Oklahoma Comprehensive Water Plan

OCWP

Southwest

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.

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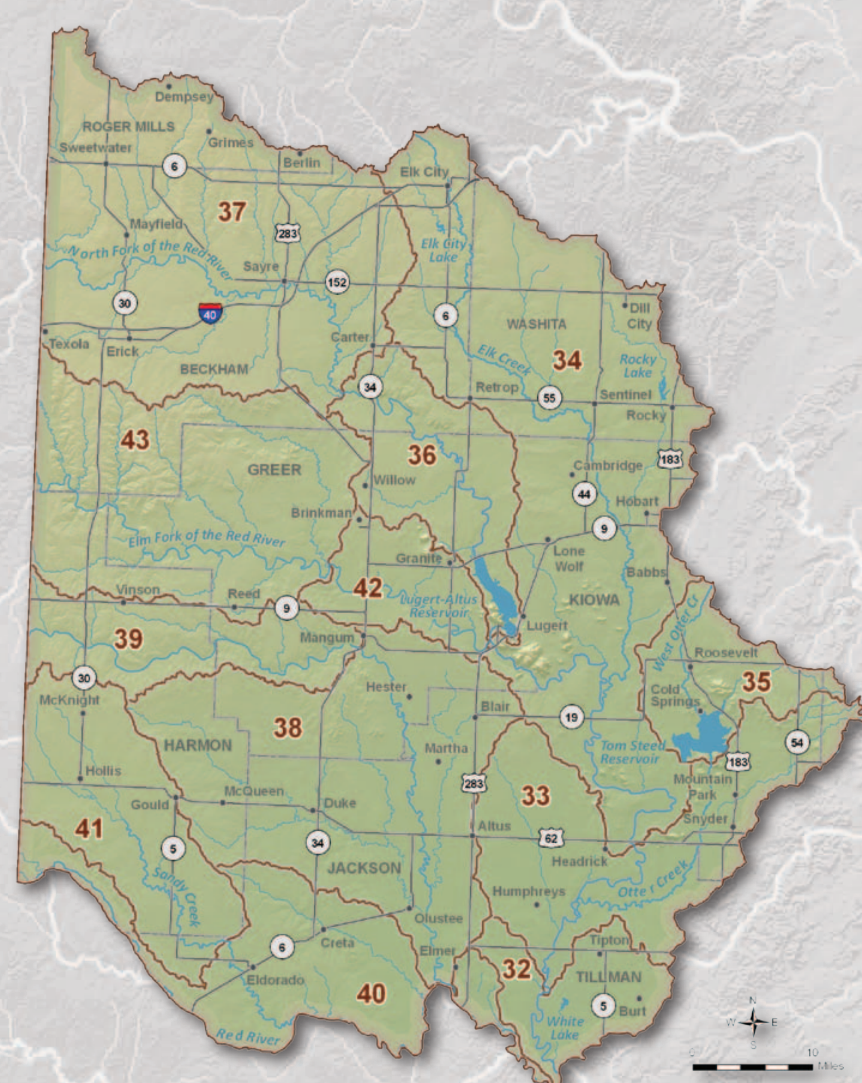
The online version of this 2012 OCWP Watershed Planning Region Report (Version 1.1) includes figures that have been updated since distribution of the original printed version. Revisions herein primarily pertain to the seasonality (i.e., the percent of total annual demand distributed by month) of Crop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

Cover photo: Quartz Mountain State Park, Michael Hardeman

Oklahoma Comprehensive Water Plan

Southwest Watershed Planning Region



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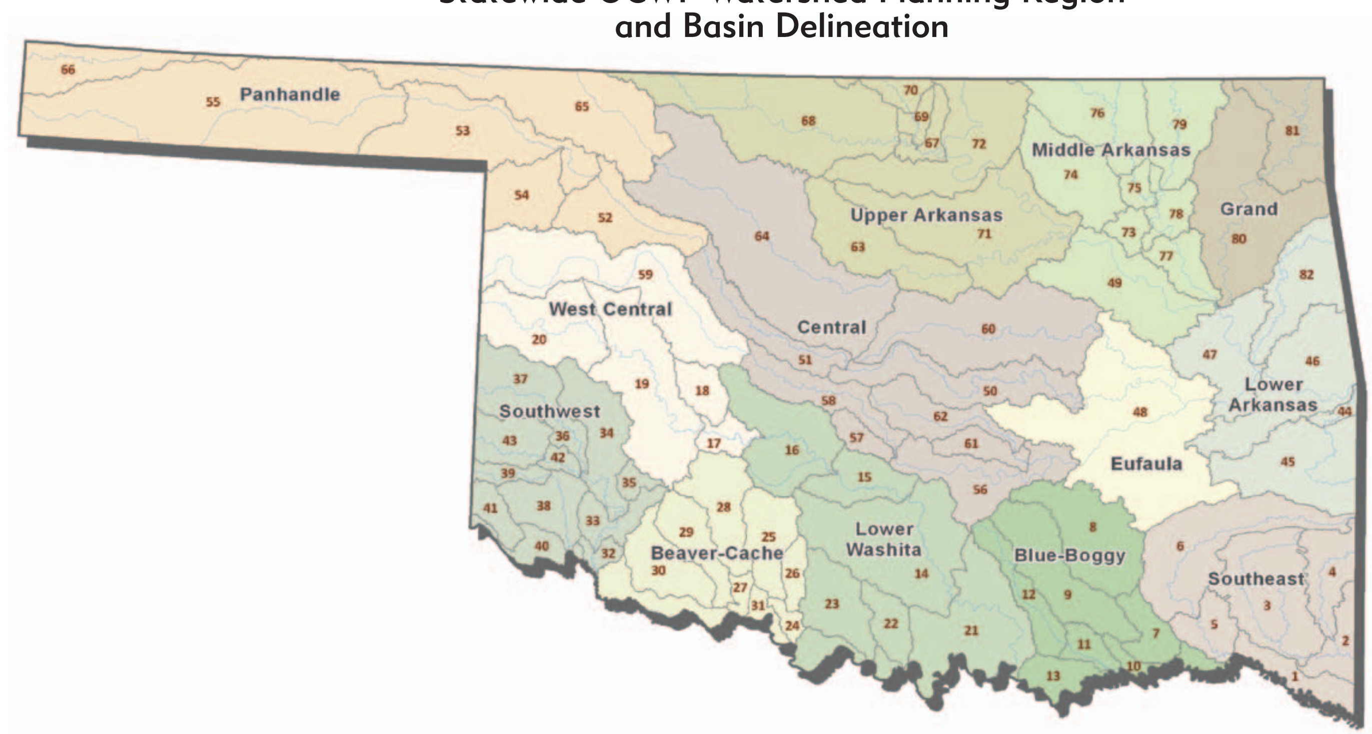


Introduction

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 subdividing 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 Southwest 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 used 58 years of publicly-available daily streamflow gage data collected by the USGS. Groundwater resources were characterized using previously-developed assessments of 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 Southwest Watershed Planning Region includes 12 basins (numbered 32-43 for reference). The region is primarily located in the Great Lowlands physiography province and encompasses 4,045 square miles in the southwest corner of Oklahoma, spanning all of Harmon, Jackson, and Greer Counties, and portions of Tillman, Kiowa, Beckham, Roger Mills, Comanche, and Washita Counties.

The region's terrain includes vast farming areas along with rolling river bottoms and the Quartz Mountains in southeastern Kiowa and Greer Counties.

The region has a generally mild climate with mild winters and long, hot summers. Average monthly temperatures vary from 59° F to 64° F. Annual average precipitation ranges from 22 inches in the west to 28 inches in the east. Annual evaporation ranges from 62 to 65 inches per year.

The largest cities in the region include Altus (2010 population of 19,813), Elk City (11,693), and Hobart (3,756). The greatest demand is from Crop Irrigation water use.

By 2060, this region is projected to have a total demand of 213,100 acre-feet per year (AFY), an increase of approximately 36,100 AFY (20%) from 2010.

Southwest Regional Summary

Synopsis

- The Southwest Watershed Planning Region relies similarly between its reservoirs, alluvial aquifers, and bedrock aquifers.
- It is anticipated that water users in the region will continue to rely on reservoirs, alluvial aquifers, and bedrock aquifers to meet future demand.
- By 2020, surface water supplies will be typically insufficient to meet demand throughout the region.
- Groundwater storage depletions may lead to higher pumping costs, the need for deeper wells, and potential changes to well yields or water quality.
- Additional conservation could reduce surface water gaps, alluvial groundwater storage depletions, and bedrock groundwater storage depletions.
- Aquifer storage (recharge) and recovery could be considered to store variable surface water supplies, increase alluvial or bedrock 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.
- Six basins (34, 36, 38, 40, 41, and 42) in the region have been identified as "hot spots," areas where more pronounced water supply availability issues are forecasted. (See "Regional and Statewide Opportunities and Solutions," *OCWP Executive Report*.)

The Southwest Region accounts for 9% of the state's total water demand. The largest demand sector is Crop Irrigation, which makes up approximately 87% of total use in the region.

Water Resources & Limitations

Surface Water

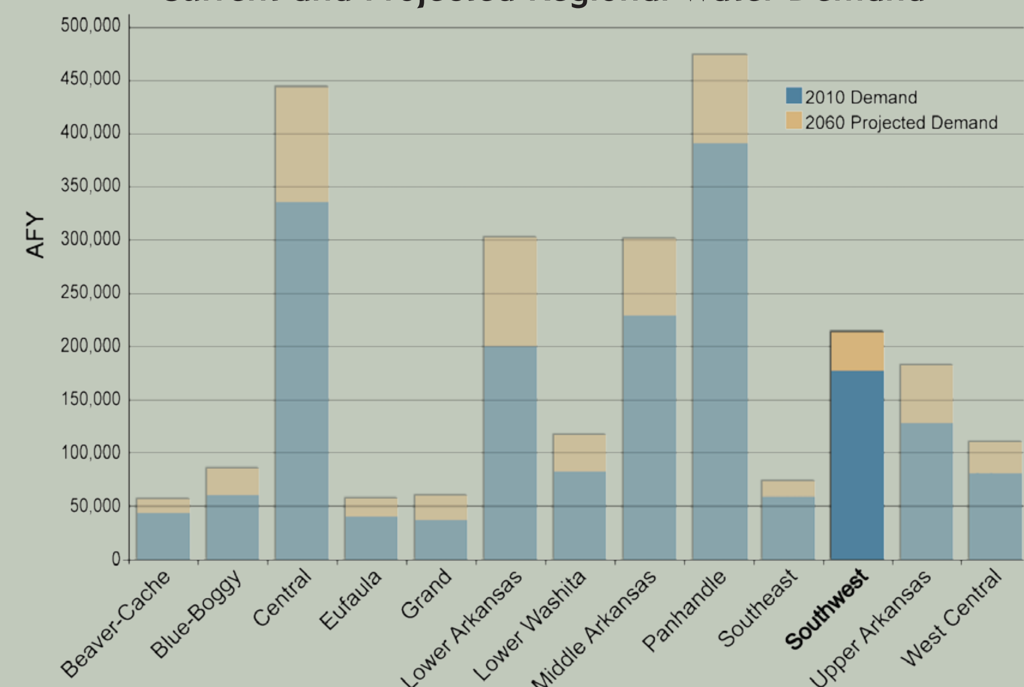
Surface water is used to meet about 38% of the region's demand. Basins throughout the region are projected to have surface water supply shortages in the future. The region is supplied by three major rivers: the North Fork of the Red River, the Elm Fork of the Red River, and the Salt Fork of the Red River. The Red River is not used as a supply source due to water quality concerns. Historically, the rivers and creeks in the region 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 to provide public water supply, irrigation water supply, flood control, and recreation. Major reservoirs in the Southwest Region include: Lugert-Altus Reservoir (supplies the Lugert-Altus Irrigation District), Elk City Lake, Tom Steed Reservoir (supplies the Mountain Park Master Conservancy District), Altus City Lake, and Rocky Lake.

Relative to other regions, surface water quality is considered poor to fair. Multiple rivers, creeks, and lakes, including the major rivers, 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) and sulfates. These impairments are scheduled to be addressed through the Total Maximum Daily Loads (TMDL) process, but the use of these supplies may be limited in the interim.

Southwest Region Demand Summary

Current Water Demand:	176,990 acre-feet/year (9% of state total)
Largest Demand Sector:	Crop Irrigation (87% of regional total)
Current Supply Sources:	38% SW 28% Alluvial GW 34% Bedrock GW
Projected Demand (2060):	213,110 acre-feet/year
Growth (2010-2060):	36,120 acre-feet/year (20%)

Current and Projected Regional Water Demand



Surface water in seven of the 12 basins is fully allocated, and an additional two basins are expected to become fully allocated by 2060.

The Lugert-Altus Irrigation District covers approximately 48,000 acres of farmland and includes about 330 landowner members. With more than $50 million annually in gross receipts, mostly from cotton production, the district is a significant contributor to the southwest Oklahoma economy. The district plans to eventually expand its system by some 150,000 acres, but this would only be possible if additional water supplies can be obtained. The Area VI chloride control project on the Elm Fork of the Red River, which has been studied for many years by the U.S. Army Corps of Engineers, is considered a potential viable source of additional water through diversion to existing infrastructure or pumped directly into Lugert-Altus Reservoir. However, the construction of proposed Headrick Lake, on the North Fork of the Red River downstream from its confluence with the Elm Fork and supplemented by the Area VI project, could provide a more reliable supply.

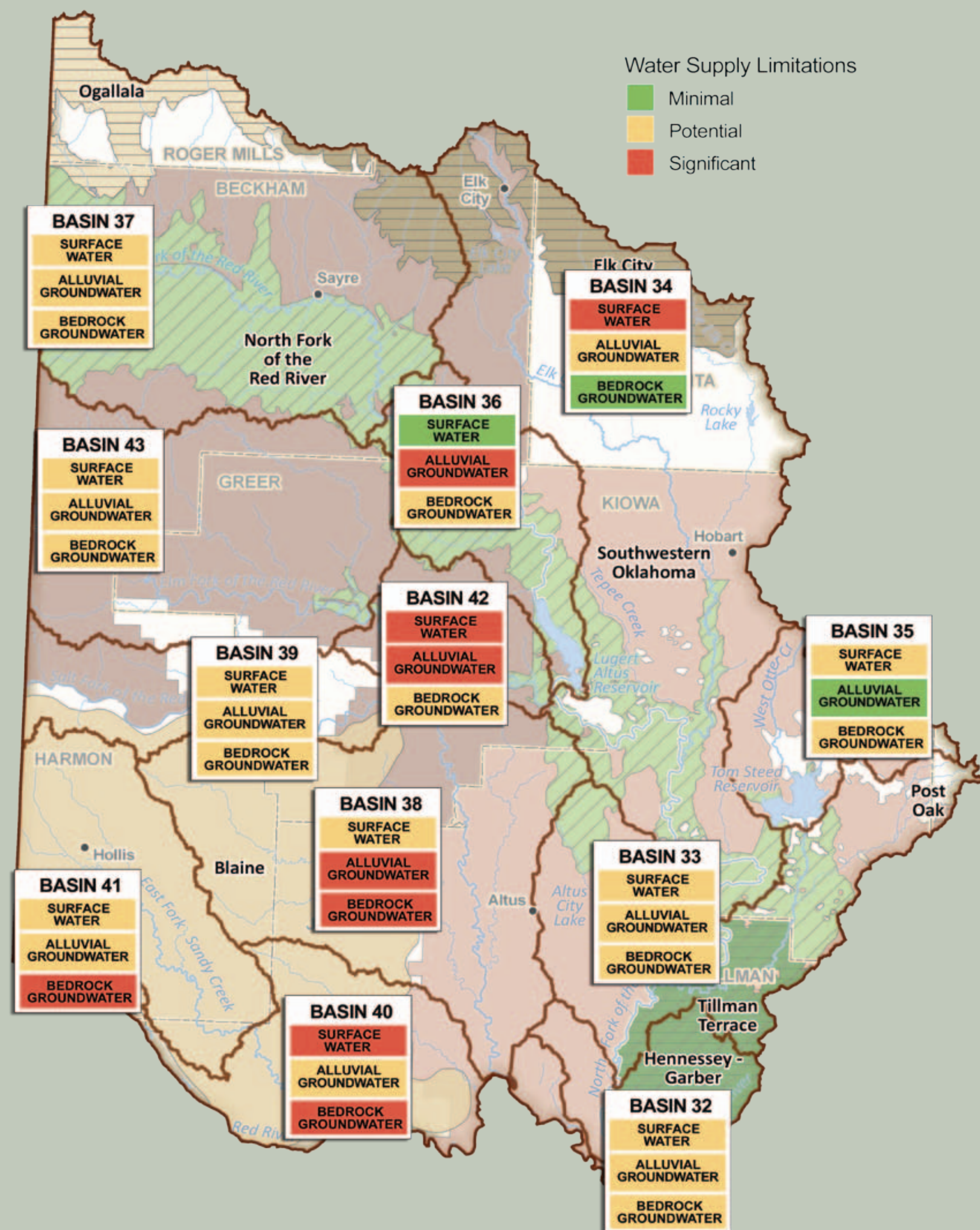
Alluvial Groundwater

Alluvial groundwater is used to meet 28% of the demand in the region. The majority of currently allocated alluvial groundwater withdrawals in the region are from the North Fork of the Red River aquifer, Tillman Terrace aquifer, and from non-delineated minor aquifers. If alluvial groundwater continues to supply a similar portion of demand in the future, storage depletions from these aquifers are likely to occur throughout the year, although these projected depletions will be small to moderate 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 34% of the demand in the region. Currently allocated and projected withdrawals are primarily from the Blaine and Ogallala major bedrock aquifers, and to a lesser extent, the Elk City and minor aquifers. The Blaine and Elk City aquifers have about 1.4 million acre-feet (AF) of groundwater storage in the Region. The Ogallala aquifer has about 420,000 AF of groundwater storage in the region. Bedrock aquifer storage depletions are likely to occur throughout the year, but will be largest in the summer months. These depletions are small relative to the amount of water in storage, but are expected to lead to adverse impacts on pumping costs, yields, and/or water quality. The availability of permits is not expected to constrain the use of bedrock groundwater supplies to meet local demand through 2060.

Water Supply Limitations
Southwest Region



Water Supply Limitations

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

Water Supply Options

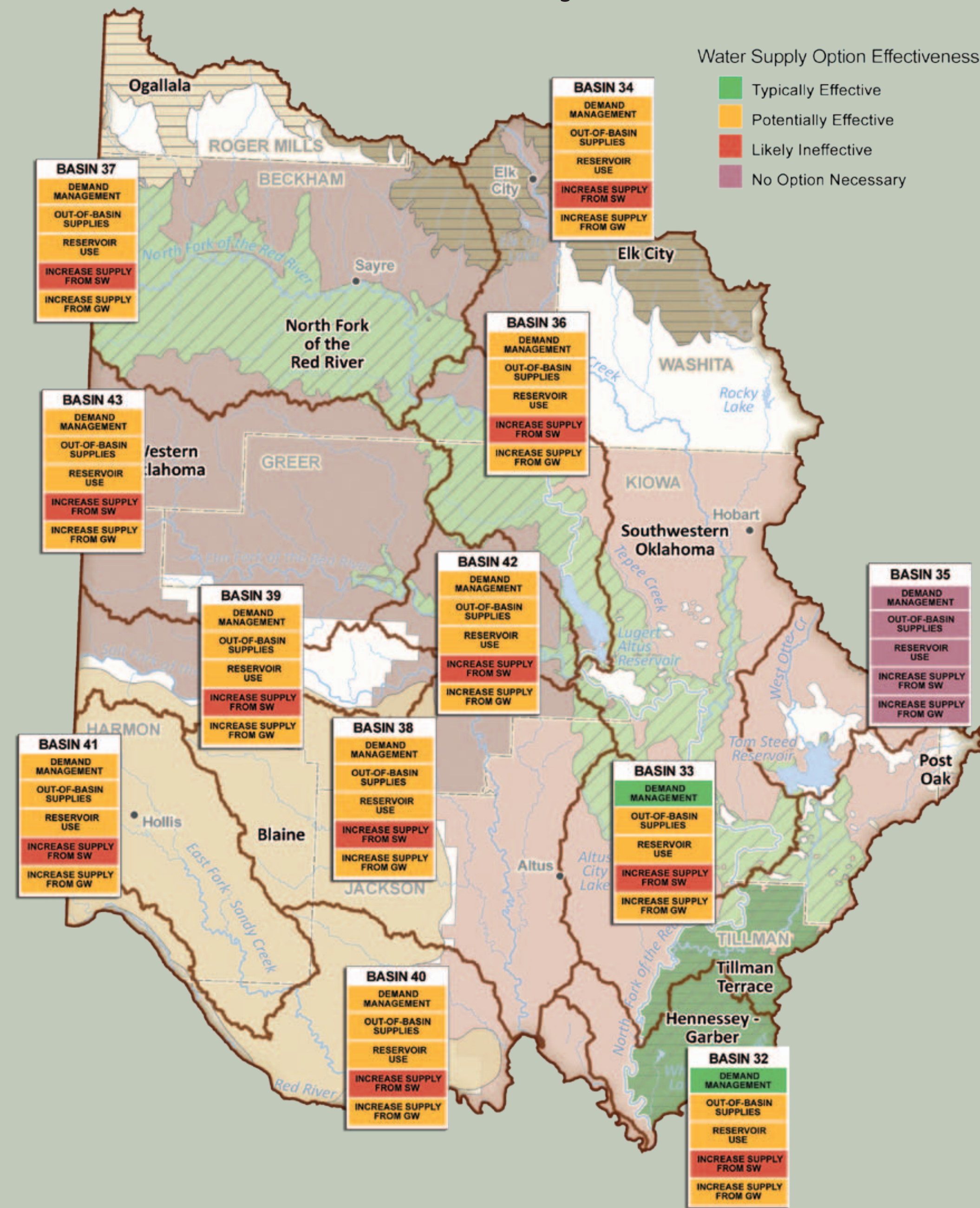
To quantify physical surface water gaps and groundwater storage depletions through 2060, use of local supplies was assumed to continue in the current (2010) proportions. Reservoirs, alluvial aquifers, and bedrock aquifers are expected to continue to supply the majority of demand in the Southwest Region. Over time, the Blaine and Ogallala aquifers may experience significant depletions. While the depletions are relatively minimal compared to total water in storage localized depletions may adversely affect user's yields, water quality, and pumping costs. Basins and users that rely on surface water are projected to have physical surface water supply shortages (gaps) in the future. Alluvial groundwater storage depletions are also projected in the future. Therefore, additional long-term water supplies should be considered.

Water conservation could aid in reducing projected gaps and groundwater storage depletions or delaying the need for additional infrastructure. Moderately expanded conservation activities, primarily from increased irrigation efficiency and increased conservation by public water suppliers, could eliminate gaps and storage depletions or provide substantial reductions. Current crops are predominantly wheat for grain, cotton, corn for grain, and forage crops. A shift from crops with high water demand (e.g., corn for grain and forage crops) to low water demand crops such as sorghum for grain or wheat for grain, along with increased efficiency, could reduce storage depletions by over 90%. Due to extended dry periods and predominant use of groundwater supplies, drought management measures alone will likely be an ineffective water supply option.

New small reservoirs (50 AF or less of storage) could enhance the dependability of surface water supplies, but are not expected to substantially decrease gaps. Basins 38, 42, and 43 have unallocated streamflow and could develop larger reservoirs to decrease local and potentially regional gaps and groundwater storage depletions. The OCWP *Reservoir Viability Study* evaluated the potential for reservoirs throughout the state. Two potential reservoir sites were identified in the Southwest Region that could serve as regional sources of supply to provide additional water to mitigate the region's groundwater storage depletions. However, due to the distance from these reservoirs to demand points in each basin, 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 storage depletions. However, increased demands would still leave users susceptible to the adverse effects of groundwater storage depletions.

Water Supply Option Effectiveness
Southwest Region



Effectiveness of water supply options in each basin in the Southwest Region. This evaluation was based upon results of physical water supply availability analyses, existing infrastructure, and other basin-specific factors.

Water Supply

Physical Water Availability

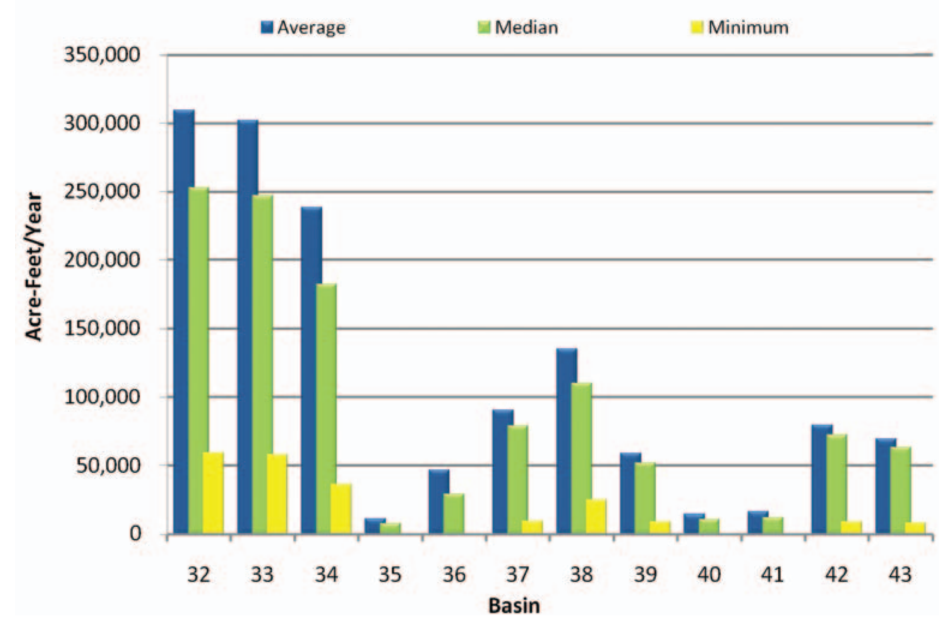
Surface Water Resources

Surface water has historically been about a third of the supply used to meet demand in the Southwest Region. The region includes tributaries to the Red River, the largest being the North Fork of the Red River, Sandy Creek, the Salt Fork of the Red River, and the Elm Fork of the Red River. There is considerable variability in streamflow throughout the region, but periods of low streamflow can occur in all basins, with Red River tributaries downstream of the North Fork of the Red River often showing very little flow.

Water in the Red River mainstem (southern border of the Southwest region), which maintains substantial flows, is highly mineralized, primarily due to high concentrations of chlorides from natural sources upstream. Without extensive water treatment or management techniques, the high chloride content of the Red River renders water generally unsuitable for most consumptive uses. For this reason, the Red River was not considered as a feasible source of supply in these analyses. As treatment technology evolves over time, treatment costs will likely decrease, and this source may become more attractive relative to other local and regional source options. Also, full implementation of the Corps of Engineers' Red River Chloride Control Project could reduce naturally occurring chloride levels in the Red River and its tributaries, thereby making it a more feasible source of future water supply.

The North Fork of the Red River mainstem (180 miles long in Oklahoma) crosses the border from Texas in the northern portion of the Southwest Region and joins the Red River at the southeastern edge of the region. The portion of the river above Lugert-Altus Reservoir is considered the Upper North Fork and the downstream portion is considered the Lower North Fork. Tributaries include Elk Creek (80 miles) and Otter Creek (20 miles). The Upper North Fork of the Red River and its tributaries are located in Basins 36 and 37. The Lower North Fork of the Red River and its tributaries are located in Basins 32, 33, 34, and 35. The North Fork is the furthest downstream major Red River tributary in the Southwest Region.

Surface Water Flows (1950-2007)
Southwest Region



Surface water supplies about one-third of the demand in the Southwest 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.

Reservoirs
Southwest Region

Reservoir Name	Primary Basin Number	Reservoir Owner/ Operator	Year Built	Purposes[1]	Normal Pool Storage	Water Supply Storage	Water Supply Yield	Irrigation Storage	Irrigation Yield	Water Quality Storage	Water Quality Yield	Permitted Withdrawals	Remaining Water Supply Yield to be Permitted
					AF	AF	AFY	AF	AFY	AF	AFY	AFY	AFY
Altus City	33	City of Altus	1940	WS, R	2,500	---	---	---	---	---	---	---	0
Elk City	34	City of Elk City	1970	FC, R	2,583	---	---	---	---	---	---	---	---
Lugert-Altus	36	Bureau of Reclamation	1947	FC, WS, IR	132,830	132,830	47,100[2]	0	0	0	0	90,430	0
Rocky	34	City of Hobart	1933	WS, R	4,210	---	---	---	---	---	---	---	784
Tom Steed	35	Bureau of Reclamation	1975	WS, FC, R, FW	88,970	88,160	16,000	0	0	0	0	16,100	0

No known information is annotated as "---"
1 The "Purposes" represent the use(s), as authorized by the funding entity or dam owner(s), for the reservoir storage when constructed.
WS=Water Supply, R=Recreation, HP=Hydroelectric Power, IR=Irrigation, WQ=Water Quality, FW=Fish & Wildlife, FC=Flood Control, LF=Low Flow Regulation, N=Navigation, C=Conservation, CW=Cooling Water
2 Includes irrigation

Surface Water Resources
Southwest Region

Reservoirs in Oklahoma 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.

The most upstream major Red River tributary in the region is the Prairie Dog Town Fork, which meets the Red River just east of the Texas-Oklahoma border in Basin 40. Sandy Creek (40 miles long) runs through the southwest portion of the region in Basins 40 and 41. The Salt Fork of the Red River (110 miles, 80 miles in Oklahoma) enters Oklahoma to the north of Sandy Creek and runs through Basins 38 and 39. The Elm Fork of the Red River (60 miles) begins to the north of the Salt Fork of the Red River and joins the North Fork of the Red River just below Lugert-Altus Reservoir.

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.

In the Southwest Region, streamflow is variable but generally intermittent. Existing reservoirs in the region increase the dependability of surface water supply for many public water systems and other users. The largest is Lugert-Altus, built in 1947 on the Upper North Fork of the Red River by the Bureau of Reclamation. Tom Steed, built in 1975 and also administered by the Bureau of Reclamation, is located on the Otter Creek tributary of the North Fork of the Red River. Several smaller reservoirs are located within the Lower North Fork of the Red River basins, including Elk City (operated by the City of Elk City), Altus City (operated by the City of Altus), and Rocky (operated by the City of Hobart). There are many other small Natural Resources Conservation Service (NRCS) and municipal and privately owned lakes in the region that provide water for public water supply, agricultural water supply, flood control and recreation.

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.

Estimated Annual Streamflow in 2060
Southwest Region

Streamflow Statistic	Basins											
	32	33	34	35	36	37	38	39	40	41	42	43
	AFY											
Average Annual Flow	239,700	233,000	172,400	10,300	21,100	47,800	99,200	27,700	11,200	13,300	57,700	50,000
Minimum Annual Flow	32,700	31,800	17,100	0	0	4,100	14,900	4,000	100	200	6,000	5,400

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

Groundwater Resources

Three major bedrock aquifers underlie the Southwest Watershed Planning Region: the Blaine, Elk City, and the Ogallala. Two major alluvial aquifers underlie the region: the Tillman Terrace and North Fork of the Red River.

The Blaine aquifer consists of a series of interbedded gypsum, shale, and dolomite 300 to 400 feet thick, overlain with a formation up to 200 feet thick of red-brown shale with thin gypsum and dolomite beds. Water from the aquifer is of poor quality with high dissolved solids and high concentrations of calcium and sulfate. Water quality makes it unsuitable as a drinking water source, but it is a major source of irrigation water. Irrigation wells are typically 100 to 300 feet deep with yields between 100 and 500 gallons per minute (gpm), although they can exceed 2,000 gpm.

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.

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

The Elk City aquifer is comprised of fine-grained, friable sandstone with a maximum thickness of about 185 feet. Wells commonly yield 25 to 300 gpm of water for irrigation, domestic, and industrial purposes.

The Ogallala aquifer consists predominantly of semi-consolidated sediment layers. While the Ogallala aquifer is the most prolific aquifer in the state, it begins to thin out in its southern reaches and only underlies a small portion of the Southwest Watershed Planning Region in Basin 37. In this area, the maximum saturated thickness is about 250 feet and averages about 60 feet. The average depth to water is 39 feet and the average aquifer yield 50 gpm. In contrast to the Oklahoma Panhandle, where groundwater levels are declining due to water withdrawals which exceed recharge, groundwater levels in Roger Mills and Beckham Counties have risen since 1980. While the maximum annual yields and equal proportionate shares have been set for most areas underlain by the Ogallala, studies have not been completed for those portions underlying Basin 37. Water quality of the aquifer is generally very good, although in local areas quality has been impaired by high concentrations of nitrate.

The North Fork of the Red River alluvial aquifer averages 70 feet in thickness. The formation consists of silt and clays grading into fine to coarse sand. The water is hard to very hard and of a generally calcium magnesium bicarbonate type. TDS values are usually less than 1,100 mg/L. The aquifer is located in portions of Basins 33, 34, 35, 36, 37, 38, 42, and 43.

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.

The Tillman Terrace aquifer, located in Tillman County, supplies large quantities of groundwater for irrigation purposes and smaller amounts for Municipal and Industrial and domestic use. The formation averages 70 feet in thickness (with an average saturated thickness of about 23 feet) and wells in the aquifer produce 200 to 500 gpm. The water exhibits significant hardness and generally requires softening to address aesthetic issues for public water supply use. Nitrate concentrations in the aquifer often exceed drinking water standards, thereby limiting use for public water supply. The Tillman Terrace aquifer underlies portions of Basins 32 and 33.

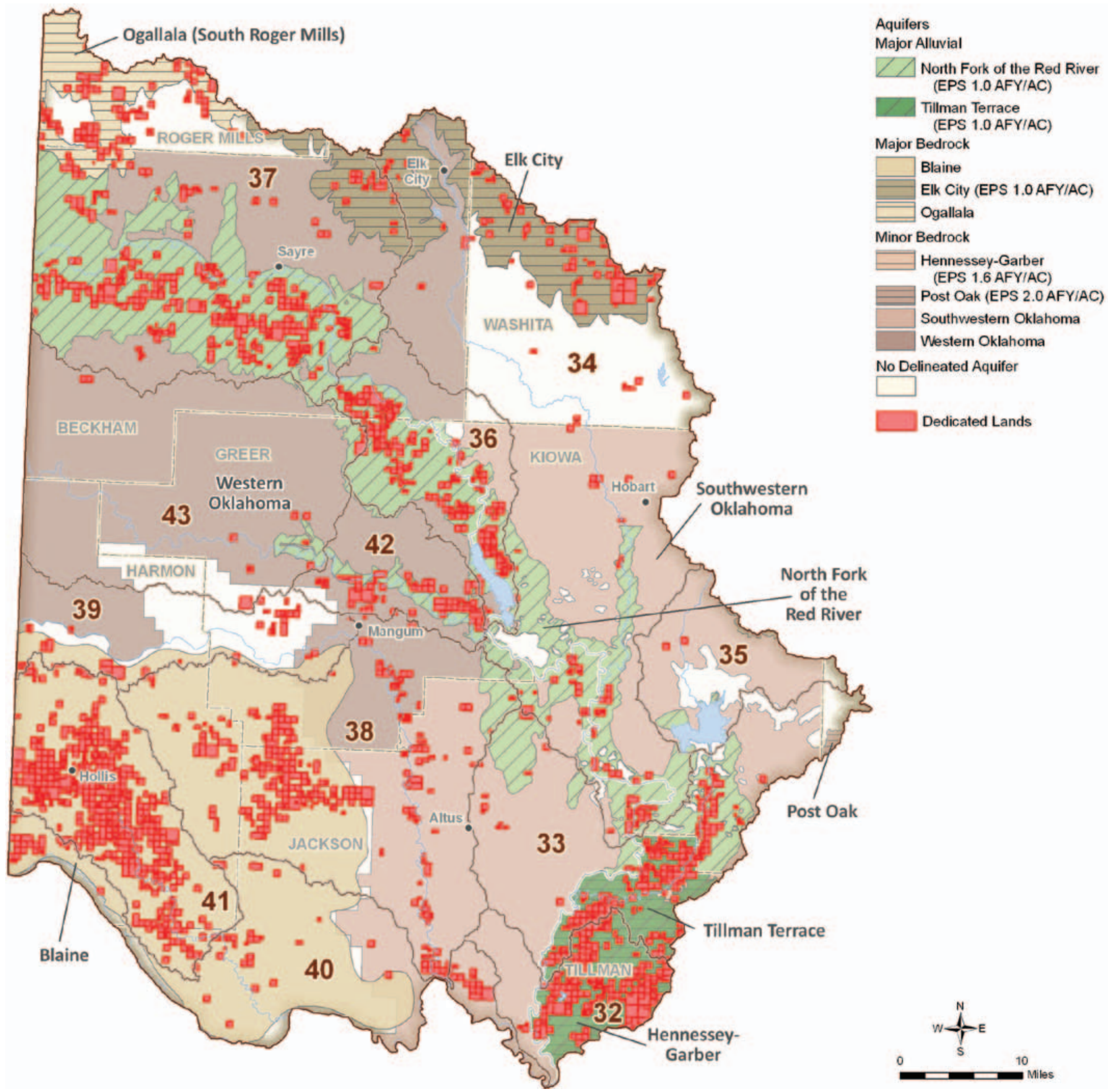
Minor aquifers in the region include the Hennessey-Garber, Post Oak, Southwestern Oklahoma, Western Oklahoma, and non-delineated aquifers. Minor aquifers may have significant amounts of water in storage and high recharge rates, but generally low yields of less than 50 gpm per well. Groundwater from minor aquifers is an important source of water for domestic and stock water use for individuals in outlying areas not served by rural water systems.

Groundwater Resources
Southwest 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
Blaine	Bedrock	Major	18%	1.5	85,500	1,403,000	temporary 2.0	744,400
Elk City	Bedrock	Major	5%	2.8	9,400	1,435,000	1.0	108,000
North Fork of the Red River	Alluvial	Major	17%	2.3	71,300	3,763,000	1.0	355,700
Ogallala	Bedrock	Major	2%	0.9	21,000	424,000	temporary 2.0	80,100
Tillman Terrace	Alluvial	Major	4%	2.9	38,000	684,000	1.0	55,600
Hennessey-Garber	Bedrock	Minor	4%	2.7	100	420,000	1.6	153,500
Post Oak	Bedrock	Minor	<1%	3.6	0	0	2.0	0
Southwestern Oklahoma	Bedrock	Minor	26%	2.25	600	1,807,000	temporary 2.0	1,317,800
Western Oklahoma	Bedrock	Minor	37%	N/A	5,600	N/A	temporary 2.0	1,897,900
Non-Delineated Groundwater Source	Alluvial	Minor			40,600			
Non-Delineated Groundwater Source	Bedrock	Minor			8,100			

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
Southwest Region



Major bedrock aquifers in the Southwest Region include the Ogallala, Elk City, and Blaine. Major alluvial aquifers in the region include Tillman Terrace and North Fork of the Red River. Major bedrock aquifers are defined as those that have an average water well yield of at least 50 gpm; major alluvial aquifers are those that yield, on average, at least 150 gpm.

Permit Availability

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

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

Projections indicate that there will be surface water available for new permits through 2060 in Basins 38, 42, and 43. Basins 32 and 33 currently have water available for new permits, but projections indicate that there will be no remaining available surface water for new permits in 2060. There is no surface water available for new permits in Basins 34, 35, 36, 37, 39, 40, and 41 in the Southwest Region. For groundwater, each aquifer's equal proportionate share (EPS) determines the amount of water available for permits. Equal proportionate shares in the Southwest Region range from 1 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 Southwest 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.

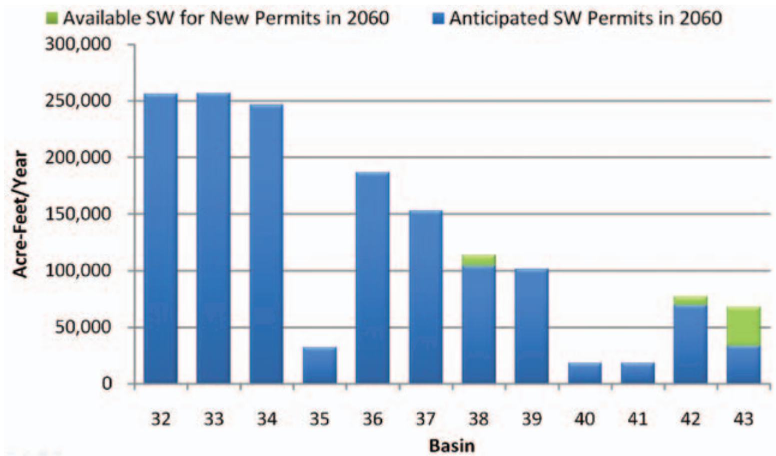
Groundwater Permit Availability

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

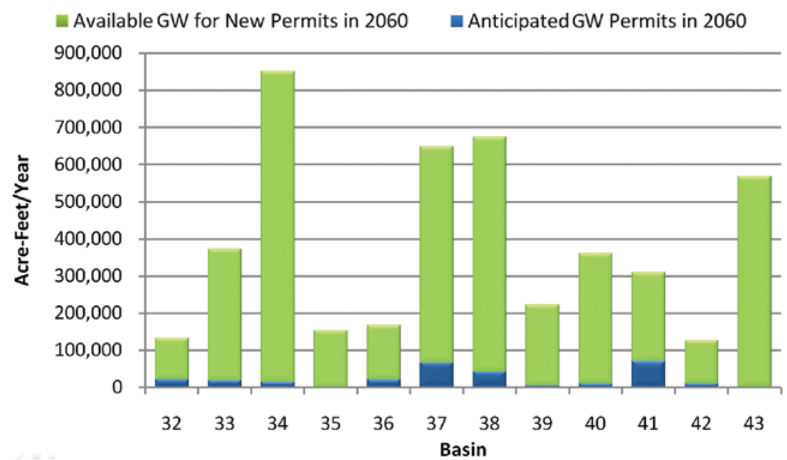
Southwest Region



Projections indicate that there will be surface water available for new permits through 2060 in Basins 38, 42, and 43. Basins 32 and 33 currently have water available for new permits but projections indicate that there will be no remaining available surface water for new permits in 2060. There is no surface water available for new permits in Basins 34, 35, 36, 37, 39, 40, and 41 in the Southwest Region.

Groundwater Permit Availability

Southwest Region



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

Water Quality

Water quality of the Southwest Watershed Planning Region varies considerably. The majority of the region lies within the Central Great Plains Ecoregion but the Southwestern Tablelands ecoregion encroaches into the west-central portion.

The central and southern and eastern borders are defined by two distinct ecoregions, the Southwestern Tablelands and the Red Prairie of the Central Great Plains, with the Wichita Mountains interspersed centrally. The Southwestern Tablelands are located in the west-central area, extending from the Texas border along northern Harmon and southern Beckham Counties, and into western Greer County. Encompassed by the Caprock Canyons, Badlands, and Breaks, the area is characterized by hills, buttes, and ledges and dominated by rangeland. Underlain by gypsum, sandstone, dolomite, and salt, the surface waters of the area contain high salt concentrations. The Elm Fork of the Red River has a mean conductivity of 46,700 microsiemens (uS) and a mean chloride concentration of 20,300 parts per million (ppm). Nutrient concentrations are relatively low with mean concentrations of nitrogen and phosphorus at 0.36 and 0.02 ppm, respectively. Water clarity is good with a mean turbidity of 18 nephelometric turbidity units (NTU) but highly saline waters limit ecological diversity. The Red Prairie ecoregion is more irregular than the surrounding Central Great Plains areas. Similar to the Caprock Canyons, it is underlain by gypsum and sandstone, and though not as saline, sodium chloride concentrations are higher than surrounding areas. Water quality can be characterized by the Elm Fork of the Red River near Granite, Lugert-Altus Reservoir, and the Red River near Davidson to the south. Though lower than the Carl station, salinity remains high near Granite with a mean conductivity of 19,600 uS and chloride concentration of 5760 ppm. With a conductivity of 2,000 uS, salinity at Lugert-Altus is more indicative of the upper North Fork of the Red. Along the southern border, mean conductivity of the Red River is 7,700 uS, with a mean chloride concentration of 2,040 ppm. Tributaries of the Elm Fork typically range from 4,000 – 10,000 uS. At 0.09 ppm, phosphorus concentrations are higher at Granite but are still relatively low, and nitrogen concentrations are similar. However, mean total phosphorus concentrations of 0.26 ppm are considerably higher along the Red River, which is hyper-eutrophic. Lugert-Altus Reservoir is eutrophic

Lake Trophic Status

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

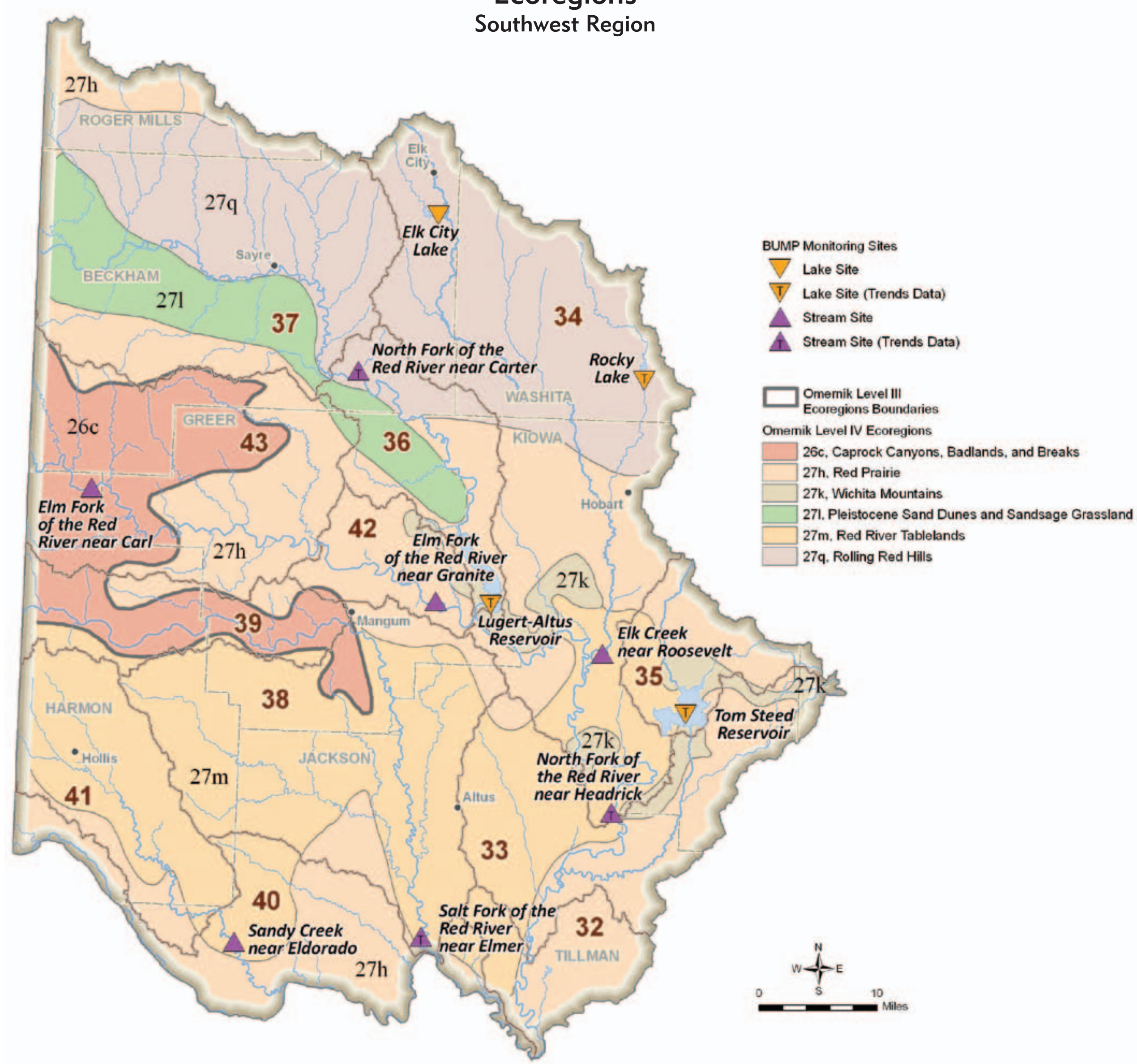
Oligotrophic: Low primary productivity and/or low nutrient levels.

Mesotrophic: Moderate primary productivity with moderate nutrient levels.

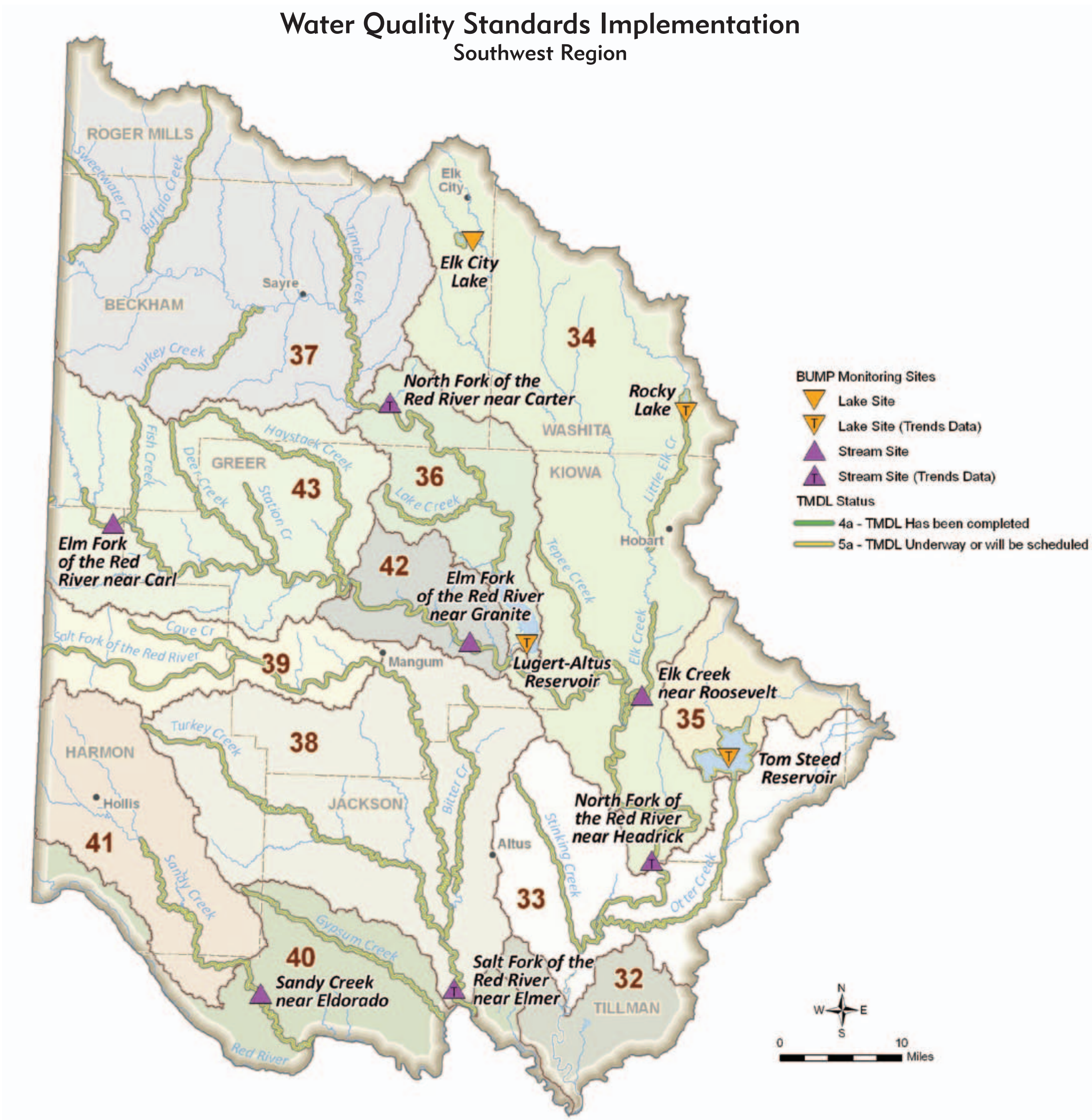
Eutrophic: High primary productivity and nutrient rich.

