather than political boundaries (counties). This new strategy involved dividing the state into 82 surface water basins for water supply availability analysis (see the OCWP *Physical Water Supply Availability Report*). Existing watershed boundaries were revised to include a United States Geological Survey (USGS) stream gage at or near the basin outlet (downstream boundary), where practical. To facilitate consideration of regional supply challenges and potential solutions, basins were aggregated into 13 distinct Watershed Planning Regions.

The primary factors in the determination of reliable future water supplies are physical supplies, water rights, water quality, and infrastructure. Gaps and depletions occur when demand exceeds supply, and can be attributed to physical supply, water rights, infrastructure, or water quality constraints.

This Watershed Planning Region report, one of 13 such documents prepared for the *2012 OCWP Update*, presents elements of technical studies pertinent to the Lower Arkansas Region. Each regional report presents information from both a regional and multiple basin perspective, including water supply/demand analysis results, forecasted water supply shortages, potential supply solutions and alternatives, and supporting technical information.

As a key foundation of OCWP technical work, a computer-based analysis tool, "Oklahoma H2O," was created to compare projected demands with physical supplies for each basin to identify areas of potential water shortages.

Integral to the development of these reports was the Oklahoma H2O tool, a sophisticated database and geographic information system (GIS) based analysis tool created to compare projected water demand to physical supplies in each of the 82 OCWP basins statewide. Recognizing that water planning is not a static process but rather a dynamic one, this versatile tool can be updated over time as new supply and demand data become available, and can be used to evaluate a variety of "what-if" scenarios at the basin level, such as a change in supply sources, demand, new reservoirs, and various other policy management scenarios.

Primary inputs to the model include demand projections for each decade through 2060, founded on widely-accepted methods and peer review of inputs and results by state and federal agency staff, industry representatives, and stakeholder groups for each demand sector. Surface water supply data for each of the 82 basins is based on 58 years of publicly-available daily streamflow gage data collected by the USGS. Groundwater resources were characterized using previously-developed assessments of groundwater aquifer storage and recharge rates.

Additional and supporting information gathered during development of the *2012 OCWP Update* is provided in the *OCWP Executive Report* and various OCWP supplemental reports. Assessments of statewide physical water availability and potential shortages are further documented in the OCWP *Physical Water Supply Availability Report*. Statewide water demand projection methods and results are detailed in the OCWP *Water Demand Forecast Report*. Permitting availability was evaluated based on the OWRB's administrative protocol and documented in the OCWP *Water Supply Permit Availability Report*. All supporting documentation can be found on the OWRB's website.

Regional Overview

The Lower Arkansas Watershed Planning Region includes five basins (numbered 44-47 and 82 for reference). The region encompasses 4,657 square miles in eastern Oklahoma, spanning all of Adair and Sequoyah Counties and parts of Delaware, Cherokee, Muskogee, Haskell, LeFlore, McIntosh, Pittsburg, and Latimer Counties.

The region includes portions of the Ouachita and Ozark Plateaus physiography provinces. The region's terrain varies from forested mountains to the rolling river basin plains of the Arkansas River and foothills of the Ozark Mountains, including the dissected plateaus of the Boston Mountains, which rise up to 800 feet above the surrounding terrain. The region is largely oak-hickory forest and cross timbers with large areas of pasture land and other agricultural land in the flatter, southern portion.

The region's climate is mild with annual mean temperatures varying from 59°F to 61°F. Annual average precipitation ranges from 45 inches in the north and west to 54 inches in the south and east. Annual evaporation ranges from 56 to 46 inches per year.

The largest cities in the region include Muskogee (2010 population 39,223), Tahlequah (15,753), Sallisaw (8,880), and Poteau (8,520).

The greatest demand is from Thermoelectric Power water use. By 2060, this region is projected to have a total demand of 319,650 acre-feet per year (AFY), an increase of 117,760 AFY (58%) from 2010.

Lower Arkansas Regional Summary

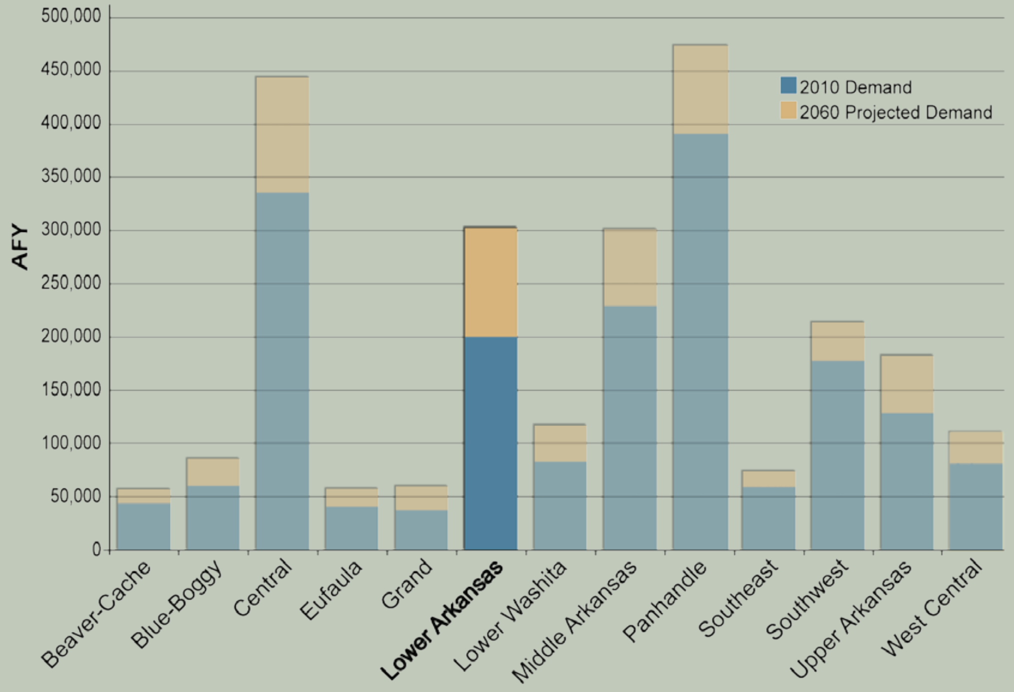
Synopsis

- The Lower Arkansas Region relies primarily on surface water supplies (including reservoirs) and to a lesser extent alluvial and bedrock groundwater.
- It is anticipated that water users in the region will continue to rely on these sources to meet future demand.
- Surface water gaps may occur by 2060 in Basin 44, by 2040 in Basin 46, and by 2020 in Basin 47.
- Alluvial groundwater storage depletions may occur by 2050 in Basin 45, by 2040 in Basin 46, and by 2020 in Basin 47. Bedrock groundwater storage depletions may occur by 2060 in Basin 44 and by 2020 in Basin 45. These depletions may lead to higher pumping costs and potential changes to well yields or water quality.
- To reduce the risk of adverse impacts on water supplies, it is recommended that gaps and storage depletions be decreased where economically feasible.
- Additional conservation could reduce or eliminate surface water gaps, alluvial groundwater storage depletions, and bedrock groundwater storage depletions.
- Developing additional groundwater supplies and/or developing new reservoirs could mitigate surface water gaps without major impacts to groundwater storage.
- No basins within the region have been identified as water availability "hot spots," areas where severe deficits or gaps in supply are anticipated. (See "Regional and Statewide Opportunities and Solutions" in the *OCWP Executive Report*.)

Lower Arkansas Region Demand Summary

Current Water Demand:	201,890 acre-feet/year (11% of state total)
Largest Demand Sector:	Thermoelectric Power (54% of regional total)
Current Supply Sources:	91% SW 7% Alluvial GW 2% Bedrock GW
Projected Demand (2060):	319,650 acre-feet/year
Growth (2010-2060):	117,760 acre-feet/year (58%)

Current and Projected Regional Water Demand



The Lower Arkansas Region accounts for about 11% of the state's total water demand. The largest demand sectors are Thermoelectric Power (54% of the region's overall demand), Municipal and Industrial (15%), and Crop Irrigation (13%).

Water Resources & Limitations

Surface Water

Surface water supplies are used to meet 91% of the Lower Arkansas Region's total water demand. The region is supplied by four major rivers: the Arkansas, Canadian, Illinois, and Poteau. The rivers and creeks in the region can have infrequent periods of low flow due to seasonal and long-term trends in precipitation. Large reservoirs have been built to provide water for public water supply, flood control, power generation, recreation, navigation, and other purposes. Large reservoirs in the Lower Arkansas Region, all constructed by the U.S. Army Corps of Engineers, include Tenkiller Ferry and Wister, which provide public water supply and other purposes, and Robert S. Kerr and Webbers Falls, which provide navigation and hydropower but do not provide municipal and industrial water supplies. There are six other smaller lakes in the region that have normal pools ranging from 1,352 AF to 3,250 AF. All basins in the region are expected to have available surface water for new permits to meet local demand through 2060. Relative to other regions in the state, surface water quality in the region is considered good except for in Basin 44. Multiple rivers, creeks, and lakes are impaired for Agricultural use (Crop Irrigation demand sector) and Public and Private Water Supply (Municipal and Industrial demand sector) due to high levels of total dissolved solids (TDS), sulfate, and chlorophyll-a. These impairments are scheduled to be addressed through the Total Maximum Daily Loads (TMDL) process, but the use of these supplies may be limited in the interim.

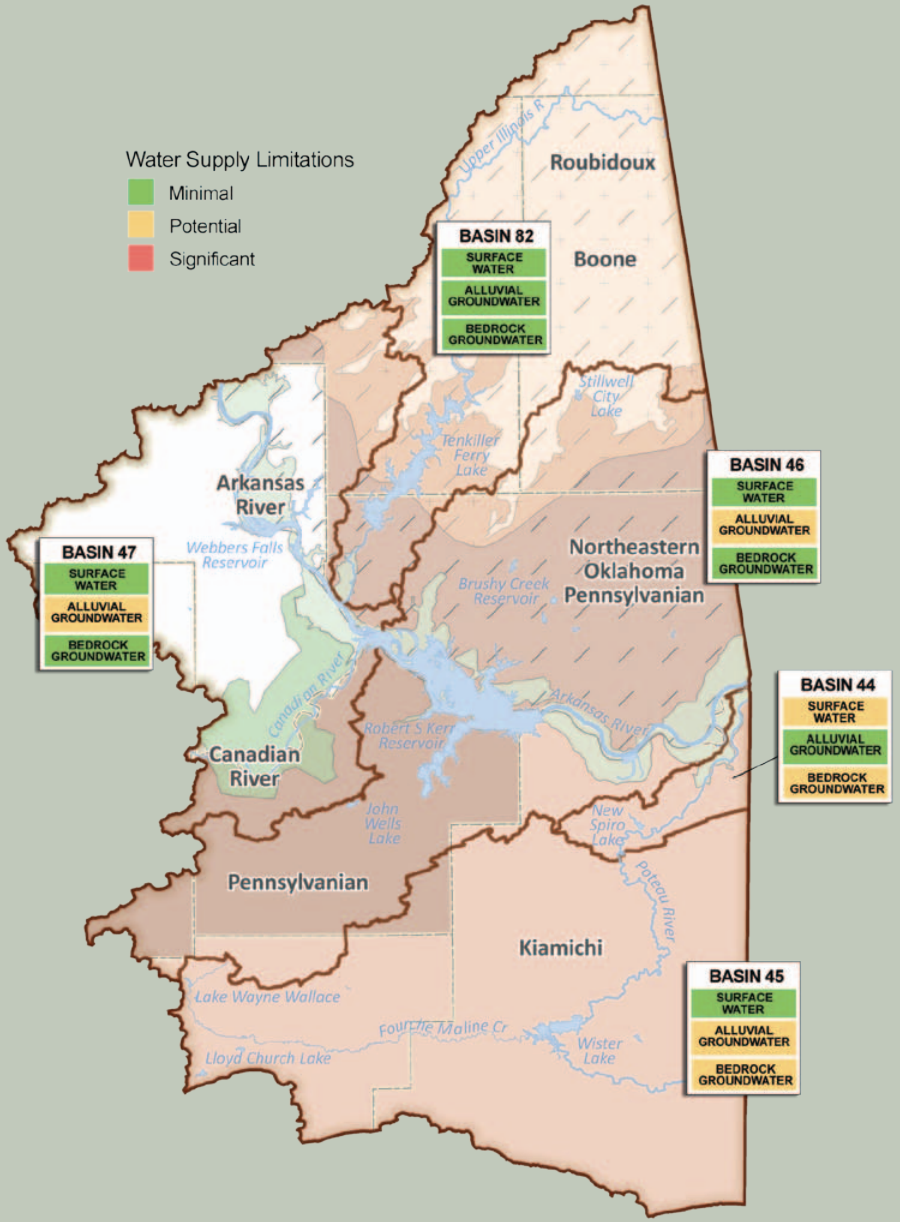
Alluvial Groundwater

Alluvial groundwater is used to meet 7% of the demand in the region. The majority of currently permitted alluvial groundwater withdrawals in the region are from the Arkansas River aquifer in Basins 46 and 47. Domestic users do not require permits and are assumed to be primarily obtaining supplies from the Arkansas River aquifer, the Canadian River aquifer, and minor alluvial aquifers throughout the region to meet their needs. If alluvial groundwater continues to supply a similar portion of demand in the future, storage depletions from these aquifers are likely to occur in summer, fall, and winter. Minor aquifers typically tend to have smaller yields; therefore, site-specific information should be considered before long-term or large-scale use of these sources. There are no significant aquifer-wide alluvial groundwater quality issues in the region. The availability of permits is not expected to constrain the use of alluvial groundwater supplies to meet local demand through 2060.

Bedrock Groundwater

Bedrock groundwater is used to meet 2% of the demand in the region. Currently permitted and projected withdrawals are primarily from the Boone minor aquifer, Kiamichi minor aquifer, and other minor aquifers. Since minor aquifers often have smaller yields, site-specific information should be considered before long-term or large-scale use. Concentrations of chloride and naturally occurring radioactivity may exceed drinking water standards in some areas of the Roubidoux aquifer. However, there are no significant aquifer-wide bedrock groundwater quality issues in the region. The availability of permits is not expected to constrain the use of bedrock groundwater supplies to meet local demand through 2060.

Water Supply Limitations
Lower Arkansas Region



Water Supply Limitations

Surface water limitations were based on physical availability, water supply availability for new permits, and water quality. Groundwater limitations were based on the total size and rate of storage depletions in major aquifers. Groundwater permits are not expected to constrain the use of groundwater through 2060, and insufficient statewide groundwater quality data are available to compare basins based on groundwater quality. Basins with the most significant water supply challenges statewide are indicated by a red box. The remaining basins with surface water gaps or groundwater storage depletions were considered to have potential limitations (yellow). Basins without gaps and storage depletions were considered to have minimal limitations (green). Detailed explanations of each basin's supplies are provided in individual basin summaries and supporting data and analysis.

Water Supply Options

To quantify physical surface water gaps and groundwater storage depletions through 2060, use of local supplies was assumed to continue in the current (2010) proportions. Surface water supplies and reservoirs are expected to continue to supply the majority of demand in the Lower Arkansas Region. Basins and users that rely on surface water are projected to have physical surface water supply shortages (gaps) in the future, except where major reservoirs can provide adequate supply. Alluvial and bedrock groundwater storage depletions are also projected in the future. The development of the Arkansas River and Canadian alluvial groundwater supplies should be considered a short- to long-term water supply option. However, additional long-term water supplies should be considered for both surface water and groundwater users.

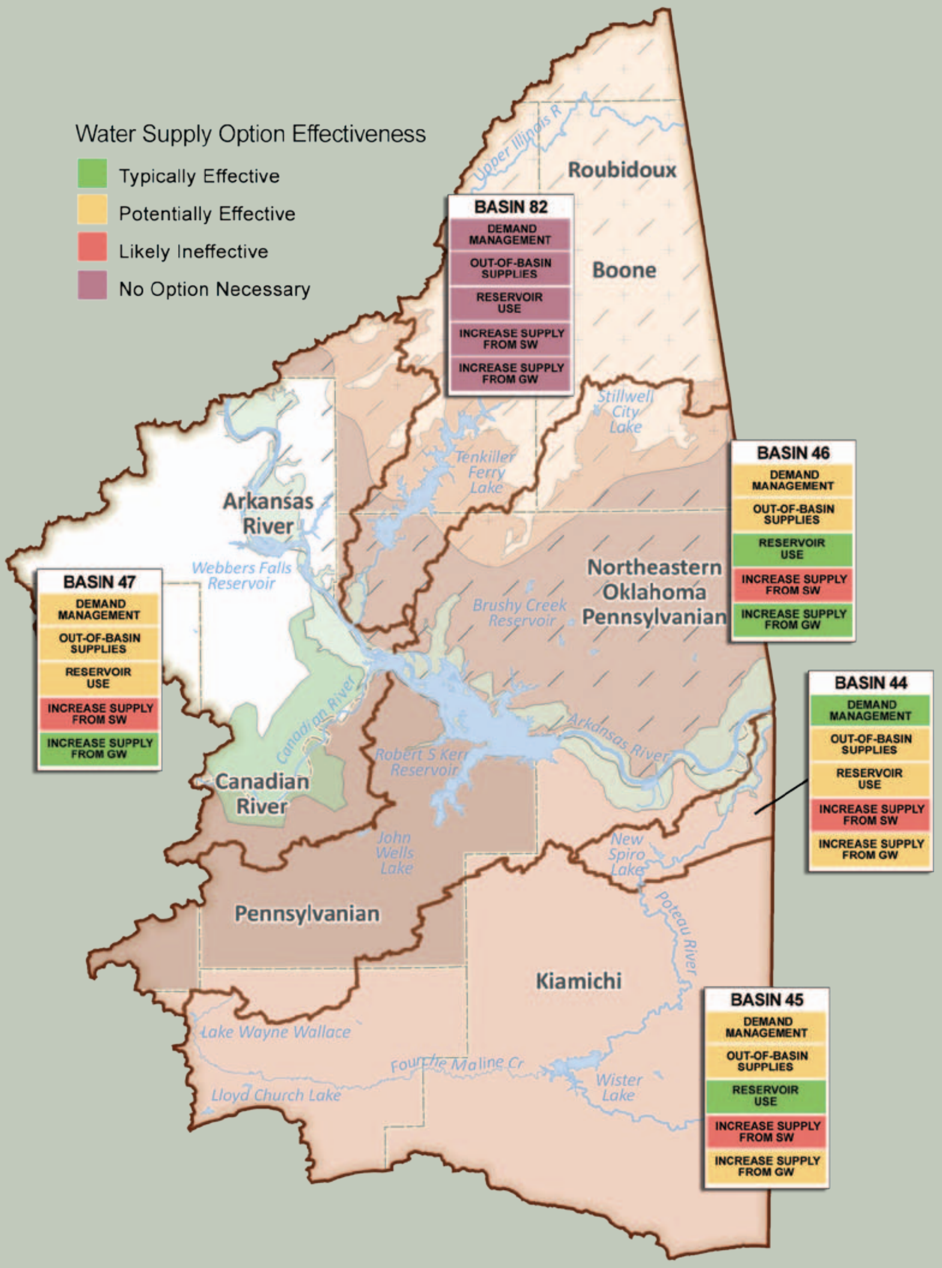
Water conservation could aid in reducing projected gaps and groundwater storage depletions or delaying the need for additional infrastructure. Moderately expanded conservation activities, primarily increased conservation by public water suppliers and from increased irrigation crop efficiency, could reduce gaps and storage depletions and eliminate surface water gaps in Basin 44. Further reductions could occur from substantially expanded conservation activities. These measures would require a shift from crops with high water demand (e.g., corn for grain and forage crops) to low water demand crops such as sorghum for grain or wheat for grain, along with increased irrigation efficiency and increased public water supplier conservation. Due to the low probability of low flows, temporary drought management measures may be an effective water supply option.

New reservoirs and expanded use of existing reservoirs could enhance the dependability of surface water supplies and eliminate gaps. Major reservoirs in the Lower Arkansas Region have little unpermitted yield, but may meet future demand of existing permit holders. Out-of-basin supplies from existing or potential reservoir sites could also provide additional supplies to mitigate the region's groundwater gaps. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified four potentially viable reservoir sites in the Lower Arkansas Watershed Planning Region. However, due to the distance to dependable supplies and substantial supplies in the region, this water supply option may not be cost-effective for some users.

The projected growth in surface water could instead be supplied in part by increased use of major alluvial groundwater aquifers, which would result in minimal increases in projected groundwater storage depletions. However, these aquifers are not widespread in the region and alluvial users would still be susceptible to the adverse effects of groundwater storage depletions.

Water Supply Option Effectiveness

Lower Arkansas Region



This evaluation was based upon results of physical water supply availability analysis, existing infrastructure, and other basin-specific factors.

Water Supply

Physical Water Availability

Surface Water Resources

Surface water has historically accounted for about 91% of the supply used to meet demand in the Lower Arkansas Region. The region's major streams include the Poteau River, Illinois River, Canadian River, and Arkansas River. Flows in the Canadian and Arkansas Rivers are generally abundant with occasional low flow conditions. Flows in the Illinois and Poteau Rivers are reliable but not as large, with periodic no flow conditions in the Poteau. The Arkansas River mainstem flows to the southeast through the Lower Arkansas Region and into the state of Arkansas. The Arkansas River and tributaries occupy Basins 82, 46, and 47 in the Lower Arkansas Region. The Poteau River (100 miles long in Oklahoma) begins in Arkansas and enters Oklahoma shortly thereafter in the southern portion of the Lower Arkansas Region. It is tributary to the Arkansas River on the border of Oklahoma and Arkansas. The Poteau River and its tributaries are located in Basins 44 and 45. The Illinois River enters Oklahoma from Arkansas in the northern portion of the region in Basin 82. It flows to the southwest to the Arkansas River. The Illinois River and its tributaries occupy Basin 82. The Canadian River (30 miles long in the eastern part of the Lower Arkansas Region) is a major tributary to the Arkansas River with its confluence in Basin 47.

> As important sources of surface water in Oklahoma, reservoirs and lakes help provide dependable water supply storage, especially when streams and rivers experience periods of low seasonal flow or drought.

Existing reservoirs in the region increase the dependability of surface water supply for many public water systems and other users. There are four major federal reservoirs in the region constructed by the U.S. Army Corps of Engineers. Tenkiller Ferry Lake in Basin 82 was constructed on the Illinois River in 1953 for the purposes of flood control and hydroelectric power. Water supply is not an authorized purpose even though the conservation pool is comprised of 25,400 AFY of water supply storage for a dependable yield of 29,800 AFY. The water is fully allocated to numerous entities whose systems extend into several counties. Wister Lake in Basin 45 was built on the Poteau River in 1945 to provide flood control, water supply, and low flow augmentation. The lake yields 31,400 AFY which is permitted primarily to AES Shady Point for power generation, the City of Heavener, and the Poteau Valley Improvement Authority, a regional entity that wholesales water to numerous water providers throughout LeFlore County and extending into Haskell County. Webbers Falls Reservoir in Basin 47 and Robert S. Kerr Reservoir in Basin 46 were constructed on the Arkansas River in 1970 as key components of the McClellan-Kerr Arkansas River Navigation System. Both were authorized for navigation and power generation purposes, and Robert S. Kerr is authorized for recreation purposes as well. Other significant lakes in the region include Lloyd Church, Stilwell City, John Wells, New Spiro, and Brushy, all of which are authorized for public water supply, and Wayne Wallace, which provides flood control and recreation. There are many other small Natural Resources Conservation Service (NRCS) and municipal and privately owned lakes in the region that provide water for public water supply, agricultural water supply, flood control, and recreation.

Reservoirs

Lower Arkansas Region

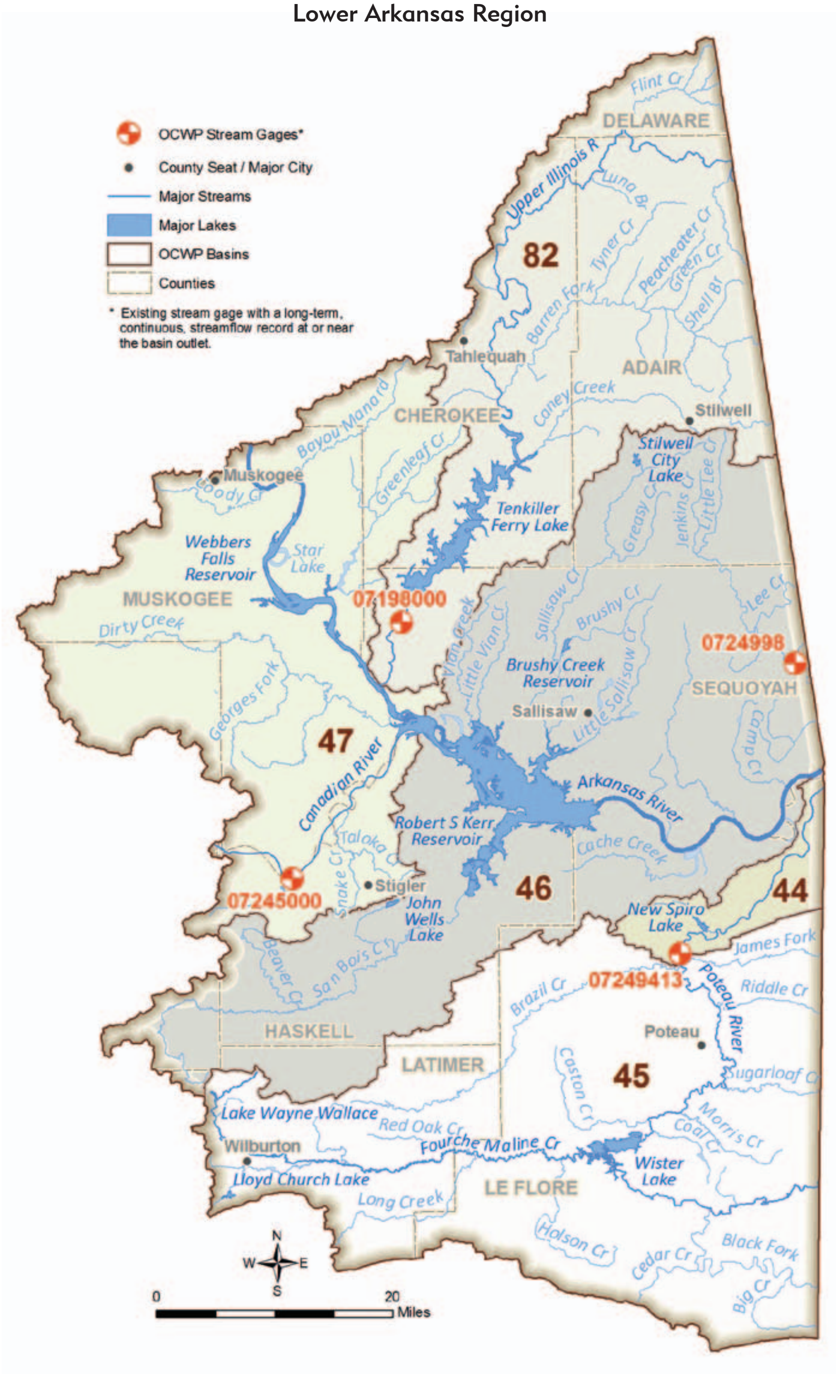
Reservoir Name	Primary Basin Number	Reservoir Owner/ Operator	Year Built	Purposes[1]	Normal Pool Storage	Water Supply		Irrigation		Water Quality		Permitted Withdrawals	Remaining Water Supply Yield to be Permitted
						Storage	Yield	Storage	Yield	Storage	Yield		
					AF	AF	AFY	AF	AFY	AF	AFY	AFY	AFY
Brushy	46	State of Oklahoma, Leased	1964	WS, FC, R	3,258	---	---	0	0	0	0	3,000	---
John Wells	46	City of Stigler	1936	WS, R	1,352	---	---	---	---	---	---	---	---
Lloyd Church	45	City of Wilburton	1964	WS, FC, R	3,025	---	1,523	0	0	0	0	1,185	338
New Spiro	44	City of Spiro	1960	WS, R	2,160	---	---	---	---	---	---	---	---
Robert S Kerr	46	USACE	1970	N, HP, R	525,700	0	0	0	0	0	0	34,623	---
Stilwell City	46	City of Stilwell	1965	WS, FC, R	3,110	---	---	---	---	---	---	---	---
Tenkiller Ferry	82	USACE	1953	FC, HP	654,100	25,400	29,792	0	0	0	0	156,645	0
Wayne Wallace	45	State of Oklahoma	1969	R, FC	1,746	---	---	---	---	---	---	---	---
Webbers Falls	47	USACE	1970	N, HP	170,100	0	0	0	0	0	0	11,202	---
Wister	45	USACE	1949	FC, WS, LF	47,414	46,557	46,250	0	0	0	0	38,417	7,833

No known information is annotated as "---"

1 The "Purposes" represent the use(s), as authorized by the funding entity or dam owner(s), for the reservoir storage when constructed.

WS=Water Supply, R=Recreation, HP=Hydroelectric Power, IR=Irrigation, WQ=Water Quality, FW=Fish & Wildlife, FC=Flood Control, LF=Low Flow Regulation, N=Navigation, C=Conservation, CW=Cooling Water

Surface Water Resources
Lower Arkansas Region



Reservoirs may serve multiple purposes, such as water supply, irrigation, recreation, hydropower generation, and flood control. Reservoirs designed for multiple purposes typically possess a specific volume of water storage assigned for each purpose.

Water Supply Availability Analysis

For OCWP physical water supply availability analysis, water supplies were divided into three categories: surface water, alluvial aquifers, and bedrock aquifers. Physically available surface water refers to water currently in streams, rivers, lakes, and reservoirs.

The range of historical surface water availability, including droughts, is well-represented in the Oklahoma H2O tool by 58 years of monthly streamflow data (1950 to 2007) recorded by the U.S. Geological Survey (USGS). Therefore, measured streamflow, which reflects current natural and human created conditions (runoff, diversions and use of water, and impoundments and reservoirs), is used to represent the physical water that may be available to meet projected demand.

The estimated average and minimum annual streamflow in 2060 were determined based on historic surface water flow measurements and projected baseline 2060 demand (see Water Demand section). The amount of streamflow in 2060 may vary from basin-level values, due to local variations in demands and local availability of supply sources. The estimated surface water supplies include changes in historical streamflow due to increased upstream demand, return flows, and increases in out-of-basin supplies from existing infrastructure. Permitting, water quality, infrastructure, non-consumptive demand, and potential climate change implications are considered in separate OCWP analyses. Past reservoir operations are reflected and accounted for in the measured historical streamflow downstream of a reservoir. For this analysis, streamflow was adjusted to reflect interstate compact provisions in accordance with existing administrative protocol.

The amount of water a reservoir can provide from storage is referred to as its yield. The yield is considered the maximum amount of water a reservoir can dependably supply during critical drought periods. The unused yield of existing reservoirs was considered for this analysis. Future potential reservoir storage was considered as a water supply option.

Groundwater supplies are quantified by the amount of water that an aquifer holds ("stored" water) and the rate of aquifer recharge. In Oklahoma, recharge to aquifers is generally from precipitation that falls on the aquifer and percolates to the water table. In some cases, where the altitude of the water table is below the altitude of the stream-water surface, surface water can seep into the aquifer.

For this analysis, alluvial aquifers are defined as aquifers comprised of river alluvium and terrace deposits, occurring along rivers and streams and consisting of unconsolidated deposits of sand, silt, and clay. Alluvial aquifers are generally thinner (less than 200 feet thick) than bedrock aquifers, feature shallow water tables, and are exposed at the land surface, where precipitation can readily percolate to the water table. Alluvial aquifers are considered to be more hydrologically connected with streams than are bedrock aquifers and are therefore treated separately.

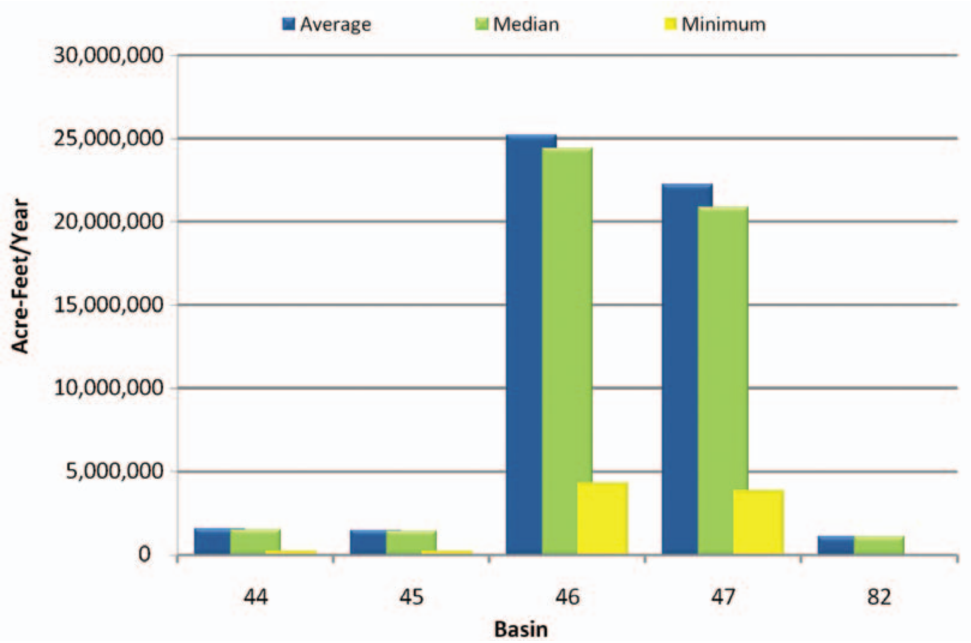
Bedrock aquifers consist of consolidated (solid) or partially consolidated rocks, such as sandstone, limestone, dolomite, and gypsum. Most bedrock aquifers in Oklahoma are exposed at land surface either entirely or in part. Recharge from precipitation is limited in areas where bedrock aquifers are not exposed.

For both alluvial and bedrock aquifers, this analysis was used to predict potential groundwater depletions based on the difference between the groundwater demand and recharge rate. While potential storage depletions do not affect the permit availability of water, it is important to understand the extent of these depletions.

More information is available in the OCWP *Physical Water Supply Availability Report* on the OWRB website.

Surface Water Flows (1950-2007)

Lower Arkansas Region



Surface water supplies about 91% of the demand in the Lower Arkansas Region. While the region's average physical surface water supply exceeds projected surface water demand in the region, gaps can occur due to seasonal, long-term hydrologic (drought), or localized variability in surface water flows. Several large reservoirs have been constructed to reduce the impacts of drier periods on surface water users.

Estimated Annual Streamflow in 2060

Lower Arkansas Region

	Basins				
	44	45	46	47	82
Streamflow Statistic	AFY				
Average Annual Flow	1,261,900	1,185,100	17,952,300	15,393,700	783,000
Minimum Annual Flow	171,200	160,600	2,722,400	2,362,000	25,300

Annual streamflow in 2060 was estimated using historical gaged flow and projections of increased surface water use from 2010 to 2060.

Groundwater Resources

The Roubidoux major bedrock aquifer underlies the northeastern portion of the Lower Arkansas Watershed Planning Region. There are two major alluvial aquifers, the Arkansas River and Canadian River, located in the central portion of the region.

Withdrawing groundwater in quantities exceeding the amount of recharge to the aquifer may result in aquifer depletion and reduced storage. Therefore, both storage and recharge were considered in determining groundwater availability.

The Roubidoux aquifer consists primarily of dolomite with some interbedded sandstone. The aquifer thickness ranges from zero to greater than 2,000 feet, with average thickness estimated at 1,000 feet. Well yields vary from less than 25 gallons per minute (gpm) to more than 1,000 gpm, with shallower well yields ranging from less than 10 gpm to more than 300 gpm. Water quality in the aquifer is mixed. In some areas, concentrations of chloride and naturally occurring radioactivity may exceed drinking water standards, and sodium chloride (salt) water is present along the western and southern edges and at depth; however, water in other areas is suitable for most purposes. Contaminated water from abandoned mines has the potential to degrade the water quality in the vicinity of Miami and Picher. The Roubidoux bedrock aquifer underlies Basins 46, 47, and 82.

Wells in the Arkansas River alluvium deposits range from 200 to 500 gpm while wells in the terrace deposits range from 100 to 200 gpm. Formation deposits are commonly 50 to 100 feet in depth with saturated thickness averaging 25 to 75 feet. The formation consists of clays, sand, silt, and gravels. Hardness is the major water quality problem and TDS values are usually less than 500 mg/L. The water is generally suitable for most municipal and industrial uses, although heavy pumping can cause chloride intrusion into the formation. The aquifer underlies a portion of Basins 44, 46, 47, and 82.

Areas without delineated aquifers may have groundwater present. However, specific quantities, yields, and water quality in these areas are currently unknown.

The Canadian River alluvial aquifer consists of clay and silt downgrading to fine- to coarse-grained sand with lenses of basal gravel. Formation thickness ranges from 20 to 40 feet in the alluvium with a maximum of 50 feet in the terrace deposits. Yields in the alluvium range between 100 and 400 gpm and between 50 and 100 gpm in the terrace. The water is a very hard calcium bicarbonate type with TDS concentrations of approximately 1,000 mg/l. However, the water is generally suitable for most municipal and industrial uses. The aquifer underlies a portion of Basin 47.

Minor bedrock aquifers in the region include the Boone, Kiamichi, Northeastern Oklahoma Pennsylvanian, and Pennsylvanian aquifers. Minor aquifers may have a significant amount of water in storage and high recharge rates, but generally low yields of less than 50 gpm per well. Groundwater from minor aquifers is an important source of water for domestic and stock water use for individuals in outlying areas not served by rural water systems, but may have insufficient yields for high volume users.

Permits to withdraw groundwater from aquifers (groundwater basins) where the maximum annual yield has not been set are "temporary" permits that allocate 2 AFY/acre. The temporary permit allocation is not based on storage, discharge or recharge amounts, but on a legislative (statute) estimate of maximum needs of most landowners to ensure sufficient availability of groundwater in advance of completed and approved aquifer studies. As a result, the estimated amount of Groundwater Available for New Permits may exceed the estimated aquifer storage amount. For aquifers (groundwater basins) where the maximum annual yield has been determined (with initial storage volumes estimated), updated estimates of amounts in storage were calculated based on actual reported use of groundwater instead of simulated usage from all lands.

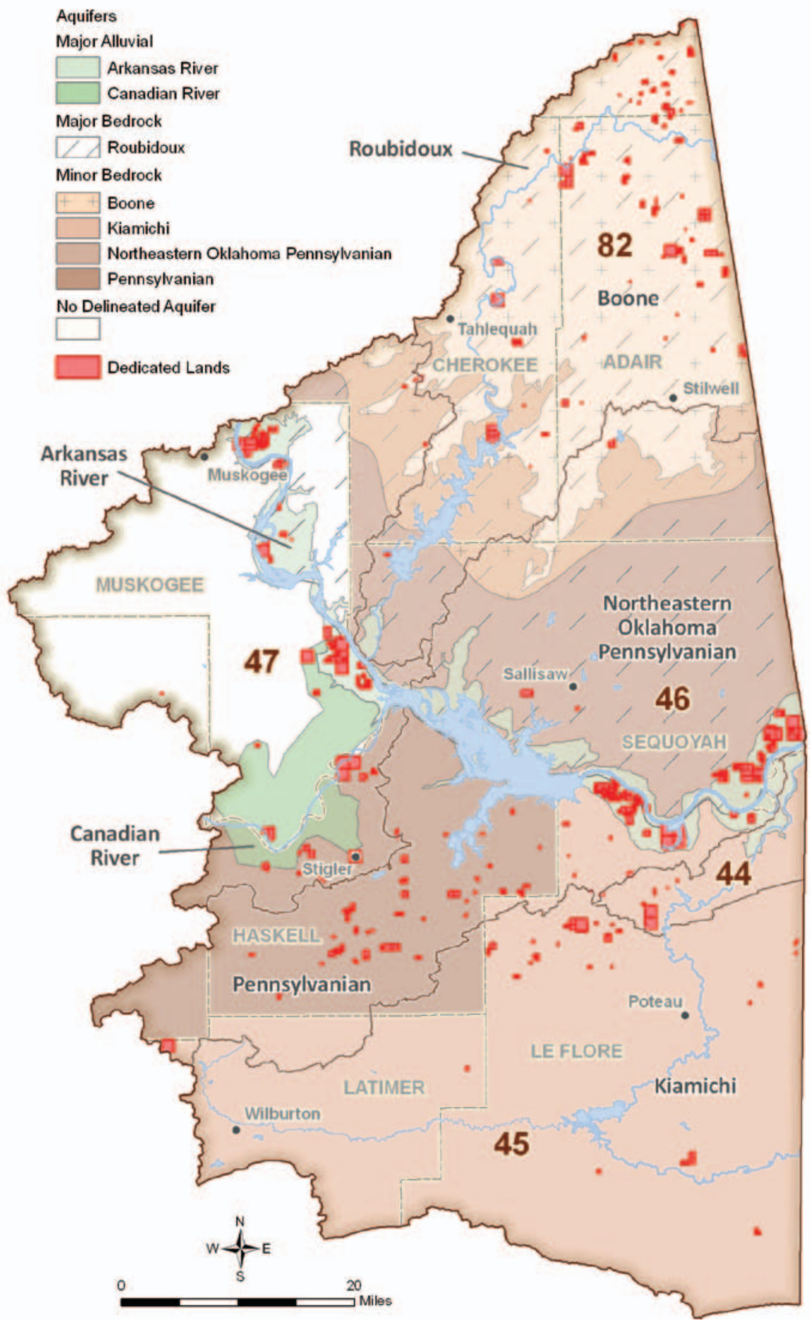
Groundwater Resources

Lower Arkansas Region

Aquifer			Portion of Region Overlaying Aquifer	Recharge Rate	Current Groundwater Rights	Aquifer Storage in Region	Equal Proportionate Share	Groundwater Available for New Permits
Name	**Type**	**Class[1]**	Percent	Inch/Yr	AFY	AF	AFY/Acre	AFY
Arkansas River	Alluvial	Major	6%	5.0	23,100	269,000	temporary 2.0	321,200
Canadian River	Alluvial	Major	3%	2.0	2,700	57,000	temporary 2.0	159,900
Roubidoux	Bedrock	Major	42%	2.5	<50	18,462,000	temporary 2.0	2,511,900
Boone	Bedrock	Minor	23%	10.5	4,100	11,912,000	temporary 2.0	1,368,400
Kiamichi	Bedrock	Minor	32%	1.1	2,600	1,279,000	temporary 2.0	1,897,000
Northeastern Oklahoma Pennsylvanian	Bedrock	Minor	23%	2.1	500	1,547,000	temporary 2.0	1,341,400
Pennsylvanian	Bedrock	Minor	13%	1.1	1,800	6,491,000	temporary 2.0	783,700
Non-Delineated Groundwater Source	Alluvial	Minor			800			
Non-Delineated Groundwater Source	Bedrock	Minor			0			

[1] Bedrock aquifers with typical yields greater than 50 gpm and alluvial aquifers with typical yields greater than 150 gpm are considered major.

Groundwater Resources
Lower Arkansas Region



The Roubidoux is the only major bedrock aquifer in the Lower Arkansas Region. Major alluvial aquifers include the Arkansas River and Canadian River. Major bedrock aquifers are defined as those that have an average water well yield of at least 50 gpm; major alluvial aquifers are those that yield, on average, at least 150 gpm.

Permit Availability

For OCWP water availability analysis, "permit availability" pertains to the amount of water that could be made available for withdrawals under permits issued in accordance with Oklahoma water law.

If water authorized by a stream water right is not put to beneficial use within the specified time, the OWRB may reduce or cancel the unused amount and return the water to the public domain for appropriation to others.

Projections indicate that there will be surface water available for new permits through 2060 in all basins. Equal proportionate shares have not been determined for any aquifer in the Lower Arkansas Region. Therefore, temporary permits are issued for 2 AFY per acre. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060.

Surface Water Permit Availability

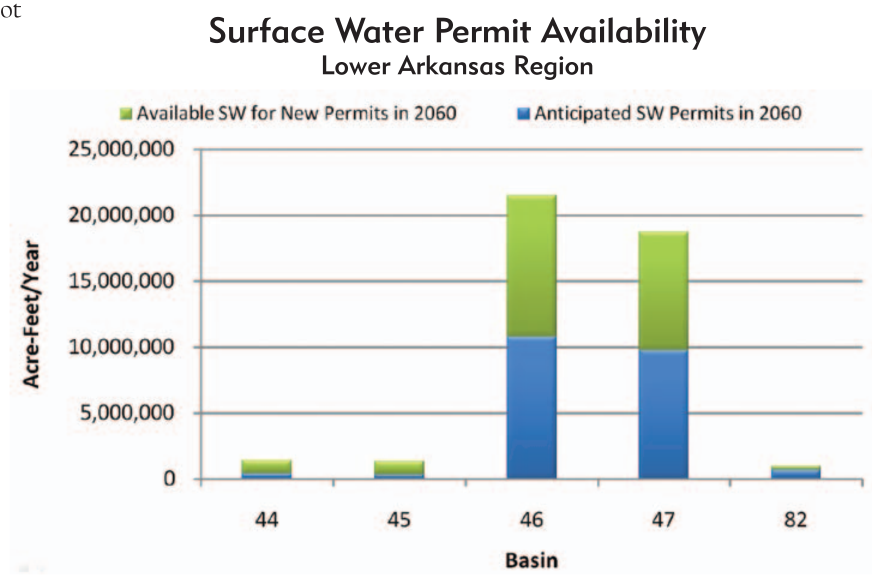
Oklahoma stream water laws are based on riparian and prior appropriation doctrines. Riparian rights to a reasonable use of water, in addition to domestic use, are not subject to permitting or oversight by the OWRB. An appropriative right to stream water is based on the prior appropriation doctrine, which is often described as "first in time, first in right." If a water shortage occurs, the diverter with the older appropriative water right will have first right among other appropriative right holders to divert the available water up to the authorized amount.

To determine surface water permit availability in each OCWP planning basin in 2060, the analysis utilized OWRB protocol to estimate the average annual streamflow at the basin's outlet point, accounting for both existing and anticipated water uses upstream and downstream, including legal obligations, such as those associated with domestic use and interstate compact requirements.

