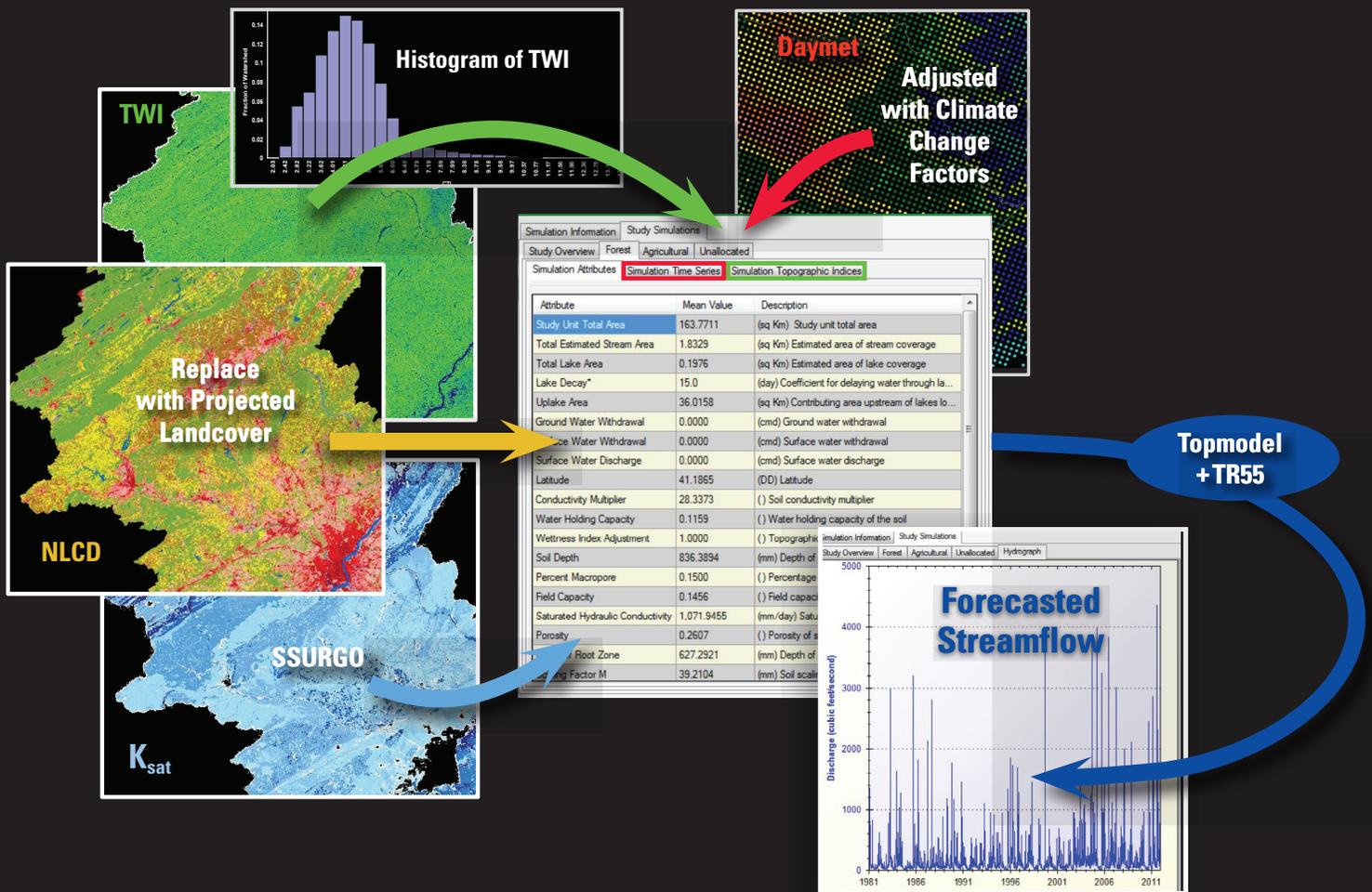


User Manuals for the Delaware River Basin Water Availability Tool for Environmental Resources (DRB–WATER) and Associated WATER Application Utilities



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By Tanja N. Williamson and Jeremiah G. Lant

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Conversion Factors

International System of Units to Inch/Pound

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
meter (m)	1.094	yard (yd)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km ²)	247.1	acre
square kilometer (km ²)	0.3861	square mile (mi ²)
	Radiative forcing	
watt per square meter (W/m ²)	0.3170	British thermal unit per hour per square foot

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

Abbreviations

cfs	cubic feet per second
DEM	digital elevation model
DRB	Delaware River Basin
DSS	decision support system
GCM	general circulation model
GUI	graphical user interface
HRU	hydrologic response unit
NLCD	National Land Cover Database
OASIS	Operational Analysis and Simulation of Integrated Systems
PET	potential evapotranspiration
PST	Planning Support Tool
RCP	representative concentration pathway
RMSE _n	Normalized Root Mean Squared Error
SSURGO	Soil Survey Geographic Database
TWI	topographic wetness index
T _{max}	maximum daily temperature
USGS	U.S. Geological Survey
WATER	Water Availability Tool for Environmental Resources

User Manuals for the Delaware River Basin Water Availability Tool for Environmental Resources (DRB–WATER) and Associated WATER Application Utilities

By Tanja N. Williamson and Jeremiah G. Lant

Abstract

The Water Availability Tool for Environmental Resources (WATER) is a decision support system (DSS) for the non-tidal part of the Delaware River Basin (DRB) that provides a consistent and objective method of simulating streamflow under historical, forecasted, and managed conditions. WATER integrates geospatial sampling of landscape characteristics, including topographic and soil properties, with a regionally calibrated hillslope-hydrology model, an impervious-surface model, and hydroclimatic models that have been parameterized using three hydrologic response units—forested, agricultural, and developed land cover. **It is this integration that enables the regional hydrologic-modeling approach used in WATER without requiring site-specific optimization or those stationary conditions inferred when using a statistical model.** The DSS provides a “historical” database, ideal for simulating streamflow for 2001–11, in addition to land-cover forecasts that focus on 2030 and 2060. The WATER Application Utilities are provided with the DSS and apply change factors for precipitation, temperature, and potential evapotranspiration to a 1981–2011 climatic record provided with the DSS. These change factors were derived from a suite of general circulation models (GCMs) and representative concentration pathway (RCP) emission scenarios. These change factors are based on 25-year monthly averages (normals) that are centered on 2030 and 2060. The WATER Application Utilities also can be used to apply a 2010 snapshot of water use for the DRB; a factorial approach enables scenario testing of increased or decreased water use for each simulation. Finally, the WATER Application Utilities can be used to reformat streamflow time series for input to statistical or reservoir management software.

Introduction

Development of the Water Availability Tool for Environmental Resources (WATER) for the Delaware River Basin (DRB) was done as part of the U.S. Geological Survey (USGS) Water Census focus area study. This work is part of implementation of the U.S. Department of the Interior Secure Water Act to Sustain and Manage America’s Resources for Tomorrow (WaterSMART, <http://water.usgs.gov/watercensus/WaterSMART.html>). WATER-DRB addresses multiple aspects of this work by providing a foundation to better understand streamflow, water use, and ecological water needs both for current conditions and for those associated with forecasted climate change and population expansion.

This report summarizes those data used to inform the model and describes how this decision support system (DSS) has been integrated with general circulation models (GCMs) and urbanization forecasts to provide resource managers with a way to objectively and consistently investigate water-management strategies. This report is separated into three sections:

1. This first section, “Focus Area and Geographic Limitations,” summarizes data sources, geographic extent of the DSS, and uncertainty associated with streamflow simulations.
2. The second section, “Instruction Manual for WATER,” explains how to install and use the WATER DSS.
3. The third section, “Instruction Manual for WATER Application Utilities,” explains how to install and use the WATER Application Utilities package.

For more detailed information about data sources, model development, the statistical evaluation process for streamflow simulations, and the uncertainty associated with streamflow simulation for historical and future time periods, see Williamson and others (2015).

Section 1. Focus Area and Geographic Limitations

The DRB encompasses 35,075 km² (13,539 mi²) and includes parts of Delaware, Maryland, New Jersey, New York, and Pennsylvania, including the population centers of Wilmington, Delaware; Philadelphia, Pennsylvania; and Trenton, New Jersey (fig. 1). The DRB occupies 0.4 percent of the continental United States, but provides water for 15 million people, about 5 percent of the U.S. population. The WATER DSS developed for the DRB includes the entire basin; however, there are some areas where WATER can provide general streamflow information but should be used cautiously. For example, WATER does not provide a method for simulating the influence of tides on streamflow, as would be expected in stream reaches downstream of Trenton along the Delaware River and in tributaries draining directly into Delaware Bay (fig. 2). Additionally, WATER does not incorporate controlled releases from dams and reservoirs in the Basin, so WATER will not accurately simulate flows on large rivers affected by these releases. This includes, in particular, the entire length of the main-stem Delaware River, but also parts of the East and West Branches of the Delaware River; Neversink, Lackawaxen, Mongaup, Lehigh, Musconetcong, Schuylkill, and Brandywine Rivers; as well as other locations (fig. 2). In anticipation of this constraint, WATER was designed to output streamflow simulations at river locations known to be inflow points for the Delaware River Basin Commission’s DRB-Planning Support Tool (PST) that incorporates the Operational Analysis and Simulation of Integrated Systems (OASIS) simulation software (<http://hydrologics.net/oasis.html>). If WATER is used to simulate streamflow for areas that include reservoirs, they will be treated as any other water body. Consequently, users should be familiar enough with their area of interest to understand whether or not streamflow is controlled by reservoir management.

Data Sources Provided with WATER and WATER Application Utilities

The DRB WATER DSS, referred to as “WATER” hereinafter, uses a process-based hydrologic model that was implemented with a spatial dataset that quantifies spatial variability in topography, climate, soil properties, and anthropogenic features that affect natural water movement in this five-state area (fig. 1). Although WATER was developed and implemented using historical data, the ultimate goal was to provide a DSS that could simulate streamflow under a broad range of forecasted climatic and land-use scenarios. Historical streamflow is simulated for 1981–2011, using the National Land Cover Database (NLCD), Soil Survey Geographic Database (SSURGO), and Daymet precipitation and temperature data (table 1). All spatial data are in the North American Datum of 1983 Albers Equal Area Projection using the Geodetic Reference System 1980 Spheroid. Because WATER has been designed to use a standard set of data sources that are available for the entire study area, snowpack and potential evapotranspiration (PET) were both simulated in the DSS using a temperature indexed approach (Hamon, 1963).

WATER also interacts with a scenario building tool (WATER Application Utilities) that provides a range of general circulation model (also known as global circulation model or global climate model; GCM) datasets that can be used to synthesize a climate record for forecasted future conditions, including two scenarios as characterized by the representative concentration pathways (RCPs) (tables 2 and 3). WATER incorporates the change factor (δ) approach and provides data for temperature, precipitation, and PET. The scenario builder also applies the water use (table 4) and reformats the simulated flow record into the desired output structure. To provide for reservoir management planning, streamflow simulations can be completed for inflow points to the reservoirs and formatted in the output required by the reservoir management model, DRB-PST, used by the Delaware River Basin Commission.

