# Drought-Ready Community

## Norman, Oklahoma


A Compilation of Reports from the 2010 Class of “Applied Climatology and Meteorology” at the University of Oklahoma (Instructor: McPherson)
March 16, 2010

# Drought-Ready Norman

## What is a Drought-Ready Community?

Community officials and other key stakeholders in a Drought-Ready Community (1) have assessed their vulnerability to drought, (2) understand past droughts and the local climate, (3) monitor drought, (4) prepare a thorough set of actions to be taken before, during, and after a drought, and (5) educate the public on this plan and the risks of the area.

A plan for a Drought-Ready Norman will enable these stakeholders to understand key factors to monitor so they may respond proactively to drought conditions early. Following this plan should assure that, when drought conditions occur, Norman does not run out of water. This report will help Norman become a Drought-Ready Community by overviewing its climate, drought, and water-use history.

## Why be a Drought-Ready community?

Since 2000, the National Oceanic and Atmospheric Administration has identified seven droughts nationwide as *billion-dollar* weather disasters based on both damages and costs, such as from crop loss. The most recent widespread drought during 2006, which affected much of Oklahoma, resulted in estimated damages and costs of over $6 billion. Drought can result in crop, pasture, and forest damage; increased livestock and wildlife mortality; increased fire hazard; threats to aquatic and wildlife habitats; increased water demand; and reduced water supplies.

Proper management of community water is necessary to protect supplies for drinking water, sanitation, and fire protection as well as to maintain economic activity. ***Because disasters affect families, neighbors, and businesses locally, community-level planning is necessary to reduce Norman's vulnerability to drought***.

## What is drought?

Drought is difficult to define. This is problematic because the impacts associated with drought are often far-reaching and devastating. A *meteorological drought* is a prolonged period when precipitation is below "normal" for the location [1]. An *agricultural drought* occurs when soils are too dry to grow healthy vegetation, particularly crops or forests. As water becomes scarce in rivers, lakes, and other water bodies, a *hydrological drought* develops. If, at any time, the water demands of society (e.g., water for drinking, maintaining lawns and gardens, washing clothes) exceed the availability of good-quality water, then a *socioeconomic drought* has occurred. A socioeconomic drought may arise even during times of normal precipitation because of increased water demand from a growing population, increased temperatures and wind speeds, new businesses, or other societal changes.

## Has our city experienced drought?

***Drought is a recurring condition in Norman, OK***, and is part of our climate. Norman's climate history can provide us insight into what we may see in the future. Being a Drought-Ready Community means, in part, that we recognize how our climate has changed over time. Let's examine our past.

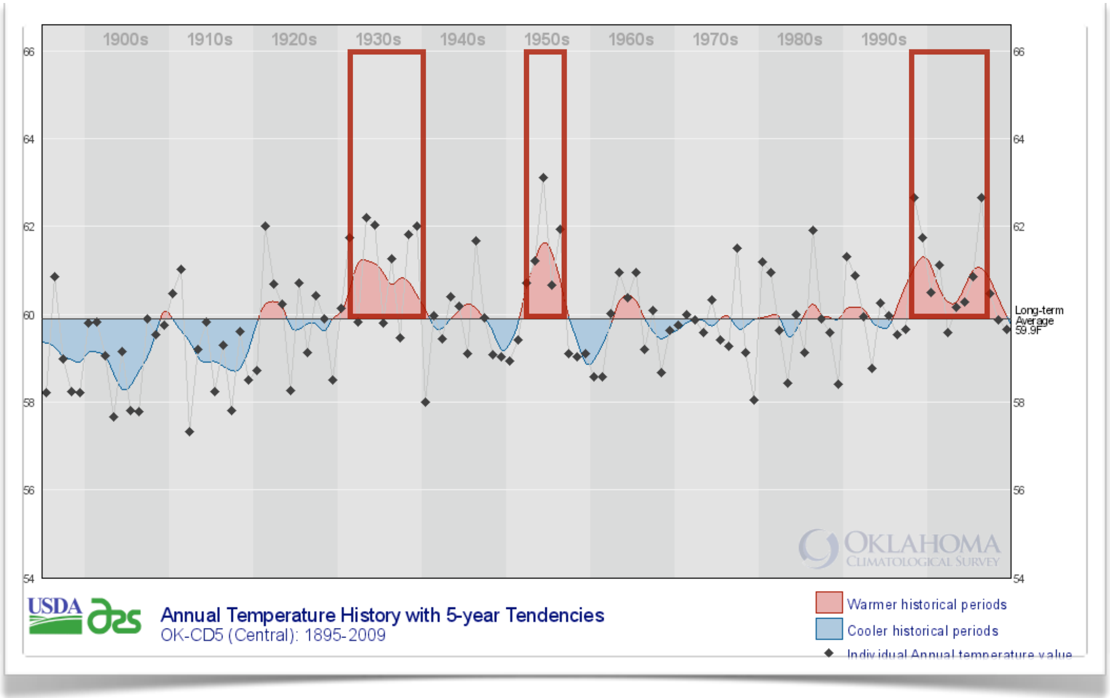
### *The Climate of Norman, Oklahoma*

Temperature and precipitation are the two main elements of our climate. Because Norman is located in the middle latitudes, east of the Rocky Mountains and northwest of the Gulf of Mexico, its residents experience a wide range of weather conditions. Hence, our climate is highly variable, from year to year, season to season, and month to month.

Figure 1 shows the annual temperature (top) and annual precipitation (bottom) in central Oklahoma, including Norman, since 1895.[1] The annual temperature for Norman averages 59.9 degrees Fahrenheit, while precipitation averages 34.5 inches. Warmer-than-average periods have spanned the 1930s, the mid-1950s, and the late 1990s to recent. Significant periods of drier-than-average conditions include the 1910s, 1930s, mid-1950s, and 1960s.

One important interpretation of the bottom graph in Figure 1 is that ***the past three decades have been significantly wetter than previous decades***. Hence, the current generation of Norman residents have not experienced as long or as intense of drought conditions as previous generations. *This fact is critical when we examine a short drought during 2006 (page 14), acknowledging that* ***it could have been much worse for Norman residents***.

[1] Data from the National Climatic Data Center and obtained from the Oklahoma Climatological Survey (http://climate.ok.gov).



