OCWP

Upper 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

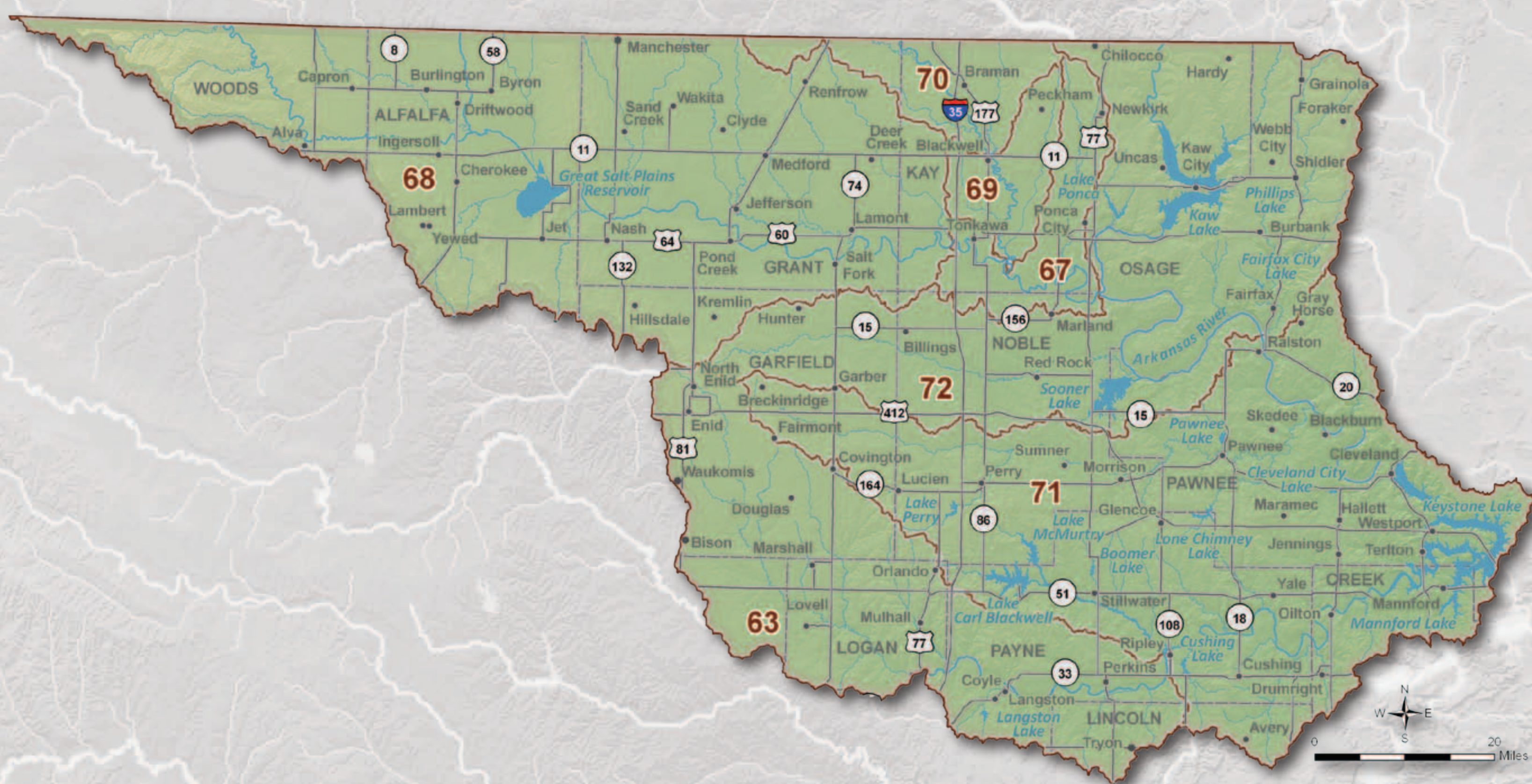
OCWP

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.

Cover photo: Keystone Lake

Oklahoma Comprehensive Water Plan

Upper Arkansas Watershed Planning Region



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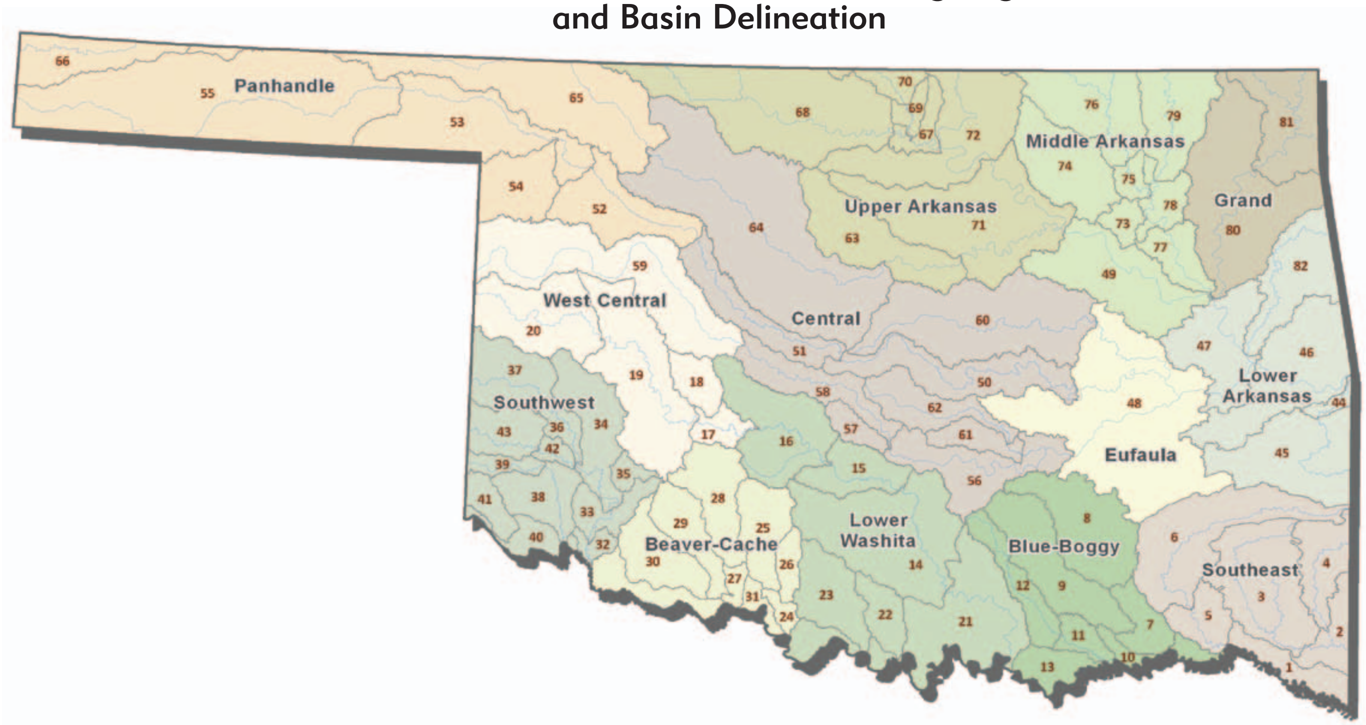


Introduction

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 Upper 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 Upper Arkansas Watershed Planning Region includes seven basins (numbered 63 and 67-72 for reference). The region encompasses 7,452 square miles in northern Oklahoma, spanning from the northeast portion of Woods County to the northwest portion of Creek County and also including all or portions of Alfalfa, Grant, Kay, Osage, Garfield, Noble, Pawnee, Kingfisher, Logan, Payne, Tulsa, and Lincoln Counties.

The region is located primarily in the Central Lowland physiography province. The terrain is dominated by broad, level-to-slightly rolling plains, with rougher, broken plains in the southern area of the region and transitioning to the rolling hills, ridges, and steep-sided valleys of the Flint Hills to the east. The Upper Arkansas Region is a mix of cropland and rangeland, with mixed prairie grasses giving way to densely forested bottomland in the east.

The climate is moist and sub-humid with the mean annual temperature of around 60°F. Annual average precipitation ranges from 24 inches in the northwest to 42 inches in the east. Rainfall peaks in the spring and fall, with May being the wettest month of the year. Annual evaporation ranges from 62 inches in the west to 55 inches in the east and often exceeds precipitation on an annual basis. Frequent droughts cause severe crop damage, but severe flooding can also occur as the result of heavy rainfall events. Thunderstorms accompanied by high winds, hail, and heavy rain increase the likelihood of flash flooding, emphasizing the necessity of watershed protection and flood prevention projects.

The largest cities in the region include Enid (2010 population 49,379), Stillwater (45,688), Ponca City (25,387), Blackwell (7,092), and Cushing (7,826). The greatest demand is from Municipal and Industrial and Thermoelectric water use.

By 2060, this region is projected to have a total demand of 182,770 acre-feet per year (AFY), an increase of approximately 54,200 AFY (42%) from 2010.

Upper Arkansas Regional Summary

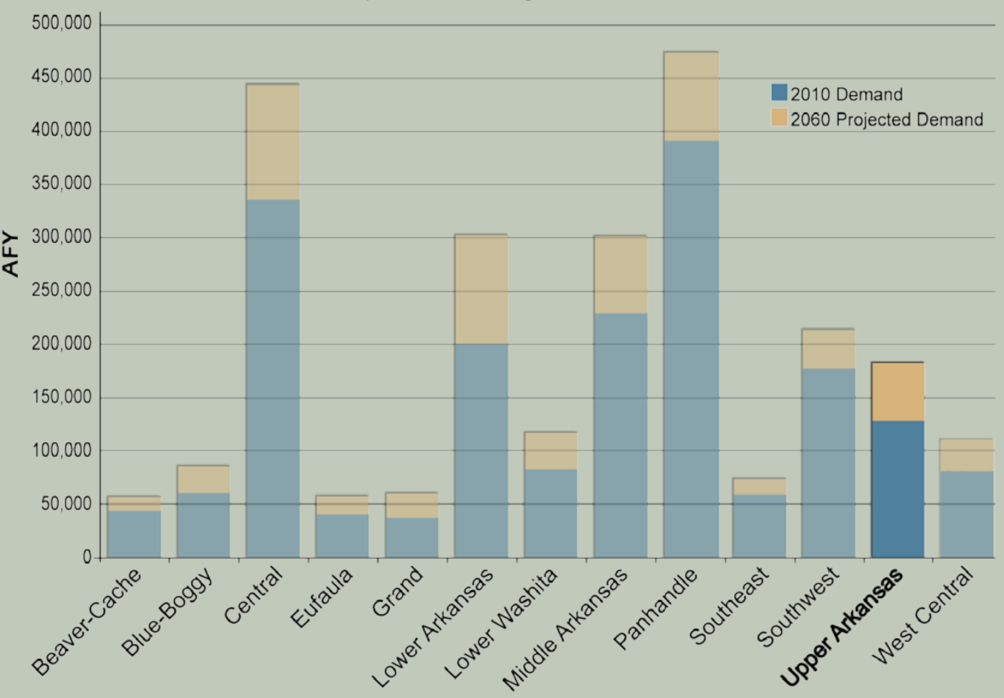
Synopsis

- The Upper Arkansas Watershed Planning Region relies primarily on surface water supplies, and to a lesser extent, bedrock groundwater and alluvial aquifers.
- It is anticipated that water users in the region will continue to rely on these sources to meet future demand.
- By 2020, surface water supplies will be insufficient to meet demand in several basins.
- Groundwater storage depletions may lead to higher pumping costs, the need for deeper wells, and changes in well yields or water quality in same basins.
- To reduce the risk of adverse impacts on water supplies, it is recommended that surface water gaps and groundwater storage depletions be decreased where economically feasible.
- Additional conservation could reduce surface water gaps, alluvial groundwater storage depletions, and bedrock groundwater storage depletions.
- Aquifer recharge and recovery could be considered to store variable surface water supplies, increase alluvial or bedrock groundwater storage, and reduce adverse effects of localized storage depletions in Basins 63 and 68.
- Surface water alternatives, such as groundwater supplies and/or developing new small reservoirs, could mitigate gaps without major impacts to groundwater storage.

Upper Arkansas Region Demand Summary

Current Water Demand:	128,570 acre-feet/year (7% of state total)		
Largest Demand Sector:	Municipal & Industrial (37% of regional total)		
Current Supply Sources:	69% SW	24% Alluvial GW	7% Bedrock GW
Projected Demand (2060):	182,770 acre-feet/year		
Growth (2010-2060):	54,200 acre-feet/year (42%)		

Current and Projected Regional Water Demand



The Upper Arkansas Region accounts for 7% of the state's total water demand. The largest demand sectors are currently Municipal and Industrial (37%), Thermoelectric Power (29%), and Crop Irrigation (15%).

Water Resources & Limitations

Surface Water

Surface water is used to meet about 69% of the region's demand. The region is supplied by three major rivers: the Arkansas, Cimarron, and Salt Fork of the Arkansas. Historically, the region's rivers and creeks have periods of low to no flow in any month of the year due to seasonal and long-term trends in precipitation. Large reservoirs have been built on several rivers and their tributaries to provide public water supply, flood control, power generation, and recreation. Large reservoirs in the Upper Arkansas Region include: Keystone, Kaw, Sooner, Carl Blackwell, and Great Salt Plains. There are ten additional municipal lakes that have normal pools ranging from 1,795 AF to 19,733 AF.

Relative to other regions, surface water quality in the region is considered poor to fair. 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), chloride, sulfate, and chlorophyll-a. These impairments are scheduled to be addressed through the Total Maximum Daily Loads (TMDL) process, but use of these supplies may be limited in the interim.

The availability of permits is not expected to constrain the use of surface water supplies to meet local demand through 2060.

Alluvial Groundwater

Alluvial groundwater is used to meet 24% of the demand in the region. The majority of currently permitted withdrawals are from the Arkansas River and the Salt Fork of the Arkansas River aquifers. If alluvial groundwater continues to supply a similar portion of demand in the future, storage depletions are likely to occur throughout the year, although these projected depletions will be small relative to the amount of water in storage. The largest storage depletions are projected to occur in the summer.

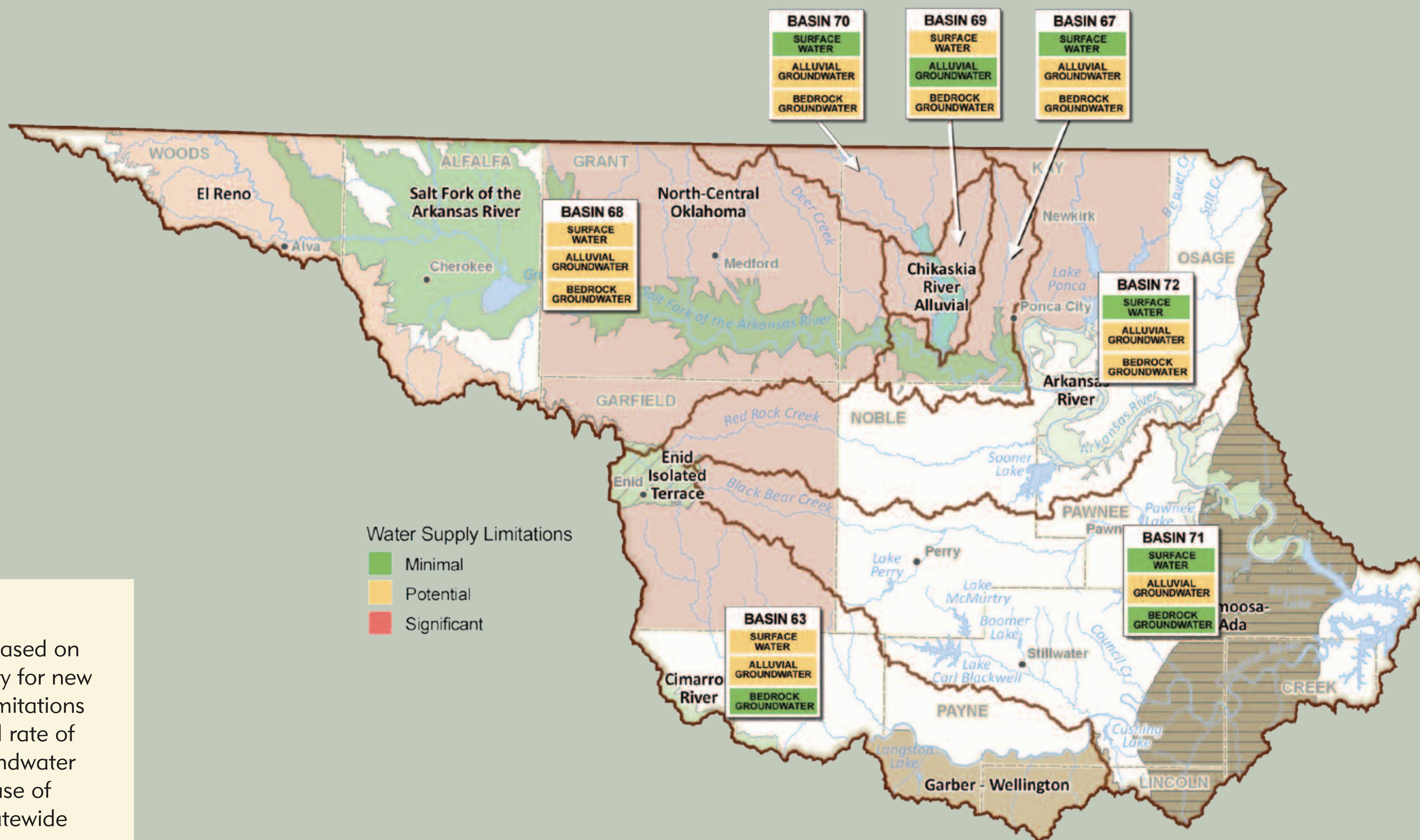
The availability of permits is not expected to constrain the use of alluvial groundwater supplies to meet local demand through 2060.

Bedrock Groundwater

Bedrock groundwater is used to meet 7% of the demand in the region. Currently permitted and projected withdrawals are primarily from the Vamoosa-Ada aquifer and North -Central Oklahoma minor aquifer. The Vamoosa-Ada has about 3.6 million acre-feet (AF) of groundwater storage in the region. Beginning in 2020, bedrock aquifer storage depletions are likely to occur throughout the year in Basin 68, but will be largest in the summer months. By 2060, bedrock aquifer depletions will occur during the summer in Basin 72. These bedrock groundwater withdrawals are expected to be from the North-Central Oklahoma minor bedrock aquifer, which may be limited by low well yields.

The availability of permits is not expected to constrain the use of bedrock groundwater supplies to meet local demand through 2060.

Water Supply Limitations
Upper Arkansas Region



Water Supply Limitations

Surface water limitations are determined based on physical availability, water supply availability for new permits, and water quality. Groundwater limitations are determined 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; 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 are 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

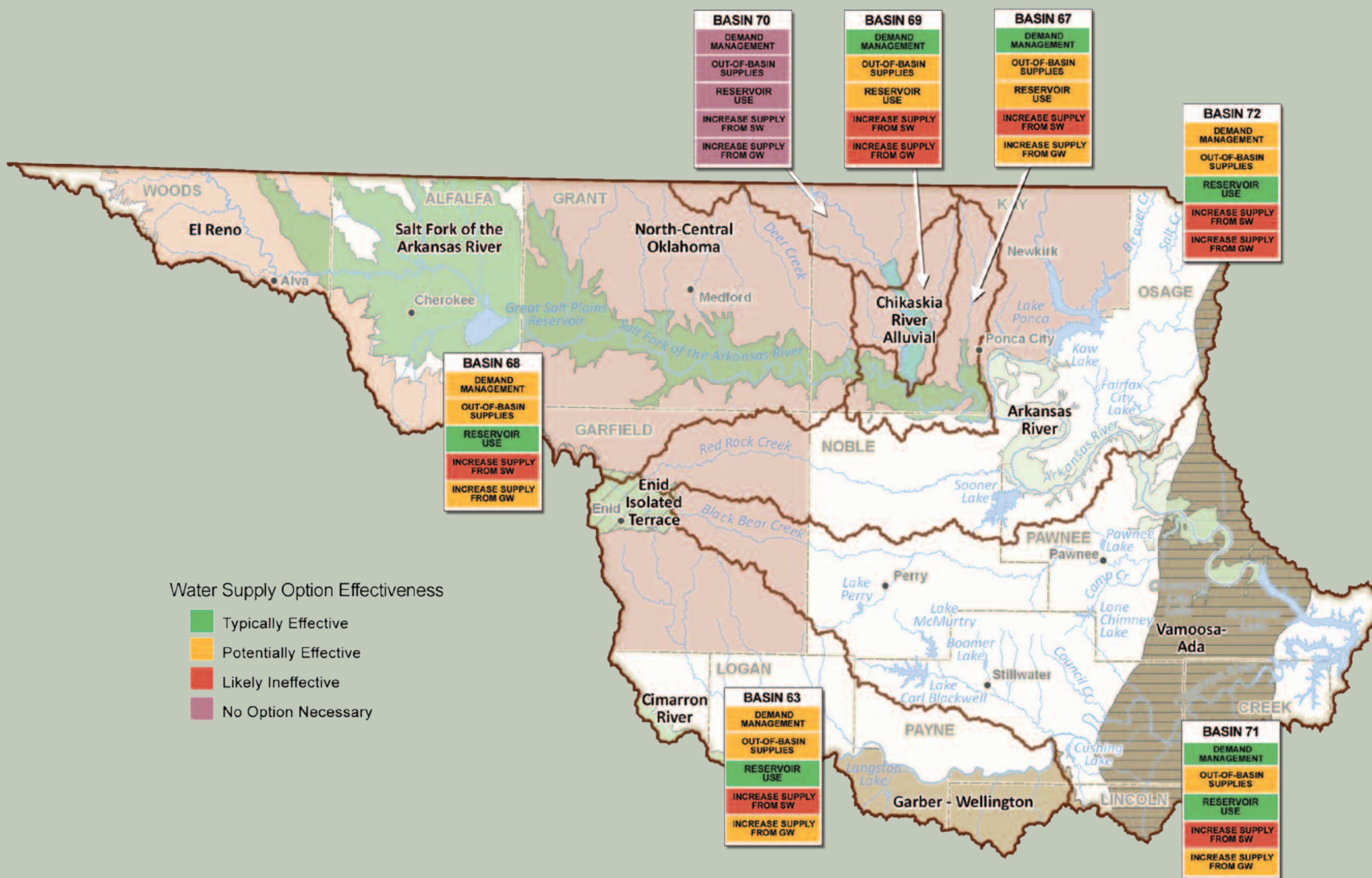
To quantify physical surface water gaps and groundwater storage depletions through 2060, use of local supplies was assumed to continue in the current (2010) proportions. Basins and users that rely on surface water are projected to have physical surface water supply shortages (gaps) in the future, except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

Water conservation could aid in reducing projected surface water gaps and groundwater storage depletions or delaying the need for additional infrastructure. Moderately expanded conservation, primarily through public water suppliers and increased irrigation efficiency, could reduce surface water gaps and storage depletions, and in Basins 67 and 69, eliminate gaps and alluvial depletions. Further future reductions could occur from substantially expanded conservation activities, which would include a shift from crops with high water demand (e.g., corn for grain and forage crops) to low water demand crops (e.g., sorghum or wheat for grain), along with increased efficiency and public water supply conservation. Due to extended dry periods and predominant use of surface water supplies, drought management measures alone will likely be an ineffective water supply option.

New reservoirs and expanded use of existing reservoirs could enhance the dependability of surface water supplies and eliminate gaps. Keystone and Kaw have unpermitted yield that could supply new users. However, poor water quality limits Keystone's use as a public supply source. The OCWP *Reservoir Viability Study* evaluated the potential for reservoirs throughout the state. Eight reservoirs were identified in the Upper Arkansas Region as having potential for future consideration. These sources could serve as regional or inter-regional supplies to provide additional water to mitigate the region's groundwater depletions. Due to the distance from the reservoirs to demand points, this water supply option may not be cost-effective for many users.

The projected growth in surface water could instead be supplied in part by increased use of aquifers, which would result in minimal increases in projected groundwater depletions. Increased demands would still leave users susceptible to the adverse effects of localized depletions.

Water Supply Option Effectiveness
Upper 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 been the primary source of supply used to meet demand in the Upper Arkansas Region. The region's major streams include the Cimarron River, the Chikaskia River, the Salt Fork of the Arkansas River, and the Arkansas River. Streams in this region generally have abundant flows, but can experience periods of low flow conditions as well as periodic flooding events.

The Arkansas River mainstem originates in Kansas and flows into Oklahoma in the Upper Arkansas Region. It runs for 110 miles through Basins 71 and 72 before flowing into the Middle Arkansas Region. Other major tributaries to the Arkansas River mainstem include Black Bear Creek (about 100 miles in Basin 71) and Red Rock Creek (80 miles in Basin 72).

The Salt Fork of the Arkansas River originates in Kansas and flows 50 miles through Basins 68 and 67 before joining the Arkansas River at the outlet of Basin 67. Major tributaries include Pond Creek (60 miles in Basin 68) and the Medicine Lodge River (14 miles in Basin 68).

The Cimarron River flows into the Upper Arkansas Region from the Central Region. It flows for 120 miles through Basins 63 and 71 before joining the Arkansas River. Major tributaries include Skeleton Creek (70 miles in Basin 62).

In the Upper Arkansas Region, streamflow is generally abundant with intermittent periods of low flow; streams in some parts of the region go dry in the late summer.

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. The largest are Keystone and Kaw, built by the U.S. Army Corps of Engineers in 1964 and 1976, respectively.

Keystone Lake, located on the mainstem of the Arkansas River in Basin 71, is authorized for flood control, water supply, hydroelectric power, navigation, and fish and wildlife. Water is released for power generation and to aid navigation on the McClellan-Kerr Arkansas River Navigation system. Poor water quality limits its use for public water supply. Most of the currently permitted water is used by the Public Service Company of Oklahoma for cooling water at its Tulsa plant.

Kaw Lake is also located on the mainstem of the Arkansas River in Basin 72. The lake is authorized

Reservoirs

Upper 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
Boomer	71	City of Stillwater	1932	CW, R	3,200	---	---	---	---	---	---	---	---
Carl Blackwell	70	Oklahoma State University	1937	WS. R	61,500	55,000	7,000	0	0	0	0	12,520	0
Cleveland City	71	City of Cleveland	1936	WS, R	2,200	---	---	---	---	---	---	---	---
Cushing	71	City of Cushing	1950	WS, R	3,304	---	---	---	---	---	---	---	---
Fairfax City	72	City of Fairfax	1936	WS, R	1,795	---	---	---	---	---	---	---	---
Great Salt Plains	68	USACE	1941	FC, C, FW	31,420	0	0	0	0	0	0	0	No Yield
Kaw	72	USACE	1976	FC, WS, HP, WQ, R, FW	428,600	171,200	187,040	0	0	31,800	43,680	141,403	45,637
Keystone	71	USACE	1964	FC, WS, HP, N, FW	557,600	20,000	22,400	0	0	0	0	13,968	8,452
Langston	63	City of Langston	1966	WS, FC, R	5,792	---	---	0	0	0	0	1,500	---
Lone Chimney	71	Tri-County Development Authority	1984	WS, FC, R	6,200	---	2,509	0	0	0	0	2,507	2
McMurtry	71	City of Stillwater	1971	WS, FC, R	19,733	13,500	3,002	0	0	0	0	2,649	353
Pawnee	71	City of Pawnee	1932	WS, R	3,855	---	---	---	---	---	---	---	---
Perry	71	City of Perry	1937	WS, FC, R	6,358	---	---	0	0	0	0	2,270	---
Ponca	72	City of Ponca City	1935	WS, R	14,440	15,300	2,529	0	0	0	0	2,529	0
Sooner	72	Oklahoma Gas and Electric Co.	1972	CW	149,000	149,000	3,600	0	0	0	0	3,600	0

1 Purpose refers to the use(s) for reservoir storage as authorized by the funding entity or dam owner(s) at the time of construction.
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
No known information is annotated as "---"

Surface Water Resources
Upper Arkansas Region

Existing reservoirs in this region provide enough storage and yield for the region's future demand. However, existing water rights would need to be taken into consideration for future planning purposes, and expanded water transmission infrastructure would be required. Modified reservoir operations or reallocation of assigned storage may provide additional flexibility to meet future water needs. 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.

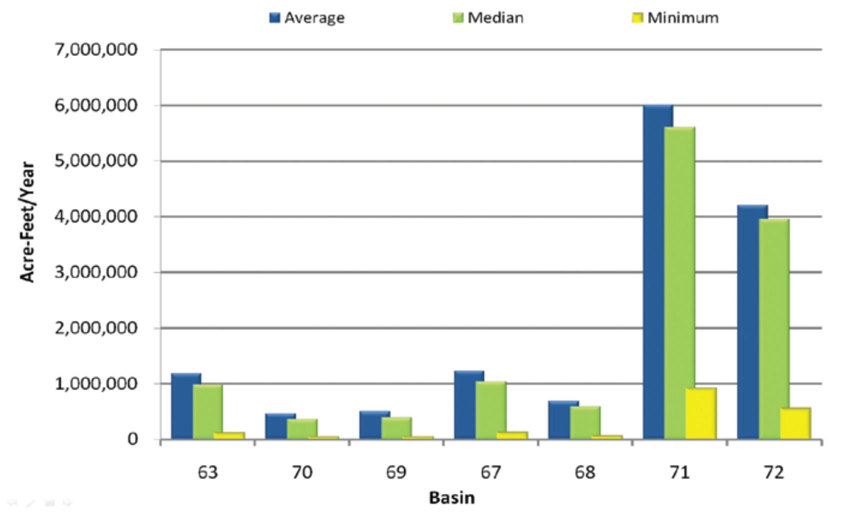
More information is available in the OCWP *Physical Water Supply Availability Report* on the OWRB website.

for flood control, water supply, hydropower, water quality, recreation, and fish and wildlife purposes. The reservoir also provides a substantial amount of water to OG&E for power generation purposes. Water quality in the reservoir is fair and suitable for most purposes.

Other major municipal lakes in the region include Langston Lake in Basin 63; Lone Chimney, Perry, Cleveland City, Cushing, Pawnee, McMurtry, and Carl Blackwell lakes in Basin 71; and Fairfax City and Ponca lakes in Basin 72. In addition, Boomer Lake primarily provides cooling water and recreational opportunities in the Stillwater area in Basin 71. Sooner Lake, located on Greasy Creek Tributary to the Arkansas River in Basin 72, is a cooling water lake owned and operated by OG&E. Great Salt Plans Lake is located on the Salt Fork of the Arkansas River in Basin 68. Except for 761 acres near the dam, which is operated by the Corps of Engineers, the Great Salt Plains National Wildlife Refuge is administered by the U.S. Fish and Wildlife Services. Due to high mineral content, the lake is not used for most beneficial purposes. There are many other small Natural Resources Conservation Service (NRCS) and municipal and privately owned lakes in the region that provide water for water supply, recreation, and flood control.

Surface Water Flows (1950-2007)

Upper Arkansas Region



Surface water is the main source of supply in the Upper 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

Upper Arkansas Region

Streamflow Statistic	Basins						
	63	67	68	69	70	71	72
	AFY						
Average Annual Flow	1,126,000	777,200	468,800	251,900	216,100	3,864,200	2,112,000
Minimum Annual Flow	110,100	78,300	44,600	27,900	24,100	465,400	150,800

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

Groundwater Resources

Two major bedrock aquifers, the Garber-Wellington and Vamoosa-Ada, and four major alluvial aquifers, Arkansas River, Cimarron River, Enid Isolated Terrace, and Salt Fork of the Arkansas River, underlie the Upper Arkansas Watershed Planning 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 Garber-Wellington aquifer consists of fine-grained sandstone interbedded with siltstone and shale. Depth to water varies from 100 to 350 feet. Well yields range from 50 gallons per minute (gpm) to more than 500 gpm, and average 200 gpm. While a major source of Municipal and Industrial water supply in the Central Planning Region, only a small portion of the aquifer's northern boundary underlies Basins 63 and 71 in the Upper Arkansas Region where there is shale and may yield as low as 10 gpm. Quality is generally good, but in some areas concentrations of nitrate, arsenic, chromium, selenium, uranium, and other elements may exceed drinking water standards. The aquifer underlies portions of Basins 63 and 71.

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

The Vamoosa-Ada aquifer consists of 125 to 1,000 feet of interbedded sandstone, shale, and conglomerate, with the proportion of shale increasing northward. Wells commonly yield 25 to 150 gpm. Water quality is generally good and suitable for use as public supply, although iron infiltration and hardness are problems in some areas, and there are local problems due to contamination resulting from past oil and gas activities. The aquifer underlies eastern portions of Basins 71 and 72.

Yields in the Arkansas River alluvium deposits range from 200 to 500 gpm while wells in the terrace deposits range from 100 to 200 gpm. 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 quality problem and TDS values are usually less than 500 mg/L. The water is generally suitable for most Municipal and Industrial (M&I) uses, although heavy pumping leads to chloride intrusion in the formation. The aquifer underlies portions of Basins 71 and 72.

The Cimarron River aquifer consists of silt and clay in the upper portion grading downward to sandy clay, sand and fine gravel with a maximum thickness of about 80 feet and a maximum saturated thickness of about 50 feet. Terrace deposits are typically overlain by dune sand as much as 100 feet thick. The aquifer is generally unconfined with well depths of 50 to 100 feet and yields of 200 to 500 gpm in the alluvium and 100 to 200 gpm in the terrace. The water is very hard and is typically classified as a calcium-magnesium bicarbonate type. Water quality is generally suitable for most purposes, except in some areas where saltwater encroachment has precluded its use for domestic purposes. The aquifer underlies a small portion of Basin 63 in the south.

The Salt Fork of the Arkansas River alluvium deposits have a maximum thickness of 60 feet while terrace deposits have a maximum thickness of 150 feet. The maximum saturated thickness is 50 feet. The formations are typically clay and silt in the upper portion, changing into fine to coarse sand with local lenses of fine gravel. The aquifer is generally unconfined with well depths of 50 to 150 feet and yields of 100 to 200 gpm in the alluvium portion and 100 to 500 gpm in the terrace. The water is very hard and generally of a calcium magnesium bicarbonate type; dissolved solids are typically less than 500 mg/L, although saltwater encroachment occurs in some areas. The aquifer underlies portions of Basins 67, 68, and 69.

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
Upper Arkansas Region

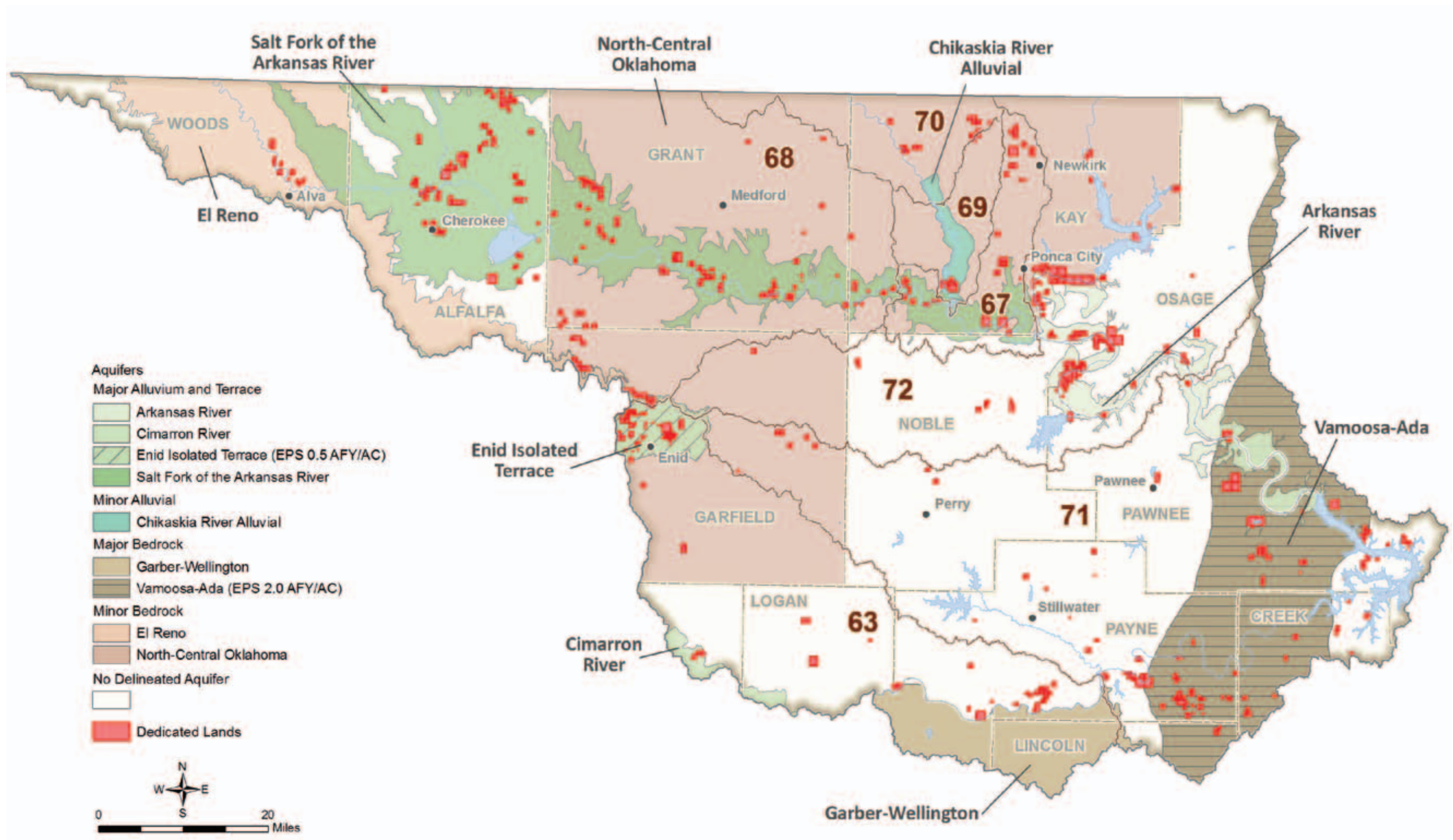
Aquifer			Portion of Region Overlaying Aquifer	Recharge Rate	Current Groundwater Rights	Aquifer Storage in Region	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type	Class[1]	Percent	Inch/Yr	AFY	AF	AFY/Acre	AFY
Arkansas River	Alluvial	Major	3%	5.0	38,000	193,000	temporary 2.0	222,600
Cimarron River	Alluvial	Major	1%	2.3	4,200	107,000	temporary 2.0	50,100
Enid Isolated Terrace	Alluvial	Major	1%	2.3	5,000	213,000	0.5	18,800
Garber-Wellington	Bedrock	Major	3%	1.6	700	2,965,000	temporary 2.0	268,400
Salt Fork of the Arkansas River	Alluvial	Major	11%	2.3	42,900	2,189,000	temporary 2.0	1,049,500
Vamoosa-Ada	Bedrock	Major	10%	0.7-1.4	10,200	3,559,000	2.0	903,000
Chikaskia River	Alluvial	Minor	1%	4.5	2,000	89,000	temporary 2.0	47,600
El Reno	Bedrock	Minor	6%	0.75	1,600	1,494,000	temporary 2.0	574,200
North-Central Oklahoma	Bedrock	Minor	37%	1.0	13,900	13,562,000	temporary 2.0	3,510,200
Non-Delineated Groundwater Source	Alluvial	Minor			7,800			
Non-Delineated Groundwater Source	Bedrock	Minor			2,200			

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

The Enid Isolated Terrace aquifer underlies approximately 81 square miles and is composed of terrace deposits that consist of discontinuous layers of clay, sandy clay, sand, and gravel. The aquifer underlies a portion of Basin 63 and small portions of Basins 68, 71, and 72.

Minor aquifers in the region include the El Reno, North-Central Oklahoma, Chikaskia River and non-delineated groundwater sources. Groundwater from minor aquifers is an important source of water for domestic and stock use in outlying areas not served by rural water systems, but may have insufficient yields for large volume users.

Groundwater Resources
Upper Arkansas Region



Major bedrock aquifers in the Upper Arkansas Region include the Garber-Wellington and Vamoosa-Ada. Major alluvial aquifers in the region include the Arkansas River, Cimarron River, Salt Fork of the Arkansas River, and Enid Isolated Terrace. 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 in the Upper Arkansas Region. For groundwater, each aquifer's equal proportionate share (EPS) determines the amount of water available for permits in studied groundwater basins. Equal proportionate shares in the Upper Arkansas Region range from 0.5 AFY per acre to 2 AFY per acre. Projections indicate that the use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060 in the Upper Arkansas Region.

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.

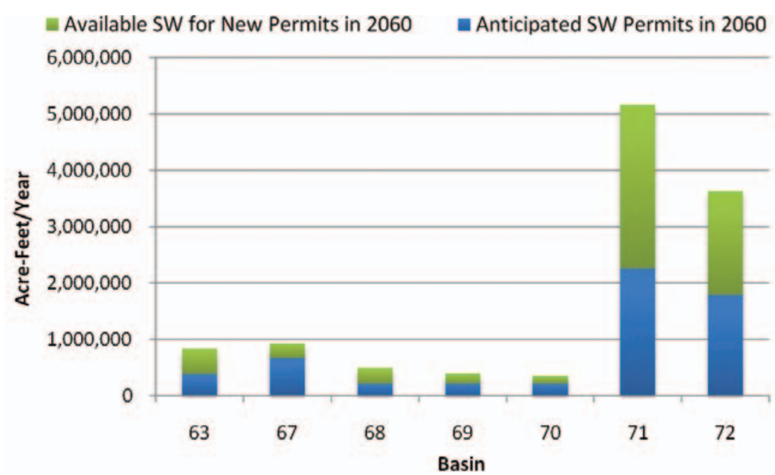
To determine surface water permit availability in each OCWP planning basin in 2060, the analysis utilized OWRB protocol to estimate the average annual streamflow at the basin's outlet point, accounting for both existing and anticipated water uses upstream and downstream, including legal obligations,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

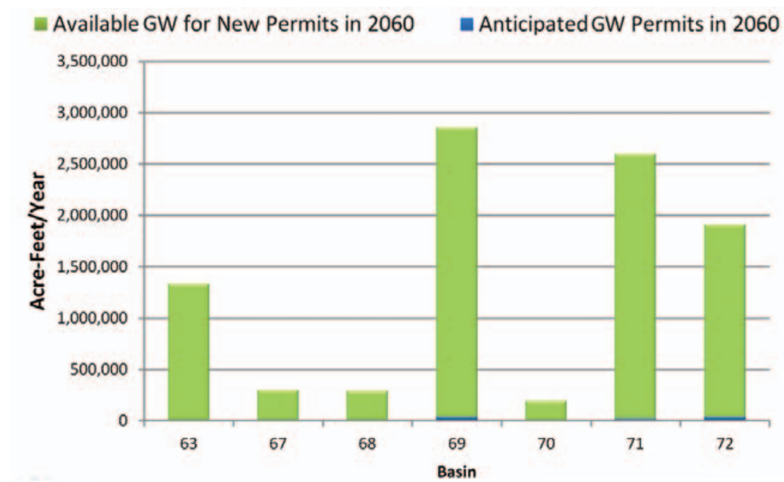
For OCWP analysis, the geographical area overlying all aquifers in each basin was determined and the respective EPS or temporary permit allocations were applied. Total current and anticipated future permit needs were then calculated to project remaining groundwater permit availability.