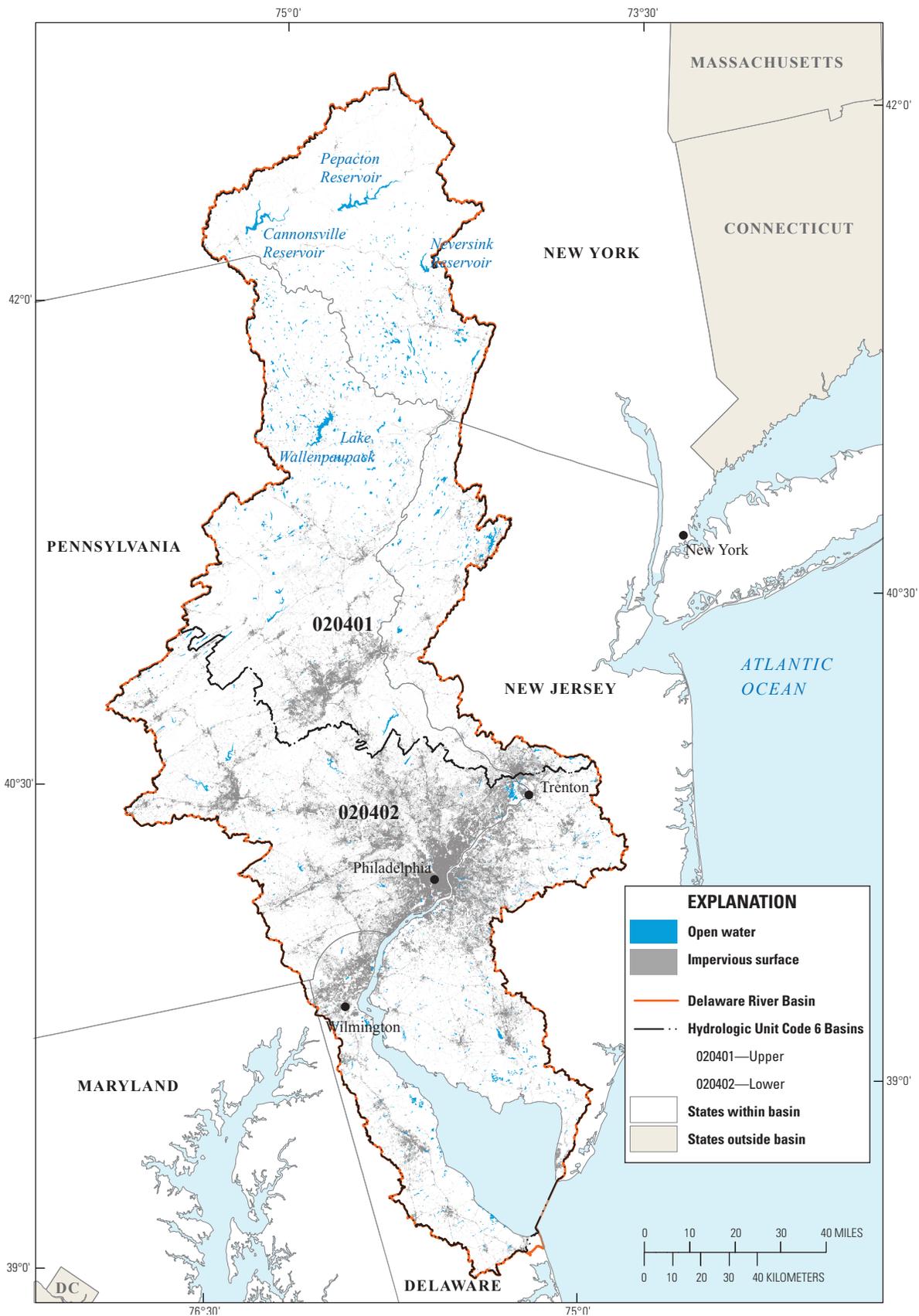


Figure 1. The Delaware River Basin, including parts of Delaware, New Jersey, New York, and Pennsylvania, as well as a small part of Maryland. Major population centers and reservoirs in the upper basin also are shown.

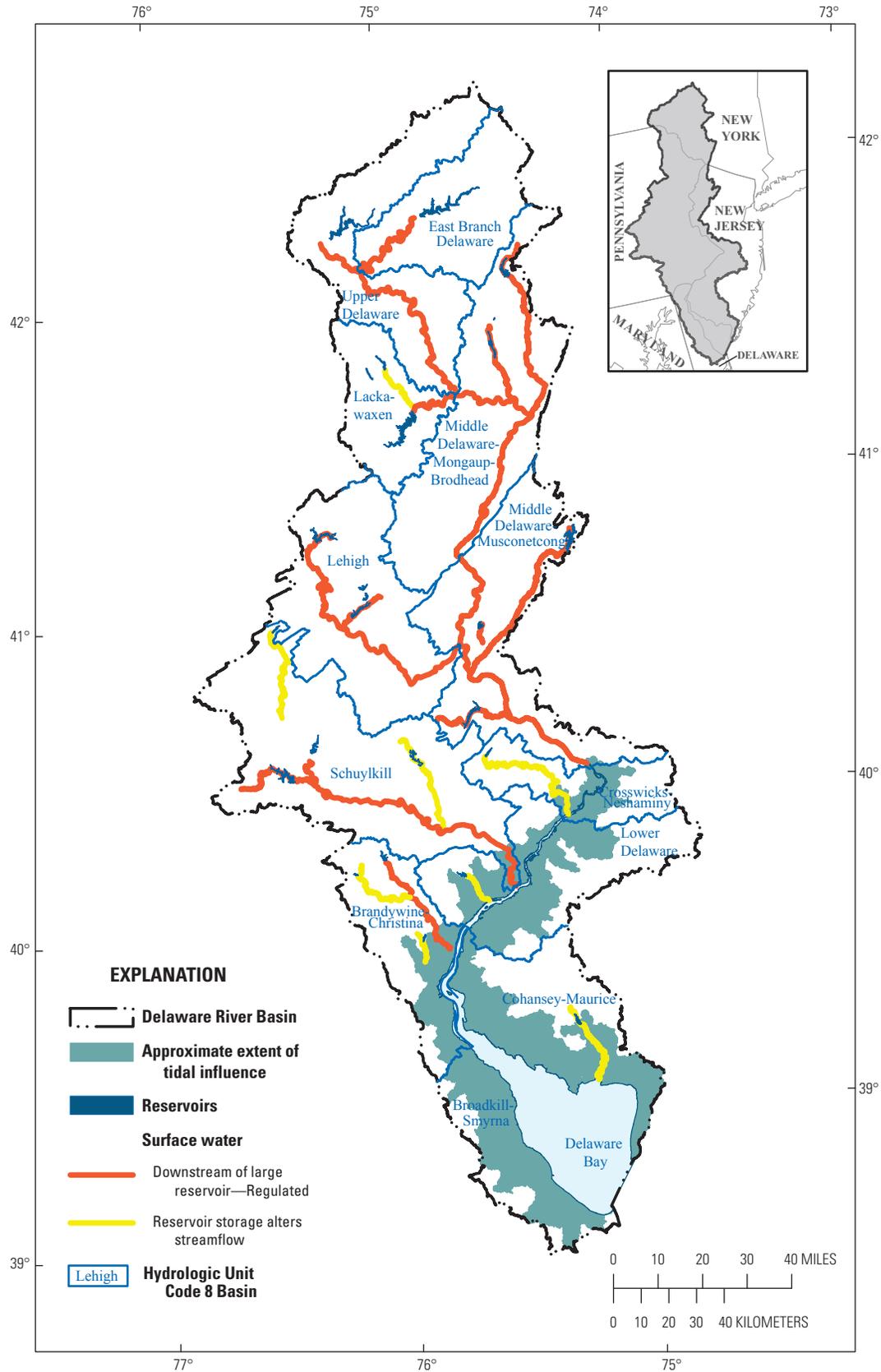


Table 2. Parts of Delaware River system where caution should be used because of stream regulation and tidal influences.

Table 1. Data sources and citations for the Delaware River Basin Water Availability Tool for Environmental Resources.

[WATER, Water Availability Tool for Environmental Resources; SSURGO, Soil Survey Geographic; NRCS, Natural Resources Conservation Service; DEM, digital elevation model; TWI, topographic wetness index; HRU, hydrologic response unit]

Data source	Contribution to WATER
Daymet (Thornton and others, 2012) http://daymet.ornl.gov/index.html	Daily temperature and precipitation data for 1980–2011.
National Elevation Dataset (Gesch and others, 2002) http://ned.usgs.gov/	Elevation data (as DEM) used for basin delineation and TWI calculations.
2011 National Land Cover Database (Jin and others, 2013) http://www.mrlc.gov/	HRUs and impervious area.
Soil Survey Geographic (SSURGO) database (SSURGO; Soil Survey Staff, 2014) http://datagateway.nrcs.usda.gov/	Hydrologic soil characteristics and TOPMODEL specific parameters.

Table 2. General circulation models provided as part of the Water Availability Tool for Environmental Resources database. The differences among models are detailed by Forster and others (2013).

Source	Abbreviation	General circulation model	Tile size (kilometers)	Documentation
National Oceanic and Atmospheric Administration —Geophysical Fluid Dynamics Laboratory	GFDL_NOAA	ESM2G	200	Dunne and others (2012).
National Aeronautics and Space Administration —Goddard Institute for Space Studies	GISS	E2-H	220	Nazarenko and others (2015).
National Center for Atmospheric Research —Community Climate System Model	NCAR_CCSM4	CCSM4	105	Gent and others (2011).
Canadian Centre for Climate Modelling and Analysis	CanESM2	CGCM4	310	von Salzen and others (2013).

Table 3. Representative concentration pathways (RCPs; summarized from van Vuuren and others, 2011)—data are provided for RCPs 4.5 and 8.5 (bolded). For comparison, the January 2015 global mean carbon dioxide (CO₂) concentration was 400.14 parts per million (ppm), up from 397.42 ppm in January 2014 (Earth System Research Laboratory, 2015; verified March 25, 2015).

[RCP, representative concentration pathway; W/m², watts per square meter; ppm, parts per million]

Representative concentration pathway	Radiative forcing	Approximate carbon dioxide concentration
RCP 8.5	Rising radiative forcing to 8.5 W/m ² by 2100	1,370 ppm CO ₂
RCP 6	Stabilization at 6 W/m ² after 2100	850 ppm CO ₂
RCP 4.5	Stabilization at 4.5 W/m ² at 2100	650 ppm CO ₂
RCP 2.6	Peak at about 3 W/m ² before 2100 and then decline to 2.6 W/m ² by 2100	490 ppm CO ₂

Table 4. Water-use categories and geospatial data type provided from 2010 National Water Census Inventory.

[Data from Hutson and others, in press]

Water-use category	Geospatial data type		
	Surface water or groundwater	Withdrawal or return	Point data or areal average
Aquaculture	Both	Withdrawal	Point.
Commercial	Both	Withdrawal	Point.
Domestic self-supply	Groundwater	Withdrawal	Areally averaged.
Industrial	Both	Both	Point.
Irrigation	Both	Both	Both.
Livestock	Groundwater	Withdrawal	Both.
Mining	Both	Withdrawal	Point.
Remediation	Groundwater	Withdrawal	Point.
Thermoelectric	Both	Withdrawal	Point.
Public water supply	Both	Both	Point.
Sewage treatment	Surface water	Return	Point.
Interbasin transfer	Surface water	Both	Point.

Uncertainty in Simulations and Relation to Scenario Investigation

The WATER DSS has been developed to provide the DRB community with an ability to assess the potential effect of different management decisions, forecasted changes in climate, and land-cover change on streamflows throughout the DRB using a process-based model that accounts for physical processes known to influence streamflow. WATER provides a consistent framework for simulation of hydrologic conditions, including high and low flows, for basins characterized by a range of size, land cover, and location within the DRB. The individual hydro-climatic components of the water budget, including evapotranspiration and snow accumulation and melt, also are effectively simulated by the WATER DSS. Because the WATER DSS relies on a mechanistic approach to predict streamflow, this regionally calibrated DSS can be used to investigate the sustainability and resiliency of water resources resulting from forecasted environmental and management scenarios. Ultimately, it is the responsibility of the user to interpret results. However, some precautions and suggestions for use of the DSS follow (Williamson and others, 2015):

1. An uncertainty of $\pm 2/-1$ average Normalized Root Mean Squared Error (RMSE_{N₅₇}) of 0.939 is recommended for daily flow simulations. This uncertainty is averaged from the confidence interval of streamflow simulation for 57 basins used in optimization of WATER (Williamson and others, 2015).
4. For those scenarios that rely on GCM data and land-cover change, mean monthly streamflows rather than daily streamflows should be used. This constraint on

the temporal resolution of streamflows stems from the fact that GCM change factors use a monthly normal, and land-cover simulations were derived at a decadal time-step. Because temporal resolution of streamflows should not be finer than the resolution of input GCM data, normalized mean monthly streamflow (that is, averaged for each month for the 25-year climate record) should be used with the mean RMSE_N for mean monthly streamflows (0.3255) to quantify the forecasted range of streamflow and water availability for a given scenario.

