Oklahoma Comprehensive Water Plan

OCWP

Grand

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: Early Morning on Grand Lake, Barry Fogerty, OWRB

Oklahoma Comprehensive Water Plan

Grand Watershed Planning Region

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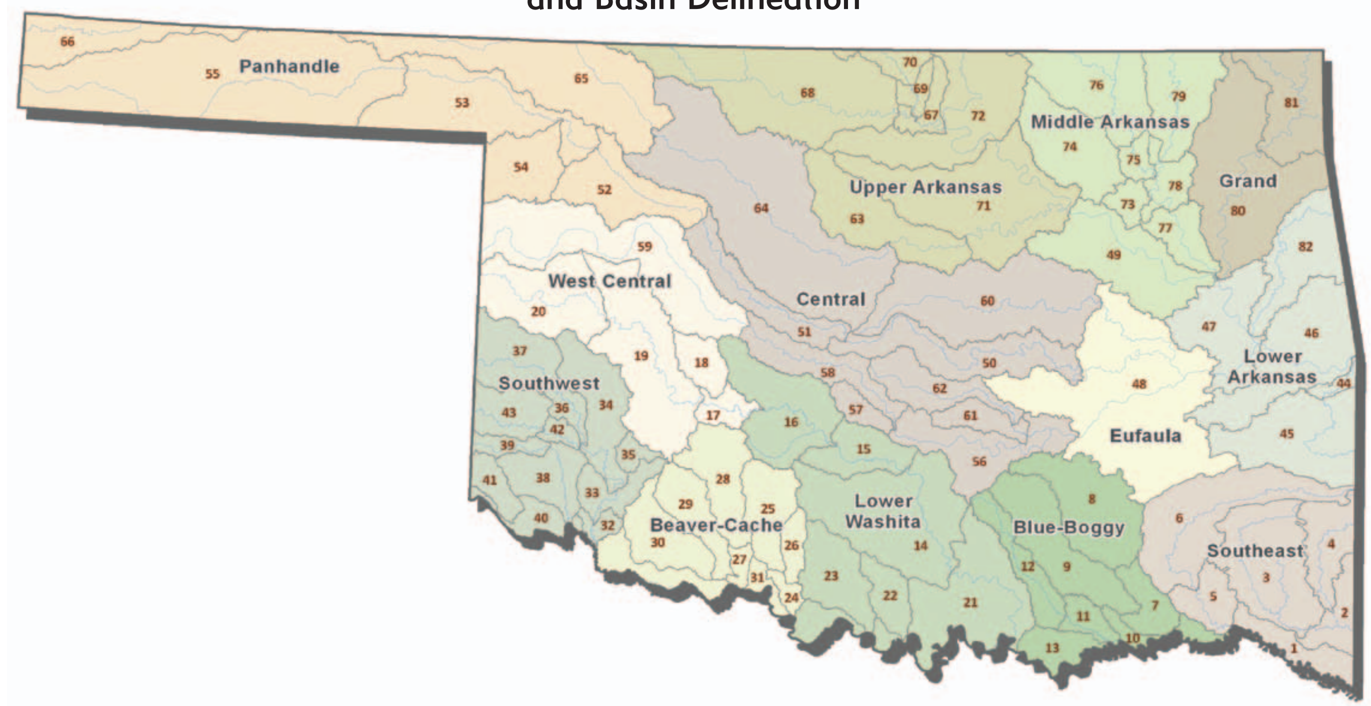
Statewide OCWP Watershed Planning Region and Basin Delineation



Introduction

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

1. Provide safe and dependable water supply for all Oklahomans while improving the economy and protecting the environment.

2. Provide information so that water providers, policy makers, and water users can make informed decisions concerning the use and management of Oklahoma's water resources.

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

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

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

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

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

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

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

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

Regional Overview

The Grand Watershed Planning Region includes two basins (numbered 80 and 81 for reference). The region encompasses 2,694 square miles in northeast Oklahoma, spanning all of Ottawa County and parts of Craig, Rogers, Mayes, Delaware, Wagoner, and Cherokee Counties.

The region is divided between the Central Lowland physiography province in the west and the Ozark Plateaus in the south and east. Encompassing some of the most scenic areas of the state, the region's terrain includes forested mountains, rolling plains, and rich river basins. Tall grass prairies in the east with a mix of rangeland and cropland give way to oak-hickory and oak-hickory-pine forests with livestock farming and logging land uses.

The region has a generally mild climate with annual mean temperatures varying from 59°F to 61°F. Annual average precipitation ranges from 42 inches in the northwest to 45 inches in the southeast. Annual evaporation is around 46 inches per year.

The largest cities in the region include Miami (2010 population 13,570), Pryor Creek (9,539), and Vinita (5,743). The greatest demand is from Municipal and Industrial water use.

By 2060, this region is projected to have a total demand of 57,550 acre-feet per year (AFY), an increase of approximately 20,250 AFY (54%) from 2010.

Grand Regional Summary

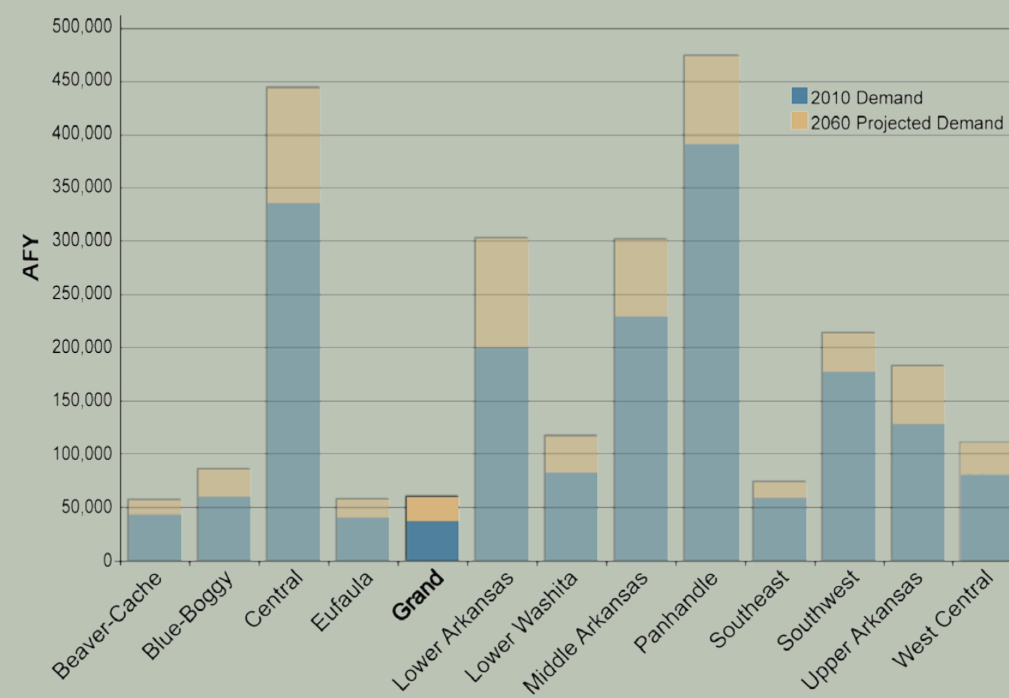
Synopsis

- The Grand Region relies primarily on bedrock groundwater and surface water supplies (including reservoirs).
- It is anticipated that water users in the region will continue to rely on these sources to meet future demand.
- By 2020, surface water gaps will occur in Basin 80 without use of the basin's reservoirs.
- By 2020, alluvial groundwater depletions in minor aquifers will occur in Basin 80.
- No bedrock groundwater storage depletions are expected in the region.
- To reduce the risk of adverse impacts on water supplies, it is recommended that surface water gaps and groundwater depletions be decreased where economically feasible.
- Additional conservation could reduce surface water gaps.
- Use of additional groundwater supplies and/or developing small reservoirs or using existing reservoirs could mitigate gaps without having major impacts to groundwater storage.
- No basins within the region have been identified as a water availability "hot spots," areas where more severe deficits or gaps in supply are anticipated. (See "Regional and Statewide Opportunities and Solutions," *2012 OCWP Executive Report*.)

Grand Region Demand Summary

Current Water Demand:	37,300 acre-feet/year (2% of state total)
Largest Demand Sector:	Municipal & Industrial (59% of regional total)
Current Supply Sources:	42% SW 2% Alluvial GW 56% Bedrock GW
Projected Demand (2060):	57,550 acre-feet/year
Growth (2010-2060):	20,250 acre-feet/year (54%)

Current and Projected Regional Water Demand



The Grand Region accounts for 2% of the state's total water demand. The largest demand sectors are Municipal and Industrial (59% of the region's 2010 overall demand), Thermoelectric Power (12%), and Livestock (17%).

Water Resources & Limitations

Surface Water

Surface water is used to meet about 42% of the Grand Region's demand. The region is supplied by the Grand River and its tributaries. The river and creeks in the region can have periods of low flow due to seasonal and long-term trends in precipitation. Fort Gibson, Hudson (Markham Ferry), and Grand lakes were built on the Grand River for flood control and hydropower purposes. W. R. Holway was constructed as a pumped storage project adjacent to Hudson. No information is available on the amount of water supply or yield of these reservoirs; therefore, the projected shortages do not account for the use of reservoir storage in the basin. Lake Spavinaw and Lake Eucha have been constructed on Spavinaw Creek to provide both out-of-basin water supply to the City of Tulsa in the Middle Arkansas Planning Region and for recreation.

Relative to other regions in the state, surface water quality in the region is considered poor to fair. Multiple creeks and major reservoirs are impaired for Agricultural use (Crop Irrigation demand sector) and Public and Private Water Supply (Municipal and Industrial demand sector) due to high levels of total dissolved solids (TDS), chloride, sulfate, and chlorophyll-a. These impairments are scheduled to be addressed through the Total Maximum Daily Loads (TMDL) process, but the use of these supplies may be limited for the interim.

The Grand River Dam Authority (GRDA) is currently responsible for administering surface water resources in the Grand Watershed Planning Region. Therefore, with the exception of a small number of water rights that were issued prior to GRDA's formation, the OWRB does not issue or administer stream water permits in the region. Instead of actual appropriation of waters, GRDA generally enters into contracts for the use of surface water resources within its jurisdiction.

Alluvial Groundwater

Alluvial groundwater is used to meet 2% of the demand in the region. Almost all the use of alluvial groundwater is for Self-Supplied Residential (domestic) purposes, which does not require permits and are assumed to be supplied from minor alluvial aquifers. If alluvial groundwater continues to supply a similar portion of demand in the future, storage depletions from these minor aquifers have a moderate probability of occurring throughout the year. The largest storage depletions are projected to occur in the summer. Site-specific information on minor aquifers should be considered before long-term or large-scale use.

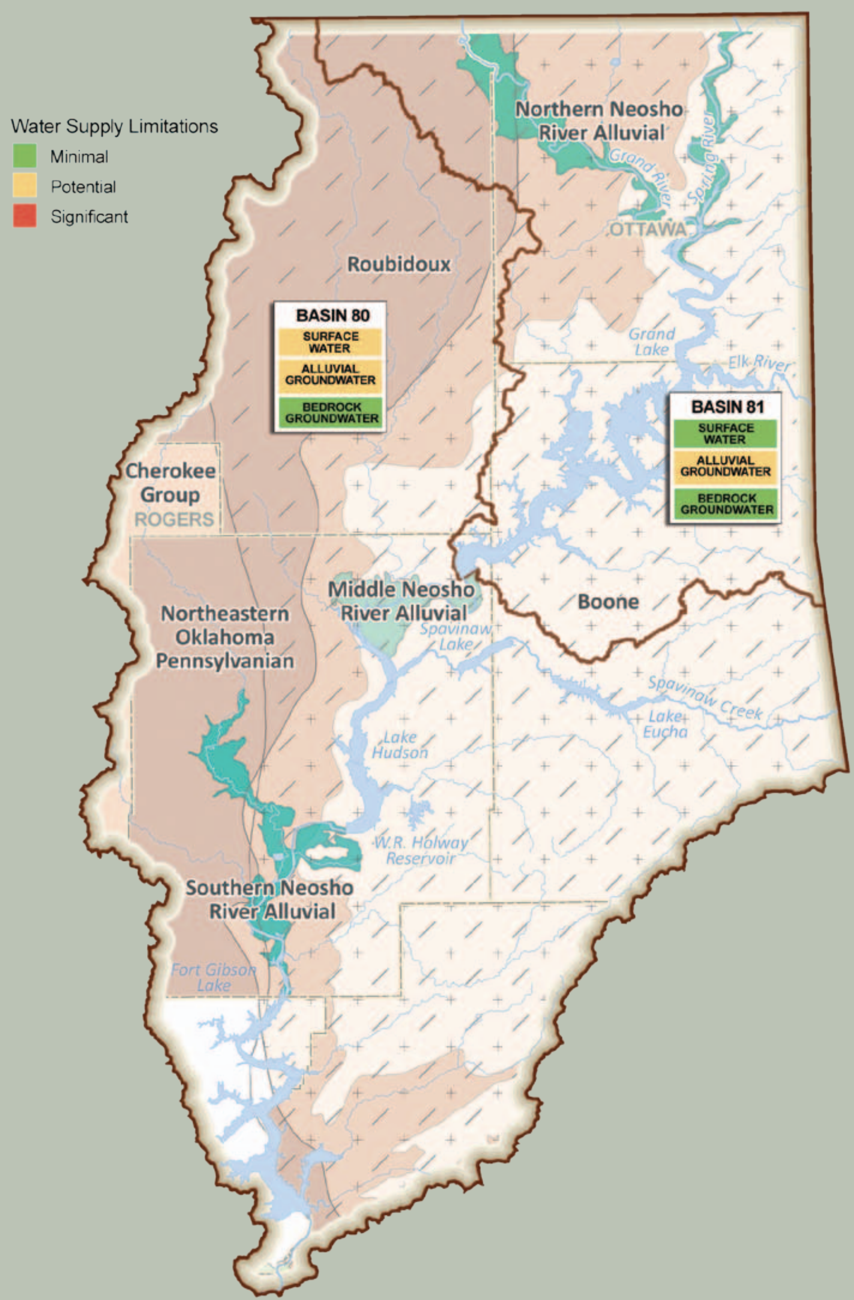
The availability of permits is not expected to constrain the use of alluvial groundwater supplies to meet local demand through 2060. There are no prevalent alluvial groundwater quality issues in the region.

Bedrock Groundwater

Bedrock groundwater is used to meet 56% of the demand in the region. Currently permitted and projected withdrawals are primarily from the Roubidoux major aquifer and Boone minor aquifer. Both aquifers have over 20 million acre-feet (AF) of groundwater storage in the region. Bedrock aquifer storage depletions are not expected in the Grand Region.

The availability of permits is not expected to constrain the use of bedrock groundwater supplies to meet local demand through 2060. Concentrations of chloride and naturally occurring radioactivity may exceed drinking water standards in some localized areas of the Roubidoux bedrock aquifer; however, there are no widespread groundwater quality issues in the region.

Water Supply Limitations
Grand Region



Water Supply Limitations

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

Water Supply Options

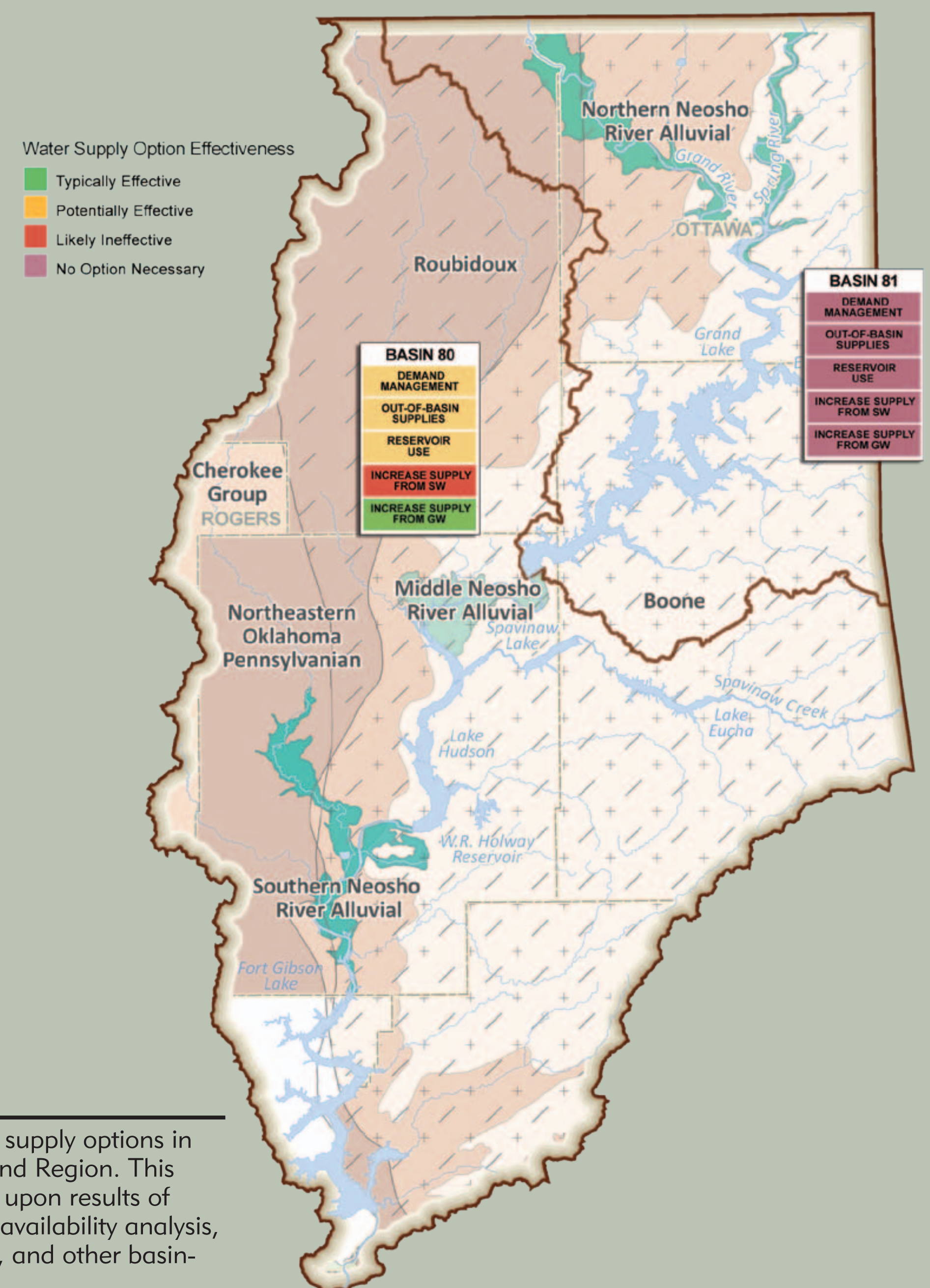
To quantify physical surface water gaps and groundwater storage depletions through 2060, use of local supplies was assumed to continue in the current (2010) proportions. Bedrock groundwater, surface water supplies, and reservoirs are expected to continue to supply the majority of demand in the Grand Region. Surface gaps and groundwater storage depletions are not expected to occur through 2060 in Basin 81; therefore, no supply options are necessary for Basin 81. Without use of the basin's substantial reservoir storage, Basin 80 is projected to have surface water supply shortages (gaps). Alluvial groundwater storage depletions are also projected in Basin 80 in the future. Therefore, additional long-term water supplies should be considered for both surface water and alluvial groundwater users in Basin 80. Bedrock aquifer storage depletions are not expected in the Grand Region.

Water conservation could aid in reducing projected surface water gaps and alluvial groundwater storage depletions or delaying the need for additional infrastructure. Moderately expanded conservation activities, primarily increased conservation by public water suppliers and increased crop irrigation efficiency, could reduce gaps and alluvial groundwater storage depletions. Further reductions could occur from substantially expanded conservation activities. These measures would require a shift from crops with high water demand (e.g., corn for grain and forage crops) to low water demand crops, such as sorghum for grain or wheat for grain, along with increased efficiency and increased public water supplier conservation. Due to the relatively low probability of gaps and storage depletions in Basin 80, temporary drought management measures may also be an effective water supply option.

The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified one potentially viable site in Basin 80; however, the GRDA has jurisdiction over the management of surface water in the Grand Region and should be consulted for the feasibility of using existing storage or developing additional reservoir storage in the basin.

The projected growth in surface water and alluvial groundwater demand in Basin 80 could instead be supplied by increased use of bedrock groundwater aquifers; however, localized storage depletions may occur.

Water Supply Option Effectiveness
Grand Region



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

Water Supply

Physical Water Availability

Surface Water Resources

Surface water has historically been almost half of the supply used to meet demand in the Grand Region. The region's major stream is the Grand (or Neosho) River. This region is unique in that it is the only area in the state where the OWRB does not have jurisdiction for surface water allocation. The GRDA was established by the State Legislature in 1935 with authority to control, store and preserve the river and to use, distribute and sell the waters of the Grand River and its tributaries to the point of confluence with Fort Gibson Dam, but has no jurisdiction below the dam. The GRDA is self-sustaining with revenue derived from the sale of power and water. The Grand River in this region generally experiences abundant streamflows, with intermittent low flow conditions and periodic flooding events. The Grand River flows from Kansas into Oklahoma in the northeast corner of the state and then through the center of the Grand Region. Major tributaries in the Grand Region include Pryor Creek (40 miles long) and Big Cabin Creek (40 miles). The Grand River and tributaries are located in Basins 80 and 81, which comprise the entire Grand Region.

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

Existing reservoirs in the region increase the dependability of surface water supply for many public water systems and other users. The largest are Fort Gibson, Hudson (Markham Ferry), and Grand, all located on the Grand River. Fort Gibson was constructed by the U.S. Army Corps of Engineers in 1953. Grand and Hudson (Markham Ferry) were completed in 1940 and 1964, respectively, by GRDA. All three reservoirs were built primarily for the purposes of flood control and hydropower generation. While significantly smaller, W. R. Holway, built in 1968 as a pumped storage project to increase hydroelectric power generation at Lake Hudson, was also constructed by GRDA.

Two major municipal lakes in this region are Spavinaw and Eucha, constructed on Spavinaw Creek in 1924 and 1952, respectively, as sources for recreation and out-of-basin water supply for the City of Tulsa that lies in the Middle Arkansas Watershed Planning Region. Spavinaw has little dependable yield of its own, acting primarily as terminal storage for releases from Eucha. The lakes have a combined dependable yield of 84,000 AFY. There are other small Natural Resources Conservation Service (NRCS) and municipal and privately owned lakes in the region that provide water supply, flood control, and recreation.