Surface Water Permit Availability
Upper Arkansas Region



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

Groundwater Permit Availability
Upper Arkansas Region



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

Water Quality

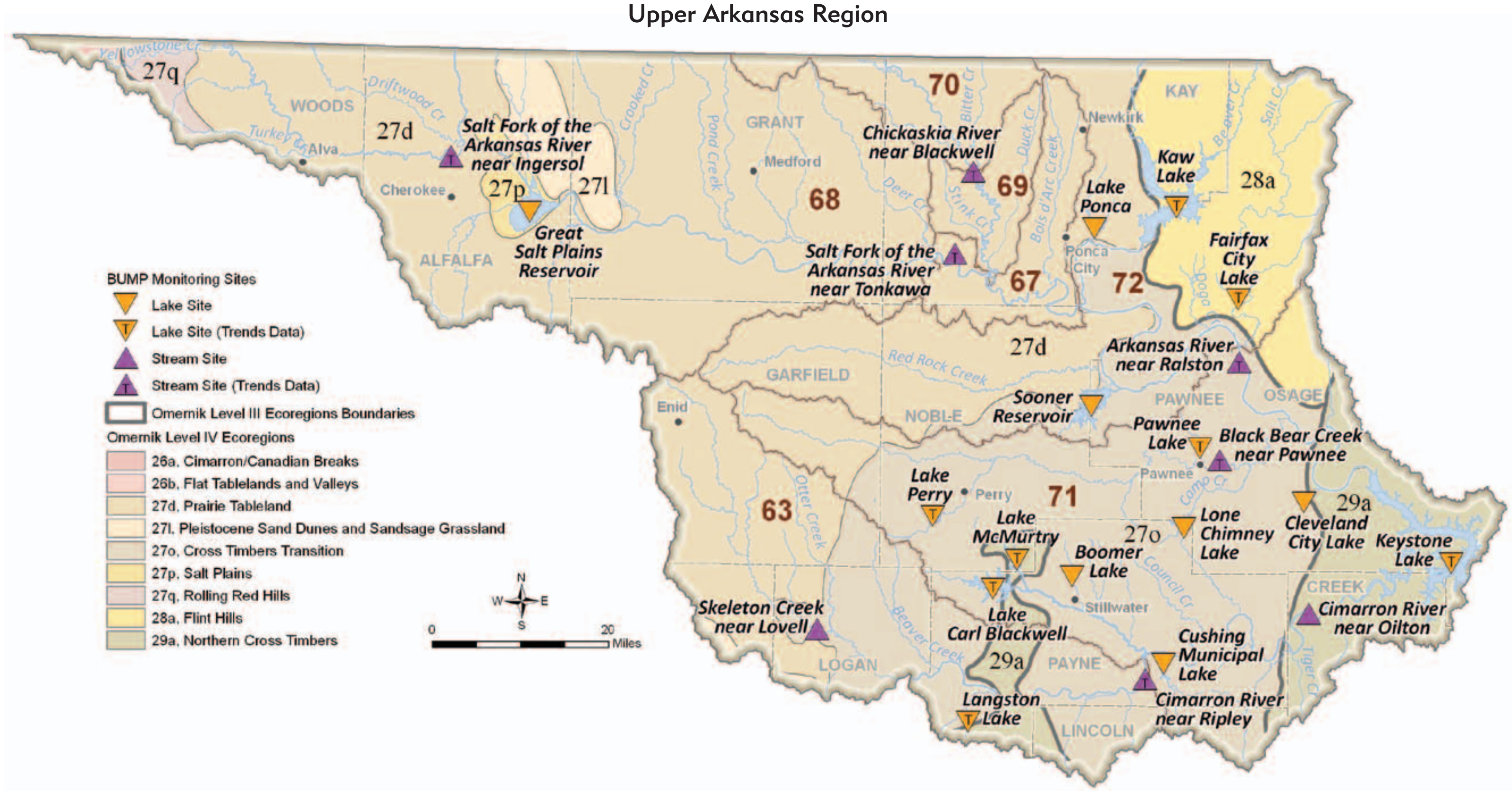
Water quality of the Upper Arkansas Watershed Planning Region is defined by two major river systems, the Arkansas and Cimarron Rivers, and numerous minor and major water supply reservoirs. The majority of the region is contained within the Central Great Plains (CGP) ecoregion, with some Cross Timbers (CT) and Flint Hills (FH) influence along the eastern border.

Except for two intervening ecoregions, the Prairie Tablelands extends from the west through over half of the region's geographical area and is drained by tributaries of the Arkansas and Cimarron Rivers. The area is nearly level, underlain by shale, sandstone, and siltstone. It is dominated by cropland with dense mixed-grass prairies. Streams are turbid and silt-dominated, lying in broad, shallow, low-gradient channels with incised banks and typified by Skeleton Creek (south), Salt Fork of the Arkansas River (north and central), and Chikaskia River (northeastern). Normally, salinity is high in the west, with mean conductivity ranging from 1,700 (Skeleton) to near 2,700 µS (Salt Fork). Northeastern salinity lowers with values ranging from 300 (Ponca) to 900 µS (Kaw and Chikaskia). Kaw and Ponca Lakes are typical water supply lakes in the east. Oligotrophic to eutrophic, nutrient values are lower on the Salt Fork and Chikaskia with concentrations ranging from 0.10 to 0.27 ppm for total phosphorus (TP) and 1.01 to 1.50 ppm of total nitrogen (TN). Skeleton is hyper-eutrophic with TP of 0.54 ppm and TN of 4.57 ppm. Lakes are phosphorus limited and mesotrophic (lower Kaw) to hyper-eutrophic (Ponca). Water clarity is fair (Chikaskia turbidity = 43 NTU) to poor (Salt Fork = 97 NTU). Lake clarity is poor to good, with an average Secchi depth of 35 (Upper Kaw) to 61 cm (Ponca). Ecological diversity varies throughout depending on salinity, habitat degradation, and sedimentation. Some unique gravel/cobble/bedrock streams support darter habitat.

The Salt Plains and Pleistocene Sand Dunes intervene in the eastern part of Alfalfa County in Basin 68. The Salt Plains have high subsurface salinity and low ecological diversity. Streams are shallow with flat banks and typically ephemeral. The Pleistocene Sand Dunes have more permeable sandy soils, interlaced with springs and inter-dune wetlands. Streams are typically sandy, with incised, highly erodible banks. The Great Salt Plains Reservoir has high salinity (max conductivity = 10,016 µS) and poor clarity (Secchi depth = 10 cm). It is nitrogen limited and hyper-eutrophic.

The south-central part of the region is dominated by the Cross Timbers Transition, a hybrid mix of rough plains covered by prairie grasses and oak/elm/cedar forests. Cropland/rangeland are the major land uses. Streams are rockier and contained in narrower, incised channels. The area is characterized by the Arkansas (including Black Bear Creek) and Cimarron drainages and water supply lakes. Conductivity is lower in the Arkansas, ranging from 840 (Black Bear) to 1,300 µS (Ralston). It increases in the Cimarron to nearly 6,000 µS. Average lake conductivity is 300 µS, but rises to 1,500 µS in Sooner Lake in Basin 72. Having high nutrient concentrations, streams are eutrophic/hyper-eutrophic, with TN of 1.47 to 1.91 ppm and TP of 0.25 to 0.39 ppm. Lakes are mesotrophic (Cushing, Perry, and Sooner) to eutrophic (Boomer, Lone Chimney, and Pawnee). Water clarity is fair (Black Bear = 44 NTU) to poor (Ripley = 160 NTU).

Ecoregions
Upper Arkansas Region



The Upper Arkansas Planning Region is dominated by Central Great Plains ecoregions but transitions to the Cross Timbers and Flint Hills in the east. Water quality is highly influenced by both geology and land use practices, and ranges from poor to good depending on drainage and location.

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.

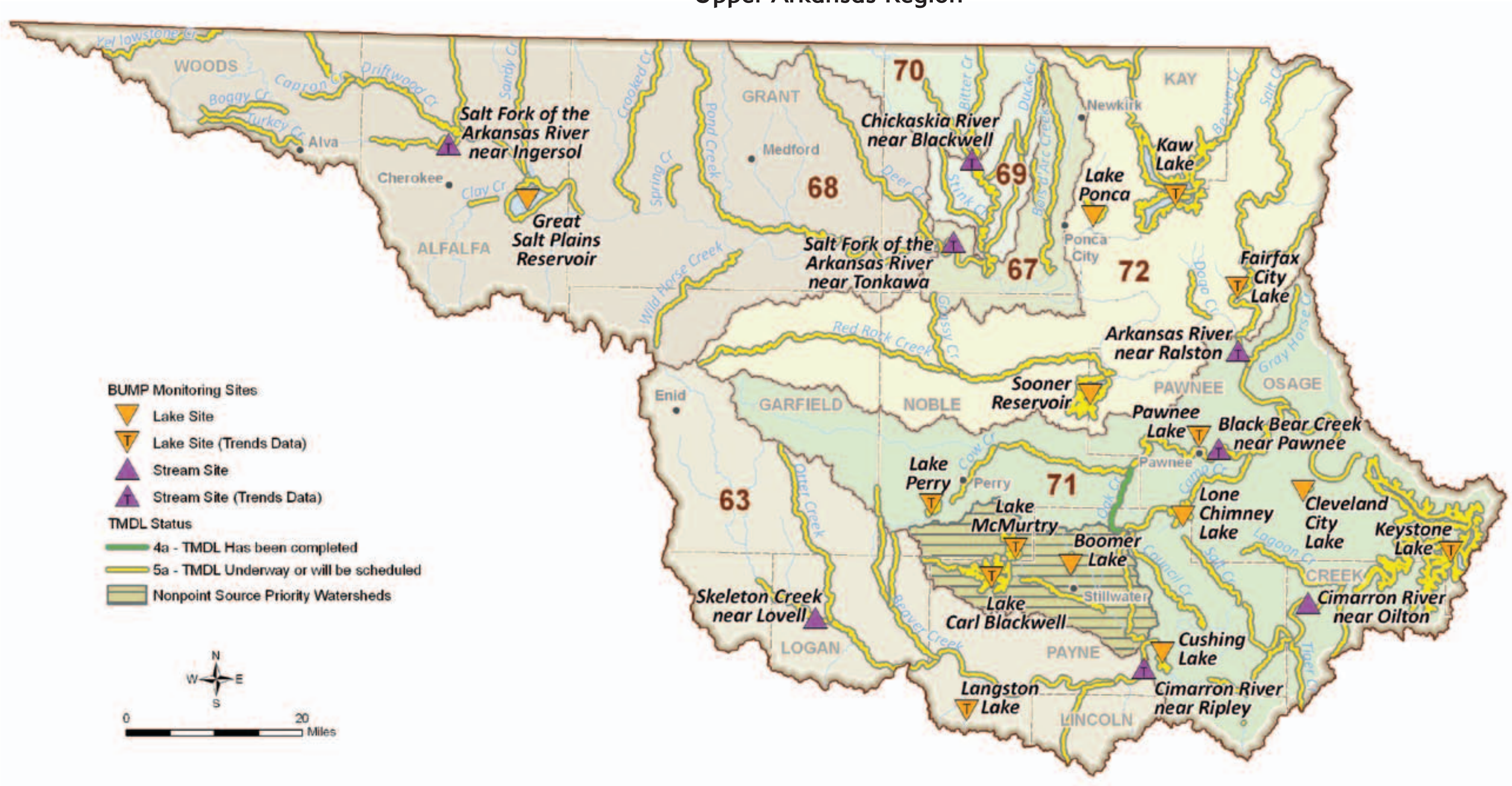
Lake clarity is poor to excellent, with mean Secchi depths ranging from 22 (Perry) to 115 cm (Sooner). Ecological diversity is variable, influenced by salinity, habitat degradation, and sedimentation.

The Flint Hills in Osage and Kay Counties in Basins 71 and 72 are underlain by shallow limestone/shale and the low hills are rangeland/grassland, including tall grass prairie. Channels are more natural, with low to incised banks and gravel/cobble bottoms. The area is characterized by Salt Creek and Fairfax Lake. Salinity is low/moderate, with conductivity values ranging from 200 (Fairfax) to 500 μS (Salt Creek). Waters are eutrophic, with means of TN/TP approximately 0.85/0.07 ppm. Clarity is fair on Salt Creek (33 NTU) to good at Fairfax (73 cm). Ecological diversity is higher because of stream morphology and lower salinity/habitat degradation.

Finally, the Northern Cross Timbers intersects the region in the southeast and western Payne County. The area is more forested than neighboring plains with intervening grasslands and mixed land use. Streams are diverse through the ecoregion. In this region, they are shallower, sand/silt dominated, and highly incised. The area is typified by Keystone Reservoir and lakes Carl Blackwell, Langston, and McMurtry. Keystone Reservoir integrates the Arkansas/Cimarron drainages from north to south. Salinity is moderate to high with conductivity ranging from 550 (Arkansas River) to nearly 7,000 μS (Cimarron River), and clarity is average, with Secchi depth ranging from 26-47 cm. Classified as eutrophic to hypertrophic, Keystone is co-limited for nitrogen/phosphorus, with relatively high concentrations. In the Payne County area, salinity is relatively low, as conductivity ranges from 300-400 μS. Clarity ranges from average (Blackwell = 37cm) to good (Langston = 70 cm). All are phosphorus limited. Nutrient concentrations are low to moderate. Langston is mesotrophic,

Water Quality Standards Implementation

Upper Arkansas Region



BUMP monitoring sites and streams with TMDL studies completed or underway. The Oklahoma Conservation Commission has begun a watershed implementation project on Stillwater Creek to address sediment and turbidity. The Oklahoma Department of Environmental Quality has completed a TMDL study on Oak Creek.

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 the state's 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.

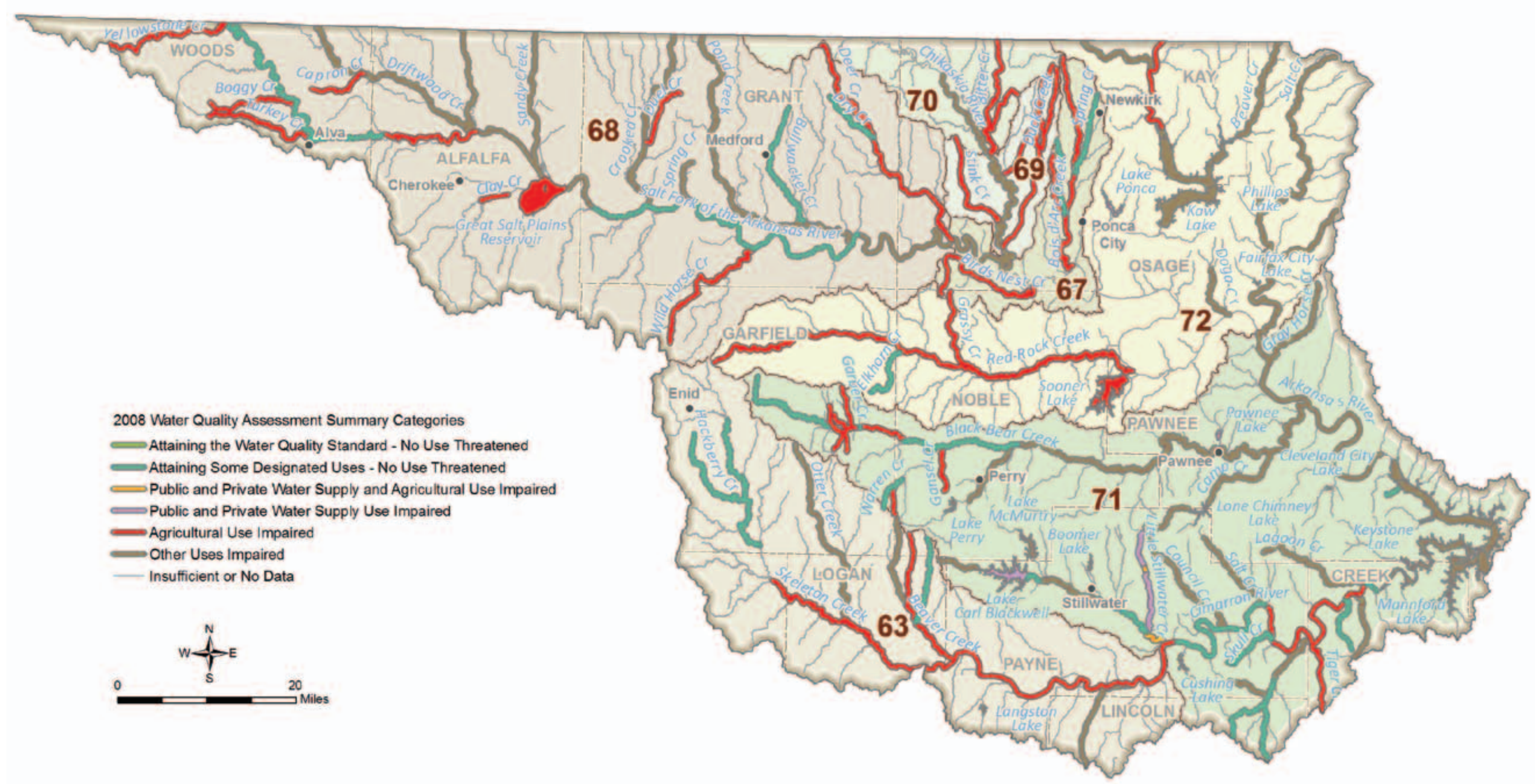
while Carl Blackwell is eutrophic. Ecological diversity is fair and impacted by poor habitat, non-native salinity, and sedimentation.

Although a statewide groundwater water quality program does not exist in Oklahoma, various aquifer studies have been completed and data are available from municipal authorities and other sources.

The Upper Arkansas region is underlain by several major and minor bedrock and alluvial aquifers. Water from the Cimarron and Salt Fork of the Arkansas River aquifers is generally suitable for most purposes, except in some areas where saltwater encroachment has precluded its use for domestic purposes. The water is generally hard and of a calcium magnesium bicarbonate type. In most areas, dissolved solids concentrations in the Cimarron and Salt Fork formations are below drinking water standards.

Major bedrock aquifers in the region include the Garber-Wellington and Vamoosa-Ada. The Garber-Wellington is in the southernmost tip of the region. It is of a calcium magnesium bicarbonate type and ranges from hard to very hard. In general, concentrations of dissolved solids, chloride, and sulfate are low. Water from the aquifer is normally suitable for public water supply, but concentrations of nitrates, sulfate, chloride, fluoride, arsenic, chromium, selenium, and uranium may exceed drinking water standards in localized areas. The Vamoosa-Ada is primarily in the far southeastern portion of the Upper Arkansas Region. Although water quality is generally good, iron infiltration and hardness are problems. Chloride and sulfate concentrations are generally low, and except for areas of local contamination resulting from past oil and gas activities, water is suitable for use as public supply.

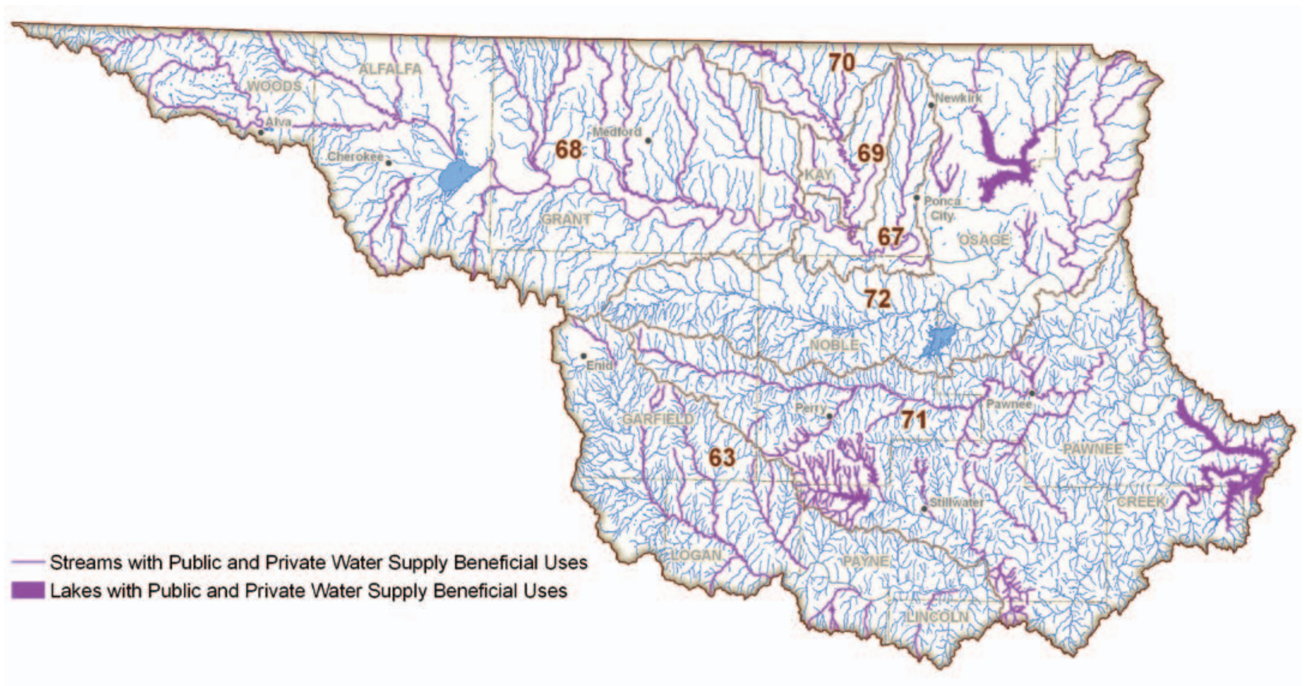
Water Quality Impairments
Upper Arkansas Region



Regional water quality impairments based on the 2008 *Oklahoma Integrated Water Quality Assessment Report*. Surface waters in this region have impacts due to turbidity as well as naturally occurring levels of salinity.

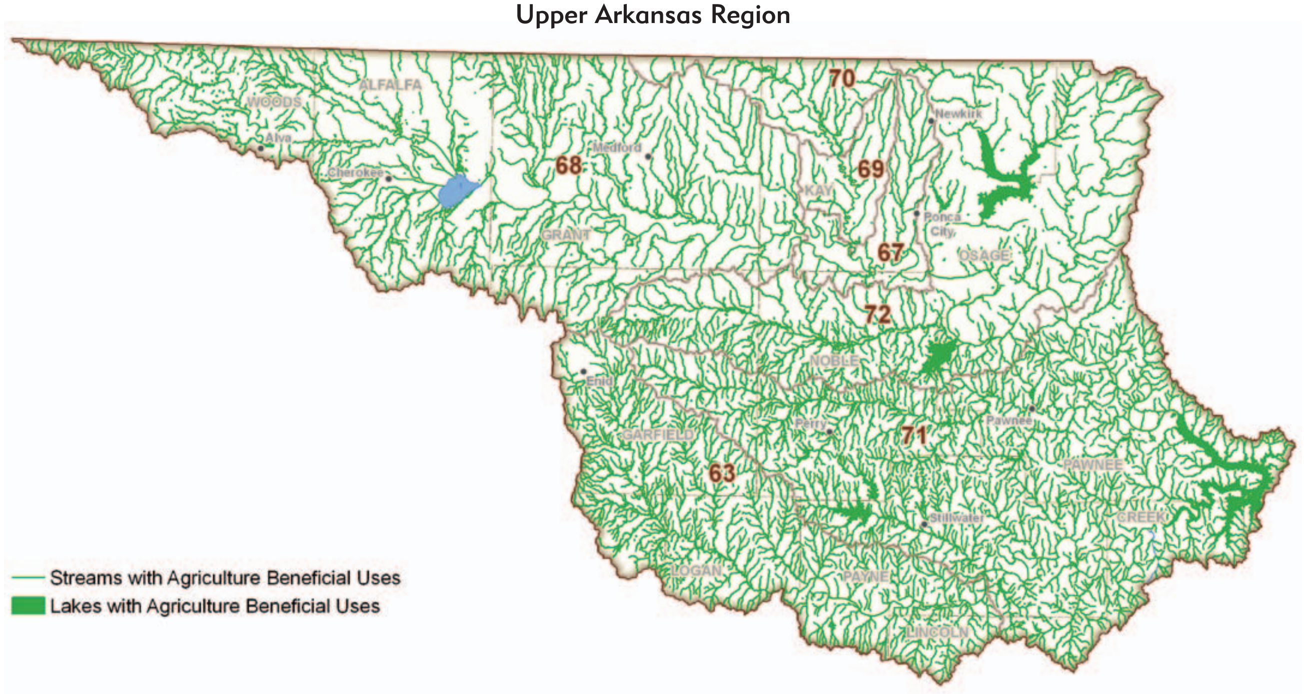
Surface Waters with Designated Beneficial Use for Public/Private Water Supply

Upper Arkansas Region



Surface Waters with Designated Beneficial Use for Agriculture

Upper 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.

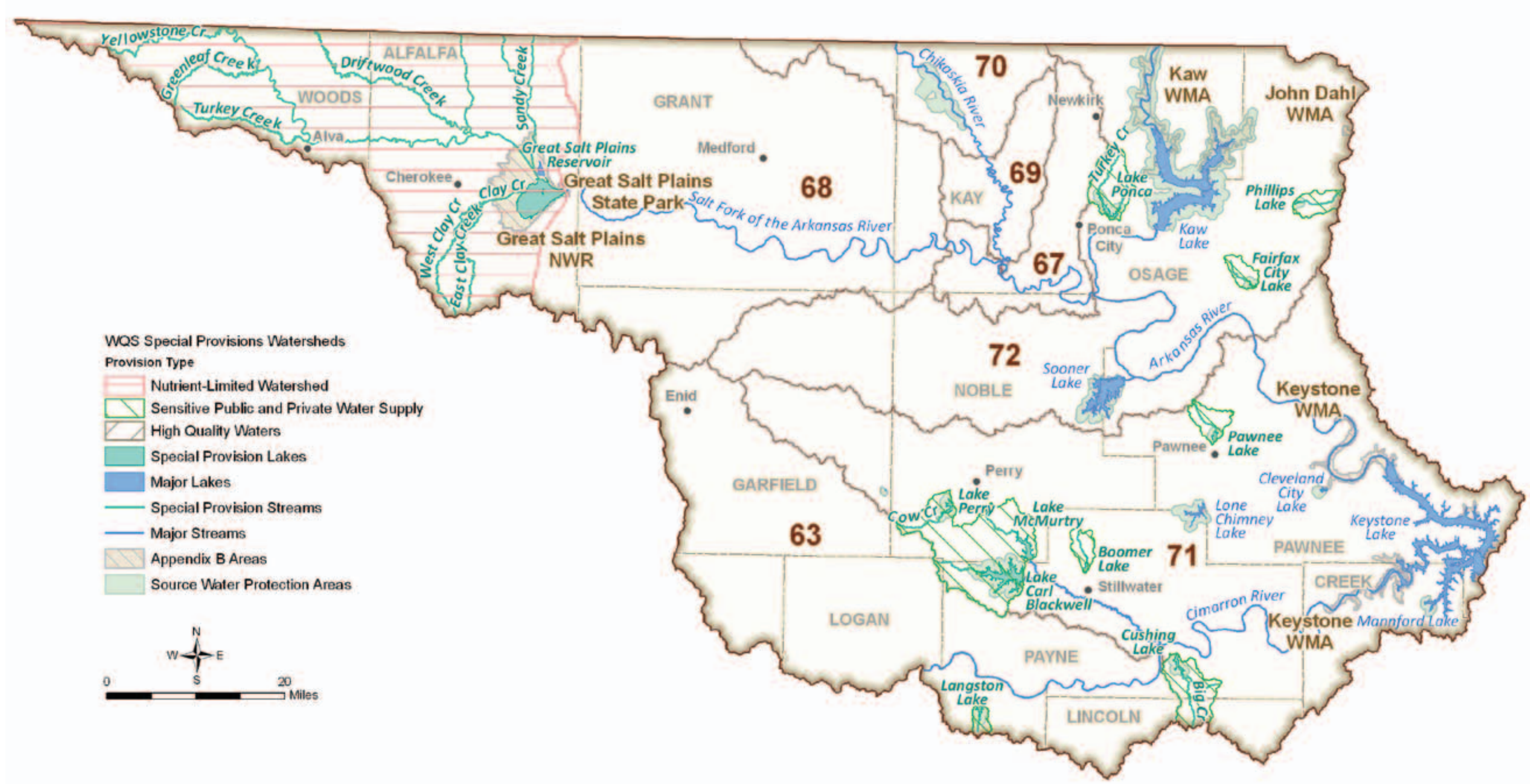
Outstanding Resource Waters are those constituting outstanding resources or of exceptional recreational and/or ecological significance. This designation prohibits any new point source discharges or additional load or increased concentration of specified pollutants.

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.

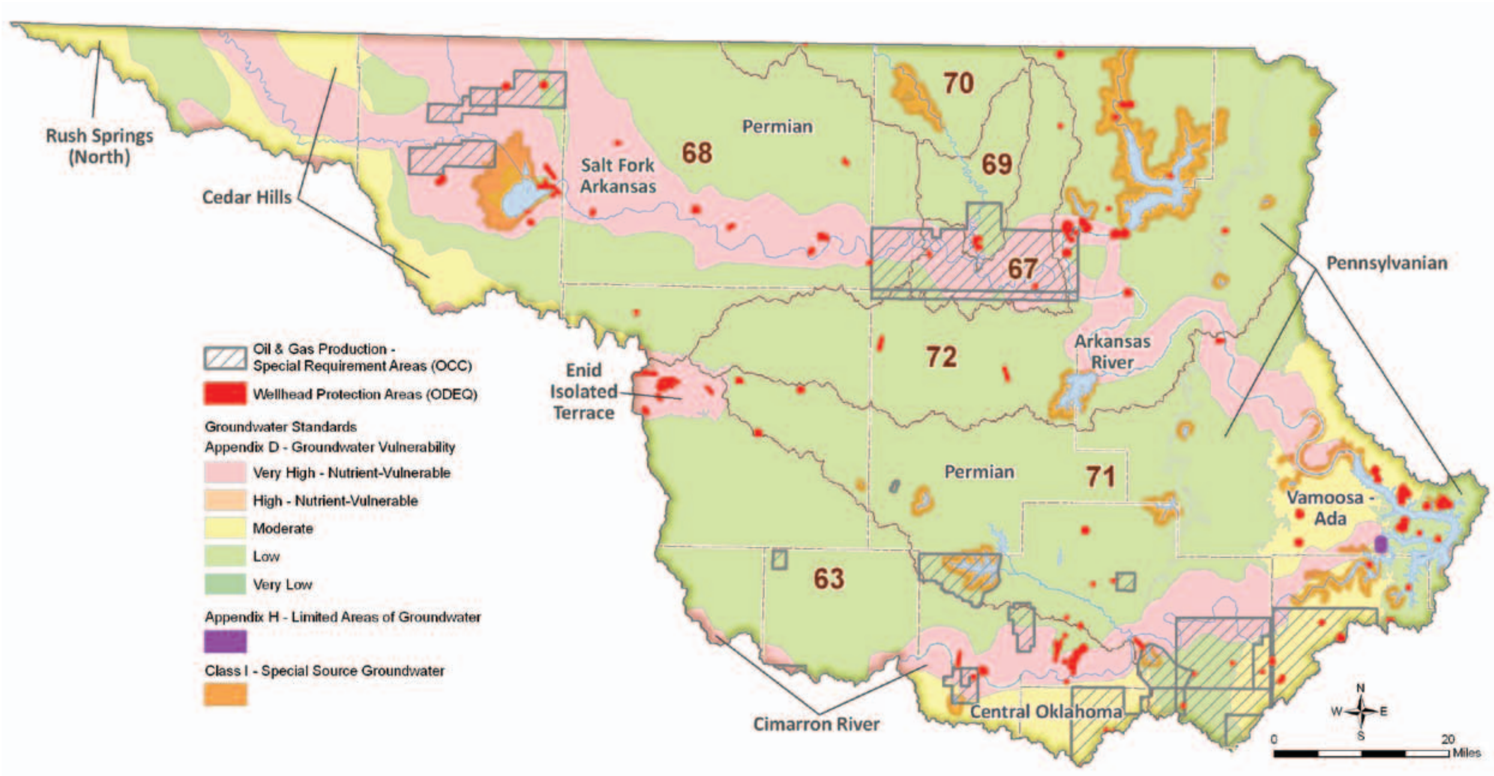
Surface Water Protection Areas

Upper Arkansas Region



Because Cleveland Reservoir and Lone Chimney Lake 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 watersheds. 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
Upper Arkansas Region



Various types of protection are in place to prevent degradation of groundwater based upon OWRB vulnerability modeling. The Enid Isolated Terrace and Cimarron River and Salt Fork of the Arkansas River alluvial aquifers have been identified by the OWRB as very highly 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

Upper Arkansas Region

Parameter	Lake Carl Blackwell (1995-2008)	Fairfax City Lake (1995-2007)	Kaw Lake (1996-2008)	Keystone Lake (1995-2009)	Langston Lake (1994-2008)	Lake McMurtry (1995-2009)	Pawnee Lake (1994-2007)	Perry Lake (1996-2007)
Chlorophyll-a (mg/m3)	↑	↑	NT	NT	NT	↑	↑	NT
Conductivity (us/cm)	NT	NT	↓	NT	NT	↑	NT	↑
Total Nitrogen (mg/L)	↑	NT	↑	↓	↑	NT	↑	↓
Total Phosphorus (mg/L)	NT	NT	NT	NT	NT	NT	NT	↓
Turbidity (NTU)	↑	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.

Notable concerns for reservoir water quality include the following:

- Significant upward trend for chlorophyll-a and total nitrogen on numerous reservoirs
- Significant upward trend for turbidity on Carl Blackwell and Langston reservoirs

Stream Water Quality Trends

Upper Arkansas Region

Parameter	Black Bear Creek near Pawnee		Chikaskia River near Blackwell		Cimarron River near Guthrie		Cimarron River near Ripley		Salt Fork of the Arkansas River near Ingersol		Salt Fork of the Arkansas River near Tonkawa	
	All Data Trend (1960-1993, 1998-2009) [1]	Recent Trend (1998-2009)	All Data Trend (1952-1993, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend 2000-2009)[1]	Recent Trend (2000-2009)	All Data Trend (1979-1993, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1951-1993, 1998-2009)[1]	Recent Trend (1998-2009)
Conductivity (us/cm)	NT	↓	↑	↑	↑	↑	NT	NT	↑	NT	↑	↑
Total Nitrogen (mg/L)	↓	NT	↓	NT	NT	NT	↑	↑	↓	NT	↓	↓
Total Phosphorus (mg/L)	↓	NT	↓	NT	NT	NT	NT	NT	↓	NT	↓	NT
Turbidity (NTU)	↑	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 recent conductivity on the Cimarron, Chikaskia, and Salt Fork Rivers
- Significant upward trend for period of record turbidity throughout the region
- Significant upward trend for total nitrogen on the Cimarron River

Water Demand

The Upper Arkansas Region's water demand accounts for about 7% of the total statewide demand. Regional demand will increase by 42% (54,200 AFY) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Municipal and Industrial and Thermoelectric Power sectors.

Thermoelectric Power demand is projected to account for 36% of the region's water demand in 2060. The Oklahoma Gas and Electric Company's Sooner Plant, which is supplied by surface water, is a large user of water for thermoelectric power generation in the region.

Municipal and Industrial (M&I) use is projected to account for about 32% of the 2060 demand. Currently, 70% of the demand from this sector is supplied by surface water, 22% by alluvial groundwater, and 8% by bedrock groundwater.

Crop Irrigation demand is expected to account for 12% of the 2060 demand. Currently, 24% of the demand from this sector is supplied by surface water, 57% by alluvial groundwater, and 19% by bedrock groundwater. Predominant irrigated crops in the Upper Arkansas Region include cotton, pasture grasses, and corn.

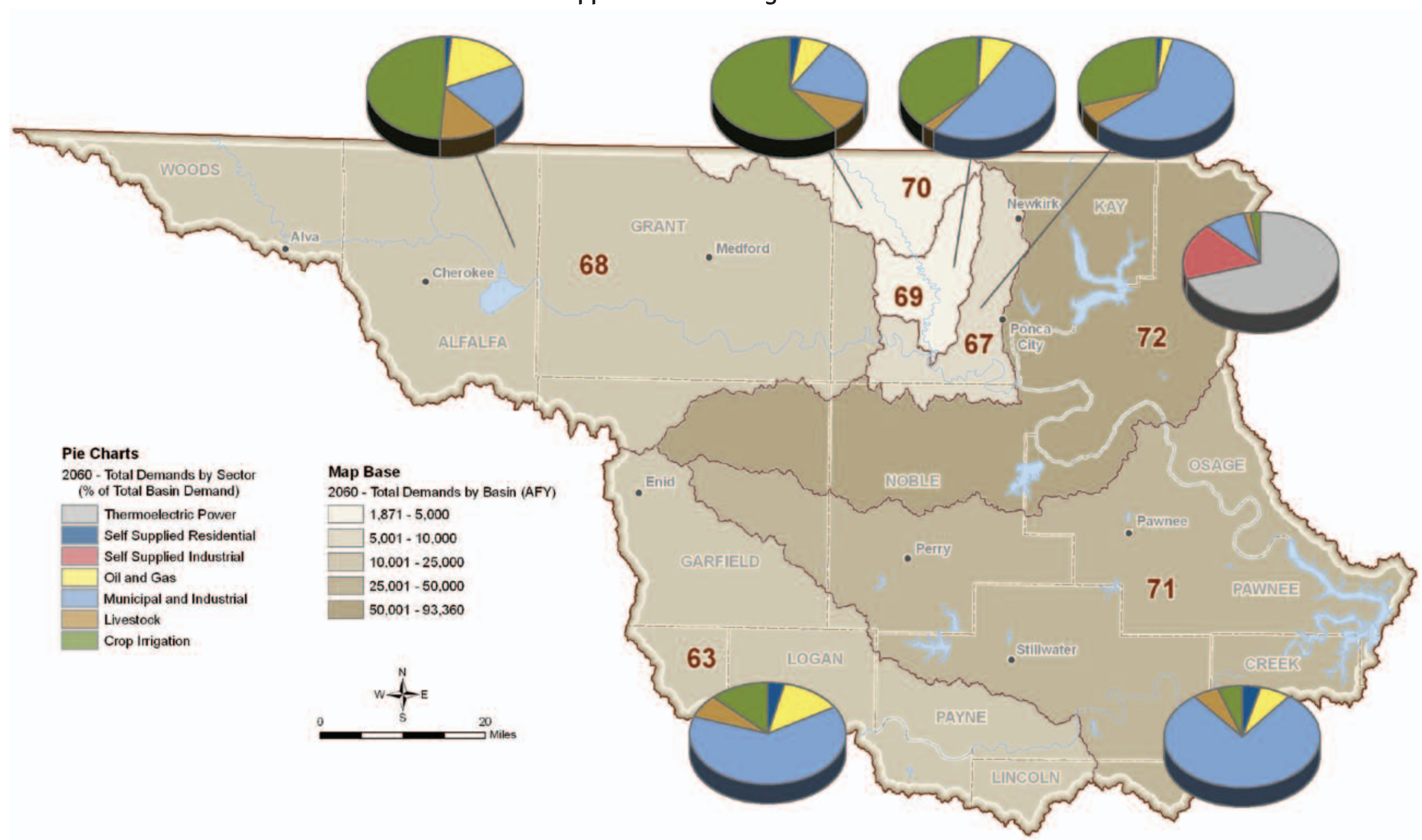
Self-Supplied Industrial demand in the region is projected to account for 7% of the 2060 demand. Currently, 82% of the demand from this sector is supplied by surface water, 16% by alluvial groundwater, and 2% by bedrock groundwater.

Oil and Gas demand is projected to account for approximately 6% of the 2060 demand. Currently, 93% of the demand from this sector is supplied by surface water, 3% by alluvial groundwater, and 4% by bedrock groundwater.

Livestock demand is projected to account for 5% of the 2060 demand. Currently, 22% of the demand from this sector is supplied by surface water, 59% by alluvial groundwater, and 19% by bedrock groundwater. Livestock use in the region is predominantly cattle for cow-calf production, followed distantly by sheep.

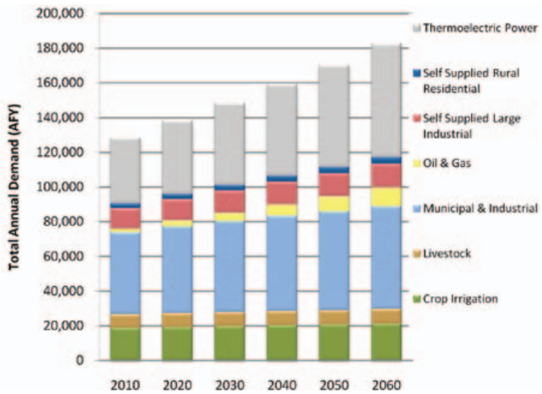
Self-Supplied Residential demand is projected to account for 2% of the 2060 demand. Currently, 92% of the demand from this sector is supplied by alluvial groundwater and 8% by bedrock groundwater.

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

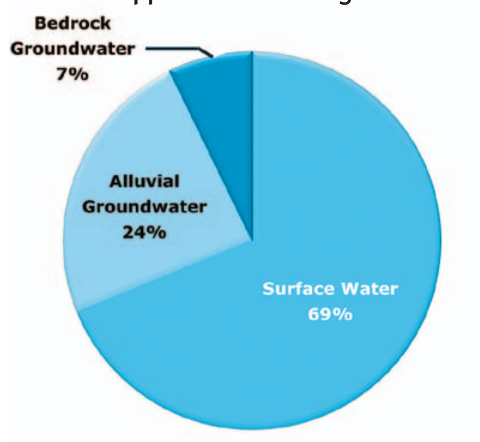


Projected water demand by sector. By 2060, 36% of the demand will come from the Thermoelectric Power sector and 32% will come from the Municipal and Industrial demand sector.

Total Water Demand by Sector
Upper Arkansas Region



Supply Sources Used to Meet Current Demand (2010)
Upper Arkansas Region



The Upper Arkansas Region's water needs account for about 7% of the total statewide demand. Regional demand will increase by 42% (54,200 AFY) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Municipal and Industrial and Thermoelectric Power sectors.

Total Water Demand by Sector
Upper Arkansas Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	18,800	7,770	47,270	2,170	11,820	2,890	37,870	128,570
2020	19,290	7,900	50,200	3,330	12,360	3,110	42,250	138,450
2030	19,780	8,040	52,710	4,780	12,660	3,320	47,140	148,430
2040	20,270	8,180	55,120	6,500	12,970	3,520	52,580	159,140
2050	20,650	8,310	57,200	8,490	13,270	3,720	58,660	170,300
2060	21,260	8,450	59,340	10,760	13,590	3,910	65,450	182,770

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.