5. All scenarios should be compared to simulation of the same site using the “historical conditions” (2011 NLCD and 2010 water use) provided with the DSS. This is similar to the approach of GCM change-factor calculations. Multiple GCMs and RCPs should be incorporated into scenario testing and the overall trend in streamflow and other hydroclimatic variables among multiple GCM simulations should be used to plan for forecasted change.

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Section 2. Instruction Manual for WATER

Using the Water Availability Tool for Environmental Resources (WATER)

The WATER decision-support system (DSS) combines the geospatial information technology (GIS) functionality with a physically based hydrologic model to estimate streamflow across the Delaware River Basin (DRB). The physically based model is based on TOPMODEL, which is a semi-distributed watershed model that simulates the variable-source-area concept of streamflow generation (Beven and Kirkby, 1979; Wolock, 1993; Kennen and others, 2008; Williamson and others, 2009, 2013). The application was developed to provide a consistent and defensible method of estimating streamflow and water availability for historical and forecasted conditions (that is, climate and land-use change). Additional information about this and associated work is available at the USGS National Water Census DRB Web page (<http://water.usgs.gov/watercensus/delaware.html>).

The three steps to installing WATER are (1) copying the database, (2) installing the program, and (3) initializing the program; these steps are described in detail in the instructions that follow. After installation is complete, WATER can be used to simulate historical streamflow throughout the DRB. Simulation of forecasted conditions using land-cover data sets provided with WATER require the user to make changes in the anthropogenic folder. Incorporation of water use requires post-processing using the WATER Application Utilities that are described in the final section of this report. Streamflow simulation using forecasted climate data provided with WATER requires a historical simulation (which one can use as a baseline) that is then post-processed using the WATER Application Utilities before being re-run with WATER with the forecasted climatic record.

Before You Install

To install the WATER DSS successfully, the ESRI ArcINFO™ 10.0 with an individual *Spatial Analyst* extension **must** be installed on every end user machine to which the WATER application is to be installed:

- Go to the Start  menu → *All Programs* → *ArcGIS* → *ArcGIS Administrator*;
- Select the *Availability* folder and look for *Spatial Analyst*.

If your system is administered by someone other than yourself, you will need administrative access to install the program.

Installation Instructions

1. Determine where you will be storing the database (about 22 GB) and simulations folders—the local C: drive is recommended. The model will run faster if these folders can be stored on your local hard drive as opposed to an external or network drive.
 - A. Create a *USGS* folder where you plan to store the database and simulations.
 - B. Copy the database into the *USGS* folder. Be sure to keep a back-up copy of the database in another location.
 - C. Your file structure should look like figure 3.
 - D. The database on which the program depends is in the *water_db* folder.
 - E. The *simulations* folder is where individual simulations will be stored until you either delete them or move them to a different location. **This folder can get very large, so you may want to store completed simulations elsewhere.**
 - F. The *extMod* folder is for storage of any external program that needs to be accessed by the DSS. It is likely that your *extMod* folder is empty.
 - G. If there are no *simulations* or *extMod* folders in your *water* folder, create them.
 - H. Confirm that the entire database has copied by comparing the size of the *USGS* folder on your local drive to the size of the corresponding folder on the source drive.

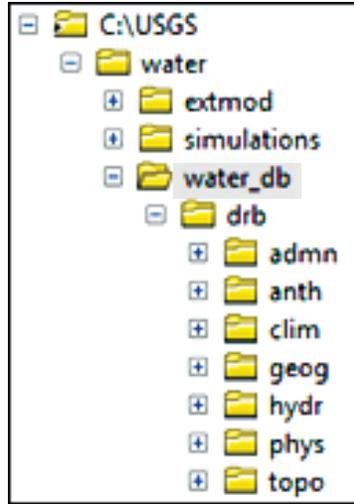


Figure 3. File structure required for WATER database.

2. Copy the *WATER_<date>* folder to your desktop, where <date> denotes the date when the software was last revised. Please save this file for reference.
 - A. This folder is likely zipped, so it will need to be extracted.
 - B. Open and click the setup executable to begin the installation process.
3. Depending on your security settings, you may see a *Security Warning* dialog box. Click Install to install the application (fig. 4).
4. Accept the suggested/default location for installation of the program.



Figure 4. Installation warning for installing program.

Initialization Instructions

A short-cut should display in your Start  menu:  DRB WATER.

5. When you start the program for the first time, it undergoes initialization—checking for up-to-date licenses, necessary folder locations, and required data files.
6. The DSS requests the main root directory. Navigate to and select the *USGS* folder (discussed in step 1 of section, “Installation Instructions”) requested by the program. If the remaining subfolders within the *water* folder have remained intact, the application will finish loading. If any subfolders are missing, navigate to the folder locations within the *Browse For Folder* dialog box.

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Note: If the application requests the location of these folders each time the DSS is opened, then:

- A. Identify the *Programs/subfolder* into which the application has loaded.
- B. Uninstall the application using the installation package or your *Control Panel*.
- C. Confirm that the WATER.exe...\\1.0.0.0\\user.config file and folder have been deleted from the C:\\Users**YourName**\\AppData\\Local\\US_Geological_Survey folder.
- D. Confirm the integrity of the *USGS* folder and restart your computer.
- E. Reinstall the application into the default directory, paying special attention to navigating to the *water* subfolder process (step 6, above).

Running the Water Application

After the initialization process, WATER should start without any need to relocate these data.

1. Start the program from the *Start*  menu.
2. You will see an index map of the entire DRB (fig. 5).
3. Access and select the magnification tool from the *Zoom* dropdown menu (fig. 5).

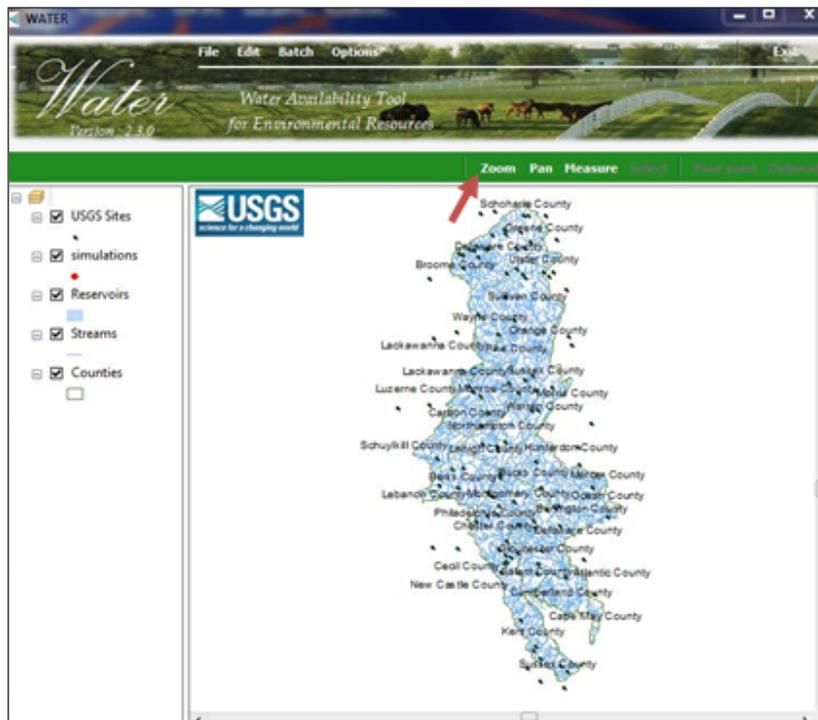


Figure 5. Index map of Delaware River Basin.

4. You can either drag the magnification tool over an area of interest or click in a single location on the map. Note: The DSS will only delineate a watershed for pour points that are on the blue streamline that is visible on the map.
5. Continue this process over your area of interest until the *Pour Point* button becomes enabled. Click *Pour Point*. You can hover over the stream reach to confirm the location (fig. 6).

Note: Zooming in and out can cause the high-resolution stream network to be disabled. If this occurs, please restart the program.

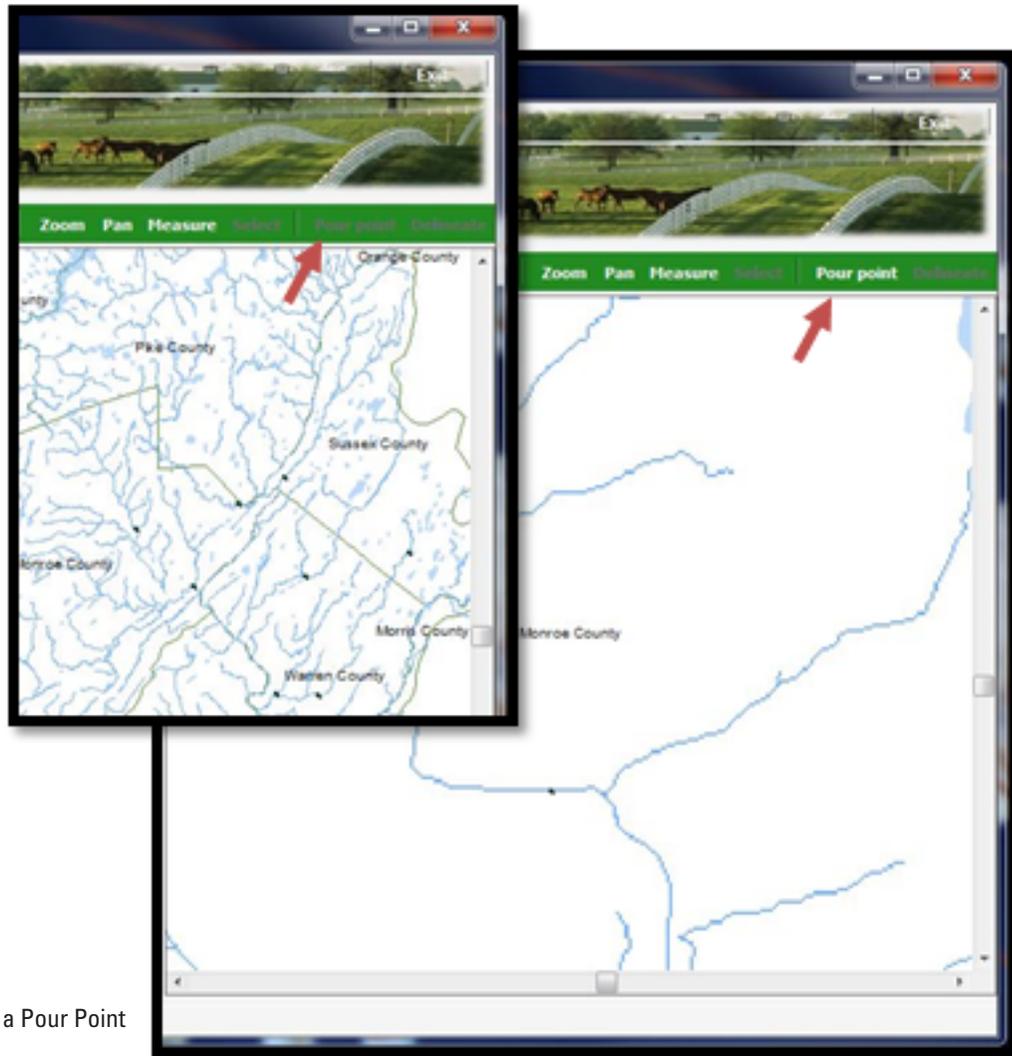


Figure 6. Creating a Pour Point in WATER.

6. Click the desired location for the pour point (the most downstream point of your basin of interest) within any stream raster cell. If the pour point is not located on a stream raster cell, it will NOT be delineated, the *Simulation Information* dialog box will not display, and you will need to click a stream cell to assign the pour point location.
7. If the pour point you select is located on a stream-raster cell, a dialogue box (fig. 7) will become visible—this is where you name your simulation and attach any notes (*12 or fewer characters*). Logical details to include in your simulation name include:
 - A. Basin name,
 - B. Date,
 - C. Project, and
 - D. Your initials if you are sharing a simulations folder.

