User Manual for the Massachusetts Firm-Yield Estimator Model Version 2.0

U.S. Department of the Interior
U.S. Geological Survey

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Installation

The Massachusetts Firm-Yield Estimator Model Version 2.0 (FYE) was designed to run on a Microsoft Windows compatible personal computer and has not been tested on other operating systems. After the installation folder has been downloaded and unzipped, click the Setup icon. A window may appear with a security warning. Click the Install button. The program will be installed on the hard drive of the computer and can be accessed from the start menu. After installation, the program will launch automatically.

Using the Firm Yield Estimator

The Firm Yield Estimator determines the maximum yield that can be extracted from a reservoir system without risk of failure during a drought period. The model comes pre-loaded with daily streamflow and climate data as well as the relevant bathymetric and aquifer data needed to estimate yields for 71 reservoirs belonging to 38 reservoir systems in Massachusetts. Users may enter optional management scenarios or reliability criteria as well as alter the default aquifer characteristics and peak usage factors. To view data or estimate the yield of a single- or multiple- reservoir system which is already included in the database, the user should press the appropriate button from the start-up screen (fig. 1).

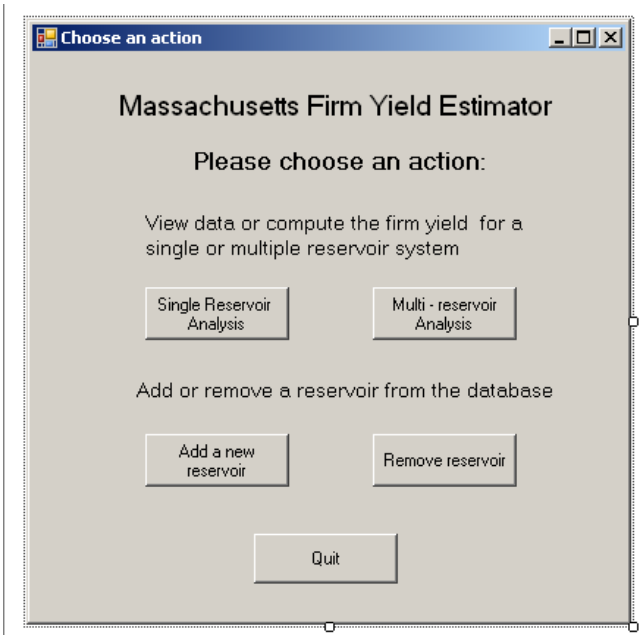

Figure 1. Start-up screen for the Firm Yield Estimator model

Users may also add new reservoirs to the database along with the necessary streamflow data, climate data and bathymetry data. To enter a new reservoir into the model, press the "Add a new reservoir" button from the first application screen. To remove a reservoir and all associated data from the model database, press the "Remove reservoir" button.

Estimating the firm yield of a single-reservoir system

A reservoir system may be made up of one or more hydrologically connected reservoirs. A single-reservoir system consists of one reservoir that does not receive or contribute water to any other reservoirs. To compute the firm yield of a single-reservoir system, click the "Single Reservoir Analysis" button on the start-up screen

Viewing and editing reservoir information

After clicking the "Single Reservoir Analysis" button, the user will be asked to select a public water supplier and reservoir from the list of suppliers and reservoirs in the FYE database. After choosing a reservoir to view, the single-reservoir-system screen will appear (fig. 2). This screen contains all the data associated with this reservoir. Data fields with a white background may be edited by the user. Data fields with a gray background cannot be changed.

There are four tabs which organize the reservoir data, supplier information, and simulation options. The first tab, displayed by default, is the Reservoir Information tab. This tab contains all the default data associated with the reservoir. Daily streamflow, precipitation, evaporation, and stage-storage tables may be viewed or exported to a comma delimited text file by selecting the appropriate buttons. These data may not be altered by the user.

