A REAL TEST FOR THE GEORGIA DROUGHT MANAGEMENT PLAN – DROUGHT INDICATORS AT WORK AND GEORGIA'S RESPONSE TO THE 2006 – 2008 DROUGHT

Wei Zeng and Inchul Kim

AUTHORS: [1]Georgia Environmental Protection Division, 2 Martin Luther King Jr. Dr., SE, Suite 1058 East Tower, Atlanta, GA 30334.
REFERENCE: *Proceedings of the 2011 Georgia Water Resources Conference*, held April 11–13, 2011, at the University of Georgia.

Abstract. Georgia Drought Management Plan (Drought Plan), which was approved by Georgia Department of Natural Resources Board On March 26, 2003, experienced the first comprehensive test by the 2006-2008 drought. Signs of drought conditions first appeared in the spring of 2006. With the exception of a short period of relatively healthy precipitation in the fall of 2006, hydrologic conditions deteriorated in the next year and half, reaching a height in late 2007. The impacts of the drought lingered on through 2008 and early 2009, before heavy precipitation ended this dry period. Georgia Environmental Protection Division has been monitoring the drought indicators prescribed by the Drought Plan. A suite of measures was put in place as responses to lessen the impacts of the drought. Conditions in 2010 seem to resemble those in 2006, raising the potential that another dry period is down the road.

INTRODUCTION

In March 2003, Georgia Department of Natural Resources (DNR) and Georgia Environmental Protection Division (EPD) published Georgia Drought Management Plan. The Plan sets forth a process of monitoring and determining the formation and progression of drought conditions. It also sets forth the procedure by which a drought response is declared.

On a regular basis, EPD staff monitors hydrological and meteorological conditions such as stream flows, lake levels, precipitation, and groundwater levels. These data are provided and routinely updated by various resource agencies, such as U.G. Geological Survey, U.S. Army Corps of Engineers, and National Drought Mitigation Center. Such data, when processed to show deviation of current or recent conditions from long-term norms, serve as Drought Indicators. On monthly basis, EPD staff process the raw data to derive values of all Drought Indicators and inform decision-makers of any changes.

Among Georgia's nine Climatic Divisions (CDs) (Figure 1), each one has between five to 10 Drought Indicators covering two to three types of hydrological conditions. For example, in CD 2 (north central Georgia) there are ten Drought Indicators representing conditions in precipitation, reservoir storage, and stream flow. In CD7 (southwest Georgia), there are eight Drought Indicators representing precipitation, stream flow, and groundwater conditions. (See Georgia DNR 2003 for details.)

Depending on the severity and extent of dryness, thresholds and levels have been established for each of the indicators. With the formation and progression of a drought, one or more of the indicators will pass the thresholds and reach certain levels. For example, for all indicators, probability of recurrence is used to link indicator values to drought levels. A probability of 0.20 to 0.35 (1 in 3 years to 1 in 5 years of recurrence) puts an indicator into Level One. A recurrence of 1 in 5 to 1 in 10 years would put an indicator into Level Two. A probability of 1 in 10 years to 1 in 20 years would put an indicator into Level Three, and a probability of less than 1 in 20 years would put it into the 4^{th} level (Figure 2).

According to the Drought Plan, when any one of the numerous indicators reaches a certain level for two consecutive months, a preliminary evaluation by the State Climatologist and EPD Director is triggered. If the preliminary evaluation indicates that there might be the need for a drought response declaration for any one of the Climatic Divisions, then the Director will consult with members of the Drought Response Committee to determine the potential severity of the drought and it impacts. The Director will then make a determination of an appropriate level of drought response.

It is important to caution the readers against confusing the level of drought severity, as shown by the indicators, with the level of drought response. The former is a technical concept that shows the comparison between the current conditions and historical ones. The latter reflects a policy resulting from the former. Depending on the severity and impacts of a drought, there are four levels of drought responses. For Municipal and Industrial water users, the responses include restrictions on the timing of outdoor watering to a complete ban on outdoor watering.

Since March 2003, the hydrological conditions have been such that no dry conditions had been severe or long enough to warrant a declaration until the year 2006.

In June 2006, a Level One Drought Response was declared.

This paper reviews the drought monitoring efforts and the first utilization of this method in determining a drought condition and the subsequent drought response. The focus of this paper is the technical aspects of the process. It is the authors' hope that this paper will provide useful information when the Drought Plan is reviewed for potential revision.

The Drought of 2006 – 2008. Signs of dryness began to emerge in the spring of 2006, as precipitation and stream flow crossed their corresponding thresholds and reached various levels in Georgia's Climatic Divisions. For example, in CD 2, after March 2006, six-month Standard Precipitation Index (SPI-6), stream flow at Chestatee River near Dahlonega, and stream flow at Etowah River at Canton reached Drought Classification Level 1 (Figure 3).

In CD 4, SPI-6 and stream flow at Flint River at Montezuma reached Level 1 as early as February 2006. In Climatic Division 7, SPI-6 and stream flow at Ichawaynochaway Creek near Milford reached Level 1 after March 2006 (Figure 4). For Climatic Division 9, the early sign came into existence after April 2006, when stream flow at Satilla River at Atkinson reached Level 1.

By June 2006, most of the Drought Indicators across the state reached Level 1 or above. Some of them reached Levels 4, the highest in Drought Classification (Figures 3 and 4). On June 21, 2006, after consultation with members of the Drought Response Committee, EPD Director declared a Level 1 Drought Response across the State.

Through the spring and summer months of 2006, dry conditions across the entire state continued to deteriorate. Multiple stream flow indicators reached Level 4 after July 2006. All 5 indicators (3 precipitation and 2 stream flow indicators) in Climatic Division 8 reached level 4 after August 2006. Stream flow condition in Climatic Division 9 reached level 4 in November 2006.