Although much of this information is stored as part of the simulation, it can be useful to see it without opening the simulation and DSS.

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8. *Accept* the simulation. The *Delineate* button will now be enabled. Click *Delineate* (fig. 7).

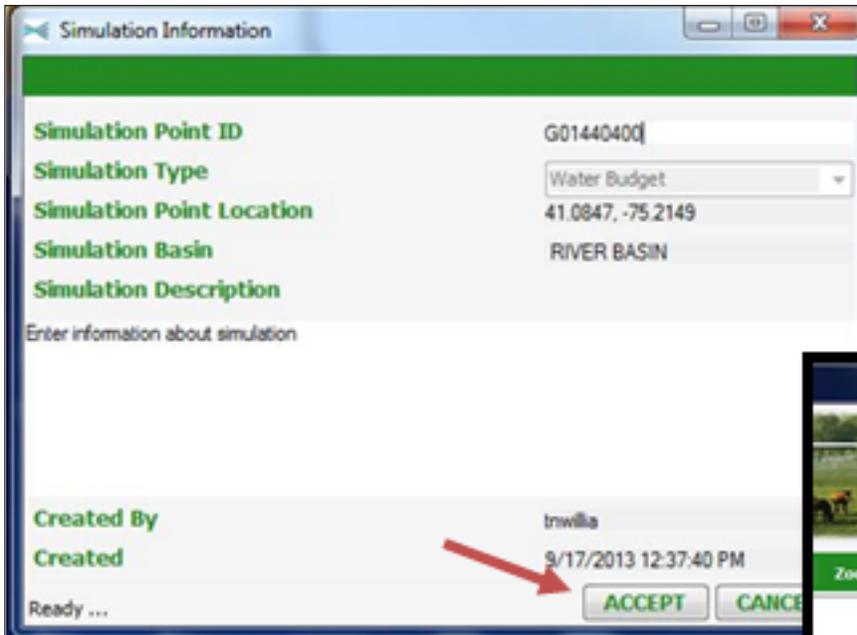
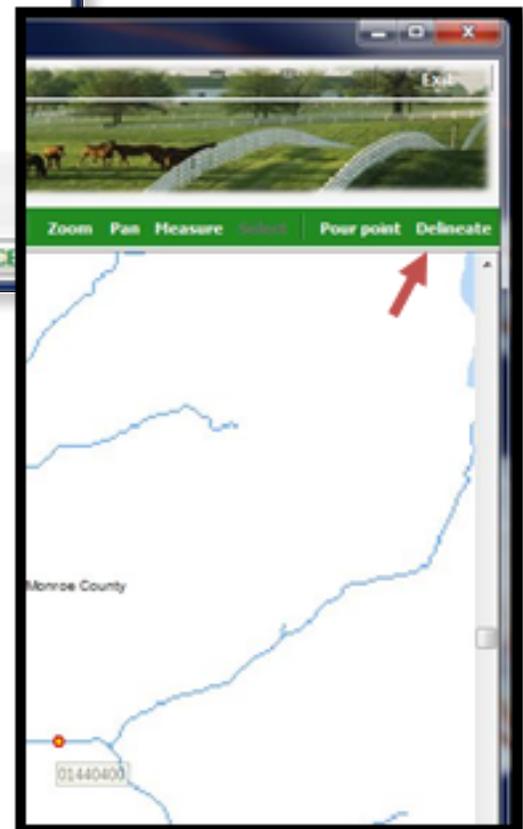


Figure 7. Dialogue box for naming simulation.



9. The program will begin to delineate your basin of interest (based on the 10-m digital elevation model [DEM] included in the database). You will see the green bar moving back and forth at the bottom of the window. Depending on the type of system you are running, the location of the database, and the basin size, this will take several minutes. For example, delineation of a 200-km² basin takes about 5 minutes on most systems.

- When the process is complete, you will see an outline of the basin. You must now click *Load Data* to load the provided data sets needed to estimate spatially averaged characteristics within the delineated basin (fig. 8). You will know this is complete when the *Run* button appears.

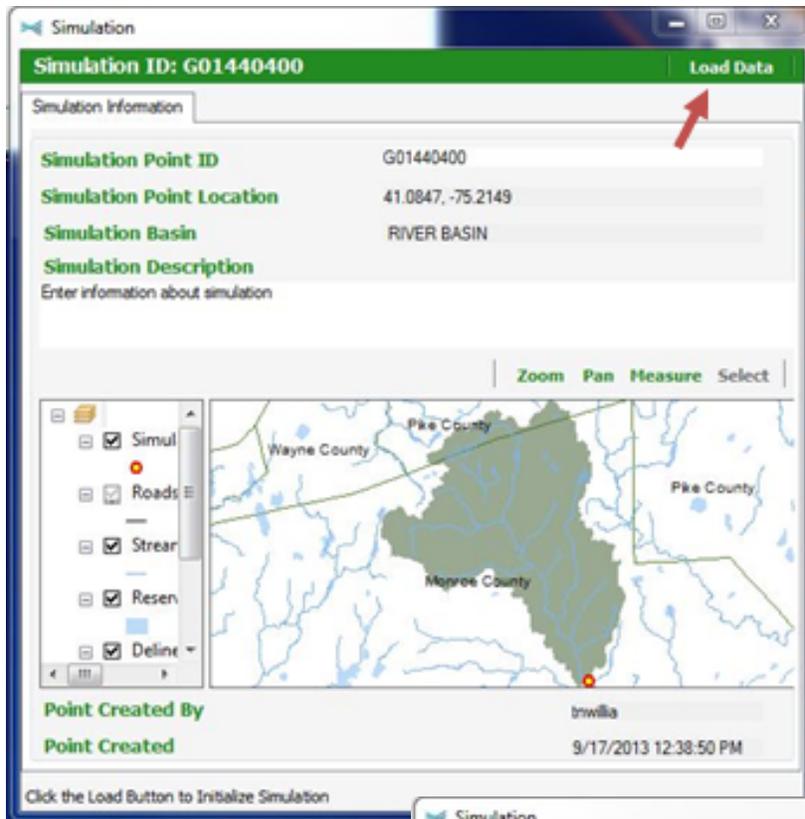
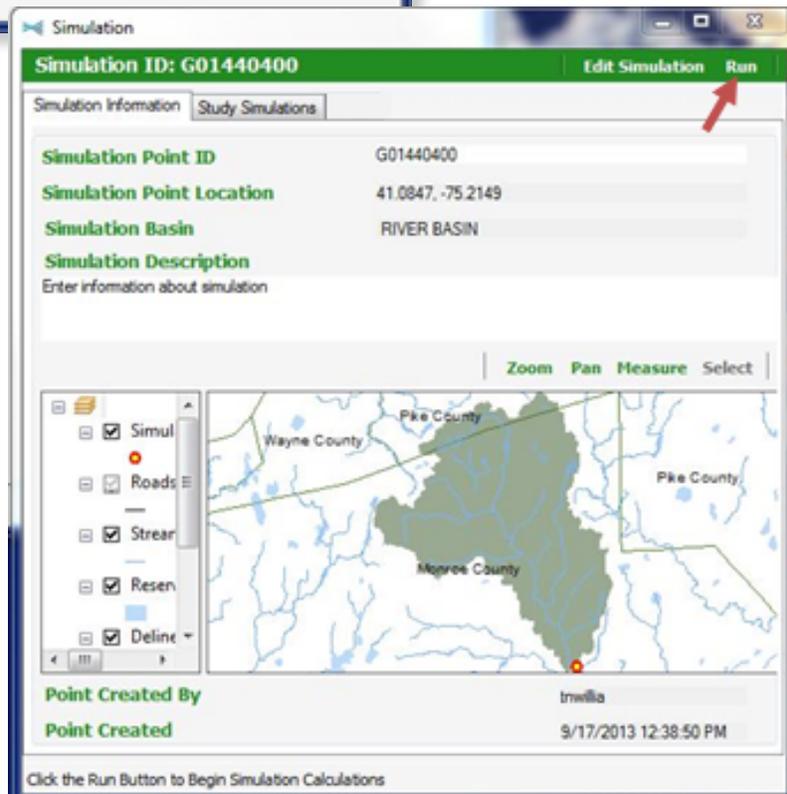


Figure 8. Loading data and running a simulation in WATER.



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11. The DSS will now gather and load those data necessary to run the hydrologic model, including climate data, land-cover distributions (Forested, Agricultural, Developed), soil characteristics, and topography. Similar to the basin delineation step, this can take several minutes depending on the size of the delineated basin.
12. When those data have been loaded, spatially-averaged basin characteristics and parameters for each land-cover type become available (fig. 9). The *Study Summary* on the *Study Simulations* page will be blank until after the model is run.

The screenshot shows a software window titled "Simulation" with a green header bar containing "Simulation ID: G01440400" and buttons for "Edit Simulation" and "View". Below the header are several tabs: "Simulation Information", "Study Simulations", and "PEST". Under "Study Simulations", there are sub-tabs for "Study Overview", "Forest", "Agricultural", "Unallocated", and "Hydrograph". The "Simulation Attributes" tab is active, showing a table with three columns: "Attribute", "Mean Value", and "Description".

Attribute	Mean Value	Description
Study Unit Total Area	161.1486	(sq Km) Study unit total area
Total Estimated Stream Area	1.8191	(sq Km) Estimated area of stream coverage
Total Lake Area	0.2025	(sq Km) Estimated area of lake coverage
Lake Decay*	1.5	(day) Coefficient for delaying water through lakes...
Uplake Area	11.6507	(sq Km) Contributing area upstream of lakes locat...
Ground Water Withdrawal	0.0000	(cmd) Ground water withdrawal
Surface Water Withdrawal	0.0000	(cmd) Surface water withdrawal
Surface Water Discharge	0.0000	(cmd) Surface water discharge
Latitude	41.1867	(DD) Latitude
Conductivity Multiplier	12.8050	() Soil conductivity multiplier
Water Holding Capacity	0.1115	() Water holding capacity of the soil
Wetness Index Adjustment	1.0000	() Topographic wetness index adjustment parame...
Soil Depth	829.7866	(mm) Depth of soil
Percent Macropore	0.2000	() Percentage of subsurface flow attributed to ma...
Field Capacity	0.1547	() Field capacity
Saturated Hydraulic Conductivity	1,073.3756	(mm/day) Saturated hydraulic conductivity
Porosity	0.2771	() Porosity of soil
Depth of Root Zone	622.3400	(mm) Depth of root zone
Scaling Factor M	70.8219	(mm) Soil scaling factor
Spatial Coefficient	0.5000	Data scalability factor
Percent Impervious	0.0810	(%) Percent impervious
Percent Road Impervious	0.0094	(%) Percent road impervious
Effective Impervious	0.7	(%) Effective impervious
Impervious Runoff Delay	0.1000	() Factor relating to delay of impervious runoff
Evapotranspiration Exponent*	0.5000	() Evapotranspiration exponent
Snow Melt Coefficient	3.0000	(mm/DegC) Snow melt only temperature-index mel...
Rain on Snow Melt Coefficient	5.0000	(mm/DegC) Rain on snow temperature-index meli...
Impervious Curve Number	90	() Curve number

Figure 9. Spatially averaged basin characteristics for the forested part of a basin.

13. You can now *Run* the model and calculate the streamflow and water budget (fig. 8). After this step has completed, the *Study Summary* will be complete and the predicted daily *Hydrograph* will be available as a new tab under the *Study Simulations* (fig. 10). You also can examine the predicted hydrograph on a monthly or yearly time-step using the View dropdown menu.
14. A text file of this time series is now in your *simulations* folder as *WATER.txt* (fig. 11). To incorporate water use, further examine the simulations, and reformat the file into a daily streamflow record that can be incorporated by other programs, you will need to use the WATER Application Utilities. The *WATERSimulation.xml* has the details of your simulation, which can be opened with an application such as Microsoft Access™.

