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WEATHERING DROUGHT: ONE STATE'S EXPERIENCE

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Oklahoma experienced one of its most severe, prolonged droughts during 2005-2006. Yet despite its severity, new tools and partnerships among agencies, developed over the previous decade, helped the state manage the drought with few crises. Water supplies shrank, in many cases to new all-time lows, but in all but a few cases both rural and urban water supply systems were able to meet demands. In addition, state and federal agencies were more coordinated and better prepared to assist both local governments and individuals who were suffering impacts from the drought.

The key to Oklahoma's recent success with drought response was primarily due to both improved communication among agencies as well as enhanced monitoring tools. The Oklahoma Mesonet (McPherson et al. 2007), the backbone of regular drought assessments, provided localized information that allowed the Oklahoma Water Resources Board (OWRB), the state agency charged with the coordination of state drought monitoring activities, to remain generally ahead of impacts. The Oklahoma Climatological Survey (OCS), which operates the Mesonet, coordinated the state's drought assessment with authors of the Drought Monitor to assure that a consistent picture was communicated to local and national decision-makers and the media. Within the state, information from the Mesonet, Drought Monitor, Corps of Engineers (reservoir levels), USGS (streamflow), and National Agricultural Statistics Service (crop conditions) were combined into a single document that was delivered at least bi-weekly to key decision-makers.

A major factor behind this success story was the OWRB's low-interest loan and grant programs for communities to upgrade water supply systems. Since 1984, more than $1.6 billion has been awarded through the agency's Financial Assistance Program to increase system and community drought resistance as well as provide other water/wastewater system improvements. In addition, during this recent drought episode, the OWRB was able to provide emergency financial assistance to address more immediate water supply problems.

Although Oklahoma was relatively well prepared to address impacts of the 2005-2006 drought, there are areas for improvement. For example, the state requires more timely and accurate impact assessment and mitigation. Also, there is a need to synthesize climate and drought data in a more timely fashion for decision-makers. The ongoing development of the National Integrated Drought Information System (NIDIS), as well as proposed creation of a state drought portal, present excellent opportunities to improve Oklahoma drought monitoring and response.

The state's recent drought experience demonstrates that quality, real-time information provided to key decision-makers, coupled with long-term planning by state and municipal water districts, is critical to drought preparedness. While Oklahoma experienced weather conditions that were at times as severe as the 1930s Dust Bowl, instead the state experienced only a short-term problem that left little social and economic disruption in its wake.

1. OKLAHOMA'S DROUGHT PLAN

The Oklahoma Drought Management Plan (Oklahoma Drought Management Team 1997) was created during the height of a severe drought that, while lasting only from October 1995 through May 1996, caused an estimated $1 billion in losses. A state Drought Task Force was convened by Executive Order, with the Oklahoma Department of Emergency Management (OEM) and Oklahoma Water Resources Board tasked to develop a plan. The process was

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entirely within the Executive Branch, with no legislative involvement. The plan implements an organizational structure for monitoring drought conditions, assessing impacts, and implementing response measures. It can be updated by the drought committee, with no other approval required. The National Drought Mitigation Center (NDMC) classifies Oklahoma's plan as response-oriented.

The Oklahoma Drought Management Team is chaired by the OEM, whose director is the State Drought Coordinator. The plan implements a phased approach to drought response: advisory, alert, warning, or emergency. Each phase is coupled with pre-defined actions (Table 1). The Coordinator makes determination of the drought phase, briefs the Governor and makes recommendations on specific actions requiring authorization. The Drought Management Team is supported by three standing committees: the Water Availability and Outlook Committee (WAOC), the Impact Assessment and Response Committee (IARC) and the Interagency Coordinating Committee (ICC).

The WAOC, which is chaired by the OWRB, is charged with developing and maintaining a mechanism to monitor the approach and onset of drought events. The primary mechanism used for communicating information is the *Oklahoma Water Resources Bulletin* (Oklahoma Water Resources Board 2007), which is published monthly during normal phases and bi-monthly or weekly during drought episodes. The WAOC is activated when drought reaches the Alert phase. The IARC, chaired by the Department of Agriculture, is activated at the Warning phase. During a drought, the IARC prepares reports on drought impacts for the Governor, other state leaders, the media, and public. In addition, the IARC is tasked with defining drought impacts, vulnerable sectors, and refining the ability to respond to those impacts. The ICC is a smaller centralized group of the WAOC and IARC which is assembled during the Emergency phase. The ICC makes decisions on re-allocating resources to manage drought and drafts requests for federal assistance, funding or legislation, which are provided to the Drought Coordinator and the Governor. As drought conditions recede below the Emergency phase, the ICC prepares a final report before disbanding.

The Oklahoma Drought Management Plan describes the state's previous efforts as "crisis management", marked by frequent formation and subsequent disbandment of *ad hoc* task forces. In 1988, the Governor created the Oklahoma Drought Action Coordinating Council, which delineated agency responsibilities and recommended a State Drought Coordinator to supervise development of a contingency plan. During the same period, Oklahoma was involved with the NDMC (then the International Drought Information Center) in identifying state drought monitoring, assessment and response activities, which resulted in NDMC's 10-step framework for drought planning (Wilhite 1991; Wilhite et al 2005). These documents were used quite extensively when Oklahoma created its drought plan, including concepts for committee structures, drought stages, and triggers. In addition to the NDMC documents, the drought management team consulted other state plans (Pennsylvania is mentioned in the document); the state water plan, which had been updated the previous year; and the 1988 Council's report. Informal input from members of the ODEM, OWRB and Oklahoma Climatological Survey were used extensively in the original draft.

2. DROUGHT MONITORING

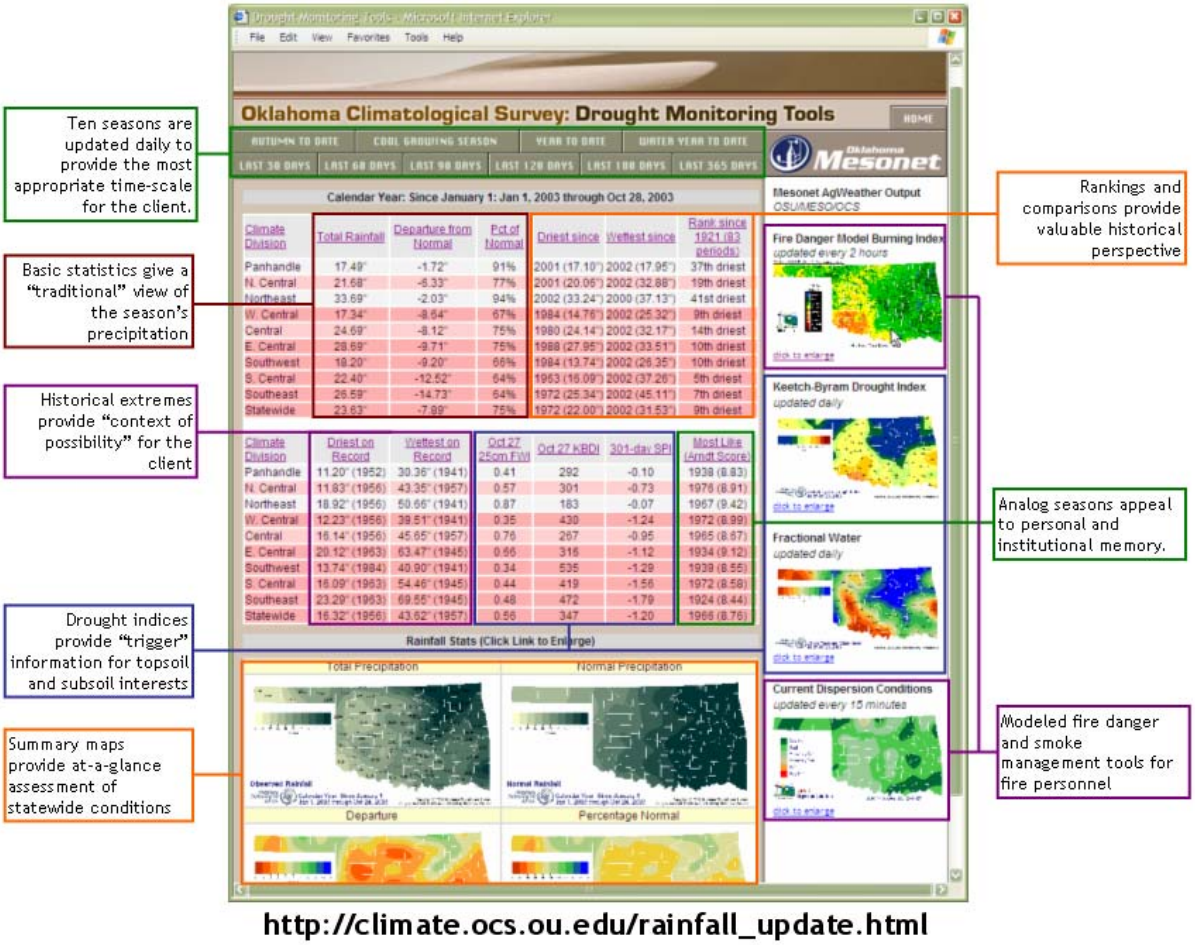
Since the onset of the extended drought in 1995, the Oklahoma Climatological Survey has been the key provider of precipitation-based drought assessments to state officials in Oklahoma. In response to the drought, OCS began producing weekly summaries of precipitation totals and departures for each climate division in the state. Since 1995, through interaction with officials at the Oklahoma Water Resources Board, other state agencies, and U.S. Drought Monitor authors, the system has developed into a mature real-time decision-support system.