Reservoirs
Grand Region

Reservoir Name	Primary Basin Number	Reservoir Owner/ Operator	Year Built	Purpose[1]	Normal Pool Storage	Water Supply		Irrigation		Water Quality		Permitted Withdrawals	Remaining Water Supply Yield to be Permitted[2]
						Storage	Yield	Storage	Yield	Storage	Yield		
					AF	AF	AFY	AF	AFY	AF	AFY	AFY	AFY
Eucha	80	City of Tulsa	1952	WS, R	79,570	110,200[2]	84,000[2]	0	0	0	0	181,000[2]	0
Fort Gibson	80	USACE	1953	FC, HP	365,200	0	0	0	0	0	0	0	---
Grand	81	Grand River Dam Authority[3]	1940	FC, HP, WS, R	1,515,414	0	0	0	0	0	0	0	---[4]
Hudson (Markham Ferry)	80	Grand River Dam Authority[3]	1964	FC, HP, WS, R	200,185	0	0	0	0	0	0	0	---[4]
Spavinaw	80	City of Tulsa	1924	WS, R, FW	30,590	see Eucha	see Eucha	0	0	0	0	see Eucha	0
W.R. Holway[5]	80	Grand River Dam Authority[3]	1968	WS, HP, R	50,372	0	0	0	0	0	0	0	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

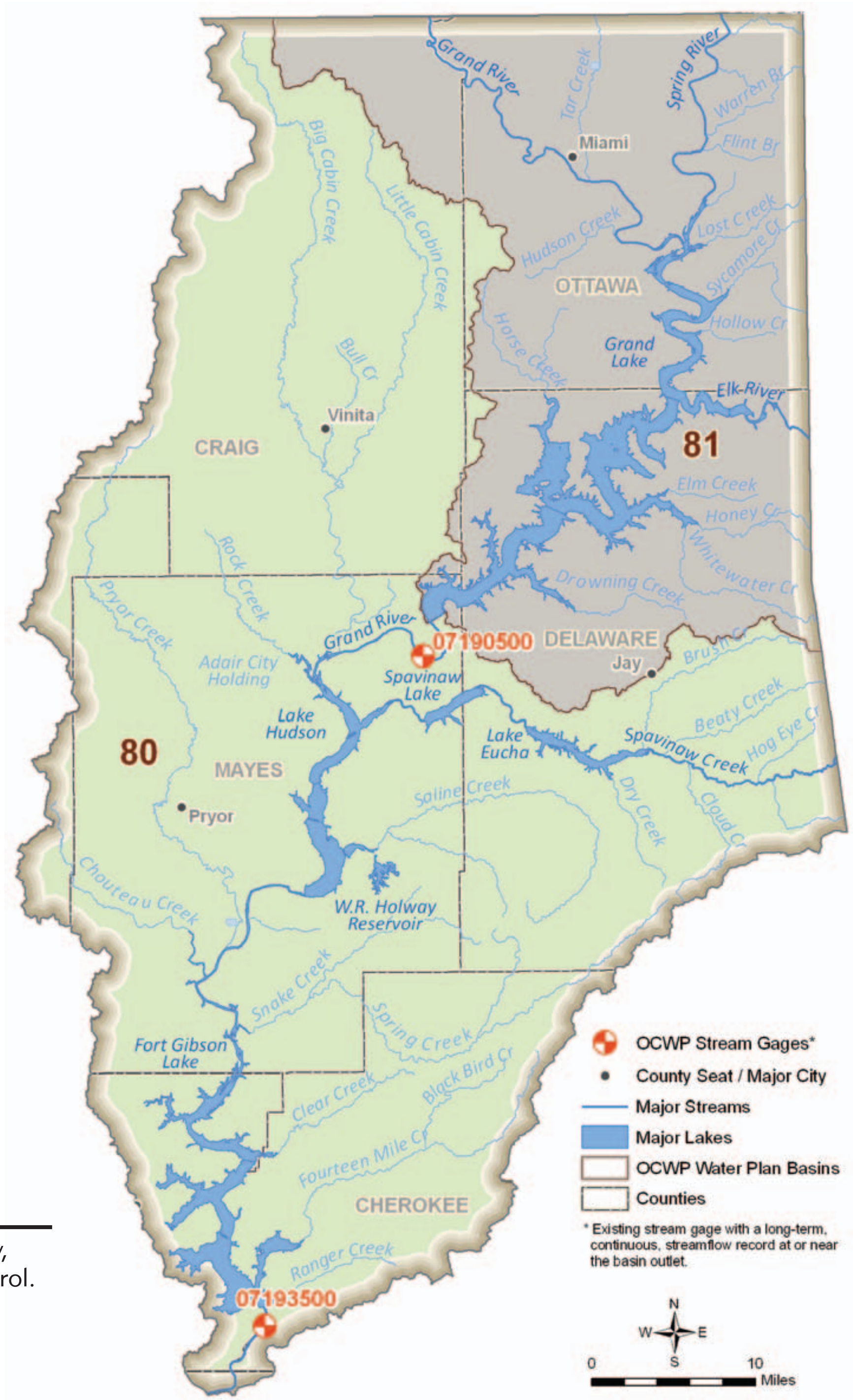
2 Total combined amount for Spavinaw and Eucha lakes.

3 The Grand River Dam Authority is the state agency responsible for controlling, storing, and distributing waters of the Grand River and its tributaries.

4 All available water is claimed by hydropower. Although there is no Water Supply (WS) use designated for Grand or Hudson Lake, existing WS contracts are in place. GRDA has the right to request an exception to its FERC mandated rule curve (water levels) to honor its current WS contracts.

5 W. R. Holway is pumped storage for Lake Hudson and does not have independent inflow or yield.

Surface Water Resources
Grand Region



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

Water Supply Availability Analysis

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

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

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

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

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

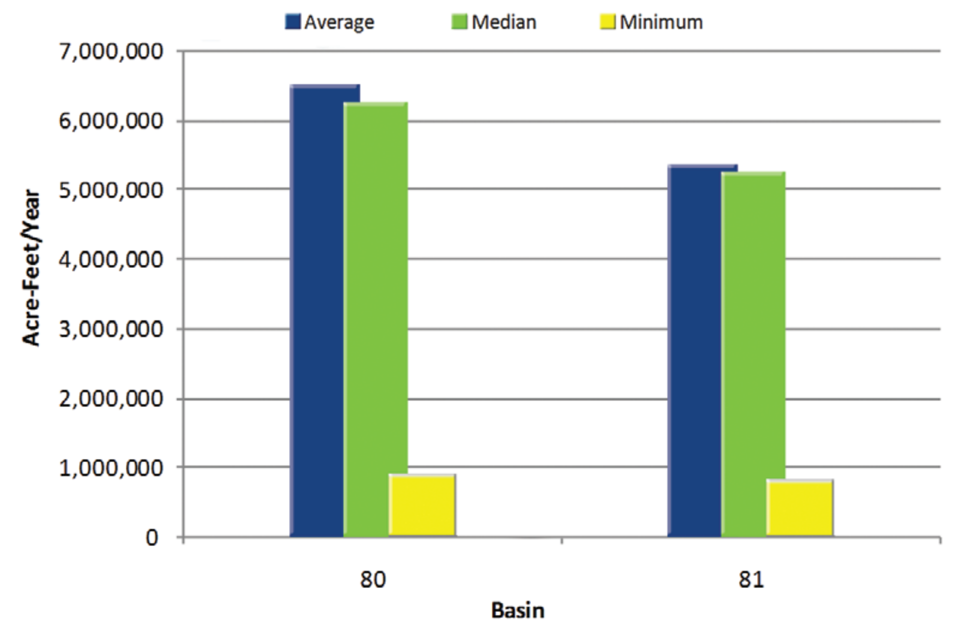
For this analysis, alluvial aquifers are defined as aquifers comprised of river alluvium and terrace deposits, occurring along rivers and streams and consisting of unconsolidated deposits of sand, silt, and clay. Alluvial aquifers are generally thinner (less than 200 feet thick) than bedrock aquifers,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

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

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

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

Surface Water Flows (1950-2007)
Grand Region



Surface water sources supply nearly half of the demand in the Grand Region. While the region's average physical surface water supply exceeds projected surface water demand in the region, localized or intermittent shortages can occur due to variability in surface water flows. Reservoirs may reduce the impacts of drier periods on surface water users.

Estimated Annual Streamflow in 2060
Grand Region

Streamflow Statistic	Basins	
	80	81
	AFY	
Average Annual Flow	3,678,800	2,639,200
Minimum Annual Flow	445,300	385,300

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

Groundwater Resources

The Roubidoux major bedrock aquifer is present in the Grand Watershed Planning Region, underlying all but the westernmost portion of the region. The Arkansas River is the only major alluvial aquifer located in the region.

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

The Roubidoux aquifer consists primarily of dolomite with some interbedded sandstone. The aquifer thickness ranges from zero to greater than 2,000 feet, with average thickness estimated at 1,000 feet. Well yields vary from less than 25 gallons per minute (gpm) to more than 1,000 gpm, with shallower well yields ranging from less than 10 gpm to more than 300 gpm. The chemical quality of the water from the Roubidoux is suitable for most purposes, but in some areas concentrations of chloride and naturally occurring radioactivity may exceed drinking water standards. Dissolved solids concentrations range from less than 200 mg/L in the eastern portion of the aquifer to greater than 1,000 mg/L in the western and southern portions. Sodium chloride (salt) water is present along the western and southern edges of the aquifer and at certain depths throughout the aquifer, making the water unsuitable for most uses. Water in other areas is suitable for most purposes. Contaminated water from the abandoned zinc and lead mines in Basin 81 has the potential to degrade the quality of the Roubidoux water in the vicinity of Miami and Picher. The Roubidoux bedrock aquifer underlies all of Basin 81 and much of Basin 80.

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

Wells in the Arkansas River alluvium deposits range from 200 to 500 gpm while wells in the terrace deposits range from 100 to 200 gpm. Formation deposits are commonly 50 to 100 feet in depth with saturated thickness averaging 25 to 75 feet. The formation consists of clays, sand, silt and gravels. Hardness is the major water quality problem and TDS values are usually less than 500 mg/L. The water is generally suitable for most Municipal and Industrial uses, although heavy pumping can cause chloride intrusion into the formation. The Arkansas River alluvium and terrace deposit underlies a very small portion of Basin 80.

Minor bedrock aquifers in the region include the Boone, Cherokee Group, and Northeastern Oklahoma Pennsylvanian aquifers. Minor alluvial aquifers include the Middle Neosho River, Northern Neosho River, and Southern Neosho River. Minor aquifers may have a significant amount of water in storage and high recharge rates, but generally have low yields of less than 50 gpm per well in bedrock aquifers and less than 150 gpm in alluvial aquifers. Groundwater from minor aquifers is an important source of water for domestic and stock water use for individuals in outlying areas not served by rural water systems, but tends to have insufficient yields for large volume users.

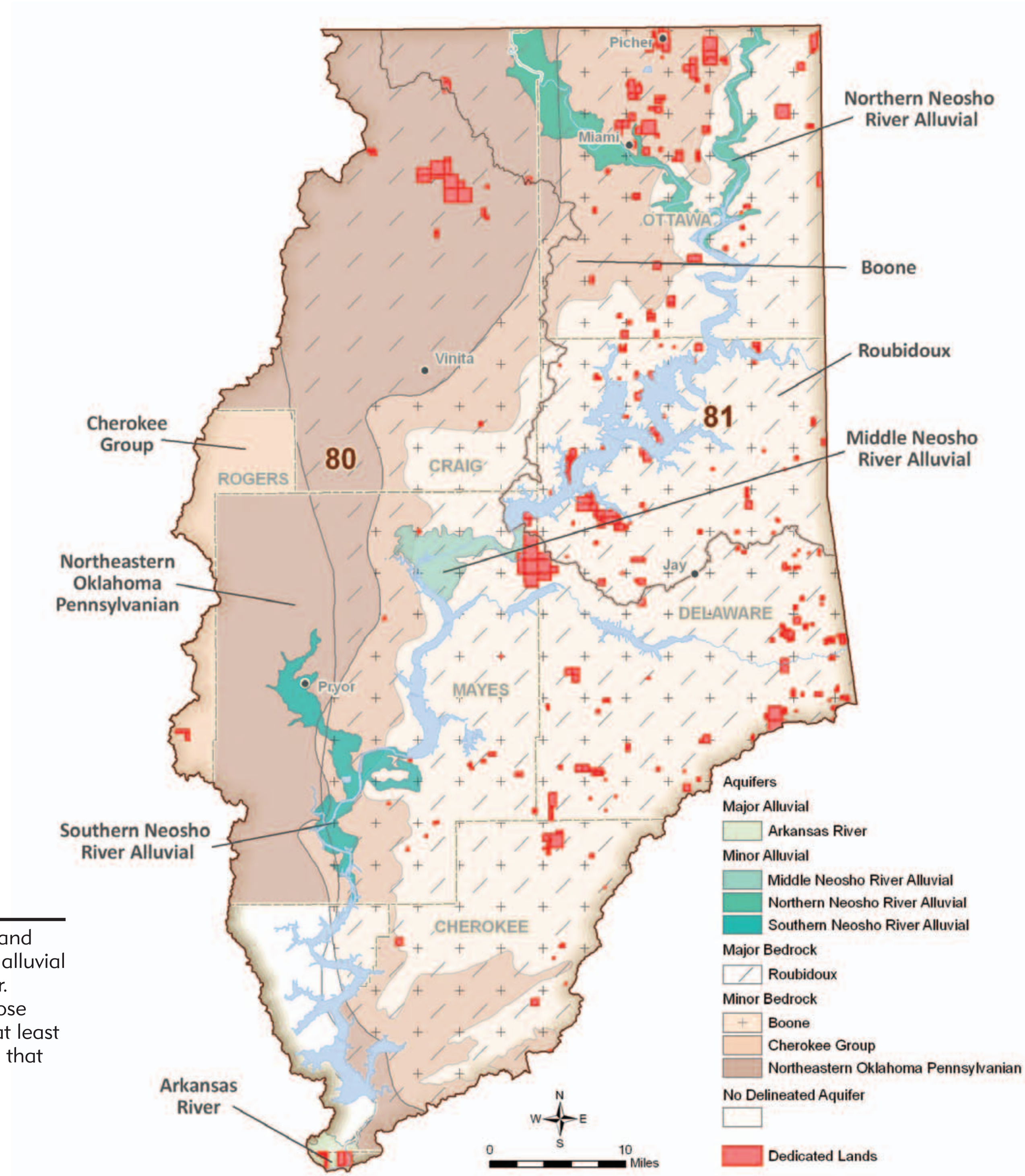
Permits to withdraw groundwater from aquifers (groundwater basins) where the maximum annual yield has not been set are "temporary" permits that allocate 2 AFY/acre. The temporary permit allocation is not based on storage, discharge or recharge amounts, but on a legislative (statute) estimate of maximum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

Groundwater Resources
Grand Region

Aquifer			Portion of Region Overlaying Aquifer	Recharge Rate	Current Groundwater Rights	Aquifer Storage in Region	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type	Class[1]	Percent	Inch/Yr	AFY	AF	AFY/Acre	AFY
Arkansas River	Alluvial	Major	<1%	5.0	<50	7,000	temporary 2.0	12,700
Roubidoux	Bedrock	Major	85%	2.5	17,200	23,751,000	temporary 2.0	3,192,200
Boone	Bedrock	Minor	67%	10.5	11,400	21,839,000	temporary 2.0	2,502,500
Cherokee Group	Bedrock	Minor	3%	3.0	200	94,000	temporary 2.0	101,600
Middle Neosho River	Alluvial	Minor	1%	4.2	0	30,000	temporary 2.0	25,600
Northeastern Oklahoma Pennsylvanian	Bedrock	Minor	44%	2.1	500	1,900,000	temporary 2.0	1,650,900
Northern Neosho River	Alluvial	Minor	2%	4.2	0	71,000	temporary 2.0	76,800
Southern Neosho River	Alluvial	Minor	1%	4.2	0	51,000	temporary 2.0	51,200
Non-Delineated Groundwater Source	Alluvial	Minor			0			
Non-Delineated Groundwater Source	Bedrock	Minor			0			

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

Groundwater Resources
Grand Region



The only major bedrock aquifer in the Grand Region is the Roubidoux. The only major alluvial aquifer in the region is the Arkansas 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.

The Grand River Dam Authority (GRDA) is currently responsible for administering surface water resources in the Grand Watershed Planning Region. Therefore, surface water permit availability was not analyzed for GRDA's area of responsibility, which includes the entire Grand Region (Basins 80 and 81). For all aquifers in the Grand Region, equal proportionate shares have yet to be determined; therefore, temporary permits are granted at 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 Grand Region.

Surface Water Permit Availability

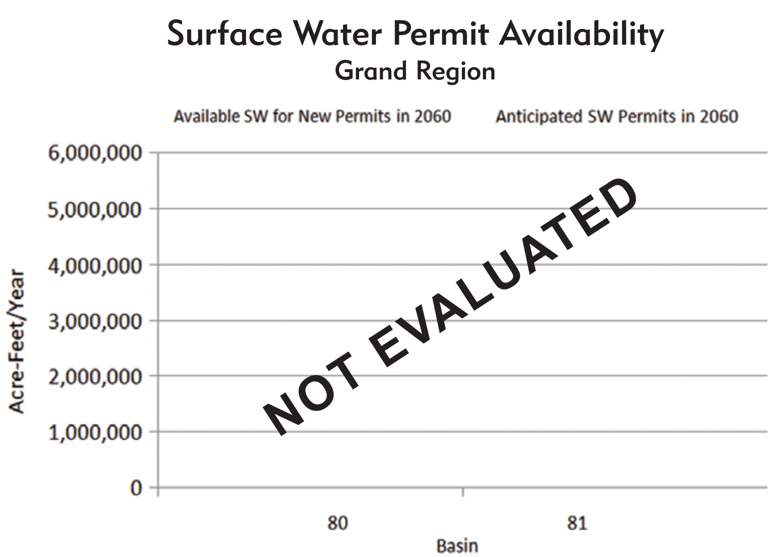
Oklahoma stream water laws are based on riparian and prior appropriation doctrines. Riparian rights to a reasonable use of water, in addition to domestic use, are not subject to permitting or oversight by the OWRB. An appropriative right to stream water is based on the prior appropriation doctrine, which 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.

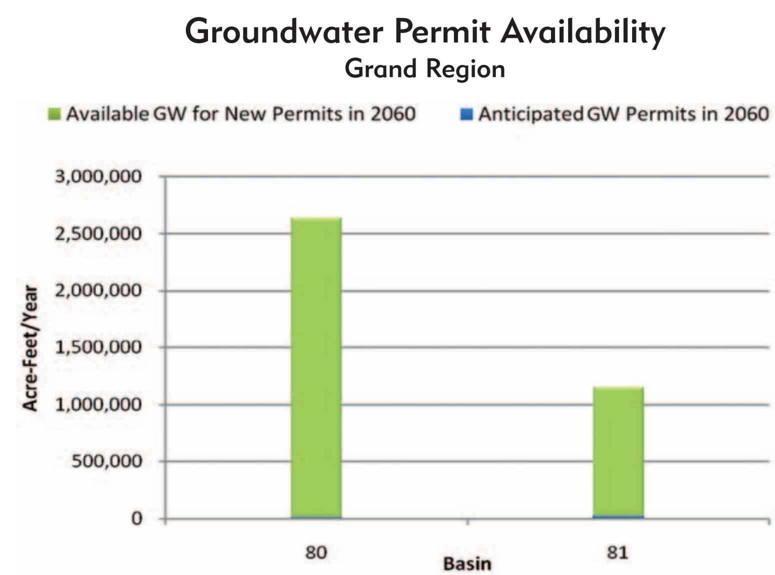
Groundwater Permit Availability

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 was not analyzed for GRDA's area of jurisdiction, which includes the entire Grand Region (Basins 80 and 81).



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

Water Quality

Water quality of the Grand Watershed Planning Region is exemplified by the Grand (Neosho) River and its tributaries, and numerous minor and major water supply/ flood control reservoirs. It is contained nearly equally in two adjacent ecoregions, the Central Irregular Plains (CIP) in the west and the Ozark Highlands in the east. A small portion of the Boston Mountains adjoins along the southern tip of the region.

The Osage Cuestas cover nearly a third of the region's western geographical area and is drained by the Middle to Lower Neosho River and tributaries, including Big Cabin and Pryor Creeks. The area is an irregular plain, underlain by sandstone, shale, and limestone. It is dominated by rangeland and some cropland, interspersed with native tall grass prairies and extensive, but disconnected oak-hickory forest. Typically, turbid and deep, streams meander in broad, low gradient valleys with incised banks. Habitat can be good, but in many areas is choked by mud/silt. The Neosho River intersects the area at the confluence of Big Cabin Creek, below Grand Lake. Also, a majority of the Hudson (Markham Ferry) and Fort Gibson Lake drainages are contained within the area. Salinity is moderate with mean conductivity ranging from 270 μS/cm (Neosho) to 530 μS/cm (Big Cabin). Reservoir salinity ranges from than 200 μS/cm to greater than 300 μS/cm. Streams are eutrophic, and total nitrogen (TN) and phosphorus (TP) values are moderate, with TP ranging from 0.18 (Pryor) to 0.30 ppm (Neosho) and TN from 0.89 (Pryor) to 1.79 ppm (Big Cabin). Reservoirs are phosphorus-limited, and Fort Gibson is eutrophic, while Hudson (Markham Ferry) is hyper-eutrophic. In streams, water clarity is good on the Neosho (turbidity = 15 NTU) to fair (Big Cabin = 30 NTU) to poor (Pryor = 75 NTU). Lake clarity is average to good, with average Secchi depths of 65 (Hudson) to 80 cm (Fort Gibson). Ecological diversity varies throughout depending on habitat degradation and sedimentation and is typically lower than ecoregions to the east but higher than to the west.

The planning region is inundated in the north-central by the Cherokee Plains of the CIP. The area is much flatter than the Osage Cuestas and underlain mostly by poorly draining clay soils and hardpan. It is dominated by cropland, with interspersed native tall grass prairie and sparse oak-hickory stands. In the northern part of the ecoregion, the Tar Creek superfund site is located in the Miami area. Streams are diverse through the ecoregion. They are wider and shallower and sand/clay dominated with some cobble/gravel. The area is typified by the upper Neosho River, and tributaries such as Tar Creek. Salinity is moderate with a typical conductivity mean of 358 μS/cm on the Neosho. Streams are typically eutrophic/ hyper-eutrophic. The TP and TN means on the Neosho are 0.17-0.21 and 1.30-1.38 ppm, respectively. Stream water clarity is fair to poor, with turbidity means ranging from 37-52 NTU. Ecological diversity is average and impacted by poor habitat, sedimentation, and toxicity related to mine tailings.