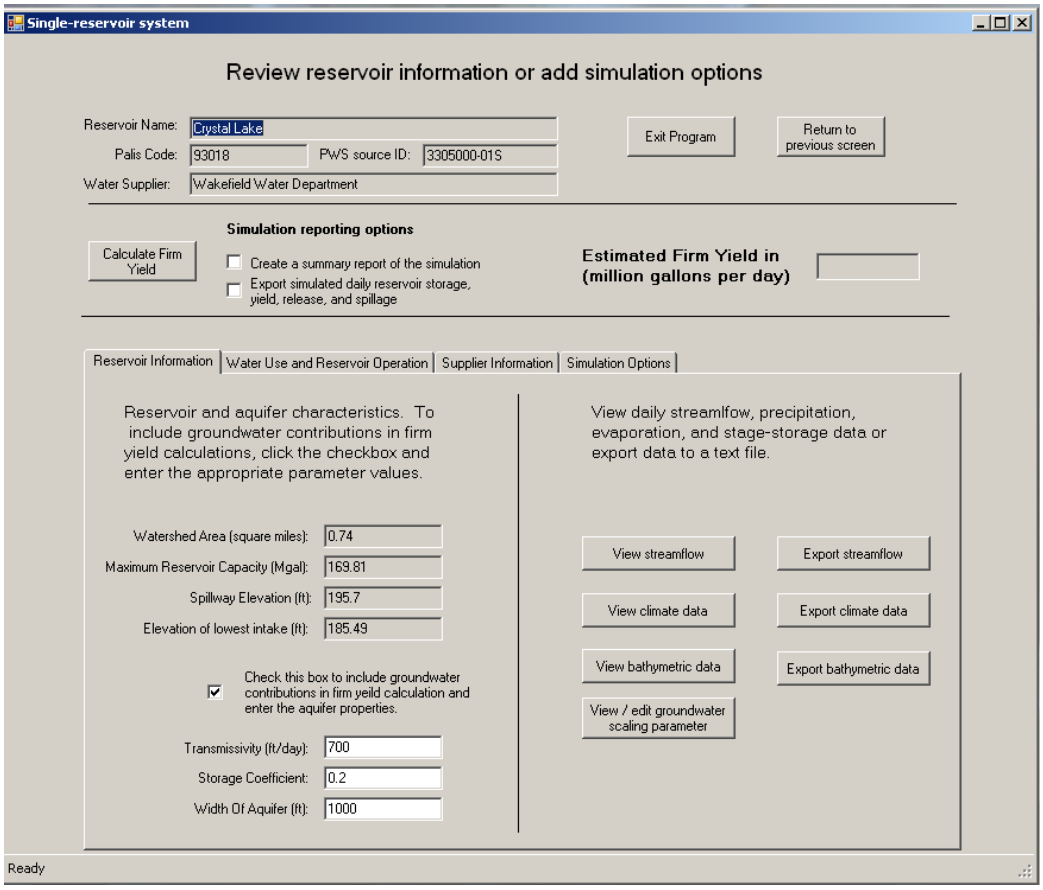

Figure 2. Firm Yield Estimator model screen for viewing and editing data for a single-reservoir system

The FYE estimates groundwater contributions to the daily water balance for reservoirs that are hydrologically connected to an aquifer. If a reservoir is connected to an aquifer, there will be a check mark in the box at the bottom of the screen and the estimated aquifer properties will be displayed below. Aquifer properties were estimated using the methods described in Levin, Archfield, and Massey (2011). Users may alter the estimated values for aquifer transmissivity, storage coefficient, or aquifer width in the appropriate text boxes. The groundwater scaling parameter may be viewed or edited by clicking the "View/edit groundwater scaling parameter" button.

Entering water use and reservoir operation information

Users may view the default reservoir peak usage factors, required releases, and withdrawals by other users by clicking on the "Water Use and Reservoir Operation" tab on the single-reservoir system form. Data may be edited by selecting the appropriate button (fig. 3). Monthly peak-usage factors are calculated as the average monthly withdrawal rate divided by the annual average withdrawal rate. Monthly peak-usage factors should add up to 12. Controlled releases are water releases from the reservoir to provide water for stream reaches below the dam. Users may specify a daily controlled-release volume for each month. Withdrawals by other users are any withdrawals taken from the reservoir for purposes other than public water supply.