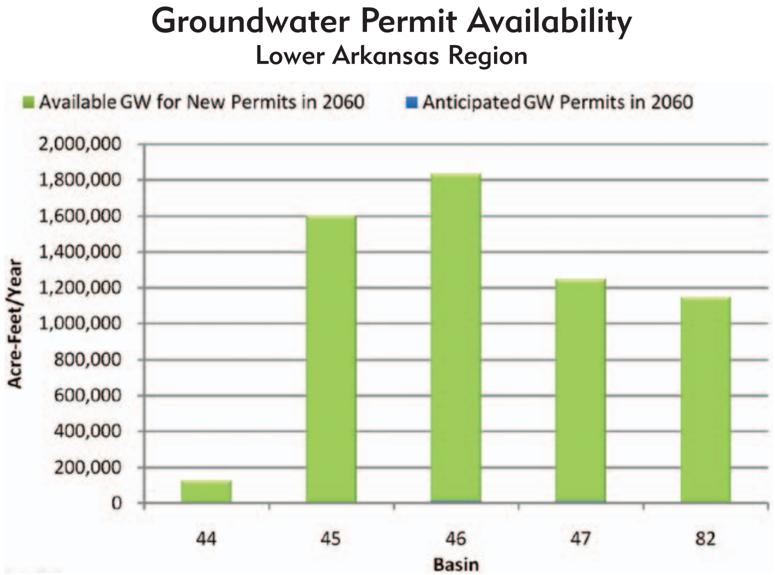
Groundwater Permit Availability

Groundwater available for permits in Oklahoma is generally based on the amount of land owned or leased that overlies a specific aquifer. For unstudied aquifers, temporary permits are granted allocating 2 AFY/acre. For studied aquifers, an "equal proportionate share" (EPS) is established based on the maximum annual yield of water in the aquifer, which is then allocated to each acre of land overlying the groundwater basin. Once an EPS has been established, temporary permits are then converted to regular permits and all new permits are based on the EPS.

For OCWP analysis, the geographical area overlying all aquifers in each basin was determined and the respective EPS or temporary permit allocations were applied. Total current and anticipated future permit needs were then calculated to project remaining groundwater permit availability.



Projections indicate that there will be surface water available for new permits through 2060 in all basins in the Lower Arkansas Region.



Projections indicate that there will be groundwater available for new permits through 2060 in all basins in the Lower Arkansas Region.

Water Quality

Water quality of the Lower Arkansas Watershed Planning Region is exemplified by the lower Arkansas River watershed and numerous minor/major water supply/flood control reservoirs. It is an ecologically diverse region with significant influence from five major North American ecoregions, including the Ozark Highlands (Ozarks), Boston Mountains (BMtns), Central Irregular Plains (CIP), Arkansas Valley (AV), and Ouachita Mountains (OMtns).

The Osage Cuestas of the CIP intersects along the region's west central edge and is drained by the middle Arkansas into Webbers Falls Reservoir. The area is an irregular plain, underlain by sandstone, shale, and limestone, and dominated by rangeland/cropland, interspersed with native tall grass prairies and extensive but disconnected oak-hickory forest. Typically, turbid deep streams meander in broad, low gradient valleys with incised banks. Habitat can be good but may be choked by mud and silt. Salinity is high with mean conductivity of 850 µS/cm on the Arkansas River and a range of 300-1,460 at Webbers Falls. The Arkansas is hyper-eutrophic with total phosphorus (TP) and nitrogen (TN) means of 0.15 and 1.16 ppm. Webbers Falls is eutrophic and potentially co-limited for TP and TN. Water clarity is average with a mean turbidity of 21 NTU on the Arkansas and mean Secchi depth of 37 cm at Webbers Falls. Ecological diversity varies depending on habitat degradation and sedimentation and is typically lower than ecoregions to the east but higher than to the west.

Lake Trophic Status

A lake's trophic state, essentially a measure of its biological productivity, is a major determinant of water quality.

Oligotrophic: Low primary productivity and/or low nutrient levels.

Mesotrophic: Moderate primary productivity with moderate nutrient levels.

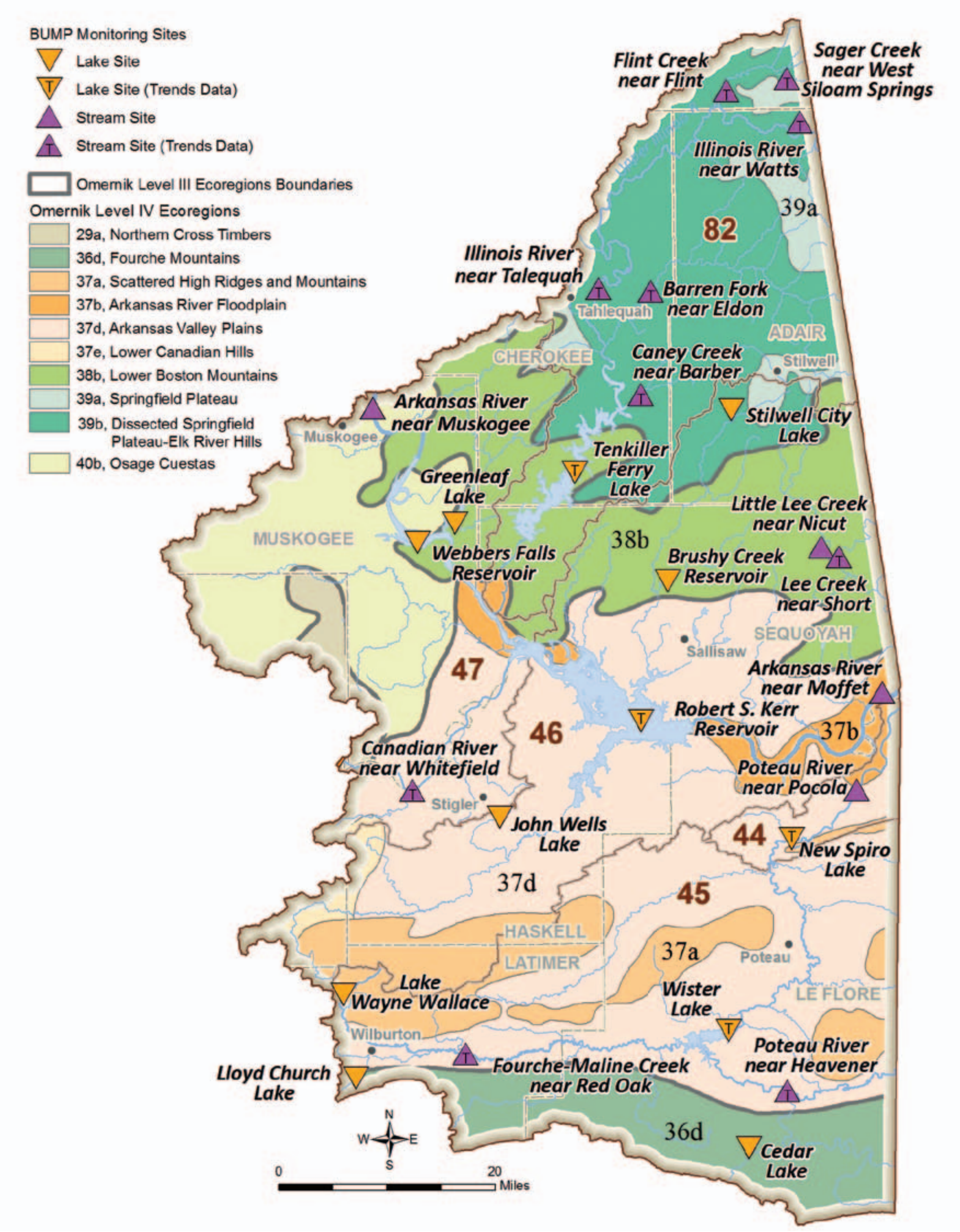
Eutrophic: High primary productivity and nutrient rich.

Hypereutrophic: Excessive primary productivity and excessive nutrients.

The northern quarter of the region is covered by Ozark Highlands represented mostly by the Dissected Springfield Plateau-Elk River Hills (Dissected-Elk Hills), with minor Springfield Plateau influence. The Ozarks are a dissected plateau underlain by flat, cherty limestone, shale, and dolomite intersected by numerous level valleys. With much greater relief than the plains ecoregions to the west, it is much less rugged than the Boston/Ouachita Mountains to the south. Sub-surface flow is karst and numerous springs feed perennial streams. Dense oak-hickory-pine forests cover uplands while native grasslands, hay fields, and pasture land are common in the low-lying valleys. Poultry feeding operations and intense sub-urbanization have become prevalent, negatively affecting water quality. Increased bank erosion degrades streams creating gravel bars and braided systems with unstable pool habitats and extensive sub-surface flow. Despite extensive riparian disturbance, habitat degradation, and increasing nutrient loads, ecological diversity remains high with several species of fish distinctive to the Ozarks. Exemplary streams include the Illinois River and tributaries—Caney, Flint, and Sager Creeks and the Barren Fork River. Reservoirs include upper Tenkiller Ferry and Stilwell City Lake. Salinity is low to moderate with mean conductivity ranging from 195 (Barren Fork) to 445 µS/cm (Sager Creek) while lakes range from 200-400 µS/cm. Streams are typically oligotrophic to mesotrophic but contain relatively high nutrient concentrations for moderate gradient streams. The TP and TN means range from 0.07 and less than 1.50 (Barren Fork/Caney Creek) to 1.16 and over 8.00 ppm (Sager Creek). Lakes are phosphorus limited and eutrophic to nearly hyper-eutrophic. Water clarity is excellent with stream turbidity means of 1-6 NTU and lake Secchi depth means of 100-160 cm.

South of the Ozarks and west of the CIP, the Lower Boston Mountains create a significant uplift through the central portion of the planning region. Underlain by sandstone/shale, they are deeply dissected with moderately high, loosely defined ridges and broad valleys,

Ecoregions
Lower Arkansas Region

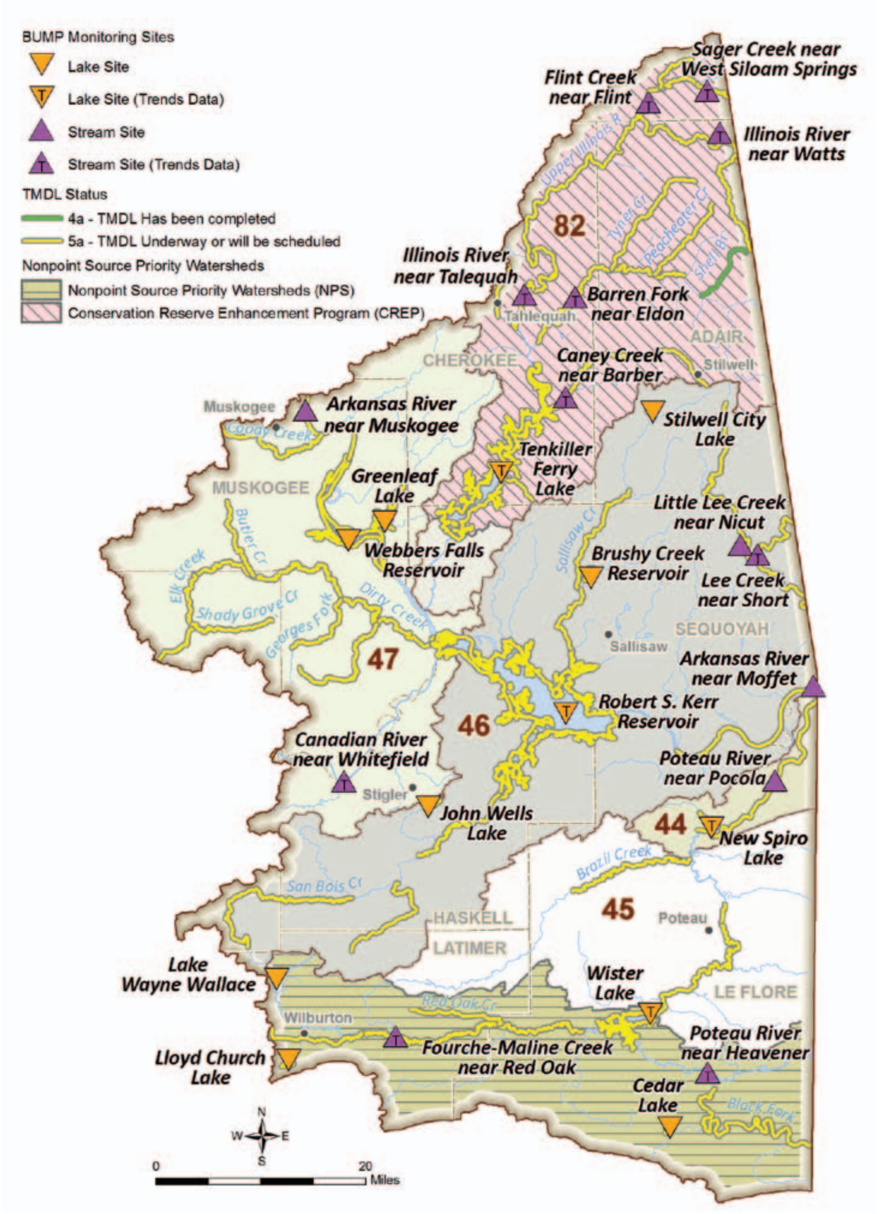


The Lower Arkansas Planning Region is diverse, with significant influence from five major North American ecoregions. Water quality is highly influenced by both geology and land use practices and is generally good to excellent depending on drainage and location.

along with areas covered by oak-hickory forests and woodlands with native grasses, hay fields, and pasture land interspersed. Sub-surface and spring flow influenced streams become a series of disconnected pools in summer. Stream habitat is diverse with cobble/gravel dominated stream beds. Representative streams include Lee and Little Lee Creeks to the east and the Lower Neosho/Arkansas watersheds to the west. Lakes include Lower Tenkiller Ferry, Brushy Creek, and Greenleaf. Stream and lake salinity typically range from 85-250 µS/cm but locally can be as high as 600 µS/cm. Stream nutrient concentrations vary from moderate in the west to very low in the east but are typically lower than surrounding ecoregions. Little Lee and Lee Creeks are oligotrophic/mesotrophic with TP and TN means of 0.01-0.03 ppm and 0.27-0.31 ppm. Lakes are phosphorus limited with lower Tenkiller classified as mesotrophic and Brushy Creek and Greenleaf as eutrophic. Water clarity is excellent with stream turbidity means of 3-5 NTU and lake Secchi depth means from 100-220 cm. Though slightly less diverse than the Ozarks, the area boasts high ecological diversity with habitat degradation and sedimentation affecting some areas.

Lying below the BMtns and CIP, the Arkansas Valley covers nearly the entire southern half of the region, dominated mostly by the Arkansas Valley Plains and interspersed with the Scattered High Ridges and Mountains to the south and the Arkansas River floodplain below Webbers Falls Reservoir. As a transitional area, the AV is a diverse ecoregion with a mixture of broad valley plains, floodplains, hills, terraces, and mountains. Prairie grasslands and oak savannas, along with pasture land and croplands, dominate the valleys while the floodplains and terraces are characterized by bottomland hardwood forests. Areas of relief have a mixture of oak-hickory and oak-hickory-pine forests. Streams lie in narrow to broad meandering channels with a mixture of soft and hard substrates and varying depths. Small streams are disconnected pools during the summer but overall have exceptional habitat. Ecological diversity is extremely high with fish diversity higher than any location

Water Quality Standards Implementation
Lower Arkansas Region



The Oklahoma Conservation Commission has begun watershed implementation projects on the Illinois River and Peacheater Creek. These projects address water quality impairments and demonstrate successful partnerships to improve water quality in the region. The ODEQ has completed a TMDL studies on Shell Branch. Several additional TMDLs are underway or scheduled, including an EPA Region 6 effort to complete a TMDL studies on the Illinois River.

Water Quality Standards and Implementation

The Oklahoma Water Quality Standards (OWQS) are the cornerstone of the state's water quality management programs. The OWQS are a set of rules promulgated under the federal Clean Water Act and state statutes, designed to maintain and protect the quality of the state's waters. The OWQS designate beneficial uses for streams, lakes, other bodies of surface water, and groundwater that has a mean concentration of Total Dissolved Solids (TDS) of 10,000 milligrams per liter or less. Beneficial uses are the activities for which a waterbody can be used based on physical, chemical, and biological characteristics as well as geographic setting, scenic quality, and economic considerations. Beneficial uses include categories such as Fish and Wildlife Propagation, Public and Private Water Supply, Primary (or Secondary) Body Contact Recreation, Agriculture, and Aesthetics.

The OWQS also contain standards for maintaining and protecting these uses. The purpose of the OWQS is to promote and protect as many beneficial uses as are attainable and to assure that degradation of existing quality of waters of the state does not occur.

The OWQS are applicable to all activities which may affect the water quality of waters of the state, and are to be utilized by all state environmental agencies in implementing their programs to protect water quality. Some examples of these implementation programs are permits for point source (e.g. municipal and industrial) discharges into waters of the state; authorizations for waste disposal from concentrated animal feeding operations; regulation of runoff from nonpoint sources; and corrective actions to clean up polluted waters.

More information about OWQS and the latest revisions can be found on the OWRB website.

Water Quality Impairments

A waterbody is considered to be impaired when its quality does not meet the standards prescribed for its beneficial uses. For example, impairment of the Public and Private Water Supply beneficial use means the use of the waterbody as a drinking water supply is hindered. Impairment of the Agricultural use means the use of the waterbody for livestock watering, irrigation or other agricultural uses is hindered. Impairments can exist for other uses such as Fish and Wildlife Propagation or Recreation.

The Beneficial Use Monitoring Program (BUMP), established in 1998 to document and quantify impairments of assigned beneficial uses of the state's lakes and streams, provides information for supporting and updating the OWQS and prioritizing pollution control programs. A set of rules known as "use support assessment protocols" is also used to determine whether beneficial uses of waterbodies are being supported.

In an individual waterbody, after impairments have been identified, a Total Maximum Daily Load (TMDL) study is conducted to establish the sources of impairments—whether from point sources (discharges) or non-point sources (runoff). The study will then determine the amount of reduction necessary to meet the applicable water quality standards in that waterbody and allocate loads among the various contributors of pollution.

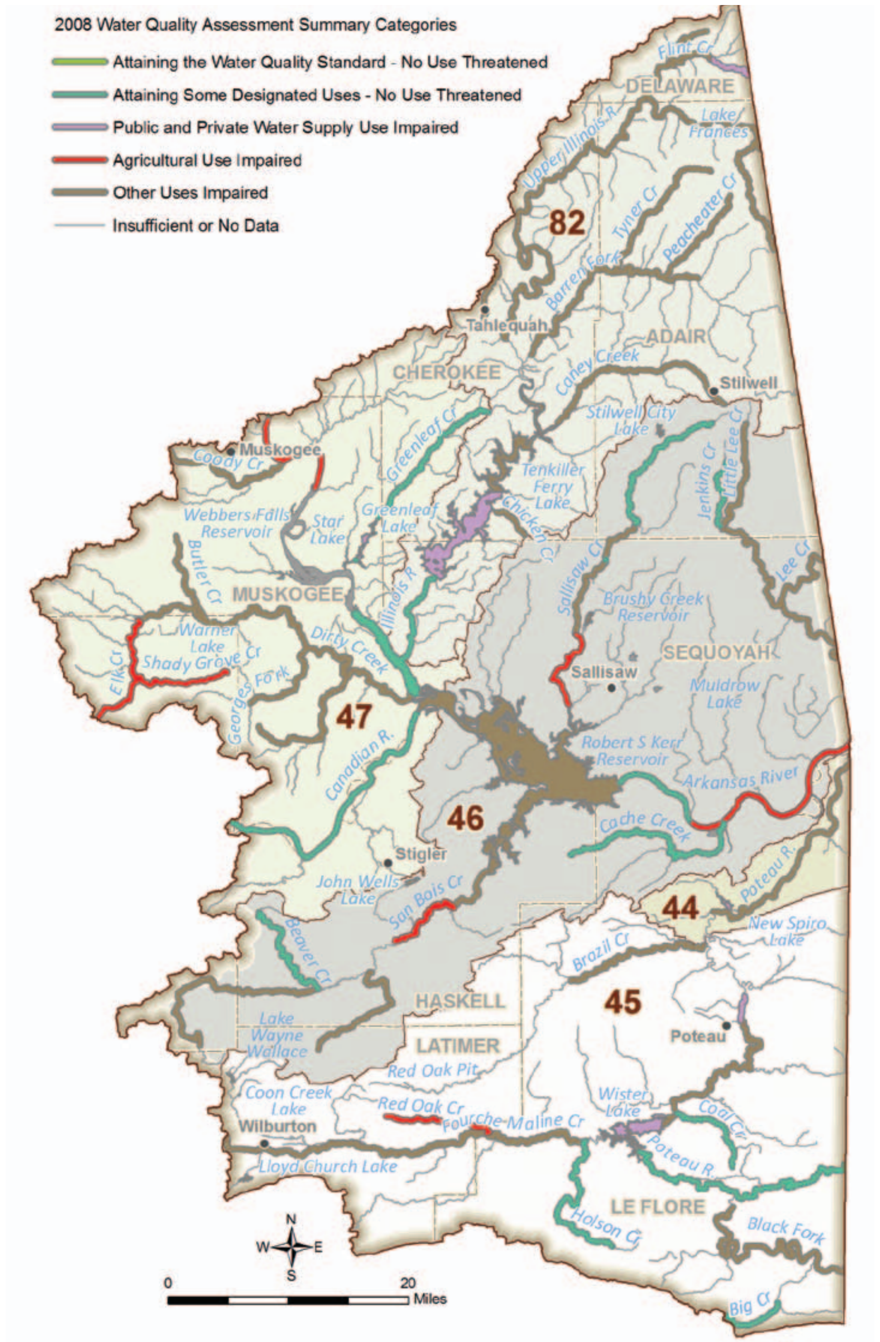
For more detailed review of water quality conditions, see the most recent versions of the OWRB's *BUMP Report*, and the Oklahoma *Integrated Water Quality Assessment Report*, a comprehensive assessment of water quality in Oklahoma's streams and lakes required by the federal Clean Water Act and developed by the ODEQ.

in the state. Diversity increases on a west to east gradient. The Arkansas Valley Plain is a mixture of grassland/savanna and forest/woodland. Characteristic watersheds include the Canadian River in the west and the Poteau River to the east, as well as John Wells, New Spiro, and Wister Lakes. Salinity gradient is west (Canadian = 480 µS/cm) to east (Poteau = 140 µS/cm). Lakes are typically below 150 µS/cm. Typical streams are mesotrophic with TP and TN means less than 0.08 and 0.70 ppm. However, the Poteau River below Lake Wister is hyper-eutrophic with TP and TN means of 0.13 and 1.07 ppm. Lakes are phosphorus limited but vary in nutrient quality. John Wells is mesotrophic with low nutrient concentrations. Both TP and TN concentrations increase at New Spiro and Wister and become hyper-eutrophic. Water clarity is excellent on the upper Poteau (14 NTU) and Canadian Rivers (7 NTU) to poor on the lower Poteau (56 NTU). Lake clarity is average (Wister = 41 cm) to excellent (John Wells = 180 cm).

The Arkansas River floodplain lies along the lower Arkansas below Webbers Falls and includes R.S. Kerr Reservoir. Salinity is high with conductivities greater than 600 µS/cm, and clarity is good (Arkansas = 27 NTU) to poor (R.S. Kerr = 26 cm). The area is eutrophic with TP and TN concentrations of approximately 0.13 and 1.00 ppm. Continuous turbidity and habitat/hydrologic modification have decreased much of the natural ecological diversity. The Scattered High Ridges and Mountains lie in a disconnected area along the southern portion of the AV ecoregion. The area is more rugged than the valley plains with a mixture of upland forests and savannas characterized by Lake Wayne Wallace. Salinity is low with conductivity less than 60 µS/cm and clarity is excellent in streams while average in Wayne Wallace (76 cm). Nutrient concentrations are lower. Wayne Wallace has TP and TN values below 0.05 and 0.60 ppm and is mesotrophic.

The southern edge of the region intersects the northern edge of the Fourche Mountains ecoregion. The area has long, rugged, steep ridges with narrow to broad shale valleys. Natural vegetation is mostly oak-hickory-pine forests with

Water Quality Impairments
Lower Arkansas Region

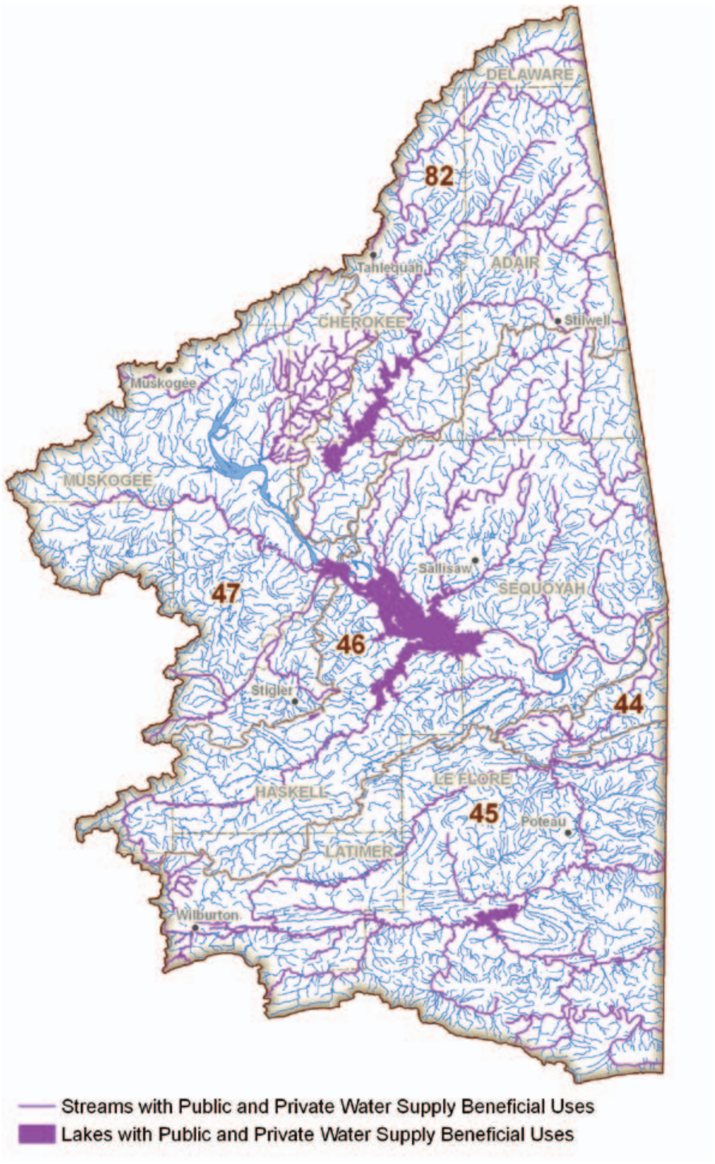


Regional water quality impairments are based on the 2008 *Oklahoma Integrated Water Quality Assessment Report*. Surface waters in this region have eutrophication impacts, particularly water supply reservoirs. Aesthetic impacts to surface waters in this region have occurred due to excessive levels of nutrients.

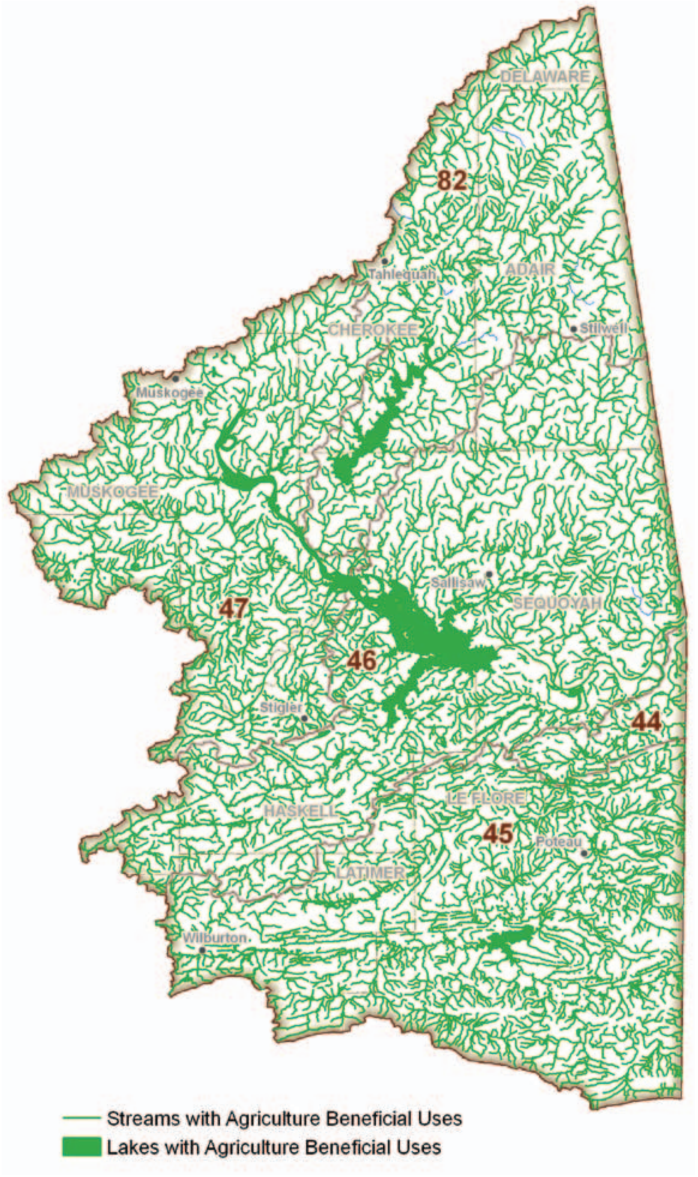
intervening native grasslands and pasture land/hay fields. Streams have excellent habitat with low to high gradients but may be turbid with disconnected pools during the summer. The area is characterized by Fourche-Maline Creek (more characteristic of the Arkansas Valley than the Ouachita Mountains), Lloyd Church Reservoir to the west, and Cedar Lake to the east. Salinity is low at less than 150 µS/cm, increasing on a west to east gradient. Nutrient values along the Fourche and at Wayne Wallace are low (TP < 0.08 and TN < 0.80 ppm) and are mesotrophic. Conversely, Cedar Lake is eutrophic with TP values greater 1.0 ppm; it is possibly co-limited for TN and TP. Clarity is good on Fourche (27 NTU) and at Lloyd Church (64 cm) but excellent in Cedar Lake (162 cm). Ecological diversity is very high, indicative of Arkansas Valley influence.

The region is underlain by several major and minor aquifers. Although a statewide groundwater water quality program does not exist in Oklahoma, various aquifer studies have been completed and data are available from various sources. Water from the Canadian and Arkansas River alluvial and terrace deposits yield water that is generally hard and typically of a calcium magnesium or sodium/calcium bicarbonate type. In some areas, drinking water standards are exceeded. The alluvium and terrace aquifers are highly vulnerable to contamination from surface activities due to high porosities and permeability and shallow water tables. However, alluvial water is generally suitable for most purposes. The major bedrock aquifer of the region is the Roubidoux. Part of the Ozark aquifer, the Roubidoux underlies the Ozark Highlands ecoregion. Water is hard with generally low mineral content. However, in the far western portion of the aquifer, concentrations of chloride, sulfate and fluoride exceed drinking water standards; naturally occurring radioactivity is also reported in some areas. Large concentrations of gross-alpha radioactivity and radium-226 occur near the western edge and appear to be correlated with chloride concentrations. The aquifer is a confined aquifer and is not vulnerable to contamination from surface activities.

Surface Waters with Designated Beneficial Use for Public/Private Water Supply
Lower Arkansas Region



Surface Waters with Designated Beneficial Use for Agriculture
Lower Arkansas Region



Surface Water Protection

The Oklahoma Water Quality Standards (OWQS) provide protection for surface waters in many ways.

Appendix B Areas are designated in the OWQS as containing waters of recreational and/or ecological significance. Discharges to waterbodies may be limited in these areas.

Source Water Protection Areas are derived from the state's Source Water Protection Program, which analyzes existing and potential threats to the quality of public drinking water in Oklahoma.

The **High Quality Waters** designation in the OWQS refers to waters that exhibit water quality exceeding levels necessary to support the propagation of fishes, shellfishes, wildlife, and recreation in and on the water. This designation prohibits any new point source discharges or additional load or increased concentration of specified pollutants.

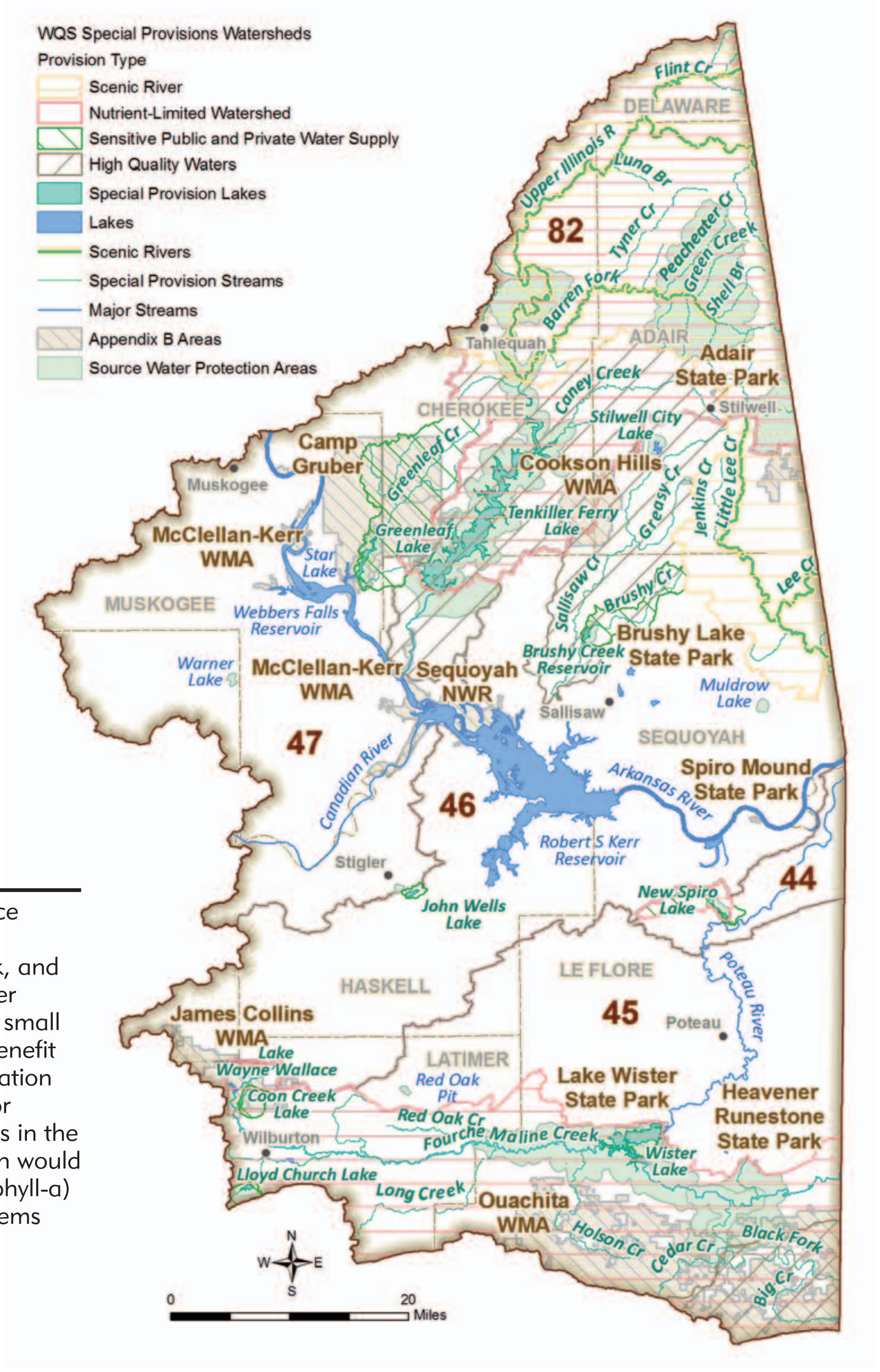
The **Sensitive Water Supplies (SWS)** designation applies to public and private water supplies possessing conditions making them more susceptible to pollution events, thus requiring additional protection. This designation restricts point source discharges in the watershed and institutes a 10 μg/L (micrograms per liter) chlorophyll-a criterion to protect against taste and odor problems and reduce water treatment costs.

Outstanding Resource Waters are those constituting outstanding resources or of exceptional recreational and/or ecological significance. This designation prohibits any new point source discharges or additional load or increased concentration of specified pollutants.

Waters designated as **Scenic Rivers** in Appendix A of the OWQS are protected through restrictions on point source discharges in the watershed. A 0.037 mg/L total phosphorus criterion is applied to all Scenic Rivers in Oklahoma.

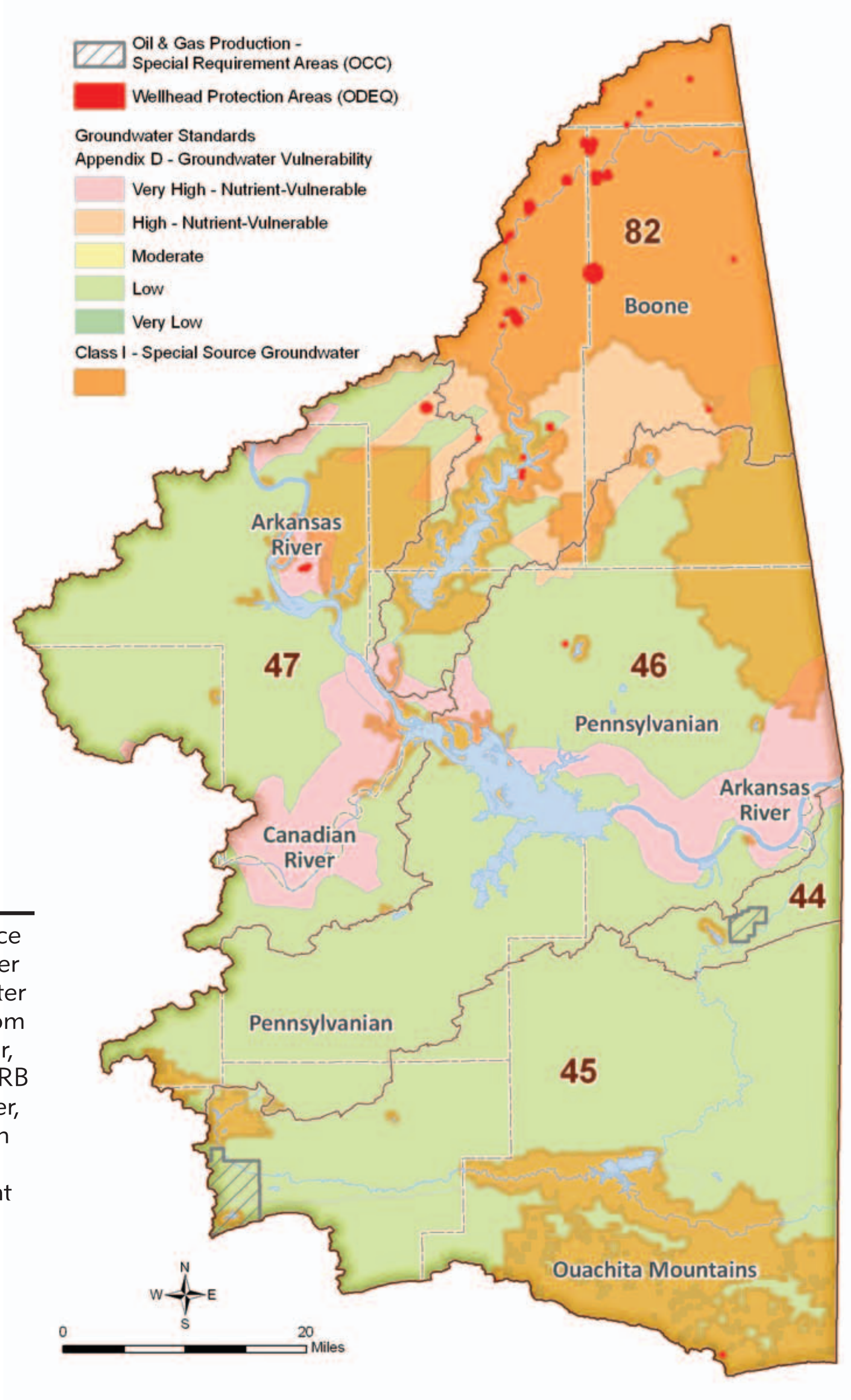
Nutrient-Limited Watersheds are those containing a waterbody with a designated beneficial use that is adversely affected by excess nutrients.

Surface Water Protection Areas
Lower Arkansas Region



Special OWQS provisions are in place to protect surface waters. Because Warner, Stilwell, Stigler, Camp Creek, and Garrison Creek lakes are public water supply reservoirs and have relatively small watersheds, they could potentially benefit from SWS designations. This designation could provide protection from new or increased loading from point sources in the watershed. This additional protection would also provide limits for algae (chlorophyll-a) that can cause taste and odor problems and increased treatment costs.

Groundwater Protection Areas
Lower Arkansas Region



Various types of protection are in place to prevent degradation of groundwater and levels of vulnerability. Groundwater quality in this region could benefit from more protection for the Boone aquifer, which has been identified by the OWRB as a "high" nutrient vulnerable aquifer, and the Arkansas River and Canadian River alluvial aquifers, which have been identified as "very high" nutrient vulnerable.

Groundwater Protection

The Oklahoma Water Quality Standards (OWQS) sets the criteria for protection of groundwater quality as follows: "If the concentration found in the test sample exceeds [detection limit], or if other substances in the groundwater are found in concentrations greater than those found in background conditions, that groundwater shall be deemed to be polluted and corrective action may be required."

Wellhead Protection Areas are established by the Oklahoma Department of Environmental Quality (ODEQ) to improve drinking water quality through the protection of groundwater supplies. The primary goal is to minimize the risk of pollution by limiting potential pollution-related activities on land around public water supplies.

Oil and Gas Production Special Requirement Areas, enacted to protect groundwater and/or surface water, can consist of specially lined drilling mud pits (to prevent leaks and spills) or tanks whose contents are removed upon completion of drilling activities; well set-back distances from streams and lakes; restrictions on fluids and chemicals; or other related protective measures.

Nutrient-Vulnerable Groundwater is a designation given to certain hydrogeologic basins that are designated by the OWRB as having high or very high vulnerability to contamination from surface sources of pollution. This designation can impact land application of manure for regulated agriculture facilities.

Class 1 Special Source Groundwaters are those of exceptional quality and particularly vulnerable to contamination. This classification includes groundwaters located underneath watersheds of Scenic Rivers, within OWQS Appendix B areas, or underneath wellhead or source water protection areas.

Appendix H Limited Areas of Groundwater are localized areas where quality is unsuitable for default beneficial uses due to natural conditions or irreversible human-induced pollution.

NOTE: The State of Oklahoma has conducted a successful surface water quality monitoring program for more than fifteen years. A new comprehensive groundwater quality monitoring program is in the implementation phase and will soon provide a comparable long-term groundwater resource data set.

Water Quality Trends Study

As part of the *2012 OCWP Update*, OWRB monitoring staff compiled more than ten years of Beneficial Use Monitoring Program (BUMP) data and other resources to initiate an ongoing statewide comprehensive analysis of surface water quality trends.

Reservoir Trends: Water quality trends for reservoirs were analyzed for chlorophyll-a, conductivity, total nitrogen, total phosphorus, and turbidity at sixty-five reservoirs across the state. Data sets were of various lengths, depending on the station's period of record. The direction and magnitude of trends varies throughout the state and within regions. However, when considered statewide, the final trend analysis revealed several notable details.

- Chlorophyll-a and nutrient concentrations continue to increase at a number of lakes. The proportions of lakes exhibiting a significant upward trend were 42% for chlorophyll-a, 45% for total nitrogen, and 12% for total phosphorus.
- Likewise, conductivity and turbidity have trended upward over time. Nearly 28% of lakes show a significant upward trend in turbidity, while nearly 45% demonstrate a significant upward trend for conductivity.

Stream Trends: Water quality trends for streams were analyzed for conductivity, total nitrogen, total phosphorus, and turbidity at sixty river stations across the state. Data sets were of various lengths, depending on the station's period of record, but generally, data were divided into historical and recent datasets and analyzed separately and as a whole. The direction and magnitude of trends varies throughout the state and within regions. However, when considered statewide, the final trend analysis revealed several notable details.

- Total nitrogen and phosphorus are very different when comparing period of record to more recent data. When considering the entire period of record, approximately 80% of stations showed a downward trend in nutrients. However, if only the most recent data (approximately 10 years) are considered, the percentage of stations with a downward trend decreases to 13% for nitrogen and 30% for phosphorus. The drop is accounted for in stations with either significant upward trends or no detectable trend.
- Likewise, general turbidity trends have changed over time. Over the entire period of record, approximately 60% of stations demonstrated a significant upward trend. However, more recently, that proportion has dropped to less than 10%.
- Similarly, general conductivity trends have changed over time, albeit less dramatically. Over the entire period of record, approximately 45% of stations demonstrated a significant upward trend. However, more recently, that proportion has dropped to less than 30%.

Typical Impact of Trends Study Parameters

Chlorophyll-a is a measure of algae growth. When algae growth increases, there is an increased likelihood of taste and odor problems in drinking water as well as aesthetic issues.

Conductivity is a measure of the ability of water to pass electrical current. In water, conductivity is affected by the presence of inorganic dissolved solids, such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Conductivity in streams and rivers is heavily dependent upon regional geology and discharges. High specific conductance indicates high concentrations of dissolved solids, which can affect the suitability of water for domestic, industrial, agricultural, and other uses. At higher conductivity levels, drinking water may have an unpleasant taste or odor or may even cause gastrointestinal distress. High concentration may also cause deterioration of plumbing fixtures and appliances. Relatively expensive water treatment processes, such as reverse osmosis, are required to remove excessive dissolved solids from water. Concerning agriculture, most crops cannot survive if the salinity of the water is too high.

Total Nitrogen is a measure of all dissolved and suspended nitrogen in a water sample. It includes kjeldahl nitrogen (ammonia + organic), nitrate, and nitrite nitrogen. It is naturally abundant in the environment and is a key element necessary for growth of plants and animals. Excess nitrogen from polluting sources can lead to significant water quality problems, including harmful algal blooms, hypoxia, and declines in wildlife and habitat.

Total Phosphorus is one of the key elements necessary for growth of plants and animals. Excess phosphorus leads to significant water quality problems, including harmful algal blooms, hypoxia, and declines in wildlife and habitat. Increases in total phosphorus can lead to excessive growth of algae, which can increase taste and odor problems in drinking water as well as increased costs for treatment.

Turbidity refers to the clarity of water. The greater the amount of total suspended solids (TSS) in the water, the murkier it appears and the higher the measured turbidity. Increases in turbidity can increase treatment costs and have negative effects on aquatic communities by reducing light penetration.

Reservoir Water Quality Trends

Lower Arkansas Region

Parameter	New Spiro Lake (1995-2006)	Robert S. Kerr Reservoir (1996-2008)	Tenkiller Ferry Lake (1985-2006)	Wister Lake (1974-2009)
Chlorophyll-a (mg/m3)	↑	NT	NT	↑
Conductivity (us/cm)	↑	NT	↑	↓
Total Nitrogen (mg/L)	NT	NT	NT	↓
Total Phosphorus (mg/L)	NT	NT	↓	NT
Turbidity (NTU)	NT	NT	NT	NT

Increasing Trend ↑ **Decreasing Trend** ↓ NT = No significant trend detected

Trend magnitude and statistical confidence levels vary for each site. Site-specific information can be obtained from the OWRB Water Quality Division.

Notable concerns for reservoir water quality include the following:

- Significant upward trends for chlorophyll-a on New Spiro and Wister Reservoirs.