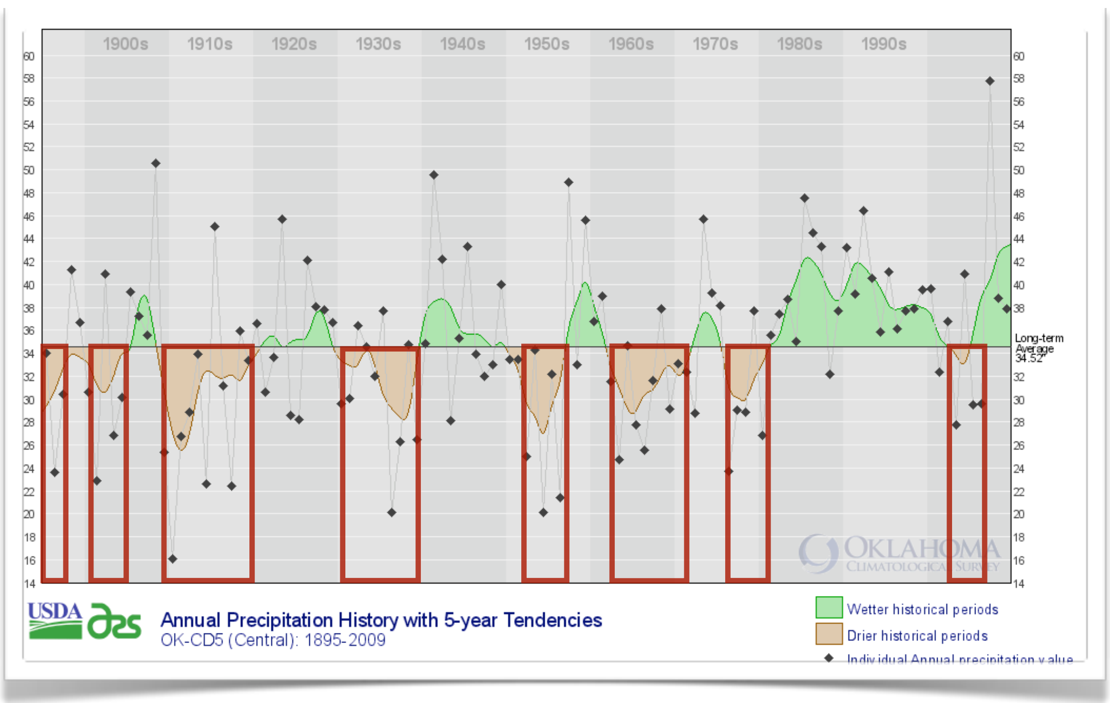
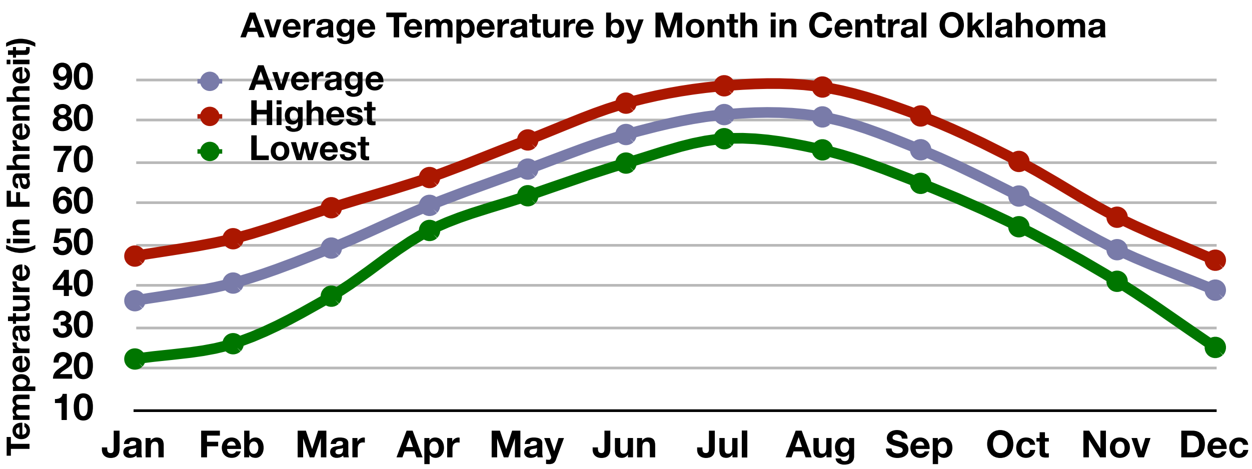




***Figure 1.*** *The average annual temperature (<u>top graph</u>) and total annual precipitation (<u>bottom graph</u>) in central Oklahoma from 1895 to 2009. To highlight warmer, cooler, wetter, or drier periods, 5-year moving averages are shaded. On the top graph, red shading (above the horizontal line) indicates warmer periods and blue shading (below the line) notes cooler periods than average. Similarly, on the bottom graph, green shading (above the horizontal line) highlights wetter periods and brown shading (below the line) highlights drier periods than average. Extended periods of relatively warm temperatures or low precipitation are outlined in red boxes.*

To understand when there is the greatest stress on water availability for Norman, the average monthly temperature and precipitation, as well as their highest and lowest values, are shown in Figure 2. Warmer temperatures result in greater water loss by evaporation and transpiration. The warmest temperatures typically occur during July and August (top of Figure 2), when there is a warm-season minimum in precipitation (bottom of Figure 2). As a result, there is great demand for landscape watering in Norman during July and August.



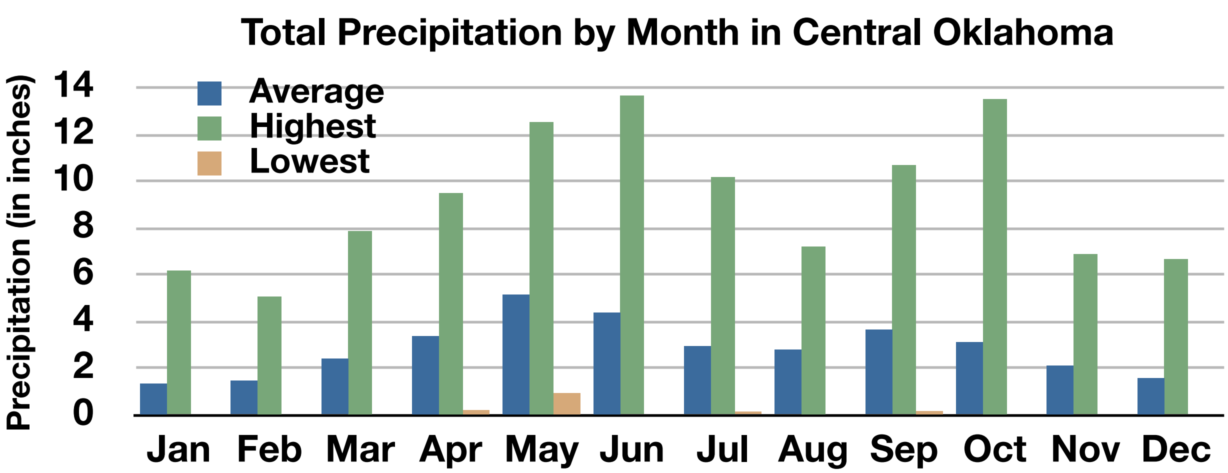




***Figure 2***. *<u>Top graph</u>: The monthly average temperature (in degrees Fahrenheit) across central Oklahoma using data from 1895 to 2009. The blue (middle) line is the average of all climate-division average temperatures for that time period. The red (top) line is the highest monthly average and the green (bottom) line is the lowest. <u>Bottom graph</u>: The average total precipitation (in inches) by month across central Oklahoma using data from 1895 to 2009. The blue (leftmost of each monthly cluster) bar is the average monthly precipitation; the green (middle of the cluster) is the highest precipitation total recorded for that month; the gold (rightmost) is the lowest precipitation total recorded for that month. [Note that zero precipitation has occurred at least once during January, February, March, June, October, November, and December.] The two peaks of precipitation, first in May and then in September, are clearly visible.*

## *Drought in Norman, Oklahoma*

Because drought it hard to define, it also is hard to measure. Understanding the need to quantify drought severity, the scientific community has developed several methods to assess drought, including departure from normal precipitation, the Palmer Drought Severity Index, and the Standardized Precipitation Index (Figure 3). All three use weather observations to diagnose drought conditions. The simplest of these is the annual departure from normal precipitation which is the actual precipitation total for the year subtracted from the annual normal. Large negative values indicate a precipitation deficit for that year.