Hypereutrophic: Excessive primary productivity and excessive nutrients.

Ecoregions
Southwest Region



The Southwest region is comprised of several distinct ecoregions, as evidenced by its diverse geology and water quality, which ranges from excellent to poor.



The Oklahoma Conservation Commission has begun a watershed implementation project on Elk City Lake Watershed to address the sources of the lake's impairments, particularly pathogens.

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 nonpoint 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.

Water Quality Impairments
Southwest Region

Regional water quality impairments based on the 2008 *Oklahoma Integrated Water Quality Assessment Report*. Natural elevated levels of salinity in this region produce agricultural and public private water supply impacts, particularly in the North Fork of the Red River and the Salt Fork of the Red River and their tributaries. In light of this, the Army Corps of Engineers has embarked on a chloride control project in this area to research and address the possibilities of reducing the chloride levels. Groundwater from the Blaine aquifer is of poor quality with dissolved solids ranging from 1,500 to 5,000 mg/L. The water has high concentrations of calcium and sulfate resulting from dissolution of the gypsum beds. Locally, in southeastern and northwestern Harmon County, the water has high sodium chloride content. Although the highly mineralized aquifer is unsuitable as a drinking water supply, it is a major source of irrigation water.

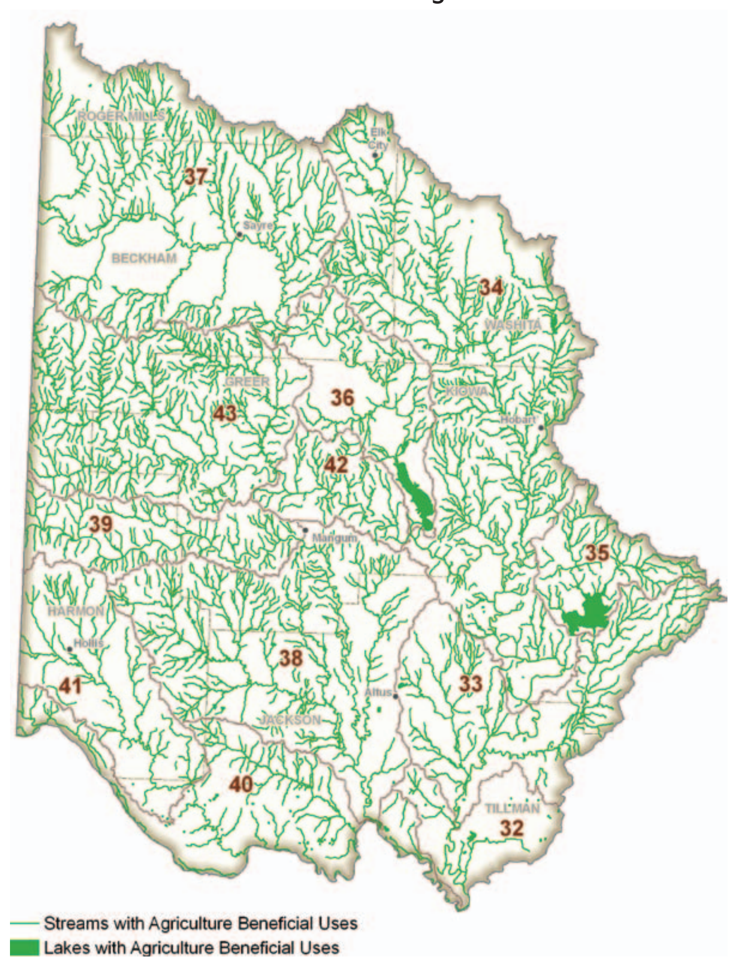
and phosphorus limited; mean total nitrogen and phosphorus concentrations are 1.0 and 0.05 ppm, respectively. Water clarity is poor to good, with an average Secchi depth of 37 cm at Lugert-Altus and river turbidity means from 18 at Granite to 88 at Davidson. Ecological diversity remains relatively low due to high salinity.

The northern portion of the region is dominated by the Rolling Red Hills ecoregion of the Central Great Plains. The area has steep hilly relief and breaks with intermixed gypsum karst features. It is dominated by rangeland with predominately mixed and short grass prairies, and wooded areas. Eastern red cedar and salt cedar are two notable invasive species. To the south, the Pleistocene Sand Dunes encompass tributaries of the North Fork. This area has permeable sandy soils, interlaced with springs and inter-dune wetlands. Streams and rivers throughout the Rolling Red Hills and Pleistocene Sand Dunes are mostly sand-bottom with low to moderate gradients, incised banks, and unstable substrates. Water quality of this area is exemplified by the North Fork and its tributaries, such as Sweetwater and Turkey Creeks. The area has multiple municipal water supply lakes, including Elk City and Rocky Lakes. With a mean conductivity of 2,620 uS, the North Fork has relatively low conductivity when compared to other parts of the region. Typically, water is of lower conductivity in northern tributaries while southern tributaries have elevated salt concentrations. Both lakes have relatively low conductivity with mean values of approximately 625 uS. On the North Fork, the mean total phosphorus concentration of 0.07 ppm is relatively low, as is the total nitrogen concentration of 1.09 ppm. Elk City and Rocky Lakes are potentially co-limited while Elk city is eutrophic and Rocky Lake is hyper-eutrophic. Water clarity is fair to poor on both the North Fork and the lakes, with mean Secchi depths of less than 20 cm and a mean turbidity of 31 NTU. Ecologically, the area is much more diverse than surrounding areas.

The Red River Tablelands ecoregion encompasses most of the southern third of the region. The area has little relief and much cropland. Like other areas of the region, it is underlain by dolomite and gypsum with relatively high levels of salinity. Water quality is more diverse than in other areas of the region and is characterized by Sandy Creek, the Salt Fork and North Fork, and Elk Creek. Conductivity values range from a mean of 1,580 uS at Elk Creek to nearly 8,500 uS on Sandy Creek. With the exception of the North Fork, chloride values are nearly a third of sulfate concentrations. Nutrient concentrations are typical of the region. Total phosphorus concentrations range from 0.09 ppm on the Salt Fork River to 0.16 ppm on the North Fork, while nitrogen values range from 0.84 ppm at the Salt Fork to a relatively high 3.67 ppm on Sandy Creek. Waters are eutrophic to hyper-eutrophic. Clarity is poor to fair. Mean turbidities range from 61 NTU on Sandy Creek to 24 on the North Fork. Tom Steed Reservoir lies along the far eastern tip of the area and is eutrophic with average water clarity and relatively low salinity. Diversity is relatively low in areas of high salinity but improves along Elk Creek.

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

Surface Waters with Designated Beneficial Use for Agriculture
Southwest Region



Although a statewide groundwater water quality program does not exist in Oklahoma, various aquifer studies have been completed and data are available from various sources. The Southwest Planning Region is underlain by several major and minor bedrock and alluvial aquifers. In most southwest alluvial aquifers, water quality is good, and except for hardness and localized nitrate problems, the water is appropriate for domestic, irrigation, industrial and municipal use. Throughout much of southwestern Oklahoma, thick deposits of salt and gypsum occur in many Permian-age formations creating high chloride and sulfate concentrations, which can migrate into portions of alluvial aquifers. Major bedrock aquifers in the region include the Blaine, Elk City, and Ogallala. The Blaine underlies the far southwestern corner extending into Greer, Harmon, and Jackson Counties. Water from the Blaine aquifer is of poor quality with dissolved solids ranging from 1,500 to 5,000 mg/L. The water has high concentrations of calcium and sulfate, reflecting dissolution of the gypsum beds. In southeastern and northwestern Harmon County, water is high in sodium chloride. Although the highly mineralized aquifer is unsuitable as a drinking water supply, it is a major source of irrigation water. The Elk City aquifer lies along the northern border of the region and is comprised of fine-grained and friable sandstone; its water is generally suitable for most uses. The Ogallala extends into the region's northwestern tip. Water is of a calcium-magnesium chloride-sulfate type. Although hard, it is suitable for public supply. However, excessive chlorides, sulfates and fluorides may make the water unsuitable in some areas.

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

Southwest Region

The watersheds of Elk City Lake and Rocky Lake have been identified by OWRB as Nutrient Limited Watersheds but currently lack protection to prevent degradation.

Groundwater Protection Areas
Southwest Region

Various types of protection are in place to prevent degradation of groundwater and address vulnerability. The Elk City and Blaine aquifers have been identified by the OWRB as highly vulnerable, while the Red River and North Fork of the Red River alluvial aquifers have been identified 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

Southwest Region

Parameter	Lugert-Altus Reservoir (1996-2005)	Rocky Lake (1995-2009)	Tom Steed Reservoir (1996-2007)
Chlorophyll-a (mg/m3)	NT	↑	NT
Conductivity (us/cm)	NT	↑	NT
Total Nitrogen (mg/L)	↑	NT	↑
Total Phosphorus (mg/L)	↓	NT	NT
Turbidity (NTU)	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 conductivity on Rocky Lake.
- Significant upward trend for total nitrogen on Lugert-Altus and Tom Steed reservoirs.

Stream Water Quality Trends

Southwest Region

Parameter	North Fork of the Red River near Carter		North Fork of the Red River near Headrick		Salt Fork of the Red River near Elmer	
	All Data Trend (1968-1993, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1958-1993, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1979-1994, 1998-2009)[1]	Recent Trend (1998-2009)
Conductivity (us/cm)	↑	NT	↑	NT	NT	NT
Total Nitrogen (mg/L)	↓	NT	↓	NT	↑	↑
Total Phosphorus (mg/L)	↓	↓	↓	NT	↓	↓
Turbidity (NTU)	↑	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 conductivity on the North Fork of the Red River.
- Significant upward trend for period of record turbidity throughout the region.

Water Demand

The Southwest Region's water demand accounts for about 9% of the total statewide demand. Regional demand will increase by 20% (36,100 AFY) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Crop Irrigation sector.

Crop Irrigation demand is expected to remain the largest demand sector in the region, accounting for 87% of the total regional demand in 2060. Currently, 36% of the demand from this sector is supplied by surface water, 29% by alluvial groundwater, and 35% by bedrock groundwater. Predominant irrigated crops in the Southwest Region include cotton, pasture grasses, and wheat.

Municipal and Industrial demand in the Southwest Region is projected to account for approximately 7% of the 2060 demand. Currently, 71% of the demand from this sector is supplied by surface water, 16% by alluvial groundwater, and 13% by bedrock groundwater.

Water demand for Oil and Gas activities is projected to account for approximately 3% of the 2060 demand. Currently, 60% of the demand from this sector is supplied by surface water, 8% by alluvial groundwater, and 32% by bedrock groundwater.

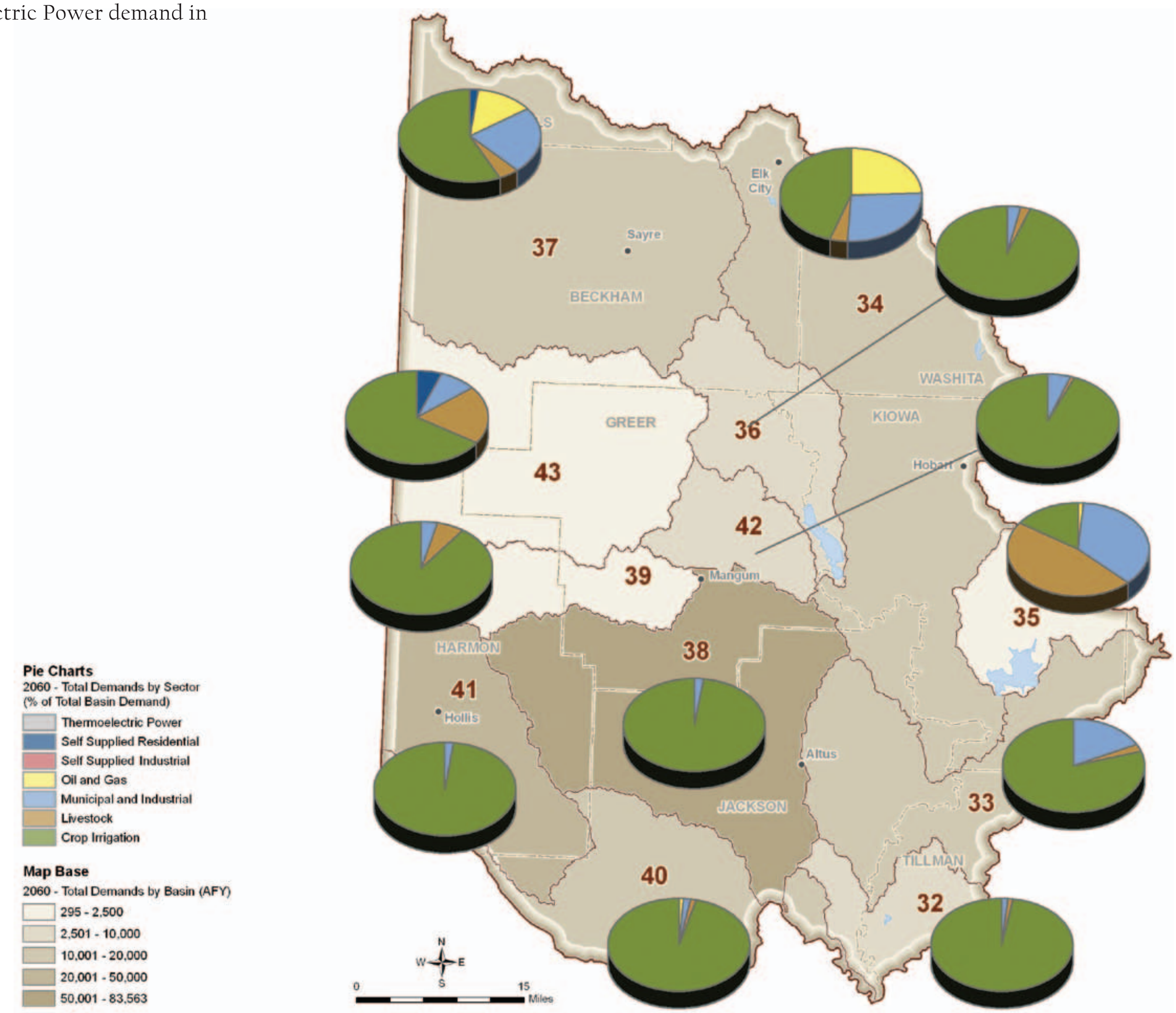
Livestock demand is projected to account for 2% of the 2060 demand. Currently, 21% of the demand from this sector is supplied by surface water, 39% by alluvial groundwater, and 40% by bedrock groundwater. Livestock use in the region is predominantly cattle for cow-calf production.

Self-Supplied Residential demand is projected to account for less than 1% of the 2060 demand. Currently, 64% of the demand from this sector is supplied by alluvial groundwater and 36% by bedrock groundwater.

Self-Supplied Industrial demand is also projected to account for less than 1% of the 2060 demand. Currently, 5% of the demand from this sector is supplied by alluvial groundwater and 95% by bedrock groundwater.

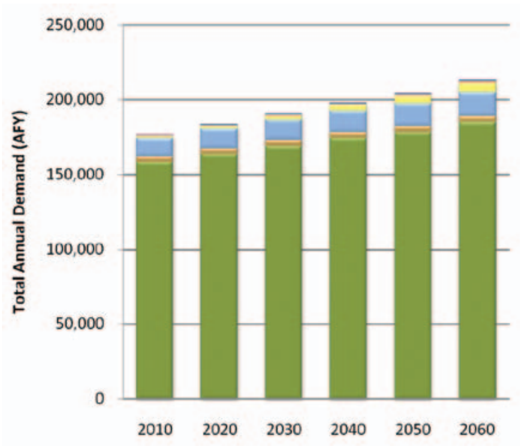
There is no Thermoelectric Power demand in the region.

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

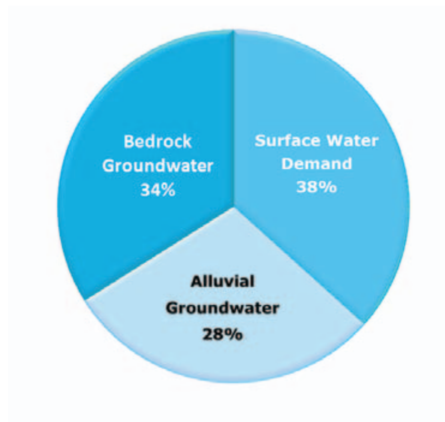


Crop Irrigation is expected to remain the largest demand sector in the region, accounting for 87% of the total regional demand in 2060.

Total Water Demand by Sector
Southwest Region



Supply Sources Used to Meet Current Demand (2010)
Southwest Region



The Southwest Region's water needs account for about 9% of the total statewide demand. Regional demand will increase by 20% (36,120 AFY) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Crop Irrigation sector.

Total Water Demand by Sector
Southwest Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Rural Residential	Thermoelectric Power	Total
	AFY							
2010	158,760	3,660	12,350	1,110	610	500	0	176,990
2020	164,000	3,760	13,060	1,850	610	540	0	183,820
2030	169,250	3,860	13,760	2,800	610	580	0	190,860
2040	174,490	3,960	14,440	3,940	640	610	0	198,090
2050	178,520	4,060	15,100	5,290	650	650	0	204,270
2060	184,980	4,160	15,770	6,840	670	690	0	213,110

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 Southwest Region includes 36 of the 785 OCWP public supply systems. 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 Altus, Elk City, Hobart, Mangum PWS, and Jackson Co. Water Corp. Together, these five systems serve about 70 percent of the combined OCWP public water providers' population 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.

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

Southwest Region

Provider	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Population Served					
				2010	2020	2030	2040	2050	2060
ALTUS	OK1011501	Jackson	200	21,840	23,148	24,235	25,111	25,832	26,409
BECKHAM CO RWD #1	OK2000505	Beckham	267	1,367	1,489	1,618	1,746	1,875	2,017
BECKHAM CO RWD #2	OK2000510	Beckham	130	422	460	500	540	580	623
BECKHAM CO RWD #3	OK2000547	Beckham	287	1,025	1,117	1,213	1,310	1,407	1,513
BLAIR PWA	OK2003304	Jackson	126	1,019	1,073	1,127	1,170	1,202	1,223
CARTER	OK3000501	Beckham	58	332	369	394	431	455	492
DILL CITY	OK2007507	Washita	77	532	552	571	581	591	601
DUKE CENTRAL VUE WATER	OK2003301	Jackson	177	322	343	356	370	377	391
DUKE PWA	OK3003311	Jackson	152	430	458	476	495	504	522
ELDORADO	OK3003301	Jackson	96	418	440	463	478	493	508
ELK CITY	OK2000501	Beckham	235	12,827	13,972	15,174	16,376	17,578	18,905
ERICK	OK2000502	Beckham	153	1,091	1,190	1,289	1,388	1,497	1,606
GOULD PWA	OK3002901	Harmon	263	212	212	212	222	222	232
GRANITE PWS	OK2002804	Greer	115	956	956	956	972	988	1,004
HARMON ELECTRIC	OK3002801	Greer	11	75	75	75	76	78	79
HARMON WATER CORP	OK2002902	Harmon	350	613	613	628	643	666	681
HEADRICK	OK3003302	Jackson	58	125	134	134	143	143	143
HOBART	OK1011502	Kiowa	128	3,880	3,880	3,920	3,960	4,040	4,121
HOLLIS	OK2002901	Harmon	240	2,333	2,333	2,394	2,466	2,538	2,609
JACKSON CO WATER CORP	OK2003306	Jackson	132	2,636	2,791	2,927	3,033	3,120	3,188
KIOWA CO RWS & SWMD #1	OK3003804	Kiowa	111	179	179	181	182	186	190
LONE WOLF	OK2003806	Kiowa	90	474	474	484	484	494	504
MANGUM PWS	OK2002802	Greer	172	2,914	2,914	2,914	2,965	3,016	3,057
MARTHA	OK3003304	Jackson	73	211	220	230	239	249	249
MOUNTAIN PARK	OK3003807	Kiowa	119	205	205	205	205	210	216
MOUNTAIN PARK MCD (Wholesaler Only)	None	Kiowa	0	0	0	0	0	0	0
OLUSTEE PWS	OK3003309	Jackson	89	661	698	734	762	780	799
QUARTZ MTN REG WATER AUTH (Wholesaler Only)	OK2003880	Kiowa	0	0	0	0	0	0	0
REED WATER CORP	OK3002802	Greer	213	175	175	175	178	181	184
ROCKY	OK3007501	Washita	67	105	111	111	111	117	117
ROOSEVELT PWA	OK2003802	Kiowa	105	280	280	280	280	290	290
SAYRE	OK2000508	Beckham	544	4,223	4,594	4,995	5,395	5,786	6,224
SENTINEL PWS	OK3007505	Washita	91	871	900	920	929	959	969
SNYDER	OK1011503	Kiowa	406	1,497	1,497	1,517	1,527	1,558	1,589
THIRSTY WATER CORP	OK2002806	Greer	137	200	200	200	203	207	210
TIPTON	OK2007101	Tillman	98	916	936	956	976	997	1,027
WILLOW	OK2002801	Greer	316	114	114	114	114	114	124

[1] SDWIS - Safe Drinking Water Information System
[2] RED ENTRY indicates data was taken from 2007 Water Rights Database. GPD=gallons per day.

Projections of Retail Water Demands

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 demands include water provided to households for domestic uses both inside and outside the home. Non-residential demands include customer uses at office buildings, shopping centers, industrial parks, schools, churches, hotels, and related locations served by a public water supply system. Retail demands do not 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

Southwest Region

Provider	SDWIS ID[1]	County	Demand					
			2010	2020	2030	2040	2050	2060
			AFY					
ALTUS	OK1011501	Jackson	4,905	5,199	5,443	5,639	5,801	5,931
BECKHAM CO RWD #1	OK2000505	Beckham	409	445	484	522	561	603
BECKHAM CO RWD #2	OK2000510	Beckham	61	67	73	78	84	91
BECKHAM CO RWD #3	OK2000547	Beckham	329	359	390	421	452	486
BLAIR PWA	OK2003304	Jackson	144	151	159	165	170	173
CARTER	OK3000501	Beckham	22	24	26	28	30	32
DILL CITY	OK2007507	Washita	46	48	49	50	51	52
DUKE CENTRAL VUE WATER	OK2003301	Jackson	64	68	71	73	75	77
DUKE PWA	OK3003311	Jackson	73	78	81	84	86	89
ELDORADO	OK3003301	Jackson	45	47	50	51	53	55
ELK CITY	OK2000501	Beckham	3,379	3,681	3,998	4,314	4,631	4,981
ERICK	OK2000502	Beckham	187	204	220	237	256	275
GOULD PWA	OK3002901	Harmon	62	62	62	65	65	68
GRANITE PWS	OK2002804	Greer	123	123	123	125	127	129
HARMON ELECTRIC	OK3002801	Greer	1	1	1	1	1	1
HARMON WATER CORP	OK2002902	Harmon	241	241	246	252	261	267
HEADRICK	OK3003302	Jackson	8	9	9	9	9	9
HOBART	OK1011502	Kiowa	557	557	562	568	580	591
HOLLIS	OK2002901	Harmon	628	628	644	663	683	702
JACKSON CO WATER CORP	OK2003306	Jackson	390	413	433	448	461	471
KIOWA CO RWS & SWMD #1	OK3003804	Kiowa	22	22	23	23	23	24
LONE WOLF	OK2003806	Kiowa	48	48	49	49	50	51
MANGUM PWS	OK2002802	Greer	560	560	560	570	580	588
MARTHA	OK3003304	Jackson	17	18	19	20	20	20
MOUNTAIN PARK	OK3003807	Kiowa	27	27	27	27	28	29
MOUNTAIN PARK MCD (Wholesaler Only)	None	Kiowa	0	0	0	0	0	0
OLUSTEE PWS	OK3003309	Jackson	66	69	73	76	77	79
QUARTZ MTN REG WATER AUTH (Wholesaler Only)	OK2003880	Kiowa	0	0	0	0	0	0
REED WATER CORP	OK3002802	Greer	42	42	42	42	43	44
ROCKY	OK3007501	Washita	8	8	8	8	9	9
ROOSEVELT PWA	OK2003802	Kiowa	33	33	33	33	34	34
SAYRE	OK2000508	Beckham	2,575	2,802	3,046	3,290	3,529	3,796
SENTINEL PWS	OK3007505	Washita	89	92	94	95	98	99
SNYDER	OK1011503	Kiowa	681	681	690	695	709	723
THIRSTY WATER CORP	OK2002806	Greer	31	31	31	31	32	32
TIPTON	OK2007101	Tillman	101	103	105	107	110	113
WILLOW	OK2002801	Greer	40	40	40	40	40	44

1 SDWIS - Safe Drinking Water Information System

Wholesale Water Transfers
Southwest Region

		Sales			**Purchases**		
Provider	**SDWIS ID[1]**	**Sells To**	**Emergency or Ongoing**	**Treated or Raw or Both**	**Purchases From**	**Emergency or Ongoing**	**Treated or Raw or Both**
ALTUS	OK1011501	Jackson Co Water Corp Duke PWA Quartz Mountain Reg Water Auth Blair PWA Olustee PWS Martha Creta Water Company	O O O O O O O	T T T T T T T	Mountain Park MCD	O	R
BECKHAM CO RWD #1	OK2000505	Sentinel PWS Carter Rocky	O O O	T T T			
BECKHAM CO RWD #3	OK2000547	Hammon		T			
CARTER	OK3000501				Beckham Co RWD #1	O	T
DUKE PWA	OK3003311	Jackson Co Water Corp	E	T	Altus	O	T
ELDORADO	OK3003301				Harmon Water Corp Creta Water Corporation	O O	T R
GOULD PWA	OK3002901				Harmon Water Corp	O	B
GRANITE PWS	OK2002804				Quartz Mountain Reg Water Auth	O	T
HARMON ELECTRIC	OK3002801				Mangum PWS Quartz Mountain Reg Water Auth	O	T
HARMON WATER CORP	OK2002902	Gould PWA Eldorado	O O	B T			
HEADRICK	OK3003302				Jackson Co Water Corp	O	T
HOBART	OK1011502	Frontier Dev Auth Butler	O O	T T	Foss Reservoir MCD	O	T
JACKSON CO WATER CORP	OK2003306	Headrick	O	T	Altus Duke Central Vue Water	O E	T T
KIOWA CO RWS & SWMD #1	OK3003804				Quartz Mountain Reg Water Auth	O	T
LONE WOLF	OK2003806				Quartz Mountain Reg Water Auth	O	T
MANGUM PWS	OK2002802	Reed Water Corp Harmon Electric	O O	T T			
MARTHA	OK3003304				Altus	O	T
MOUNTAIN PARK	OK3003807				Snyder	O	T
MOUNTAIN PARK MCD	None	Altus Frederick (Beaver-Cache Region) Snyder	O O O	R R R			
OLUSTEE PWS	OK3003309				Altus Creta Water Corporation	O E	T T
QUARTZ MTN REG WATER AUTH (Wholesaler Only)	OK2003880	Granite PWS Lone Wolf Kiowa Co RWS & SWMD #1 Harmon Electric	O O	T T T	Altus		
REED WATER CORP	OK3002802				Mangum PWS	O	T
ROCKY	OK3007501				Beckham Co RWD #1	O	T
SENTINEL PWS	OK3007505				Beckham Co RWD #1	O	T
SNYDER	OK1011503	Comanche Co RWD #4 Mountain Park, Town of	O O	T T	Mountain Park MCD	O	B
TIPTON	OK2007101				Frederick	O	T

1 SDWIS - Safe Drinking Water Information System

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 demands. 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.

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)

Southwest Region

Provider	SDWIS ID[1]	County	Permitted Quantity	Source		
				Permitted Surface Water	Permitted Alluvial Groundwater	Permitted Bedrock Groundwater
			AFY	Percent		
ALTUS	OK1011501	Jackson	4,800	100%	0%	0%
BECKHAM CO RWD #1	OK2000505	Beckham	1,212	0%	100%	0%
BECKHAM CO RWD #2	OK2000510	Beckham	134	0%	90%	10%
BECKHAM CO RWD #3	OK2000547	Beckham	282	0%	0%	100%
BLAIR PWA	OK2003304	Jackson	274	0%	58%	42%
CARTER	OK3000501	Beckham	---	---	---	---
DILL CITY	OK2007507	Washita	377	0%	0%	100%
DUKE CENTRAL VUE WATER	OK2003301	Jackson	---	---	---	---
DUKE PWA	OK3003311	Jackson	209	0%	100%	0%
ELDORADO	OK3003301	Jackson	86	0%	0%	100%
ELK CITY	OK2000501	Beckham	7,303	0%	100%	0%
ERICK	OK2000502	Beckham	776	0%	100%	0%
GOULD PWA	OK3002901	Harmon	60	0%	100%	0%
GRANITE PWS	OK2002804	Greer	760	0%	100%	0%
HARMON ELECTRIC	OK3002801	Greer	---	---	---	---
HARMON WATER CORP	OK2002902	Harmon	725	0%	100%	0%
HEADRICK	OK3003302	Jackson	---	---	---	---
HOBART	OK1011502	Kiowa	1,731	100%	0%	0%
HOLLIS	OK2002901	Harmon	1,120	0%	100%	0%
JACKSON CO WATER CORP	OK2003306	Jackson	885	0%	100%	0%
KIOWA CO RWS & SWMD #1	OK3003804	Kiowa	---	---	---	---
LONE WOLF	OK2003806	Kiowa	443	0%	100%	0%
MANGUM PWS	OK2002802	Greer	1,220	0%	100%	0%
MARTHA	OK3003304	Jackson	---	---	---	---
MOUNTAIN PARK	OK3003807	Kiowa	---	---	---	---
MOUNTAIN PARK MCD	None	Kiowa	16,100	100%	0%	0%
OLUSTEE PWS	OK3003309	Jackson	29	0%	100%	0%
QUARTZ MTN REG WATER AUTH (Wholesaler Only)	OK2003880	Kiowa	---	---	---	---
REED WATER CORP	OK3002802	Greer	---	---	---	---
ROCKY	OK3007501	Washita	---	---	---	---
ROOSEVELT PWA	OK2003802	Kiowa	75	0%	100%	0%
SAYRE	OK2000508	Beckham	1,605	0%	100%	0%
SENTINEL PWS	OK3007505	Washita	---	---	---	---
SNYDER	OK1011503	Kiowa	---	---	---	---
THIRSTY WATER CORP	OK2002806	Greer	23	---	100%	---
TIPTON	OK2007101	Tillman	727	0%	100%	0%
WILLOW	OK2002801	Greer	35	0%	100%	0%

1 SDWIS - Safe Drinking Water Information System

OCWP Provider Survey
Southwest Region

City of Altus (Jackson County)
Current Source of Supply
Primary source: Mountain Park MCD, Lugert-Altus Irrigation District
Short-Term Needs
Infrastructure improvements: refurbish water tower; replace raw water line.
Long-Term Needs
Infrastructure improvements: replace distribution system lines, pumps and motors; add emergency generator and raw water pump station; rehab 8 multimedia filters and RO plant.

Beckham County RWD 1
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.

Beckham County RWD 2
Current Source of Supply
Primary source: None identified
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Beckham County RWD 3
Current Source of Supply
Primary source: Elk City Sandstone aquifer
Short-Term Needs
New supply source: drill additional wells.
Long-Term Needs
None identified.

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

Town of Carter (Beckham County)
Current Source of Supply
Primary source: Beckham County RWD 1
Short-Term Needs
Infrastructure improvements: refurbish standpipe.
Long-Term Needs
None identified.

Dill City (Washita County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: drill additional well.
Long-Term Needs
New supply source: drill additional wells.

Duke Central Vue Water (Jackson County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: drill additional well.
Long-Term Needs
New supply source: drill additional well.

Duke PWA (Jackson County)
Current Source of Supply
Primary source: City of Altus
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Eldorado (Jackson County)
Current Source of Supply
Primary source: Creta Water Corp., Harmon Water Corp.
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Elk City (Beckham County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: drill additional wells.
Long-Term Needs
None required.

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

Gould PWA (Harmon County)
Current Source of Supply
Primary source: Harmon Water Corporation
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Granite PWS (Greer County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace storage tank, upgrades to water treatment plant.

Harmon Electric (Greer County)
Current Source of Supply
Primary source: Quartz Mountain Regional Water Authority, Mangum PWS.
Short-Term Needs
None identified.
Long-Term Needs
None identified.

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

Town of Headrick (Jackson County)
Current Source of Supply
Primary source: Jackson County Water Corp.
Short-Term Needs
None identified.
Long-Term Needs
None identified.

City of Hobart (Kiowa County)
Current Source of Supply
Primary source: Rocky Lake
Short-Term Needs
None required.
Long-Term Needs
None required.

City of Hollis (Harmon County)
Current Source of Supply
Primary sources: groundwater
Short-Term Needs
New supply source: drill additional wells.
Long-Term Needs
New supply source: drill additional well.

Jackson County Water Corp.
Current Source of Supply
Primary source: groundwater, City of Altus
Short-Term Needs
New supply source: drill additional well.
Long-Term Needs
New supply source: drill additional wells.

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

Town of Lone Wolf (Kiowa County)
Current Source of Supply
Primary source: Quartz Mountain
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Provider Supply Plans

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

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

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

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

Town of Martha (Jackson County)
Current Source of Supply
Primary source: City of Altus
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Mountain Park (Kiowa County)
Current Source of Supply
Primary source: Town of Snyder
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Mountain Park MCD (Kiowa County)
Current Source of Supply
Primary source: Tom Steed Reservoir
Needs
No Information.

Olustee PWS (Jackson County)
Current Source of Supply
Primary source: City of Altus
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Quartz Mountain RWA (Kiowa 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.

Reed Water Corp. (Greer County)
Current Source of Supply
Primary source: Mangum PWS
Short-Term Needs
Infrastructure improvements: replace distribution lines and refurbish storage tank.
Long-Term Needs
None identified.

Town of Rocky (Washita County)
Current Source of Supply
Primary source: Beckham County RWD 1
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
None required.

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

City of Sayre (Beckham County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: new wells, water tower and distribution system lines.
Long-Term Needs
Infrastructure improvements: drill additional wells, replace distribution lines.

Sentinel PWS (Washita County)
Current Source of Supply
Primary source: Beckham County RWD 1
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: Refurbish existing wells.

City of Snyder (Kiowa County)
Current Source of Supply
Primary source: Mountain Park MCD
Short-Term Needs
Infrastructure improvements: new RO water treatment plant.
Long-Term Needs
None identified.

Thirsty Water Corp. (Greer County)
Current Source of Supply
Primary source: Mountain Park MCD
Short-Term Needs
None identified.
Long-Term Needs
New supply source: drill additional wells.

Town of Tipton (Tillman County)
Current Source of Supply
Primary source: City of Frederick/Frederick Lake
Short-Term Needs
Infrastructure improvements: refurbish existing well.
Long-Term Needs
None identified.

Town of Willow (Greer 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: add storage.

Infrastructure Cost Summary
Southwest Region

Provider System Category[1]	Infrastructure Need (millions of 2007 dollars)			
	Present-2020	2021-2040	2041-2060	Total Period
Small	$272	$483	$137	$892
Medium	$130	$65	$43	$238
Large	$0	$0	$0	$0
Reservoir[2]	$0	$7	$133	$140
TOTAL	$402	$555	$313	$1,270

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 and fewer people.

2 The "reservoir" category is for rehabilitation projects.

- Approximately $1.27 billion is needed to meet the projected drinking water infrastructure needs of the Southwest Region over the next 50 years. The largest infrastructure costs are expected to occur from 2021 to 2040.
- Distribution and transmission projects account for more than 90% of the providers' estimated infrastructure costs, followed distantly by water treatment and storage projects.
- Small providers have the largest overall drinking water infrastructure costs.
- Projects involving rehabilitation of existing reservoirs account for approximately 11% 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)

Southwest 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			
Mangum (Lower Dam Site)	4	Salt Fork of the Red River	39	WS, R	47,043	2,604	0	18,494	2005	USACE	N/A
Port	3	Elk Creek	34	FC, WS, FW, R	115,700	4,480	42,000	9,000	1973	Bureau of Reclamation	$112,065,000

N/A indicates information not available.

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 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
Southwest Region

Data & Analysis
Southwest Watershed Planning Region

Basin 32

Basin 32 Summary

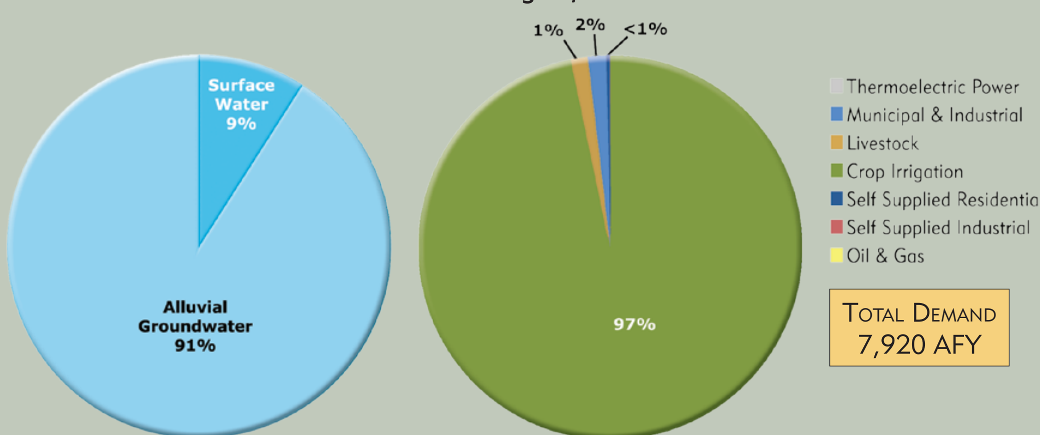
Synopsis

- Most water users are expected to continue to rely on 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.
- By 2050, 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 groundwater storage depletions be decreased where economically feasible.
- Additional conservation could mitigate surface water gaps and the adverse effects of alluvial groundwater storage depletions.
- Use of additional groundwater supplies and/or developing additional small reservoir storage could mitigate gaps. These supply sources could be used without major impacts to groundwater storage.

Basin 32 accounts for about 5% of the water demand in the Southwest Watershed Planning Region. The Crop Irrigation demand sector accounts for 97% of the demand in the basin. Surface water satisfies about 9% of the total demand in the basin. Alluvial groundwater satisfies about 91% of the total demand in the basin. The peak summer demand is 152 times the winter monthly demand, which is much more pronounced than the overall statewide pattern.

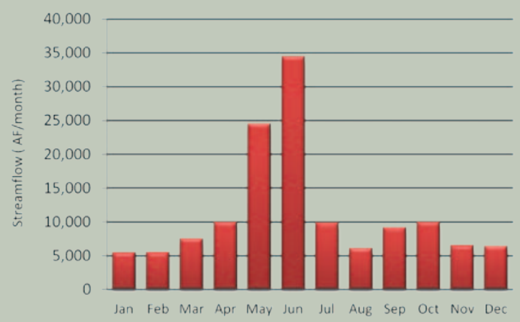
There are no major reservoirs in Basin 32; however, the far northwest tip of the basin receives out-of-basin supplies from the Lugert-Altus Irrigation District. The North Fork of the Red River, the major stream in this basin, typically has flows greater than 5,000 AF/month, but can also have prolonged periods of low flow in any month of the year. Basin 32 currently has surface water available for new permits but is expected to be fully allocated by

Current Demand by Source and Sector
Southwest Region, Basin 32

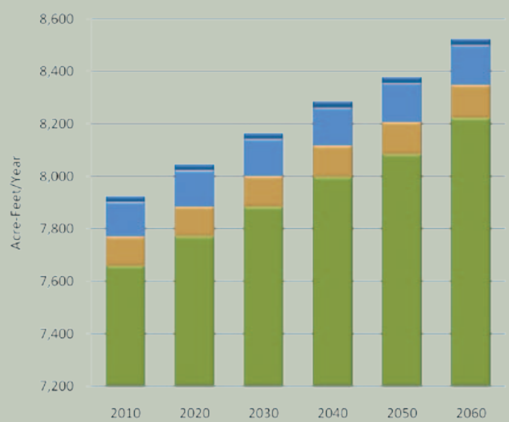


Water Resources
Southwest Region, Basin 32

Median Historical Streamflow at the Basin Outlet
Southwest Region, Basin 32



Projected Water Demand
Southwest Region, Basin 32



2060. Relative to other basins in the state, the surface water quality in Basin 32 is considered poor. However, individual lakes and streams may have acceptable water quality.

The majority of current groundwater rights are from the Tillman Terrace aquifer, which underlies about 70% of the basin and has about 370,000 AF of in-basin groundwater storage. Minor bedrock aquifers are present in the basin, but are not widely used. 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.

The projected 2060 water demand of 8,520 AFY reflects a 600 AFY increase (8%) over the 2010 demand.

Gaps & Depletions

Based on projected demand and historical hydrology, alluvial groundwater storage depletions may occur by 2020, while surface water gaps may occur by 2050. Surface water gaps will be minimal (20 AFY) on a basin-scale. Alluvial groundwater storage depletions will be as high as 180 AFY by 2060, and will have a 12% probability of occurring in at least one month of the year. Surface water gaps and alluvial groundwater storage depletions are expected in the spring, summer, and fall. Projected annual alluvial groundwater storage depletions are minimal relative to volume of water in storage in Basin 32's portion of the Tillman Terrace aquifer. However, localized groundwater storage depletions may adversely affect users' well yield, water levels, or water quality. No bedrock groundwater demands are expected in the future based on current water use.

Options

Most water users are expected to continue to heavily rely on alluvial groundwater supplies. 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 Crop Irrigation sector could mitigate gaps and storage depletions. Temporary drought management could reduce surface water demand, largely from irrigation, and may mitigate gaps. Temporary drought management may not be needed for alluvial groundwater users, since aquifer storage could continue to provide supplies during droughts.

The Lugert-Altus Irrigation District currently provides supplies to the basin, but is not expected to provide supplies to new irrigators in the future unless the District obtains additional water supplies. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin

Water Supply Limitations
Southwest Region, Basin 32

Source	Rating
Surface Water	Potential
Alluvial Groundwater	Potential
Bedrock Groundwater	Potential

Minimal · Potential · Significant

Water Supply Option Effectiveness
Southwest Region, Basin 32

Option	Rating
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

sites in the Southwest Region. However, in light of the basin's groundwater resources and distance to other reliable surface water supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

New reservoir storage can increase the dependability of available surface water supplies and mitigate gaps or adverse effects of localized storage depletions. The flow in Basin 32 will be fully permitted by 2060, which will severely limit the size and location of new reservoirs. However, if permittable, the basin's entire growth in demand from 2010 to 2060 could be supplied by a new river diversion and a 200 AF reservoir at the basin outlet.

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

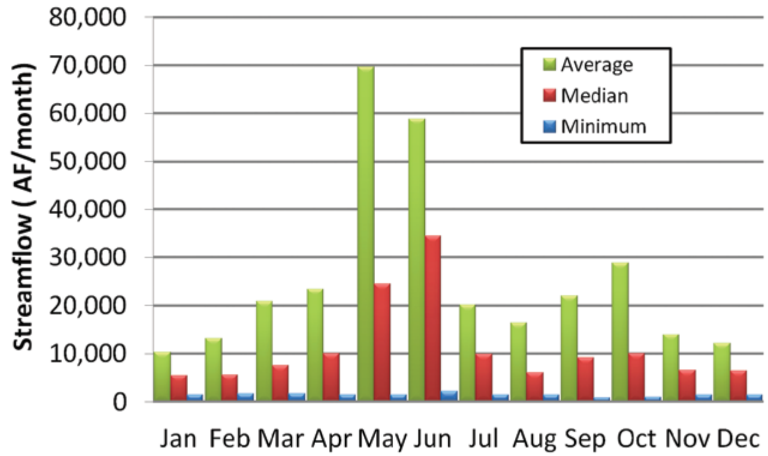
Increased reliance on alluvial groundwater may mitigate surface water gaps, but will increase storage depletions. Any increases in storage depletions would be small in size relative to the volume of water in storage in Basin 32's portion of the Tillman Terrace aquifer. However, localized groundwater storage depletions may adversely affect users' well yield, water quality, and/or pumping costs.

Basin 32 Data & Analysis

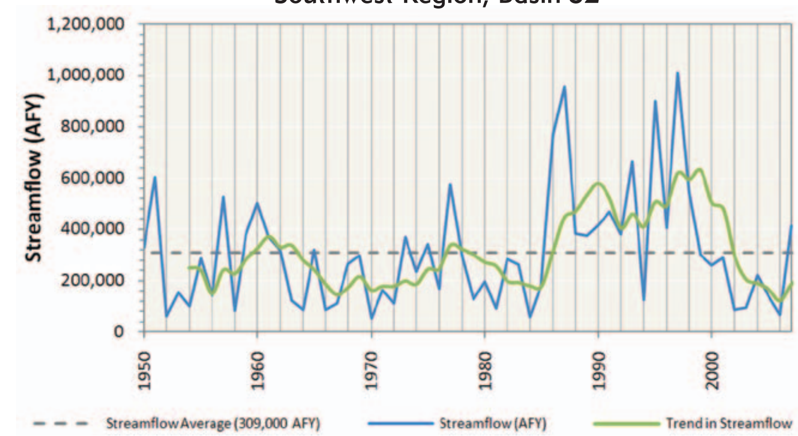
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The North Fork of the Red River upstream of the Red River had a prolonged period of below average flow from the early 1960s to the mid 1970s. From the mid 1980s to early 2000s, the basin went through a prolonged period of above-average streamflow, demonstrating hydrologic variability in the basin.
- The median flow of the North Fork of Red River upstream of the Red River is greater than 5,000 AF/month throughout the year and greater than 24,000 AF/month in May and June. However, the river can have prolonged periods of low flow in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 32 is considered poor. However, individual lakes and streams may have acceptable water quality.
- There are no major reservoirs in the basin.

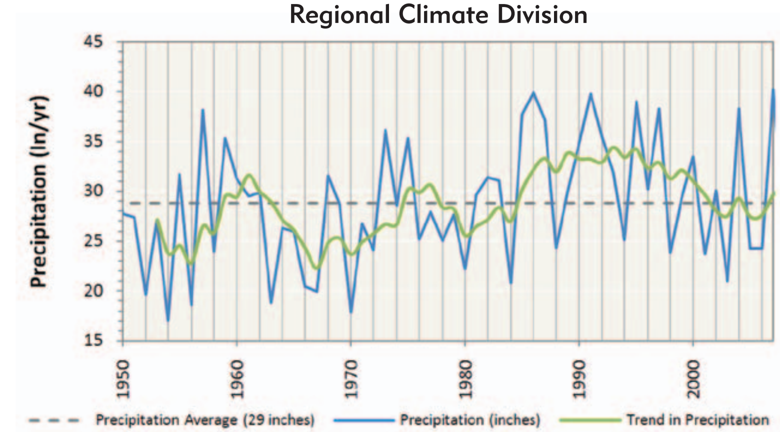
Monthly Historical Streamflow at the Basin Outlet
Southwest Region, Basin 32



Historical Streamflow at the Basin Outlet
Southwest Region, Basin 32



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)

Southwest Region, Basin 32

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
Tillman Terrace	Alluvial	Major	69%	24,200	372,000	1.0	26,000
Hennessey-Garber	Bedrock	Minor	69%	0	224,000	1.6	81,900
Southwestern Oklahoma	Bedrock	Minor	31%	0	69,000	temporary 2.0	50,700
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	200	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

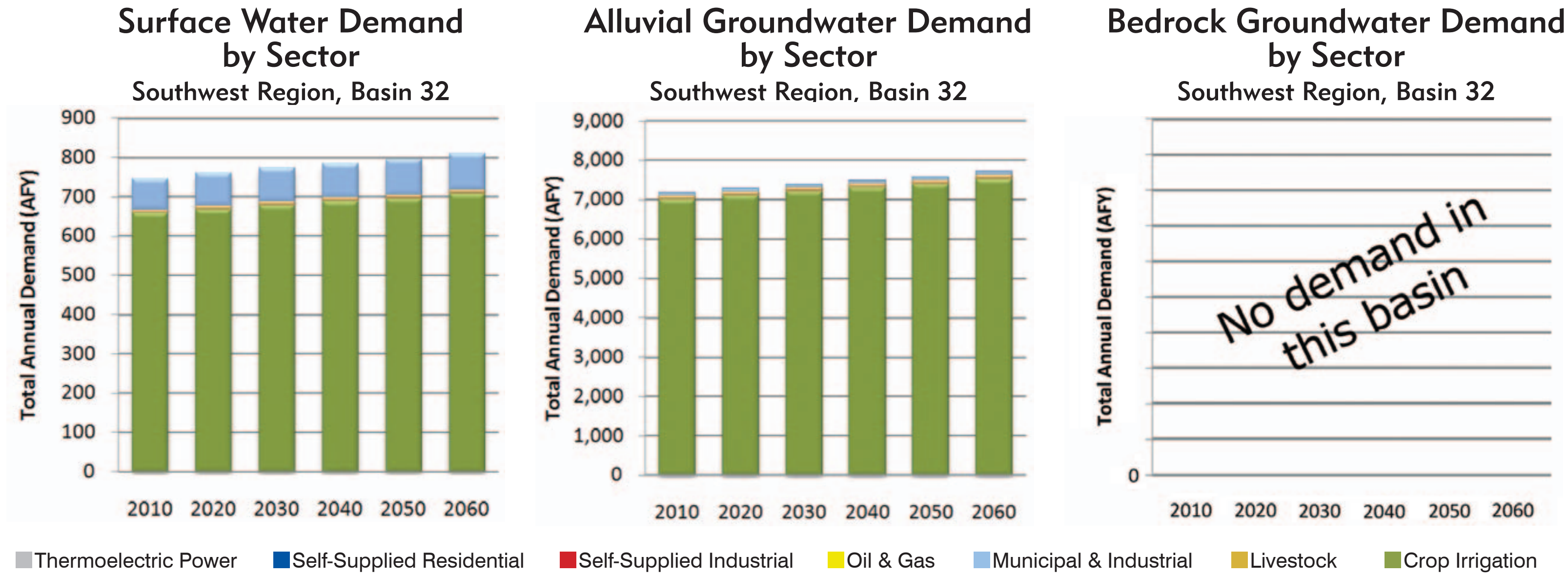
- The majority of groundwater rights in the basin are from the Tillman Terrace aquifer.
- High concentrations of nitrates have been found in some well fields in the Tillman Terrace, so site specific information is recommended before drilling wells for public water supply. There are no other significant 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 32 account for about 5% of the demand in the Southwest Watershed Planning Region. The demand is expected to increase by 8% (600 AF) from 2010 to 2060. The majority of the demand and growth in demand during this period will be from the Crop Irrigation demand sector.
- Surface water and out-of-basin supplies are used to meet 9% of the total demand in the basin. Surface water use will increase by 8% (60 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use during this period will be from the Crop Irrigation sector.
- Alluvial groundwater is used to meet 91% of the total demand in the basin. Alluvial groundwater use will increase by 8% (540 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use during this period will be from the Crop Irrigation sector.
- Bedrock groundwater is not currently used to meet demand in Basin 32; therefore no future use of this source is assumed.