Each morning before dawn, precipitation totals from the Oklahoma Mesonet are incorporated into a suite of tables and maps that provide assessments on precipitation departures, historical context, and key drought indices. The Mesonet data are merged with historical National Weather Service (NWS) Cooperative Observer data to determine rankings, records, and analog periods. Assessments for selected time periods ranging from 30 days to 365 days plus standard measures such as calendar year, water year, and current season, are available through the decision-support system (Figure 1).

Table 1. Sequence of Drought Response Actions

Drought Response Stage	**State Drought Coordinator**	**Water Availability & Outlook Committee**	**Impact Assessment & Response Committee**	**Interagency Coordinating Committee**
		Developing Drought		
Normal	Review routine information	Stand-down Water Resources Bulletin published seasonally	Stand-down	
I – Advisory (incipient drought)	Request assistance from weather/climate representatives for trend evaluation	Stand-down Water Resources Bulletin published bi-weekly	Stand-down	
II – Alert (mild drought)	Activate Water Availability and Outlook Committee	Monitor trends and provide information Water Resources Bulletin published weekly	Stand-down	
III – Warning (moderate drought)	Meet with committee chairpersons to outline actions Forward reports to Governor, other state leaders, media & public	Prepare "Memorandum of Potential Drought Emergency" for Governor to activate IARC Water Resources Bulletin published weekly	Assess current and potential impacts Initiate response within capabilities of state agencies & determine unmet needs	
IV – Emergency (severe drought or additional required resources	Direct ICC activities Consider request to Governor or assistance	Continue monitoring Water Resources Bulletin published weekly	Prepare "Drought Emergency Proclamation" for Governor to activate ICC	Assume response role Determine resource allocation options Assemble data to support Governor's request for federal declaration
		Receding Drought		
IV – Emergency (severe drought or requirements being met)	Continue pursuit of potential assistance & coordination	Continue monitoring Water Resources Bulletin published weekly	Continue monitoring, assessment, response and reporting activities	Prepare "End to Drought Emergency Proclamation" for Governor Prepare final report
III – Warning (conditions improving)	Continue general coordination of contingency planning activities	Continue monitoring Water Resources Bulletin published bi-weekly	Resume drought response / coordination role	
II – Alert (conditions improving)	Continue general coordination of contingency planning activities	Continue monitoring Water Resources Bulletin published bi-weekly	Terminate formal contingency planning activities Stand-down	
II – Advisory (conditions improving)	Solicit advice from WAOC on drought trends	Terminate formal contingency planning activities Water Resources Bulletin published monthly	Stand-down	
I - Normal	Review routine information	Stand-down Water Resources Bulletin published seasonally	Stand-down	

Figure 1. Oklahoma's real-time drought monitoring system.



The OCS drought report is automatically updated and immediately available via the world-wide-web. The timing and automation of the report allow drought decision-makers instant access to the latest precipitation, fire danger and soil moisture data when they arrive at their desk, 24 hours per day, seven days per week. Each morning's report contains information complete through midnight, a turnaround time of less than five hours. The automation helps maximize the reader's efficiency by eliminating the need to prompt (and wait for) action from OCS. It also helps OCS staff reduce the time spent preparing reports and focus on more valuable interpretive and explanatory support.

OCS represents the meteorological / climatological community's input into the state drought assessment processes. OCS collects the data and develops tools to portray information for state decision-makers. OWRB officials, who are charged by statute with monitoring responsibilities, monitors the decision-support system and includes information from it in its *Water Resources Bulletin*, sent to top agency officials, legislative leaders and Governor's staff to keep informed on drought status by region in Oklahoma.

The system has solidified the relationship between state agency officials and the climate community. One official stated: "I really trust the information and the data that you guys put on your website or the information that you give me personally, I don't even question it." This success was achieved because of responsiveness and attentiveness to the decision-makers' needs. New indices, maps, time periods, and links have been added at the request of individual decision-makers. Prototypes were tested by these key user groups as new changes were implemented.

Although this system is built upon real-time quality-controlled information from the Mesonet, the decision-support system has been expanded to use a real-time cooperative observer data feed. A parallel feed of cooperative observer data was developed utilizing the Applied Climate Information System, supplied by the Southern Regional Climate

Center. Results indicated that even without a real-time Mesonet, reasonable real-time depictions of drought conditions could be obtained with existing daily observations. Similar climate division tables are now being produced for all states.

In addition to directly providing information to the OWRB, climatologists at OCS also provide information for the Drought Monitor, a weekly web-based publication that identifies drought stages in various parts of the country. Authors include individuals from the U.S. Department of Agriculture (USDA), NOAA, the NDMC, and the National Climatic Data Center (NCDC). Each author typically serves two weeks on a rotating schedule. Information used to produce the Drought Monitor maps comes from data collected from observing networks, computer-generated models and indices, and direct feedback from individuals through a 'Drought Exploder' e-mail list.

The Drought Monitor was created in 1999 and has been produced weekly ever since. Authors rate drought severity, using the indices, data, and direct guidance, as one of 5 categories: abnormally dry (D0), moderate drought (D1), severe drought (D2), extreme drought (D3) and exceptional drought (D4). The drought category designated by the Drought Monitor author requires assessment of a variety of objective indices blended with subjective assessments based on information of impacts (Table 2). Because indices will frequently show different designations, the author's judgment is the final determination. The designation may be given based on impacts on either agricultural or hydrological concerns. The D4 category is reserved for severity in accordance with a one in fifty year event. USDA assistance is in some cases tied to the designation assigned by the Drought Monitor authors.