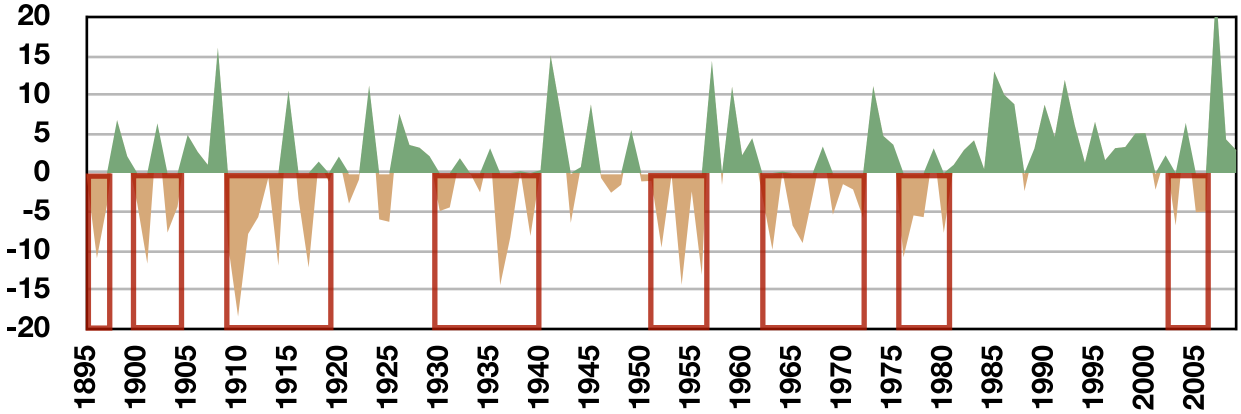
The Palmer Drought Severity Index uses observations or estimates of precipitation, temperature, and soil water content. Values typically range from +4 representing extremely wet conditions to –4 representing extremely dry conditions. Values less than –1 indicate some level of drought, and the values become more negative with less rainfall and hotter temperatures. The lowest value on record for Cleveland County was –7.43 in June 1911.

The Palmer Drought Severity Index helps to diagnose agricultural drought because it is sensitive to soil moisture conditions and works well at relatively long time scales. The index does not account for reservoir levels and streamflow, so it has drawbacks for diagnosing hydrological drought.

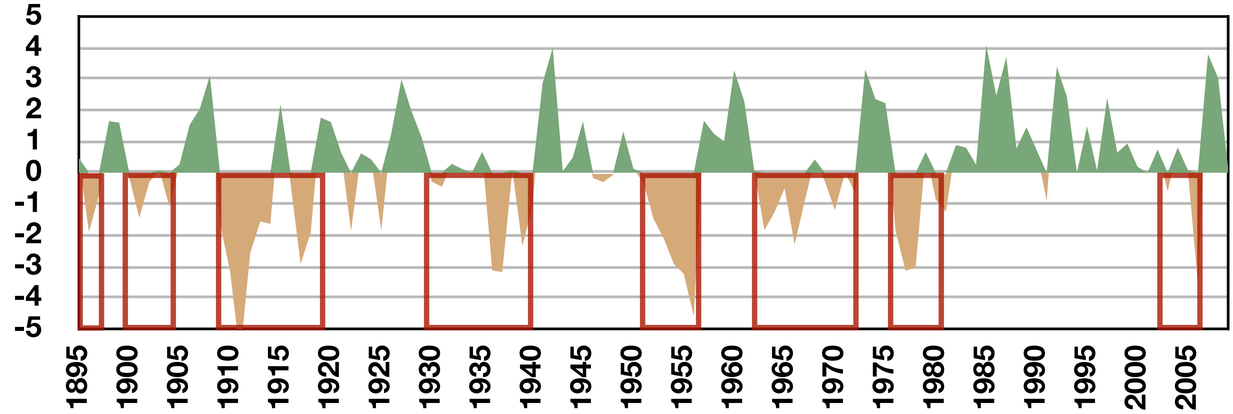
The Standardized Precipitation Index is based solely on precipitation but has the advantage of multiple time scales (e.g., 3 months, 6 months, 1 year) to better highlight short-term versus long-term droughts. Values typically range from +2 as extremely wet to –2 as extremely dry, with values less than –1 representing drought.

Figure 3 displays the departure from normal precipitation, Palmer Drought Severity Index, and two-year Standardized Precipitation Index for central Oklahoma from 1895 to recent. Red boxes outline the same drier-than-average periods highlighted in Figure 1. ***It is evident from these three drought indicators that Norman has experienced long and extreme droughts in its past. In addition, the most recent drought in 2006 pales in comparison to droughts of the past. Hence, Norman officials, businesses, and residents must be prepared for a prolonged, extreme drought***.

**Annual Departure from Normal for Central Oklahoma**




**Palmer Drought Severity Index for Central Oklahoma**




**2-Year Standardized Precipitation Index for Central Oklahoma**

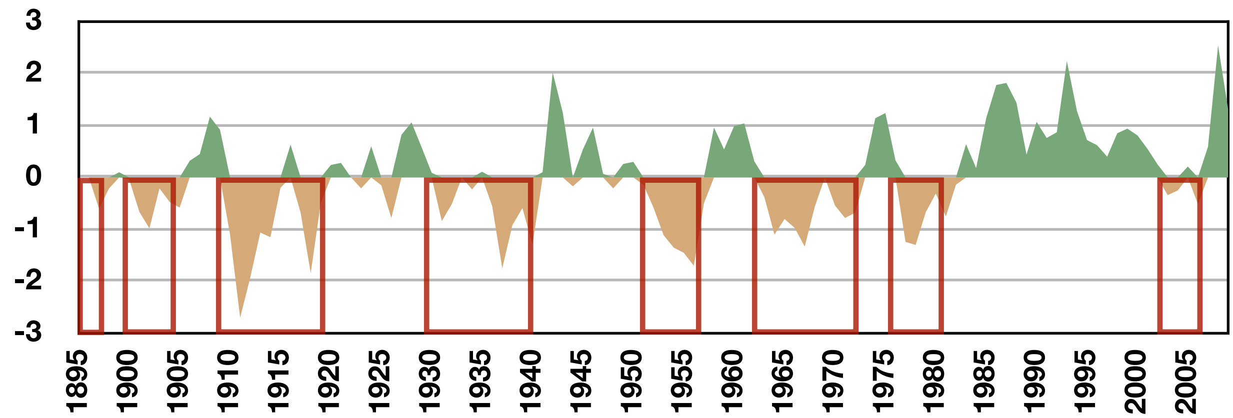



***Figure 3**. Top graph: Annual departure from normal precipitation (actual precipitation total for the year subtracted from the annual normal) for central Oklahoma from 1895 to 2009. Middle graph: Palmer Drought Severity Index for central Oklahoma from 1895 to 2009. Bottom graph: The 2-year Standardized Precipitation Index for central Oklahoma from 1895 to 2009. Red boxes outline the same drier-than-average periods highlighted in Figure 1.*

Hydrological drought can be assessed best using water measurements, such as reservoir or groundwater levels and streamflow. In the case of Norman, most of the city's water supply is from Lake Thunderbird (Figure 4), on the far east side of town. Additional sources are groundwater wells drilling into the Garber-Wellington Aquifer that underlies Norman and two pipelines (12-inch and 20-inch diameter pipes) from northwest Oklahoma City. The pipelines serve as emergency supply because of the high expense to obtain this water.

