DROUGHT IN SOUTHWEST GEORGIA AND THE USE OF ENSEMBLE STREAMFLOW PREDICTION

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Abstract. Ensemble Streamflow Prediction (ESP) was used to produce medium to long-range streamflow forecasts at two sites within the upper part of the Flint River Basin in Georgia.

Forecasts using ESP for mean monthly streamflows from July through September 2000 were produced. These were compared to actual streamflows by using provisional data from the U.S. Geological Survey (USGS).

ESP has been used mainly assuming that each year of meteorological data is equally likely to occur in the future. This means that equal yearly weights are assigned. In this paper, an alternative is presented, that of deriving variable yearly weights based on precipitation outlooks. Precipitation outlooks issued by the National Oceanic and Atmospheric Administration (NOAA) through the Climate Prediction Center (CPC) were used in this study.

Curves showing probability of exceedance were derived for equal and variable weights. It is thought that variable weights should be adopted; however, further investigation on their derivation is suggested. An evaluation of the range of influence of initial conditions should also be considered so that a meaningful forecast window can be determined.

INTRODUCTION

During water years 1999 and 2000, several sites within the Flint River Basin in Southwest Georgia have experienced new minimum monthly streamflows for most of the summer season. In addition, several sites in the area recorded precipitation deficits, with some having record rainfall deficits. Southwest Georgia could be categorized as a zone of hydrologic drought during this period.

The occurrence of extreme events (floods and/or droughts) highlights the need for improved water planning schemes. One of the tools available at the National Weather Service (NWS) that could prove to be helpful for planning purposes is Ensemble Streamflow Prediction (ESP). This can be used to produce medium to long-range probabilistic streamflow and streamflow related forecasts. The discussion in this paper is focused on the use of ESP to investigate the effects of initial conditions and test the use of weights based on precipitation outlooks.

ESP was initially used to forecast monthly streamflows from July to December 2000. Later, these predicted flows were compared to the monthly flows computed by the U.S. Geological Survey (USGS). It was decided that the incorporation of a climatological outlook could be helpful in the forecast results.

Currently the NWS is working toward linking the future precipitation predictions with the generation of probabilistic forecasts. That capability was also tested using the Climatic Prediction Center's (CPC) outlook for precipitation. The CPC forecast results were then compared to forecasts that did not include CPC input.

HYDROLOGIC CONDITIONS

The Southwest Georgia area was classified by the National Weather Service (NWS) as the driest area within the state of Georgia for several months within water year 2000. Several indices can be used to categorize the drought, and one of them is the Palmer Drought Severity Index (PDSI). Developed by Palmer in 1965, it is a "meteorological" drought index and responds to weather conditions that have been abnormally dry or wet. When conditions change from dry to normal or wet, for example, the drought measured by the PDSI ends without taking into account streamflow, lake and reservoir levels, and other long-term hydrologic impacts.

Based on the PDSI issued by the NWS on June 10, 2000, the lower part of the Flint River Basin was depicted as one of "extreme drought" within the state of Georgia. A week later, the same index showed the entire Flint River Basin under the category of "extreme drought." The National Oceanic and Atmospheric Administration

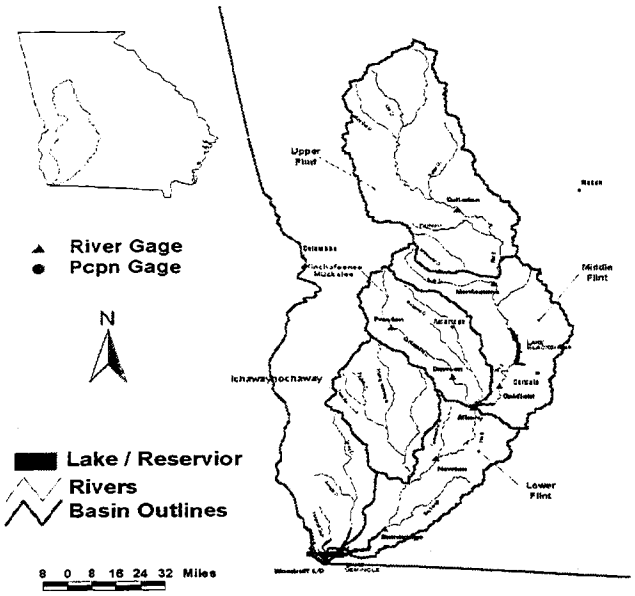

Figure 1. Flint River Basin, Georgia.