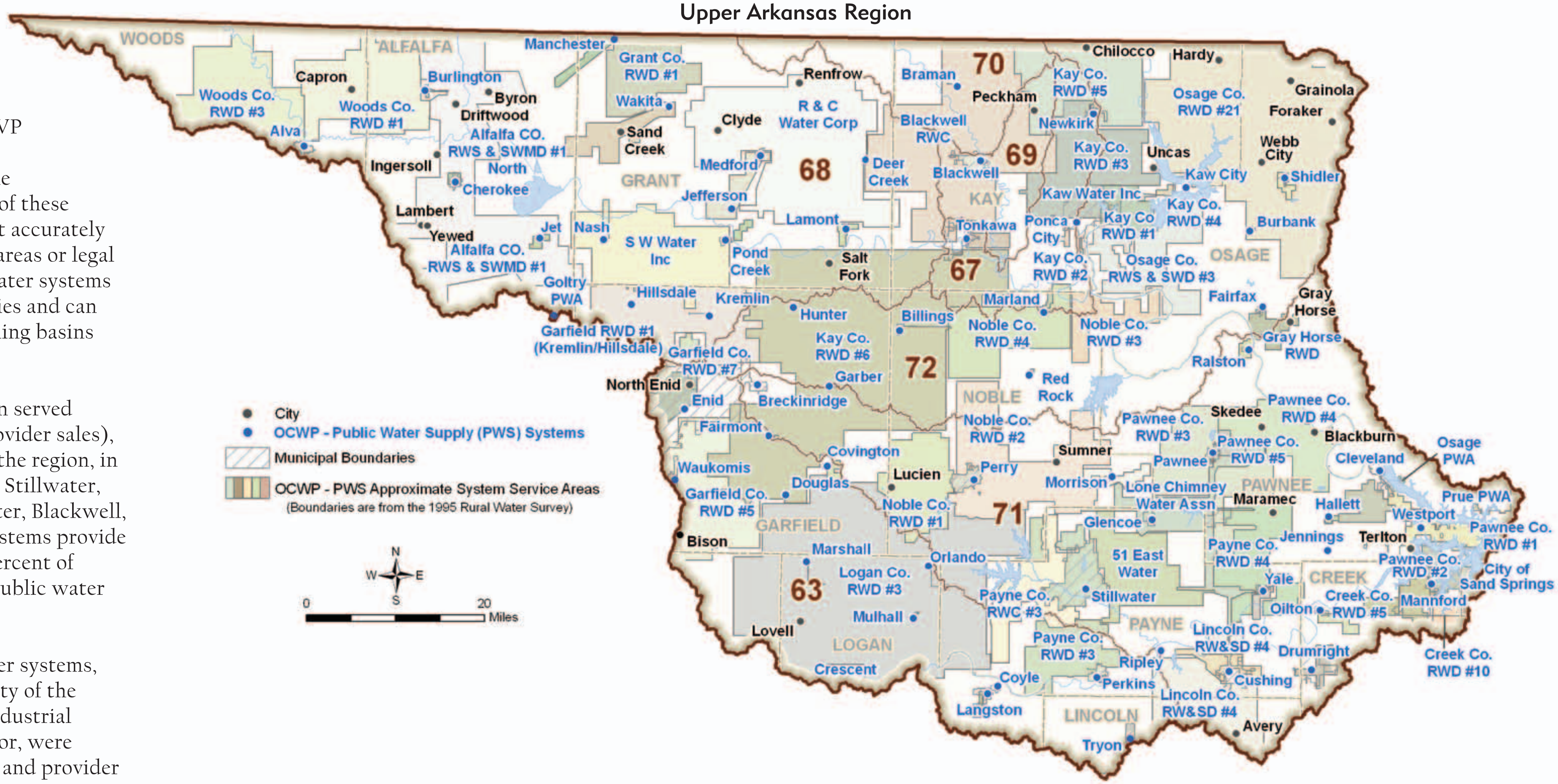
The Upper Arkansas Region includes 99 of the 785 public supply systems analyzed for the 2012 OCWP Update. The Public Water Providers map indicates the approximate service areas of these systems. (The map may not accurately represent existing service areas or legal boundaries. In addition, water systems 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 Enid, Stillwater, Ponca City Municipal Water, Blackwell, and Cushing. These five systems provide service for more than 60 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
Upper 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)

Upper Arkansas Region

Provider	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Population Served					
				2010	2020	2030	2040	2050	2060
51 EAST CORP	OK3006003	Payne	73	2,121	2,282	2,452	2,618	2,736	2,849
ALFALFA CO RWS & SWMD #1	OK2000202	Alfalfa	133	1,635	1,635	1,635	1,635	1,660	1,688
ALVA	OK2007603	Woods	288	5,235	5,235	5,294	5,353	5,411	5,519
BILLINGS PWA	OK2005201	Noble	154	557	581	606	630	642	654
BLACKWELL	OK1021101	Kay	153	9,428	9,753	10,006	10,235	10,464	10,717
BLACKWELL RW CORP	OK3003601	Kay	164	927	959	984	1,006	1,029	1,054
BRAMAN	OK3003616	Kay	94	244	254	254	264	264	273
BRECKINRIDGE PWA	OK2002420	Garfield	190	239	249	259	269	269	279
BURBANK	OK3005752	Osage	77	161	170	180	189	198	208
BURLINGTON	OK3000202	Alfalfa	160	156	156	156	156	156	166
CHEROKEE	OK2000208	Alfalfa	221	1,638	1,638	1,638	1,638	1,669	1,689
CLEVELAND NORTH	OK1021210	Pawnee	152	3,384	3,750	4,088	4,446	4,812	5,188
COVINGTON	OK3002419	Garfield	63	559	569	588	598	608	628
COYLE	OK2004203	Logan	117	336	380	415	450	486	530
CREEK CO RWD #5	OK2001994	Creek	57	2,824	3,020	3,173	3,318	3,463	3,619
CREEK CO RWD #10	OK2001907	Creek	136	25	26	28	29	30	31
CUSHING	OK2006061	Payne	131	8,655	9,319	10,011	10,694	11,176	11,631
DEER CREEK	OK2002711	Grant	90	147	147	147	147	157	157
DOUGLAS	OK3002414	Garfield	75	32	32	32	32	32	32
DRUMRIGHT	OK2001902	Creek	183	3,066	3,279	3,445	3,603	3,760	3,930
ENID	OK2002412	Garfield	200	47,989	49,453	50,668	51,804	52,691	53,747
FAIRFAX	OK1021204	Osage	113	1,528	1,638	1,721	1,794	1,868	1,951
FAIRMONT	OK2002413	Garfield	64	147	157	157	157	167	167
GARBER	OK2002416	Garfield	95	857	877	896	916	936	955
GARFIELD CO RWD #1 (KREM-HILL)	OK2002402	Garfield	161	705	727	744	761	774	790
GARFIELD CO RWD #4	OK3002406	Garfield	50	322	333	340	348	354	361
GARFIELD CO RWD #5	OK2002444	Garfield	119	1,317	1,358	1,390	1,421	1,445	1,474
GARFIELD CO RWD #7	OK3002408	Garfield	166	315	325	333	340	346	353
GLENCOE	OK3006040	Payne	61	658	708	768	817	857	887
GRANT CO RWD #1	OK3002707	Grant	160	100	102	104	104	107	110
GRAYHORSE RWD	OK3005717	Osage	164	102	109	115	120	125	130
HALLETT PWA	OK2005905	Pawnee	89	174	193	212	232	251	270
HILLSDALE PWA	OK3002404	Garfield	80	101	111	111	111	111	121
HUNTER	OK3002415	Garfield	69	310	310	328	328	345	345
JEFFERSON	OK3002702	Grant	61	57	57	57	57	57	57
JENNINGS	OK2005904	Pawnee	65	412	452	492	533	583	623

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

Upper Arkansas Region

Provider	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Population Served					
				2010	2020	2030	2040	2050	2060
JET	OK2000211	Alfalfa	125	256	256	256	256	256	268
KAW CITY WA	OK2003605	Kay	169	372	382	392	401	411	421
KAW WATER INC	OK3003618	Kay	122	90	92	95	97	99	102
KAY CO RWD #1	OK3003605	Kay	140	1,778	1,839	1,885	1,930	1,972	2,018
KAY CO RWD #2	OK3003604	Kay	748	50	52	53	55	56	57
KAY CO RWD #3	OK3003602	Kay	97	1,058	1,094	1,122	1,148	1,173	1,201
KAY CO RWD #4	OK3003624	Kay	111	101	104	107	109	112	114
KAY CO RWD #5 (DALE WATER CORP)	OK3003603	Kay	150	770	797	817	836	855	875
KAY CO RWD #6	OK2002415	Garfield	87	1,290	1,330	1,361	1,392	1,415	1,444
KREMLIN	OK3002403	Garfield	87	717	717	746	775	775	803
LAMONT	OK2002705	Grant	176	465	475	485	485	505	516
LANGSTON PWA	OK1020911	Logan	51	1,735	1,944	2,135	2,326	2,517	2,717
LOGAN CO RWS & SWMD #3	OK2004230	Logan	220	1,558	1,749	1,919	2,091	2,260	2,441
LONE CHIMNEY WA	OK1021221	Pawnee	115	187	207	225	245	265	286
MANCHESTER	OK2002703	Grant	100	104	114	114	114	114	125
MANNFORD	OK1020909	Creek	90	3,067	3,275	3,441	3,594	3,760	3,927
MARLAND	OK2005204	Noble	100	280	299	309	319	328	328
MARSHALL	OK3004201	Logan	191	263	300	327	354	382	418
MEDFORD	OK2002704	Grant	378	1,600	1,628	1,669	1,669	1,738	1,766
MORRISON PWA	OK3005205	Noble	73	1,018	1,064	1,094	1,125	1,155	1,185
MULHALL	OK3004203	Logan	134	244	281	308	335	362	389
NASH	OK2002701	Grant	340	191	200	200	200	208	208
NEWKIRK	OK2003604	Kay	215	2,296	2,376	2,436	2,497	2,547	2,607
NOBLE CO RWD #1 (LUCIEN)	OK1021205	Noble	171	340	357	369	380	389	397
NOBLE CO RWD #2	OK3005203	Noble	83	1,523	1,600	1,651	1,702	1,740	1,778
NOBLE CO RWD #3	OK2005207	Noble	76	152	160	165	170	174	178
NOBLE CO RWD #4	OK3005201	Noble	63	256	269	277	286	292	299
OILTON	OK2001901	Creek	93	1,225	1,319	1,382	1,445	1,508	1,581
ORLANDO	OK3004202	Logan	160	205	232	250	277	295	321
OSAGE CO RWD #3 (MCCORD)	OK3005747	Osage	154	1,838	1,968	2,066	2,155	2,244	2,344
OSAGE CO RWS & SWD #3 (BRADEN)	OK3005748	Osage	114	715	766	803	838	872	912
OSAGE CO RWD #21	OK2003616	Osage	93	1,531	1,640	1,721	1,795	1,870	1,954
OSAGE PWA	OK2005701	Osage	100	172	184	194	202	210	220
PAWNEE	OK1021209	Pawnee	75	2,298	2,552	2,778	3,014	3,268	3,522
PAWNEE CO RWD #1	OK2005931	Pawnee	69	3,297	3,660	3,985	4,329	4,691	5,054
PAWNEE CO RWD #2	OK3005921	Pawnee	93	1,829	2,030	2,210	2,401	2,602	2,804
PAWNEE CO RWD #3	OK3005911	Pawnee	113	663	735	801	870	943	1,016

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

Upper Arkansas Region

Provider	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Population Served					
				2010	2020	2030	2040	2050	2060
PAWNEE CO RWD #4	OK3005913	Pawnee	70	500	555	604	656	711	766
PAWNEE CO RWD #5	OK3005902	Pawnee	517	133	148	161	174	189	204
PAYNE CO RW CORP #3	OK3006030	Payne	151	3,035	3,265	3,508	3,746	3,914	4,076
PAYNE CO RWD #3	OK2006011	Payne	73	1,423	1,531	1,645	1,756	1,835	1,911
PAYNE CO RWD #4	OK3006001	Payne	51	871	937	1,007	1,075	1,124	1,170
PERKINS	OK2006012	Payne	99	2,348	2,531	2,722	2,904	3,040	3,159
PERRY WATER & LIGHT DEPT	OK1021206	Noble	85	5,281	5,546	5,723	5,901	6,033	6,166
PONCA CITY MUNICIPAL WATER	OK1021202	Kay	345	27,197	28,143	28,862	29,530	30,187	30,906
POND CREEK	OK2002702	Grant	325	890	910	920	920	950	970
PRUE PWA	OK2005703	Osage	89	456	496	515	535	555	585
R&C WATER CORP	OK3002703	Grant	107	525	535	544	544	563	576
RALSTON	OK2005901	Pawnee	159	361	401	436	474	514	554
RED ROCK	OK2005202	Noble	142	299	314	324	334	341	349
RIPLEY PWA	OK2006013	Payne	144	385	416	447	478	501	516
SALT FORK WA	OK3002418	Garfield	160	25	26	27	27	28	28
SHIDLER	OK1021203	Osage	70	531	569	588	617	636	664
STILLWATER WATER PLANT	OK1021220	Payne	166	47,582	51,204	55,008	58,748	61,395	63,914
SW WATER INC	OK3002706	Grant	186	204	208	211	211	219	224
TONKAWA	OK2003603	Kay	138	3,323	3,441	3,520	3,599	3,678	3,766
TRYON	OK2004103	Lincoln	181	454	501	529	567	605	643
WAKITA	OK2002706	Grant	179	420	420	430	430	450	450
WAUKOMIS PWA	OK2002410	Garfield	92	1,314	1,355	1,386	1,416	1,436	1,467
WESTPORT UTILITY AUTH TRUST	OK2005910	Pawnee	90	178	198	216	234	254	273
WOODS CO RWD #1	OK3007602	Woods	243	245	245	247	250	252	257
WOODS CO RWD #3	OK3007605	Woods	260	360	360	363	367	370	378
YALE	OK3006039	Payne	78	1,493	1,600	1,717	1,834	1,912	1,990

1 SDWIS - Safe Drinking Water Information System
2 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, the weighted average per capita demand was used for the provider's county. In some cases, provider 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)

Upper Arkansas Region

Provider	SDWIS ID[1]	County	Demand 2010	2020	2030	2040	2050	2060
			AFY					
51 EAST CORP	OK3006003	Payne	174	187	201	215	224	234
ALFALFA CO RWS & SWMD #1	OK2000202	Alfalfa	244	244	244	244	248	252
ALVA	OK2007603	Woods	1,692	1,692	1,711	1,730	1,749	1,783
BILLINGS PWA	OK2005201	Noble	96	101	105	109	111	113
BLACKWELL	OK1021101	Kay	1,615	1,671	1,714	1,753	1,792	1,836
BLACKWELL RW CORP	OK3003601	Kay	171	177	181	185	189	194
BRAMAN	OK3003616	Kay	26	27	27	28	28	29
BRECKINRIDGE PWA	OK2002420	Garfield	51	53	55	57	57	59
BURBANK	OK3005752	Osage	14	15	16	16	17	18
BURLINGTON	OK3000202	Alfalfa	28	28	28	28	28	30
CHEROKEE	OK2000208	Alfalfa	405	405	405	405	412	417
CLEVELAND NORTH	OK1021210	Pawnee	577	640	698	759	821	885
COVINGTON	OK3002419	Garfield	40	40	42	42	43	44
COYLE	OK2004203	Logan	44	50	54	59	64	69
CREEK CO RWD #5	OK2001994	Creek	181	193	203	212	222	232
CREEK CO RWD #10	OK2001907	Creek	4	4	4	4	5	5
CUSHING	OK2006061	Payne	1,274	1,372	1,474	1,574	1,645	1,712
DEER CREEK	OK2002711	Grant	15	15	15	15	16	16
DOUGLAS	OK3002414	Garfield	3	3	3	3	3	3
DRUMRIGHT	OK2001902	Creek	629	672	706	739	771	806
ENID	OK2002412	Garfield	10,728	11,056	11,327	11,581	11,779	12,016
FAIRFAX	OK1021204	Osage	194	208	218	228	237	248
FAIRMONT	OK2002413	Garfield	10	11	11	11	12	12
GARBER	OK2002416	Garfield	91	93	95	97	99	101
GARFIELD CO RWD #1 (KREM-HILL)	OK2002402	Garfield	128	132	135	138	140	143
GARFIELD CO RWD #4	OK3002406	Garfield	18	19	19	19	20	20
GARFIELD CO RWD #5	OK2002444	Garfield	176	182	186	190	193	197
GARFIELD CO RWD #7	OK3002408	Garfield	59	61	62	63	64	66
GLENCOE	OK3006040	Payne	45	48	52	56	59	61
GRANT CO RWD #1	OK3002707	Grant	18	18	19	19	19	20
GRAYHORSE RWD	OK3005717	Osage	19	20	21	22	23	24
HALLETT PWA	OK2005905	Pawnee	17	19	21	23	25	27
HILLSDALE PWA	OK3002404	Garfield	9	10	10	10	10	11
HUNTER	OK3002415	Garfield	24	24	25	25	26	26
JEFFERSON	OK3002702	Grant	4	4	4	4	4	4

Public Water Provider Demand Forecast (2 of 3)
Upper Arkansas Region

Provider	SDWIS ID[1]	County	Demand					
			2010	2020	2030	2040	2050	2060
			AFY					
JENNINGS	OK2005904	Pawnee	30	33	36	39	42	45
JET	OK2000211	Alfalfa	36	36	36	36	36	38
KAW CITY WA	OK2003605	Kay	71	72	74	76	78	80
KAW WATER INC	OK3003618	Kay	12	13	13	13	14	14
KAY CO RWD #1	OK3003605	Kay	278	288	295	302	309	316
KAY CO RWD #2	OK3003604	Kay	42	44	45	46	47	48
KAY CO RWD #3	OK3003602	Kay	115	119	122	124	127	130
KAY CO RWD #4	OK3003624	Kay	13	13	13	14	14	14
KAY CO RWD #5 (DALE WATER CORP)	OK3003603	Kay	130	134	138	141	144	147
KAY CO RWD #6	OK2002415	Garfield	126	130	133	136	139	141
KREMLIN	OK3002403	Garfield	70	70	73	75	75	78
LAMONT	OK2002705	Grant	92	94	96	96	100	102
LANGSTON PWA	OK1020911	Logan	99	111	122	133	144	155
LOGAN CO RWS & SWMD #3	OK2004230	Logan	384	431	473	515	557	601
LONE CHIMNEY WA	OK1021221	Pawnee	24	27	29	32	34	37
MANCHESTER	OK2002703	Grant	12	13	13	13	13	14
MANNFORD	OK1020909	Creek	308	329	345	361	377	394
MARLAND	OK2005204	Noble	31	34	35	36	37	37
MARSHALL	OK3004201	Logan	56	64	70	76	82	89
MEDFORD	OK2002704	Grant	677	688	706	706	735	747
MORRISON PWA	OK3005205	Noble	83	87	89	92	94	97
MULHALL	OK3004203	Logan	37	42	46	50	54	58
NASH	OK2002701	Grant	73	76	76	76	79	79
NEWKIRK	OK2003604	Kay	553	572	587	601	613	628
NOBLE CO RWD # 4	OK3005201	Noble	18	19	20	20	21	21
NOBLE CO RWD #1 (LUCIEN)	OK1021205	Noble	65	68	71	73	74	76
NOBLE CO RWD #3	OK2005207	Noble	13	14	14	14	15	15
NOBLE CO RWD #2	OK3005203	Noble	142	149	154	159	162	166
OILTON	OK2001901	Creek	128	138	145	151	158	166
ORLANDO	OK3004202	Logan	37	42	45	50	53	58
OSAGE CO RWD #3 (MCCORD)	OK3005747	Osage	316	339	356	371	386	403
OSAGE CO RWS & SWD #3 (BRADEN)	OK3005748	Osage	91	98	103	107	111	116
OSAGE CO RWD #21	OK2003616	Osage	160	171	179	187	195	204
OSAGE PWA	OK2005701	Osage	19	21	22	23	24	25
PAWNEE	OK1021209	Pawnee	193	214	233	253	275	296
PAWNEE CO RWD #1	OK2005931	Pawnee	254	282	307	333	361	389
PAWNEE CO RWD #2	OK3005921	Pawnee	190	211	229	249	270	291

Public Water Provider Demand Forecast (3 of 3)

Upper Arkansas Region

Provider	SDWIS ID[1]	County	Demand 2010	2020	2030	2040	2050	2060
			AFY					
PAWNEE CO RWD #3	OK3005911	Pawnee	84	93	101	110	119	129
PAWNEE CO RWD #4	OK3005913	Pawnee	39	44	47	52	56	60
PAWNEE CO RWD #5	OK3005902	Pawnee	77	85	93	101	110	118
PAYNE CO RW CORP #3	OK3006030	Payne	515	554	595	635	664	691
PAYNE CO RWD #3	OK2006011	Payne	116	125	134	143	149	156
PAYNE CO RWD #4	OK3006001	Payne	50	54	58	62	64	67
PERKINS	OK2006012	Payne	261	281	302	322	337	350
PERRY WATER & LIGHT DEPT	OK1021206	Noble	502	527	544	561	573	586
PONCA CITY MUN WATER	OK1021202	Kay	10,518	10,884	11,162	11,420	11,675	11,953
POND CREEK	OK2002702	Grant	324	331	335	335	346	353
PRUE PWA	OK2005703	Osage	45	49	51	53	55	58
R&C WATER CORP	OK3002703	Grant	63	64	65	65	67	69
RALSTON	OK2005901	Pawnee	64	71	78	84	92	99
RED ROCK	OK2005202	Noble	47	50	51	53	54	55
RIPLEY PWA	OK2006013	Payne	62	67	72	77	81	83
SALT FORK WA	OK3002418	Garfield	5	5	5	5	5	5
SHIDLER	OK1021203	Osage	42	45	46	48	50	52
STILLWATER WATER PLANT	OK1021220	Payne	8,864	9,539	10,247	10,944	11,437	11,906
SW WATER INC	OK3002706	Grant	43	43	44	44	46	47
TONKAWA	OK2003603	Kay	515	533	545	557	570	583
TRYON	OK2004103	Lincoln	92	102	107	115	123	130
WAKITA	OK2002706	Grant	84	84	86	86	90	90
WAUKOMIS PWA	OK2002410	Garfield	136	140	143	146	148	151
WESTPORT UTILITY AUTH TRUST	OK2005910	Pawnee	18	20	22	24	26	28
WOODS CO RWD #1	OK3007602	Woods	67	67	67	68	69	70
WOODS CO RWD #3	OK3007605	Woods	105	105	106	107	108	110
YALE	OK3006039	Payne	131	140	151	161	168	175

1 SDWIS - Safe Drinking Water Information System

Public Water Provider Wholesale Water Transfers (1 of 3)

Upper 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
51 EAST CORP	OK3006003				Stillwater Water Plant Lone Chimney Water Association	O O	T T
ALFALFA CO RWS & SWMD #1	OK2000202	Burlington	O	R			
ALVA	OK2007603	Woods Co RWD#3 Woods Co RWD#1 Woods Co RWD #4 Dacoma PWA	O O O	T T T			
BLACKWELL	OK1021101	Blackwell RW Corp	O	T			
BLACKWELL RW CORP	OK3003601	Braman	O	T	Blackwell	O	T
BRAMAN	OK3003616				Blackwell RW Corp	O	T
BURBANK	OK3005752				Osage Co RWD #3 (Braden)		
BURLINGTON	OK3000202				Alfalfa Co RWS $ SWMD #1	O	R
CLEVELAND NORTH	OK1021210				Lone Chimney WA	O	T
COVINGTON	OK3002419				Enid	O	T
CUSHING	OK2006061	Lincoln Co RWD # 4	E	T			
DOUGLAS	OK3002414				Kay County RWD #6		T
ENID	OK2002412	Salt Fork Water Authority Waukomis PWA Lahoma PWA Garfield Co RWD #7 Garfield Co RWD #4 Drummond	O O O O O O	T T R T R T			
FAIRFAX	OK1021204	Grayhorse RWD	O	T			
GARFIELD CO RWD #4	OK3002406				Enid	O	R
GARFIELD CO RWD #5	OK2002444	Drumond	E	T			
GARFIELD CO RWD #1 (KREM-HILL)	OK2002402	Kremlin Hillsdale PWA	O O	T T			
GARFIELD CO RWD #7	OK3002408				Enid	O	T
GLENCOE	OK3006040				Lone Chimney WA	O	T
GRANT CO RWD #1	OK3002707				Manchester	O	T
GRAYHORSE RWD	OK3005717				Fairfax	O	T
HILLSDALE PWA	OK3002404				Garfield Co RWD #1 Kremlin	O	T T
HUNTER	OK3002415				Kay Co RWD #6		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.

Public Water Provider Wholesale Water Transfers (2 of 3)
Upper Arkansas Region

Provider	SDWIS ID[1]	Sales: Sells To	Sales: Emergency or Ongoing	Sales: Treated or Raw or Both	Purchases: Purchases from	Purchases: Emergency or Ongoing	Purchases: Treated or Raw or Both
JEFFERSON	OK3002702				Medford	O	T
KAW CITY WA	OK2003605	Kay Co RWD #4	O	T			
KAW WATER INC	OK3003618				Kay Co RWD #4		
KAY CO RWD #1	OK3003605				Ponca City Municipal Water	O	T
KAY CO RWD #2	OK3003604				Ponca City Mun Water		T
KAY CO RWD #3	OK3003602				Ponca City Mun Water	O	T
KAY CO RWD #4	OK3003624				Kaw City WA	O	T
KAY CO RWD #5 (DALE WATER CORP)	OK3003603				Newkirk		T
KAY CO RWD #6	OK2002415	Douglas Hunter		T T			
KREMLIN	OK3002403	Hillsdale PWA		T			
LOGAN CO RWS & SWMD #3	OK2004230	Mulhall Orlando Noble Co RWD #1 Marshall	 O	T T T T			
ORLANDO	OK3004202				Logan County RWD #3	O	O
OSAGE CO RWS & SWD #3 (BRADEN)	OK3005748	Burbank			Washington Co RWD #3 Ponca City Mun Water	E	T T
PAWNEE	OK1021209				Lone Chimney WA	O	T
PAWNEE CO RWD #1	OK2005931	Westport Utility Auth Trust	O	T			
PAWNEE CO RWD #2	OK3005921				Lone Chimney WA	O	T
PAWNEE CO RWD #3	OK3005911				Lone Chimney WA		T
PAWNEE CO RWD #4	OK3005913				Lone Chimney WA	O	T
PAWNEE CO RWD #5	OK3005902				Ralston		T
PAYNE CO RW CORP #3	OK3006030				Stillwater Water Plant	O	T
PAYNE CO RWD #4	OK3006001				Lone Chimney WA	O	T
PONCA CITY MUN WATER	OK1021202	Kay Co RWD #1 Kay Co RWD #3 Osage Co RWD #3 Kay Co RWD #2 Osage Co RWD #3 (McCord)	O O	T T T T			

Public Water Provider Wholesale Water Transfers (3 of 3)

Upper 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
POND CREEK	OK2002702	SW Water Inc	O	T			
R&C WATER CORP	OK3002703				Medford	O	T
RALSTON	OK2005901	Pawnee Co RWD #5		T			
SALT FORK WA	OK3002418	Covington	O	T	Enid	O	T
STILLWATER WATER PLANT	OK1021220	Payne Co RWD #3 51 East Corp Noble Co RWD #2 Morrison	O O O	T T T R			
SW WATER INC	OK3002706	Pond Creek	O	T	Pond Creek	O	T
WAUKOMIS PWA	OK2002410				Enid	E	T
WESTPORT UTILITY AUTH TRUST	OK2005910				Pawnee Co Rwd #1	O	T
WOODS CO RWD #1	OK3007602	Freedom	O	T	Alva	O	T
WOODS CO RWD #3	OK3007605				Alva Waynoka	O O	T T
YALE	OK3006039				Lone Chimney WA	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)

Upper Arkansas Region

Provider	SDWIS ID[1]	County	Permitted Quantity	Source		
				Permitted Surface Water	Permitted Alluvial Groundwater	Permitted Bedrock Groundwater
			AFY	Percent		
51 EAST CORP	OK3006003	Payne	---	---	---	---
ALFALFA CO RWS & SWMD #1	OK2000202	Alfalfa	560	0%	0%	100%
ALVA	OK2007603	Woods	4,018	0%	100%	0%
BILLINGS PWA	OK2005201	Noble	1,045	0%	100%	0%
BLACKWELL	OK1021101	Kay	3,725	100%	0%	0%
BLACKWELL RW CORP	OK3003601	Kay	---	---	---	---
BRAMAN	OK3003616	Kay	30	0%	0%	100%
BRECKINRIDGE PWA	OK2002420	Garfield	---	---	---	---
BURBANK	OK3005752	Osage	43	0%	100%	0%
BURLINGTON	OK3000202	Alfalfa	12	0%	100%	0%
CHEROKEE	OK2000208	Alfalfa	535	0%	100%	0%
CLEVELAND NORTH	OK1021210	Pawnee	1,231	0%	0%	100%
COVINGTON	OK3002419	Garfield	---	---	---	---
COYLE	OK2004203	Logan	---	---	---	---
CREEK CO RWD #5	OK2001994	Creek	675	0%	0%	100%
CREEK CO RWD #10	OK2001907	Creek	---	---	---	---
CUSHING	OK2006061	Payne	9,261	34%	26%	39%
DEER CREEK	OK2002711	Grant	200	---	100%	---
DOUGLAS	OK3002414	Garfield	---	---	---	---
DRUMRIGHT	OK2001902	Creek	1,416	0%	0%	100%
ENID	OK2002412	Garfield	38,355	0%	93%	7%
FAIRFAX	OK1021204	Osage	1,095	91%	9%	0%
FAIRMONT	OK2002413	Garfield	25	0%	0%	100%
GARBER	OK2002416	Garfield	311	0%	0%	100%
GARFIELD CO RWD #1 (KREM-HILL)	OK2002402	Garfield	---	---	---	---
GARFIELD CO RWD #4	OK3002406	Garfield	---	---	---	---
GARFIELD CO RWD #5	OK2002444	Garfield	1,070	0%	100%	0%
GARFIELD CO RWD #7	OK3002408	Garfield	---	---	---	---
GLENCOE	OK3006040	Payne	16	0%	0%	100%
GRANT CO RWD #1	OK3002707	Grant	---	---	---	---
GRAYHORSE RWD	OK3005717	Osage	---	---	---	---
HALLETT PWA	OK2005905	Pawnee	1,280	0%	0%	100%
HILLSDALE PWA	OK3002404	Garfield	---	---	---	---
HUNTER	OK3002415	Garfield	49	0%	0%	100%

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

Provider	SDWIS ID[1]	County	Permitted Quantity	Source		
				Permitted Surface Water	Permitted Alluvial Groundwater	Permitted Bedrock Groundwater
			AFY	Percent		
JEFFERSON	OK3002702	Grant	---	---	---	---
JENNINGS	OK2005904	Pawnee	80	0%	0%	100%
JET	OK2000211	Alfalfa	84	0%	100%	0%
KAW CITY WA	OK2003605	Kay	272	---	100%	---
KAW WATER INC	OK3003618	Kay	---	---	---	---
KAY CO RWD #1	OK3003605	Kay	---	---	---	---
KAY CO RWD #2	OK3003604	Kay	---	---	---	---
KAY CO RWD #3	OK3003602	Kay	---	---	---	---
KAY CO RWD #4	OK3003624	Kay	---	---	---	---
KAY CO RWD #5 (DALE WATER CORP)	OK3003603	Kay	---	---	---	---
KAY CO RWD #6	OK2002415	Garfield	444	0%	100%	0%
KREMLIN	OK3002403	Garfield	300	0%	100%	0%
LAMONT	OK2002705	Grant	1,415	0%	100%	0%
LANGSTON PWA	OK1020911	Logan	---	---	---	---
LOGAN CO RWS & SWMD #3	OK2004230	Logan	716	0%	100%	0%
LONE CHIMNEY WA	OK1021221	Pawnee	2,507	100%	0%	0%
MANCHESTER	OK2002703	Grant	320	0%	100%	0%
MANNFORD	OK1020909	Creek	1,120	100%	0%	0%
MARLAND	OK2005204	Noble	---	---	---	---
MARSHALL	OK3004201	Logan	---	---	---	---
MEDFORD	OK2002704	Grant	1,827	0%	100%	0%
MORRISON PWA	OK3005205	Noble	---	---	---	---
MULHALL	OK3004203	Logan	80	0%	0%	100%
NASH	OK2002701	Grant	104	---	100%	---
NEWKIRK	OK2003604	Kay	1,878	60%	40%	0%
NOBLE CO RWD #1 (LUCIEN)	OK1021205	Noble	---	---	---	---
NOBLE CO RWD #2	OK3005203	Noble	---	---	---	---
NOBLE CO RWD #3	OK2005207	Noble	25	---	100%	---
NOBLE CO RWD #4	OK3005201	Noble	---	---	---	---
OILTON	OK2001901	Creek	163	0%	0%	100%
ORLANDO	OK3004202	Logan	---	---	---	---
OSAGE CO RWD #3 (MCCORD)	OK3005747	Osage	37	0%	100%	0%
OSAGE CO RWS & SWD #3 (BRADEN)	OK3005748	Osage	16	0%	100%	0%
OSAGE CO RWD #21	OK2003616	Osage	320	---	100%	---
OSAGE PWA	OK2005701	Osage	92	0%	100%	0%

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

Upper Arkansas Region

Provider	SDWIS ID[1]	County	Permitted Quantity	Source		
				Permitted Surface Water	Permitted Alluvial Groundwater	Permitted Bedrock Groundwater
			AFY	Percent		
PAWNEE	OK1021209	Pawnee	438	100%	0%	0%
PAWNEE CO RWD #1	OK2005931	Pawnee	614	0%	33%	67%
PAWNEE CO RWD #2	OK3005921	Pawnee	470	0%	0%	100%
PAWNEE CO RWD #3	OK3005911	Pawnee	---	---	---	---
PAWNEE CO RWD #4	OK3005913	Pawnee	---	---	---	---
PAWNEE CO RWD #5	OK3005902	Pawnee	---	---	---	---
PAYNE CO RW CORP #3	OK3006030	Payne	---	---	---	---
PAYNE CO RWD #3	OK2006011	Payne	---	---	---	---
PAYNE CO RWD #4	OK3006001	Payne	---	---	---	---
PERKINS	OK2006012	Payne	1,384	64%	36%	0%
PERRY WATER & LIGHT DEPT	OK1021206	Noble	4,008	100%	0%	0%
PONCA CITY MUN WATER	OK1021202	Kay	2,529	54%	46%	0%
POND CREEK	OK2002702	Grant	1,319	0%	100%	0%
PRUE PWA	OK2005703	Osage	680	---	---	100%
R&C WATER CORP	OK3002703	Grant	---	---	---	---
RALSTON	OK2005901	Pawnee	480	0%	100%	0%
RED ROCK	OK2005202	Noble	36	0%	100%	0%
RIPLEY PWA	OK2006013	Payne	100	0%	100%	0%
SALT FORK WA	OK3002418	Garfield	---	---	---	---
SHIDLER	OK1021203	Osage	336	100%	0%	0%
STILLWATER	OK1021220	Payne	58,706	100%	0%	0%
SW WATER INC	OK3002706	Grant	---	---	---	---
TONKAWA	OK2003603	Kay	5,005	56%	44%	0%
TRYON	OK2004103	Lincoln	---	---	---	---
WAKITA	OK2002706	Grant	803	0%	100%	0%
WAUKOMIS PWA	OK2002410	Garfield	334	0%	0%	100%
WESTPORT UTILITY AUTH TRUST	OK2005910	Pawnee	113	0%	0%	100%
WOODS CO RWD #1	OK3007602	Woods	---	---	---	---
WOODS CO RWD #3	OK3007605	Woods	---	---	---	---
YALE	OK3006039	Payne	437	0%	100%	0%

1 SDWIS - Safe Drinking Water Information System

OCWP Provider Survey
Upper Arkansas Region

51 East Corp. (Payne County)
Current Source of Supply
Primary source: Loan Chimney Water Association
Short-Term Needs
Infrastructure improvements: replace distribution system lines, add storage.
Long-Term Needs
Infrastructure improvements: replace distribution system lines, add looping lines.

Alfalfa County RWS & SWMD 1
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Alva (Woods County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: refurbish existing wells.
Long-Term Needs
New supply source: drill additional wells.

Billings PWA (Noble County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
New supply source: drill additional wells.

City of Blackwell (Kay County)
Current Source of Supply
Primary source: Chikaskia River
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines, add storage.

Blackwell RW Corp. (Kay County)
Current Source of Supply
Primary source: City of Blackwell
Short-Term Needs
Infrastructure improvements: add & replace distribution system lines, add storage
Long-Term Needs
Infrastructure improvements: replace distribution system lines and pumps.

Town of Braman (Kay County)
Current Source of Supply
Primary source: Blackwell Rural Water Corp.
Short-Term Needs
Infrastructure improvements: refurbish existing storage tower and add valves to distribution system lines.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

Breckinridge PWA (Garfield County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Burbank (Osage County)
Current Source of Supply
Primary source: Alfalfa County RWD
Short-Term Needs
Infrastructure improvements: add distribution system lines.
Long-Term Needs
Infrastructure improvements: refurbish water tower.

Town of Burlington (Alfalfa County)
Current Source of Supply
Primary source: Alfalfa County RWD
Short-Term Needs
None identified.
Long-Term Needs
None identified.

City of Cherokee (Alfalfa County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
None identified.

City of Cleveland North (Pawnee County)
Current Source of Supply
Primary source: Cleveland Lake
Short-Term Needs
Infrastructure improvements: add chloramines system.
Long-Term Needs
Infrastructure improvements: add distribution system lines & storage.

Town of Covington (Garfield County)
Current Source of Supply
Primary source: Salt Fork Water Authority
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace portion of distribution system lines.

City of Coyle (Logan County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Creek County RWD 5
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines and add storage.

Creek County RWD 10
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: refurbish well; replace storage tank; add distribution system lines for looping.
Long-Term Needs
Infrastructure improvements: replace water main lines.

City of Cushing (Payne County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: drill additional wells.
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
None required.

Deer Creek (Grant County)
Current Source of Supply
Primary sources: groundwater
Short-Term Needs
New supply sources: possibly from RNC Medford, purchase and blend for the reduction of nitrates.
Long-Term Needs
None required.

City of Douglas (Garfield County)
Current Source of Supply
Primary source: Kay County RWD 6
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines and refurbish storage tank.

City of Drumright (Creek County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: modify clearwell.
Long-Term Needs
Infrastructure improvements: construct new reservoir.

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.

City of Enid (Garfield County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: add Storage and drill additional wells.
Long-Term Needs
None identified.

Town of Fairfax (Osage County)
Current Source of Supply
Primary source: Fairfax City Lake, groundwater
Emergency source: groundwater
Short-Term Needs
Infrastructure improvements: replace distribution system line from well to town
Long-Term Needs
Infrastructure improvements: replace well pump and construct new water treatment plant.

Town of Fairmont (Garfield County)
Current Source of Supply
Primary source: None identified.
Short-Term Needs
None identified.
Long-Term Needs
None identified.

City of Garber (Garfield County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: drill additional wells.
Long-Term Needs
None identified.

Garfield County RWD 4
Current Source of Supply
Primary source: City of Enid
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Garfield County RWD 5
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: drill additional wells.

Garfield County RWD 1 (KREM-HILL)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: drill additional wells.

Garfield County RWD 7
Current Source of Supply
Primary source: Enid
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Glencoe (Payne County)
Current Source of Supply
Primary source: Lone Chimney Water Association
Short-Term Needs
Infrastructure improvements: add storage and replace portion of main lines.
Long-Term Needs
Infrastructure improvements: replace portion of distribution system lines.

Grant County RWD 1
Current Source of Supply
Primary source: City of Manchester
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: drill additional wells.

Grayhorse RWD (Osage County)
Current Source of Supply
Primary source: City of Fairfax
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace water meters.

Hallett PWA (Pawnee County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: replace well pumps.
Long-Term Needs
New supply source: drill additional well.

Hillsdale PWA (Garfield County)
Current Source of Supply
Primary source: No information
Short-Term Needs
No information
Long-Term Needs
No information

Town of Hunter (Garfield County)
Current Source of Supply
Primary source: Kay County RWD 6
Short-Term Needs
Infrastructure improvements: replace distribution system lines and fire hydrants.
Long-Term Needs
None identified.

Town of Jefferson (Grant County)
Current Source of Supply
Primary source: City of Medford
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Jennings (Pawnee County)
Current Source of Supply
Primary source: City of Medford
Short-Term Needs
New supply source: drill additional wells.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

Town of Jet (Alfalfa County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: drill additional wells.
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
None identified.

Kaw City WA (Kay County)
Current Source of Supply
Primary source: Kaw Reservoir, Arkansas River
Short-Term Needs
New supply source: need additional well capacity.
Infrastructure improvements: replace transmission lines; install meter on lake line.
Long-Term Needs
Infrastructure improvements: new treatment plant; additional distribution lines.

Kaw Water Inc. (Kay County)
Current Source of Supply
Primary source: Kay County RWD 4
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace portion of distribution system lines.

Kay County RWD 1
Current Source of Supply
Primary source: Ponca City
Short-Term Needs
Infrastructure improvements: replace portion of distribution system lines.
Long-Term Needs
Infrastructure improvements: replace portion of distribution system lines.

Kay County RWD 3
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: replace portion of distribution system lines.
Long-Term Needs
Infrastructure improvements: replace portion of distribution system lines.

Kay County RWD 5
Current Source of Supply
Primary source: Newkirk
Short-Term Needs
Infrastructure improvements: replace distribution lines.
Long-Term Needs
Infrastructure improvements: replace pumps

Kay County RWD 6 (Garfield County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
New supply source: drill additional wells.

Kay County RWD 4
Current Source of Supply
Primary source: City of Kaw City
Short-Term Needs
Infrastructure improvements: replace portion of distribution system lines; add fire hydrants.
Long-Term Needs
Infrastructure improvements: add storage and pump station.

Kay County RWD 2
Current Source of Supply
Primary source: Ponca City
Short-Term Needs
Infrastructure improvements: replace portion of distribution system lines.
Long-Term Needs
Infrastructure improvements: replace portion of distribution system lines.

Town of Kremlin (Garfield County)
Current Source of Supply
Primary source: Kremlin RWD
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Lamont (Grant County)
Current Source of Supply
Primary source: groundwater
Emergency source: groundwater
Short-Term Needs
New supply sources: plug emergency source and add new PWS.
Infrastructure improvements: replace portion of distribution system lines.
Long-Term Needs
New supply sources: same as short-term.
Infrastructure improvements: replace storage tower.

Langston PWA (Logan County)
Current Source of Supply
Primary source: Langston Lake
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Logan County RWS & SWMD 3
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: drill additional wells.

Lone Chimney WA (Pawnee County)
Current Source of Supply
Primary source: Lone Chimney Lake
Short-Term Needs
Infrastructure improvements: replace Stillwater raw water line; replace filter media at plant; replace portion of distribution lines.
Long-Term Needs
None identified.

Town of Manchester (Grant County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: replace portion of distribution system lines.
Long-Term Needs
Infrastructure improvements: add storage.

Town of Mannford (Creek County)
Current Source of Supply
Primary source: Mannford Lake
Short-Term Needs
Infrastructure improvements: refurbish storage tanks.
Long-Term Needs
Infrastructure improvements: add storage; new treatment plant.

Town of Marland (Logan County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: replace distribution lines; drill additional wells.
Long-Term Needs
Infrastructure improvements: replace distribution lines; drill additional wells.

Town of Marshall (Logan County)
Current Source of Supply
Primary source: Logan County RWD 3
Short-Term Needs
None identified.
Long-Term Needs
None identified.

McCord RWD 3 (Osage County)
Current Source of Supply
Primary source: Ponca City
Short-Term Needs
Infrastructure improvements: replace distribution lines; add storage.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

City of Medford (Grant County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: add water main lines; drill additional wells.
Long-Term Needs
Infrastructure improvements: add storage.