Not too long after some of the indicators reached the highest level, conditions in some of the Climatic Divisions started to improve. Five out of six indicators for Climatic Division 1 started falling after October 2006. Six out of ten indicators for Climatic Division 2 fell after the same month. Six out of nine indications for Climatic Division 3 were at a lower level after October 2006. A few of the indicators for Climatic Division 5 improved to lower levels after November 2006. Such temporary improvement did not occur in Climatic Divisions 6, 8, and 9 until the beginning of 2007. In any case, the improvement proved to be short-lived.

By the end of April 2007, people's hope for a return to hydrological normalcy had all but disappeared. Whatever temporary improvement after several month of near normal precipitation, especially in the northern part of the state, was over. Drought Indicators in all CD's were mostly in elevated state, and some were at Levels 3 and 4 (Figures 3 and 4). A state-wide Level Two Drought Response was declared by the Director of Georgia EPD.

The lack of normal precipitation persisted through the summer and fall of 2007, leaving streams with extremely low flows and reservoirs to dangerously low levels not seen before. Composite storage of the federal reservoirs in the Apalachicola-Chattahoochee-Flint (ACF) River system dropped from more than 1.4 million acre-feet in March 2007 to just over 500,000 acre-feet, or about a third of the system capacity, in a matter of eight months (Figure 5). This was at least partly the result of extremely low inflows to the system. By our calculation, Basin Inflow had hovered around two to three thousand cubic feet per second (cfs) for prolonged period in the summer and fall. The lowest Basin Inflow was around 1,500 cfs (Figure 6).

As the drought deteriorated, Drought Indicator values reached unprecedented levels. By October 2007, all but one of the ten indicators were at Level 4 classification in CD2 (Figure 3). In CD7, six of the eight Drought Indicators were at Level 4 by July 2007 (Figure 4).

The drought's impacts were deeply felt too. A Level Four Drought Response was announced in September 2007, prohibiting outdoor watering by all residential water users.

The total outdoor watering ban lasted a little less than two years for tens of north Georgia Counties. Some flexibility was provided as Georgia EPD considered and granted petitions from water users outside the upper portion of the Chattahoochee Basin for deviations from the state-wide restrictions. This is denoted as Drought Response Level 4' in Figures 3 and 4.

The progression of this drought was also unequivocally documented by tracking of cumulative deficit in precipitation in Georgia's Climatic Divisions. (See Figure 7 for CD3.) US Drought Monitor (http://www.drought.unl.edu/dm/monitor.html) shows both temporal and spatial variations of the extent of this drought. We provide a selection of the snap shots in Figures 8 through 11. The overall deterioration of hydrological conditions as well as the spatial heterogeneity can be clearly seen from these figures.

Below normal precipitation ended in early 2008 in northern Georgia, but a few month earlier in southern Georgia. Our short-tem precipitation indicators for CD2 were mostly back to normal since March 2008 (Figure 3). For CD7, this took place as early as November 2007 (Figure 4). However, the effects of the drought lingered on. It took another 10 months before stream flow conditions were somewhat back to normal and about a year and a half for the reservoirs to recover to normal elevations.

In June 2009, the State of Georgia declared the drought over and outdoor residential water use was allowed to go back to normal schedules. At this point, short- and mid-term precipitation indicators were back to normal. Stream flow indicators still showed some dryness a few months after the declaration. The full recovery of the reservoirs took a little longer.

CONCLUSIONS

The 2006 – 2008 drought was the first one by which the State of Georgia's Drought Management Plan was in effect and tested. In terms of detecting a developing drought, the indicators worked well. Elevated indicator values correspond well to the inception and the height of the drought.

One shortcoming of the Drought Indicators is the coarse spatial resolution. The entire state is divided into nine CDs, with each one incorporating multiple counties and overlapping multiple river basins. It is not easy to form drought response measures tailored to specific counties or river basins using data that are representative of the CDs.

The lack of soil moisture data in the Drought Indicators may be another aspect that can be improved upon. The amount of moisture in the soil serves as indicators of potential runoff. Lower soil moisture means lower runoff potential when compared with higher soil moisture with the same amount of precipitation.

When the drought was nearing its end, the drought monitoring system had a little difficulty in helping us determine whether the drought was indeed over. As of now, the lowering of Drought Indicator values require hydrological conditions to improve or stay as improved for four consecutive months. This is prudent practice, but it causes the indicators respond fairly slowly to improved conditions. This is one other reason for incorporating current soil moisture data into consideration, since a healthy soil moisture content, aside from back to normal precipitation, would surly signal the return to normalcy.

With the experience acquired in this drought, we are reasonably confident that the Drought Indicators are a reliable, although not at all predictive, tool in detecting chronicle drought conditions as those existed in the 2006 to 2008 period. The indicators also reflect well the extent of dryness and consequent impacts. The State used this tool successfully, in combination with information provided by the US Drought Monitor and State Climatologist's Office, in its determination to implement measures as responses to the challenge.

It is noted that conditions in September and October of this year (2010) were such that some of the Drought Indicators showed elevated values (Figures 3 and 4). All signs are pointing toward the possibility of another dry spell in 2011. Georgia EPD's Hydrology Unit will be closely monitoring the Drought Indicators and other available information.

REFERENCE

Georgia Department of Natural Resources (2003). Georgia Drought Management Plan. Atlanta, Georgia, 2003.