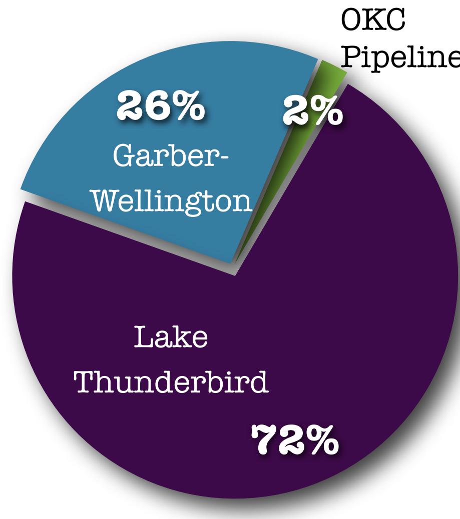



***Figure 4**. Sources of water for the City of Norman and its customers. On average, 72% of the water supply is from Lake Thunderbird (dark violet), 26% from the Garber-Wellington Aquifer, and 2% from the Oklahoma City pipelines.*

Figure 5 displays reservoir storage for Lake Thunderbird from January 1, 1996 to December 31, 2009. Abnormally warm and dry conditions during 2006 resulted in a significant decline in reservoir storage, primarily from greater demand by Norman residents to keep their landscapes green and healthy. Direct evaporation off of the lake during the hot days also reduced supply. Of note, the initial decrease in water level, starting in late 2005, was quite gradual and it occurred *before* the largest values of drought indices were recorded. Hence, it is important to recognize the precursors to drought and be prepared to act quickly as conditions deteriorate.

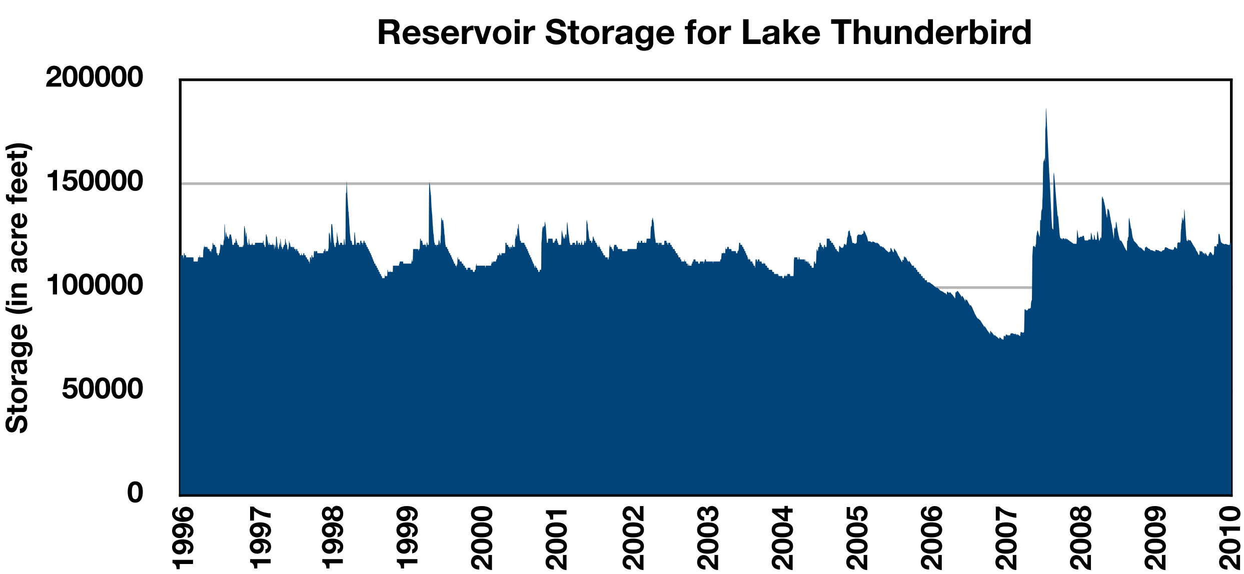



***Figure 5**. Storage (in acre feet) of the Lake Thunderbird Reservoir in eastern Norman. Drought conditions are evident in 2006 to mid-2007. Data courtesy of the U.S. Geological Survey.*

Streamflow observations also provide insight into the availability of water from upstream precipitation or recharge from aquifers (water bodies below ground). Figure 6 displays river discharge measurements along the Canadian River near Purcell, Oklahoma (downstream from Norman). Discharge is the volume of water (in cubic feet) per second that passes the stream gauge. Low discharge values indicate minimal flow in the channel, typically from seasonal decreases in precipitation or from drought.

The seasonality of streamflow near Norman is evident in Figure 6, with the lowest discharge values typically occurring in July and August. A dry period from the summer of 1980 through the spring of 1981 is consistent with abnormally low precipitation and negative values of drought indices (Figure 3) during the same time. While not as obvious, the 2006 drought appears in the streamflow record with lower peak values of streamflow throughout the year than is typical.

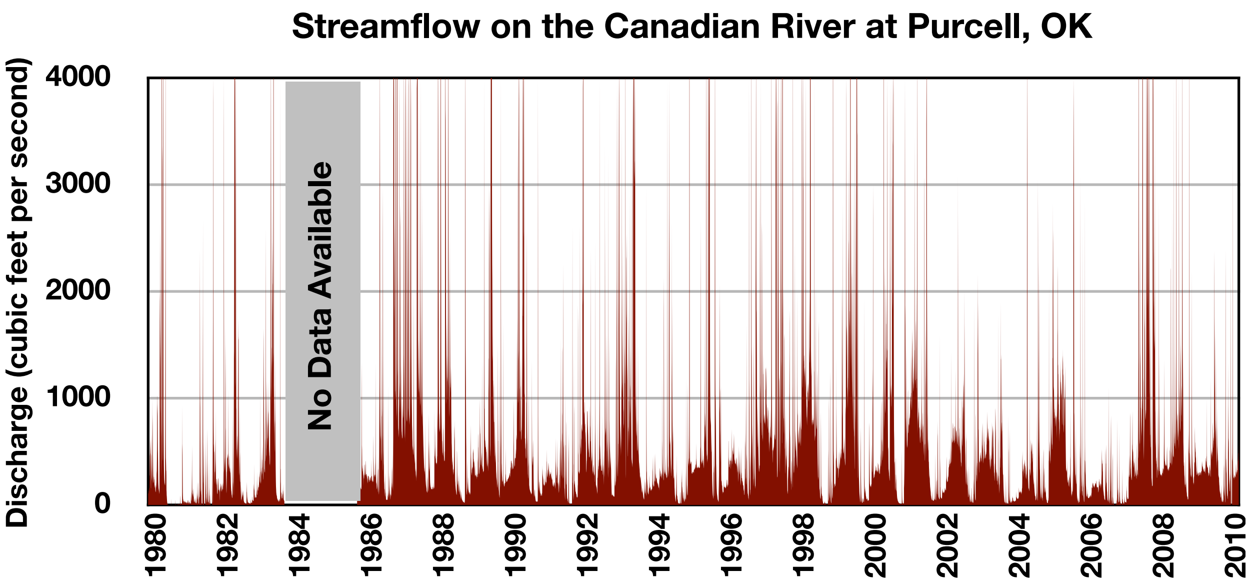



***Figure 6***. *River discharge, as measured by the U.S. Geological Survey, along the Canadian River at Purcell, downstream from Norman. Values are indicated in cubic feet per second. For better clarity during drought periods, discharge values greater than 4,000 cubic feet per second are not shown. [Note: Gauge values at Norman were not used because of the incompleteness of the record. Observations at Purcell were missing from October 1983 through September, 1985.]*

A more recent method to measure drought intensity is the U.S. Drought Monitor (Figure 7). This product depicts weekly drought conditions for the United States on a drought intensity scale of D0 to D4, with D0 representing areas that are abnormally dry and D4 representing areas of exceptional drought. Although the levels are subjectively determined, they are established through expert review of weather and water data, including local observations (e.g., Oklahoma Mesonet), as well as reports of drought impacts from local, tribal, state, and federal officials as well as the public and media. Figure 8 displays the weekly percentage of Cleveland County affected by D0 through D4 drought since 2000. Again, the 2006 drought is evident, though it never reached D4 status.