Total Demand by Sector

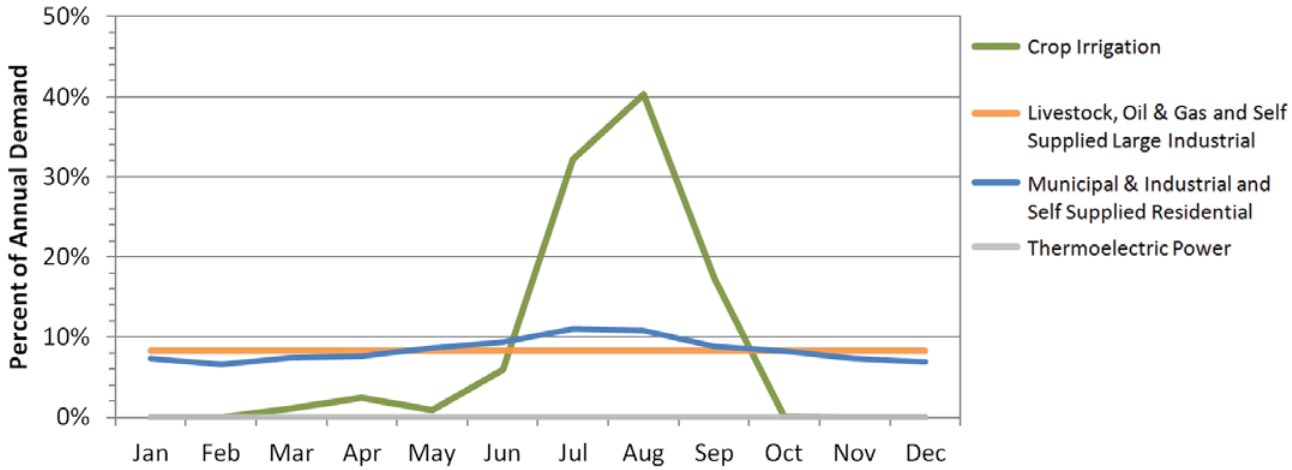
Southwest Region, Basin 32

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	7,660	110	130	0	0	20	0	7,920
2020	7,770	110	140	0	0	20	0	8,040
2030	7,880	120	140	0	0	20	0	8,160
2040	8,000	120	150	0	0	20	0	8,290
2050	8,080	120	150	0	0	20	0	8,370
2060	8,220	130	150	0	0	20	0	8,520

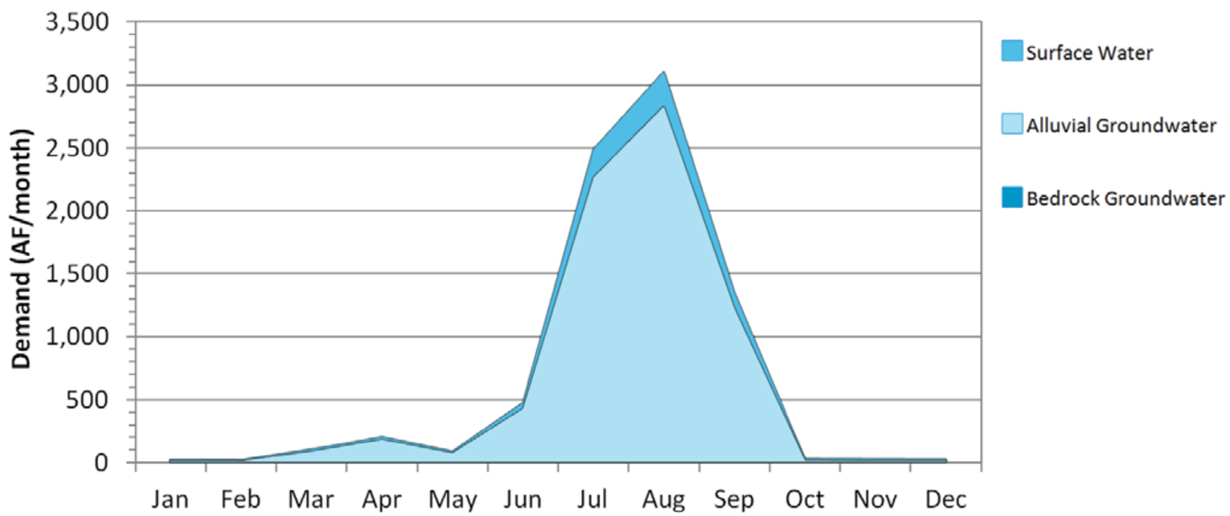
Notes & Assumptions

- 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)
Southwest Region, Basin 32



Monthly Demand Distribution by Source (2010)
Southwest Region, Basin 32



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 50% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer demand month in Basin 32 is 152.2 times the winter demand, which is much more pronounced than the overall statewide pattern. The peak summer month surface water demand is 41.5 times the monthly winter demand. The peak summer month alluvial groundwater water demand is 205.4 times the monthly winter use due to the seasonality of Crop Irrigation water use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, alluvial groundwater storage depletions have a possibility of occurring by 2020, while surface water gaps may occur by 2050. There is not expected to be bedrock groundwater storage depletions through 2060.
- Surface water gaps in Basin 32 may occur during the summer. Surface water gaps in 2060 will be up to 7% (20 AF/month) of the surface water demand in the peak summer month and have a 3% probability of occurring in at least one month of the year. Surface water gaps are considered minimal on a basin-scale.
- Alluvial groundwater storage depletions in Basin 32 may occur during the spring and summer. Alluvial groundwater storage depletions in 2060 will be up to 6% (180 AF/month) of the alluvial groundwater demand in the peak summer month, and up to 10% (10 AF/month) of the peak spring month's alluvial groundwater demand. There will be a 12% probability of storage depletions occurring in at least one month of the year by 2060.
- Projected annual storage depletions are minimal relative to volume of water stored in Basin 32's portion of the Tillman Terrace aquifer. However, localized storage depletions may occur and adversely affect yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)

Southwest Region, Basin 32

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	15	3%
Sep-Nov (Fall)	0	0	0%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 32

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	10	10	7%
Jun-Aug (Summer)	180	120	5%
Sep-Nov (Fall)	10	10	2%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Southwest Region, Basin 32

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	10	0	0%	2%
2030	0	20	0	0%	5%
2040	0	30	0	0%	5%
2050	10	110	0	2%	9%
2060	20	180	0	3%	12%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 32

Months (Season)	Maximum 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

Southwest Region, Basin 32

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	20	180	0	3%	12%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	0	0	0%	0%
Moderately Expanded Conservation in M&I Water Use	20	150	0	3%	9%
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

Southwest Region, Basin 32

Reservoir Storage	Diversion
AF	AFY
100	300
500	1,300
1,000	2,600
2,500	5,600
5,000	8,300
Required Storage to Meet Growth in Demand (AF)	200
Required Storage to Meet Growth in Surface Water Demand (AF)	<100

Water Supply Options & Effectiveness

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

Demand Management

Moderately expanded permanent conservation activities in the Crop Irrigation sector could mitigate gaps and storage depletions. Temporary drought management could reduce surface water demand, largely from irrigation, and may mitigate gaps. Temporary drought management may not be needed for alluvial groundwater users, since aquifer storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

The Lugert-Altus Irrigation District in Basin 36 currently provides supplies to the basin, but is not expected to provide supplies to new irrigators in the future unless the District obtains additional water supplies. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Southwest Region: Port in Basin 34 and Mangum (Lower) in Basin 39. However, in light of the basin's groundwater resources and distance to other reliable surface water supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

Reservoir Use

New reservoir storage can increase the dependability of available surface water supplies and mitigate gaps or adverse effects of localized storage depletions. However, substantial permit issues must be resolved in order to construct new reservoirs. If permittable, the basin's entire growth in demand from 2010 to 2060 could be supplied by a new river diversion and a 200 AF reservoir at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions.

Increasing Reliance on Surface Water

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

Increasing Reliance on Groundwater

Increased reliance on alluvial groundwater may mitigate surface water gaps, but will increase storage depletions. Basin 32 has abundant groundwater resources in the Tillman Terrace aquifer. Based on the findings of a 2002 Oklahoma Water Resources Board Report, the recharge to the Tillman Terrace is less than predicted in the baseline analysis, which will result in larger storage depletions. However, any increases in storage depletions would be small in size relative to the volume of water stored in Basin 32's portion of the aquifer. Localized storage depletions may occur and adversely affect yields, water quality and/or pumping costs. 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.

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
Southwest Watershed Planning Region

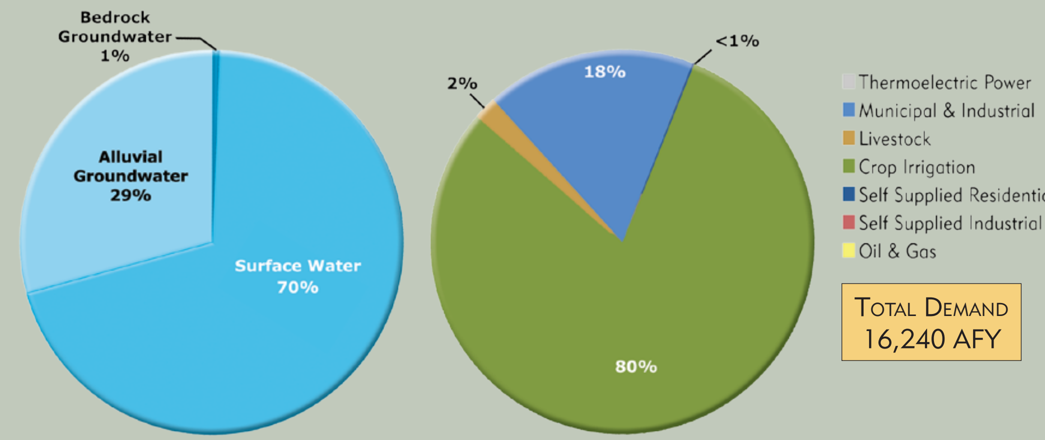
Basin 33

Basin 33 Summary

Synopsis

- Most water users are expected to continue to rely on surface water and alluvial groundwater supplies.
- Lugert-Altus Reservoir in Basin 36 currently provides supplies to the basin, primarily for irrigation purposes; however, the lake is fully utilized and growth of the Lugert-Altus Irrigation District is constrained by water availability.
- 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.
- 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 the adverse effects of alluvial groundwater storage depletions and reduce surface water gaps.
- Use of additional groundwater supplies and/or developing additional small reservoir storage could mitigate gaps. These supply sources could be used without major impacts to groundwater storage.

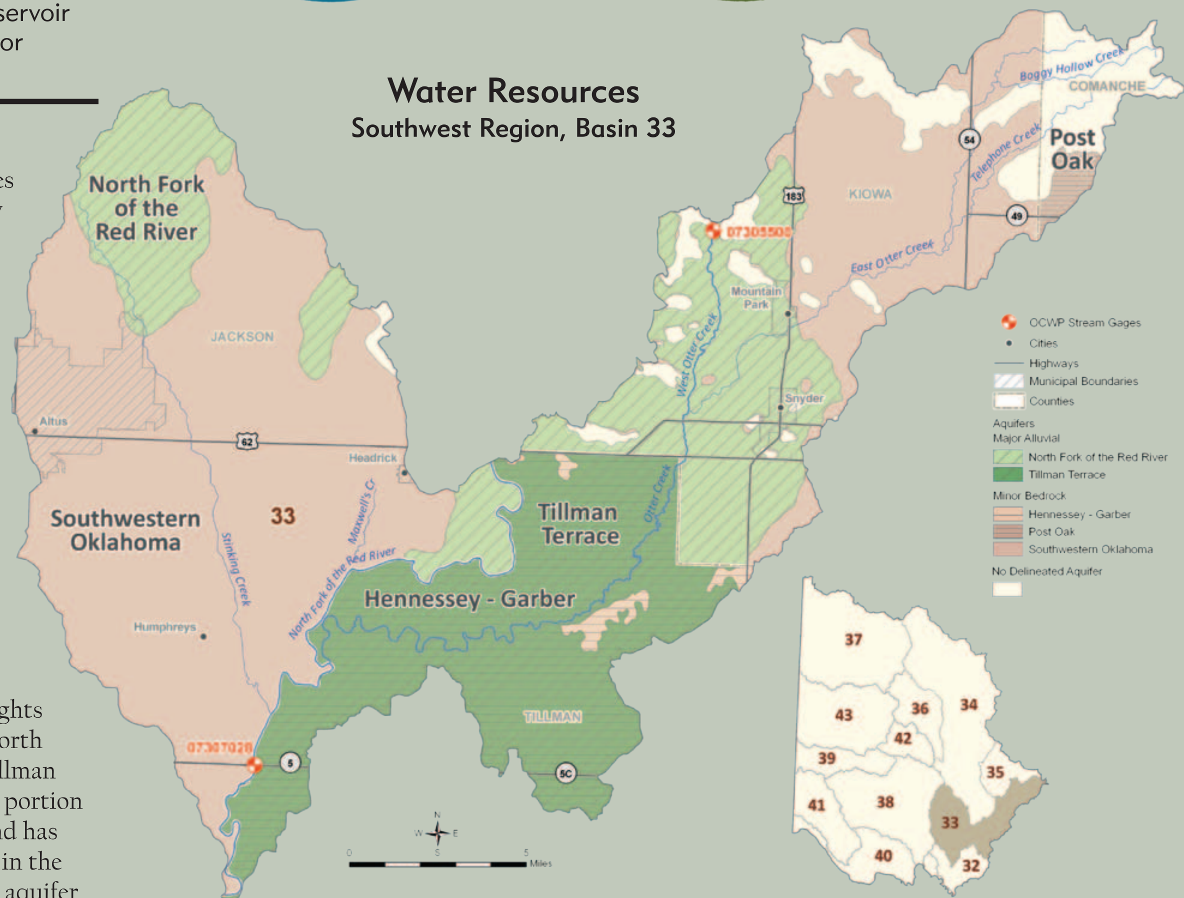
Current Demand by Source and Sector
Southwest Region, Basin 33



Basin 33 accounts for about 9% of the water demand in the Southwest Watershed Planning Region. About 80% of the demand is in the Crop Irrigation demand sector. Municipal and Industrial (18%) is the second-largest demand sector. Surface water satisfies about 70% of the total demand in the basin. Groundwater satisfies about 30% of the total demand (29% alluvial and 1% bedrock). The peak summer demand is 24.8 times the winter monthly demand, which is much more pronounced than the overall statewide pattern.

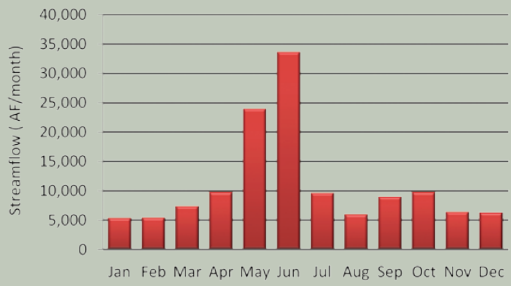
Lugert-Altus Reservoir, a Bureau of Reclamation project located in Basin 36 on the North Fork of the Red River, currently supplies much of the Crop Irrigation water demand in the western portion of Basin 33. The reservoir is fully allocated, with the majority of the water rights permitted to the Lugert-Altus Irrigation District. The District is not expected to provide supplies to new irrigators in the future unless additional water can be secured. Altus City Lake, located on a tributary to the North Fork of the Red River, currently provides water to the City of Altus. The water supply yield is unknown; therefore, the ability of this reservoir to provide future water supplies could not be evaluated. The median flow of the North Fork of the Red River near Tipton is typically greater than 5,000 AF/month. However, the river can have prolonged periods of low flow in any month of the year. The North Fork of the Red River is impaired for Agricultural use due to high levels of total dissolved solids (TDS) and chloride. Basin 33 currently has water available for new permits. However, surface water is expected to be fully allocated by 2020, limiting diversions to permitted amounts. Relative to other basins in the state, the surface water quality in Basin 33 is considered fair.

The majority of current groundwater rights are from the Tillman Terrace and the North Fork of the Red River aquifers. . The Tillman Terrace aquifer is located in the central portion of the basin (about 21% of the basin) and has over 310,000 AF of groundwater stored in the basin. The North Fork of the Red River aquifer



Median Historical Streamflow at the Basin Outlet

Southwest Region, Basin 33



Projected Water Demand

Southwest Region, Basin 33

is located in the basin's northwestern portion (about about20% of the basin) and has over 360,000 AF of groundwater stored in the basin. Minor bedrock aquifers are present in the basin, but are not widely used. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. High concentration of nitrates have been found in some well sites in the Tillman Terrace. Otherwise, there are no significant basin-wide groundwater quality issues.

The expected 2060 water demand of 18,090 AFY reflects a 1,850 AFY increase (11%) over the 2010 demand.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps may occur by 2020, while alluvial groundwater storage depletions may occur by 2030. Bedrock groundwater storage depletions were not analyzed, due to the minimal demand growth from this source. Surface water gaps are expected to be as high as 320 AFY and have a 12% probability of occurring in at least one month of the year by 2060. When surface water gaps occur, they are expected in the winter, spring, and summer, peaking in size in the summer. Alluvial groundwater storage depletions are expected to be up to 160 AFY, and have a 9% probability of occurring in at least one month of the year by 2060. 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 well yields, water quality, and/or pumping costs.

Options

Water users are expected to continue to rely on surface water supplies and major 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 demand sectors could mitigate gaps and storage depletions. Temporary drought management could reduce demand, largely from irrigation, and mitigate gaps. Temporary drought management may not be needed for alluvial groundwater users, since aquifer storage could continue to provide supplies during droughts.

The Lugert-Altus Irrigation District currently provides supplies to the basin, but is not expected to provide supplies to new irrigators in the future unless additional water supplies can be secured. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two

Water Supply Limitations

Southwest Region, Basin 33

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness

Southwest Region, Basin 33

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

potentially viable out-of-basin sites in the Southwest Region. However, in light of the basin's groundwater resources and distance to other reliable surface water supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

Increased reliance on groundwater use may mitigate surface water gaps, but will increase groundwater storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in Basin 33's portion of the North Fork of the Red River and Tillman Terrace aquifers.

New small reservoirs (less than 50 AF) could be used mitigate surface water gaps or adverse effects of localized storage depletions. Substantial permit issues must be resolved in order to construct larger reservoirs. However, if permittable, the basin's entire growth in demand from 2010 to 2060 could be supplied by a new river diversion and a 500 AF reservoir at the basin outlet.

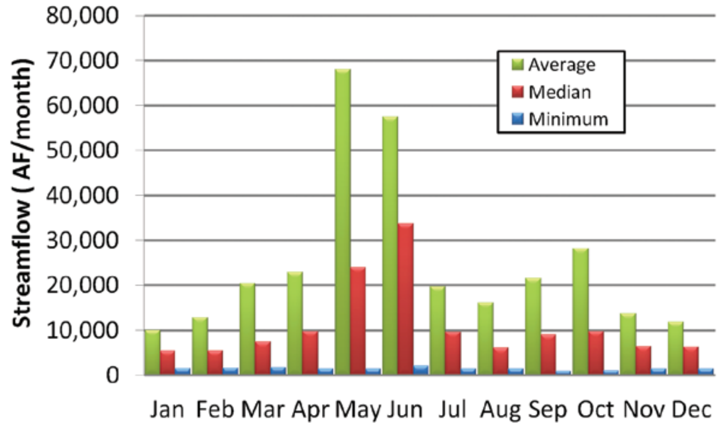
Increased reliance on groundwater use may mitigate surface water gaps, but will increase groundwater storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in Basin 33's portion of the North Fork of the Red River and Tillman Terrace aquifers.
Bedrock groundwater supplies are from minor aquifers; therefore, increased reliance on these supplies is not recommended without site-specific information.

Basin 33 Data & Analysis

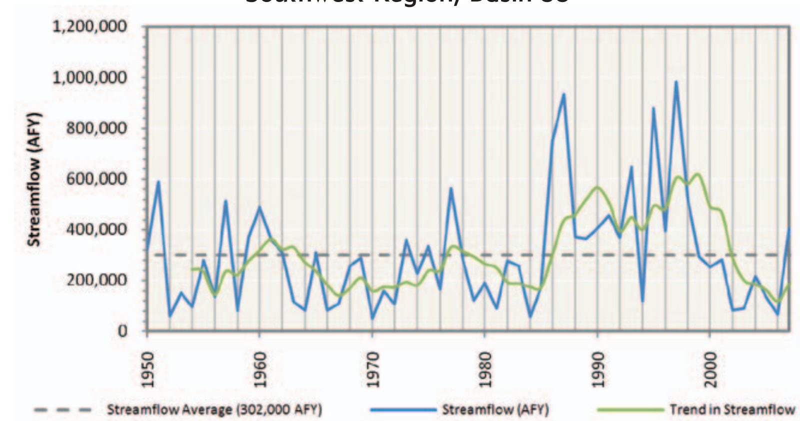
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The North Fork of the Red River near Tipton had a prolonged period of below-average streamflow from the mid 1960s to the mid 1970s, corresponding to a period of below-average precipitation. The mid 1980s to early 2000s had higher-than-average streamflow and precipitation, demonstrating the hydrologic variability in the basin.
- The median flow in the North Fork of the Red River near Tipton is at least 5,000 AF/month throughout the year and greater than 23,000 AF/month in May and June.. However, the river can have prolonged periods of low flow in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 33 is considered fair.
- Altus City Lake was built in 1940 for water supply and recreational purposes and has 2,500 AF of normal storage. The water supply yield is unknown; therefore the ability of this reservoir to provide future water supplies could not be evaluated.

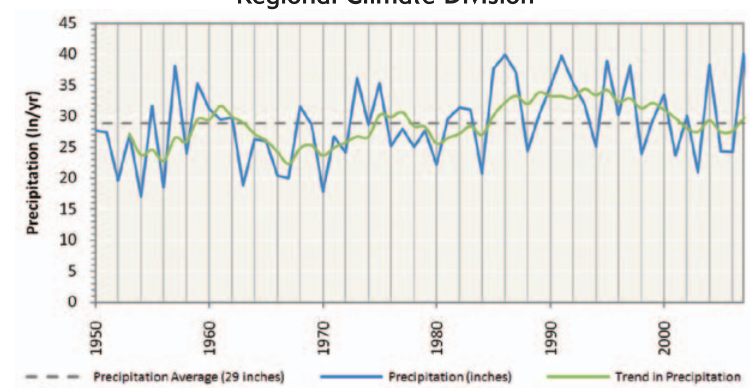
Monthly Historical Streamflow at the Basin Outlet
Southwest Region, Basin 33



Historical Streamflow at the Basin Outlet
Southwest Region, Basin 33



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)

Southwest Region, Basin 33

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
North Fork of the Red River	Alluvial	Major	20%	5,700	369,000	1.0	39,600
Tillman Terrace	Alluvial	Major	21%	13,800	312,000	1.0	29,600
Hennessey-Garber	Bedrock	Minor	21%	100	196,000	1.6	71,600
Southwestern Oklahoma	Bedrock	Minor	70%	0	413,000	temporary 2.0	305,100
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	500	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	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 Tillman Terrace aquifer.
- The Tillman Terrace aquifer underlies about 21% of the basin and has 312,000 AF of storage. The North Fork of the Red River aquifer underlies about about 20% of the basin and has 369,000 AF of storage. There are also water rights in the Hennessey-Garber aquifer and from non-delineated groundwater sources.
- High concentrations of nitrates have been found in some well fields in the Tillman Terrace; consequently, site specific information should also be evaluated in this aquifer before drilling wells for public water supply purposes. Otherwise, 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.

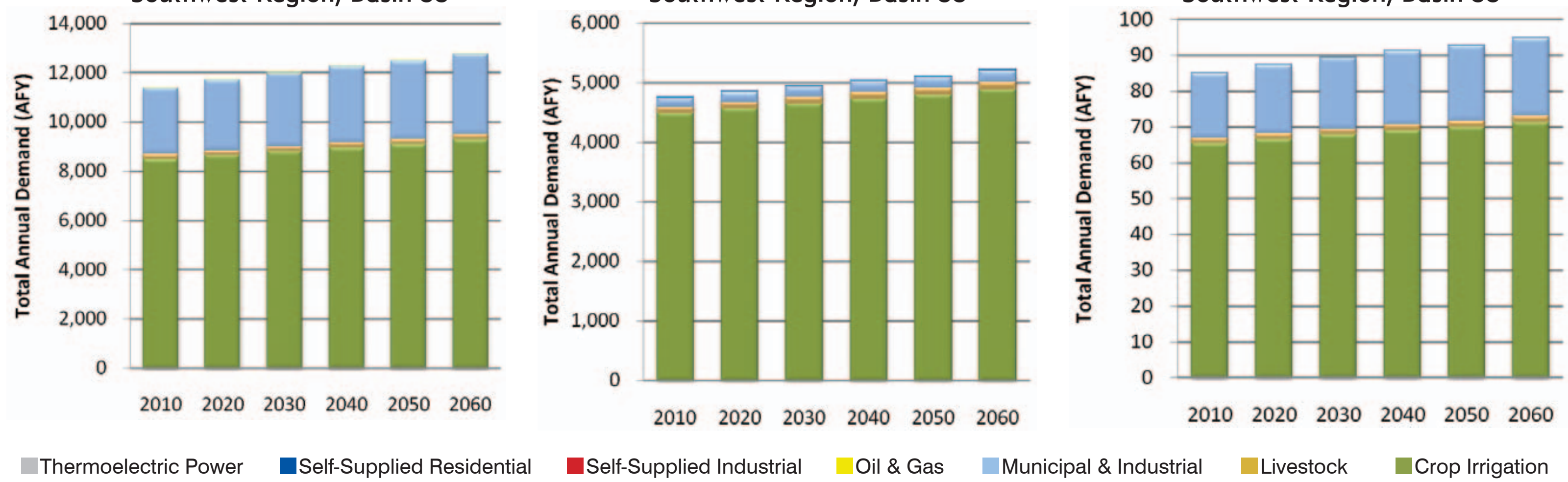
Water Demand

- The water needs of Basin 33 account for about 9% of the demand in the Southwest Watershed Planning Region. The demand is expected to increase by 11% (1,850 AF) from 2010 to 2060. The majority of the demand and growth in demand during this period will be from the Crop Irrigation demand sector.
- Surface water and out-of-basin supplies are used to meet 70% of total demand in the basin and will increase by 12% (1,370 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use during this period will be from the Crop Irrigation demand sector.
- Alluvial groundwater is used to meet 29% of total demand in the basin. Alluvial groundwater use will increase by 10% (470 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use during this period will be from the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet 1% of total demand in the basin. Bedrock groundwater use will increase by 12% (10 AFY) from 2010 to 2060. This increase in bedrock groundwater demand is minimal at a basin-scale.

Surface Water Demand by Sector
Southwest Region, Basin 33

Alluvial Groundwater Demand by Sector
Southwest Region, Basin 33

Bedrock Groundwater Demand by Sector
Southwest Region, Basin 33

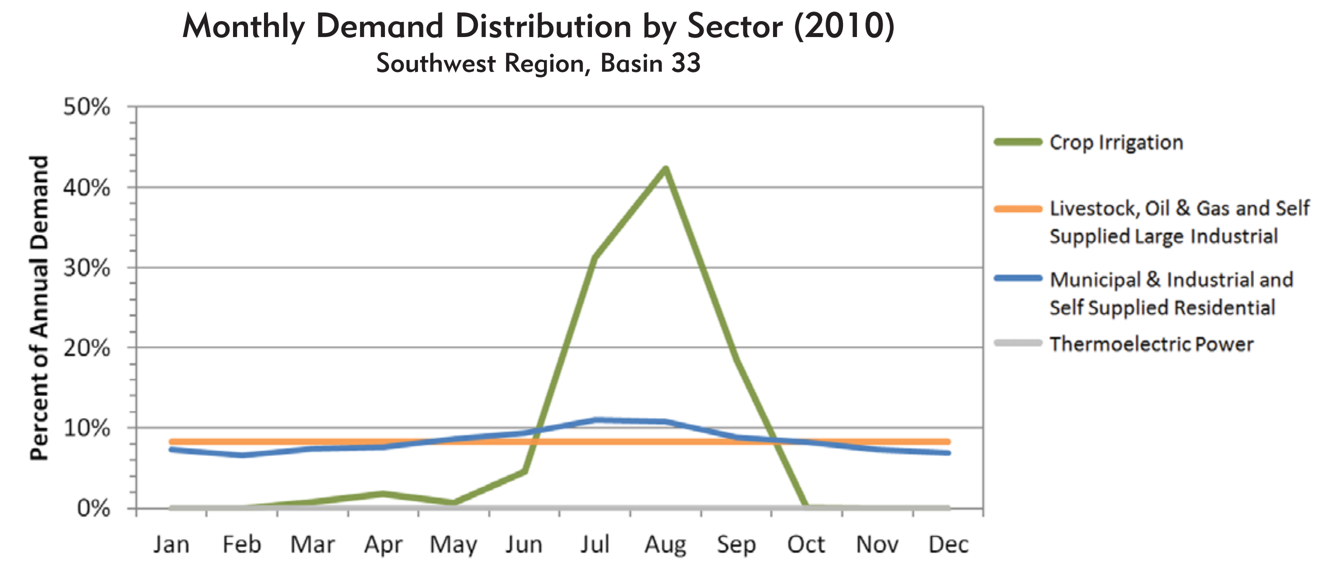


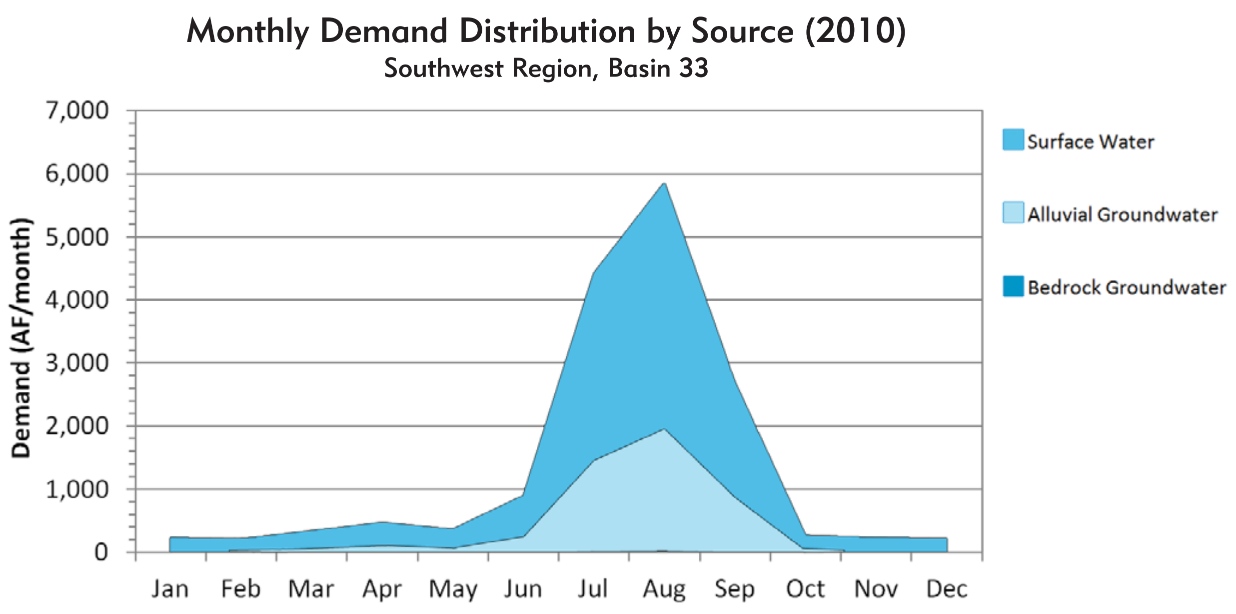
Total Demand by Sector
Southwest Region, Basin 33

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	13,050	300	2,870	0	0	20	0	16,240
2020	13,290	310	3,040	0	0	20	0	16,660
2030	13,530	330	3,170	0	0	30	0	17,060
2040	13,760	340	3,280	0	0	30	0	17,410
2050	13,950	350	3,370	10	0	30	0	17,710
2060	14,240	360	3,450	10	0	30	0	18,090

Notes & Assumptions

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





Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 50% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 33 is 24.8 times the monthly winter demand, which is much more pronounced than the overall statewide pattern. Surface water use in the peak summer month is 18.3 times the monthly winter use. The peak summer month alluvial groundwater use is 89.2 times the monthly winter use. The peak summer month bedrock groundwater demand is 20.6 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps may occur by 2020, while alluvial groundwater storage depletions may occur by 2030. Bedrock groundwater storage depletions are not expected, due to the minimal demand growth from this source.
- Surface water gaps in Basin 33 may occur in winter, spring, and summer, peaking in size during the summer. Surface water gaps in 2060 will be up to 7% (320 AF/month) of the surface water demand in the peak summer month, and as much as 4% (10 AF/month) of the peak winter month surface water demand. There will be a 12% probability of gaps occurring in at least one month of the year by 2060.
- Alluvial groundwater storage depletions in Basin 33 may occur in spring and summer. Alluvial groundwater storage depletions in 2060 will be up to 8% (180 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 9% (10 AF/month) of the peak spring month alluvial groundwater demand. There will be a 9% probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2060.
- Projected annual storage depletions are minimal relative to the amount of water in storage in major aquifers in the basin. However, localized storage depletions may adversely impact yields, water quality and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)

Southwest Region, Basin 33

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	10	10	2%
Mar-May (Spring)	20	20	7%
Jun-Aug (Summer)	320	80	5%
Sep-Nov (Fall)	0	0	0%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 33

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	10	10	5%
Jun-Aug (Summer)	160	40	5%
Sep-Nov (Fall)	0	0	0%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Southwest Region, Basin 33

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	10	0	0	2%	0%
2030	30	10	0	7%	2%
2040	40	10	0	7%	2%
2050	150	80	0	9%	3%
2060	320	160	0	12%	9%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 33

Months (Season)	Maximum 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 the largest amount for any one month in the 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
Southwest Region, Basin 33

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	320	160	0	12%	9%
Moderately Expanded Conservation in Crop Irrigation Water Use	10	0	0	3%	0%
Moderately Expanded Conservation in M&I Water Use	270	130	0	5%	3%
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
Southwest Region, Basin 33

Reservoir Storage	Diversion
AF	AFY
100	400
500	1,700
1,000	3,300
2,500	8,000
5,000	11,400
Required Storage to Meet Growth in Demand (AF)	500
Required Storage to Meet Growth in Surface Water Demand (AF)	400

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 and Crop Irrigation demand sectors could mitigate gaps and storage depletions. Temporary drought management could reduce demand, largely from irrigation, and may mitigate gaps. Temporary drought management may not be needed for alluvial groundwater users, since aquifer storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

(Potentially Effective) The Lugert-Altus Irrigation District in Basin 36 currently provides supplies to the basin, but is not expected to provide supplies to new irrigators in the future unless supplemental sources of water are secured. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Southwest Region: Port in Basin 34 and Mangum (Lower) in Basin 39. However, in light of the basin's groundwater resources and distance to other reliable surface water supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

Reservoir Use

(Potentially Effective) New small reservoirs (less than 50 AF) could be used to mitigate surface water gaps or adverse effects of localized storage depletions. Substantial permit issues must be resolved in order to construct larger reservoirs. If permittable, the basin's entire growth in demand from 2010 to 2060 could be supplied by a new river diversion and 500 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions.

Increasing Reliance on Surface Water

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

Increasing Reliance on Groundwater

(Likely Ineffective) Increased reliance on groundwater use may mitigate surface water gaps, but will increase groundwater storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in Basin 33's portion of the North Fork of the Red River and Tillman Terrace aquifers. A shift from surface water to alluvial groundwater can 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. Bedrock groundwater supplies are from minor aquifers; therefore, increased reliance on these supplies is not recommended without site-specific information.

Notes & Assumptions

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

Oklahoma Comprehensive Water Plan

Data & Analysis
Southwest Watershed Planning Region

Basin 34

Basin 34 Summary

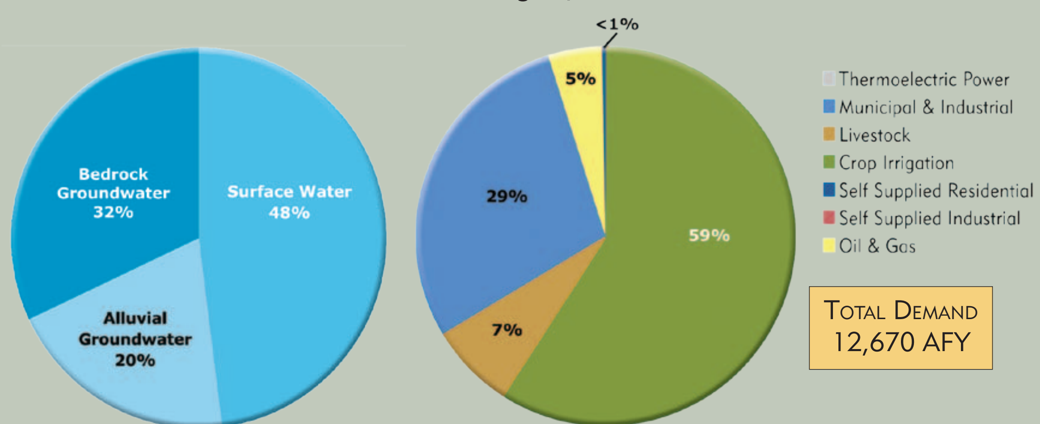
Synopsis

- Water users are expected to continue to rely on all types of supply sources (surface water, alluvial groundwater, and bedrock groundwater).
- 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.
- Surface water in the basin is fully allocated.
- Surface water quality may limit supplies for some users.
- By 2020, there is a moderate probability of surface water gaps from increased demand 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 reduce surface water gaps and the adverse effects of alluvial groundwater storage depletions.
- Use of additional groundwater supplies and/or developing additional small reservoir storage could mitigate surface water gaps. These supply sources could be used without major impacts to groundwater storage.
- Basin 34 has been identified as a water availability "hot spot" due to surface water and alluvial groundwater availability issues. (See "Regional and Statewide Opportunities and Solutions," *2012 OCWP Executive Report*.)

Basin 34 accounts for about 7% of the water demand in the Southwest Watershed Planning Region. About 59% of the demand is from the Crop Irrigation demand sector. Municipal and Industrial (29%) is the second-largest demand sector. The peak summer month demand in Basin 31 is 9.2 times the winter demand, which is more pronounced than the overall statewide pattern. Surface water satisfies about 48% of the total demand

Current Demand by Source and Sector

Southwest Region, Basin 34

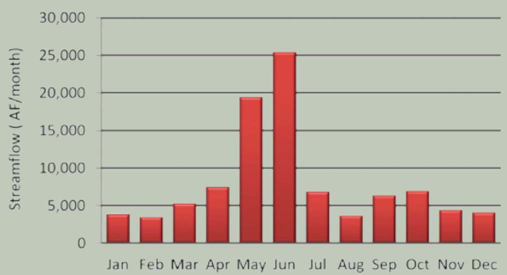


Water Resources

Southwest Region, Basin 34

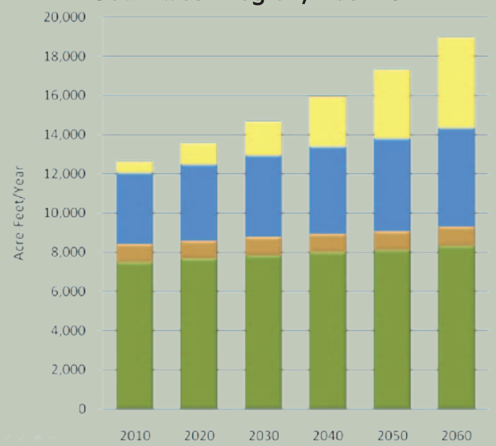
Median Historical Streamflow at the Basin Outlet

Southwest Region, Basin 34



Projected Water Demand

Southwest Region, Basin 34



in the basin. Groundwater satisfies about 52% of the total demand (32% bedrock and 20% alluvial).

There are two major reservoirs in the basin: Elk City Lake and Rocky Lake. Rocky Lake was built by the City of Hobart in 1933 for water supply and recreation. Elk City Lake was built in 1970 for flood control for Elk City and recreation. The water supply yields of these reservoirs are unknown; therefore, their ability to provide future water supplies could not be evaluated. Historically, the flows of the North Fork of the Red River near Headrick are greater than 3,500 AF/month throughout the year. However, the river can have prolonged periods of low flow in any month of the year.

Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts. Relative to other basins in the state, the surface water quality in Basin 34 is considered poor. The North Fork of the Red River and several of its tributaries in Basin 34 are impaired for Agricultural use due to high levels of total dissolved solids (TDS), chloride, and sulfate. Rocky Lake is impaired for Public and Private Water Supply due to high levels of chlorophyll-a. However, individual lakes and streams may have acceptable water quality.

The majority of groundwater rights are in the North Fork of the Red River and Elk City aquifers, which underlie the central and northwest portions of the basin (about a third of the basin area). The Elk City aquifer has over 1.1 million AF of ground storage in Basin 34 and receives an estimated 21,000 AFY of recharge from the basin. The North Fork of the Red River aquifer has almost 700,000 AF of groundwater storage in the basin. To a lesser extent, there are groundwater rights in the Western Oklahoma and non-delineated aquifers in the basin. Site-specific information on the reliability of these minor aquifers should be considered before large scale use. 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.

The expected 2060 water demand of 19,010 AFY in Basin 34 reflects a 6,340 AFY increase (50%) over the 2010 demand.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and alluvial groundwater storage depletions may occur by 2020. The recharge to the Elk City aquifer is expected to be sufficient to meet future bedrock groundwater demands. Surface water gaps will be up to 2,500 AFY and have a 64% probability of occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions will be up to 470 AFY, and have a 64% probability of occurring in at least one month of the year by 2060. Surface water gaps and alluvial groundwater storage depletions are expected to occur throughout the year and peak in size during the summer. Alluvial groundwater storage depletions are minimal compared to the groundwater storage in this basin. However, localized storage depletions may adversely impact users' yields, water quality, and/or pumping costs.

Water Supply Limitations

Southwest Region, Basin 34

Source	Limitation
Surface Water	Significant
Alluvial Groundwater	Potential
Bedrock Groundwater	Minimal

Minimal Potential Significant

Water Supply Option Effectiveness

Southwest Region, Basin 34

Option	Effectiveness
Demand Management	Potentially 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

Options

Water supply options were evaluated to assess potential ways of providing dependable long-range water supplies for Basin 34. 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.

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce gaps and storage depletions. Temporary drought management activities will likely be ineffective since gaps have a moderate probability of occurring and aquifer storage could continue to provide supplies during droughts.

Out-of-basin supplies could also mitigate gaps and storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified one potentially viable out-of-basin site in the Southwest Region. In light of the basin's groundwater resources and the distance to dependable surface water supplies, out-of-basin supplies may not be cost-effective for users in the basin.

New small reservoirs could increase the dependability of available surface water supplies and mitigate gaps in the basin. The OCWP *Reservoir Viability Study* identified one potential site in the basin. However, substantial permit issues must be resolved in order to construct new reservoir storage of significant size.

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

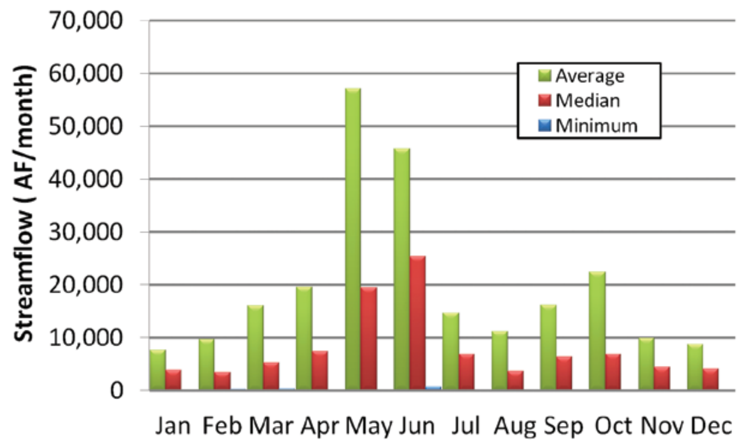
Increased reliance on either alluvial or bedrock groundwater use may mitigate surface water gaps, but will increase storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in major aquifers in the basin. However, these aquifers only underlie about 40% of the basin.

Basin 34 Data & Analysis

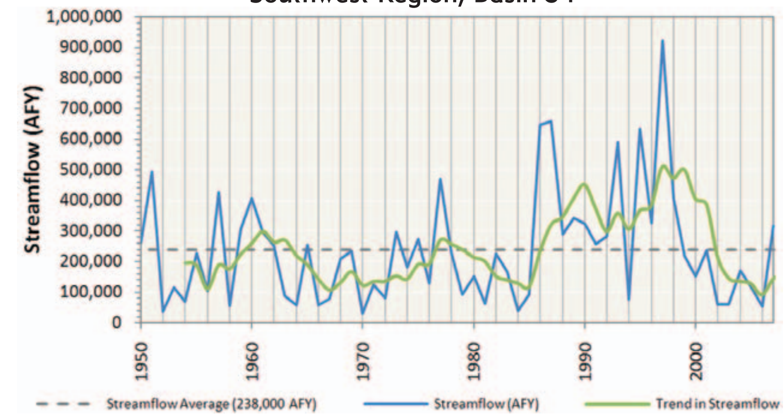
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The North Fork of the Red River near Headrick had a prolonged period of below average flow from the early 1960s to the mid 1970s, corresponding to a period of below-average precipitation. From the late 1980s to early 2000s the basin went through a prolonged period of above-average streamflow, demonstrating hydrologic variability in the basin.
- The median flow in the North Fork Red River near Headrick is greater than 3,500 AF/month throughout the year and greater than 19,000 AF/month in May and June. Historically, periods of low to zero flow have occurred in the basin in each month of the year.
- Relative to other basins in the state, the surface water quality in Basin 34 is considered poor. However, individual lakes and streams may have acceptable water quality.
- Rocky Lake provides flood control and recreation for the City of Hobart, and Elk City Lake provides water supply and recreation for Elk City. The water supply yields of these lakes are unknown; therefore, the ability of these reservoirs to provide future water supplies could not be evaluated.

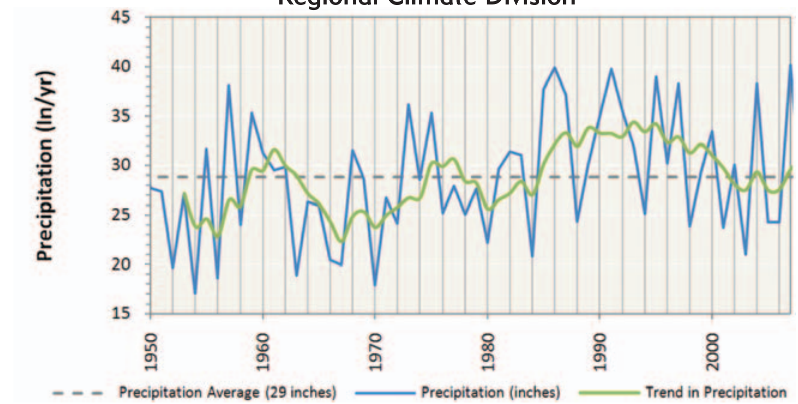
Monthly Historical Streamflow at the Basin Outlet
Southwest Region, Basin 34



Historical Streamflow at the Basin Outlet
Southwest Region, Basin 34



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)

Southwest Region, Basin 34

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
North Fork of the Red River	Alluvial	Major	16%	4,100	695,000	1.0	76,900
Elk City	Bedrock	Major	17%	7,500	1,121,000	1.0	78,000
Southwestern Oklahoma	Bedrock	Minor	45%	0	620,000	temporary 2.0	459,700
Western Oklahoma	Bedrock	Minor	17%	200	314,706	temporary 2.0	179,000
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	1,400	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	500	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

- For Basin 34, groundwater rights total 7,500 AFY in the Elk City aquifer, which underlies 17% of the basin, and 4,100 AFY in the North Fork of the Red River aquifer, which underlies 16% of the basin. There are also water rights in minor aquifers and non-delineated groundwater sources. The Elk City aquifer has more than 1.1 million AF of storage in the basin and receives an estimated 21,000 AFY of recharge. The North Fork of the Red River aquifer has 695,000 AF of storage in the basin.
- There are no significant groundwater quality issues in the basin.

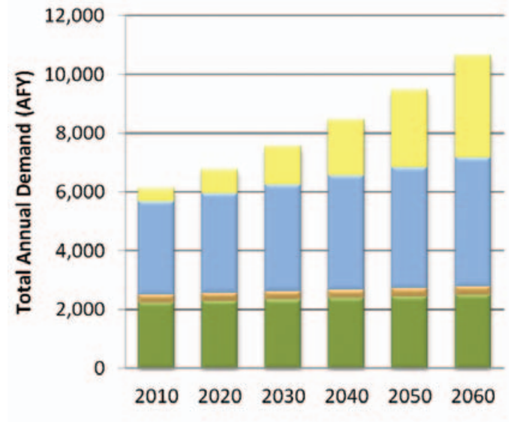
Notes & Assumptions

- 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.

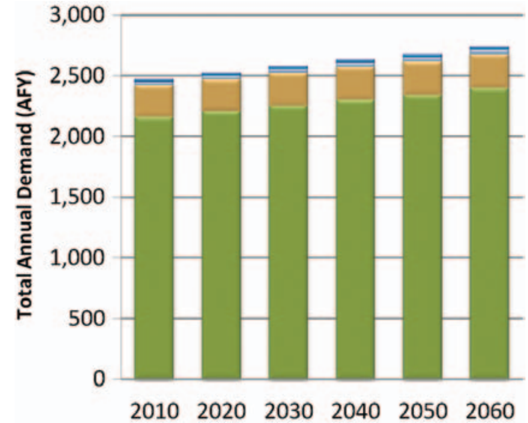
Water Demand

- The water needs of Basin 34 account for about 7% of the total demand in the Southwest Watershed Planning Region and will increase by 50% (6,340 AFY) from 2010 to 2060. The largest demand during this period is currently from the Crop Irrigation demand sector. However, the largest growth in demand is projected to be from the Oil and Gas demand sector.
- Surface water is used to meet 48% of the total demand in 2010 and is expected to increase to 38% of the total demand by 2060. Surface water use will increase by 74% (4,520 AFY) from 2010 to 2060. Oil and Gas will surpass Crop Irrigation as the largest demand sector by 2050.
- Alluvial groundwater is used to meet 20% of the total demand in 2010 and is expected to increase to 32% of total demand by 2060. Alluvial groundwater use will increase by 11% (270 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 32% of the total demand in 2010. Bedrock groundwater use will increase by 38% (1,550 AFY) from 2010 to 2060. The majority of bedrock groundwater use is currently in the Crop Irrigation demand sector. However, the largest growth in bedrock groundwater use will be in the Oil and Gas demand sector.