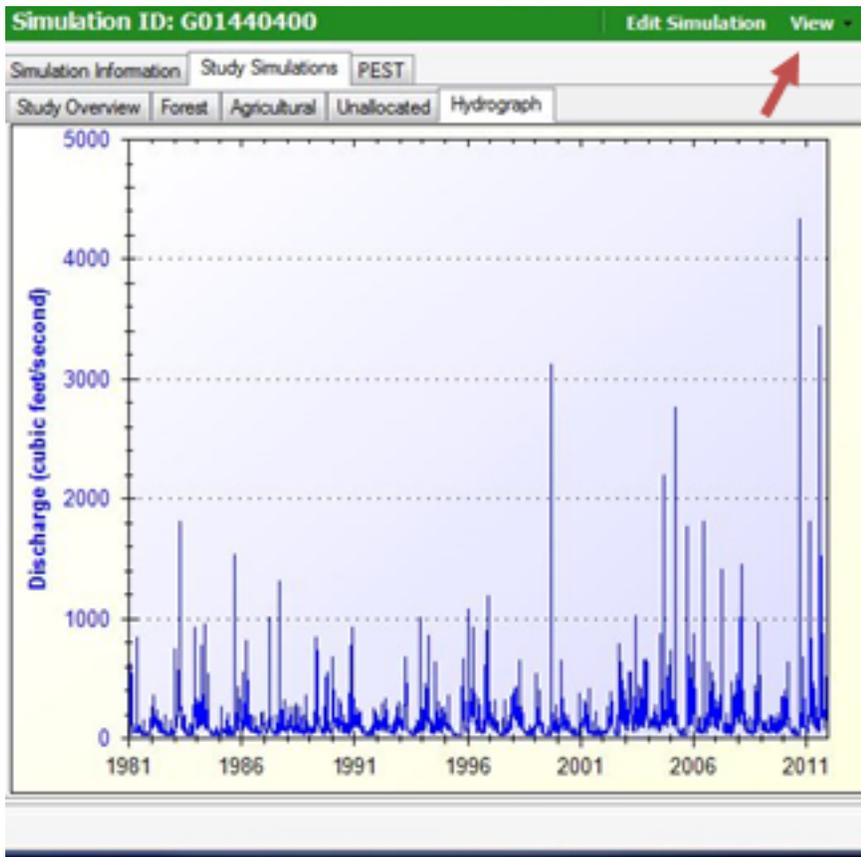
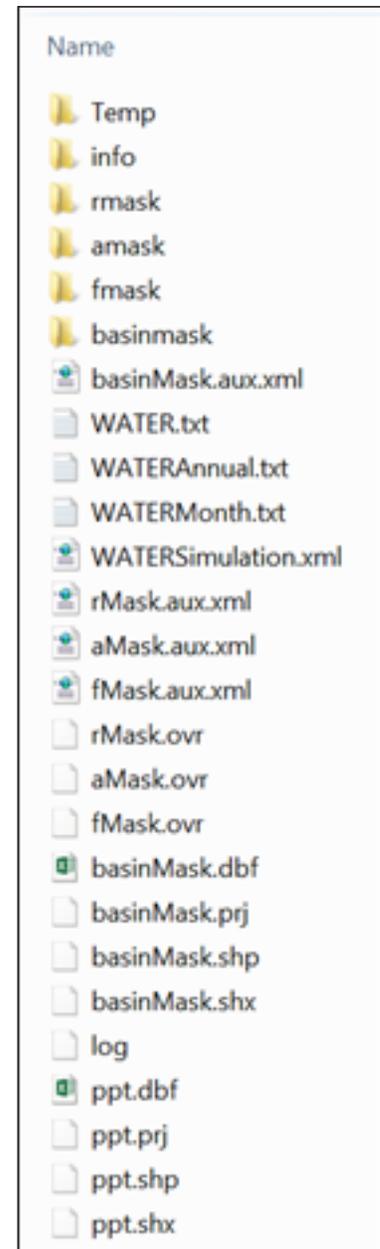
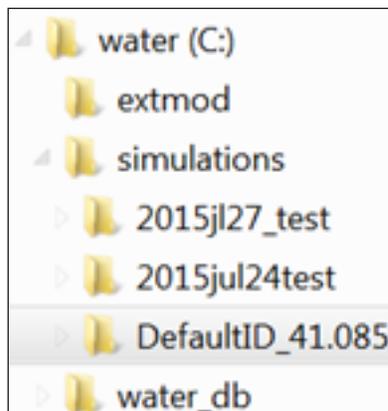


Figure 10. After simulation has run in WATER.

Figure 11. File structure after simulation has been run.



The Batch Mode

As an alternative, you can run a *Batch* file of previously delineated basins. This is most effective if the individual basins were constructed using the WATER DSS, because the basin boundaries will coincide with the 10-m DEM raster and there will be no chance of the basin extending beyond the spatial extent of those data layers included in the DSS—for example, this might occur when basins include the headwaters of the DRB and were delineated either by hand from topographic maps or using a coarser-resolution DEM than that used by WATER. If you run a *Batch* file, you will need to aggregate individual basins into a single shapefile and give them a unique identifier. You also can use a previously delineated set of basins from another source as long as they are in the **North American Datum of 1983 Albers Equal Area Projection using the Geodetic Reference System 1980 Spheroid**. It is critical that there be no loops in the polygons and that no basins extend beyond the geospatial layers in the WATER database.

1. From the *Batch* dropdown menu, select *New* → *From Shape File* (fig. 12).
2. You will need to enter the simulation information (fig. 13):
 - A. Name the Batch Project,
 - B. Browse to the desired shapefile of basins,
 - C. Select the attribute to be used as the Basin Field Name (your identifier), and then
 - D. Click *ACCEPT*.
3. Return to the *Batch* dropdown menu and select *Run*.

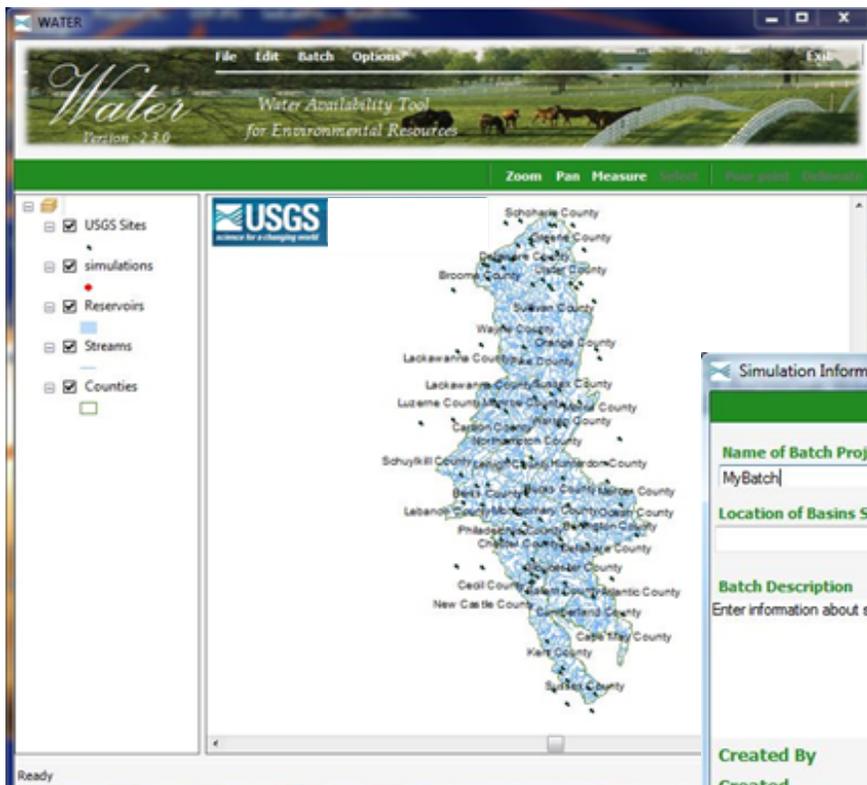


Figure 12. Starting a **Batch** of basins in WATER.

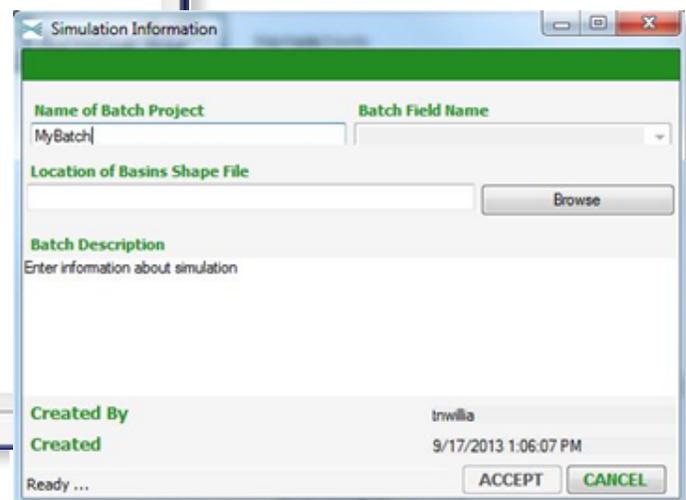


Figure 13. The **Batch** dialogue box.

This process will run each basin individually—it does not matter if the basins are nested. Depending on how many basins you have, this process could take several hours.

Areal Limitations

WATER was developed for basins characterized by areas of less than 2,000 km²; this coincides with the largest, unregulated basins in the DRB. Simulation of daily streamflow will be less accurate for basins larger than 2,000 km² because there is no routing to account for delayed streamflow in large basins. WATER will not simulate streamflow for basins that are larger than 17,000 km² in areal extent because of memory limitations.

Time Period Included in Simulations

The database provided with WATER includes a climatic record that extends from January 1, 1980, through December 31, 2011. The first year will not be included in the simulation output, providing a year for the model to equilibrate or “spin up”; this provides 11,322 days. Scenario testing that involves GCMs (discussed below in Section 3 of this report) uses the same climatic record altered by GCM- and RCP-specific change factors, enabling comparison between historical and forecasted time periods.

General Circulation Model Simulations

After using the **waterapputils** (discussed in Section 3 of this report) to generate “changed” simulations that incorporate general circulation model (GCM) change factors, individual basins must be run separately—even if they were originally processed as part of a batch. If the potential evapotranspiration (PET) change-factor approach is to be incorporated (as is recommended):

1. Open WATER.
2. Select File -> Open.
3. Navigate to the location of a GCM simulation. This will be nested inside a folder that is nested in the original basin folder. For example: *USGS/water/simulations/BatchName/BasinID/waterapputils-gcmdelta_NCAR_RCP85_2060/WATERSimulation* (this is an XML document).
4. Open this file and allow it to load.
5. Click Run, as in the individual basin approach.

This process can take several hours depending on the size of the basin, because it is replacing the original Hamon-based daily PET with that calculated using the radiation-based change factor ($\delta_{\text{PET}_{\text{rFC}}}$ discussed in Williamson and others, 2015).

In some cases, forecasted streamflow can be estimated without using the changed PET; however, **this usually will lead to an overestimate of PET**. To do this, move or rename the *pet-timeseries* file. This simulation will run faster, similar to a historical simulation.

Land-Cover Projections

Land-cover layers for 2030 and 2060, analogous to the NLCD produced by the Multi-Resolution Land Characteristics Consortium, are included in the “anth” (anthropogenic) folder. These forecasted layers use the same land-cover classification as the 2011 version used for historical simulations. It is best to keep a labeled copy of all three time periods—2011, 2030, and 2060. To use one of these forecasts, the “mrlc” raster must be replaced with the desired snapshot by deleting the current “mrlc,” creating a copy of land cover for the desired time period, and renaming this copy as “mrlc”; you also can use your metadata to differentiate these rasters. **WATER only will use the version referred to as “mrlc.”**

Section 3. Instruction Manual for WATER Application Utilities—waterapputils version 1.0.0

Description

waterapputils is a tool used for analyzing, processing, and updating model simulations from the Water Availability Tool for Environmental Resources (WATER) decision support system (DSS) of the [U.S. Geological Survey Indiana and Kentucky Water Science Center](#). The **waterapputils** tool is written in Python™ (<https://www.python.org/>), and adds new functionality, outside the WATER DSS, by allowing users to apply various management scenarios using:

- A change-factor (delta or δ) approach with data from the Coupled Model Intercomparison Project (CMIP5), and
- Aggregated water-use data to evaluate potential scenarios of water availability.

waterapputils has a [Command Line Interface](#) and a [Graphical User Interface](#) along with batch scripts, including [Run Sample Datasets Shell Script](#) and [Process Many Simulations Shell Script](#), to help automate processing tasks and run unit tests.