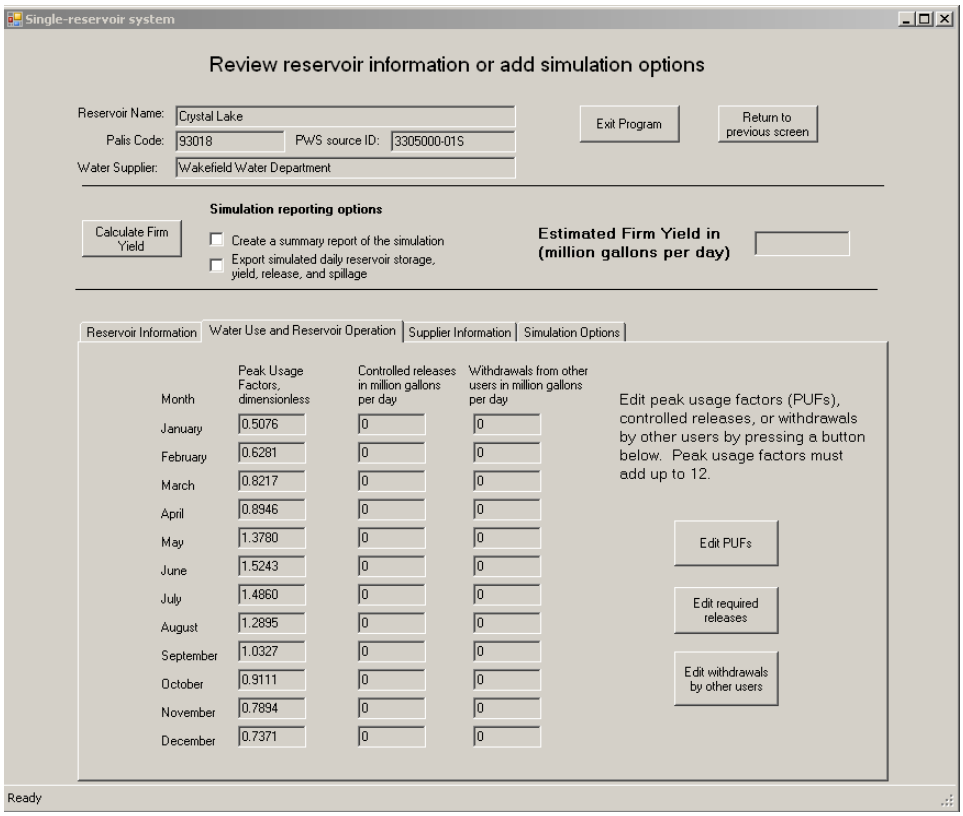

Figure 3. Firm Yield Estimator model screen for viewing and editing monthly water usage and controlled releases for a single-reservoir system.

Viewing supplier information

Information regarding the water supplier can be accessed by clicking on the "Supplier Information" tab.

Entering summer water-restriction scenarios and desired reservoir reliability

Demand management scenarios and reliability criteria may be set by clicking on the "Simulation Options" tab (fig. 4). Reservoir reliability is calculated as one minus the percentage of days during the simulation that the reservoir is allowed to fail. The 44-year simulation period consists of 16,071 days. The default reliability criteria of 100 percent does not allow the reservoir to fail during the entire simulation. Users may change the reliability criteria by entering the total number of allowable failure days during the simulation. The reliability will be automatically calculated from the user input and displayed directly below.

Reservoir failures may occur in many short failure events or a few long duration failure events. The magnitude of a failure is calculated as the difference between the daily water demand and the daily amount of water that was available for withdrawal during the failure. When a reliability criterion is specified, the average number and duration of failure events is calculated during simulation, as well as the average failure magnitude. These statistics are displayed in the appropriate text boxes under the "Simulation Options" tab after simulation has completed.

Summer water demand management scenarios may also be entered by the user. Summer water restrictions are often implemented when reservoir storage falls to a critically low level. Many water demand management plans specify multi-tiered approaches which implement increasing water-use restrictions as the reservoir drops to successively lower storage levels. The FYE allows users to specify summer water restriction scenarios with up to 3 levels of water-use reductions. At each reduction level, potential water-use reduction is specified as a percentage by which water-use may be reduced. Users must also specify the critical storage level at which restrictions will be implemented. Critical storage is expressed as a percentage of maximum total storage. During simulation, for each day that the reservoir storage falls below the critical storage specified in the demand management scenario, the daily yield will be reduced by the reduction percentage. As soon as reservoir storage rises above the critical storage level, the daily yield will be restored back to 100 percent. If a multi-tiered strategy is to be used, they should be entered in order of implementation, with the highest critical storage value first.