Other indicators are used in drought monitoring, both by the OWRB and by the Drought Monitor, including:

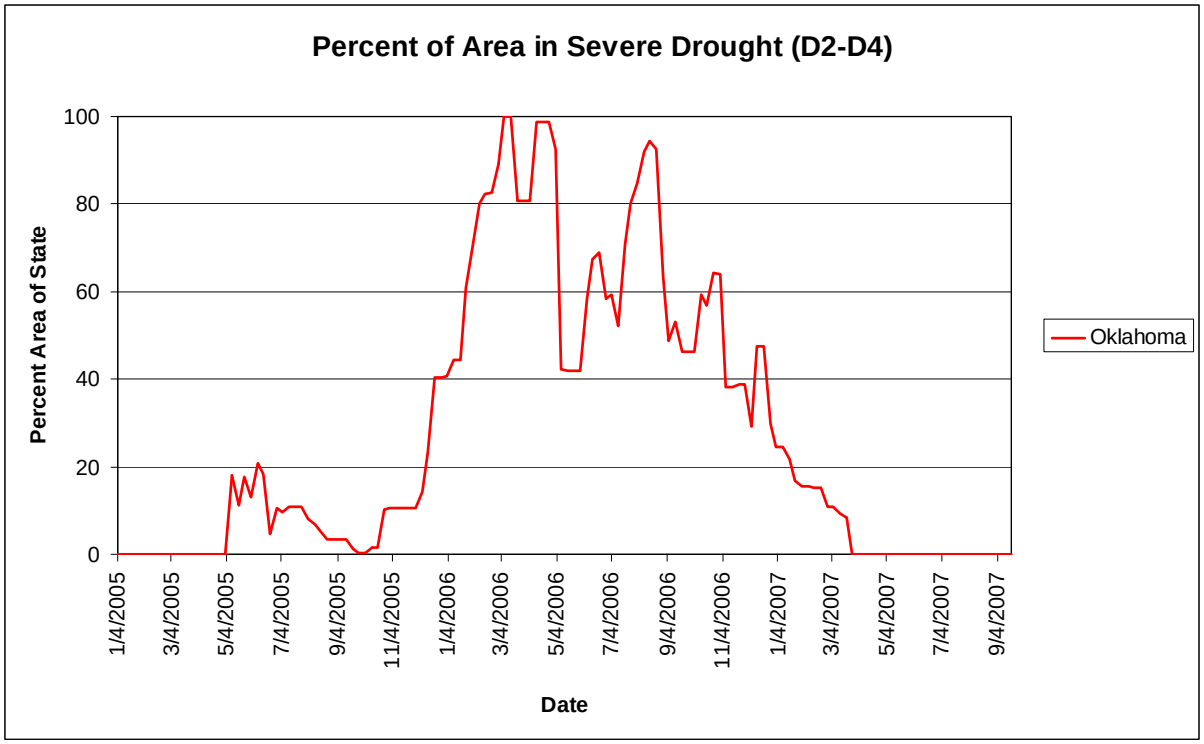
- Streamflow (U.S. Geological Survey)
- Reservoir levels (U.S. Army Corps of Engineers)
- Crop Reports (from National Agricultural Statistics Service, USDA)
- WSR-88D radar-estimated rainfall totals (used by Drought Monitor only)

These sources help to corroborate the impacts side of the drought equation. Streamflow and reservoir levels are usually indicators of long-term, hydrological impacts. Crop reports provide documentation of stresses on vegetation to corroborate both short-term and seasonal precipitation deficits. Sometimes indicators will conflict with each other – not just short-term versus long-term indicators but even within a similar timeframe. For example, precipitation deficits may indicate drought but have few tangible impacts, or impacts may be more severe than what would be expected from precipitation deficits alone. This emphasizes the role of human judgment in sorting out these conflicts

Table 2. Drought Severity Classification. *Source: National Drought Mitigation Center* http://www.drought.unl.edu/dm/classify.htm.

		Ranges (Primary Objective Indices)				
Category	Description	Palmer Drought Index	CPC Soil Moisture Index (Percentiles)	USGS Weekly Streamflow (Percentiles)	Standardized Precipitation Index (SPI)	Objective Short and Long-Term Drought Indicator Blends (Percentiles)
D0	Abnormally Dry	-1.0 to -1.9	21-30	21-30	-0.5 to -0.7	21-30
D1	Moderate Drought	-2.0 to -2.9	11-20	11-20	-0.8 to -1.2	11-20
D2	Severe Drought	-3.0 to -3.9	6-10	6-10	-1.3 to -1.5	6-10
D3	Extreme Drought	-4.0 to -4.9	3-5	3-5	-1.6 to -1.9	3-5
D4	Exceptional Drought	-5.0 or less	0-2	0-2	-2.0 or less	0-2
	Possible Impacts					
D0	Going into drought: short-term dryness slowing planting, growth of crops or pastures; fire risk above average. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered.					
D1	Some damage to crops, pastures; fire risk high; streams, reservoirs, or wells low, some water shortages developing or imminent, voluntary water use restrictions requested.					
D2	Crop or pasture losses likely; fire risk very high; water shortages common; water restrictions imposed.					
D3	Major crop/pasture losses; extreme fire danger; widespread water shortages or restrictions.					
D4	Exceptional and widespread crop/pasture losses; exceptional fire risk; shortages of water in reservoirs, streams, and wells, creating water emergencies.					

Figure 2. Area of Oklahoma designated as severe (D2) to exceptional (D4) drought, 2005-2007.



to come up with a unified portrayal of drought.

3. DROUGHT TIMELINE

Oklahoma experienced one its most severe, prolonged droughts during 2005-2006. The drought drained farm ponds, left water supplies critically low, and decimated Oklahoma's agricultural economy. Back-to-back poor harvests in 2005 and 2006, the latter producing the lowest yields for winter wheat since 1957, left many farmers facing financial hardships. The cattle industry suffered as pastures failed to produce and hay prices soared to over $70 per bale. Wildfires spread across the state, burning more acres than ever before recorded in Oklahoma's history. At its peak, the entire state of Oklahoma was designated as being in severe to exceptional drought according to the Drought Monitor (Figure 2).

3.1 Drought Beginning. The beginning of the drought has generally been traced back to February 2005, although determining an exact start date is impossible. First indications developed during the spring and by April 2005 it became apparent that Oklahoma was in drought conditions. On April 5, the Drought Monitor first indicated "abnormal dryness" (D0) in south central Oklahoma. Within a week it was upgraded to "moderate drought" (D1). During the course of May, drought areas gradually expanded to cover most of Oklahoma, with south central Oklahoma growing to "severe drought" (D2). Figure 3 shows conditions in late May.

Figure 3. Drought Monitor depiction for May 24, 2005.

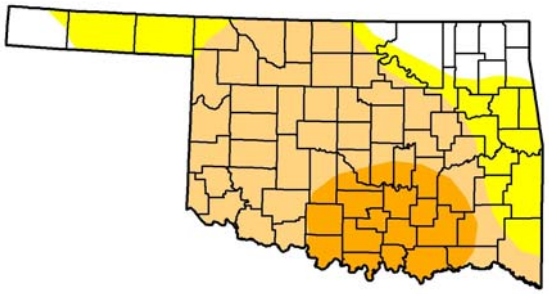


Figure 4. Drought Monitor depiction for September 13, 2005.

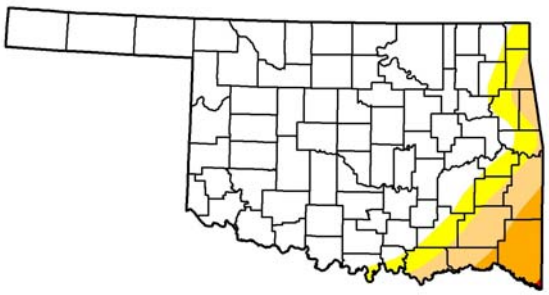


Figure 5. Drought Monitor depiction for December 27, 2005.

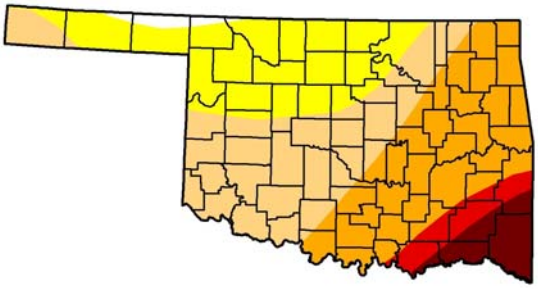
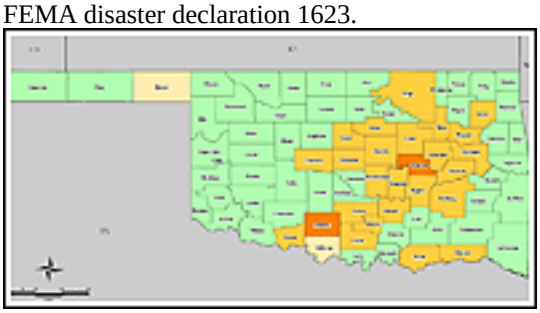


Figure 6. Counties designated for assistance under FEMA disaster declaration 1623.