Morrison PWA (Noble County)
Current Source of Supply
Primary source: Lone Chimney
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

Town of Mulhall (Logan County)
Current Source of Supply
Primary sources: Logan County RWD 3
Short-Term Needs
New supply sources: possibly from RNC Medford, purchase and blend for the reduction of nitrates.
Long-Term Needs
None required.

Town of Nash (Grant County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
None identified.

City of Newkirk (Kay County)
Current Source of Supply
Primary source: Arkansas River, Sandy Creek aquifer
Short-Term Needs
New supply source: drill additional wells.
Infrastructure improvements: add distribution system; add flow meters; remote control well equip; add storage.
Long-Term Needs
New supply source: drill additional wells.

Noble County RWD 4
Current Source of Supply
Primary source: Town of Marland
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution lines.

Noble County RWD 1 (Lucien)
Current Source of Supply
Primary source: Logan County RWD 3
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Noble County RWD 3
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: replace distribution lines; add computer control equipment and housing; add booster pump station.
Long-Term Needs
Infrastructure improvements: replace distribution lines and valves; add fire hydrants; refurbish storage tower.

Noble County RWD 2
Current Source of Supply
Primary sources: Lone Chimney, Perry, Stillwater
Short-Term Needs
Infrastructure improvements: replace distribution lines; add distribution lines; add variable frequency drive to pumps.
Long-Term Needs
Infrastructure improvements: replace distribution lines.

City of Oilton (Creek County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: drill additional well.
Infrastructure improvements: replace distribution lines.
Long-Term Needs
Infrastructure improvements: replace distribution lines; replace storage tanks.

Town of Orlando (Logan County)
Current Source of Supply
Primary source: Logan county RWD 3
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Osage County RWD 21
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: add treatment at wells to handle iron and manganese.
Long-Term Needs
New supply source: drill additional wells.

Osage County RWS & SWD 3 (Braden)
Current Source of Supply
Primary source: Ponca City Municipal Water
Short-Term Needs
Infrastructure improvements: add storage.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; refurbish pump station.

Osage PWA (Osage County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
New supply source: drill additional wells.
Infrastructure improvements: replace distribution system lines.

City of Pawnee (Pawnee County)
Current Source of Supply
Primary sources: Lone Chimney WA, Pawnee Lake
Short-Term Needs
Infrastructure improvements: add storage; need multi-level intake structure.
Long-Term Needs
Infrastructure improvements: replace distribution lines.

Pawnee County RWD 1
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: drill additional wells.
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
Infrastructure improvements: complete infrastructure rebuild; add automatic more reliable meter readers.

Pawnee County RWD 2
Current Source of Supply
Primary source: Lone Chimney WA
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution lines.

Pawnee County RWD 3
Current Source of Supply
Primary source: Lone Chimney WA
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
Infrastructure improvements: add & replace distribution system lines; add storage.

Pawnee County RWD 4
Current Source of Supply
Primary source: Lone Chimney WA
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

Pawnee County RWD 5
Current Source of Supply
Primary source: Town of Ralston
Short-Term Needs
New supply source: drill additional well.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; refurbish standpipe.

Payne County RW Corp. 3
Current Source of Supply
Primary source: System inactive - now part of Stillwater
Short-Term Needs
New supply source: Stillwater.
Long-Term Needs
None identified.

Payne County RWD 3
Current Source of Supply
Primary source: groundwater - switching to Stillwater
Short-Term Needs
New supply source: Stillwater.
Infrastructure improvements: add pump station.
Long-Term Needs
Infrastructure improvements: replace distribution lines.

Payne County RWD 4
Current Source of Supply
Primary source: Lone Chimney WA
Emergency Source: groundwater
Short-Term Needs
New supply source: drill additional well.
Infrastructure improvements: add & replace distribution lines.
Long-Term Needs
Infrastructure improvements: add water office/shop & storage building.

Town of Perkins (Payne County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply sources: Increase water supply or create a secondary source.
Infrastructure improvements: none identified.
Long-Term Needs
New supply sources: access water rights on Kaw Lake; MOU in place with Stillwater.
Infrastructure improvements: none identified.

Perry Water and Light Dept. (Noble County)
Current Source of Supply
Primary source: Perry and McMurtry Lakes
Short-Term Needs
None identified.
Long-Term Needs
New supply sources: use existing additional water rights from McMurtry.
Infrastructure improvements: none identified.

Ponca City Municipal Water (Kay County)
Current Source of Supply
Primary sources: Ponca City Municipal. Lake, Ponca City well field, Kaw Lake
Short-Term Needs
New supply source: drill additional wells.
Infrastructure improvements: additional storage; upgrades to plant.
Long-Term Needs
None identified.

City of Pond Creek (Grant County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: drill additional wells.
Infrastructure improvements: none identified
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

Prue PWA (Osage County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: add water meters; add fencing around storage towers.
Long-Term Needs
Infrastructure improvements: drill additional wells; refurbish storage towers.

R&C Water Corp. (Grant County)
Current Source of Supply
Primary source: City of Medford
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Ralston (Pawnee County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: add storage; replace distribution system lines.
Long-Term Needs
New supply source: drill additional wells.
Infrastructure improvements: none identified.

Town of Red Rock (Noble County)
Current Source of Supply
Primary source: groundwater.
Short-Term Needs
Infrastructure improvements: replace portion of distribution system lines & water main lines; refurbish storage tank.
Long-Term Needs
Infrastructure improvements: replace portion of distribution system lines.

Ripley PWA (Payne County)
Current Source of Supply
Primary source: Oscar-Vanoss
Short-Term Needs
Infrastructure improvements: refurbish storage tank.
Long-Term Needs
New supply source: connect to RWD 3;
Infrastructure improvements: replace storage tower.

Salt Fork WA (Garfield County)
Current Source of Supply
Primary source: City of Enid
Short-Term Needs
None identified.
Long-Term Needs
None identified.

City of Shidler (Osage County)
Current Source of Supply
Primary source: Lake Charlotte
Short-Term Needs
Infrastructure improvements: replace distribution lines; new lab equipment; flow meters; chemical pumps; water plant pumps.
Long-Term Needs
Infrastructure improvements: new water treatment plant.

Stillwater Water Plant (Payne County)
Current Source of Supply
Primary source: Kaw Lake
Short-Term Needs
Infrastructure improvements: add & replace distribution system lines; add booster pumps; add auto meters.
Long-Term Needs
Infrastructure improvements: add raw water line.

SW Water Inc. (Grant County)
Current Source of Supply
Primary source: City of Pond Creek
Short-Term Needs
None identified.
Long-Term Needs
None identified.

City of Tonkawa (Kay County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: drill additional wells; add storage; replace portion of water main lines; replace distribution system lines and fire hydrants; add lines for looping and valving; add generator for emergency well.
Long-Term Needs
New supply source: drill additional wells.
Infrastructure improvements: replace distribution lines; replace storage basin.

Town of Tryon (Lincoln County)
Current Source of Supply
Primary source: None identified.
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Wakita (Grant County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Waukomis PWA (Garfield County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: drill additional wells.
Long-Term Needs
New supply source: drill additional wells.

OCWP Provider Survey
Upper Arkansas Region

Westport Utility Auth Trust (Pawnee County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: add booster pump station; add fencing to wells and storage tank.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; add water meters.

Woods County RWD 1
Current Source of Supply
Primary sources: Alva
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Woods County RWD 3
Current Source of Supply
Primary source: Alva, Waynoka
Short-Term Needs
Infrastructure improvements: add storage; add pump station.
Long-Term Needs
Infrastructure improvements: add storage; add pump station; replace distribution system lines.

City of Yale (Payne County)
Current Source of Supply
Primary source: Lone Chimney WA
Short-Term Needs
Infrastructure improvements: add storage; add pump stations.
Long-Term Needs
Infrastructure improvements: add storage; add pump station. replace distribution system lines.

Infrastructure Cost Summary
Upper Arkansas Region

Provider System Category[1]	Infrastructure Need (millions of 2007 dollars)			
	Present-2020	2021-2040	2041-2060	Total Period
Small	$705	$160	$111	$976
Medium	$335	$336	$374	$1,045
Large	$0	$0	$0	$0
Reservoir[2]	$0	$88	$3	$91
Total	$1,040	$584	$488	$2,112

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 $2.11 billion is needed to meet the projected drinking water infrastructure needs of the Upper Arkansas region over the next 50 years. The largest infrastructure costs are expected to occur within the next 20 years.
- Distribution and transmission projects account for more than 80 percent of the providers' estimated infrastructure costs, followed distantly by water treatment projects.
- Small and medium providers have approximately equal drinking water infrastructure costs. There are no large providers in the Upper Arkansas Region.
- Projects involving rehabilitation of existing reservoirs make up approximately four 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)

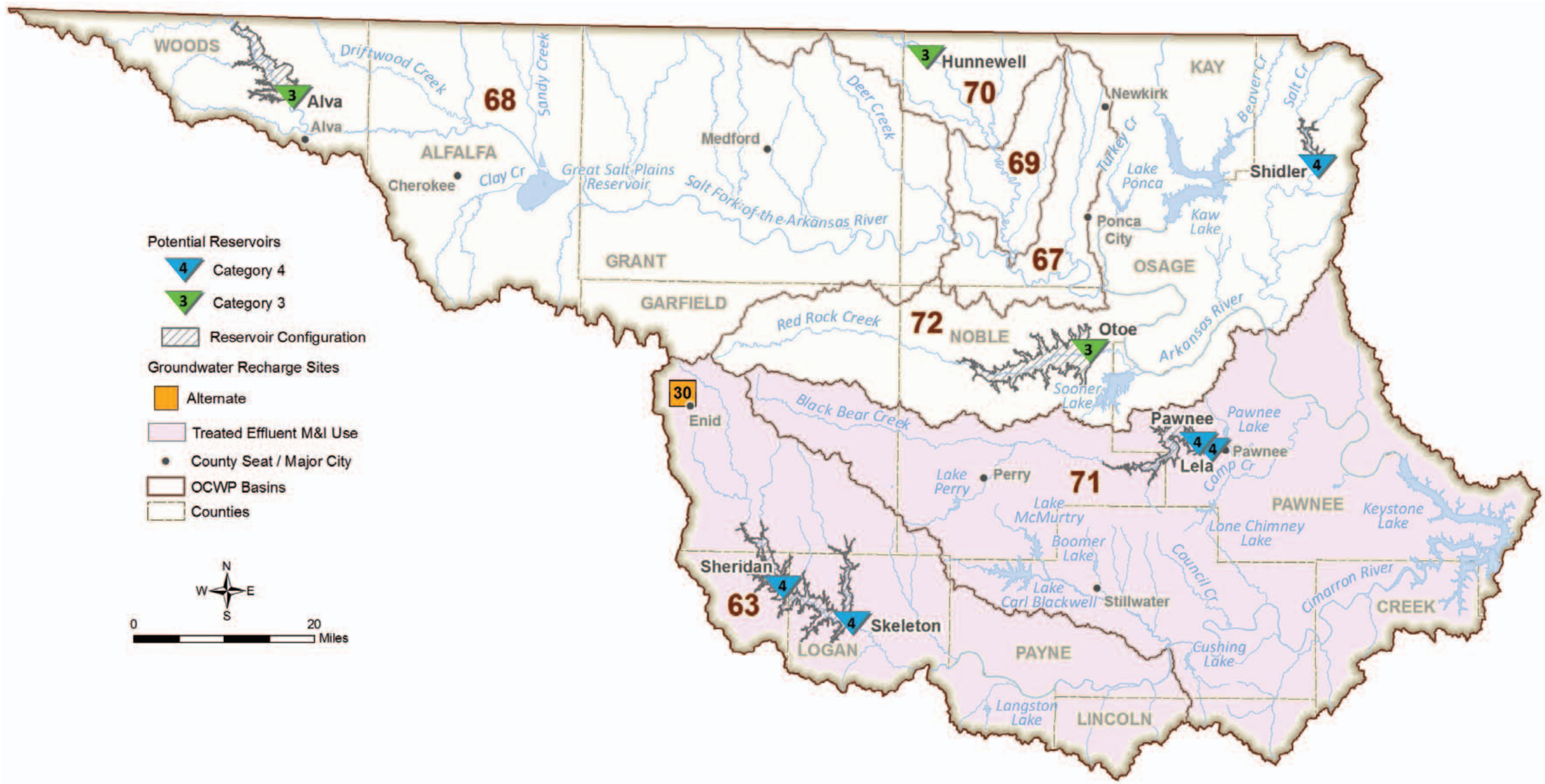
Upper Arkansas Region

Name	Category	Stream	Basin	Purposes[1]	Total Storage	Conservation Pool			Primary Study		Updated Cost Estimate[2] (2010 dollars)
						Surface Area	Storage	Dependable Yield	Date	Agency	
					AF	Acres	AF	AFY			
Alva	3	Salt Fork of the Arkansas	68	IR, FW, R	0	10,000	200,500	32,486	1973	Bureau of Reclamation	$412,756,000
Hunnewell	3	Chikaskia River	70	WS, FC, FW, R	645,100	18,750	473,400	54,700	1995	USACE	$208,441,000
Lela (Watchorn or Pawnee)	4	Black Bear Creek	71	WS, R, FW	224,300	9,700	165,500	47,000	1973	Bureau of Reclamation	$211,905,000
Otoe	3	Red Rock Creek	72	WS, FC, R, FW	670,200	19,950	403,300	46,000	1995	USACE	$370,743,000
Pawnee	4	Black Bear Creek	71	FC, WS, R, FW	0	10,000	210,350	48,170	1985	USACE	$328,410,000
Sheridan	4	Skeleton Creek	63	FC, WS, R, FW	0	9,100	127,600	23,525	1985	USACE	$347,552,000
Shidler	4	Salt Creek	72	FC, WS, WQ, R, FW	108,100	2,450	54,920	16,803	1971	USACE	$58,264,000
Skeleton	4	Skeleton Creek	63	FC, WS, FW, R	0	14,000	250,000	41,448	1985	USACE	$287,932,000

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 the costs as estimated in previous project reports combined with the USACE 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.

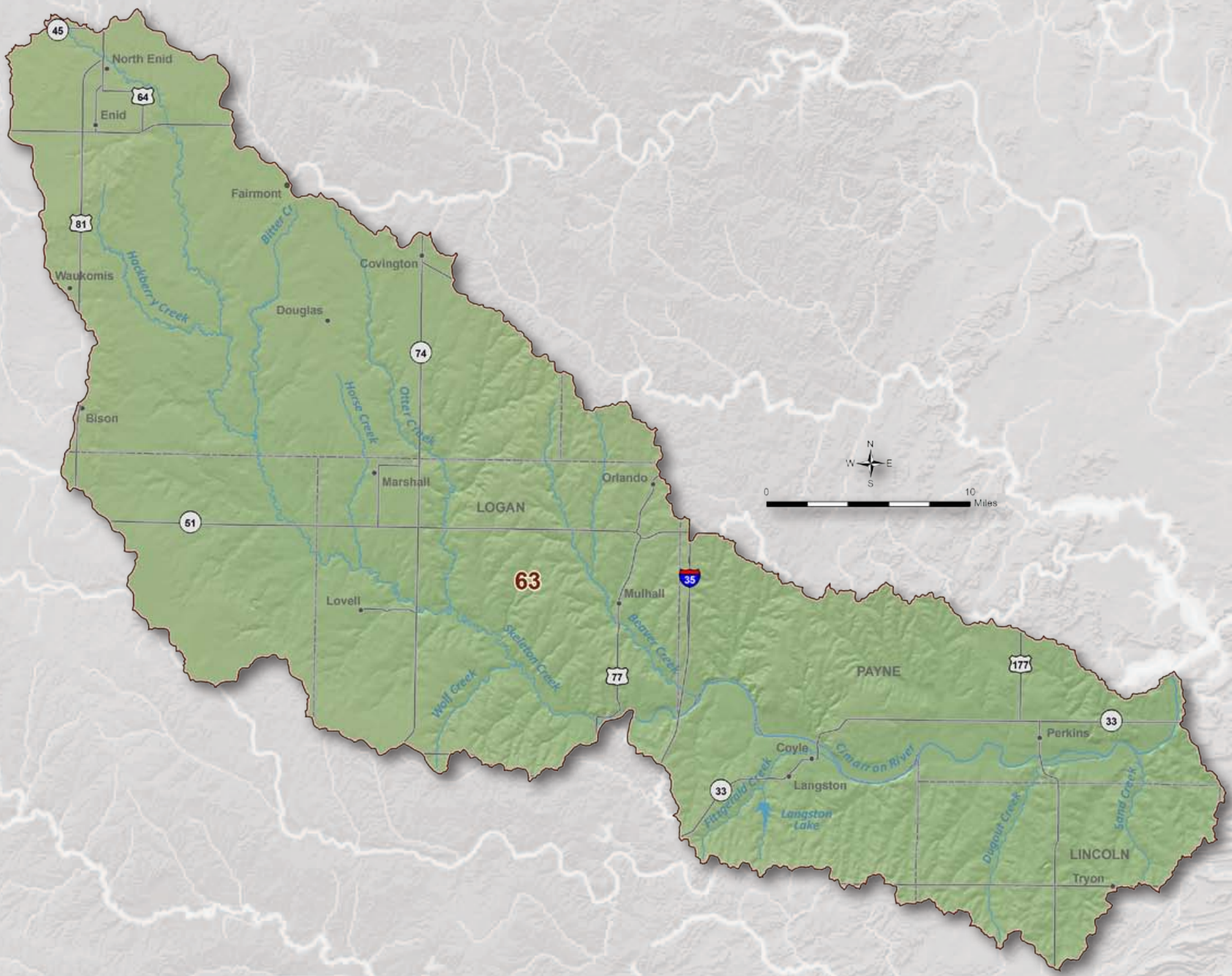
Expanded Water Supply Options
Upper Arkansas Region



Data & Analysis

Upper Arkansas Watershed Planning Region

Basin 63

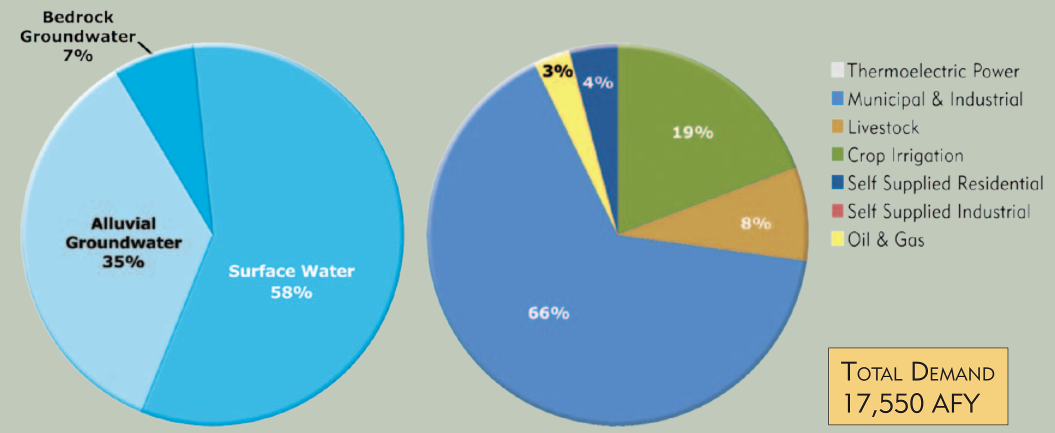


Basin 63 Summary

Synopsis

- Water users are expected to continue to rely primarily on a mixture of surface water and alluvial groundwater supplies.
- Starting in 2020, there is a moderate 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 mitigate surface water gaps and reduce the adverse effects of localized alluvial groundwater storage depletions.
- Aquifer storage (recharge) and recovery could be considered to store variable surface water supplies, increase alluvial groundwater storage, and reduce adverse effects of localized groundwater storage depletions.
- Use of additional groundwater supplies and/or developing small reservoirs could mitigate surface water gaps without having major impacts to groundwater storage.

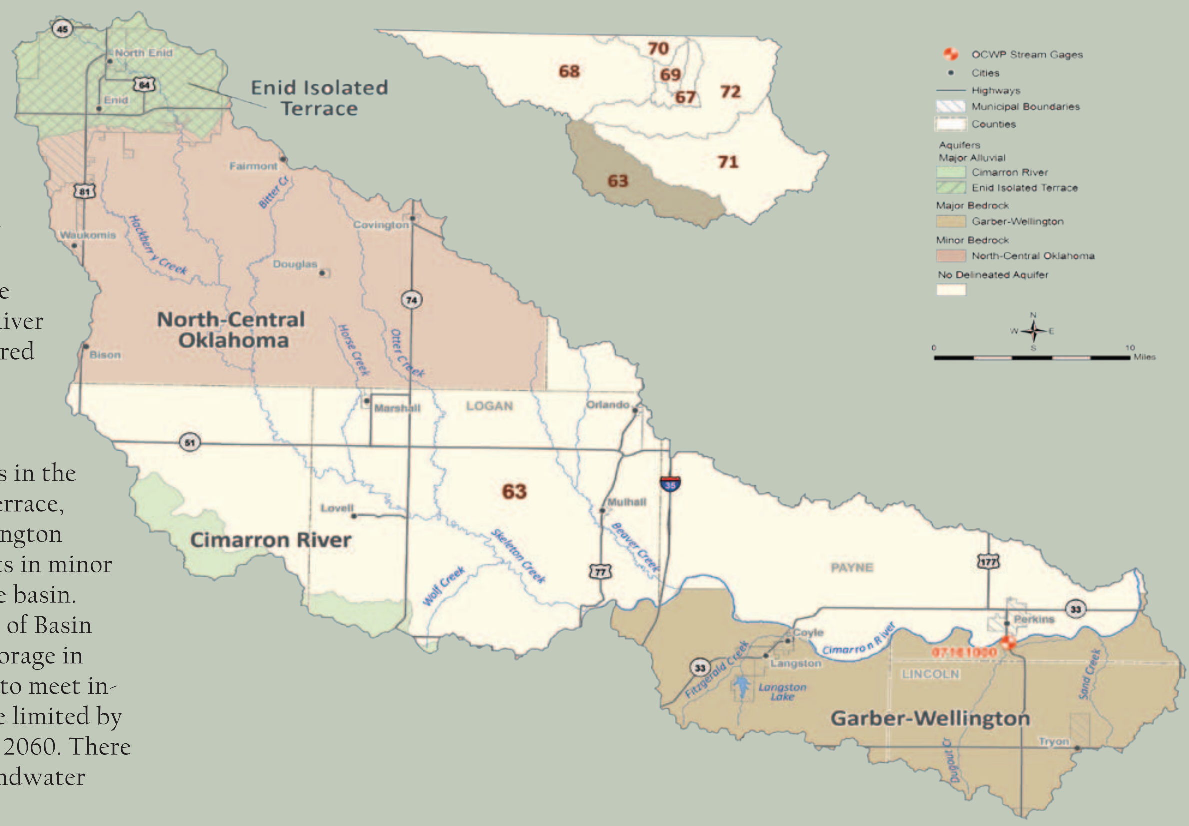
Current Demand by Source and Sector
Upper Arkansas Region, Basin 63



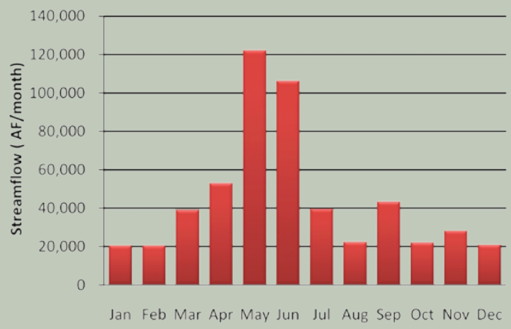
Basin 63 accounts for about 14% of the current water demand in the Upper Arkansas Watershed Planning Region. About 66% of the current demand is from the Municipal and Industrial demand sector. Surface water and out-of-basin supplies are used to satisfy about 58% of the current demand in the basin. Groundwater satisfies about 42% of the current demand (35% alluvial and 7% bedrock). The peak summer month demand in Basin 63 is 3 times the winter demand, which is similar to the overall statewide pattern.

Langston Lake, located on Fitzgerald Creek, provides water supplies to the City of Langston. The yield for Langston Lake is not known; therefore, it is unclear if the lake will be able to provide additional water supplies in the future. Flow in the Cimarron River downstream of Headquarters Creek is typically greater than 20,000 acre-feet/month. However, the river can have prolonged periods of low to no flow in any month of the year. 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 63 is considered fair. Water quality may constrain future Agricultural use in the Cimarron River and Beaver Creek, which are impaired due to elevated levels of total dissolved solids (TDS).

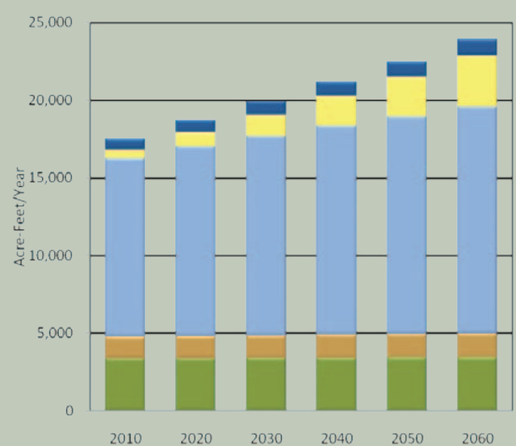
The majority of groundwater rights in the basin are from the Enid Isolated Terrace, Cimarron River, and Garber-Wellington aquifers. There are also water rights in minor alluvial and bedrock aquifers in the basin. Major aquifers underlie about 25% of Basin 63 and have over 3 million AF of storage in the basin. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant basin-wide groundwater quality issues.



Median Historical Streamflow at the Basin Outlet
Upper Arkansas Region, Basin 63



Projected Water Demand
Upper Arkansas Region, Basin 63



The projected 2060 water demand of 23,920 AFY in Basin 63 reflects a 6,370 AFY increase (36%) over the 2010 demand. The majority of growth in demand will occur in the Municipal and Industrial and Oil and Gas demand sectors.

Gaps & Depletions

Based on historical hydrology and projected demand, surface water gaps and alluvial groundwater depletions may occur by 2020. Surface water gaps will be up to 3,050 AFY in 2060 and have a 33% probability of occurring in at least one month in the year. Alluvial groundwater depletions will be up to 1,480 AFY in 2060, peaking in size during the summer, and have a 33% probability of occurring in at least one month in the year. The projected groundwater depletions are minimal relative to the volume of water stored in the major alluvial aquifers underlying the basin. However, localized storage depletions may adversely affect yields, water quality and/or pumping costs. No bedrock groundwater depletions are expected in this basin through 2060.

The City of Enid is the largest public water provider and a major alluvial groundwater user in the basin. A substantial portion of the City of Enid's supplies are from out-of-basin supplies in nearby well fields in the Cimarron River aquifer or Enid Isolated Terrace aquifer. In the future, additional supplies from these well fields or new surface water supplies may be used to meet the City of Enid's growth in demand.

Options

Water supply options were evaluated to assess potential ways of providing dependable long-range water supplies for Basin 63. Water users are expected to continue to rely primarily on surface water supplies and alluvial aquifers. To reduce the risk of adverse impacts on water supplies, it is recommended that storage depletions and gaps be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce gaps and storage depletions. Temporary drought management could reduce demand, largely from irrigation, and may reduce gaps. Temporary drought management activities may not be necessary for many alluvial groundwater users since the storage in the major aquifers could continue to provide supplies during droughts.

New out-of-basin supplies could be used to augment supplies and mitigate gaps and storage depletions. Kaw Lake and Keystone Lake, which are located in the northern and southeastern parts of the Upper Arkansas Region, respectively, have unpermitted yield that could be used as a source of out-of-basin supply water. However, Keystone's relatively poor quality as a public supply source somewhat limits its use. In addition, supplies from out-of-basin well fields could help meet the growth demand from the City of Enid and connected systems. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified six potentially viable out-of-basin sites in the Upper Arkansas Region. However, due to the distance to these supplies, out-of-basin supplies may not be cost-effective for some users.

New reservoirs could increase the dependability of available surface water supplies and mitigate gaps and storage depletions in the basin. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 4,600 AF of storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified two potentially viable sites in Basin 63.

Water Supply Limitations
Upper Arkansas Region, Basin 63

Surface Water	Potential
Alluvial Groundwater	Potential
Bedrock Groundwater	Minimal

Minimal | Potential | Significant

Water Supply Option Effectiveness
Upper Arkansas Region, Basin 63

Demand Management	Potentially Effective
Out-of-Basin Supplies	Potentially Effective
Reservoir Use	Typically Effective
Increasing Supply from Surface Water	Likely Ineffective
Increasing Supply from Groundwater	Potentially Effective

Typically Effective | Potentially Effective | Likely Ineffective | No Option Necessary

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

Increased reliance on alluvial or bedrock groundwater use may mitigate surface water gaps. While groundwater storage depletions will be increased, any increases would be minimal relative to the volume of water stored in major aquifers in the basin. However, major alluvial and bedrock aquifers underlie only about 25% of the basin, thus are not readily available to all users.

The Aquifer Recharge Workgroup identified a site near Enid (site # 30) as having potential feasibility for aquifer recharge and recovery. With treatment, water could potentially be withdrawn from the Cimarron River to recharge the Enid Isolated Terrace aquifer.

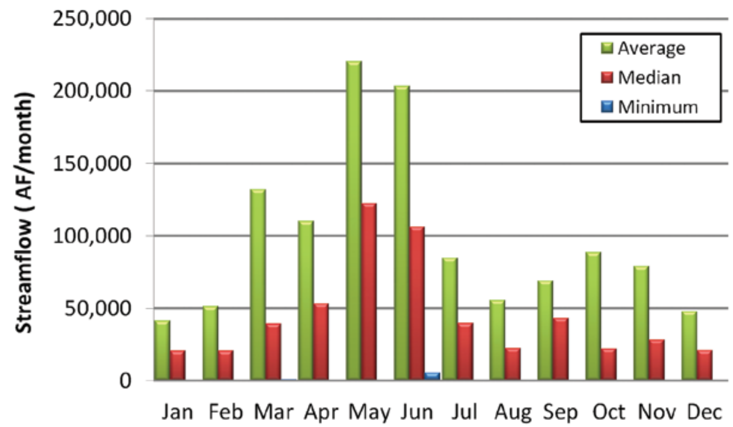
Basin 63 Data & Analysis

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 to the early 1970s, corresponding to a period of below-average precipitation. From the mid 1980s to early 2000s, the basin underwent a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median flow in the lower Cimarron River downstream of Headquarters Creek has been greater than 20,000 AF/month throughout the year and greater than 100,000 AF/month in May and June. However, Basin 63 can have periods of low or no flow in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 63 is considered fair.
- Langston Lake was built in 1966 to provide water supply, flood control and recreation to the City of Langston. The water supply yield is unknown; therefore the ability of this reservoir to provide future water supplies could not be evaluated.

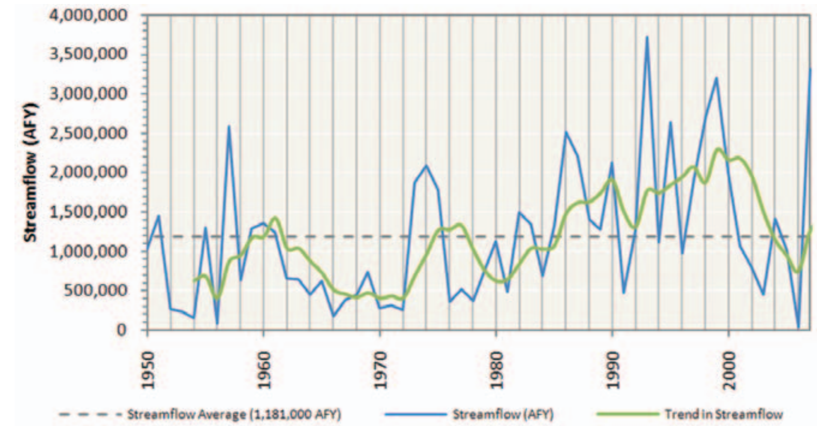
Monthly Historical Streamflow at the Basin Outlet

Upper Arkansas Region, Basin 63



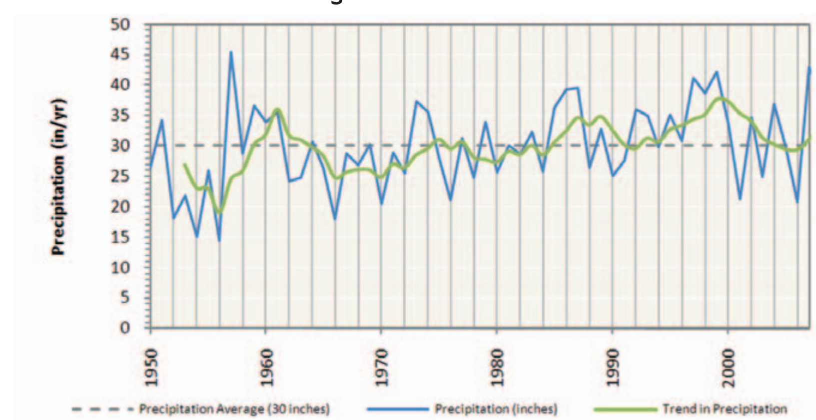
Historical Streamflow at the Basin Outlet

Upper Arkansas Region, Basin 63



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)

Upper Arkansas Region, Basin 63

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
Cimarron River	Alluvial	Major	2%	4,200	85,000	temporary 2.0	37,300
Enid Isolated Terrace	Alluvial	Major	6%	4,200	196,000	0.5	16,600
Garber-Wellington	Bedrock	Major	18%	1,200	2,900,000	temporary 2.0	255,600
North-Central Oklahoma	Bedrock	Minor	33%	100	1,769,000	temporary 2.0	460,800
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	200	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	400	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 Garber-Wellington receives about 15,000 AFY of recharge from the basin. There are also water rights from non-delineated groundwater sources.
- 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.

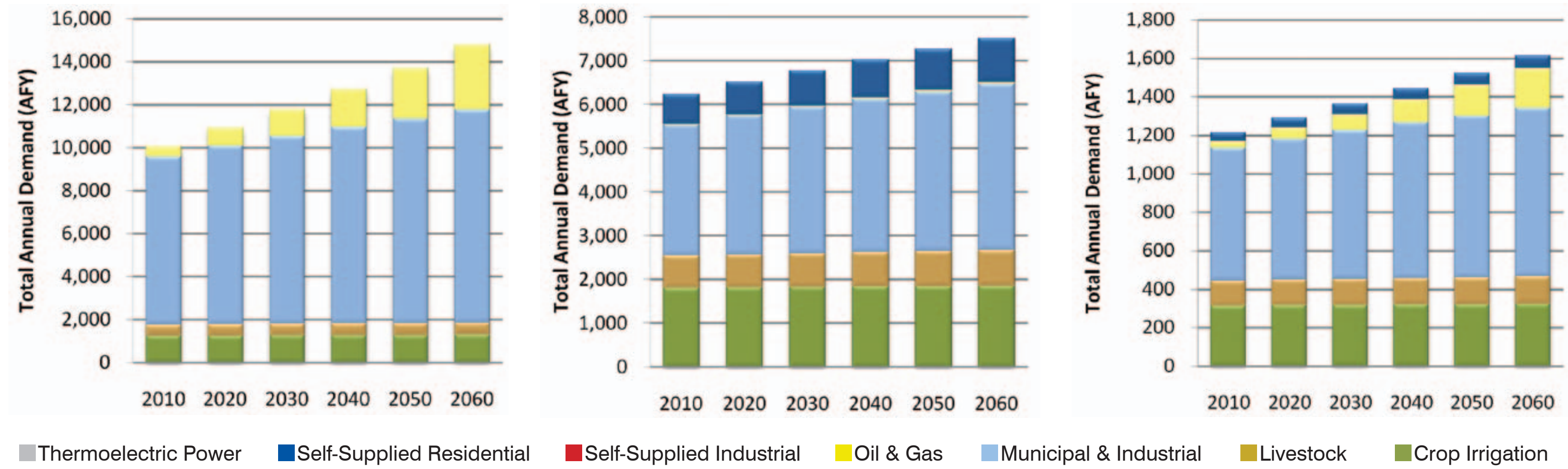
Water Demand

- The water demand in Basin 63 accounts for about 14% of the total demand in the Upper Arkansas Watershed Planning Region and will increase by 36% (6,370 AFY) from 2010 to 2060. The majority of demand and largest growth in demand will be from the Municipal and Industrial demand sector. There will also be substantial growth in Oil and Gas demand in the basin.
- Surface water is used to meet 58% of the total demand in the basin and its use will increase by 47% (4,690 AFY) from 2010 to 2060. The majority of surface water use during this period will be in the Oil and Gas and Municipal and Industrial demand sectors. However, the largest growth in demand will be from the Oil and Gas demand sector.
- Alluvial groundwater is used to meet 35% of the total demand in the basin and its use will increase by 21% (1,280 AFY) from 2010 to 2060. The largest alluvial groundwater use and growth in alluvial groundwater use during this period will be from the Municipal and Industrial demand sector.
- Bedrock groundwater is used to meet 7% of the total demand in the basin and its use will increase by 33% (400 AFY) from 2010 to 2060. The majority of bedrock groundwater use and largest growth in bedrock groundwater use during this period will be from the Municipal and Industrial demand sector.

Surface Water Demand by Sector
Upper Arkansas Region, Basin 63

Alluvial Groundwater Demand by Sector
Upper Arkansas Region, Basin 63

Bedrock Groundwater Demand by Sector
Upper Arkansas Region, Basin 63

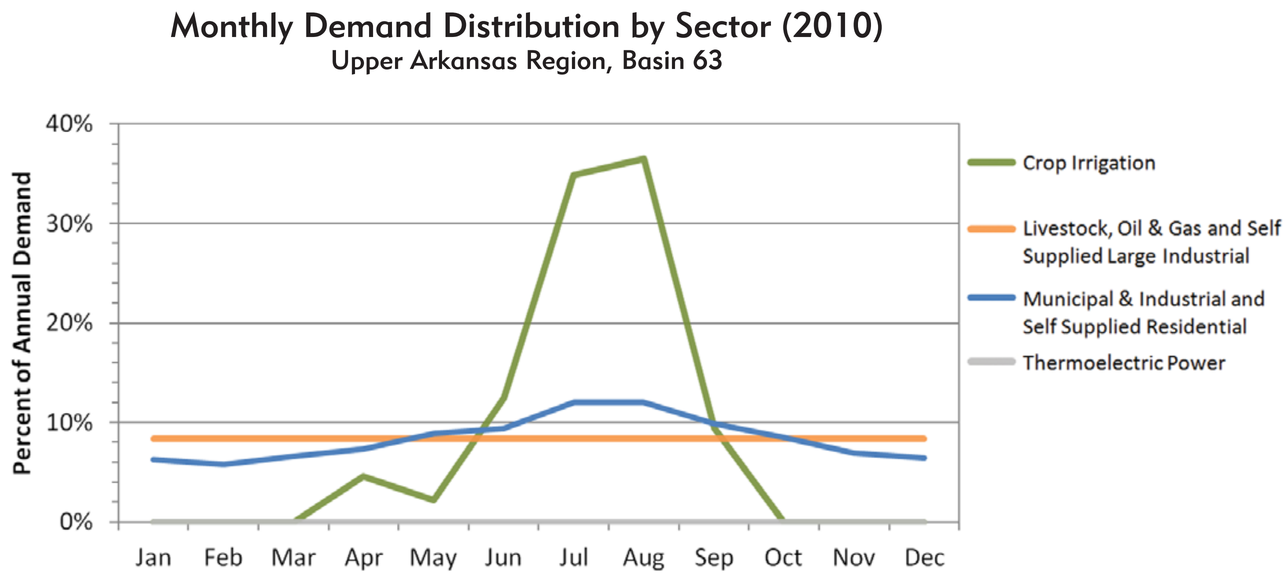


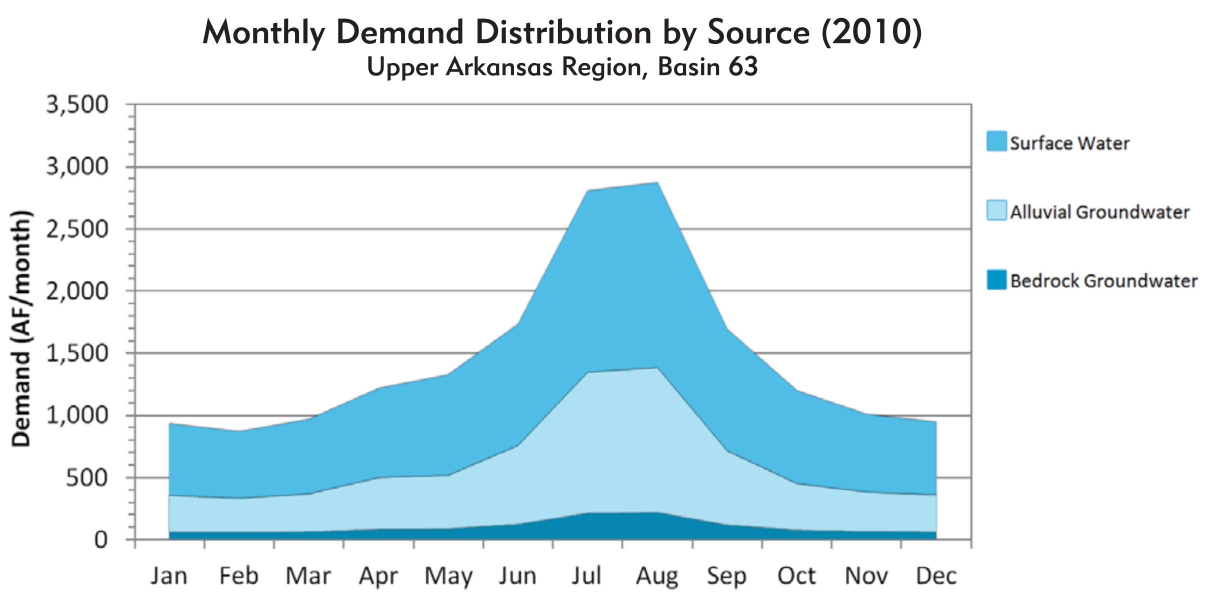
Total Demand by Sector
Upper Arkansas Region, Basin 63

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	3,380	1,390	11,510	550	0	720	0	17,550
2020	3,400	1,410	12,240	900	0	790	0	18,740
2030	3,420	1,440	12,870	1,350	0	860	0	19,940
2040	3,440	1,470	13,480	1,900	0	930	0	21,220
2050	3,450	1,500	14,020	2,530	0	990	0	22,490
2060	3,470	1,520	14,600	3,270	0	1,060	0	23,920

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)

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 81% 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.