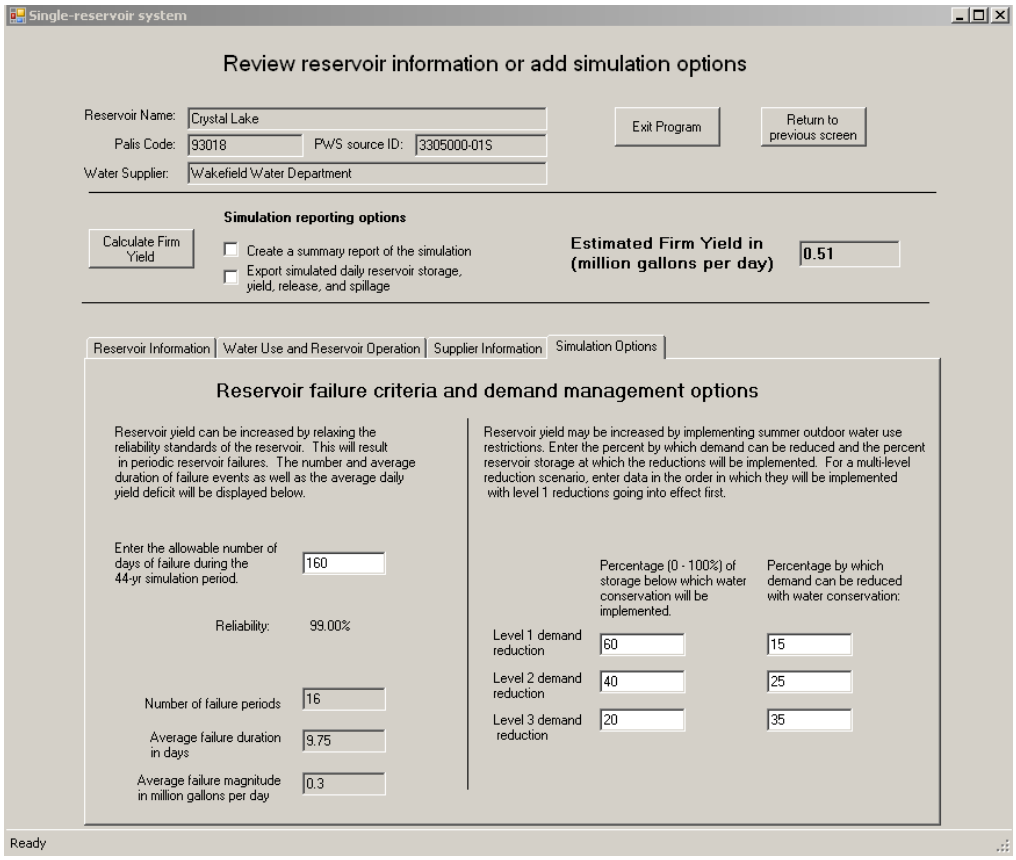

Figure 4. Firm Yield Estimator model screen for specifying reservoir reliability criteria and water-demand reduction scenarios

Once all the data has been reviewed and management scenarios have been entered, the firm yield may be estimated by pressing the “Calculate Firm Yield” button on the left side of the screen. The firm yield will be displayed in the text box to the right. Simulation run times are generally less than one minute; however, due to the iterative algorithm for estimating groundwater flows, simulations for reservoirs connected to groundwater aquifers may take substantially longer.

A summary report of the simulation can be created by checking the top checkbox next to the “Calculate Firm Yield” button. The summary report will be automatically generated at the end of the

simulation and will contain the estimated firm yield, basic reservoir and supplier information, peak usage factors, withdrawals by other users, and controlled releases, as well as any management options that were entered by the user. The report may be printed or saved by the user by clicking the appropriate icons at the top of the page. Daily time series of reservoir storage, yield, controlled releases and uncontrolled spillage estimated by the simulation may be exported to a comma delimited text file by checking the bottom checkbox next to the "Calculate Firm Yield" button. If this check box is selected, the user will be asked to enter a location and file name to save the data.