The WATER DSS is a graphical user interface (GUI), written in VB.NET, wrapped around a variant of the semi-distributed rain-fall-runoff model referred to as TOPMODEL (TOPography based hydrological MODEL) developed by Keith Beven, Professor at Lancaster University. TOPMODEL estimates river discharge and spatial soil-water deficit patterns for a particular catchment basin using topographic, climatic, and pedologic input-data parameters. WATER combines TOPMODEL with an estimation of runoff from impervious surfaces derived by using the curve number approach described in U.S. Department of Agriculture (USDA) Technical Release 55 (TR-55; USDA, 1986) to evaluate runoff generated from impervious areas. The original WATER DSS was developed by the U.S. Geological Survey. Additional references for the WATER DSS include Williamson and others (2009, 2013).

Some sample highlights of **waterapputils** include:

- Processes WATER simulation output files (txt format).
- Processes WATER simulation database files that store information about a particular model simulation (xml format).
- Applies various general circulation models (GCMs; table 2) to model simulations for a particular basin or set of basins based on the spatial intersection of the watershed(s) of interest with the GCM scenario coverage of interest. Four CMIP5 models are included, with two representative concentration pathway (RCP) scenarios each (RCPs 4.5 and 8.5; table 3); data represent 25-year normals (means) centered on 2030 and 2060.
- Applies water-use data to model simulations for a particular watershed or set of watersheds based on the spatial intersection of the watershed(s) of interest with the water-use coverage.
- Generates plots of all parameters in WATER output files (txt format) with simple statistics.
- Generates plots of time series parameters in WATER-simulation database files (xml format) (fig. 14).
- Generates comparison and difference plots between two WATER-simulation output files.
- Generates comparison and difference plots between two WATER-simulation database files.
- Generates maps of the study area for a particular model simulation using [basemap](http://matplotlib.org/basemap/) (<http://matplotlib.org/basemap/>), a python library for plotting two-dimensional data.
- Logs errors and tracebacks.
- Provides a multithreaded GUI referred to as `waterapputils_gui`, allowing the user to execute tools in the background without the software becoming unresponsive.

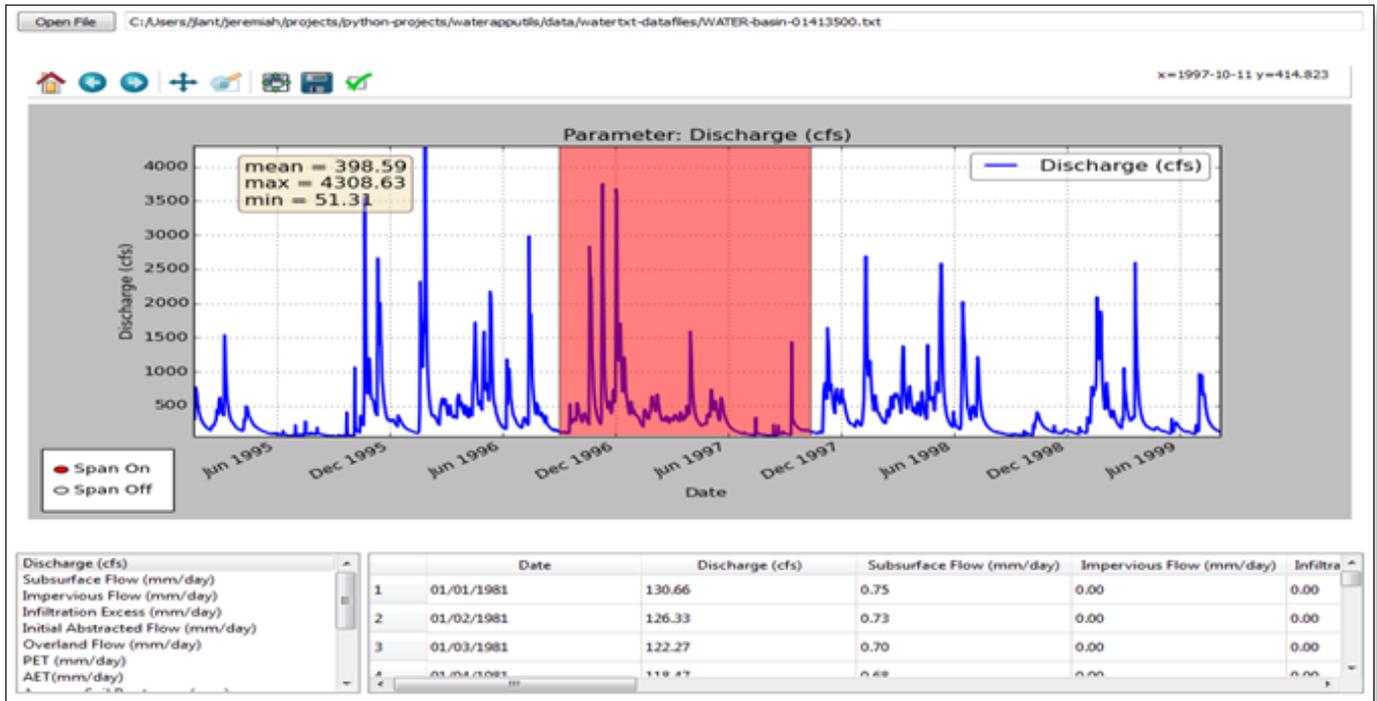


Figure 14. Sample hydrograph produced after processing and analyzing WATER output files using the graphical user interface.

Documentation

Documentation of the code, guides detailing the processes involved in applying water use and the GCM deltas, additional information about **waterapputils**, and a gallery of output images are available at <http://jlant-usgs.github.io/waterapputils/docs/html/index.html>.

Additionally, the documentation pages can be viewed by navigating to the `docs/_build/html` directory included with **waterapputils** and opening the `index.html` file in a Web browser (Chrome™, Firefox®, Internet Explorer®, etc.).

Tutorials

A series of video tutorials were made that describe and detail how to use **waterapputils** with many of the example sample data sets.

The following are the tutorial topics covered:

1. General Overview (48 minutes),
2. Command Line Interface (73 minutes),
3. Graphical User Interface (46 minutes).

Download the **waterapputils** video tutorials at

<ftp://ftpext.usgs.gov/pub/er/ky/louisville/jglant/waterapputils/waterapputils-video-tutorials.zip>.

Software Requirements

The **waterapputils** software can be launched from the **waterapputils** folder after the python libraries necessary to run **waterapputils** are installed in the suggested/default location for your system. *A full installation of one of the Python distributions that follow is recommended for the dependencies to match the Python 2.7 download.* This full installation is available using the dropdown menu—it may not be the default option. Otherwise, some of these dependencies will not be installed or will not install the required version. The pythonxy and Basemap downloads are provided here: <ftp://ftpext.usgs.gov/pub/er/ky/louisville/jglant/waterapputils/waterapputils-pythonxy2.7.6.1-downloads.zip>.

It is recommended that this combination be used to avoid any complications. However, in some cases, alternative approaches might be necessary:

- **pythonxy**—This program is recommended because of how it interacts with the Microsoft Windows® operating system. (A full installation, which is not the default option, is required).
- **Anaconda**®
- **Enthought**

The following is a list of dependencies required by the program. Instead of installing these dependencies independently, it is strongly recommended that users install one of the scientific Python distributions noted earlier in this section that will come bundled with most of these dependencies (excluding Basemap):

- **Python** == 2.7.* —This is the version of Python required to run the program.
- **NumPy** >= 1.8.0
- **matplotlib** >= 1.3.1
- **nose** >= 1.3.0
- **GDAL** >= 1.11.0
- **PyQt4** >= 4.9.6
- **Basemap** >= 1.0.2—This dependency must be installed separately even when using a full installation.

The PythonXY 2.7.6.1 version, which includes all the requirements listed above, and the Basemap 1.0.2 plugin can be downloaded from: <ftp://ftpext.usgs.gov/pub/er/ky/louisville/jglant/waterapputils/waterapputils-pythonxy2.7.6.1-downloads.zip>.

Downloading and Installing the Program

waterapputils is available at the top of the waterapputils page: <http://jglant-usgs.github.io/waterapputils/>. The program can be downloaded as a ZIP file, which can be copied and extracted anywhere on your system.

This site also includes a link to view additional information about the program on GitHub.

Running waterapputils

Navigate to the `\waterapputils-master\waterapputils-master\waterapputils` folder that you extracted.

Select the `waterapputils_gui` python (PY) file and “right-click” to select “Open with python.” Please be patient, as this could take as many as 5 minutes to launch depending on your system and what else is running. You now can apply water use, process .xml files for GCM scenarios, and compare simulations using the GUI (fig. 15).

If, instead, you prefer to use the command line, an explanation of individual commands is available [here](#) and at the [GitHub site](#).

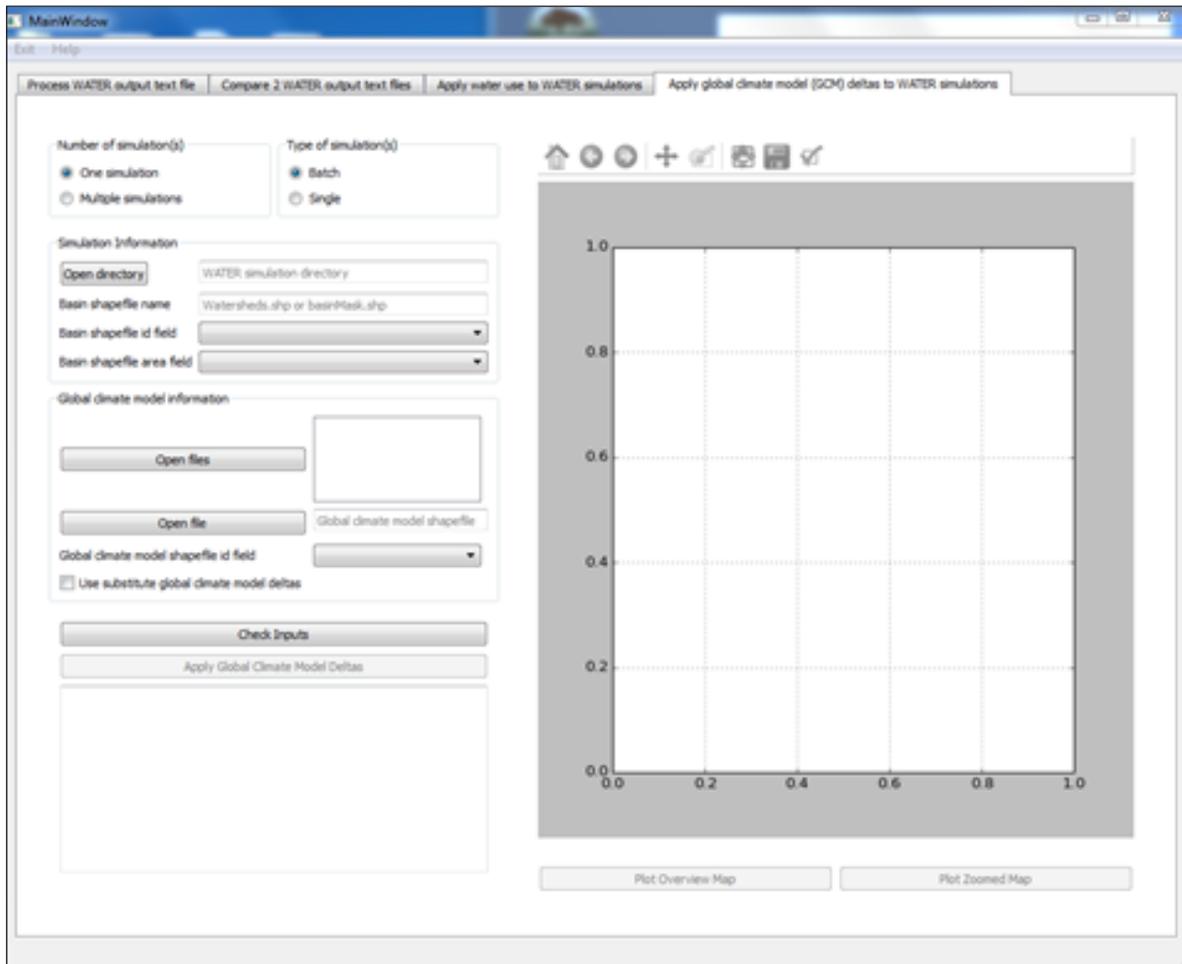


Figure 15. The `waterapputils` graphical user interface.