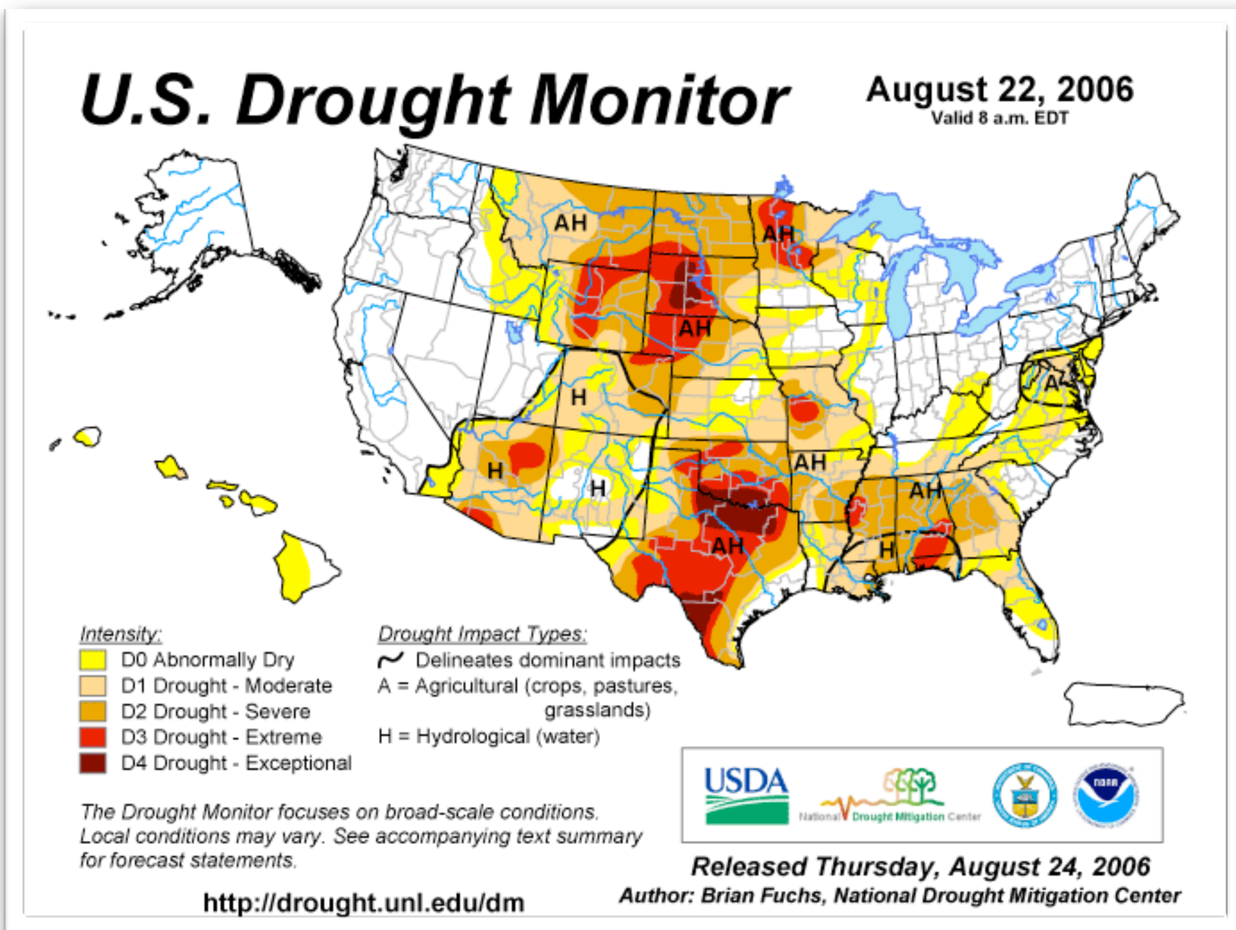



***Figure 7****. Example map of the U.S. Drought Monitor from the drought assessment issued for the week preceding August 22, 2006. The color scale (yellow to dark red) displays the level of drought from D0 (abnormally dry) to D4 (exceptional drought). Significant regional impacts on agriculture are designated with an "*A*" and regional impacts on water supply are designated with an "*H*". The maps are released each Thursday at 8:30 a.m. Eastern Time. Courtesy of the National Drought Mitigation Center.*

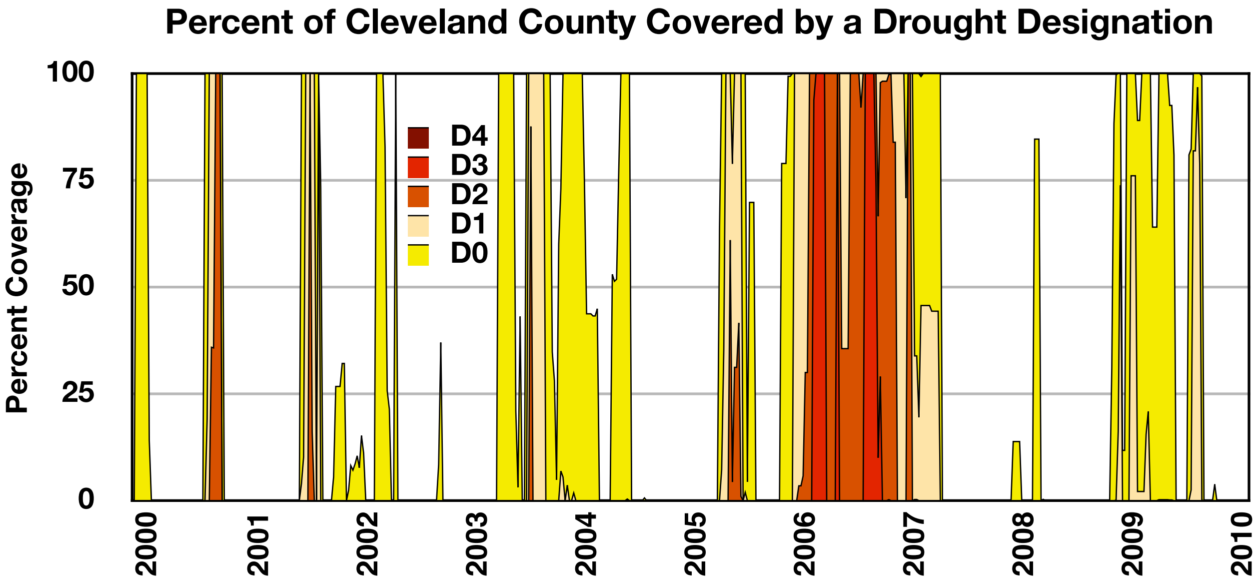



***Figure 8***. *Drought history for Cleveland County, OK, as designated by the U.S. Drought Monitor. The color scale is identical to that in Figure 7. Note that Cleveland County was experiencing severe (orange) to extreme drought (bright red) across most of the county during much of 2006.*

## *Norman's "Drought-of-Record"*

For purpose of planning, we consider the "drought-of-record" to be the drought with the worst environmental conditions rather than the drought with the worst recorded impacts on Norman. Hence, a shorter and less severe drought with high monetary losses in our recent past (e.g., during 2006) will not outweigh a long and severe drought in our early history, when fewer people lived in Norman. We choose to prepare for the worst.

Options for the drought-of-record include the droughts in the 1910s, late 1930s, and mid-1950s. The longest period of dry conditions undoubtably was during the 1910s. Table 1 compares Palmer Drought Severity Indices for these droughts, as well as the most recent (hence, memorable) drought of 2005-2006. Using these indices, the drought of the 1910s well exceeds the duration and intensity of all other droughts; hence, ***the period from February 1909 to August 1918 is Norman's drought-of-record***.