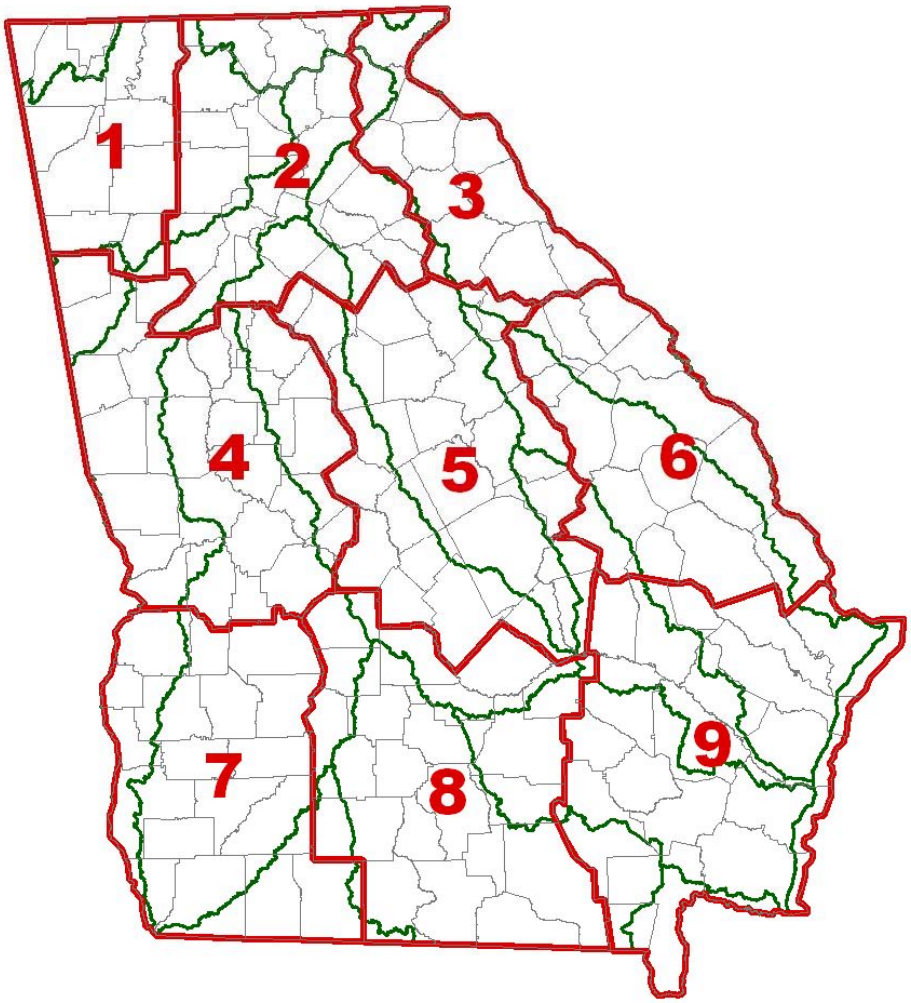


Figure 1. Georgia's nine Climatic Divisions

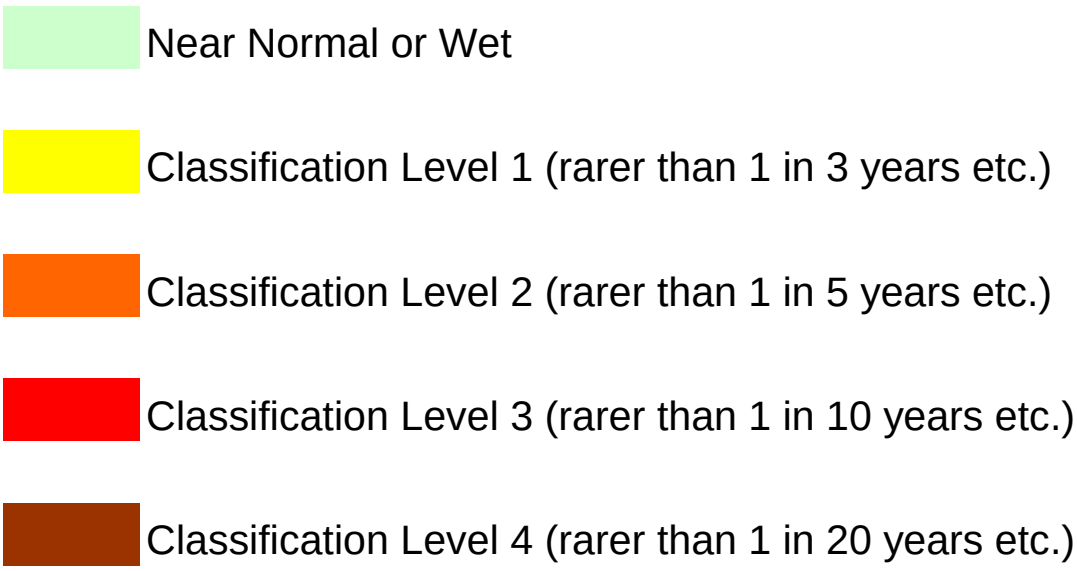


Figure 2. Levels of drought classification and color-code expression

Date	SPI-3 (2)	SPI-6 (2)	SPI-12 (2)	Lake Lanier (2)	Lake Lanier GC (2)	Lake Allatoona (2)	Etowah at Canton PCT (2)	Etowah at Canton AAD (2)	Chestatee near Dahlonega PCT (2)	Chestatee near Dahlonega AAD (2)	Drought Response Level
Jan-06	0	0	0	0	1	0	0	0	0	0	
Feb-06	0	0	0	0	1	0	0	0	0	0	
Mar-06	0	1	0	0	1	1	1	0	1	0	
Apr-06	1	1	0	0	1	2	2	0	2	0	
May-06	3	1	0	1	1	2	2	0	2	0	Level 1
Jun-06	3	2	0	2	2	2	3	4	2	0	←
Jul-06	1	2	0	2	3	2	3	4	2	3	
Aug-06	1	3	1	2	3	2	3	4	3	3	
Sep-06	1	3	1	2	4	2	3	4	3	3	
Oct-06	0	1	1	2	4	2	1	1	0	1	
Nov-06	0	0	1	1	4	1	0	1	0	0	
Dec-06	0	0	1	1	4	1	0	1	0	0	
Jan-07	0	0	1	0	3	1	0	1	0	0	
Feb-07	0	0	1	0	3	1	0	1	0	0	Level 2
Mar-07	2	0	1	0	3	1	2	1	1	0	←
Apr-07	2	1	1	1	1	1	2	1	1	0	
May-07	4	3	2	1	1	2	3	4	3	3	
Jun-07	4	4	2	2	1	3	3	4	3	4	
Jul-07	4	4	2	2	3	3	3	4	3	4	
Aug-07	3	4	2	2	4	2	3	4	3	4	Level 4
Sep-07	3	4	3	2	4	2	4	4	4	4	←
Oct-07	4	4	4	3	4	4	4	4	4	4	
Nov-07	4	4	4	3	4	4	4	4	4	4	
Dec-07	2	4	4	4	4	4	4	4	4	4	
Jan-08	1	4	4	4	4	3	4	4	4	3	
Feb-08	1	3	4	4	4	2	4	4	3	3	
Mar-08	0	2	4	4	4	1	3	3	2	1	
Apr-08	0	1	4	4	4	0	3	3	2	1	Level 4’
May-08	0	1	4	4	4	0	3	4	3	4	←
Jun-08	1	1	4	4	4	1	3	4	3	4	
Jul-08	1	1	4	4	4	1	3	4	3	4	
Aug-08	1	1	3	4	4	1	3	4	3	4	
Sep-08	0	1	2	4	4	0	3	4	3	3	
Oct-08	0	1	2	4	4	0	4	4	3	3	
Nov-08	0	1	2	4	4	0	4	4	3	3	
Dec-08	0	0	1	4	4	0	4	4	3	3	
Jan-09	0	0	1	4	4	0	0	0	0	0	
Feb-09	0	0	1	4	3	0	0	0	0	0	
Mar-09	0	0	1	4	3	0	1	0	1	0	
Apr-09	0	0	1	4	4	0	1	0	1	0	End
May-09	0	0	0	3	4	0	0	0	0	0	←
Jun-09	0	0	0	3	3	0	0	0	0	0	
Jul-09	0	0	0	2	3	0	2	4	1	0	
Aug-09	1	0	0	2	3	0	2	4	1	1	
Sep-09	1	0	0	2	3	0	2	4	1	1	
Oct-09	0	0	0	0	3	0	0	0	0	0	
Nov-09	0	0	0	0	1	0	0	0	0	0	
Dec-09	0	0	0	0	1	0	0	0	0	0	
Jan-10	0	0	0	0	0	0	0	0	0	0	
Feb-10	0	0	0	0	0	0	0	0	0	0	
Mar-10	0	0	0	0	0	0	0	0	0	0	