Estimating the firm yield of a multiple reservoir system

The Firm Yield Estimator allows the estimation of firm yield from multi-reservoir systems with any number of reservoirs in many different configurations, however there are some reservoir configurations which cannot be adequately simulated by the FYE. Reservoir configurations must contain only one terminal reservoir. Terminal reservoirs may not contribute water to any other reservoir in the system. Reservoirs in the system may receive water from up to 3 other reservoirs however non-terminal reservoirs may transfer water to only one other reservoir.

Specifying system configuration

The multiple reservoir system screen allows the user to enter reservoirs for a multiple reservoir system (fig. 5). Reservoirs may be added to the system by clicking the "Add reservoir to system" button on the left of the form. A reservoir may be removed by clicking the "Remove last reservoir" button. For each reservoir added to the system, select the reservoir name from the dropdown box on the left. Next, select the method by which water is transferred from the current reservoir to the next reservoir in the list box to the right. If water is pumped to the next reservoir in the system, a pumping capacity should be specified. If no capacity is specified, the default of 1,000,000 gallons per minute will be used. If water flows through an open channel, aqueduct, or stream corridor, select "By Gravity". Each reservoir in the system may only transfer water to one other reservoir. Next, any reservoirs that contribute water to the current reservoir should be selected in the dropdown boxes on the right. A reservoir may receive water from up to three upstream reservoirs. If the reservoir does not receive any water from other reservoirs, select "None".