(NOAA) issues a seasonal drought outlook through the Climate Prediction Center (CPC). At this time, the outlook classified this area with a "likely to persist" drought during the period of June-July-August 2000.

Monthly precipitation deficits for water years 1999 and 2000 were computed for four selected sites within the area (figure 1). In the case of the precipitation station at Macon during the period of October-July of water year 2000, the deficit was already 14.9 inches greater than the total deficit registered during water year 1999. These deficits were reduced considerably during the months of August and September, mainly due to the rainfall produced by hurricanes that occurred that season. Therefore, when comparing totals for water years 1999 and 2000, the deficit in 1999 was the largest.

Provisional data provided by the U.S. Geological Survey for water years 1999 and 2000 were used to examine the streamflow conditions in the Flint River at the following sites: Culloden, Montezuma, Oakfield, and Newton. In water year 1999, several of these sites set records for monthly minimum flows. During water year 2000, the flows were even lower, setting new records for most of the summer months. Because 1999 and the first two-thirds of 2000 were so dry, many low-flow records for the Upper Flint River were set.

From a hydrological perspective, a persistent drought condition emphasizes the need for improved water planning schemes. Consequently, the evaluation of tools that would aid in this planning is essential. That is the context under which ESP was tested in this paper.

ENSEMBLE STREAMFLOW PREDICTION (ESP)

ESP is a procedure for making medium and long-range probabilistic forecasts of streamflow and streamflow-related variables. It uses conceptual rainfall/runoff models within the National Weather Service River Forecast System (NWSRFS) to predict streamflow utilizing the current basin conditions (i.e., soil moisture, streamflow, and reservoir storage) with historical meteorological data. In this case, the meteorological data used is historical mean areal precipitation.

In this paper, the historical data comprised precipitation from 1950 to 1987 (37 years). This period contains parts of at least three of the major droughts in Georgia: 1950-57, 1980-82, and 1985-89 (National Water Summary 1988-89 Floods and Droughts: Georgia, U.S. Geological Survey, Water Supply Paper 2375).

The ESP procedure assumes that meteorological events that occurred in the past are representative of events that might occur in the future; thus, each year of historical precipitation data is used to simulate a possible future streamflow trace. The ensemble of streamflow traces can be statistically analyzed, resulting in probabilistic forecasts. ESP has the potential of assigning equal or variable weights among the years considered. Equal weights imply that each year represents an equally likely precipitation scenario. Variable weights imply that some years represent more likely scenarios and other years represent less likely scenarios. For instance, if the outlook indicates that drier than normal conditions are likely, then years that had less than normal precipitation would be given more weight, and years that had more than normal precipitation would be given less weight.

ESP results using equal and variable (CPC) weights will be discussed at two of the selected sites: Culloden and Montezuma. When equal weights were used, a weight of 0.026 was assigned to each of 37 years. When using variable weights based on CPC outlooks, yearly weights were assigned for each category listed on table 1.

Precipitation yearly, monthly, or seasonal totals can be used to group the data into categories and assign variable weights. In this study, the yearly totals were considered. The data is ranked by ascending magnitude of observed precipitation and then divided into three groups. The first group includes the years with the lowest yearly totals of rainfall, or the driest. The second group consists of the middle years, or the ones that are closest to average. The third group considers those years with the highest amount of rainfall, or the wet years. Based on meteorological models, the CPC outlook indicated that dry conditions were expected to continue through the study period.

Table 1. Total and yearly weights

		Equal		CPC	
Rank	Category	Weights using equally weighted years	Total of weights for this category	Weights using CPC outlook	Total of weights for this category
1-13	Dry	0.026	0.338	0.045	0.588
14-25	Average	0.026	0.312	0.026	0.312
26-37	Wet	0.026	0.312	0.006	0.062

This suggested that heavier weights should be given to the dry group. The total weights for dry years were assumed to be 0.25 percentage points higher than the average group(0.588 = 0.338 + 0.25), while for the wet years they would be 0.25 percentage points lower than the average group (table 1). The average group has the average weight that would be used if all three had equal weights. The increase or decrease of 0.25 was the maximum allowed by the program used, and it was selected to magnify changes in the results.

First, mean monthly flows were generated by running ESP with equal weights. The simulations were initialized with soil moisture conditions for June 15, 2000, and July 1, 2000. The results were used as indicators of the influence of the soil moisture conditions in the simulation. It was observed that the changes in streamflow are more noticeable for the first month (July), but as we go into the second and third months, the changes diminish, i.e., the influence of the initial conditions decreases.