Apr-10	1	0	0	0	1	0	0	0	0	0	
May-10	1	0	0	0	1	0	0	0	0	0	
Jun-10	1	0	0	0	1	0	0	0	0	0	
Jul-10	0	0	0	0	1	0	1	1	0	0	
Aug-10	0	0	0	0	1	0	1	1	0	0	
Sep-10	0	0	0	0	1	0	1	1	0	0	
Oct-10	0	0	0	0	1	0	2	3	0	0	

Figure 3. Drought Indicator values in Georgia Climatic Division 2 (2006 - 2010)

Date	SPI-3 (2)	SPI-6 (2)	SPI-12 (2)	Spring near Iron City PCT (2)	Spring near Iron City AAD (2)	Ichawaynochaway at Milford PCT (2)	Ichawaynochaway at Milford AAD (2)	Groundwater (2)	Drought Response Level
Jan-06	0	0	0	0	0	0	0	0	
Feb-06	0	0	0	0	0	0	0	0	
Mar-06	0	1	0	0	0	1	0	0	
Apr-06	2	1	0	1	0	2	0	0	
May-06	3	1	0	1	1	2	0	0	Level 1
Jun-06	3	1	0	1	1	2	0	1	←
Jul-06	2	2	1	2	4	3	3	1	
Aug-06	2	4	2	3	4	3	3	1	
Sep-06	2	4	2	3	4	3	1	1	
Oct-06	1	2	2	0	3	2	0	1	
Nov-06	0	1	2	0	3	2	0	1	
Dec-06	0	1	2	0	1	1	0	1	
Jan-07	0	0	2	0	1	0	0	1	
Feb-07	0	0	2	0	0	0	0	0	Level 2
Mar-07	0	0	2	0	0	1	0	0	
Apr-07	2	1	2	1	0	3	0	1	←
May-07	3	2	2	2	1	3	0	2	
Jun-07	4	3	3	4	4	4	4	3	
Jul-07	4	4	3	4	4	4	4	3	
Aug-07	4	4	2	4	4	4	4	3	Level 4
Sep-07	1	4	2	4	4	4	4	3	
Oct-07	1	3	3	4	4	4	3	3	←
Nov-07	0	2	3	4	4	4	1	3	
Dec-07	0	1	3	4	4	4	1	4	
Jan-08	0	0	3	4	4	2	0	4	
Feb-08	0	0	3	0	0	0	0	2	
Mar-08	0	0	1	0	0	0	0	2	
Apr-08	0	0	1	0	0	1	0	1	Level 4’
May-08	0	0	1	1	0	1	0	1	←
Jun-08	2	0	0	3	4	3	1	2	
Jul-08	2	1	0	4	4	3	1	2	
Aug-08	2	1	0	4	4	3	1	2	
Sep-08	0	0	0	0	0	0	0	1	
Oct-08	0	0	0	0	0	0	0	0	
Nov-08	0	0	0	0	1	0	0	0	
Dec-08	0	0	0	0	1	0	0	0	
Jan-09	0	0	0	0	0	0	0	0	
Feb-09	0	0	0	0	0	0	0	0	
Mar-09	1	0	0	0	0	1	0	1	
Apr-09	1	0	0	0	0	1	0	1	End
May-09	0	0	0	0	0	0	0	0	
Jun-09	0	0	0	0	0	0	0	0	←
Jul-09	0	0	0	0	1	0	0	0	
Aug-09	1	0	0	0	1	0	0	0	
Sep-09	1	0	0	0	1	0	0	0	
Oct-09	1	0	0	0	1	0	0	0	
Nov-09	0	0	0	0	1	0	0	0	
Dec-09	0	0	0	0	1	0	0	0	
Jan-10	0	0	0	0	0	0	0	0	
Feb-10	0	0	0	0	0	0	0	0	
Mar-10	0	0	0	0	0	0	0	0	
Apr-10	0	0	0	0	0	0	0	0	
May-10	0	0	0	0	0	0	0	0	
Jun-10	0	0	0	0	0	0	0	0	
Jul-10	0	0	0	0	1	0	0	0	
Aug-10	0	1	0	2	3	1	0	0	
Sep-10	2	1	0	3	4	1	0	0	
Oct-10	2	1	0	4	4	2	0	1	