3.2 Drought Intensification. During the summer of 2005, drought conditions improved in south central Oklahoma but intensified in southeastern Oklahoma, particularly in the Ark-La-Tex region in the southeast corner, which was raised to "extreme drought" (D3) on June 28. Except for the southeast corner of the state, Oklahoma looked to be in good condition by early fall (Figure 4).

Drought conditions improved in southeast Oklahoma and the Ark-La-Tex region during September, but the early fall rains failed to continue. After a dry October, D3, which had been eliminated in late September, returned to southeast Oklahoma and then rapidly expanded across much of eastern Oklahoma. By late November, the entire state was designated as at least D0 and, by the end of the year, severe drought (D2) covered 40% of Oklahoma. D4 – the top designation of "exceptional drought" was introduced into the Ark-La-Tex region on December 20 (Figure 5). Governor Brad Henry instituted a statewide outdoor burning ban on November 15.

This set the stage for the worst outbreak of wildfires in Oklahoma's history, beginning in December 2005 and extending until April 2006. The axis of the most severe impacts stretched from south central through northeast Oklahoma (Figure 6). Although this was outside of the areas designated as worst drought impacts, it is not infrequent for wildfires to develop in less severe drought conditions.

By March 7, 2006, severe drought designations covered the entire state. D4 covered a large swath of eastern Oklahoma, where lakes began setting record low levels (Figure 7). Spring rains finally returned in eastern Oklahoma, leading to improvement of drought conditions throughout the spring. However, by mid-April, it was obvious that rain in western Oklahoma – the prime area for growing winter wheat – was insufficient to support crops, culminating in the worst wheat harvest for the state in half a century.

In May 2006, an OCS headline stated that "May is the Babe Ruth of months when it comes to delivering rainfall. If we come into May in drought, or teetering on drought, we need May to deliver. Historically speaking, June is decent, but the line-up gets pretty bleak until September and October." By the middle of June, headlines continued to lament the meager spring precipitation totals, declaring "with summer only just now officially beginning, the prospects of such organized, widespread rains become even more remote." As a result, deterioration in the west offset improvement in the east, causing a westward shift of the core of extreme drought (Figure 8).

Figure 7. Drought Monitor depiction for March 7, 2006.

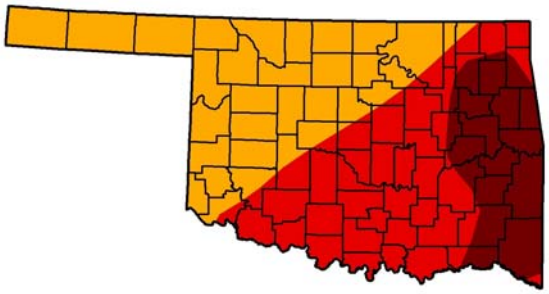
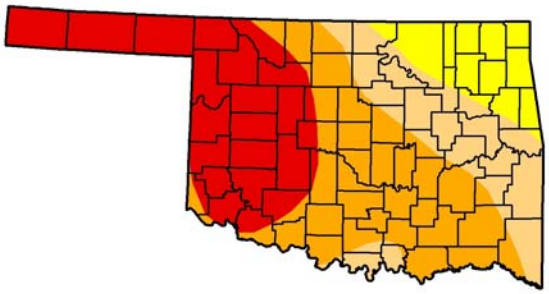


Figure 8. Drought Monitor depiction for June 13, 2006.



3.3 A False Recovery? The drought was not yet out of surprises. What looked like improvement during the summer proved to be short-lived as water supply issues became severe. The first indication came from a report sent in to the Drought Monitor by an individual signed "Jack the Toad" on July 18. The report, from Alfalfa County in north central Oklahoma, painted a dire picture:

> "In Alfalfa County in NW Oklahoma for the month of June I recorded 1.3 inch of rainfall west of Manchester. Wells are running dry and we are drilling new wells. Most all farm ponds are dry and many streams are dry. Water is hauled to livestock from Manchester. We had two very short cuttings of alfalfa hay at 10 percent of average yield. There will not be a 3rd cutting in many fields. The 4th of July we received .35 inch rain. The Palmer Drought Index is off track once again. The extreme drought leads much farther east than is shown on their map clear into Grant County. Kansas is receiving beneficial rains. As close as 15 miles north and east 2 inches of rain was recorded in Anthony, Kansas, and east of Anthony. I would feed my cattle hay, if I had it or could afford to buy it."

This caught both OCS and OWRB by surprise. Indicators used to measure drought severity did not portray such severe conditions, but there was no doubt that water issues were real. Further east, communities served by a small lake, Lone Chimney Lake, in Pawnee County reported that their supply would last only a matter of weeks. D3 was expanded across much of the state with a large section of D4 along the Red River (Figure 9).

Perhaps the most visible news story was one issued on September 11, 2006, which noted that the period from March 1, 2005 through September 10, 2006 was the driest such period on record. Subsequently, media, state officials, and even the Governor, were heard to declare this episode as the worst drought in Oklahoma history – quite a statement when one considers the dramatic effects of the dust bowl! While the drought proved to be of much shorter duration than some of the historical events experienced in the state, it was at its peak as severe as any on record.

3.4 Recovery. The drought's grip was finally broken during the Fall of 2006. Several rain events crossed the state during the autumn months, gradually recharging water supplies and replenishing soil moisture. But the path to recovery was not easy. Rain that fell in areas with deficits in the tens of inches over the previous several years had several levels of water supply to replenish, from soil moisture, surface water, to deep wells and aquifers. As evidenced by the Oklahoma Mesonet's soil moisture observations, even short-term improvements can be fleeting if not quickly reinforced by more precipitation. This created many challenges in depicting drought conditions, a process presently being repeated in some of the hard-hit areas of the Southeastern U.S.

The great difficulty lay in the selection of indicators. Although many different indices are included in the Drought Monitor process, the problems of recovery were driven by deep layers of the soil and aquifers, beyond the reach of instrumentation. Thus, there were no observations of these critical components that went into the depiction, causing a disconnect between indicators and impacts. As a result, severe drought impacts lingered through the winter, especially in north central Oklahoma where "Jack the Toad" had first reported the most severe impacts (Figure 10).

Just as there is uncertainty as to when droughts begin, there is often uncertainty as to when they end. However, in this case there was no doubt. Rainfall returned with a vengeance during the spring of 2007. In May, which the Governor had routinely proclaimed as Flood Awareness Month, the proclamation came not a day too soon. The wildfire disaster declared a year earlier was replaced with four separate flood disaster declarations during spring and

Figure 9. Drought Monitor depiction for August 8, 2006.

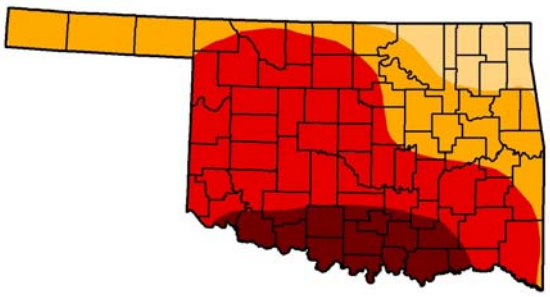
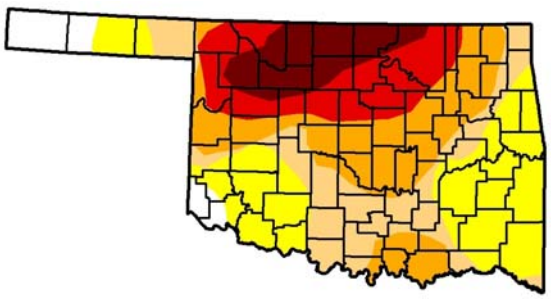


Figure 10. Drought Monitor depiction for December 19, 2006.



summer 2007. On April 3, the Drought Monitor ended drought designations, although lingering effects still remained in pastures and reservoirs. By May 8, the last vestiges of D0 were removed from Oklahoma.