The Ozark Highlands covers the eastern two-thirds of the area and is represented by two intermingled ecoregions—the Springfield Plateau (Plateau) and the Dissected Springfield Plateau-Elk River Hills (Dissected-Elk Hills). The Ozarks are comprised of a dissected plateau underlain by flat, cherty limestone, shale, and dolomite, and intersected by numerous level valleys. With much greater relief than the plains ecoregions to the west, it is much less rugged than the Boston and Ouachita Mountains to the south. Sub-surface flow is karst and

Lake Trophic Status

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

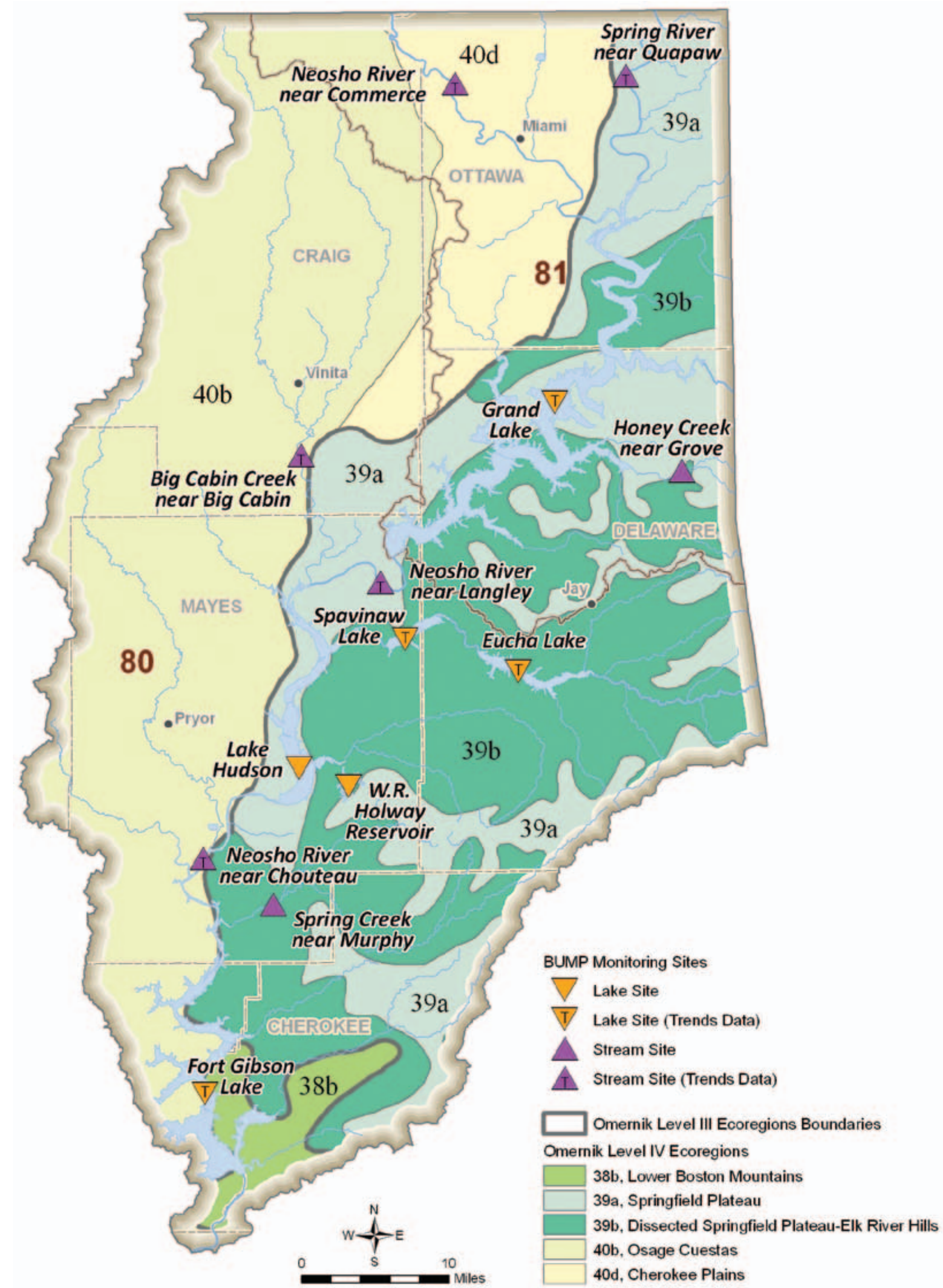
Oligotrophic: Low primary productivity and/or low nutrient levels.

Mesotrophic: Moderate primary productivity with moderate nutrient levels.

Eutrophic: High primary productivity and nutrient rich.

Hypereutrophic: Excessive primary productivity and excessive nutrients.

Ecoregions
Grand Region

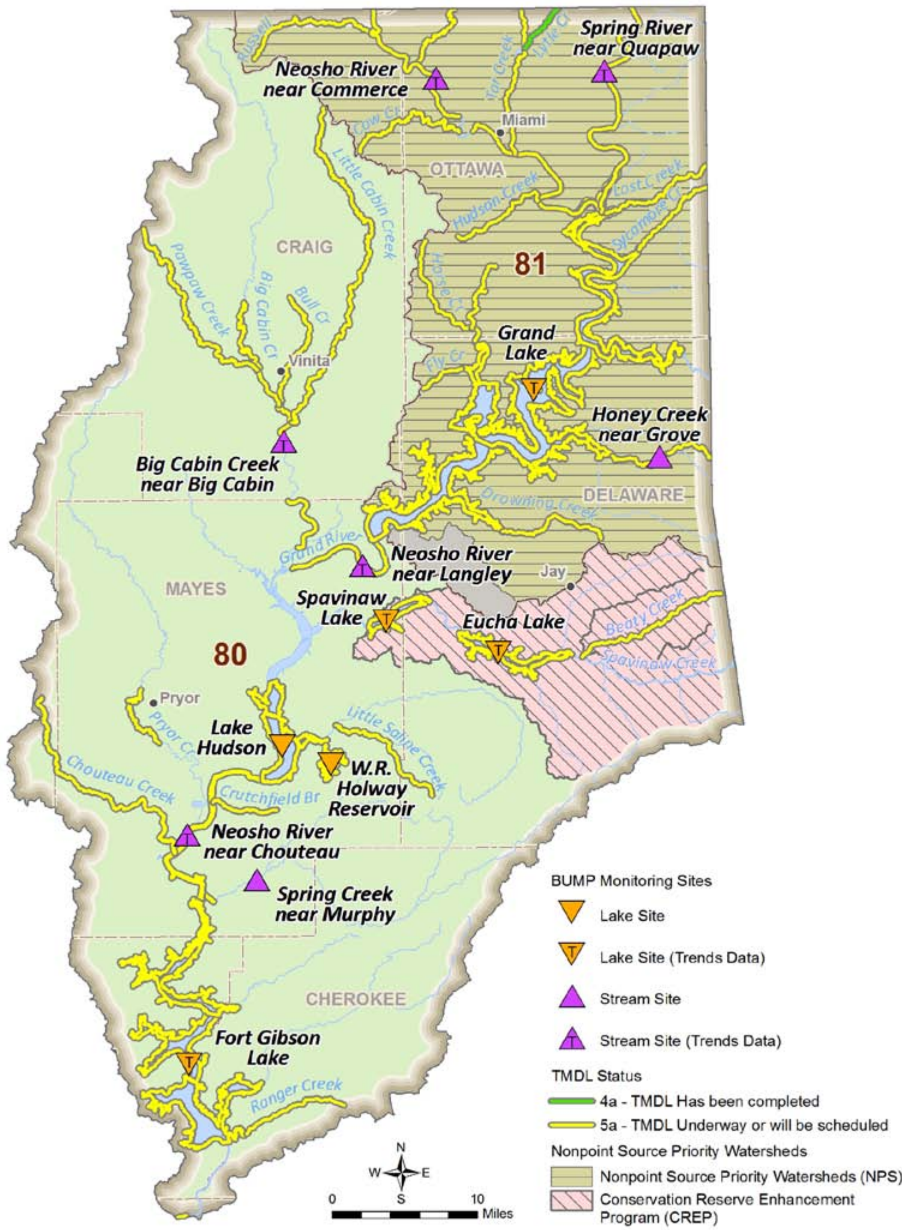


The Grand Planning Region is dominated by the Ozark Highlands to the east and the Central Irregular Plains to the west. Water quality is highly influenced by both geology and land use practices and ranges from good to excellent depending on drainage and location.

numerous springs feed typically perennials streams. Dense oak-hickory-pine forests cover uplands, while native grasslands, hay fields, and pasture land are common in the low-lying valleys. Poultry feeding operations and intense sub-urbanization have become more prevalent and have negatively affected water quality. Increasing bank erosion has increased gravel loads to streams and created braided systems, with unstable pool habitats and extensive sub-surface flow. Despite extensive riparian disturbance, habitat degradation, and increasing nutrient loads, ecological diversity remains high, with several species of fish distinctive to the Ozarks in Oklahoma, including the shadow bass and northern hogsucker. The main differences between the two ecoregions are greater forest density, more intense relief and dissection, and narrower valleys in the Dissected-Elk Hills. Representative Plateau streams include the middle Honey Creek, Neosho, Spring, and Elk Rivers. Grand and Hudson Lakes are representative Plateau lakes. Spring Creek exemplifies the Dissected-Elk Hills, as well as Eucha and Spavinaw Lakes and W. R. Holway Reservoir. Salinity is moderate in the Plateau with mean conductivity ranging from 200 (Spring River) to 545 µS/cm (Honey Creek), while lower in the Dissected-Elk Hills (Spring Creek = 154 µS/cm). Lakes typically range from 170 to nearly 400 µS/cm. In streams, nutrient concentrations range from lows of TP = 0.02 and TN = 0.63 ppm at Spring Creek, to highs of 0.21 (Spring River TP) and 2.86 ppm (Honey Creek TN). Trophic status in streams varies from oligotrophic (Spring and Honey Creeks) to mesotrophic (Neosho and Elk Rivers) to eutrophic (Spring River). Lakes are typically phosphorus limited and on the high end of mesotrophic to nearly hyper-eutrophic. Stream clarity ranges from good (Spring River = 18 NTU) to excellent, with turbidity means less than 3 at Elk River and Spring and Honey

Water Quality Standards Implementation

Grand Region



The Oklahoma Conservation Commission (OCC) has begun a demonstration and education project on the Grand Lake watershed focused on educating citizens about reducing nonpoint source runoff. The OCC has also begun a watershed implementation project on Honey Creek as well as Spavinaw/Beaty Creek. These projects are intended to reduce the amount of bacteria, phosphorus, and sediment entering the streams and lake. These projects have indicated that this region could benefit from additional nonpoint source restoration programs. The Oklahoma Department of Environmental Quality has completed a TMDL study on Lytle Creek.

Water Quality Standards and Implementation

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

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

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

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

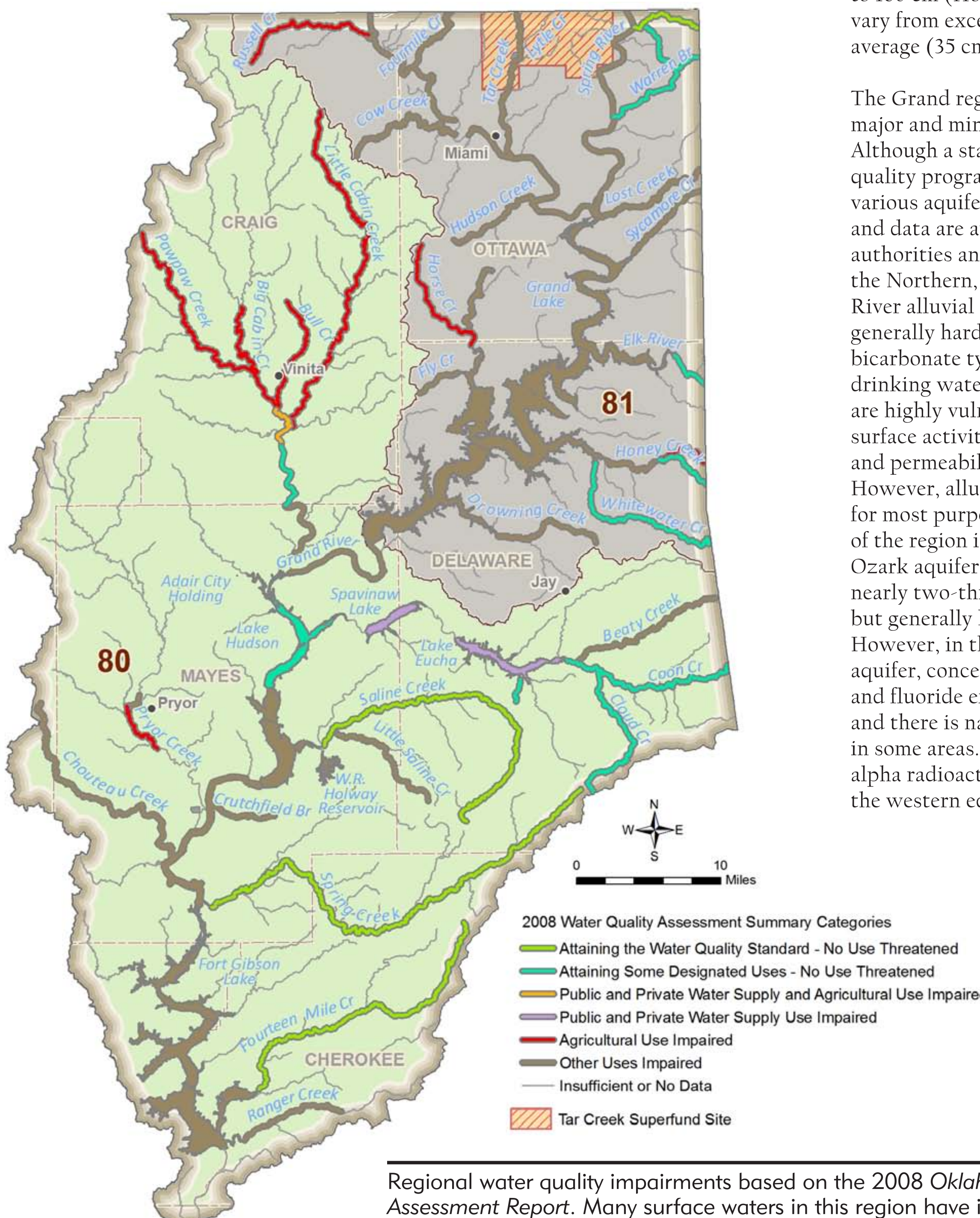
Tar Creek Superfund Site

The Tar Creek Superfund Site is a 40-square mile former lead and zinc mining area. Located in northeastern Oklahoma, the site is part of a larger area known as the Tri-State Mining District. This 2,500-square-mile District in parts of Missouri, Kansas, and Oklahoma once ranked as one of the world's largest producers of lead and zinc. The Tar Creek site includes the five towns of Picher, Cardin, Quapaw, Commerce, and North Miami, as well as other areas within Ottawa County. A significant amount of land at the site is allotted Tribal Land.

Underground mining for lead and zinc by the room-and-pillar method began in 1891 and lasted through early 1970. As water filled the mines, the native sulfide minerals dissolved creating acid mine water. Acid mine drainage containing high concentrations of heavy metals began discharging into Tar Creek in 1979 from natural springs, boreholes, and open mine shafts. It is estimated that seventy six thousand (76,000) acre-feet of shallow ground water is contaminated, approximately 75 million tons of mining waste piles (known as "chat") remain on the surface of the ground, and flotation ponds (wet or dry ponds containing mine tailings) cover approximately 800 acres. The chat contains heavy metal pollutants, such as lead, cadmium, and zinc.

The principal groundwater-bearing units within the Site are the Mississippian Boone Formation and the Cambro-Ordovician Roubidoux Formation. The headwaters of Tar Creek are located in Cherokee County, Kansas; the creek flows southward through the site and into the Grand River. Lytle Creek is a major tributary of Tar Creek. The headwaters of Beaver Creek are located north of Quapaw; the creek flows through the Quapaw powwow grounds and into the Spring River. Tar Creek and Beaver Creek are impacted by contaminated mine drainage, and the entire site is located within the watershed of Grand Lake. Water impairments include surface water degradation by the discharge of acid mine water, and the threat of contamination of the Roubidoux aquifer by downward migration of acid mine water from the overlying Boone aquifer through abandoned wells connecting the two.

Water Quality Impairments
Grand Region



Regional water quality impairments based on the 2008 *Oklahoma Integrated Water Quality Assessment Report*. Many surface waters in this region have impacts from eutrophication, particularly in water supply reservoirs.

Creeks. Lake clarity is excellent at many lakes, with mean Secchi depths from 100 (Spavinaw) to 160 cm (Holway). Grand Lake Secchi depths vary from excellent (110 cm) near the dam to average (35 cm) on the upper end.

The Grand region is underlain by several major and minor bedrock and alluvial aquifers. Although a statewide groundwater water quality program does not exist in Oklahoma, various aquifer studies have been completed, and data are available from municipal authorities and other sources. Water from the Northern, Middle, and Lower Neosho River alluvial aquifers yield water that is generally hard, typically of a sodium/calcium bicarbonate type and in some areas exceeds drinking water standards. Alluvial aquifers are highly vulnerable to contamination from surface activities due to their high porosities and permeability and shallow water tables. However, alluvial water is generally suitable for most purposes. The major bedrock aquifer of the region is the Roubidoux. Part of the Ozark aquifer, the Roubidoux underlies nearly two-thirds of the region. Water is hard but generally has low total mineral content. However, in the far western portion of the aquifer, concentrations of chloride, sulfate, and fluoride exceed drinking water standards, and there is naturally occurring radioactivity in some areas. Large concentrations of gross-alpha radioactivity and radium-226 occur near the western edge and appear to be correlated

Water Quality Impairments

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

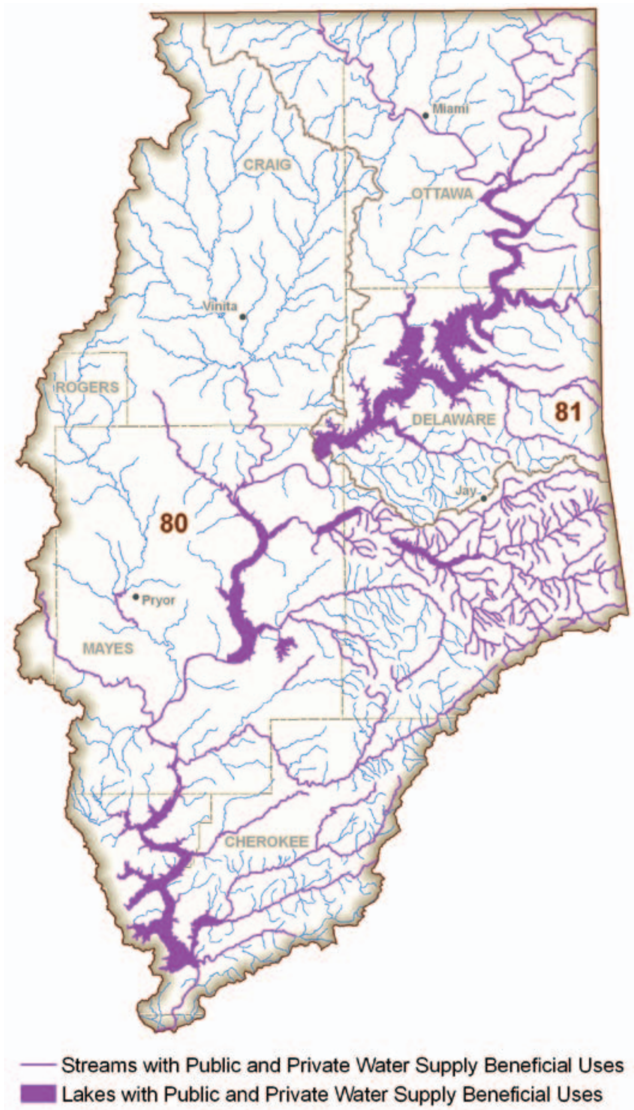
The Beneficial Use Monitoring Program (BUMP), established in 1998 to document and quantify impairments of assigned beneficial uses of the state's lakes and streams, provides information for supporting and updating the OWQS and prioritizing pollution control programs. A set of rules known as "use support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

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

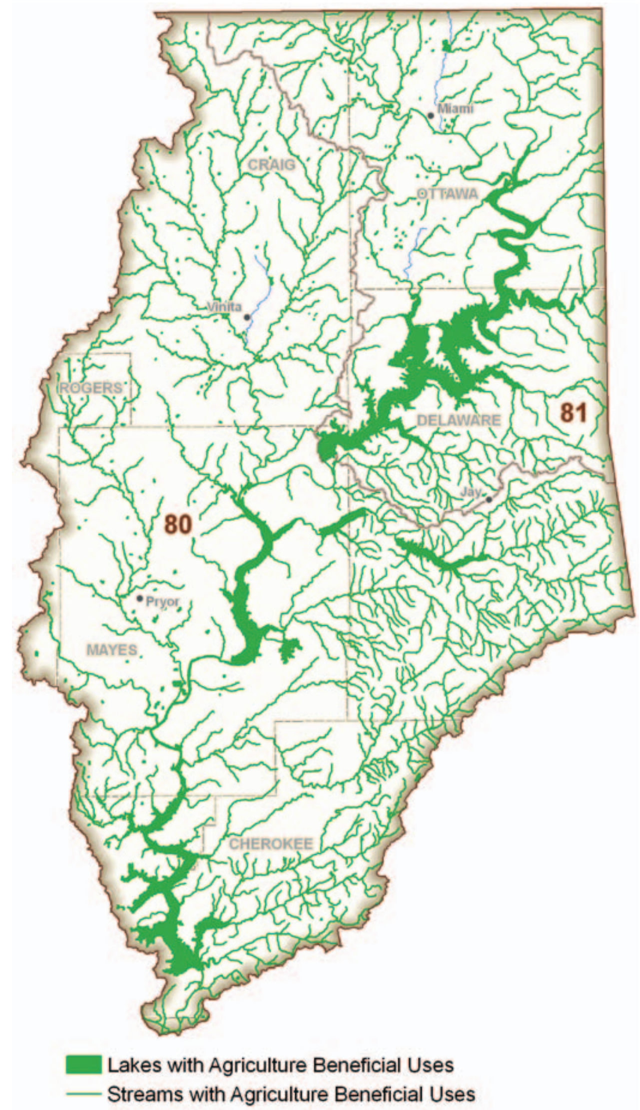
For more detailed review of the state's water quality conditions, see the most recent versions of the OWRB's BUMP Report, and the Oklahoma *Integrated Water Quality Assessment Report*, a comprehensive assessment of water quality in Oklahoma's streams and lakes required by the federal Clean Water Act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

with chloride concentrations. The aquifer is a confined aquifer and is not vulnerable to contamination from surface activities. Water from the adjacent minor Boone Formation is of good quality, but due to its lithology, the aquifer is susceptible to contamination from surface sources. Sinkholes and fractures provide direct conduits for precipitation and runoff to transport contaminants to the water table. Lead and zinc ores were mined from the Boone Formation in northeastern Oklahoma, southeastern Kansas, and southwestern Missouri from about 1890 to 1970. Water in the abandoned zinc and lead mines is contaminated with acid mine water.