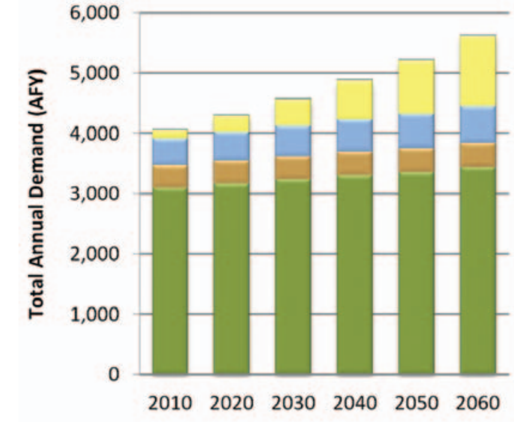
Surface Water Demand by Sector
Southwest Region, Basin 34



Alluvial Groundwater Demand by Sector
Southwest Region, Basin 34



Bedrock Groundwater Demand by Sector
Southwest Region, Basin 34



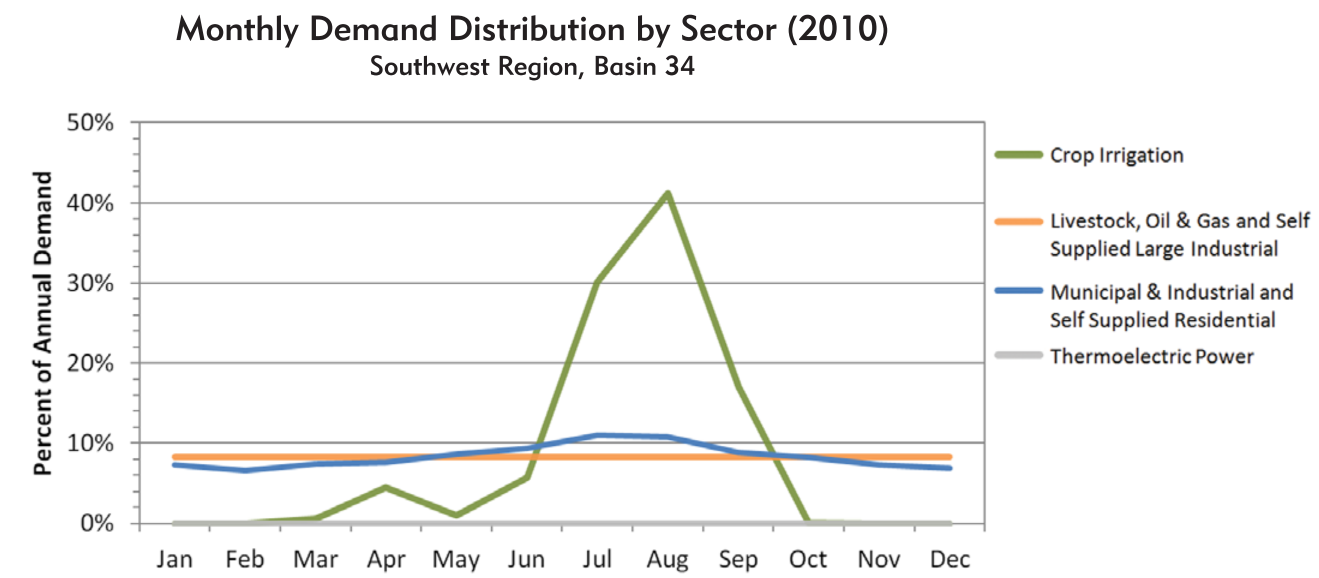
Thermoelectric Power | Self-Supplied Residential | Self-Supplied Industrial | Oil & Gas | Municipal & Industrial | Livestock | Crop Irrigation

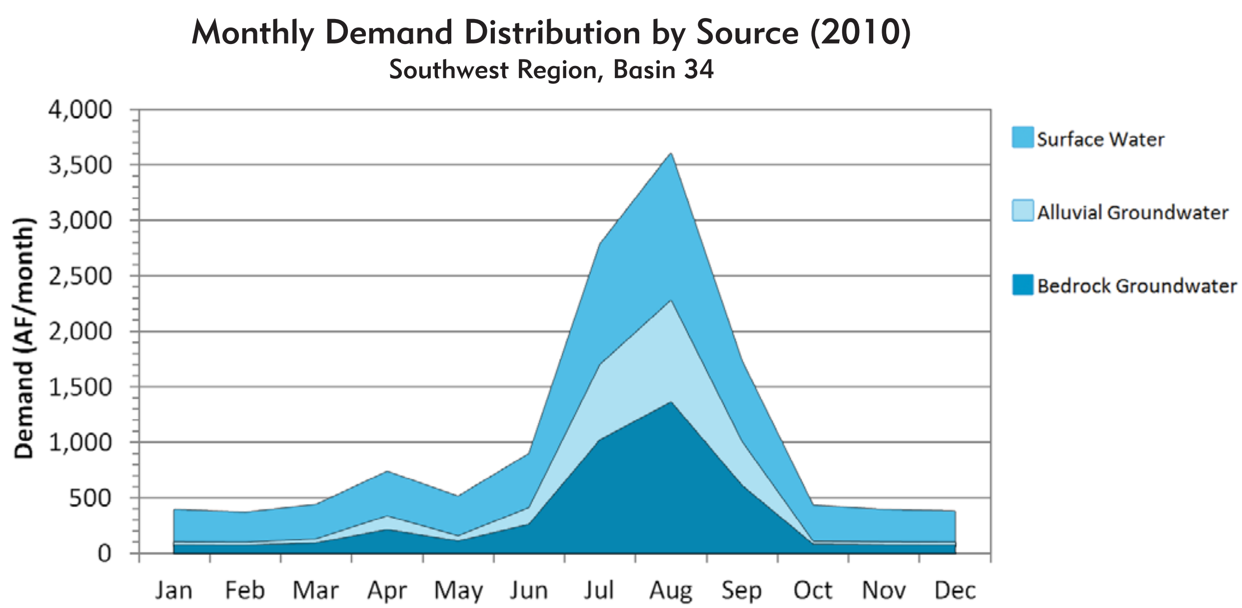
Total Demand by Sector
Southwest Region, Basin 34

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	7,490	920	3,640	590	0	30	0	12,670
2020	7,660	930	3,900	1,090	0	30	0	13,610
2030	7,830	940	4,180	1,750	0	30	0	14,730
2040	8,000	950	4,450	2,560	0	30	0	15,990
2050	8,120	960	4,740	3,530	0	30	0	17,380
2060	8,330	970	5,040	4,640	0	30	0	19,010

Notes & Assumptions

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





Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use about 50% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 34 is 9.2 times the monthly winter demand, which is slightly more pronounced than the overall statewide pattern. The ratio of surface water use in the peak summer month relative to monthly winter use is 4.6. The peak summer month alluvial groundwater demand is 35.7 times the monthly winter demand. The peak summer month bedrock groundwater demand is 17.9 times the monthly winter demand.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and alluvial groundwater storage depletions are projected to occur by 2020. Bedrock groundwater use is not expected to exceed the recharge to the Elk City aquifer.
- Surface water gaps in Basin 34 may occur throughout the year, peaking in size during the summer. Surface water gaps in 2060 will be up to 16% (290 AF/month) of the surface water demand in the peak summer month, and as high as 35% (220 AF/month) of the peak winter month's surface water demand. By 2060, there will be a 64% probability of gaps occurring in at least one month of the year. Surface water gaps are most likely to occur during winter months.
- Alluvial groundwater storage depletions in Basin 34 may occur throughout the year, peaking in size during the summer. The peak summer month alluvial groundwater storage depletions in 2060 will be up to 15% (150 AF/month) of the alluvial groundwater demand, and as high as 33% (10 AF/month) of the peak winter month's alluvial groundwater demand. By 2060, there will be a 64% probability of storage depletions occurring in at least one month of the year. Alluvial groundwater storage depletions are most likely to occur during winter months.
- Alluvial groundwater storage depletions are minimal compared to the groundwater storage in this basin. However, localized storage depletions may adversely impact users' yields, water quality, or pumping costs.

Surface Water Gaps by Season (2060 Demand)

Southwest Region, Basin 34

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	220	210	52%
Mar-May (Spring)	230	210	33%
Jun-Aug (Summer)	290	265	33%
Sep-Nov (Fall)	230	225	21%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 34

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	10	10	45%
Mar-May (Spring)	40	15	31%
Jun-Aug (Summer)	150	125	33%
Sep-Nov (Fall)	80	20	21%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Southwest Region, Basin 34

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	190	50	0	53%	28%
2030	580	140	0	53%	34%
2040	1,140	280	0	55%	55%
2050	1,750	380	0	59%	59%
2060	2,500	470	0	64%	64%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 34

Months (Season)	Maximum 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 the largest amount for any one month in the 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

Southwest Region, Basin 34

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	2,500	470	0	64%	64%
Moderately Expanded Conservation in Crop Irrigation Water Use	2,050	270	0	59%	57%
Moderately Expanded Conservation in M&I Water Use	2,050	430	0	64%	62%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	1,600	210	0	57%	55%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	1,290	120	0	53%	52%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Southwest Region, Basin 34

Reservoir Size	Diversion
AF	AFY
100	1,300
500	2,100
1,000	2,800
2,500	4,700
5,000	7,200
Required Storage to Meet Growth in Demand (AF)	4,200
Required Storage to Meet Growth in Surface Water Demand (AF)	2,300

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 gaps and alluvial storage depletions by about 36% and about 55%, respectively. Temporary drought management activities will likely be ineffective since gaps have a moderate probability of occurring and aquifer storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

Out-of-basin supplies could be developed to supplement the basin's supplies and mitigate gaps and storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified one potentially viable out-of-basin site in the Southwest Region: Mangum (Lower) in Basin 39. However, due to the distance to reliable surface water supplies, out-of-basin supplies may not be cost-effective for some users.

Reservoir Use

New small reservoirs (less than 50 AF) could be used to meet the demand of surface water users or groundwater users experiencing adverse affects of localized storage depletions. The OCWP *Reservoir Viability Study* identified Port Reservoir as a potentially viable site in the basin that could be used as a source of in-basin and regional supply. However, substantial permit issues must be resolved in order to construct larger reservoirs. If permittable, the basin's entire growth in demand from 2010 to 2060 could be supplied by a new river diversion and 4,200 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions.

Increasing Reliance on Surface Water

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

Increasing Reliance on Groundwater

Increased reliance on either alluvial or bedrock groundwater use may mitigate surface water gaps, but will increase storage depletions. Any increases in groundwater storage depletions would be minimal relative to the volume of water in alluvial aquifer storage in the basin. A shift from surface water to alluvial groundwater could potentially decrease the amount of surface water gaps, but may not decrease the probability of surface water gaps due to the interconnection between the supply sources.

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
Southwest Watershed Planning Region

Basin 35

Basin 35 Summary

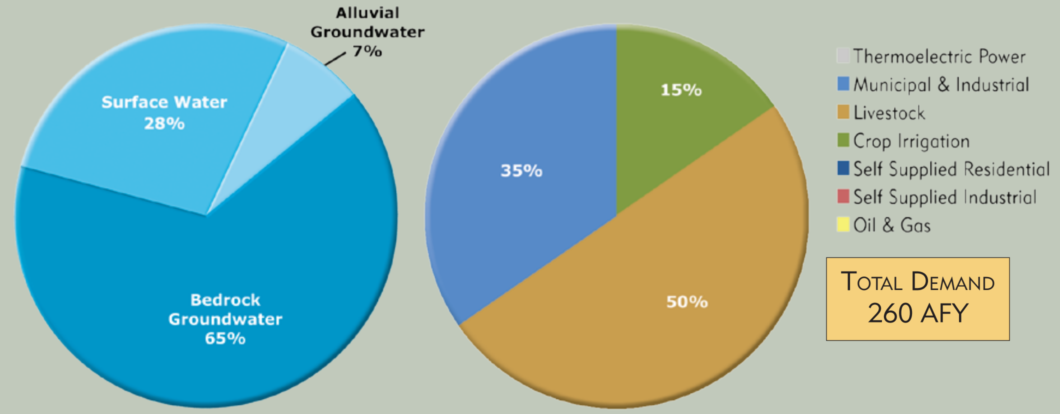
Synopsis

- Water users are expected to continue to rely on bedrock groundwater and surface water supplies.
- Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts.
- Water quality is a potential concern for surface water users.
- Basin 35 is expected to have sufficient water resources to meet the basin's growth in demand from 2010 to 2060.
- No water supply options were evaluated, since surface water gaps and groundwater storage depletions are not expected through 2060.

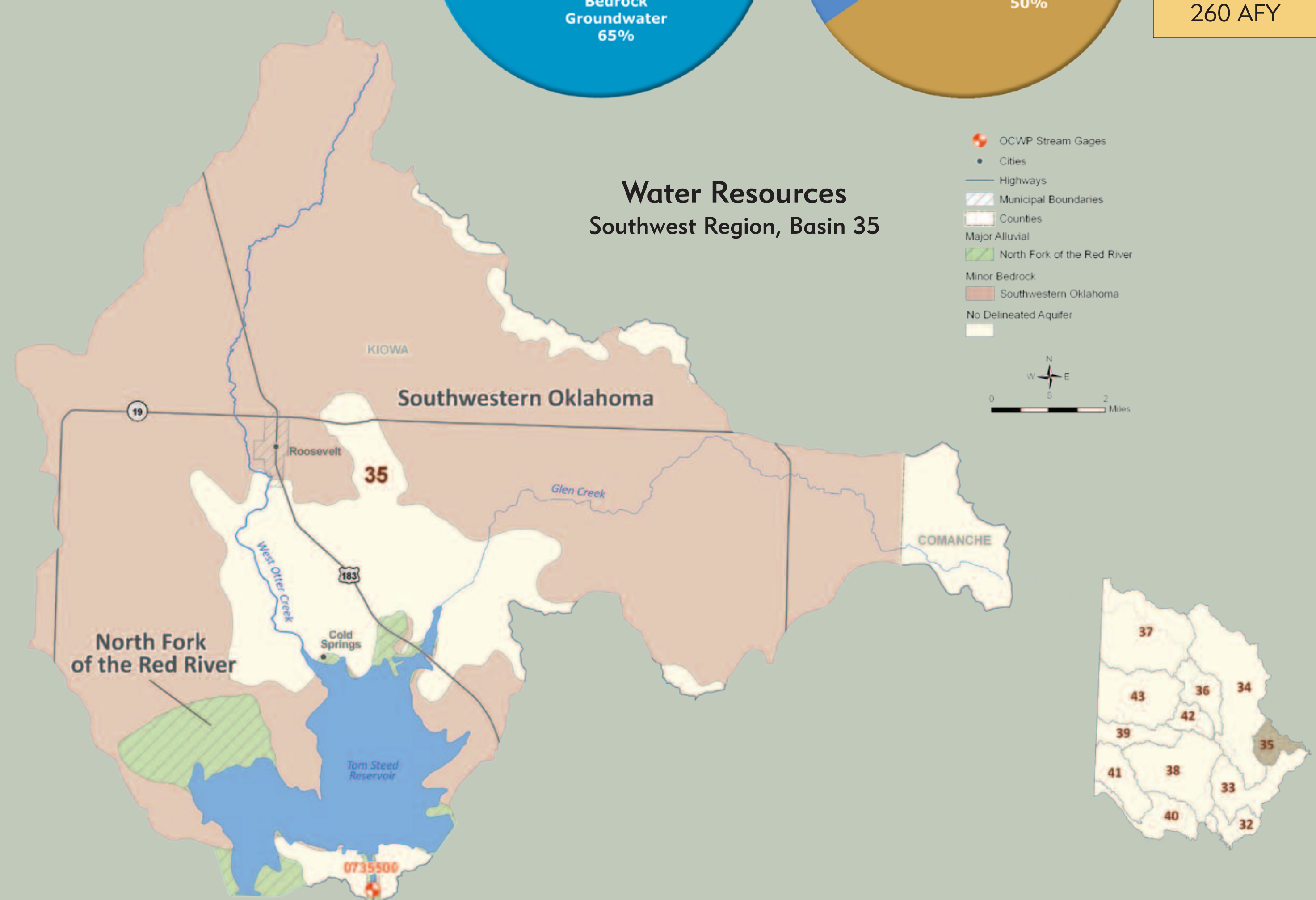
Basin 35 accounts for less than 1% of the water demand in the Southwest Watershed Planning Region. About 50% of the demand is from the Livestock demand sector. Municipal and Industrial (35%) is the second-largest demand sector. Surface water satisfies about 28% of the total demand in the basin. Groundwater satisfies about 72% of the total demand (65% bedrock and 7% alluvial). The peak summer demand is 2 times the winter monthly demand, which is similar to the overall statewide average.

Tom Steed Reservoir, located at the basin outlet, impounds West Otter Creek and supplies out-of-basin to the Mountain Park Master Conservancy Districts member cities. The reservoir supplies a dependable yield of around 16,000 AFY and is expected to provide additional water supplies to its users in the future. Tom Steed does not typically release flow to the creek, except in May and June or during wet periods. Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts. Relative to other basins in the state, the surface water quality in Basin 35 is considered poor. However, individual lakes and streams may have acceptable water quality. Tom Steed is impaired for Public and Private Water Supply use due to high levels of chlorophyll-a.

Current Demand by Source and Sector
Southwest Region, Basin 35

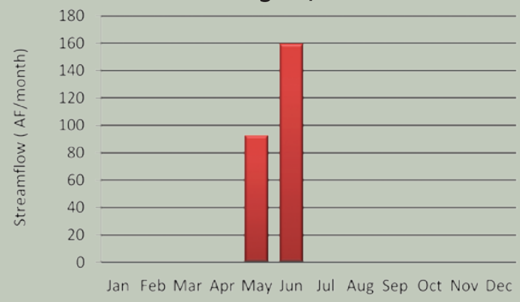


Water Resources
Southwest Region, Basin 35



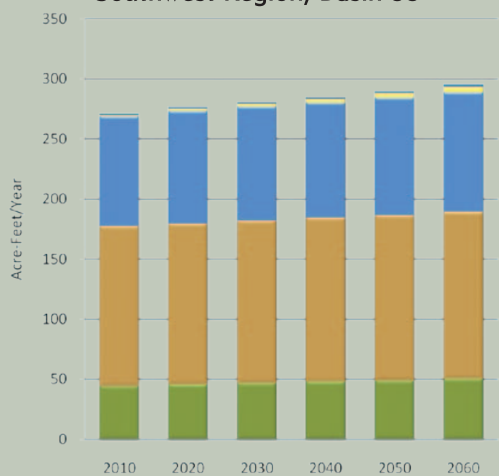
Median Historical Streamflow at the Basin Outlet

Southwest Region, Basin 35



Projected Water Demand

Southwest Region, Basin 35



Groundwater rights in Basin 35 are small in size relative to other basins in the Southwest Region. The majority of groundwater rights are in the Southwestern Oklahoma minor aquifer, which underlies 80% of the basin. Site-specific information on the reliability of minor aquifers should be considered before large scale use. There are also water rights in the North Fork of the Red River aquifer. However, this aquifer only underlies about 10% of 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.

Water Supply Limitations

Southwest Region, Basin 35

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness

Southwest Region, Basin 35

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

The expected increase in water demand from 2010 to 2060 is very small, increasing from 260 AFY to 290 AFY. The demand and growth in demand from 2010 to 2060 will be in the Crop Irrigation, Municipal and Industrial, and Livestock demand sectors.

Gaps & Depletions

Basin 35 has minimal growth in demand on a basin scale; therefore surface water gaps and groundwater storage depletions were not analyzed.

Options

Basin 35 water users are expected to continue to use current supply sources. No water supply options were evaluated, since surface water gaps and groundwater storage depletions were not expected through 2060.

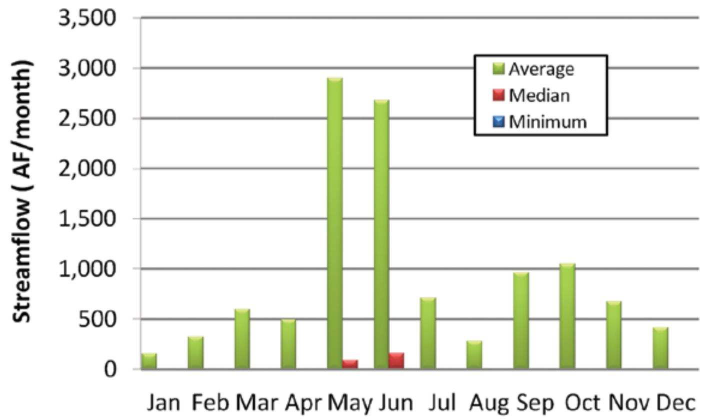
Basin 35 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The West Otter Creek at Snyder Lake, near Mountain Park, Oklahoma, had a prolonged period of below-average streamflow from the late 1990s to the mid 2000s. From the mid 1980s to mid 1990s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating the hydrologic variability in the basin.
- The median flow released from Tom Steed Reservoir to West Otter Creek is very low to zero throughout the year, except in May and June. However, during years of higher flows, substantial releases from the reservoir can occur in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 35 is considered poor. However, individual lakes and streams may have acceptable water quality.
- Tom Steed Reservoir, which is located at the basin outlet, supplies the Mountain Park Master Conservancy District, which provides out-of-basin water to Altus, Frederick and Snyder. The reservoir supplies a dependable yield of 16,000 AFY and is expected to provide additional water supplies to meet its users future needs.

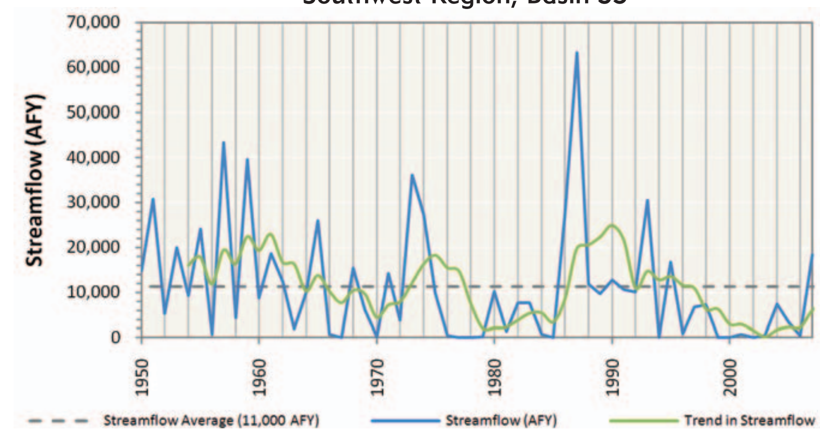
Monthly Historical Streamflow at the Basin Outlet

Southwest Region, Basin 35



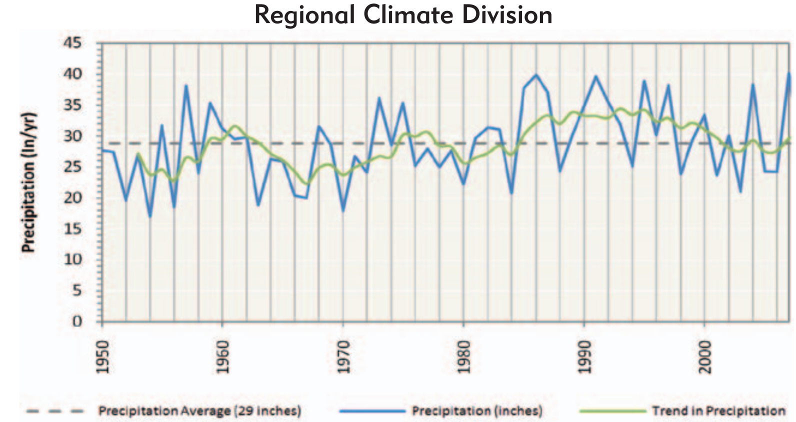
Historical Streamflow at the Basin Outlet

Southwest Region, Basin 35



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)

Southwest Region, Basin 35

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
North Fork of the Red River	Alluvial	Major	11%	100	72,000	1.0	6,300
Southwestern Oklahoma	Bedrock	Minor	80%	600	172,000	temporary 2.0	127,400
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

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

Groundwater Resources

- The majority of groundwater rights in the basin are from the Southwestern Oklahoma aquifer.
- For Basin 35, groundwater rights total 600 AFY in the Southwestern Oklahoma aquifer, which underlies 80% of the basin, and 100 AFY in the North Fork of the Red River aquifer, which underlies 11% of the basin.
- There are no significant groundwater quality issues in the basin.

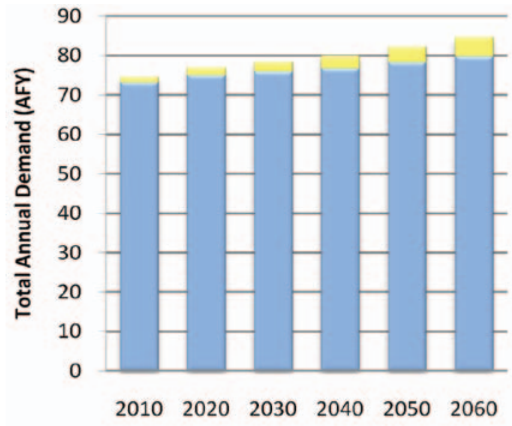
Notes & Assumptions

- 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.

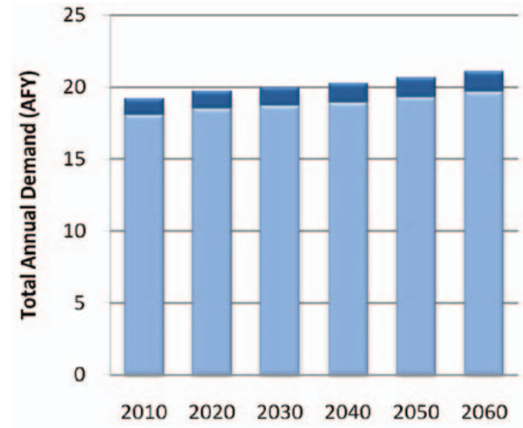
Water Demand

- The water needs of Basin 35 account for less than 1% of the total Southwest Region demand and is projected to increase by 9% (30 AFY) from 2010 to 2060. The majority of the demand and growth in demand during this period will be from the Municipal and Industrial and Livestock demand sectors.
- Surface water is used to meet 28% of total demand in the basin and its use will increase by 13% (10 AFY) from 2010 to 2060. This increase in surface water demand is minimal on a basin-scale.
- Alluvial groundwater is used to meet 7% of total demand in the basin and its use will increase by 10% (less than 10 AFY) from 2010 to 2060. This increase in alluvial groundwater demand is minimal on a basin-scale.
- Bedrock groundwater is used to meet 65% of total demand in the basin and its use will increase by 7% (20 AFY) from 2010 to 2060. This increase in bedrock groundwater demand is minimal on a basin-scale.

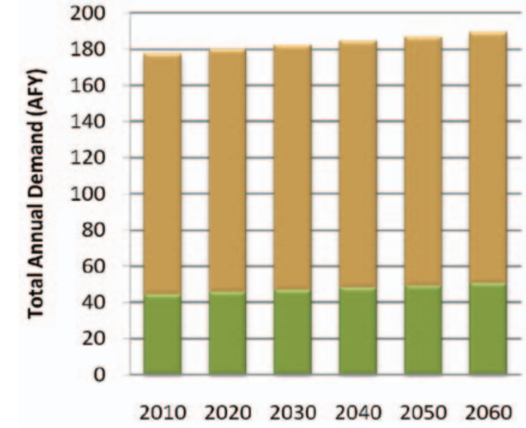
Surface Water Demand by Sector
Southwest Region, Basin 35



Alluvial Groundwater Demand by Sector
Southwest Region, Basin 35



Bedrock Groundwater Demand by Sector
Southwest Region, Basin 35

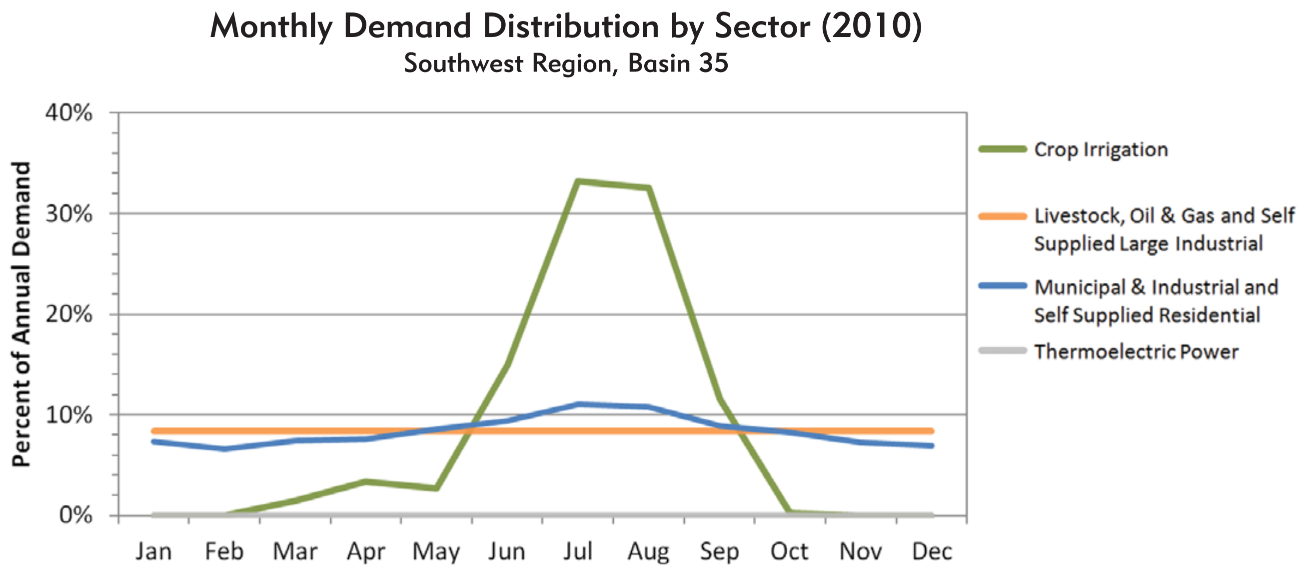


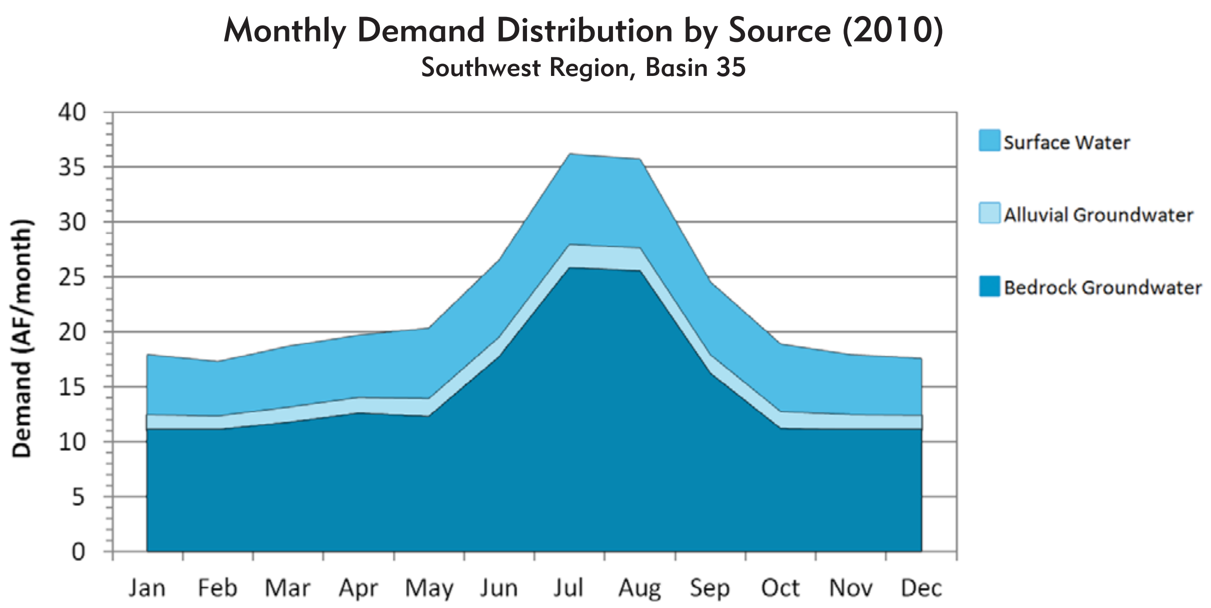
Total Demand by Sector
Southwest Region, Basin 35

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	40	130	90	0	0	0	0	260
2020	50	130	90	0	0	0	0	270
2030	50	140	90	0	0	0	0	280
2040	50	140	100	0	0	0	0	290
2050	50	140	100	0	0	0	0	290
2060	50	140	100	0	0	0	0	290

Notes & Assumptions

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





Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use about 50% more water in summer months than winter use. Crop Irrigation has a high demand during summer months and little to no demand during winter months. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 35 is 2 times the winter demand, which is similar to the overall statewide pattern. Surface water and alluvial groundwater demand in the peak summer month is 1.5 times the monthly winter use. Bedrock groundwater use in the peak summer month is 2.3 times the monthly winter use.

Gaps and Storage Depletions

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

Surface Water Gaps by Season (2060 Demand)

Southwest Region, Basin 35

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 the largest amount for any one month in the season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 35

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 the largest amount for any one month in the season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions

Southwest Region, Basin 35

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

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 35

Months (Season)	Maximum 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 the largest amount for any one month in the 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

Southwest Region, Basin 35

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.

Water Supply Options & Effectiveness

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

Analyses indicate that no surface water gaps or groundwater storage depletions are anticipated through 2060 assuming that current supply sources are used to meet future demand.

Demand Management

No option necessary.

Out-of-Basin Supplies

No option necessary.

Reservoir Use

No option necessary.

Increasing Reliance on Surface Water

No option necessary.

Increasing Reliance on Groundwater

No option necessary.

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Southwest Region, Basin 35

Reservoir Storage	Diversion
AF	AFY
100	<100
500	200
1,000	200
2,500	400
5,000	700
Required Storage to Meet Growth in Demand (AF)	0
Required Storage to Meet Growth in Surface Water Demand (AF)	0

Notes & Assumptions

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

Data & Analysis
Southwest Watershed Planning Region

Basin 36

Basin 36 Summary

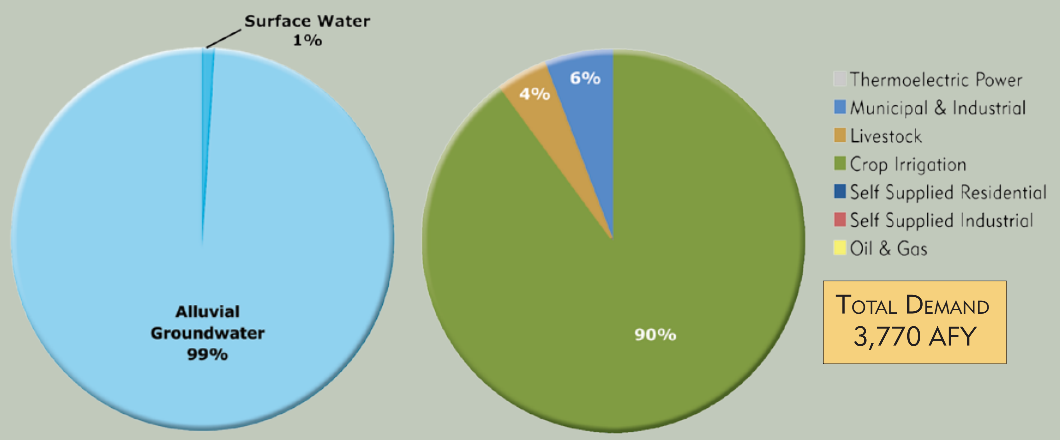
Synopsis

- Water users are expected to continue to rely heavily on 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.
- Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts.
- By 2060, there is a very high 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 reduce the adverse effects of bedrock groundwater storage depletions.
- Use of additional groundwater supplies and/or developing additional small reservoir storage could mitigate surface water gaps. These supply sources could be used without major impacts to groundwater storage.
- Basin 36 has been identified as a water availability "hot spot" due to alluvial bedrock groundwater availability issues. (See "Regional and Statewide Opportunities and Solutions," *2012 OCWP Executive Report*.)

Basin 36 accounts for about 2% of the water demand in the Southwest Watershed Planning Region. About 90% of the demand is from the Crop Irrigation demand sector. Surface water satisfies about 1% of the total demand in the basin. Groundwater satisfies about 99% of the total demand (100% alluvial). The peak summer demand month in Basin 36

Current Demand by Source and Sector

Southwest Region, Basin 36

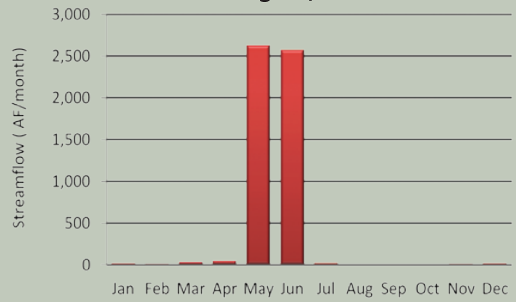


Water Resources

Southwest Region, Basin 36

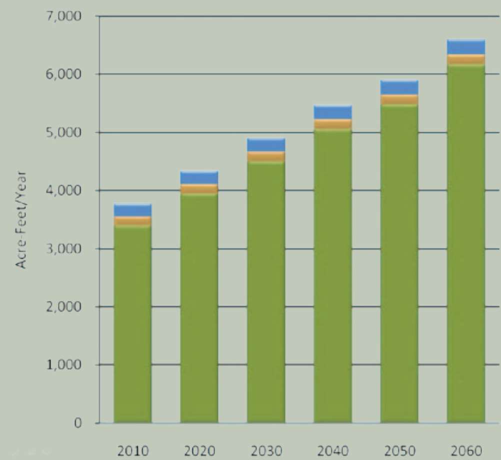
Median Historical Streamflow at the Basin Outlet

Southwest Region, Basin 36



Projected Water Demand

Southwest Region, Basin 36



is 43.1 times the winter demand, which is much more pronounced than the overall statewide pattern.

Lugert-Altus Reservoir, which is located at the basin outlet, impound water out-of-basin to the North Fork of the Red River and supplies the Lugert-Altus Irrigation District and the City of Altus. The reservoir supplies a dependable yield of 47,100 AFY, but is over allocated with permitted withdrawals of 85,630 AFY to the irrigation district and 4,800 AFY to the City of Altus. Lugert-Altus does not typically release substantial flow to the river, except in May and June or during wet periods. However, during higher flow years substantial releases from the reservoir can occur in any month of the year. The North Fork of the Red River and Otter Creek are impaired for Agricultural use by total dissolved solids (TDS) and chlorides. Surface water in the Basin is fully allocated, limiting diversions to existing permitted amounts. Relative to other basins in the state, the surface water quality in Basin 36 is considered fair.

The North Fork of the Red River aquifer underlies about 60% of the basin and has 675,000 AF of in-basin storage. 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.

The expected 2060 water demand of 6,600 AFY reflects a 2,830 AFY increase (75%) over the 2010 demand.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and alluvial groundwater storage depletions may occur by 2020 and surface water gaps may occur by 2060. The surface water gaps will occur in summer of almost every year, but will be small in size (20 AFY). Alluvial groundwater storage depletions are expected to occur in every year and will be up to 2,540 AFY. Alluvial groundwater storage depletions are expected to occur during the spring, summer, and fall, peaking in size during the summer. Projected annual alluvial groundwater storage depletions are small in size relative to the volume of water stored in Basin 36's portion of the North Fork of the Red River aquifer. Localized groundwater storage depletions may have adverse affects on well yield, water quality, and/or pumping costs.

Options

Water users in Basin 36 are expected to continue to rely almost entirely on the North Fork of the Red River for water supply. 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

Water Supply Limitations

Southwest Region, Basin 36

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness

Southwest Region, Basin 36

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 alluvial groundwater storage depletions. Additional conservation activities are not expected to decrease the size of surface water gaps. Temporary drought management activities will likely be ineffective, since surface water gaps will occur in almost every year and aquifer storage could continue to provide supplies during droughts.

Out-of-basin supplies could mitigate gaps and storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Southwest Region. However, in light of the basin's groundwater resources and the distance to reliable surface water supplies, out-of-basin supplies may not be cost-effective for users in the basin.

The development of additional reservoir storage in Basin 36 is not expected to provide substantial dependable yield. New small reservoirs (less than 50 AF) could be used mitigate surface water gaps and reduce the adverse effects of localized storage depletions. Substantial permit issues must be resolved in order to construct larger reservoirs.

Increased reliance on surface water would increase surface water gaps and the basin is fully allocated. Therefore this water supply option is not recommended.

Increased reliance on alluvial groundwater sources may mitigate surface water supplies, but will increase storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in the North Fork of the Red River aquifer underlying the basin.

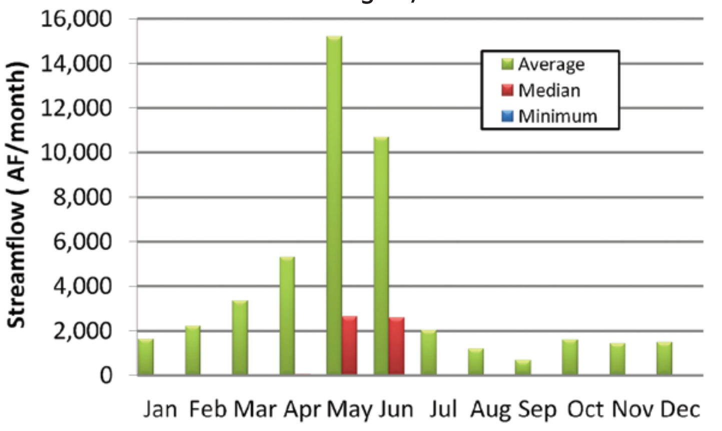
Basin 36 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The lower North Fork of the Red River below Altus Dam had a prolonged period of below-average streamflow from the mid 1960s to the mid 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 released from Lugert-Altus Reservoir to the river is less than 50 AF/month, except in May and June. However, during years of higher flows, substantial releases from the reservoir can occur in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 36 is considered fair.
- Lugert-Altus Reservoir provides 47,100 AFY of dependable yield to the Lugert-Altus Irrigation District and the City of Altus. The reservoir is not expected to provide additional supplies to new irrigators or other users in the future unless supplemental water supplies are secured.

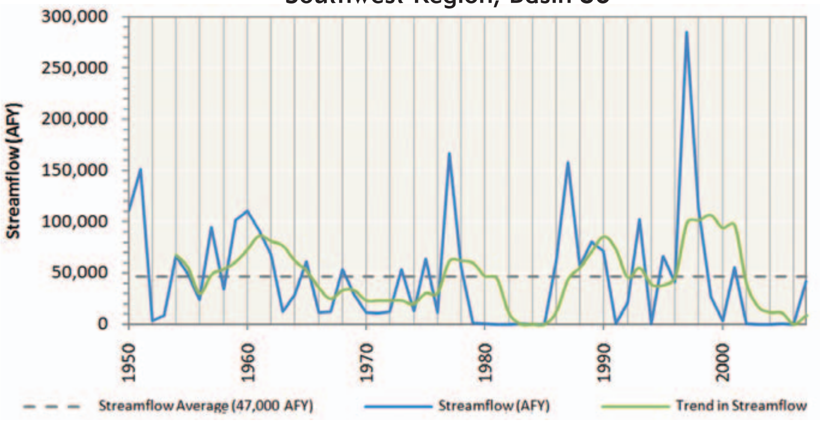
Monthly Historical Streamflow at the Basin Outlet

Southwest Region, Basin 36



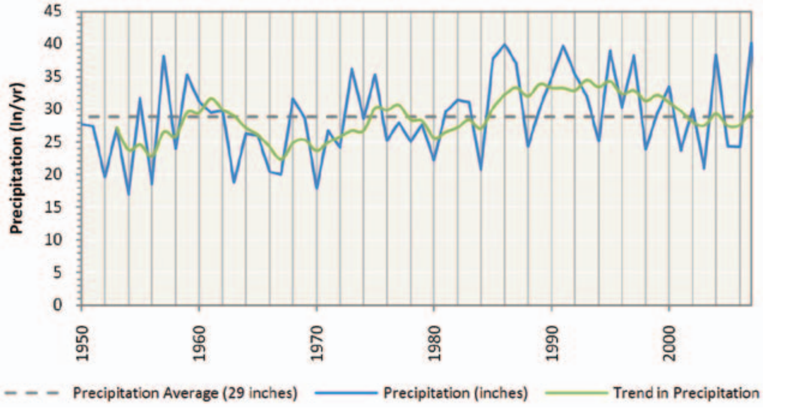
Historical Streamflow at the Basin Outlet

Southwest Region, Basin 36



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)

Southwest Region, Basin 36

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
North Fork of the Red River	Alluvial	Major	62%	20,600	675,000	1.0	53,700
Southwestern Oklahoma	Bedrock	Minor	24%	0	86,000	temporary 2.0	64,000
Western Oklahoma	Bedrock	Minor	71%	0	312,928	temporary 2.0	179,200
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

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

Groundwater Resources

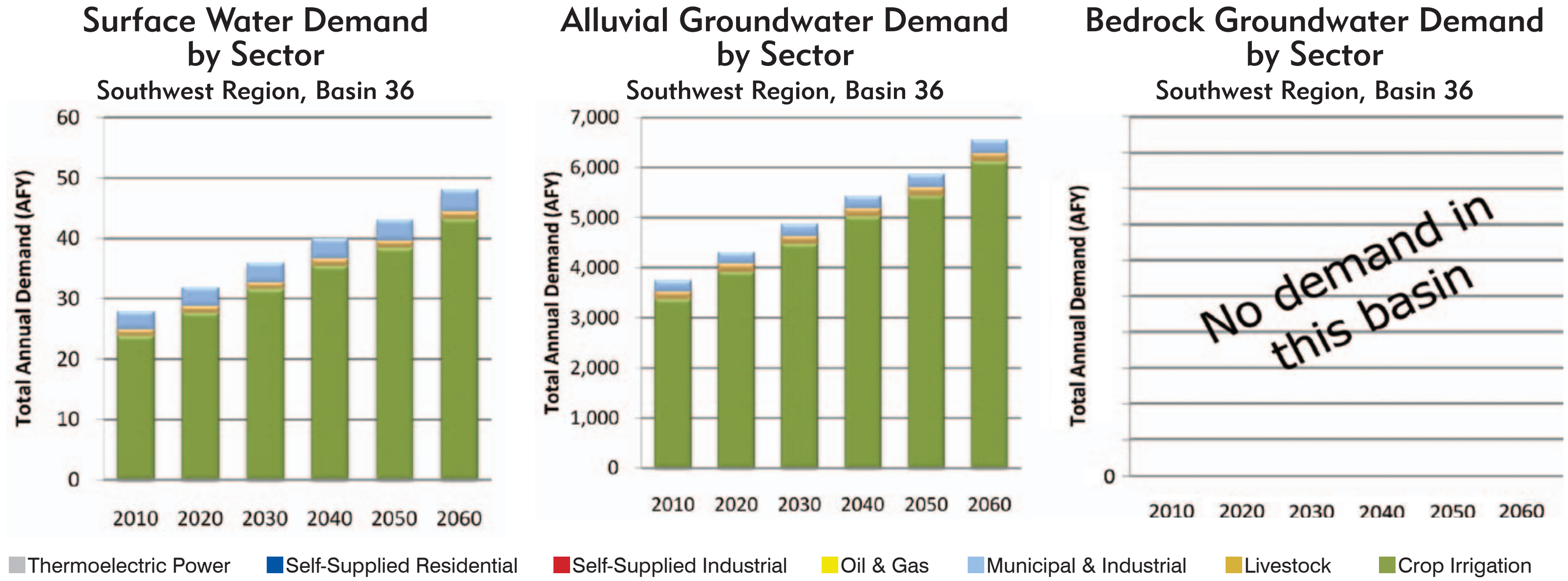
- All of the current groundwater rights in the basin are from the North Fork of the Red River aquifer.
- For Basin 36, groundwater rights total 20,600 AFY in the North Fork of the Red River aquifer, which underlies 62% of the basin and has 675,000 AF of storage.
- There are no significant groundwater 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 36 account for about 2% of the Southwest Watershed Planning Region's total demand and will increase by 75% (2,830 AFY) from 2010 to 2060. The majority of demand and growth in demand during this period will be from the Crop Irrigation demand sector.
- Surface water is used to supply about 1% of total demand in Basin 36 in 2010. Surface water use is expected to increase by 72% (20 AFY) from 2010 to 2060. The majority of surface water use and growth during this period will be from the Crop Irrigation demand sector.
- Alluvial groundwater is used to supply about 99% of total demand in Basin 36 in 2010. Alluvial groundwater use will increase by 75% (2,810 AFY) from 2010 to 2060. The majority of water use and growth in alluvial groundwater use during this period will be from the Crop Irrigation demand sector.
- There is no current bedrock groundwater use in Basin 36; therefore, no future demand was assumed.

