Climate Change and Drought Scenarios for Water Supply Planning

Analyses of the sensitivity of water availability (surface water and groundwater) and water demand to climate change and drought will be conducted for the water supply planning initiatives in north-east and east-central Illinois.

A. Climate Change and Water Demand Scenarios

Professor Ben Dziegielewski at Southern Illinois University is conducting climate change and drought sensitivity analyses for water demand in both regions with the Base Line scenario to 2050.

The base climate data for the scenarios, and the departure point for climate change and drought analysis, is the current climate normal period 1971-2000.

The climate change factors to 2050, selected by reviewing the climate scenarios for Illinois produced by 140 global climate model runs, are 0 to + 6 degrees Fahrenheit (F) and +/– 5 inches of precipitation http://www.sws.uiuc.edu/wsp/climate/ClimateTom_human.asp.

There is great variability in the simulation of regional climates by global climate models; therefore these factors should not be regarded as deterministic forecasts or predictions of future climate conditions. They represent a plausible range of possible future climate conditions.

Scientists currently treat the results of each model run as being equal, although extremes have been eliminated by selecting the 5th and 95th percentile limits of all the model runs, which thus encompass 90 percent of all model scenarios. Within the 5th and 95 percentile limits, the model results cover all scenarios in between. These time series are smoothed to reduce year-to-year variability while retaining the long-term features. The climate-change scenarios are based on many assumptions regarding, e.g. population, economic and emission growth rates, and varying climate model structures. Given the large uncertainty in the range of possible future climate change, refining the distribution of temperature across a year is not meaningful, and temperature change will be applied uniformly to all months. The change in temperature also will be applied across the years assuming a linear rate of change from 2000 to 2050.

Based on the ISWS Center for Atmospheric Sciences' recommendations, the following precipitation ranges are being used at year 2050: +2.5 to -3.5 inches for the growing season (May-August); +2.5 to -1.5 inches for the balance of the year. Based on the climate model scenarios of precipitation departures from the 1971-2000 norm, Dr. Dziegielewski is assuming all of the precipitation change will occur by 2015. These factors are applied to the public and industry and commerce sectors. They also are applied to the agriculture sector where an evapotranspiration factor was included as well (see below). In this initial study, analyses will not be conducted on the impacts of climate change on water demand for the electric power generation sector or for the other water demand scenarios. Such analyses may be conducted at a later date.

The Center for Atmospheric Sciences looked at the impact of increased temperature on rates of evapotranspiration and the potential for increased water deficits that would increase agricultural irrigation rates. It was determined that a factor of .1 inch of precipitation deficit should be used for each 1 degree F increase in temperature during the growing season. The application of this factor was later refined to application of 0.5 to 0.7 of the factor for May; 0.9 to 1.0 for June, and 1.0 for July and August. This refinement is not included in the water demand scenarios modeling, because the model is not designed for adjustments within the growing season and changing the model is not practical.

In addition to studying possible changes in average-day demand, possible changes in peak-day demand also will be examined. Peak-day withdrawal data from the IWIP program, some data from the Center for Watershed Science, and an engineering report for some Lake County communities have been gathered for north-east Illinois to develop peak-day withdrawal factors. These will be applied to the Base Line scenario.

B. Drought and Water Demand Scenarios

In addition to possible changes in mean annual temperature and precipitation, it can be expected that periodic droughts will occur in the future. There are significant differences in the impacts of short-term and long-term droughts. These differences generally are characterized with short-term droughts having a greater impact on average-day demand, whereas longer-term droughts have a greater impact on water availability.

The sensitivity of water demand to drought will be conducted on the Base Line scenario, consistent with the application of climate change sensitivity. For these drought studies the 1971-2000 precipitation for the growing season will be reduced by 40 percent to represent a worst-case historical drought. Average-day water demand during a worst-case historical drought will be calculated for the public, industrial and commercial, agricultural and irrigation, and domestic use sectors.