Stream Water Quality Trends

Lower Arkansas Region

Parameter	Flint Creek near Kansas		Fourche-Maline Creek near Red Oak		Illinois River near Watts		Illinois River near Tahlequah		Lee Creek near Short		Poteau River near Heavener		Sager Creek near West Siloam Springs	
	All Data Trend (1975-1996, 1997-2009)[1]	Recent Trend (1997-2009)	All Data Trend (1975-1996, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1969-1988, 1988-2009)[1]	Recent Trend (1988-2009)	All Data Trend (1975-1988, 1988-2009)[1]	Recent Trend (1988-2009)	All Data Trend (1976-1981, 1995-2009)[1]	Recent Trend (1995-2009)	All Data Trend (1992-2009)[1]	Recent Trend (1992-2009)	All Data Trend (1997-2009)[1]	Recent Trend (1997-2009)
Conductivity (us/cm)	↑	NT	↑	↑	↑	↑	↑	↑	↓	NT	NT	NT	↑	↑
Total Nitrogen (mg/L)	↑	NT	↑	↑	↓	NT	↓	NT	↓	NT	NT	NT	NT	NT
Total Phosphorus (mg/L)	↑	↑	↑	↑	↓	↓	↓	↑	↓	↓	↓	↓	↑	↑
Turbidity (NTU)	NT	NT	NT	NT	↓	↓	↑	NT	NT	↓	↓	↓	NT	NT

Increasing Trend ↑ **Decreasing Trend** ↓ NT = No significant trend detected

Trend magnitude and statistical confidence levels vary for each site. Site-specific information can be obtained from the OWRB Water Quality Division.

[1] *Date ranges for analyzed data represent the earliest site visit date and may not be representative of all parameters.*

Notable concerns for stream water quality include the following:

- Significant upward trend for total nitrogen and phosphorus on Fourche-Maline Creek.
- Significant upward trend for total phosphorus on Sager Creek.

Water Demand

The Lower Arkansas Region's water needs account for about 11% of the total statewide demand. Regional demand will increase by 58% (117,760 AFY) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Thermoelectric Power sector.

Thermoelectric Power demand is expected to remain the largest demand sector in the region, accounting for 59% of the 2060 demand. The AES Shady Point plant and the Oklahoma Gas and Electric Company's Muskogee plant are the major users of water for thermoelectric power generation in the region. Currently, 99% of the demand from this sector is supplied by surface water and 1% by alluvial groundwater.

Municipal and Industrial demand is projected to account for approximately 14% of the region's 2060 demand. Currently, 98% of the demand from this sector is supplied by surface water, about 1% by bedrock groundwater, and 1% by alluvial groundwater.

Crop Irrigation demand is expected to account for 10% of the 2060 demand. Currently, 64% of the demand from this sector is supplied by surface water, 26% by alluvial groundwater, and 10% by bedrock groundwater. Predominant irrigated crops in the Lower Arkansas Region include corn, pasture grasses, and soybeans.

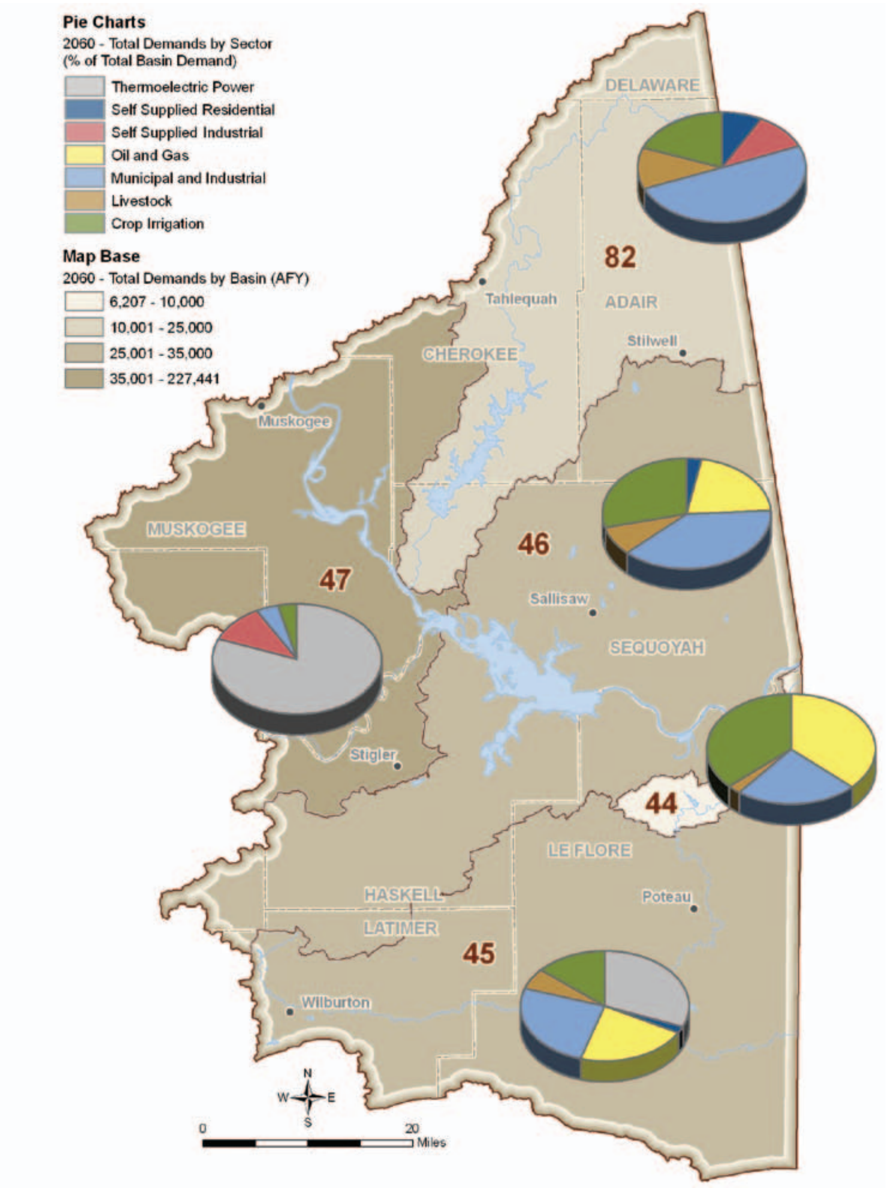
Self-Supplied Industrial demand in the region is projected to account for 8% of the 2060 demand. Currently, 97% of the demand from this sector is supplied by surface water and 3% by alluvial groundwater.

Oil and Gas demand is projected to account for approximately 6% of the 2060 demand. Currently, 98% of the demand from this sector is supplied by surface water and 2% by bedrock groundwater.

Livestock demand is projected to account for 2% of the 2060 demand. Currently, 63% of the demand from this sector is supplied by surface water, 22% by alluvial groundwater, and 15% by bedrock groundwater. Livestock use in the region is predominantly chicken, followed distantly by cattle for cow-calf production and horses.

Self-Supplied Residential demand is projected to account for 1% of the 2060 demand. Currently, 98% of the demand from this sector is supplied by alluvial groundwater and 2% by bedrock groundwater.

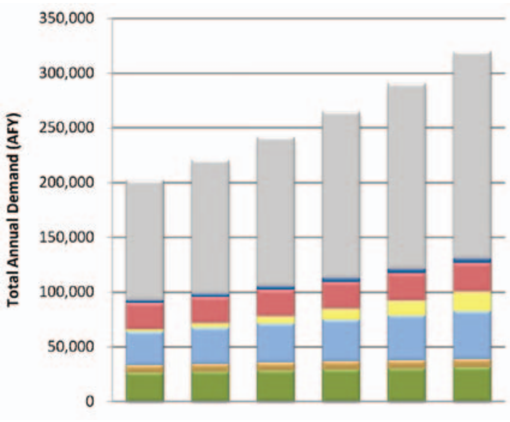
Total 2060 Water Demand by Sector and Basin
(Percent of Total Basin Demand)
Lower Arkansas Region



Thermoelectric Power is expected to remain the largest demand sector in the region, accounting for 59% of the total regional demand in 2060.

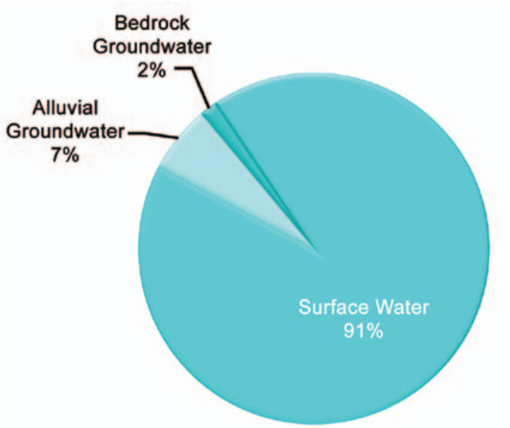
Total Water Demand by Sector

Lower Arkansas Region



Supply Sources Used to Meet Current Demand (2010)

Lower Arkansas Region



The Lower Arkansas Region's water needs account for about 11% of the total statewide demand. Regional demand will increase by 58% (117,760 AFY) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Thermoelectric Power sector.

Total Water Demand by Sector

Lower Arkansas Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	26,370	6,980	30,460	2,130	23,820	2,840	109,280	201,890
2020	27,320	7,090	33,070	4,160	23,840	3,170	121,910	220,570
2030	28,270	7,190	35,750	6,700	23,940	3,510	136,010	241,370
2040	29,220	7,290	38,440	9,870	24,270	3,840	151,730	264,670
2050	29,950	7,400	41,160	13,640	24,970	4,180	169,270	290,580
2060	31,120	7,500	43,960	18,020	25,670	4,530	188,840	319,650

Water Demand

Water demand refers to the amount of water required to meet the needs of people, communities, industry, agriculture, and other users. Growth in water demand frequently corresponds to growth in population, agriculture, industry, or related economic activity. Demands have been projected from 2010 to 2060 in ten-year increments for seven distinct consumptive water demand sectors.

Water Demand Sectors

- ⬜ **Thermoelectric Power:** Thermoelectric power producing plants, using both self-supplied water and municipal-supplied water, are included in the thermoelectric power sector.
- 🟦 **Self-Supplied Residential:** Households on private wells that are not connected to a public water supply system are included in the SSR sector.
- 🟥 **Self-Supplied Industrial:** Demands from large industries that do not directly depend upon a public water supply system are included in the SSI sector. Water use data and employment counts were included in this sector, when available.
- 🟨 **Oil and Gas:** Oil and gas drilling and exploration activities, excluding water used at oil and gas refineries (typically categorized as Self-Supplied Industrial users), are included in the oil and gas sector.
- 🟦 **Municipal and Industrial:** These demands represent water that is provided by public water systems to homes, businesses, and industries throughout Oklahoma, excluding water supplied to thermoelectric power plants.
- 🟫 **Livestock:** Livestock demands were evaluated by livestock group (beef, poultry, etc.) based on the 2007 Agriculture Census.
- 🟩 **Crop Irrigation:** Water demands for crop irrigation were estimated using the 2007 Agriculture Census data for irrigated acres by crop type and county. Crop irrigation requirements were obtained primarily from the Natural Resource Conservation Service Irrigation Guide Reports.

OCWP demands were not projected for non-consumptive or instream water uses, such as hydroelectric power generation, fish and wildlife, recreation and instream flow maintenance. Projections, which were augmented through user/stakeholder input, are based on standard methods using data specific to each sector and OCWP planning basin.

Projections were initially developed for each county in the state, then allocated to each of the 82 basins. To provide regional context, demands were aggregated by Watershed Planning Region. Water shortages were calculated at the basin level to more accurately determine areas where shortages may occur. Therefore, gaps, depletions, and options are presented in detail in the basin summaries and subsequent sections. Future demand projections were developed independent of available supply, water quality, or infrastructure considerations. The impacts of climate change, increased water use efficiency, conservation, and non-consumptive uses, such as hydropower, are presented in supplemental OCWP reports.

Present and future demands were applied to supply source categories to facilitate an evaluation of potential surface water gaps and alluvial and bedrock aquifer storage depletions at the basin level. For this baseline analysis, the proportion of each supply source used to meet future demands for each sector was held constant at the proportion established through current, active water use permit allocations. For example, if the crop irrigation sector in a basin currently uses 80% bedrock groundwater, then 80% of the projected future crop irrigation demand is assumed to use bedrock groundwater. Existing out-of-basin supplies are represented as surface water supplies in the receiving basin.

Public Water Providers

There are more than 1,600 Oklahoma water systems permitted or regulated by the Oklahoma Department of Environmental Quality (ODEQ); 785 systems were analyzed in detail for the 2012 OCWP Update. The public systems selected for inclusion, which collectively supply approximately 94 percent of the state's current population, consist of municipal or community water systems and rural water districts that were readily identifiable as non-profit, local governmental entities. This and other information provided in the OCWP will support provider-level planning by providing insight into future supply and infrastructure needs.

The Lower Arkansas Region includes 76 of the 785 public supply systems analyzed for the 2012 OCWP Update. The Public Water Providers map indicates the approximate service areas of these systems. (The map may not accurately represent existing service areas or legal boundaries. In addition, water systems often serve multiple counties and can extend into multiple planning basins and regions.)

In terms of 2010 population served (excluding provider-to-provider sales), the five largest systems in the region, in decreasing order, are Muskogee, Tahlequah PWA, Sequoyah County Water Association, Sallisaw, and Poteau PWA. These five systems provide service for approximately 40 percent of the population served by public water providers in the region.

Demands upon public water systems, which comprise the majority of the OCWP's Municipal and Industrial (M&I) water demand sector, were analyzed at both the basin and provider level. Retail demand projections detailed in the Public Water Provider Demand Forecast table were developed for each of the OCWP providers in the region. These projections include estimated system losses, defined as water lost either during water production or distribution to residential homes and businesses. Retail demands do not include wholesaled water.

OCWP provider demand forecasts are not intended to supersede water demand forecasts developed by individual providers. OCWP analyses were made using a consistent methodology based on accepted data available on a statewide basis. Where available, provider-generated forecasts were also reviewed as part of this effort.


Public Water Providers
Lower Arkansas Region

Population and Demand Projection Data

Provider level population and demand projection data, developed specifically for OCWP analyses, focus on retail customers for whom the system provides direct service. These estimates were generated from Oklahoma Department of Commerce population projections. In addition, the 2008 OCWP Provider Survey contributed critical information on water production and population served that was used to calculate per capita water use. Population for 2010 was estimated and may not reflect actual 2010 Census values. Exceptions to this methodology are noted.

Public Water Providers/Retail Population Served (1 of 3)

Lower Arkansas Region

Provider	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Population Served					
				2010	2020	2030	2040	2050	2060
ADAIR CO RWD #1 (CHERRY TREE)	OK3000104	Adair	148	2,097	2,445	2,793	3,141	3,497	3,854
ADAIR CO RWD #2	OK3000105	Adair	154	912	1,063	1,215	1,366	1,521	1,677
ADAIR CO RWD #3	OK3000106	Adair	70	3,984	4,645	5,307	5,968	6,644	7,323
ADAIR CO RWD #4	OK3000107	Adair	72	1,075	1,253	1,431	1,610	1,792	1,975
ADAIR CO RWD #5	OK1021770	Adair	212	708	825	943	1,060	1,180	1,301
ADAIR CO RWS & SWMD #6	OK2000145	Adair	75	28	33	38	42	47	52
ARKOMA	OK3004013	LeFlore	54	2,226	2,398	2,560	2,713	2,875	3,038
BOKOSHE PWA	OK3004012	LeFlore	74	462	500	529	558	596	625
BRAGGS WATER WORKS	OK2005104	Muskogee	78	1,061	1,095	1,129	1,163	1,197	1,197
BURNT CABIN RWD	OK1021763	Cherokee	193	283	326	367	410	451	493
CAMERON PWA	OK3004011	LeFlore	104	321	350	369	389	418	438
CHECOTAH	OK1020515	McIntosh	288	3,586	4,021	4,465	4,964	5,518	6,119
CHEROKEE CO RWD #1 (FT GIBSON)	OK1021621	Cherokee	154	710	710	710	710	710	710
CHEROKEE CO RWD #2 (KEYS)	OK1021711	Cherokee	70	1,564	1,797	2,027	2,260	2,486	2,719
CHEROKEE CO RWD #3 (GRANDVIEW)	OK4001117	Cherokee	73	4,072	4,678	5,275	5,882	6,471	7,076
CHEROKEE CO RWD #7 (WELLING)	OK3001126	Cherokee	147	609	700	789	880	968	1,058
CHEROKEE CO RWD #8 (BRIGGS)	OK3001118	Cherokee	325	420	483	544	607	667	730
CHEROKEE CO RWD #12	OK2001189	Cherokee	90	93	107	121	135	149	162
CHEROKEE CO RWD #13	OK1021721	Cherokee	66	2,625	3,016	3,401	3,792	4,172	4,562
EAST CENTRAL OKLA WATER AUTH	OK1021713	Sequoyah	80	1,232	1,274	1,312	1,344	1,378	1,410
FORT GIBSON	OK1021622	Muskogee	252	4,325	4,472	4,608	4,723	4,839	4,954
GANS UTIL AUTH	OK3006802	Sequoyah	69	642	725	781	837	921	977
GORE PWA	OK1021773	Sequoyah	117	1,859	2,054	2,250	2,426	2,622	2,817
HASKELL CO WATER COMPANY	OK1020301	Haskell	128	6,029	6,833	7,679	8,574	9,463	10,444
HEAVENER UTILITY AUTH/PSG	OK1020101	LeFlore	110	3,320	3,571	3,804	4,036	4,268	4,510
KEOTA PWA	OK3003112	Haskell	79	531	603	674	755	827	917
LATIMER CO RWD #1	OK3003904	Latimer	157	3,224	3,374	3,549	3,756	3,958	4,195
LATIMER CO RWD #3	OK3003908	Latimer	113	134	141	148	157	165	175
LATIMER CO RWD #4	OK1020110	Latimer	68	526	550	579	612	645	684
LEE CREEK RWD	OK3006820	Sequoyah	98	258	286	312	338	364	390
LEFLORE CO, CONSOLIDATED RWD #1	OK3004040	LeFlore	148	1,838	1,982	2,110	2,238	2,367	2,502
LEFLORE CO RWD #1	OK3004003	LeFlore	91	1,757	1,894	2,016	2,139	2,261	2,391
LEFLORE CO RWD #2	OK3004007	LeFlore	99	3,677	3,963	4,220	4,477	4,733	5,005
LEFLORE CO RWD #5	OK3004010	LeFlore	150	1,627	1,754	1,867	1,981	2,094	2,215
LEFLORE CO RWD #14	OK3004001	LeFlore	122	6,751	7,277	7,748	8,219	8,691	9,189
LEFLORE CO RWD #15	OK3004046	LeFlore	360	354	382	407	431	456	482

Public Water Providers/Retail Population Served (2 of 3)

Lower Arkansas Region

Provider	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Population Served					
				2010	2020	2030	2040	2050	2060
MCCURTAIN	OK3003101	Haskell	54	580	656	744	831	919	1,017
MCINTOSH CO RWD #1	OK3004916	McIntosh	40	357	400	444	493	549	608
MCINTOSH CO RWS & SWMD #2 (ONAPA)	OK1020535	McIntosh	66	985	1,102	1,225	1,361	1,515	1,679
MCINTOSH CO RWD #3 (VICTOR)	OK3004903	McIntosh	58	1,588	1,778	1,975	2,195	2,443	2,707
MCINTOSH CO RWD #5	OK3004939	McIntosh	120	1,552	1,737	1,930	2,145	2,387	2,645
MCINTOSH CO RWD #7	OK3004920	McIntosh	142	207	232	257	286	318	353
MULDROW PWA	OK1020208	Sequoyah	132	3,204	3,556	3,880	4,195	4,519	4,843
MUSKOGEE	OK1021607	Muskogee	342	36,178	37,399	38,527	39,498	40,470	41,432
MUSKOGEE CO RWD #1 (OKTAHA)	OK3005106	Muskogee	83	376	399	410	422	433	444
MUSKOGEE CO RWD #2 (GOOSENECK)	OK3005102	Muskogee	107	1,008	1,042	1,073	1,100	1,127	1,154
MUSKOGEE CO RWD #4	OK3005104	Muskogee	74	862	891	917	940	963	986
MUSKOGEE CO RWD #5	OK3005107	Muskogee	98	4,016	4,151	4,275	4,382	4,490	4,597
MUSKOGEE CO RWD #6	OK3005105	Muskogee	131	1,638	1,693	1,743	1,787	1,831	1,875
MUSKOGEE CO RWD #7	OK3005103	Muskogee	97	1,723	1,781	1,834	1,880	1,927	1,973
PANAMA PWA	OK3004016	LeFlore	200	1,391	1,499	1,596	1,693	1,790	1,893
PORUM PWA	OK1020302	Muskogee	91	731	756	778	798	817	837
POTEAU PWA	OK3004015	LeFlore	126	8,111	8,742	9,308	9,874	10,441	11,039
PVIA (WHOLESALER ONLY)	OK1020104	LeFlore	0	0	0	0	0	0	0
QUINTON	OK3006123	Pittsburg	74	1,083	1,132	1,181	1,230	1,290	1,349
RED OAK PWA	OK1020105	Latimer	88	587	606	646	685	724	763
ROLAND	OK1020212	Sequoyah	229	3,203	3,547	3,880	4,193	4,527	4,850
SALLISAW	OK1020206	Sequoyah	274	8,674	9,608	10,483	11,339	12,214	13,089
SEQUOYAH CO RWD #3	OK3006804	Sequoyah	208	1,074	1,190	1,299	1,405	1,513	1,622
SEQUOYAH CO RWD #4	OK3006809	Sequoyah	112	1,193	1,322	1,442	1,560	1,681	1,802
SEQUOYAH CO RWD #5	OK3006815	Sequoyah	54	2,478	2,747	2,997	3,242	3,492	3,744
SEQUOYAH CO RWD #7	OK3006806	Sequoyah	154	3,044	3,374	3,681	3,983	4,290	4,599
SEQUOYAH CO WATER ASSOC	OK1020210	Sequoyah	175	14,715	16,309	17,795	19,251	20,736	22,228
SPIRO	OK1020106	LeFlore	91	2,293	2,476	2,640	2,804	2,958	3,132
SPIRO EAST RW	OK3004005	LeFlore	119	3,643	3,934	4,195	4,455	4,700	4,975
STIGLER	OK1020303	Haskell	232	3,013	3,408	3,832	4,274	4,727	5,208
STILWELL	OK1020205	Adair	455	3,462	4,028	4,604	5,179	5,764	6,357
TAHLEQUAH PWA	OK1021701	Cherokee	214	16,169	18,574	20,953	23,358	25,702	28,107
VIAN	OK3006812	Sequoyah	59	1,406	1,559	1,701	1,840	1,982	2,124
WARNER	OK1020409	Muskogee	134	1,452	1,502	1,541	1,581	1,621	1,661
WATER DIST INC	OK3004009	LeFlore	122	4,188	4,514	4,806	5,098	5,391	5,700
WATTS	OK3000108	Adair	100	1,156	1,344	1,531	1,719	1,906	2,125

Public Water Providers/Retail Population Served (3 of 3)

Lower Arkansas Region

Provider	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Population Served					
				2010	2020	2030	2040	2050	2060
WEST SILOAM SPRINGS	OK3002109	Delaware	100	920	1,054	1,188	1,322	1,474	1,625
WESTVILLE	OK3000109	Adair	111	1,885	2,197	2,520	2,832	3,155	3,477
WILBURTON	OK1020103	Latimer	128	3,061	3,201	3,361	3,551	3,751	3,971
WISTER	OK3004014	LeFlore	155	1,019	1,105	1,172	1,238	1,314	1,391

1 SDWIS - Safe Drinking Water Information System

2 RED ENTRY indicates data were taken from 2007 OWRB Water Rights Database. GPD=gallons per day.

Projections of Retail Water Demand

Each public water supply system has a “retail” demand, defined as the amount of water used by residential and non-residential customers within that provider’s service area. Public-supplied residential demand includes water provided to households for domestic uses both inside and outside the home. Non-residential demand includes customer uses at office buildings, shopping centers, industrial parks, schools, churches, hotels, and related locations served by a public water supply system. Retail demand doesn’t include wholesale water to other providers.

Municipal and Industrial (M&I) demand is driven by projected population growth and specific customer characteristics. Demand forecasts for each public system are estimated from average water use (in gallons per capita per day) multiplied by projected population. Oklahoma Department of Commerce 2002 population projections (unpublished special tabulation for the OWRB) were calibrated to 2007 Census estimates and used to establish population growth rates for cities, towns, and rural areas through 2060. Population growth rates were applied to 2007 population-served values for each provider to project future years’ service area (retail) populations.

The main source of data for per capita water use for each provider was the 2008 OCWP Provider Survey conducted by the OWRB in cooperation with the Oklahoma Rural Water Association and Oklahoma Municipal League. For each responding provider, data from the survey included population served, annual average daily demand, total water produced, wholesale purchases and sales between providers, and estimated system losses.

For missing or incomplete data, weighted average per capita demand was used for the provider’s county. In some cases, survey data were supplemented with data from the OWRB water rights database. Per capita supplier demands can vary over time due to precipitation and service area characteristics, such as commercial and industrial activity, tourism, or conservation measures. For the baseline demand projections described here, the per capita demand was held constant through each of the future planning year scenarios. OCWP estimates of potential reductions in demand from conservation measures are analyzed on a basin and regional level, but not for individual provider systems.

Public Water Provider Demand Forecast (1 of 3)

Lower Arkansas Region

Provider	SDWIS ID[1]	County	Demand					
			2010	2020	2030	2040	2050	2060
			AFY					
ADAIR CO RWD #1 (CHERRY TREE)	OK3000104	Adair	347	404	462	520	579	638
ADAIR CO RWD #2	OK3000105	Adair	157	183	209	236	262	289
ADAIR CO RWD #3	OK3000106	Adair	313	365	417	469	522	575
ADAIR CO RWD #4	OK3000107	Adair	87	101	116	130	145	160
ADAIR CO RWD #5	OK1021770	Adair	168	196	224	252	280	309
ADAIR CO RWS & SWMD #6	OK2000145	Adair	2	3	3	4	4	4
ARKOMA	OK3004013	LeFlore	134	144	154	163	173	183
BOKOSHE PWA	OK3004012	LeFlore	38	42	44	46	50	52
BRAGGS WATER WORKS	OK2005104	Muskogee	93	96	98	101	104	104
BURNT CABIN RWD	OK1021763	Cherokee	61	70	79	88	97	106
CAMERON PWA	OK3004011	LeFlore	38	41	43	45	49	51
CHECOTAH	OK1020515	McIntosh	1,158	1,298	1,441	1,602	1,781	1,975
CHEROKEE CO RWD #1 (FT GIBSON)	OK1021621	Cherokee	123	123	123	123	123	123
CHEROKEE CO RWD #2 (KEYS)	OK1021711	Cherokee	123	141	159	177	195	213
CHEROKEE CO RWD #3 (GRANDVIEW)	OK4001117	Cherokee	335	385	434	484	533	583
CHEROKEE CO RWD #7 (WELLING)	OK3001126	Cherokee	100	115	130	145	159	174
CHEROKEE CO RWD #8 (BRIGGS)	OK3001118	Cherokee	153	176	198	221	243	266
CHEROKEE CO RWD #12	OK2001189	Cherokee	9	11	12	14	15	16
CHEROKEE CO RWD #13	OK1021721	Cherokee	194	223	251	280	308	337
EAST CENTRAL OKLA WATER AUTH	OK1021713	Sequoyah	111	114	118	121	124	127
FORT GIBSON	OK1021622	Muskogee	1,221	1,262	1,300	1,333	1,365	1,398
GANS UTIL AUTH	OK3006802	Sequoyah	49	56	60	65	71	75
GORE PWA	OK1021773	Sequoyah	243	268	294	317	343	368
HASKELL CO WATER COMPANY	OK1020301	Haskell	864	979	1,100	1,228	1,356	1,496
HEAVENER UTILITY AUTH/PSG	OK1020101	LeFlore	409	440	469	497	526	556
KEOTA PWA	OK3003112	Haskell	47	53	59	66	73	81
LATIMER CO RWD #1	OK3003904	Latimer	566	592	623	659	695	737
LATIMER CO RWD #3	OK3003908	Latimer	17	18	19	20	21	22
LATIMER CO RWD #4	OK1020110	Latimer	40	42	44	47	49	52
LEE CREEK RWD	OK3006820	Sequoyah	28	32	34	37	40	43
LEFLORE CO, CONSOLIDATED RWD #1	OK3004040	LeFlore	305	329	350	371	392	415
LEFLORE CO RWD #1	OK3004003	LeFlore	180	194	206	219	231	244
LEFLORE CO RWD # 2	OK3004007	LeFlore	407	439	467	496	524	554
LEFLORE CO RWD # 5	OK3004010	LeFlore	273	295	314	333	352	372
LEFLORE CO RWD #14	OK3004001	LeFlore	921	993	1,057	1,121	1,186	1,254
LEFLORE CO RWD #15	OK3004046	LeFlore	143	154	164	174	184	195

Public Water Provider Demand Forecast (2 of 3)

Lower Arkansas Region

Provider	SDWIS ID[1]	County	Demand					
			2010	2020	2030	2040	2050	2060
			AFY					
MCCURTAIN	OK3003101	Haskell	35	39	45	50	55	61
MCINTOSH CO RWD #1	OK3004916	McIntosh	16	18	20	22	25	27
MCINTOSH CO RWD #3 (VICTOR)	OK3004903	McIntosh	103	115	128	143	159	176
MCINTOSH CO RWD #5	OK3004939	McIntosh	209	233	259	288	321	356
MCINTOSH CO RWD #7	OK3004920	McIntosh	33	37	41	45	50	56
MCINTOSH CO RWS & SWMD #2 (ONAPA)	OK1020535	McIntosh	72	81	90	100	112	124
MULDROW PWA	OK1020208	Sequoyah	475	527	575	622	670	718
MUSKOGEE	OK1021607	Muskogee	13,857	14,325	14,757	15,129	15,501	15,870
MUSKOGEE CO RWD #1 (OKTAHA)	OK3005106	Muskogee	35	37	38	39	40	41
MUSKOGEE CO RWD #2 (GOOSENECK)	OK3005102	Muskogee	121	125	129	132	135	138
MUSKOGEE CO RWD #4	OK3005104	Muskogee	71	74	76	78	80	81
MUSKOGEE CO RWD #5	OK3005107	Muskogee	440	455	468	480	492	504
MUSKOGEE CO RWD #6	OK3005105	Muskogee	240	249	256	262	269	275
MUSKOGEE CO RWD #7	OK3005103	Muskogee	187	193	199	204	209	214
PANAMA PWA	OK3004016	LeFlore	312	336	358	379	401	424
PORUM PWA	OK1020302	Muskogee	75	77	79	81	83	85
POTEAU PWA	OK3004015	LeFlore	1,144	1,233	1,313	1,393	1,473	1,558
PVIA (WHOLESALER ONLY)	OK1020104	LeFlore	0	0	0	0	0	0
QUINTON	OK3006123	Pittsburg	90	94	98	102	107	112
RED OAK PWA	OK1020105	Latimer	58	60	64	67	71	75
ROLAND	OK1020212	Sequoyah	822	910	995	1,076	1,161	1,244
SALLISAW	OK1020206	Sequoyah	2,660	2,947	3,215	3,478	3,746	4,015
SEQUOYAH CO RWD #3	OK3006804	Sequoyah	250	277	303	327	353	378
SEQUOYAH CO RWD #4	OK3006809	Sequoyah	149	165	180	195	210	225
SEQUOYAH CO RWD #5	OK3006815	Sequoyah	150	167	182	197	212	227
SEQUOYAH CO RWD #7	OK3006806	Sequoyah	526	583	636	688	741	795
SEQUOYAH CO WATER ASSOC	OK1020210	Sequoyah	2,892	3,205	3,497	3,783	4,075	4,368
SPIRO	OK1020106	LeFlore	234	253	270	287	302	320
SPIRO EAST RW	OK3004005	LeFlore	486	525	559	594	627	663
STIGLER	OK1020303	Haskell	782	884	994	1,109	1,227	1,352
STILWELL	OK1020205	Adair	1,763	2,051	2,344	2,637	2,935	3,237
TAHLEQUAH PWA	OK1021701	Cherokee	3,881	4,458	5,029	5,607	6,169	6,747
VIAN	OK3006812	Sequoyah	93	104	113	122	132	141
WARNER	OK1020409	Muskogee	218	225	231	237	243	249

Public Water Provider Demand Forecast (3 of 3)

Lower Arkansas Region

Provider	SDWIS ID[1]	County	Demand					
			2010	2020	2030	2040	2050	2060
			AFY					
WATER DIST INC	OK3004009	LeFlore	572	617	657	696	736	779
WATTS	OK3000108	Adair	129	150	171	192	213	237
WEST SILOAM SPRINGS	OK3002109	Delaware	103	118	133	148	165	182
WESTVILLE	OK3000109	Adair	235	273	314	352	393	433
WILBURTON	OK1020103	Latimer	440	460	483	511	539	571
WISTER	OK3004014	LeFlore	177	192	203	215	228	241

1 SDWIS - Safe Drinking Water Information System

Wholesale Water Transfers (1 of 3)

Lower Arkansas Region

		Sales			Purchases		
Provider	SDWIS ID[1]	Sells To	Emergency or Ongoing	Treated or Raw or Both	Purchases from	Emergency or Ongoing	Treated or Raw or Both
ADAIR CO RWD #1 (CHERRY TREE)	OK3000104				Stilwell	O	T
ADAIR CO RWD #2	OK3000105				Stilwell	O	T
ADAIR CO RWD #3	OK3000106				Stilwell	O	T
ADAIR CO RWD #4	OK3000107				Stilwell	O	T
BOKOSHE PWA	OK3004012				PVIA	O	T
CAMERON PWA	OK3004011				PVIA	O	T
CHECOTAH	OK1020515	McIntosh CO RWD #5 McIntosh Co RWD #9 McIntosh Co RWD #7 McIntosh Co RWD #3 McIntosh Co RWD #1	O O O O O	T T T T T			
CHEROKEE CO RWD #3 (GRANDVIEW)	OK4001117				Tahlequah PWA	O	T
CHEROKEE CO RWD #7 (WELLING)	OK3001126				Tahlequah PWA Adair Co RWD #2	O	T
CHEROKEE CO RWD #8 (BRIGGS)	OK3001118				Tahlequah PWA	O	T
FORT GIBSON	OK1021622	Muskogee Co RWD #7 Muskogee Co RWD #4	O O	T T			
GANS UTIL AUTH	OK3006802				Sequoyah Co RWD #3	O	T
HASKELL CO WATER COMPANY	OK1020301	Quinton Keota PWA	O O	T T	Stigler Muskogee	O	T
HEAVENER UTILITY AUTH/PSG	OK1020101	Water Dist Inc	O	T	PVIA	E	T
KEOTA PWA	OK3003112				Haskell Co Water Company	O	T
LATIMER CO RWD #1	OK3003904				Wilburton	O	T
LATIMER CO RWD #3	OK3003908				Talihina	O	T
LEFLORE CO, CONSOLIDATED RWD #1	OK3004040				PVIA		
LEFLORE CO RWD #1	OK3004003				PVIA	O	T
LEFLORE CO RWD #2	OK3004007				PVIA LeFlore Co	O	T
LEFLORE CO RWD #5	OK3004010				PVIA	O	T
LEFLORE CO RWD #14	OK3004001				Spiro	E	T

Wholesale Water Transfers

Some providers sell water on a "wholesale" basis to other providers, effectively increasing the amount of water that the selling provider must deliver and reducing the amount that the purchasing provider diverts from surface and groundwater sources. Wholesale water transfers between public water providers are fairly common and can provide an economical way to meet demand. Wholesale quantities typically vary from year to year depending upon growth, precipitation, emergency conditions, and agreements between systems.

Water transfers between providers can help alleviate costs associated with developing or maintaining infrastructure, such as a reservoir or pipeline; allow access to higher quality or more reliable sources; or provide additional supplies only when required, such as in cases of supply emergencies. Utilizing the 2008 OCWP Provider Survey and OWRB water rights data, the Wholesale Water Transfers table presents a summary of known wholesale arrangements for providers in the region. Transfers can consist of treated or raw water and can occur on a regular basis or only during emergencies. Providers commonly sell to and purchase from multiple water providers.

Wholesale Water Transfers (2 of 3)

Lower Arkansas Region

Provider	SDWIS ID[1]	Sales			Purchases		
		Sells To	Emergency or Ongoing	Treated or Raw or Both	Purchases from	Emergency or Ongoing	Treated or Raw or Both
MCCURTAIN	OK3003101				PVIA	O	T
MCINTOSH CO RWD #1	OK3004916				Checotah	O	T
MCINTOSH CO RWD #3 (VICTOR)	OK3004903				Checotah	O	T
MCINTOSH CO RWD #5	OK3004939				Checotah	O	T
MULDROW PWA	OK1020208	Sequoyah Co RWD #7	O	T			
MUSKOGEE	OK1021607	Muskogee Co RWD # 1	O				
		Muskogee Co RWD # 2	O				
		Muskogee Co RWD #5	O	T			
		Muskogee Co RWD #6	O	T			
		Muskogee Co RWD # 9	O				
		Muskogee Co RWD #10	O	T			
		Porter PWA	O	T			
MUSKOGEE CO RWD #1 (OKTAHA)	OK3005106				Muskogee		
MUSKOGEE CO RWD #2 (GOOSENECK)	OK3005102				Muskogee	O	
MUSKOGEE CO RWD #4	OK3005104				Fort Gibson	O	T
MUSKOGEE CO RWD #5	OK3005107				Muskogee	O	T
MUSKOGEE CO RWD #6	OK3005105				Muskogee	O	T
MUSKOGEE CO RWD #7	OK3005103				Fort Gibson	O	T
PANAMA PWA	OK3004016				PVIA	O	T
POTEAU PWA	OK3004015	LeFlore Co RWD #1	O	T	PVIA	O	T
PVIA	OK1020104	Bokoshe PWA	O	T			
		Cameron PWA	O	T			
		Heavener Utility Auth/PSG	E	T			
		LeFlore Co RWD #1 Consolidated	O	T			
		LeFlore Co RWD #2	O	T			
		LeFlore Co RWD #5	O	T			
		LeFlore Co RWD #14	O	T			
		LeFlore Co RWD #15	O	T			
		Panama PWA	O	T			
		Poteau PWA	O	T			
		Water Dist Inc	O	T			
		Wister	O	T			
QUINTON	OK3006123				Haskell Co Water Company	O	
RED OAK PWA	OK1020105	Water Dist Inc	O	T			
ROLAND	OK1020212	Sequoyah Co Water Assoc	O	T	Sequoyah Co Water Assoc	E	T
		Sequoyah Co RWD #7	E	T	Sequoyah Co RWD #7	E	T

Wholesale Water Transfers (3 of 3)

Lower Arkansas Region

Provider	SDWIS ID[1]	Sales			Purchases		
		Sells To	Emergency or Ongoing	Treated or Raw or Both	Purchases from	Emergency or Ongoing	Treated or Raw or Both
SALLISAW	OK1020206	Sequoyah Co RWD #3 Sequoyah Co RWD #4	O O	T T	Sequoyah Co Water Assoc	E	T
SEQUOYAH CO RWD #3	OK3006804	Gans Util Auth	O	T	Sallisaw	O	T
SEQUOYAH CO RWD #4	OK3006809				Sallisaw	O	T
SEQUOYAH CO RWD #5	OK3006815				Sequoyah Co Water Assoc	O	T
SEQUOYAH CO RWD #7	OK3006806	Roland	E	T	Muldrow PWA Roland	O E	T T
SEQUOYAH CO WATER ASSOC	OK1020210	Vian Sequoyah Co RWD #5 Sallisaw Roland	O O E E	T T T T	Roland	O	T
SPIRO EAST RW	OK3004005				PVIA	O	T
STIGLER	OK1020303	Haskell County Water Company	O	T			
STILWELL	OK1020205	Adair Co RWD #1 Adair Co RWD #2 Adair Co RWD #3 Adair Co RWD #4	O O O O	T T T T			
TAHLEQUAH PWA	OK1021701	Cherokee Co RWD #3 Cherokee Co RWD #7 Cherokee Co RWD #8 Cherokee Co RWD #11	O O O O	T T T T			
VIAN	OK3006812				Sequoyah Co Water Assoc	O	T
WATER DIST INC	OK3004009				PVIA Heavener Utility Auth/PSG Red Oak PWA	O O O	T T T
WILBURTON	OK1020103	Latimer Co RWD #1	O	T			
WISTER	OK3004014				PVIA	O	T

1 SDWIS - Safe Drinking Water Information System

Provider Water Rights

Public water providers using surface water or groundwater obtain water rights from the OWRB. Water providers purchasing water from other suppliers or sources are not required to obtain water rights as long as the furnishing entity has the appropriate water right or other source of authority. Each public water provider's current water right(s) and source of supply have been summarized in this report. The percentage of each provider's total 2007 water rights from surface water, alluvial groundwater, and bedrock groundwater supplies was also calculated, indicating the relative proportions of sources available to each provider.

A comparison of existing water rights to projected demands can show when additional water rights or other sources and in what amounts might be needed. Forecasts of conditions for the year 2060 indicate where additional water rights may be needed to satisfy demands by that time. However, in most cases, wholesale water transfers to other providers must also be addressed by the selling provider's water rights. Thus, the amount of water rights required will exceed the retail demand for a selling provider and will be less than the retail demand for a purchasing provider.

In preparing to meet long-term needs, public water providers should consider strategic factors appropriate to their sources of water. For example, public water providers who use surface water can seek and obtain a "schedule of use" as part of their stream water right, which addresses projected growth and consequent increases in stream water use. Such schedules of use can be employed to address increases that are anticipated to occur over many years or even decades, as an alternative to the usual requirement to use the full authorized amount of stream water in a seven-year period. On the other hand, public water providers that utilize groundwater should consider the prospect that it may be necessary to purchase or lease additional land in order to increase their groundwater rights.

Public Water Provider Water Rights and Withdrawals - 2010 (1 of 3)

Lower Arkansas Region

Provider	SDWIS ID[1]	County	Permitted Quantity	Source		
				Permitted Surface Water	Permitted Alluvial Groundwater	Permitted Bedrock Groundwater
			AFY	Percent		
ADAIR CO RWD #1 (CHERRY TREE)	OK3000104	Adair	---	---	---	---
ADAIR CO RWD #2	OK3000105	Adair	---	---	---	---
ADAIR CO RWD #3	OK3000106	Adair	---	---	---	---
ADAIR CO RWD #4	OK3000107	Adair	---	---	---	---
ADAIR CO RWD #5	OK1021770	Adair	160	100%	0%	0%
ADAIR CO RWS & SWMD #6	OK2000145	Adair	---	---	---	---
ARKOMA	OK3004013	LeFlore	---	---	---	---
BOKOSHE PWA	OK3004012	LeFlore	---	---	---	---
BRAGGS WATER WORKS	OK2005104	Muskogee	90	100 %	---	---
BURNT CABIN RWD	OK1021763	Cherokee	90	100%	0%	0%
CAMERON PWA	OK3004011	LeFlore	---	---	---	---
CHECOTAH	OK1020515	McIntosh	2,502	100%	0%	0%
CHEROKEE CO RWD #1 (FT GIBSON)	OK1021621	Cherokee	---	---	---	---
CHEROKEE CO RWD #3 (GRANDVIEW)	OK4001117	Cherokee	---	---	---	---
CHEROKEE CO RWD #7 (WELLING)	OK3001126	Cherokee	---	---	---	---
CHEROKEE CO RWD #8 (BRIGGS)	OK3001118	Cherokee	---	---	---	---
CHEROKEE CO RWD #12	OK2001189	Cherokee	---	---	---	---
CHEROKEE CO RWD #13	OK1021721	Cherokee	293	100%	0%	0%
EAST CENTRAL OKLA WATER AUTH	OK1021713	Sequoyah	1,422	100%	0%	0%
FORT GIBSON	OK1021622	Muskogee	5,677	100%	0%	0%
GANS UTIL AUTH	OK3006802	Sequoyah	---	---	0%	0%
GORE PWA	OK1021773	Sequoyah	560	100%	0%	0%
HASKELL CO WATER COMPANY	OK1020301	Haskell	1,713	100%	0%	0%
HEAVENER UTILITY AUTH/PSG	OK1020101	LeFlore	4,426	84%	0%	16%
KEOTA PWA	OK3003112	Haskell	---	---	---	---
LATIMER CO RWD #1	OK3003904	Latimer	---	---	---	---
LATIMER CO RWD #3	OK3003908	Latimer	---	---	---	---
LATIMER CO RWD #4	OK1020110	Latimer	---	---	---	---
LEE CREEK RWD	OK3006820	Sequoyah	---	---	---	---
LEFLORE CO, CONSOLIDATED RWD #1	OK3004040	LeFlore	---	---	---	---
LEFLORE CO RWD #1	OK3004003	LeFlore	---	---	---	---
LEFLORE CO RWD #2	OK3004007	LeFlore	---	---	---	---
LEFLORE CO RWD #5	OK3004010	LeFlore	---	---	---	---
LEFLORE CO RWD #14	OK3004001	LeFlore	---	---	---	---
LEFLORE CO RWD #15	OK3004046	LeFlore	---	---	---	---

Public Water Provider Water Rights and Withdrawals - 2010 (2 of 3)

Lower Arkansas Region

				Source		
Provider	**SDWIS ID[1]**	**County**	**Permitted Quantity**	**Permitted Surface Water**	**Permitted Alluvial Groundwater**	**Permitted Bedrock Groundwater**
			AFY	Percent		
MCCURTAIN	OK3003101	Haskell	---	---	---	---
MCINTOSH CO RWD #1	OK3004916	McIntosh	---	---	---	---
MCINTOSH CO RWD #3 (VICTOR)	OK3004903	McIntosh	---	---	---	---
MCINTOSH CO RWD #5	OK3004939	McIntosh	331	100%	0%	0%
MCINTOSH CO RWD #7	OK3004920	McIntosh	---	---	---	---
MCINTOSH CO RWS & SWMD #2 (ONAPA)	OK1020535	McIntosh	1,000	100%	0%	0%
MULDROW PWA	OK1020208	Sequoyah	372	100%	0%	0%
MUSKOGEE	OK1021607	Muskogee	55,720	100%	0%	0%
MUSKOGEE CO RWD #1 (OKTAHA)	OK3005106	Muskogee	---	---	---	---
MUSKOGEE CO RWD #2 (GOOSENECK)	OK3005102	Muskogee	---	---	---	---
MUSKOGEE CO RWD #4	OK3005104	Muskogee	---	---	---	---
MUSKOGEE CO RWD #5	OK3005107	Muskogee	---	---	---	---
MUSKOGEE CO RWD #6	OK3005105	Muskogee	---	---	---	---
MUSKOGEE CO RWD #7	OK3005103	Muskogee	---	---	---	---
PANAMA PWA	OK3004016	LeFlore	31	0%	0%	100%
PORUM PWA	OK1020302	Muskogee	1,015	100%	0%	0%
POTEAU PWA	OK3004015	LeFlore	1	100%	0%	0%
PVIA	OK1020104	LeFlore	21,789	100%	0%	0%
QUINTON	OK3006123	Pittsburg	---	---	---	---
RED OAK PWA	OK1020105	Latimer	---	---	---	---
ROLAND	OK1020212	Sequoyah	920	100%	---	---
SALLISAW	OK1020206	Sequoyah	18,377	100%	0%	0%
SEQUOYAH CO RWD #3	OK3006804	Sequoyah	---	---	---	---
SEQUOYAH CO RWD #4	OK3006809	Sequoyah	---	---	---	---
SEQUOYAH CO RWD #5	OK3006815	Sequoyah	320	100%	---	---
SEQUOYAH CO RWD #7	OK3006806	Sequoyah	---	---	---	---
SEQUOYAH CO WATER ASSOC	OK1020210	Sequoyah	12,789	99%	0%	1%
SPIRO	OK1020106	LeFlore	329	100%	0%	0%
SPIRO EAST RW	OK3004005	LeFlore	---	---	---	---
STIGLER	OK1020303	Haskell	690	49%	51%	0%
STILWELL	OK1020205	Adair	3,130	100%	0%	0%
TAHLEQUAH PWA	OK1021701	Cherokee	16,994	100%	0%	0%
VIAN	OK3006812	Sequoyah	---	---	---	---

Public Water Provider Water Rights and Withdrawals - 2010 (3 of 3)

Lower Arkansas Region

Provider	SDWIS ID[1]	County	Permitted Quantity	Source		
				Permitted Surface Water	Permitted Alluvial Groundwater	Permitted Bedrock Groundwater
			AFY	Percent		
WARNER	OK1020409	Muskogee	761	100%	0%	0%
WATER DIST INC	OK3004009	LeFlore	---	---	---	---
WATTS	OK3000108	Adair	---	---	---	---
WEST SILOAM SPRINGS	OK3002109	Delaware	---	---	---	---
WESTVILLE	OK3000109	Adair	568	0%	0%	100%
WILBURTON	OK1020103	Latimer	1,965	100%	0%	0%
WISTER	OK3004014	LeFlore	---	---	---	---

1 SDWIS - Safe Drinking Water Information System

OCWP Provider Survey

Lower Arkansas Region

Adair County RWD 1 (Cherry Tree)

Current Source of Supply

Primary sources: City of Stilwell

Short-Term Needs

Infrastructure improvements: refurbish standpipes; replace pump stations.