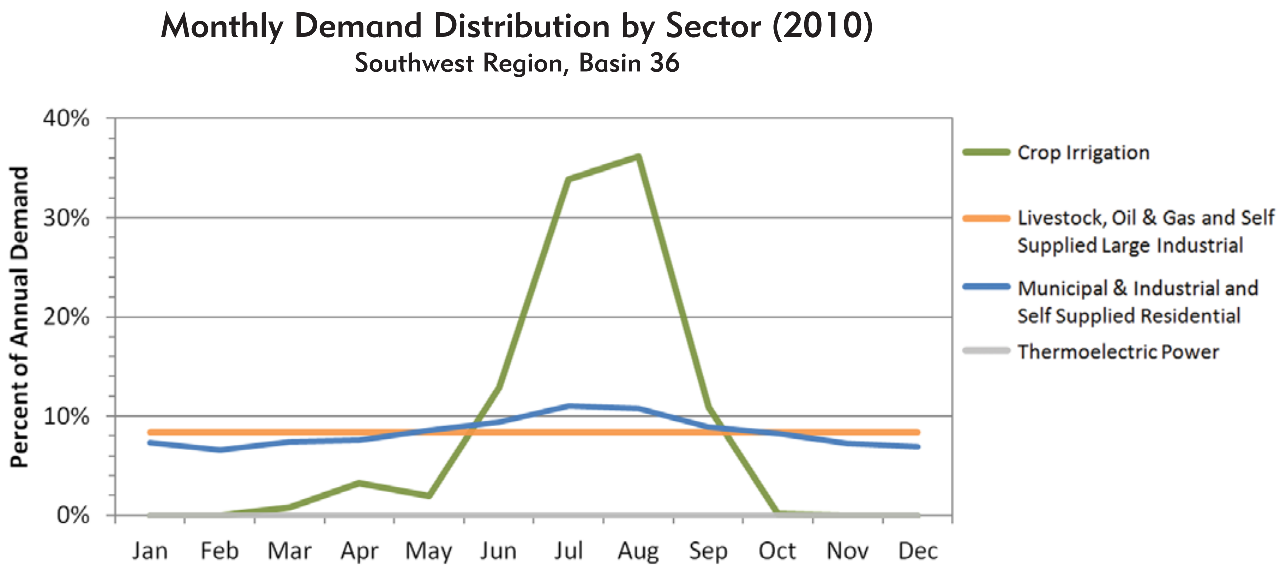


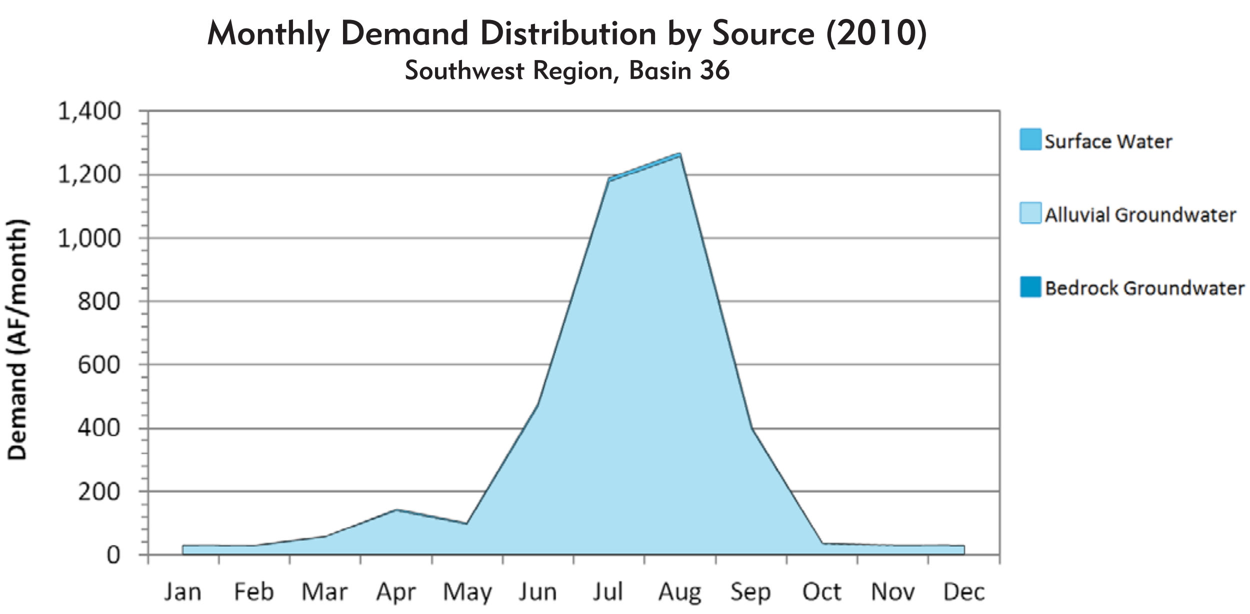
Total Demand by Sector
Southwest Region, Basin 36

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	3,390	160	220	0	0	0	0	3,770
2020	3,950	160	230	0	0	0	0	4,340
2030	4,500	170	230	0	0	0	0	4,900
2040	5,050	170	240	0	0	0	0	5,460
2050	5,480	170	260	0	0	0	0	5,910
2060	6,160	170	270	0	0	0	0	6,600

Notes & Assumptions

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





Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use about 50% more water in summer months than winter months. Crop Irrigation has a high demand during summer months and little to no demand during winter months. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 36 is 43.1 times the winter demand, which is much more pronounced than the overall statewide pattern. The peak summer month surface water demand is 28.9 times the monthly winter use. Alluvial groundwater has a similarly high ratio of the peak month summer demand to the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, alluvial groundwater depletions may occur by 2020, while surface water gaps may occur by 2060.
- Surface water gaps will have a 97% probability of occurring in at least one month of each summer. Surface water gaps in 2060 will be up to 50% (10 AF/month) of the surface water demand in the peak summer month.
- Alluvial groundwater storage depletions are expected to occur in at least one month of each year (100% probability) and may occur during the spring, summer, and fall, peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 40% (910 AF/month) of the peak summer alluvial groundwater demand, and as much as 39% (90 AF/month) of the peak spring months' alluvial groundwater demand.
- 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 occur and adversely affect yields, water quality, and/or pumping costs.
- A detailed analysis of alluvial groundwater recharge may result in decreased storage depletions due to the potential reduction of basin outlet streamflow (used for estimating recharge) from the yield of Lugert-Altus Reservoir.

Surface Water Gaps by Season (2060 Demand)
Southwest Region, Basin 36

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)	10	10	97%
Sep-Nov (Fall)	0	0	0%

1 Amount shown represent the largest amounts for any one month in the season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)
Southwest Region, Basin 36

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	90	50	91%
Jun-Aug (Summer)	910	850	98%
Sep-Nov (Fall)	280	270	98%

1 Amount shown represent the largest amounts for any one month in the season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions
Southwest Region, Basin 36

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	500	0	0%	100%
2030	0	1,000	0	0%	100%
2040	0	1,520	0	0%	100%
2050	0	1,930	0	0%	100%
2060	20	2,540	0	97%	100%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)
Southwest Region, Basin 36

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

1 Amount shown represent the largest amounts for any one month in the 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

Southwest Region, Basin 36

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	20	2,540	0	97%	100%
Moderately Expanded Conservation in Crop Irrigation Water Use	20	2,180	0	97%	100%
Moderately Expanded Conservation in M&I Water Use	20	2,510	0	97%	100%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	20	2,160	0	97%	100%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	1,360	0	0%	100%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Southwest Region, Basin 36

Reservoir Storage	Diversion
AF	AFY
100	<100
500	<100
1,000	100
2,500	100
5,000	200
Required Storage to Meet Growth in Demand (AF)	Insufficient Surface Water Supplies
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

Potentially Effective: Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce alluvial groundwater storage depletions by 15%. Additional conservation activities are not expected to decrease the size of surface water gaps. Temporary drought management activities will likely be ineffective since surface water gaps will occur in almost every year and aquifer storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

Potentially Effective: Out-of-basin supplies could mitigate gaps and storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Southwest Region: Port in Basin 34 and Mangum (Lower) in Basin 39. However, in light of the basin's groundwater resources and the distance to reliable surface water supplies, out-of-basin supplies may not be cost-effective for users in the basin.

Reservoir Use

Potentially Effective: The development of additional reservoir storage in Basin 36 is not expected to provide substantial dependable yield. Lugert-Altus Reservoir currently uses the majority of flow to supply dependable yield to its users and is not expected to provide additional supplies in the future unless supplemental water resources are found. New small reservoirs (less than 50 AF) could be used to mitigate surface water gaps and reduce the adverse effects of localized storage depletions. Substantial permit issues must be resolved in order to construct larger reservoirs. However, if permittable, a new river diversion and 200 AF of reservoir storage at the basin outlet could meet the change in surface water demand from 2010 to 2060. 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 Surface Water

Likely Ineffective: Increased reliance on surface water would increase surface water gaps and the basin is fully allocated. Therefore this water supply option is not recommended.

Increasing Reliance on Groundwater

Likely Ineffective: Increased reliance on alluvial groundwater sources may mitigate surface water gaps, but will increase storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in the North Fork of the Red River aquifer underlying the basin. A shift from surface water to alluvial groundwater is not expected to substantially change the maximum storage depletions, but could provide storage to meet the needs of new users.

Notes & Assumptions

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

Oklahoma Comprehensive Water Plan

Data & Analysis
Southwest Watershed Planning Region

Basin 37

Basin 37 Summary

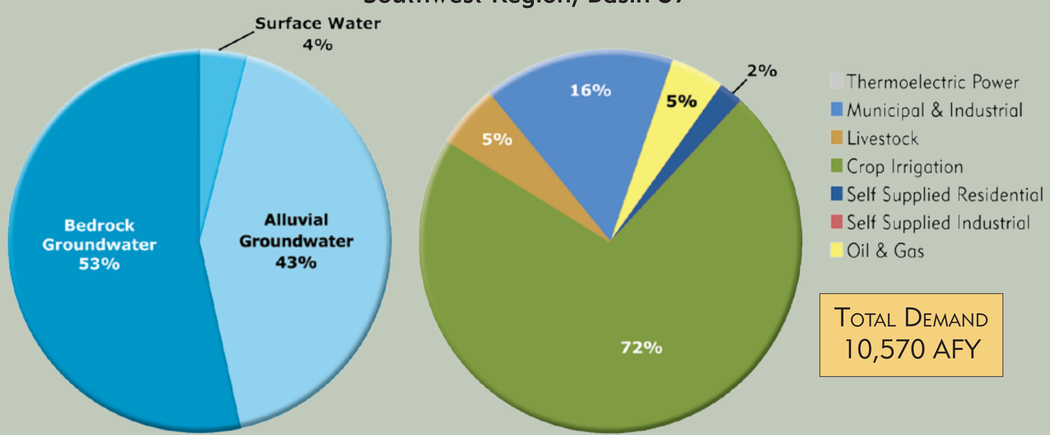
Synopsis

- Water users are expected to continue to rely primarily on alluvial groundwater and bedrock groundwater supplies.
- Alluvial and bedrock 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.
- Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts.
- By 2030, 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 and storage depletions be decreased where economically feasible.
- Additional conservation could reduce the adverse effects of localized groundwater storage depletions.
- Aquifer storage 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 additional small reservoir storage could mitigate surface water gaps. These supply sources could be used without major impacts to groundwater storage.

Basin 37 accounts for about 6% of the water demand in the Southwest Watershed Planning Region. About 72% of the demand is from the Crop Irrigation demand sector. Municipal and Industrial (16%) is the second-largest demand sector. Surface water satisfies about 4% of the total demand in the basin. Groundwater satisfies about 96% of the total demand (53% bedrock and 43% alluvial). The peak summer demand month in Basin 37 is 15 times the winter demand, which

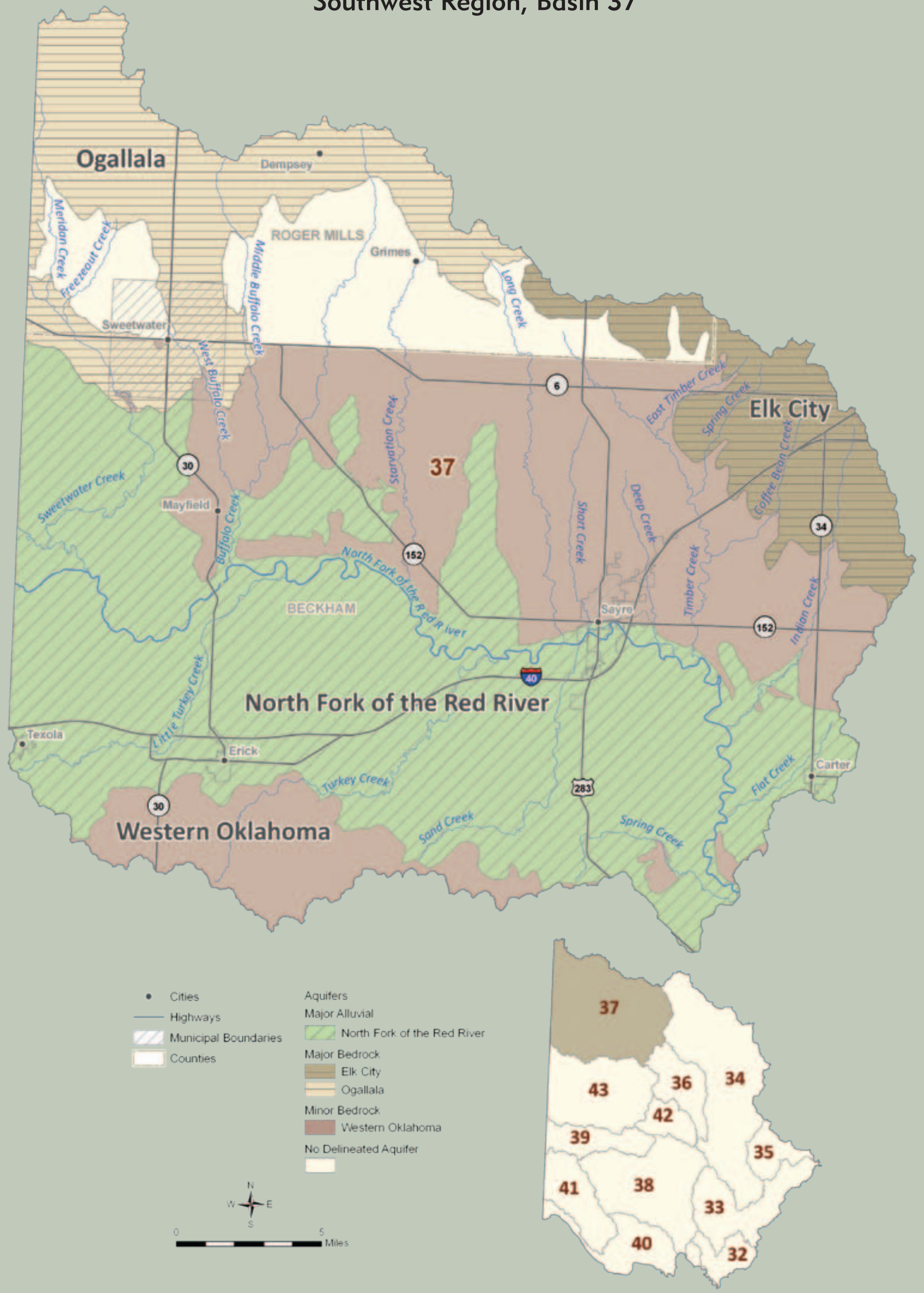
Current Demand by Source and Sector

Southwest Region, Basin 37

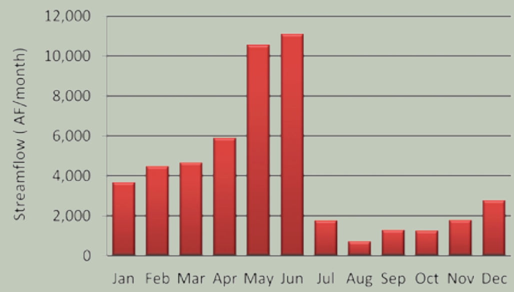


Water Resources

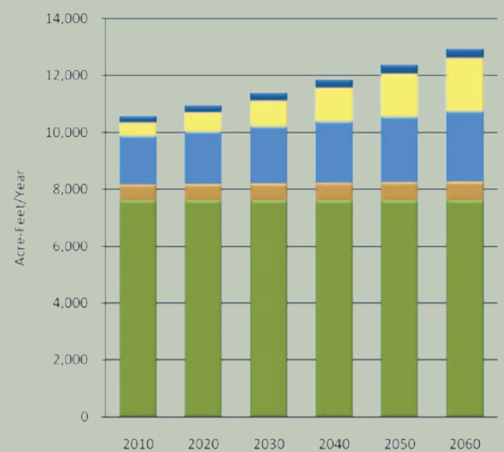
Southwest Region, Basin 37



Median Historical Streamflow at the Basin Outlet
Southwest Region, Basin 37



Projected Water Demand
Southwest Region, Basin 37



is more pronounced than the overall statewide pattern.

There are no major reservoirs in this basin. Historically, the flow of the North Fork of the Red River near Carter is greater than 1,200 AF/month throughout the year, except August, and greater than 10,000 AF/month in May and June. However, the river can also have prolonged periods of low to no flow in any month of the year. Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts. Relative to other basins in the state, the surface water quality in Basin 37 is considered fair. The North Fork of the Red River is impaired for Public and Private Water Supply use due to high levels of nitrates. Buffalo Creek and Sweetwater Creek are impaired for Agricultural use by high levels of total dissolved solids (TDS).

The majority of groundwater rights in the basin are from the North Fork of the Red River and Ogallala aquifers. The North Fork of the Red River aquifer underlies the southern portion of the basin (about 42% of the basin area) and has over 1.6 million AF of in-basin groundwater storage. The Ogallala underlies the northwestern portion of the basin (about 12% of the basin area) and has about 424,000 AF of groundwater storage in the basin. There are also water rights from the Elk City aquifer, the Western Oklahoma aquifer, and non-delineated minor aquifers. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant basin-wide groundwater quality issues. However, localized areas with high levels of nitrate have been found in the Ogallala aquifer and may occur in Basin 37.

The expected 2060 water demand of 12,950 AFY in Basin 37 reflects a 2,380 AFY increase (22%) over the 2010 demand.

Gaps & Depletions

Based on projected demand and historical hydrology, groundwater storage depletions may occur by 2020 and surface water gaps may occur by 2030. Surface water gap will be up to 250 AFY and will have a 76% probability of occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions will be up to 840 AFY and will have a 78% probability of occurring in at least one month of the year by 2060. Surface water gaps and alluvial groundwater storage depletions are expected to occur throughout the year, but are most likely in summer and fall. Bedrock groundwater storage depletions will be 200 AFY on average and will occur during the summer. Projected annual alluvial and bedrock storage depletions are minimal relative to volume of water stored in the major aquifers underlying the basin. However, localized groundwater storage depletions may have adverse affects on well yield, water quality, and/or pumping costs.

Water Supply Limitations
Southwest Region, Basin 37

Source	Limitation
Surface Water	Potential
Alluvial Groundwater	Potential
Bedrock Groundwater	Potential

Minimal · Potential · Significant

Water Supply Option Effectiveness
Southwest Region, Basin 37

Option	Effectiveness
Demand Management	Potentially 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

Options

Water users are expected to continue to rely on the North Fork of the Red River aquifer and the Ogallala aquifer. 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 demand sectors could reduce the size of alluvial groundwater storage depletions and mitigate bedrock groundwater storage depletions. There is expected to be a small reduction in surface water gaps from additional conservation activities. Temporary drought management activities will likely be ineffective since reductions would likely not affect the Oil and Gas demand sector and aquifer storage could continue to provide supplies during droughts.

Out-of-basin supplies could also mitigate gaps and storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Southwest Region. However, in light of the basin's groundwater resources and the distance to reliable surface water supplies, out-of-basin supplies may not be cost-effective for users in the basin.

New small reservoirs (less than 50 AF) could be used to reduce surface water gaps or adverse effects of localized storage depletions. Substantial permit issues must be resolved in order to construct larger reservoirs.

Increased reliance on surface water, without reservoir storage, will increase surface water gaps and the basin is fully allocated. Therefore, this water supply option is not recommended.

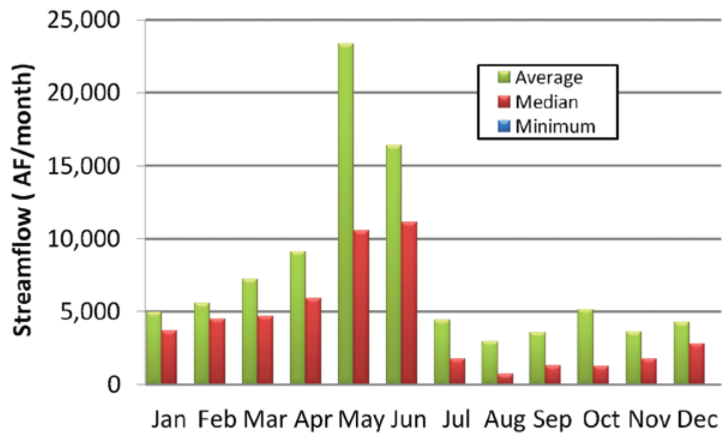
Increased reliance on alluvial or bedrock groundwater use could mitigate surface water gaps, but groundwater storage depletions will increase. Any increases in storage depletions would be minimal relative to the volume of water in storage in the basin. However, major aquifers only underlie about 60% of the basin. The Aquifer Recharge Workgroup identified a site near Elk City (site # 21) as potentially feasible for aquifer recharge and recovery. Water could potentially be withdrawn from the North Fork of the Red River to recharge the North Fork of the Red River aquifer.

Basin 37 Data & Analysis

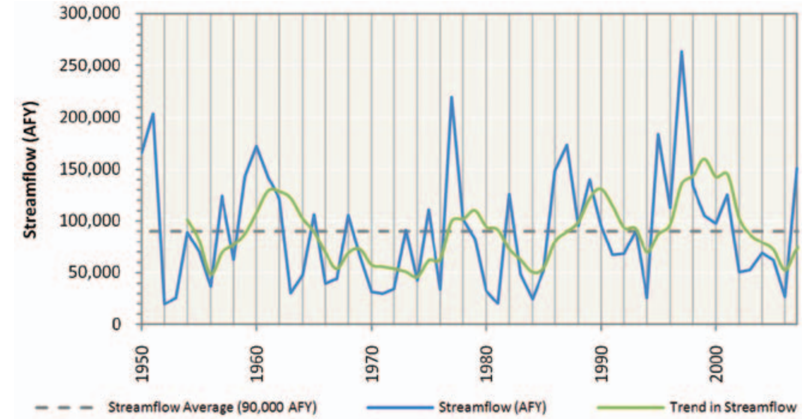
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The upper North Fork of the Red River near Carter had a prolonged period of below-average streamflow from the early 1960s to the mid 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 of the North Fork of the Red River near Carter is greater than 1,200 AF/month throughout the year, except August, and greater than 10,000 AF/month in May and June. However, the river can have prolonged periods of low to no flow in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 37 is considered fair.
- There are no major reservoirs in Basin 37.

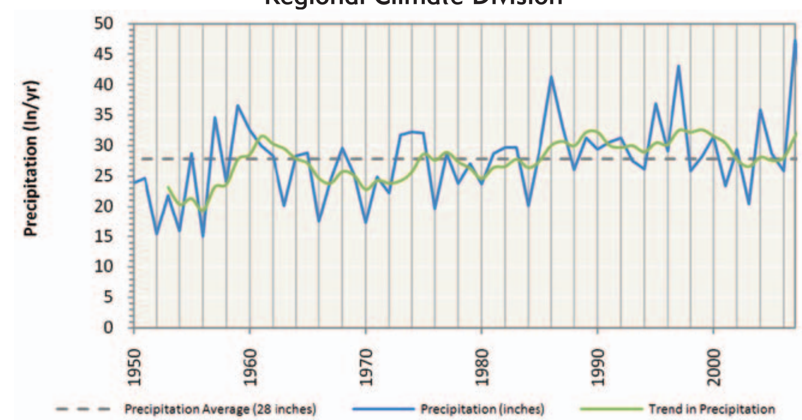
Monthly Historical Streamflow at the Basin Outlet
Southwest Region, Basin 37



Historical Streamflow at the Basin Outlet
Southwest Region, Basin 37



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)

Southwest Region, Basin 37

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
North Fork of the Red River	Alluvial	Major	42%	35,700	1,641,000	1.0	153,300
Elk City	Bedrock	Major	7%	1,900	314,000	1.0	30,000
Ogallala	Bedrock	Major	12%	21,000	424,000	temporary 2.0	80,100
Western Oklahoma	Bedrock	Minor	78%	4,900	N/A	temporary 2.0	671,800
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	5,300	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 majority of groundwater rights in the basin are from the North Fork of the Red River aquifer.
- The Ogallala has 424,000 AF of storage in the basin and receives an estimated 11,000 AFY of recharge. Where these aquifers are not accessible, there are water rights in the Elk City aquifer, the Western Oklahoma aquifer, and non-delineated groundwater sources.
- There are no significant groundwater quality issues in the basin. However, high levels of nitrates have been found in localized areas of the Ogallala and may occur in Basin 37.

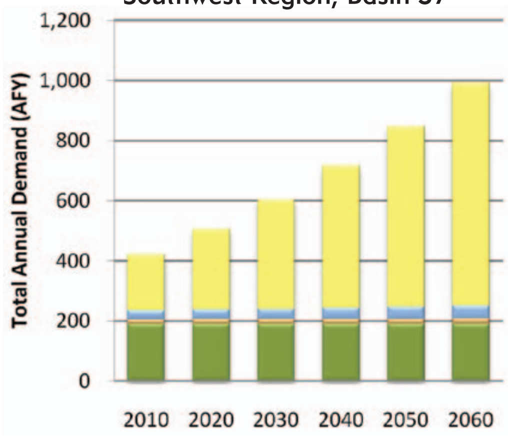
Notes & Assumptions

- 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.

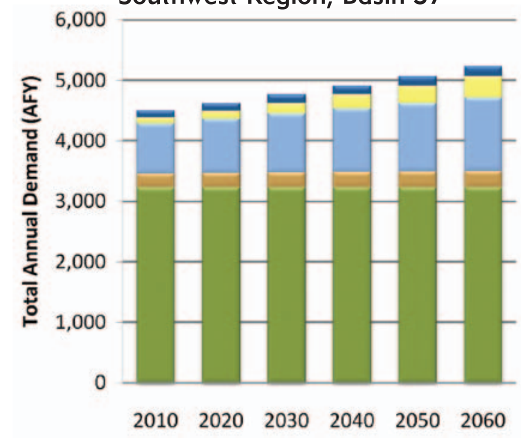
Water Demand

- The water needs of Basin 37 account for about 6% of the Southwest Watershed Planning Region's total demand and will increase by 22% (2,380 AFY) from 2010 to 2060. The majority of demand during this period will be from the Crop Irrigation demand sector. However, the majority of growth in demand from 2010 to 2060 will be in the Municipal and Industrial and Oil and Gas demand sectors.
- Surface water is used to supply 4% of the total demand in Basin 37 and its use will increase by about 130% (570 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use during this period will be from the Oil and Gas demand sector.
- Alluvial groundwater is used to supply 43% of the total demand in Basin 37 and its use will increase by 16% (740 AFY) from 2010 to 2060. The majority of demand during this period will be in the Crop Irrigation demand sector. However, the majority of the growth in demand will be from the Municipal and Industrial and Oil and Gas demand sectors.
- Bedrock groundwater is used to supply 53% of the total demand in Basin 37 and its use will increase by 19% (1,070 AFY) from 2010 to 2060. The majority of demand during this period will be in the Crop Irrigation demand sector. However, almost all of the growth in demand will be in the Municipal and Industrial and Oil and Gas demand sectors.

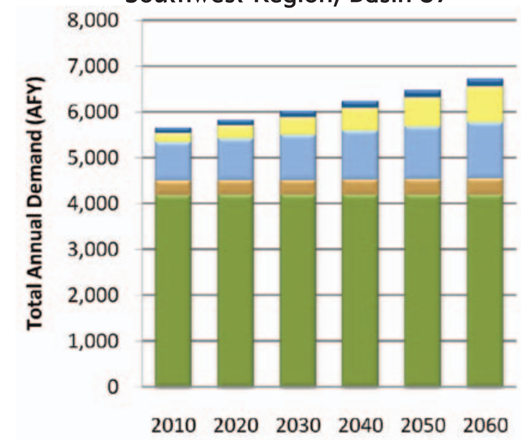
Surface Water Demand by Sector
Southwest Region, Basin 37



Alluvial Groundwater Demand by Sector
Southwest Region, Basin 37



Bedrock Groundwater Demand by Sector
Southwest Region, Basin 37



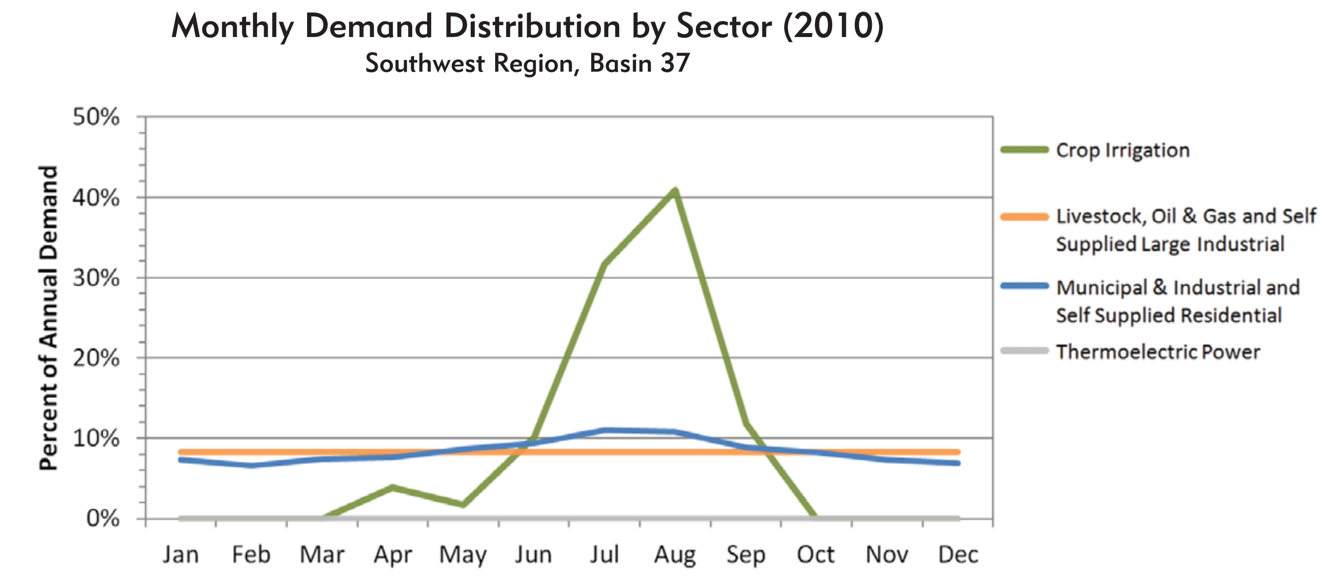
Thermoelectric Power | Self-Supplied Residential | Self-Supplied Industrial | Oil & Gas | Municipal & Industrial | Livestock | Crop Irrigation

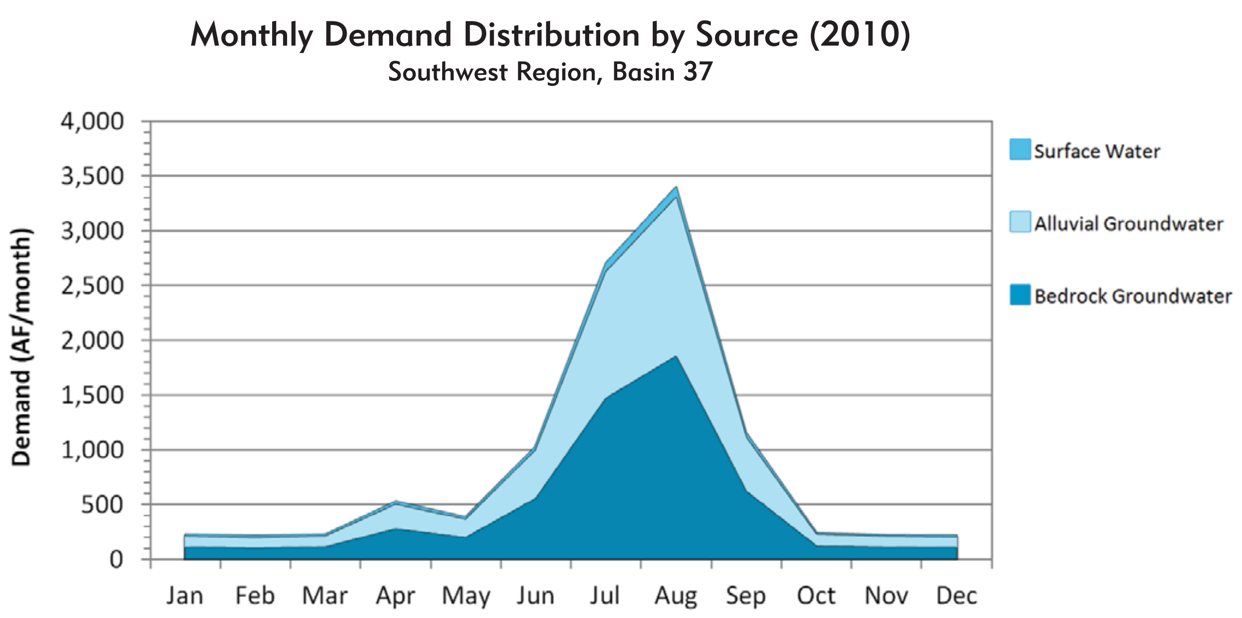
Total Demand by Sector
Southwest Region, Basin 37

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	7,600	560	1,710	480	0	220	0	10,570
2020	7,610	580	1,850	680	0	240	0	10,960
2030	7,610	590	2,000	920	0	260	0	11,380
2040	7,610	610	2,160	1,200	0	280	0	11,860
2050	7,610	630	2,310	1,520	0	300	0	12,370
2060	7,610	650	2,490	1,880	0	320	0	12,950

Notes & Assumptions

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





Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 50% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total demand in Basin 37 is 15 times the winter demand, which is more pronounced than the overall statewide pattern. The peak summer month surface water demand is 5.1 times the monthly winter use. The ratio of the peak alluvial and bedrock groundwater summer demand month to monthly winter use is similar to the total demand.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, groundwater storage depletions may occur by 2020 and surface water gaps may occur by 2030.
- Surface water gaps in Basin 37 may occur throughout the year. Surface water gaps in 2060 will be up to 22% (20 AF/month) of the surface water demand in the peak summer month, and as high as 43% (30 AF/month) of the other seasons' peak monthly surface water demand. There will be a 76% probability of gaps occurring in at least one month of the year by 2060. Surface water gaps are most likely to occur during summer and fall months.
- Alluvial groundwater storage depletions in Basin 37 may occur throughout the year. Alluvial groundwater storage depletions in 2060 will be up to 9% (110 AF/month) of the alluvial groundwater demand in the peak summer month, and as high as 47% (70 AF/month) of the peak winter month alluvial groundwater demand. There will be a 78% probability of storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions are most likely to occur during summer and fall months.
- Bedrock groundwater storage depletions in Basin 37 may occur during the summer and will be up to 6% (100 AF/month) of the bedrock groundwater demand on average in the peak summer month.
- Projected annual alluvial and bedrock 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 and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)

Southwest Region, Basin 37

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	30	30	21%
Mar-May (Spring)	30	20	12%
Jun-Aug (Summer)	20	10	53%
Sep-Nov (Fall)	30	25	52%

1 Amount shown represent the largest amounts for any one month in the season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 37

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	70	70	21%
Mar-May (Spring)	80	80	12%
Jun-Aug (Summer)	110	110	53%
Sep-Nov (Fall)	90	80	52%

1 Amount shown represent the largest amounts for any one month in the season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions

Southwest Region, Basin 37

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	120	40	0%	59%
2030	60	300	80	26%	64%
2040	100	460	120	64%	69%
2050	170	640	160	71%	74%
2060	250	840	200	76%	78%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 37

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

1 Amount shown represent the largest amounts for any one month in the 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

Southwest Region, Basin 37

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	250	840	200	76%	78%
Moderately Expanded Conservation in Crop Irrigation Water Use	230	710	40	66%	76%
Moderately Expanded Conservation in M&I Water Use	300	490	120	72%	76%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	280	370	0	57%	74%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	270	290	0	45%	55%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Southwest Region, Basin 37

Reservoir Storage	Diversion
AF	AFY
100	100
500	600
1,000	1,100
2,500	2,600
5,000	5,100
Required Storage to Meet Growth in Demand (AF)	2,200
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 demand sectors could reduce the size of alluvial groundwater storage depletions by 56% and mitigate bedrock groundwater storage depletions; however, since the conservation scenarios assume that conservation measures occur throughout the state and Basin 37 relies on return flows from M&I in the upstream basins, surface water gaps will actually increase due to reduced return flows to the stream from upstream basins. There is expected to be a small reduction in surface water gaps from additional conservation activities. Temporary drought management activities will likely be ineffective since reductions would likely not affect Oil and Gas surface water use and aquifer storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

Out-of-basin supplies could also mitigate gaps and storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Southwest Region: Port in Basin 34 and Mangum (Lower) in Basin 39. However, in light of the basin's groundwater resources and distance to reliable surface water supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

Reservoir Use

New small reservoirs (less than 50 AF) could be used to reduce surface water gaps or adverse effects of localized storage depletions. However, no viable reservoir sites were identified for Basin 37. Additionally, substantial permit issues must be resolved in order to construct larger reservoirs. If permittable, the basin's entire growth in demand from 2010 to 2060 could be supplied by a new river diversion and 2,200 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions.

Increasing Reliance on Surface Water

Increased reliance on surface water through direct diversions, without reservoir storage, will increase surface water gaps and is not recommended; the basin is fully allocated. Therefore, this water supply option is not recommended.

Increasing Reliance on Groundwater

Basin 37 has abundant groundwater recharge and storage from the North Fork of the Red River alluvial aquifer, Ogallala aquifer, or Elk City aquifer. Increased reliance on these supplies will increase groundwater depletions but the increase would be minimal relative to the volume of water stored in the major aquifers underlying the basin and increased depletions may create localized adverse impacts to users. These aquifers do not underlie the entire basin. The Aquifer Recharge Workgroup identified a site near Elk City (site #21) as potentially feasible for aquifer recharge and recovery. Water could potentially be withdrawn from the North Fork of the Red River to recharge the North Fork of the Red River 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.

Oklahoma Comprehensive Water Plan

Data & Analysis
Southwest Watershed Planning Region

Basin 38

Basin 38 Summary

Synopsis

- Water users are expected to continue to rely on surface water and to a lesser extent, alluvial and bedrock groundwater supplies.
- Alluvial and bedrock groundwater storage depletions may occur by 2020, but will be small in size relative to aquifer storage in the basin. However, localized storage depletions may cause adverse effects for users.
- By 2020, there is a moderate probability of surface water gaps from increased demands on existing supplies during low flow periods.
- To reduce risk of adverse impacts on water supplies, it is recommended that storage depletions and gaps be decreased where feasible.
- Additional conservation could mitigate surface water gaps and groundwater storage depletions.
- Aquifer storage and recovery could be considered to store variable surface water supplies, increase bedrock groundwater storage, and reduce adverse effects of localized storage depletions.
- Use of additional groundwater supplies and/or developing additional small reservoir storage could mitigate surface water gaps. These supply sources could be used without major impacts to groundwater storage.
- Basin 38 has been identified as a water availability "hot spot" due to alluvial and bedrock groundwater availability issues. (See "Regional and Statewide Opportunities and Solutions," *2012 OCWP Executive Report*.)

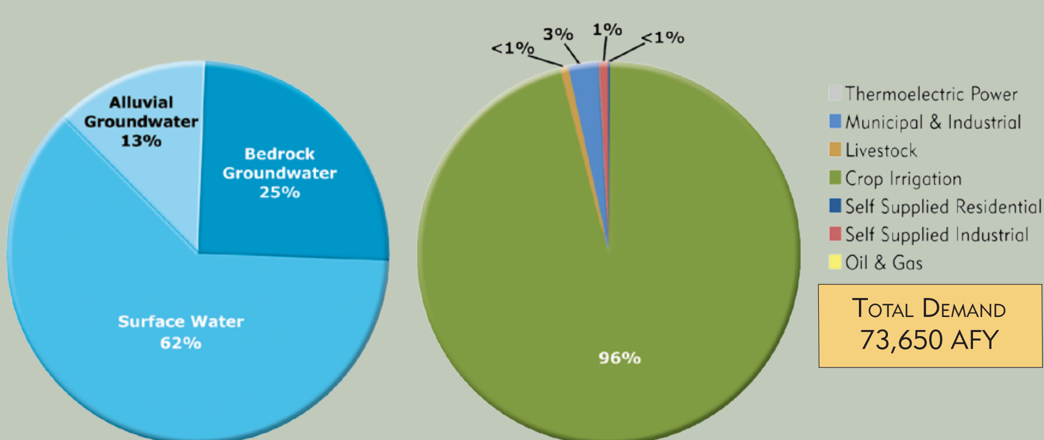
Basin 38 accounts for about 42% of the water demand in the Southwest Watershed Planning Region. About 96% of the demand is from the Crop Irrigation demand sector.

Surface water satisfies about 62% of the total demand in the basin. Groundwater satisfies about 38% of the total demand (25% bedrock and 13% alluvial). The peak summer month demand in Basin 38 is 141.6 times the winter demand, which is much more pronounced than the overall statewide pattern.

There are no major reservoirs in this basin; however, the basin receives out-of-basin supplies from the Lugert-Altus Irrigation District in Basin 36. The Irrigation District is not expected to provide additional supplies to new irrigators in the future unless the District can secure additional water supplies. Flow in the Salt Fork of the Red River near Elmer is typically greater than 2,500 AF/month throughout the year and greater than 13,000

Current Demand by Source and Sector

Southwest Region, Basin 38



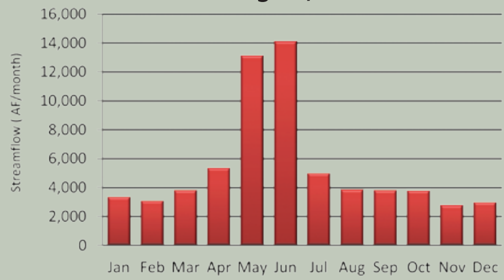
TOTAL DEMAND
73,650 AFY

Water Resources

Southwest Region, Basin 38

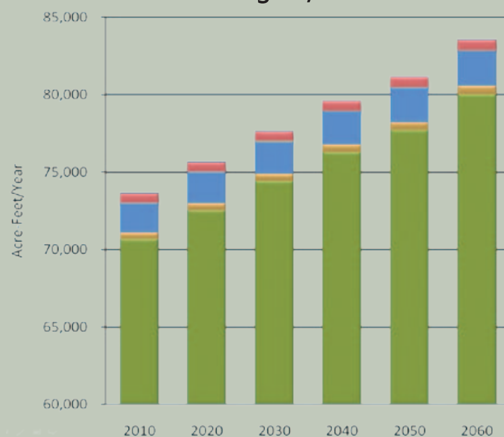
Median Historical Streamflow at the Basin Outlet

Southwest Region, Basin 38



Projected Water Demand

Southwest Region, Basin 38



AF/month in May and June. However, the basin can have periods of low to very low 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 38 is considered poor. However, individual lakes and streams may have acceptable water quality. The Salt Fork of the Red River is impaired for Public and Private Water Supply due to high levels of selenium. Turkey Creek and Bitter Creek are impaired for Agricultural use due to high levels of total dissolved solids (TDS), chloride, and sulfate.

The majority of groundwater withdrawals in the basin are from the Blaine bedrock aquifer. There is about 494,000 AF of water stored in Basin 38's portion of the Blaine aquifer, which underlies about half of the basin. The majority of alluvial groundwater rights are in non-delineated minor aquifers along the Salt Fork of the Red River and Turkey Creek. Site- specific information on the reliability of minor aquifers should be considered before large scale use. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. Water quality issues from high TDS concentrations are expected to limit the use of the Blaine aquifer to agriculture (Crop Irrigation and Livestock demand sectors). Otherwise, there are no significant groundwater quality issues in other aquifers in the basin. The projected 2060 water demand of 83,580 AFY in Basin 38 reflects a 9,930 AFY increase (13%) over the 2010 demand.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions may occur by 2020. Surface water gap will be up to 4,510 AFY, peaking in size in summer, and there will be a 53% probability of a gap occurring in at least one month of each year by 2060. Alluvial groundwater storage depletions will be up to 970 AFY, peaking in size in summer, and there will be a 53% probability of a gap occurring in at least one month of each year by 2060. Bedrock groundwater storage depletions will be 2,260 AFY on average and occur during the summer and fall. Bedrock groundwater storage depletions are minimal compared to the groundwater storage in Basin 38. However, localized groundwater storage depletions may have adverse effects on well yield, 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 38.To reduce the risk of adverse impacts on water supplies, it is recommended that gaps and storage depletions be decreased where economically feasible.

Water Supply Limitations

Southwest Region, Basin 38

Surface Water	Potential
Alluvial Groundwater	Significant
Bedrock Groundwater	Significant

Minimal · Potential · Significant

Water Supply Option Effectiveness

Southwest Region, Basin 38

Demand Management	Potentially 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 Crop Irrigation demand sector could mitigate surface water gaps and groundwater storage depletions. Temporary drought management activities are likely ineffective, since gaps have a moderate probability of occurring and aquifer storage could continue to provide supplies during droughts.

The Lugert-Altus Irrigation District currently provides out-of-basin supplies to the basin, but is not expected to provide supplies to new irrigators in the future unless they secure additional water supplies. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Southwest Region. However, in light of the basin's groundwater resources and the distance to reliable surface water supplies, out-of-basin supplies may not be cost-effective for some users in the basin.

Reservoir storage could provide dependable supplies to mitigate surface water gaps and adverse effects of localized storage depletions. Unlike many basins in the Southwest Region, the development of reservoir storage is not expected to be limited by the availability of permits. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 8,700 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.

Basin 38 has substantial groundwater recharge and storage from the Blaine aquifer. Increased reliance on this supply source could mitigate surface water gaps, but would increase the amount of storage depletions. Increases in storage depletions could be moderate in size relative to the volume of water stored in the Blaine aquifer underlying the basin. However, localized storage depletions may occur and adversely affect users' yields, water quality, and pumping costs. Additionally, the Blaine aquifer may not be accessible for all water users.

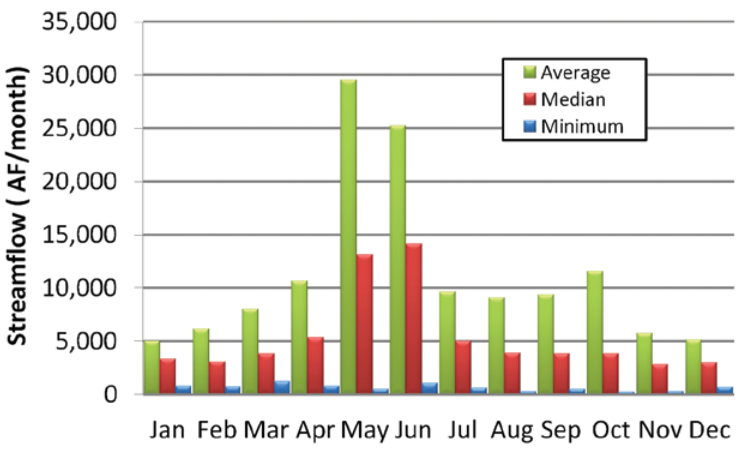
The Southwest Soil and Water Conservation District and water users in Basin 41 have used aquifer storage and recovery of surface water to increase the recharge to the Blaine aquifer for over 25 years. This practice could also be considered in Basin 38 to reduce localized storage depletions.

Basin 38 Data & Analysis

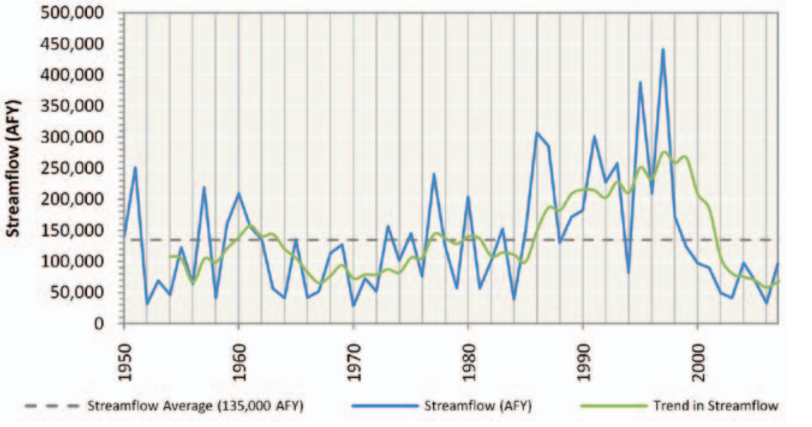
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Salt Fork of the Red River near Elmer, had a prolonged period of below average flow from the early 1960s to the mid 1970s, corresponding to a period of below-average precipitation. From the late 1980s to early 2000s, the basin had a period of prolonged above-average streamflow, demonstrating hydrologic variability in the basin.
- The median flow in the Salt Fork of the Red River near Elmer is greater than 2,500 AF/month throughout the year and greater than 13,000 AF/month in May and June. However, the river can have periods of low to very low flow in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 38 is considered poor. However, individual lakes and streams may have acceptable water quality.
- There are no major reservoirs in Basin 38.

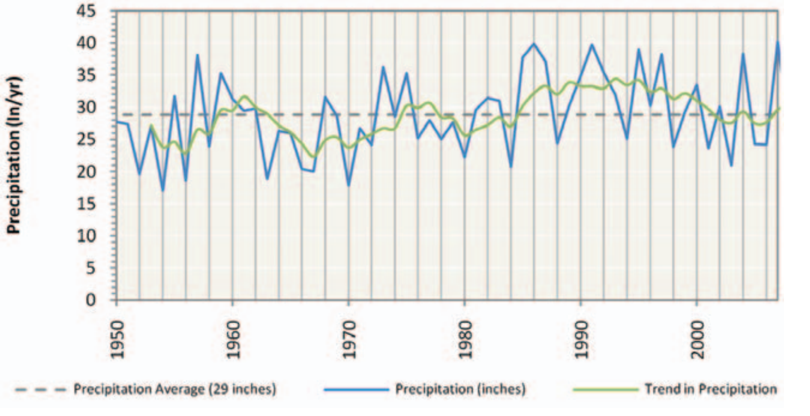
Monthly Historical Streamflow at the Basin Outlet
Southwest Region, Basin 38



Historical Streamflow at the Basin Outlet
Southwest Region, Basin 38



Historical Precipitation
Regional Climate Division



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- 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)

Southwest Region, Basin 38

Aquifer			Portion of Basin Overlying 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
North Fork of the Red River	Alluvial	Major	2%	300	75,000	1.0	6,000
Blaine	Bedrock	Major	48%	25,100	494,000	temporary 2.0	279,200
Southwestern Oklahoma	Bedrock	Minor	35%	0	327,000	temporary 2.0	228,100
Western Oklahoma	Bedrock	Minor	19%	0	N/A	temporary 2.0	123,800
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	1,100	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	14,800	N/A	temporary 2.0	N/A

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

Groundwater Resources

- The majority of groundwater rights in the basin are from the Blaine aquifer.
- The Blaine aquifer, which underlies 48% of the basin, has 494,000 AF of storage, and receives an estimated 20,000 AF of recharge. Groundwater rights total 300 AFY in the North Fork of the Red River aquifer, and there are substantial water rights in non-delineated groundwater sources.
- Due to high total dissolved solids (TDS) concentrations the Blaine aquifer is used primarily for agriculture (Crop Irrigation and Livestock demand sectors). There are no other significant groundwater quality issues in other aquifers in the basin.

Notes & Assumptions

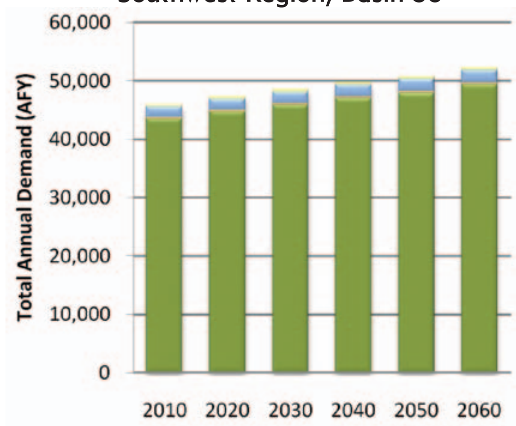
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater 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 38 account for about 42% of the total demand in the Southwest Region and will increase by 13% (9,930 AFY) from 2010 to 2060. The majority of the demand and growth in demand during this period will be from the Crop Irrigation demand sector.
- Surface water and out-of-basin supplies are used to meet 62% of the current total demand and its use will increase by 14% (6,190 AF/month) from 2010 to 2060. The majority of surface water use and growth in surface water use during this period will be from the Crop Irrigation demand sector.
- Alluvial groundwater is used to meet 13% of current total demand and its use will increase by 13% (1,290 AF/month) from 2010 and 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use during this period will be from the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet 25% of current total demand and its use will increase by 13% (2,450 AF/month) from 2010 and 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use during this period will be from the Crop Irrigation demand sector.