Even so, temperatures were cooler than normal during the 1910s (Figure 1, top), reducing evaporation from surface waters (e.g., lakes, rivers), vegetation, and the ground. Because of its intense heat combined with non-stop dry conditions, ***June 1952 through February 1957 comes in second for Norman's drought-of-record***.

Table 1: Comparison of Palmer Drought Severity Indices (PDSI) for Several Droughts Affecting Cleveland County, OK

| Time Period | Months with PDSI less than –1 | Months with PDSI less than –4 | Lowest PDSI Value |
|---|---|---|---|
| February 1909 – August 1918 | 150 (of 178 months) | 16 consecutive | –7.43 |
| March 1936 – June 1940 | 44 (of 52 months) | 3 | –5.76 |
| June 1952 – February 1957 | 57 (of 57 months) | 17 | –6.17 |
| November 2005 – November 2006 | 13 (of 13 months) | 6 consecutive | –4.85 |

## What might the future hold?

Times have changed since Norman's worst two droughts. Many of today's residents use washing machines, dishwashers, lawn sprinklers, pools, hot tubs, and whirlpool baths, greatly increasing our per capita water usage (Figure 9). As the population of Norman has increased over time, so too has the demand for water (Figure 10). Historically, severe droughts have rarely been dangerous or life threatening to Norman's population, but future changes in demographics could significantly increase the vulnerability of our community.

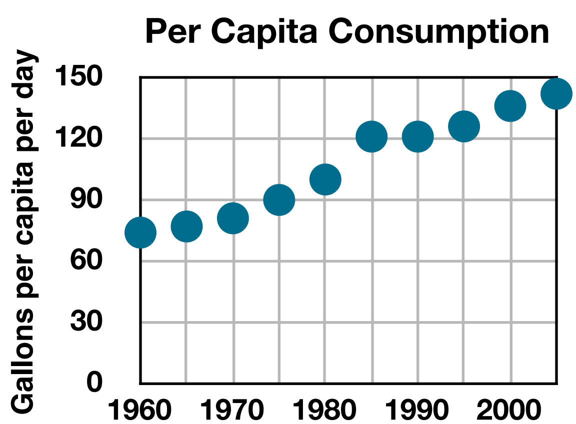



***Figure 9***. *Daily water consumption per person from 1960 to present. Data courtesy of the City of Norman (Water Conservation Plan 2006).*

Between 1900 and 2000, the population of Norman grew from 2,225 to 96,065 (Figure 11). By 2040, the city's population is projected to increase to 158,000, placing even larger burden on the City's Utilities Division to deliver water. Although additional water may be purchased from Oklahoma City, it must be done at a significant cost to the residents.

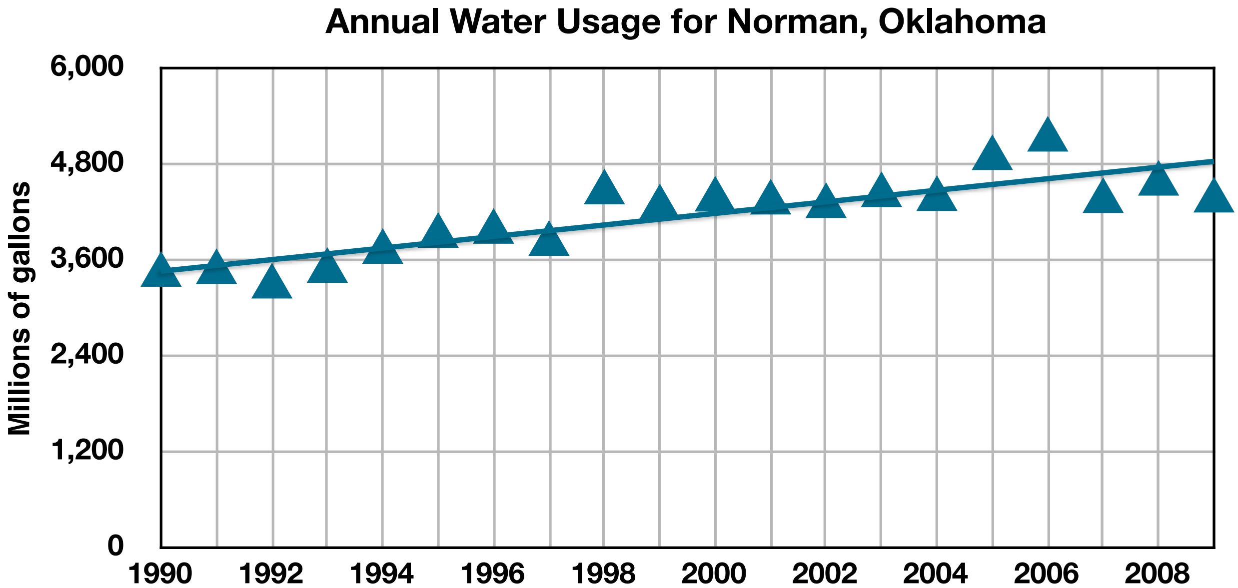



***Figure 10***. *Annual water usage (in millions of gallons) for Norman from 1990 to present. Data courtesy of the City of Norman. The line depicts the average increase in water usage over the past two decades.*