The impact of drought on water withdrawals is related significantly to the infrastructure capacity of each water supply system, and to water supply availability. Drought impact on water withdrawals also varies significantly depending upon the water supply source. Withdrawals during a drought are not limited by the source when the supply is Lake Michigan, although they are tempered by existing conservation measures and limited by system infrastructure capacities. Water withdrawals during a drought also generally are not limited by the source when the supply is a deep aquifer, but can be limited by infrastructure capacities. The impact on withdrawals during a drought when the supply is from a shallow aquifer depends on the aquifer's connectivity to the surface and on infrastructure capacities. The most direct impact on water withdrawals during a drought is when the supply source is a surface water supply, other than Lake Michigan, that is dependant on precipitation and shallow groundwater flow. Quite often it is estimates of peak-day demand that form the basis for water-facility operators to plan future facilities.

The ISWS water demand/analysis report will include examples of the impact of infrastructure and the source of supply on water demand during a drought and examples of the size and impact of peak-day factors. Through these examples, individual community water supply systems will be encouraged to analyze what is needed to be well prepared for a severe drought and peak-day demand.

Drought impacts on water demand will be studied in combination with the analysis below of drought impacts on water availability.

C. Drought and Climate Change Impacts on Surface Water Availability

The analysis of the impact of drought on surface water availability will start with the climate base being used for water demand: the 1971-2000 thirty-year data.
The impacts of climate change on water availability will be assessed for the years 2025 and 2050 for the Base Line scenario. The impact on surface water will incorporate climate change by using a temperature change scenario of + 6 degrees F at 2050. The temperature change factor will be halved for application to 2025. A precipitation change of -5 inches from the 1971-2000 annual normal will be used for a dry climate scenario. All of this precipitation change will be applied to both 2025 and 2050, consistent with the water demand climate change assumption that all precipitation change will occur by 2015.

The drought experiences of the mid-twentieth century (1931 through 1960) will be evaluated and included in the drought scenarios as appropriate, since the 1971-2000 data do not include an extended drought period. The 1931-1960 precipitation record represents the driest 30-year climate period on record for most Illinois locations, with 30-year average annual precipitation more than 3 inches below that of the 1971-2000 base-line condition. The 1931-1960 period also contains several extended droughts, which were not experienced in 1971-2000. For this reason, the 1931-1960 sequence of precipitation provides an alternate example of low-flow conditions for comparison to the -5” scenarios. There is no alternate historical sequence that provides a similar type of comparison to the +5” scenario, as the 1971-2000 base condition already represents the wettest 30 years on record.

Climate Change and Hydrology

<u>Simulated streamflows corresponding to hypothetical climate change scenarios</u>

1. Using a watershed model, simulate base-line streamflow conditions corresponding to 1971-2000 temperature and precipitation conditions.

2. Assuming no temperature increase, run the following conditions:

i. +5” annual adjustment to 1971-2000 precipitation (+2.5” summer precipitation; +2.5” precipitation for balance of year)
ii. -5” annual adjustment to 1971-2000 precipitation (-3.5” summer precipitation; -1.5” precipitation for balance of year)

3. Assuming a +3°F temperature increase to 2025, run the following conditions:
i. No change in precipitation
ii. +5” annual adjustment to 1971-2000 precipitation (+2.5” summer precipitation; +2.5”precipitation for balance of year)
iii.-5” annual adjustment to 1971-2000 precipitation (-3.5” summer precipitation; -1.5” precipitation for balance of year)

4. Assuming a +6°F temperature increase to 2050, run the following conditions:
i. No change in precipitation
ii. +5” annual adjustment to 1971-2000 precipitation (+2.5” summer precipitation; +2.5” precipitation for balance of year)
iii. -5” annual adjustment to 1971-2000 precipitation (-3.5” summer precipitation; -1.5” precipitation for balance of year)

5. Simulate streamflow using the 1931-1960 historical precipitation and temperature and compare to simulated flows using the scenario of a -5” annual adjustment to 1971-2000 precipitation and increasing temperature.

6. Simulate streamflows combining the effects of selected climate scenarios and scenarios of increases in future water demand, such as to simulate potential flow conditions in the year 2050. Potential additional discharges of treated waste water to streams will be included in the streamflow scenarios.

No model analysis of land-cover change is contemplated at this time. Available watershed models used to simulate the impact of land cover on flood magnitudes lack detailed simulation of the baseflow processes that might affect water supply availability in streams. In addition, results from available studies analyzing land-cover impacts on low streamflows show inconsistent trends. The ISWS analysis will discuss the current state of knowledge regarding land-cover impacts on baseflow, but will not investigate the impacts of alternate land-cover scenarios.