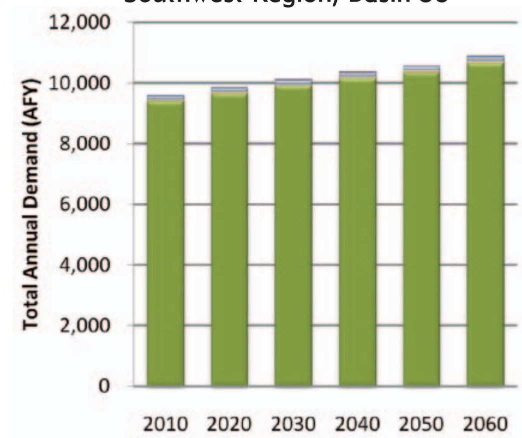
Surface Water Demand by Sector

Southwest Region, Basin 38



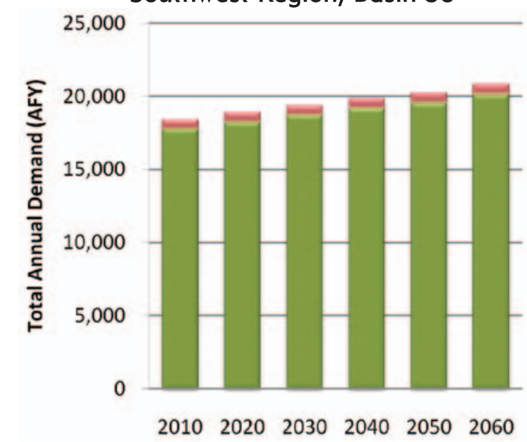
Alluvial Groundwater Demand by Sector

Southwest Region, Basin 38



Bedrock Groundwater Demand by Sector

Southwest Region, Basin 38



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

Total Demand by Sector

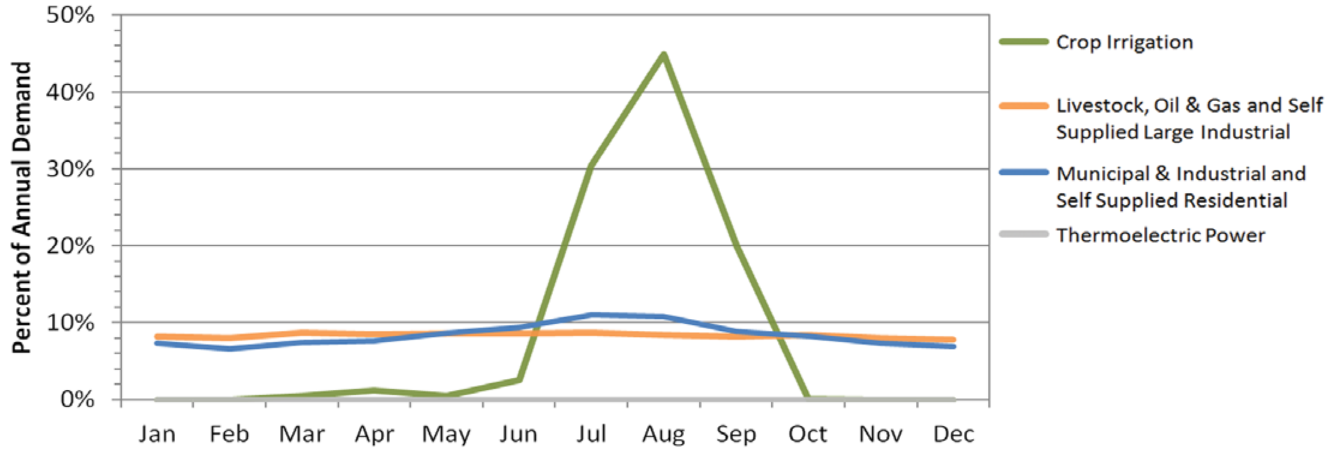
Southwest Region, Basin 38

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	70,670	420	1,930	0	610	20	0	73,650
2020	72,550	440	2,020	10	610	20	0	75,650
2030	74,420	460	2,100	10	610	20	0	77,620
2040	76,300	480	2,170	10	640	20	0	79,620
2050	77,730	500	2,230	10	650	20	0	81,140
2060	80,050	530	2,280	20	670	30	0	83,580

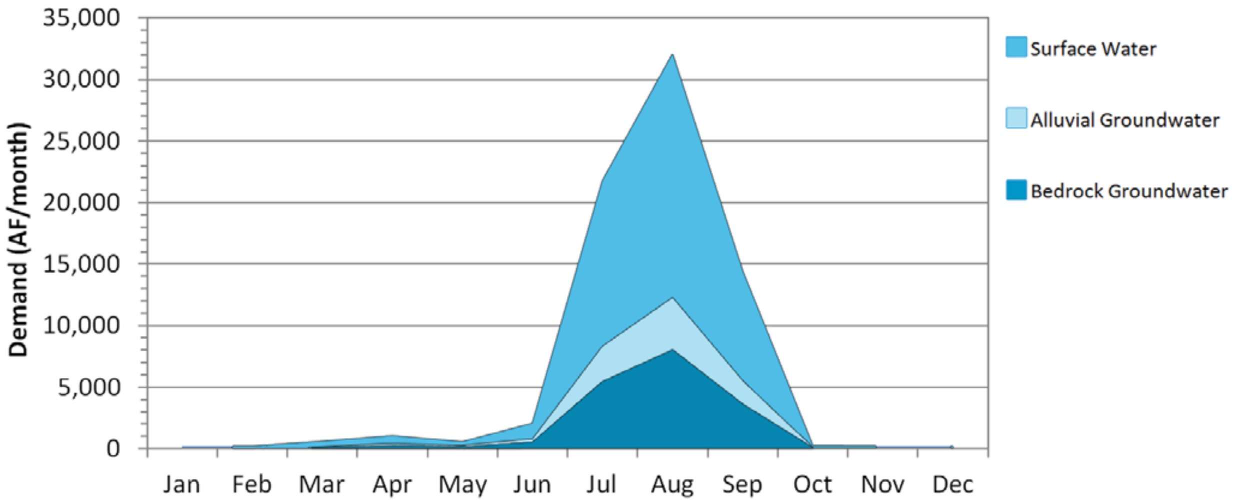
Notes & Assumptions

- 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)
Southwest Region, Basin 38



Monthly Demand Distribution by Source (2010)
Southwest Region, Basin 38



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 50% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 38 is 141.6 times the winter demand, which is much more pronounced than the overall statewide pattern. The ratio of peak summer month demand to the monthly winter use is very high for all sources in Basin 38.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions may occur by 2020.
- Surface water gaps in Basin 38 may occur during spring, summer, and fall, peaking in size in the summer. Surface water gaps in 2060 will be up to 11% (2,370 AF/month) of the surface water demand in the peak summer month, and as much as 8% (60 AF/month) of the peak spring month surface water demand. There will be a 53% probability of gaps occurring in at least one month of the year by 2060. Surface water gaps are most likely to occur during summer months.
- Alluvial groundwater storage depletions in Basin 38 may occur during spring, summer, and fall, peaking in size in the summer. Alluvial groundwater storage depletions in 2060 will be up to 11% (510 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 7% (10 AF/month) of the peak spring month alluvial groundwater demand. There will be a 53% probability of storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions are most likely to occur during summer months.
- Bedrock groundwater storage depletions in Basin 38 may occur in the summer and fall, peaking in size in the summer. Bedrock groundwater storage depletions in 2060 will be up to 12% (1,060 AF/month) on average in summer months and will be up to 12% (480 AF/month) on average in the fall months.
- Projected annual bedrock storage depletions are minimal relative to the volume of water stored in Basin 38's portion of the Blaine aquifer. Current alluvial withdrawals are largely from non-delineated minor aquifers. Therefore, the severity of the storage depletions cannot be evaluated due to lack of information. However, localized groundwater storage depletions may occur and adversely affect yields, water quality and/or pumping costs.

Surface Water Gaps by Season (2060 Demand)

Southwest Region, Basin 38

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	60	45	7%
Jun-Aug (Summer)	2,370	870	52%
Sep-Nov (Fall)	1,060	195	21%

1 Amount shown represent the largest amounts for any one month in the season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 38

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	10	10	3%
Jun-Aug (Summer)	510	190	52%
Sep-Nov (Fall)	230	40	21%

1 Amount shown represent the largest amounts for any one month in the season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions

Southwest Region, Basin 38

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	550	120	460	17%	10%
2030	1,450	320	900	28%	19%
2040	2,480	540	1,360	40%	36%
2050	3,270	700	1,700	45%	45%
2060	4,510	970	2,260	53%	53%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 38

Months (Season)	Maximum Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	1,060
Sep-Nov (Fall)	480

1 Amount shown represent the largest amounts for any one month in the 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

Southwest Region, Basin 38

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	4,510	970	2,260	53%	53%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	0	0	0%	0%
Moderately Expanded Conservation in M&I Water Use	4,410	940	2,260	52%	52%
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

Southwest Region, Basin 38

Reservoir Storage	Diversion
AF	AFY
100	300
500	1,100
1,000	1,800
2,500	3,400
5,000	6,000
Required Storage to Meet Growth in Demand (AF)	8,700
Required Storage to Meet Growth in Surface Water Demand (AF)	5,200

Water Supply Options & Effectiveness

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

Demand Management

Moderately expanded permanent conservation activities in the Crop Irrigation demand sector could mitigate surface water gaps and alluvial and bedrock groundwater depletions. Temporary drought management activities will likely be ineffective since gaps have a moderate probability of occurring and aquifer storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

The Lugert-Altus Irrigation District currently provides out-of-basin supplies to Basin 38, but is not expected to provide supplies to new irrigators in the future unless additional water supplies are secured. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Southwest Region: Port in Basin 34 and Mangum (Lower) in Basin 39. However, in light of the basin's groundwater resources and distance to other reliable surface water supplies, out-of-basin supplies may not be cost-effective for some users in the basin.

Reservoir Use

Reservoir storage could provide dependable supplies to mitigate surface water gaps and adverse effects of localized storage depletions. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 8,700 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, will increase surface water gaps and is not recommended.

Increasing Reliance on Groundwater

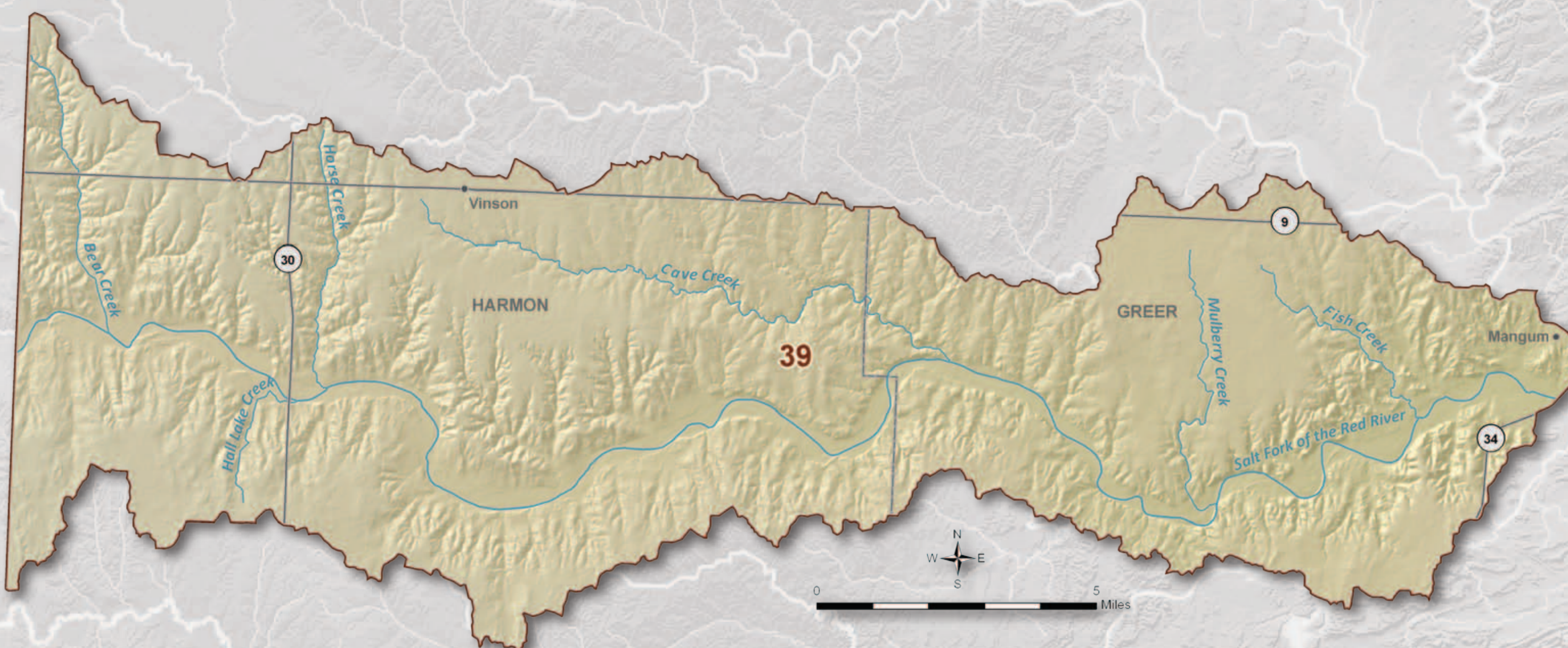
Increased reliance on bedrock groundwater use may mitigate surface water gaps and adverse effects from localized alluvial groundwater storage depletions, but will increase bedrock storage depletions. Increases in storage depletions could be moderate in size relative to the volume of water stored in the Blaine aquifer underlying the basin. However, local depletions may occur and adversely affect yields, water quality or pumping costs. Increased reliance on alluvial aquifers is not suggested without considering site-specific information on reliability of the non-delineated minor aquifers in the basin. The Southwest Soil and Water Conservation District and water users in Basin 41 have used aquifer storage and recovery of surface water to increase the recharge to the Blaine aquifer for over 25 years. Increased use of this practice could be effective in reducing the impacts of localized storage depletions in Basin 38.

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
Southwest Watershed Planning Region

Basin 39

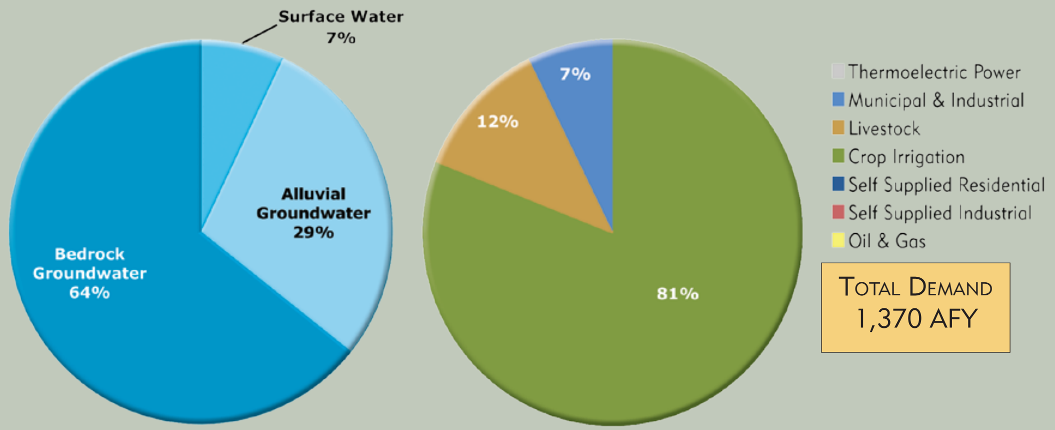


Basin 39 Summary

Synopsis

- Water users are expected to continue to rely on all types of supply sources (surface water, alluvial groundwater, and bedrock groundwater).
- Alluvial and bedrock 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.
- Surface water in the basin is fully allocated, limiting availability for new permits.
- By 2060, 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 storage depletions and gaps be decreased where economically feasible.
- Additional conservation could mitigate surface water gaps and reduce the adverse effects of localized alluvial and bedrock groundwater storage depletions.
- Aquifer storage 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 additional small reservoir storage could mitigate surface water gaps. These supply sources could be used without major impacts to groundwater storage.

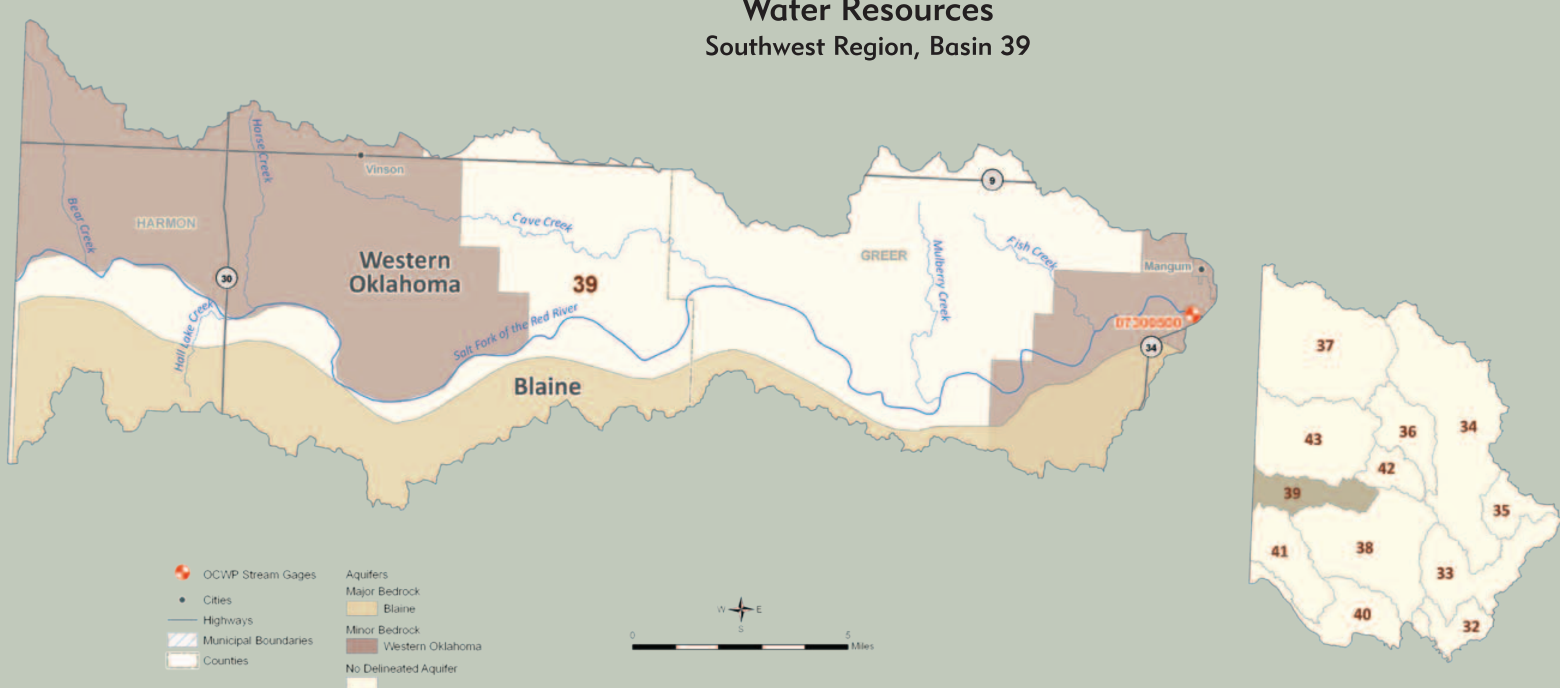
Current Demand by Source and Sector
Southwest Region, Basin 39



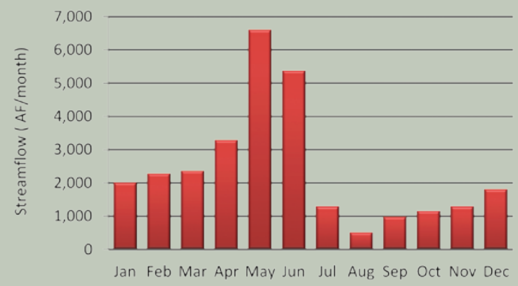
Basin 39 accounts for about 1% of the water demand in the Southwest Watershed Planning Region. About 81% of the demand is from the Crop Irrigation demand sector. Livestock (12%) is the second-largest demand sector. Surface water satisfies about 7% of the total demand in the basin. Groundwater satisfies about 93% of the demand (64% bedrock and 29% alluvial). The peak summer month demand in Basin 39 is 20 times the winter demand, which is much more pronounced than the overall statewide pattern.

There are no major reservoirs in the basin. Historically, the flow of the Salt Fork of the Red River at Mangum is typically greater than 500 AF/month throughout the year and greater than about 2,000 AF/month in the winter, spring, and early summer. However, flow in Basin 39 can have periods of low or no flow in any month of the year. Surface water in the basin is fully allocated, limiting

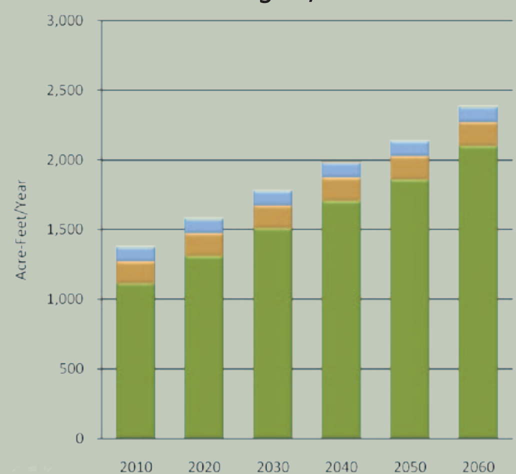
Water Resources
Southwest Region, Basin 39



Median Historical Streamflow at the Basin Outlet
Southwest Region, Basin 39



Projected Water Demand
Southwest Region, Basin 39



diversions to existing permitted amounts. Relative to other basins in the state, the surface water quality in Basin 39 is considered fair. The Salt Fork of the Red River in Basin 39 is impaired for Agricultural use due to high levels of total dissolved solids (TDS), chlorides, and sulfates.

The majority of groundwater withdrawals in the basin are from the Blaine aquifer. There is about 73,000 AF of water stored in Basin 39's portion of the Blaine aquifer, which underlies about one-quarter of the basin along its southern boundary. Alluvial groundwater rights in Basin 39 are from the non-delineated minor aquifers along the Salt Fork of the Red River. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. Water quality issues due to high levels of TDS are expected to limit the use of the Blaine aquifer to agriculture (Crop Irrigation and Livestock water use sectors). There are no significant basin-wide groundwater quality issues in other aquifers.

The expected 2060 water demand of 2,380 AFY in Basin 39 reflects a 1,010 AFY increase (73%) over the 2010 demand.

Gaps & Depletions

Based on projected demand and historical hydrology, alluvial and bedrock groundwater storage depletions may occur by 2020 and surface water gaps are projected to occur by 2060. Surface water gaps will be up to 20 AFY in the summer and will have a 34% probability of occurring in one or more months of the year by 2060. Alluvial groundwater storage depletions will be up to 210 AFY, peaking in size in summer, and will have a 60% probability of occurring in one or more months of the year by 2060. Bedrock groundwater storage depletions are expected to be 470 AFY on average in 2060 and occur during the summer. Bedrock groundwater storage depletions are small in size relative to the groundwater storage in Basin 39. However, localized groundwater storage depletions may have adverse effects on water yield, water level, and water quality.

Options

Water supply options were evaluated to assess potential ways of providing dependable long-range water supplies for Basin 39. 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.

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation demand sectors may mitigate surface water gaps and decrease alluvial and bedrock groundwater storage depletions. Temporary drought management activities will likely be unnecessary since gaps have a moderate probability of occurring and aquifer storage could continue to provide supplies during droughts.

Out-of-basin supplies could be developed to supplement the basin's water supplies and mitigate gaps and storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified one potentially viable out-of-basin site in the Southwest Region. However, in light of the basin's groundwater resources and the distance to reliable surface water supplies, out-of-basin supplies may not be cost-effective for users in the basin.

Water Supply Limitations
Southwest Region, Basin 39

Source	Limitation
Surface Water	Potential
Alluvial Groundwater	Potential
Bedrock Groundwater	Potential

Minimal · Potential · Significant

Water Supply Option Effectiveness
Southwest Region, Basin 39

Option	Effectiveness
Demand Management	Potentially 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

New small reservoirs (less than 50 AF) could be used to mitigate surface water gaps and adverse effects of localized groundwater storage depletions. The OCWP *Reservoir Viability Study* identified one potential site in the basin. However, substantial permit issues must be resolved in order to construct larger reservoirs.

Increased reliance on surface water, without reservoir storage, will increase surface water gaps and the basin is fully allocated. Therefore, this water supply option is not recommended.

Basin 39 has substantial groundwater recharge and storage from the Blaine aquifer. Groundwater is expected to supply over 98% of the demand in the basin. Increased reliance on bedrock groundwater can be used to mitigate surface water gaps or adverse effects of localized alluvial groundwater storage depletions. However, the Blaine aquifer underlies only about a quarter of the basin along its southern edge and may not be accessible for all users. Any increases in storage depletions would be small in size relative to the volume of water stored in the Blaine aquifer underlying the basin but localized adverse impacts could occur to users.

The Southwest Soil and Water Conservation District and water users in Basin 41 have used aquifer storage and recovery of surface water to increase the recharge to the Blaine aquifer for over 25 years. This practice could also be considered in Basin 39 to reduce localized storage depletions.

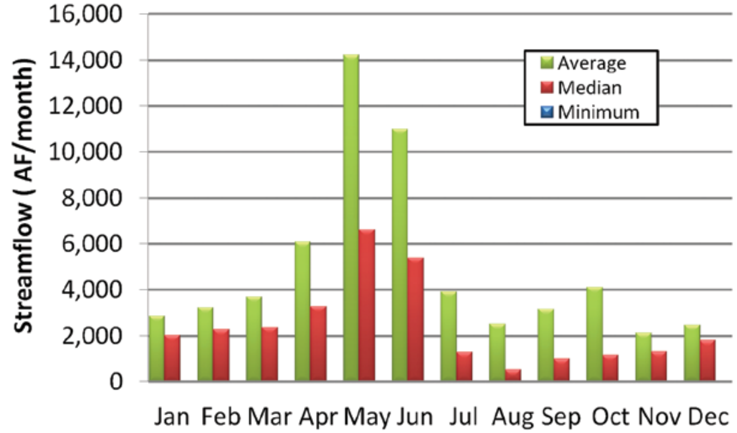
Basin 39 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Salt Fork of the Red River at Mangum had a prolonged period of below-average streamflow from the early 2000s through the end of the period of record (2007), corresponding to a period of below-average precipitation. From the mid 1990s to the early 2000s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median streamflow in Basin 39 is greater than 500 AF/month throughout the year and greater than about 2,000 AF/month in the winter, spring, and early summer. However, the river 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 39 is considered fair.
- There are no major reservoirs in this basin.

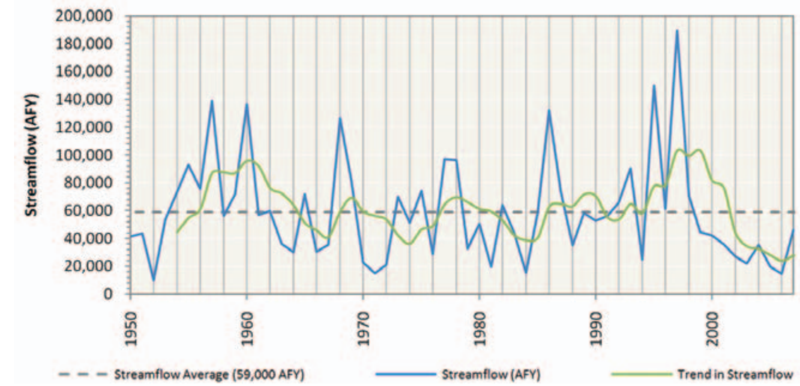
Monthly Historical Streamflow at the Basin Outlet

Southwest Region, Basin 39



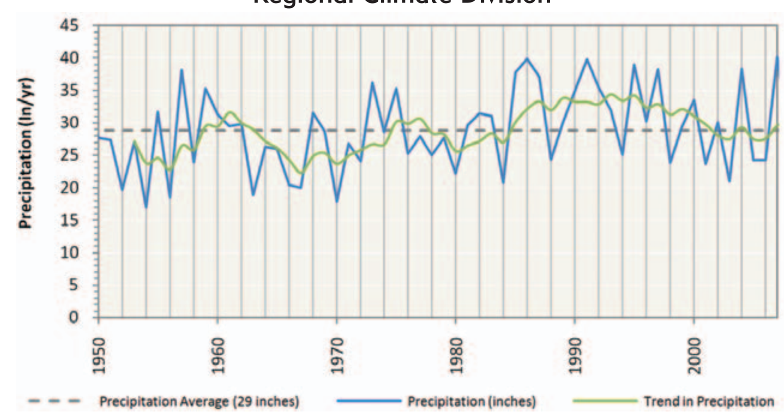
Historical Streamflow at the Basin Outlet

Southwest Region, Basin 39



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)

Southwest Region, Basin 39

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
Blaine	Bedrock	Major	22%	2,400	73,000	temporary 2.0	43,300
Western Oklahoma	Bedrock	Minor	39%	0	0	temporary 2.0	89,600
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	2,300	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 Blaine aquifer.
- For Basin 39, groundwater rights total 2,400 AFY in the Blaine aquifer, which underlies 22% of the basin and receives an estimated 3,000 AFY of recharge.
- The Blaine aquifer is used primarily for agriculture purposes only (Crop Irrigation and Livestock demand sectors) due to high total dissolved solids (TDS) concentrations. There are no other known groundwater quality issues in the basin.

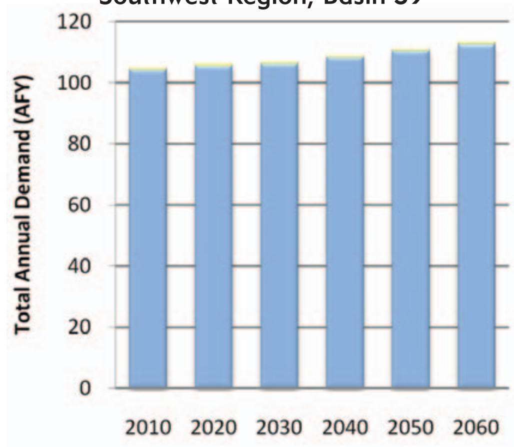
Notes & Assumptions

- 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.

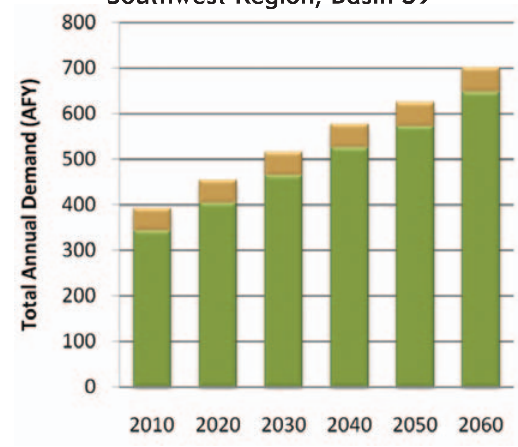
Water Demand

- The water needs of Basin 39 account for about 1% of the total demand in the Southwest Watershed Planning Region and will increase by 73% (1,010 AFY) from 2010 to 2060. The majority of the demand and growth in demand during this period will be from the Crop Irrigation demand sector.
- Surface water is used to meet 7% of the total demand in 2010 and will increase by 9% (10 AFY) form 2010 to 2060. Surface water is the primary source of supply for the Municipal & Industrial demand sector.
- Alluvial groundwater is used to meet 29% of the total demand in 2010 and its use will increase by 79% (310 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use during this period will be from the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet 64% of the total demand in 2010 and its use will increase by 79% (690 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use during this period will be from the Crop Irrigation demand sector.

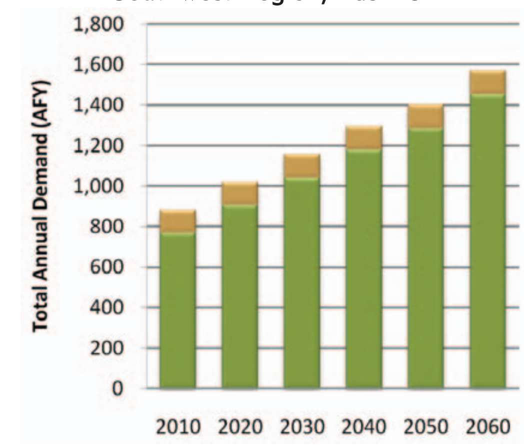
Surface Water Demand by Sector
Southwest Region, Basin 39



Alluvial Groundwater Demand by Sector
Southwest Region, Basin 39



Bedrock Groundwater Demand by Sector
Southwest Region, Basin 39



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

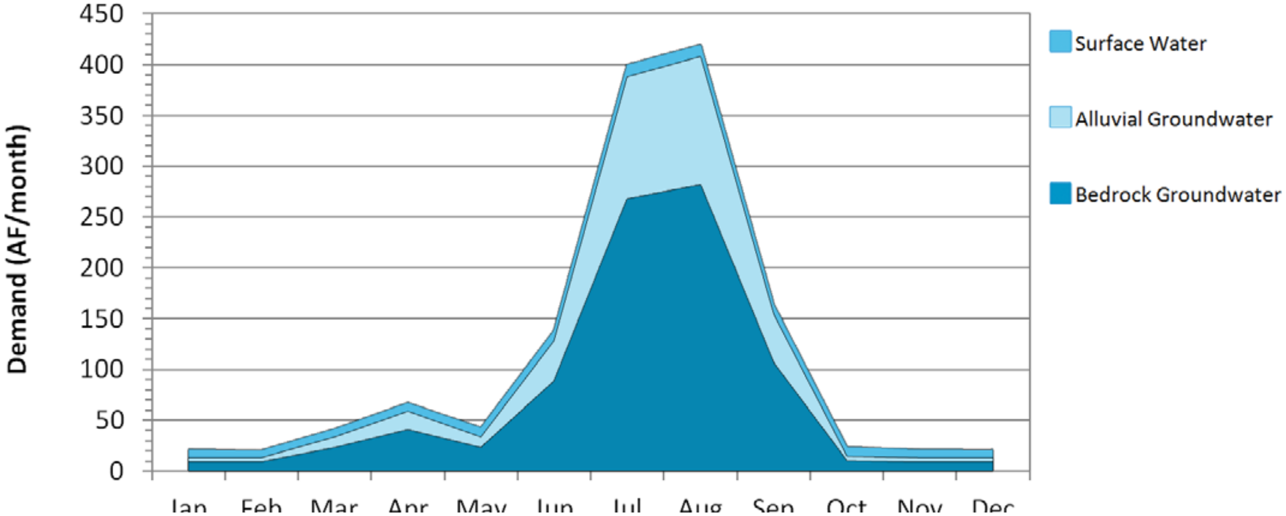
Total Demand by Sector
Southwest Region, Basin 39

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	1,110	160	100	0	0	0	0	1,370
2020	1,310	160	110	0	0	0	0	1,580
2030	1,510	160	110	0	0	0	0	1,780
2040	1,700	170	110	0	0	0	0	1,980
2050	1,860	170	110	0	0	0	0	2,140
2060	2,100	170	110	0	0	0	0	2,380

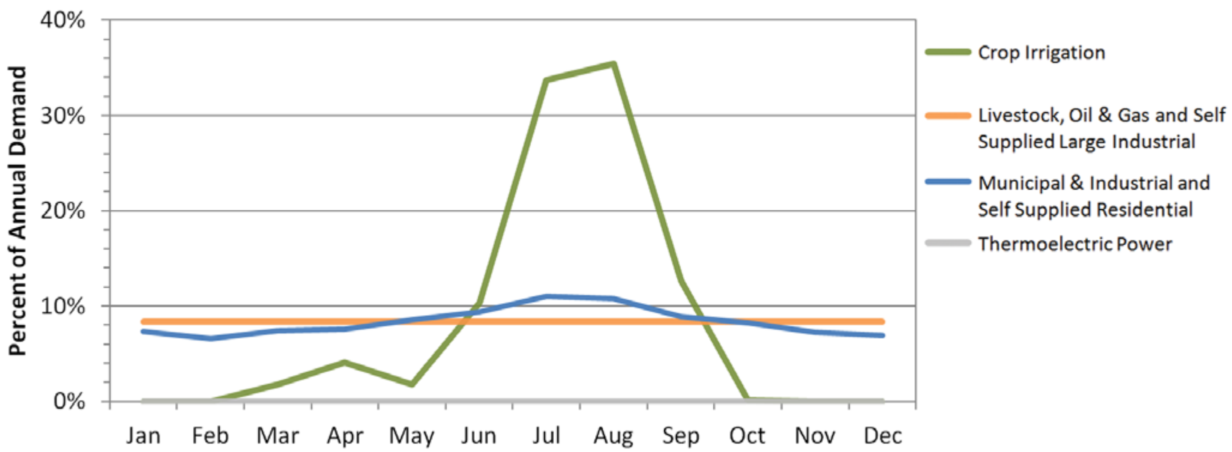
Notes & Assumptions

- 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)
Southwest Region, Basin 39



Monthly Demand Distribution by Source (2010)
Southwest Region, Basin 39



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use about 50% more water in summer months than winter use. Crop Irrigation has a high demand during summer months and little to no demand during winter months. Other demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 39 is 20 times the winter monthly demand, which is much more pronounced than the overall statewide pattern. Surface water use in the peak summer month is 1.5 times the monthly winter use. Alluvial and bedrock groundwater use in the peak summer month is 30.7 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, groundwater storage depletions may occur by 2020 and surface water gaps may occur by 2060.
- Surface water gaps in Basin 39 are expected to occur during the summer and will be minimal (10 AF/month) on a basin-scale.
- Alluvial groundwater storage depletions in Basin 39 may occur during the spring, summer, and fall, peaking in size in the summer. Alluvial groundwater storage depletions in 2060 will be up to 41% (90 AF/month) of the alluvial groundwater demand in the peak summer month, and up to 22% (20 AF/month) of the peak fall month alluvial groundwater demand.
- There will be a 60% probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions are most likely to occur during summer months.
- Bedrock groundwater storage depletions in Basin 39 may occur during the summer and will be up to 240 AF/month on average by 2060.
- Projected annual bedrock groundwater storage depletions are small in size relative to the amount of water in storage in the aquifer. However, localized groundwater storage depletions may occur and adversely affects yields, water quality and/or pumping costs. Current alluvial withdrawals are largely from non-delineated minor aquifers. Therefore, the severity of the storage depletions cannot be evaluated.

Surface Water Gaps by Season (2060 Demand)

Southwest Region, Basin 39

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)	10	10	34%
Sep-Nov (Fall)	0	0	0%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 39

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	10	10	5%
Jun-Aug (Summer)	90	90	53%
Sep-Nov (Fall)	20	20	24%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Southwest Region, Basin 39

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	50	100	0%	38%
2030	0	80	190	0%	47%
2040	0	120	290	0%	53%
2050	0	170	350	0%	57%
2060	20	210	470	34%	60%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 39

Months (Season)	Maximum Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	240
Sep-Nov (Fall)	0

1 Amount shown represent the largest amount for any one month in the 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

Southwest Region, Basin 39

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	20	210	470	34%	60%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	180	390	0%	57%
Moderately Expanded Conservation in M&I Water Use	0	210	470	0%	60%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	0	180	390	0%	57%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	0	130	300	0%	53%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Southwest Region, Basin 39

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

Water Supply Options & Effectiveness

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

Demand Management

Moderately expanded permanent conservation activities in the Crop Irrigation and Municipal and Industrial demand sectors could mitigate surface water gaps and reduce alluvial and bedrock groundwater depletions by about 14% and 17%, respectively. Temporary drought management activities will likely not be needed since gaps have a moderate probability of occurring and aquifer storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

Out-of-basin supplies could be developed to supplement the basin's water supplies and mitigate gaps and storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified one potentially viable out-of-basin site in the Southwest Region: Port in Basin 34. However, due to the distance to reliable surface water supplies, out-of-basin supplies may not be cost-effective for some users.

Reservoir Use

New small reservoirs (less than 50 AF) could be used to mitigate surface water gaps and adverse effects of localized storage depletions. Substantial permit issues must be resolved in order to construct larger reservoirs. If permittable, the basin's entire growth in demand from 2010 to 2060 could be supplied by a new river diversion and 1,000 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions. The OCWP *Reservoir Viability Study* identified Lower Mangum Reservoir as a potentially viable reservoir site in the basin that could be used as a source of in-basin and regional supply.

Increasing Reliance on Surface Water

Increased reliance on surface water, without reservoir storage, will increase surface water gaps and the basin is fully allocated for surface water permits. Therefore, this water supply option is not recommended.

Increasing Reliance on Groundwater

Groundwater is expected to supply over 98% of the demand in the basin. Increased reliance on bedrock groundwater can be used to mitigate surface water gaps or adverse effects of localized alluvial groundwater storage depletions. However, the Blaine aquifer underlies about a quarter of the basin and may not be accessible for all users. In addition, its water quality limits use primarily to irrigation. Any increases in storage depletions would be small in size relative to the volume of water in stored in the Blaine aquifer underlying the basin. However, localized adverse impacts may occur. A shift from surface water to alluvial groundwater could 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. The Southwest Soil and Water Conservation District and water users in Basin 41 have used aquifer storage and recovery of surface water to increase the recharge to the Blaine aquifer for over 25 years. Increased use of this practice could be effective in reducing the effects of localized bedrock groundwater storage depletions in Basin 39.

Notes & Assumptions

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

Oklahoma Comprehensive Water Plan

Data & Analysis
Southwest Watershed Planning Region

Basin 40

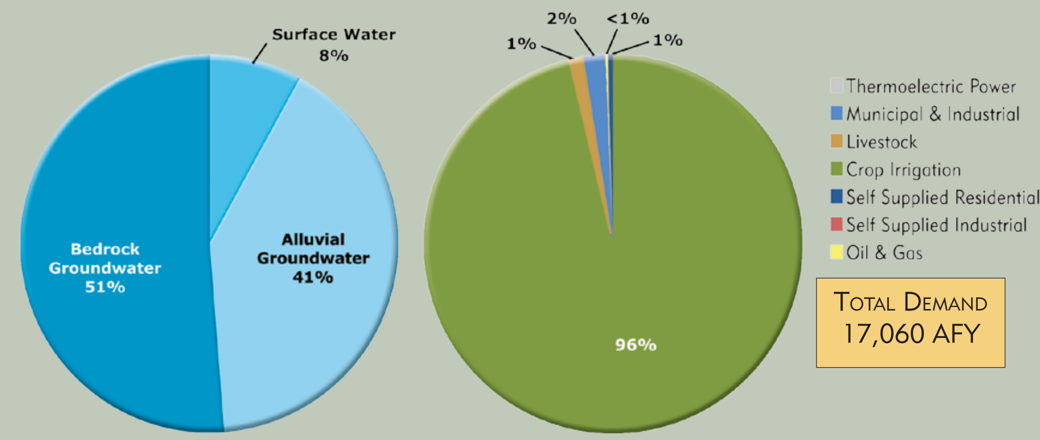
Basin 40 Summary

Synopsis

- Water users are expected to continue to rely primarily on groundwater sources.
- Bedrock 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.
- Alluvial groundwater storage depletions may occur from minor aquifers by 2020.
- Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts.
- Surface water quality may limit future supplies.
- By 2020, there is a high 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 storage depletions and gaps be decreased where economically feasible.
- Additional conservation could mitigate bedrock groundwater storage depletions and reduce surface water gaps and the adverse effects of localized alluvial groundwater storage depletions.
- Aquifer storage and recovery could be considered to store variable surface water supplies, increase bedrock groundwater storage, and reduce adverse effects of localized storage depletions.
- Use of additional groundwater supplies and/or developing additional small reservoir storage could mitigate surface water gaps. These supply sources could be used without major impacts to groundwater storage.
- Basin 40 has been identified as a water availability "hot spot" due to surface water and bedrock groundwater availability issues. (See "Regional and Statewide Opportunities and Solutions," *2012 OCWP Executive Report*.)

Current Demand by Source and Sector

Southwest Region, Basin 40



Water Resources

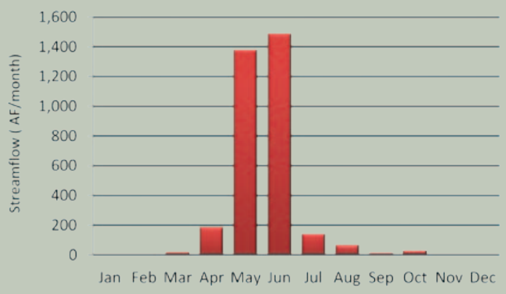
Southwest Region, Basin 40

Basin 40 accounts for about 10% of the water demand in the Southwest Watershed Planning Region. Approximately 96% of the basin's demand is from the Crop Irrigation demand sector. The monthly pattern of water use in the basin is based largely on the seasonality of the Crop Irrigation demand sector. Surface water satisfies about 8% of the total demand in the basin. Groundwater satisfies about 92% of the demand (51% bedrock and 41% alluvial). The peak summer month demand in Basin 40 is 150 times the winter demand, which is much more pronounced than the overall statewide pattern.

There are no major reservoirs in the basin. Historically, tributaries to the Red River downstream of the North Fork Red River (e.g., Sandy Creek and Gypsum Creek) have typically had less than 200 AF/month of flow, except during May and June when flow is about 1,400 AF/month. Additionally, future streamflow in Sandy Creek is expected to be further reduced by upstream compact obligations. The Red River is not considered as a feasible water supply source at this time due to water quality considerations. However, future conditions and/or technological advances may make this a more viable source of supply in the future. Surface water in the basin

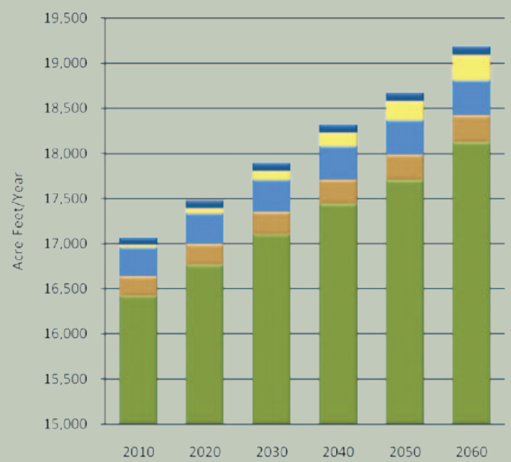
Median Historical Streamflow at the Basin Outlet

Southwest Region, Basin 40



Projected Water Demand

Southwest Region, Basin 40



is fully allocated, limiting diversions to existing permitted amounts. Relative to other basins in the state, the surface water quality in Basin 40 is considered poor. Sandy Creek and Gypsum Creek are impaired for Agricultural use due to high levels of total dissolved solids (TDS), chlorides, and sulfates. However, individual lakes and streams may have acceptable water quality.

The majority of water rights in the basin are from the Blaine aquifer, which has about 370,000 AF of storage in the basin and underlies about 68% of the basin. There is an estimated 15,000 AFY of recharge to the Blaine aquifer from Basin 40. The majority of alluvial groundwater rights are from non-delineated minor aquifers along the Red River or Sandy Creek. There are also water rights from non-delineated minor bedrock aquifers. Site-specific information on the suitability of the minor aquifers for supply should be considered before large scale use. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. Water quality issues, including high TDS concentrations, are expected to limit the use of the Blaine aquifer to agriculture (Crop Irrigation and Livestock water use sectors).

The expected 2060 water demand of 19,180 AFY reflects a 2,120 AFY increase (12%) over the 2010 demand.

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 260 AFY and occur throughout the year, peaking in size in summer. Alluvial groundwater storage depletions will be up to 800 AFY and occur throughout the year, peaking in size in summer. Surface water gaps and alluvial groundwater depletions are expected to occur in almost every year by 2060 (97% probability). Current alluvial withdrawals are largely from non-delineated minor aquifers. Therefore, the severity of the storage depletions cannot be evaluated due to insufficient information. Bedrock groundwater storage depletions are expected to be 870 AFY on average by 2060 and occur during the summer and fall. Projected bedrock storage depletions are minimal relative to the amount of water in storage in the basin. However, localized groundwater storage depletions may have adverse affects on well yield, 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 40. 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

Southwest Region, Basin 40

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness

Southwest Region, Basin 40

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

Moderately expanded permanent conservation activities in the Crop Irrigation demand sector may mitigate bedrock groundwater storage depletions. Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could substantially decrease surface water gaps and alluvial groundwater storage depletions. Temporary drought management activities will likely be ineffective since gaps will occur in almost every year and aquifer storage could continue to provide supplies during droughts.

Out-of-basin supplies could be developed to mitigate gaps and storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Southwest Region. However, due to the distance to dependable surface water supplies and substantial in-basin groundwater supplies, out-of-basin supplies may not be cost-effective for many users.

New small reservoirs (less than 50 AF) could be used to meet the demand of surface water users or groundwater users experiencing adverse effects of localized storage depletions. Substantial permit issues must be resolved in order to construct larger reservoirs.

Increased reliance on surface water, without reservoir storage, will increase surface water gaps and streamflow in the basin is fully allocated. Therefore, this water supply option is not recommended.

Increased reliance on bedrock groundwater can be used to mitigate surface water gaps or adverse effects from localized alluvial groundwater storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in the Blaine aquifer underlying the basin.

Alluvial groundwater supplies are from non-delineated minor aquifers; therefore, increased reliance on these supplies is not recommended without site-specific information.

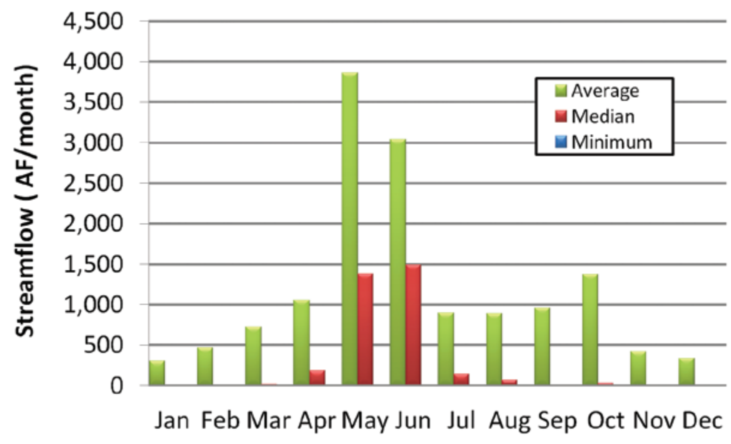
The Southwest Soil and Water Conservation District and water users in Basin 41 have used aquifer storage and recovery of surface water to increase the recharge to the Blaine aquifer for over 25 years. This practice could also be considered in Basin 40 to reduce localized storage depletions.

Basin 40 Data & Analysis

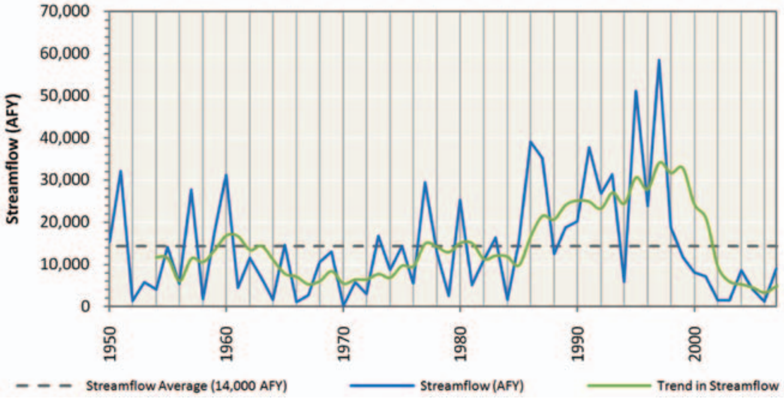
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Red River is not used as a source of supply in Basin 40 due to water quality considerations. Tributaries to the Red River downstream of North Fork Red River had a prolonged period of below-average flow from the mid 2000s to 2007, corresponding to a period of below-average precipitation. From the late 1980s to early 2000s, the basin went through a period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median flow in tributaries to the Red River downstream of North Fork Red River is less than 200 AF/month, except in May and June when it is about 1,400 AF/month. The river can have prolonged periods of low flow in May and June as well.
- There are no major reservoirs in this basin.