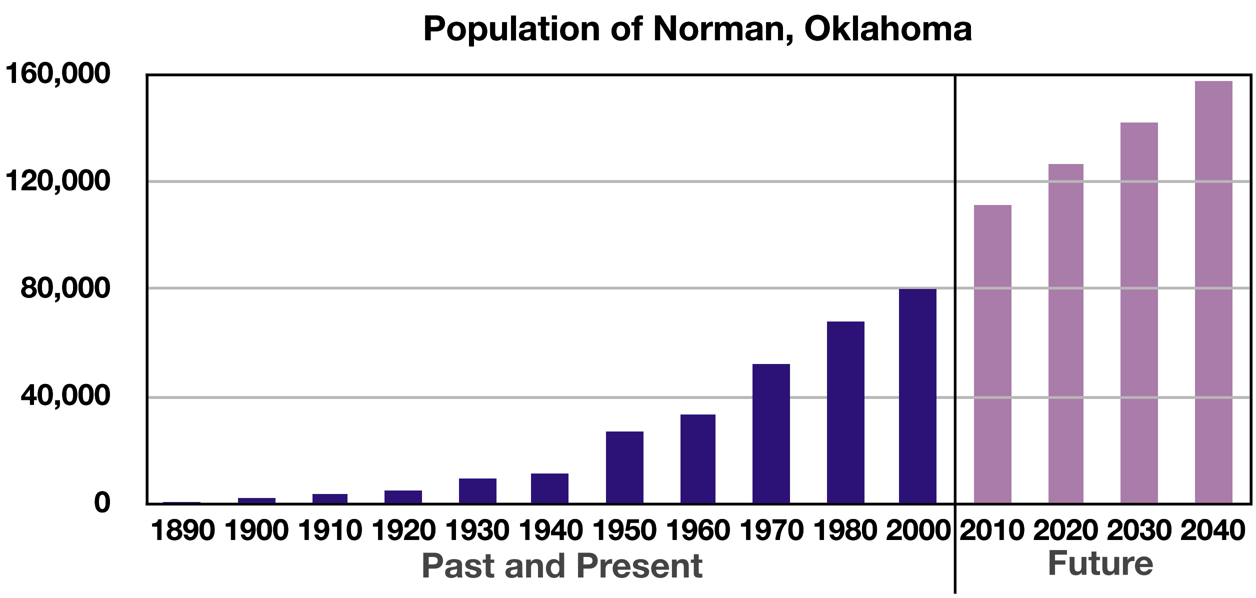


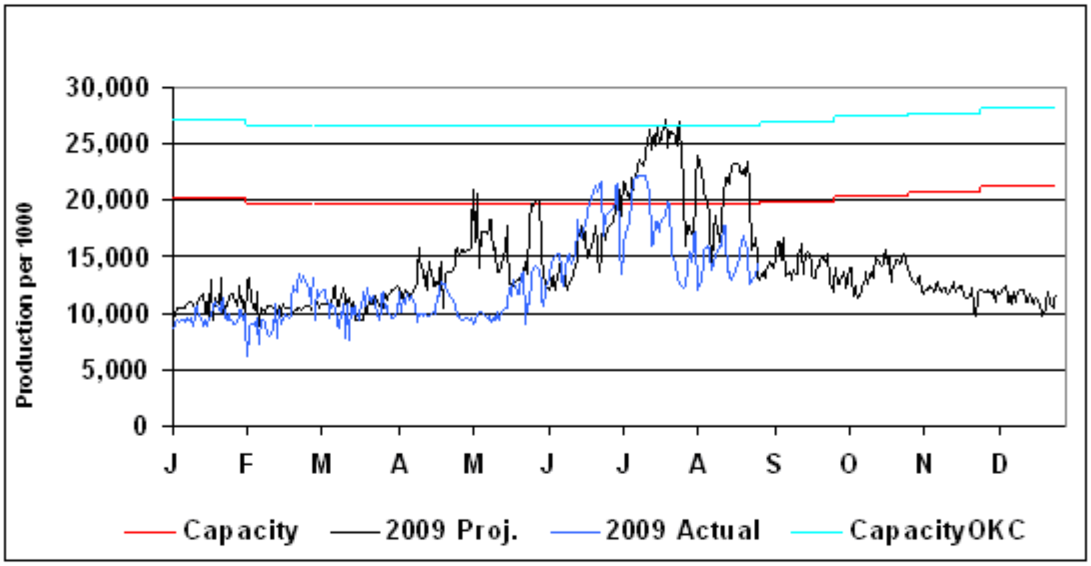

***Figure 11***. *Actual (dark blue) and projected (light purple) population of Norman, Oklahoma, from 1890 to 2040. Data courtesy of the U.S. Census Bureau and the City of Norman (Water Conservation Plan 2006).*

### *Current shortages*

Even during years not suffering from drought, the City of Norman cannot supply enough water as demanded by users during part of the summer without accessing external supplies. In addition, Norman is allotted less water from Lake Thunderbird than it actually uses. Currently, other cities in the Central Oklahoma Master Conservancy District use less than their allotment and allow Norman to access some of their water; however, an extreme or exceptional drought may force those cities to cap Norman's usage.

The City of Norman can produce a maximum output of 20 million gallons per day using water from Lake Thunderbird and its groundwater wells, so additional water typically is purchased from Oklahoma City in late July and August. This emergency supply can provide an additional 8 million gallons per day, if necessary.

Figure 12 depicts the annual cycle of water consumption by City of Norman customers during a typical year (2009) and during the drought year of 2006. During 2006, Norman had to buy water almost daily from mid-May to late August. That year, Oklahoma was in moderate to extreme drought statewide. Burn bans were issued across the state. The 2006 winter wheat production for Cleveland County was the third lowest for the previous 20 years (1987–2006). In May 2006, the water level in Lake Thunderbird decreased by four feet, forcing the closure of five out of nine boat ramps around the lake. In June 2006, the Norman City Council began to ask residents to conserve water so as to avoid a water crisis later that summer. Efforts also were made to encourage reducing the use of water between 10 a.m. and 6 p.m.



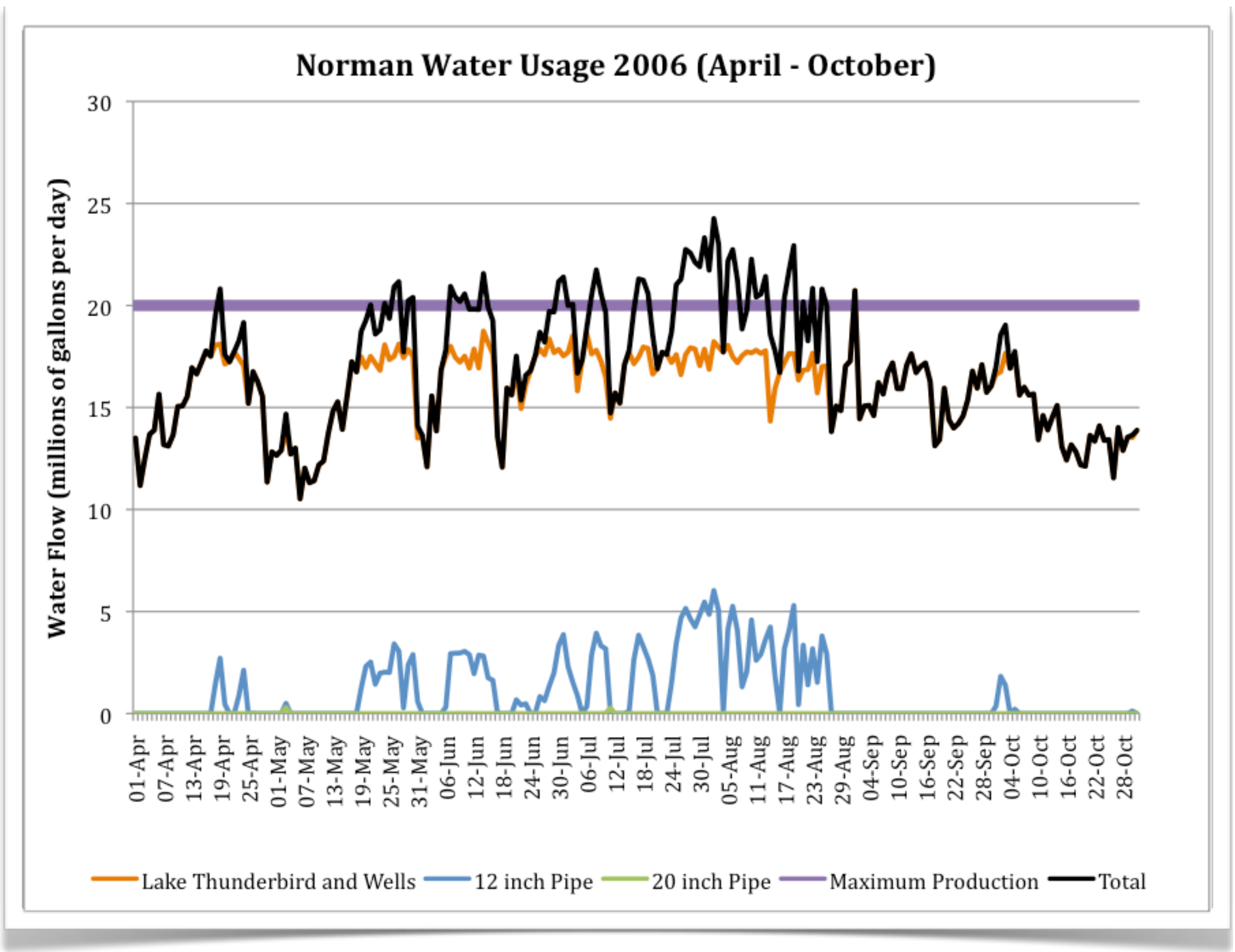




***Figure 12***. *Top graph: Water usage (blue line) from all sources during 2009. Bottom graph: Water usage (black line) from all sources during 2006.*

### *Our changing climate*

As documented by the Intergovernmental Panel on Climate Change, the Earth's climate of has warmed during the past 100 years. Although the climatic record of Oklahoma still is dominated by natural variability, it is expected that the warm season of Oklahoma will arrive earlier and last longer than in the past. The resulting increase in evaporation and transpiration will place more burden on Norman's water supply, as residents demand additional water for irrigation during the longer growing season.