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



Surface Waters with Designated Beneficial Use for Agriculture
Grand Region



Surface Water Protection

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

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

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

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

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

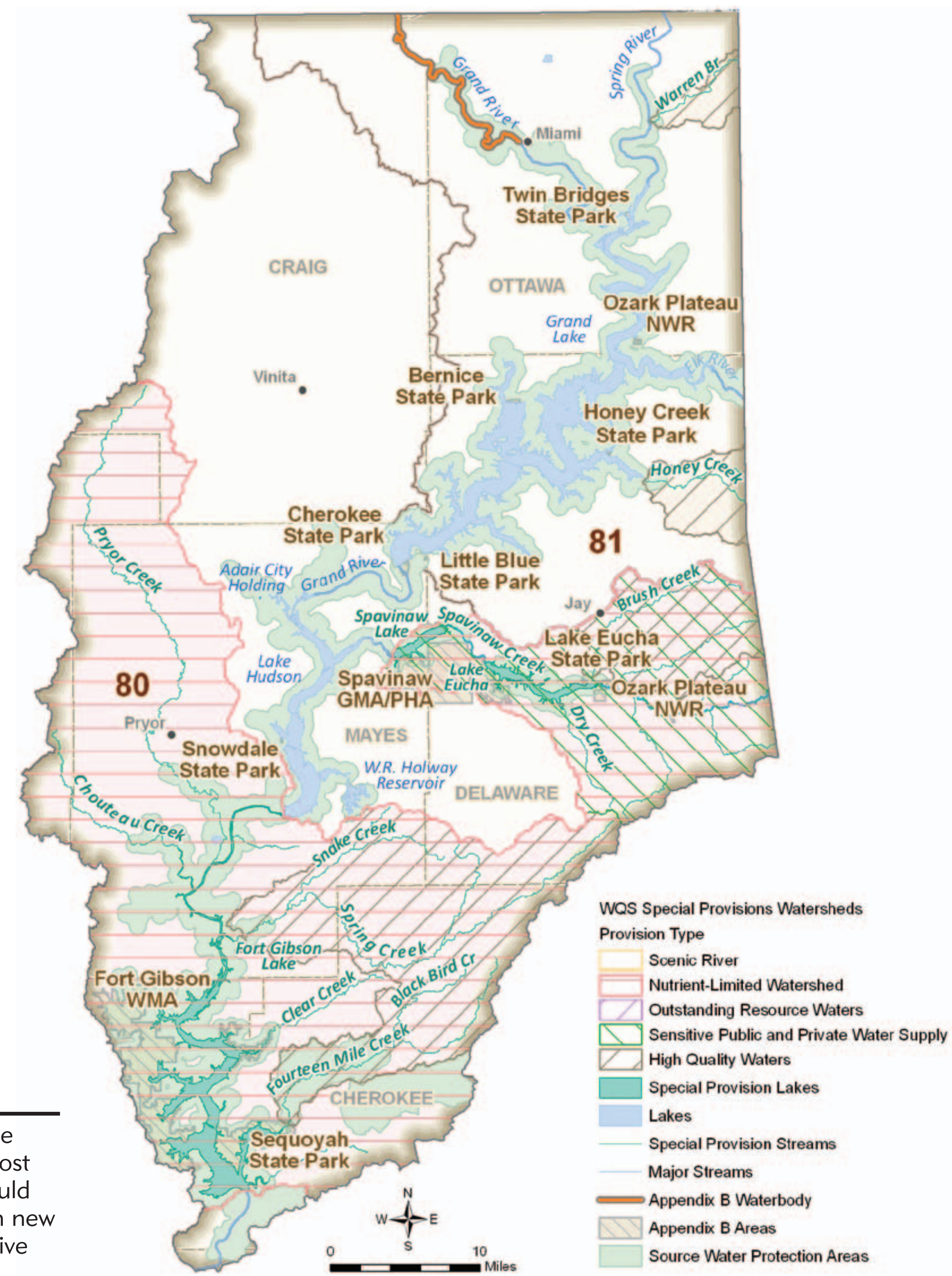
Outstanding Resource Waters are those constituting outstanding resources or of exceptional recreational and/or ecological significance. This designation prohibits any new point source discharges or additional load or increased concentration of specified pollutants.

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

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

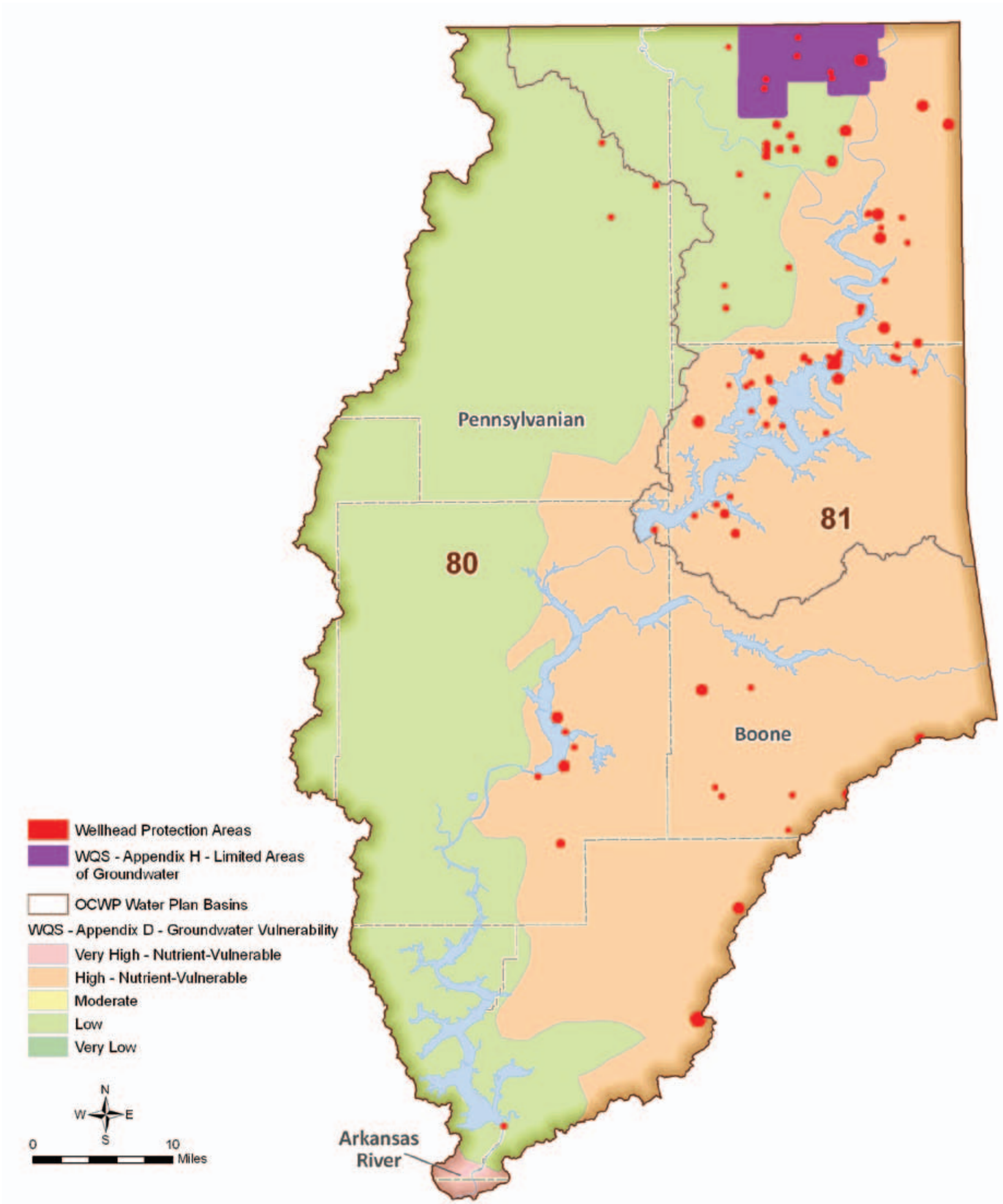
Surface Water Protection Areas

Grand Region



Special OWQS provisions are in place to protect surface waters covering most of this region. These protections should limit new pollutant discharges. When new water supplies are established Sensitive Water Supply protection should be considered.

Groundwater Protection Areas
Grand Region



Various types of protection are in place to prevent degradation of groundwater and address vulnerability. The Arkansas River alluvial aquifer has 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

Grand Region

Parameter	Lake Eucha (1995-2009)	Fort Gibson Lake (1991-2007)	Grand Lake (1995-2009)	Spavinaw Lake (1996-2009)
Chlorophyll-a (mg/m3)	NT	↑	NT	↑
Conductivity (us/cm)	NT	↑	↑	NT
Total Nitrogen (mg/L)	NT	↓	NT	NT
Total Phosphorus (mg/L)	NT	↑	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.

Notable concerns for reservoir water quality include the following:

- Significant upward trends for both chlorophyll-a and total phosphorus on Fort Gibson and Spavinaw reservoirs.
- Significant upward trends for turbidity on Eucha and Spavinaw reservoirs.

Stream Water Quality Trends

Grand Region

Parameter	Big Cabin Creek near Big Cabin		Neosho (Grand) River near Chouteau		Neosho (Grand) River near Commerce		Neosho (Grand) River near Langley		Spring River near Quapaw	
	All Data Trend (1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1975-1993, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1944-1993, 2000-2009)[1]	Recent Trend (2000-2009)	All Data Trend (1975-1993, 1998-2009)[1]	Recent Trend (1998-2009)	All Data Trend (1975-1993, 1998-2009)[1]	Recent Trend (1998-2009)
Conductivity (us/cm)	NT	NT	NT	↑	↓	NT	↓	NT	↑	NT
Total Nitrogen (mg/L)	NT	NT	↓	NT	↓	↓	↓	NT	↓	↑
Total Phosphorus (mg/L)	NT	NT	↑	NT	↑	↓	NT	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.

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 period of record turbidity and total phosphorus on Neosho River.
- Significant upward trend for period of record turbidity on Spring River.

Water Demand

The Grand Region's water needs account for about 2% of the total statewide demand. Regional demand will increase by 54% (20,250 AFY) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Municipal and Industrial sector.

Municipal and Industrial demand is projected to remain the largest demand sector in the region, accounting for approximately 59% of the total regional demand in 2060. Currently, 49% of the demand from this sector is supplied by surface water and 51% by bedrock groundwater.

Thermoelectric Power demand is projected to account for approximately 13% of the 2060 demand. The Associated Electric facility, which is supplied by surface water, is the largest user of water for thermoelectric power generation in the region.

Livestock demand is projected to account for 12% of the 2060 demand. Currently, 4% of the demand from this sector is supplied by surface water and 96% by bedrock groundwater. Livestock use in the region is predominantly chicken, followed distantly by cattle for cow-calf production, dairy cows, and sheep.

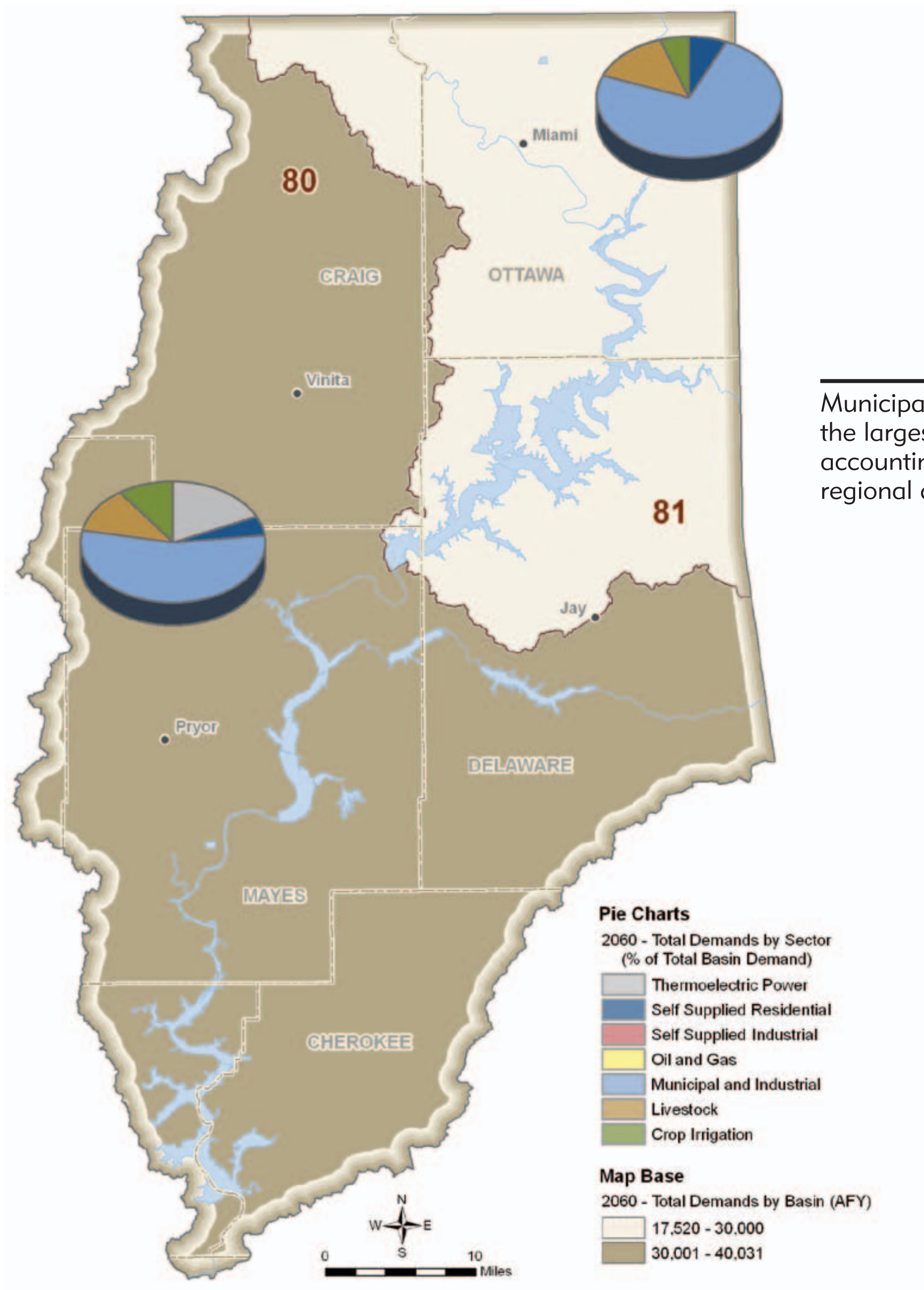
Crop Irrigation demand is expected to account for 10% of the 2060 demand. Currently, 3% of the demand from this sector is supplied by surface water and 97% by bedrock groundwater. The predominant irrigated crops in the Grand Region are pasture grasses.

Self-Supplied Residential demand is projected to account for 5% of the 2060 demand. Currently, 39% of the demand from this sector is supplied by alluvial groundwater and 61% by bedrock groundwater.

Oil and Gas demand is projected to account for less than 1% of the 2060 demand. Currently, demand from this sector is supplied by bedrock groundwater.

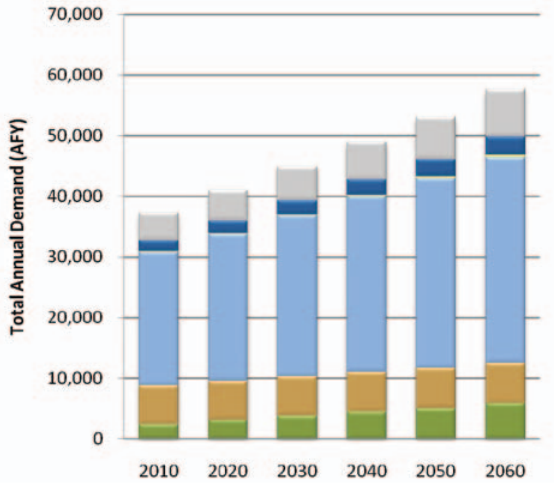
There is no Self-Supplied Industrial demand in the region.

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

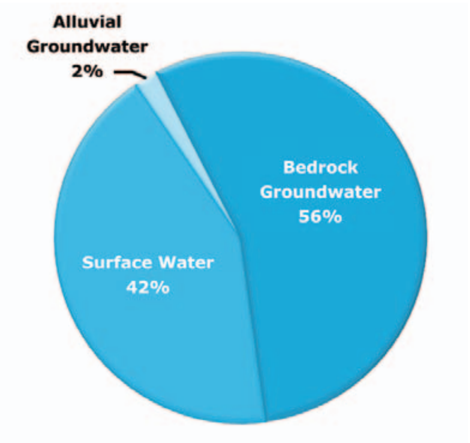


Municipal and Industrial is projected to remain the largest demand sector in the region, accounting for approximately 59% of the total regional demand in 2060.

Total Water Demand by Sector
Grand Region



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



The Grand Region's water needs account for about 2% of the total statewide demand. Regional demand will increase by 54% (20,250 AFY) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Municipal and Industrial sector.

Total Water Demand by Sector
Grand Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	2,430	6,320	22,060	70	0	1,920	4,490	37,300
2020	3,110	6,400	24,270	100	0	2,150	5,010	41,040
2030	3,780	6,480	26,560	140	0	2,360	5,590	44,920
2040	4,460	6,560	28,930	190	0	2,590	6,240	48,970
2050	4,980	6,630	31,380	240	0	2,830	6,960	53,020
2060	5,810	6,710	33,890	290	0	3,080	7,760	57,550

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.

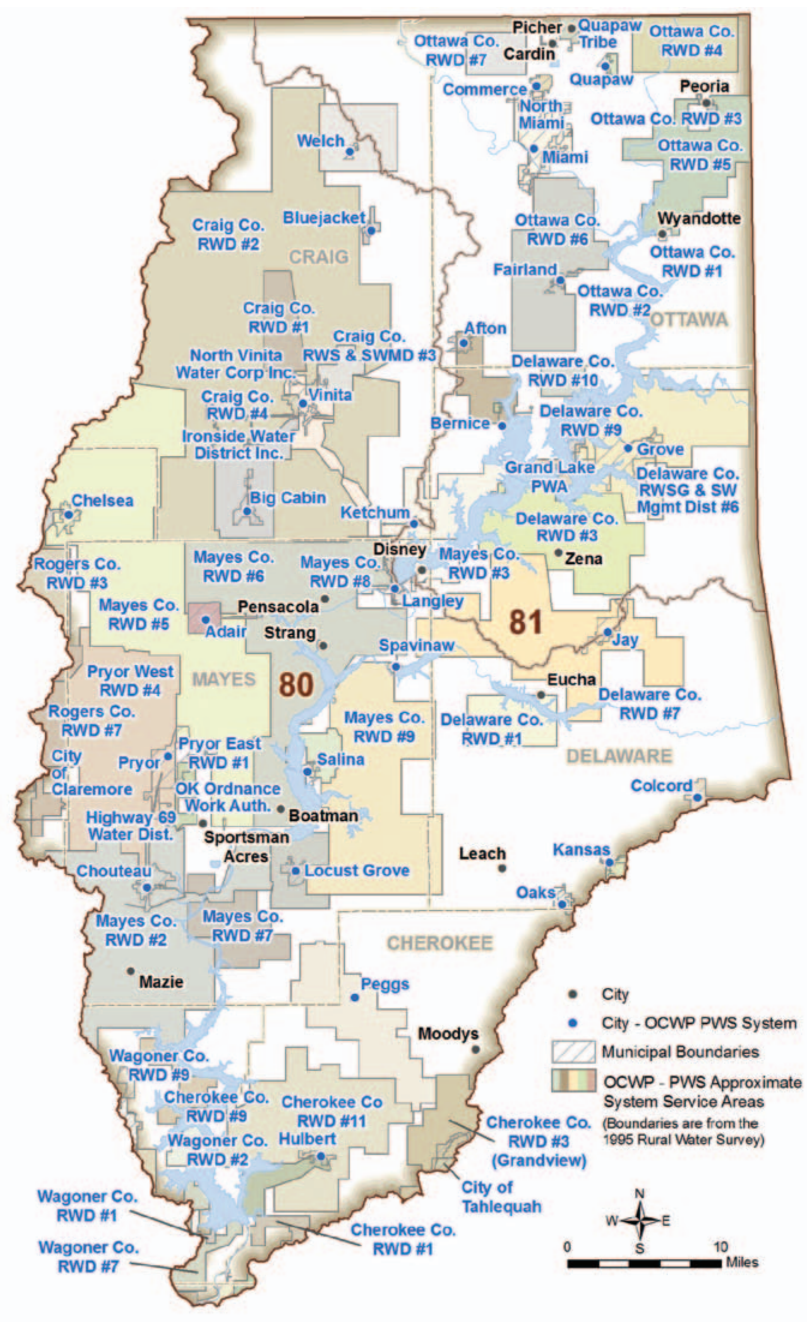
The Grand Watershed Planning Region includes 65 of the 785 public supply systems analyzed for the 2012 OCWP Update. The Public Water Providers map indicates the approximate service areas of these systems. (The map may not accurately represent existing service areas or legal boundaries. In addition, water systems often serve multiple counties and can extend into multiple planning basins and regions.)

In terms of 2010 population served (excluding provider-to-provider sales), the five largest systems in the region, in decreasing order, are Miami, Grove Municipal Services Authority, Vinita PWA, Pryor, and Mayes County RWD #2. These five systems provide service for approximately 40 percent of the population served by public water providers in the region.