Monthly Demand Distribution by Source (2010)

- The peak summer month total water demand in Basin 63 is 3 times the winter monthly demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is 2.5 times the monthly winter demand. Alluvial and bedrock groundwater use peaks in the summer at 3.9 and 3.6 times the 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 2020. No bedrock groundwater depletions are expected in this basin due to the minimal growth in demand from 2010 through 2060.
- Surface water gaps in Basin 63 may occur throughout the year. Surface water gaps in 2060 will be up to 20% (390 AF/month) of the surface water demand in the peak summer month, and as much as 33% (310 AF/month) of the monthly winter surface water demand. There will be a 33% probability of gaps occurring in at least one month of the year. Surface water gaps are least likely to occur during spring months.
- Alluvial groundwater storage depletions in Basin 63 may occur throughout the year, peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 19% (250 AF/month) of the alluvial groundwater demand in the peak summer month, and as high as 32% (120 AF/month) of the monthly winter alluvial groundwater demand. There will be a 33% probability of alluvial groundwater storage depletions occurring in at least one month of the year. Alluvial groundwater storage depletions are least likely to occur during spring months.
- Projected annual storage depletions are minimal relative to the volume of water stored in the major alluvial and terrace aquifers underlying the basin. However, localized storage depletions may adversely affect well yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)

Upper Arkansas Region, Basin 63

Months (Season)	Maximum Gap [1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	310	300	19%
Mar-May (Spring)	350	320	7%
Jun-Aug (Summer)	390	390	17%
Sep-Nov (Fall)	360	350	22%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Upper Arkansas Region, Basin 63

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	120	120	19%
Mar-May (Spring)	160	150	7%
Jun-Aug (Summer)	250	250	17%
Sep-Nov (Fall)	180	150	22%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Upper Arkansas Region, Basin 63

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	540	310	0	33%	33%
2030	1,100	600	0	33%	33%
2040	1,720	900	0	33%	33%
2050	2,340	1,190	0	33%	33%
2060	3,050	1,480	0	33%	33%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Upper Arkansas Region, Basin 63

Months (Season)	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

Upper Arkansas Region, Basin 63

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	3,050	1,480	0	33%	33%
Moderately Expanded Conservation in Crop Irrigation Water Use	3,020	1,460	0	33%	33%
Moderately Expanded Conservation in M&I Water Use	1,620	770	0	33%	33%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	1,570	750	0	33%	33%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	710	280	0	26%	26%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Upper Arkansas Region, Basin 63

Reservoir Storage	Diversion
AF	AFY
100	100
500	700
1,000	1,400
2,500	3,400
5,000	6,900
Required Storage to Meet Growth in Demand (AF)	4,600
Required Storage to Meet Growth in Surface Water Demand (AF)	3,400

Water Supply Options & Effectiveness

Typically Effective | Potentially Effective | Likely Ineffective | No Option Necessary

Demand Management

(Potentially Effective) Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce surface water gaps and alluvial groundwater storage depletions by 49%. Temporary drought management could reduce demand, largely from irrigation, and may reduce gaps or adverse affects from localized storage depletions. Temporary drought management activities may not be necessary for many alluvial groundwater users since the storage in the major alluvial aquifers could continue to provide supplies during droughts.

Out-of-Basin Supplies

(Potentially Effective) Enid is the largest public water supplier and a major alluvial groundwater user in the basin. Enid also obtains substantial supplies from well fields in the Cimarron River alluvial aquifer and Enid Isolated Terrace aquifer in Basin 64. New surface water supplies may be needed to meet Enid's growth in demand. New out-of-basin supplies from other sources could be used to augment supplies and mitigate gaps and storage depletions. An out-of-basin supply from Kaw Lake, in Basin 72, is currently supplying the City of Stillwater in Basin 72, which is adjacent to Basin 63. In addition, supplies from out-of-basin well fields could help meet the growth demand from Enid and connected systems. Kaw Lake currently has unpermitted yield that could be used as a source of out-of-basin supply for Basin 63. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified six out-of-basin sites in the region: Alva in Basin 68, Hunnewell in Basin 70, Lela and Pawnee in Basin 71, and Otoe and Shidler in Basin 72.

Reservoir Use

(Typically Effective) Reservoir storage could provide dependable supplies to mitigate surface water gaps and effects of localized storage depletions. The entire increase in demand through 2060 could be met by a river diversion and 4,600 AF of storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions. The OCWP *Reservoir Viability Study* also identified Sheridan and Skeleton Reservoirs as potentially viable sites in Basin 63. These sites would provide much more water than needed for the basin but might present opportunities for regional or inter-regional supply options.

Increasing Reliance on Surface Water

(Likely Ineffective) Increased reliance on surface water through direct diversions, without reservoir storage, would increase gaps and is not recommended.

Increasing Reliance on Groundwater

(Potentially Effective) Increased reliance on groundwater supplies may mitigate surface water gaps, but will increase alluvial groundwater depletions and may create bedrock groundwater depletions. Any increases in depletions would be minimal relative to the volume of water in storage in major aquifers in the basin. However, major aquifers underlie only about 25% of the basin, and localized depletions may adversely impact well yields, water quality and pumping costs. The Aquifer Recharge Workgroup identified a site near Enid (#30) as having potential feasibility for aquifer recharge and recovery. With treatment, water could potentially be withdrawn from the Cimarron River to recharge the Enid Isolated Terrace aquifer.

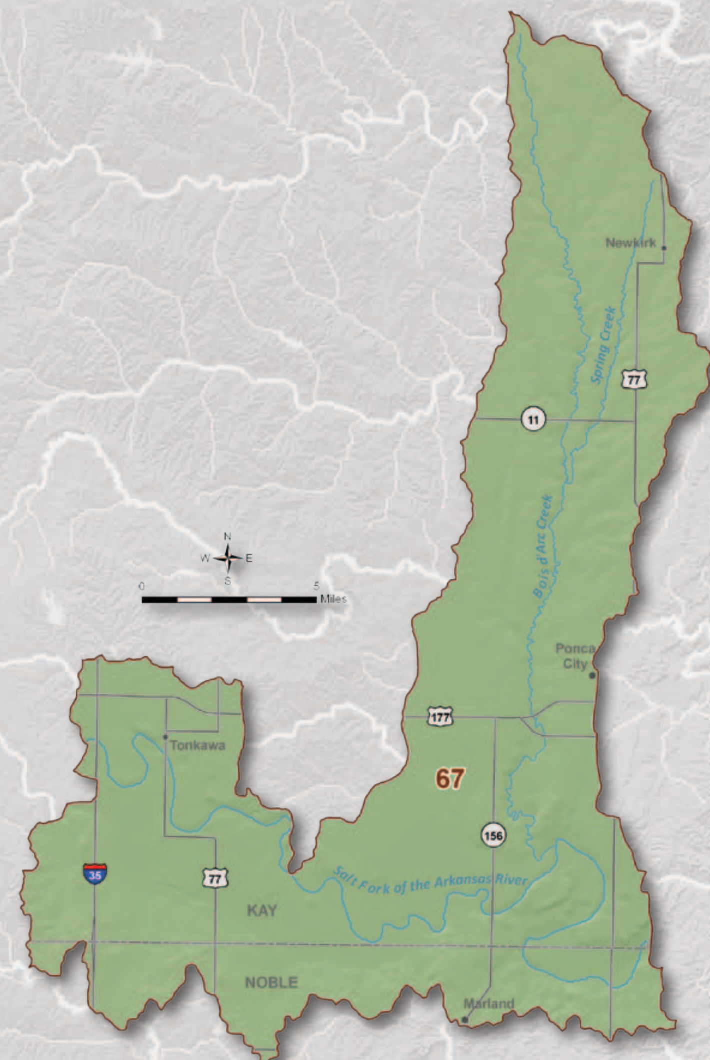
Notes & Assumptions

- 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.

Data & Analysis

Upper Arkansas Watershed Planning Region

Basin 67



Basin 67 Summary

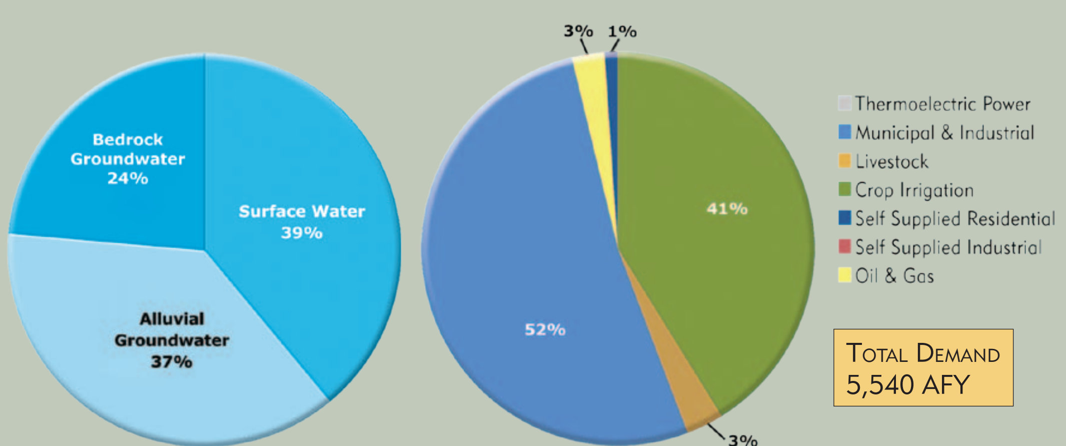
Synopsis

- Water users are expected to continue to rely on surface water, alluvial groundwater, and bedrock groundwater supplies.
- Alluvial groundwater storage depletions may occur by 2030, but will be minimal in size relative to aquifer storage in the basin. However, localized storage depletions may cause adverse effects for users.
- Starting in 2030, there is a low probability of surface water gaps from increased demands on existing supplies during low flow periods in the summer.
- 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 mitigate surface water gaps and reduce the adverse effects of localized alluvial groundwater storage depletions.
- Use of additional groundwater supplies and/or developing small reservoirs could mitigate surface water gaps without having major impacts to groundwater storage.

Basin 67 accounts for about 4% of the current water demand in the Upper Arkansas Watershed Planning Region. About 52% of the demand is in the Municipal and Industrial water use sector. Crop Irrigation is the second largest water use sector at 41%. Surface water satisfies about 39% of the current demand in the basin. Groundwater satisfies about 61% of the current demand (37% alluvial and 24% bedrock). The peak summer month demand in Basin 67 is 6.9 times the winter demand, which is similar to the overall statewide pattern.

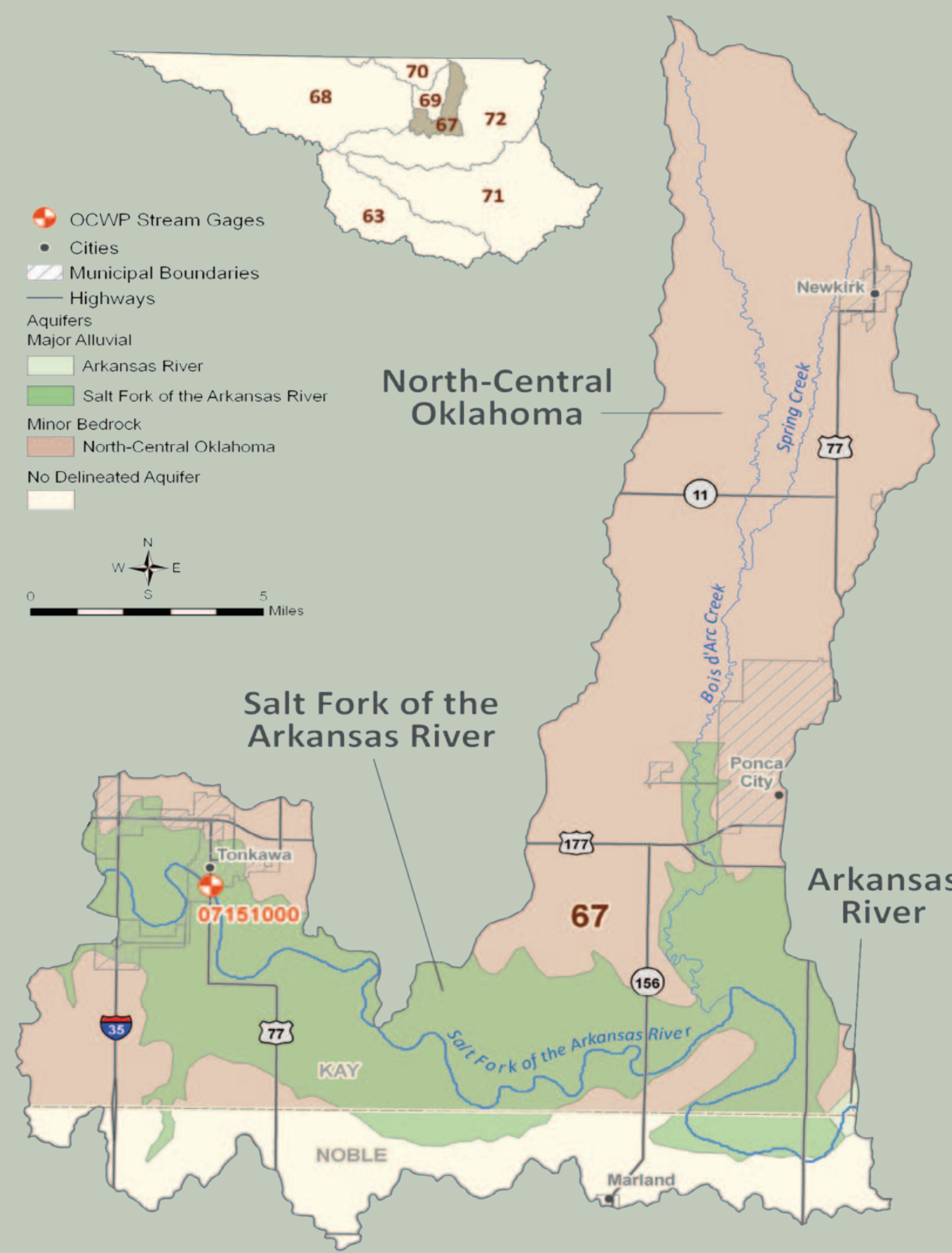
There are no major reservoirs in the basin. The lower Salt Fork of the Arkansas River upstream of the Arkansas River typically has flows greater than 25,000 AF/month, where peak flows occur in May and June. However, Basin 67 can have infrequent periods of low flow in any month of the year. Relative to other basins in the state, the surface water

Current Demand by Source and Sector
Upper Arkansas Region, Basin 67

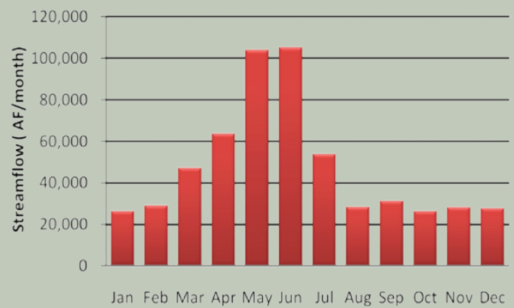


Total Demand
5,540 AFY

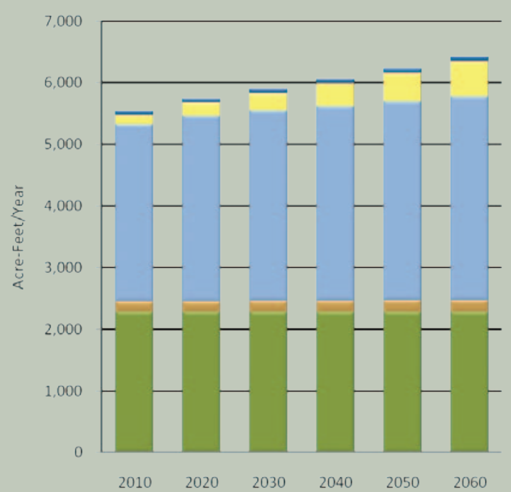
Water Resources
Upper Arkansas Region, Basin 67



Median Historical Streamflow at the Basin Outlet
Upper Arkansas Region, Basin 67



Projected Water Demand
Upper Arkansas Region, Basin 67



quality in Basin 67 is considered good. However, Bird's Nest Creek, Bois D' Arc Creek, and Cattle Creek are impaired for Agricultural use due to elevated levels of chlorides, sulfates, and turbidity. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060.

About two-thirds of the current groundwater rights in the basin are from the North-Central minor bedrock aquifer. Site-specific information on the suitability of the minor aquifer for supply should be considered before large scale use. The Salt Fork of the Arkansas River aquifer and non-delineated minor alluvial aquifers are also used. There are no significant basin-wide groundwater quality issues in Basin 67. However, the Salt Fork of the Arkansas River aquifer is impacted by high chloride levels where concentrations decrease with distance from the river. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060.

The projected 2060 water demand of 6,420 AFY in Basin 67 reflects an 880 AFY increase (16%) over the 2010 demand. The majority of growth in demand will occur in the Municipal and Industrial and Oil and Gas demand sectors. The Crop Irrigation demand sector will continue to be a major water user in Basin 67; however, Crop Irrigation use is not projected to grow over this period.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and alluvial groundwater depletions may occur by 2030. No bedrock groundwater depletions are expected in this Basin due to the minimal growth in demand from 2010 through 2060. Surface water gaps will be up to 120 AF/month in 2060, but will be infrequent (7% probability of occurring in at least one month of the year). Alluvial groundwater storage depletions will be up to 90 AF/month in 2060, but will also be infrequent (7% probability of occurring in at least one month of the year). Projected annual alluvial storage depletions are minimal relative to volume of water stored in the Salt Fork of the Arkansas River aquifer underlying the basin. However, localized storage depletions may adversely affect yields, water quality and/or pumping costs.

Options

Water supply options were evaluated to assess potential ways of providing dependable long-range water supplies for Basin 67. Water users are expected to continue to rely on surface water supplies, alluvial aquifers, and bedrock aquifers. To reduce the risk of adverse impacts on water supplies, it is recommended that storage depletions and gaps be decreased where economically feasible.

Water Supply Limitations
Upper Arkansas Region, Basin 67

Surface Water	Minimal
Alluvial Groundwater	Potential
Bedrock Groundwater	Potential

Minimal Potential Significant

Water Supply Option Effectiveness
Upper Arkansas Region, Basin 67

Demand Management	Typically Effective
Out-of-Basin Supplies	Potentially Effective
Reservoir Use	Potentially Effective
Increasing Supply from Surface Water	Likely Ineffective
Increasing Supply from Groundwater	Potentially Effective

Typically Effective Potentially Effective Likely Ineffective No Option Necessary

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce gaps and storage depletions. Temporary drought management could reduce demand, largely from irrigation, and may reduce surface water gaps. Temporary drought management activities may not be necessary for many alluvial groundwater users since the storage in the major aquifers could continue to provide supplies during droughts.

New out-of-basin supplies could be used to augment supplies and mitigate gaps and storage depletions. Ponca City is currently supplied in part by Kaw Lake, located in Basin 72, just east of Basin 67. Kaw Lake has unpermitted yield and could be used as a source of out-of-basin water supply. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified eight potentially viable out-of-basin sites in the Upper Arkansas Region. However, due to the distance to this supply, out-of-basin supplies may not be cost-effective for some users.

New reservoirs could increase the dependability of available surface water supplies and mitigate gaps and storage depletions in the basin. The entire increase in demand from 2010 to 2060 could be met by 200 AF of storage at the basin outlet.

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

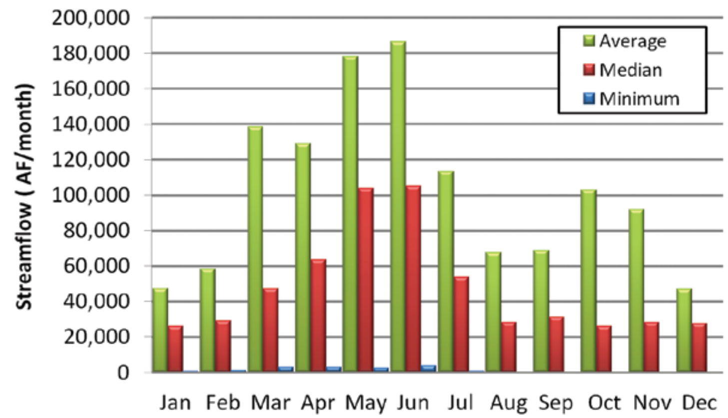
Increased reliance on alluvial groundwater could mitigate surface water gaps, but would increase storage depletions. Any increases in groundwater storage depletions would be minimal relative to the volume of water stored in major alluvial aquifers in the basin. However, the Salt Fork of the Arkansas River aquifer only underlies about 30% of the basin, thus is not easily available to all users in the basin.

Basin 67 Data & Analysis

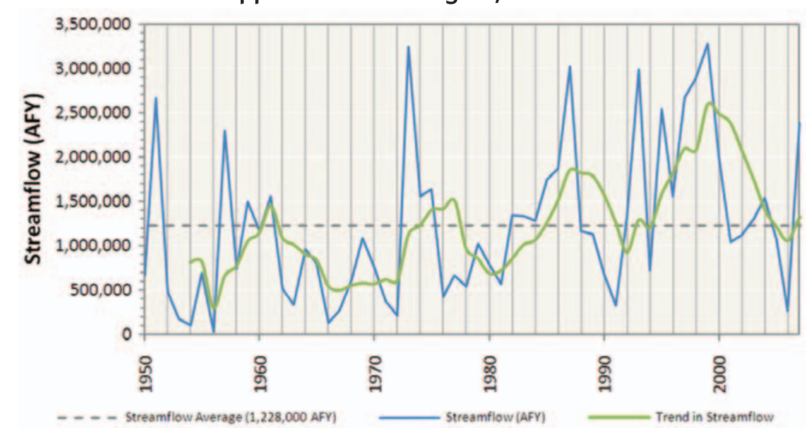
Surface Water Resources

- 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 to the early 1970s, corresponding to a period of below-average precipitation. From the mid 1990s to 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 Salt Fork of the Arkansas River upstream of the Arkansas River is greater than 25,000 AF/month throughout the year and greater than 100,000 AF/month in May and June. However, Basin 67 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 67 is considered good.
- There are no major reservoirs in this basin.

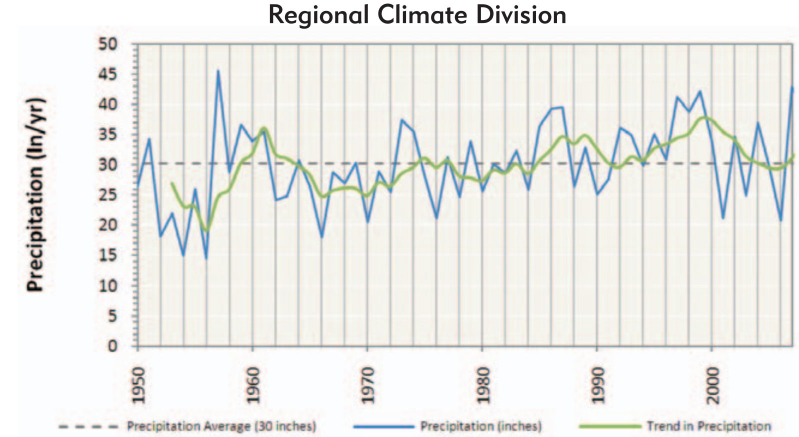
Monthly Historical Streamflow at the Basin Outlet
Upper Arkansas Region, Basin 67



Historical Streamflow at the Basin Outlet
Upper Arkansas Region, Basin 67



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)

Upper Arkansas Region, Basin 67

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
Salt Fork of the Arkansas River	Alluvial	Major	31%	1,600	109,000	temporary 2.0	86,800
North-Central Oklahoma	Bedrock	Minor	85%	4,500	983,000	temporary 2.0	245,700
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	900	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

- Site-specific information on the suitability of minor aquifers for supply should be considered before increased or large scale use.
- There are no significant groundwater quality issues in the basin. However, the Salt Fork of the Arkansas River aquifer is impacted by high chloride levels; concentrations decrease with distance from the river.

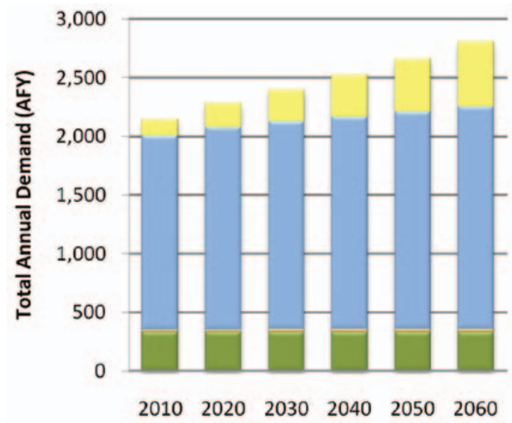
Notes & Assumptions

- 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.

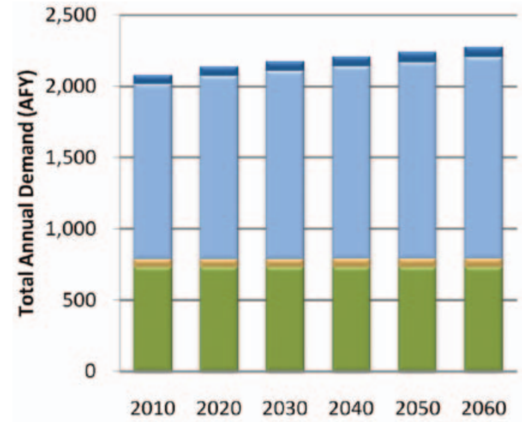
Water Demand

- The demand in Basin 67 accounts for about 4% of the total demand in the Upper Arkansas Watershed Planning Region and will increase by 16% (880 AF) from 2010 to 2060. The majority of demand and largest growth in demand will be from the Municipal and Industrial demand sector. The Crop Irrigation demand sector will continue to be a major water user in Basin 67; however, Crop Irrigation use is not projected to grow during this period.
- Surface water is used to meet 39% of the total demand in the basin and its use will increase by 31% (660 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use will be from the Municipal and Industrial demand sector.
- Alluvial groundwater is used to meet 37% of the total demand and its use will increase by 10% (200 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use will be from the Municipal and Industrial demand sector.
- Bedrock groundwater is used to meet 24% of the total demand in the basin and its use will increase by 1% (20 AFY) from 2010 to 2060. The increase in bedrock groundwater use in the basin is minimal.

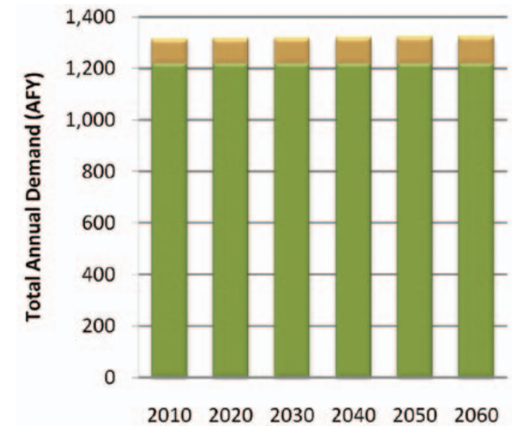
Surface Water Demand by Sector
Upper Arkansas Region, Basin 67



Alluvial Groundwater Demand by Sector
Upper Arkansas Region, Basin 67



Bedrock Groundwater Demand by Sector
Upper Arkansas Region, Basin 67



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

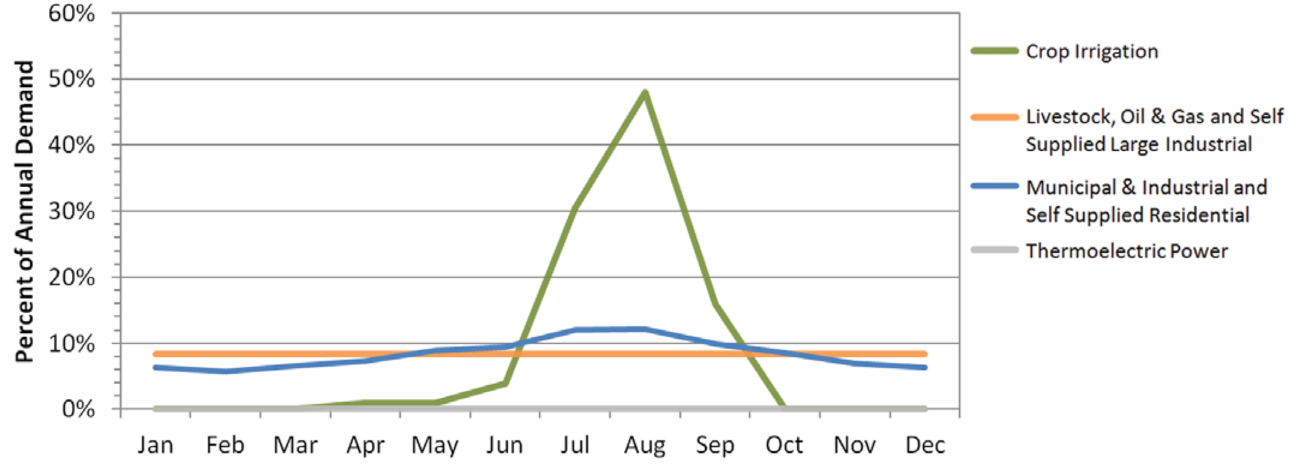
Total Demand by Sector
Upper Arkansas Region, Basin 67

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	2,280	170	2,880	150	0	60	0	5,540
2020	2,280	170	3,010	210	0	60	0	5,730
2030	2,280	180	3,090	280	0	70	0	5,900
2040	2,280	180	3,160	370	0	70	0	6,060
2050	2,280	190	3,230	460	0	70	0	6,230
2060	2,280	190	3,310	570	0	70	0	6,420

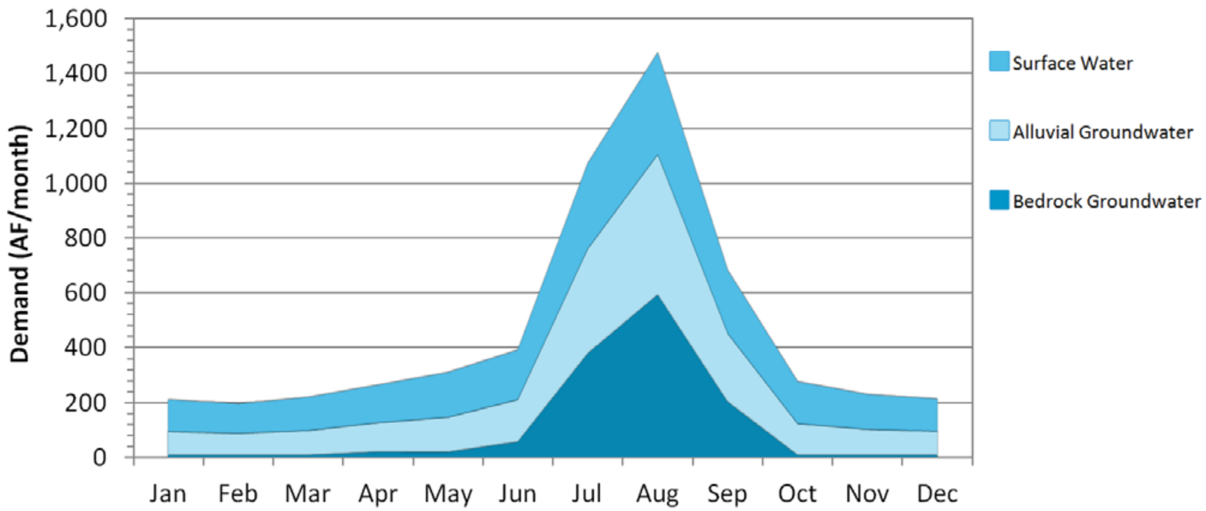
Notes & Assumptions

- 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)
Upper Arkansas Region, Basin 67



Monthly Demand Distribution by Source (2010)
Upper Arkansas Region, Basin 67



Monthly Demand Distribution by Sector (2010)

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 82% 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. Livestock and Oil and Gas demand sectors have a more consistent demand throughout the year.

Monthly Demand Distribution by Source (2010)

- The peak summer month total water demand in Basin 67 is 6.9 times the winter demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is 3.1 times the monthly winter use. Monthly bedrock groundwater use peaks in the summer at 76.5 times the monthly winter use. Monthly alluvial groundwater use peaks in the summer at 5.9 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 2030. No bedrock groundwater depletions are expected in this basin due to the minimal growth in demand from 2010 through 2060.
- There will be a 7% probability of surface water gaps occurring in at least one month of the year and gaps have less than a 3% probability of occurring in any season by 2060. Surface water gaps in Basin 67 may occur during the winter, summer, and fall. Surface water gaps in 2060 will be up to 14% (40 AF/month) of the monthly surface water demand in the fall, and up to 9% (40 AF/month) of the surface water demand in the peak summer month.
- There will be a 7% probability of alluvial groundwater storage depletions occurring in at least one month of the year and depletions have less than a 3% probability of occurring in any season by 2060. Alluvial groundwater storage depletions in Basin 67 may occur during the winter, summer, and fall. Alluvial groundwater storage depletions in 2060 will be up to 8% (40 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 10% (10 AF/month) of the monthly winter alluvial groundwater demand.
- Projected alluvial groundwater storage depletions are minimal relative to the volume of water stored in the Salt Fork of the Arkansas River aquifer underlying the basin. However, localized storage depletions may adversely affect well yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)
Upper Arkansas Region, Basin 67

Months (Season)	Maximum Gap [1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	20	20	2%
Mar - May (Spring)	0	0	0%
Jun-Aug (Summer)	40	40	2%
Sep-Nov (Fall)	40	40	3%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)
Upper Arkansas Region, Basin 67

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	10	10	2%
Mar - May (Spring)	0	0	0%
Jun-Aug (Summer)	40	40	2%
Sep-Nov (Fall)	30	25	3%

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

Magnitude and Probability of Annual Gaps and Storage Depletions
Upper Arkansas Region, Basin 67

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	20	20	0	3%	3%
2040	50	50	0	5%	5%
2050	90	80	0	7%	5%
2060	120	90	0	7%	7%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)
Upper Arkansas Region, Basin 67

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

Upper Arkansas Region, Basin 67

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	120	90	0	7%	7%
Moderately Expanded Conservation in Crop Irrigation Water Use	90	70	0	7%	7%
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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Upper Arkansas Region, Basin 67

Reservoir Storage	Diversion
AF	AFY
100	400
500	1,700
1,000	3,100
2,500	6,300
5,000	10,700
Required Storage to Meet Growth in Demand (AF)	200
Required Storage to Meet Growth in Surface Water Demand (AF)	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 demand sector could mitigate surface water gaps and alluvial groundwater storage depletions. Due to the low probability of gaps and storage depletions, temporary drought management could be an effective means of reducing demand, largely from irrigation, and may mitigate gaps and adverse effects of localized storage depletions. Temporary drought management activities may not be necessary for alluvial groundwater users since the storage in major aquifers could continue to provide supplies during droughts.

Out-of-Basin Supplies

New out-of-basin supplies could be used to augment supplies and mitigate gaps and storage depletions. Ponca City is currently supplied in part by Kaw Lake, which is located to the east of Basin 67. Kaw Lake has unpermitted yield and could be used as a source of out-of-basin supply. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified eight potentially viable out-of-basin sites in the Upper Arkansas Region: Sheridan and Skeleton in Basin 63, Alva in Basin 68, Hunnewell in Basin 70, Lela and Pawnee in Basin 71, and Otoe and Shidler in Basin 72. However, due to the distance to out-of-basin supply, these sources may not be cost-effective for some users.

Reservoir Use

New reservoirs could increase the dependability of available surface water supplies and mitigate gaps and storage depletions in the basin. The entire increase in demand from 2010 to 2060 could be met by a river diversion and 200 AF of 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, would increase surface water gaps in the basin and is not recommended.

Increasing Reliance on Groundwater

Increased reliance on alluvial groundwater could mitigate surface water gaps, but would increase storage depletions. Any increases in storage depletions would be minimal relative to the volume of water in major alluvial aquifer storage in the basin. However, the Salt Fork of the Arkansas River aquifer only underlies about 30% of the basin. A shift from surface water to alluvial groundwater could potentially decrease the size of surface water gaps, but may not decrease the probability of remaining surface water gaps due to the interconnection between the supply sources. Increased use of the North-Central Oklahoma bedrock aquifer 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.

Data & Analysis

Upper Arkansas Watershed Planning Region

Basin 68

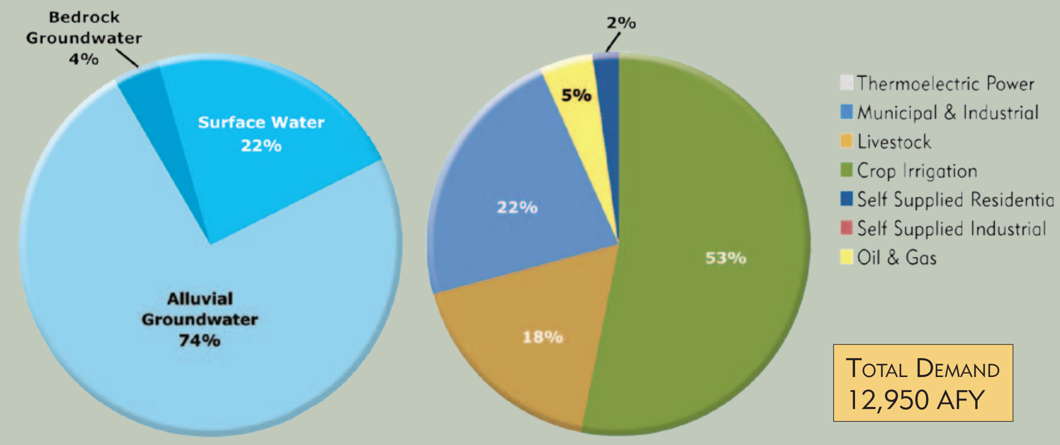
Basin 68 Summary

Synopsis

- Water users are expected to continue to rely primarily on groundwater supplies.
- 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, such as lowered well yields and higher pumping costs.
- By 2020, there is a low probability of surface water gaps from increased demands on existing supplies during low flow periods.
- 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 mitigate surface water gaps and reduce the adverse effects of localized alluvial and bedrock storage depletions.
- Aquifer storage (recharge) and recovery could be considered to store variable surface water supplies, increase alluvial groundwater storage, and reduce adverse effects of localized storage depletions.
- Use of additional groundwater supplies and/or developing small reservoirs could mitigate surface water gaps without having major impacts to groundwater storage.

Current Demand by Source and Sector

Upper Arkansas Region, Basin 68

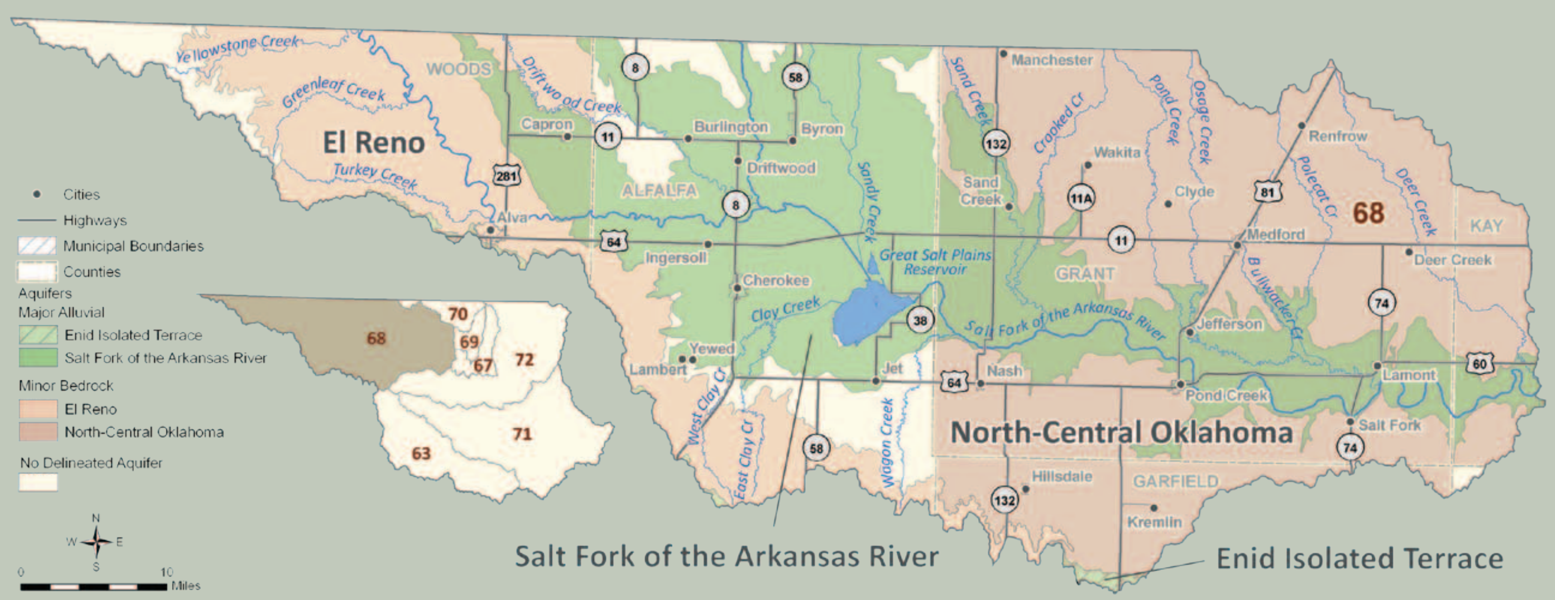


Basin 68 accounts for about 10% of the current water demand in the Upper Arkansas Watershed Planning Region. About 53% of the demand is from the Crop Irrigation demand sector. Municipal and Industrial (22%) and Livestock (18%) are the next largest demand sectors. Surface water satisfies about 22% of the current demand in the basin. Groundwater satisfies about 78% of the current demand (74% alluvial and 4% bedrock). The peak summer month demand in Basin 68 is 6.6 times the winter demand, which is more pronounced than the overall statewide pattern.

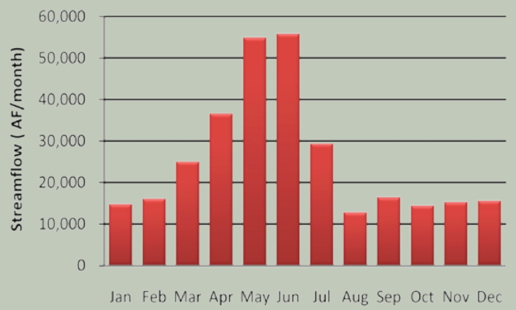
There are no major water supply reservoirs in the basin. The upper Salt Fork of the Arkansas River downstream of Pond Creek typically has greater than 12,500 AF/month of flow throughout the year, and peaks in May and June. Historically, Basin 68 can have periods of low flow in any month. Relative to other basins in the state, the surface water quality in Basin 68 is considered poor. Wild Horse Creek, Turkey Creek, and Clay Creek are impaired for Agricultural use due to

Water Resources

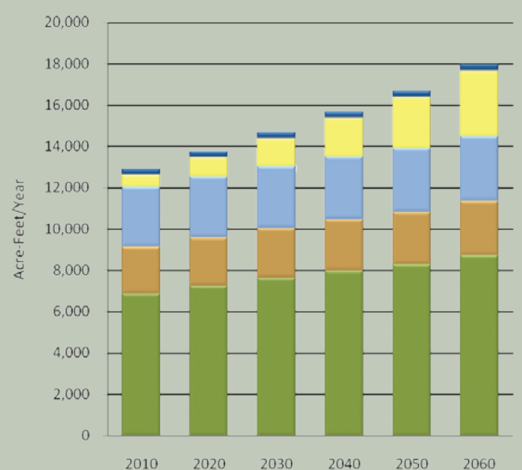
Upper Arkansas Region, Basin 68



Median Historical Streamflow at the Basin Outlet
Upper Arkansas Region, Basin 68



Projected Water Demand
Upper Arkansas Region, Basin 68



elevated levels of chlorides, turbidity, and total dissolved solids (TDS). However, individual lakes and streams may have acceptable water quality. The Great Salt Plains Reservoir, built in 1941 for flood control, does not provide water supplies. Salt from the Salt Fork of the Arkansas River settles in the Great Salt Plains Reservoir, potentially contributing high salinity downstream and to connected water sources. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060.