It's somewhat standard for Oklahoma's severe drought episodes to end with a deluge instead of a trickle. The state's most notable droughts, the 1930s Dust Bowl and the 1950s, were both broken in a spectacularly wet fashion. The Dust Bowl episode was whittled away in early 1941 before being blasted from existence by a statewide average rainfall of 11.32 inches in October, the wettest Oklahoma month on record. The 1952-57 drought, considered the state's worst statistically, ended rather abruptly in May 1957 with heavy rains and major flooding on the state's largest river systems. That year still stands as the wettest in Oklahoma history at 48.21 inches.

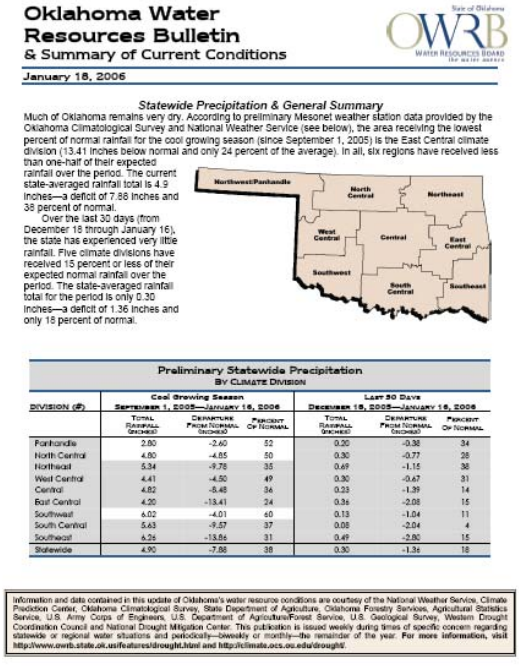
4. DROUGHT COMMUNICATION

The central component of drought management in Oklahoma is the *Water Resources Bulletin*, produced on a regular basis by the Oklahoma Water Resources Board, regardless of whether it is wet or dry. The *Bulletin* integrates information from multiple sources and provides a summary view of drought indicators on a variety of timescales and impacted sectors. It is produced monthly under normal conditions and bi-weekly during severe drought. The current *Bulletin* as well as all archives are posted on the OWRB website: http://www.owrb.ok.gov/supply/drought/bulletin.php. Some pages from the Bulletin published at the height of the wildfire outbreaks is shown in Figure 11.

During most of the drought event, the full *Bulletin* consisted of the following:

- Statewide Precipitation & General Summary ;
- Regional and statewide precipitation – by climate division and overall: total, departure from normal, and percent of normal for current growing season and last 30 days (from the Oklahoma Mesonet);
- Drought Indices – a written summary of Palmer Drought Severity Index, Standardized Precipitation Index (3, 9, 9 and 12 month), and Keetch-Byram Drought Index plus Statewide Wildfire Preparedness from Oklahoma Department of Agriculture, Food, and Forestry and Burning Ban / Red Flag Fire Alert status; accompanied by division and statewide tables for each;
- Soil moisture maps for topsoil (5 cm) and deeper soil (60 cm) (from Oklahoma Mesonet);
- Streamflow Conditions at 6 selected locations around the state – written summary and 18-month graphs

Figure 11. Pages 1 and 5 (of 8) of the *Water Resources Bulletin* published January 18, 2006.



Oklahoma Water Resources Bulletin
& Summary of Current Conditions

OWRB Water Resources Board

January 18, 2006

Statewide Precipitation & General Summary

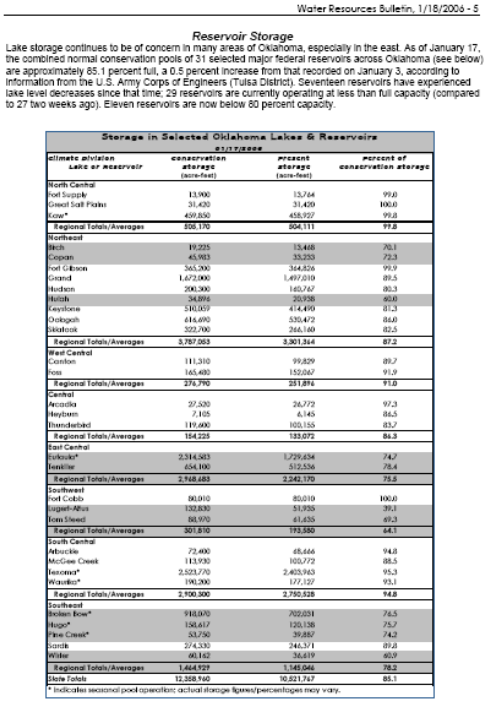
Much of Oklahoma remains very dry. According to preliminary Mesonet weather station data provided by the Oklahoma Climatological Survey and National Weather Service (see below), the area receiving the lowest percent of normal rainfall for the cool growing season (since September 1, 2005) is the East Central climate division (13.41 inches below normal and only 24 percent of the average). In all, six regions have received less than one-half of their expected rainfall over the period. The current state-averaged rainfall total is 4.9 inches—a deficit of 7.88 inches and 38 percent of normal.

Over the last 30 days (from December 18 through January 16), the state has experienced very little rainfall. Five climate divisions have received 15 percent or less of their expected normal rainfall over the period. The state-averaged rainfall total for the period is only 0.30 inches—a deficit of 1.36 inches and only 18 percent of normal.

Preliminary Statewide Precipitation
By Climate Division

DIVISION (#)	Cool Growing Season September 1, 2005—January 16, 2006			Last 30 Days December 18, 2005—January 16, 2006		
	Total Rainfall (inches)	Departure From Normal (inches)	Percent Of Normal	Total Rainfall (inches)	Departure From Normal (inches)	Percent Of Normal
Panhandle	2.80	-2.60	52	0.20	-0.38	34
North Central	4.80	-4.85	50	0.30	-0.77	28
Northeast	5.34	-9.78	35	0.69	-1.15	38
West Central	4.41	-4.50	49	0.30	-0.67	31
Central	4.82	-8.48	36	0.23	-1.39	14
East Central	4.20	-13.41	24	0.36	-2.08	15
Southwest	6.02	-4.01	60	0.13	-1.04	11
South Central	5.63	-9.57	37	0.08	-2.04	4
Southeast	6.26	-13.86	31	0.49	-2.80	15
Statewide	4.90	-7.88	38	0.30	-1.36	18

Information and data contained in this update of Oklahoma's water resource conditions are courtesy of the National Weather Service, Climate Prediction Center, Oklahoma Climatological Survey, State Department of Agriculture, Oklahoma Forestry Services, Agricultural Statistics Service, U.S. Army Corps of Engineers, U.S. Department of Agriculture/Forest Service, U.S. Geological Survey, Western Drought Coordination Council and National Drought Mitigation Center. This publication is issued weekly during times of specific concern regarding statewide or regional water situations and periodically—biweekly or monthly—the remainder of the year. **For more information, visit http://www.owrb.state.ok.us/features/drought.html and http://climate.ocs.ou.edu/drought/.**



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Reservoir Storage

Lake storage continues to be of concern in many areas of Oklahoma, especially in the east. As of January 17, the combined normal conservation pools of 31 selected major federal reservoirs across Oklahoma (see below) are approximately 85.1 percent full, a 0.5 percent increase from that recorded on January 3, according to information from the U.S. Army Corps of Engineers (Tulsa District). Seventeen reservoirs have experienced lake level decreases since that time; 29 reservoirs are currently operating at less than full capacity (compared to 27 two weeks ago). Eleven reservoirs are now below 80 percent capacity.