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

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

Public Water Providers
Grand Region



Population and Demand Projection Data

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

Public Water Providers/Retail Population Served (1 of 2)

Grand Region

Provider	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Population Served					
				2010	2020	2030	2040	2050	2060
ADAIR	OK1021613	Mayes	107	721	796	861	936	1,011	1,086
AFTON PWA	OK1021696	Ottawa	98	1,422	1,518	1,602	1,699	1,807	1,916
BERNICE	OK2002166	Delaware	70	2,606	3,004	3,357	3,754	4,152	4,594
BIG CABIN PWA	OK3001805	Craig	215	318	358	388	427	457	497
BLUE JACKET PWA	OK2001802	Craig	131	280	317	345	382	410	447
CHELSEA ECONOMIC DEV AUTH	OK1021504	Rogers	211	2,597	2,918	3,197	3,455	3,712	3,991
CHEROKEE CO RWD #9	OK1021733	Cherokee	50	157	181	204	228	250	274
CHEROKEE CO RWD #11	OK1221637	Cherokee	109	3,507	4,029	4,543	5,066	5,573	6,095
CHOUTEAU	OK3004615	Mayes	120	1,987	2,184	2,372	2,568	2,775	2,981
COLCORD PWA	OK2002157	Delaware	82	856	981	1,106	1,231	1,374	1,517
COMMERCE	OK2005810	Ottawa	80	3,704	3,957	4,210	4,477	4,757	5,023
CRAIG CO RWD #1	OK3001801	Craig	128	325	360	393	430	468	507
CRAIG CO RWD #2	OK3001802	Craig	101	4,070	4,510	4,930	5,396	5,868	6,361
CRAIG CO RWD #4	OK3001803	Craig	65	95	105	115	126	137	148
CRAIG CO RWS & SWMD #3	OK2001807	Craig	154	529	586	640	701	762	826
DELAWARE CO RWD #1	OK3002134	Delaware	224	94	108	122	136	151	167
DELAWARE CO RWD #3	OK1221615	Delaware	50	683	786	885	987	1,097	1,212
DELAWARE CO RWD #7	OK3002138	Delaware	87	419	481	542	605	672	743
DELAWARE CO RWD #10	OK6002158	Delaware	164	1,465	1,685	1,897	2,116	2,353	2,599
DELAWARE CO RWD #9	OK3002144	Delaware	63	879	1,011	1,138	1,270	1,412	1,560
DELAWARE RWSG & SW MGMT DIST #6	OK3002137	Delaware	55	452	520	585	653	726	802
FAIRLAND	OK2005809	Ottawa	100	1,042	1,110	1,177	1,255	1,332	1,409
GRAND LAKE PWA	OK1021691	Delaware	219	1,988	2,286	2,575	2,872	3,193	3,528
GROVE MUNICIPAL SERVICES AUTH.	OK1021614	Delaware	214	11,517	13,242	14,909	16,634	18,493	20,429
HIGHWAY 69 WATER DIST	OK3004610	Mayes	232	103	113	123	133	144	155
HULBERT PWA	OK1021620	Cherokee	77	1,360	1,572	1,763	1,976	2,167	2,358
IRONSIDE WATER DIST INC	OK3001804	Craig	148	309	343	374	410	446	483
JAY	OK1021674	Delaware	403	2,600	2,984	3,359	3,744	4,163	4,601
KANSAS PWA	OK2002135	Delaware	153	717	825	932	1,040	1,157	1,273
KETCHUM PWA	OK1021612	Craig	179	4,046	4,425	4,804	5,310	5,689	6,195
KETCHUM PWA DELAWARE CO SYSTEM	OK1221638	Delaware	348	2,099	2,414	2,718	3,033	3,371	3,725
LANGLEY	OK1021604	Mayes	186	1,284	1,424	1,547	1,671	1,811	1,952
LOCUST GROVE	OK1021668	Mayes	93	1,646	1,811	1,964	2,129	2,294	2,469
MAYES CO RWD #2	OK3004608	Mayes	146	7,721	8,490	9,223	9,992	10,781	11,589
MAYES CO RWD #3	OK1021640	Mayes	62	2,471	2,717	2,951	3,198	3,450	3,708
MAYES CO RWD #4	OK3004617	Mayes	176	4,220	4,642	5,042	5,464	5,895	6,334
MAYES CO RWD #5	OK3004616	Mayes	92	3,346	3,679	3,996	4,330	4,672	5,022
MAYES CO RWD #6	OK1021666	Mayes	124	4,303	4,732	5,140	5,569	6,009	6,459

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

Grand Region

Provider	SDWIS ID[1]	County	Retail Per Capita (GPD)[2]	Population Served					
				2010	2020	2030	2040	2050	2060
MAYES CO RWD #7	OK3004627	Mayes	92	438	481	523	566	611	657
MAYES CO RWD #8	OK3004637	Mayes	50	463	509	553	600	647	695
MAYES CO RWD #9	OK1021678	Mayes	86	2,265	2,491	2,705	2,931	3,162	3,399
MIAMI	OK2005813	Ottawa	130	13,914	14,870	15,788	16,782	17,825	18,858
NORTH MIAMI	OK3005801	Ottawa	61	445	474	503	532	570	599
NORTH VINITA WATER COOP INC	OK3001806	Craig	133	142	158	172	189	205	222
OAKS WATER WORKS INC	OK2002159	Delaware	78	429	496	553	620	687	753
OKLAHOMA ORDNANCE WORKS AUTH	OK1021602	Mayes	135	3,900	4,289	4,659	5,048	5,447	5,855
OTTAWA CO RWD #1	OK2005805	Ottawa	70	465	497	528	561	596	630
OTTAWA CO RWD #2	OK2005804	Ottawa	133	711	760	806	857	910	963
OTTAWA CO RWD #3	OK2005806	Ottawa	107	162	173	183	195	207	219
OTTAWA CO RWD #4	OK2005801	Ottawa	112	662	708	751	799	848	897
OTTAWA CO RWD #5	OK2005840	Ottawa	153	762	814	864	919	975	1,032
OTTAWA CO RWD #6	OK2005859	Ottawa	108	407	435	462	491	522	552
OTTAWA CO RWD #7	OK2005860	Ottawa	80	508	543	576	612	650	688
PEGGS WATER COMPANY	OK1221630	Cherokee	85	2,021	2,322	2,619	2,920	3,212	3,513
PRYOR	OK3004611	Mayes	149	8,954	9,847	10,697	11,589	12,504	13,441
PRYOR EAST RWD #1	OK3004609	Mayes	55	129	141	154	167	180	193
QUAPAW	OK2005811	Ottawa	159	1,012	1,081	1,147	1,220	1,295	1,371
QUAPAW TRIBE	OK2005812	Ottawa	77	1,933	2,064	2,190	2,326;	2,467	2,624
SALINA PWA	OK1021603	Mayes	177	1,461	1,611	1,742	1,892	2,033	2,192
SPAVINAW	OK1021616	Mayes	69	580	636	692	748	814	870
VINITA PWA	OK1021611	Craig	181	11,491	12,747	13,938	15,257	16,593	17,977
WAGONER CO RWD #1	OK1021650	Wagoner	100	414	463	503	540	576	614
WAGONER CO RWD #2	OK1021643	Wagoner	70	2,072	2,314	2,515	2,700	2,881	3,072
WAGONER CO RWD #9	OK1021527	Wagoner	110	3,927	4,386	4,766	5,116	5,460	5,822
WELCH PWA	OK2001801	Craig	87	1,285	1,421	1,558	1,713	1,850	2,005

1 SDWIS - Safe Drinking Water Information System

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

Public Water Provider Demand Forecast (1 of 2)
Grand Region

Provider	SDWIS ID[1]	County	Demand 2010 (AFY)	2020	2030	2040	2050	2060
ADAIR	OK1021613	Mayes	86	95	103	112	121	130
AFTON PWA	OK1021696	Ottawa	156	166	176	186	198	210
BERNICE	OK2002166	Delaware	204	236	263	294	326	360
BIG CABIN PWA	OK3001805	Craig	76	86	93	103	110	120
BLUE JACKET PWA	OK2001802	Craig	41	47	51	56	60	66
CHELSEA ECONOMIC DEV AUTH	OK1021504	Rogers	613	689	755	816	877	942
CHEROKEE CO RWD #9	OK1021733	Cherokee	9	10	11	13	14	15
CHEROKEE CO RWD #11	OK1221637	Cherokee	429	493	556	620	682	746
CHOUTEAU	OK3004615	Mayes	266	292	317	344	371	399
COLCORD PWA	OK2002157	Delaware	79	90	102	113	126	139
COMMERCE	OK2005810	Ottawa	331	353	376	400	425	448
CRAIG CO RWD #1	OK3001801	Craig	47	52	56	62	67	73
CRAIG CO RWD #2	OK3001802	Craig	462	512	559	612	666	722
CRAIG CO RWD #4	OK3001803	Craig	7	8	8	9	10	11
CRAIG CO RWS & SWMD #3	OK2001807	Craig	91	101	110	121	131	143
DELAWARE CO RWD #1	OK3002134	Delaware	24	27	31	34	38	42
DELAWARE CO RWD #3	OK1221615	Delaware	38	44	50	55	61	68
DELAWARE RWSG & SW MGMT DIST #6	OK3002137	Delaware	28	32	36	40	45	49
DELAWARE CO RWD #7	OK3002138	Delaware	41	47	53	59	66	72
DELAWARE CO RWD #9	OK3002144	Delaware	62	71	80	90	100	110
DELAWARE CO RWD #10	OK6002158	Delaware	269	309	349	389	432	478
FAIRLAND	OK2005809	Ottawa	117	124	132	141	149	158
GRAND LAKE PWA	OK1021691	Delaware	488	561	632	705	783	865
GROVE MUNICIPAL SERVICES AUTH	OK1021614	Delaware	2,756	3,169	3,568	3,981	4,425	4,889
HIGHWAY 69 WATER DIST	OK3004610	Mayes	27	29	32	35	37	40
HULBERT PWA	OK1021620	Cherokee	118	136	152	171	187	204
IRONSIDE WATER DIST INC	OK3001804	Craig	51	57	62	68	74	80
JAY	OK1021674	Delaware	1,173	1,347	1,516	1,689	1,879	2,077
KANSAS PWA	OK2002135	Delaware	123	142	160	179	199	219
KETCHUM PWA	OK1021612	Craig	812	888	965	1,066	1,142	1,244
KETCHUM PWA DELAWARE CO SYSTEM	OK1221638	Delaware	818	941	1,060	1,182	1,314	1,452
LANGLEY	OK1021604	Mayes	267	297	322	348	377	407
LOCUST GROVE	OK1021668	Mayes	171	188	204	221	238	256

Projections of Retail Water Demand

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

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

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

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

Public Water Provider Demand Forecast (2 of 2)

Grand Region

Provider	SDWIS ID[1]	County	Demand 2010	2020	2030	2040	2050	2060
			AFY					
MAYES CO RWD #2	OK3004608	Mayes	1,264	1,390	1,510	1,636	1,765	1,897
MAYES CO RWD #3	OK1021640	Mayes	170	187	204	221	238	256
MAYES CO RWD #4	OK3004617	Mayes	831	914	993	1,076	1,161	1,248
MAYES CO RWD #5	OK3004616	Mayes	346	380	413	448	483	519
MAYES CO RWD #6	OK1021666	Mayes	596	656	712	772	832	895
MAYES CO RWD #7	OK3004627	Mayes	45	50	54	58	63	68
MAYES CO RWD #8	OK3004637	Mayes	26	28	31	33	36	39
MAYES CO RWD #9	OK1021678	Mayes	219	241	262	284	306	329
MIAMI	OK2005813	Ottawa	2,026	2,165	2,299	2,444	2,596	2,746
NORTH MIAMI	OK3005801	Ottawa	30	32	34	36	39	41
NORTH VINITA WATER COOP INC	OK3001806	Craig	21	23	26	28	31	33
OAKS WATER WORKS INC	OK2002159	Delaware	37	43	48	54	60	66
OKLAHOMA ORDNANCE WORKS AUTH	OK1021602	Mayes	592	651	707	766	827	889
OTTAWA CO RWD #1	OK2005805	Ottawa	36	39	41	44	47	49
OTTAWA CO RWD #2	OK2005804	Ottawa	106	113	120	128	136	144
OTTAWA CO RWD #3	OK2005806	Ottawa	19	21	22	23	25	26
OTTAWA CO RWD #4	OK2005801	Ottawa	83	89	94	100	106	113
OTTAWA CO RWD #5	OK2005840	Ottawa	131	139	148	157	167	177
OTTAWA CO RWD #6	OK2005859	Ottawa	49	53	56	59	63	67
OTTAWA CO RWD #7	OK2005860	Ottawa	46	49	52	55	58	62
PEGGS WATER COMPANY	OK1221630	Cherokee	192	220	248	277	305	333
PRYOR	OK3004611	Mayes	1,499	1,648	1,790	1,940	2,093	2,250
PRYOR EAST RWD #1	OK3004609	Mayes	8	9	9	10	11	12
QUAPAW	OK2005811	Ottawa	180	193	204	217	231	244
QUAPAW TRIBE	OK2005812	Ottawa	167	178	189	201	213	227
SALINA PWA	OK1021603	Mayes	290	320	346	376	404	435
SPAVINAW	OK1021616	Mayes	44	49	53	57	62	67
VINITA PWA	OK1021611	Craig	2,335	2,590	2,832	3,101	3,372	3,653
WAGONER CO RWD #1	OK1021650	Wagoner	46	52	56	60	65	69
WAGONER CO RWD #2	OK1021643	Wagoner	162	181	197	212	226	241
WAGONER CO RWD #9	OK1021527	Wagoner	483	539	586	629	671	716
WELCH PWA	OK2001801	Craig	126	139	152	167	181	196

1 SDWIS - Safe Drinking Water Information System

Wholesale Water Transfers (1 of 2)
Grand Region

Provider	SDWIS ID[1]	Sales			Purchases		
		Sells To	Emergency or Ongoing	Treated or Raw or Both	Purchases from	Emergency or Ongoing	Treated or Raw or Both
AFTON PWA	OK1021696	Bernice	E	T	Bernice	E	T
BERNICE	OK2002166	Afton PWA	E	T	Afton PWA	E	T
BIG CABIN PWA	OK3001805				Vinita PWA	O	T
CHELSEA ECONOMIC DEV AUTH	OK1021504	Consolidated RWD #1 Nowata & Rogers Co Mayes Co RWD #5	O E	T T			
CHEROKEE CO RWD #11	OK1221637	Hulbert PWA	E	T	Tahlequah PWA	O	T
CHOUTEAU	OK3004615				Oklahoma Ordnance Works Auth	O	T
CRAIG CO RWD #1	OK3001801				Vinita PWA	O	T
CRAIG CO RWD #2	OK3001802				Vinita PWA Ketchum PWA	O O	T T
CRAIG CO RWD #4	OK3001803				Ironside Water Dist Inc		
DELAWARE CO RWD #1	OK3002134				Jay	O	T
DELAWARE RWSG & SW MGMT DIST #6	OK3002137				Grove Municipal Services Auth	O	T
DELAWARE CO RWD #7	OK3002138				Ketchum PWA	O	T
DELAWARE CO RWD #9	OK3002144				Grove Municipal Services Auth	O	T
GROVE MUNICIPAL SERVICES AUTH	OK1021614	Delaware Co RWD #9 Delaware Co RWD #6	O O	T T			
HIGHWAY 69 WATER DIST	OK3004610				Pryor	O	T
HULBERT PWA	OK1021620				Cherokee Co RWD #11	E	T
IRONSIDE WATER DIST INC	OK3001804	Craig Co RWD #4			Vinita PWA	O	T
JAY	OK1021674	Delaware Co RWD #1	O	T	Tulsa (Lake Eucha)	O	R
KETCHUM PWA	OK1021612	Delaware Co RWD 7 Craig Co RWD 2	O O	T T	Langley	E	T
KETCHUM PWA DELAWARE CO SYSTEM	OK1221638	Delaware Co RWD #7 Craig Co RWD #2	O O	T T	Langley	E	T
LANGLEY	OK1021604	Mayes Co RWD #8 Ketchum PWA Delaware Co System Ketchum PWA	O E E	T T T	Ketchum PWA	E	T
LOCUST GROVE	OK1021668	Mayes Co RWD #9	O	T			
MAYES CO RWD #2	OK3004608	Inola Water Works Inc Rogers Co RWD #6	O	T	Oklahoma Ordnance Works Auth	O	T
MAYES CO RWD #4	OK3004617	Rogers Co RWD #7 Mayes Co RWD #5	O O	T T	Oklahoma Ordnance Works Auth	O	T

Wholesale Water Transfers

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

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

Wholesale Water Transfers (2 of 2)
Grand Region

Provider	SDWIS ID[1]	Sales: Sells To	Sales: Emergency or Ongoing	Sales: Treated or Raw or Both	Purchases: Purchases from	Purchases: Emergency or Ongoing	Purchases: Treated or Raw or Both
MAYES CO RWD #5	OK3004616				Mayes Co RWD #4	O	T
					Pryor West RWD #4	O	T
					Oklahoma Ordnance Works Authority		T
					Chelsea Economic Dev Auth	E	
MAYES CO RWD #7	OK3004627				Oklahoma Ordnance Works Auth	O	T
MAYES CO RWD #8	OK3004637				Langley	O	T
					Mayes Co RWD #6		
MAYES CO RWD #9	OK1021678				Locust Grove	O	T
MIAMI	OK2005813	North Miami		T			
NORTH MIAMI	OK3005801				Miami		T
NORTH VINITA WATER COOP INC	OK3001806				Vinita PWA		T
OKLAHOMA ORDNANCE WORKS AUTH	OK1021602	Broken Arrow WTP	O	T			
		Pryor	O	T			
		Chouteau	O	T			
		Mayes Co RWD #2	O	T			
		Mayes Co RWD #4	O	T			
		Mayes Co RWD #5	O	T			
		Mayes Co RWD #7	O	T			
PRYOR	OK3004611	Highway 69 Water Dist	O	T	Oklahoma Ordnance Works Auth	O	T
		Pryor East RWD #1	O	T			
PRYOR EAST RWD #1	OK3004609				Pryor	O	T
VINITA PWA	OK1021611	Big Cabin PWA	O	T			
		Craig Co RWD #2	O	T			
		Craig Co RWD #1		T			
		Ironside Water Dist Inc		T			
		North Vinita Water Co-op Inc		T			

1 SDWIS - Safe Drinking Water Information System

Public Water Provider Water Rights and Withdrawals - 2010 (1 of 2)

Grand Region

Provider	SDWIS ID[1]	County	Permitted Quantity	Source: Permitted Surface Water	Source: Permitted Alluvial Groundwater	Source: Permitted Bedrock Groundwater
			AFY	Percent	Percent	Percent
ADAIR	OK1021613	Mayes	---	---	---	---
ADAIR CO RWS & SWMD #6	OK2000145	Adair	---	---	---	---
AFTON PWA	OK1021696	Ottawa	---	---	---	---
BERNICE	OK2002166	Delaware	146	0%	0%	100%
BIG CABIN PWA	OK3001805	Craig	---	---	---	---
BLUE JACKET PWA	OK2001802	Craig	70	0%	0%	100%
CHELSEA ECONOMIC DEV AUTH	OK1021504	Rogers	1094	100%	0%	0%
CHEROKEE CO RWD #2 (KEYS)	OK1021711	Cherokee	329	100%	0%	0%
CHEROKEE CO RWD #9	OK1021733	Cherokee	---	---	---	---
CHEROKEE CO RWD #11	OK1221637	Cherokee	---	---	---	---
CHOUTEAU	OK3004615	Mayes	---	---	---	---
COLCORD PWA	OK2002157	Delaware	320	0%	0%	100%
COMMERCE	OK2005810	Ottawa	1170	---	---	100
CRAIG CO RWD #1	OK3001801	Craig	---	---	---	---
CRAIG CO RWD #2	OK3001802	Craig	140	0%	0%	100%
CRAIG CO RWS & SWMD #3	OK2001807	Craig	620	0%	0%	100%
CRAIG CO RWD #4	OK3001803	Craig	---	---	---	---
DELAWARE CO RWD #1	OK3002134	Delaware	200	0%	0%	100%
DELAWARE CO RWD #3	OK1221615	Delaware	---	---	---	---
DELAWARE RWSG & SW MGMT DIST #6	OK3002137	Delaware	---	---	---	---
DELAWARE CO RWD #7	OK3002138	Delaware	---	---	---	---
DELAWARE CO RWD #9	OK3002144	Delaware	---	---	---	---
DELAWARE CO RWD #10	OK6002158	Delaware	169	---	---	100
FAIRLAND	OK2005809	Ottawa	81	0%	0%	100%
GRAND LAKE PWA	OK1021691	Delaware	---	---	---	---
GROVE MUNICIPAL SERVICES AUTH	OK1021614	Delaware	---	---	---	---
HIGHWAY 69 WATER DIST	OK3004610	Mayes	---	---	---	---
HULBERT PWA	OK1021620	Cherokee	---	---	---	---
IRONSIDE WATER DIST INC	OK3001804	Craig	---	---	---	---
JAY	OK1021674	Delaware	---	---	---	---
KANSAS PUBLIC WORKS AUTH	OK2002135	Delaware	179	0%	0%	100%
KETCHUM PWA	OK1021612	Craig	---	---	---	---
KETCHUM PWA DELAWARE CO SYSTEM	OK1221638	Delaware	---	---	---	---
LANGLEY	OK1021604	Mayes	---	---	---	---
LOCUST GROVE	OK1021668	Mayes	---	---	---	---
MAYES CO RWD #2	OK3004608	Mayes	---	---	---	---

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 (2 of 2)

Grand Region

Provider	SDWIS ID[1]	County	Permitted Quantity	Source		
				Permitted Surface Water	Permitted Alluvial Groundwater	Permitted Bedrock Groundwater
			AFY	Percent		
MAYES CO RWD #3	OK1021640	Mayes	262	---	---	100
MAYES CO RWD #4	OK3004617	Mayes	---	---	---	---
MAYES CO RWD #5	OK3004616	Mayes	---	---	---	---
MAYES CO RWD #6	OK1021666	Mayes	---	---	---	---
MAYES CO RWD #7	OK3004627	Mayes	---	---	---	---
MAYES CO RWD #8	OK3004637	Mayes	---	---	---	---
MAYES CO RWD #9	OK1021678	Mayes	---	---	---	---
MIAMI	OK2005813	Ottawa	5,336.4	0%	0%	100%
NORTH MIAMI	OK3005801	Ottawa	---	---	---	---
NORTH VINITA WATER COOP INC	OK3001806	Craig	---	---	---	---
OAKS WATER WORKS INC	OK2002159	Delaware	---	---	---	---
OKLAHOMA ORDNANCE WORKS AUTH	OK1021602	Mayes	---	---	---	---
OTTAWA CO RWD #1	OK2005805	Ottawa	322	0%	0%	100%
OTTAWA CO RWD #2	OK2005804	Ottawa	502	0%	0%	100%
OTTAWA CO RWD #3	OK2005806	Ottawa	322	0%	0%	100%
OTTAWA CO RWD #4	OK2005801	Ottawa	769.8	0%	0%	100%
OTTAWA CO RWD #5	OK2005840	Ottawa	50	0%	0%	100%
OTTAWA CO RWD #6	OK2005859	Ottawa	640	0%	0%	100%
OTTAWA CO RWD #7	OK2005860	Ottawa	320	0%	0%	100%
PEGGS WATER COMPANY	OK1221630	Cherokee	---	---	---	---
PRYOR	OK3004611	Mayes	2,382	100%	0%	0%
PRYOR EAST RWD #1	OK3004609	Mayes	---	---	---	---
QUAPAW	OK2005811	Ottawa	2,368	0%	0%	100%
QUAPAW TRIBE	OK2005812	Ottawa	1,225	---	---	100%
SALINA PWA	OK1021603	Mayes	---	---	---	---
VINITA PWA	OK1021611	Craig	3,620	100%	0%	0%
SPAVINAW	OK1021616	Mayes	---	---	---	---
WAGONER CO RWD #1	OK1021650	Wagoner	---	---	---	---
WAGONER CO RWD #2	OK1021643	Wagoner	---	---	---	---
WAGONER CO RWD #9	OK1021527	Wagoner	---	---	---	---
WELCH PWA	OK2001801	Craig	78	0%	0%	100%

1 SDWIS - Safe Drinking Water Information System

OCWP Provider Survey
Grand Region

City of Adair (Mayes County)
Current Source of Supply
Primary source: Adair City Lake
Short-Term Needs
New supply source: complete project to connect and purchase water from Mayes County RWD #6.
Infrastructure improvements: replace portion of distribution system lines.
Long-Term Needs
Infrastructure improvements: add and replace portion of distribution system lines.

Adair County RWS & SWMD #6
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: possible water Flint Ridge RWD.
Long-Term Needs
None identified.

Afton PWA (Ottawa County)
Current Source of Supply
Primary source: Grand Lake
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; WTP upgrades.

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

Big Cabin PWA (Craig County)
Current Source of Supply
Primary source: Vinita Utilities Authority
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
New supply source: connect to Craig County RWD #2 to obtain water with Vinita.

Blue Jacket (Craig County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: replace the rest of the asbestos cement water lines in the distribution system; move the chlorine station.
Long-Term Needs
None identified.

Chelsea Economic Dev. Auth (Rogers County)
Current Source of Supply
Primary source: Oologah Lake
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: add distribution system lines.