Figure 4. Drought Indicator values in Georgia Climatic Division 7 (2006 - 2010)

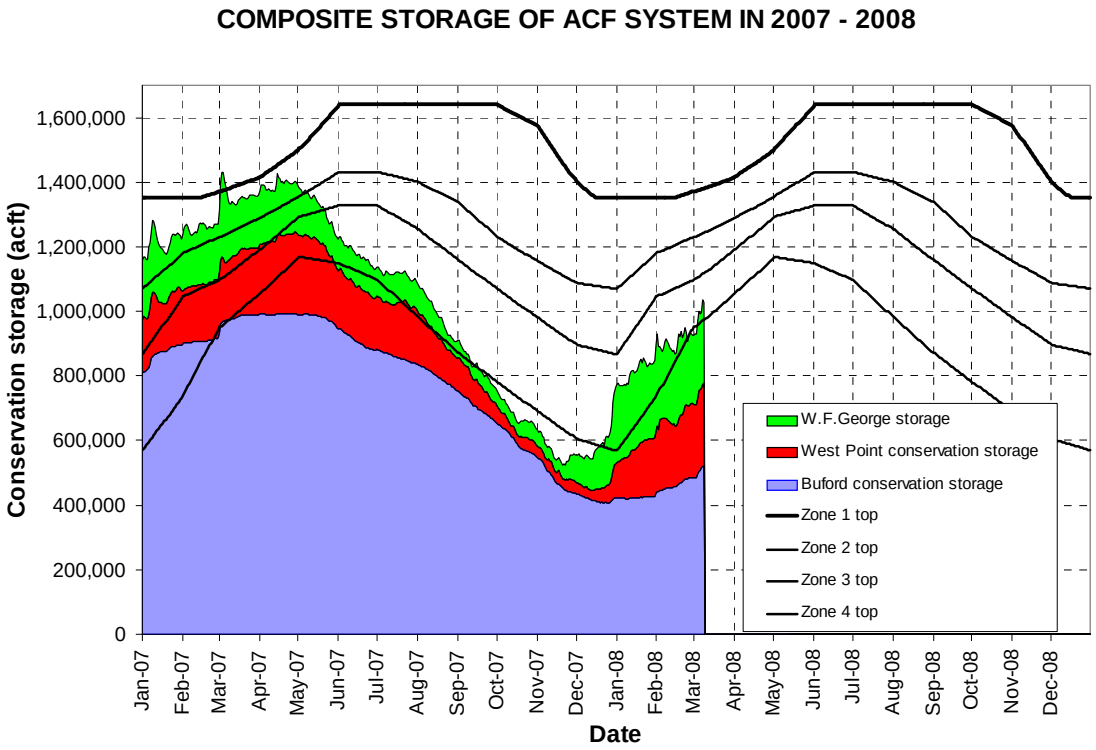
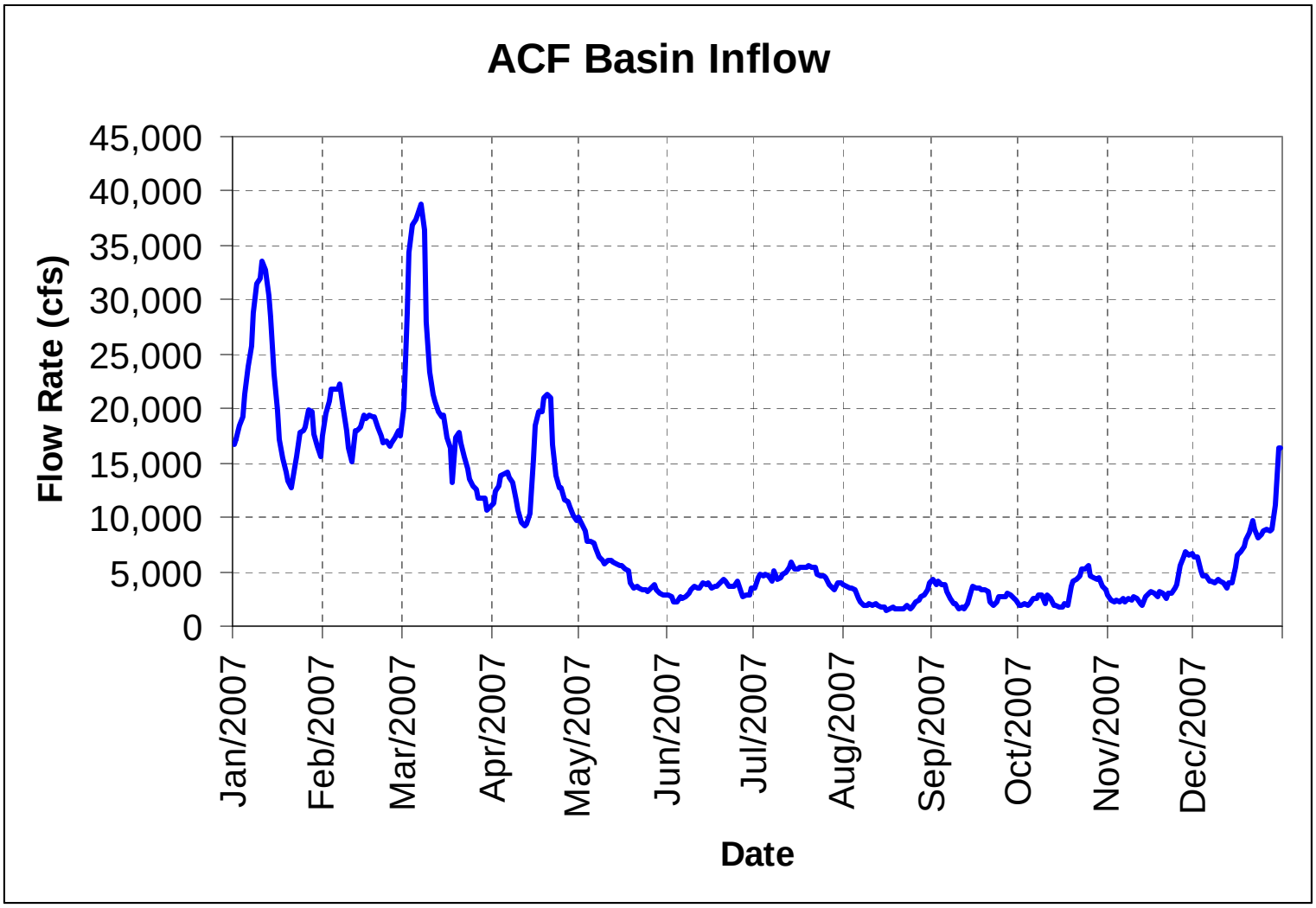


