New Jersey Water-Supply Drought Indicators

Introduction

Precipitation in the form of rain and snow varies naturally from year to year, and droughts occur when less precipitation than normal falls for an extended period of time. A water-supply drought is declared when the volume of water needed is greater than what is available. Several droughts a decade may be experienced and most of the time all of the State is not effected equally. Defining the hardest hit areas helps to manage the water supply. Droughts can also begin or end quickly or slowly. Deciding when a lack of precipitation has become a threat to water supply is determined by: (1) amount of water in storage, (2) anticipated water demands, (3) the severity of the precipitation deficit, and (4) specific water sources in a region.

New Jersey experienced a drought during 1998 and 1999. When it was over, the New Jersey Department of Environmental Protection (DEP) analyzed the factors affecting the State's water resources and its response to the situation. The State's ability to manage the situation was made difficult by not having a way to compare the severity of drought in different parts of the State and then communicate this information to the public.

In response to these difficulties, the DEP devised a set of drought indicators to monitor regional water-supply sources. The indicators are designed to: (1) integrate large amounts of data about water-supply sources; (2) communicate to the public and decision makers accurate information; (3) be reasonable; (4) be based on real-time data; and (5) be distributed quickly over the Internet.

There are drought indicators for precipitation, streamflow, reservoir levels, and groundwater levels. Each is assigned to one of four conditions: (1) near or above normal, (2) moderately dry, (3) severely dry, or (4) extremely dry. New Jersey is divided into six drought regions (fig. 1) and indicators are evaluated for the water-supply sources important to each (fig. 2). These are updated weekly during dry periods and the results are available on the Internet.

These indicators are not triggers that automatically cause a change in drought status. DEP water-supply professionals evaluate them with best professional judgment and input from purveyors and recommend an appropriate drought status for each region (normal, watch, warning or emergency). The DEP Commissioner has the authority to declare drought watches and warnings, but only the Governor can declare or lift a drought emergency.

Before 2000 New Jersey had declared only drought warnings and emergencies, but now an additional stage, drought watch, has been added. A drought watch is a period of time that will allow DEP staff and water-supply professionals to prepare for the more serious levels of warning and emergency.

In addition to developing indicators, DEP has increased drought monitoring by adding stream and precipitation gages, and observation wells. Much of the data collected are now available on the Internet within hours of being measured. Improved communication between purveyors and DEP has also helped improve overall management of the State's water resources.

This effort is solely aimed at better defining and managing water-supply droughts. There are other kinds of droughts, such as agricultural or ecological, that would require different indicators than those discussed here.

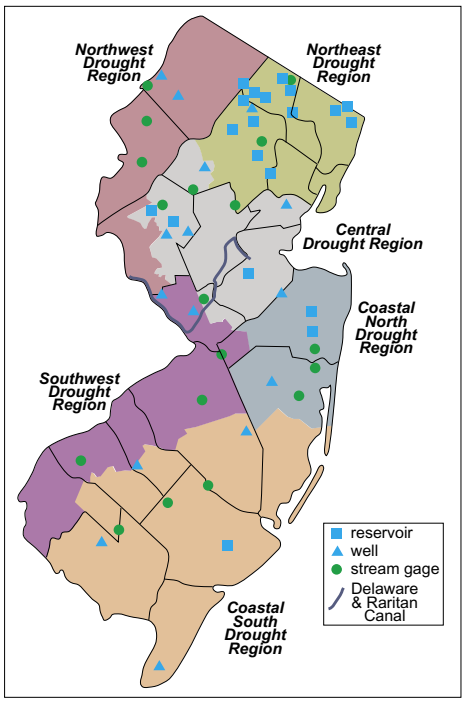

Figure 1. Drought regions, stream gages and wells in New Jersey.

Drought Regions

Drought regions allow the State to respond to changing conditions without imposing restrictions on areas not experiencing water-supply shortages (Hoffman, 2001). New Jersey is divided into six drought regions (fig. 1) that are based on regional similarities in water-supply sources and rainfall patterns. These generally correspond closely to natural watershed boundaries. Region boundaries match municipal boundaries in order to facilitate enforcement of potential water-use restrictions.

Drought Region	Reservoirs		Rivers	Unconfined Ground Water
	New Jersey	DE River Basin		
Northeast	■	□	■	■
Central	■	■	■	■
Coastal North	■	□	■	■
Coastal South	■	□	■	■
Northwest	■	■	■	■
Southwest	□	■	■	■

■ major ■ minor □ none

Figure 2. Water-source importance to New Jersey's water supply by drought region.