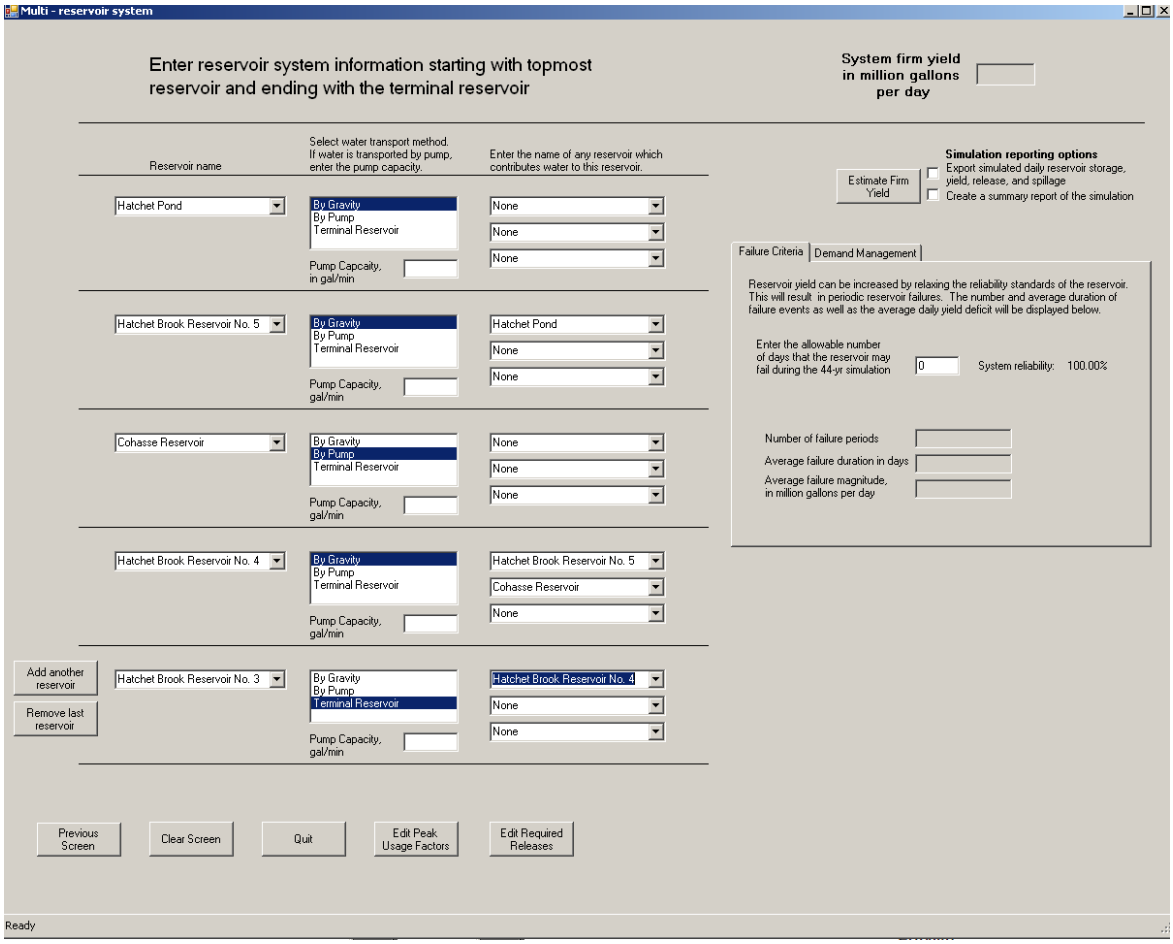

Figure 5. Firm Yield Estimator model screen for a multiple reservoir system.

Reservoirs should be entered into the form in the order in which water flows through the system. Reservoirs that receive water either through pumping or a gravity-fed stream or channel, must be added to the system after the upstream reservoir. The terminal reservoir must be entered last. Reservoir system configurations for the reservoirs included in the FYE database can be found in Appendix 3 on of the report (Levin, Archfield, and Massey, 2011) or in previous firm yield reports (Waldron and Archfield, 2006). Figure 5 shows the multiple-reservoir system screen configured for the Southbridge Water Department reservoir system.

Entering management scenarios

Peak usage factors and controlled releases for each reservoir in the system may be viewed and edited by clicking on the appropriate buttons at the bottom of the form. Each reservoir in the system may have different peak usage factors and controlled releases. Controlled releases for gravity-fed systems are routed downstream and will contribute to flows entering a downstream reservoir. Controlled releases in a pumped system do not contribute to other reservoirs in the system. The system failure criterion and demand management scenarios may be specified for the system in the same manner as for a single-reservoir system. The failure criterion and demand management scenarios are applied to each reservoir in the system individually.

Entering a new reservoir in the database

In order to estimate the firm yield of a reservoir system that is not currently in the Firm Yield Estimator model database, the user may compile all the required reservoir and climate data and enter it into the FYE model database. To enter a new reservoir into the system, click the "Add new reservoir" from the start-up screen. This will bring up the Add Reservoir screen (fig. 6). The user must first enter reservoir and supplier information into the appropriate text boxes on the Add Reservoir screen. Required fields are indicated with an asterisk and include the reservoir name, maximum usable storage in million gallons, the drainage area to the lake, excluding lake surface area, in square miles, a 7-digit public water supplier ID number and supplier name. In addition, if the reservoir is connected to a groundwater aquifer, the checkbox on the right of the form should be selected and the transmissivity, storage coefficient, and aquifer width should be specified according to the methods outlined in the FYE report (Levin, Archfield, and Massey, 2011). After all the required fields are entered on the form, press "Add new reservoir" button at the bottom of the form. This will enable buttons allowing the user to import data files with reservoir bathymetry data, daily streamflow and climate data, and enter default peak usage factors for the reservoir.