Long-Term Needs

Infrastructure improvements: replace distribution system lines; add a connection to Sequoyah County Water Association.

Adair County RWD 2

Current Source of Supply

Primary source: City of Stilwell

Short-Term Needs

Infrastructure improvements: replace portion of distribution system lines.

Long-Term Needs

None identified.

Adair County RWD 3

Current Source of Supply

Primary source: City of Stilwell

Short-Term Needs

Infrastructure improvements: add storage tank.

Long-Term Needs

Infrastructure improvements: replace distribution system lines; add storage tank and booster pump station.

Adair County RWD 4

Current Source of Supply

Primary source: City of Stilwell

Short-Term Needs

Infrastructure improvements: refurbish pressure reducing stations in distribution system.

Long-Term Needs

Infrastructure improvements: add standpipe.

Adair County RWD 5

Current Source of Supply

Primary source: Barren Fork Creek

Short-Term Needs

Infrastructure improvements: add storage.

Long-Term Needs

Infrastructure improvements: increase water treatment capacity.

Adair County RWS & SWMD 6

Current Source of Supply

Primary source: groundwater

Short-Term Needs

New supply source: possible water Flint Ridge RWD.

Long-Term Needs

None identified.

Arkoma (LeFlore County)

Current Source of Supply

Primary source: Ft. Smith, AR

Short-Term Needs

Infrastructure improvements: replace storage tank.

Long-Term Needs

None identified.

Bokoshe PWA (LeFlore County)

Current Source of Supply

Primary source: Poteau Valley Improvement Authority

Short-Term Needs

None identified.

Long-Term Needs

None identified.

Braggs Water Works (Muskogee County)

Current Source of Supply

Primary source: Arkansas River

Short-Term Needs

Infrastructure improvements: replace distribution system lines.

Long-Term Needs

Infrastructure improvements: replace storage tank and distribution system lines.

Burnt Cabin RWD (Cherokee County)

Current Source of Supply

Primary source: Tenkiller Ferry Lake

Short-Term Needs

None identified.

Long-Term Needs

Infrastructure improvements: replace distribution system lines; increase water treatment capacity.

Cameron PWA (LeFlore County)

Current Source of Supply

Primary source: Poteau Valley Improvement Authority

Short-Term Needs

None identified.

Long-Term Needs

Infrastructure improvements: replace distribution system lines.

City of Checotah (McIntosh County)

Current Source of Supply

Primary source: Lake Eufaula

Short-Term Needs

None identified.

Long-Term Needs

None identified.

Cherokee County RWD 1 (Ft. Gibson)

Current Source of Supply

Primary sources: None identified

Short-Term Needs

None identified.

Long-Term Needs

None identified.

Cherokee County RWD 2 (Keys)

Current Source of Supply

Primary source: Tenkiller Ferry Lake

Short-Term Needs

None identified.

Long-Term Needs

New supply source: possible water purchase from Tahlequah.

Cherokee Co RWD 3

Current Source of Supply

Primary source: City of Tahlequah, Seminary Springs

Short-Term Needs

Infrastructure improvements: replace main distribution system lines.

Long-Term Needs

Infrastructure improvements: replace water tower and booster pump station; increase water treatment capacity.

Cherokee County RWD 7 (Welling)

Current Source of Supply

Primary source: City of Tahlequah, Adair County RWD 2

Short-Term Needs

Infrastructure improvements: replace distribution system lines; add distribution system looping lines upgrade pump station pumps; connection to Adair County RWD 2.

Long-Term Needs

Infrastructure improvements: upsize distribution system lines; add storage and pump capacity.

Cherokee County RWD 8 (Briggs)

Current Source of Supply

Primary source: City of Tahlequah

Short-Term Needs

Infrastructure improvements: replace distribution system lines; add storage.

Long-Term Needs

Infrastructure improvements: replace portion of main water lines; replace pump station pumps.

Cherokee County RWD 12

Current Source of Supply

Primary source: groundwater

Short-Term Needs

New supply source: drill additional well.

Infrastructure improvements: drill deeper wells; add pumps.

Long-Term Needs

Infrastructure improvements: add generator.

Cherokee County RWD 13

Current Source of Supply

Primary source: Tenkiller Ferry Lake

Short-Term Needs

None identified.

Long-Term Needs

None identified.

Provider Supply Plans

In 2008, a survey was sent to 785 municipal and rural water providers throughout Oklahoma to collect vital background water supply and system information. Additional detail for each of these providers was solicited in 2010 as part of follow-up interviews conducted by the ODEQ. The 2010 interviews sought to confirm key details of the earlier survey and document additional details regarding each provider's water supply infrastructure and plans. This included information on existing sources of supply (including surface water, groundwater, and other providers), short-term supply and infrastructure plans, and long-term supply and infrastructure plans.

In instances where no new source was identified, maintenance of the current source of supply is expected into the future. Providers may or may not have secured the necessary funding to implement their stated plans concerning infrastructure needs, commonly including additional wells or raw water conveyance, storage, and replacement/upgrade of treatment and distribution systems.

Additional support for individual water providers wishing to pursue enhanced planning efforts is documented in the *Public Water Supply Planning Guide*. This guide details how information contained in the OCWP Watershed Planning Region Reports and related planning documents can be used to formulate provider-level plans to meet present and future needs of individual water systems.

OCWP Provider Survey

Lower Arkansas Region

Consolidated RWD 1 (LeFlore County)

Current Source of Supply

Primary source: Poteau Valley Improvement Authority

Short-Term Needs

Infrastructure improvements: replace portion of distribution system lines; refurbish water towers and add check valve.

Long-Term Needs

Infrastructure improvements: replace distribution system lines; add standpipes, booster stations, backup power and security fencing.

East Central OK. Water Auth. (Sequoyah Co.)

Current Source of Supply

Primary source: Tenkiller Ferry Lake

Short-Term Needs

Infrastructure improvements: replace portion of main water line that crosses the Arkansas River.

Long-Term Needs

None identified.

City of Ft. Gibson (Muskogee County)

Current Source of Supply

Primary sources: Arkansas River

Short-Term Needs

Infrastructure improvements: replace water main lines; add storage.

Long-Term Needs

Infrastructure improvements: add storage; increase water treatment capacity.

Gans Utility Auth. (Sequoyah County)

Current Source of Supply

Primary source: Sequoyah County RWD 3

Short-Term Needs

Infrastructure improvements: replace portion of distribution system lines; add storage.

Long-Term Needs

None identified.

Gore PWA (Sequoyah County)

Current Source of Supply

Primary source: Tenkiller Ferry Lake

Short-Term Needs

Infrastructure improvements: replace portion of distribution system lines; add storage.

Long-Term Needs

Infrastructure improvements: increase water treatment capacity.

Haskell County Water Company

Current Source of Supply

Primary source: Lake Eufaula, City of Stigler

Short-Term Needs

None identified.

Long-Term Needs

Infrastructure improvements: add two new filters to water treatment plant.

Heavener Utility Auth. / PSG (LeFlore County)

Current Source of Supply

Primary source: Poteau River

Short-Term Needs

None identified.

Long-Term Needs

None identified.

Keota PWA (Haskell County)

Current Source of Supply

Primary source: Haskell County Water Company

Short-Term Needs

None identified.

Long-Term Needs

Infrastructure improvements: refurbish storage tank.

Latimer County RWD 1

Current Source of Supply

Primary source: City of Wilburton

Short-Term Needs

None identified.

Long-Term Needs

None identified.

Latimer County RWD 3

Current Source of Supply

Primary source: City of Talihina

Short-Term Needs

None identified.

Long-Term Needs

None identified.

Latimer County RWD 4

Current Source of Supply

Primary source: Strip Pit

Short-Term Needs

None identified.

Long-Term Needs

None identified.

Lee Creek RWD (Sequoyah County)

Current Source of Supply

Primary source: City of Ft. Smith, AR

Short-Term Needs

Infrastructure improvement: replace distribution system lines.

Long-Term Needs

Infrastructure improvement: replace distribution system lines.

LeFlore County RWD 1

Current Source of Supply

Primary source: Lake Wister Poteau Valley Improvement Auth.

Short-Term Needs

Infrastructure improvement: replace distribution system lines.

Long-Term Needs

New supply source: improvements for expansion from Poteau.

LeFlore County RWD 2

Current Source of Supply

Primary source: Poteau Valley Improvement Authority

Short-Term Needs

Infrastructure improvement: replace distribution system lines; add distribution system lines.

Long-Term Needs

Infrastructure improvement: replace distribution system lines; add distribution system lines; add storage.

LeFlore County RWD 4

Current Source of Supply

Primary source: Poteau Valley Improvement Authority

Short-Term Needs

None identified.

Long-Term Needs

None identified.

LeFlore County RWD 5

Current Source of Supply

Primary source: Poteau Valley Improvement Authority

Short-Term Needs

Infrastructure improvement: replace distribution system lines; add storage.

Long-Term Needs

Infrastructure improvement: add meters.

LeFlore County RWD 14

Current Source of Supply

Primary source: Poteau Valley Improvement Authority

Short-Term Needs

Infrastructure improvement: replace distribution system lines.

Long-Term Needs

None identified.

LeFlore County RWD 15

Current Source of Supply

Primary source: Lake Wister Poteau Valley Improvement Auth.

Short-Term Needs

Infrastructure improvement: replace portion of distribution system lines.

Long-Term Needs

None identified.

City of McCurtain (Haskell County)

Current Source of Supply

Primary source: Poteau Valley Improvement Authority

Short-Term Needs

Infrastructure improvement: replace distribution system lines.

Long-Term Needs

Infrastructure improvement: upgrade the distribution and water system; pipeline construction to Bokoshe PWA; obtain supplies from PVIA. New Supply Source: PVIA.

McIntosh County RWD 1

Current Source of Supply

Primary source: City of Checotah

Short-Term Needs

None identified.

Long-Term Needs

None identified.

McIntosh County RWD 5

Current Source of Supply

Primary source: City of Checotah (Eufaula Lake)

Short-Term Needs

Infrastructure improvement: add distribution system lines; add storage.

Long-Term Needs

None identified.

McIntosh County RWD 7

Current Source of Supply

Primary sources: None identified

Short-Term Needs

None identified.

Long-Term Needs

None identified.

McIntosh County RWS & SWMD 2 (Onapa)

Current Source of Supply

Primary source: Lake Eufaula

Short-Term Needs

None identified.

Long-Term Needs

None identified.

McIntosh County RWD 3

Current Source of Supply

Primary sources: City of Checotah

Short-Term Needs

None identified.

Long-Term Needs

None identified.

Muldrow PWA (Sequoyah County)

Current Source of Supply

Primary source: Muldrow City Lake

Short-Term Needs

None identified.

Long-Term Needs

Infrastructure improvements: add storage; add new clarifier and two new filters to water treatment plant.

City of Muskogee

Current Source of Supply

Primary source: Ft. Gibson Lake

Short-Term Needs

Infrastructure improvements: replace portion of distribution system lines.

Long-Term Needs

None identified.

OCWP Provider Survey

Lower Arkansas Region

Muskogee County RWD 1 (Oktaha)

Current Source of Supply

Primary source: City of Muskogee

Short-Term Needs

None identified.

Long-Term Needs

Infrastructure improvements: add standpipe; upsize water main lines.

Muskogee County RWD 2 (Gooseneck)

Current Source of Supply

Primary source: City of Muskogee

Short-Term Needs

Infrastructure improvements: replace portion of distribution system lines.

Long-Term Needs

Infrastructure improvements: replace distribution system lines; replace pumps.

Muskogee County RWD 4

Current Source of Supply

Primary source: City of Ft. Gibson

Short-Term Needs

None identified.

Long-Term Needs

None identified.

Muskogee County RWD 5

Current Source of Supply

Primary source: City of Muskogee

Short-Term Needs

Infrastructure improvements: add distribution system lines.

Long-Term Needs

Infrastructure improvements: replace water main lines.

Muskogee County RWD 6

Current Source of Supply

Primary source: City of Muskogee

Short-Term Needs

None identified.

Long-Term Needs

Infrastructure improvements: add storage.

Muskogee County RWD 7

Current Source of Supply

Primary source: City of Ft. Gibson

Short-Term Needs

Infrastructure improvements: replace pump station; add storage.

Long-Term Needs

New supply source: Working to purchase water from Tenkiller Utilities Auth.

Panama PWA (LeFlore County)

Current Source of Supply

Primary source: Poteau Valley Improvement Authority

Short-Term Needs

Infrastructure improvements: replace portion of distribution system lines; refurbish storage tower.

Long-Term Needs

Infrastructure improvements: replace portion of distribution system lines.

Porum PWA (Muskogee Co.)

Current Source of Supply

Primary source: Lake Eufaula

Short-Term Needs

Infrastructure improvements: replace portion of distribution system lines; add storage.

Long-Term Needs

Infrastructure improvements: water treatment plant upgrades.

Poteau PWA (LeFlore County)

Current Source of Supply

Primary source: Poteau Valley Improvement Auth., Wister Lake

Short-Term Needs

Infrastructure improvements: replace portion of distribution system lines.

Long-Term Needs

Infrastructure improvements: replace portion of distribution system lines; add storage.

Poteau Valley Improvement Auth. (LeFlore County)

Current Source of Supply

Primary source: Wister Lake

Short-Term Needs

Infrastructure improvements: add intake structure.

New supply source: Lower Poteau River.

Long-Term Needs

None identified.

City of Quinton (Pittsburg County)

Current Source of Supply

Primary source: Haskell County Water Authority

Short-Term Needs

Infrastructure improvements: add distribution system lines.

Long-Term Needs

None identified.

Red Oak PWA (Latimer County)

Current Source of Supply

Primary sources: Strip Pit

Short-Term Needs

None identified.

Long-Term Needs

None identified.

City of Roland (Sequoyah County)

Current Source of Supply

Primary source: Roland Municipal Lake

Short-Term Needs

None identified.

Long-Term Needs

None identified.

City of Sallisaw (Sequoyah County)

Current Source of Supply

Primary source: Brushy Lake

Short-Term Needs

New supply source: surface water.

Long-Term Needs

New supply source: purchase water from Sequoyah Co. Water Assn.

Infrastructure improvements: additional reservoir / lake storage.

Sequoyah County RWD 3

Current Source of Supply

Primary source: City of Sallisaw

Short-Term Needs

Infrastructure improvements: replace distribution system lines.

Long-Term Needs

Infrastructure improvements: replace distribution system lines.

Sequoyah County RWD 4

Current Source of Supply

Primary source: City of Sallisaw

Short-Term Needs

None identified.

Long-Term Needs

None identified.

Sequoyah County RWD 5

Current Source of Supply

Primary source: Illinois River

Short-Term Needs

None identified.

Long-Term Needs

Infrastructure improvement: replace distribution system lines; add storage.

Sequoyah County RWD 7

Current Source of Supply

Primary source: City of Ft. Smith, AR

Short-Term Needs

Infrastructure improvement: replace distribution system lines; add storage; upgrade pump stations.

Long-Term Needs

None identified.

Sequoyah County Water Association

Current Source of Supply

Primary source: Tenkiller Ferry Lake

Short-Term Needs

Infrastructure improvement: replace distribution system lines; add distribution system lines.

Long-Term Needs

None identified.

City of Spiro (Sequoyah County)

Current Source of Supply

Primary source: Holi-Tuska Creek

Short-Term Needs

None identified.

Long-Term Needs

Infrastructure improvement: replace distribution system lines.

Spiro East RWS (LeFlore County)

Current Source of Supply

Primary source: Poteau Valley Improvement Authority

Short-Term Needs

None identified.

Long-Term Needs

None identified.

City of Stigler (Haskell County)

Current Source of Supply

Primary source: Stigler Lake

Short-Term Needs

None identified.

Long-Term Needs

None identified.

City of Stilwell (Adair County)

Current Source of Supply

Primary source: Stilwell City Lake (Carson Lake), Evansville Creek, Starr Springs

Short-Term Needs

None identified.

Long-Term Needs

None identified.

Tahlequah PWA (Cherokee County)

Current Source of Supply

Primary source: Illinois River

Short-Term Needs

None identified.

Long-Term Needs

Infrastructure improvement: replace distribution system lines; add storage.

City of Vian (Sequoyah County)

Current Source of Supply

Primary source: Sequoyah County Water Association

Short-Term Needs

Infrastructure improvement: replace distribution system lines.

Long-Term Needs

Infrastructure improvement: replace distribution system lines.

City of Warner (Muskogee County)

Current Source of Supply

Primary source: Lake Eufaula

Short-Term Needs

Infrastructure improvement: replace distribution system lines.

Long-Term Needs

None identified.

Water Distributors Company, Inc.

Current Source of Supply

Primary source: Poteau Valley Improvement Authority

Short-Term Needs

None identified.

Long-Term Needs

Infrastructure improvement: replace distribution system lines; add storage; upgrade pump station.

City of Watts (Adair County)

Current Source of Supply

Primary source: City of Siloam Springs, Arkansas

Short-Term Needs

None identified.

Long-Term Needs

Infrastructure improvement: replace distribution system lines; add distribution system lines.

City of Westville (Adair County)

Current Source of Supply

Primary source: Benton/Washington Regional Public Water Authority, Arkansas

Short-Term Needs

None identified.

Long-Term Needs

None identified.

City of Wilburton (Latimer County)

Current Source of Supply

Primary source: Lloyd Church Lake

Short-Term Needs

None identified.

Long-Term Needs

None identified.

City of Wister (LeFlore County)

Current Source of Supply

Primary source: Poteau Valley Improvement Authority

Short-Term Needs

Infrastructure improvement: replace distribution system lines.

Long-Term Needs

None identified.

West Siloam Springs (Delaware County)

Current Source of Supply

Primary source: Siloam Springs, Arkansas

Short-Term Needs

None identified.

Long-Term Needs

None identified.

Infrastructure Cost Summary

Lower Arkansas Region

Provider System Category[1]	Infrastructure Need (millions of 2007 dollars)			
	Present-2020	2021-2040	2041-2060	Total Period
Small	$85	$175	$727	$987
Medium	$357	$408	$605	$1,370
Large	$0	$0	$0	$0
Reservoir[2]	$0	$1	$42	$43
Total	$442	$584	$1,374	$2,400

1 Large providers are defined as those serving more than 100,000 people, medium systems as those serving between 3,301 and 100,000 people, and small systems as those serving 3,300 or fewer people.

2 The "reservoir" category refers specifically to rehabilitation projects.

- Approximately $2.4 billion is needed to meet the projected drinking water infrastructure needs of the Lower Arkansas region over the next 50 years. The largest infrastructure costs are expected to occur after 2040.
- Distribution and transmission projects account for more than 80 percent of the providers' estimated infrastructure costs, followed distantly by water treatment projects.
- Medium-sized providers have the largest overall drinking water infrastructure costs.
- Projects involving rehabilitation of existing reservoir make up approximately two percent of the total costs.

Drinking Water Infrastructure Cost Summary

As part of the public water provider analysis, regional cost estimates to meet system drinking water infrastructure needs over the next 50 years were prepared. While it is difficult to account for changes that may occur within this extended time frame, it is beneficial to evaluate, at least on the order-of-magnitude level, the long-range costs of providing potable water.

Project cost estimates were developed for a selection of existing water providers, and then weighted to determine total regional costs. The OCWP method is similar to that utilized by the EPA to determine national drinking water infrastructure costs in 2007. However, the OCWP uses a 50-year planning horizon while the EPA uses a 20-year period. Also, the OCWP includes a broader spectrum of project types rather than limiting projects to those eligible for the Drinking Water State Revolving Fund program. While estimated costs for new reservoirs are not included, rehabilitation project costs for existing major reservoirs were applied at the regional level.

More information on the methodology and cost estimates is available in the OCWP *Drinking Water Infrastructure Needs Assessment by Region* report.

Water Supply Options

Limitations Analysis

For each of the state's 82 OCWP basins, an analysis of water supply and demand was followed by an analysis of limitations for surface water, bedrock groundwater, and alluvial groundwater use. Physical availability limitations for surface water were referred to as gaps. Availability limitations for alluvial and bedrock groundwater were referred to as depletions.

For surface water, the most pertinent limiting characteristics considered were (1) physical availability of water, (2) permit availability, and (3) water quality. For alluvial and bedrock groundwater, permit availability was not a limiting factor through 2060, and existing data were insufficient to conduct meaningful groundwater quality analyses. Therefore, limitations for major alluvial and bedrock aquifers were related to physical availability of water and included an analysis of both the amount of any forecasted depletion relative to the amount of water in storage and rate at which the depletion was predicted to occur.

Methodologies were developed to assess limitations and assign appropriate scores for each supply source in each basin. For surface water, scores were calculated weighting the characteristics as follows: 50% for physical availability, 30% for permit availability, and 20% for water quality. For alluvial and bedrock groundwater scores, the magnitude of depletion relative to amount of water in storage and rate of depletion were each weighted 50%.

The resulting supply limitation scores were used to rank all 82 basins for surface water, major alluvial groundwater, and major bedrock groundwater sources (see Water Supply Limitations map in the regional summary). For each source, basins ranking the highest were considered to be "significantly limited" in the ability of that source to meet forecasted demands reliably. Basins with intermediate rankings were considered to be "potentially limited" for that source. For bedrock and alluvial groundwater rankings, "potentially limited" was also the baseline default given to basins lacking major aquifers due to typically lower yields and insufficient data. Basins with the lowest rankings were considered to be "minimally limited" for that source and not projected to have any gaps or depletions.

Based on an analysis of all three sources of water, the basins with the most significant limitations ranking were identified as "Hot Spots." A discussion of the methodologies used in identifying Hot Spots, results, and recommendations can be found in the *OCWP Executive Report*.

Primary Options

To provide a range of potential solutions for mitigation of water supply shortages in each of the 82 OCWP basins, five primary options were evaluated for potential effectiveness: (1) demand management, (2) use of out-of-basin supplies, (3) reservoir use, (4) increasing reliance on surface water, and (5) increasing reliance on groundwater. For each basin, the potential effectiveness of each primary option was assigned one of three ratings: (1) typically effective, (2) potentially effective, and (3) likely ineffective (see Water Supply Option Effectiveness map in the regional summary). For basins where shortages are not projected, no options are necessary and thus none were evaluated.

Demand Management

"Demand management" refers to the potential to reduce water demands and alleviate gaps or depletions by implementing conservation or drought management measures. Demand management is a vitally important tool that can be implemented either temporarily or permanently to decrease demand and increase available supply. "Conservation measures" refer to long-term activities that result in consistent water savings throughout the year, while "drought management" refers to short-term measures, such as temporary restrictions on outdoor watering. Municipal and industrial conservation techniques can include modifying customer behaviors, using more efficient plumbing fixtures, or eliminating water leaks. Agricultural conservation techniques can include reducing water demand through more efficient irrigation systems and production of crops with decreased water requirements.

Two specific scenarios for conservation were analyzed for the OCWP—moderate and substantial—to assess the relative effectiveness in reducing statewide water demand in the two largest demand sectors, Municipal/Industrial and Crop Irrigation. For the Watershed Planning Region reports, only moderately expanded conservation activities were considered when assessing the overall effectiveness of the demand management option for each basin. A broader analysis of moderate and substantial conservation measures statewide is discussed below and summarized in the "Expanded Options" section of the *OCWP Executive Report*.

Demand management was considered to be "typically effective" in basins where it would likely eliminate both gaps and storage depletions and "potentially effective" in basins where it would likely either reduce gaps and depletions or eliminate either gaps or depletions (but not both). There were no basins where demand management could not reduce gaps and/or storage depletions to at least some extent; therefore this option was not rated "likely ineffective" for any basin.

Out-of-Basin Supplies

Use of "out-of-basin supplies" refers to the option of transferring water through pipelines from a source in one basin to another basin. This option was considered a "potentially effective" solution in all basins due to its general potential in eliminating gaps and depletions. The option was not rated "typically effective" because complexity and cost make it only practical as a long-term solution. The effectiveness of this option for a basin was also assessed with the consideration of potential new reservoir sites within the respective region as identified in the Expanded Options section below and the OCWP *Reservoir Viability Study*.

Reservoir Use

"Reservoir Use" refers to the development of additional in-basin reservoir storage. Reservoir storage can be provided through increased use of existing facilities, such as reallocation of existing purposes at major federal reservoir sites or rehabilitation of smaller NRCS projects to include municipal and/or industrial water supply, or the construction of new reservoirs.

The effectiveness rating of reservoir use for a basin was based on a hypothetical reservoir located at the furthest downstream basin outlet. Water transmission and legal or water quality constraints were not considered; however, potential constraints in permit availability were noted. A site located further upstream could potentially provide adequate yield to meet demand, but would likely require greater storage than a site located at the basin outlet. The effectiveness rating was also largely contingent upon the existence of previously studied reservoir sites (see the Expanded Options section below) and/or the ability of new streamflow diversions with storage to meet basin water demands.

Reservoir use was considered "typically effective" in basins containing one or more potentially viable reservoir sites unless the basin was fully allocated for surface water and had no permit availability. For basins with no permit availability, reservoir use was considered "potentially effective," since diversions would be limited to existing permits. Reservoir use was also considered "potentially effective" in basins that generate sufficient reservoir yield to meet future demand. Statewide, the reservoir use option was considered "likely ineffective" in only three basins (Basins 18, 55, and 66), where it was determined that insufficient streamflow would be available to provide an adequate reservoir yield to meet basin demand.

Increasing Reliance on Surface Water

"Increasing reliance on surface water" refers to changing the surface water-groundwater use ratio to meet future demands by increasing surface water use. For baseline analysis, the proportion of future demand supplied by surface water and groundwater for each sector is assumed equal to current proportions. Increasing the use of surface water through direct diversions without reservoir storage or releases upstream from storage provides a reliable supply option in limited areas of the state and has potential to mitigate bedrock groundwater depletions and/or alluvial groundwater depletions. However, this option largely depends upon local conditions concerning the specific location, amount, and timing of the diversion.

Due to this uncertainty, the pronounced periods of low streamflow in many river systems across the state, and the potential to create or augment surface water gaps, this option was considered "typically ineffective" for all basins. The preferred alternative statewide is reservoir use, which provides the most reliable surface water supply source.

Increasing Reliance on Groundwater

"Increasing reliance on groundwater" refers to changing the surface water-groundwater use ratio to meet future demands by increasing groundwater use. Supplies from major aquifers are particularly reliable because they generally exhibit higher well yields and contain large amounts of water in storage. Minor aquifers can also contain large amounts of water in storage, but well yields are typically lower and may be insufficient to meet the needs of high volume water users. Site-specific information on the suitability of minor aquifers for supply should be considered prior to large-scale use. Additional groundwater supplies may also be developed through artificial recharge (groundwater storage and recovery), which is summarized in the "Expanded Options" section of the *OWRB Executive Report*.

Increased reliance on groundwater supplies was considered "typically effective" in basins where both gaps and depletions could be mitigated in a measured fashion that did not lead to additional groundwater depletions. This option was considered "potentially effective" in basins where surface water gaps could be mitigated by increased groundwater use, but would likely result in increased depletions in either alluvial or bedrock groundwater storage. Increased reliance on groundwater supplies was considered "typically ineffective" in basins where there were no major aquifers.

Expanded Options

In addition to the standard analysis of primary options for each basin, specific OCWP studies were conducted statewide on several more advanced though less conventional options that have potential to reduce basin gaps and depletions. More detailed summaries of these options are available in the *OWRB Executive Report*. Full reports are available on the OWRB website.

Expanded Conservation Measures

Water conservation was considered an essential component of the "demand management" option in basin-level analysis of options for reducing or eliminating gaps and storage depletions. At the basin level, moderately expanded conservation measures were used as the basis for analyzing effectiveness. In a broader OCWP study, summarized in the *OCWP Executive Report* and documented in the OCWP *Water Demand Forecast Report Addendum: Conservation and Climate Change*, both moderately and substantially expanded conservation activities were analyzed at a statewide level for the state's two largest demand sectors: Municipal/Industrial (M&I) and Crop Irrigation. For each sector, two scenarios were analyzed: (1) moderately expanded conservation activities, and (2) substantially expanded conservation activities. Water savings for the municipal and industrial and crop irrigation water use sectors were assessed, and for the M&I sector, a cost-benefit analysis was performed to quantify savings associated with reduced costs in drinking water production and decreased wastewater treatment. The energy savings and associated water savings realized as a result of these decreases were also quantified.

Artificial Aquifer Recharge

In 2008, the Oklahoma Legislature passed Senate Bill 1410 requiring the OWRB to develop and implement criteria to prioritize potential locations throughout the state where artificial recharge demonstration projects are most feasible to meet future water supply challenges. A workgroup of numerous water agencies and user groups was organized to identify suitable locations in both alluvial and bedrock aquifers. Fatal flaw and threshold screening analyses resulted in identification of six alluvial sites and nine bedrock sites. These sites were subjected to further analysis that resulted in five sites deemed by the workgroup as having the best potential for artificial recharge demonstration projects.

Where applicable, potential recharge sites are noted in the "Increasing Reliance on Groundwater" option discussion in basin data and analysis sections of the Watershed Planning Region Reports. The site selection methodology and results for the five selected sites are summarized in the *OCWP Executive Report*; more detailed information on the workgroup and study is presented in the OCWP *Artificial Aquifer Recharge Issues and Recommendations* report.

Marginal Quality Water Sources

In 2008, the Oklahoma Legislature passed Senate Bill 1627 requiring the OWRB to establish a technical workgroup to analyze the expanded use of marginal quality water (MQW) from various sources throughout the state. The group included representatives from state and federal agencies, industry, and other stakeholders. Through facilitated discussions, the group defined MQW as that which has been historically unusable due to technological or economic issues associated with diverting, treating, and/or conveying the water. Five categories of MQW were identified for further characterization and technical analysis: (1) treated wastewater effluent, (2) stormwater runoff, (3) oil and gas flowback/produced water, (4) brackish surface and groundwater, and (5) water with elevated levels of key constituents, such as nitrates, that would require advanced treatment prior to beneficial use.

A phased approach was utilized to meet the study's objectives, which included quantifying and characterizing MQW sources and their locations for use through 2060, assessing constraints to MQW use, and matching identified sources of MQW with projected water shortages across the state. Feasibility of actual use was also reviewed. Of all the general MQW uses evaluated, water reuse—beneficially using treated wastewater to meet certain demand—is perhaps the most commonly applied elsewhere in the U.S. Similarly, wastewater was determined to be one of the most viable sources of marginal quality water for short-term use in Oklahoma. Results of the workgroup's study are summarized in the *OCWP Executive Report*; more detailed information on the workgroup and study is presented in the OCWP *Marginal Quality Water Issues and Recommendations* report.

Potential Reservoir Development

Oklahoma is the location of many reservoirs that provide a dependable, vital water supply source for numerous purposes. While economic, environmental, cultural, and geographical constraints generally limit the construction of new reservoirs, significant interest persists due to their potential in meeting various future needs, particularly those associated with municipalities and regional public supply systems.

As another option to address Oklahoma's long-range water needs, the OCWP *Reservoir Viability Study* was initiated to identify potential reservoir sites throughout the state that have been analyzed to various degrees by the OWRB, Bureau of Reclamation (BOR), U.S. Army Corps of Engineers (USACE), Natural Resources Conservation Service (NRCS), and other public or private agencies. Principal elements of the study included extensive literature search; identification of criteria to determine a reservoir's viability; creation of a database to store essential information for each site; evaluation of sites; Geographic Information System (GIS) mapping of the most viable sites; aerial photograph and map reconnaissance; screening of environmental, cultural, and endangered species issues; estimates of updated construction costs; and categorical assessment of viability. The study revealed more than 100 sites statewide. Each was assigned a ranking, ranging from Category 4 (sites with at least adequate information that are viable candidates for future development) to Category 0 (sites that exist only on a historical map and for which no study data can be verified).

This analysis does not necessarily indicate an actual need or specific recommendation to build any potential project. Rather, these sites are presented to provide local and regional decision-makers with additional tools as they anticipate future water supply needs and opportunities. Study results present only a cursory examination of the many factors associated with project feasibility or implementation. Detailed investigations would be required in all cases to verify feasibility of construction and implementation. A summary of potential reservoir sites statewide is available in the *OCWP Executive Report*; more detailed information on the study is presented in the OCWP *Reservoir Viability Study*. Potential reservoir development sites for this Watershed Planning Region appear on the following table and map.

Reservoir Project Viability Categorization

Category 4: Sites with at least adequate information that are viable candidates for future development.

Category 3: Sites with sufficient data for analysis, but less than desirable for current viability.

Category 2: Sites that may contain fatal flaws or other factors that could severely impede potential development.

Category 1: Sites with limited available data and lacking essential elements of information.

Category 0: Typically sites that exist only on an historical map. Study data cannot be located or verified.

Potential Reservoir Sites (Categories 3 & 4)

Lower Arkansas Region

Name	Category	Stream	Basin	Purposes[1]	Total Storage	Conservation Pool			Primary Study		Updated Cost Estimate[2] (2010 dollars)
						Surface Area	Storage	Yield	Date	Agency	
						Acres	AF	AFY			
Brazil	4	Brazil Creek	45	FC, WS, FW, R, HP	299,640	8,700	195,200	8,962[3]	1982	USACE	$163,756,000
Greasy	3	Greasy Creek	46	FC, WS, R, FW	0	500	16,350	6,721	1985	USACE	$129,410,000
Hackett	3	James Fork Creek	45	WS, FW, R	79,000	0	4,000	6,721	1982	USACE, Bureau of Reclamation, Soil Conservation Service, and Tennessee Valley Authority for RedArk Development	$148,551,000
Vian	3	Vian Creek	46	FC, WS, FW, R	218,000	35,000	17,500	10,082	1985	USACE	$109,071,000

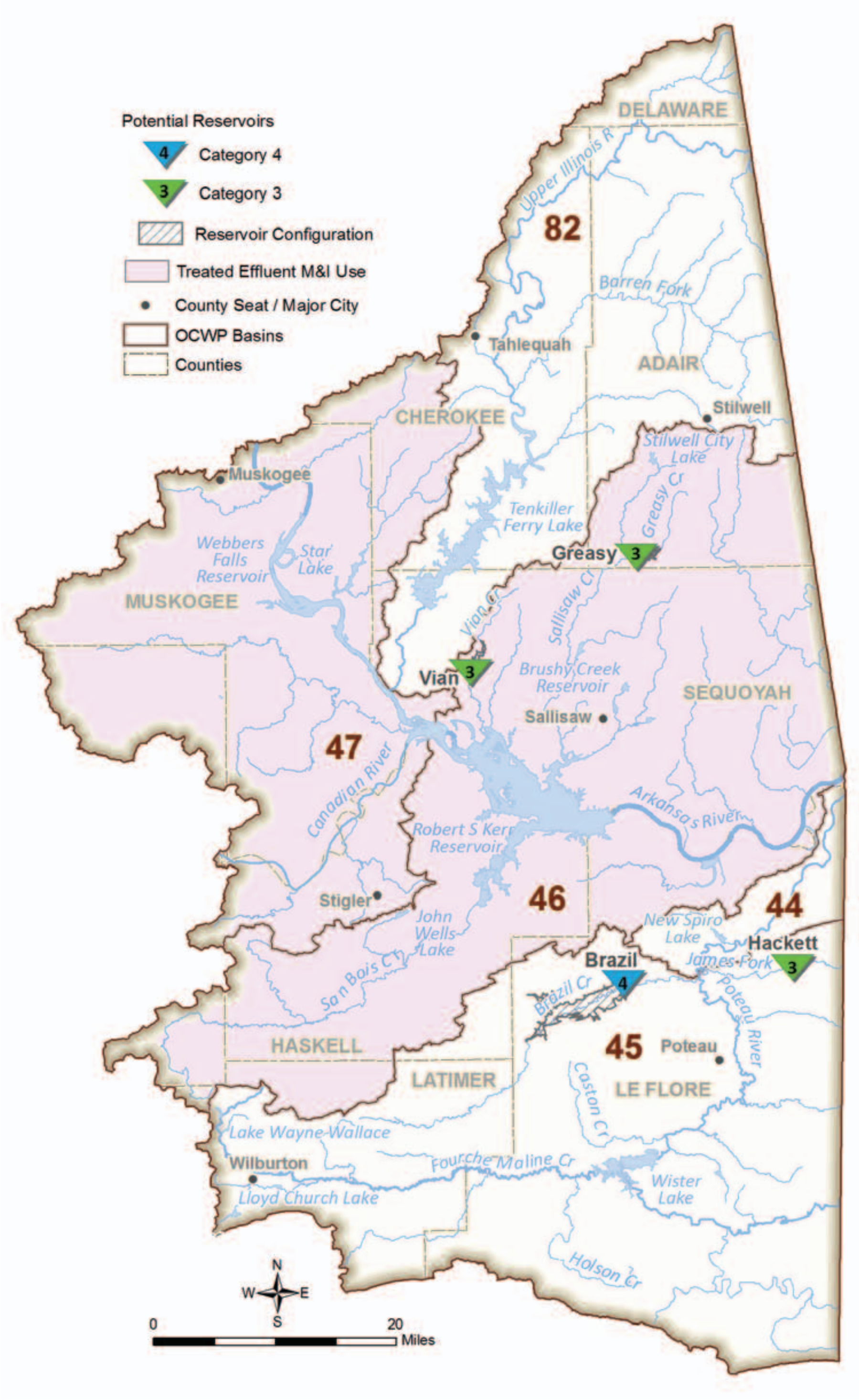
1 WS=Water Supply, R=Recreation, HP=Hydroelectric Power, IR=Irrigation, WQ=Water Quality, FW=Fish & Wildlife, FC=Flood Control, LF=Low Flow Regulation, N=Navigation, C=Conservation, CW=Cooling Water

2 The majority of cost estimates were updated using estimated costs from previous project reports combined with the U.S. Army Corps of Engineers Civil Works Construction Cost Index System (CWCCIS) annual escalation figures to scale the original cost estimates to present-day cost estimates. These estimated costs may not accurately reflect current conditions at the proposed project site and are meant to be used for general comparative purposes only.

3 Dependable yield increases to 87,000 AF when hydroelectric power is excluded.

Expanded Water Supply Options

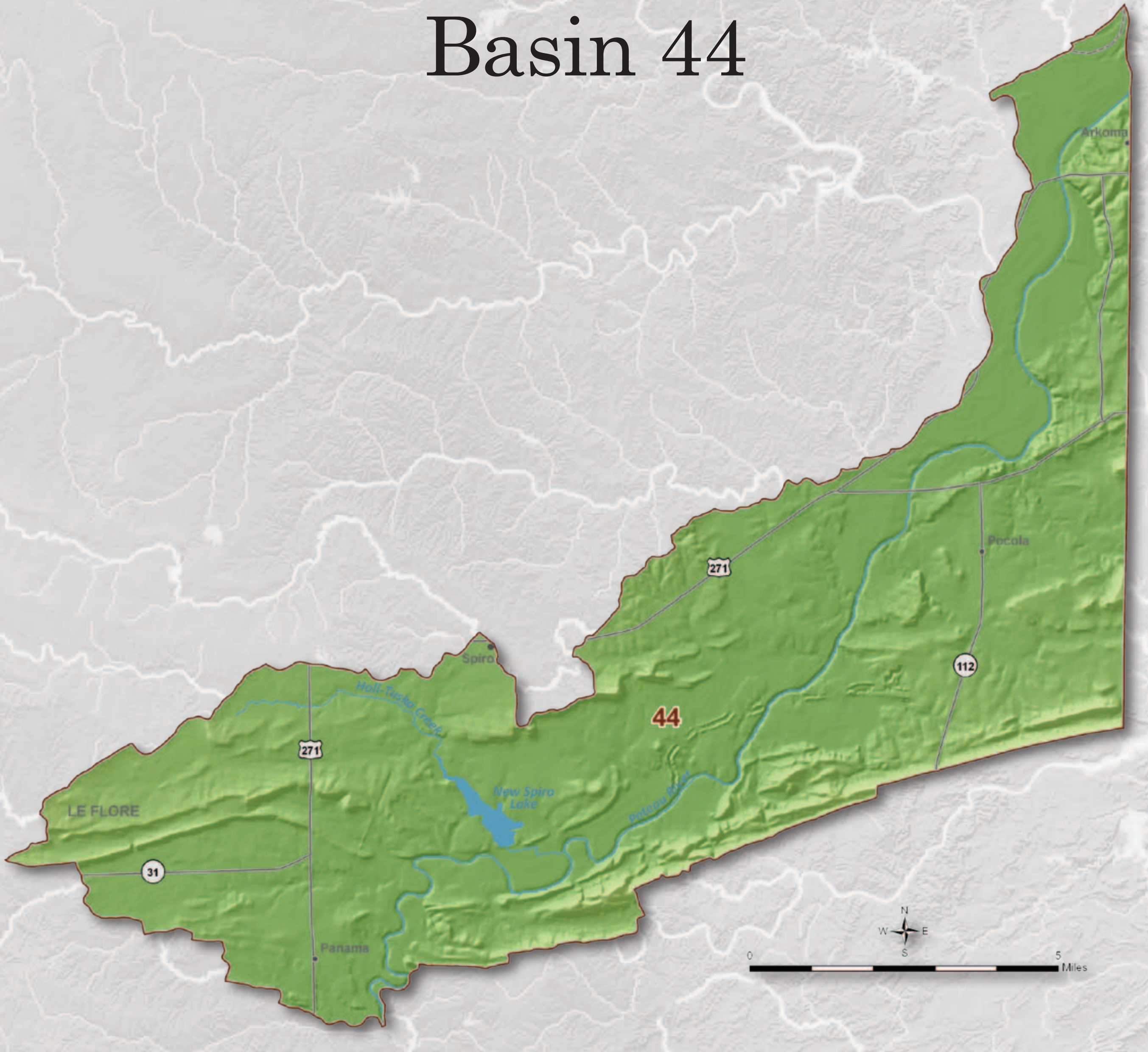
Lower Arkansas Region



Oklahoma Comprehensive Water Plan

Data & Analysis
Lower Arkansas Watershed Planning Region

Basin 44



Basin 44 Summary

Synopsis

- Water users are expected to continue to rely primarily on surface water supplies.
- Starting in 2060, there is a low probability of surface water gaps from increased demands on existing supplies during low flow periods.
- Bedrock groundwater storage depletions may occur in minor aquifers by 2060 and cause adverse effects for users.
- To reduce the risk of adverse impacts on water supplies, it is recommended that gaps and storage depletions be decreased where economically feasible.
- Additional conservation measures or temporary drought management activities could mitigate surface water gaps.
- To mitigate surface water gaps and impacts from localized groundwater storage depletions, new small reservoirs could be used as alternatives.

Basin 44 accounts for about 2% of the current water demand in the Lower Arkansas Watershed Planning Region. About 56% of the basin demand is from the Crop Irrigation demand sector. Municipal and Industrial (34%) is the second-largest demand sector. Surface water supplies about 99% of the total water demand in the basin. Groundwater satisfies about 1% of the total water demand in the basin. The peak summer month total water demand in Basin 44 is about 8.8 times the winter demand, which is more pronounced than the overall statewide pattern.

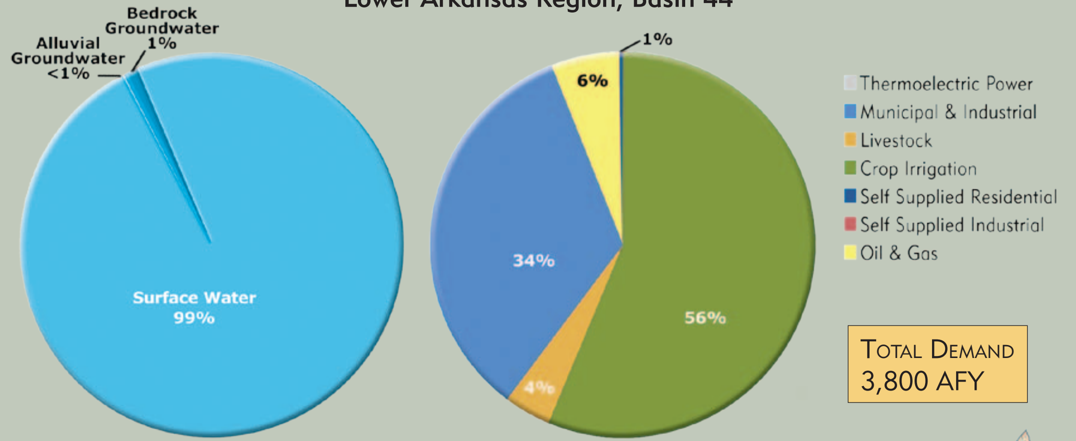
The Poteau River near Panama typically has flows greater than 16,500 AF/month. However, the river can have periods of low flow in any month of the year. Basin 44 is a small basin, just 100 square miles; therefore, the majority of the flow in the river is generated upstream. New Spiro Lake provides water supply and recreation to the City of Spiro. The water supply yield of this reservoir is unknown; therefore, the ability of this reservoir to provide future water supplies could not be evaluated. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. Relative to other basins in the state, the surface water quality in Basin 44 is considered poor. New Spiro Lake is impaired for Public and Private Water Supply use due to elevated levels of chlorophyll-a. However, individual lakes and streams may have acceptable water quality.