Cherokee County RWD 2 (Keys)
Current Source of Supply
Primary source: Lake Tenkiller
Short-Term Needs
None identified.
Long-Term Needs
New supply source: possible water purchase from Tahlequah.

Cherokee County RWD 9
Current Source of Supply
Primary source: Fort Gibson Reservoir
Short-Term Needs
New supply source: connect to Cherokee County RWD 11.
Long-Term Needs
None identified.

Cherokee County RWD 11
Current Source of Supply
Primary source: Double Spring Creek
Short-Term Needs
New supply source: Fourteen Mile Creek.
Long-Term Needs
None identified.

Town of Chouteau (Mayes County)
Current Source of Supply
Primary sources: Oklahoma Ordnance Works Authority
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: add and replace distribution system lines.

Colcord PWA (Delaware County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: drill additional well.
Long-Term Needs
Infrastructure improvements: rehabilitate two filters and replace water lines within the water treatment plant.

City of Commerce (Ottawa County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: drill additional well.
Long-Term Needs
None identified.

Craig County RWD 1
Current Source of Supply
Primary source: Vinita Utilities Authority
Short-Term Needs
Infrastructure improvements: loop distribution system lines. Relocate water lines.
Long-Term Needs
None identified.

Craig County RWD 2
Current Source of Supply
Primary source: Vinita Utilities Authority, Ketchum PWA
Short-Term Needs
New supply source: increase supplies from Ketchum PWA.
Long-Term Needs
Infrastructure improvements: new 30 mile pipeline from Ketchum.

Craig County RWD 4
Current Source of Supply
Primary source: Ironside Water District
Short-Term Needs
New supply source: drill additional wells.
Infrastructure improvements: add standpipe.
Long-Term Needs
None identified.

Craig County RWS & SWMD 3
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: refurbish wells.
Long-Term Needs
New supply source: drill additional wells.
Infrastructure improvements: add standpipe.

Delaware County RWD 1
Current Source of Supply
Primary source: Jay
Short-Term Needs
Infrastructure improvements: refurbish standpipe; add distribution system lines.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

Delaware County RWD 3
Current Source of Supply
Primary source: Grand Lake
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: add storage; replace distribution system lines.

Provider Supply Plans

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

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

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

OCWP Provider Survey
Grand Region

Delaware County RWD 7
Current Source of Supply
Primary source: Ketchum PWA
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
None identified.

Delaware County RWD 10
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Repair leaks in distribution lines.
Long-Term Needs
New supply source: drill additional wells.
Infrastructure improvements: add standpipe; new WTP.

Delaware County RWD 9
Current Source of Supply
Primary source: Grand Lake
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Delaware County RWSG & SW Mgmt Dist. 6
Current Source of Supply
Primary source: City of Grove
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Town of Fairland (Ottawa County)
Current Source of Supply
Primary source: groundwater; Ottawa County RWD 6
Emergency source: Ottawa County RWD 6
Short-Term Needs
New supply source: drill additional wells; purchase water from Ottawa County RWD 6
Long-Term Needs
None identified.

Grand Lake PWA (Delaware County)
Current Source of Supply
Primary source: Grand Lake
Short-Term Needs
None identified.
Long-Term Needs
New supply source: groundwater; drill new wells.
Infrastructure improvements: add storage and standpipe; add distribution system lines.

Grove Municipal Serv. Auth. (Delaware County)
Current Source of Supply
Primary source: Grand Lake
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: Expand surface WTP; add storage.

Highway 69 Water District (Mayes County)
Current Source of Supply
Primary sources: City of Pryor
Short-Term Needs
Infrastructure improvements: replace portion of distribution system lines.
Long-Term Needs
Infrastructure improvements: replace portion of distribution system lines.

Hulbert PWA (Cherokee County)
Current Source of Supply
Primary sources: 14 Mile Creek
Short-Term Needs
Infrastructure improvements: New booster pump for existing standpipe.
Long-Term Needs
Infrastructure improvements: new WTP.

Ironside Water District Inc. (Craig County)
Current Source of Supply
Primary sources: Vinita Utilities Authority
Short-Term Needs
Infrastructure improvements: replace portion of main and distribution lines; add chlorine booster station.
Long-Term Needs
Infrastructure improvements: new interconnects between Big Cabin and Craig County RWD 2.

Jay (Delaware County)
Current Source of Supply
Primary sources: Lake Eucha
Short-Term Needs
Infrastructure improvements: refurbish storage tanks.
Long-Term Needs
Infrastructure improvements: rehab 2 clarifiers at existing surface WTP; new WTP.

Kansas Public Works Auth. (Delaware County)
Current Source of Supply
Primary sources: groundwater
Short-Term Needs
Infrastructure improvements: repair fire hydrants; rehabilitate 2 filters at WTP.
Long-Term Needs
Infrastructure improvements: add main line to connect to Flint Ridge RWD for emergency connection.

Ketchum PWA (Craig County)
Current Source of Supply
Primary sources: Grand Lake
Short-Term Needs
Infrastructure improvements: replace portion of water main lines.
Long-Term Needs
Infrastructure improvements: New WTP to replace 2 old WTPs.

Ketchum PWA Delaware County System
Current Source of Supply
Primary sources: Grand Lake
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: New WTP to replace 2 old WTPs.

Town of Langley (Mayes County)
Current Source of Supply
Primary sources: Grand Lake
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

Town of Locust Grove (Mayes County)
Current Source of Supply
Primary sources: Grand Lake
Short-Term Needs
Infrastructure improvements: replace distribution system lines
Long-Term Needs
Infrastructure improvements: replace distribution system lines; add clarifier to WTP; add carbon feed system; add discharge to lake.

Mayes County RWD 2
Current Source of Supply
Primary sources: Oklahoma Ordnance Works Authority
Short-Term Needs
Infrastructure improvements: replace a portion of distribution system lines
Long-Term Needs
Infrastructure improvements: replace a portion of distribution system lines.

Mayes County RWD 3
Current Source of Supply
Primary sources: Grand Lake
Short-Term Needs
Infrastructure improvements: replace distribution system lines; add distribution system lines.
Long-Term Needs
Infrastructure improvements: add distribution system lines

Mayes County RWD 4
Current Source of Supply
Primary source: Oklahoma Ordnance Works Authority
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Mayes County RWD 5
Current Source of Supply
Primary sources: Oklahoma Ordnance Works Authority, Mayes County RWD 4
Short-Term Needs
Infrastructure improvements: replace distribution system lines
Long-Term Needs
Infrastructure improvements: upgrade distribution system pumps and lines.

Mayes County RWD 6
Current Source of Supply
Primary sources: Lake Hudson (Markham Ferry)
Short-Term Needs
Infrastructure improvements: replace portion of distribution system lines; add water tower.
Long-Term Needs
Infrastructure improvements: replace portion of distribution system lines; increase WTP capacity.

Mayes County RWD 7
Current Source of Supply
Primary source: Oklahoma Ordnance Works Authority
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Mayes County RWD 8
Current Source of Supply
Primary source: Mayes County RWD 6
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace portion of distribution system lines.

Mayes County RWD 9
Current Source of Supply
Primary source: W. R. Holway Reservoir
Short-Term Needs
Infrastructure improvements: expanding water treatment plant and rehabilitating two water towers.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

OCWP Provider Survey
Grand Region

City of Miami (Ottawa County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
New supply source: drill additional well.
Infrastructure improvements: add pressure pumps.

North Miami (Ottawa County)
Current Source of Supply
Primary source: City of Miami
Short-Term Needs
New supply source: drill additional well.
Long-Term Needs
New supply source: drill another additional well.

North Vinita Water Coop Inc. (Craig County)
Current Source of Supply
Primary source: Town of Vinita
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Oaks Water Works Inc. (Delaware County)
Current Source of Supply
Primary source: groundwater.
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

OK Ordnance Works Auth. (Mayes County)
Current Source of Supply
Primary source: Grand River
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: add distribution system lines.

Ottawa County RWD 1
Current Source of Supply
Primary source: groundwater, Wyandotte Nation
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Ottawa County RWD 2
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: drill additional well.
Infrastructure improvements: replace a portion of distribution system lines.
Long-Term Needs
New supply source: drill additional well.
Infrastructure improvements: replace a portion of distribution system lines.

Ottawa County RWD 3
Current Source of Supply
Primary sources: groundwater
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Ottawa County RWD 4
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: drill additional well.
Infrastructure improvements: replace a portion of distribution system lines.
Long-Term Needs
New supply source: drill additional well.
Infrastructure improvements: replace a portion of distribution system lines.

Ottawa County RWD 5
Current Source of Supply
Primary source: groundwater
Short-Term Needs
Infrastructure improvements: add storage tank.
Long-Term Needs
New supply source: drill additional well.

Ottawa County RWD 6
Current Source of Supply
Primary source: groundwater
Short-Term Needs
New supply source: drill additional well.
Infrastructure improvements: replace a portion of distribution system lines.
Long-Term Needs
New supply source: drill additional well.
Infrastructure improvements: replace a portion of distribution system lines.

Ottawa County RWD 7
Current Source of Supply
Primary source: groundwater, City of Commerce
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Peggs Water Company (Cherokee County)
Current Source of Supply
Primary source: Spring Creek
Short-Term Needs
New supply source: drill additional wells.
Infrastructure improvements: replace portion of distribution lines.
Long-Term Needs
None identified.

City of Pryor (Mayes County)
Current Source of Supply
Primary sources: Oklahoma Ordnance Works Auth.
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Pryor East RWD 1 (Mayes County)
Current Source of Supply
Primary source: Jay
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines.

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

Quapaw Tribe (Ottawa County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Salina PWA (Mayes County)
Current Source of Supply
Primary source: groundwater
Short-Term Needs
None identified.
Long-Term Needs
Infrastructure improvements: replace distribution system lines; upgrades to WTP.

Town of Spavinaw (Mayes County)
Current Source of Supply
Primary source: Spavinaw Lake
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Vinita PWA (Craig County)
Current Source of Supply
Primary source: None identified.
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Wagoner County RWD 1
Current Source of Supply
Primary source: Ft. Gibson Reservoir
Short-Term Needs
None identified.
Long-Term Needs
None identified.

Wagoner County RWD 2
Current Source of Supply
Primary source: Ft. Gibson Reservoir
Short-Term Needs
Infrastructure improvements: refurbish water tanks; replace distribution system lines.
Long-Term Needs
Infrastructure improvements: add filter to WTP.

Wagoner County RWD 9
Current Source of Supply
Primary source: Fort Gibson Lake
Short-Term Needs
Infrastructure improvements: replace distribution system lines.
Long-Term Needs
Infrastructure improvements: new WTP.

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

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.

Infrastructure Cost Summary
Grand Region

Provider System Category[1]	Infrastructure Need (millions of 2007 dollars)			
	Present-2020	2021-2040	2041-2060	Total Period
Small	$277	$450	$109	$836
Medium	$237	$562	$383	$1,182
Large	$0	$0	$0	$0
Reservoir[2]	$0	$26	$110	$136
Total	$514	$1,038	$602	$2,154

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

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

- Approximately $2.2 billion is needed to meet the projected drinking water infrastructure needs of the Grand Region over the next 50 years. The largest infrastructure costs are expected to occur between 2021 and 2040.
- Distribution and transmission projects account for more than 90 percent of the providers' estimated infrastructure costs, followed distantly by water treatment projects.
- Medium-sized providers have the largest overall drinking water infrastructure costs.
- Projects involving rehabilitation of existing reservoirs comprise approximately six percent of the total costs.

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)

Grand 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			
Chelsea	4	Prior Creek	80	FC, WS, R, FW	0	4,500	65,000	21,284	1986	USACE	$160,317,000

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

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

Expanded Water Supply Options
Grand Region

Oklahoma Comprehensive Water Plan

Data & Analysis
Grand Watershed Planning Region

Basin 80

Basin 80 Summary

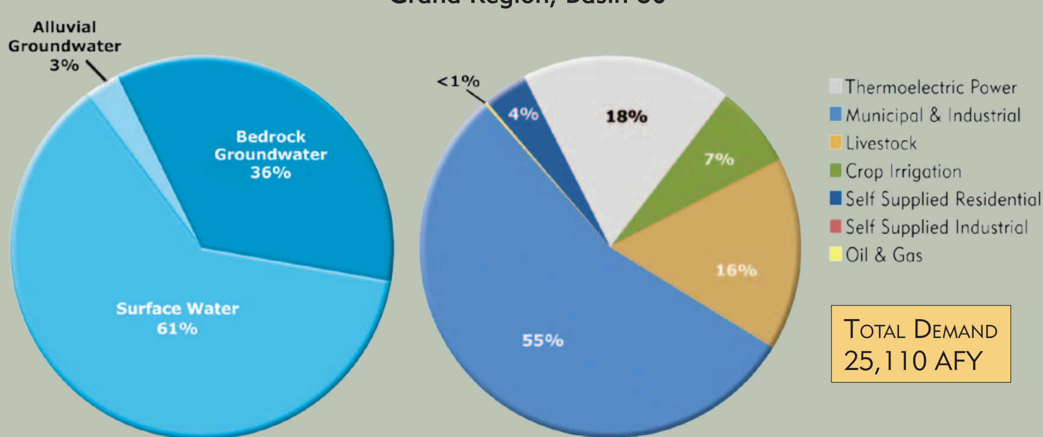
Synopsis

- Water users are expected to continue to rely largely on surface water and bedrock groundwater supplies.
- By 2020, alluvial groundwater storage depletions have a moderate probability of occurring.
- By 2020, there is a moderate probability of surface water gaps from increased demands on surface water supplies during low flow periods, but the use of existing in-basin reservoirs could mitigate those gaps.
- The Grand River Dam Authority (GRDA) has jurisdiction over the streamflow in Basin 80 and should be consulted for the availability of surface water supplies in the basin.
- 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 alluvial groundwater storage depletions.
- To mitigate surface water gaps, dependable groundwater supplies and/or reservoir storage could be used as alternatives. These supply sources could be used without major impacts to groundwater storage.

Basin 80 accounts for about 67% of the current water demand in the Grand Watershed Planning Region. About 55% of the demand is in the Municipal and Industrial demand sector. Thermoelectric Power (18%) and Livestock (16%) are the next largest demand sectors. Surface water is used to supply about 61% of current demand in the basin. Groundwater is used to satisfy about 39% of the current demand (3% alluvial and 36% bedrock). The peak summer month demand in Basin 80 is about 1.7 times the winter demand, which is less pronounced than the overall statewide pattern.

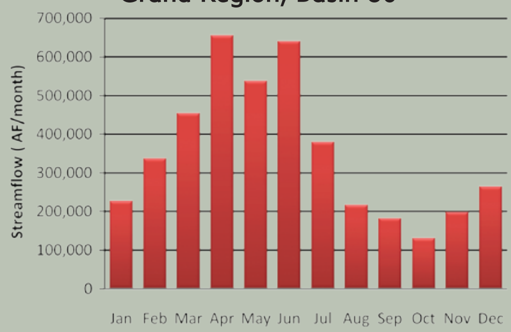
There are five major reservoirs in Basin 80: Fort Gibson, Hudson (Markham Ferry), W.R. Holway, Eucha, and Spavinaw. Hudson

Current Demand by Source and Sector
Grand Region, Basin 80

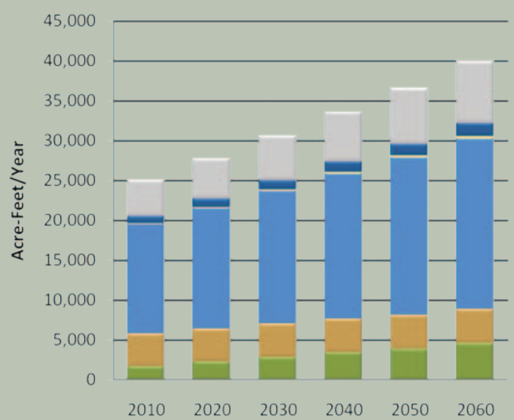


Water Resources
Grand Region, Basin 80

Median Historical Streamflow at the Basin Outlet
Grand Region, Basin 80



Projected Water Demand
Grand Region, Basin 80



(Markham Ferry) and W. R. Holway are operated by the Grand River Dam Authority (GRDA) for hydroelectric power generation and by the U.S. Army Corps of Engineers for flood control. Fort Gibson is operated by the Corps of Engineers for both hydroelectric power generation and flood control. The GRDA should be consulted for the availability of water supply from these reservoirs. Lakes Eucha and Spavinaw are major sources of out-of-basin supply for the City of Tulsa, located in the Middle Arkansas Watershed Planning Region. The combined yield of these reservoirs is 84,000 AFY. With the exception of a small number of water rights that were issued prior to the formation of the GRDA (Lakes Eucha and Spavinaw, for example), GRDA has jurisdiction over the streamflow in Basin 80 and should be consulted for the availability of surface water supplies in the basin. The Grand River typically has flow greater than 120,000 AF/month throughout the year and greater than 450,000 AF/month in the spring and early summer. 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 80 is considered poor. Big Cabin Creek and its tributaries and a portion of Pryor Creek are impaired for Agricultural use due to high levels of sulfates, chloride, and total dissolved solids (TDS). Spavinaw and Eucha lakes are impaired for Public and Private Water Supply due to high levels of Chlorophyll-a. However, individual lakes and streams may have acceptable water quality.

Basin 80 has substantial groundwater supplies. The majority of groundwater rights are in the Roubidoux major bedrock aquifer. The Roubidoux aquifer underlies 79% of the total basin area and has more than 14.6 million AF of storage in the basin. The estimated major bedrock aquifer recharge to this aquifer from Basin 80 is 214,000 AFY. There are also substantial groundwater rights in the Boone minor bedrock aquifer and a small number of water rights in other minor bedrock aquifers. Self-Supplied Residential demand (domestic use) which does not require a permit, is assumed to be supplied by groundwater sources. Concentrations of chloride and naturally occurring radioactivity may exceed drinking water standards in some localized areas of the Roubidoux aquifer. However, there are no widespread groundwater quality issues in the basin. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060.

The projected 2060 water demand of 40,030 AFY reflects a 14,920 AFY increase (59%) over the 2010 demand.

Gaps & Depletions

Based on projected demands and historical hydrology, surface water gaps and alluvial groundwater storage depletions in Basin 80 may occur by 2020. Bedrock groundwater depletions are not expected by 2060. Surface water gaps will be up to 4,930 AFY and have a 24% probability of occurring in at least one month of the year by 2060. Surface water gaps may occur throughout the year, peaking in size during the summer. Alluvial groundwater storage depletions will be up to 250 AFY and have a 24% probability of occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions may occur throughout the year. Future alluvial groundwater withdrawals are expected to occur from non-delineated minor aquifers. Therefore, the extent of the storage depletions cannot be fully evaluated.

Water Supply Limitations
Grand Region, Basin 80

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal Potential Significant

Water Supply Option Effectiveness
Grand Region, Basin 80

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

Typically Effective Potentially Effective
Likely Ineffective No Option Necessary

Options

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

Moderately expanded permanent conservation activities in the Municipal and Industrial demand sector could reduce surface water gaps and alluvial groundwater storage depletions. Temporary drought management could be effective in reducing surface water use and subsequent gaps. However, since groundwater storage could continue to provide supplies during droughts, temporary drought management may not be needed to meet alluvial groundwater demand.

Due to the abundance of in-basin reservoir storage and groundwater supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified Chelsea Reservoir as a viable site in Basin 80. However, the GRDA has jurisdiction over the management of surface water in Basin 80 and should be consulted for the feasibility of using existing storage or developing additional reservoir storage in the basin.

In general, increased reliance on surface water, without reservoir storage, may increase gaps and is not recommended.

Increased reliance on the Roubidoux aquifer and minor bedrock aquifers could mitigate surface water gaps and alluvial groundwater depletions without major impacts to bedrock storage. However, localized seasonal storage depletions could occur. In addition, minor aquifers may have smaller yields, thus site specific studies should be conducted before large-scale use.

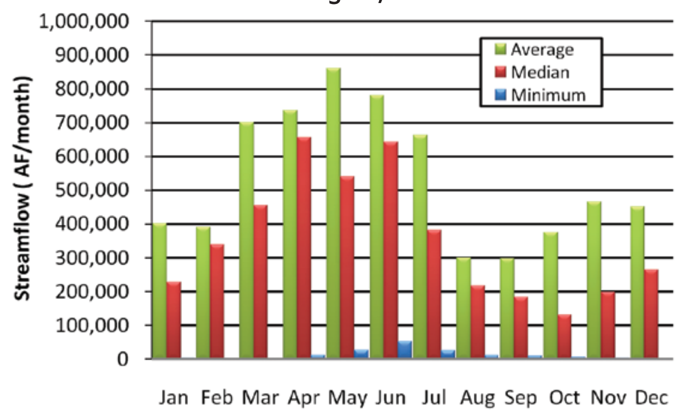
Basin 80 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the potential range of future surface water supplies. The basin had a prolonged period of below-average streamflow between the early 1960s and the early 1970s, corresponding to a period of below-average precipitation. From the late 1990s to the late 2000s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median streamflow in the Grand River upstream of the Arkansas River is greater than 130,000 AF/month throughout the year. However, the river can have prolonged periods of low flow in the fall and winter months.
- Relative to other basins in the state, the surface water quality in Basin 80 is considered poor. However, individual lakes and streams may have acceptable water quality.
- There are five major reservoirs in Basin 80. Hudson, W. R. Holway, and Fort Gibson are operated primarily for hydroelectric power generation and for flood control. Lakes Eucha and Spavinaw are major sources of supply for the City of Tulsa. With the exception of a small number of water rights that were issued prior to the formation of the GRDA (Lakes Eucha and Spavinaw, for example), GRDA has jurisdiction for the administration of surface water in this basin and should be consulted for the availability of water supplies from their reservoirs.