Editing Settings in `user_settings.py`

All settings for running `waterapputils` are contained in the `user_settings.py` file. A user can edit the settings by editing the Python string variables. Most variables are *path* variables to required data files and basin shapefile attribute variables. A user typically will only edit the section referred to as *WATER simulation information*. This section contains information about a WATER simulation. A WATER simulation can be either a *single* simulation or a *batch* simulation. Each simulation type has a few different outputs along with a different directory structure.

A *single* simulation corresponds to basins that were *delineated* within the WATER DSS using a pour point. A *batch* simulation corresponds to basins that were *pre-delineated* and were run within the WATER DSS.

Command Line Interface

This program must be executed from the waterapputils directory.

Usage:

```
$ python waterapputils.py [option]
```

Command Line Arguments:

Commands	Description
-h	Show list of available commands
-watertxt	List WATER simulation output file(s) to process; WATER.txt
-watertxtfd	Open file dialog window to select WATER simulation output file(s) to process; WATER.txt
-watertxtcmp	List two WATER simulation output file(s) to compare; WATER.txt
-watertxtcmpfd	Open file dialog window to select two WATER simulation output file(s) to compare; WATER.txt
-waterxml	List WATER simulation database file(s) to process; WATERSimulation.xml
-waterxmlfd	Open file dialog window to select WATER simulation database file(s) to process; WATERSimulation.xml
-waterxmlcmp	List two WATER simulation database file(s) to compare; WATERSimulation.xml
-waterxmlcmpfd	Open file dialog window to select two WATER simulation database files to compare; WATERSimulation.xml
-applygcmdeltas	Apply GCM deltas to WATER-simulation file(s); WATERSimulation.xml; details specified in user_settings.py
- applysubgcmdeltas applysubgcmdeltas	Apply updated GCM deltas from sub_gcm_delta_info_file_name variable in user_settings.py to WATER-simulation file(s); WATERSimulation.xml; details specified in user_settings.py
-applywateruse	Apply water-use data to WATER-simulation output file(s); WATER.txt; details specified in user_settings.py
-applysubwateruse	Apply water-use data from sub_wateruse_info_file_name variable in user_settings.py to WATER-simulation output file(s); NOTE: this is necessary if no water-use points are intersected by a basin—the file has been written to default to zero water use; WATER.txt; details specified in user_settings.py
-oasis	List WATER-simulation output file(s) to process; creates output data file(s) for Delaware River Basin Commission’s DRB-Planning Support Tool program—a tab delimited file(s) of timeseries of discharge. NOTE: WATER-simulation output file must have the Discharge + Water Use column. If no water use is preferred, water use should be applied using a factor of zero
-ecoflowstationid	List WATER-simulation output file(s) to process; creates output data file(s) for EflowStats R program (Thompson and Archfield, 2014)—a comma separated file(s) of timeseries of discharge for a specific basin (station) id
-ecoflowdaxml	List WATER-simulation database xml file(s) to process; creates output data file(s) for EflowStats R program—a comma separated file(s) of basin (station) id and its respective drainage area in square miles calculated using data in the WATERSimulation.xml
-ecoflowdashp	List basin or watershed shapefile(s) to process; creates output data file(s) for EflowStats R program—a comma separated file(s) of basin (station) id and its respective drainage area in square miles calculated from the shapefile(s)

Command Line Arguments:—Continued

Commands	Description
-outfilename	OPTIONAL : output filename to be used with -ecoflowdaxml or -ecoflowdashp commands in writing the drainage area comma separated file
-labelfield	OPTIONAL : label field name (basin number / station id) to be used with -ecoflowdashp command in writing the drainage area comma separated file; default label field is the FID in the basin(s) shapefile
-areafield	OPTIONAL : area field name in a basin(s) shapefile to be used with -ecoflowdashp command in writing the drainage area comma separated file; default action is to calculate area from the shapefile(s)
-samplesingle	OPTIONAL : flag used with -applywateruse, -applysubwateruse, -applygcmdeltas, -applysubgcmdeltas to specify the use of the sample single simulation datasets
-samplebatch	OPTIONAL : flag used with -applywateruse, -applysubwateruse, -applygcmdeltas, -applysubgcmdeltas to specify the use of the sample batch simulation datasets
-simdir	OPTIONAL : flag used with -applywateruse, -applysubwateruse, -applygcmdeltas, -applysubgcmdeltas to specify a path to a specific WATER simulation instead of specifying it in user_settings.py

Example—processing a WATER.txt file:

```
$ python waterapputils.py -watertxt <path-to-WATER.txt-file>
```

Example—running water use using the settings in user_settings.py:

```
$ python waterapputils.py -applywateruse
```

Example—running water use by supplying a path to a simulations directory instead of specifying the simulations directory in user_settings.py:

```
$ python waterapputils.py -applywateruse -simdir <path-to-simulations-directory>
```

Run Sample Datasets Shell Script with `run_sample_datasets.sh`

The shell script `run_sample_datasets.sh` is a shell script that can be used to run automated tests and run many of the command line arguments using the sample datasets provided with `waterapputils`.

Usage—shell script to test `waterapputils`:

```
$ run_sample_datasets.sh [option]
$ run_sample_datasets.sh [[[-txt] [-xml] [-wateruse] [-oasis] [-ecoflowstationid]
[ecoflowdaxml] [-ecoflowdashp] [-gcmdelta] [-mapsim] [-all] [-tests] -makeclean] |
[-h]]
```

Command Line Arguments for the Shell Script `run_sample_datasets.sh`:

Commands	Description
<code>-h</code>	Show list of available commands
<code>-txt</code>	Run <code>-watertxt</code> and <code>-watertxtcmp</code> using the sample WATER simulation output TEXT files (<code>WATER.txt</code>)
<code>-xml</code>	Run <code>-waterxml</code> and <code>-waterxmlcmp</code> using the sample WATER simulation output XML files (<code>WATERSimulation.xml</code>)
<code>-wateruse</code>	Run and apply water-use data to sample WATER simulations; single and batch simulations
<code>-subwateruse</code>	Run and apply substitute water-use data to sample WATER simulations; single and batch simulations
<code>-gcmdelta</code>	Run and apply general circulation model data to sample WATER simulations; single and batch simulations
<code>-subgcmdelta</code>	Run and apply substitute water-use data to sample WATER simulations; single and batch simulations
<code>-oasis</code>	Create a Delaware River Basin Commission's DRB-Planning Support Tool formatted water-use output file using the sample water use applied WATER TEXT file
<code>-ecoflowstationid</code>	Create an EflowStats formatted water-use output file using the sample water use applied WATER TEXT file
<code>-ecoflowdaxml</code>	Create an EflowStats formatted drainage area output file using the sample WATER XML file to calculate basin area
<code>-ecoflowdashp</code>	Create an EflowStats formatted drainage area output file using the sample basin shapefiles
<code>-mapsim</code>	Create maps for single and batch simulations
<code>-all</code>	Run series of commands, including <code>-tests</code> , <code>-txt</code> , <code>-xml</code> , <code>-wateruse</code> , <code>-gcmdelta</code> , <code>-oasis</code> , <code>-ecoflowstationid</code> , <code>-ecoflowdaxml</code> , <code>-ecoflowdashp</code> , <code>mapsim</code>
<code>-tests</code>	Run units tests; use <code>nosetests</code>
<code>-makeclean</code>	Cleans/removes all output of running sample dataset in in the <code>sample-water-simulations</code> directory

Example—apply water use to delineated and batch simulations:

```
$ run_sample_datasets.sh -wateruse
```

Applying Water Use or General Circulation Model Change Factors to Many WATER Simulations Using `run_simulations.sh`

The shell script `run_simulations.sh` is a shell script that can be used to automate the processing of many WATER simulations. `run_simulations.sh` can be used to apply water use or general circulation model (CGM) change scenarios to multiple WATER simulations that are contained in the same directory. A user will provide a valid option along with the **path to the directory containing all WATER simulations** that need to be processed. This directory should contain all the same type of WATER simulations: *delineated* (that is, delineated within WATER GUI from a pour point) or *batch*, but not both. A user should ensure that the proper settings for processing a *delineated* or *batch* simulation are set in the `user_settings.py` file. Note that the `simulation_directory` variable will be ignored when using this script, but all other settings will be used accordingly.

Usage—shell script for applying water use or GCM deltas to WATER simulations:

```
$ run_simulations.sh [option] <path-to-simulations-directory>
$ run_simulations.sh [[[-applywateruse] [-applysubwateruse] [-applygcmdelta]
[-applysubgcmdelta]] <path-to-simulations-directory> | [-h]]
```

Command Line Arguments for the Shell Script `run_simulations.sh`:

Commands	Description
-h	Show list of available commands
-applywateruse	Run and apply water-use data to sample WATER simulations; individual and batch simulations
-applysubwateruse	Run and apply substitute water-use data to sample WATER simulations; individual and batch simulations
-applygcmdelta	Run and apply GCM deltas to sample WATER simulations; single and batch simulations
-applysubgcmdelta	Run and apply substitute water-use data to sample WATER simulations; individual and batch simulations

Example—apply water use to many WATER simulations:

```
$ run_simulations.sh -applywateruse <path-to-simulations-directory>
```

Graphical User Interface

The multithreaded GUI, referred to as *waterapputils_gui*, can be started using the following command or by double-clicking the *waterapputils_gui.py* file:

```
$ python waterapputils_gui.py
```

The GUI consists of four tabs:

1. Process WATER output text file
2. Compare two WATER output text files
3. Apply water use to WATER simulations
4. Apply GCM deltas to WATER simulations

Process WATER output text file

A user opens a WATER-simulation output text file (WATER.txt), and all parameters and corresponding data are processed. The first parameter in the data file is plotted initially and the user can use the list on the bottom left of the tab to select different parameters to plot. The plot includes a text area showing some simple statistics for the parameter. All parameters and corresponding data also are placed in a read-only table. A user can interact with the plot using the buttons at the top of the plotting area (zoom, pan, etc.). Additionally, a user can enable a *span selector* that allows a user to query the data for specific time periods. Upon using the *span selector*, the simple stats display in the text area with the simple statistics updates for the selected time period.

Compare two WATER output text files

A user opens two WATER simulation output text files, and the *Compare* button is enabled. Upon clicking the *Compare* button, all parameters and corresponding data are processed and compared. The first parameters in the data file are overlaid together with the first file colored as blue and the second file colored as red. A second plot is made, which shows the difference between the respective parameters in each file. The user can use the list at the bottom left of the tab to select different parameters to compare. All parameters and corresponding data for both files are placed in read-only tables. A user can interact with the plots using the buttons at the top of the plotting area (zoom, pan, etc.). Note that the difference plot is tied to the overlay plot, meaning that when a user pans or zooms on the overlay plot, the difference plot will zoom or pan with the overlay plot.

Apply water use to WATER simulations

This tab allows a user to apply water-use data to WATER simulation output text files (WATER.txt).

Number of simulation(s)—a user selects the number of WATER simulations.

- *One simulation* (default)—one batch- or individual-type WATER simulation.
- *Multiple simulations*—more than one batch- or individual-type WATER simulations.

NOTE: The directory containing all WATER simulations to be processed must *only* contain WATER simulations. Do not include extraneous files or directories in the directory (folder). Additionally, the basin shapefile (*Watersheds.shp*) must match with the simulations in the folder.