Climatic changes are expected to impact water supplies, especially during the summer months when extreme drought may be experienced. Although the annual totals of rainfall may remain fairly constant, or even slightly increase, there may be less water available for public consumption. How can this be? If precipitation is more intense and less frequent, water may need to be discharged from reservoirs to avoid flooding, and intense runoff during extreme precipitation events likely will pollute the water, rendering large volumes unsuitable for human consumption.

## So what can Norman do to prepare?

Key stakeholders (e.g., City and University utility officials), business leaders, and Norman residents can contribute to ensuring that Norman is prepared for the next drought. Water management officials of both the City of Norman, the University of Oklahoma, and surrounding communities must monitor and report drought conditions every Thursday (or Friday) morning.

### *Monitoring and reporting drought conditions*

There are several ways to monitor drought. The most obvious for water managers in Norman is checking the water level of Lake Thunderbird, our main source of water. Larger-than-average decreases in the height of the water for a given month may indicate (1) more evaporation from the lake than normal and (2) a greater residential water demand to maintain healthy plants in the landscape.

Another excellent monitoring tool is the U.S. Drought Monitor, hosted by the National Drought Mitigation Center at the University of Nebraska. Dozens of federal, state, and local agencies contribute to the Drought Monitor through local reports of drought conditions (such as reports from Norman officials and residents) and observations from weather and water instrumentation (such as the Oklahoma Mesonet). As noted previously, drought categories range from D0 as abnormally dry to D4 as exceptional drought. Many federal drought assistance programs activate at D2 drought.

More locally, the Oklahoma Climatological Survey provides a drought monitoring web site at http://climate.mesonet.org/rainfall_update.html. The products on this site use precipitation, temperature, soil moisture, and other data from the Oklahoma Mesonet, the state's weather monitoring network. Tables summarize the current precipitation totals to past years across a variety of time scales (e.g., water year, current season, last 90 days), as shown in Figure 13.

**Last 90 Days: Jan 24, 2010 through Apr 23, 2010**

| Climate Division | Total Rainfall | Departure from Normal | Pct of Normal | Driest since | Wettest since | Rank since 1921 (89 periods) |
|---|---|---|---|---|---|---|
| Panhandle | 5.42" | +1.60" | 142% | 2008 (3.05") | 2007 (5.80") | 10th wettest |
| N. Central | 5.55" | -0.86" | 87% | 2006 (2.34") | 2008 (7.00") | 40th wettest |
| Northeast | 7.53" | -1.59" | 83% | 2006 (4.01") | 2008 (16.14") | 41st driest |
| W. Central | 6.97" | +1.21" | 121% | 2008 (6.31") | 2007 (9.00") | 14th wettest |
| Central | 8.00" | -0.16" | 98% | 2006 (3.56") | 2008 (11.26") | 30th wettest |
| E. Central | 8.30" | -2.09" | 80% | 2007 (5.56") | 2008 (18.43") | 32nd driest |
| Southwest | 7.39" | +1.48" | 125% | 2008 (7.07") | 2002 (8.00") | 14th wettest |
| S. Central | 9.53" | +0.40" | 104% | 2007 (6.94") | 2008 (12.63") | 28th wettest |
| Southeast | 11.31" | -0.48" | 96% | 2007 (5.58") | 2008 (24.16") | 41st wettest |
| Statewide | 7.73" | -0.09" | 99% | 2007 (7.47") | 2008 (11.66") | 30th wettest |

| Climate Division | Driest on Record | Wettest on Record | Apr 23 25cm FWI | Apr 23 KBDI | 90-day SPI | Most Like (Arndt Score) |
|---|---|---|---|---|---|---|
| Panhandle | 0.14" (1936) | 7.36" (1973) | 0.86 | 165 | +1.19 | 1928 (8.57) |
| N. Central | 0.46" (1936) | 11.75" (1999) | 0.85 | 139 | +0.20 | 2003 (9.40) |
| Northeast | 1.98" (1936) | 16.35" (1973) | 0.84 | 94 | -0.08 | 1961 (8.93) |
| W. Central | 0.62" (1996) | 10.58" (1973) | 0.92 | 37 | +0.91 | 1942 (7.95) |
| Central | 1.06" (1936) | 16.26" (1990) | 0.93 | 34 | +0.49 | 1952 (8.49) |
| E. Central | 2.81" (1936) | 26.64" (1945) | 0.80 | 95 | -0.27 | 1974 (8.55) |
| Southwest | 0.77" (1936) | 11.82" (1990) | 0.91 | 10 | +0.97 | 1941 (8.57) |
| S. Central | 2.69" (1936) | 19.04" (1990) | 0.95 | 41 | +0.52 | 1983 (8.65) |
| Southeast | 3.72" (1936) | 27.32" (1945) | 0.88 | 122 | -0.00 | 1931 (8.47) |
| Statewide | 1.56" (1936) | 14.00" (1945) | 0.88 | 82 | +0.39 | 1923 (8.35) |

***Figure 13**. Example of a drought monitoring product from the Oklahoma Climatological Survey (http://climate.ok.gov). Norman is located in the Central Climate Division. This example provides an assessment of the past 90 days ending on April 23, 2010 and includes the following information: total rainfall for the period, departure (difference) from normal rainfall for the period, how wet or dry the period has been compared to previous years, soil moisture as represented by the fractional water index (FWI), the Keetch-Byram Drought Index (KBDI), the 90-day Standardized Precipitation Index (SPI), and the previous period most similar to the current one.*

Table 2 summarizes several excellent sources of information for drought monitoring and reporting, ranging from national to local.

## Table 2: Sources of Drought Information & Tools

| Source | Web Address | Uses |
|---|---|---|
| ***Major Sources of Information*** | | |
| National Integrated Drought Information System | www.drought.gov | Consolidated source of drought information, monitoring & reporting tools, including many of the other sources listed below |
| National Drought Mitigation Center | drought.unl.edu | Consolidated source of drought information, including drought planning, monitoring reporting, risks, and impacts |
| Oklahoma Climatological Survey | climate.ok.gov | Consolidated source of Oklahoma climate information |
| Oklahoma Mesonet | www.mesonet.org | Oklahoma's weather observing network |
| ***Specific Drought-Related Tools*** | | |
| U.S. Drought Monitor: *National Drought Mitigation Center* | drought.unl.edu/dm/monitor.html | Current and past diagnoses of drought conditions, both nearby and across the United States |
| Oklahoma Drought Monitor: *Oklahoma Climatological Survey* | climate.mesonet.org/rainfall_update.html | Current precipitation information, comparisons of conditions across a range of time periods, & drought indices |
| Water Level for Lake Thunderbird: *U.S. Geological Survey* | waterdata.usgs.gov/ok/nwis/uv/?site_no=07229900&agency_cd=USGS | Current and past water levels measured in Lake Thunderbird, Norman's primary supply of water |
| U.S. Seasonal Drought & Precipitation Outlooks: *Climate Prediction Center* | www.cpc.noaa.gov | Large-scale trends in drought across the U.S. for the next few months; Expert assessments (not forecasts) of possible changes in precipitation conditions over a range of times (6-10 days, 8-14 days, 1 month, & 3 months) |

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