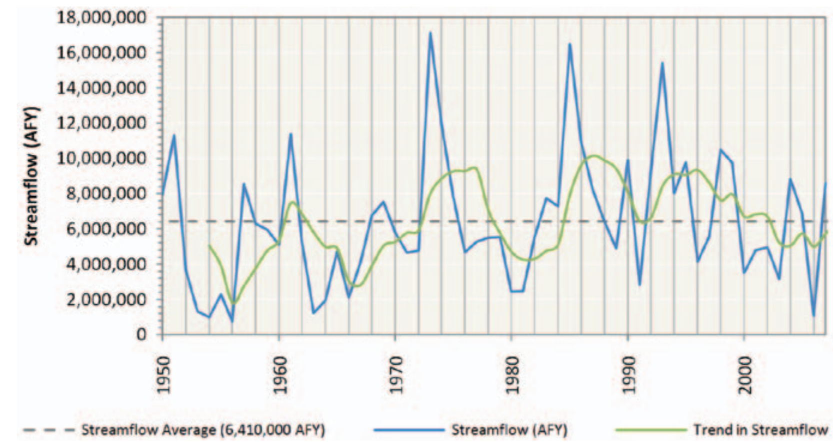
Monthly Historical Streamflow at the Basin Outlet

Grand Region, Basin 80



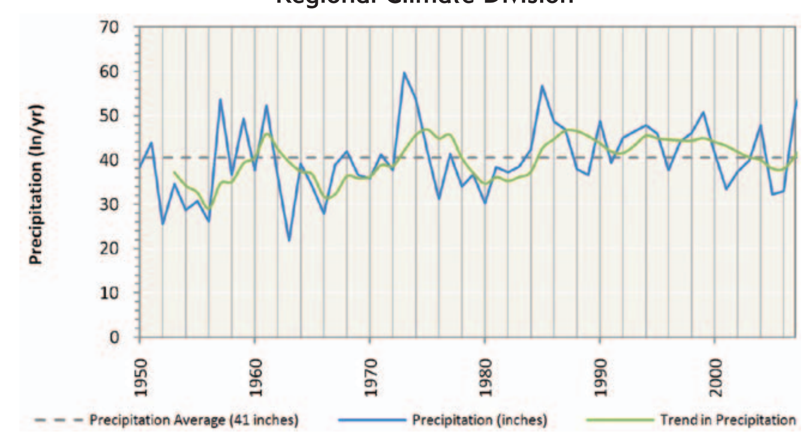
Historical Streamflow at the Basin Outlet

Grand Region, Basin 80



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)

Grand Region, Basin 80

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type	Class[1]	Percent	AFY	AF	AFY/Acre	AFY
Arkansas River	Alluvial	Major	<1%	<50	7,000	temporary 2.0	12,700
Roubidoux	Bedrock	Major	79%	5,800	14,669,000	temporary 2.0	2,072,100
Boone	Bedrock	Minor	57%	3,900	13,015,000	temporary 2.0	1,488,000
Cherokee Group	Bedrock	Minor	4%	200	94,000	temporary 2.0	101,600
Middle Neosho River	Alluvial	Minor	1%	0	30,000	temporary 2.0	25,600
Northeastern Oklahoma Pennsylvanian	Bedrock	Minor	49%	400	1,473,000	temporary 2.0	1,279,700
Southern Neosho River	Alluvial	Minor	2%	0	51,000	temporary 2.0	51,200
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

- Basin 80 has substantial groundwater supplies. The majority of groundwater rights are in the Roubidoux major bedrock aquifer. The estimated major bedrock aquifer recharge to this aquifer from Basin 80 is 214,000 AFY. There are also substantial groundwater rights in the Boone minor bedrock aquifer and smaller amounts in other minor bedrock aquifers.
- There are no significant widespread groundwater quality issues in the basin. However, concentrations of chloride and naturally occurring radioactivity may exceed drinking water standards in some localized areas of the Roubidoux aquifer.

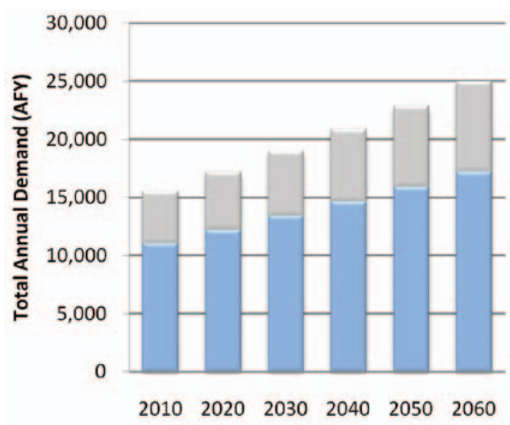
Notes & Assumptions

- 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.

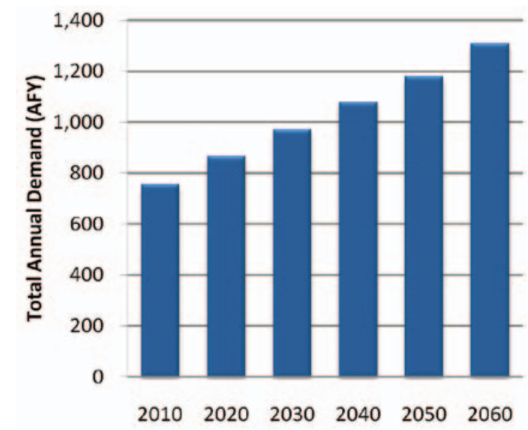
Water Demand

- The water needs of Basin 80 account for about 67% of the total demand in the Grand Watershed Planning Region and will increase by 59% (14,920 AFY) from 2010 to 2060. The demand and growth in demand during this period will be in the Municipal and Industrial and Thermoelectric Power demand sectors.
- Surface water is used to meet 61% of the total demand in Basin 80 and its use will increase by 61% (9,330 AFY) from 2010 to 2060. All surface water use and growth in surface water use during this period is from the Municipal and Industrial and Thermoelectric Power demand sectors.
- Alluvial groundwater is used to meet 3% of total demand in the basin. Alluvial groundwater use will increase by 73% (550 AFY) from 2010 to 2060. All alluvial demand and growth in alluvial demand is from the Self-Supplied Residential demand sector.
- Bedrock groundwater is used to meet 36% of total demand in Basin 80 and its use will increase by 56% (5,040 AFY) from 2010 to 2060. The majority of bedrock groundwater demand will come from the Livestock demand sector. However the highest growth in demand will be from the Crop Irrigation and Municipal and Industrial demand sectors.

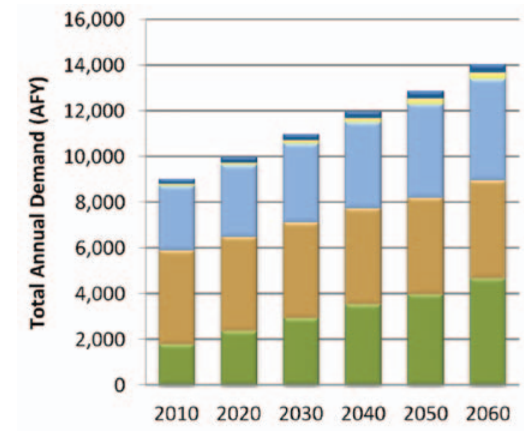
Surface Water Demand by Sector
Grand Region, Basin 80



Alluvial Groundwater Demand by Sector
Grand Region, Basin 80



Bedrock Groundwater Demand by Sector
Grand Region, Basin 80



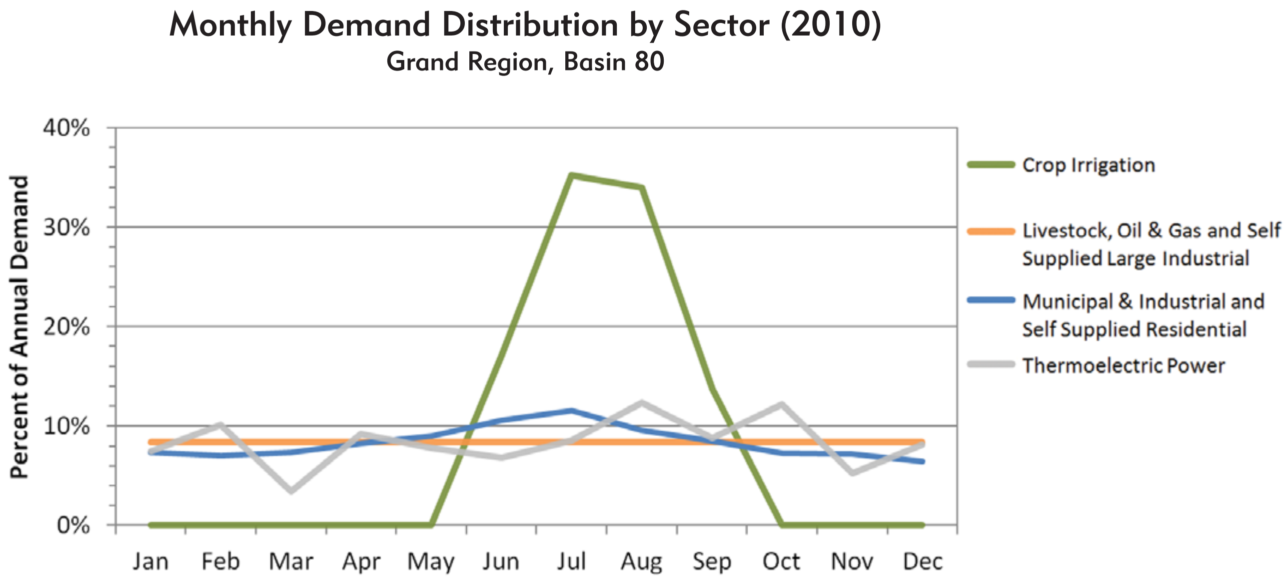
Thermoelectric Power | Self-Supplied Residential | Self-Supplied Industrial | Oil & Gas | Municipal & Industrial | Livestock | Crop Irrigation

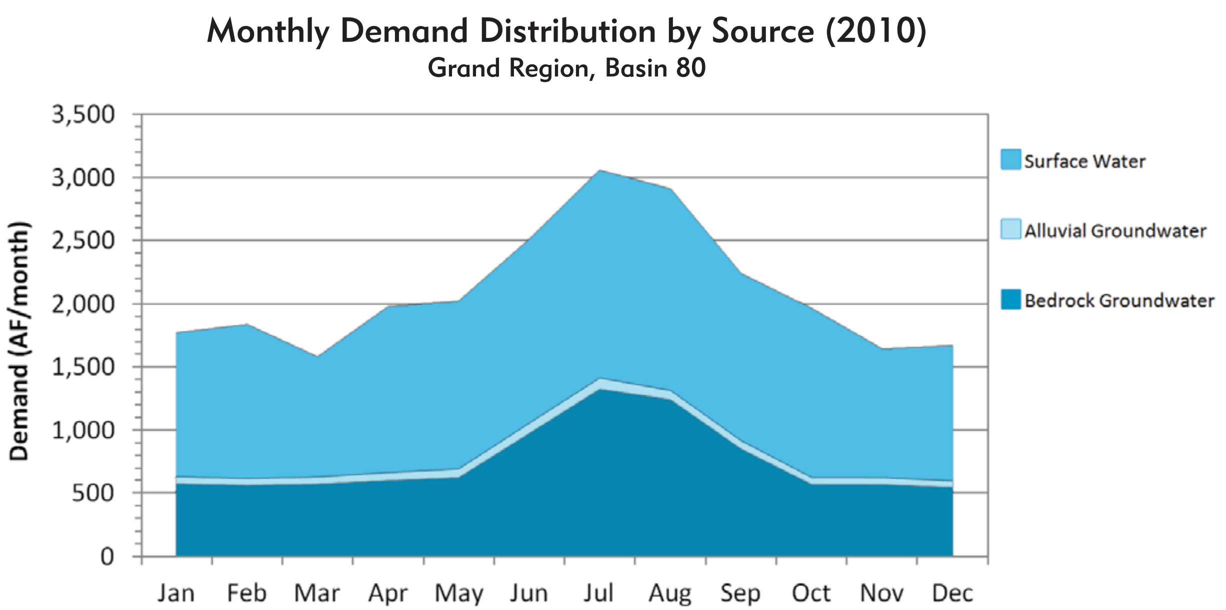
Total Demand by Sector
Grand Region, Basin 80

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	1,770	4,100	13,740	70	0	940	4,490	25,110
2020	2,350	4,140	15,150	100	0	1,070	5,010	27,820
2030	2,930	4,180	16,660	140	0	1,200	5,590	30,700
2040	3,510	4,210	18,210	190	0	1,340	6,240	33,700
2050	3,960	4,250	19,780	240	0	1,480	6,960	36,670
2060	4,670	4,290	21,390	290	0	1,630	7,760	40,030

Notes & Assumptions

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





Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self-Supplied Residential demand sectors use 52% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Thermoelectric Power demand is highest in August and October and lowest in March and November. 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 80 is about 1.7 times the peak winter demand, which is less pronounced than the overall statewide pattern. Surface water use in the peak summer month is about 1.4 times the peak winter month demand. Bedrock groundwater use in the peak summer month is about 2.3 times the monthly winter demand. Alluvial groundwater demand in the peak summer month is about 1.6 times the winter demand.

Gaps and Storage Depletions

- Based on projected demands and historical hydrology, surface water gaps and alluvial groundwater storage depletions may occur in Basin 80 by 2020. Bedrock groundwater depletions are not expected through 2060.
- Surface water gaps in Basin 80 may occur throughout the year. Surface water gaps in 2060 will be up to 39% (760 AF/month) of the peak winter month surface water demand and will be about 38% (990 AF/month) of the peak summer month demand. These gaps do not account for the use of storage in major reservoirs in the basin due to lack of yield information. Gaps could be reduced or eliminated if reservoir yield information was known.
- There will be a 24% probability of surface water gaps occurring in at least one month of the year by 2060. Surface water gaps are most likely to occur during fall and winter months.
- Alluvial groundwater storage depletions in Basin 80 may occur throughout the year, peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 50% (60 AF/month) of the alluvial groundwater demand in the peak summer month, and up to 36% (40 AF/month) of the peak spring month alluvial groundwater demand.
- There will be a 24% 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 fall and winter months.
- Future alluvial groundwater withdrawals are expected to occur from non-delineated minor aquifers. Therefore, the extent of the storage depletions cannot be fully evaluated.

Surface Water Gaps by Season (2060 Demand)

Grand Region, Basin 80

Months (Season)	Maximum Gap [1]	Median Gap	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	760	690	12%
Mar-May (Spring)	810	680	5%
Jun-Aug (Summer)	990	990	2%
Sep-Nov (Fall)	840	810	16%

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Grand Region, Basin 80

Months (Season)	Maximum Storage Depletion[1]	Median Storage Depletion	Probability
	AF/month	AF/month	Percent
Dec-Feb (Winter)	40	30	12%
Mar-May (Spring)	40	35	5%
Jun-Aug (Summer)	60	60	2%
Sep-Nov (Fall)	50	40	16%

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Grand Region, Basin 80

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial Groundwater	Bedrock Groundwater	Surface Water	Alluvial Groundwater
	AFY			Percent	
2020	870	70	0	21%	21%
2030	1,800	70	0	21%	21%
2040	2,790	140	0	21%	21%
2050	3,840	210	0	22%	22%
2060	4,930	250	0	24%	24%

Bedrock Groundwater Storage Depletions by Season (2060 Demand)

Grand Region, Basin 80

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

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Grand Region, Basin 80

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	4,930	250	0	24%	24%
Moderately Expanded Conservation in Crop Irrigation Water Use	4,930	250	0	24%	24%
Moderately Expanded Conservation in M&I Water Use	3,270	150	0	22%	22%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	3,270	150	0	22%	22%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	2,300	110	0	21%	21%

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Grand Region, Basin 80

NOT EVALUATED

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

Water Supply Options & Effectiveness

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

Demand Management

Moderately expanded permanent conservation activities in the Municipal and Industrial demand sector could reduce surface water gaps by about 34% and could reduce alluvial groundwater storage depletions by about 40%. Temporary drought management could be effective to reduce surface water use and subsequent gaps. However, since groundwater storage could continue to provide supplies during droughts, temporary drought management may not be needed to meet alluvial groundwater demand.

Out-of-Basin Supplies

Due to the abundance of in-basin reservoir storage and groundwater supplies, out-of-basin supplies may not be cost-effective for many users in the basin.

Reservoir Use

The OCWP *Reservoir Viability Study*, which evaluated the potential for reservoirs throughout the state, identified Chelsea Reservoir as a potentially viable site in Basin 80. The GRDA should be consulted for the feasibility of using existing storage or developing additional reservoir storage in the basin. The Grand River Dam Authority has jurisdiction over the administration of surface water in Basin 80. Instead of actual appropriation of waters, the agency enters into repayment contracts for the use of surface water resources in the basin. Several public water providers contract with GRDA for water supply from its lakes, and GRDA should be consulted for the availability of surface water supplies in the basin.

Increasing Reliance on Surface Water

In general, increased reliance on surface water through direct diversions, without reservoir storage, may increase gaps and is not recommended.

Increasing Reliance on Groundwater

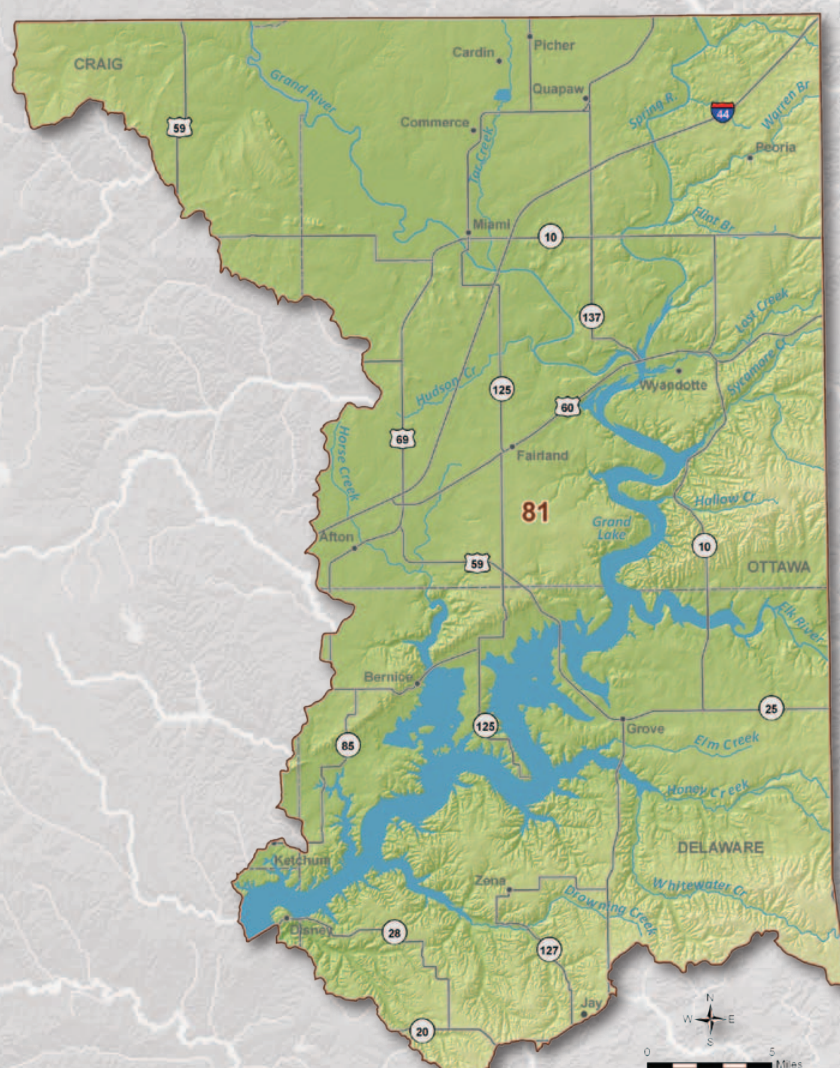
Increased reliance on the Roubidoux aquifer and minor bedrock aquifers could mitigate surface water gaps and alluvial groundwater depletions without major impacts to bedrock storage. However, localized seasonal storage depletions could occur. In addition, minor aquifers may have smaller yields, thus site specific studies should be conducted before large-scale use.

Notes & Assumptions

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

Data & Analysis
Grand Watershed Planning Region

Basin 81



Basin 81 Summary

Synopsis

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

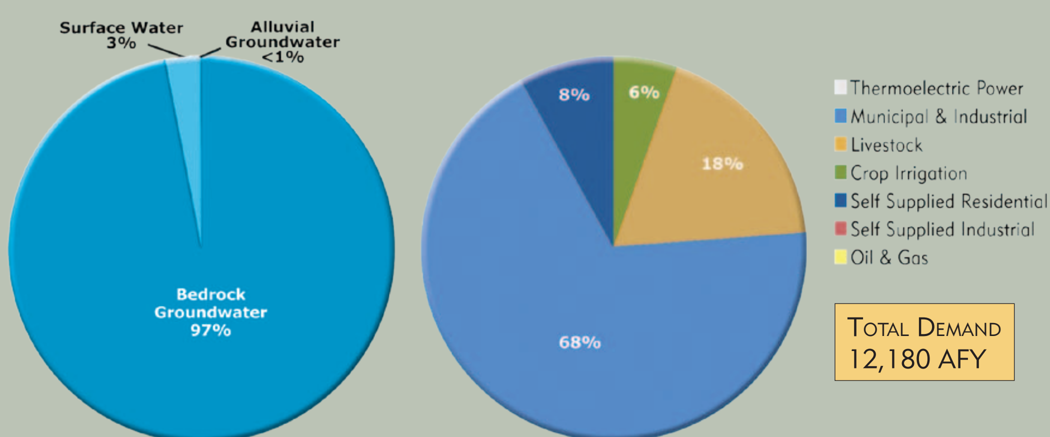
Basin 81 accounts for about 33% of the current demand in the Grand Watershed Planning Region. About 68% of the demand is in the Municipal and Industrial demand sector. Livestock (18%) is the second-largest demand sector. Surface water is used to satisfy only about 3% of the current demand in the basin. Bedrock groundwater satisfies about 97% of the current demand in the basin. The peak summer month demand in Basin 81 is about 1.7 times the winter demand, which is less pronounced than the overall statewide pattern.

Grand Lake is operated by the Grand River Dam Authority (GRDA) for hydroelectric power generation and flood control. The GRDA has jurisdiction over the streamflow in Basin 81 and should be consulted for the availability of surface water supplies in the basin. The Grand River near Langley typically has flows greater than 130,000 AF/month throughout the year and greater than 400,000 AF/month in the spring and early summer. Peak flows generally occur during May and June each year. 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 81 is considered fair. Horse Creek, Russell Creek, and Cave Springs Branch are impaired for Agricultural use due to high levels of sulfates, chloride, and total dissolved solids (TDS).