Secondly, still using equal weights, mean monthly flows were forecast using ESP for the Flint River near Culloden and near Montezuma for July through September during water year 2000. These flows were later compared to the actual flows that occurred at those sites. The provisional monthly streamflow data obtained from the U. S. Geological Survey were much lower than those resulting from the ESP analysis (table 2). One of the reasons could be the equal weight given to all the years, when in fact the drought continued.

Based on these results, it was decided to test the changes that could be expected in the results if the CPC-derived weights were used. Since July 1, 2000, was used for the initial soil moisture conditions, the assumption was made that July would be the most sensitive month for the analysis. Hence the flows for

Table 2. Actual and ESP-derived mean monthly flows in cubic feet per second

	Flint River at Culloden			Flint River at Montezuma		
	July	Aug	Sep	Jul	Aug	Sep
ESP Eq. Wts	554	639	663	1019	1159	1059
Actual Flow USGS	85	198	814	511	542	961

different probabilities of exceedances, for equal and CPC-based weights, are depicted in figures 2 and 3.

It can be observed in figures 2 and 3 that the probability of reaching or exceeding a flow decreases if the conditions are heavily weighted toward the dry category, as it was done in the CPC scenario. The inverse could be expected if the heavy weight is placed in the wet category.

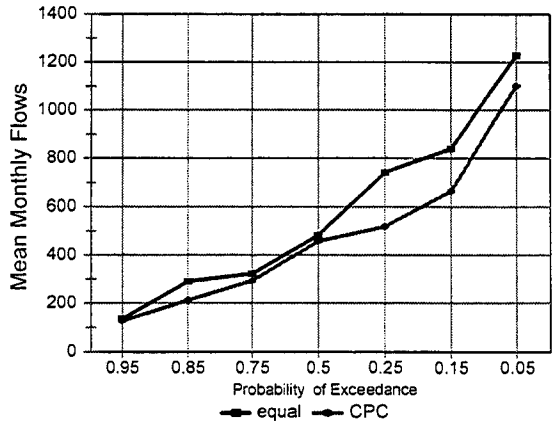

Figure 2. Probability of exceedance for Culloden.

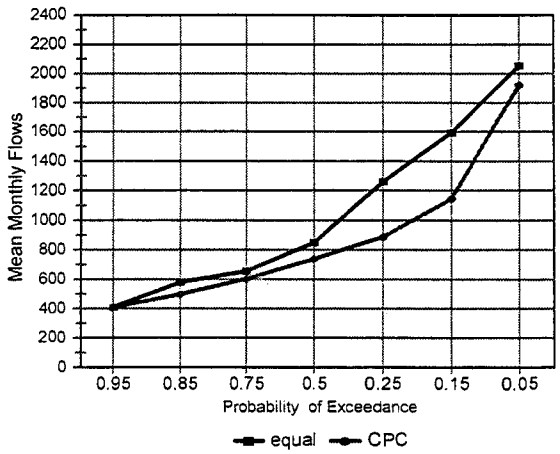

Figure 3. Probability of exceedance for Montezuma.

SUMMARY AND CONCLUSIONS

During water years 1999 and 2000, several sites in Southwest Georgia experienced record low monthly flows and high precipitation deficits, classifying this area as a zone of hydrologic drought. The occurrence of extreme events (floods and/or droughts) demonstrates the need for water planning schemes. ESP is a program used by the NWS to produce medium to long-range probabilistic streamflow forecasts. This program could prove to be a most helpful tool for planning purposes.

This paper describes a test performed to show the capabilities of ESP. Probabilistic forecasts for mean monthly flows were computed at two sites: Flint River at Culloden and Flint River at Montezuma. These flows were compared to those that actually occurred. Based on the results, it was decided that a precipitation outlook should be incorporated into probabilistic forecasts. Once this was accomplished, curves of probability of exceedance were generated to compare curves of variable weights to curves of equal weights.

It is thought that when an outlook exists, such as the one produced by CPC, one should benefit from it and use variable weights. This would provide the user another scenario to aid in the management of water resources.

The tool exists, but it is still in its infancy; therefore, future work needs to be done to improve results. Further research should include the determination of a meaningful forecast window, i.e., determine how long initial soil moisture conditions influence the streamflow forecast. An evaluation of the methodology for assigning weights would be beneficial. If different weighting methods and/or outlooks are developed, a family of exceedance curves could be developed, representing the different scenarios.

Some ESP products, using equal weights, are available for selected basins within the forecast area covered by the Southeast River Forecast Center. The application of ESP could be valuable for planning purposes, and there is a great interest in making it available.

SELECTED REFERENCES

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