The majority of groundwater rights are from the Salt Fork of the Arkansas River aquifer, which underlies about 35% of the basin and has over 2 million AF of storage in the basin.

Bedrock groundwater rights are currently from the El Reno and North Central Oklahoma minor bedrock aquifers, but low yields may not meet the needs of many high-volume users. There are no significant basin-wide groundwater quality issues in Basin 68. However, the Salt Fork of the Arkansas River aquifer is impacted by high chloride levels although concentrations decrease with distance from the river. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060.

The projected 2060 water demand of 17,970 AFY in Basin 68 reflects a 5,020 AFY increase (39%) over the 2010 demand. The majority of growth in demand from 2010 to 2060 will be in the Oil and Gas and Crop Irrigation demand sectors.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions may occur by 2020. Surface water gaps will be up to 420 AFY and have a 10% probability of occurring in at least one month of the year by 2060. Alluvial groundwater depletions will be up to 1,020 AFY and have a 10% probability of occurring in at least one month of the year by 2060. Bedrock groundwater storage depletions will be up to 240 AFY. Alluvial groundwater storage depletions are minimal compared to the storage in the basin's portion of the Salt Fork of the Arkansas River aquifer. However, localized storage depletions may adversely affect well yields, water quality and pumping costs. Withdrawals from the El Reno and North-Central Oklahoma minor bedrock aquifers may be limited by well yields.

Options

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

Moderately expanded permanent conservation activities in the Municipal and Industrial and

Water Supply Limitations
Upper Arkansas Region, Basin 68

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal   Potential   Significant

Water Supply Option Effectiveness
Upper Arkansas Region, Basin 68

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

Crop Irrigation sectors could reduce gaps and storage depletions. Due to the low probability of gaps and storage depletions, temporary drought management could be an effective means of reducing demand, and may mitigate gaps and adverse effects of localized storage depletions. However, reductions would likely not affect the Oil and Gas demand sector which is projected to have the majority of growth in demand in the basin. Temporary drought management activities may not be necessary for groundwater users since the storage in major aquifers could continue to provide supplies during droughts.

Out-of-basin supplies could be used to augment supplies and mitigate gaps and storage depletions. Kaw Lake and Keystone Lake, located in the northern and southeastern parts of the Upper Arkansas Region, respectively, have unpermitted yield that could be used as a source of out-of-basin supply water. However, poor quality somewhat limits Keystone's use as a public supply source. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified seven potentially viable out-of-basin sites in the Upper Arkansas Region. However, due to the distance to these supply sources, out-of-basin supplies may not be cost-effective for many users.

New reservoirs could reduce surface water gaps and storage depletions. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 1,500 AF of storage at the basin outlet. The OCWP *Reservoir Viability Study* also identified one potentially viable site in Basin 68.

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

The Aquifer Recharge Workgroup identified a site near Cherokee (site # 31) as having potential feasibility for aquifer recharge and recovery. Water could potentially be withdrawn from the Salt Fork of the Arkansas River to recharge the Salt Fork of the Arkansas River aquifer.

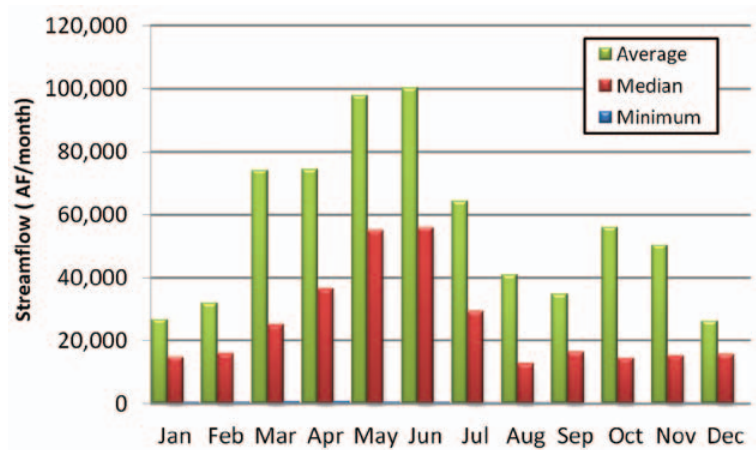
Increased reliance on alluvial groundwater supplies could be used to meet future demand on surface water, but would increase groundwater storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in the basin's portion of the Salt Fork of the Arkansas aquifer. The El Reno and North-Central aquifers are not recommended for large volume supply needs without site-specific information.

Basin 68 Data & Analysis

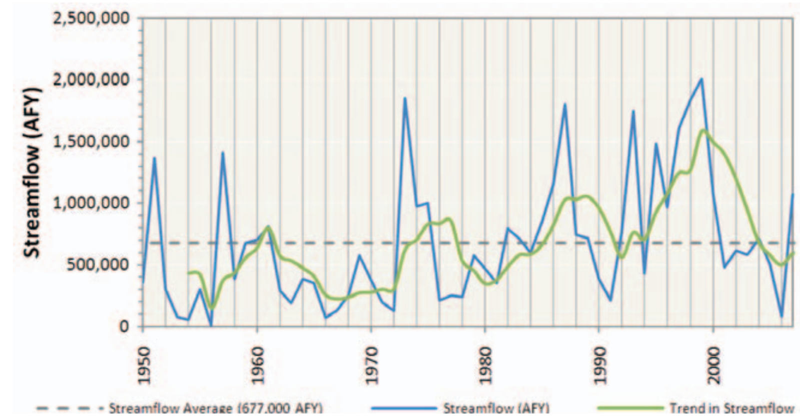
Surface Water Resources

- 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 to the early 1970s, corresponding to a period of below-average precipitation. From the early 1990s to 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 Upper Salt Fork of the Arkansas River downstream of Pond Creek is greater than 12,500 AF/month throughout the year and peaks in May and June. However, Basin 68 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 68 is considered poor. However, individual lakes and streams may have acceptable water quality.
- There are no major water supply reservoirs in the basin. Great Salt Plains Reservoir, built for flood control, recreation and fish and wildlife, does not provide water supplies due to the high mineral content. Salt from natural chloride emissions upstream from the lake settles in the lake, causing potentially high salinity to downstream and connected water sources.

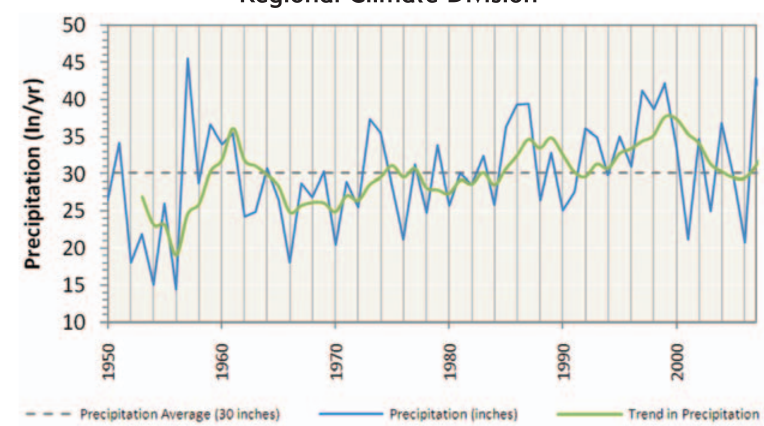
Monthly Historical Streamflow at the Basin Outlet
Upper Arkansas Region, Basin 68



Historical Streamflow at the Basin Outlet
Upper Arkansas Region, Basin 68



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)

Upper Arkansas Region, Basin 68

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
Enid Isolated Terrace	Alluvial	Major	<1%	800	17,000	0.5	2,200
Salt Fork of the Arkansas River	Alluvial	Major	35%	40,300	2,075,000	temporary 2.0	958,900
El Reno	Bedrock	Minor	20%	1,300	1,493,000	temporary 2.0	574,600
North-Central Oklahoma	Bedrock	Minor	52%	100	5,749,000	temporary 2.0	1,496,500
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	507		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 current groundwater rights in the basin are from the Salt Fork of the Arkansas River aquifer. There are also groundwater rights in the Enid Isolated Terrace, North-Central Oklahoma, and El Reno aquifers.
- There are no significant groundwater quality issues in the basin. However, the Salt Fork of the Arkansas River aquifer is impacted by high chloride levels, although concentrations decrease with distance from the river.

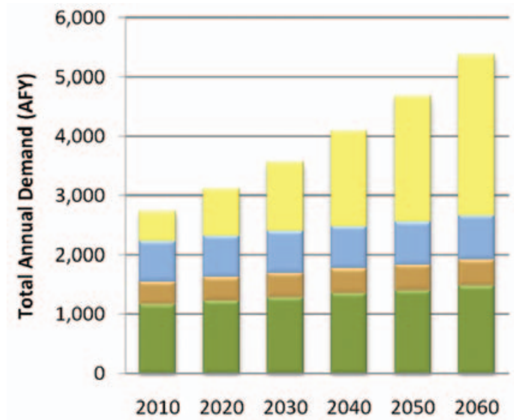
Notes & Assumptions

- 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.

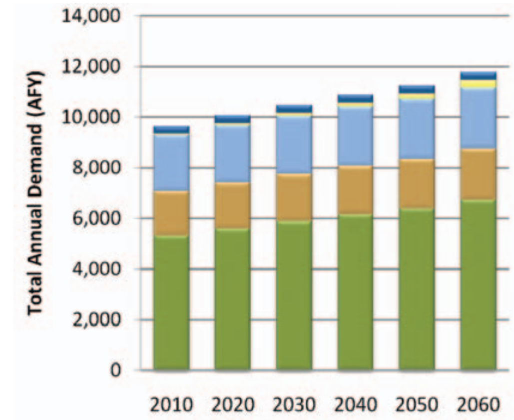
Water Demand

- The demand in Basin 68 accounts for about 10% of the total demand in the Upper Arkansas Watershed Planning Region and will increase by 39% (5,020 AFY) from 2010 to 2060. The majority of the demand will be from the Crop Irrigation demand sector. However, the majority of growth in demand will be from the Oil and Gas demand sector.
- Surface water is used to meet 22% of the total demand in Basin 68 and its use will increase by 96% (2,630 AFY) from 2010 to 2060. The majority of the growth in surface water use during this period will be from the Oil and Gas demand sector. Oil and Gas is projected to be the largest surface water user by 2040.
- Alluvial groundwater is used to meet 74% of the total demand in the basin and its use will increase by 22% (2,130 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use during this period will be in the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet 4% the of total demand in the basin and its use will increase by 45% (260 AFY) from 2010 to 2060. The majority of bedrock groundwater use during this period will be in the Crop Irrigation demand sector, but significant growth is expected in the Crop Irrigation and Oil and Gas demand sectors.

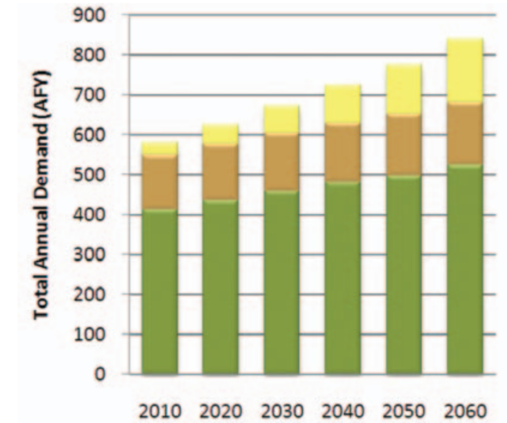
Surface Water Demand by Sector
Upper Arkansas Region, Basin 68



Alluvial Groundwater Demand by Sector
Upper Arkansas Region, Basin 68



Bedrock Groundwater Demand by Sector
Upper Arkansas Region, Basin 68



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

Total Demand by Sector
Upper Arkansas Region, Basin 68

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	6,890	2,280	2,910	590	0	280	0	12,950
2020	7,260	2,350	2,970	930	0	280	0	13,790
2030	7,630	2,420	3,010	1,360	0	280	0	14,700
2040	8,000	2,480	3,040	1,870	0	280	0	15,670
2050	8,280	2,550	3,100	2,470	0	290	0	16,690
2060	8,740	2,620	3,160	3,160	0	290	0	17,970

Notes & Assumptions

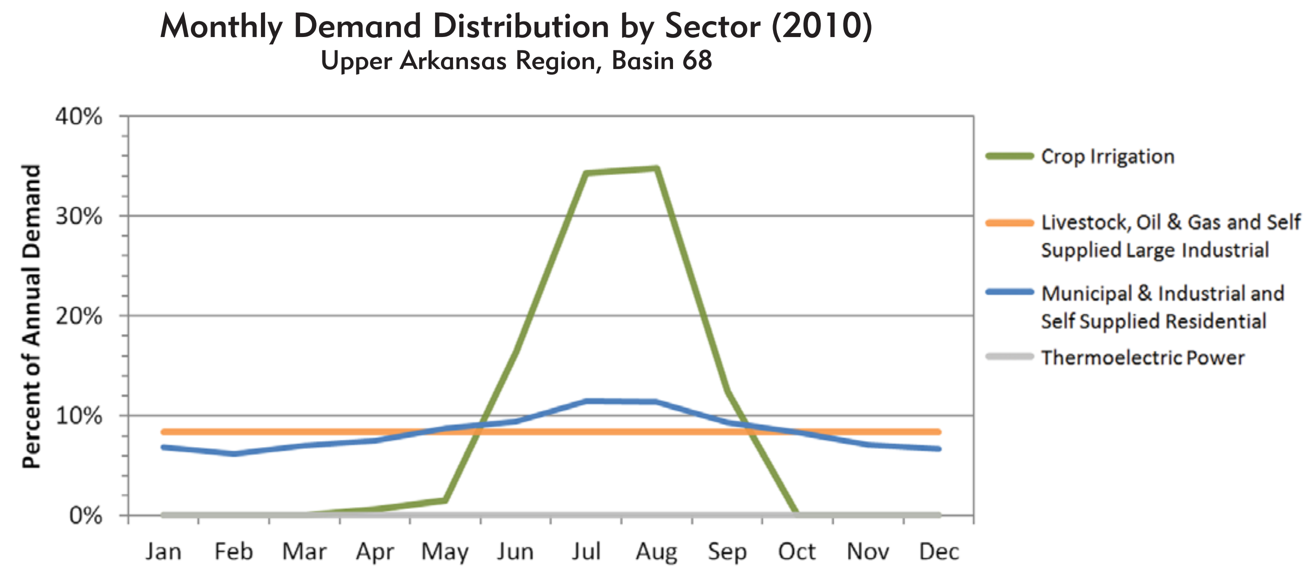
- Demand values represent total demand (the amount of water pumped or diverted to meet the needs of the user).
- Values are based on the baseline demand forecast from the OCWP *Water Demand Forecast Report*.
- The effect of climate change, conservation, and non-consumptive uses, such as hydropower, are 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.

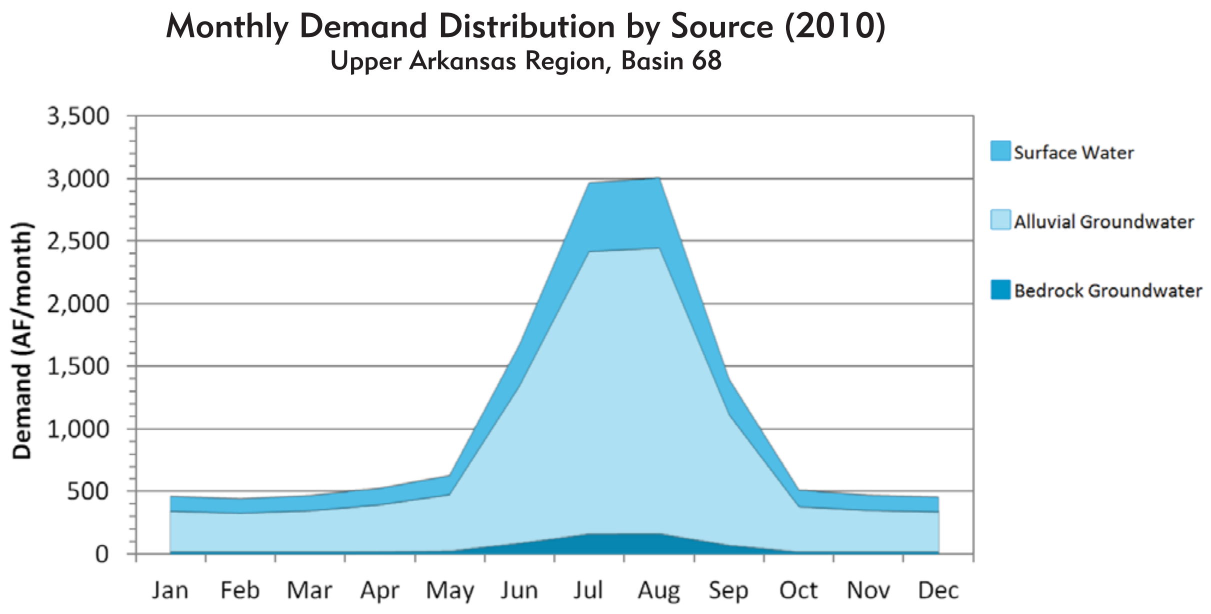
Monthly Demand Distribution by Sector (2010)

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 63% 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.

Monthly Demand Distribution by Source (2010)

- The peak summer month total water demand in Basin 68 is 6.6 times the winter demand, which is more pronounced than the overall statewide pattern. Surface water use in the peak summer month is 4.6 times the winter use. Monthly alluvial and bedrock groundwater use peaks in the summer at 7.1 and 11.4 times the winter use, respectively.





Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions are projected to occur by 2020.
- There will be a 10% probability of surface water gaps occurring in at least one month of the year, with gaps having 5% or less probability of occurring in any season by 2060. Surface water gaps in Basin 68 may occur during the winter, summer, and fall. Surface water gaps in 2060 will be up to 16% (140 AF/month) of the surface water demand in the peak summer month, and as high as 25% (130 AF/month) of the surface water demand in the fall months.
- There will be a 10% probability of alluvial groundwater storage depletions occurring in at least one month of the year, with storage depletions having a 5% or less probability of occurring in any season by 2060. Alluvial groundwater storage depletions in Basin 68 may occur during the winter, summer, and fall. Alluvial groundwater storage depletions in 2060 will be up to 15% (440 AF/month) of the alluvial groundwater demand in the peak summer month, and as high as 25% (320 AF/month) of the alluvial groundwater monthly fall demand.
- Bedrock groundwater storage depletions of minor aquifers in Basin 68 may occur throughout the year, peaking in size during the summer. Bedrock groundwater storage depletions in 2060 will be 24% (50 AF/month) of the bedrock groundwater demand on average in the peak summer month, and 33% (10 AF/month) on average of the monthly winter bedrock groundwater demand.
- Projected annual alluvial groundwater storage depletions are minimal relative to the amount of water in storage in the aquifer. However, localized storage depletions may adversely affect yields, water quality, or pumping costs. Bedrock withdrawals from the El Reno and North-Central Oklahoma aquifers may be limited by both well yield and available storage.

Surface Water Gaps by Season (2060 Demand)
Upper Arkansas Region, Basin 68

Months (Season)	Maximum Gap [1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	40	40	2%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	140	90	5%
Sep-Nov (Fall)	130	100	5%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)
Upper Arkansas Region, Basin 68

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	50	50	2%
Mar-May (Spring)	0	0	0%
Jun-Aug (Summer)	440	280	5%
Sep-Nov (Fall)	320	130	5%

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

Magnitude and Probability of Annual Gaps and Storage Depletions
Upper Arkansas Region, Basin 68

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	20	70	20	3%	5%
2030	70	210	60	5%	5%
2040	150	420	170	5%	5%
2050	240	670	200	7%	7%
2060	420	1,020	240	10%	10%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)
Upper Arkansas Region, Basin 68

Months (Season)	Average Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	10
Mar-May (Spring)	10
Jun-Aug (Summer)	50
Sep-Nov (Fall)	30

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

Upper Arkansas Region, Basin 68

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	420	1,020	240	10%	10%
Moderately Expanded Conservation in Crop Irrigation Water Use	360	840	210	7%	7%
Moderately Expanded Conservation in M&I Water Use	340	830	240	9%	9%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	280	640	210	7%	7%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	110	170	110	7%	7%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Upper Arkansas Region, Basin 68

Reservoir Storage	Diversion
AF	AFY
100	800
500	2,200
1,000	3,700
2,500	7,800
5,000	10,700
Required Storage to Meet Growth in Demand (AF)	1,500
Required Storage to Meet Growth in Surface Water Demand (AF)	500

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 31%, alluvial groundwater depletions by 37%, and bedrock groundwater storage depletions by 13%. Due to the low probability of gaps and storage depletions, temporary drought management could be an effective means of reducing demand, largely from irrigation, and may mitigate gaps and adverse effects from localized depletions. Reductions would likely not affect the Oil and Gas sector, which is projected to have the majority of growth in basin demand. Temporary drought management activities may not be necessary for groundwater users since major aquifer storage could also provide supplies during droughts.

Out-of-Basin Supplies

New out-of-basin supplies could be used to augment supplies and mitigate gaps and storage depletions. Kaw Lake in Basin 72 has unpermitted yield that could be used as a source of out-of-basin supply. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified seven potentially viable out-of-basin sites in the Upper Arkansas Region: Sheridan and Skeleton in Basin 63, Hunnewell in Basin 70, Lela and Pawnee in Basin 71, and Otoe and Shidler in Basin 72. However, due to the distance to these supply sources, out-of-basin supplies may not be cost-effective for many users.

Reservoir Use

Reservoir storage could provide dependable supplies to mitigate surface water gaps and storage depletions. The entire increase in demand from 2010 to 2060 may be met by a river diversion and 1,500 AF of storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions. The OCWP *Reservoir Viability Study* also identified Alva Reservoir site as a potentially viable site in Basin 68 that could provide water to meet local demand in the basin; therefore, it may be able to provide out-of-basin supplies for nearby basins.

Increasing Reliance on Surface Water

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

Increasing Reliance on Groundwater

Increased reliance on alluvial groundwater could mitigate surface water gaps but would increase storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in the basin's portion of the Salt Fork of the Arkansas River aquifer. However, the aquifer only underlies about one-third of the basin. A shift from surface water to alluvial groundwater could potentially decrease the size of surface water gaps but may not decrease the probability of remaining gaps due to the interconnection between the supply sources. The El Reno and North-Central aquifers are not recommended for large scale supplies without site-specific information. The Aquifer Recharge Workgroup identified a site near Cherokee (site # 31) as potentially feasible for aquifer recharge and recovery.

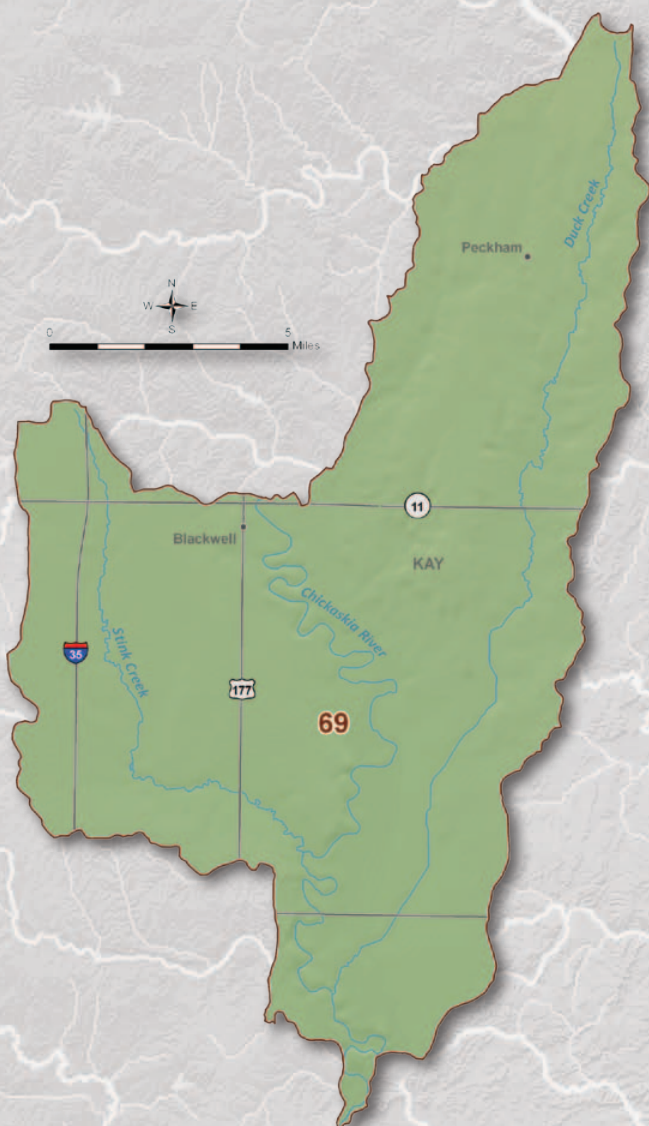
Notes & Assumptions

- 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.

Data & Analysis

Upper Arkansas Watershed Planning Region

Basin 69



Basin 69 Summary

Synopsis

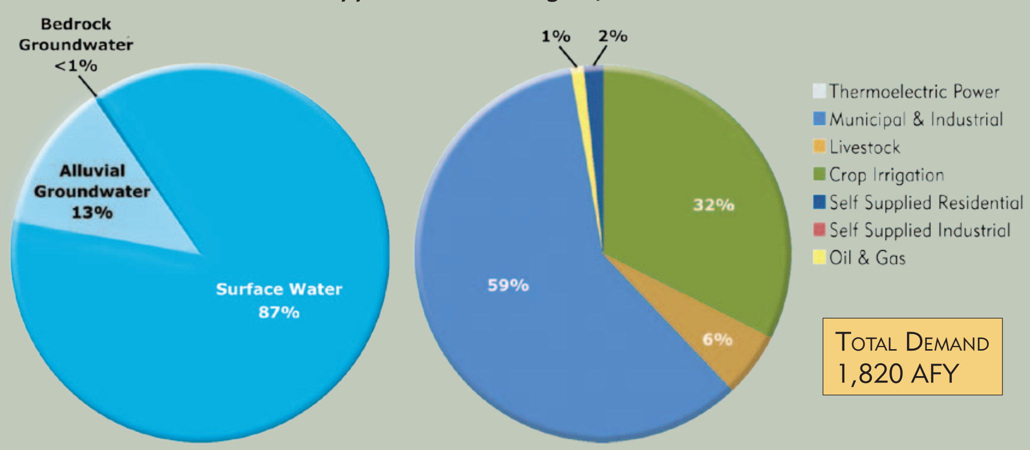
- Water users are expected to continue to rely on a mixture of surface water and alluvial groundwater supplies.
- By 2050, there is a moderate probability of surface water gaps from increased demands on existing supplies during low flow periods.
- To reduce the risk of adverse impacts on water supplies, it is recommended that gaps be decreased where economically feasible.
- Additional conservation could mitigate surface water gaps.
- Additional reservoir storage could mitigate surface water gaps.

Basin 69 accounts for less than 1% of the current water demand in the Upper Arkansas Watershed Planning Region. About 59% of the demand is from the Municipal and Industrial demand sector. Crop Irrigation (32%) is the second-largest demand sector. Surface water satisfies about 87% of the current demand in the basin. Groundwater satisfies about 13% of the current demand in the basin. The peak summer month demand in Basin 69 is 5.4 times the winter demand, which is similar to the overall statewide pattern.

There are no major reservoirs in this basin. The Chikaskia River upstream of the Salt Fork of the Arkansas River can have extended periods of low flow in any month of the year. Basin 69 typically has flows greater than 10,000 AF/month, peaking in May and June. Basin 69 is a small basin, just 150 square miles; therefore, the majority of the flow is generated upstream. Development in upstream basins and Kansas is expected to decrease the flow in Basin 69 in the future. Relative to other basins in the state, the surface water quality in Basin 69 is considered fair. Duck Creek and Stink Creek are impaired for Agricultural use due to elevated levels of sulfates, total dissolved solids (TDS), and turbidity. The availability of permits is not expected to limit

Current Demand by Source and Sector

Upper Arkansas Region, Basin 69



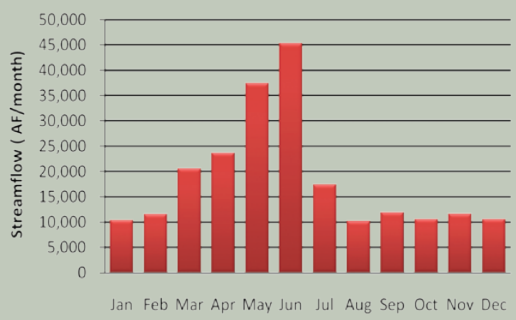
TOTAL DEMAND
1,820 AFY

Water Resources

Upper Arkansas Region, Basin 69

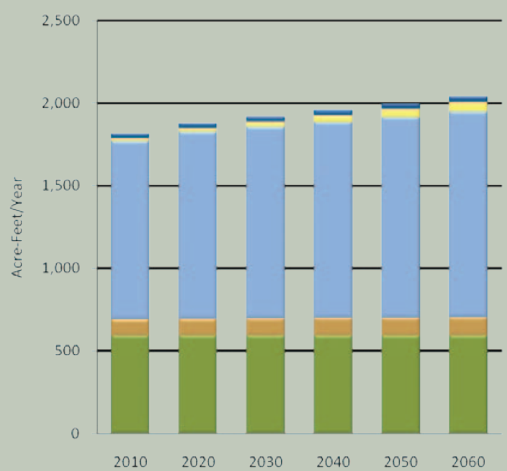
Median Historical Streamflow at the Basin Outlet

Upper Arkansas Region, Basin 69



Projected Water Demand

Upper Arkansas Region, Basin 69



the development of surface water supplies for in-basin use through 2060.

Groundwater rights in the basin are primarily from the Chikaskia River minor alluvial aquifer. The Chikaskia River aquifer has approximately 70,000 AF of storage and underlies about 20% of the basin. The North-Central Oklahoma minor bedrock aquifer underlies the basin, but currently is not used. There are no significant groundwater quality issues 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.

The projected 2060 water demand of 2,030 AFY reflects a 210 AFY (12%) increase over the 2010 demand. The majority of growth in demand will occur in the Municipal and Industrial demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps may occur by 2050. Alluvial and bedrock groundwater storage depletions were not evaluated in detail due to the minimal increase in their use from 2010 to 2060. There is a small probability (3%) of surface water gaps occurring in least one month in 2060. Surface water gaps will be up to 30 AFY in 2060.

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 should be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial demand sector could mitigate surface water gaps. Due to the low probability of gaps, temporary drought management is also recommended to reduce demand and subsequent gaps.

Out-of-basin supplies could be used to augment supplies and mitigate gaps. Kaw Lake, which is to the east in Basin 72, has unpermitted yield and could be used as a source of out-of-basin water. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified eight potentially viable out-of-basin sites in the Upper Arkansas Region. However, due to the distance to these sources, out-of-basin supplies may not be cost-effective for some users.

Reservoir storage could provide dependable supplies and mitigate surface water gaps. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and less than 100 AF of storage at the basin outlet.

Water Supply Limitations

Upper Arkansas Region, Basin 69

Surface Water	Potential
Alluvial Groundwater	Minimal
Bedrock Groundwater	Potential

Minimal / Potential / Significant

Water Supply Option Effectiveness

Upper Arkansas Region, Basin 69

Demand Management	Typically Effective
Out-of-Basin Supplies	Potentially Effective
Reservoir Use	Potentially Effective
Increasing Supply from Surface Water	Likely Ineffective
Increasing Supply from Groundwater	Likely Ineffective

Typically Effective / Potentially Effective / Likely Ineffective / No Option Necessary

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

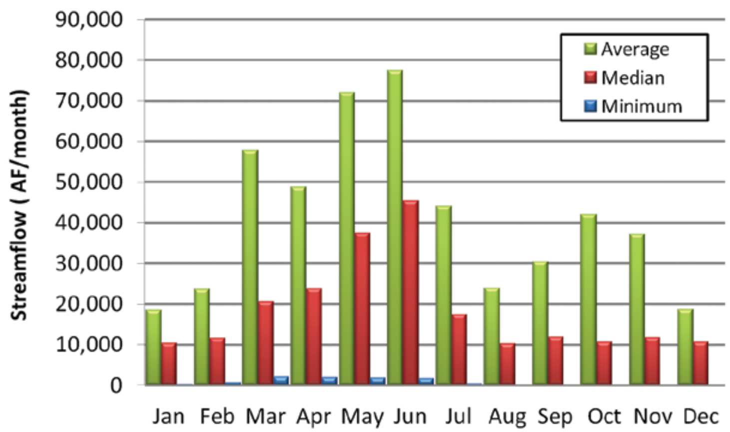
Increased reliance on groundwater could mitigate surface water gaps, but may increase groundwater depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in the basin's portion of the Chikaskia River aquifer. However this aquifer only underlies about a fifth of the basin. The North-Central minor bedrock aquifer is not recommended for large scale supplies without site-specific information.

Basin 69 Data & Analysis

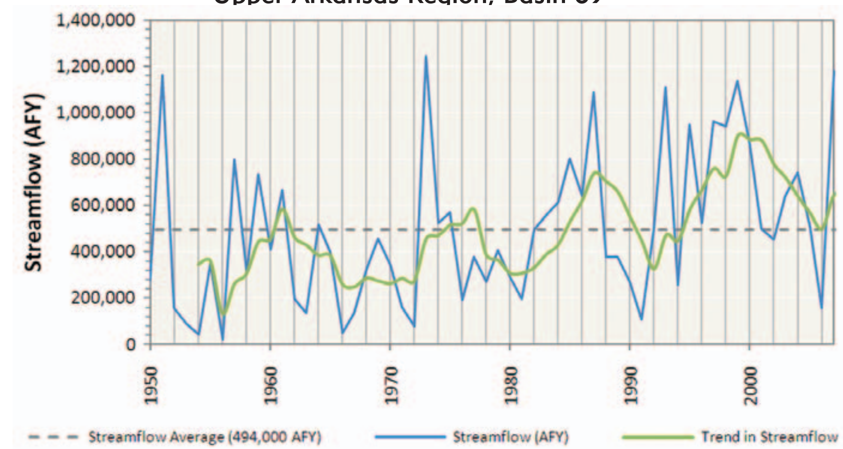
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. Basin 69 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 early 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 in the Chikaskia River upstream of the Salt Fork of the Arkansas River is greater than 10,000 AF/month in each month of the year, peaking in May and June. However, Basin 69 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 69 is considered fair.
- There are no major reservoirs in Basin 69.

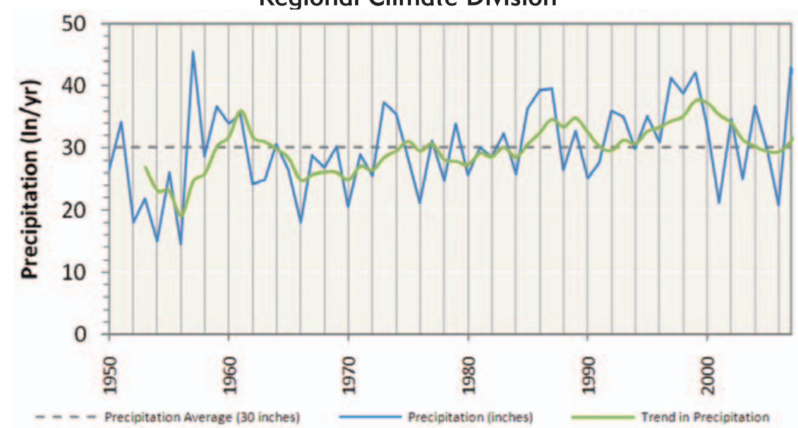
Monthly Historical Streamflow at the Basin Outlet
Upper Arkansas Region, Basin 69



Historical Streamflow at the Basin Outlet
Upper Arkansas Region, Basin 69



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)

Upper Arkansas Region, Basin 69

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
Chikaskia River	Alluvial	Minor	18%	1,200	67,000	temporary 2.0	35,100
North-Central Oklahoma	Bedrock	Minor	100%	<50	737,000	temporary 2.0	191,900

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

- A majority of groundwater rights are from the Chikaskia River aquifer. Site-specific information on the suitability of the minor aquifers for supply should be considered before large scale use.
- There are no significant groundwater quality issues in the basin.

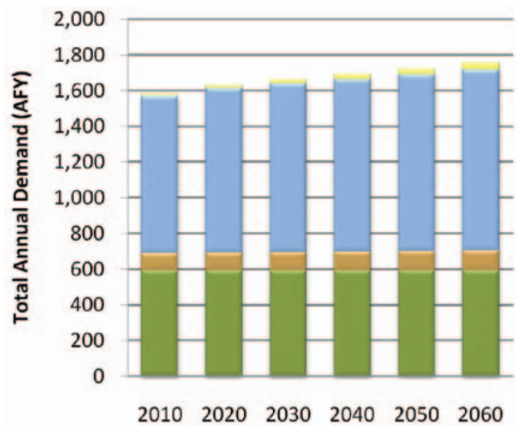
Notes & Assumptions

- 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.

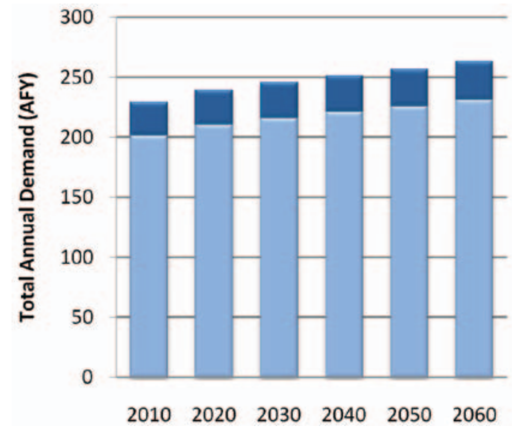
Water Demand

- The demand in Basin 69 accounts for less than 1% of the total demand in the Upper Arkansas Watershed Planning Region and will increase by 12% (210 AFY) from 2010 to 2060. The majority of demand and growth in demand will be from the Municipal and Industrial demand sector.
- Surface water is used to meet 87% of the total demand in Basin 69 and its use will increase by 11% (170 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use will be from the Municipal and Industrial demand sector.
- Alluvial groundwater is used to meet 13% of total demand in the basin and its use will increase by 15% (30 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use will be from the Municipal and Industrial demand sector.
- Bedrock groundwater is used to meet less than 1% of total demand in the basin. The growth in bedrock groundwater use from 2010 to 2060 will be from the Oil and Gas demand sector and is minimal on a basin scale.

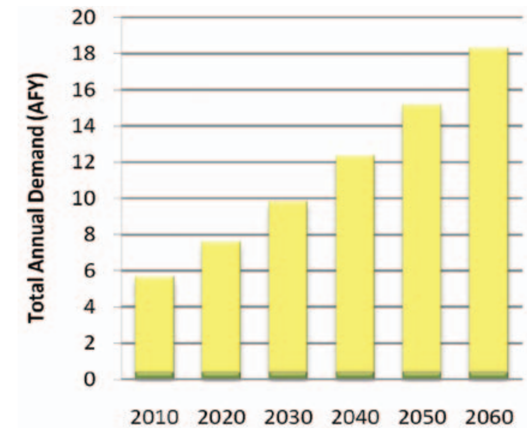
Surface Water Demand by Sector
Upper Arkansas Region, Basin 69



Alluvial Groundwater Demand by Sector
Upper Arkansas Region, Basin 69



Bedrock Groundwater Demand by Sector
Upper Arkansas Region, Basin 69



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

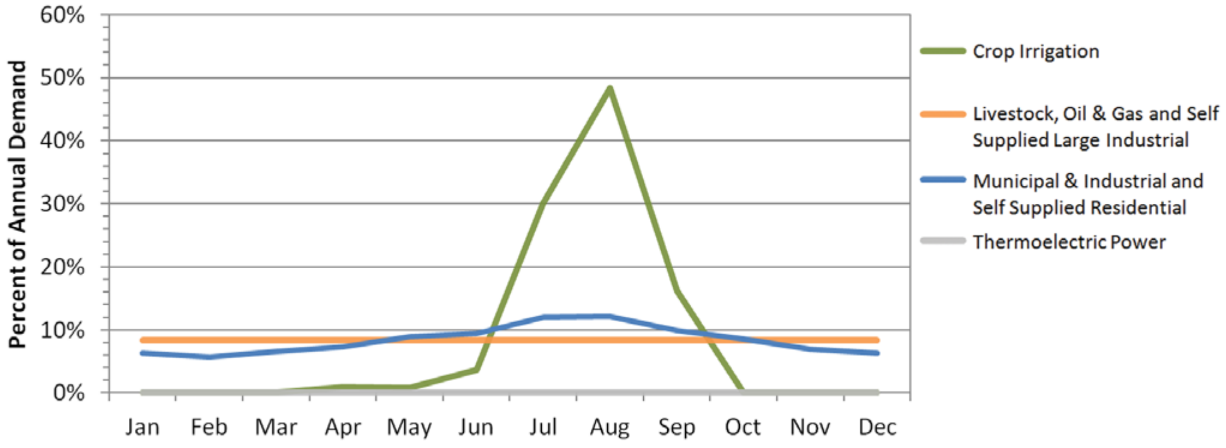
Total Demand by Sector
Upper Arkansas Region, Basin 69

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	590	100	1,080	20	0	30	0	1,820
2020	590	100	1,130	20	0	30	0	1,870
2030	590	100	1,160	30	0	30	0	1,910
2040	590	110	1,190	40	0	30	0	1,960
2050	590	110	1,210	50	0	30	0	1,990
2060	590	110	1,240	60	0	30	0	2,030

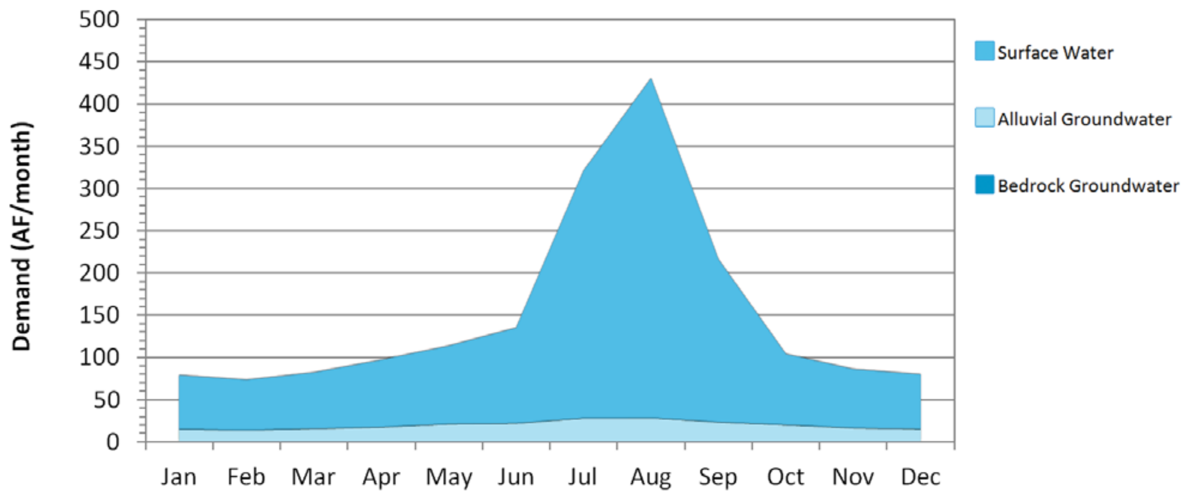
Notes & Assumptions

- 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)
Upper Arkansas Region, Basin 69



Monthly Demand Distribution by Source (2010)
Upper Arkansas Region, Basin 69



Monthly Demand Distribution by Sector (2010)

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 82% 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.