Drought Indicators

The goal of each drought indicator is to summarize the status of a single factor affecting water supply in a given region. The DEP plans to update the drought indicators biweekly during wet periods and weekly during dry times.

As seen in figure 2, not all sources of water are of equal importance to the supply of a given region. Drought indicators are evaluated only for those water supplies that are significant for each region.

Precipitation

When there is less precipitation than normal New Jersey experiences drought. But just a few dry days, or even a month of dry weather, doesn't create a water-supply drought. It takes several months of less than average rainfall to do this.

The difference between the actual amount of precipitation measured during a month and the historical average for that month is either a negative or positive number, indicating a deficit or surplus, respectively (fig. 3). The monthly surplus or deficit can vary significantly from month to month and is not a good indicator of a water-supply drought. A better method is to use a running 3-month total (fig. 3). This number is the surplus or deficit in a given month added to the values of the two previous months. To use this indictor on a daily basis, precipitation during the previous 90 days is compared to average in past years. These data come from the Office of the New Jersey State Climatologist at Rutgers University, New Brunswick, New Jersey and the National Weather Service's Middle Atlantic River Forecast Center.

Reservoirs

Reservoirs help ease the effects of water-supply droughts by collecting and storing

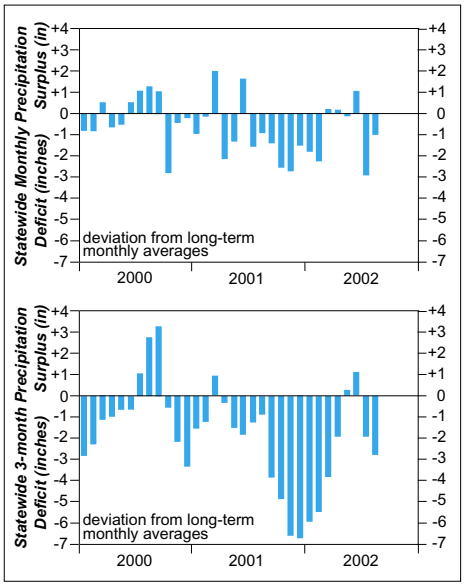

Figure 3. Monthly and 3-month precipitation surplus/deficit for New Jersey, January 2000 - August 2002.

water for use during dry periods. New Jersey has a system of reservoirs, primarily located in the northern part of the State (fig. 1).

Reservoir water levels are normally high in the spring and low in the fall. A "rule curve" is a graph that shows the normal storage in a reservoir during the course of a year. This kind of graph may also show expected storage at the beginning of a drought watch, a warning or an emergency. Figure 4 is a rule curve for combined storage in the New York City reservoirs in the upper Delaware Basin. Most reservoir systems have a similar set of curves that are used to show storage conditions.

On figure 4 the long-term median storage volume is shown in blue. The purple line shows actual volumes between January 1, 2001 and August 14, 2002. For this reservoir system, the approximate start of drought watch, warning and emergency are shown. This particular system went into drought watch in October 2001, warning in November, and emergency in December 2001. It came out of these in March, April, and May, 2002, in reverse order.

In the northeast, central and coastal north

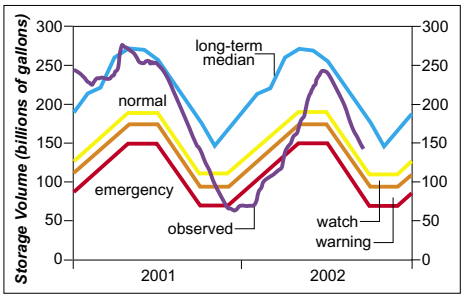

Figure 4. Delaware Basin Reservoir observed levels, January 2001 - September 2002, with rule curves. Data from Delaware River Basin Commission website.

drought regions of New Jersey, the status of reservoir levels are a major indicator of the overall drought conditions in the region. However, it is possible that a region's drought status might be different from what reservoir levels in the region indicate. This is because the drought status is based on more than just the conditions of one water-supply source. This is especially true for drought regions where reservoirs are not a significant contributor to the overall water resources of the region.

Reservoirs in one region may be important to other regions. For example, the reservoirs in the Delaware River basin in New York are important to both New Jersey's northwest and southwest drought regions. These regions are part of the Delaware River Basin and take some water from the river. But the New York reservoirs are also important to the Central drought region, which roughly coincides with the Raritan River Basin. In normal conditions the Delaware and Raritan Canal (fig. 1) moves 100 million gallons of water per day from the Delaware watershed to the Raritan watershed. During a declared drought emergency the volume decreases to 65 million gallons per day.