There are 100 AFY of groundwater rights from the Kiamichi minor bedrock aquifer in Basin 44. There are no groundwater rights from alluvial aquifers in the basin, but domestic users, who are not required to have a permit, are assumed to be obtaining supplies from the Arkansas River major alluvial aquifer or minor aquifers. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant basin-wide groundwater quality issues in the basin.

Water demand in Basin 44 will increase by 63% (2,410 AFY) from 2010 to 2060. The majority of the demand over this period will be in the Crop Irrigation and Municipal and Industrial demand sectors. However, the majority of the growth in demand will be in the Oil and Gas demand sector, which is currently a small water user in the basin.

Current Demand by Source and Sector

Lower Arkansas Region, Basin 44



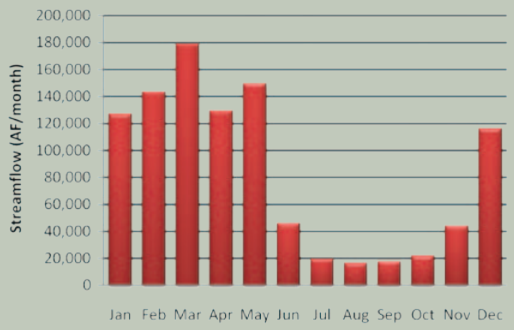
TOTAL DEMAND
3,800 AFY

Water Resources

Lower Arkansas Region, Basin 44

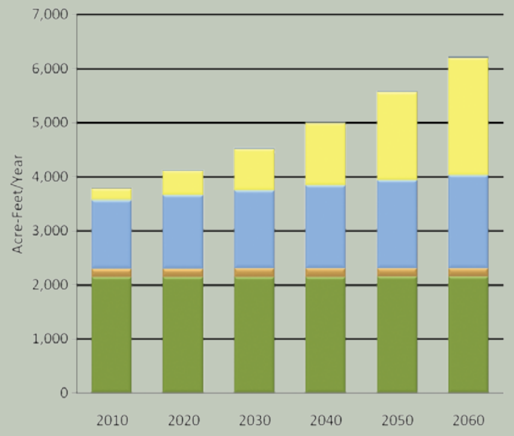
Median Historical Streamflow at the Basin Outlet

Lower Arkansas Region, Basin 44



Projected Water Demand

Lower Arkansas Region, Basin 44



Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and bedrock groundwater depletions may occur by 2060. Surface water gaps in Basin 44 have a small probability (2%) of occurring during the winter and will be negligible (10 AFY) on a basin-scale. Bedrock groundwater storage depletions in 2060 will be small (40 AFY) on a basin-scale, but are expected to represent the entire month's demand when they occur in the summer and fall. Future bedrock groundwater withdrawals will occur from minor aquifers, which cannot be fully evaluated due to insufficient information.

Options

Water users are expected to continue to rely primarily on surface water supplies. To reduce the risk of adverse impacts to the basin's water users, gaps and storage depletions should be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial demand sector could mitigate surface water gaps. Permanent conservation measures in the Municipal and Industrial and Crop Irrigation demand sectors are not anticipated to be effective in reducing 2060 bedrock depletions due to the low bedrock groundwater demand and/or growth in demand from these sectors. Due to the low probability of gaps, temporary drought management may be an effective option to reduce surface water use and subsequent gaps. Temporary drought management activities may not be necessary for bedrock groundwater users since aquifer storage could continue to provide supplies during droughts.

Out-of-basin supplies could mitigate surface water gaps and groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified four potential out-of-basin sites in the Lower Arkansas Region. However, due to the presence of abundant in-basin surface water supplies and the very low probability of gaps, out-of-basin supplies may not be necessary or cost-effective compared to other options.

New reservoir storage could increase the dependability of available surface water supplies and mitigate gaps in the basin. The entire growth in demand in the basin from 2010 to 2060 could be supplied by a new river diversion and less than 100 AF of reservoir storage at the basin outlet.

Increased reliance on surface water supplies, without reservoir storage, will increase surface water gaps and is not recommended.

Increased reliance on alluvial groundwater could mitigate surface water gaps and bedrock groundwater depletions, but may cause alluvial depletions. While, alluvial depletions may be minimal compared to the amount of water in storage in the basin, potential depletions may adversely impact well yields, water quality and pumping costs. In addition, the Arkansas River major alluvial aquifer only underlies about one-tenth of the northeast portion of the basin. Bedrock groundwater supplies are from minor aquifers, which generally have lower well yields and insufficient information to determine their reliability as major sources of supply. Therefore, site specific information on minor groundwater supplies should be considered before increased reliance on these sources or before large-scale use.

Water Supply Limitations

Lower Arkansas Region, Basin 44

Surface Water	🟨
Alluvial Groundwater	🟩
Bedrock Groundwater	🟨

🟩 Minimal 🟨 Potential 🟥 Significant

Water Supply Option Effectiveness

Lower Arkansas Region, Basin 44

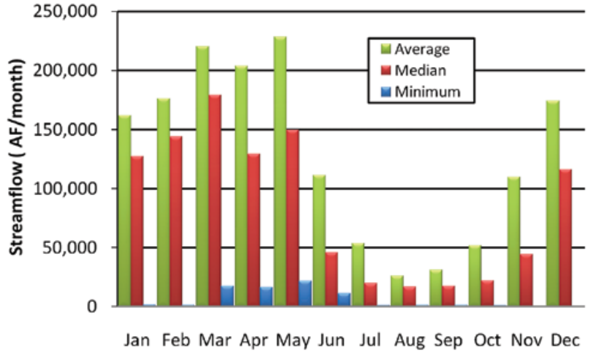
Demand Management	🟩
Out-of-Basin Supplies	🟨
Reservoir Use	🟨
Increasing Supply from Surface Water	🟥
Increasing Supply from Groundwater	🟨

🟩 Typically Effective 🟨 Potentially Effective
🟥 Likely Ineffective 🟪 No Option Necessary

Basin 44 Data & Analysis

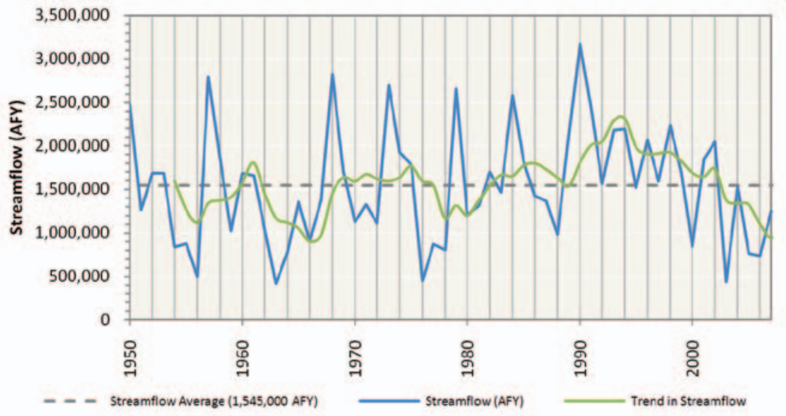
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. This basin had a period of below-average streamflow during the early to mid 1960s. From the late 1980s through the late 1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median flow in the Poteau River near Panama is greater than 16,500 AF/month throughout the year and greater than 110,000 AF/month in the winter and spring. However, the river can have periods of low flow in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 44 is considered poor. However, individual lakes and streams may have acceptable water quality.
- New Spiro Lake provides water supply and recreation to the city of Spiro. The water supply yield of this reservoir is unknown; therefore, the ability of this reservoir to provide future water supplies could not be evaluated.



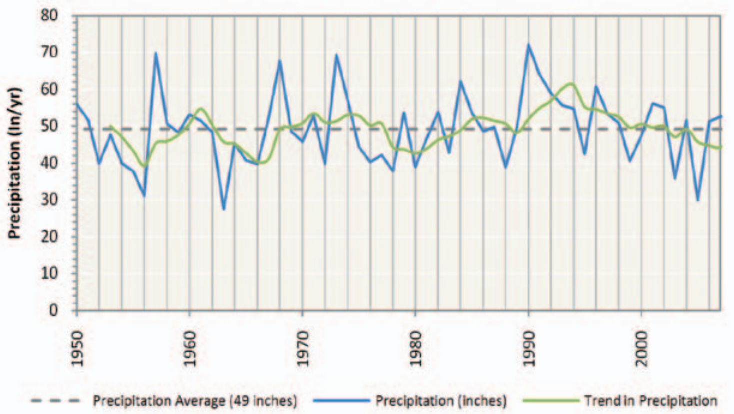
Monthly Historical Streamflow at the Basin Outlet

Lower Arkansas Region, Basin 44



Historical Streamflow at the Basin Outlet

Lower Arkansas Region, Basin 44



Historical Precipitation

Regional Climate Division

Notes & Assumptions

- Precipitation data are based on regional information, while streamflow is basin-specific.
- Measured streamflow implicitly reflects the conditions that exist in the stream at the time the data were recorded (e.g., hydrology, diversions, reservoirs, and infrastructure).
- For water supply planning, the range of potential future hydrologic conditions, including droughts, is represented by 58 years of monthly surface water flows (1950 to 2007). Climate change variations to these flows are documented in a separate OCWP report.
- Surface water supplies are calculated by adjusting the historical streamflow to account for upstream demands, return flows, and out-of-basin supplies.
- The upstream state is assumed to use 60 percent of the flow at the state line based on OWRB permitting protocol.
- Historical flow is based on USGS stream gages at or near the basin outlet. Where a gage did not exist near the outlet or there were missing data in the record, an estimation of flow was determined from representative, nearby gages using statistical techniques.
- Existing surface water rights may restrict the quantity of available surface water to meet future demands. Additional permits would decrease the amount of available water.

Groundwater Resources - Aquifer Summary 2010

Lower Arkansas Region, Basin 44

Name	Type	Class[1]	Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
			Percent	AFY	AF	AFY/Acre	AFY
Arkansas River	Alluvial	Major	11%	0	13,000	temporary 2.0	12,800
Kiamichi	Bedrock	Minor	100%	100	86,000	temporary 2.0	125,100
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

1 Bedrock aquifers with typical yields greater than 50 gpm and alluvial aquifers with typical yields greater than 150 gpm are considered major.

Groundwater Resources

- The majority of groundwater rights in the basin are from the Kiamichi minor bedrock aquifer.
- There are no significant groundwater quality issues in the basin.

Notes & Assumptions

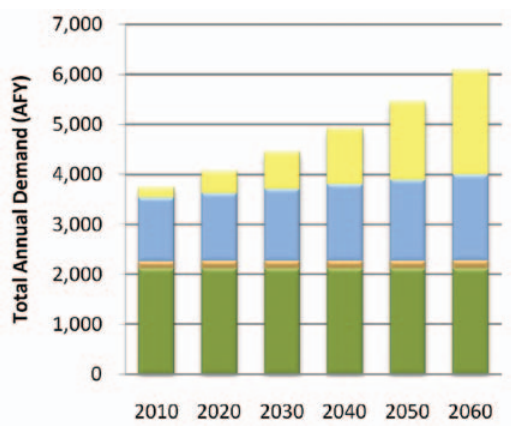
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater recharge.
- Site-specific information on minor aquifers should be considered before large scale use. Suitability for long term supply is typically based on recharge, storage yield, capital and operational costs, and water quality.
- Groundwater permit availability is generally based on the amount of land owned or leased that overlies a specific aquifer.
- Temporary permit amounts are subject to change when the aquifer's equal proportionate share is set by the OWRB.
- Current groundwater rights represent the maximum allowable use. Actual use may be lower than the permitted amount.
- Bedrock groundwater recharge is the long-term annual average recharge to aquifers in the basin. Recharge rates on a county- or aquifer-wide level of detail were established from literature (published reports) of each aquifer. Seasonal or annual variability is not considered; therefore the modeled bedrock groundwater supply is independent of changing hydrologic conditions.

Water Demand

- Basin 44's water needs account for about 2% of the demand in the Lower Arkansas Watershed Planning Region and will increase by 63% (2,410 AFY) from 2010 to 2060. The majority of the demand during this period will be from the Crop Irrigation and Municipal and Industrial demand sectors. However, the majority of the growth in demand will be in the Oil and Gas demand sector, which is currently a small water user in the basin.
- Surface water is used to meet 99% of the total demand in Basin 44 and its use will increase by 62% (2,330 AFY) from 2010 to 2060. The majority of surface water use is in the Crop Irrigation and Municipal and Industrial demand sectors. The majority of growth in surface water use from 2010 to 2060 will be from the Oil and Gas demand sector.
- Alluvial groundwater is used to meet less than 1% of the total demand in Basin 44, supplying the Self-Supplied Residential demand sector. The increase in alluvial groundwater use from 2010 to 2060 is minimal on a basin-scale.
- Bedrock groundwater is used to meet about 1% of the total demand in Basin 44 and its use will increase by 173% (80 AFY) from 2010 to 2060. The majority of bedrock groundwater use in 2060 will be from the Oil and Gas demand sector.

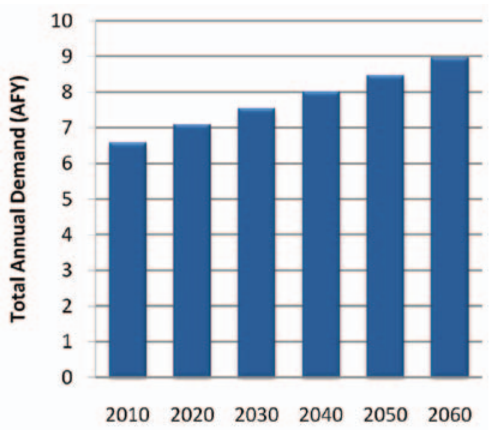
Surface Water Demand by Sector

Lower Arkansas Region, Basin 44



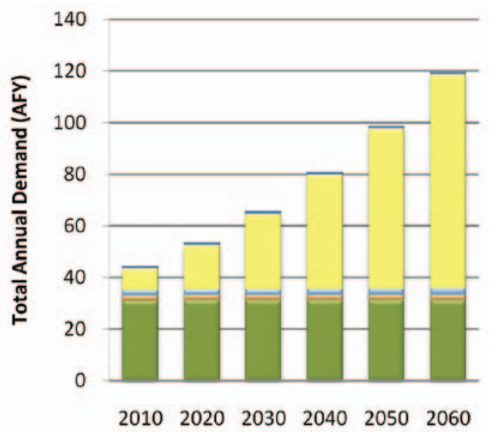
Alluvial Groundwater Demand by Sector

Lower Arkansas Region, Basin 44



Bedrock Groundwater Demand by Sector

Lower Arkansas Region, Basin 44



▨ Thermoelectric Power ▨ Self-Supplied Residential ▨ Self-Supplied Industrial ▨ Oil & Gas ▨ Municipal & Industrial ▨ Livestock ▨ Crop Irrigation

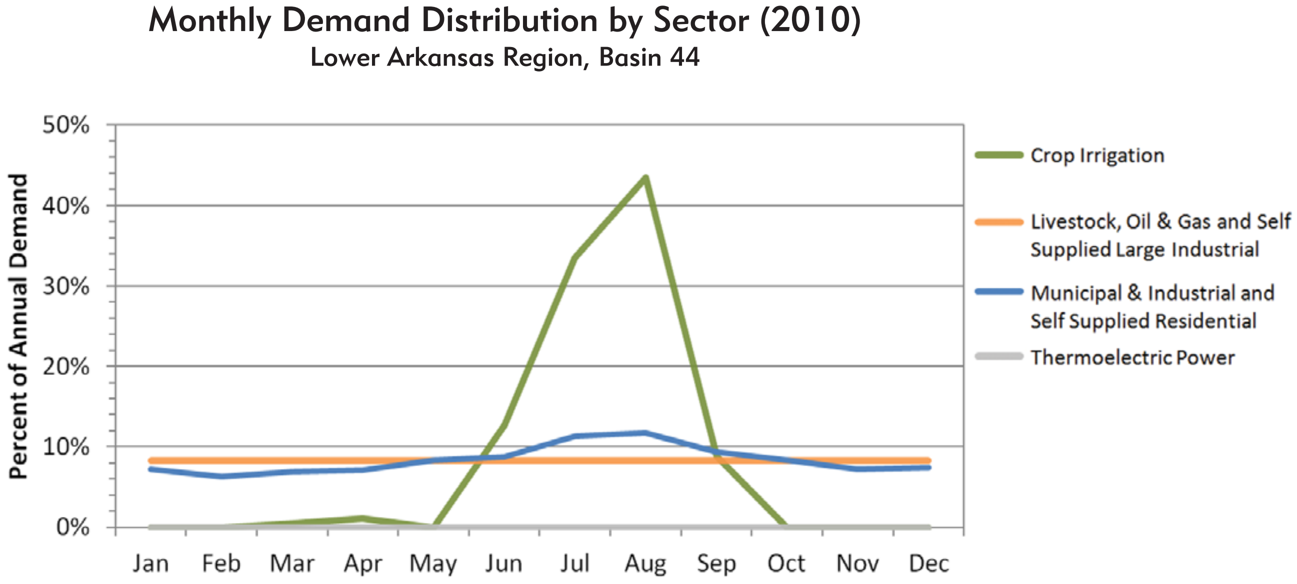
Total Demand by Sector

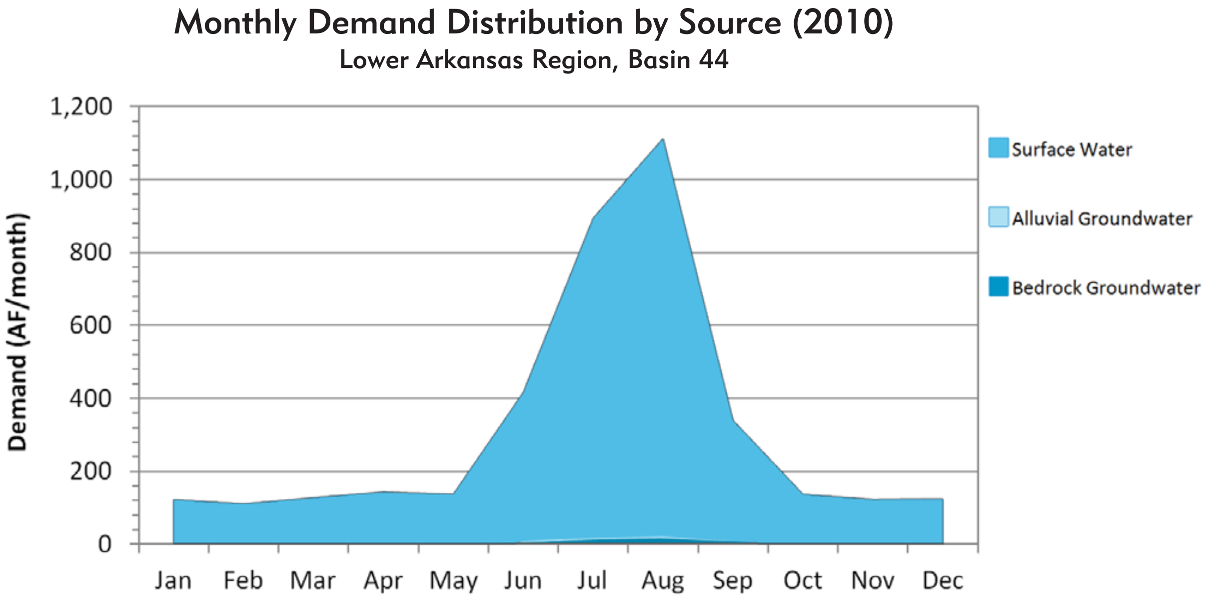
Lower Arkansas Region, Basin 44

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	2,140	150	1,280	220	0	10	0	3,800
2020	2,150	150	1,360	460	0	10	0	4,130
2030	2,150	150	1,450	770	0	10	0	4,530
2040	2,150	160	1,540	1,160	0	10	0	5,020
2050	2,150	160	1,630	1,620	0	10	0	5,570
2060	2,150	160	1,720	2,170	0	10	0	6,210

Notes & Assumptions

- Demand values represent total demand (the amount of water pumped or diverted to meet the needs of the user).
- Values are based on the baseline demand forecast from the OCWP *Water Demand Forecast Report*.
- The effect of climate change, conservation, and non-consumptive uses, such as hydropower, are not represented in this baseline demand analysis but are documented in separate OCWP reports.
- The proportion of each supply source used to meet each water use sector's demand was assumed to be equal to the existing proportion, as represented in water rights.
- The proportions of future demands between water use sectors will vary due to differing growth rates.
- The overall proportion of supplies used to meet demand will change due to differing growth rates among the water use sectors.





Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors typically use 52% more water in the summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. The Oil and Gas and Livestock demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 44 is about 8.8 times the winter demand, which is more pronounced than the overall statewide pattern. Surface water use in the peak summer month is about 8.8 times the peak winter month demand. Monthly bedrock groundwater use peaks in the summer at about 14 times the monthly winter use. The monthly pattern of alluvial groundwater use peaks in the summer at about 1.6 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and bedrock groundwater depletions may occur by 2060.
- Surface water gaps in Basin 44 have a small probability (2%) of occurring during the winter and will be minimal (10 AFY) on a basin-scale.
- Bedrock groundwater storage depletions in Basin 44 may occur during the summer or fall. Monthly bedrock groundwater storage depletions in 2060 will be small (10 AF/month) on a basin-scale, but are expected to represent the entire month's demand when they occur. Localized storage depletions may occur and adversely impact well yields, water quality, and/or pumping costs.
- Future bedrock groundwater withdrawals will occur from minor aquifers.

Surface Water Gaps by Season (2060 Demand)

Lower Arkansas Region, Basin 44

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	10	10	2%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	0	0	0%
Sep-Nov (Fall)	0	0	0%

1 Amount shown represents largest amount for any one month in season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Lower Arkansas Region, Basin 44

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	0	0	0%
Sep-Nov (Fall)	0	0	0%

1 Amount shown represents largest amount for any one month in season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions

Lower Arkansas Region, Basin 44

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	0	0	0	0%	0%
2030	0	0	0	0%	0%
2040	0	0	0	0%	0%
2050	0	0	0	0%	0%
2060	10	0	40	2%	0%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Lower Arkansas Region, Basin 44

Months (Season)	Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	10
Sep-Nov (Fall)	10

1 Amount shown represents largest amount for any one month in season indicated.

Notes & Assumptions

- Gaps and Storage Depletions reflect deficiencies in physically available water. Permitting, water quality, infrastructure, and nonconsumptive demand constraints are considered in separate OCWP analyses.
- Local gaps and storage depletions may vary from basin-level values due to local variations in demands and local availability of supply sources.
- For this baseline analysis, each basin's future demand is met by the basin's available supplies.
- For this baseline analysis, the proportion of future demand supplied by surface water and groundwater for each sector is assumed equal to current proportions.
- The amount of available surface water supplies used for OCWP water supply availability analysis includes changes in historical streamflow due to increased upstream demand, return flows, and increases in out-of-basin supplies from existing infrastructure.
- Analysis of bedrock groundwater supplies is based upon recharge from major aquifers.
- Groundwater storage depletions are defined as the amount that future demands exceed available recharge.
- Median gaps and storage depletions are based only on months with gaps or storage depletions.
- Annual probability is based upon the number of years that a gap or depletion occurs in at least one month of that year.

Reducing Water Needs Through Conservation

Lower Arkansas Region, Basin 44

Conservation Activities[1]	2060 Gap/Storage Depletion			2060 Gap/Storage Depletion Probability	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
	AFY			Percent	
Existing Conditions	10	0	40	2%	0%
Moderately Expanded Conservation in Crop Irrigation Water Use	10	0	40	2%	0%
Moderately Expanded Conservation in M&I Water Use	0	0	40	0%	0%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	40	0%	0%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	40	0%	0%

[1] *Conservation Activities are documented in the OCWP Water Demand Forecast Report*

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Lower Arkansas Region, Basin 44

Reservoir Storage	Diversion
AF	AFY
100	2,700
500	4,300
1,000	6,200
2,500	11,600
5,000	20,100
Required Storage to Meet Growth in Demand (AF)	<100
Required Storage to Meet Growth in Surface Water Demand (AF)	<100

Water Supply Options & Effectiveness

🟩 Typically Effective
🟨 Potentially Effective
🟥 Likely Ineffective
🟪 No Option Necessary

Demand Management

🟩 Moderately expanded permanent conservation activities in the Municipal and Industrial demand sector could mitigate surface water gaps. Demand reduction from Municipal and Industrial and Crop Irrigation conservation practices is not expected to be effective in reducing bedrock groundwater depletions because of the low bedrock groundwater demand and/or growth in demand from these sectors. Due to the low probability of gaps, temporary drought management may be an effective option. Temporary drought management activities could reduce demand, largely from outdoor water use and irrigation, and may reduce gaps. Temporary drought management activities may not be necessary for bedrock groundwater users since those activities may not affect the Oil and Gas demand, and aquifer storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

🟨 Out-of-basin supplies could mitigate surface water gaps and groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified four potential out-of-basin sites in the Lower Arkansas Region: Brazil and Hackett in Basin 45 and Greasy and Vian in Basin 46. However, due to the very low probability of gaps and groundwater storage depletions, out-of-basin supplies may not be cost-effective when compared to demand management or in-basin supplies.

Reservoir Use

🟨 New reservoir storage could increase the dependability of available surface water supplies and mitigate gaps in the basin. The entire growth in demand in the basin from 2010 to 2060 could be supplied by a new river diversion and less than 100 AF of reservoir storage at the basin outlet. However, no potentially viable reservoir sites were identified in the basin. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions.

Increasing Reliance on Surface Water

🟥 Increased reliance on surface water through direct diversions, without reservoir storage, will increase surface water gaps and is not recommended.

Increasing Reliance on Groundwater

🟨 Increased reliance on alluvial groundwater could mitigate surface water gaps, but may cause storage depletions. Additionally, the Arkansas River aquifer only underlies about 10 percent of the basin area. Bedrock groundwater supplies are from minor aquifers; therefore, increased reliance on these supplies is not recommended without site-specific information.

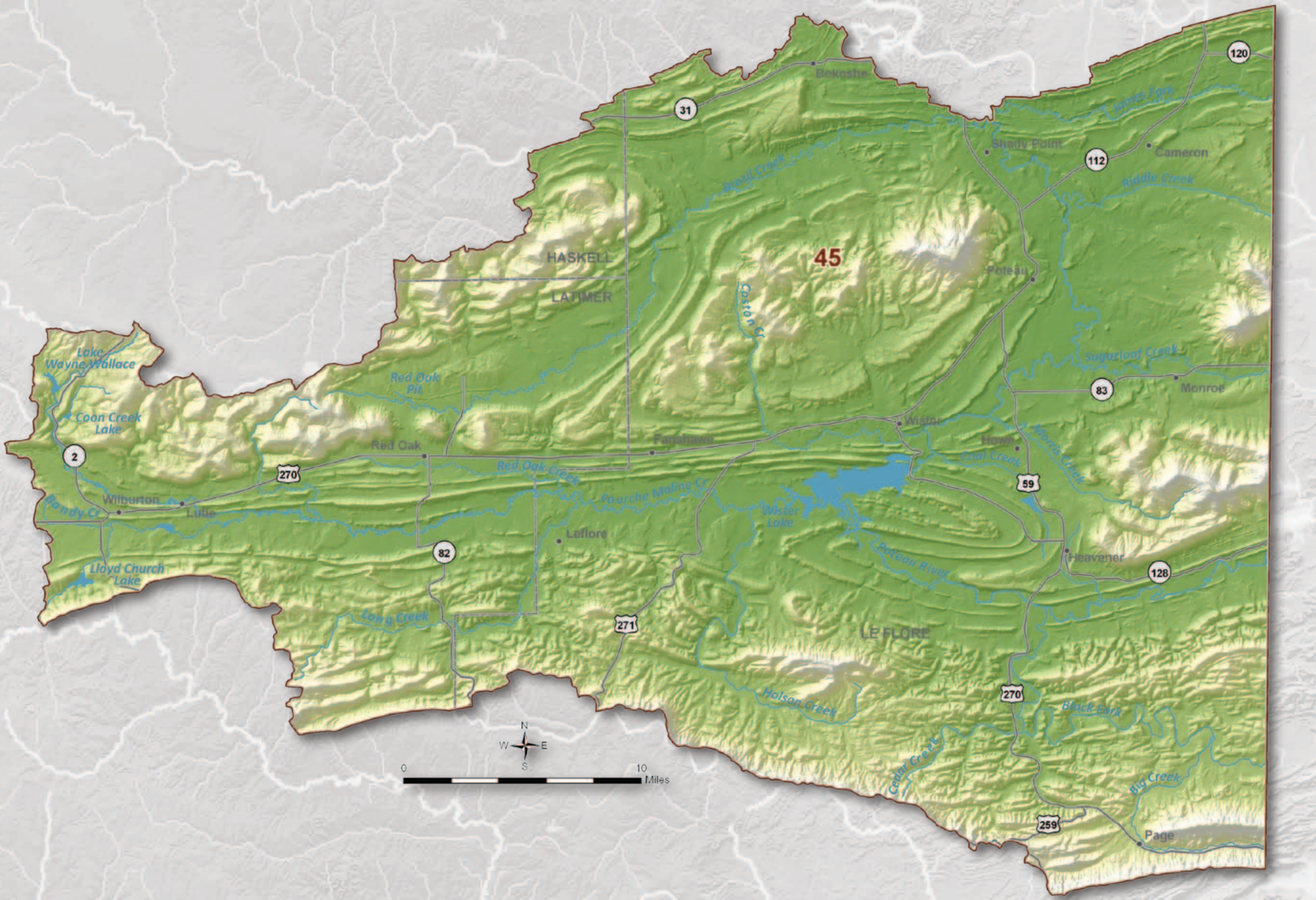
Notes & Assumptions

- Water quality may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands will vary based on local acceptance of additional conservation and temporary drought management activities.
- Gaps and depletions may be mitigated in individual calendar months without reductions in the annual probability (chance of having shortage during another month).
- River diversion for new or additional reservoir storage is based on a hypothetical on-channel reservoir at the basin outlet. Reported yields will vary depending upon the reservoir location; placement at the basin outlet would likely result in a higher yield.
- Aquifer storage and recovery may provide additional storage or an alternative to surface storage and should be evaluated on a case by case basis.

Oklahoma Comprehensive Water Plan

Data & Analysis
Lower Arkansas Watershed Planning Region

Basin 45



Basin 45 Summary

Synopsis

- Water users are expected to continue to rely largely on surface water and to a lesser extent bedrock groundwater supplies.
- Alluvial and bedrock groundwater storage depletions from minor aquifers may occur by 2050 and 2020, respectively.
- To reduce the risk of adverse impacts on water supplies, it is recommended that storage depletions be decreased where economically feasible.
- Additional conservation could slightly reduce bedrock groundwater storage depletions.
- To reduce adverse effects of localized groundwater storage depletions, new reservoirs could be developed.

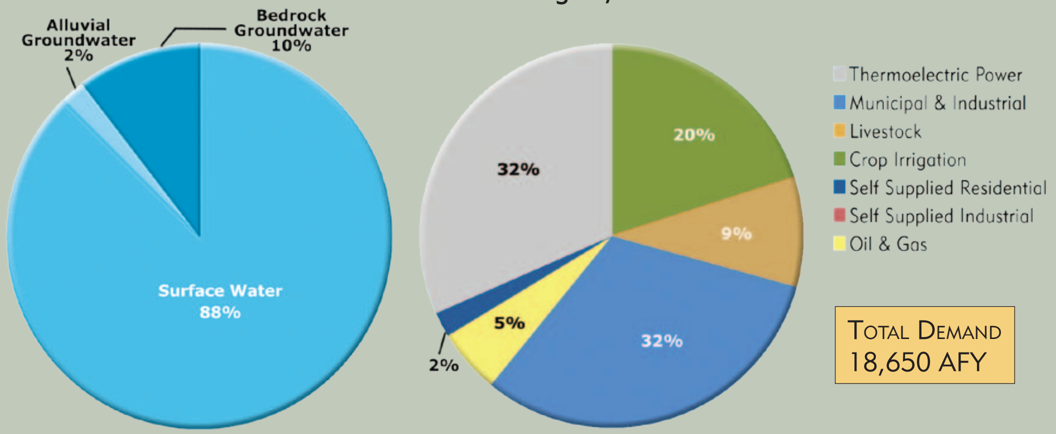
Basin 45 accounts for about 9% of the current water demand in the Lower Arkansas Watershed Planning Region. The Municipal and Industrial and Thermoelectric Power demand sectors each comprise about one-third of the demand. Crop Irrigation (20%) is the next largest demand sector in 2010. Surface water satisfies 88% of the total water demand in the basin. Almost all groundwater rights in Basin 45 are in the Kiamichi minor bedrock aquifer, which underlies 97% of the basin. The peak summer month total basin demand is about 2.5 times the winter demand, which is similar to the overall statewide pattern.

The Poteau River upstream of the Black Fork typically has flows greater than 18,000 AF/month throughout the year and greater than 100,000 AF/month in the winter and spring. Wister Lake, constructed by the U.S. Army Corps of Engineers in 1949, has a dependable water supply yield of 46,250 AFY. The majority of the water rights in Wister are allocated to the AES Shady Point for power generation, City of Heavener, and Poteau Valley Improvement Authority, which is a regional public trust that wholesales water both in- and out-of-basin to water providers throughout LeFlore and a portion of Haskell Counties. Wister Reservoir is expected to continue to meet the needs of its existing users and may have water supply available to meet additional future demands. Lloyd Church Lake provides water supplies to the City of Wilburton and may have a small amount of unpermitted dependable yield that could be used to supply additional demand in the future. Lake Wayne Wallace, which is operated by the State of Oklahoma for flood control and recreation, is not expected to provide water supplies in the future. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. Relative to other basins in the state, the surface water quality in Basin 45 is considered fair to good. Wister Lake is impaired for Public and Private Water Supply use due to high levels of chlorophyll-a. A short segment of the Poteau River is also impaired for Public and Private Water Supply use due to high levels of lead. Red Oak Creek is impaired for Agricultural use due to high levels of sulfates and total dissolved solids (TDS).

There are less around 2,500 AFY of groundwater rights on file for Basin 45. Almost all groundwater rights in Basin 45 are in the Kiamichi minor bedrock aquifer, which underlies 97% of the basin. In addition to the Kiamichi aquifer, the basin has a small amount of groundwater rights within non-delineated alluvial groundwater sources. The use of

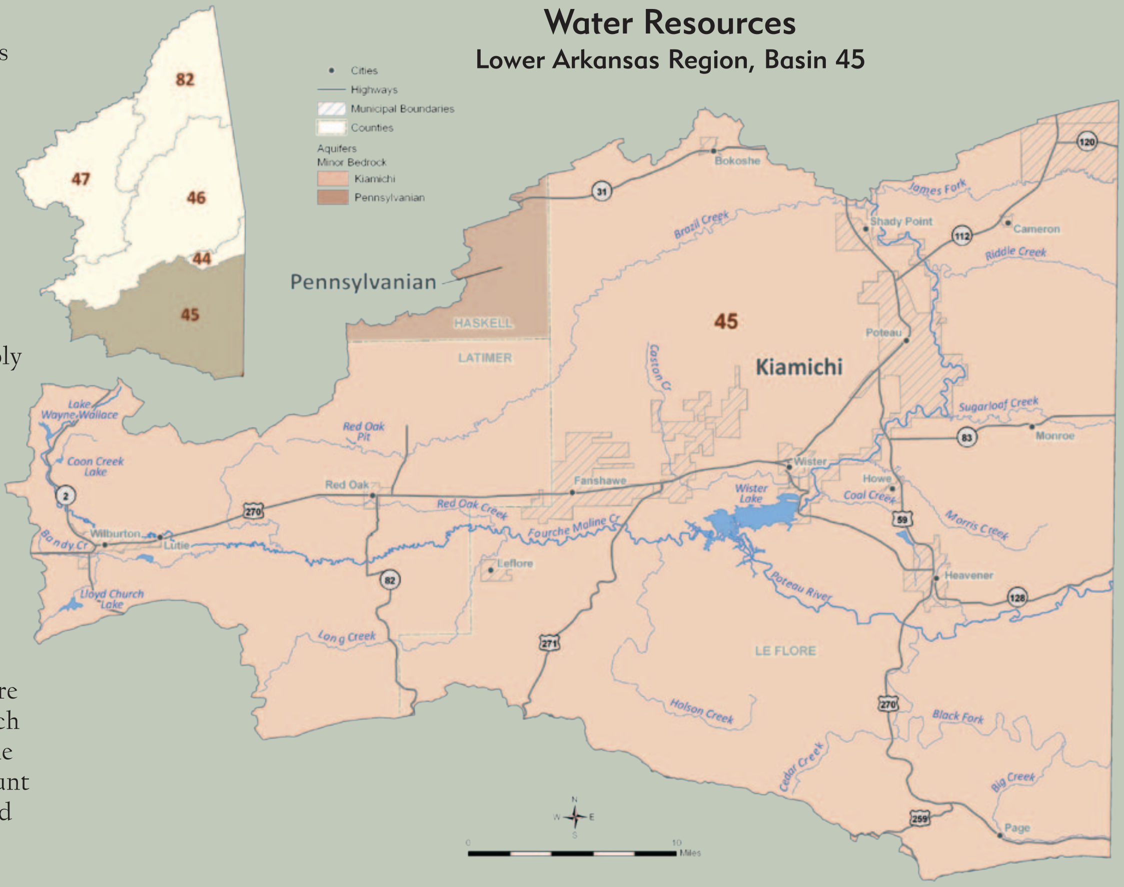
Current Demand by Source and Sector

Lower Arkansas Region, Basin 45



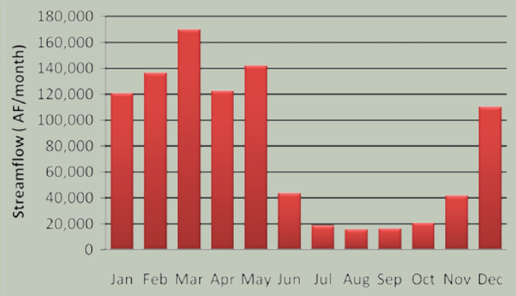
Water Resources

Lower Arkansas Region, Basin 45



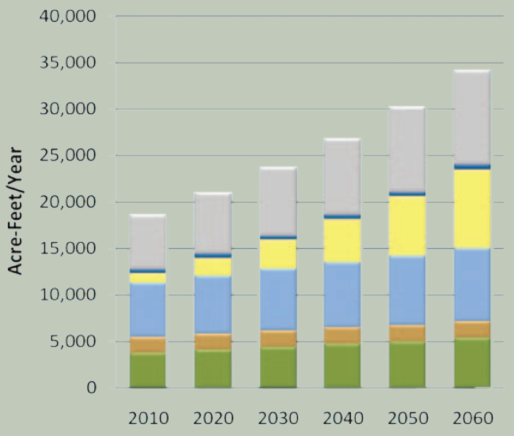
Median Historical Streamflow at the Basin Outlet

Lower Arkansas Region, Basin 45



Projected Water Demand

Lower Arkansas Region, Basin 45



groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

The projected 2060 water demand of 34,160 AFY in Basin 45 reflects a 15,510 AFY increase (83%) over the 2010 demand. The largest demand over this period will be in the Thermoelectric Power and Municipal and Industrial demand sectors. The largest growth in demand from 2010 to 2060 will be in the Oil and Gas demand sector; however, substantial growth will also occur in the Thermoelectric Power, Municipal and Industrial, and Crop Irrigation demand sectors.

Gaps and Depletions

Based on projected demand and historical hydrology, alluvial groundwater storage depletions may occur by 2050 and bedrock groundwater storage depletions may occur by 2020. Surface water gaps are not expected to occur by 2060. Wister Lake is capable of providing dependable water supplies to its existing users, and with new infrastructure, could be used to meet all of the Basin 45's future surface water demand during periods of low streamflow. However, growth in Oil and Gas water use is typically geographically dispersed and may not be able to utilize Wister Lake's supplies. Therefore, localized gaps are expected to occur, but cannot be quantified.

Alluvial groundwater storage depletions in 2060 will be small (30 AFY) on a basin-scale and have a small probability (12%) of occurring. Alluvial groundwater storage depletions in Basin 45 may occur during summer, fall, and winter. Bedrock groundwater storage depletions are expected to be 690 AFY by 2060 and occur throughout the year. Future alluvial and bedrock groundwater withdrawals are expected to occur from minor aquifers, which could not be fully evaluated due to insufficient information. While storage depletions may be minimal compared to the total amount of water in storage, localized storage depletions may adversely impact well yields, water quality, and/or pumping costs.

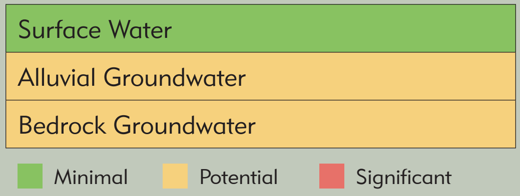
Options

Water users are expected to continue to rely primarily on surface water supplies. To reduce the risk of adverse impacts to the basin's water users, localized storage depletions should be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce bedrock storage depletions by about 14%. Temporary drought management activities may not be necessary for this basin since the storage in aquifers could potentially continue to provide supplies during droughts.

Water Supply Limitations

Lower Arkansas Region, Basin 45

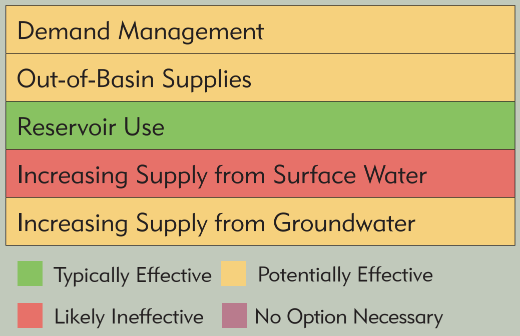


Surface Water	🟩
Alluvial Groundwater	🟨
Bedrock Groundwater	🟨

🟩 Minimal 🟨 Potential 🟥 Significant

Water Supply Option Effectiveness

Lower Arkansas Region, Basin 45



Demand Management	🟨
Out-of-Basin Supplies	🟨
Reservoir Use	🟩
Increasing Supply from Surface Water	🟥
Increasing Supply from Groundwater	🟨

🟩 Typically Effective 🟨 Potentially Effective
🟥 Likely Ineffective 🟪 No Option Necessary

Out-of-basin supplies could be used to augment supplies and meet demand. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potential out-of-basin sites in the Lower Arkansas Watershed Planning Region. However, due to the substantial reservoir storage and in-basin surface water supplies, out-of-basin supplies may not be cost-effective.

New reservoir storage could increase the reliability of available surface water supplies and mitigate the adverse effects of localized storage depletions. The entire increase in demand from 2010 to 2060 could be met from a new river diversion and 1,800 AF of reservoir storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified two potential sites in Basin 45.

Increased reliance on surface water supplies, without reservoir storage, will likely create surface water gaps and is not recommended.

Only minor aquifers underlie Basin 45; therefore, increased reliance on groundwater supplies without site-specific information may be ineffective for larger users.

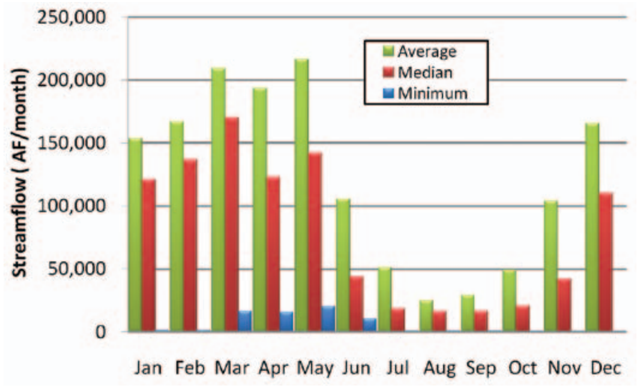
Basin 45 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. This basin had a prolonged period of below-average streamflow from the mid to late 1960s, corresponding to a period of below-average precipitation. From the mid 1990s to the early 2000s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median flow of the Poteau River upstream of Black Fork is greater than 16,000 AF/month throughout the year and greater than 100,000 AF/month in the winter and spring. However, the river can have periods of low flow in any month.
- Relative to other basins in the state, the surface water quality in Basin 45 is considered good.
- Basin 45 has one major reservoir and two large lakes. Wister Lake has 46,250 AFY of dependable yield, which may be able to supply additional water users in the future. Lloyd Church Lake provides water supplies to the City of Wilburton and may be able to supply additional demand in the future. Lake Wayne Wallace, which is operated by the State of Oklahoma for flood control and recreation, is not expected to provide water supplies in the future.

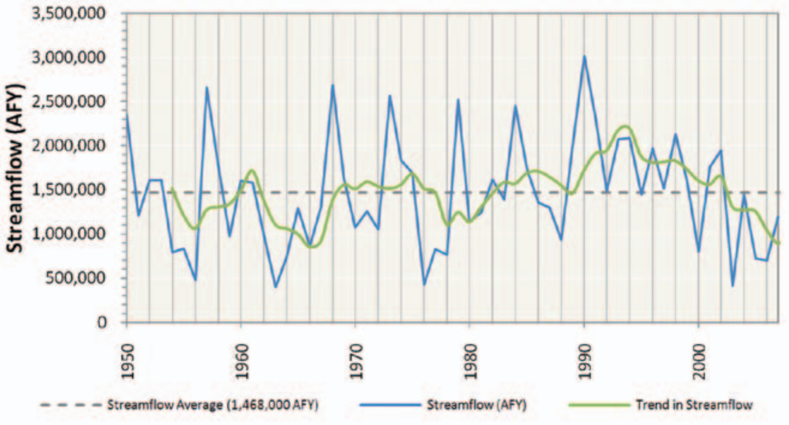
Monthly Historical Streamflow at the Basin Outlet

Lower Arkansas Region, Basin 45



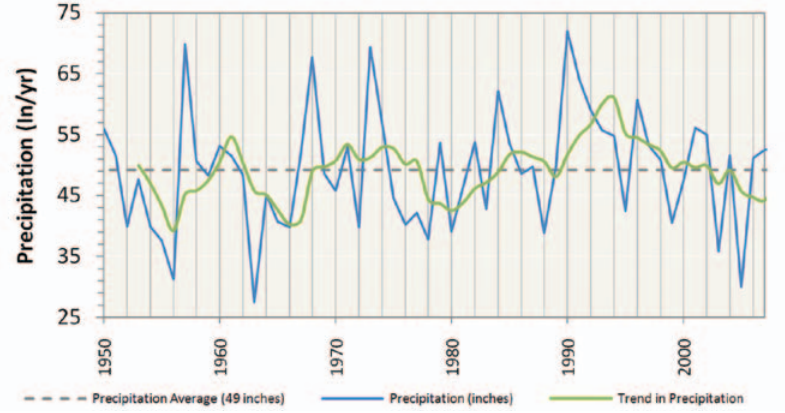
Historical Streamflow at the Basin Outlet

Lower Arkansas Region, Basin 45



Historical Precipitation

Regional Climate Division



Notes & Assumptions

- Precipitation data are based on regional information, while streamflow is basin-specific.
- Measured streamflow implicitly reflects the conditions that exist in the stream at the time the data were recorded (e.g., hydrology, diversions, reservoirs, and infrastructure).
- For water supply planning, the range of potential future hydrologic conditions, including droughts, is represented by 58 years of monthly surface water flows (1950 to 2007). Climate change variations to these flows are documented in a separate OCWP report.
- Surface water supplies are calculated by adjusting the historical streamflow to account for upstream demands, return flows, and out-of-basin supplies.
- The upstream state is assumed to use 60 percent of the flow at the state line based on OWRB permitting protocol.
- Historical flow is based on USGS stream gages at or near the basin outlet. Where a gage did not exist near the outlet or there were missing data in the record, an estimation of flow was determined from representative, nearby gages using statistical techniques.
- Existing surface water rights may restrict the quantity of available surface water to meet future demands. Additional permits would decrease the amount of available water.