The majority of groundwater rights in Basin 81 are in the Roubidoux major bedrock

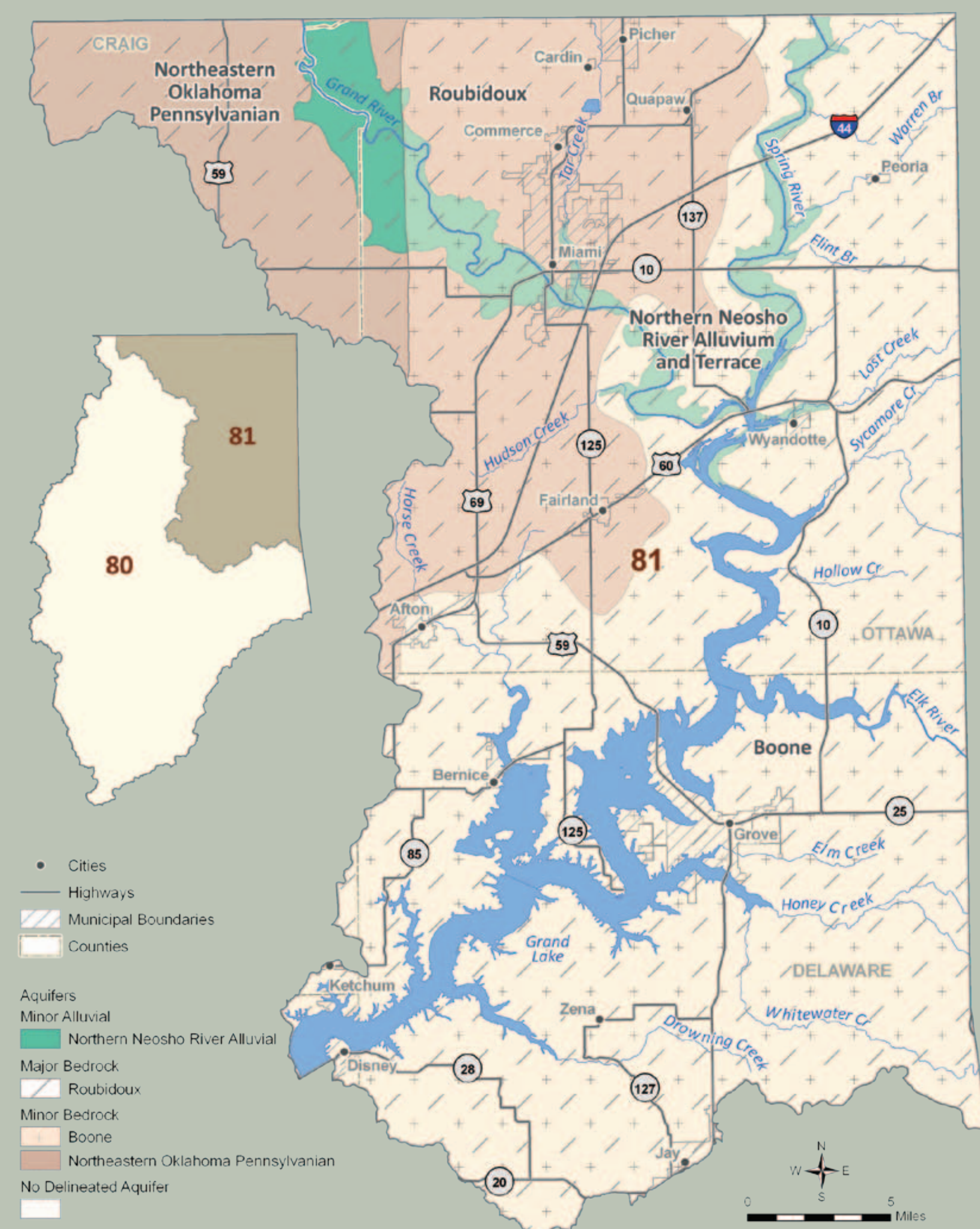
Current Demand by Source and Sector

Grand Region, Basin 81



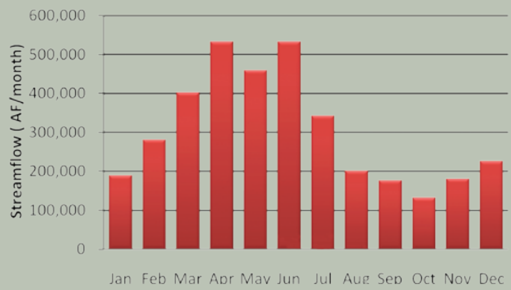
Water Resources

Grand Region, Basin 81



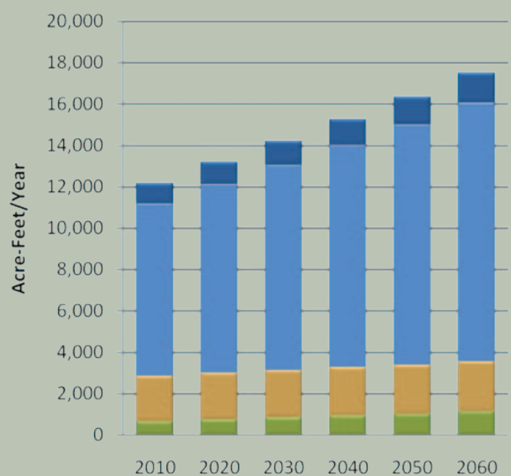
Median Historical Streamflow at the Basin Outlet

Grand Region, Basin 81



Projected Water Demand

Grand Region, Basin 81



aquifer. The Roubidoux aquifer receives an estimated 119,000 AFY of recharge in Basin 81 and has over 9 million AF of storage in the basin. There are also substantial groundwater rights in the Boone minor bedrock aquifer and a small number of water rights in the Northeastern Oklahoma Pennsylvanian minor bedrock aquifer. Self-Supplied Residential demand (domestic use), which does not require a permit, is assumed to be supplied by groundwater sources. There are no significant widespread groundwater quality issues in the basin. However, concentrations of chloride and naturally occurring radioactivity may exceed drinking water standards in some localized areas of the Roubidoux aquifer. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060.

Water Supply Limitations

Grand Region, Basin 81

Surface Water
Alluvial Groundwater
Bedrock Groundwater

Minimal   Potential   Significant

Water Supply Option Effectiveness

Grand Region, Basin 81

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 projected 2060 water demand of 17,510 AFY in Basin 81 reflects a 5,330 AFY increase (44%) over the 2010 demand.

Gaps & Depletions

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

Options

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

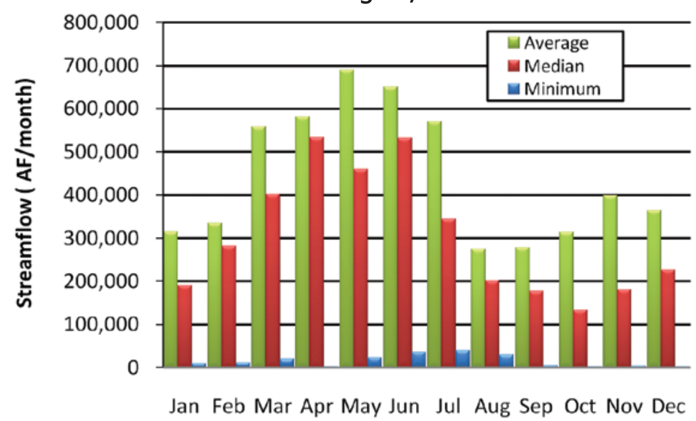
Basin 81 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. Basin 81 had a prolonged period of below-average streamflow from the early 1960s and early 1970s, corresponding to a period of below-average precipitation. From the early 1990s to the early 2000s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating hydrologic variability in the basin.
- The median streamflow in the Grand River upstream of the Arkansas River is greater than 130,000 AF/month throughout the year and greater than 400,000 AF/month in the spring and early summer. 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 81 is considered fair.
- Grand Lake is operated by the Grand River Dam Authority (GRDA) for hydroelectric power generation and by the Corps of Engineers for flood control. The GRDA should be consulted for the availability of water supply from this reservoir.

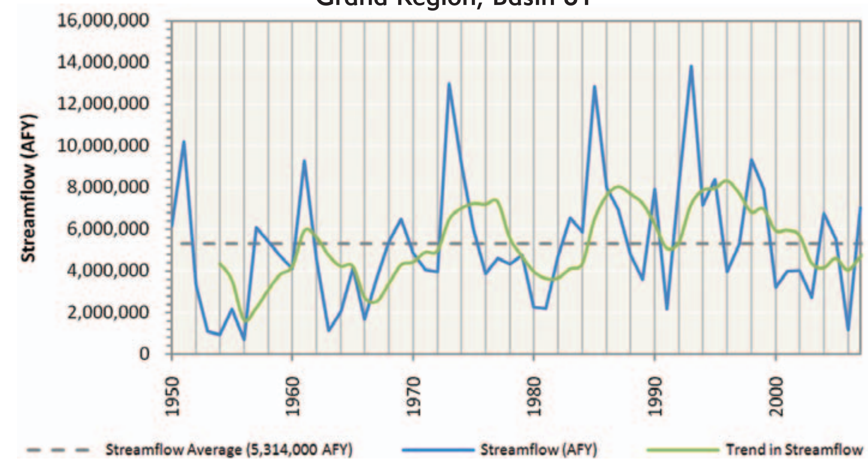
Monthly Historical Streamflow at the Basin Outlet

Grand Region, Basin 81



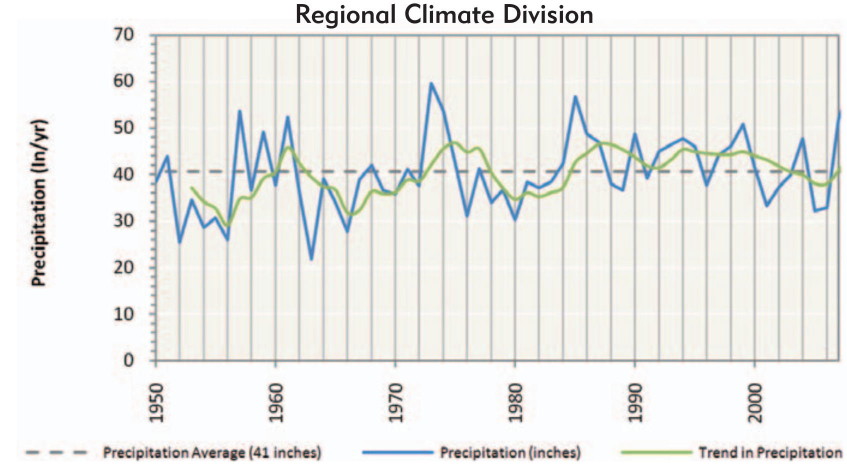
Historical Streamflow at the Basin Outlet

Grand Region, Basin 81



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)

Grand Region, Basin 81

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
Roubidoux	Bedrock	Major	99%	11,400	9,082,000	temporary 2.0	1,120,100
Boone	Bedrock	Minor	89%	7,500	8,824,000	temporary 2.0	1,014,500
Northeastern Oklahoma Pennsylvanian	Bedrock	Minor	32%	100	427,000	temporary 2.0	371,200
Northern Neosho River	Alluvial	Minor	7%	0	71,000	temporary 2.0	76,800
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

- Basin 81 has substantial groundwater supplies. The majority of groundwater rights are in the Roubidoux major bedrock aquifer. The estimated major bedrock aquifer recharge to this aquifer from Basin 81 is 119,000 AFY. There are also substantial groundwater rights in the Boone minor bedrock aquifer and a small number of water rights in the Northeastern Oklahoma Pennsylvanian minor bedrock aquifer.
- There are no significant widespread groundwater quality issues in the basin. However, concentrations of chloride and naturally occurring radioactivity may exceed drinking water standards in some localized areas of the Roubidoux aquifer.

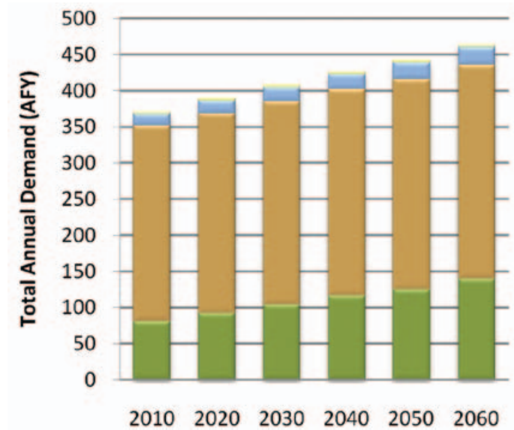
Notes & Assumptions

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

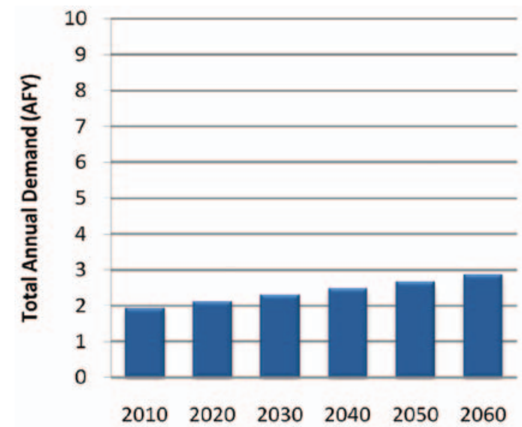
Water Demand

- Basin 81 accounts for about 33% of the total water demand in the Grand Region and will increase by 44% (5,330 AFY) from 2010 to 2060. The majority of the demand and growth in demand during this period will be in the Municipal and Industrial demand sector.
- Surface water is used to meet 3% of the total demand in Basin 81 and its use will increase by 25% (90 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use during this period will be in the Crop Irrigation and Livestock demand sectors.
- Alluvial groundwater demands are projected to be less than 3 AFY in 2060, which is minimal on a basin scale. All alluvial groundwater use is from the Self-Supplied Residential demand sector.
- Bedrock groundwater is used to meet 97% of total demand in Basin 81 and its use will increase by 44% (5,250 AFY) from 2010 to 2060. The majority of bedrock groundwater use and increase in bedrock groundwater use during this period will be in the Municipal and Industrial demand sector.

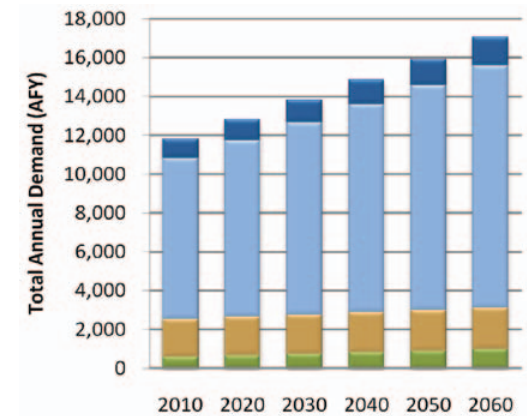
Surface Water Demand by Sector
Grand Region, Basin 81



Alluvial Groundwater Demand by Sector
Grand Region, Basin 81



Bedrock Groundwater Demand by Sector
Grand Region, Basin 81



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

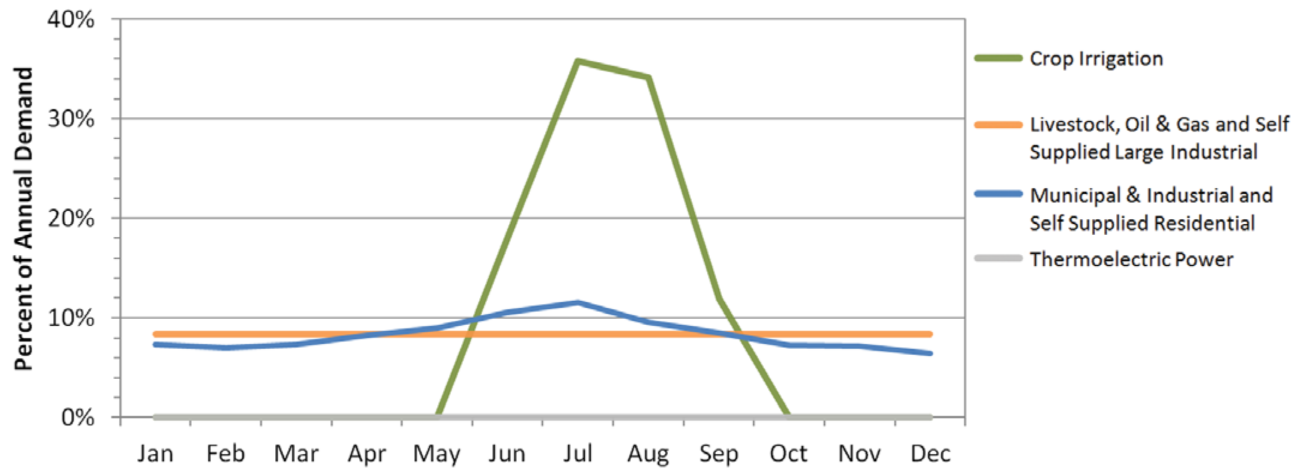
Total Demand by Sector
Grand Region, Basin 81

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self-Supplied Industrial	Self-Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	660	2,220	8,320	0	0	980	0	12,180
2020	760	2,260	9,120	0	0	1,070	0	13,210
2030	850	2,300	9,900	0	0	1,160	0	14,210
2040	950	2,340	10,730	0	0	1,250	0	15,270
2050	1,020	2,380	11,600	0	0	1,350	0	16,350
2060	1,140	2,430	12,490	0	0	1,450	0	17,510

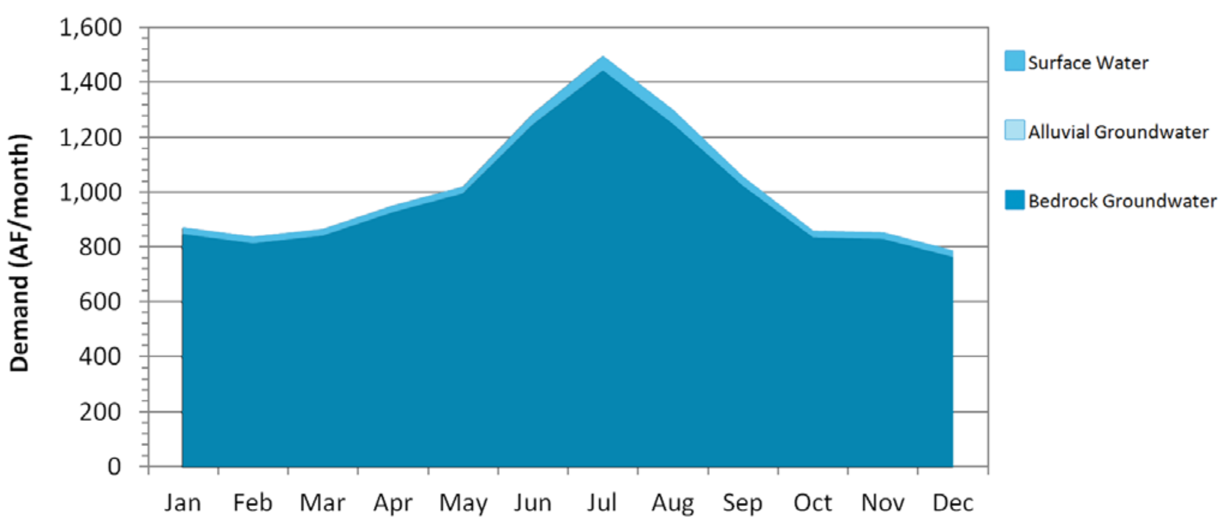
Notes & Assumptions

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

Monthly Demand Distribution by Sector (2010)
Grand Region, Basin 81



Monthly Demand Distribution by Source (2010)
Grand Region, Basin 81



Current Monthly Demand Distribution by Sector

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

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 81 is about 1.7 times the peak winter month demand, which is less pronounced than the overall statewide pattern. Surface water use in the peak summer month is about 2.2 times the peak winter month demand. Alluvial groundwater use in the peak summer month is about 1.6 times the peak winter month demand. Bedrock groundwater use in the peak summer month is about 1.7 times the peak winter month demand.

Gaps and Storage Depletions

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

Surface Water Gaps by Season (2060 Demand)

Grand Region, Basin 81

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

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

Alluvial Groundwater Storage Depletions by Season (2060 Demand)

Grand Region, Basin 81

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

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

Magnitude and Probability of Annual Gaps and Storage Depletions

Grand Region, Basin 81

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)

Grand Region, Basin 81

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

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

Notes & Assumptions

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

Reducing Water Needs Through Conservation

Grand Region, Basin 81

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

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

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Grand Region, Basin 81

NOT EVALUATED

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

Water Supply Options & Effectiveness

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

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

Demand Management

No 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.

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.

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.

Non-delineated groundwater source: an area where no major or minor aquifer has been studied that may or may not supply a well yield; also referred to as a "non-delineated minor aquifer."

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

Sources

AMEC Earth & Environmental. (2011). *Climate Impacts to Streamflow*. Commissioned by the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2009). *Programmatic Work Plan*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2009). *Provider Survey Summary Report*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2010). *Artificial Aquifer Recharge Issues and Recommendations*. Data and technical input provided by the OCWP Artificial Aquifer Recharge Workgroup. Commissioned by the Oklahoma State Legislature in 2008 and published through an agreement with the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2010). *Conjunctive Water Management in Oklahoma and Other States*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2010). *Marginal Quality Water Issues and Recommendations*. Data and technical input provided by the OCWP Marginal Quality Water Workgroup. Commissioned by the Oklahoma State Legislature in 2008 and published through an agreement with the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2011). *Conservation and Climate Change (Water Demand Addendum)*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2011). *Drinking Water Infrastructure Needs Assessment by Region*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2011). *Physical Water Supply Availability Report*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2011). *Public Water Supply Planning Guide*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2011). *Water Demand Forecast Report*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2011). *Water Supply Hot Spot Report*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

CDM. (2011). *Water Supply Permit Availability Report*. Published through a cooperative agreement with the Oklahoma Water Resources Board and U.S. Army Corps of Engineers as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

C.H. Guernsey & Company. (2010). *Reservoir Viability Study*. Commissioned by the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

C.H. Guernsey & Company. (2011). *Water Conveyance Study*. Commissioned by the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

FirstSouthwest Bank. (2011). *Infrastructure Financing Needs and Opportunities*. Commissioned by the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

INTERA. (2011). *Instream Flow Issues and Recommendations*. Data and technical input provided by the OCWP Instream Flow Workgroup. Published through an agreement with the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Climatological Survey. (2010). *Climate Issues and Recommendations*. Published through an agreement with the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Department of Environmental Quality. (2008). *Integrated Water Quality Assessment Report*. Published by the Oklahoma Department of Environmental Quality. Available online at http://www.deq.state.ok.us/wqdnew/305b_303d/ (October 2011).

Oklahoma State University Division of Agriculture Sciences and Natural Resources (DASNR). (2011). *Agricultural Water Issues and Recommendations*. Commissioned by the Oklahoma Water Resources Board and the Oklahoma Department of Agriculture Food and Forestry as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (1980). *1980 Update of the Oklahoma Comprehensive Water Plan*. Published by the Oklahoma Water Resources Board. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (1995). *1995 Update of the Oklahoma Comprehensive Water Plan*. Published by the Oklahoma Water Resources Board. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2007). *Oklahoma Water Atlas*. Published by the Oklahoma Water Resources Board.

Oklahoma Water Resources Board. (2011). *2012 OCWP Executive Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as the principal report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Beaver-Cache Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2009). *Beneficial Use Monitoring Program Report*. Published by the Oklahoma Water Resources Board. Available online at http://www.owrb.ok.gov/quality/monitoring/bump.php (October 2011).

Oklahoma Water Resources Board. (2011). *Blue-Boggy Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Central Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Eufaula Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Grand Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Lower Arkansas Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Lower Washita Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Middle Arkansas Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Oklahoma Statewide Water Quality Trends Analysis*. Published by the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Panhandle Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Southeast Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Southwest Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Upper Arkansas Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Water Policy and Related Recommendations for Oklahoma*. Published by the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *Water Quality Issues and Recommendations*. Analysis provided by the OCWP Water Quality Workgroup. Published by the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Oklahoma Water Resources Board. (2011). *West Central Watershed Planning Region Report*. Published by the Oklahoma Water Resources Board under the authority of the Oklahoma State Legislature as an ancillary report for the official update of the Oklahoma Comprehensive Water Plan. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Robertson, Lindsay. *Tribal Water Issues and Recommendations*. (2011). Commissioned through an agreement with the Oklahoma Water Resources Board as a supplement to the *2012 Update of the Oklahoma Comprehensive Water Plan*. Available online at http://www.owrb.ok.gov/ocwp (October 2011).

Wahl, Kenneth L.; Tortorelli, Robert L. *Changes in Flow in the Beaver-North Canadian River Basin Upstream from Canton Lake, Western Oklahoma*. (1997). WRI; 96-4304 Published by the United States Geological Survey. Available online at http://pubs.usgs.gov/wri/wri964304/.