Figure 5. Composite storage in the Apalachicola-Chattahoochee-Flint River system in 2007 to 2008


ACF Basin Inflow
Flow Rate (cfs)
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan/2007
Feb/2007
Mar/2007
Apr/2007
May/2007
Jun/2007
Jul/2007
Aug/2007
Sep/2007
Oct/2007
Nov/2007
Dec/2007
Date

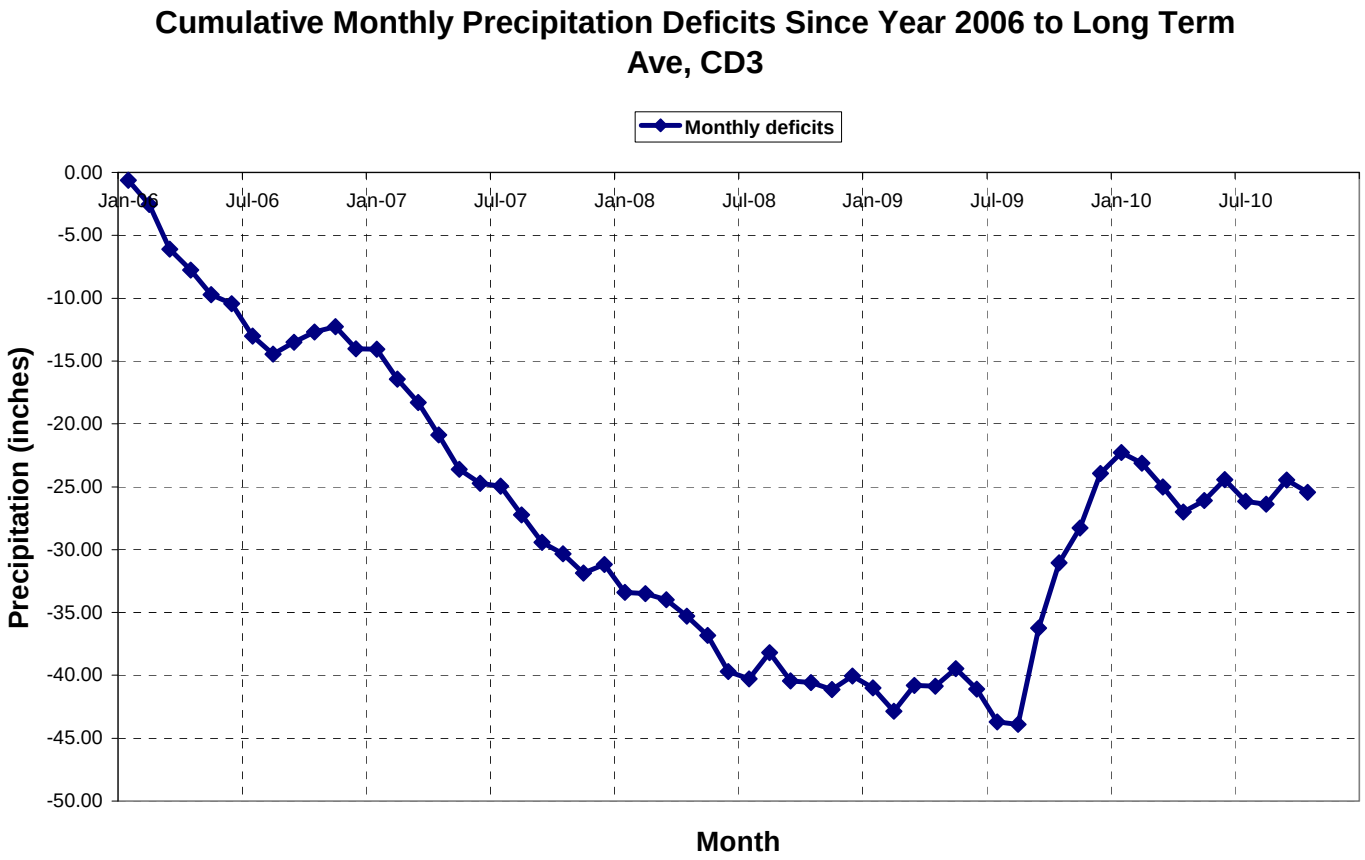


Figure 7. Cumulative precipitation deficit in CD3

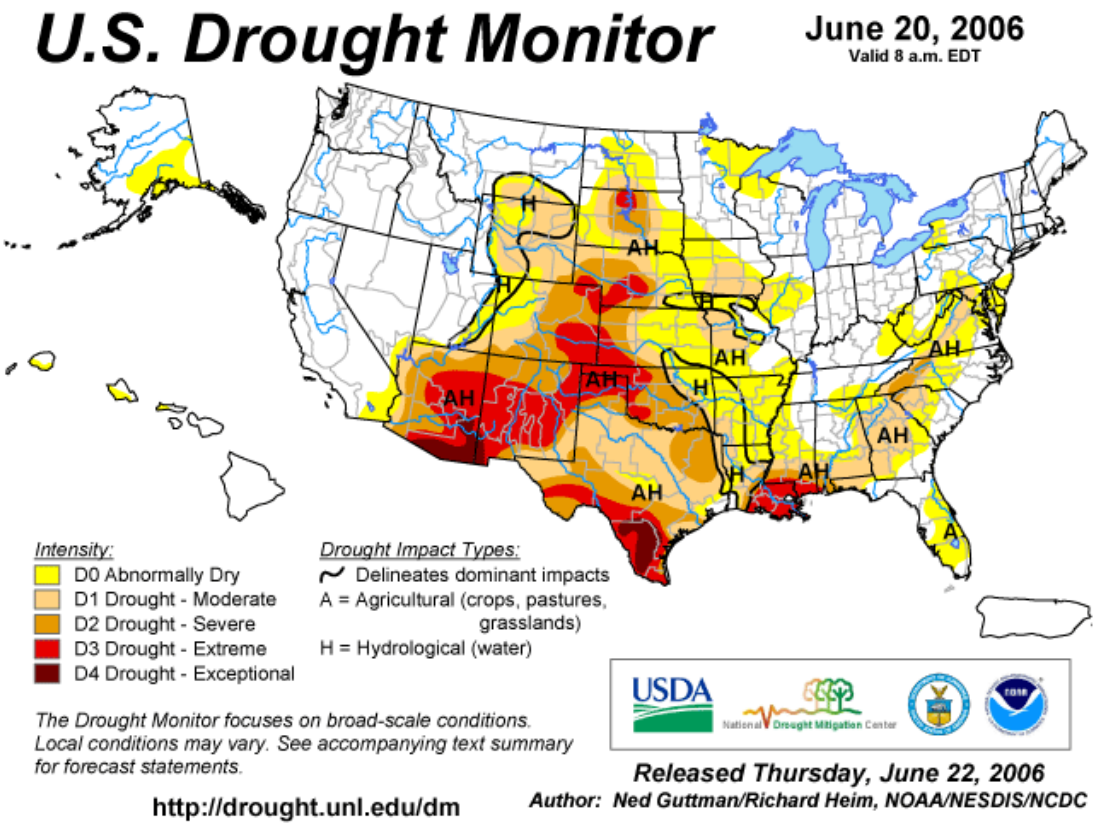


Figure 8. Early stages of the drought – US Drought Monitor – June 20, 2006

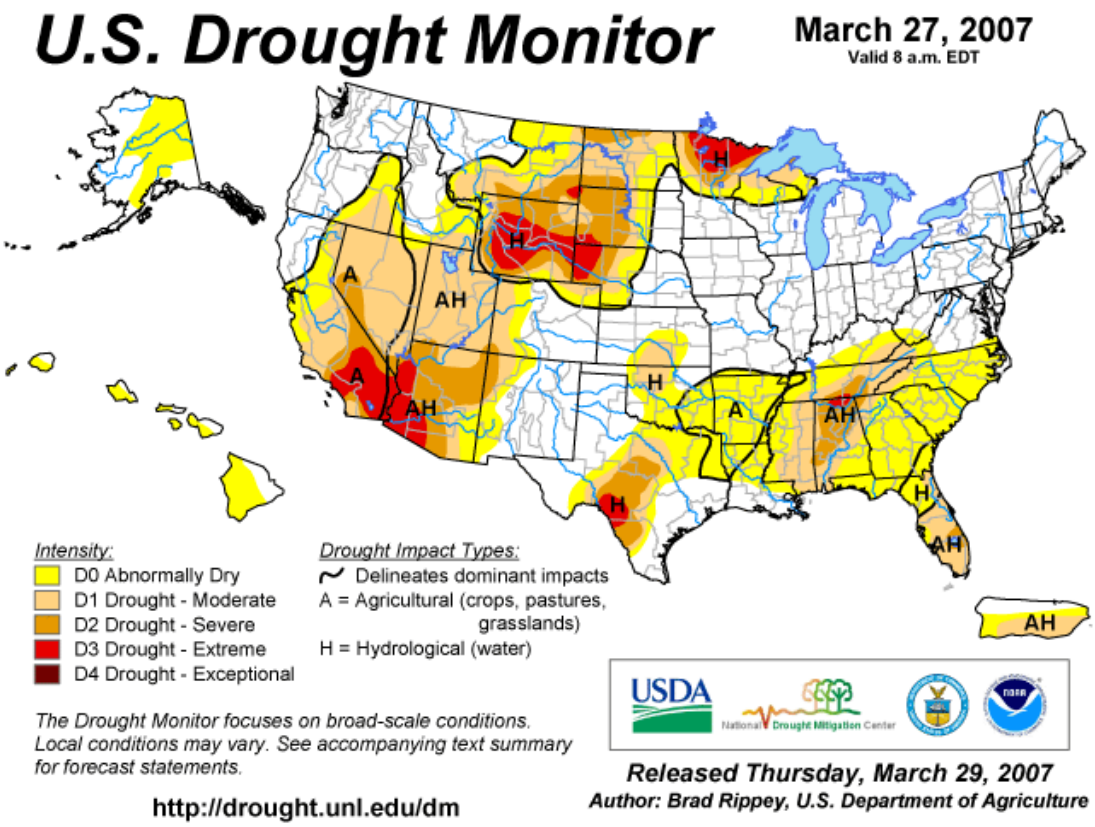