Storage in Selected Oklahoma Lakes & Reservoirs
01/17/2006

climatic division Lake or Reservoir	conservation storage (acre-feet)	recent storage (acre-feet)	percent of conservation storage
North Central			
Fort Supply	13,900	13,744	99.0
Great Salt Plains	31,420	31,420	100.0
Kaw*	459,850	458,927	99.8
Regional Totals/Averages	505,170	504,111	99.8
Northeast			
Birch	19,225	13,468	70.1
Copan	45,983	33,233	72.3
Fort Gibson	365,200	364,826	99.9
Grand	1,673,000	1,497,010	89.5
Hudson	200,300	160,767	80.3
Hulah	34,896	20,938	60.0
Keystone	510,059	414,490	81.3
Oologah	616,690	530,472	86.0
Skiatook	322,700	266,160	82.5
Regional Totals/Averages	3,787,053	3,301,364	87.2
West Central			
Canton	111,310	99,829	89.7
Foss	165,480	152,047	91.9
Regional Totals/Averages	276,790	251,876	91.0
Central			
Arcadia	27,520	26,772	97.3
Heyburn	7,105	6,145	86.5
Thunderbird	119,600	100,155	83.7
Regional Totals/Averages	154,225	133,072	86.3
East Central			
Eufaula*	2,334,583	1,729,634	74.7
Tenkiller	654,100	512,536	78.4
Regional Totals/Averages	2,988,683	2,242,170	75.5
Southwest			
Fort Cobb	80,010	80,010	100.0
Lugert-Altus	132,830	51,935	39.1
Tom Steed	88,970	61,655	69.3
Regional Totals/Averages	301,810	193,580	64.7
South Central			
Arbuckle	72,400	68,666	94.8
McGee Creek	113,930	100,772	88.5
Texoma*	2,523,770	2,403,965	95.3
Wanella*	190,200	177,127	93.1
Regional Totals/Averages	2,900,300	2,750,528	94.8
Southeast			
Broken Bow*	918,070	702,031	76.5
Hugo*	158,617	120,138	75.7
Pine Creek*	53,750	39,887	74.2
Sardis	274,330	246,371	89.8
Wister	80,162	36,619	80.9
Regional Totals/Averages	1,464,929	1,145,046	78.2
State Totals	12,388,960	10,521,767	85.1

* Indicates seasonal pool operation; actual storage figures/percentages may vary.

showing actual discharge and mean discharge, by date (from U.S. Geological Survey);
- Long-range forecast, written summary (from NOAA Climate Prediction Center);
- Crop Report summary (from National Agricultural Statistics Service);
- Reservoir Storage – present storage and percent of conservation storage for major water supplies in Oklahoma (from U.S. Army Corps of Engineers, Tulsa District).

The *Bulletin* format was updated in February 2006 to include the Drought Monitor map, associated tables for Oklahoma and excerpt from the accompanying written narrative, and the Drought Outlook map from the Climate Prediction Center (Figure 12). In addition, precipitation ranks for each climate division were added to the growing season and last-30-day tables, along with departure maps for each. Wildfire risk graphics were added showing the Keetch-Byram Drought Index and counties under burn bans or advisories.

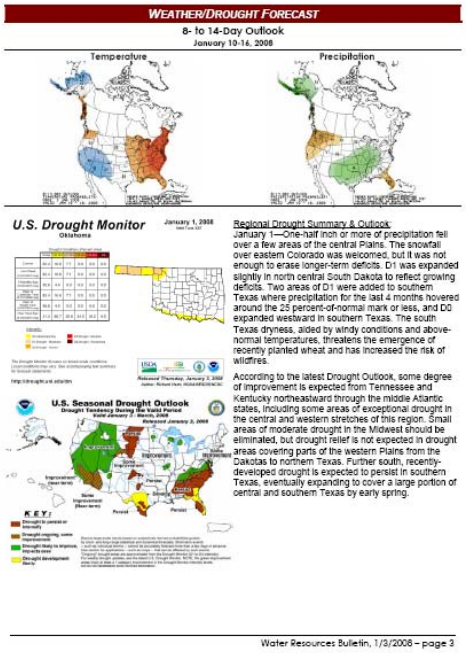
The *Bulletin* is distributed via e-mail to 60 organizations, including state and federal agencies, local governments and water districts, legislative leaders and the Governor's Office, tribal governments, media, university departments, non-profit organizations, and out-of-state water associations. The *Bulletin* is also posted on the OWRB website, where it generates a lot of traffic.

4.1 Comparing Reports

Comparing these reports to the Drought Monitor depictions shows good agreement, even before the Drought Monitor was included directly in the *Bulletin* itself. In early 2005, the reports noted "a general surplus of moisture continues to exist throughout Oklahoma." This gave way to first indications of dryness in the March 16 report, which noted that "a recent dry spell is beginning to impact many areas of Oklahoma," particularly in southeast and east central parts of the state. This actually preceded the D0 designation in Oklahoma, which was introduced in the April 5 Drought Monitor.

The *Bulletin* continued to note dryness, particularly in southeast, east central and central Oklahoma throughout the spring. In the June 8 edition, the *Bulletin* reported that "Oklahoma recorded its lowest March-April-May period precipitation since record keeping began in 1895 … many areas of the state are beginning to experience drought-like conditions."

Figure 12. Revised *Water Resources Bulletin* format showing inclusion of Drought Monitor and Drought Outlook.



Even as drought conditions improved in much of the state during the summer and early fall, the *Bulletin* continued to report dryness in the southeast. These reports were consistent with Drought Monitor depictions. The *Bulletin* noted significant improvement in its September 14 edition as well as its October 12 edition, but by November 9 it showed the returning drought conditions. Three weeks later, on November 30, the *Bulletin* called attention to the "meager rainfall" that had fallen in most areas of the state over the preceding 30 days.

By the December 21 issue, wildfires had begun in the state, although the most severe events were still to come. The *Bulletin* noted that "drought-related fire conditions continue to be of concern." At this point, the report shifted to a bi-weekly publication. As drought intensified statewide through the winter and spring, the *Bulletin* picked up on many of the impacts: much below normal flow on streams and declining reservoirs, particularly in the east, drying up ponds, and cattle sales. With Oklahomans' eager for some good news to combat the extreme wildfires, the *Bulletin* cautioned (February 1, 2006) that "despite some beneficial rainfall late last week, much of Oklahoma remains very dry."

On February 15, the *Bulletin's* new format was introduced. The new format relied more on graphics and less narrative. The severity of the drought was immediately apparent in the addition of the climate division and statewide precipitation rankings, which revealed that the cool growing season (beginning September 1) was the driest such period on record.

The recovery in eastern Oklahoma shown in the Drought Monitor was mirrored in the *Bulletin*, as reservoir levels improved beginning in March and extending through May. The April 26 edition called attention to continued moisture decreases statewide, as the area of D3 in the Drought Monitor depiction was expanded dramatically, particularly across western Oklahoma. Meanwhile, the continued improvement in the east continued to show in a rebound of reservoir levels and streamflows as depicted in the *Bulletin*.

The crop report section of the May 24 *Bulletin* noted ominously that "with the recent hot temperatures and a lack of rainfall, some producers were irrigating row crops much earlier than normal." This indicated some of the deep water supply problems that were not yet fully apparent to authors and contributors to the Drought Monitor. These would not be revealed until July 18 when the "Jack the Toad" report led to a reassessment. Throughout the remainder of spring and summer, the *Bulletin* continued to track reservoir level declines on almost every report, especially through the change metrics such as "17 reservoirs are currently operating at less than full capacity (compared to 15 three weeks ago)."