Stream Flow

The water in a stream comes from precipitation. In the form of rain, some will run off the ground surface and go directly to a stream or brook. Some of the water also enters the ground and is released to the stream days, weeks, months or even years later. During dry times stream flow is sustained by ground-water discharge. Precipitation in the form of snow may remain on the ground unavailable for weeks or months until it melts.

Daily streamflow can fluctuate greatly from the impact of recent rains. At times, below average streamflow may be measured during wet periods. Conversely, above average streamflow may be measured during a drought. Therefore, daily streamflow is not a good indicator of water-supply droughts. However, when daily values are listed over a period of at least 90 days and compared to historical values, daily streamflow values become a more valuable indication of how wet or dry a region is.

The streamflow indicator is based on three stream gages in each drought region (fig. 1). Daily values are posted over the Internet by the United States Geological Survey (USGS). For each stream-flow gage the cumulative flow over the previous 90 days is compared to the average for that month of the year. The difference is then calculated and ranked on a percent scale where 0% is the lowest deficit ever measured for that month, and 100% the greatest surplus. This is calculated for three gages in each region and the results are averaged. If the average is less than 10% then the streamflow drought indicator for that region is classified as extremely dry. An average between 10% and 30% is severely dry, between 30% and 50% is moderately dry, and over 50% is near normal.

Ground-Water Levels

DEP developed a network of real-time ground-water observation wells across New Jersey (fig. 1). USGS posts water levels from these wells over the Internet (Jones and others, 2002). By September 2002 there were 15 wells in the Statewide network. The goal is to eventually have at least one well per county.

The DEP analyzed data from each well and calculated the median, lowest 10%, and lowest 30% level for each well and month. The ground-water drought status in each well is determined by comparing current reported ground-water levels to these calculated statistics.

Figure 5 shows water levels and calculated statistics in the Green Pond observation well in Morris County for January 1998 through August 2002. The four lines represent the observed water level (purple), the median water level (green), the 30% frequency line (orange), and the 10% frequency line (red). When the observed water level (purple) falls below the red line on the graph, the ground-water condition in that well is set to extremely dry. When it falls between the red and orange lines the condition is severely dry, between orange and green is moderately dry, and above the green line is considered near normal. The ground-water drought indicator in a region is based on the status of all wells in that region and that of wells in nearby regions installed in similar aquifers.

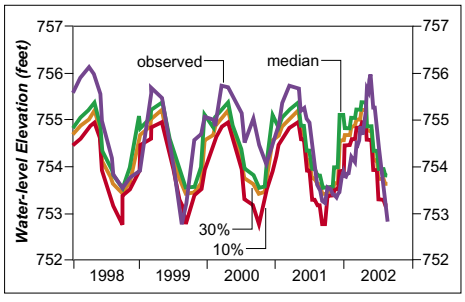

Figure 5. Water levels and calculated statistics in the Green Pond observation well.

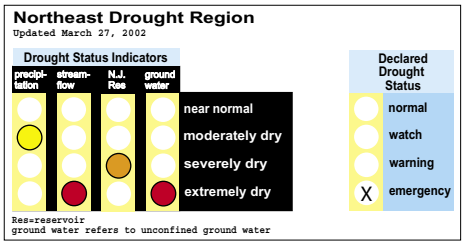

Figure 6. Drought indicators and declared drought status for the northeast drought region, March 27, 2002.

How the Indicators are Used

The drought indicators are designed to provide an overview of the general condition of water-supply sources in a region. Figure 6 is an example from the northeast drought region on March 27, 2002, and shows that the region was in a drought emergency at the time.

The New Jersey drought indicators are not triggers that automatically specify when a certain drought condition begins or ends. There are several reasons for this. First, different water sources vary in importance to the overall water supply in each region (fig. 2). Second, anticipating what the demand for water will be in the future is critical in determining an appropriate drought condition. Lastly, DEP staff and the State's water-supply purveyors apply professional experience and judgement when making a drought status declaration. The indicators current status and more drought information are listed on DEP's official drought Web site (www.njdrought.org).

References

Hoffman, J.L., 2001, Development of New Jersey drought regions: N.J. Geological Survey Technical Memorandum 01-1, 18p.

Jones, W.D., Navoy, A.S., Pope, D.A., 2002, Real-time ground-water-level monitoring in New Jersey, 2001: U.S. Geological Survey Fact Sheet FS-011-02, 4p.

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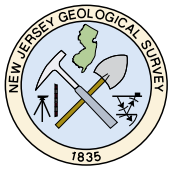

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