Figure 9. Beginning of the plunge – US Drought Monitor – March 27, 2007

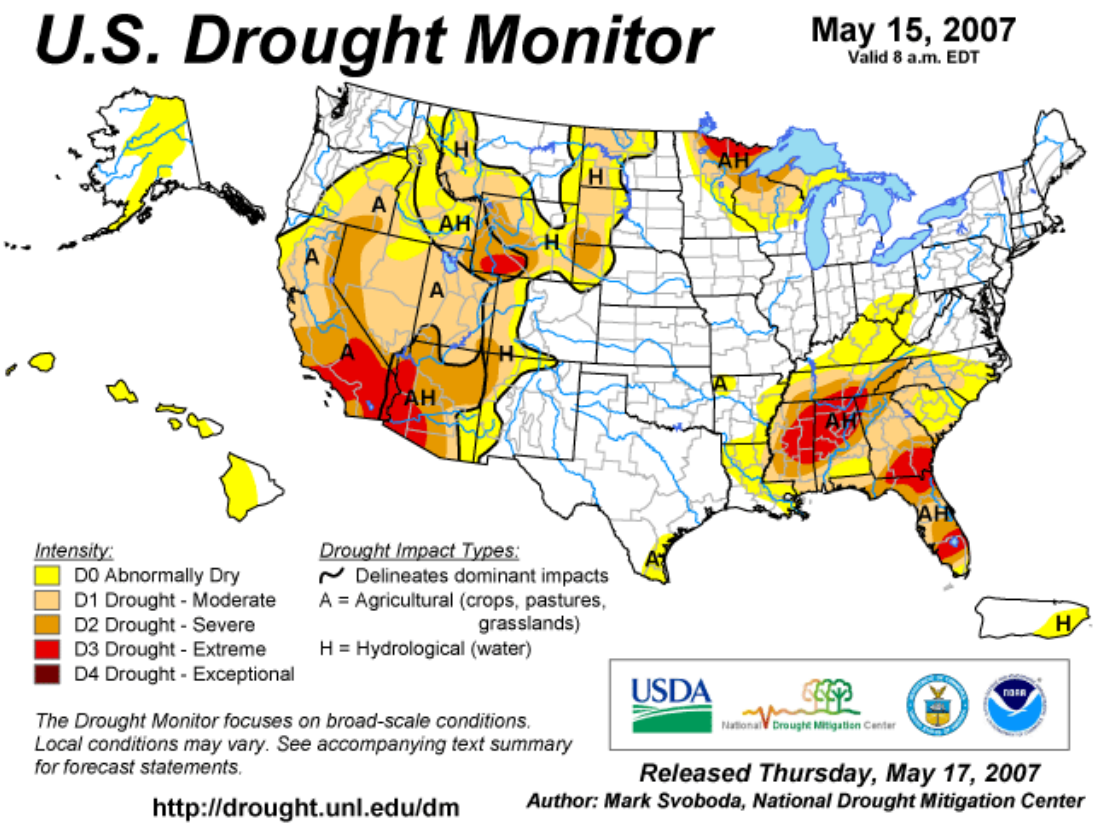


Figure 10. Conditions deteriorate – US Drought Monitor – May 15, 2007

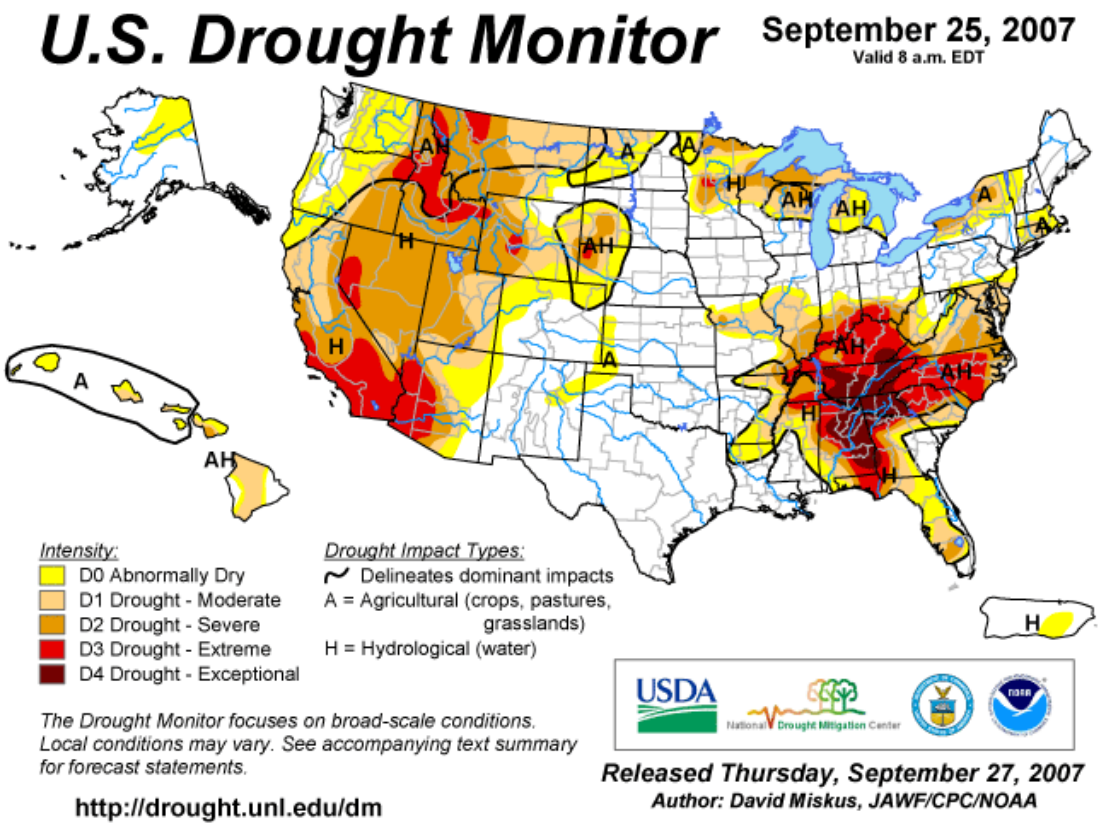


Figure 11. Height of the drought – US Drought Monitor – September 25, 2007