Monthly Demand Distribution by Source (2010)

- The peak summer month total water demand in Basin 69 is 5.4 times the winter demand, which is similar to the overall statewide pattern. Surface water demand in the peak summer month is 6.2 times the winter demand. Alluvial and bedrock groundwater use in the peak summer month are 1.9 and 1.4 times the winter use, respectively.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps may occur by 2050. Alluvial and bedrock groundwater storage depletions are not forecasted through 2060.
- There is a small probability (3%) of surface water gaps occurring in least one month by 2060. Surface water gaps in Basin 69 may occur during the summer and fall. Surface water gaps in 2060 will be up to 5% (20 AF/month) of the surface water demand in the peak summer month, and as much as 5% (10 AF/month) of the monthly fall surface water demand.

Surface Water Gaps by Season (2060 Demand)

Upper Arkansas Region, Basin 69

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)	20	20	2%
Sep-Nov (Fall)	10	10	3%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Upper Arkansas Region, Basin 69

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

Upper Arkansas Region, Basin 69

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	20	0	0	2%	0%
2060	30	0	0	3%	0%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Upper Arkansas Region, Basin 69

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

Upper Arkansas Region, Basin 69

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	30	0	0	3%	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.

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Upper Arkansas Region, Basin 69

Reservoir Storage	Diversion
AF	AFY
100	400
500	1,400
1,000	2,300
2,500	4,600
5,000	8,100
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

[Typically Effective] Moderately expanded permanent conservation activities in the Municipal and Industrial demand sector could mitigate surface water gaps. Due to the low probability of gaps, temporary drought management is also recommended to reduce demand and surface water gaps.

Out-of-Basin Supplies

[Potentially Effective] Out-of-basin supplies could be used to augment supplies and mitigate gaps. Kaw Lake, which is located in Basin 72, has unpermitted yield and could be used as a source of out-of-basin supply. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified eight potentially viable out-of-basin sites in the Upper Arkansas Region: Sheridan and Skeleton in Basin 63, Alva in Basin 68, Hunnewell in Basin 70, Lela and Pawnee in Basin 71, and Otoe and Shidler in Basin 72. However, due to the distance to these supplies and minimal gaps in Basin 69, out-of-basin supplies may not be cost-effective for some users.

Reservoir Use

[Potentially Effective] Reservoir storage could provide dependable supplies to mitigate surface water gaps. The entire increase in demand from 2010 to 2060 may be met by a river diversion and less than 100 AF of storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions.

Increasing Reliance on Surface Water

[Likely Ineffective] Increased reliance on surface water, without reservoir storage, would increase gaps and is not recommended.

Increasing Reliance on Groundwater

[Likely Ineffective] Increased reliance on groundwater could mitigate surface water gaps, but may cause storage depletions. Additionally, a shift from surface water to alluvial groundwater could potentially decrease the size of surface water gaps, but may not decrease the probability of remaining surface water gaps due to the interconnection between the supply sources. Site-specific information should be considered before large scale use of the Chikaskia River or the North-Central aquifers.

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.

Data & Analysis

Upper Arkansas Watershed Planning Region

Basin 70

Basin 70 Summary

Synopsis

- Water users are expected to continue to rely on a mixture of surface water and groundwater 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 were evaluated. However, localized gaps and storage depletions may occur.

Basin 70 accounts for about 1% of the current water demand in the Upper Arkansas Watershed Planning Region. About 68% of the demand is from the Crop Irrigation demand sector. Municipal and Industrial (18%) is the second-largest demand sector. Surface water satisfies about 45% of the current demand in the basin. Groundwater satisfies about 55% of current demand (40% bedrock and 15% alluvial). The peak summer month demand in Basin 70 is 16.3 times the winter demand, which is more pronounced than the overall statewide pattern.

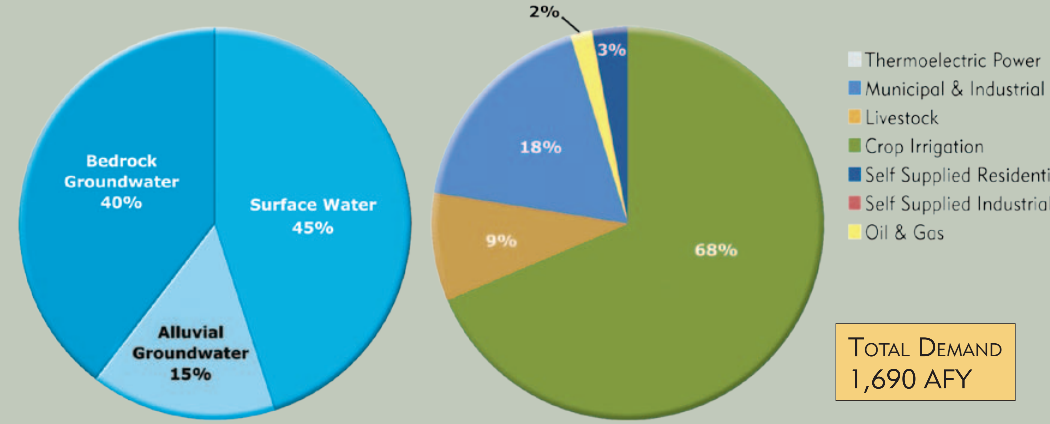
There are no major reservoirs. Typically, the Chikaskia River downstream of Bitter Creek has flows greater than 10,000 AF/month, but it can have periods of low flow in any month of the year. Relative to other basins in the state, the surface water quality in Basin 70 is considered fair. Bitter Creek and Scatter Creek are impaired for Agricultural use due to elevated levels of chloride, sulfates, turbidity, and total dissolved solids (TDS). The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060.

The majority of groundwater rights are from the North-Central Oklahoma minor bedrock aquifer, which underlies the entire basin. There are also water rights from the minor Chikaskia River minor alluvium and terrace aquifer, which underlies a small portion of the basin. Site-specific information on the suitability of the minor aquifers for supply should be considered before large scale use. There are no significant groundwater quality issues 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.

The projected 2060 water demand of 1,870 AFY in Basin 70 reflects a 180 AFY (11%) increase over the 2010 demand. The majority of growth in demand will be in the Oil and Gas demand sector. The Crop Irrigation demand sector will continue to be the largest water use sector in the basin; however, Crop Irrigation use is not projected to grow over this period.

Current Demand by Source and Sector

Upper Arkansas Region, Basin 70

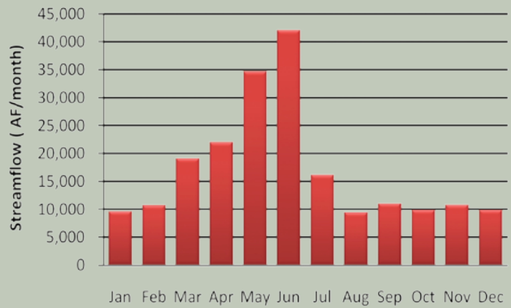


Water Resources

Upper Arkansas Region, Basin 70

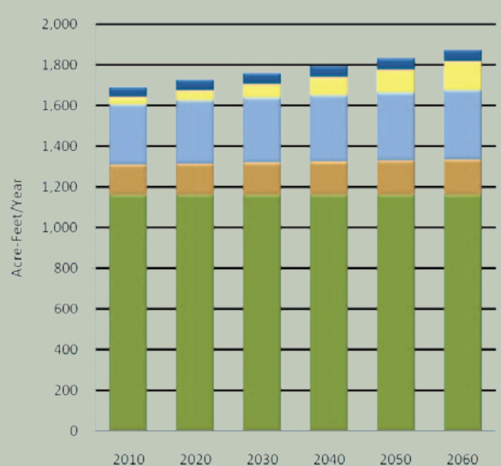
Median Historical Streamflow at the Basin Outlet

Upper Arkansas Region, Basin 70



Projected Water Demand

Upper Arkansas Region, Basin 70



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 were evaluated.

Water Supply Limitations

Upper Arkansas Region, Basin 70

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness

Upper Arkansas Region, Basin 70

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

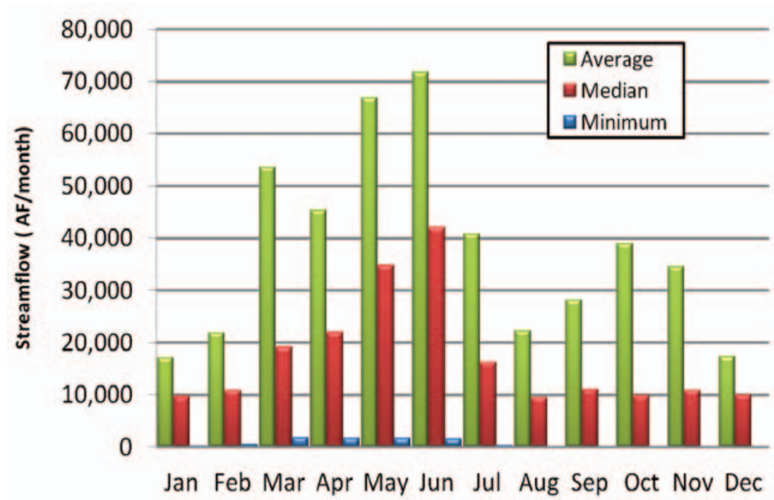
Typically Effective Potentially Effective
Likely Ineffective No Option Necessary

Basin 70 Data & Analysis

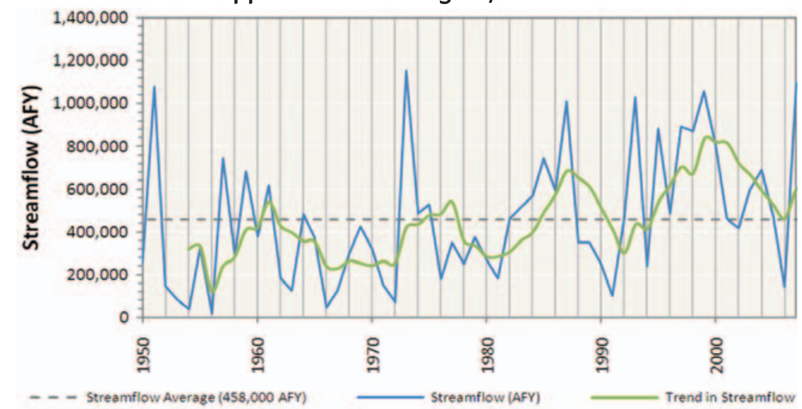
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Chikaskia River downstream of Bitter Creek had a prolonged period of below-average streamflow from the mid 1960s to the early 1970s, corresponding to below-average precipitation. From the late 1990s until the mid 2000s, the basin went through a prolonged period of above-average precipitation and streamflow, demonstrating hydrologic variability in the basin.
- The median flow in the Chikaskia River downstream of Bitter Creek is greater than 10,000 AF/month throughout the year. However, Basin 70 can have periods of low flow in any month of the year.
- There are no major reservoirs in this basin.

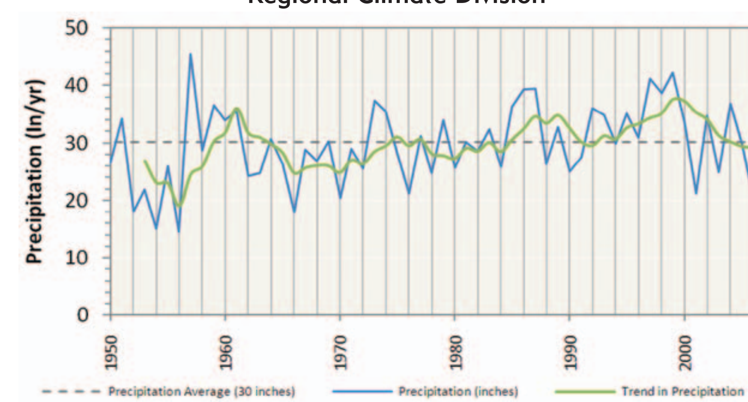
Monthly Historical Streamflow at the Basin Outlet
Upper Arkansas Region, Basin 70



Historical Streamflow at the Basin Outlet
Upper Arkansas Region, Basin 70



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)

Upper Arkansas Region, Basin 70

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
Chikaskia River	Alluvial	Minor	3%	800	22,000	temporary 2.0	12,500
North-Central Oklahoma	Bedrock	Minor	100%	3,900	1,081,000	temporary 2.0	279,200

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

- For Basin 70, the majority of groundwater rights are from the North-Central Oklahoma aquifer, which underlies the entire basin. There are also water rights from the Chikaskia aquifer, which underlies a small portion of the basin.
- There are no significant groundwater quality issues in the basin.

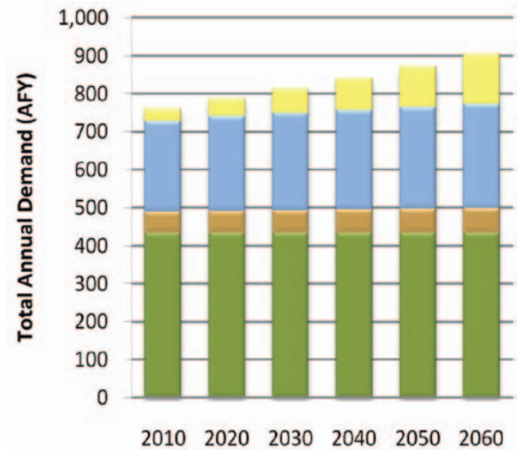
Notes & Assumptions

- 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.

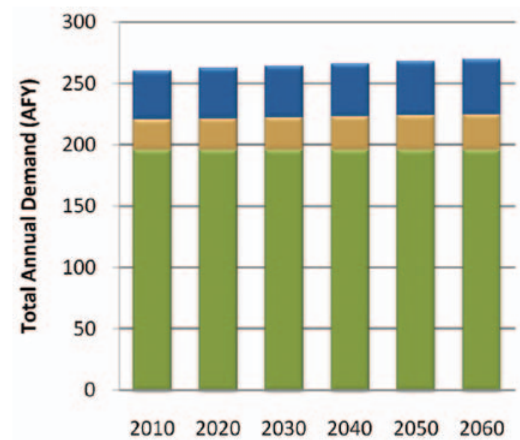
Water Demand

- The demand in Basin 70 accounts for about 1% of the total demand in the Upper Arkansas Watershed Planning Region and is projected to increase by 11% (180 AFY) from 2010 to 2060. The majority of the demand is from the Crop Irrigation demand sector. However, the majority of growth in demand is projected to come from the Oil and Gas demand sector.
- Surface water is used to meet 45% of the total demand in Basin 70 and its use is projected to increase by 19% (140 AFY) from 2010 to 2060. The majority of surface water use is from Crop Irrigation; however the majority of growth in surface water use is projected to come from Oil and Gas demand.
- Alluvial groundwater is used to meet 15% of the total demand in the basin and its use is projected to increase by 4% (10 AFY) from 2010 to 2060. The change in alluvial groundwater use from 2010 to 2060 is projected to be minimal on a basin scale.
- Bedrock groundwater is used to meet 40% of the total demand in the basin and its use is projected to increase by 4% (30 AFY) from 2010 to 2060. The change in bedrock groundwater use from 2010 to 2060 is projected to be minimal on a basin scale.

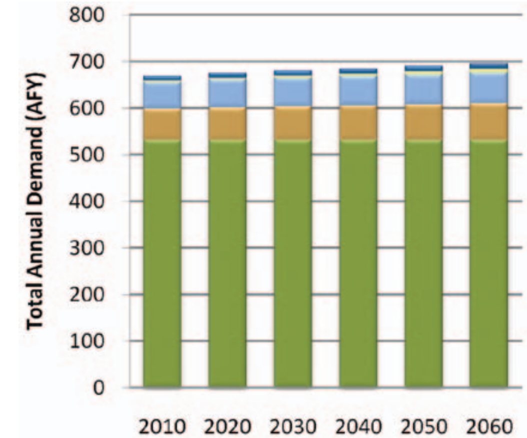
Surface Water Demand by Sector
Upper Arkansas Region, Basin 70



Alluvial Groundwater Demand by Sector
Upper Arkansas Region, Basin 70



Bedrock Groundwater Demand by Sector
Upper Arkansas Region, Basin 70



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

Total Demand by Sector
Upper Arkansas Region, Basin 70

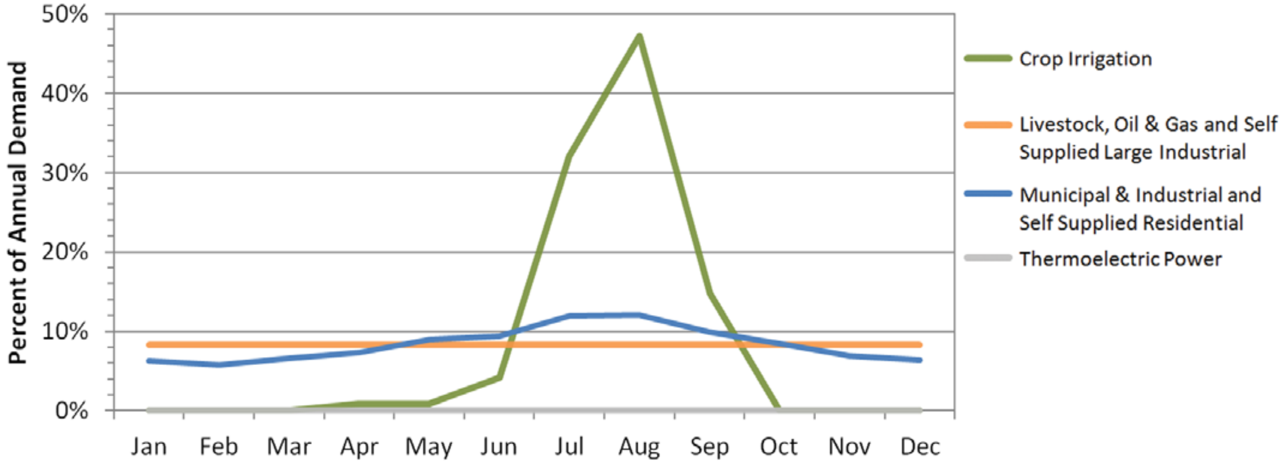
Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	1,160	150	300	30	0	50	0	1,690
2020	1,160	150	310	50	0	50	0	1,720
2030	1,160	160	320	70	0	50	0	1,760
2040	1,160	160	330	90	0	50	0	1,790
2050	1,160	170	330	110	0	50	0	1,820
2060	1,160	170	340	140	0	60	0	1,870

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.

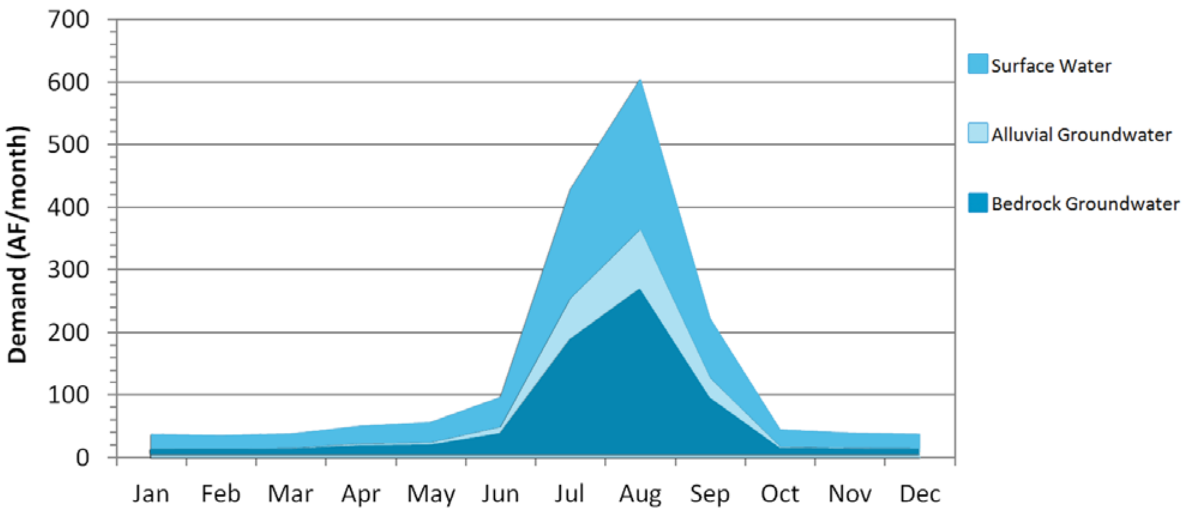
Monthly Demand Distribution by Sector (2010)

Upper Arkansas Region, Basin 70



Monthly Demand Distribution by Source (2010)

Upper Arkansas Region, Basin 70



Monthly Demand Distribution by Sector (2010)

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 82% 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.

Monthly Demand Distribution by Source (2010)

- The peak summer month total water demand in Basin 70 is 16.3 times the winter demand, which is more pronounced than the overall statewide pattern. Surface water use in the peak summer month is 10.7 times the monthly winter use. Monthly alluvial and bedrock groundwater use peaks in the summer at 21.6 and 26.3 times the winter use, respectively.

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 for all evaluated planning horizons. However, localized gaps and groundwater storage depletions may occur.

Surface Water Gaps by Season (2060 Demand)
Upper Arkansas Region, Basin 70

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF	AF	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)
Upper Arkansas Region, Basin 70

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF	AF	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
Upper Arkansas Region, Basin 70

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AF			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)
Upper Arkansas Region, Basin 70

Months (Season)	Average Storage Depletion[1]
	AF
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

Upper Arkansas Region, Basin 70

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	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.

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Upper Arkansas Region, Basin 70

Reservoir Storage	Diversion
AF	AFY
100	600
500	1,500
1,000	2,400
2,500	4,600
5,000	8,000
Required Storage to Meet Growth in Demand (AF)	0
Required Storage to Meet Growth in Surface Water Demand (AF)	0

Water Supply Options & Effectiveness

Typically Effective | Potentially Effective | Likely Ineffective | No Option Necessary

- Analyses of current and projected water use patterns indicate that no surface water gaps or groundwater storage depletions should occur through 2060.

Demand Management

No water shortages anticipated.

Out-of-Basin Supplies

No supply options recommended.

Reservoir Use

No supply options recommended.

Increasing Reliance on Surface Water

No supply options recommended.

Increasing Reliance on Groundwater

No supply options recommended.

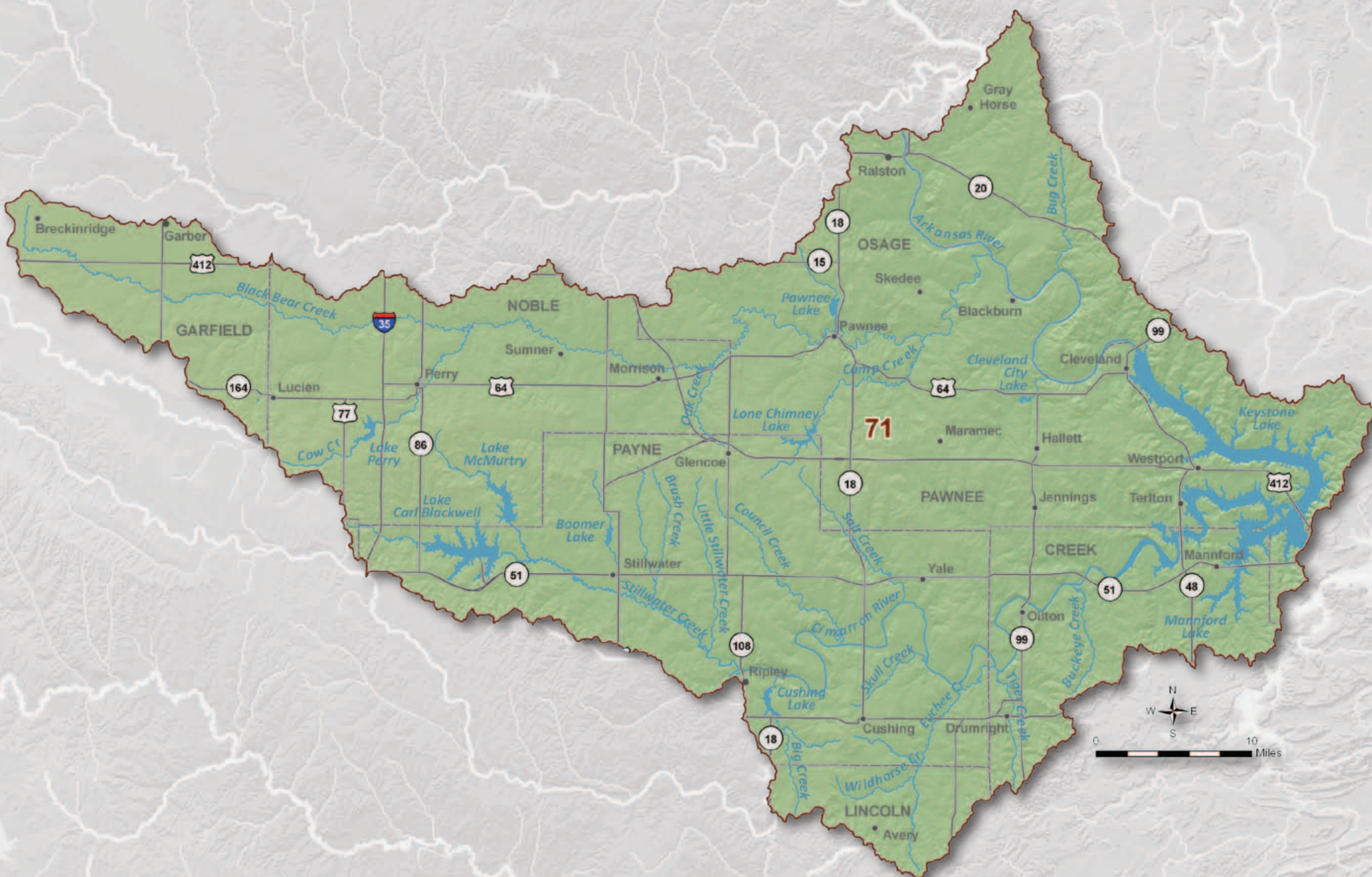
Notes & Assumptions

- 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.

Data & Analysis

Upper Arkansas Watershed Planning Region

Basin 71



Basin 71 Summary

Synopsis

- Water users are expected to continue to rely on a mixture of surface water and groundwater supplies.
- 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 storage depletions be decreased where economically feasible.
- Additional conservation could mitigate the adverse effects of localized alluvial groundwater storage depletions.
- Use of additional bedrock groundwater supplies and/or developing small reservoirs could mitigate alluvial storage depletion without having major impacts to groundwater storage.

Basin 71 accounts for about 21% of the current water demand in the Upper Arkansas Watershed Planning Region. About 77% of the demand is from the Municipal and Industrial demand sector. Crop Irrigation (8%) and Livestock (8%) are the next largest demand sectors. Surface water satisfies about 70% of the current demand in the basin. Groundwater satisfies about 30% of the current demand (15% alluvial and 15% bedrock). The peak summer month demand in Basin 71 is 2.1 times the winter demand, which is similar to the overall statewide pattern.

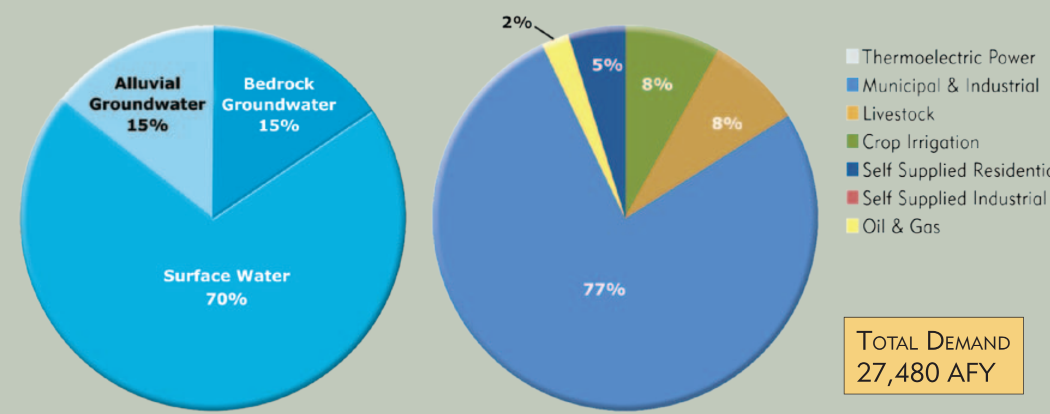
The City of Stillwater, the basin's largest city, also obtains out-of-basin water supplies from Basin 72's Kaw Reservoir. Historically, the upper Arkansas River below Keystone Lake has substantial streamflow throughout the year. Water supplies are also supplemented by major reservoirs, including Keystone, McMurtry, and Carl Blackwell. Relative to other basins in the state, the surface water quality in Basin 71 is considered good. However, the Cimarron River is impaired for Agricultural use due to elevated levels of chloride, sulfates, and total dissolved solids (TDS). Additionally, Lake Carl Blackwell is impaired for Public and Private Water Supply due to chlorophyll-a and poor water quality in Keystone Lake limits beneficial uses. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060.

The majority of current groundwater rights in the basin are from the Vamoosa-Ada bedrock aquifer, which underlies about a third of the basin. The majority of alluvial groundwater rights are from the Arkansas River aquifer and non-delineated aquifers along the Cimarron River. There are no significant groundwater quality issues 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.

The projected 2060 water demand of 37,190 AFY reflects a 9,710 AFY increase (35%) over the 2010 demand. The majority of the demand and growth in demand is expected to

Current Demand by Source and Sector

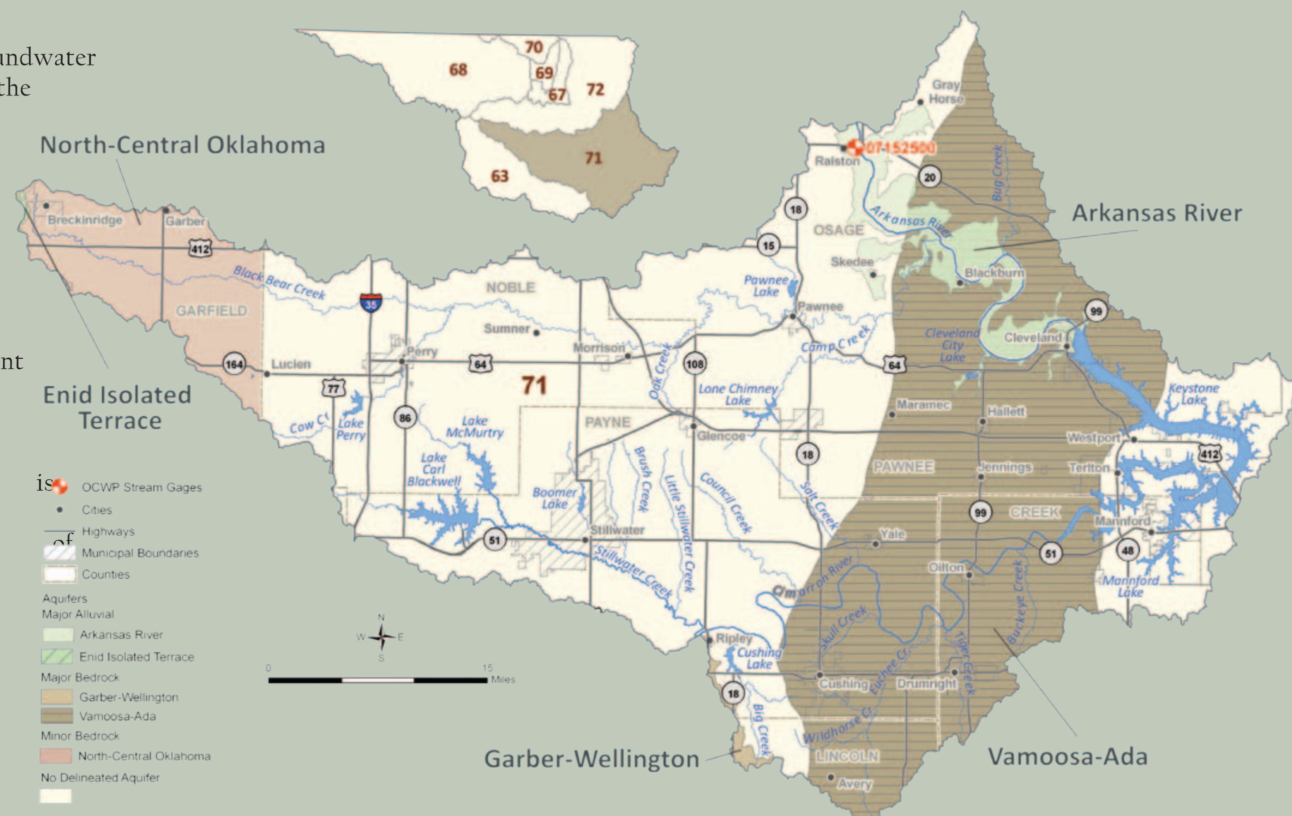
Upper Arkansas Region, Basin 71



Total Demand
27,480 AFY

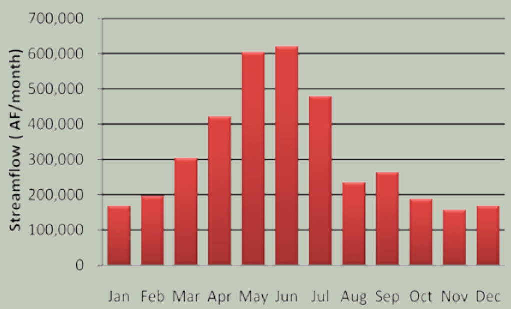
Water Resources

Upper Arkansas Region, Basin 71



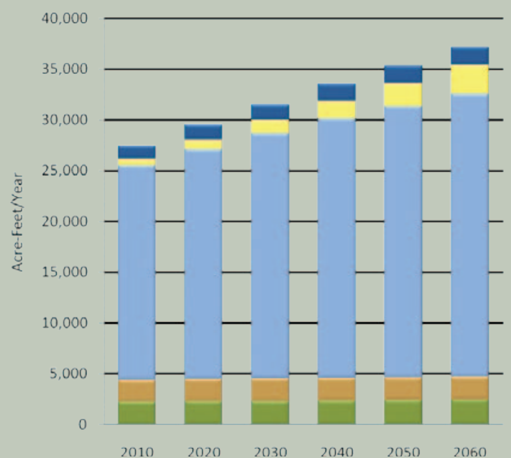
Median Historical Streamflow at the Basin Outlet

Upper Arkansas Region, Basin 71



Projected Water Demand

Upper Arkansas Region, Basin 71



occur in the Municipal and Industrial demand sector. Substantial growth in demand is also expected in the Oil and Gas demand sector.

Gaps & Depletions

Based on projected demand and historical hydrology, alluvial groundwater depletions may occur by 2020. There are no surface water gaps or bedrock groundwater depletions expected for 2060 demand conditions in this basin. Alluvial groundwater depletions are expected to be up to 210 AFY and have a 21% probability of occurring in at least one month of the year by 2060. Projected annual alluvial groundwater storage depletions are minimal relative to the volume of water stored in the major aquifers underlying the basin. However, localized storage depletions may adversely affect yields, water quality, and/or pumping costs.

The major reservoirs in Basin 71, which include Lake McMurtry, Lake Carl Blackwell and Keystone Lake, are capable of providing dependable water supplies to its existing users, and with new infrastructure, could be used to meet all of Basin 71's future surface water demand during periods of low streamflow. However, water quality is a concern at Keystone Lake and advanced treatment may be necessary.

Options

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

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce storage depletions. Temporary drought management activities are not recommended since the storage in major aquifers could continue to provide supplies during droughts.

Out-of-basin supplies from Kaw Lake in Basin 72 are expected to continue to supply the City of Stillwater in the future. Additional out-of-basin supplies could be developed to supplement the basin's water supplies and mitigate alluvial groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified six potential out-of-basin sites in the Upper Arkansas Region. However, out-of-basin supplies may not be cost-effective for many users.

Reservoir storage could provide dependable supplies for alluvial groundwater users experiencing adverse effects of localized storage depletions. The entire increase in demand from 2010 to 2060 could be met by Keystone Lake or by a new river diversion and 1,200 AF of storage at the basin outlet. However, quality concerns at Keystone somewhat limit its use for public supply The OCWP *Reservoir Viability Study* also identified Lela and Pawnee Reservoirs as potentially viable sites in Basin 71. .

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

Increased reliance on bedrock groundwater could mitigate alluvial groundwater storage depletions. There is more than 3.4 million AF of storage in Basin 71's portion of the Vamoosa-Ada aquifer. Any depletions in bedrock groundwater storage would be minimal relative to the volume of water stored in the aquifer.

Site-specific information on the suitability of minor aquifers for supply should be considered before future large scale use.

Water Supply Limitations

Upper Arkansas Region, Basin 71

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness

Upper Arkansas Region, Basin 71

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

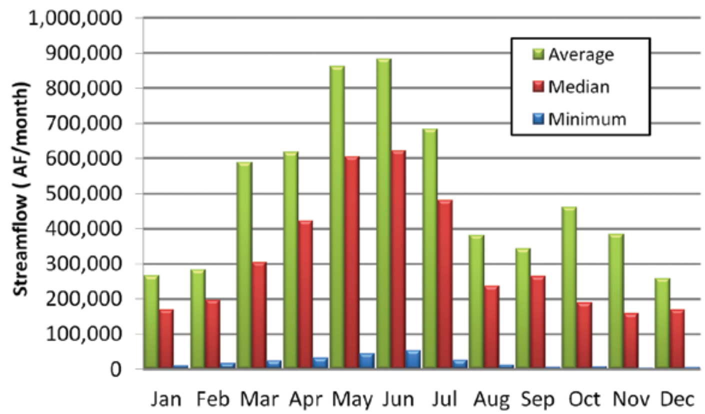
Typically Effective Potentially Effective
Likely Ineffective No Option Necessary

Basin 71 Data & Analysis

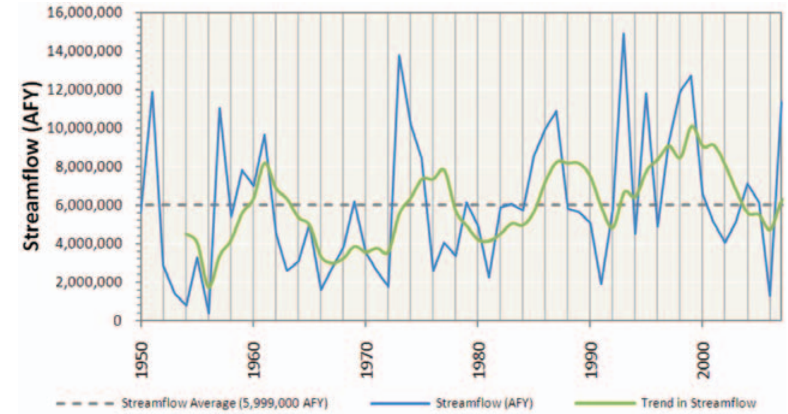
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Upper Arkansas River below Keystone Lake 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 early 1990s until the early 2000s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating local hydrologic variability.
- Median flow in the Upper Arkansas River below Keystone Lake is greater than 150,000 AF/month throughout the year. However, Basin 71 can have periods of low flow in the summer, fall, or winter.
- Basin 71 has 9 major reservoirs. Keystone has a dependable yield of 22,400 AFY, of which about 8,452 AFY is unpermitted and available to meet future demand. McMurtry provides a yield of 3,002 AFY, of which 2,649 AFY is permitted to the Cities of Stillwater and Perry and 353 AFY of yield is available to meet future demand. Carl Blackwell and Lone Chimney, with a dependable yield of 7,000 AFY and 2,509 AFY, respectively, are fully allocated. The water supply yield of Perry, Pawnee, Cushing, Boomer, and Cleveland City Lake are unknown so their ability to provide future supplies could not be evaluated.

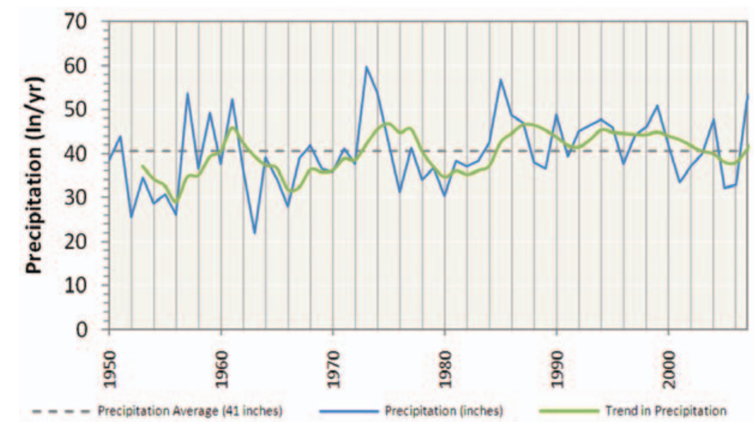
Monthly Historical Streamflow at the Basin Outlet
Upper Arkansas Region, Basin 71



Historical Streamflow at the Basin Outlet
Upper Arkansas Region, Basin 71



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)

Upper Arkansas Region, Basin 71

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	4%	3,100	82,000	temporary 2.0	100,700
Garber-Wellington	Bedrock	Major	<1%	100	65,000	temporary 2.0	12,800
Vamoosa-Ada	Bedrock	Major	34%	10,200	3,486,000	2.0	851,800
North-Central Oklahoma	Bedrock	Minor	7%	1,500	688,000	temporary 2.0	177,100
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	1,300	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	5,400	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 current groundwater rights in the basin are from the Vamoosa-Ada aquifer, which underlies about a third of the basin. The estimated recharge to the Vamoosa-Ada aquifer is 39,000 AFY. The majority of alluvial groundwater rights are from the Arkansas River aquifer and non-delineated alluvial aquifers along the Cimarron River. There are additional water rights in the Garber-Wellington and minor alluvial and bedrock aquifers. Site-specific information on the suitability of the minor aquifers for supply should be considered before large scale use.
- There are no significant groundwater quality issues in the basin.

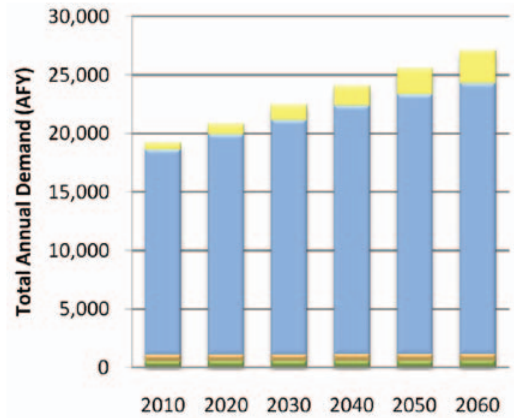
Notes & Assumptions

- 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.