Type of simulation(s) —a user selects the type of WATER simulation.

- *Batch*—basins that were *pre-delineated* and were run within the WATER DSS.
- *Delineated*—A single basin that was delineated within the WATER DSS.

The following are the directory structures created by WATER for batch and single simulations:

Batch Simulation:

```
simulation/
    basin1/
        amask/
        basinmask/
        fmask/
        info/
        rmask/
        Temp/
        .
        .
        WATER.txt
        WATERSimulation.xml
    basin2/
    basin3/
    .
    .
    Water.txt
    Watersheds.shp
```

Delineated Simulation:

```
simulation/
    amask/
    basinmask/
    fmask/
    info/
    rmask/
    Temp/
    .
    .
    basinMask.shp
    WATER.txt
    WATERSimulation.xml
```

Simulation information—a user selects the WATER simulation of interest for application of water use.

If a valid WATER simulation is selected, the rest of the inputs in the *Simulation Information* section will auto-populate. A user can select the proper *Basin shapefile id field* that was used when running the WATER application. The *Basin shapefile id field* is used by the WATER application to name the output basin directories in the simulation directory structure. The *Basin shapefile area field* is used to obtain the areas of each respective basin for use in an external ecoflow program.

NOTE: A batch WATER simulation will contain a shapefile of the basins referred to as *Watersheds.shp*. A delineated WATER simulation will contain a shapefile of the basin referred to as *basinMask.shp*. A WATER simulation must have an associated *Watersheds.shp* or *basinMask.shp* file.

Water-use information—a user selects the seasonal water-use data files and associated information.

A user selects four seasonal water-use files (provided with WATER database):

1. January, February, March,
2. April, May, June,
3. July, August, September,
4. October, November, December.

A user selects a water-use factor file, which can be used to adjust the water-use data values in the seasonal water-use files.

A user selects the water-use shapefile, which is a shapefile of water-use points across the entire modeling domain.

For the DRB, these files are *season_nCPcarb3736_date* and *dem_basin_centroids*.

NOTE: All WATER application shapefiles are in the Albers NAD 83 projection.

A user selects the *id* field from the water-use shapefile that corresponds to the *id* field used in the water-use data files.

NOTE: The sample water-use files and water-use shapefile have *newhydroid* as the *id* field; this also is the case for those provided with the WATER database.

If those basins in the WATER simulation do not overlap/intersect with water-use points, then the user can choose to apply substitute water use (`-applysubwateruse`) based on that for another basin.

NOTE: To apply substitute water use, the user must first apply water use without this option. The `waterapputils` program will warn and log any basins in the WATER simulation that do not overlap/intersect with the water-use shapefile points.

The `waterapputils` program will create a file referred to as *wateruse_non_intersecting_centroids.txt* in the `/waterapputils-info/` directory with a list of the basins that do not overlap/intersect any water-use points. This file is designed to apply zero water use in those basins that did not intersect any water-use points. A user must manually enter the desired water-use *id* (that is, *newhydroid*) values to be used when applying the substitute water use. To apply substitute water use, the `/waterapputils/wateruse_non_intersecting_centroids.txt` file must exist and be updated by the user.

A user clicks the *Check Inputs* button, which checks and ensures that all fields have been entered. After all fields have been entered and the *Check Inputs* button has been pressed, the *Apply Water Use*, *Plot Overview Map*, and *Plot Zoomed Map* buttons are enabled. If a user clicks the *Apply Water Use*, then `waterapputils` applies water use to the WATER simulation using those data provided by the user. The `waterapputils_gui` will apply water use in a separate thread, meaning that the process will be run in the background, allowing the user to continue using other parts of the `waterapputils_gui` without interfering with the water-use processing.

NOTE: When processing water use, a warning about a QPixmap may display. This is not an error, but only a warning that, in this case, can safely be ignored. The warning stems from using the same plotting code used in the command line version of `waterapputils` when applying water use.

If a user clicks the *Plot Overview Map*, a map of the WATER basin shapefile (*Watersheds.shp* or *basinMask.shp*) is plotted in a zoomed-out view or the entire modeling domain. If a user clicks the *Plot Zoomed Map*, a map of the WATER basin shapefile (*Watersheds.shp* or *basinMask.shp*) is plotted in a zoomed-in view with additional shapefiles (that is, USGS streamgages).

Apply GCM change factors to WATER simulations

This tab allows a user to apply GCM deltas to WATER simulation files (*WATERSimulation.xml*).

Number of simulation(s)—a user selects the number of WATER simulations.

- *One simulation* (default)—one batch- or delineated-type WATER simulation.
- *Multiple simulations*—more than one batch- or delineated-type WATER simulations.

NOTE: The directory containing all WATER simulations to be processed must *only* contain WATER simulations. Do not include extraneous files or directories in the parent directory (folder).

Type of simulation(s)—a user selects the type of WATER simulation.

- *Batch*—basins that were *pre-delineated* and were run within the WATER DSS.
- *Delineated*—A single basin that was delineated within the WATER DSS. The following are the directory structures created by WATER for batch and delineated simulations:

Batch Simulation:

```
simulation/
    basin1/
        amask/
        basinmask/
        fmask/
        info/
        rmask/
        Temp/
        .
        .
        WATER.txt
        WATERSimulation.xml
    basin2/
    basin3/
    .
    .
    Water.txt
    Watersheds.shp
```

Single Simulation:

```
simulation/
    amask/
    basinmask/
    fmask/
    info/
    rmask/
    Temp/
    .
    .
    basinMask.shp
    WATER.txt
    WATERSimulation.xml
```

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Simulation Information—a user selects the WATER simulation of interest to apply GCM deltas.

If a valid WATER simulation is selected, the rest of the inputs in the *Simulation Information* section will auto-populate. A user can select the proper *Basin shapefile id field* that was used when running the WATER application. The *Basin shapefile id field* is used by the WATER application to name the output basin directories in the simulation directory structure. The *Basin shapefile area field* is used to obtain the areas of each respective basin.

NOTE: A batch WATER simulation will contain a shapefile of the basins referred to as *Watersheds.shp*. A delineated WATER simulation will contain a shapefile of the basin referred to as *basinMask.shp*. A WATER simulation must have an associated *Watersheds.shp* or *basinMask.shp* file.

General circulation model change factor information—a user selects three GCM delta files and associated information.

A user selects three GCM delta files from those provided in the *GCMdeltas* folder of the WATER database:

1. PET.txt,
2. Ppt.txt, and
3. Tmax.txt.

A user selects the GCM shapefile, which is a shapefile of tiles for the corresponding GCM that covers the entire modeling domain.

NOTE: All WATER application shapefiles are in the Albers NAD 83 projection.

A user selects the tile identification field from the GCM shapefile that corresponds to the tile identification field used in the three GCM delta files.

NOTE: The sample GCM delta files and GCM shapefile have Tile as the id field.

If the basins in the WATER use simulation do not overlap/intersect with the GCM shapefile tiles, then the user can choose to apply substitute GCM deltas.

NOTE: To apply substitute GCM deltas, the user must first apply GCM deltas without this option. The *waterapputils* program will warn and log any basins in the WATER simulation that do not overlap/intersect with the GCM deltas shapefile tiles. The *waterapputils* program will create a file referred to as *gcm_delta_non_intersecting_tiles.txt* in a directory referred to as *waterapputils-info* with a list of the basins that do not overlap/intersect. A user must manually enter the proper GCM delta shapefile id (that is, Tile) values to be used when applying the substitute GCM deltas. To apply substitute GCM deltas, the file referred to as */waterapputils-info/gcm_delta_non_intersecting_tiles.txt* must exist.

A user clicks the *Check Inputs* button, which checks and ensures that all fields have been entered. After all fields have been entered and the *Check Inputs* button has been pressed, the *Apply Water Use*, *Plot Overview Map*, and *Plot Zoomed Map* buttons are enabled. If a user clicks *Apply General Circulation Model Deltas*, then *waterapputils* applies GCM deltas to the WATER simulation given the data provided by the user. The *waterapputils_gui* will apply GCM deltas in a separate thread, meaning that the process will be run in the background, allowing the user to continue using other parts of the *waterapputils_gui* without interfering with the GCM delta processing.

NOTE: When processing GCM deltas, a warning about a *QPixmap* may display. This is not an error, but only a warning that, in this case, can safely be ignored. The warning stems from using the same plotting code used in the command line version of *waterapputils* when applying GCM deltas.

If a user clicks the *Plot Overview Map*, a map of the WATER basin shapefile (*Watersheds.shp* or *basinMask.shp*) is plotted in a zoomed-out view or the entire modeling domain. If a user clicks the *Plot Zoomed Map*, a map of the WATER basin shapefile (*Watersheds.shp* or *basinMask.shp*) is plotted in a zoomed-in view with additional shapefiles (that is, USGS streamgages).

Testing

Automated tests for **waterapputils** were written using the `nose` library, and are contained in the `tests` directory. The `nose` library must be installed to run tests. Automated tests can be run using the `nosetests` command at the project level directory (not within the `tests` directory, but the `waterapputils` directory containing the `tests` directory). A successful test run will look something like the following:

```
$ pwd
/path/to/waterapputils

$ nosetests
SETUP: deltatxt tests
.....TEARDOWN: deltatxt tests
...
SETUP: waterxml tests
.....TEARDOWN: waterxml tests
-----
Ran 91 tests in 1.049s

OK
```

Repository Layout

```
bin/                # executables/scripts
data/              # sample data files to use with software and associ-
ated information
  deltas-gcm/      # statistically downscaled general circulation model
data
  sample-water-simulations # sample WATER application simulations and datasets
  sample-batch-simulation # sample WATER application batch run simulation
  sample-datasets       # sample WATER application simulation datasets
  sample-single-simulation # sample WATER application single run simulation
  spatial-datafiles/    # spatial data; shapefile format
  watertxt-datafiles/  # sample WATER.txt files
  wateruse-batch-run/  # sample batch run output from WATER
  wateruse-datafiles/  # sample water-use files
  waterxml-datafiles/  # sample WATERSimulation.xml files
docs/              # Sphinx code documentation
tests/            # tests
  deltas_tests.py    # tests for deltas module
  helpers_tests.py   # tests for helper module
  spatialvectors_test.py # tests for spatialvectors module
  watertxt_tests.py  # tests for watertxt module
  wateruse_tests.py  # tests for wateruse module
  waterxml_tests.py  # tests for waterxml module
waterapputils/    # directory containing code modules
  waterapputils.py   # main controller; calls respective module
  user_settings.py   # user settings to control and specify data inputs
for water use and general circulation model processing along with control of naming outputs
```

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```
gui/                                # gui specific files
modules/
  deltas.py                          # handles processing of GCM data
  deltas_viewer.py                   # handles view (plotting) of GCM data
  gcm_delta_processing.py            # handles the GCM delta factors processing using
settings from the user_settings.py file
  helpers.py                         # helper functions
  spatialdata_viewer.py              # handles view (mapping) of spatial data; uses
basemap library
  spatialvectors.py                  # handles spatial data
  specific_output_file_processing.py # handles specific output file processing for external
OASIS and EflowStats programs
  water_files_processing.py           # handles the WATER application output and database
file processing using settings from the user_settings.py file
  waterapputils_logging.py           # handles error logging
  watertxt.py                        # handles processing of WATER.txt simulation output
files
  watertxt_viewer.py                 # handles view (plotting) of WATER.txt simulation
output files
  wateruse.py                        # handles processing of water-use data
  wateruse_processing.py              # handles the water-use processing using settings
from the user_settings.py file
  waterxml.py                        # handles processing of WATERSimulation.xml simula-
tion database files
  waterxml_viewer.py                 # handles view (plotting) of WATERSimulation.xml
simulation database files
Makefile                             # makefile to help clean directories
LICENSE.txt                          # USGS Software User Rights Notice
README.md                             # README file
requirements.txt                      # list of requirements/dependencies
setup.py                              # code for building, distributing, and installing mod-
ules
run_sample_datasets.sh                # bash script used to run specific or all sample datas-
ets
run_simulations.sh                   # bash script used to apply water use and/or GCM deltas
to multiple WATER simulations
```