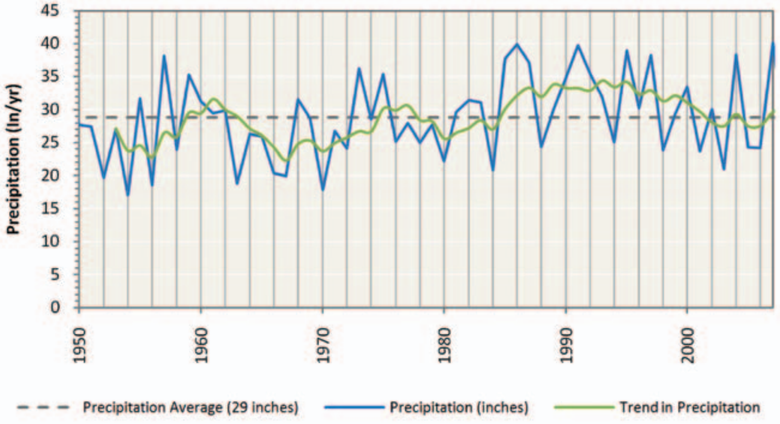
Monthly Historical Streamflow at the Basin Outlet
Southwest Region, Basin 40



Historical Streamflow at the Basin Outlet
Southwest Region, Basin 40



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)

Southwest Region, Basin 40

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
Blaine	Bedrock	Major	68%	4,700	372,000	temporary 2.0	227,700
Southwestern Oklahoma	Bedrock	Minor	25%	0	120,000	temporary 2.0	82,800
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	800	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	3,800	N/A	temporary 2.0	N/A

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

Groundwater Resources

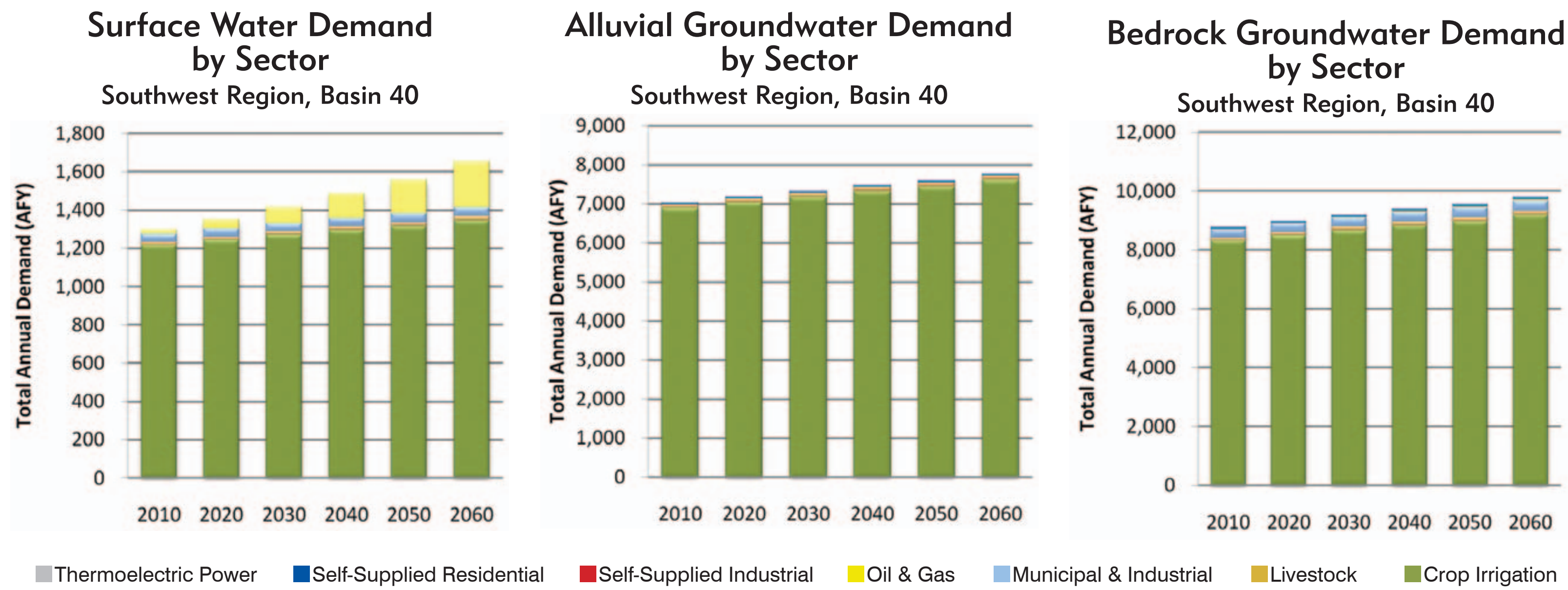
- The majority of groundwater rights in the basin are from the Blaine aquifer.
- For Basin 40, groundwater rights total 4,700 AFY in the Blaine aquifer, which underlies 68% of the basin, has 372,000 AF of storage, and receives an estimated 15,000 AFY of recharge. Groundwater rights total 4,600 AFY in non-delineated groundwater sources.
- The Blaine aquifer is used primarily for agriculture (Crop Irrigation and Livestock demand sectors) due to high total dissolved solids (TDS) concentrations. There are no other significant groundwater quality issues in other aquifers 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 40 account for about 10% of the total demand in the Southwest Watershed Planning Region and is projected to increase by 12% (2,120 AFY) from 2010 to 2060. The majority of demand and growth in demand during this period will be from the Crop Irrigation demand sector.
- Surface water is used to meet 8% of the total demand in 2010 and its use will increase by 27% (350 AFY) from 2010 to 2060. The majority of surface water demand is from the Crop Irrigation demand sector. However, the majority of growth in surface water use will be from the Oil and Gas demand sector.
- Alluvial groundwater is used to meet 41% of the total demand in 2010 and its use will increase by 11% (750 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use during this period will be from the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet 51% of the total demand in 2010 and its use will increase by 12% (1,020 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use during this period will be from the Crop Irrigation demand sector.

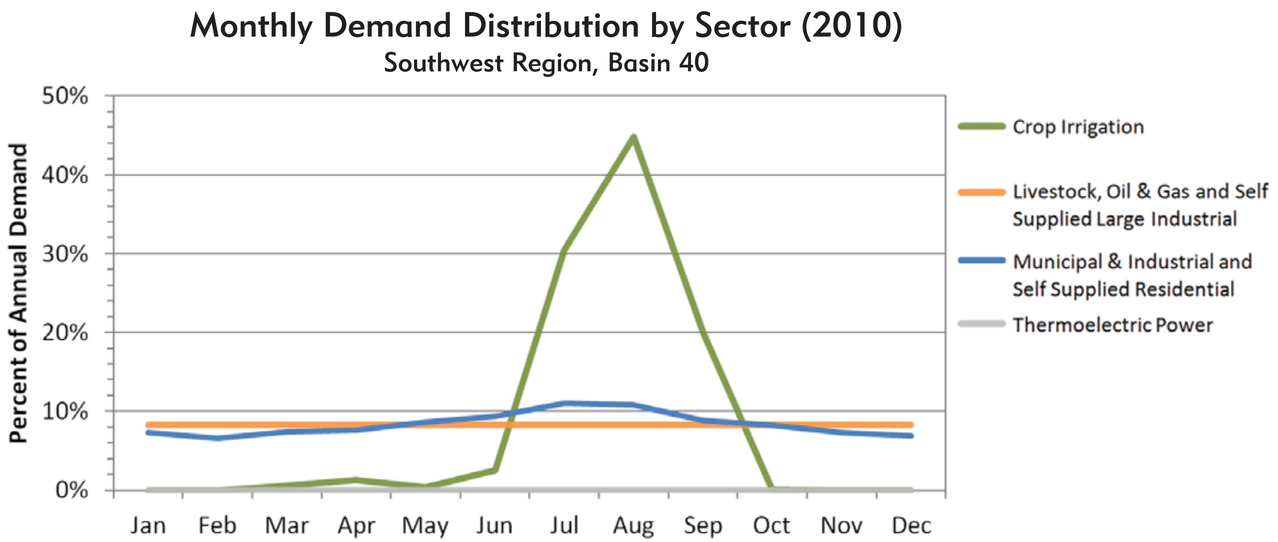


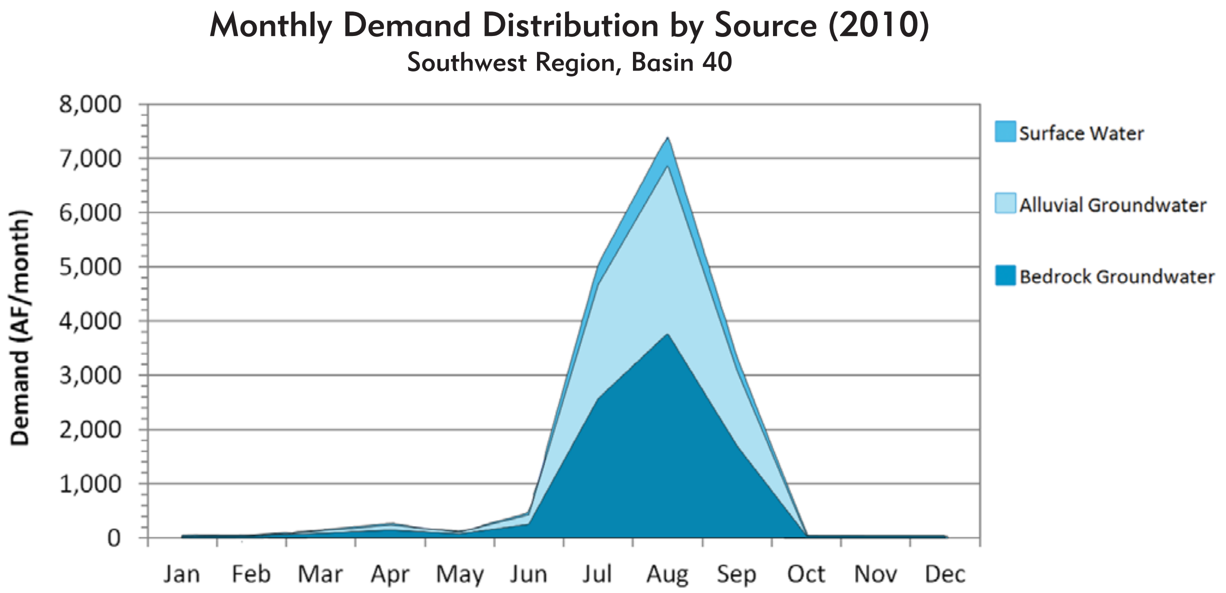
Total Demand by Sector
Southwest Region, Basin 40

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	16,420	210	320	30	0	80	0	17,060
2020	16,760	230	340	60	0	80	0	17,470
2030	17,100	250	360	100	0	90	0	17,900
2040	17,440	270	370	150	0	90	0	18,320
2050	17,700	280	380	210	0	90	0	18,660
2060	18,120	300	390	280	0	90	0	19,180

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.





Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use about 50% more water in summer months than winter use. Crop Irrigation has a high demand during summer months and little to no demand during winter months. The Livestock and Oil and Gas demand sectors have more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 40 is 150 times the winter demand, which is much more pronounced than the overall statewide pattern. The ratio of peak summer month demand to the monthly winter use is high for all water sources in basin.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions may occur by 2020.
- Surface water gaps are expected to occur in at least one month of almost every year by 2060. Surface water gaps in Basin 40 may occur throughout the year, peaking in size in the summer. Surface water gaps in 2060 will be up to 10% (60 AF/month) of the surface water demand in the peak summer month, and as high as 67% (20 AF/month) of the months' winter surface water demand.
- Alluvial groundwater storage depletions are expected to occur in at least one month of almost every year by 2060. Alluvial groundwater storage depletions in Basin 40 may occur throughout the year, peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 9% (310 AF/month) of the alluvial groundwater demand in the peak summer month and, while much smaller in size (10 AF/month), storage depletions during winter months may equal the entire alluvial groundwater demand.
- Bedrock groundwater storage depletions in Basin 40 may occur during the summer and fall, peaking in size in the summer. Bedrock groundwater storage depletions in 2060 will be 10% (190 AF/month) of the monthly fall bedrock groundwater demand and will be up to 10% (400 AF/month) of the monthly summer demand.
- Projected annual bedrock groundwater storage depletions are minimal relative to the amount of water stored in Basin 40's portion of the Blaine aquifer. However, localized storage depletions may occur and adversely affect yields, water quality and / or pumping costs.

Surface Water Gaps by Season (2060 Demand)

Southwest Region, Basin 40

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	20	20	83%
Mar-May (Spring)	10	10	64%
Jun-Aug (Summer)	60	40	86%
Sep-Nov (Fall)	30	20	83%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 40

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	10	10	83%
Mar-May (Spring)	20	20	67%
Jun-Aug (Summer)	310	210	86%
Sep-Nov (Fall)	150	10	83%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Southwest Region, Basin 40

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	30	130	170	76%	79%
2030	50	300	340	84%	90%
2040	120	450	520	93%	91%
2050	180	610	650	95%	95%
2060	260	800	870	97%	97%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 40

Months (Season)	Maximum Storage Depletion[1]
	Acre-feet
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	400
Sep-Nov (Fall)	190

1 Amount shown represent the largest amount for any one month in the 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

Southwest Region, Basin 40

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	260	800	870	97%	97%
Moderately Expanded Conservation in Crop Irrigation Water Use	110	80	0	83%	84%
Moderately Expanded Conservation in M&I Water Use	220	800	840	97%	97%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	70	80	0	83%	84%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	60	70	0	83%	83%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Southwest Region, Basin 40

Reservoir Storage	Diversion
AF	AFY
100	100
500	400
1,000	600
2,500	1,200
5,000	1,900
Required Storage to Meet Growth in Demand (AF)	5,600
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 Crop Irrigation sector could mitigate bedrock storage depletions. Moderately expanded permanent conservation activities in the Crop Irrigation and Municipal and Industrial demand sectors could reduce alluvial groundwater depletions by 90% and surface water gaps by 73%. Temporary drought management activities are not recommended since gaps will occur in almost every year and aquifer storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

Out-of-basin supplies could be developed to mitigate gaps and storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Southwest Region: Port in Basin 34 and Mangum (Lower) in Basin 39. However, due to the distance to dependable surface water supplies and availability of substantial in-basin groundwater supplies, out-of-basin supplies may not be cost-effective for many users.

Reservoir Use

New small reservoirs (less than 50 AF) could be used to reduce surface water gaps or adverse effects of localized storage depletions. Substantial permit issues must be resolved in order to construct larger reservoirs. If permittable, the basin's entire growth in demand from 2010 to 2060 could be supplied by a new river diversion and a 5,600 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions.

Increasing Reliance on Surface Water

Increased reliance on surface water through direct diversions, without reservoir storage, will increase surface water gaps. Also, the basin is fully allocated. Therefore, this water supply option is not recommended.

Increasing Reliance on Groundwater

Groundwater is expected to supply over 90% of the demand in the basin. Increased reliance on bedrock groundwater could be used to mitigate surface water gaps or adverse effects from localized alluvial groundwater storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in the Blaine aquifer underlying the basin. However, increases in localized storage depletions may adversley effect yields, water quality, and pumping costs. Alluvial groundwater supplies are from non-delineated minor aquifers; therefore, increased reliance on these supplies is not recommended without site-specific information. The Southwest Soil and Water Conservation District and water users in Basin 41 have used aquifer storage and recovery of surface water to increase the recharge to the Blaine aquifer for over 25 years. Increased use of this practice can be very effective at reducing the effects of localized storage depletions in Basin 40.

Notes & Assumptions

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

Oklahoma Comprehensive Water Plan

Data & Analysis
Southwest Watershed Planning Region

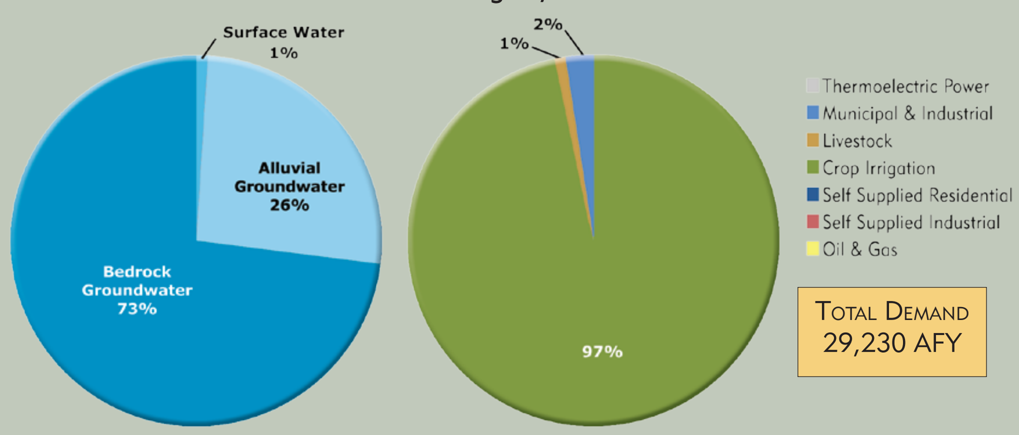
Basin 41

Basin 41 Summary

Synopsis

- Water users are expected to continue to rely primarily on alluvial and bedrock groundwater sources.
- Bedrock 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.
- Alluvial groundwater storage depletions of minor aquifers may occur by 2020.
- Surface water is fully allocated, limiting diversions to existing permitted amounts.
- Starting in 2050, there is a moderate probability of surface water gaps from increased demands on existing supplies during low flow periods, which will increase to a 64% probability by 2060.
- To reduce the risk of adverse impacts on water supplies, it is recommended that storage depletions and gaps be decreased where economically feasible.
- Additional conservation could mitigate surface water gaps and adverse effects of localized groundwater depletions.
- Aquifer storage and recovery could be considered to store variable surface water supplies, increase bedrock groundwater storage, and reduce adverse effects of localized storage depletions.
- Use of additional groundwater supplies and/or developing additional small reservoir storage could mitigate surface water gaps and adverse effects of localized alluvial ground water storage depletions. However, localized bedrock groundwater storage depletions may result from increased use of the Blaine aquifer.
- Basin 41 has been identified as a water availability "hot spot" due to bedrock groundwater availability issues. (See "Regional and Statewide Opportunities and Solutions," *2012 OCWP Executive Report*.)

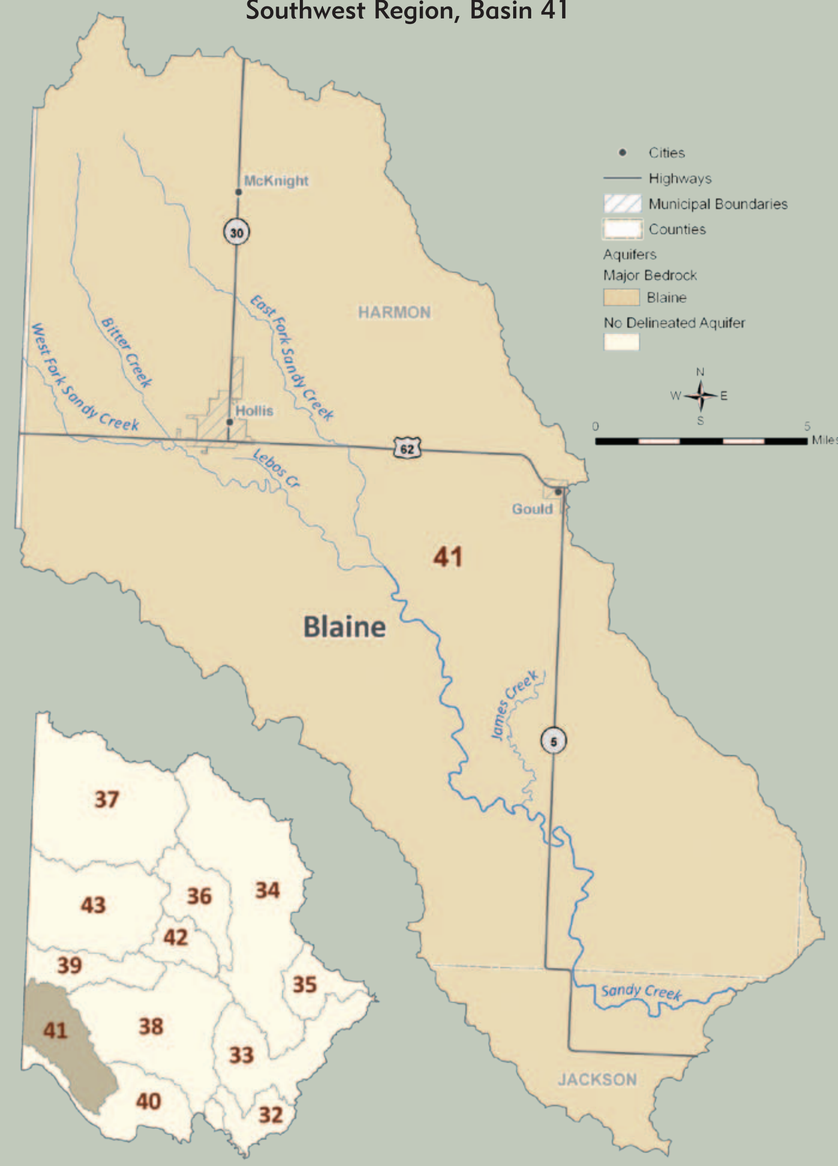
Current Demand by Source and Sector
Southwest Region, Basin 41



Basin 41 accounts for about 16% of the water demand in the Southwest Watershed Planning Region. About 97% of the basin's demand is from the Crop Irrigation demand sector. Surface water satisfies about 1% of the total demand in the basin.

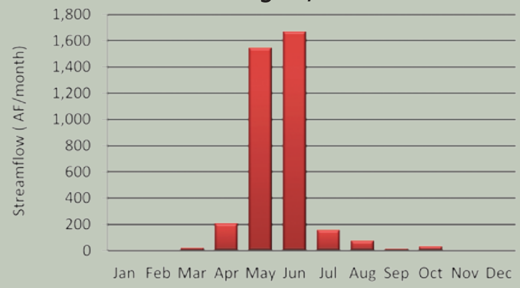
Groundwater satisfies about 99% of the total demand (73% bedrock and 26% alluvial). The monthly pattern of water use in the basin is based largely on the seasonality of the Crop Irrigation demand sector. The peak summer month demand

Water Resources
Southwest Region, Basin 41



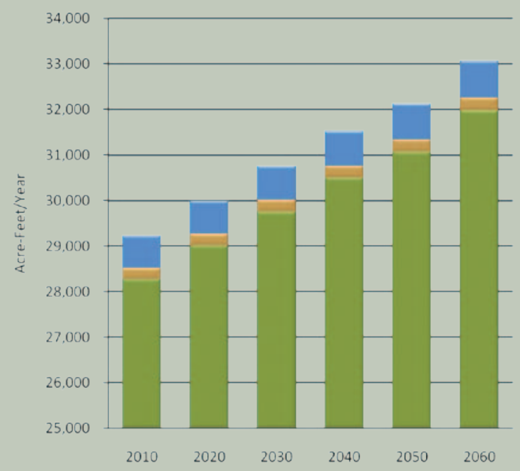
Median Historical Streamflow at the Basin Outlet

Southwest Region, Basin 41



Projected Water Demand

Southwest Region, Basin 41



in Basin 41 is 155.7 times the winter demand, which is much more pronounced than the overall statewide pattern.

Historically, Sandy Creek near Eldorado typically has flows less than 200 AF/month, except in May and June when it is greater than 1,500 AF/month. However, the river can have periods of low flow in May and June as well. Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts. Relative to other basins in the state, the surface water quality in Basin 41 is considered poor. Sandy Creek and Gypsum Creek are impaired for Agricultural use due to high levels of total dissolved solids (TDS), chlorides, and sulfates.

The majority of groundwater rights in the basin are in the Blaine and minor alluvial aquifers. There is about 464,000 AF of water stored in Basin 41's portion of the Blaine aquifer, which underlies about 99% of the basin. The majority of alluvial groundwater rights are in non-delineated minor aquifers along Sandy Creek and the Red River. Site-specific information on the reliability of these aquifers should be considered before large scale use. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. Water quality issues, including high TDS concentrations, are expected to limit the use of the Blaine aquifer to agriculture (Crop Irrigation and Livestock water use sectors).

The expected 2060 water demand of 33,060 AFY reflects a 3,830 AFY increase (13%) over the 2010 demand.

Gaps & Depletions

Based on projected demand and historical hydrology, alluvial and bedrock groundwater depletions may occur by 2020, while surface water gaps may occur by 2050. Surface water gaps will be up to 20 AFY and has a 64% probability of occurring in at least one month of almost every year by 2060. Surface water gaps may occur in the summer. Alluvial groundwater storage depletions will be 890 AFY by 2060 and have an 95% probability of occurring in at least one month of the year. Alluvial groundwater storage depletions may occur throughout the year, peaking in size in the summer. Bedrock groundwater storage depletions will be 2,420 AFY on average by 2060 and occur in summer and fall, peaking in size in the summer. Projected bedrock storage depletions are small in size relative to the amount of water stored in Basin 41's portion of the Blaine aquifer. However, localized storage depletions may occur and adversely affect yields, water quality and/or pumping costs. Current alluvial withdrawals are largely from a non-delineated ground water source. Therefore, the severity of the storage depletions could not be evaluated due to insufficient storage information.

Water Supply Limitations

Southwest Region, Basin 41

Surface Water	Potential
Alluvial Groundwater	Potential
Bedrock Groundwater	Significant

Minimal   Potential   Significant

Water Supply Option Effectiveness

Southwest Region, Basin 41

Demand Management	Potentially 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

Options

Water supply options were evaluated to assess potential ways of providing dependable long-range water supplies for Basin 41. 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.

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation demand sectors could mitigate gaps and storage depletions. Temporary drought management activities could be effective since gaps are not expected until 2050 and aquifer storage could continue to provide supplies during droughts.

Out-of-basin supplies may mitigate groundwater storage depletions and surface water gaps. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Southwest Region. However, due to the distance to reliable surface water supplies and in-basin groundwater supplies, out-of-basin supplies may not be cost-effective for many users.

New small reservoirs (less than 50 AF) could be used to mitigate surface water gaps or adverse effects of localized alluvial groundwater storage depletions. Substantial permit issues must be resolved in order to construct larger reservoirs.

Increased reliance on surface water, without reservoir storage, will increase surface water gaps and Basin 41 is fully allocated. Therefore, this water supply option is not recommended.

Increased reliance on the Blaine aquifer could be used to mitigate surface water gaps or adverse effects of localized alluvial groundwater storage depletions, but would increase the amount of bedrock groundwater storage depletions. The resulting storage depletions may be moderate in size compared to the extent of the Blaine aquifer's storage in Basin 41, potentially creating localized storage depletions. Alluvial groundwater supplies are from non-delineated minor aquifers; therefore, increased reliance on these supplies is not recommended without site-specific information.

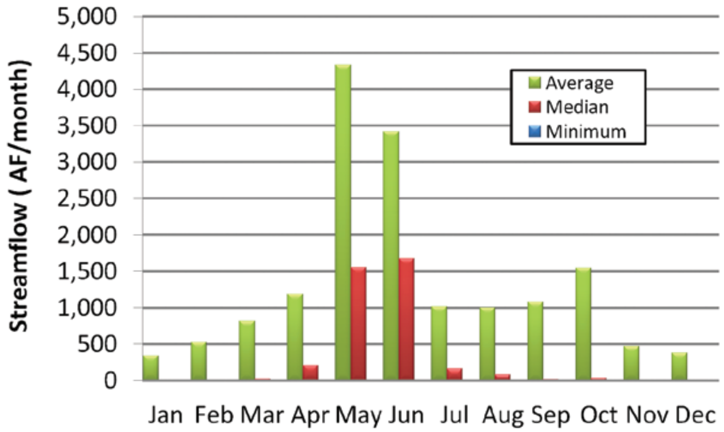
The Southwest Soil and Water Conservation District and water users in this basin have used aquifer storage and recovery of surface water to increase the recharge to the Blaine aquifer for over 25 years. Increased use of this practice could be effective at reducing the effects of localized storage depletions.

Basin 41 Data & Analysis

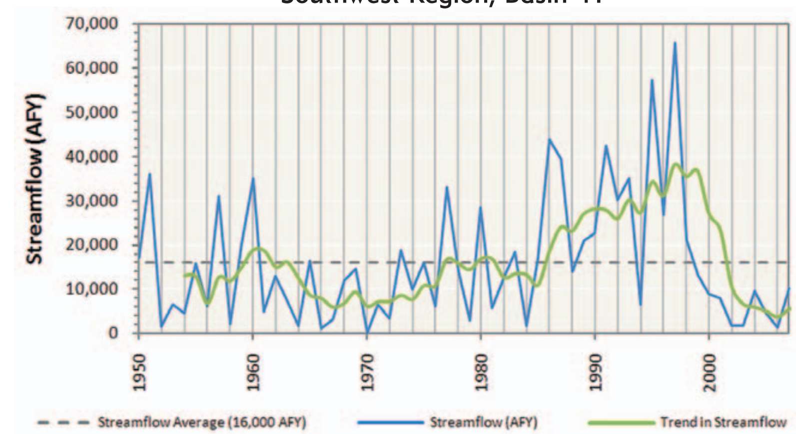
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. Sandy Creek near Eldorado had a prolonged period of below-average flow from the early 1960s to mid 1970s, corresponding to a period of below-average precipitation. From the mid 1980s to early 2000s, the basin had a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- Historically, the median flow in Sandy Creek near Eldorado has been less than 200 AF/month, except in May and June when it is greater than 1,500 AF/month. However, the river can have periods of low flow in May and June as well.
- Relative to other basins in the state, the surface water quality in Basin 41 is considered poor. However, individual lakes and streams may have acceptable water quality.
- There are no major reservoirs in this basin.

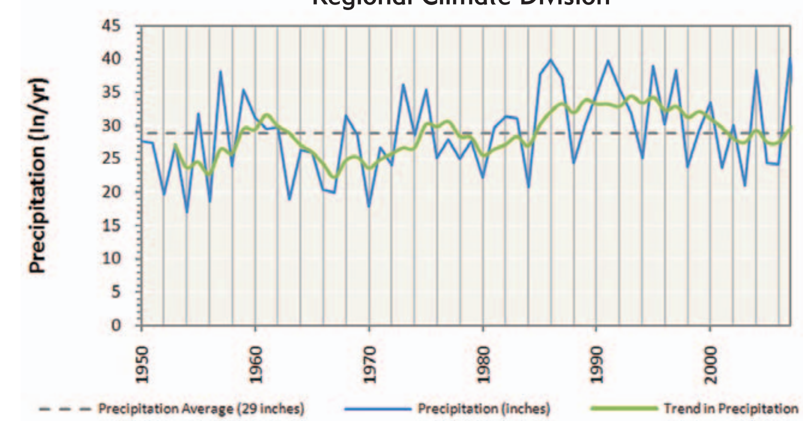
Monthly Historical Streamflow at the Basin Outlet
Southwest Region, Basin 41



Historical Streamflow at the Basin Outlet
Southwest Region, Basin 41



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)

Southwest Region, Basin 41

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
Blaine	Bedrock	Major	99%	53,300	464,000	temporary 2.0	194,200
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	0	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	17,100	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

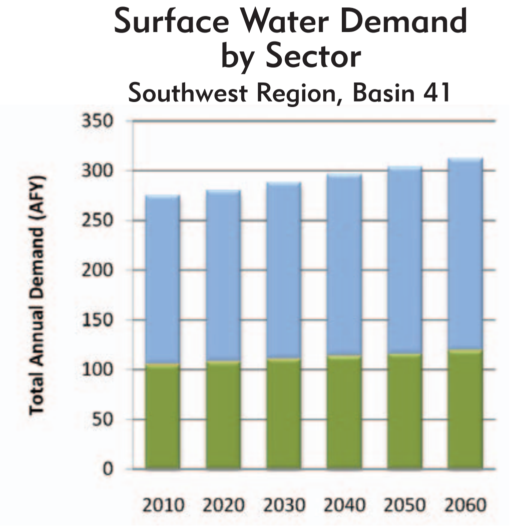
- The majority of groundwater rights in the basin are from the Blaine aquifer which has an estimated 19,000 AFY of recharge.
- The Blaine aquifer is used primarily for agriculture (Crop Irrigation and Livestock demand sectors) due to high total dissolved solids (TDS) concentrations. There are no other significant groundwater quality issues in the basin.

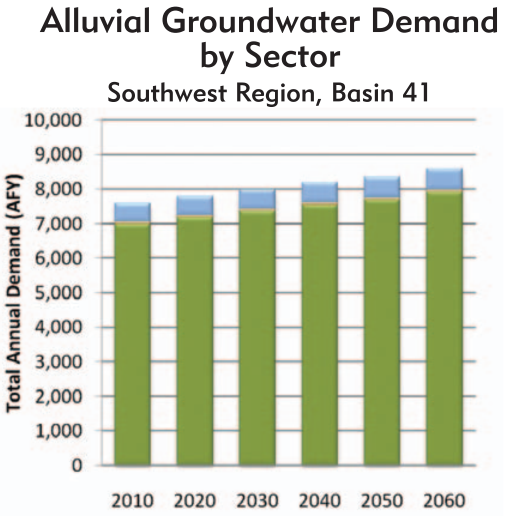
Notes & Assumptions

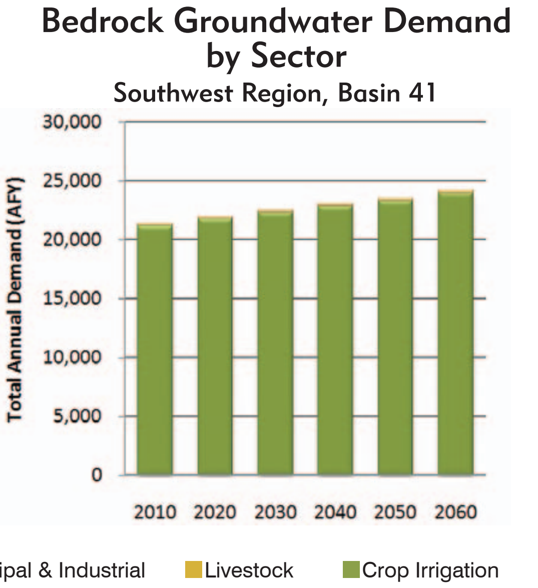
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater 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 41 account for about 16% of the total demand in the Southwest Watershed Planning Region and will increase by 13% (3,830 AFY) from 2010 to 2060. The majority of demand and growth in demand during this period will be from the Crop Irrigation demand sector.
- Surface water is used to meet 1% of the total demand in 2010 and its use will increase by 13% (30 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use during this period will be from the Municipal and Industrial demand sector.
- Alluvial groundwater is used to meet 26% of the total demand in 2010 and its use will increase by 13% (1,000 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use during this period will be from the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet 73% of the total demand in 2010 and its use will increase by 13% (2,800 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use during this period will be from the Crop Irrigation demand sector.







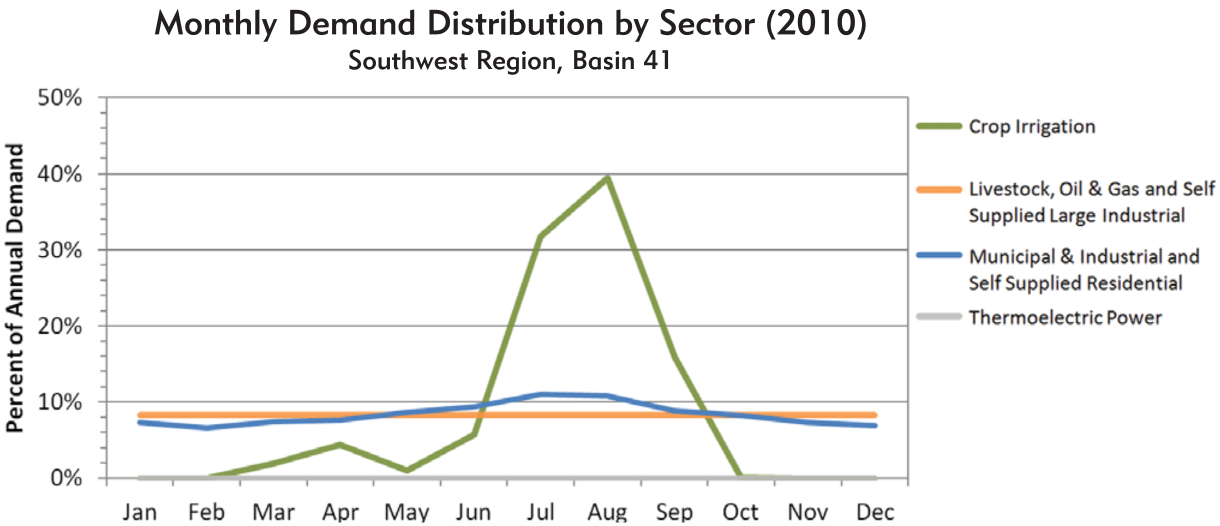
Total Demand by Sector

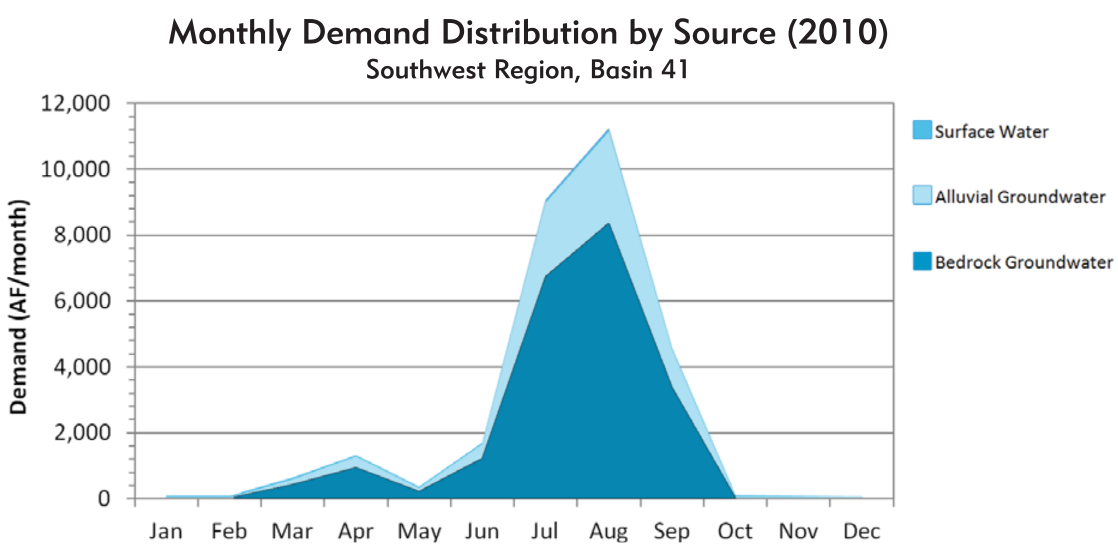
Southwest Region, Basin 41

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	28,270	250	710	0	0	0	0	29,230
2020	29,020	260	710	0	0	0	0	29,990
2030	29,760	260	740	0	0	0	0	30,760
2040	30,500	270	760	0	0	0	0	31,530
2050	31,070	270	780	0	0	0	0	32,120
2060	31,980	280	800	0	0	0	0	33,060

Notes & Assumptions

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





Current Monthly Demand Distribution by Sector

- The Municipal and Industrial demand sector uses 52% more water in summer months than in winter. Crop Irrigation has a high demand during summer months and little to no demand during winter months. Other demand sectors have more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 41 is 155.7 times the winter demand, which is much more pronounced than the overall statewide pattern. Surface water use in the peak summer month is 4.8 times the monthly winter use. Alluvial and bedrock groundwater have a similarly high ratio of the peak month summer demand to the monthly winter use. The ratio of peak alluvial and bedrock groundwater summer month demand to winter monthly demand closely resembles the seasonality of the Crop Irrigation demand sector.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, alluvial and bedrock groundwater depletions may occur by 2020 while surface water gaps are expected by 2050.
- There will be a 64% probability of surface water gaps occurring in at least one month of the year by 2060. Surface water gaps in Basin 41 may occur in the summer and in 2060 will be up to 17% (10 AF/month) of the surface water demand in the peak summer month.
- There will be a 95% probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions are most likely to occur during winter months. Alluvial groundwater storage depletions in Basin 41 may occur during the spring, summer, and fall. Alluvial groundwater storage depletions in 2060 will be up to 11% (340 AF/month) of the alluvial groundwater demand in the peak summer month and as much as 20% (10 AF/month) of the monthly winter alluvial groundwater demand.
- Bedrock groundwater storage depletions in Basin 41 may occur during the summer and fall. Bedrock storage depletions in 2060 will be 12% (1,100 AF/month) of the bedrock groundwater demand on average in the peak summer month and 12% (440 AF/month) on average of the monthly fall bedrock groundwater demand.
- Projected annual bedrock storage depletions are small in size relative to the amount of water in storage in the aquifer. However, localized storage depletions may occur and adversely affect yields, water quality and/or pumping costs. Current alluvial withdrawals are largely from a non-delineated groundwater source. Hence, the severity of the storage depletions could not be evaluated more thoroughly due to insufficient information.

Surface Water Gaps by Season (2060 Demand)

Southwest Region, Basin 41

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)	10	10	64%
Sep-Nov (Fall)	0	0	0%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 41

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	10	10	83%
Mar-May (Spring)	30	20	62%
Jun-Aug (Summer)	340	270	76%
Sep-Nov (Fall)	140	10	78%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Southwest Region, Basin 41

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	160	510	0%	78%
2030	0	340	970	0%	84%
2040	0	500	1,460	0%	86%
2050	10	640	1,830	48%	93%
2060	20	890	2,420	64%	95%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 41

Months (Season)	Maximum Storage Depletion[1]
	Acre-feet
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	1,100
Sep-Nov (Fall)	440

1 Amount shown represent the largest amount for any one month in the 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

Southwest Region, Basin 41

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	20	890	2,420	64%	95%
Moderately Expanded Conservation in Crop Irrigation Water Use	0	60	0	0%	83%
Moderately Expanded Conservation in M&I Water Use	20	780	2,420	60%	90%
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

Southwest Region, Basin 41

Reservoir Storage	Diversion
AF	AFY
100	100
500	400
1,000	800
2,500	1,500
5,000	2,200
Required Storage to Meet Growth in Demand (AF)	12,200
Required Storage to Meet Growth in Surface Water Demand (AF)	<100

Water Supply Options & Effectiveness

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

Demand Management

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation demand sectors could mitigate gaps and storage depletions. Temporary drought management activities could be effective since gaps are not expected to occur until 2050 and aquifer storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

Out-of-basin supplies may mitigate groundwater storage depletions and surface water gaps. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Southwest Region: Port in Basin 34 and Mangum (Lower) in Basin 39. However, due to the distance to reliable surface water supplies and availability of in-basin groundwater supplies, out-of-basin supplies may not be cost-effective for many users.

Reservoir Use

New small reservoirs (less than 50 AF) could be used to mitigate surface water gaps or adverse effects of localized alluvial groundwater storage depletions. However, no viable reservoir sites were identified for Basin 41. Additionally, substantial permit issues must be resolved in order to construct larger reservoirs However, if permittable, the basin's entire growth in demand from 2010 to 2060 could be supplied by a new river diversion and a12,200 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions.

Increasing Reliance on Surface Water

Increased reliance on surface water through direct diversions, without reservoir storage, will increase surface water gaps. Also, Basin 41 is fully allocated for surface water permits. Therefore, this water supply option is not recommended.

Increasing Reliance on Groundwater

Increased reliance on the Blaine aquifer could be used to mitigate surface water gaps or adverse effects of localized alluvial groundwater storage depletions, but would increase the amount of bedrock groundwater storage depletions. The resulting storage depletions may be moderate in size compared to the Blaine aquifer's storage in Basin 41 but may create localized storage depletions. Alluvial groundwater supplies are from non-delineated minor aquifers; therefore, increased reliance on these supplies is not recommended without site-specific information. The Southwest Soil and Water Conservation District and water users in this basin have used aquifer storage and recovery of surface water to increase the recharge to the Blaine aquifer for over 25 years. Increased use of this practice could be effective at reducing the effects of localized storage depletions.

Notes & Assumptions

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

Oklahoma Comprehensive Water Plan

Data & Analysis
Southwest Watershed Planning Region

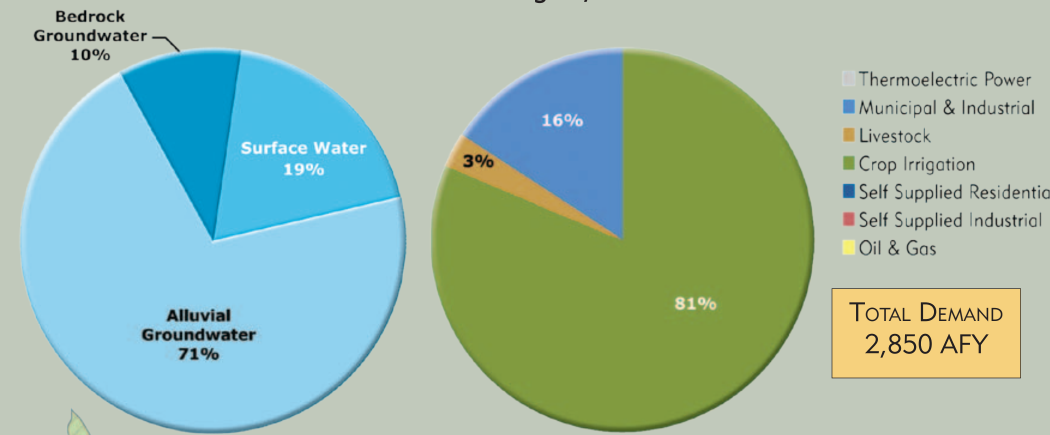
Basin 42

Basin 42 Summary

Synopsis

- Water users are expected to continue to rely primarily on groundwater supplies.
- Alluvial storage depletions may occur by 2020 and be moderate in size relative to total aquifer storage in the basin. Localized storage depletions may cause adverse effects for users.
- Bedrock storage depletions in non-delineated minor aquifers may occur by 2020; however, the severity of the storage depletions cannot be evaluated due to insufficient information.
- By 2020, 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 and storage depletions be decreased where economically feasible.
- Additional conservation could mitigate surface water gaps and adverse effects from localized alluvial and bedrock groundwater storage depletions.
- Use of additional groundwater supplies and/or developing additional small reservoir storage could mitigate surface water gaps. These supply sources could be used without major impacts to groundwater storage.
- Basin 42 has been identified as a water availability "hot spot" due to surface water and alluvial groundwater availability issues. (See "Regional and Statewide Opportunities and Solutions," *2012 OCWP Executive Report*.)

Current Demand by Source and Sector
Southwest Region, Basin 42

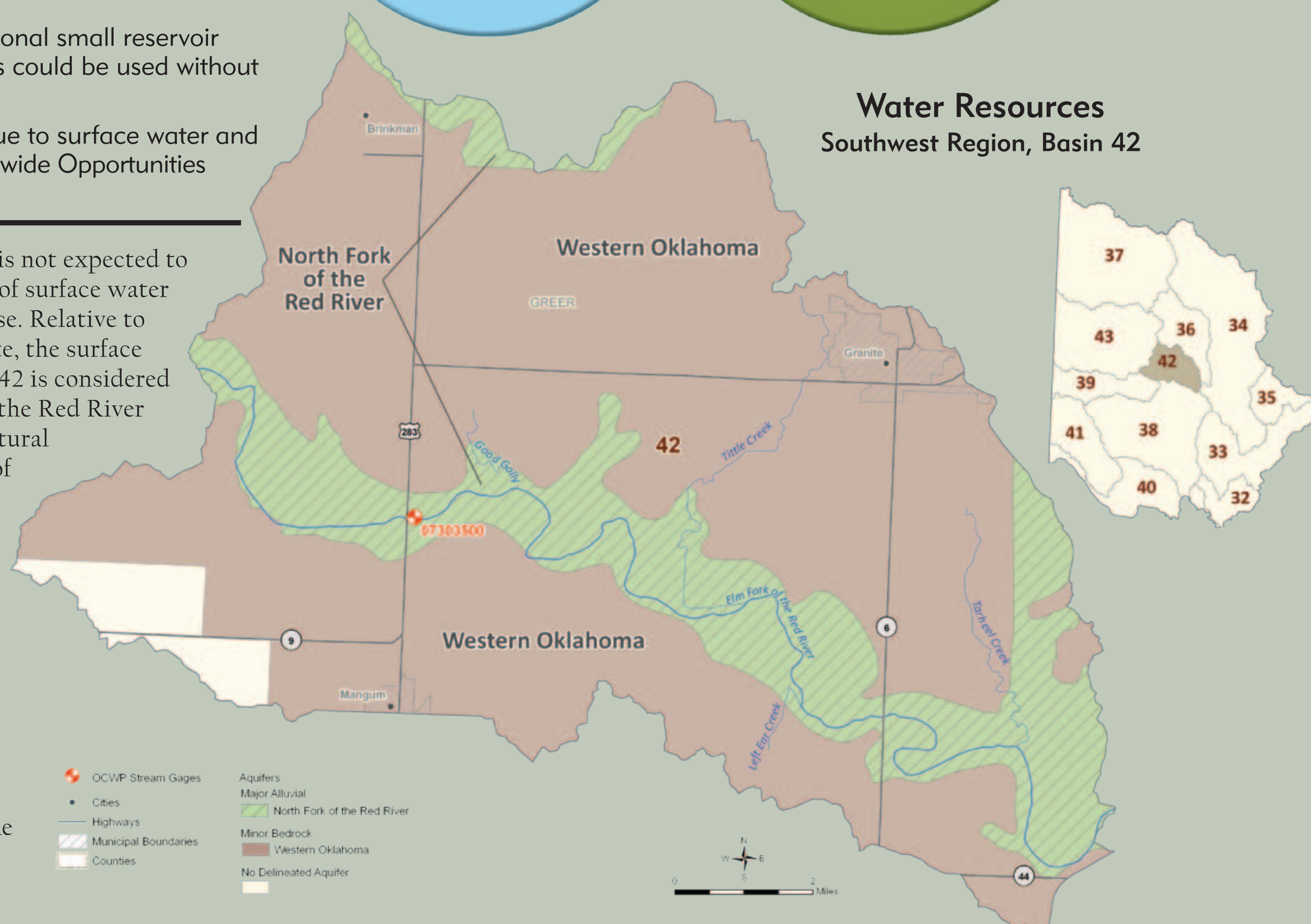


Basin 42 accounts for about 2% of the water demand in the Southwest Watershed Planning Region. About 81% of the basin's demand is from the Crop Irrigation demand sector. Municipal and Industrial (16%) is the second-largest demand sector. Surface water satisfies about 19% of the total demand in the basin. Groundwater satisfies about 81% of the demand (71% alluvial and 10% bedrock). The peak summer demand month in Basin 42 is about 22.5 times the winter demand, which is much more pronounced than the overall statewide pattern.