In October, a clearly-defined pattern of improvement across the southern parts of Oklahoma and continuation of extreme drought conditions in northern Oklahoma was apparent in both the *Bulletin* and the Drought Monitor. As the drought area shrank, the *Bulletin* resumed a monthly publication schedule with October 25 marking the end of the bi-weekly production. The indicators in the November 22 *Bulletin* showed the demarcation of the improved areas compared to the remaining core, especially in the soil moisture and fire danger products. The remaining core north central Oklahoma remained apparent in a number of the indicators published in the *Bulletin* through March 21. By the April 18 publication, virtually all vestiges of the drought had been erased.

4.2 Other Methods

Several other methods are used to complement the Bulletin. These include press releases, website postings, media interviews, and the OCS/Mesonet Ticker (http://ticker.mesonet.org), a newsletter distributed via e-mail. Many of these Ticker articles provided comparative tables showing the severity of drought by regions of the state and differing time scales. Written discussion in terms geared for a public audience accompanied the data. Some of these articles, as well as more formal press releases and website homepage stories, were picked up by the media, both television and print.

Beginning in early 2006, OCS produced a one-page (two-sided) "Drought Update" summary that highlighted key indicators (Figure 13). This was updated periodically throughout the duration of the event. The summary was posted on the Ticker and OCS websites and distributed directly to state officials.

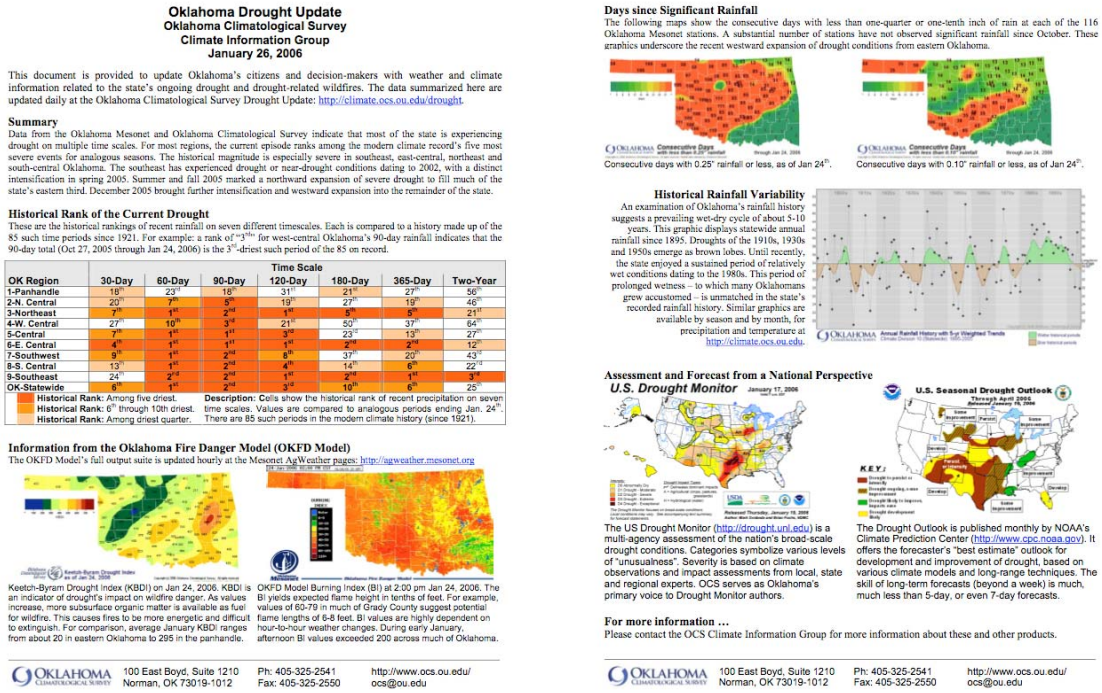
Together, these releases helped keep drought prominent in the media and on the minds of state and local leaders, even at a time when precipitation had apparently returned to normal.

5. ASSESSMENT

Despite its severity, Oklahomans had few surprises during the event. A billion-dollar drought a decade earlier had awoken Oklahoma leaders to the effects of drought, spurring development of a new drought plan and most importantly, new drought tools and institutional partnerships that proved effective for communicating information during subsequent episodes. The system and plans were fine-tuned in several drought episodes over the intervening decade, leaving a system that performed beyond expectations at its most critical juncture.

One factor that substantially increased resiliency was the OWRB's Financial Assistance Program. The Program was established in 1983 to address challenges faced by communities and rural water systems who had wrestled with a severe drought three years earlier. The Program created a water/wastewater project loan and grant program to increase the ability of cities and towns to withstand future drought episodes and keep pace with community growth. From the initial $25 million investment, the Program has directly funded more than $1.6 billion in facility

Figure 13. Drought Update summary issued by OCS.



Oklahoma Drought Update
Oklahoma Climatological Survey
Climate Information Group
January 26, 2006

This document is provided to update Oklahoma's citizens and decision-makers with weather and climate information related to the state's ongoing drought and drought-related wildfires. The data summarized here are updated daily at the Oklahoma Climatological Survey Drought Update: http://climate.ocs.ou.edu/drought.

Summary

Data from the Oklahoma Mesonet and Oklahoma Climatological Survey indicate that most of the state is experiencing drought on multiple time scales. For most regions, the current episode ranks among the modern climate record's five most severe events for analogous seasons. The historical magnitude is especially severe in southeast, east-central, northeast and south-central Oklahoma. The southeast has experienced drought or near-drought conditions dating to 2002, with a distinct intensification in spring 2005. Summer and fall 2005 marked a northward expansion of severe drought to fill much of the state's eastern third. December 2005 brought further intensification and westward expansion into the remainder of the state.

Historical Rank of the Current Drought

These are the historical rankings of recent rainfall on seven different timescales. Each is compared to a history made up of the 85 such time periods since 1921. For example: a rank of "3rd" for west-central Oklahoma's 90-day rainfall indicates that the 90-day total (Oct 27, 2005 through Jan 24, 2006) is the 3rd-driest such period of the 85 on record.

	Time Scale						
OK Region	30-Day	60-Day	90-Day	120-Day	180-Day	365-Day	Two-Year
1-Panhandle	16th	23rd	16th	31st	21st	27th	56th
2-N. Central	20th	7th	5th	19th	27th	19th	46th
3-Northeast	7th	1st	2nd	1st	5th	5th	21st
4-W. Central	27th	10th	3rd	21st	50th	37th	64th
5-Central	7th	1st	1st	3rd	23rd	13th	27th
6-E. Central	4th	1st	1st	1st	2nd	2nd	12th
7-Southwest	9th	1st	2nd	8th	37th	20th	43rd
8-S. Central	13th	1st	2nd	4th	14th	6th	22nd
9-Southeast	24th	2nd	2nd	1st	2nd	1st	8th
OK-Statewide	6th	1st	2nd	3rd	19th	6th	25th

Historical Rank: Among five driest.
Historical Rank: 6th through 10th driest.
Historical Rank: Among driest quarter.

Description: Cells show the historical rank of recent precipitation on seven time scales. Values are compared to analogous periods ending Jan. 24th. There are 85 such periods in the modern climate history (since 1921).

Information from the Oklahoma Fire Danger Model (OKFD Model)

The OKFD Model's fall output suite is updated hourly at the Mesonet AgWeather pages: http://agweather.mesonet.org

Keetch-Byram Drought Index (KBDI) on Jan 24, 2006. KBDI is an indicator of drought's impact on wildfire danger. As values increase, more subsurface organic matter is available as fuel for wildfire. This causes fires to be more energetic and difficult to extinguish. For comparison, average January KBDI ranges from about 20 in eastern Oklahoma to 295 in the panhandle.

OKFD Model Burning Index (BI) at 2:00 pm Jan 24, 2006. The BI yields expected flame height in tenths of feet. For example, values of 60-79 in much of Grady County suggest potential flame lengths of 6-8 feet. BI values are highly dependent on hour-to-hour weather changes. During early January, afternoon BI values exceeded 200 across much of Oklahoma.