Groundwater Resources - Aquifer Summary (2010)

Lower Arkansas Region, Basin 45

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	**Type**	**Class[1]**	.Percent	AFY	AF	AFY/Acre	AFY
Kiamichi	Bedrock	Minor	97%	2,500	1,047,000	temporary 2.0	1,556,100
Pennsylvanian	Bedrock	Minor	3%	0	314,000	temporary 2.0	38,400
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	<50	N/A	temporary 2.0	N/A

[1] Bedrock aquifers with typical yields greater than 50 gpm and alluvial aquifers with typical yields greater than 150 gpm are considered major.

Groundwater Resources

- The majority of groundwater rights in the basin are from the Kiamichi minor bedrock aquifer.
- There are no significant groundwater quality issues in the basin.

Notes & Assumptions

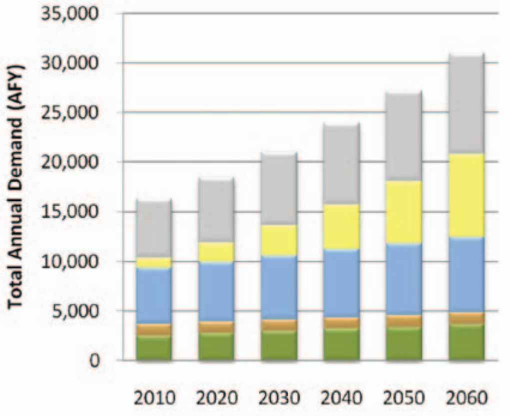
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater recharge.
- Site-specific information on minor aquifers should be considered before large scale use. Suitability for long term supply is typically based on recharge, storage yield, capital and operational costs, and water quality.
- Groundwater permit availability is generally based on the amount of land owned or leased that overlies a specific aquifer.
- Temporary permit amounts are subject to change when the aquifer's equal proportionate share is set by the OWRB.
- Current groundwater rights represent the maximum allowable use. Actual use may be lower than the permitted amount.
- Bedrock groundwater recharge is the long-term annual average recharge to aquifers in the basin. Recharge rates on a county- or aquifer-wide level of detail were established from literature (published reports) of each aquifer. Seasonal or annual variability is not considered; therefore the modeled bedrock groundwater supply is independent of changing hydrologic conditions.

Water Demand

- The water needs of Basin 45 are about 9% of the total demand in the Lower Arkansas Watershed Planning Region and will increase by 83% (15,510 AFY) from 2010 to 2060. The largest demand during this period will be in the Thermoelectric Power and Municipal and Industrial demand sectors. The largest growth in demand from 2010 to 2060 will be in the Oil and Gas demand sector; however, substantial growth will also occur in the Thermoelectric Power, Municipal and Industrial, and Crop Irrigation demand sectors.
- Surface water is used to meet 88% of the total water demand in the basin and its use will increase by 90% (14,650 AFY) from 2010 to 2060. The largest amounts of surface water use and growth in surface water use during this period will be in the Oil and Gas, Municipal and Industrial, and Thermoelectric Power demand sectors.
- Alluvial groundwater is used to meet 2% of the total demand in the basin and its use will increase by 41% (160 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use during this period will be in the Self-Supplied Residential demand sector.
- Bedrock groundwater is used to meet 10% of the total demand in the basin and its use will increase by 36% (700 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use during this period will be in the Crop Irrigation demand sector.

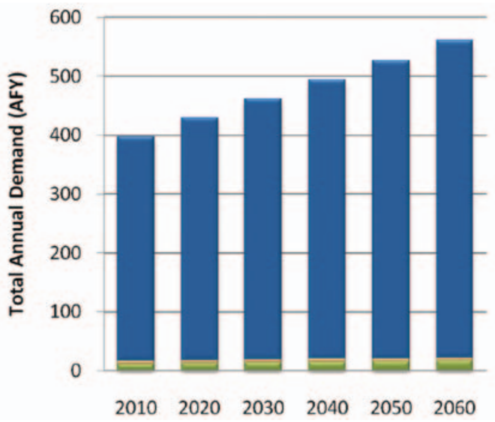
Surface Water Demand by Sector

Lower Arkansas Region, Basin 45



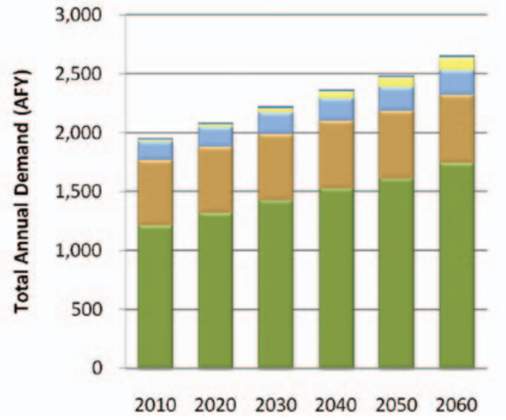
Alluvial Groundwater Demand by Sector

Lower Arkansas Region, Basin 45



Bedrock Groundwater Demand by Sector

Lower Arkansas Region, Basin 45



Total Demand by Sector

Lower Arkansas Region, Basin 45

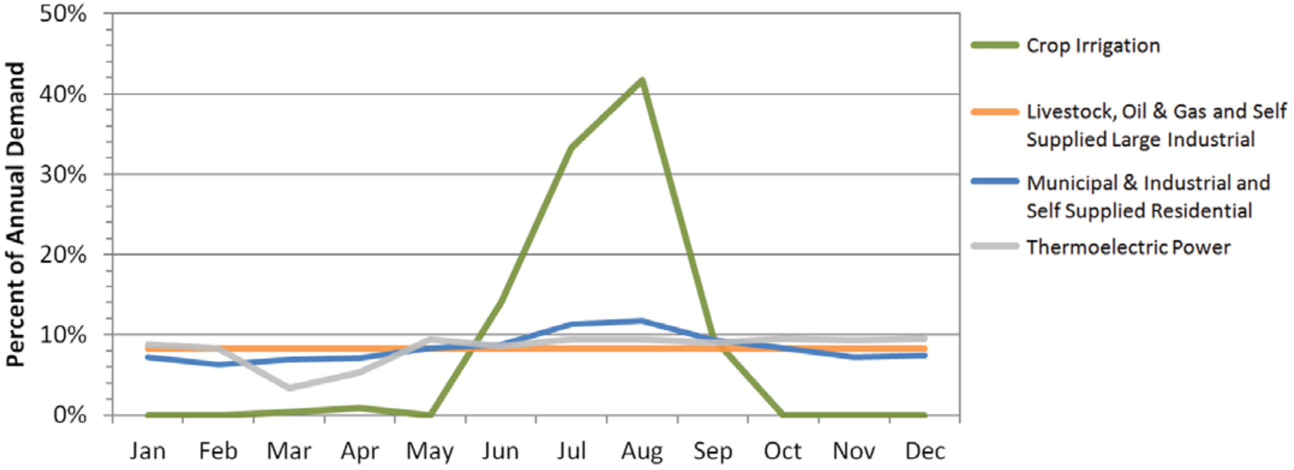
Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	3,740	1,720	5,890	1,020	0	390	5,890	18,650
2020	4,070	1,730	6,270	1,940	0	420	6,570	21,000
2030	4,400	1,750	6,660	3,130	0	450	7,320	23,710
2040	4,730	1,760	7,060	4,600	0	490	8,170	26,810
2050	4,980	1,770	7,460	6,350	0	520	9,120	30,200
2060	5,380	1,780	7,890	8,390	0	550	10,170	34,160

Notes & Assumptions

- Demand values represent total demand (the amount of water pumped or diverted to meet the needs of the user).
- Values are based on the baseline demand forecast from the OCWP *Water Demand Forecast Report*.
- The effect of climate change, conservation, and non-consumptive uses, such as hydropower, are not represented in this baseline demand analysis but are documented in separate OCWP reports.
- The proportion of each supply source used to meet each water use sector's demand was assumed to be equal to the existing proportion, as represented in water rights.
- The proportions of future demands between water use sectors will vary due to differing growth rates.
- The overall proportion of supplies used to meet demand will change due to differing growth rates among the water use sectors.

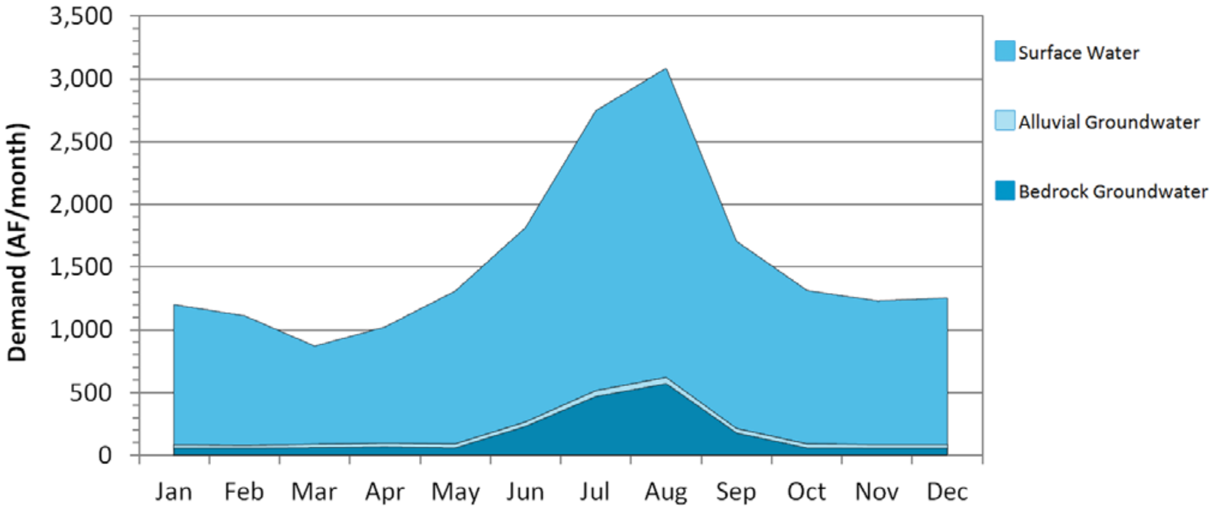
Monthly Demand Distribution by Sector (2010)

Lower Arkansas Region, Basin 45



Monthly Demand Distribution by Source (2010)

Lower Arkansas Region, Basin 45



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 52% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Thermoelectric Power has relatively constant demand during winter, summer, and fall, and lower demand in spring. The other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month demand in Basin 45 is 2.5 times the winter demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is about 2.1 times the peak winter month demand. Monthly alluvial groundwater use peaks in the summer at about 1.7 times the monthly winter demand. Monthly bedrock groundwater use peaks in the summer at about 9.5 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, alluvial groundwater storage depletions may occur by 2050 and bedrock groundwater storage depletions may occur by 2020. Surface water gaps are not expected to occur through 2060.
- Alluvial groundwater storage depletions in Basin 45 may occur during summer, fall, and winter. These depletions in 2060 will be up to 14% (10 AF/month) of the alluvial groundwater demand in the peak summer month and as much as 25% (10 AF/month) of the peak winter month alluvial demand. There will be a 12% probability of alluvial storage depletions occurring in at least one month of the year by 2060. They are most likely to occur in summer, but the probability is low (9%).
- Bedrock groundwater storage depletions in Basin 45 may occur throughout the year, peaking in size during the summer. Bedrock groundwater storage depletions in 2060 will be 30% (240 AF/month) of the bedrock groundwater demand in the peak summer month, and 14% (10 AF/month) of the peak winter month bedrock groundwater demand.
- Future alluvial and bedrock groundwater withdrawals are expected to occur from minor aquifers, which could not be fully evaluated due to insufficient information. Localized storage depletions may adversely impact well yields, water quality, and/or pumping costs.
- Wister Lake is capable of providing dependable water supplies to its existing users, and with new infrastructure, could be used to meet all of Basin 45's future surface water demand during periods of low streamflow. However, growth in Oil and Gas water use is typically geographically dispersed and may not be able to utilize Wister Lake's supplies. Therefore, localized gaps are expected to occur but cannot be quantified.

Surface Water Gaps by Season (2060 Demand)

Lower Arkansas Region, Basin 45

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	0	0	0%
Sep-Nov (Fall)	0	0	0%

1 Amount shown represents largest amount for any one month in season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Lower Arkansas Region, Basin 45

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	10	10	3%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	10	10	9%
Sep-Nov (Fall)	10	10	3%

1 Amount shown represents largest amount for any one month in season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions

Lower Arkansas Region, Basin 45

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	0	0	120	0%	0%
2030	0	0	250	0%	0%
2040	0	0	420	0%	0%
2050	0	20	530	0%	5%
2060	0	30	690	0%	12%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Lower Arkansas Region, Basin 45

Months (Season)	Average Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	10
Mar-May (Spring)	20
Jun-Aug (Summer)	240
Sep-Nov (Fall)	70

1 Amount shown represents largest amount for any one month in season indicated.

Notes & Assumptions

- Gaps and Storage Depletions reflect deficiencies in physically available water. Permitting, water quality, infrastructure, and nonconsumptive demand constraints are considered in separate OCWP analyses.
- Local gaps and storage depletions may vary from basin-level values due to local variations in demands and local availability of supply sources.
- For this baseline analysis, each basin's future demand is met by the basin's available supplies.
- For this baseline analysis, the proportion of future demand supplied by surface water and groundwater for each sector is assumed equal to current proportions.
- The amount of available surface water supplies used for OCWP water supply availability analysis includes changes in historical streamflow due to increased upstream demand, return flows, and increases in out-of-basin supplies from existing infrastructure.
- Analysis of bedrock groundwater supplies is based upon recharge from major aquifers.
- Groundwater storage depletions are defined as the amount that future demands exceed available recharge.
- Median gaps and storage depletions are based only on months with gaps or storage depletions.
- Annual probability is based upon the number of years that a gap or depletion occurs in at least one month of that year.

Reducing Water Needs Through Conservation

Lower Arkansas Region, Basin 45

Conservation Activities[1]	2060 Gap/Storage Depletion			2060 Gap/Storage Depletion Probability	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
	AFY			Percent	
Existing Conditions	0	30	690	0%	12%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	30	620	0%	12%
Moderately Expanded Conservation in M&I Water Use	0	30	640	0%	7%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	30	590	0%	5%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	20	320	0%	5%

[1] Conservation Activities are documented in the OCWP Water Demand Forecast Report

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Lower Arkansas Region, Basin 45

Reservoir Storage	Diversion
AF	AFY
100	7,700
500	10,100
1,000	12,200
2,500	17,800
5,000	25,000
Required Storage to Meet Growth in Demand (AF)	1,800
Required Storage to Meet Growth in Surface Water Demand (AF)	1,700

Water Supply Options & Effectiveness

🟩 Typically Effective
🟨 Potentially Effective
🟥 Likely Ineffective
🟪 No Option Necessary

Demand Management

🟨 Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce bedrock storage depletions by about 14%. Temporary drought management activities may not be necessary for this basin since the storage in aquifers could potentially continue to provide supplies during droughts.

Out-of-Basin Supplies

🟨 Out-of-basin supplies could be used to augment supplies and meet demand. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potential out-of-basin sites in the Lower Arkansas Region: Greasy and Vian in Basin 46. However, due to the substantial reservoir storage and in-basin surface water supplies, out-of-basin supplies may not be cost-effective for many users.

Reservoir Use

🟩 New reservoir storage could increase the reliability of available surface water supplies and mitigate the adverse effects of localized storage depletions. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 1,800 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions. Existing storage in Wister Lake could provide additional water supply to the basin. The OCWP *Reservoir Viability Study* also identified Brazil and Hackett Lakes as potential sites in the basin.

Increasing Reliance on Surface Water

🟥 Increased reliance on surface water through direct diversions, without reservoir storage, will likely create surface water gaps and is not recommended.

Increasing Reliance on Groundwater

🟨 Only minor aquifers underlie Basin 45, thus limiting dependable resources; therefore, increased reliance on groundwater supplies without site-specific information may be ineffective for large-scale use.

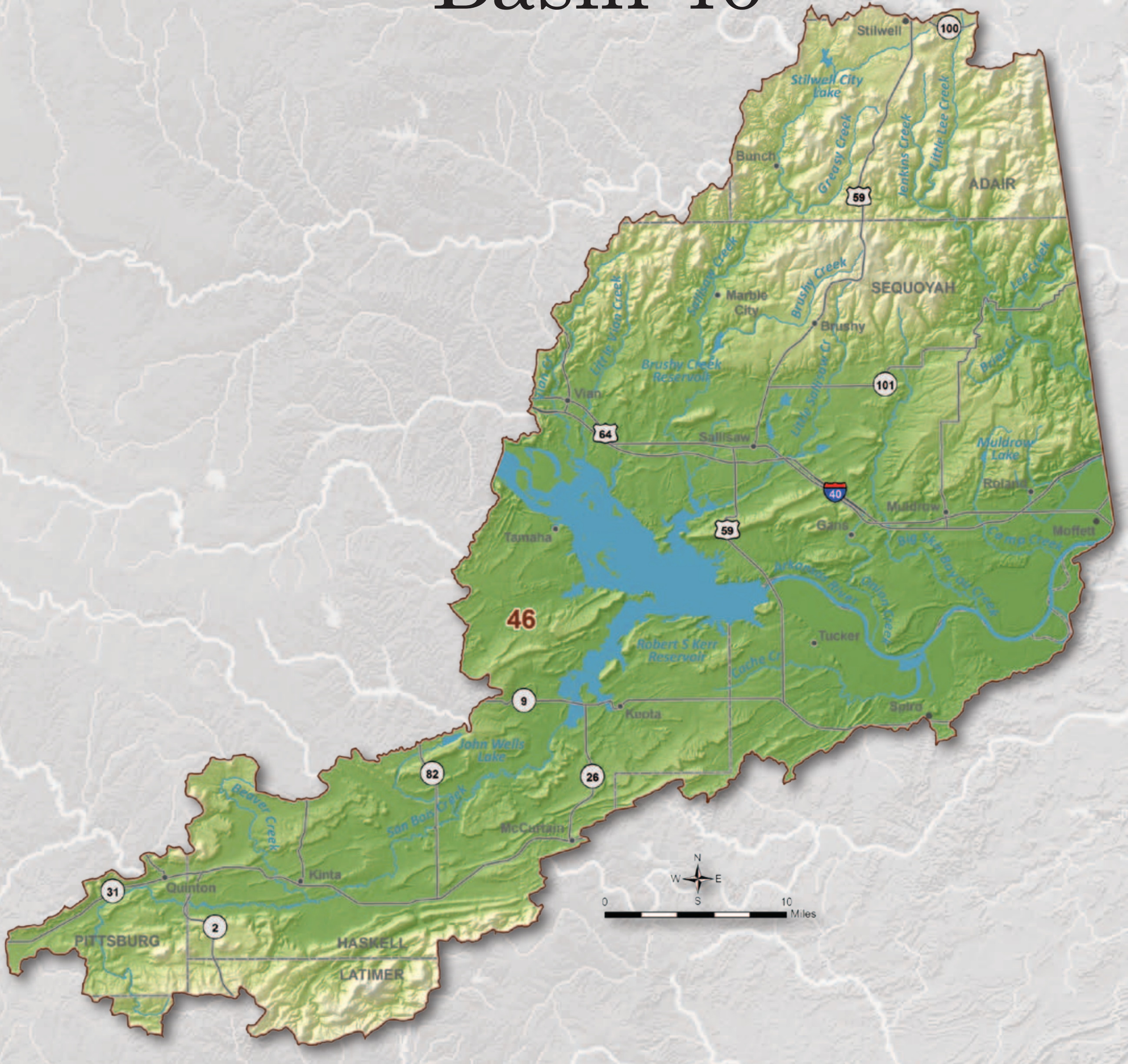
Notes & Assumptions

- Water quality may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands will vary based on local acceptance of additional conservation and temporary drought management activities.
- Gaps and depletions may be mitigated in individual calendar months without reductions in the annual probability (chance of having shortage during another month).
- River diversion for new or additional reservoir storage is based on a hypothetical on-channel reservoir at the basin outlet. Reported yields will vary depending upon the reservoir location; placement at the basin outlet would likely result in a higher yield.
- Aquifer storage and recovery may provide additional storage or an alternative to surface storage and should be evaluated on a case by case basis.

Oklahoma Comprehensive Water Plan

Data & Analysis
Lower Arkansas Watershed Planning Region

Basin 46



Basin 46 Summary

Synopsis

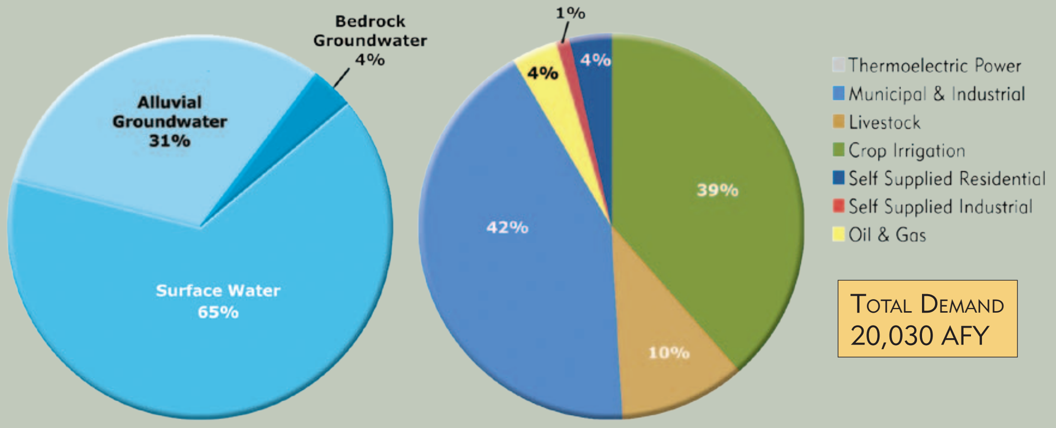
- Water users are expected to continue to rely on a mixture of surface water and alluvial groundwater supplies.
- Starting in 2040, there is a low probability of surface water gaps from increased demands on existing supplies during low flow periods.
- Alluvial storage depletions may occur by 2040, but will be minimal in size relative to aquifer storage in the basin. However, localized storage depletions may cause adverse effects for users.
- To reduce the risk of adverse impacts on water supplies, it is recommended that gaps and storage depletions be decreased where economically feasible.
- Additional conservation or temporary drought management activities could reduce surface water gaps.
- New reservoirs or increased use of alluvial groundwater could be used as alternative supplies without major impacts to groundwater storage.

Basin 46 accounts for about 10% of the current water demand in the Lower Arkansas Watershed Planning Region. Municipal and Industrial (42% of the 2010 demand) and Crop Irrigation (39%) are the two largest demand sectors. Livestock (10%) is the next largest demand sector. Surface water supplies 65% of the total water demand in the basin. Groundwater supplies 35% of the total water demand in the basin (31% alluvial and 4% bedrock). The peak summer month demand in Basin 46 is 4.7 times the peak winter demand, which is similar to the overall statewide pattern.

The Arkansas River at the Oklahoma/Arkansas state line typically has flows greater than 700,000 AF/month throughout the year and greater than 2 million AF/month in the spring. Robert S. Kerr Reservoir was constructed on the Arkansas River by the Corps of Engineers as a key component of the McClellan-Kerr Arkansas River Navigation System. The

Current Demand by Source and Sector

Lower Arkansas Region, Basin 46

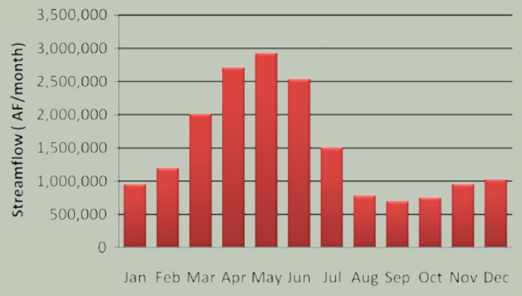


Water Resources

Lower Arkansas Region, Basin 46

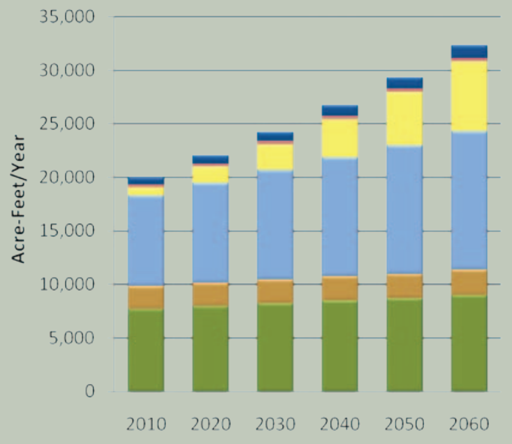
Median Historical Streamflow at the Basin Outlet

Lower Arkansas Region, Basin 46



Projected Water Demand

Lower Arkansas Region, Basin 46



reservoir was constructed in 1970 for navigation, hydroelectric power and recreation purposes. Brushy Lake serves as the City of Sallisaw's sole water source. Water supply yields for Brushy Lake, John Wells Lake, and Stilwell City Lake are unknown; therefore, the ability of these reservoirs to provide future water supplies could not be evaluated. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. Relative to other basins in the state, the surface water quality in Basin 46 is considered good. However, the Arkansas River, Sallisaw Creek, and San Bois Creek are impaired for Agriculture due to elevated levels of total dissolved solids (TDS) and sulfates.

The majority of groundwater rights in the basin are from the Arkansas River major alluvial aquifer. There are also water rights in the Pennsylvanian minor bedrock aquifer, non-delineated minor alluvial aquifers, and other minor bedrock aquifers. There is an estimated 106,000 AFY of recharge to the Roubidoux major bedrock aquifer in Basin 46; however, the aquifer is currently not used in the basin. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. Concentrations of chloride and naturally occurring radioactivity may exceed drinking water standards in some areas of the Roubidoux aquifer. However, there are no significant aquifer-wide groundwater quality issues in the basin.

The projected 2060 water demand of 32,320 AFY in Basin 46 reflects a 12,290 AFY increase (61%) over the 2010 demand. The majority of demand over this period will be in the Municipal and Industrial and Crop Irrigation demand sectors. The largest growth in demand from 2010 to 2060 will occur in the Oil and Gas and Municipal and Industrial demand sectors.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and alluvial groundwater depletions may occur by 2040. There is a very small probability (2%) of surface water gaps and alluvial groundwater storage depletions occurring during the winter in Basin 46. By 2060, surface water gaps will be up to 640 AFY and alluvial groundwater storage depletions will be up to 80 AFY. Projected annual alluvial storage depletions are minimal relative to the amount of water in storage in the Arkansas River aquifer. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs. No bedrock groundwater storage depletions are projected to occur if future demand is met by the Roubidoux aquifer. Currently, minor aquifers are being used to meet the bedrock groundwater demand. Therefore, localized storage depletions may occur, but could not be quantified.

Water Supply Limitations

Lower Arkansas Region, Basin 46

🟩 Surface Water
🟨 Alluvial Groundwater
🟩 Bedrock Groundwater

🟩 Minimal 🟨 Potential 🟥 Significant

Water Supply Option Effectiveness

Lower Arkansas Region, Basin 46

🟨 Demand Management
🟨 Out-of-Basin Supplies
🟩 Reservoir Use
🟥 Increasing Supply from Surface Water
🟩 Increasing Supply from Groundwater

🟩 Typically Effective 🟨 Potentially Effective
🟥 Likely Ineffective 🟪 No Option Necessary

Options

Water users are expected to continue to rely primarily on surface water and alluvial groundwater supplies. To reduce the risk of adverse impacts to the basin's water users, gaps and storage depletions should be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce surface water gaps by more than half. Alluvial groundwater storage depletions are not expected to be reduced by additional conservation activities. Due to the low probability of gaps, temporary drought management may be effective. Temporary drought management activities may not be necessary for the alluvial groundwater users since aquifer storage could continue to provide supplies during droughts.

Out-of-basin supplies could mitigate surface water gaps and groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potential out-of-basin sites in the Lower Arkansas Region. However, due to the very low probability of gaps and storage depletions, out-of-basin supplies may not be cost-effective compared to other options.

New reservoir storage could increase the dependability of available surface water supplies and mitigate gaps and storage depletions in the basin. The entire growth in demand in the basin from 2010 to 2060 could be supplied by a new river diversion and 700 AF of reservoir storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified Greasy and Vian Reservoirs as potentially viable sites in Basin 46.

Increased reliance on surface water through direct diversions, without reservoir storage, will increase gaps and is not recommended.

Increased reliance on alluvial groundwater could mitigate surface water gaps, but will increase alluvial groundwater storage depletions. Projected annual alluvial storage depletions are minimal relative to volume of water in stored in Basin 46's portion of the Arkansas River aquifer. Bedrock groundwater supplies are currently from minor aquifers; therefore, increased reliance on these supplies is not recommended without site-specific information. However, use of the Roubidoux aquifer could provide reliable supplies to many users.

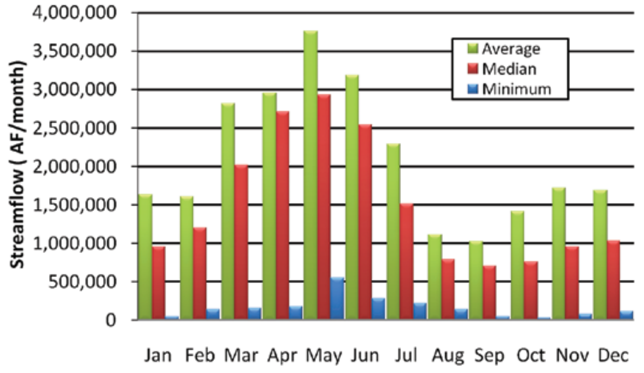
Basin 46 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. This basin had a prolonged period of below-average streamflow from the early 1960s through the early 1970s, corresponding to a period of below-average precipitation. From the mid 1980s to the late 1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median flow in the Arkansas River at the Oklahoma/Arkansas state line is at least 700,000 AF/month throughout the year and greater than 2 million AF/month in the spring. Increased upstream withdrawals may reduce streamflow and lead to infrequent periods of low flow in the future.
- Robert S. Kerr Reservoir is operated by the Corps of Engineers for the McClellan-Kerr Arkansas River Navigation System, power generation and recreation. Brushy Lake is used for flood control, recreation, and water supply for the City of Sallisaw. The water supply yield of Brushy Lake, John Wells Lake and Stilwell City Lake are unknown, so their ability to provide future water supplies could not be evaluated. Relative to other basins in the state, the surface water quality in Basin 46 is considered good.

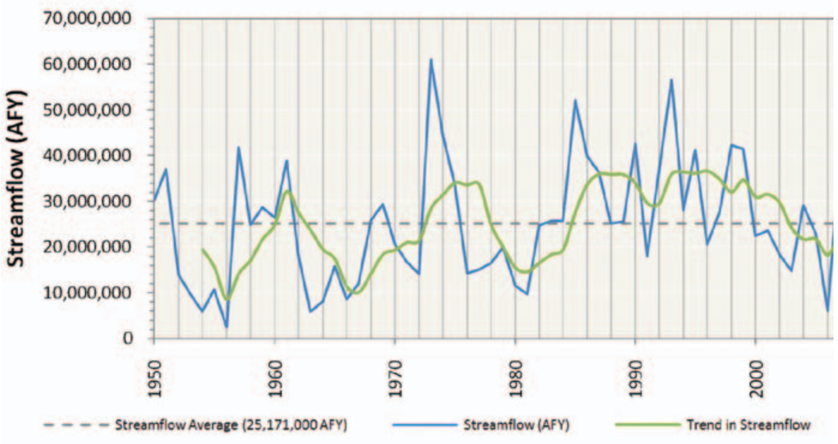
Monthly Historical Streamflow at the Basin Outlet

Lower Arkansas Region, Basin 46



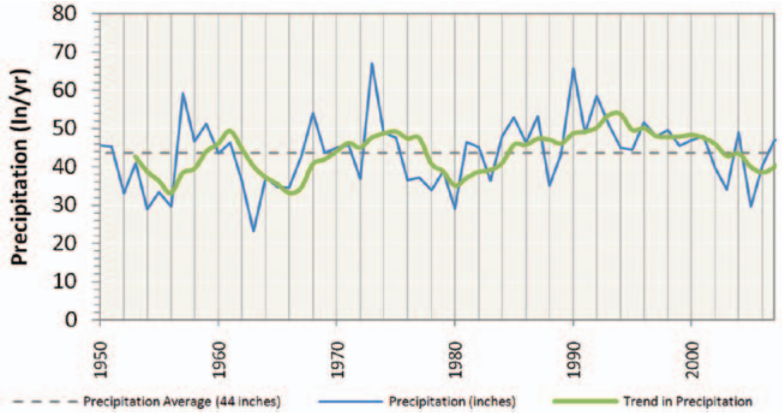
Historical Streamflow at the Basin Outlet

Lower Arkansas Region, Basin 46



Historical Precipitation

Regional Climate Division



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- Measured streamflow implicitly reflects the conditions that exist in the stream at the time the data were recorded (e.g., hydrology, diversions, reservoirs, and infrastructure).
- For water supply planning, the range of potential future hydrologic conditions, including droughts, is represented by 58 years of monthly surface water flows (1950 to 2007). Climate change variations to these flows are documented in a separate OCWP report.
- Surface water supplies are calculated by adjusting the historical streamflow to account for upstream demands, return flows, and out-of-basin supplies.
- The upstream state is assumed to use 60 percent of the flow at the state line based on OWRB permitting protocol.
- Historical flow is based on USGS stream gages at or near the basin outlet. Where a gage did not exist near the outlet or there were missing data in the record, an estimation of flow was determined from representative, nearby gages using statistical techniques.
- Existing surface water rights may restrict the quantity of available surface water to meet future demands. Additional permits would decrease the amount of available water.

Groundwater Resources - Aquifer Summary (2010)

Lower Arkansas Region, Basin 46

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	**Type**	**Class[1]**	Percent	AFY	AF	AFY/Acre	AFY
Arkansas River	Alluvial	Major	12%	14,700	162,000	temporary 2.0	189,200
Roubidoux	Bedrock	Major	57%	0	7,149,000	temporary 2.0	1,036,800
Boone	Bedrock	Minor	12%	<50	1,875,000	temporary 2.0	217,300
Kiamichi	Bedrock	Minor	12%	<50	146,000	temporary 2.0	215,800
Northeastern Oklahoma Pennsylvanian	Bedrock	Minor	51%	300	1,075,000	temporary 2.0	933,900
Pennsylvanian	Bedrock	Minor	32%	1,400	4,816,000	temporary 2.0	581,100
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	<50	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	800	N/A	temporary 2.0	N/A

[1] Bedrock aquifers with typical yields greater than 50 gpm and alluvial aquifers with typical yields greater than 150 gpm are considered major.

Groundwater Resources

- The majority of groundwater rights in the basin are in the Arkansas River major alluvial aquifer. There are also water rights in the Pennsylvanian minor bedrock aquifer, non-delineated minor alluvial aquifers, and other minor bedrock aquifers. There is an estimated 106,000 AFY of recharge to the Roubidoux major bedrock aquifer in Basin 46; however, there are currently no water rights in the basin.
- Concentrations of chloride and naturally occurring radioactivity may exceed drinking water standards in some areas of the Roubidoux aquifer. However, there are no significant aquifer-wide groundwater quality issues in the basin.

Notes & Assumptions

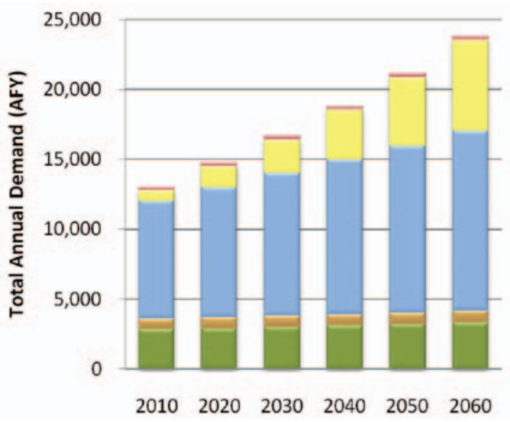
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater recharge.
- Site-specific information on minor aquifers should be considered before large scale use. Suitability for long term supply is typically based on recharge, storage yield, capital and operational costs, and water quality.
- Groundwater permit availability is generally based on the amount of land owned or leased that overlies a specific aquifer.
- Temporary permit amounts are subject to change when the aquifer's equal proportionate share is set by the OWRB.
- Current groundwater rights represent the maximum allowable use. Actual use may be lower than the permitted amount.
- Bedrock groundwater recharge is the long-term annual average recharge to aquifers in the basin. Recharge rates on a county- or aquifer-wide level of detail were established from literature (published reports) of each aquifer. Seasonal or annual variability is not considered; therefore the modeled bedrock groundwater supply is independent of changing hydrologic conditions.

Water Demand

- The water needs of Basin 46 are about 10% of the total demand in the Lower Arkansas Watershed Planning Region and will increase by 61% (12,290 AFY) from 2010 to 2060. The majority of demand during this period will be in the Municipal and Industrial and Crop Irrigation demand sectors. The largest growth in demand from 2010 to 2060 will occur from the Oil and Gas and Municipal and Industrial demand sectors.
- Surface water is used to meet 65% of the total demand in the basin and its use will increase by 82% (10,740 AFY) from 2010 to 2060. The majority of surface water use during this period will be in the Municipal and Industrial demand sector. The majority of growth in surface water use from 2010 to 2060 will be from the Oil and Gas demand sector, but the Municipal and Industrial demand sector will also have substantial growth in surface water use.
- Alluvial groundwater is used to meet 31% of the total demand in the basin and its use will increase by 82% (1,360 AFY) from 2010 to 2060. The majority of the alluvial groundwater use and growth in alluvial groundwater use during this period will be from the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet 4% of the total basin demand and its use will increase by 28% (190 AFY) from 2010 to 2060. The majority of the bedrock groundwater use will be in the Crop Irrigation sector. The largest growth in bedrock groundwater use will occur from the Crop Irrigation and Oil and Gas demand sectors.

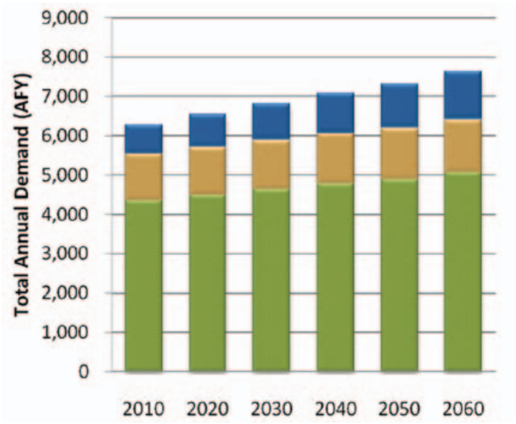
Surface Water Demand by Sector

Lower Arkansas Region, Basin 46



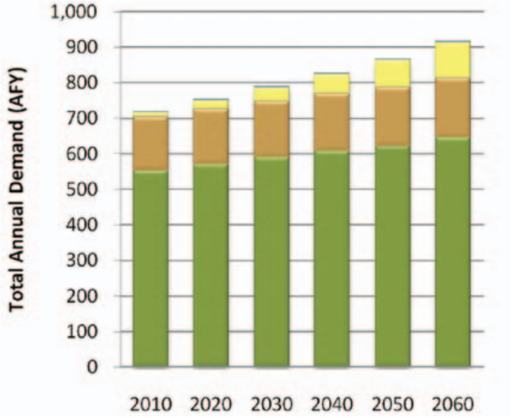
Alluvial Groundwater Demand by Sector

Lower Arkansas Region, Basin 46



Bedrock Groundwater Demand by Sector

Lower Arkansas Region, Basin 46



■ Thermoelectric Power ■ Self-Supplied Residential ■ Self-Supplied Industrial ■ Oil & Gas ■ Municipal & Industrial ■ Livestock ■ Crop Irrigation

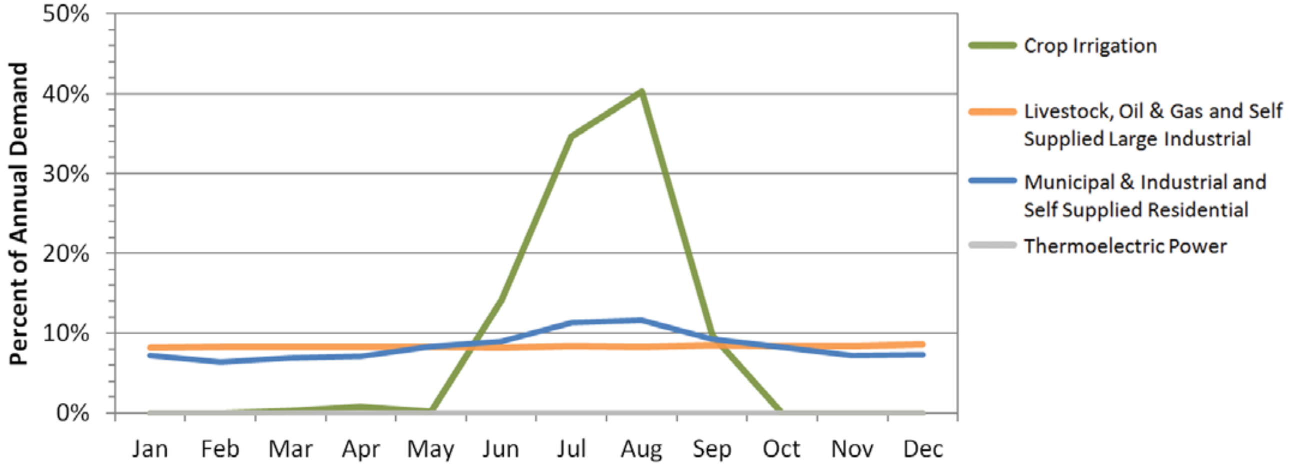
Total Demand by Sector

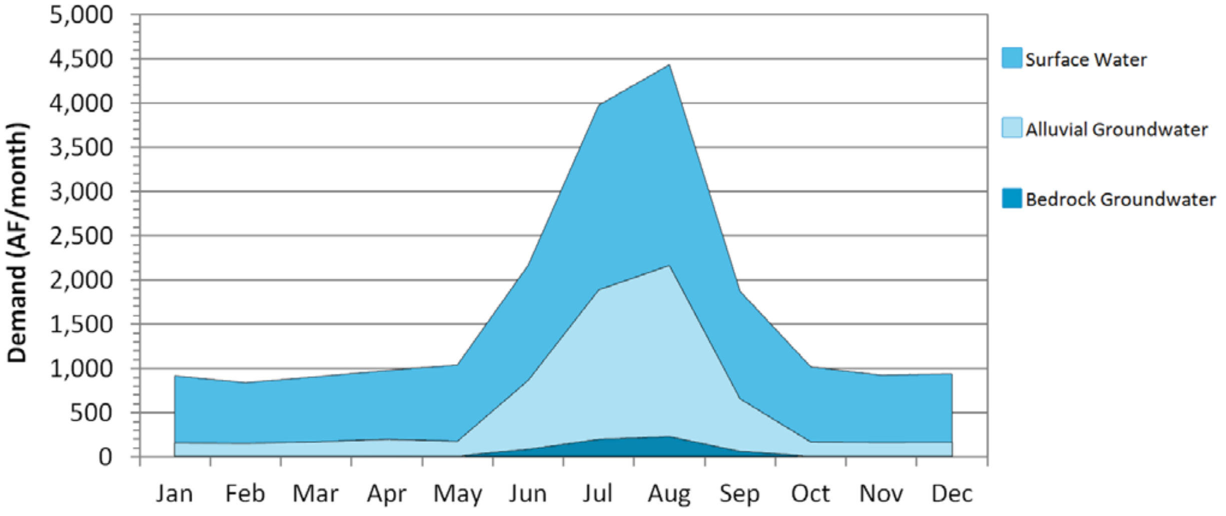
Lower Arkansas Region, Basin 46

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	7,720	2,110	8,500	780	210	710	0	20,030
2020	7,980	2,160	9,360	1,560	210	800	0	22,070
2030	8,240	2,200	10,240	2,460	220	900	0	24,260
2040	8,500	2,250	11,120	3,610	240	1,000	0	26,720
2050	8,700	2,290	12,020	4,980	250	1,100	0	29,340
2060	9,020	2,340	12,930	6,560	270	1,200	0	32,320

Notes & Assumptions

- Demand values represent total demand (the amount of water pumped or diverted to meet the needs of the user).
- Values are based on the baseline demand forecast from the OCWP *Water Demand Forecast Report*.
- The effect of climate change, conservation, and non-consumptive uses, such as hydropower, are not represented in this baseline demand analysis but are documented in separate OCWP reports.
- The proportion of each supply source used to meet each water use sector's demand was assumed to be equal to the existing proportion, as represented in water rights.
- The proportions of future demands between water use sectors will vary due to differing growth rates.
- The overall proportion of supplies used to meet demand will change due to differing growth rates among the water use sectors.


Monthly Demand Distribution by Sector (2010)
Lower Arkansas Region, Basin 46


Monthly Demand Distribution by Source (2010)
Lower Arkansas Region, Basin 46

Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 52% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 46 is nearly 4.7 times the peak winter month demand, which is similar to the overall statewide pattern. Monthly surface water use peaks in the summer at about 2.9 times the monthly winter use. Monthly alluvial and bedrock groundwater use peaks in the summer by at least 12.4 and 16.7 times the peak monthly winter use, respectively.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and alluvial groundwater storage depletions may occur by 2040.
- There is a very low probability (2%) of surface water gaps occurring during the winter in Basin 46, which will be up to 41% (640 AF/month) of the peak winter month surface water demand in 2060.
- There is a very low probability (2%) of alluvial groundwater storage depletions occurring during the winter in Basin 46, which will be up to 40% (80 AF/month) of the peak winter month alluvial groundwater demand in 2060. Projected annual storage depletions are minimal relative to the amount of water in storage in the Arkansas River aquifer. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs.
- No bedrock groundwater storage depletions are projected to occur if future demand is met by the Roubidoux aquifer. Currently, minor aquifers are being used to meet the bedrock groundwater demand. Localized storage depletions may occur, but could not be quantified due to insufficient information.