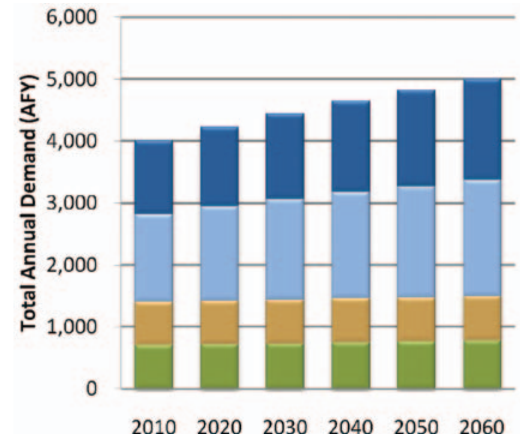
Water Demand

- The water needs of Basin 71 account for about 21% of the total demand in the Upper Arkansas Region and will increase by 9,710 AFY (35%) from 2010 to 2060. The majority of the demand and growth in demand during this period will occur from the Municipal and Industrial demand sector.
- Surface water is used to meet 70% of the total demand in Basin 71 and its use will increase by 41% (7,830 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use during this period will be in the Municipal and Industrial demand sector.
- Alluvial groundwater is used to meet 15% of the total demand in the basin and its use will increase by 25% (1,000 AFY) from 2010 to 2060. The majority of alluvial groundwater use will be in the Municipal and Industrial demand sector, but significant growth is anticipated in the Self-Supplied Residential demand sector.
- Bedrock groundwater is used to meet 15% of the total demand in Basin 71 and its use will increase by 25% (1,000 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use during this period will be from the Municipal and Industrial demand sector.

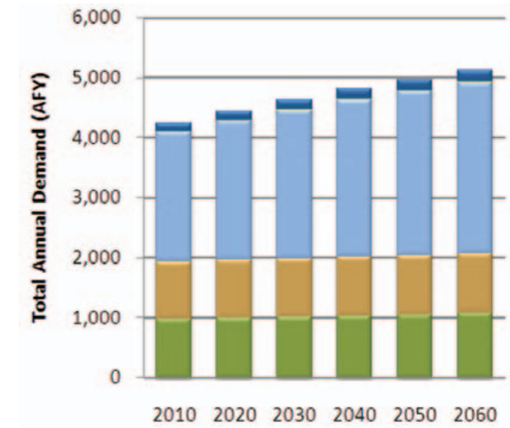
Surface Water Demand by Sector
Upper Arkansas Region, Basin 71



Alluvial Groundwater Demand by Sector
Upper Arkansas Region, Basin 71



Bedrock Groundwater Demand by Sector
Upper Arkansas Region, Basin 71



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

Total Demand by Sector
Upper Arkansas Region, Basin 71

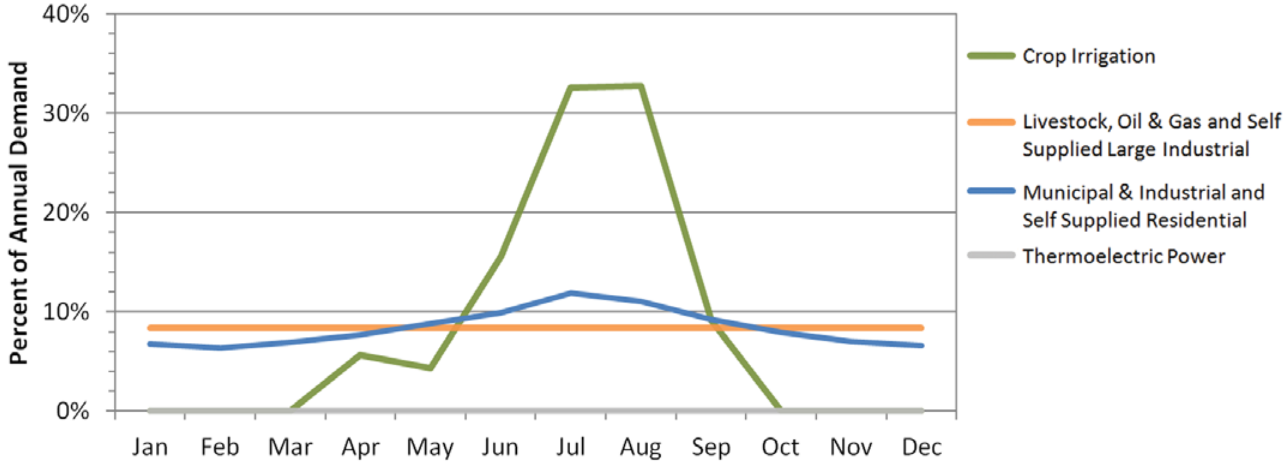
Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	2,220	2,190	21,120	630	0	1,320	0	27,480
2020	2,260	2,210	22,670	930	0	1,430	0	29,500
2030	2,310	2,220	24,140	1,300	0	1,530	0	31,500
2040	2,360	2,240	25,570	1,740	0	1,630	0	33,540
2050	2,390	2,250	26,720	2,230	0	1,730	0	35,320
2060	2,450	2,270	27,850	2,800	0	1,820	0	37,190

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.

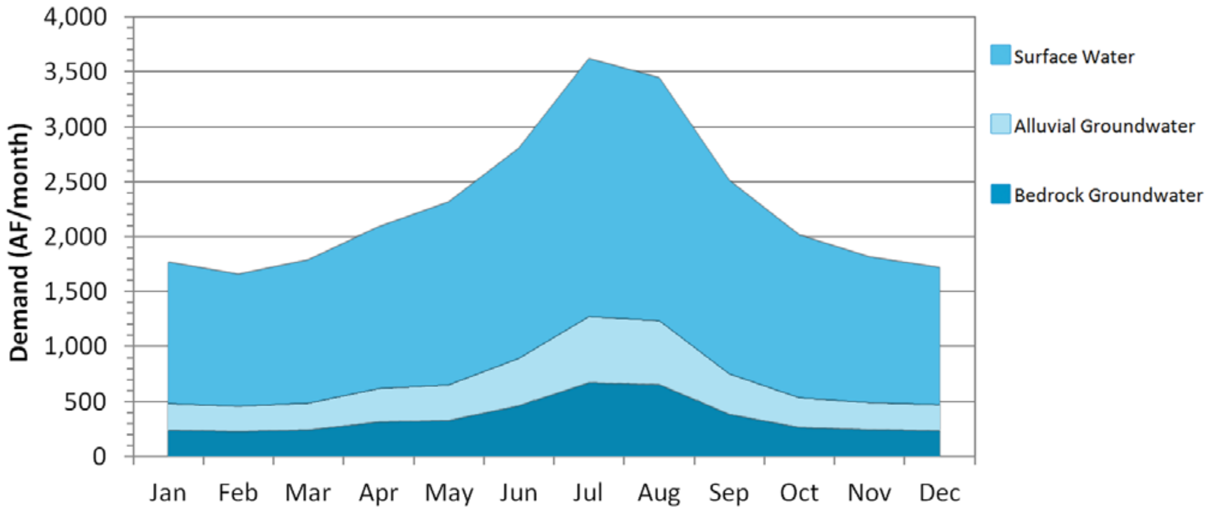
Monthly Demand Distribution by Sector (2010)

Upper Arkansas Region, Basin 71



Monthly Demand Distribution by Source (2010)

Upper Arkansas Region, Basin 71



Monthly Demand Distribution by Sector (2010)

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 66% 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.

Monthly Demand Distribution by Source (2010)

- The peak summer month total water demand in Basin 71 is 2.1 times the winter demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is 1.8 times the winter use. Water demand from alluvial and bedrock groundwater sources during the peak summer month is 2.5 and 2.8 times the winter demand, respectively.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, alluvial groundwater depletions may occur by 2020. There are no surface water gaps or bedrock groundwater depletions expected for 2060 demand conditions in this basin.
- Alluvial groundwater storage depletions in Basin 71 may occur throughout the year, peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 17% (120 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 17% (50 AF/month) of the monthly winter alluvial groundwater demand. There will be a 21% probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2050. Alluvial groundwater storage depletions are most likely to occur during fall months.
- Projected annual alluvial groundwater storage depletions are minimal relative to volume of water stored in the major aquifers underlying the basin. However, localized storage depletions may adversely affect yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)

Upper Arkansas Region, Basin 71

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)

Upper Arkansas Region, Basin 71

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	50	50	9%
Mar-May (Spring)	60	60	3%
Jun-Aug (Summer)	120	120	3%
Sep-Nov (Fall)	80	60	14%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Upper Arkansas Region, Basin 71

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	40	0	0%	19%
2030	0	70	0	0%	19%
2040	0	110	0	0%	19%
2050	0	160	0	0%	21%
2060	0	210	0	0%	21%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Upper Arkansas Region, Basin 71

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

Upper Arkansas Region, Basin 71

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	210	0	0%	21%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	210	0	0%	21%
Moderately Expanded Conservation in M&I Water Use	0	20	0	0%	9%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	20	0	0%	9%
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.

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Upper Arkansas Region, Basin 71

Reservoir Storage	Diversion
AF	AFY
100	3,500
500	6,500
1,000	8,900
2,500	16,000
5,000	25,800
Required Storage to Meet Growth in Demand (AF)	1,200
Required Storage to Meet Growth in Surface Water Demand (AF)	800

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 alluvial storage depletions by 90%. Temporary drought management activities are not recommended since the storage in major aquifers could continue to provide supplies during droughts.

Out-of-Basin Supplies

The City of Stillwater currently supplements its in-basin sources with out-of-basin supplies from Kaw Reservoir in Basin 72. Additional out-of-basin supplies could be developed to supplement Basin 71's water supplies and mitigate alluvial groundwater storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified six potentially viable out-of-basin sites in the Upper Arkansas Region: Sheridan and Skeleton in Basin 63, Alva in Basin 68, Hunnewell in Basin 70, and Otoe and Shidler in Basin 72. However, due to the substantial in-basin reservoir storage, out-of-basin supplies may not be cost-effective for many users.

Reservoir Use

Reservoir storage could provide dependable supplies for alluvial groundwater users experiencing adverse effects of localized storage depletions. The entire increase in demand from 2010 to 2060 could be met by a river diversion and 1200 AF of storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions. Keystone Lake has over 8,400 AF of dependable yield that has not been permitted and could supply the entire growth in demand from all sources; however, water quality in the reservoir is very poor for public water supply purposes and 93% of the current water rights are for power generation in the Middle Arkansas Planning Region. The OCWP *Reservoir Viability Study* also identified Lela and Pawnee Reservoirs as potentially viable sites in Basin 71. Either site would probably provide much more water than needed for the basin, but might present opportunities for regional or inter-regional supply options.

Increasing Reliance on Surface Water

Increased reliance on surface water supplies, without reservoir storage, could lead to surface water gaps and is not recommended.

Increasing Reliance on Groundwater

Increased reliance on bedrock groundwater could mitigate alluvial groundwater storage depletions. There is more than 3.4 million AF of storage in Basin 71's portion of the Vamoosa-Ada aquifer. Any increases in storage depletions would be minimal relative to the volume of water stored in the aquifer. Site-specific information on the suitability of minor aquifers for supply should be considered before increased large scale use.

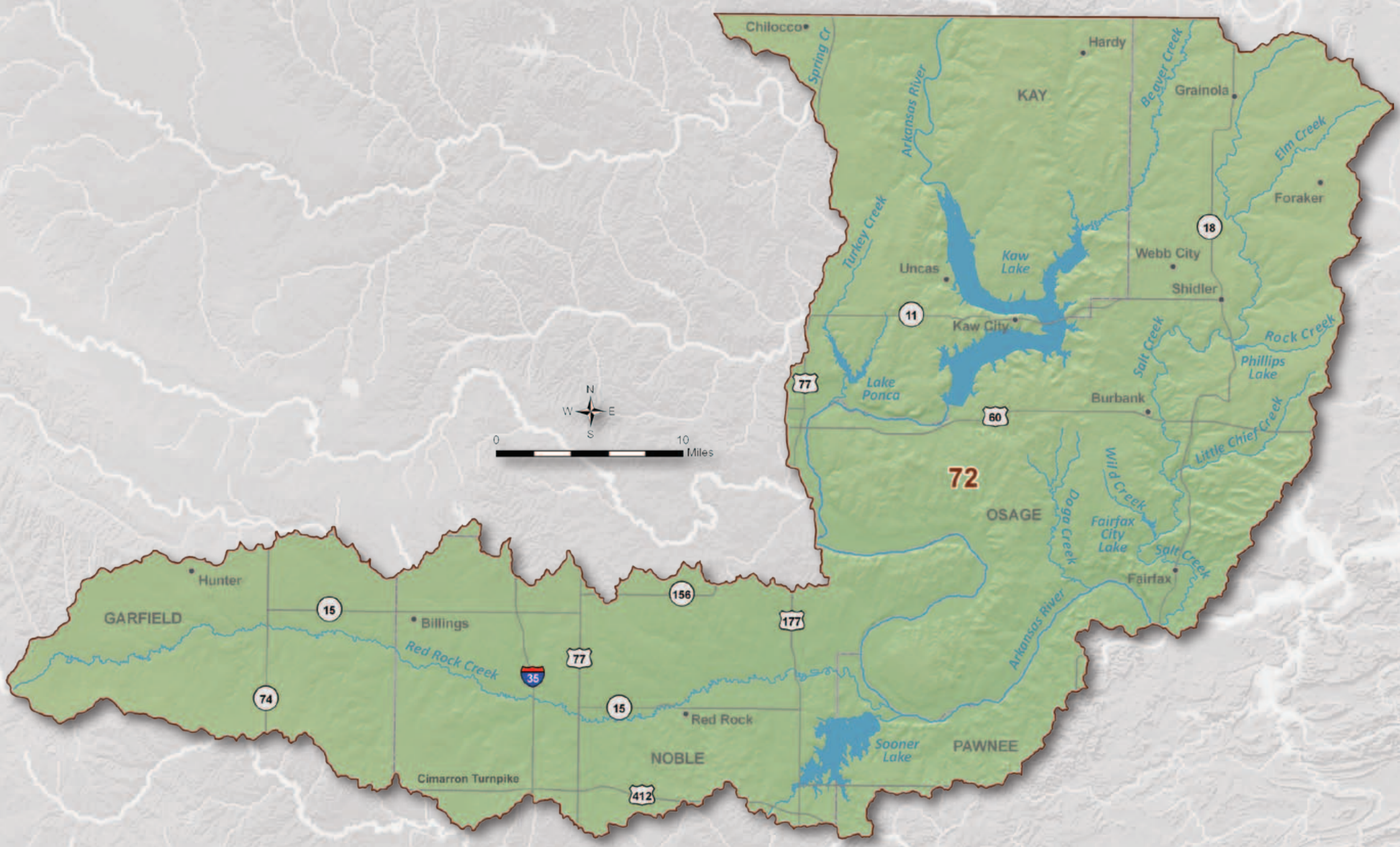
Notes & Assumptions

- 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.

Data & Analysis

Upper Arkansas Watershed Planning Region

Basin 72



Basin 72 Summary

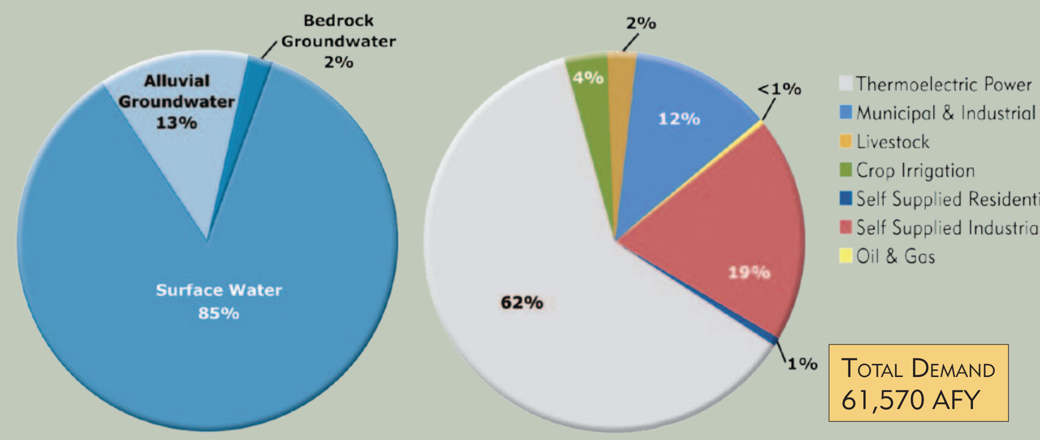
Synopsis

- Water users are expected to continue to rely primarily on surface water, and to a lesser extent, alluvial groundwater supplies.
- 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.
- Kaw Lake is capable of providing dependable water supplies to its existing users, and with new infrastructure, could be used to meet all of Basin 72's future surface water demand.
- To reduce the risk of adverse impacts on water supplies, it is recommended that groundwater storage depletions be decreased where economically feasible.
- Additional conservation could reduce the adverse effects of alluvial groundwater storage depletions.
- Use of additional reservoir storage could mitigate depletions.

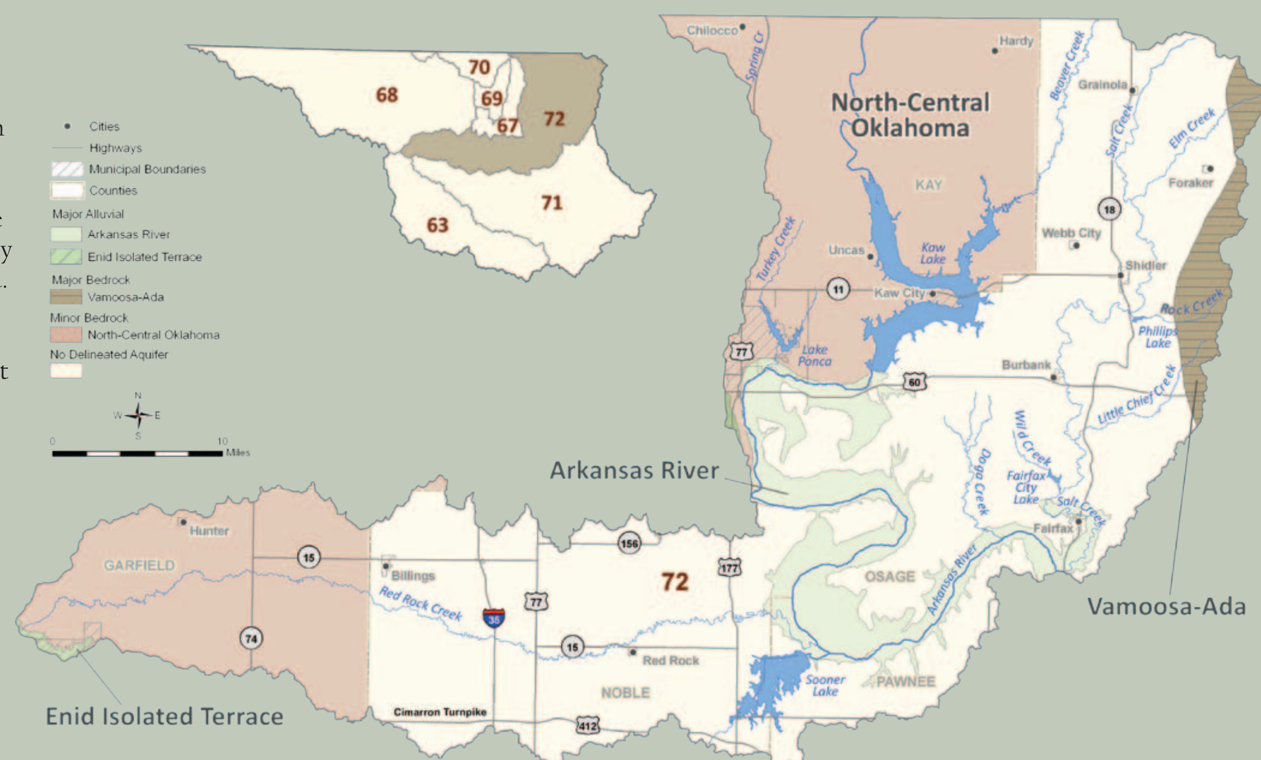
Basin 72 accounts for about 48% of the current water demand in the Upper Arkansas Watershed Planning Region. About 62% of the demand is from the Thermoelectric demand sector. Self-Supplied Industrial (19%) is the second-largest demand sector. Surface water satisfies about 85% of the current demand in the basin. Groundwater satisfies about 15% of the current demand (13% alluvial and 2% bedrock). The peak summer month demand in Basin 72 is 1.2 times the winter demand, which is less pronounced than the overall statewide pattern.

Basin 72 has 4 major reservoirs: Kaw, Sooner, Ponca, and Fairfax City. Kaw Lake, operated by the USACE for flood control, water supply, water quality, recreation, and fish and wildlife purposes, has 171,200 AFY of water supply storage and provides a dependable yield of 187,040 AFY of which 45,637 AFY is unpermitted and available to meet future demand. Kaw Lake also has 31,800 AFY of water quality storage capable of providing a dependable yield of 43,680 AFY. Sooner Lake is used to provide cooling water for the Oklahoma Gas and Electric Company and is not expected provide additional supplies for other users in the future. Ponca Lake has a dependable yield of 2,529 AFY and is not expected to provide additional supplies to other users in the future. The water supply yield of Fairfax City Lake is unknown; therefore, the ability of this reservoir to provide future water supplies could not be evaluated. The Arkansas River typically has flow greater than 120,000 AF/month. However, Basin 72 can have periods of low flow in the summer, fall, and winter. Relative to other basins in the state, the surface water quality in Basin 72 is considered good. However, Red Rock Creek, Grassy Creek, and Sooner Lake, located in the southwest portion of the basin, are impaired for Agricultural use due to elevated levels of sulfates. Ponca Lake is impaired for Public and Private Water Supply due to high levels of chlorophyll-a. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060.

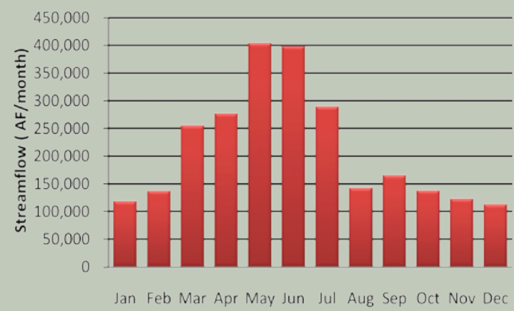
Current Demand by Source and Sector
Upper Arkansas Region, Basin 72



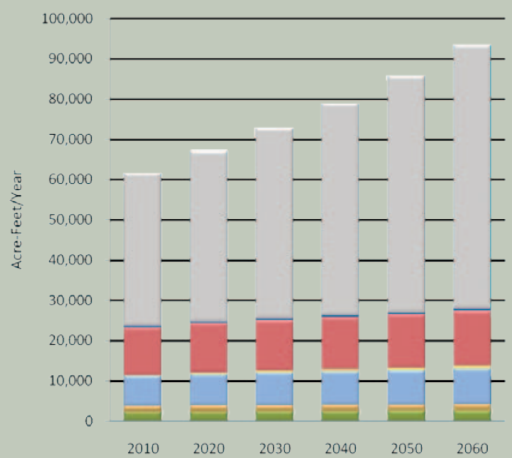
Water Resources
Upper Arkansas Region, Basin 72



Median Historical Streamflow at the Basin Outlet
Upper Arkansas Region, Basin 72



Projected Water Demand
Upper Arkansas Region, Basin 72



The majority of groundwater rights are in the Arkansas River aquifer, which only underlies 8% of the basin. The majority of bedrock groundwater rights are from the North-Central Oklahoma minor aquifer, which underlies about a third of the basin. There are additional rights from non-delineated aquifers. There are no significant groundwater quality issues 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.

The projected 2060 water demand of 93,350 AFY reflects a 31,800 AFY increase (52%) over the 2010 demand. The majority of the demand and growth will be in the Thermoelectric Power demand sector. The Oklahoma Gas and Electric Sooner Generating Station, which makes up the Thermoelectric Power demand sector, is currently supplied by Kaw Lake and Sooner Lake.

Gaps & Depletions

Based on projected demand and historical hydrology, alluvial groundwater depletions may occur by 2020, while bedrock groundwater storage depletions are expected by 2050. Alluvial groundwater depletions are expected to be up to 770 AFY and have a 36% probability of occurring in at least one month of the year by 2060. Projected annual alluvial and bedrock storage depletions are minimal relative to the amount of water in storage in the basin's aquifers. However, localized storage depletions may adversely affect yields, water quality, and/or pumping costs.

Kaw Lake is capable of providing dependable water supplies to its existing users, and with new infrastructure, could be used to meet all of Basin 72's future surface water demand.

Options

Water users are expected to continue to rely primarily on major reservoirs and alluvial groundwater supplies. To reduce the risk of adverse impacts to the basin's water users, storage depletions and potential gaps for users without access to major reservoirs should be decreased where economically feasible.

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could mitigate bedrock groundwater storage depletions and reduce alluvial groundwater storage depletions by about 20%. Temporary drought management activities are not recommended for alluvial and bedrock groundwater users since the storage could continue to provide supplies during droughts.

Out-of-basin supplies could be developed to supplement the basin's water supplies and mitigate adverse affects of localized storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified six potential out-of-basin sites in the Upper Arkansas Region. However, due to the substantial in-basin reservoir storage, out-of-basin supplies may not be cost-effective for many users.

Reservoir storage could provide dependable supplies for alluvial groundwater users experiencing adverse effects of localized storage depletions. Kaw Lake has 45,637 AF of yield that has not been permitted and can supply the entire growth in demand from all use sectors. The entire increase in demand from 2010 to 2060 could also be met by 6,500 AF of storage from either Kaw Lake's existing storage or a new reservoir. The OCWP *Reservoir Viability Study* also identified Otoe and Shidler Reservoirs as potentially viable sites in Basin 72.

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

Major aquifers underlie only small portions of the basin and may not be available to all users. Site-specific information on the suitability of minor aquifers for supply should be considered before large scale use.

Water Supply Limitations
Upper Arkansas Region, Basin 72

Surface Water	Minimal
Alluvial Groundwater	Potential
Bedrock Groundwater	Potential

Minimal | Potential | Significant

Water Supply Option Effectiveness
Upper Arkansas Region, Basin 72

Demand Management	Potentially Effective
Out-of-Basin Supplies	Potentially Effective
Reservoir Use	Typically Effective
Increasing Supply from Surface Water	Likely Ineffective
Increasing Supply from Groundwater	Likely Ineffective

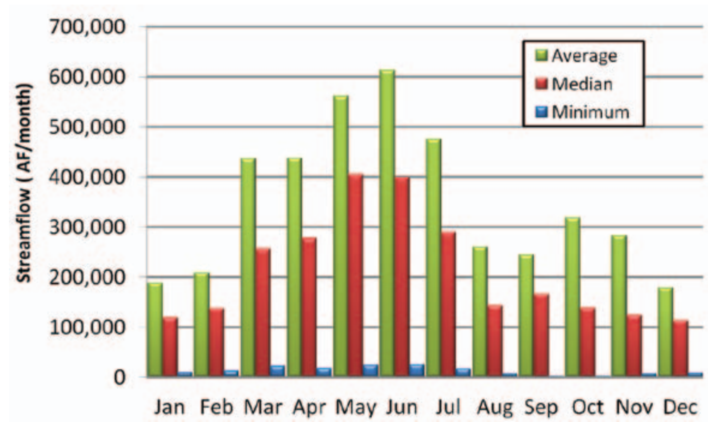
Typically Effective | Potentially Effective | Likely Ineffective | No Option Necessary

Basin 72 Data & Analysis

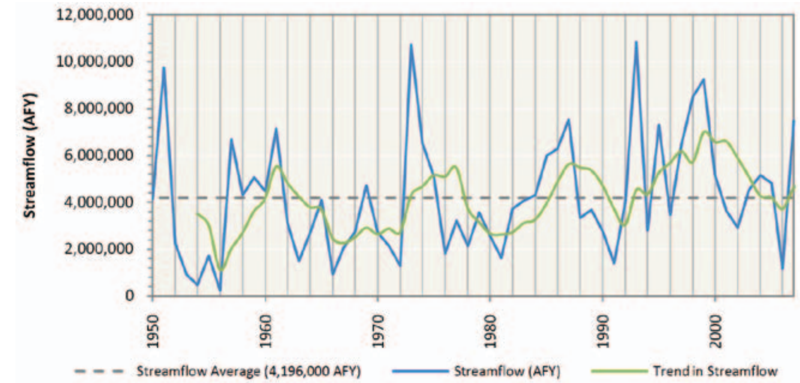
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the potential range of future surface water supplies. The Upper Arkansas River downstream of Salt Creek had a prolonged period of below-average streamflow from the mid 1960s to the early 1970s, corresponding to a period of below-average precipitation. From the mid 1990s to the early 2000s, the basin had a prolonged period of above-average streamflow and precipitation, demonstrating the hydrologic variability in the basin.
- The median flow in the Upper Arkansas River downstream of Salt Creek is greater than 120,000 AF/month throughout the year. However, Basin 72 can have periods of low flow in the summer, fall, or winter.
- Relative to other basins in the state, the surface water quality in Basin 72 is considered good.
- Basin 72 has 4 major reservoirs. Kaw Lake has a dependable yield of 187,040 AFY. About 45,637 AFY of that yield is unpermitted and available to meet future demand. Sooner Lake and Ponca City Lake are fully utilized and not expected to provide additional supplies in the future. The water supply yield of Fairfax City Lake is unknown; therefore the ability of this reservoir to provide future water supplies could not be evaluated.

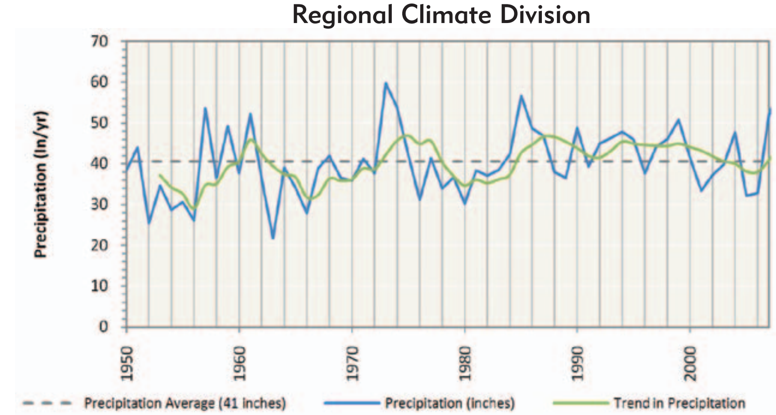
Monthly Historical Streamflow at the Basin Outlet
Upper Arkansas Region, Basin 72



Historical Streamflow at the Basin Outlet
Upper Arkansas Region, Basin 72



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)

Upper Arkansas Region, Basin 72

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	8%	34,900	111,000	temporary 2.0	121,900
Vamoosa-Ada	Bedrock	Major	3%	0	73,000	2.0	51,200
North-Central Oklahoma	Bedrock	Minor	35%	3,500	2,555,000	temporary 2.0	659,000
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	<50	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	1,100	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 Arkansas River aquifer; however, the aquifer only underlies 8% of the basin. The majority of bedrock groundwater rights are from the North-Central Oklahoma aquifer, which underlies about a third of the basin. There are additional rights from non-delineated groundwater sources. There is an estimated 2,000 AFY of recharge to the Vamoosa-Ada aquifer.
- There are no significant groundwater quality issues in the basin.

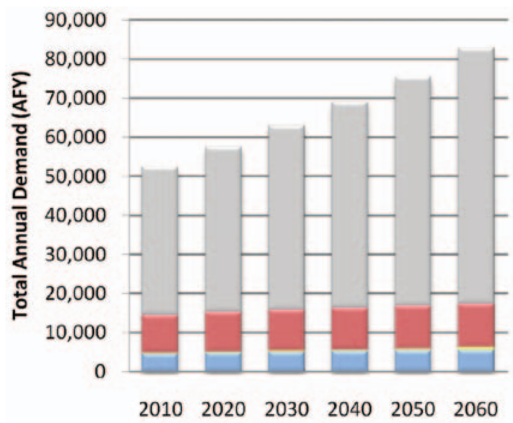
Notes & Assumptions

- 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.

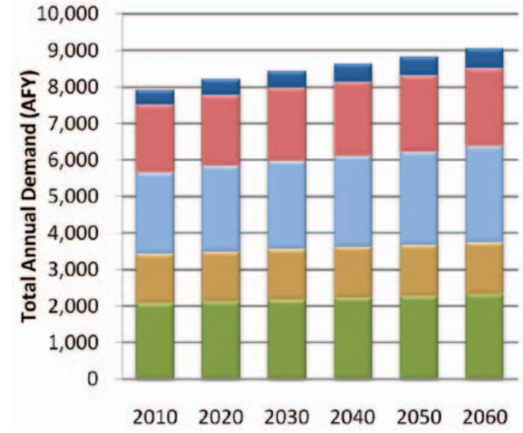
Water Demand

- Basin 72's water needs account for about 48% of the demand in the Upper Arkansas Watershed Planning Region and will increase by 31,780 AFY (52%) from 2010 to 2060. The majority of the demand and growth in demand is expected to occur from the Thermoelectric Power demand sector.
- Surface water is used to meet 85% of the total demand in Basin 72 and its use will increase by 58% (30,420 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use during this period will be in Thermoelectric Power demand sector. The Oklahoma Gas and Electric Sooner Generating Station, which makes up the Thermoelectric Power demand sector, is currently supplied by Kaw Lake and Sooner Lake.
- Alluvial groundwater is used to meet 13% of the total demand in the basin and its use will increase by 14% (1,140 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use during this period will be from the Municipal and Industrial demand sector.
- Bedrock groundwater is used to meet 2% of the total demand in Basin 72 and its use will increase by 18% (220 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use during this period will be from the Municipal and Industrial demand sector.

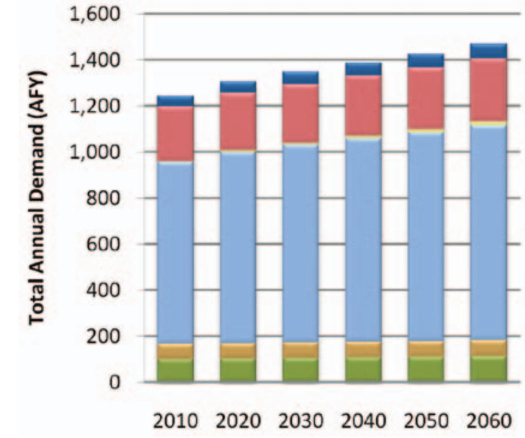
Surface Water Demand by Sector
Upper Arkansas Region, Basin 72



Alluvial Groundwater Demand by Sector
Upper Arkansas Region, Basin 72



Bedrock Groundwater Demand by Sector
Upper Arkansas Region, Basin 72



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

Total Demand by Sector
Upper Arkansas Region, Basin 72

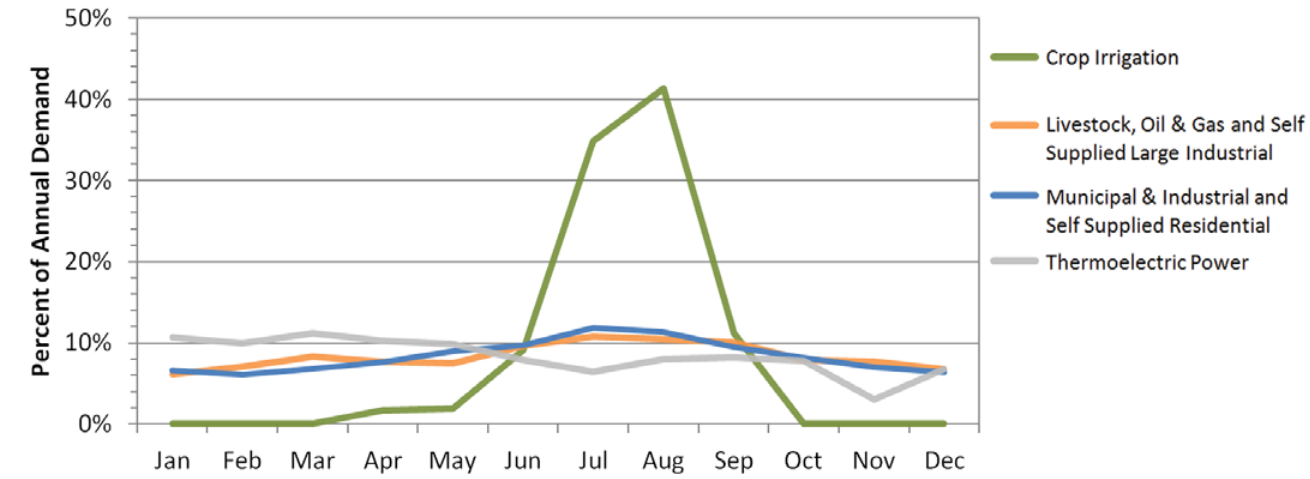
Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	2,280	1,500	7,470	200	11,820	430	37,870	61,570
2020	2,330	1,510	7,860	280	12,360	470	42,250	67,060
2030	2,390	1,520	8,120	380	12,660	500	47,140	72,710
2040	2,450	1,540	8,360	490	12,970	520	52,580	78,910
2050	2,490	1,550	8,590	630	13,270	550	58,660	85,740
2060	2,560	1,560	8,840	770	13,590	580	65,450	93,350

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.

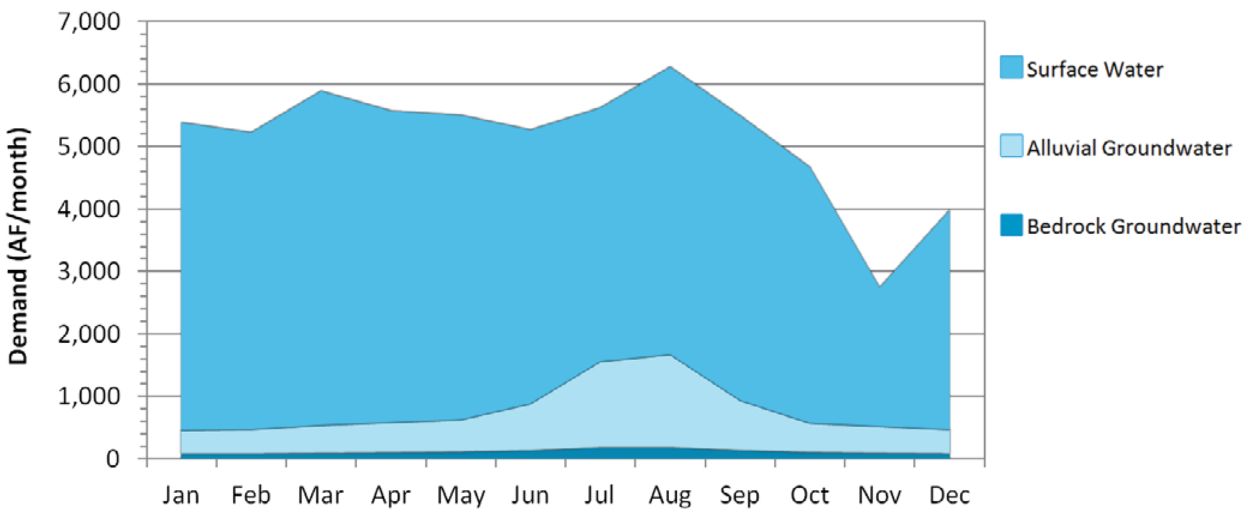
Monthly Demand Distribution by Sector (2010)

Upper Arkansas Region, Basin 72



Monthly Demand Distribution by Source (2010)

Upper Arkansas Region, Basin 72



Monthly Demand Distribution by Sector (2010)

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 72% 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 demand is highest in winter and spring and lowest in the fall. Other demand sectors have a more consistent demand throughout the year.

Monthly Demand Distribution by Source (2010)

- The peak summer month total water demand in Basin 72 is 1.2 times the winter demand, which is less pronounced than the overall statewide pattern. Surface water use in the peak summer month is 0.9 times the monthly winter use. Monthly alluvial groundwater use peaks in the summer at 3.8 times the monthly winter use. Monthly bedrock groundwater use peaks in the summer at 2.3 times the winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, alluvial groundwater depletions may occur by 2020, while bedrock groundwater storage depletions are expected by 2060.
- Alluvial groundwater storage depletions in Basin 72 may occur throughout the year, peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 31% (270 AF/month) of the alluvial groundwater demand in the peak summer month, and as high as 40% (170 AF/month) of the monthly winter alluvial groundwater demand. There will be a 36% probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2040. Alluvial groundwater storage depletions are most likely to occur during spring and fall months.
- Bedrock groundwater storage depletions are negligible on a basin scale.
- Projected annual alluvial and bedrock storage depletions are minimal relative to the amount of water in storage in the aquifer. However, localized storage depletions may adversely affect yields, water quality, and/or pumping costs.
- Kaw Lake is capable of providing dependable water supplies to its existing users, and with new infrastructure, could be used to meet all of Basin 72's future surface water demand.

Surface Water Gaps by Season (2060 Demand)
Upper Arkansas Region, Basin 72

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)
Upper Arkansas Region, Basin 72

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	170	160	9%
Mar-May (Spring)	210	195	14%
Jun-Aug (Summer)	270	155	3%
Sep-Nov (Fall)	290	190	19%

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

Magnitude and Probability of Annual Gaps and Storage Depletions
Upper Arkansas Region, Basin 72

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	140	0	0%	31%
2030	0	280	0	0%	33%
2040	0	420	0	0%	36%
2050	0	540	10	0%	36%
2060	0	770	20	0%	36%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)
Upper Arkansas Region, Basin 72

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

Upper Arkansas Region, Basin 72

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	770	20	0%	36%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	730	20	0%	36%
Moderately Expanded Conservation in M&I Water Use	0	600	0	0%	36%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	600	0	0%	36%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	550	0	0%	36%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Upper Arkansas Region, Basin 72

Reservoir Storage	Diversion
AF	AFY
100	500
500	2,400
1,000	4,900
2,500	12,200
5,000	24,300
Required Storage to Meet Growth in Demand (AF)	6,500
Required Storage to Meet Growth in Surface Water Demand (AF)	6,300

Water Supply Options & Effectiveness

Typically Effective | Potentially Effective | Likely Ineffective | No Option Necessary

Demand Management

(Potentially Effective) Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could mitigate bedrock groundwater storage depletions and reduce alluvial groundwater storage depletions by 22%. Temporary drought management may not be necessary for alluvial and bedrock groundwater users since the storage in major aquifers could continue to provide supplies during droughts.

Out-of-Basin Supplies

(Potentially Effective) Out -of-basin supplies may be developed to supplement the basin's water supplies and mitigate storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified six potentially viable out-of-basin sites in the Upper Arkansas Region: Sheridan and Skeleton in Basin 63, Alva in Basin 68, Hunnewell in Basin 70, and Lela and Pawnee in Basin 71. However, due to the substantial in-basin reservoir storage, out-of-basin supplies may not be cost-effective for many users.

Reservoir Use

(Typically Effective) Reservoir storage could provide dependable supplies for alluvial groundwater users experiencing adverse effects of localized storage depletions. Kaw Lake has over 45,600AF of dependable yield that has not been permitted and could supply the entire growth in demand from all sources in the basin. The entire increase in demand from 2010 to 2060 could also be met by a river diversion and 6,500 AF of storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions. The OCWP *Reservoir Viability Study* also identified Otoe and Shidler Reservoirs as potentially viable sites in Basin 72. Either site would probably provide more water than needed for the basin but might present opportunities for regional or inter-regional supply options.

Increasing Reliance on Surface Water

(Likely Ineffective) Increased reliance on surface water supplies, without reservoir storage, could create surface water gaps and is not recommended.

Increasing Reliance on Groundwater

(Likely Ineffective) Major aquifers underlie only a small portion of the basin and may not be available to all users. Site-specific information on the suitability of minor aquifers for supply should be considered before 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.

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

Initial Unit \ Desired Unit	CFS	GPM	MGD	AFY	AFD
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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