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Days since Significant Rainfall

The following maps show the consecutive days with less than one-quarter or one-tenth inch of rain at each of the 116 Oklahoma Mesonet stations. A substantial number of stations have not observed significant rainfall since October. These graphics underscore the recent westward expansion of drought conditions from eastern Oklahoma.

Consecutive days with 0.25" rainfall or less, as of Jan 24th.

Consecutive days with 0.10" rainfall or less, as of Jan 24th.

Historical Rainfall Variability

An examination of Oklahoma's rainfall history suggests a prevailing wet-dry cycle of about 5-10 years. This graphic displays statewide annual rainfall since 1895. Droughts of the 1910s, 1930s and 1950s emerge as brown lobes. Until recently, the state enjoyed a sustained period of relatively wet conditions dating to the 1980s. This period of prolonged wetness – to which many Oklahomans grew accustomed – is unmatched in the state's recorded rainfall history. Similar graphics are available by season and by month, for precipitation and temperature at http://climate.ocs.ou.edu.

Assessment and Forecast from a National Perspective

U.S. Drought Monitor January 17, 2006

The US Drought Monitor (http://drought.unl.edu) is a multi-agency assessment of the nation's broad-scale drought conditions. Categories symbolize various levels of "unusualness". Severity is based on climate observations and impact assessments from local, state and regional experts. OCS serves as Oklahoma's primary voice to Drought Monitor authors.

U.S. Seasonal Drought Outlook Through April 2006

The Drought Outlook is published monthly by NOAA's Climate Prediction Center (http://www.cpc.noaa.gov). It offers the forecaster's "best estimate" outlook for development and improvement of drought, based on various climate models and long-range techniques. The skill of long-term forecasts (beyond a week) is much, much less than 5-day, or even 7-day forecasts.

For more information …

Please contact the OCS Climate Information Group for more information about these and other products.

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improvements. Having completed these improvements over the previous two decades contributed to Oklahoma communities and rural water districts being able to withstand a much longer, more severe drought episode than the one in 1980 that had caused so many water supply issues for them. The importance of the OWRB Financial Assistance Program is not accounted for in the state drought plan, but is clearly a long-term mitigation measure for drought.

With regards to the specific performance of the Drought Plan, it should be noted that there were several requirements that were never formally activated during the 2005-2006 drought. This does not imply that the Plan necessarily should have been followed in all instances; rather improvisation may have improved agency performance during the event and it may be that the Plan should be revised. It should also be kept in mind that the Drought Monitor did not exist at the time the Drought Plan was adopted, in 1997. Many monitoring and reporting procedures in the state plan may have been superseded by the ongoing process of assembling the weekly Drought Monitor maps.

Beginning with the monitoring process, the Drought Plan requires the *Water Resources Bulletin* to be published bi-weekly at the stage of 'incipient drought' and weekly from "mild drought" until conditions begin to improve. It was not until December 21, 2005 that the *Bulletin* went bi-weekly and it never did go to weekly publication. According to the schedule, the *Bulletin* should have gone to bi-weekly publication in early April, when D0 was introduced into the state, and almost immediately to weekly publication when D1 (moderate drought) was introduced a week later. If severe drought rather than mild drought is used as a criteria, the publication should have been weekly beginning May 10, when D2 was introduced.

In retrospect, it is clear that the criteria set forth in the plan were too stringent. First, there is no evidence that more frequent reporting would have changed outcomes. The mere presence of the *Bulletin* provided a resource to decision-makers that was not available during previous episodes. A formal study of the process, including interviews with top decision-makers, should be undertaken to assess if more frequent reporting was desired, but anecdotal evidence suggests that was not the case. Perhaps a more reasonable criteria, balancing the need for information with the workload demands of producing the *Bulletin*, would be for bi-weekly publication at the D2 stage and weekly e-mail distribution of the Drought Monitor map and narrative.

Remaining focused on the monitoring aspect, the Drought Plan requires the Water Availability Outlook Committee (WAOC) to meet monthly beginning with the Alert stage (D1) and continuing until a return to Advisory conditions (D0). During the 2005-2006 drought episode, the WAOC never formally met. Again, this requirement may have been superseded by the existence of the Drought Monitor. The group meeting requirement was intended to encourage communication among monitoring agencies. Many of these individuals participate in the Drought Monitor discussions each week, either formally through the national listserve or informally among themselves, as well as providing data to the *Bulletin*. It appears that there was no lack of communication among these agencies during the event. It might be prudent for the WAOC to meet on at least an annual basis, regardless of drought status, to encourage familiarity with each other as personnel engaged in the process change, and perhaps quarterly during drought episodes, but monthly meetings do not appear to have been needed.

Perhaps the single area where the process would have benefited from following the plan more closely was the activation of the Impact Assessment and Response Committee (IARC). The IARC never formally convened during the event; rather the response was *ad hoc* much as previous drought episodes had been. There was coordination among key agencies, effectively those who would be members of the IARC, but the lack of a formal process inhibited the flow of impact information to other members of the Drought Team, primarily to those engaged in monitoring efforts.

A key requirement of the IARC is that the committee is supposed to issue "a report of the state's current drought impact situation and associated recommendations" to the Drought Coordinator and Drought Team Members after each meeting (held as often as needed). No such reports were issued. Instead, those monitoring the situation had to rely upon other channels of reporting to corroborate what the indicators seemed to be suggesting. In fact, the resurgence of drought during the summer of 2006 was first identified by an individual farmer/rancher who reported the impacts to the National Drought Mitigation Center, which then forwarded the report to members of the WAOC via the Drought Monitor process.

Similarly, the Interagency Coordinating Committee (ICC) never formally convened. This is not to suggest a lack of coordination; in fact the leadership of the primary drought management and response agencies – Oklahoma Emergency Management, Oklahoma Water Resources Board, and Oklahoma Department of Agriculture, Food, and Forestry – were in frequent contact with each other and with the Governor's Office. It has not been ascertained when these communications began in earnest and how that corresponded to the Plan timeline. The ICC is required to convene and take command at the Emergency stage (severe drought, D2). In practice, this timeline should probably be replaced by designation of D3, extreme drought, which is a much less frequent occurrence. Most episodes of severe drought can be managed sufficiently through regular agency processes informed by the WAOC and IARC.

Another requirement of the ICC is issuance of a final report when it disbands. Such a document would serve an important purpose of identifying weaknesses in the drought management process, that can be used to revised the Drought Plan accordingly. However, the manner in which the drought episode ended – an immediate transition into disastrous floods – shifted the attention of the top decision-makers and left little time for a *post mortem*.

None of this is intended as an indictment of the Drought Plan or the process. In fact, the issues that were addressed during formulating the plan clarified many organizational responsibilities that improved the response during subsequent episodes. Creation of a routine publication, the *Water Resources Bulletin*, was a major development. At a minimum, it keeps the potential for drought on the forefront of people's minds, including those representing the media. To date, 226 issues of the *Bulletin* have been published since its inception in 2000.

As we continue to monitor rainfall patterns, we should pause and realize how vulnerable we remain to the effects of water, both too little last year and too much now. Water management is a critical issue for Oklahoma, both in managing excess to limit damages and preserving sufficient resources for the dry times. Climate change scenarios suggest that this will only get worse in coming decades. The value of an active process of monitoring and communication has been demonstrated through this event.

ACKNOWLEDGEMENTS

The authors want to extend their appreciation to the countless individuals who provided advice, guidance, and input during the severe drought episode. In particular, we wish to acknowledge the Drought Monitor authors who continue to work so tirelessly to improve our awareness and understanding of drought: Brian Fuchs, Ned Guttman, Mike Hayes, Tom Heddinghaus, Richard Heim, Doug LeComte, Dave Miskus, Brad Rippey, Mark Svoboda, Candace Tankersley and Rich Tinker. We also extend appreciation to Victor Murphy from the NOAA NWS Southern Region Headquarters, who provided a great deal of input through the Drought Monitor process each week. Last, and by no means least, we appreciate the heroic efforts of Oklahoma's firefighters and emergency managers who had to endure so much hardship during the wildfire outbreaks.

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