There are no major reservoirs in the basin. Flow in the Elm Fork Red River upstream of North Fork Red River is typically greater than 1,000 AF/month throughout the year and greater than 9,000 AF/month in April and May. However, the river can have periods of low flow in any month of the year. Future streamflow is expected to be further reduced by upstream compact obligations. The availability of permits is not expected to limit the development of surface water supplies for in-basin use. Relative to other basins in the state, the surface water quality in Basin 42 is considered poor. The Elm Fork of the Red River is impaired for Agricultural use due to high levels of chloride. However, individual lakes and streams may have acceptable water quality.

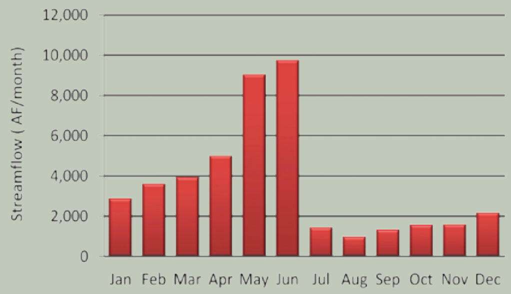
The majority of groundwater rights in the basin are from the North Fork of the Red River aquifer, located along the Elm Fork of the Red River. This aquifer underlies about 21% of the basin and has about

Water Resources
Southwest Region, Basin 42



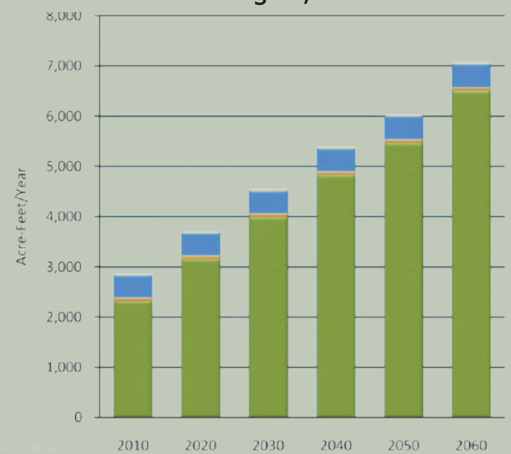
Median Historical Streamflow at the Basin Outlet

Southwest Region, Basin 42



Projected Water Demand

Southwest Region, Basin 42



136,000 AF of groundwater storage in the basin. Additional alluvial groundwater rights exist for non-delineated minor aquifers and terrace deposit of the Salt Fork of the Red River. Bedrock groundwater rights are from the Western Oklahoma and non-delineated minor aquifers. Site-specific information on the reliability of these groundwater sources should be considered before large scale use. 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.

The expected 2060 water demand of 7,070 AFY reflects a 4,220 AFY increase (148%) over the 2010 demand.

Gaps & Depletions

Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions may occur by 2020. Surface water gaps in 2060 will be up to 270 AFY and will have a 79% probability of occurring in at least one month in each year. Alluvial groundwater storage depletions in 2060 will be up to 2,650 AFY and will have a 78% probability of occurring in at least one month in each year. Surface water gaps and alluvial groundwater storage depletions in Basin 42 may occur during spring, summer and fall, peaking in size during the summer. Projected alluvial groundwater storage depletions are moderate in size relative to the amount of water in storage in the aquifer. Localized storage depletions may occur and adversely affect yields, water quality, and/or pumping costs. Bedrock groundwater storage depletions are expected to be 440 AFY on average by 2060, peaking in size in summer. Bedrock groundwater rights are largely from a non-delineated ground water source; therefore, the severity of the storage depletions cannot be evaluated due to insufficient information on water in storage.

Options

Water supply options were evaluated to assess potential ways of providing dependable long-range water supplies for Basin 42. Water users are expected to continue to rely primarily on 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 alluvial storage depletions and bedrock groundwater depletions. Additional conservation activities are not expected to reduce surface water gaps. Temporary drought management activities will likely be ineffective since gaps have a moderate probability of occurring and aquifer storage could continue to provide supplies during droughts.

Water Supply Limitations

Southwest Region, Basin 42

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness

Southwest Region, Basin 42

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

Typically Effective Potentially Effective
Likely Ineffective No Option Necessary

Out-of-basin supplies could mitigate gaps and storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Southwest Region. However, due to the distance to reliable surface water supplies, out-of-basin supplies may not be cost-effective for many users.

Reservoir storage could mitigate surface water gaps and the adverse affects of localized storage depletions. A new river diversion and 3,900 AF of reservoir storage at the basin outlet could meet the entire growth in demand from 2010 to 2060.

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

Basin 42 has substantial groundwater recharge and storage from the North Fork of the Red River aquifer. Increased reliance on this aquifer could mitigate surface water gaps and the adverse effects of localized bedrock groundwater storage depletions. Any resulting storage depletions would be moderate in size relative to the volume of available water in the North Fork aquifer.

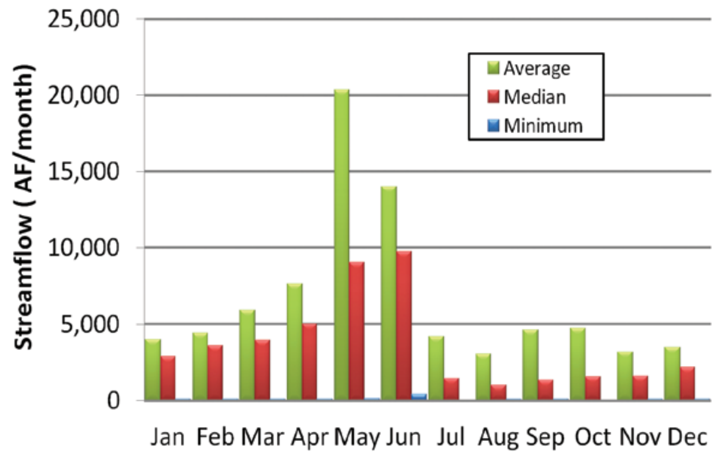
Bedrock groundwater supplies are from non-delineated minor aquifers; therefore, increased reliance on these supplies is not recommended without site-specific information.

Basin 42 Data & Analysis

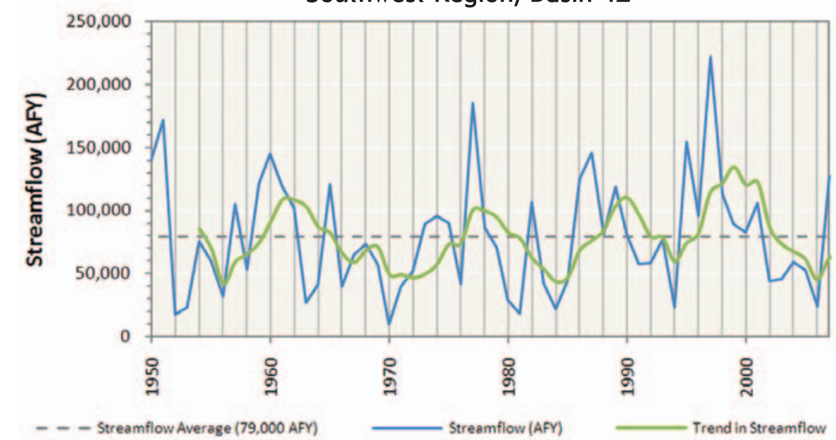
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. Elm Fork Red River upstream of North Fork Red River had a prolonged period of below average flow from the mid 1960s to mid 1970s, corresponding to a period of below-average precipitation. From the mid 1990s to early 2000s the basin had a prolonged period of above-average streamflow, demonstrating hydrologic variability in the basin.
- The median flow at Elm Fork Red River upstream of North Fork Red River is greater than about 1,000 AF/month throughout the year and greater than 9,000 AF/month in May and June. However, the river can have periods of low flow in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 42 is considered poor. However, individual lakes and streams may have acceptable water quality.
- There are no major reservoirs in this basin.

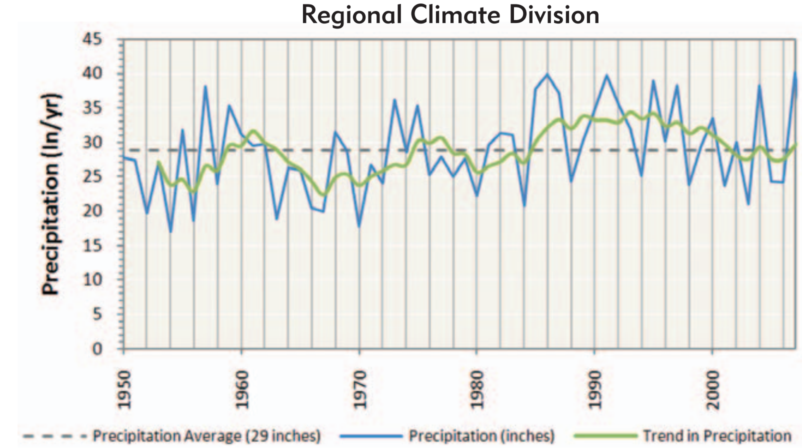
Monthly Historical Streamflow at the Basin Outlet
Southwest Region, Basin 42



Historical Streamflow at the Basin Outlet
Southwest Region, Basin 42



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)

Southwest Region, Basin 42

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	AF/acre	AFY
North Fork of the Red River	Alluvial	Major	21%	4,300	136,000	1.0	8,400
Western Oklahoma	Bedrock	Minor	97%	200	0	temporary 2.0	131,300
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	800	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	2,800	N/A	temporary 2.0	N/A

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

Groundwater Resources

- The majority of groundwater rights in the basin are from the North Fork of the Red River aquifer.
- For Basin 42, groundwater rights total 4,300 AFY in the North Fork of the Red River aquifer, which underlies 21% of the basin and has 136,000 AF of storage. Groundwater rights total 200 AFY in the Western Oklahoma aquifer and 3,600 in non-delineated groundwater sources.
- There are no significant groundwater quality issues in the basin.

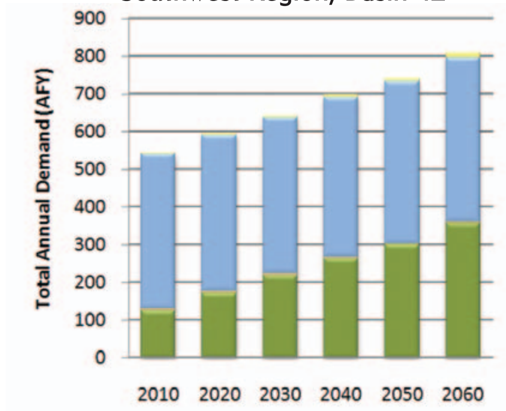
Notes & Assumptions

- 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.

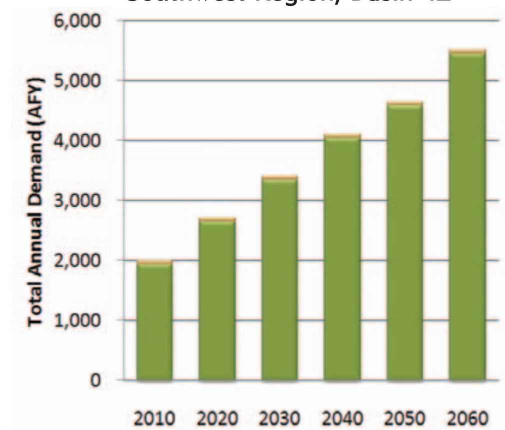
Water Demand

- The water needs of Basin 42 account for about 2% of the total demand in the Southwest Watershed Planning Region and will increase by 148% (4,220 AFY) from 2010 to 2060. The majority of demand and growth in demand during this period will be in the Crop Irrigation demand sector.
- Surface water is used to meet 19% of the total demand in 2010 and its use will increase by 48% (260 AFY) from 2010 to 2060. The majority of surface water use during this period will be in the Municipal and Industrial demand sector. However, the majority of growth in surface water use from 2010 to 2060 will be in the Crop Irrigation demand sector.
- Alluvial groundwater is used to meet 71% of the total demand in 2010 and its use will increase by 175% (3,510 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 10% of the total demand in 2010 and its use will increase by 153% (450 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use during this period will be in the Crop Irrigation demand sector.

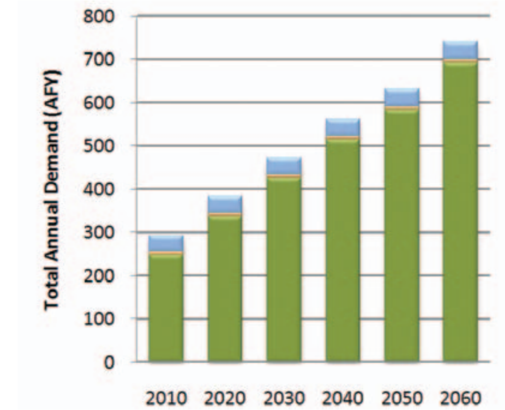
Surface Water Demand by Sector
Southwest Region, Basin 42



Alluvial Groundwater Demand by Sector
Southwest Region, Basin 42



Bedrock Groundwater Demand by Sector
Southwest Region, Basin 42



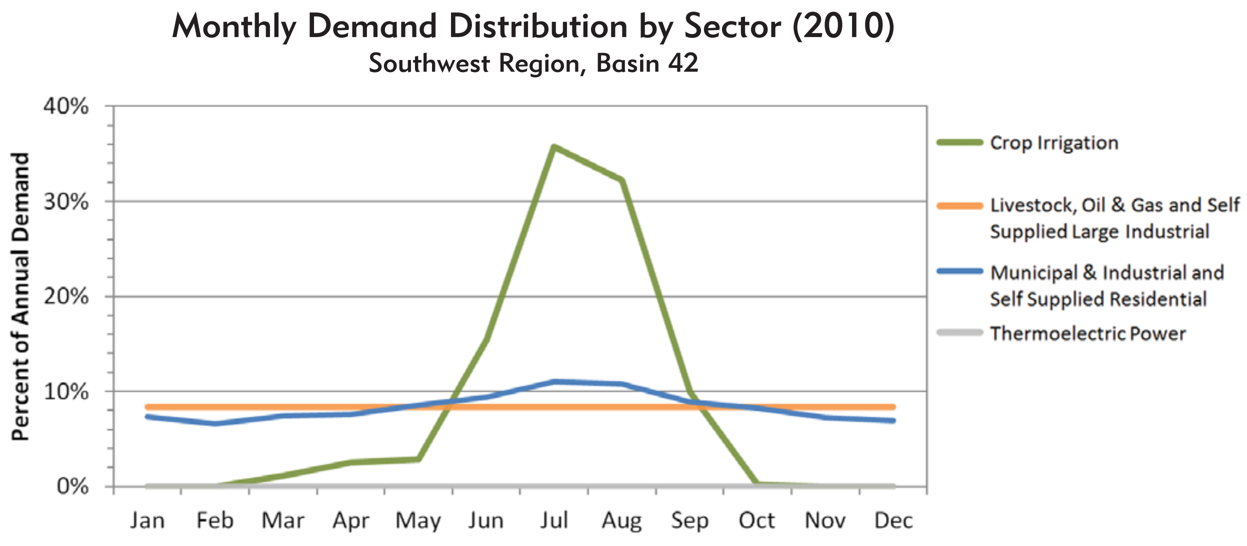
Thermoelectric Power | Self-Supplied Residential | Self-Supplied Industrial | Oil & Gas | Municipal & Industrial | Livestock | Crop Irrigation

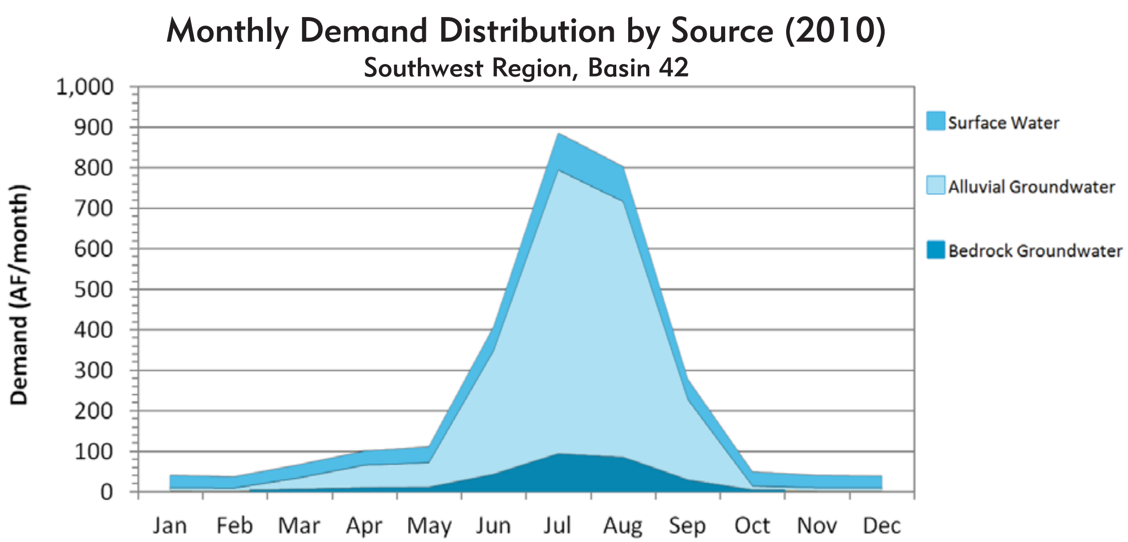
Total Demand by Sector
Southwest Region, Basin 42

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	2,320	80	450	0	0	0	0	2,850
2020	3,150	80	450	0	0	0	0	3,680
2030	3,990	80	450	10	0	0	0	4,530
2040	4,830	80	460	10	0	0	0	5,380
2050	5,470	80	470	10	0	0	0	6,030
2060	6,500	80	480	10	0	0	0	7,070

Notes & Assumptions

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





Current Monthly Demand Distribution by Sector

- The Municipal and Industrial demand sector uses 52% more water in summer months than winter use. Crop Irrigation has a high demand during summer months and little to no demand during winter months. Other demand sectors have more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer demand month in Basin 42 is 22.5 times the monthly winter demand, which is much more pronounced than the overall statewide pattern. Surface water demand in the peak summer month is 3 times the monthly winter demand. Monthly alluvial groundwater use peaks in the summer at 132 times the monthly winter use. Bedrock groundwater use in the peak summer month is 27 times the monthly winter use.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and groundwater depletions may occur by 2020.
- Surface water gaps in Basin 42 may occur during spring, summer and fall, peaking in size during the summer. Surface water gaps in 2060 will be up to 56% (100 AF/month) of the surface water demand in the peak summer month, and as much as 25% (10 AF/month) of the peak spring month's demand. There will be a 79% probability of gaps occurring in at least one month of the year by 2060. Surface water gaps are most likely to occur during the summer months.
- Alluvial groundwater storage depletions in Basin 42 may occur during spring, summer and fall, peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 57% (1,110 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 21% (30 AF/month) of the peak spring month's demand. There will be a 78% probability of storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions are most likely to occur during summer months.
- Bedrock groundwater storage depletions in Basin 42 may occur during spring, summer and fall, peaking in size during the summer. Bedrock groundwater storage depletions in 2060 will be 64% (160 AF/month) of the bedrock groundwater demand on average in the peak summer month, and while much smaller in size (10 AF/month), storage depletions during the peak spring month may equal the entire bedrock groundwater demand.
- Projected annual alluvial groundwater storage depletions are moderate relative to the volume of water in Basin 42's portion of the amount of water stored in the North Fork of the Red River aquifer. Localized depletions may occur and adversely affect users. Bedrock groundwater rights are largely from a non-delineated groundwater source. Therefore, the severity of the storage depletions cannot be evaluated.

Surface Water Gaps by Season (2060 Demand)

Southwest Region, Basin 42

Months (Season)	Maximum Gap[1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	10	10	5%
Jun-Aug (Summer)	100	90	71%
Sep-Nov (Fall)	40	40	38%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 42

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	0	0	0%
Mar-May (Spring)	30	20	5%
Jun-Aug (Summer)	1,110	980	71%
Sep-Nov (Fall)	290	290	38%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Southwest Region, Basin 42

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	40	390	80	47%	47%
2030	100	880	180	53%	55%
2040	150	1,390	280	59%	64%
2050	200	1,880	330	76%	78%
2060	270	2,650	440	79%	78%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Southwest Region, Basin 42

Months (Season)	Maximum Storage Depletion[1]
	Acre-feet
Dec-Feb (Winter)	0
Mar-May (Spring)	10
Jun-Aug (Summer)	160
Sep-Nov (Fall)	40

1 Amount shown represent the largest amount for any one month in the 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

Southwest Region, Basin 42

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	270	2,650	440	79%	78%
Moderately Expanded Conservation in Crop Irrigation Water Use	260	2,400	400	79%	78%
Moderately Expanded Conservation in M&I Water Use	260	2,620	430	78%	78%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	220	2,370	400	78%	78%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	160	1,770	290	71%	72%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Southwest Region, Basin 42

Reservoir Storage	Diversion
AF	AFY
100	200
500	700
1,000	1,300
2,500	2,800
5,000	5,400
Required Storage to Meet Growth in Demand (AF)	3,900
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 and Crop Irrigation demand sectors could reduce surface water gaps by about 19% and groundwater depletions by about 10%. Temporary drought management activities will likely be ineffective since gaps will occur in almost every year and aquifer storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

Out-of-basin supplies could mitigate gaps and storage depletions. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Southwest Region: Port in Basin 34 and Mangum (Lower) in Basin 39. However, due to the distance to reliable surface water supplies and the availability of in-basin groundwater supplies, out-of-basin supplies may not be cost-effective for many users.

Reservoir Use

New reservoirs may be an effective option to mitigate surface water gaps and the adverse effects of localized storage depletions. A new river diversion and 3,900 AF of reservoir storage at the basin outlet could meet the entire growth in demand from 2010 to 2060. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions.

Increasing Reliance on Surface Water

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

Increasing Reliance on Groundwater

Basin 42 has substantial groundwater recharge and storage from the North Fork of the Red River aquifer. Increased reliance on this aquifer could mitigate surface water gaps and adverse effects of localized bedrock groundwater storage depletions, but would increase the amount of storage depletions. Any increases in storage depletions would be small relative to the volume of water in aquifer storage in 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. Bedrock groundwater supplies are from non-delineated minor aquifers; therefore, increased reliance on these supplies is not recommended without site-specific information.

Notes & Assumptions

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

Oklahoma Comprehensive Water Plan

Data & Analysis
Southwest Watershed Planning Region

Basin 43

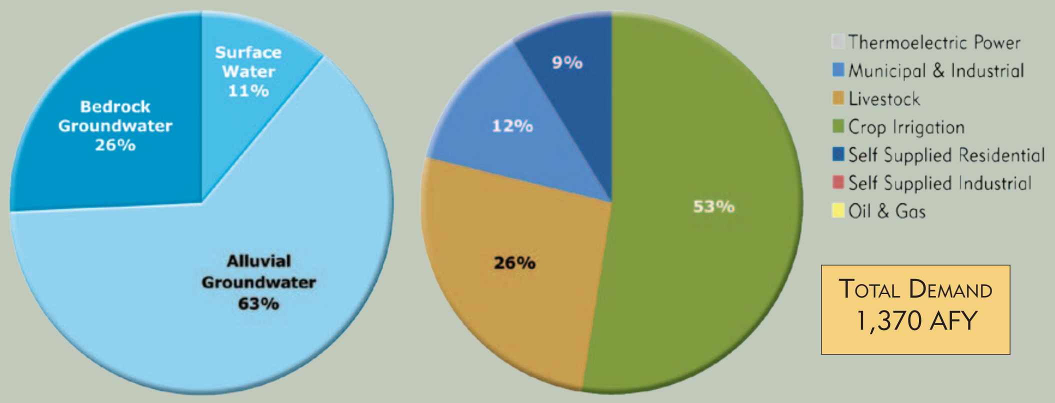
Basin 43 Summary

Synopsis

- Water users are expected to continue to rely primarily on groundwater supplies.
- Alluvial 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.
- Bedrock storage depletions on minor aquifers may occur by 2020.
- By 2030, 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 reduce surface water gaps and adverse effects of localized groundwater storage depletions.
- Aquifer storage 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 additional small reservoir storage could mitigate surface water gaps. These supply sources could be used without major impacts to groundwater storage.

Current Demand by Source and Sector

Southwest Region, Basin 43



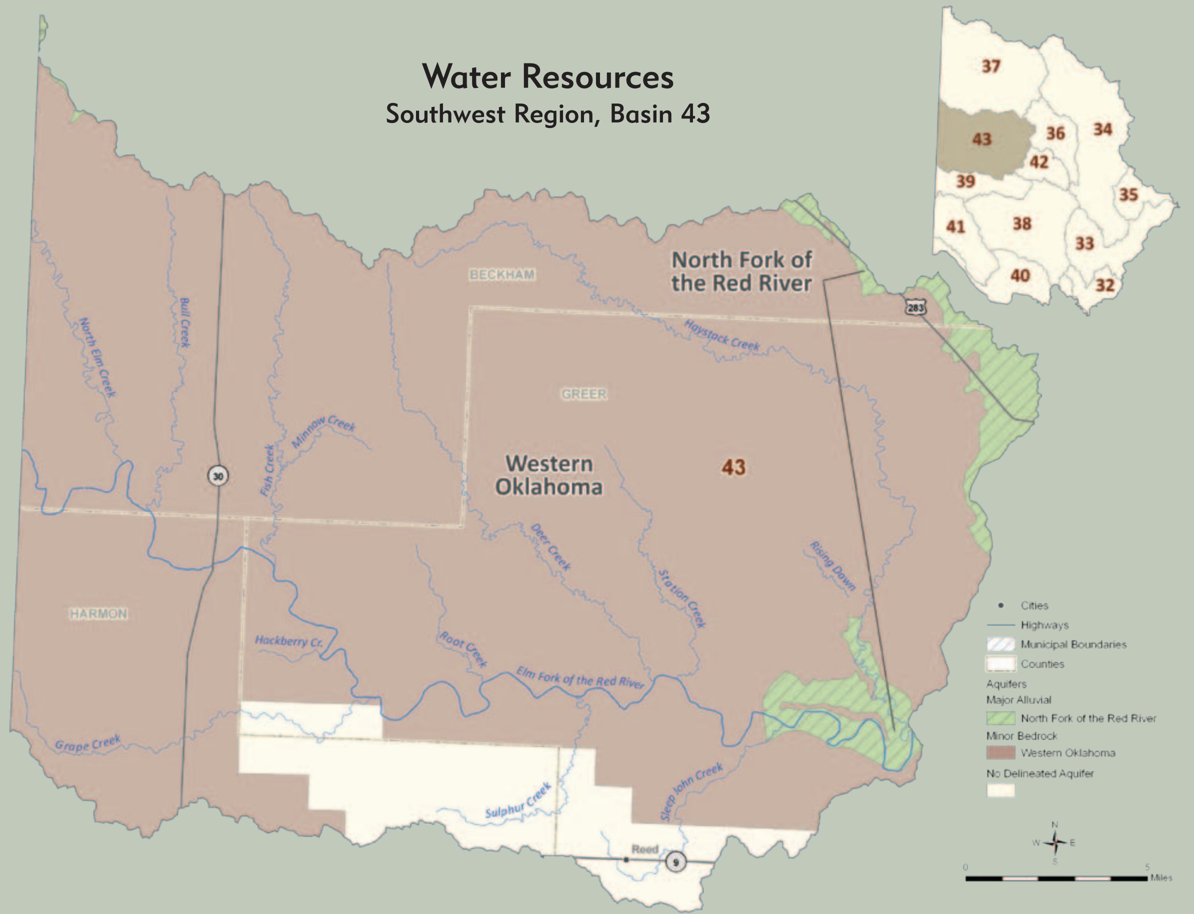
Basin 43 accounts for about 1% of the water demand in the Southwest Watershed Planning Region. About 53% of the basin's demand is from the Crop Irrigation demand sector. Livestock (26%) is the second-largest demand sector. Surface water satisfies about 11% of the total demand in the basin. Groundwater satisfies about 89% of the total demand (63% alluvial and 26% bedrock). The peak summer demand month in Basin 43 is 6.2 times the winter demand, which is more pronounced than the overall statewide pattern.

There are no major reservoirs in the basin. Historically, the flow in the Elm Fork of the Red River downstream of Haystack Creek is typically greater than 850 AF/month throughout the year and greater than 7,900 AF/month in May and June. However, the river can have periods of low 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. Relative to other basins in the state, the surface water quality in Basin 43 is considered poor. The Elm Fork of the Red River is impaired for Agricultural use due to high levels of chloride. However, individual lakes and streams may have acceptable water quality.

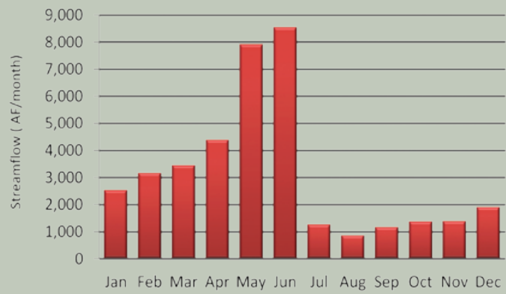
The majority of current groundwater rights are from the North Fork of the Red River and other non-delineated minor aquifers along the Elm Fork of the Red River. However, the North Fork of the Red River aquifer only underlies about 4% of the basin. Bedrock groundwater rights are from the Western Oklahoma aquifer, which underlies almost the entire basin. Site-specific information on the suitability of these minor aquifers for supply should be

Water Resources

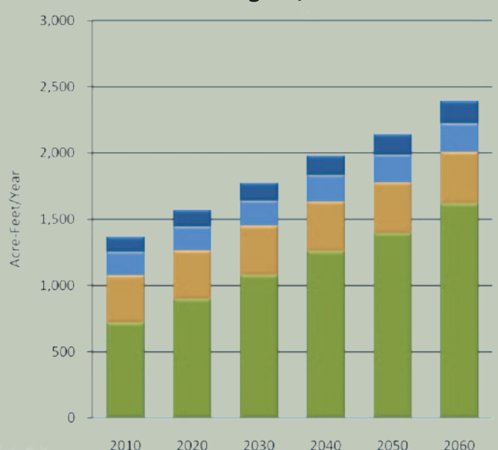
Southwest Region, Basin 43



Median Historical Streamflow at the Basin Outlet
Southwest Region, Basin 43



Projected Water Demand
Southwest Region, Basin 43



considered before large scale use. 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.

The expected 2060 water demand of 2,400 AFY reflects a 1,030 AFY increase (75%) over the 2010 demand.

Gaps & Depletions

Based on projected demand and historical hydrology, groundwater storage depletions may occur by 2020, and surface water gaps may occur starting in 2030. Surface water gaps will be up to 20 AFY in the summer and will have a 38% probability of occurring in at least one month of each summer by 2060. Alluvial groundwater storage depletions in Basin 43 may occur during summer. Alluvial groundwater storage depletions will be 260 AFY and will have a 47% probability of occurring in at least one month of each year by 2060. Projected alluvial storage depletions are minimal relative to the amount of water in storage in the North Fork of the Red River aquifer. However, localized storage depletions may occur and adversely affect yields, water quality, and/or pumping costs. Bedrock groundwater storage depletions in Basin 43 may occur during spring, summer, and fall, peaking in size during the summer. Bedrock groundwater storage depletions are expected to be 290 AFY on average. Current bedrock withdrawals are largely from an unstudied ground water source, therefore, the severity of the storage depletions cannot be evaluated.

Options

Water supply options were evaluated to assess potential ways of providing dependable long-range water supplies for Basin 43. 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.

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce alluvial storage depletions and bedrock groundwater depletions. Additional conservation activities are not expected to reduce surface water gaps. Temporary drought management activities will likely be ineffective since gaps have a moderate probability of occurring and aquifer storage could continue to provide supplies during droughts.

Out-of-basin supplies may mitigate groundwater storage depletions and surface water gaps. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Southwest Region. However, due to the distance to reliable surface water supplies, out-of-basin supplies may not be cost-effective for some users.

Reservoir storage could increase the dependability of surface water supplies in Basin 43 and mitigate surface water gaps and adverse effects of storage depletions. The entire change in demand from 2010 to 2060 could be met through a new river diversion and a 600 AF reservoir at the basin outlet.

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

Increased reliance on alluvial groundwater could be used to meet the demand of surface water users or bedrock groundwater users with adverse affects from localized storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in Basin 43's portion of the North Fork of the Red River aquifer; however, the aquifer only underlies a small portion of the basin.

Bedrock groundwater supplies are from non-delineated minor aquifers; therefore, increased reliance on these supplies is not recommended without site-specific information.

Water Supply Limitations
Southwest Region, Basin 43

Source	Rating
Surface Water	Potential
Alluvial Groundwater	Potential
Bedrock Groundwater	Potential

Minimal · Potential · Significant

Water Supply Option Effectiveness
Southwest Region, Basin 43

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

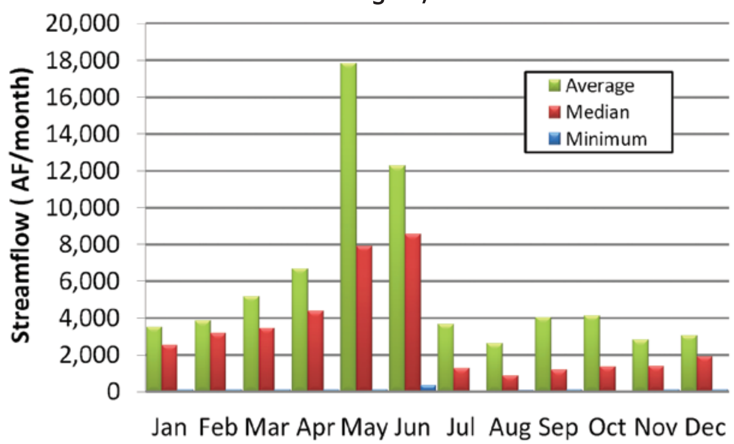
Typically Effective · Potentially Effective · Likely Ineffective · No Option Necessary

Basin 43 Data & Analysis

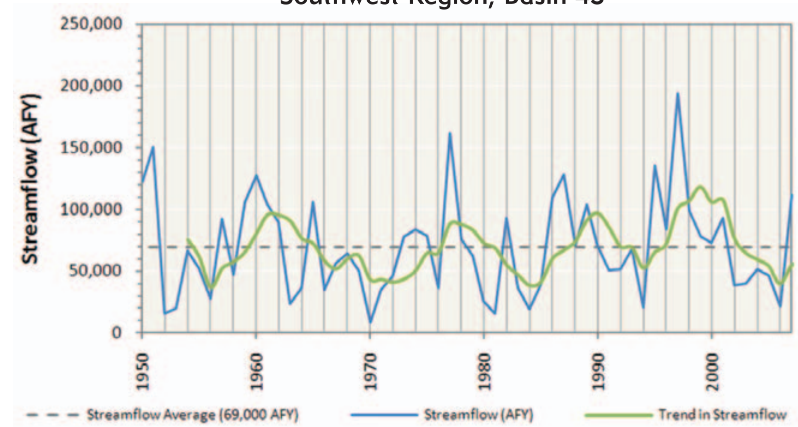
Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. Elm Fork North Fork Red River downstream of Haystack Creek had a prolonged period of below-average flow from the mid 1960s to mid 1980s, corresponding to a period of below-average precipitation. From the mid 1990s to early 2000s the basin had a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median flow in the North Fork of the Red River downstream of Haystack Creek is greater than 850 AF/month throughout the year, but greater than 7,900 AF/month in May and June. However, the river can have periods of low flow in any month of the year.
- Relative to other basins in the state, the surface water quality in Basin 43 is considered poor. However, individual lakes and streams may have acceptable water quality.
- There are no major reservoirs in this basin.

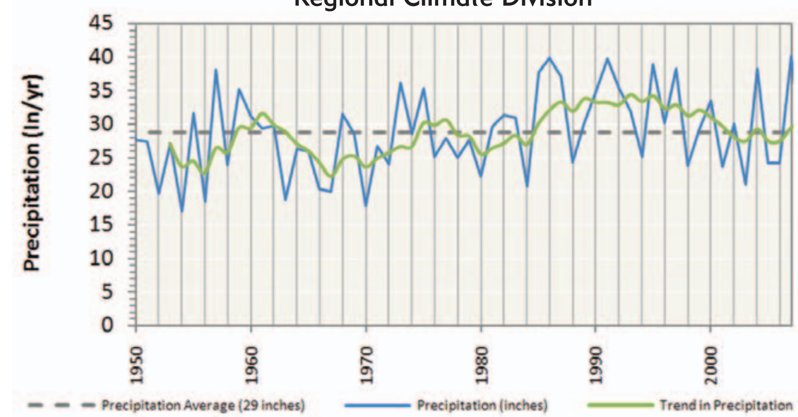
Monthly Historical Streamflow at the Basin Outlet
Southwest Region, Basin 43



Historical Streamflow at the Basin Outlet
Southwest Region, Basin 43



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)

Southwest Region, Basin 43

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
North Fork of the Red River	Alluvial	Major	4%	400	100,000	1.0	11,500
Western Oklahoma	Bedrock	Minor	91%	300	0	temporary 2.0	523,200
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	<50	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	300	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

- For Basin 43, groundwater rights total 400 AFY in the North Fork of the Red River aquifer, which underlies 4% of the basin and has 100,000 AF of storage. There are also groundwater rights in the Western Oklahoma aquifer and from non-delineated groundwater sources.
- There are no significant groundwater quality issues in the basin.

Notes & Assumptions

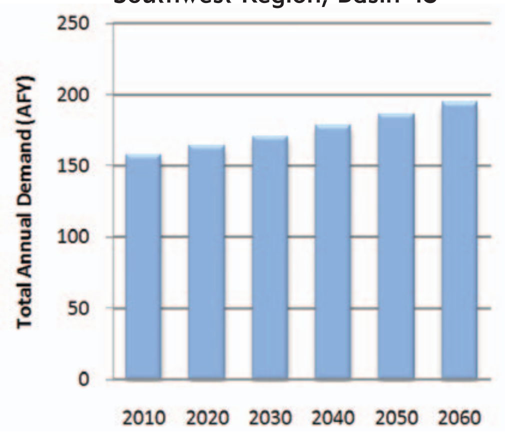
- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater 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 needs of Basin 43 account for about 1% of the total demand in the Southwest Watershed Planning Region and will increase by 75% (1,030 AFY) from 2010 to 2060. The majority of demand and growth in demand during this period will be from the Crop Irrigation demand sector.
- Surface water is used to meet 11% of the total demand in 2010 and its use will increase by 23% (40 AFY) from 2010 to 2060. Surface water use and growth in surface water use during this period will be from the Municipal and Industrial demand sector.
- Alluvial groundwater is used to meet 63% of the total demand in 2010 and its use will increase by 80% (690 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use during this period will be from the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet 26% of the total demand in 2010 and its use will increase by 86% (300 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use during this period will be from the Crop Irrigation demand sector.

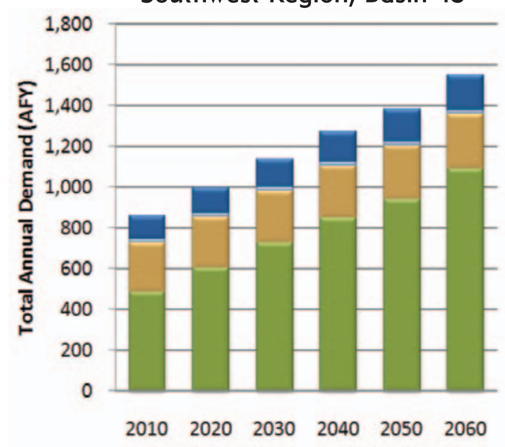
Surface Water Demand by Sector

Southwest Region, Basin 43



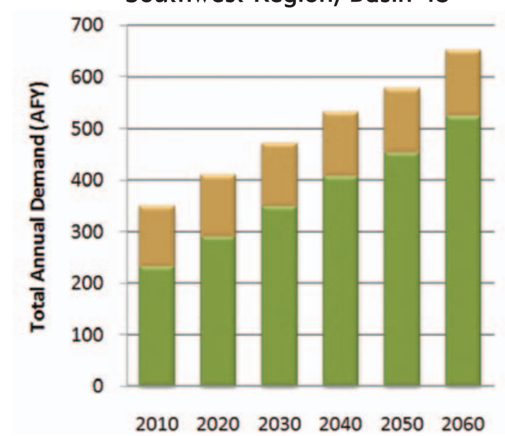
Alluvial Groundwater Demand by Sector

Southwest Region, Basin 43



Bedrock Groundwater Demand by Sector

Southwest Region, Basin 43



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

Total Demand by Sector

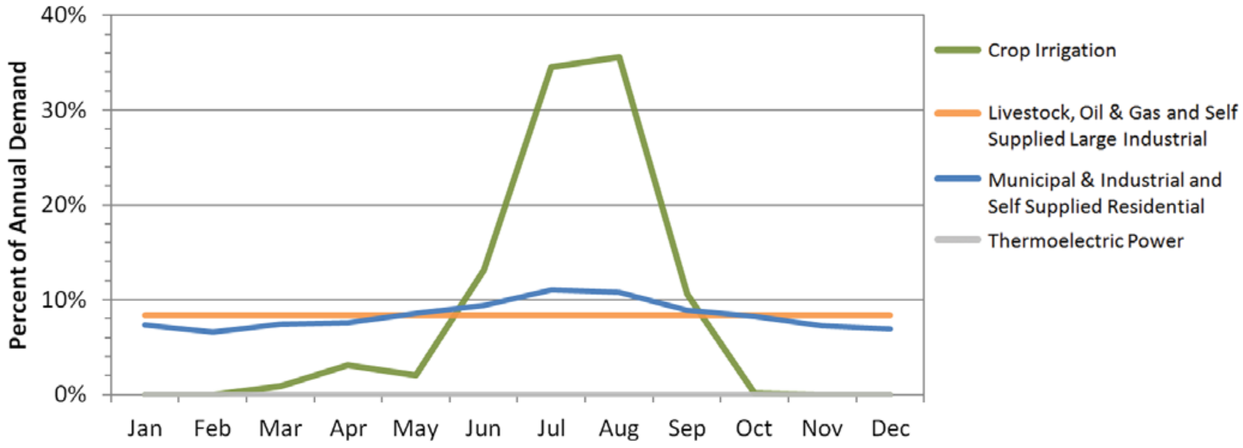
Southwest Region, Basin 43

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	720	360	170	0	0	120	0	1,370
2020	900	370	180	0	0	130	0	1,580
2030	1,080	370	190	0	0	140	0	1,780
2040	1,260	380	200	0	0	150	0	1,990
2050	1,390	380	210	0	0	160	0	2,140
2060	1,620	390	220	0	0	170	0	2,400

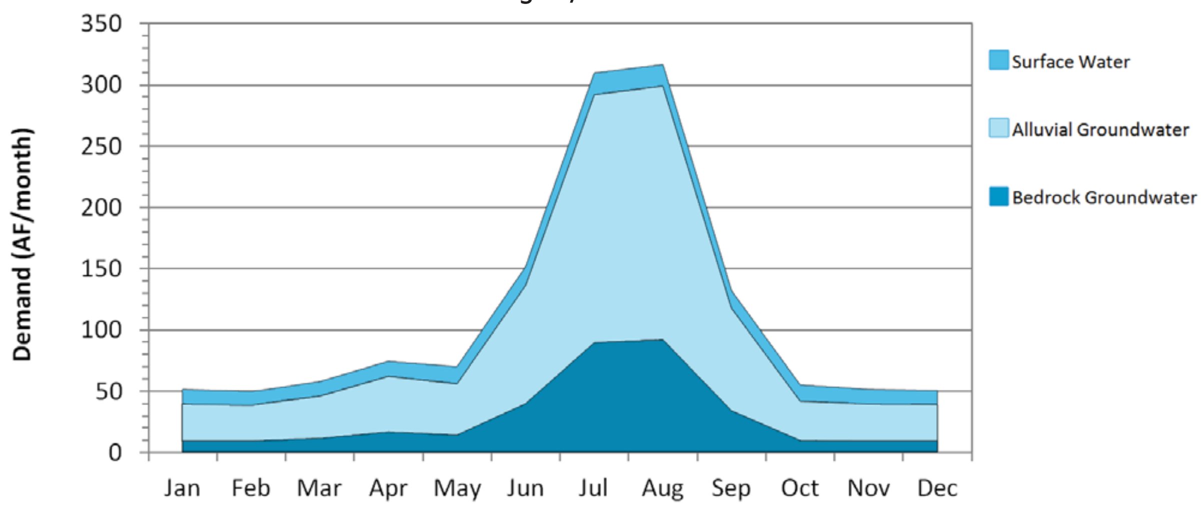
Notes & Assumptions

- 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)
Southwest Region, Basin 43



Monthly Demand Distribution by Source (2010)
Southwest Region, Basin 43



Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use about 50% more water in summer months than in winter months. Crop Irrigation has a high demand during summer months and little to no demand during winter months. Other demand sectors have more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 43 is 6.2 times the winter demand, which is higher than the overall statewide pattern. Surface water demand in the peak summer month is 1.5 times the monthly winter use. Monthly alluvial and bedrock groundwater use peaks in the summer at greater than 6.9 and 9.5 times the monthly winter use, respectively.

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, alluvial and bedrock groundwater depletions may occur by 2020, while surface water gaps are expected by 2030.
- Surface water gaps in Basin 43 may occur during the summer and will be up to 50% (10 AF/month) of the surface water demand in the peak summer month. By 2060, there will be a 38% probability of gaps occurring during summer months.
- Alluvial groundwater storage depletions in Basin 43 may occur during summer. Alluvial groundwater storage depletions in 2060 will be up to 45% (190 AF/month) of the alluvial groundwater demand in the peak summer month. There will be a 47% probability of alluvial storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions are most likely to occur during summer months.
- Bedrock groundwater storage depletions in Basin 43 may occur during spring, summer, and fall, peaking in size during the summer. Bedrock groundwater storage depletions in 2060 will be 53% (100 AF/month) of the bedrock groundwater demand on average in the peak summer month, and 43% (30 AF/month) on average of the peak fall month bedrock groundwater demand.
- Projected annual alluvial groundwater storage depletions are minimal relative to the amount of water in storage in the North Fork of the Red River aquifer. However, localized storage depletions may occur and adversely affect yields, water quality, and/or pumping costs. Current bedrock withdrawals are largely from an unstudied ground water source. Therefore, the severity of the storage depletions cannot be evaluated.

Surface Water Gaps by Season (2060 Demand)
Southwest Region, Basin 43

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)	10	10	38%
Sep-Nov (Fall)	0	0	0%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)
Southwest Region, Basin 43

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)	190	130	47%
Sep-Nov (Fall)	0	0	0%

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

Magnitude and Probability of Annual Gaps and Storage Depletions
Southwest Region, Basin 43

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	60	0%	2%
2030	10	70	110	2%	26%
2040	10	110	170	2%	41%
2050	10	170	230	3%	43%
2060	20	260	290	38%	47%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)
Southwest Region, Basin 43

Months (Season)	Maximum Storage Depletion[1]
	AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	10
Jun-Aug (Summer)	100
Sep-Nov (Fall)	30

1 Amount shown represent the largest amount for any one month in the 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

Southwest Region, Basin 43

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	20	260	290	38%	47%
Moderately Expanded Conservation in Crop Irrigation Water Use	20	230	270	33%	47%
Moderately Expanded Conservation in M&I Water Use	20	250	290	31%	47%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	20	220	270	24%	47%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	10	160	190	2%	43%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Southwest Region, Basin 43

Reservoir Storage	Diversion
AF	AFY
100	300
500	900
1,000	1,600
2,500	3,300
5,000	5,900
Required Storage to Meet Growth in Demand (AF)	600
Required Storage to Meet Growth in Surface Water Demand (AF)	<100

Water Supply Options & Effectiveness

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

Demand Management

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce alluvial storage depletions by 15% and bedrock groundwater depletions by 7%. Additional conservation activities are not expected to reduce surface water gaps. Temporary drought management activities will likely be ineffective since gaps have a moderate probability of occurring and aquifer storage could continue to provide supplies during droughts.

Out-of-Basin Supplies

Out-of-basin supplies may mitigate groundwater storage depletions and surface water gaps. The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified two out-of-basin sites in the Southwest Region: Port in Basin 34 and Mangum (Lower) in Basin 39. However, due to the distance to reliable surface water supplies, out-of-basin supplies may not be cost-effective for some users.

Reservoir Use

Reservoir storage could increase the dependability of surface water supplies in Basin 43 and mitigate surface water gaps and adverse effects of storage depletions. The entire increase in demand from 2010 to 2060 could be met through a new river diversion of 600 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions.

Increasing Reliance on Surface Water

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

Increasing Reliance on Groundwater

Increased reliance on alluvial groundwater could be used to mitigate surface water gaps and adverse effects of bedrock storage depletions. Any increases in storage depletions would be minimal relative to the volume of water stored in Basin 43's portion of the North Fork of the Red River aquifer; however, the aquifer only underlies a small portion 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. Bedrock groundwater supplies are from non-delineated minor aquifers; therefore, increased reliance on these supplies is not recommended without site-specific information.

Notes & Assumptions

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

Glossary

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

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

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

Alluvial groundwater: water found in an alluvial aquifer.

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

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

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

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

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

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

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

Basin: see Surface water basin.

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

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

Bedrock groundwater: water found in a bedrock aquifer.

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

Board: Oklahoma Water Resources Board.

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

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

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

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

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

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

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

CWSRF: see State Revolving Fund (SRF).

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

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

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

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

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

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

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

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

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

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

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

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

DWSRF: see State Revolving Fund (SRF).

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

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

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

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

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

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

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

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

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

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

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

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

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

Groundwater recharge: see Recharge.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Potable: describing water suitable for drinking.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Withdrawal: water removed from a supply source.

AF: acre-foot or acre-feet

AFD: acre-feet per day

AFY: acre-feet per year

BMPs: best management practices

BOD: biochemical oxygen demand

cfs: cubic feet per second

CWAC: Cool Water Aquatic Community

CWSRF: Clean Water State Revolving Fund

DO: dissolved oxygen

DWSRF: Drinking Water State Revolving Fund

EPS: equal proportionate share

FACT: Funding Agency Coordinating Team

gpm: gallons per minute

HLAC: Habitat Limited Aquatic Community

HQW: High Quality Waters

HUC: hydrologic unit code

M&I: municipal and industrial

MAY: maximum annual yield

mgd: million gallons per day

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

mg/L: milligrams per liter

NLW: nutrient-limited watershed

NPS: nonpoint source

NPDES: National Pollutant Discharge Elimination System

NRCS: Natural Resources Conservation Service

NTU: Nephelometric Turbidity Unit (see "Turbidity")

OCWP: Oklahoma Comprehensive Water Plan

ODEQ: Oklahoma Department of Environmental Quality

O&G: Oil and Gas

ORW: Outstanding Resource Water

OWQS: Oklahoma Water Quality Standards

OWRB: Oklahoma Water Resources Board

PBCR: Primary Body Contact Recreation

pH: hydrogen ion activity

ppm: parts per million

RD: Rural Development

REAP: Rural Economic Action Plan

SBCR: Secondary Body Contact Recreation

SDWIS: Safe Drinking Water Information System

SRF: State Revolving Fund

SSI: Self-Supplied Industrial

SSR: Self-Supplied Residential

SWS: Sensitive Water Supply

TDS: total dissolved solids

TMDL: total maximum daily load

TSI: Trophic State Index

TSS: total suspended solids

USACE: United States Army Corps of Engineers

USEPA: United States Environmental Protection Agency

USGS: United States Geological Survey

WLA: wasteload allocation

WWAC: Warm Water Aquatic Community

Water Quantity Conversion Factors

Desired Unit

Initial 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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