Surface Water Gaps by Season (2060 Demand)

Lower Arkansas Region, Basin 46

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	640	640	2%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	0	0	0%
Sep-Nov (Fall)	0	0	0%

[1] Amount shown represents largest amount for any one month in season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Lower Arkansas Region, Basin 46

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	80	80	2%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	0	0	0%
Sep-Nov (Fall)	0	0	0%

[1] Amount shown represents largest amount for any one month in season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions

Lower Arkansas Region, Basin 46

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	0	0	0	0%	0%
2030	0	0	0	0%	0%
2040	330	50	0	2%	2%
2050	470	70	0	2%	2%
2060	640	80	0	2%	2%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Lower Arkansas Region, Basin 46

Months (Season)	Average Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	0
Sep-Nov (Fall)	0

[1] Amount shown represents largest amount for any one month in season indicated.

Notes & Assumptions

- Gaps and Storage Depletions reflect deficiencies in physically available water. Permitting, water quality, infrastructure, and nonconsumptive demand constraints are considered in separate OCWP analyses.
- Local gaps and storage depletions may vary from basin-level values due to local variations in demands and local availability of supply sources.
- For this baseline analysis, each basin's future demand is met by the basin's available supplies.
- For this baseline analysis, the proportion of future demand supplied by surface water and groundwater for each sector is assumed equal to current proportions.
- The amount of available surface water supplies used for OCWP water supply availability analysis includes changes in historical streamflow due to increased upstream demand, return flows, and increases in out-of-basin supplies from existing infrastructure.
- Analysis of bedrock groundwater supplies is based upon recharge from major aquifers.
- Groundwater storage depletions are defined as the amount that future demands exceed available recharge.
- Median gaps and storage depletions are based only on months with gaps or storage depletions.
- Annual probability is based upon the number of years that a gap or depletion occurs in at least one month of that year.

Reducing Water Needs Through Conservation

Lower Arkansas Region, Basin 46

	2060 Gap/Storage Depletion			2060 Gap/ Storage Depletion Probability	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
Conservation Activities[1]	AFY			Percent	
Existing Conditions	640	80	0	2%	2%
Moderately Expanded Conservation in Crop Irrigation Water Use	640	80	0	2%	2%
Moderately Expanded Conservation in M&I Water Use	300	90	0	2%	2%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	300	80	0	2%	2%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	300	80	0	2%	2%

1 Conservation Activities are documented in the OCWP Water Demand Forecast Report

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Lower Arkansas Region, Basin 46

Reservoir Storage	Diversion
AF	AFY
100	3,300
500	9,000
1,000	16,100
2,500	37,500
5,000	73,000
Required Storage to Meet Growth in Demand (AF)	700
Required Storage to Meet Growth in Surface Water Demand (AF)	700

Water Supply Options & Effectiveness

🟩 Typically Effective
🟨 Potentially Effective
🟥 Likely Ineffective
🟪 No Option Necessary

Demand Management

🟨 Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce surface water gaps by about 50%. No significant reduction in alluvial groundwater storage depletions is expected from additional conservation activities. Due to the low probability of gaps, temporary drought management measures may be effective. Temporary drought management activities may not be necessary for the alluvial groundwater users since aquifer storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

🟨 Out-of-basin supplies could mitigate surface water gaps and groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potential out-of-basin sites in the Lower Arkansas Region: Brazil and Hackett in Basin 45. However, due to the very low probability of gaps and storage depletions, out-of-basin supplies may not be cost-effective for many users.

Reservoir Use

🟩 New reservoir storage could increase the dependability of available surface water supplies and mitigate gaps and adverse effects of localized storage depletions in the basin. The entire growth in demand in the basin from 2010 to 2060 could be supplied by a new river diversion and 700 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions. The OCWP *Reservoir Viability Study* also identified Greasy and Vian Reservoirs as potentially viable sites in Basin 46.

Increasing Reliance on Surface Water

🟥 Increased reliance on surface water through direct diversions, without reservoir storage, will increase gaps and is not recommended.

Increasing Reliance on Surface Water

🟩 Increased reliance on alluvial groundwater could mitigate surface water gaps but will increase alluvial groundwater storage depletions. Projected annual alluvial storage depletions are minimal relative to the volume of water stored in Basin 46's portion of the Arkansas River aquifer. Bedrock groundwater supplies are currently from minor aquifers; therefore, increased reliance on these supplies is not recommended without site-specific information. However, use of the Roubidoux aquifer could provide reliable supplies to many users.

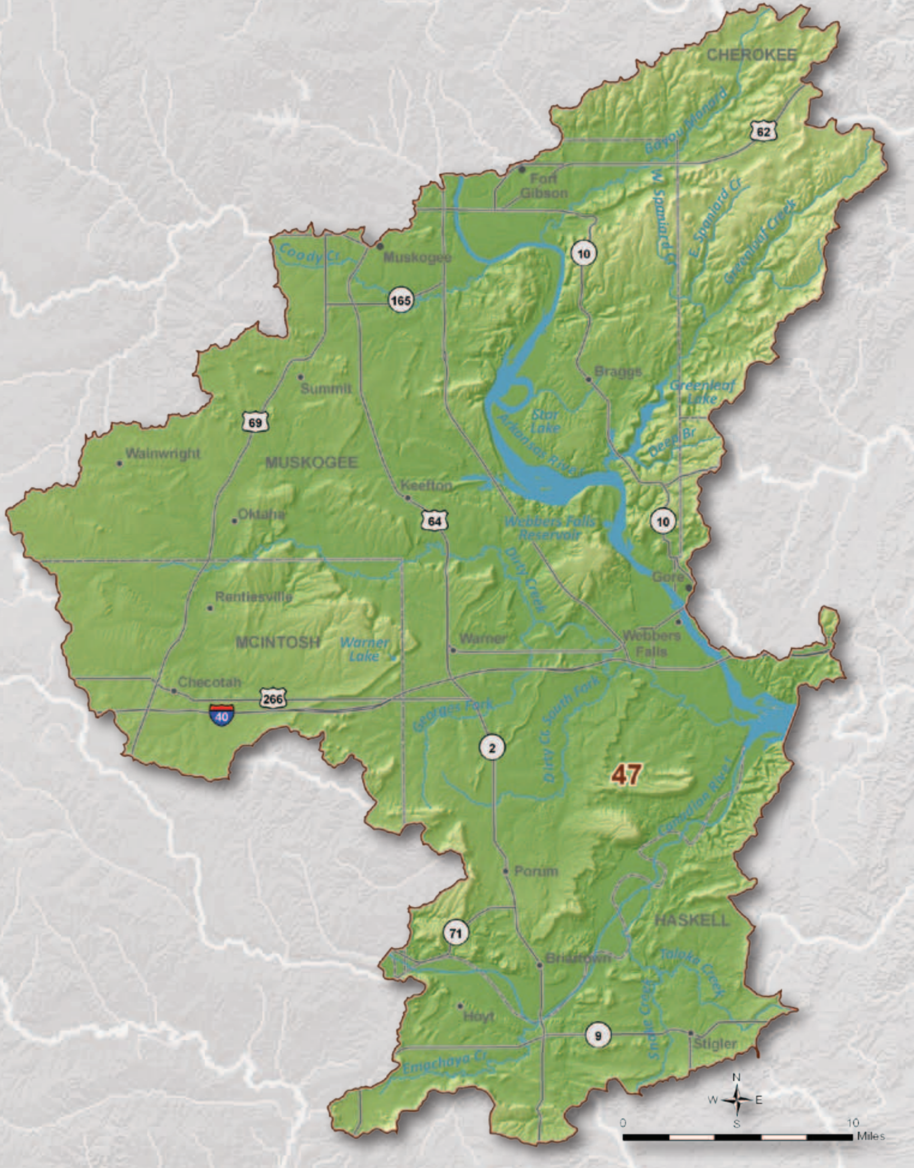
Notes & Assumptions

- Water quality may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands will vary based on local acceptance of additional conservation and temporary drought management activities.
- Gaps and depletions may be mitigated in individual calendar months without reductions in the annual probability (chance of having shortage during another month).
- River diversion for new or additional reservoir storage is based on a hypothetical on-channel reservoir at the basin outlet. Reported yields will vary depending upon the reservoir location; placement at the basin outlet would likely result in a higher yield.
- Aquifer storage and recovery may provide additional storage or an alternative to surface storage and should be evaluated on a case by case basis.

Oklahoma Comprehensive Water Plan

Data & Analysis
Lower Arkansas Watershed Planning Region

Basin 47



Basin 47 Summary

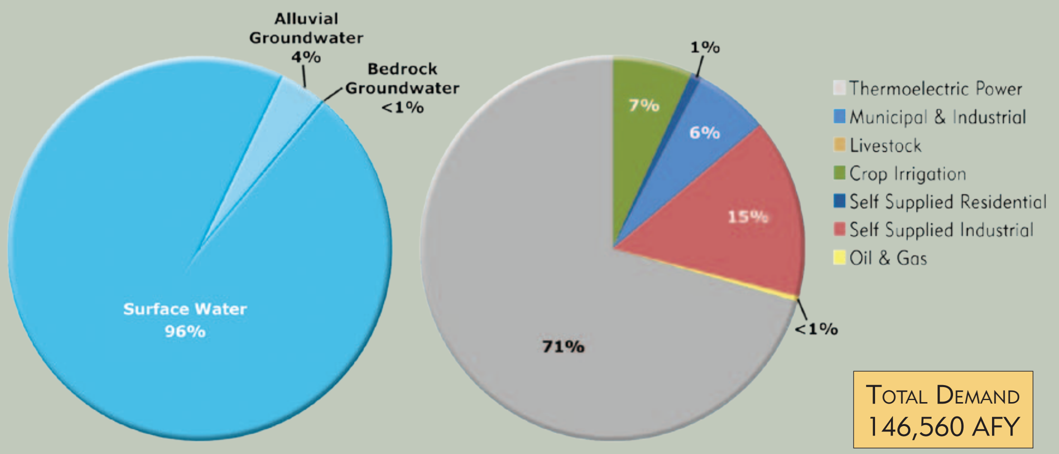
Synopsis

- Water users are expected to continue to rely largely on surface water and to a much lesser extent alluvial groundwater supplies.
- By 2020, there is a low probability of surface water gaps from increased demands on existing supplies during low flow periods.
- Alluvial groundwater storage depletions may occur by 2020, but will be minimal in size relative to aquifer storage in the basin. However, localized storage depletions may cause adverse effects for users.
- To reduce the risk of adverse impacts on water supplies, it is recommended that gaps and storage depletions be decreased where economically feasible.
- Additional conservation could reduce surface water gaps and the adverse effects of localized alluvial groundwater storage depletions. Due to the low probability of gaps, temporary drought management measures for surface water users may be effective. Temporary drought management activities may not be necessary for the alluvial groundwater users since aquifer storage could continue to provide supplies during droughts.
- Use of additional dependable groundwater supplies and/or developing additional small reservoir storage could mitigate surface water gaps. These supply sources could be used without major impacts to groundwater storage.

Basin 47 accounts for about 73% of the current water demand in the Lower Arkansas Watershed Planning Region. About 71% of the demand is from the Thermoelectric Power sector. Self-Supplied Industrial (15%) is the second-largest demand sector in 2010. Surface water satisfies about 96% of the total demand in the basin. Groundwater supplies about 4% of the total demand in the basin (less than 1% is bedrock). The peak summer month total water demand in Basin 47 is 1.4 times the peak

Current Demand by Source and Sector

Lower Arkansas Region, Basin 47



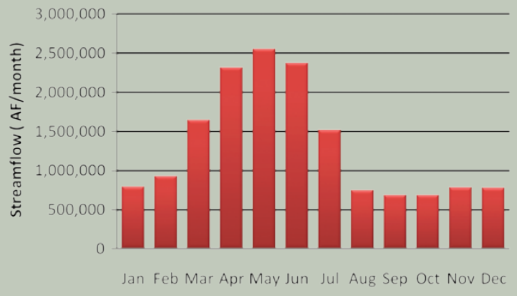
Total Demand
146,560 AFY

Water Resources

Lower Arkansas Region, Basin 47

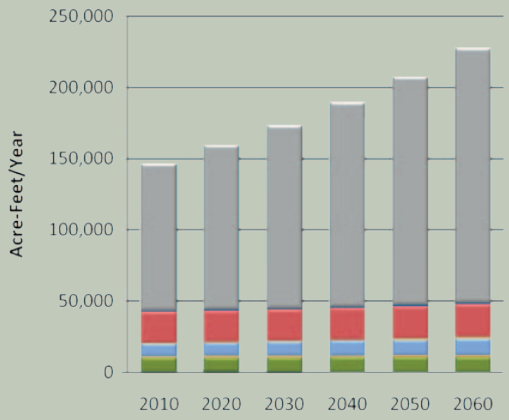
Median Historical Streamflow at the Basin Outlet

Lower Arkansas Region, Basin 47



Projected Water Demand

Lower Arkansas Region, Basin 47



winter demand, which is less pronounced than the overall statewide pattern.

The Arkansas River near its confluence with the Canadian River typically has flows greater than 680,000 AF/month throughout the year and greater than 1.5 million AF/month in the spring. Increased upstream withdrawals may reduce streamflow and lead to infrequent periods of low flow. The major reservoir in the region is Webbers Falls Reservoir, which was constructed by the U.S. Army Corps of Engineers in 1970 for the McClellan-Kerr Arkansas River Navigation System as well as for power generation. The reservoir is not expected to provide water supplies in the future. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. Relative to other basins in the state, the surface water quality in Basin 47 is considered good. Portions of the Arkansas River and Elk Creek are impaired for Agricultural use by high levels of total dissolved solids (TDS) and chloride. Greenleaf Lake is impaired for Public and Private Water Supply use due to high levels of chlorophyll-a.

The majority of groundwater rights are from the Arkansas River major alluvial aquifer and the Canadian River major alluvial aquifer. There are relatively few bedrock groundwater rights in the basin, which are primarily from minor aquifers. There is about 35,000 AFY of recharge to the Roubidoux major bedrock aquifer in Basin 47; however, there are currently less than 50 AFY of water rights from this aquifer in the basin. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. Concentrations of chloride and naturally occurring radioactivity may exceed drinking water standards in some areas of the Roubidoux aquifer. However, there are no significant aquifer-wide groundwater quality issues in the basin.

The projected 2060 water demand of 227,430 AFY in Basin 47 reflects an 80,870 AFY increase (55%) over the 2010 demand. The majority of demand and growth in demand over this period will be in the Thermoelectric Power demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and alluvial groundwater depletions in Basin 47 may occur by 2020. There is a low probability (5%) of surface water gaps and alluvial groundwater storage depletions occurring in 2060 during the fall. By 2060, surface water gaps will be up to 6,120 AFY and alluvial groundwater storage depletions will be up to 200 AFY. Projected annual alluvial groundwater storage depletions are minimal relative to the amount of water in storage in the Arkansas River and Canadian River aquifers. However, localized storage depletions may occur and adversely affect well yields, water quality, and/or pumping costs. No bedrock groundwater storage depletions are projected to occur if future demand is met by the Roubidoux aquifer. Currently, minor aquifers are being used to meet the bedrock groundwater demand. Therefore, localized storage depletions may occur, but could not be fully quantified due to insufficient information.

Water Supply Limitations

Lower Arkansas Region, Basin 47

🟩 Surface Water
🟨 Alluvial Groundwater
🟩 Bedrock Groundwater

🟩 Minimal 🟨 Potential 🟥 Significant

Water Supply Option Effectiveness

Lower Arkansas Region, Basin 47

🟨 Demand Management
🟨 Out-of-Basin Supplies
🟨 Reservoir Use
🟥 Increasing Supply from Surface Water
🟩 Increasing Supply from Groundwater

🟩 Typically Effective 🟨 Potentially Effective
🟥 Likely Ineffective 🟪 No Option Necessary

Options

Water users are expected to continue to rely primarily on surface water supplies. To reduce the risk of adverse impacts to the basin's water users, gaps and storage depletions should be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could result in small reductions in surface water gaps and alluvial groundwater depletions. Due to the low probability of gaps, temporary drought management measures may be effective for surface water users. Temporary drought management activities may not be necessary for the alluvial groundwater users since aquifer storage could continue to provide supplies during droughts.

Out-of-basin supplies could mitigate surface water gaps and groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified four potential out-of-basin sites in the Lower Arkansas Region. However, due to the very low probability of gaps and storage depletions, out-of-basin supplies may not be cost-effective.

New reservoir storage could increase the dependability of available surface water supplies and mitigate gaps and adverse effects of localized storage depletions in the basin. The entire growth in demand in the basin from 2010 to 2060 could be supplied by a new river diversion and 6,400 AF of reservoir storage at the basin outlet.

Increased reliance on surface water supplies, without reservoir storage, will increase surface water gaps and is not recommended.

Increased reliance on alluvial groundwater could mitigate surface water gaps, but will increase alluvial groundwater storage depletions. Projected annual alluvial storage depletions are minimal relative to the volume of water stored in Basin 47's portion of the Arkansas and Canadian River aquifers. Bedrock groundwater supplies are from minor aquifers; therefore, increased reliance on these supplies is not recommended without site-specific information. The Roubidoux aquifer may be capable of providing dependable supplies, but is currently not used.

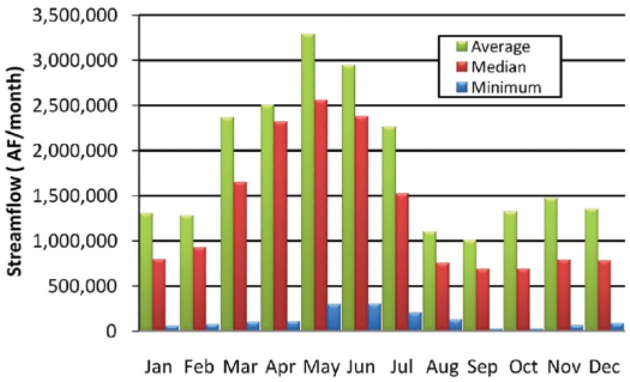
Basin 47 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. This basin had a prolonged period of below-average streamflow from the early 1960s through the early 1970s, corresponding to a period of below-average precipitation. From the mid 1980s to the early 2000s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median flow in the Arkansas River near its confluence with the Canadian River is at least 680,000 AF/month throughout the year and greater than 1.5 million AF/month in spring. Increased upstream withdrawals may reduce streamflow and lead to infrequent periods of low flow.
- Relative to other basins in the state, surface water quality in Basin 47 is considered good.
- Webbers Falls Reservoir is operated by the U.S. Army Corps of Engineers for the McClellan-Kerr Arkansas River Navigation System, as well as for power generation. The reservoir is not expected to provide water supplies in the future.

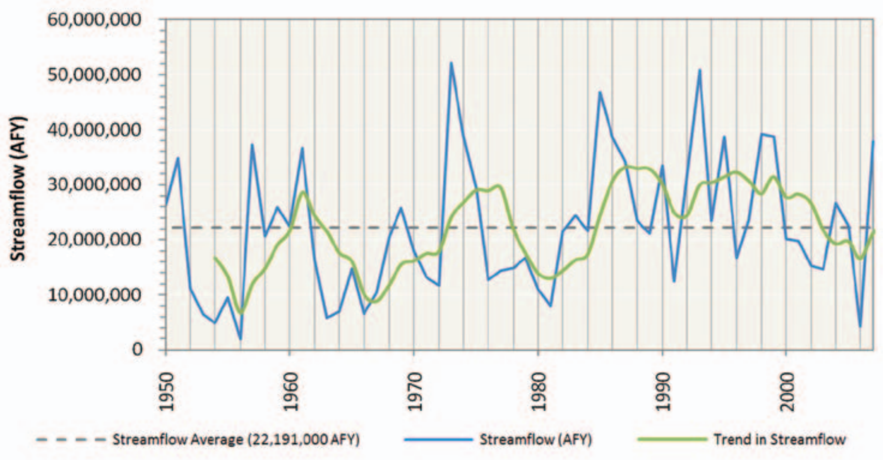
Monthly Historical Streamflow at the Basin Outlet

Lower Arkansas Region, Basin 47



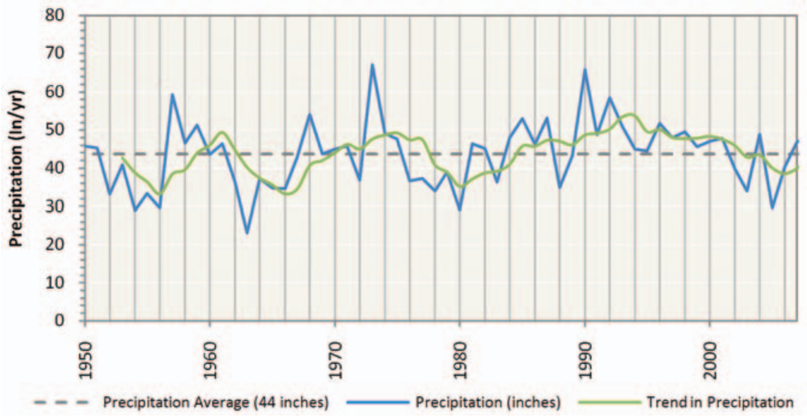
Historical Streamflow at the Basin Outlet

Lower Arkansas Region, Basin 47



Historical Precipitation

Regional Climate Division



Notes & Assumptions

- Precipitation data are based on regional information, while streamflow is basin-specific.
- Measured streamflow implicitly reflects the conditions that exist in the stream at the time the data were recorded (e.g., hydrology, diversions, reservoirs, and infrastructure).
- For water supply planning, the range of potential future hydrologic conditions, including droughts, is represented by 58 years of monthly surface water flows (1950 to 2007). Climate change variations to these flows are documented in a separate OCWP report.
- Surface water supplies are calculated by adjusting the historical streamflow to account for upstream demands, return flows, and out-of-basin supplies.
- The upstream state is assumed to use 60 percent of the flow at the state line based on OWRB permitting protocol.
- Historical flow is based on USGS stream gages at or near the basin outlet. Where a gage did not exist near the outlet or there were missing data in the record, an estimation of flow was determined from representative, nearby gages using statistical techniques.
- Existing surface water rights may restrict the quantity of available surface water to meet future demands. Additional permits would decrease the amount of available water.

Groundwater Resources - Aquifer Summary (2010)

Lower Arkansas Region, Basin 47

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type	Class[1]	Percent	AFY	AF	AFY/Acre	AFY
Arkansas River	Alluvial	Major	9%	8,400	87,000	temporary 2.0	106,400
Canadian River	Alluvial	Major	13%	2,700	57,000	temporary 2.0	159,900
Roubidoux	Bedrock	Major	27%	<50	2,319,000	temporary 2.0	325,800
Boone	Bedrock	Minor	9%	200	993,000	temporary 2.0	114,900
Northeastern Oklahoma Pennsylvanian	Bedrock	Minor	13%	0	177,000	temporary 2.0	153,600
Pennsylvanian	Bedrock	Minor	13%	400	1,361,000	temporary 2.0	164,200
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

1 Bedrock aquifers with typical yields greater than 50 gpm and alluvial aquifers with typical yields greater than 150 gpm are considered major.

Groundwater Resources

- The majority of groundwater rights are from the Arkansas River major alluvial aquifer and the Canadian River major alluvial aquifer. There are relatively few bedrock groundwater rights, most of which are from minor aquifers. There is about 35,000 AFY of recharge to the Roubidoux major bedrock aquifer in Basin 47; however, there are currently less than 50 AFY of water rights in this aquifer in the basin.
- Concentrations of chloride and naturally occurring radioactivity may exceed drinking water standards in some areas of the Roubidoux aquifer. However, there are no significant aquifer-wide groundwater quality issues in the basin.

Notes & Assumptions

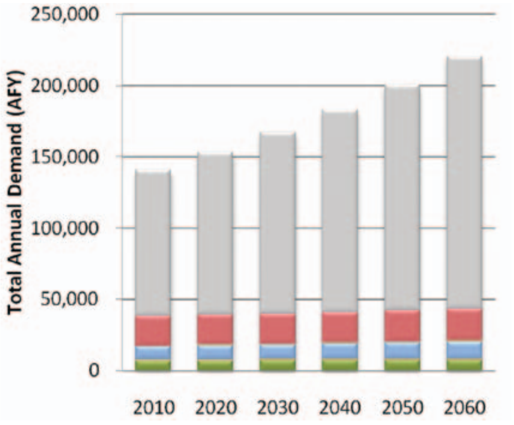
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater recharge.
- Site-specific information on minor aquifers should be considered before large scale use. Suitability for long term supply is typically based on recharge, storage yield, capital and operational costs, and water quality.
- Groundwater permit availability is generally based on the amount of land owned or leased that overlies a specific aquifer.
- Temporary permit amounts are subject to change when the aquifer's equal proportionate share is set by the OWRB.
- Current groundwater rights represent the maximum allowable use. Actual use may be lower than the permitted amount.
- Bedrock groundwater recharge is the long-term annual average recharge to aquifers in the basin. Recharge rates on a county- or aquifer-wide level of detail were established from literature (published reports) of each aquifer. Seasonal or annual variability is not considered; therefore the modeled bedrock groundwater supply is independent of changing hydrologic conditions.

Water Demand

- The water needs of Basin 47 are about 73% of the total demand in the Lower Arkansas Watershed Planning Region and will increase by 55% (80,870 AFY) from 2010 to 2060. The majority of demand and over 90% of the growth in demand during this period will be in the Thermoelectric Power demand sector. There will be demand and growth in demand from all seven OCWP demand sectors.
- Surface water is used to meet 96% of the total demand in the basin and its use will increase by 57% (79,550 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use during this period will be from the Thermoelectric Power demand sector.
- Alluvial groundwater is used to meet almost 4% of the total demand in the basin and its use will increase by 23% (1,300 AFY) from 2010 to 2060. The majority of alluvial groundwater use during this period will be in the Crop Irrigation demand sector. The majority of growth in alluvial groundwater use during this period will be from the Thermoelectric Power demand sector.
- Bedrock groundwater is used to meet less than 1% of total demand in the basin. The growth in bedrock groundwater water use from 2010 to 2060 is minimal on a basin scale.

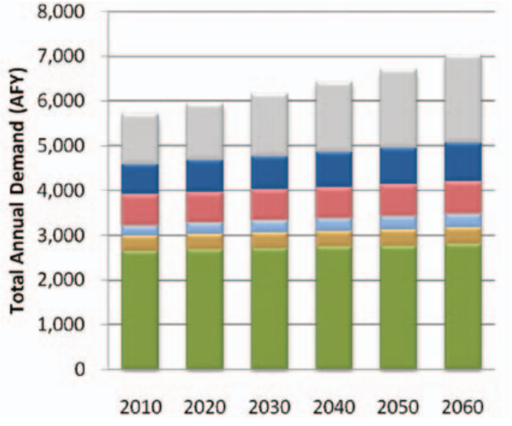
Surface Water Demand by Sector

Lower Arkansas Region, Basin 47



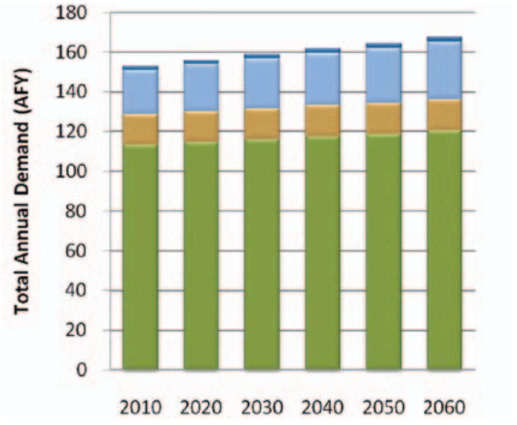
Alluvial Groundwater Demand by Sector

Lower Arkansas Region, Basin 47



Bedrock Groundwater Demand by Sector

Lower Arkansas Region, Basin 47



⬜ Thermoelectric Power 🟦 Self-Supplied Residential 🟥 Self-Supplied Industrial 🟨 Oil & Gas 🟦 Municipal & Industrial 🟧 Livestock 🟩 Crop Irrigation

Total Demand by Sector

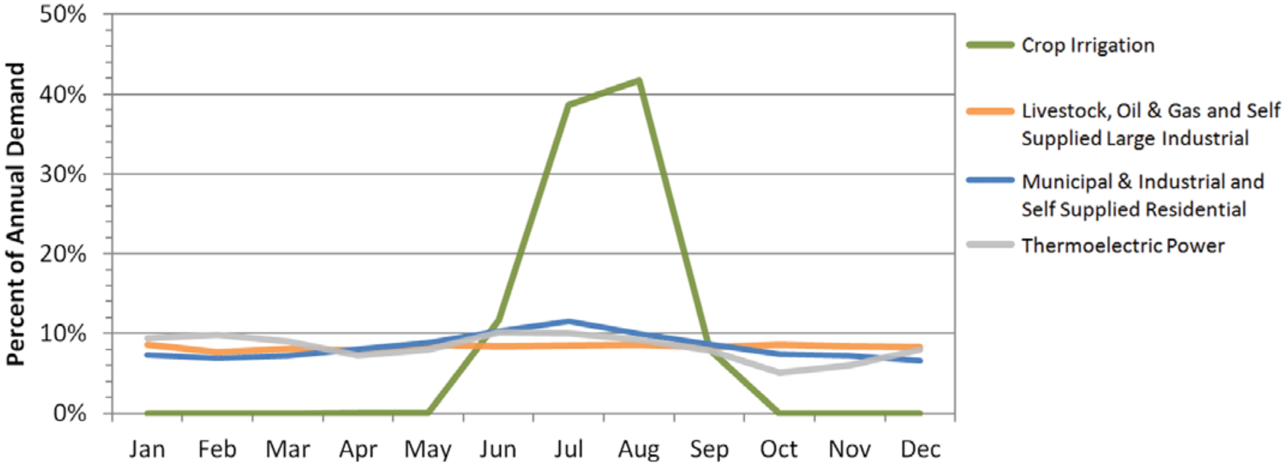
Lower Arkansas Region, Basin 47

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	9,940	1,330	9,030	110	22,080	680	103,390	146,560
2020	10,070	1,350	9,590	200	22,100	720	115,350	159,380
2030	10,190	1,360	10,100	330	22,120	760	128,680	173,540
2040	10,310	1,370	10,600	490	22,290	800	143,560	189,420
2050	10,410	1,380	11,110	680	22,840	840	160,160	207,420
2060	10,560	1,390	11,640	910	23,390	870	178,670	227,430

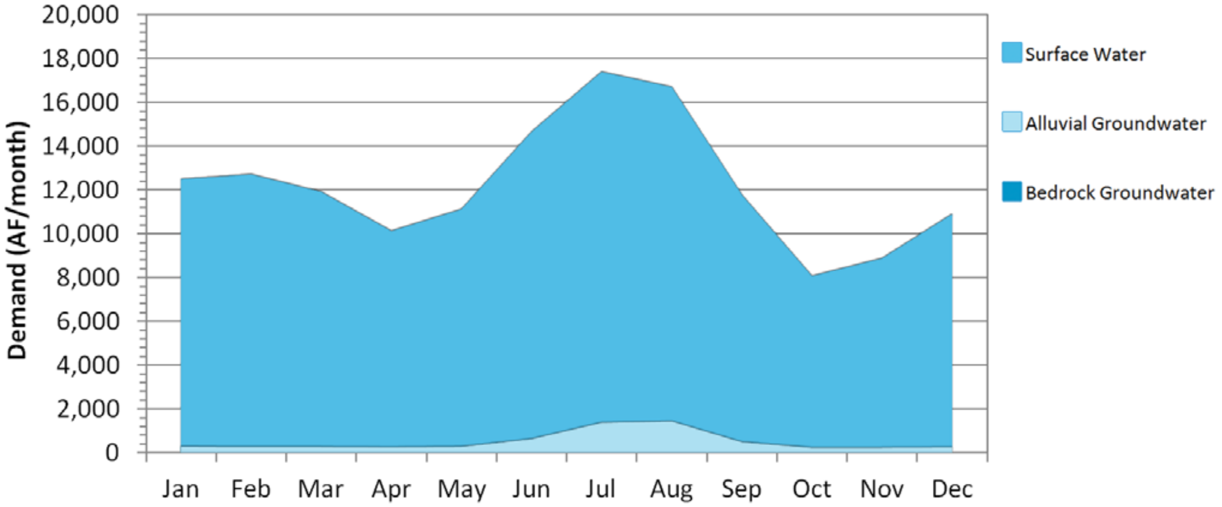
Notes & Assumptions

- Demand values represent total demand (the amount of water pumped or diverted to meet the needs of the user).
- Values are based on the baseline demand forecast from the OCWP *Water Demand Forecast Report*.
- The effect of climate change, conservation, and non-consumptive uses, such as hydropower, are not represented in this baseline demand analysis but are documented in separate OCWP reports.
- The proportion of each supply source used to meet each water use sector's demand was assumed to be equal to the existing proportion, as represented in water rights.
- The proportions of future demands between water use sectors will vary due to differing growth rates.
- The overall proportion of supplies used to meet demand will change due to differing growth rates among the water use sectors.

Monthly Demand Distribution by Sector (2010)
Lower Arkansas Region, Basin 47



Monthly Demand Distribution by Source (2010)
Lower Arkansas Region, Basin 47



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 52% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Thermoelectric Power has its highest demand in winter and summer months. The other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 47 is 1.4 times the peak winter month demand, which is less pronounced than the overall statewide pattern. Surface water use in the peak summer month is 1.3 times the use in the peak winter month. Monthly alluvial groundwater use peaks in the summer at about 5.2 times the monthly winter use. Monthly bedrock groundwater use peaks in the summer at about 16.5 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and alluvial groundwater depletions may occur by 2020.
- There is a low probability (5%) of surface water gaps occurring during the fall in Basin 47, which will be up to 35% (6,120 AF/month) of the surface water demand by 2060.
- There is a low probability (5%) of alluvial groundwater storage depletions occurring during the fall in Basin 47, which will be up to 35% (200 AF/month) of the fall alluvial groundwater demand by 2060. Projected annual storage depletions are minimal relative to the amount of water in storage in the Arkansas River and Canadian River aquifers. However, localized storage depletions may occur and adversely affect users' yields, water quality, or pumping costs.
- No bedrock groundwater storage depletions are projected to occur if future demand is met by the Roubidoux aquifer. Currently, minor aquifers are being used to meet the bedrock groundwater demand. Localized storage depletions may occur, but could not be fully quantified due to insufficient information.

Surface Water Gaps by Season (2060 Demand)

Lower Arkansas Region, Basin 47

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	0	0	0%
Sep-Nov (Fall)	6,120	4,060	5%

[1] Amount shown represents largest amount for any one month in season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Lower Arkansas Region, Basin 47

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	0	0	0%
Sep-Nov (Fall)	200	100	5%

[1] Amount shown represents largest amount for any one month in season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions

Lower Arkansas Region, Basin 47

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	950	40	0	5%	5%
2030	2,010	70	0	5%	5%
2040	3,220	110	0	5%	5%
2050	4,590	150	0	5%	5%
2060	6,120	200	0	5%	5%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Lower Arkansas Region, Basin 47

Months (Season)	Average Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	0
Sep-Nov (Fall)	0

[1] Amount shown represents largest amount for any one month in season indicated.

Notes & Assumptions

- Gaps and Storage Depletions reflect deficiencies in physically available water. Permitting, water quality, infrastructure, and nonconsumptive demand constraints are considered in separate OCWP analyses.
- Local gaps and storage depletions may vary from basin-level values due to local variations in demands and local availability of supply sources.
- For this baseline analysis, each basin's future demand is met by the basin's available supplies.
- For this baseline analysis, the proportion of future demand supplied by surface water and groundwater for each sector is assumed equal to current proportions.
- The amount of available surface water supplies used for OCWP water supply availability analysis includes changes in historical streamflow due to increased upstream demand, return flows, and increases in out-of-basin supplies from existing infrastructure.
- Analysis of bedrock groundwater supplies is based upon recharge from major aquifers.
- Groundwater storage depletions are defined as the amount that future demands exceed available recharge.
- Median gaps and storage depletions are based only on months with gaps or storage depletions.
- Annual probability is based upon the number of years that a gap or depletion occurs in at least one month of that year.

Reducing Water Needs Through Conservation

Lower Arkansas Region, Basin 47

	2060 Gap/Storage Depletion			2060 Gap/Storage Depletion Probability	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
Conservation Activities[1]	AFY			Percent	
Existing Conditions	6,120	200	0	5%	5%
Moderately Expanded Conservation in Crop Irrigation Water Use	6,090	190	0	5%	5%
Moderately Expanded Conservation in M&I Water Use	5,920	180	0	5%	5%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	5,890	180	0	5%	5%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	5,620	180	0	5%	5%

[1] *Conservation Activities are documented in the OCWP Water Demand Forecast Report*

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Lower Arkansas Region, Basin 47

Reservoir Storage	Diversion
AF	AFY
100	2,600
500	7,600
1,000	13,800
2,500	32,600
5,000	63,900
Required Storage to Meet Growth in Demand (AF)	6,400
Required Storage to Meet Growth in Surface Water Demand (AF)	6,200

Water Supply Options & Effectiveness

🟩 Typically Effective
🟨 Potentially Effective
🟥 Likely Ineffective
🟪 No Option Necessary

Demand Management

🟨 Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce surface water gaps by less than 5% and alluvial groundwater storage depletions by 10%. Due to the low probability of gaps, temporary drought management measures may be effective for surface water users. Temporary drought management activities may not be necessary for the alluvial groundwater users since aquifer storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

🟨 Out-of-basin supplies could mitigate surface water gaps and groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified four potential out-of-basin sites in the Lower Arkansas Watershed Planning Region: Brazil and Hackett in Basin 45 and Greasy and Vian in Basin 46. However, due to the very low probability of gaps and storage depletions, out-of-basin supplies may not be cost-effective for many users.

Reservoir Use

🟨 New reservoir storage can increase the dependability of available surface water supplies and mitigate gaps and adverse effects of localized storage depletions in the basin. The entire growth in demand in the basin from 2010 to 2060 could be supplied by a new river diversion and 6,400 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions.

Increasing Reliance on Surface Water

🟥 Increased reliance on surface water through direct diversions, without reservoir storage, will increase gaps and is not recommended.

Increasing Reliance on Groundwater

🟩 Increased reliance on alluvial groundwater could mitigate surface water gaps, but will increase alluvial groundwater storage depletions. Projected annual alluvial storage depletions are minimal relative to volume of water stored in Basin 47's portion of the Arkansas River and Canadian River aquifers. Bedrock groundwater supplies are from minor aquifers; therefore, increased reliance on these supplies is not recommended without site-specific information. The Roubidoux aquifer may be capable of providing dependable supplies, but is currently not used.

Notes & Assumptions

- Water quality may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands will vary based on local acceptance of additional conservation and temporary drought management activities.
- Gaps and depletions may be mitigated in individual calendar months without reductions in the annual probability (chance of having shortage during another month).
- River diversion for new or additional reservoir storage is based on a hypothetical on-channel reservoir at the basin outlet. Reported yields will vary depending upon the reservoir location; placement at the basin outlet would likely result in a higher yield.
- Aquifer storage and recovery may provide additional storage or an alternative to surface storage and should be evaluated on a case by case basis.

Oklahoma Comprehensive Water Plan

Data & Analysis
Lower Arkansas Watershed Planning Region

Basin 82

Basin 82 Summary

Synopsis

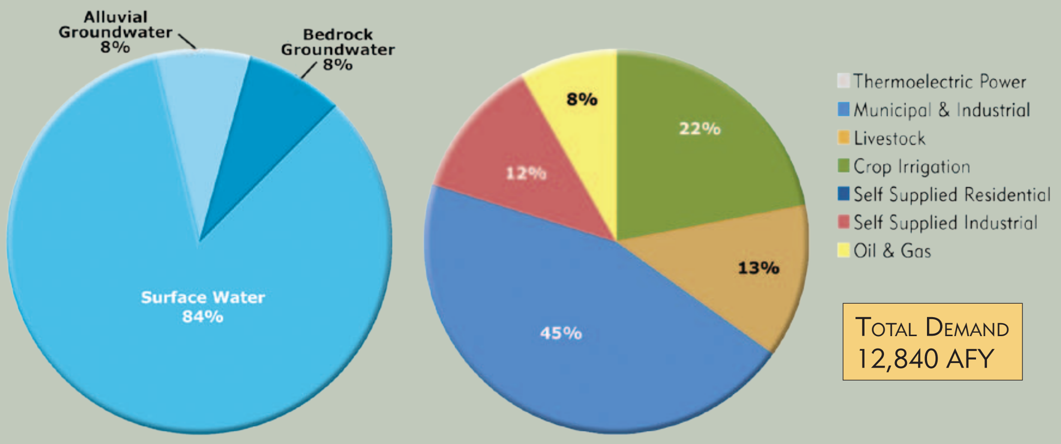
- Water users are expected to continue to rely primarily on surface water supplies.
- Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions are not are expected to occur in this basin through 2060. Therefore, no supply options are necessary.

Basin 82 accounts for 6% of the current water demand in the Lower Arkansas Watershed Planning Region. Nearly half of the demand (45%) is in the Municipal and Industrial demand sector. Crop Irrigation (22%) and Livestock (13%) are the next largest demand sectors in 2010. Surface water satisfies 84% of the total water demand in the basin. Groundwater is used to meet 16% of the demand in the basin (8% alluvial and 8% bedrock). The peak summer month demand in Basin 82 is about 2.7 times the winter demand, which is similar to the overall statewide pattern

The Illinois River downstream of Deep Branch typically has flows greater than 25,000 AF/month throughout the year and greater than 50,000 AF/month in the winter and spring. Basin 82 can have extended periods of low flow in any month of the year. Tenkiller Ferry Lake was constructed in 1953 on the Illinois River by the U.S. Army Corps of Engineers. The lake is authorized for flood control and hydroelectric power. Water supply is not an authorized purpose even though the conservation pool is comprised of 25,400 AFY of water supply storage for a dependable yield of 29,792 AFY. Tenkiller Ferry is currently fully allocated; therefore, any potential user of this source would need to take into consideration existing water rights. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. Relative to other basins in the state, the surface water quality in Basin 82 is considered good. However, Tenkiller Ferry is impaired for Public and Private Water Supply use due to high levels of chlorophyll-a.

Current Demand by Source and Sector

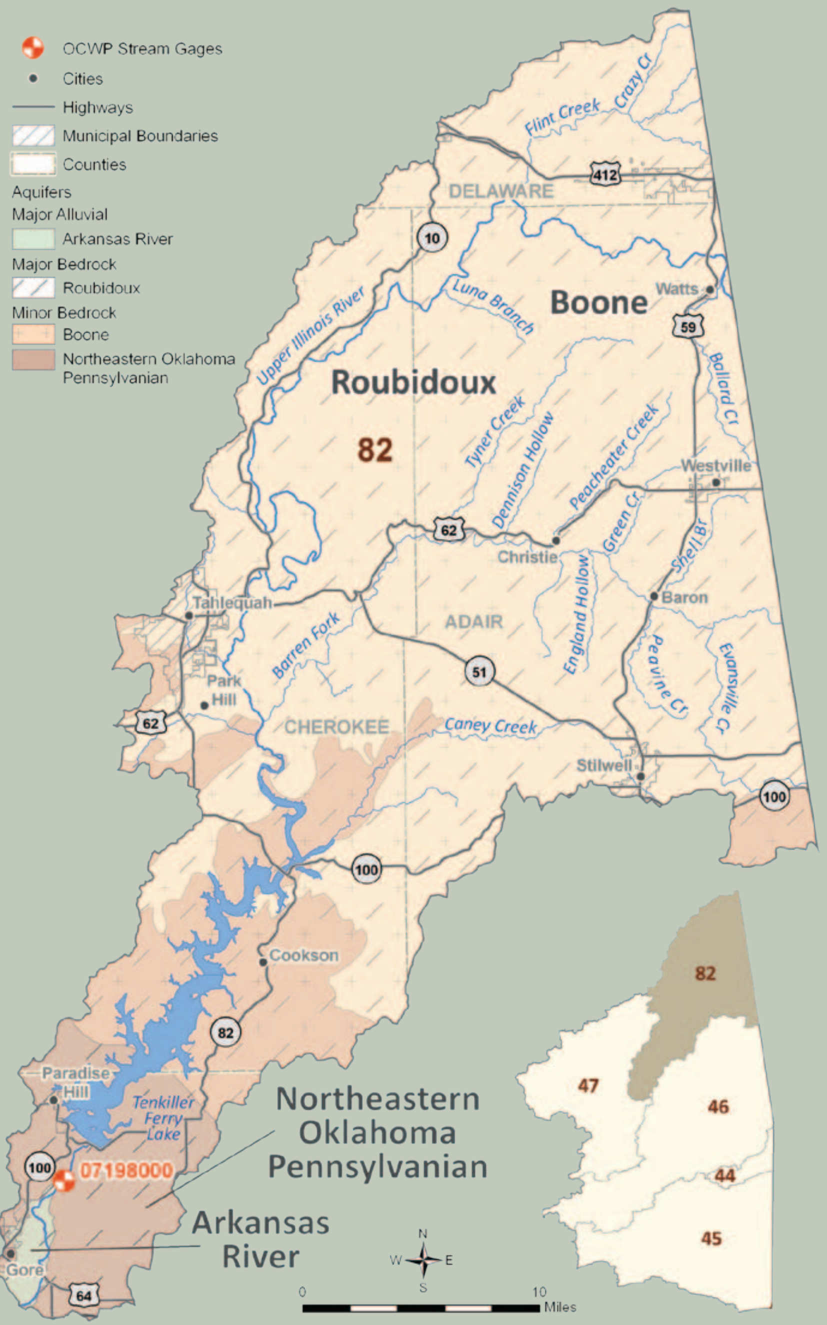
Lower Arkansas Region, Basin 82



Total Demand
12,840 AFY

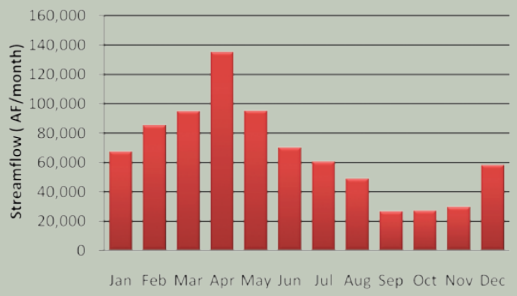
Water Resources

Lower Arkansas Region, Basin 82



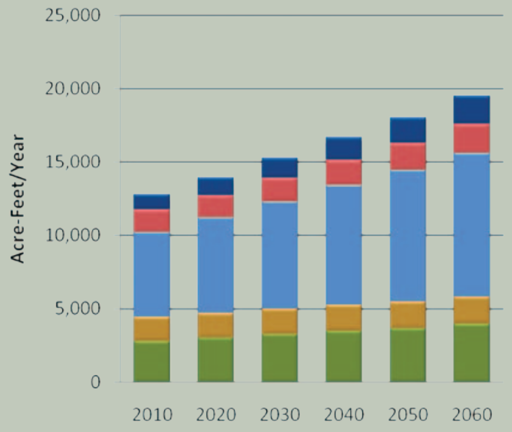
Median Historical Streamflow at the Basin Outlet

Lower Arkansas Region, Basin 82



Projected Water Demand

Lower Arkansas Region, Basin 82



The majority of groundwater rights are from the Boone minor bedrock aquifer. There are some additional permits in minor alluvial and bedrock aquifers in the basin. Nearly all of the alluvial groundwater use is for domestic purposes, which does not require a water right. There is about 120,000 AFY of recharge to the Roubidoux major bedrock aquifer in Basin 82; however, there are currently less than 50 AFY of water rights in this aquifer in the basin. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. Concentrations of chloride and naturally occurring radioactivity may exceed drinking water standards in some areas of the Roubidoux aquifer. However, there are no significant aquifer-wide groundwater quality issues in the basin.