D. Drought and Climate Change Impacts on Groundwater Availability

Available data and tools are insufficient to characterize the impacts of changes in temperature and precipitation on groundwater recharge rates in Illinois. The results of a project to examine the relationships between climate variability (e.g., precipitation, soil moisture) and shallow groundwater levels using available WARM and ICN data will not be available until June 2009. However, available data from selected wells within the two study areas will be plotted and examined for usability.

As the Fox River Basin groundwater flow model allows, reduced baseflow conditions due to climate change/drought using the previously described scenarios of higher temperatures and lower precipitation will be used as streamflow targets in the Fox River Basin groundwater model with data supplied by the ISWS Center for Watershed Science. Similar reductions on tributary streams likely also will be assumed (e.g., if the Fox River model shows a 30 percent reduction in flow, it will be assumed that similar reductions in flow will occur on tributary streams such as Blackberry Creek, Mill Creek, etc.).

Initial model estimates of groundwater recharge and discharge will be made using the Pattern Recognition Organizer – Groundwater Recharge and Discharge Estimator (PRO-GRADE). PRO-GRADE was developed at the ISWS in cooperation with the Department of Civil and Environmental Engineering at the University of Illinois at Urbana-Champaign; it uses several image processing algorithms to extract spatial patterns from a simple mass-balance model based on three sets of commonly available data (hydraulic conductivity, water table and bedrock elevation data) to quickly estimate groundwater recharge and discharge rates. The software runs within the geographical information system package ArcGIS 9.2. PRO-GRADE can generate multiple alternative recharge and discharge maps within days. Those alternative maps can be either manually selected or systematically prioritized by using Spatial Pattern To Learn (SP2Learn) for further groundwater flow modeling. SP2Learn was developed at the ISWS in cooperation with the National Center for Supercomputing Applications, it uses machine learning algorithms to match the pattern of recharge and discharge maps with auxiliary data (e.g., soil type maps and surface water features).

Similar climate change impacts may be pursued for the Mahomet Aquifer groundwater flow model; however, not all impacted streams over the Mahomet are being modeled (Mackinaw R., Sugar Cr., Iroquois R., Middle and North Forks of the Vermilion R.) and those that are may not have generated output in time for the September 2008 report release. Further, the connectedness of shallow sands to these streams is much more speculative than, for example, in Kane County. Therefore, for the Mahomet Aquifer model simulations, selected recharge deficit scenarios (e.g., -10 percent) will be run in lieu of modeling attempts to match reduced fluxes to surface streams.

No analysis of climate change or drought will be performed on the deep bedrock model, as it is presumed to be immune to such changes over relatively extended time periods. ISWS scientists believe that the current data do not permit the identification of a firm drought signal in deep bedrock wells. Also, recent modeling of the deep bedrock using “wet” and “dry” scenarios suggests little difference in the results.

No model analysis of land-cover change is contemplated at this time. Groundwater flow modeling does not generally involve surface land-cover change, and it is beyond the scope of current ISWS work to speculate on what land-cover changes may occur between now and 2050. The ISWS’ water supply/demand analysis will conceptually address the issue of climate change and land-cover change impacts on groundwater recharge, including the state of knowledge regarding rates and recharge areas.

E. Water Level of Lake Michigan

The ISWS Center for Atmospheric Science is planning to run output from global climate models through the Great Lakes Water Levels Model developed by the Great Lakes Environmental Research Laboratory. An outline of the tasks, with final deliverables, follows:

1. Download monthly global climate model data for all available20th and 21st Century model runs for Intergovernmental Panel on Climate Change emissions scenarios (A2 (high), A1B (medium), and B1 (low) from data archives for the following variables:
    - Precipitation;
    - Temperature;
    - Wind speed;
    - Humidity;
    - Cloud cover;
    - Solar radiation.
2. Data file preparation:
    - Determine grid point index range;
    - Calculate climate change values by grid point and create one file for each variable in appropriate format.
3. Run the Great Lakes Water Levels Model.
4. Conduct statistical analysis of Lake Michigan lake level and analyze model output files:
    - Mean Lake Michigan level changes;
    - Extreme Lake Michigan level changes.
5. Prepare summary graphics.
6. Deliverables:
    - Lake level changes for 1 extreme model scenario;
    - Lake level changes for a spectrum of models/scenarios;
    - Update web page.

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