The projected 2060 total water demand of 19,510 AFY in Basin 82 reflects a 6,670 AFY increase (52%) over the 2010 demand The largest demand and growth in demand over this period will be in the Municipal and Industrial demand sector. There will also be significant demand and growth in demand in the Crop Irrigation, Self-Supplied Industrial, and Self-Supplied Residential demand sectors..

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions are not expected to occur in this basin through 2060. However, localized gaps and storage depletions may occur.

Options

Surface water gaps and groundwater storage depletions are not expected through 2060; therefore, no supply options are necessary.

Water Supply Limitations

Lower Arkansas Region, Basin 82

Surface Water	🟩
Alluvial Groundwater	🟩
Bedrock Groundwater	🟩

🟩 Minimal 🟨 Potential 🟥 Significant

Water Supply Option Effectiveness

Lower Arkansas Region, Basin 82

Demand Management	🟪
Out-of-Basin Supplies	🟪
Reservoir Use	🟪
Increasing Supply from Surface Water	🟪
Increasing Supply from Groundwater	🟪

🟩 Typically Effective 🟨 Potentially Effective
🟥 Likely Ineffective 🟪 No Option Necessary

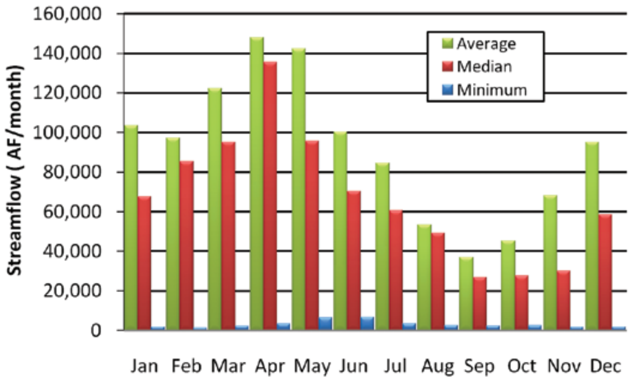
Basin 82 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. Streamflow data for Basin 82 are from measured data. This basin had a prolonged period of below-average streamflow from the early 1960s through the early 1970s, corresponding to a period of below-average precipitation. From the mid 1980s to the early 2000s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median flow in the Illinois River downstream of Deep Branch is greater than 25,000 AF/month throughout the year and greater than 50,000 AF/month in the winter and spring. However, Basin 82 can have periods of low flow in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 82 is considered good.
- Tenkiller Ferry Lake provides 29,792 AFY of dependable yield. Tenkiller is currently fully allocated so any potential user would need to consider existing water rights.

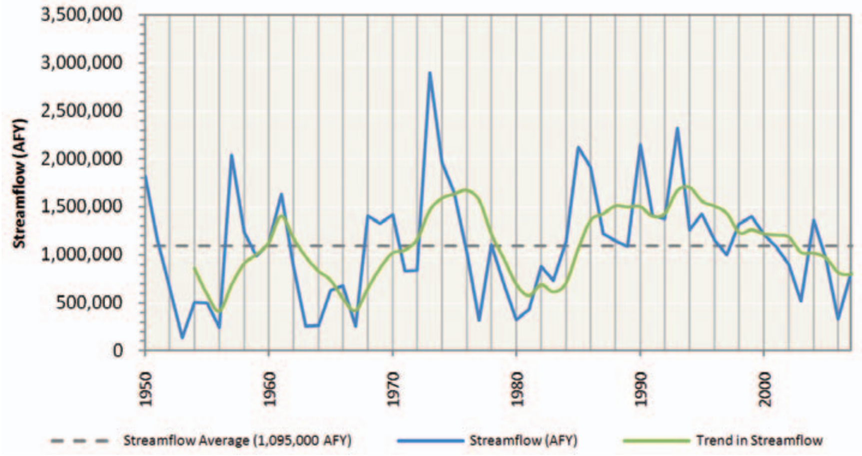
Monthly Historical Streamflow at the Basin Outlet

Lower Arkansas Region, Basin 82



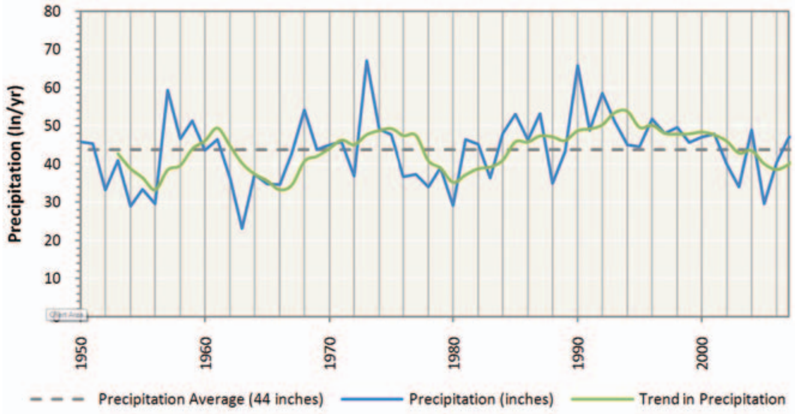
Historical Streamflow at the Basin Outlet

Lower Arkansas Region, Basin 82



Historical Precipitation

Regional Climate Division



Notes & Assumptions

- Precipitation data are based on regional information, while streamflow is basin-specific.
- Measured streamflow implicitly reflects the conditions that exist in the stream at the time the data were recorded (e.g., hydrology, diversions, reservoirs, and infrastructure).
- For water supply planning, the range of potential future hydrologic conditions, including droughts, is represented by 58 years of monthly surface water flows (1950 to 2007). Climate change variations to these flows are documented in a separate OCWP report.
- Surface water supplies are calculated by adjusting the historical streamflow to account for upstream demands, return flows, and out-of-basin supplies.
- The upstream state is assumed to use 60 percent of the flow at the state line based on OWRB permitting protocol.
- Historical flow is based on USGS stream gages at or near the basin outlet. Where a gage did not exist near the outlet or there were missing data in the record, an estimation of flow was determined from representative, nearby gages using statistical techniques.
- Existing surface water rights may restrict the quantity of available surface water to meet future demands. Additional permits would decrease the amount of available water.

Groundwater Resources - Aquifer Summary (2010)

Lower Arkansas Region, Basin 82

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	**Type**	**Class¹**	Percent	AFY	AF	AFY/Acre	AFY
Arkansas River	Alluvial	Major	1%	0	7,000	temporary 2.0	12,800
Roubidoux	Bedrock	Major	100%	<50	8,994,000	temporary 2.0	1,149,300
Boone	Bedrock	Minor	91%	3,900	9,044,000	temporary 2.0	1,036,200
Northeastern Oklahoma Pennsylvanian	Bedrock	Minor	23%	200	295,000	temporary 2.0	253,900
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	<50	N/A	temporary 2.0	N/A

1 Bedrock aquifers with typical yields greater than 50 gpm and alluvial aquifers with typical yields greater than 150 gpm are considered major.

Groundwater Resources

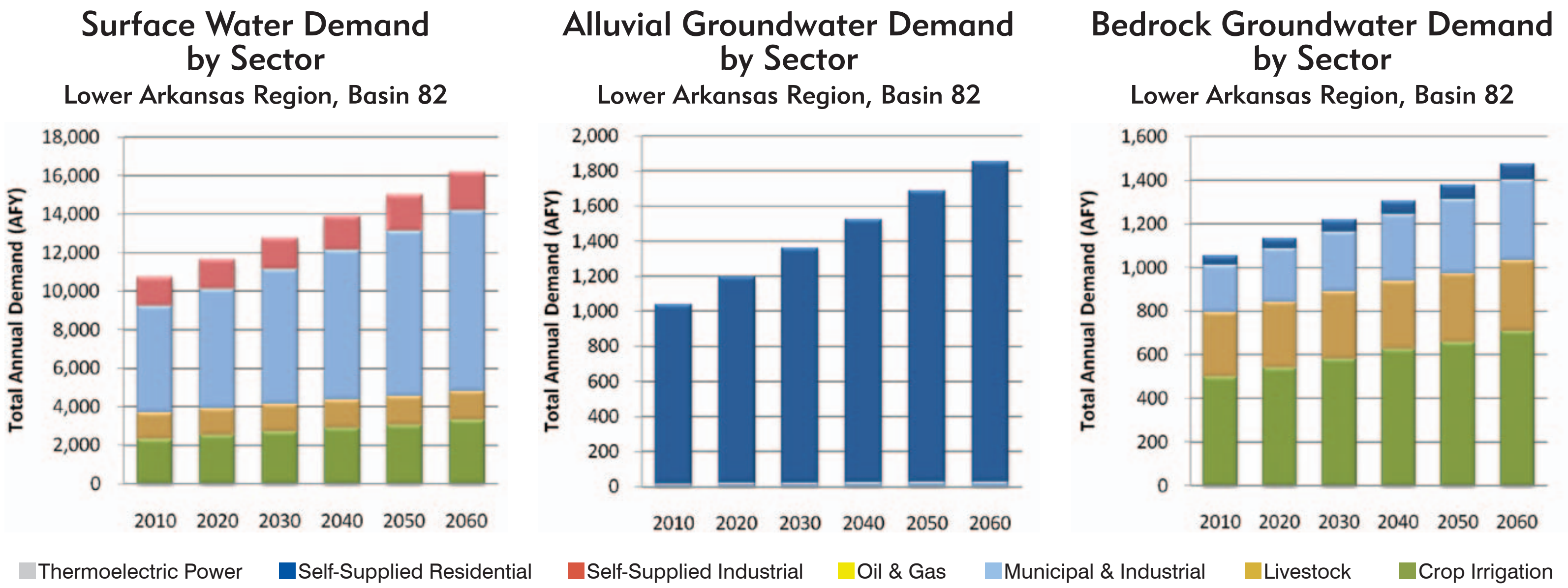
- The majority of groundwater rights are from the Boone minor bedrock aquifer. There are lesser quantities of permitted groundwater from minor alluvial and bedrock aquifers. There is about 120,000 AFY of recharge to the Roubidoux major bedrock aquifer in Basin 82; however, there are currently less than 50 AFY of water rights in this aquifer in the basin.
- Concentrations of chloride and naturally occurring radioactivity may exceed drinking water standards in some areas of the Roubidoux aquifer. However, there are no significant aquifer-wide groundwater quality issues in the basin.

Notes & Assumptions

- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater recharge.
- Site-specific information on minor aquifers should be considered before large scale use. Suitability for long term supply is typically based on recharge, storage yield, capital and operational costs, and water quality.
- Groundwater permit availability is generally based on the amount of land owned or leased that overlies a specific aquifer.
- Temporary permit amounts are subject to change when the aquifer's equal proportionate share is set by the OWRB.
- Current groundwater rights represent the maximum allowable use. Actual use may be lower than the permitted amount.
- Bedrock groundwater recharge is the long-term annual average recharge to aquifers in the basin. Recharge rates on a county- or aquifer-wide level of detail were established from literature (published reports) of each aquifer. Seasonal or annual variability is not considered; therefore the modeled bedrock groundwater supply is independent of changing hydrologic conditions.

Water Demand

- The water needs of Basin 82 are about 6% of the total demand in the Lower Arkansas Watershed Planning Region and will increase by 52% (6,670 AFY) from 2010 to 2060. The largest demand and growth in demand during this period will be in the Municipal and Industrial demand sector. There will also be significant demand and growth in demand from the Crop Irrigation, Self-Supplied Industrial, and Self-Supplied Residential demand sectors.
- Surface water is used to meet 84% of the total demand in the basin and its use will increase by 50% (5,430 AFY) from 2010 to 2060. The majority of demand and growth in surface water use during this period will be from the Municipal and Industrial demand sector.
- Alluvial groundwater is used to meet 8% of the total demand in the basin and its use will increase by 79% (810 AFY) from 2010 to 2060. Nearly all of the alluvial groundwater use and growth in alluvial groundwater use during this period will be from the Self-Supplied Residential demand sector.
- Bedrock groundwater is used to meet 8% of the total demand in the basin and its use will increase by 40% (430 AFY) from 2010 to 2060. The largest bedrock groundwater use and growth in bedrock groundwater use during this period will be from the Crop Irrigation and Municipal and Industrial demand sectors.



Surface Water Demand by Sector
Lower Arkansas Region, Basin 82

Alluvial Groundwater Demand by Sector
Lower Arkansas Region, Basin 82

Bedrock Groundwater Demand by Sector
Lower Arkansas Region, Basin 82

Total Demand by Sector
Lower Arkansas Region, Basin 82

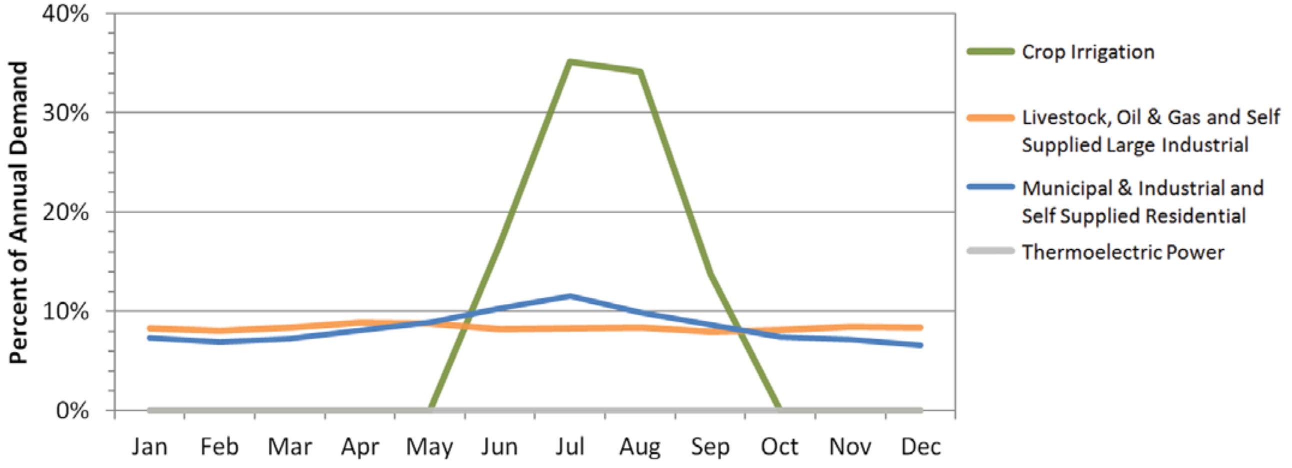
Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	2,820	1,660	5,770	0	1,530	1,060	0	12,840
2020	3,060	1,700	6,480	0	1,530	1,220	0	13,990
2030	3,290	1,730	7,300	0	1,610	1,390	0	15,320
2040	3,530	1,760	8,120	0	1,740	1,550	0	16,700
2050	3,710	1,800	8,940	0	1,870	1,720	0	18,040
2060	4,000	1,830	9,780	0	2,010	1,890	0	19,510

Notes & Assumptions

- Demand values represent total demand (the amount of water pumped or diverted to meet the needs of the user).
- Values are based on the baseline demand forecast from the OCWP *Water Demand Forecast Report*.
- The effect of climate change, conservation, and non-consumptive uses, such as hydropower, are not represented in this baseline demand analysis but are documented in separate OCWP reports.
- The proportion of each supply source used to meet each water use sector's demand was assumed to be equal to the existing proportion, as represented in water rights.
- The proportions of future demands between water use sectors will vary due to differing growth rates.
- The overall proportion of supplies used to meet demand will change due to differing growth rates among the water use sectors.

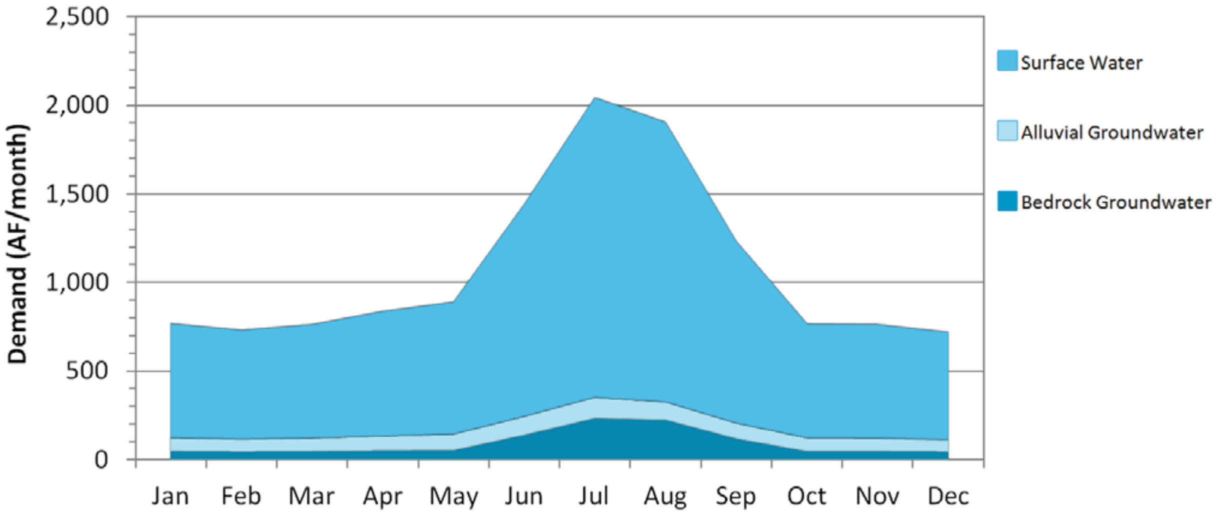
Monthly Demand Distribution by Sector (2010)

Lower Arkansas Region, Basin 82



Monthly Demand Distribution by Source (2010)

Lower Arkansas Region, Basin 82



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 52% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. The other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 82 is about 2.7 times the winter demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is almost 2.6 times the peak winter month demand. Monthly alluvial groundwater use peaks in the summer at about 1.6 times the peak winter month demand. Monthly bedrock groundwater use peaks in the summer at about 5.3 times the peak winter month demand.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions are not expected to occur in this basin through 2060.

Surface Water Gaps by Season (2060 Demand)

Lower Arkansas Region, Basin 82

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	0	0	0%
Sep-Nov (Fall)	0	0	0%

1 Amount shown represents largest amount for any one month in season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Lower Arkansas Region, Basin 82

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	0	0	0%
Sep-Nov (Fall)	0	0	0%

1 Amount shown represents largest amount for any one month in season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions

Lower Arkansas Region, Basin 82

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	0	0	0	0%	0%
2030	0	0	0	0%	0%
2040	0	0	0	0%	0%
2050	0	0	0	0%	0%
2060	0	0	0	0%	0%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Lower Arkansas Region, Basin 82

Months (Season)	Average Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	0
Sep-Nov (Fall)	0

1 Amount shown represents largest amount for any one month in season indicated.

Notes & Assumptions

- Gaps and Storage Depletions reflect deficiencies in physically available water. Permitting, water quality, infrastructure, and nonconsumptive demand constraints are considered in separate OCWP analyses.
- Local gaps and storage depletions may vary from basin-level values due to local variations in demands and local availability of supply sources.
- For this baseline analysis, each basin's future demand is met by the basin's available supplies.
- For this baseline analysis, the proportion of future demand supplied by surface water and groundwater for each sector is assumed equal to current proportions.
- The amount of available surface water supplies used for OCWP water supply availability analysis includes changes in historical streamflow due to increased upstream demand, return flows, and increases in out-of-basin supplies from existing infrastructure.
- Analysis of bedrock groundwater supplies is based upon recharge from major aquifers.
- Groundwater storage depletions are defined as the amount that future demands exceed available recharge.
- Median gaps and storage depletions are based only on months with gaps or storage depletions.
- Annual probability is based upon the number of years that a gap or depletion occurs in at least one month of that year.

Reducing Water Needs Through Conservation

Lower Arkansas Region, Basin 82

	2060 Gap/Storage Depletion			2060 Gap/Storage Depletion Probability	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
Conservation Activities[1]	AFY			Percent	
Existing Conditions	0	0	0	0%	0%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	0	0	0%	0%
Moderately Expanded Conservation in M&I Water Use	0	0	0	0%	0%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	0	0%	0%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	0	0	0%	0%

1 Conservation Activities are documented in the OCWP Water Demand Forecast Report

Water Supply Options & Effectiveness

🟩 Typically Effective
🟨 Potentially Effective
🟥 Likely Ineffective
🟪 No Option Necessary

Demand Management

🟪 No option necessary.

Out-of-Basin Supplies

🟪 No option necessary.

Reservoir Use

🟪 No option necessary.

Increasing Reliance on Surface Water

🟪 No option necessary.

Increasing Reliance on Groundwater

🟪 No option necessary.

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Lower Arkansas Region, Basin 82

Reservoir Storage	Diversion
AF	AFY
100	12,600
500	15,300
1,000	17,500
2,500	22,400
5,000	25,900
Required Storage to Meet Growth in Demand (AF)	0
Required Storage to Meet Growth in Surface Water Demand (AF)	0

Notes & Assumptions

- Water quality may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands will vary based on local acceptance of additional conservation and temporary drought management activities.
- Gaps and depletions may be mitigated in individual calendar months without reductions in the annual probability (chance of having shortage during another month).
- River diversion for new or additional reservoir storage is based on a hypothetical on-channel reservoir at the basin outlet. Reported yields will vary depending upon the reservoir location; placement at the basin outlet would likely result in a higher yield.
- Aquifer storage and recovery may provide additional storage or an alternative to surface storage and should be evaluated on a case by case basis.

Glossary

Acre-foot: volume of water that would cover one acre of land to a depth of one foot; equivalent to 43,560 cubic feet or 325,851 gallons.

Alkalinity: measurement of the water's ability to neutralize acids. High alkalinity usually indicates the presence of carbonate, bicarbonates, or hydroxides. Waters that have high alkalinity values are often considered undesirable because of excessive hardness and high concentrations of sodium salts. Waters with low alkalinity have little capacity to buffer acidic inputs and are susceptible to acidification (low pH).

Alluvial aquifer: aquifer with porous media consisting of loose, unconsolidated sediments deposited by fluvial (river) or aeolian (wind) processes, typical of river beds, floodplains, dunes, and terraces.

Alluvial groundwater: water found in an alluvial aquifer.

Alluvium: sediments of clay, silt, gravel, or other unconsolidated material deposited over time by a flowing stream on its floodplain or delta; frequently associated with higher-lying terrace deposits of groundwater.

Appendix B areas: waters of the state into which discharges may be limited and that are located within the boundaries of areas listed in Appendix B of OWRB rules Chapter 45 on Oklahoma's Water Quality Standards (OWQS); including but not limited to National and State parks, forests, wilderness areas, wildlife management areas, and wildlife refuges. Appendix B may include areas inhabited by federally listed threatened or endangered species and other appropriate areas.

Appropriative right: right acquired under the procedure provided by law to take a specific quantity of water by direct diversion from a stream, an impoundment thereon, or a playa lake, and to apply such water to a specific beneficial use or uses.

Aquifer: geologic unit or formation that contains sufficient saturated, permeable material to yield economically significant quantities of water to wells and springs.

Artificial recharge: any man-made process specifically designed for the primary purpose of increasing the amount of water entering into an aquifer.

Attainable uses: best uses achievable for a particular waterbody given water of adequate quality.

Background: ambient condition upstream or upgradient from a facility, practice, or activity that has not been affected by that facility, practice or activity.

Basin: see Surface water basin.

Basin outlet: the furthest downstream geographic point in an OCWP planning basin.

Bedrock aquifer: aquifer with porous media consisting of lithified (semi-consolidated or consolidated) sediments, such as limestone, sandstone, siltstone, or fractured crystalline rock.

Bedrock groundwater: water found in a bedrock aquifer.

Beneficial use: (1) The use of stream or groundwater when reasonable intelligence and diligence are exercised in its application for a lawful purpose and as is economically necessary for that purpose. Beneficial uses include but are not limited to municipal, industrial, agricultural, irrigation, recreation, fish and wildlife, etc., as defined in OWRB rules Chapter 20 on stream water use and Chapter 30 on groundwater use. (2) A classification in OWQS of the waters of the State, according to their best uses in the interest of the public set forth in OWRB rules Chapter 45 on OWQS.

Board: Oklahoma Water Resources Board.

Chlorophyll-a: primary photosynthetic plant pigment used in water quality analysis as a measure of algae growth.

Conductivity: a measure of the ability of water to pass electrical current. High specific conductance indicates high concentrations of dissolved solids.

Conjunctive management: water management approach that takes into account the interactions between groundwaters and surface waters and how those interactions may affect water availability.

Conservation: protection from loss and waste. Conservation of water may mean to save or store water for later use or to use water more efficiently.

Conservation pool: reservoir storage of water for the project's authorized purpose other than flood control.

Consumptive use: a use of water that diverts it from a water supply.

Cultural eutrophication: condition occurring in lakes and streams whereby normal processes of eutrophication are accelerated by human activities.

CWSRF: see State Revolving Fund (SRF).

Dam: any artificial barrier, together with appurtenant works, which does or may impound or divert water.

Degradation: any condition caused by the activities of humans resulting in the prolonged impairment of any constituent of an aquatic environment.

Demand: amount of water required to meet the needs of people, communities, industry, agriculture, and other users.

Demand forecast: estimate of expected water demands for a given planning horizon.

Demand management: adjusting use of water through temporary or permanent conservation measures to meet the water needs of a basin or region.

Demand sectors: distinct consumptive users of the state's waters. For OCWP analysis, seven demand sectors were identified: thermoelectric power, self-supplied residential, self-supplied industrial, oil and gas, municipal and industrial, livestock, and crop irrigation.

Dependable yield: the maximum amount of water a reservoir can dependably supply from storage during a drought of record.

Depletion: a condition that occurs when the amount of existing and future demand for groundwater exceeds available recharge.

Dissolved oxygen: amount of oxygen gas dissolved in a given volume of water at a particular temperature and pressure, often expressed as a concentration in parts of oxygen per million parts of water. Low levels of dissolved oxygen facilitate the release of nutrients from sediments.

Diversion: to take water from a stream or waterbody into a pipe, canal, or other conduit, either by pumping or gravity flow.

Domestic use: in relation to OWRB permitting, the use of water by a natural individual or by a family or household for household purposes, for farm and domestic animals up to the normal grazing capacity of the land whether or not the animals are actually owned by such natural individual or family, and for the irrigation of land not exceeding a total of three acres in area for the growing of gardens, orchards, and lawns. Domestic use also includes: (1) the use of water for agriculture purposes by natural individuals, (2) use of water for fire protection, and (3) use of water by non-household entities for drinking water purposes, restroom use, and the watering of lawns, provided that the amount of water used for any such purposes does not exceed five acre-feet per year.

Drainage area: total area above the discharge point drained by a receiving stream.

DWSRF: see State Revolving Fund (SRF).

Drought management: short-term measures to conserve water to sustain a basin's or region's needs during times of below normal rainfall.

Ecoregion (ecological region): an ecologically and geographically defined area; sometimes referred to as a bioregion.

Effluent: any fluid emitted by a source to a stream, reservoir, or basin, including a partially or completely treated waste fluid that is produced by and flows out of an industrial or wastewater treatment plant or sewer.

Elevation: elevation in feet in relation to mean sea level (MSL).

Equal proportionate share (EPS): portion of the maximum annual yield of water from a groundwater basin that is allocated to each acre of land overlying the basin or subbasin.

Eutrophic: a water quality characterization, or "trophic status," that indicates abundant nutrients and high rates of productivity in a lake, frequently resulting in oxygen depletion below the surface.

Eutrophication: the process whereby the condition of a waterbody changes from one of low biologic productivity and clear water to one of high productivity and water made turbid by the accelerated growth of algae.

Flood control pool: reservoir storage of excess runoff above the conservation pool storage capacity that is discharged at a regulated rate to reduce potential downstream flood damage.

Floodplain: the land adjacent to a body of water which has been or may be covered by flooding, including, but not limited to, the one-hundred year flood (the flood expected to be equaled or exceeded every 100 years on average).

Fresh water: water that has less than five thousand (5,000) parts per million total dissolved solids.

Gap: an anticipated shortage in supply of surface water due to a deficiency of physical water supply or the inability or failure to obtain necessary water rights.

Groundwater: fresh water under the surface of the earth regardless of the geologic structure in which it is standing or moving outside the cut bank of a definite stream.

Groundwater basin: a distinct underground body of water overlain by contiguous land having substantially the same geological and hydrological characteristics and yield capabilities. The area boundaries of a major or minor basin can be determined by political boundaries, geological, hydrological, or other reasonable physical boundaries.

Groundwater recharge: see Recharge.

Hardness: a measure of the mineral content of water. Water containing high concentrations (usually greater than 60 ppm) of iron, calcium, magnesium, and hydrogen ions is usually considered "hard water."

High Quality Waters (HQW): a designation in the OWQS referring to waters that exhibit water quality exceeding levels necessary to support the propagation of fishes, shellfishes, wildlife, and recreation in and on the water. This designation prohibits any new point source discharge or additional load or increased concentration of specified pollutants.

Hydraulic conductivity: the capacity of rock to transmit groundwater under pressure.

Hydrologic unit code: a numerical designation utilized by the United States Geologic Survey and other federal and state agencies as a way of identifying all drainage basins in the U.S. in a nested arrangement from largest to smallest, consisting of a multi-digit code that identifies each of the levels of classification within two-digit fields.

Hypereutrophic: a surface water quality characterization, or "trophic status," that indicates excessive primary productivity and excessive nutrient levels in a lake.

Impaired water: waterbody in which the quality fails to meet the standards prescribed for its beneficial uses.

Impoundment: body of water, such as a pond or lake, confined by a dam, dike, floodgate, or other barrier established to collect and store water.

Infiltration: the gradual downward flow of water from the surface of the earth into the subsurface.

Instream flow: a quantity of water to be set aside in a stream or river to ensure downstream environmental, social, and economic benefits are met (further defined in the OCWP *Instream Flow Issues & Recommendations* report).

Interbasin transfer: the physical conveyance of water from one basin to another.

Levee: a man-made structure, usually an earthen embankment, designed and constructed to contain, control, or divert the flow of water so as to provide protection from temporary flooding.

Major groundwater basin: a distinct underground body of water overlain by contiguous land and having essentially the same geological and hydrological characteristics and from which groundwater wells yield at least fifty (50) gallons per minute on the average basinwide if from a bedrock aquifer, and at least one hundred fifty (150) gallons per minute on the average basinwide if from an alluvium and terrace aquifer, or as otherwise designated by the OWRB.

Marginal quality water: waters that have been historically unusable due to technological or economic issues associated with diversion, treatment, or conveyance.

Maximum annual yield (MAY): determination by the OWRB of the total amount of fresh groundwater that can be produced from each basin or subbasin allowing a minimum twenty-year life of such basin or subbasin.

Mesotrophic: a surface water quality characterization, or "trophic status," describing those lakes with moderate primary productivity and moderate nutrient levels.

Million gallons per day (mgd): a rate of flow equal to 1.54723 cubic feet per second or 3.0689 acre-feet per day.

Minor groundwater basin: a distinct underground body of water overlain by contiguous land and having substantially the same geological and hydrological characteristics and which is not a major groundwater basin.

Nitrogen limited: in reference to water chemistry, where growth or amount of primary producers (e.g., algae) is restricted in a waterbody due in large part to available nitrogen.

Non-consumptive use: use of water in a manner that does not reduce the amount of supply, such as navigation, hydropower production, protection of habitat for hunting, maintaining water levels for boating recreation, or maintaining flow, level and/or temperature for fishing, swimming, habitat, etc.

Nonpoint source (NPS): a source of pollution without a well-defined point of origin. Nonpoint source pollution is commonly caused by sediment, nutrients, and organic or toxic substances originating from land use activities. It occurs when the rate of material entering a waterbody exceeds its natural level.

Normal pool elevation: the target lake elevation at which a reservoir was designed to impound water to create a dependable water supply; sometimes referred to as the top of the conservation pool.

Normal pool storage: volume of water held in a reservoir when it is at normal pool elevation.

Numerical criteria: concentrations or other quantitative measures of chemical, physical or biological parameters that are assigned to protect the beneficial use of a waterbody.

Numerical standard: the most stringent of the OWQS numerical criteria assigned to the beneficial uses for a given stream.

Nutrient-impaired reservoir: reservoir with a beneficial use or uses impaired by human-induced eutrophication as determined by a Nutrient-Limited Watershed Impairment Study.

Nutrient-Limited Watershed (NLW): watershed of a waterbody with a designated beneficial use that is adversely affected by excess nutrients as determined by a Carlson's Trophic State Index (using chlorophyll-a) of 62 or greater, or is otherwise listed as "NLW" in Appendix A of the OWQS.

Nutrients: elements or compounds essential as raw materials for an organism's growth and development; these include carbon, oxygen, nitrogen, and phosphorus.

Oklahoma Water Quality Standards (OWQS): rules promulgated by the OWRB in Oklahoma Administrative Code Title 785, Chapter 45, which establish classifications of uses of waters of the state, criteria to maintain and protect such classifications, and other standards or policies pertaining to the quality of such waters.

Oligotrophic: a surface water quality characterization, or "trophic status," describing those lakes with low primary productivity and/or low nutrient levels.

Outfall: a point source that contains the effluent being discharged to the receiving water.

Percolation: the movement of water through unsaturated subsurface soil layers, usually continuing downward to the groundwater or water table (distinguished from Seepage).

Permit availability: the amount of water that could be made available for withdrawals under permits issued in accordance with Oklahoma water law.

pH: the measurement of the hydrogen-ion concentration in water. A pH below 7 is acidic (the lower the number, the more acidic the water, with a decrease of one full unit representing an increase in acidity of ten times) and a pH above 7 (to a maximum of 14) is basic (the higher the number, the more basic the water). In Oklahoma, fresh waters typically exhibit a pH range from 5.5 in the southeast to almost 9.0 in central areas.

Phosphorus limited: in reference to water chemistry, where growth or amount of primary producers (e.g., algae) is restricted in a waterbody due in large part to the amount of available phosphorus.

Physical water availability: amount of water currently in streams, rivers, lakes, reservoirs, and aquifers; sometimes referred to as "wet water."

Point source: any discernible, confined and discrete conveyance, including any pipe, ditch, channel, tunnel, well, discrete fissure, container, rolling stock or concentrated animal feeding operation from which pollutants are or may be discharged. This term does not include return flows from irrigation agriculture.

Potable: describing water suitable for drinking.

Primary Body Contact Recreation (PBCR): a classification in OWQS of a waterbody's use; involves direct body contact with the water where a possibility of ingestion exists. In these cases, the water shall not contain chemical, physical or biological substances in concentrations that irritate the skin or sense organs or are toxic or cause illness upon ingestion by human beings.

Primary productivity: the production of chemical energy in organic compounds by living organisms. In lakes and streams, this is essentially the lowest denominator of the food chain (phytoplankton) bringing energy into the system via photosynthesis.

Prior groundwater right: comparable to a permit, a right to use groundwater recognized by the OWRB as having been established by compliance with state groundwater laws in effect prior to 1973.

Provider: private or public entity that supplies water to end users or other providers. For OCWP analyses, "public water providers" included approximately 785 non-profit, local governmental municipal or community water systems and rural water districts.

Recharge: the inflow of water to an alluvial or bedrock aquifer.

Reservoir: a surface depression containing water impounded by a dam.

Return water or return flow: the portion of water diverted from a water supply that returns to a watercourse.

Reverse osmosis: a process that removes salts and other substances from water. Pressure is placed on the stronger of two unequal concentrations separated by a semi-permeable membrane; a common method of desalination.

Riparian water right (riparian right): the right of an owner of land adjoining a stream or watercourse to use water from that stream for reasonable purposes.

Riverine: relating to, formed by, or resembling a river (including tributaries), stream, etc.

Salinity: the concentration of salt in water measured in milligrams per liter (mg/L) or parts per million (ppm).

Salt water: any water containing more than five thousand (5,000) parts per million total dissolved solids.

Saturated thickness: thickness below the zone of the water table in which the interstices are filled with groundwater.

Scenic Rivers: streams in "Scenic River" areas designated by the Oklahoma Legislature that possess unique natural scenic beauty, water conservation, fish, wildlife and outdoor recreational values. These areas are listed and described in Title 82 of Oklahoma Statutes, Section 1451.

Sediment: particles transported and deposited by water deriving from rocks, soil, or biological material.

Seepage: the movement of water through saturated material often indicated by the appearance or disappearance of water at the ground surface, as in the loss of water from a reservoir through an earthen dam (distinguished from Percolation).

Sensitive sole source groundwater basin or subbasin: a major groundwater basin or subbasin all or a portion of which has been designated by the U.S. Environmental Protection Agency (EPA) as a "Sole Source Aquifer" and serves as a mechanism to protect drinking water supplies in areas with limited water supply alternatives. It includes any portion of a contiguous aquifer located within five miles of the known areal extent of the surface outcrop of the designated groundwater basin or subbasin.

Sensitive Water Supplies (SWS): designation that applies to public and private water supplies possessing conditions that make them more susceptible to pollution events. This designation restricts point source discharges in the watershed and institutes a 10 µg/L (micrograms per liter) chlorophyll-a criterion to protect against taste and odor problems and reduce water treatment costs.

Soft water: water that contains little to no magnesium or calcium salts.

State Revolving Fund (SRF): fund or program used to provide loans to eligible entities for qualified projects in accordance with Federal law, rules and guidelines administered by the EPA and state. Two separate SRF programs are administered in Oklahoma: the Clean Water SRF is intended to control water pollution and is administered by OWRB; the Drinking Water SRF was created to provide safe drinking water and is administered jointly by the OWRB and ODEQ.

Storm sewer: a sewer specifically designed to control and convey stormwater, surface runoff, and related drainage.

Stream system: drainage area of a watercourse or series of watercourses that converges in a large watercourse with defined boundaries.

Stream water: water in a definite stream that includes water in ponds, lakes, reservoirs, and playa lakes.

Streamflow: the rate of water discharged from a source indicated in volume with respect to time.

Surface water: water in streams and waterbodies as well as diffused over the land surface.

Surface water basin: geographic area drained by a single stream system. For OCWP analysis, Oklahoma has been divided into 82 surface water basins (also referenced as "planning basins").

Temporary permit: for groundwater basins or subbasins for which a maximum annual yield has not been determined, temporary permits are granted to users allocating two acre-feet of water per acre of land per year. Temporary permits are for one-year terms that can be revalidated annually by the permittee. When the maximum annual yield and equal proportionate share are approved by the OWRB, all temporary permits overlying the studied basin are converted to regular permits at the new approved allocation amount.

Terrace deposits: fluvial or wind-blown deposits occurring along the margin and above the level of a body of water and representing the former floodplain of a stream or river.

Total dissolved solids (TDS): a measure of the amount of dissolved material in the water column, reported in mg/L, with values in fresh water naturally ranging from 0-1000 mg/L. High concentrations of TDS limit the suitability of water as a drinking and livestock watering source as well as irrigation supply.

Total maximum daily load (TMDL): sum of individual wasteload allocations for point sources, safety reserves, and loads from nonpoint source and natural backgrounds.

Total nitrogen: for water quality analysis, a measure of all forms of nitrogen (organic and inorganic). Excess nitrogen can lead to harmful algae blooms, hypoxia, and declines in wildlife and habitat.

Total phosphorus: for water quality analysis, a measure of all forms of phosphorus, often used as an indicator of eutrophication and excessive productivity.

Transmissivity: measure of how much water can be transmitted horizontally through an aquifer. Transmissivity is the product of hydraulic conductivity of the rock and saturated thickness of the aquifer.

Tributary: stream or other body of water, surface or underground, that contributes to another larger stream or body of water.

Trophic State Index (TSI): one of the most commonly used measurements to compare lake trophic status, based on algal biomass. Carlson's TSI uses chlorophyll-a concentrations to define the level of eutrophication on a scale of 1 to 100, thus indicating the general biological condition of the waterbody.

Trophic status: a lake's trophic state, essentially a measure of its biological productivity. The various trophic status levels (Oligotrophic, Mesotrophic, Eutrophic, and Hypereutrophic) provide a relative measure of overall water quality conditions in a lake.

Turbidity: a combination of suspended and colloidal materials (e.g., silt, clay, or plankton) that reduce the transmission of light through scattering or absorption. Turbidity values are generally reported in Nephelometric Turbidity Units (NTUs).

Vested stream water right (vested right): comparable to a permit, a right to use stream water recognized by the OWRB as having been established by compliance with state stream water laws in effect prior to 1963.

Waste by depletion: unauthorized use of wells or groundwater; drilling a well, taking, or using fresh groundwater without a permit, except for domestic use; taking more fresh groundwater than is authorized by permit; taking or using fresh groundwater so that the water is lost for beneficial use; transporting fresh groundwater from a well to the place of use in such a manner that there is an excessive loss in transit; allowing fresh groundwater to reach a pervious stratum and be lost into cavernous or otherwise pervious materials encountered in a well; drilling wells and producing fresh groundwater there from except in accordance with well spacing requirements; or using fresh groundwater for air conditioning or cooling purposes without providing facilities to aerate and reuse such water.

Waste by pollution: permitting or causing the pollution of a fresh water strata or basin through any act that will permit fresh groundwater polluted by minerals or other waste to filter or intrude into a basin or subbasin, or failure to properly plug abandoned fresh water wells.

Water quality: physical, chemical, and biological characteristics of water that determine diversity, stability, and productivity of the climax biotic community or affect human health.

Water right: right to the use of stream or groundwater for beneficial use reflected by permits or vested rights for stream water or permits or prior rights for groundwater.

Wastewater reuse: treated municipal and industrial wastewater captured and reused commonly for non-potable irrigation and industrial applications to reduce demand upon potable water systems.

Water supply: a body of water, whether static or moving on or under the surface of the ground, or in a man-made reservoir, available for beneficial use on a dependable basis.

Water supply availability: for OCWP analysis, the consideration of whether or not water is available that meets three necessary requirements: physical water is present, the water is of a usable quality, and a water right or permit to use the water has been or can be obtained.

Water supply options: alternatives that a basin or region may implement to meet changing water demands. For OCWP analysis, "primary options" include demand management, use of out-of-basin supplies, reservoir use, increasing reliance on surface water, and increasing reliance on groundwater; "expanded options" include expanding conservation measures, artificial aquifer recharge, use of marginal quality water sources, and potential reservoir development.

Water table: The upper surface of a zone of saturation; the upper surface of the groundwater.

Waterbody: any specified segment or body of waters of the state, including but not limited to an entire stream or lake or a portion thereof.

Watercourse: the channel or area that conveys a flow of water.

Waters of the state: all streams, lakes, ponds, marshes, watercourses, waterways, wells, springs, irrigation systems, drainage systems, and other bodies or accumulations of water, surface and underground, natural or artificial, public or private, which are contained within, flow through, or border upon the state.

Watershed: the boundaries of a drainage area of a watercourse or series of watercourses that diverge above a designated location or diversion point determined by the OWRB.

Well: any type of excavation for the purpose of obtaining groundwater or to monitor or observe conditions under the surface of the earth; does not include oil and gas wells.

Well yield: amount of water that a water supply well can produce (usually in gpm), which generally depends on the geologic formation and well construction.

Wholesale: for purposes of OCWP Public Water Provider analyses, water sold from one public water provider to another.

Withdrawal: water removed from a supply source.

AF: acre-foot or acre-feet

AFD: acre-feet per day

AFY: acre-feet per year

BMPs: best management practices

BOD: biochemical oxygen demand

cfs: cubic feet per second

CWAC: Cool Water Aquatic Community

CWSRF: Clean Water State Revolving Fund

DO: dissolved oxygen

DWSRF: Drinking Water State Revolving Fund

EPS: equal proportionate share

FACT: Funding Agency Coordinating Team

gpm: gallons per minute

HLAC: Habitat Limited Aquatic Community

HQW: High Quality Waters

HUC: hydrologic unit code

M&I: municipal and industrial

MAY: maximum annual yield

mgd: million gallons per day

µS/cm: microsiemens per centimeter (see specific conductivity)

mg/L: milligrams per liter

NLW: nutrient-limited watershed

NPS: nonpoint source

NPDES: National Pollutant Discharge Elimination System

NRCS: Natural Resources Conservation Service

NTU: Nephelometric Turbidity Unit (see “Turbidity”)

OCWP: Oklahoma Comprehensive Water Plan

ODEQ: Oklahoma Department of Environmental Quality

O&G: Oil and Gas

ORW: Outstanding Resource Water

OWQS: Oklahoma Water Quality Standards

OWRB: Oklahoma Water Resources Board

PBCR: Primary Body Contact Recreation

pH: hydrogen ion activity

ppm: parts per million

RD: Rural Development

REAP: Rural Economic Action Plan

SBCR: Secondary Body Contact Recreation

SDWIS: Safe Drinking Water Information System

SRF: State Revolving Fund

SSI: Self-Supplied Industrial

SSR: Self-Supplied Residential

SWS: Sensitive Water Supply

TDS: total dissolved solids

TMDL: total maximum daily load

TSI: Trophic State Index

TSS: total suspended solids

USACE: United States Army Corps of Engineers

USEPA: United States Environmental Protection Agency

USGS: United States Geological Survey

WLA: wasteload allocation

WWAC: Warm Water Aquatic Community

Water Quantity Conversion Factors

		Desired Unit				
		CFS	GPM	MGD	AFY	AFD
Initial Unit	CFS	—	450	.646	724	1.98
	GPM	.00222	—	.00144	1.61	.00442
	MGD	1.55	695	—	1120	3.07
	AFY	.0014	.62	.00089	—	.00274
	AFD	.504	226	.326	365	—

EXAMPLE: Converting from MGD to CFS. To convert from an initial value of 140 MGD to CFS, multiply 140 times 1.55 to come up with the desired conversion, which would be 217 CFS (140 X 1.55 = 217).

CFS: cubic feet per second
GPM: gallons per minute
MGD: millions gallons per day

AFY: acre-feet per year
AFD: acre-feet per day

1 acre-foot: 325,851 gallons

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