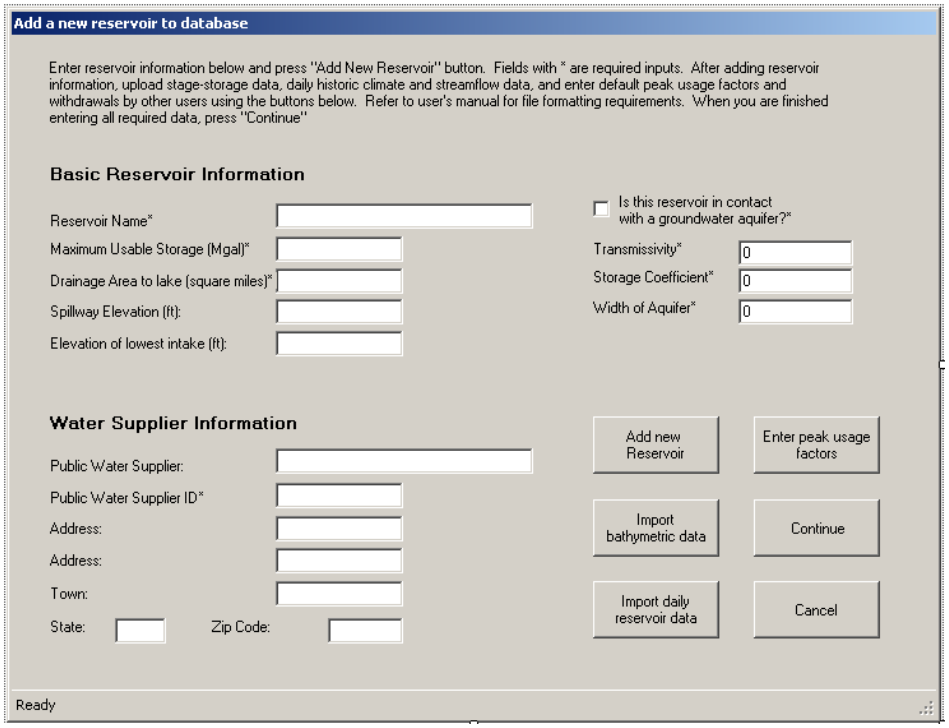

Figure 6. Firm Yield Estmiator model screen to add a new reservoir to the database

Uploading data files

After entering basic reservoir information, bathymetric data, daily streamflow, and climate data must be uploaded from comma-delimited text files. Stage-storage data is needed to relate reservoir volume, elevation, and surface area at various contour elevations. In addition, this file contains the groundwater scaling parameter, L, for reservoirs in contact with an aquifer. Reservoir contour data should be determined using the methods outlined in the Firm Yield documentation report (Levin, Archfield, and Massey, 2011). For reservoirs which do not receive groundwater contributions, a value of 0 should be included for the scaling parameter, L, at each contour elevation.

The stage – storage data file should contain the following columns of data, in the order presented, with the first row containing column names (fig. 7):

Reservoir surface elevation, in feet, starting with the lowest elevation lowest point in the reservoir and continuing at contour intervals of any value up to the full pool surface elevation. Values in between these contour intervals will be linearly interpolated by the program.

Cumulative storage volume, in million gallons, at each contour elevation. This should equal the total volume of water including dead storage below the spillway at each contour elevation.

Area of the reservoir surface, in square miles at each contour elevation.

Groundwater scaling parameter. This parameter can be estimated by the perimeter in contact with sand and gravel at each contour, in feet, and should increase with surface area.

```
elev_ft,  vol_mg,      area_sqmi,  L_ft
1871,     0,           0,           0
1872,     0.000146943, 4.6971E-06,  0
1874,     0.213125497, 0.001016497, 0
1876,     0.950196568, 0.002517628, 0
1878,     2.324706702, 0.004072904, 0
1880,     4.433802317, 0.006039834, 0
1882,     7.590496495, 0.009095953, 0
1884,     11.94526569, 0.011784391, 0
1886,     17.41009566, 0.014418497, 0
1888,     23.96434623, 0.017007969, 0
1890,     31.58248687, 0.01951966,  0
1892,     40.25678918, 0.022072076, 0
1894,     49.96509669, 0.024477532, 0
1896,     60.70139122, 0.027001091, 0
1898,     72.60599293, 0.030079357, 0
1900,     86.15209179, 0.034871778, 0
```

Figure 7. Sample bathymetric data input file for the Massachusetts Firm Yield Estimator

Climate and streamflow data for the reservoir can be uploaded by pressing the “Import daily reservoir data” button. Daily precipitation, lake evaporation, and streamflow data are required for the simulation period from 10/1/1960–9/30/2004. The daily reservoir data file should be stored as a comma delimited file with the first row containing column headers. The following columns of data should be included in the file, in the following order: date, daily precipitation in hundredths of inches, daily lake evaporation in hundredths of inches, daily streamflow in cubic feet per second. Default peak usage factors and withdrawals by other users may be added by clicking the “Enter Peak Usage” button.

Once all the necessary data has been added to the database, press the “Continue” button to return to the start-up screen.

Removing a reservoir from the database

A reservoir and all its associated data may be removed from the FYE database by clicking on the “Remove reservoir” button on the FYE start-up screen and selecting the reservoir from the list.

References Cited

Levin, S.B., Archfield, S.A., and Massey, A.J., 2011, Refinement and evaluation of the Massachusetts firm-yield estimator model version 2.0; U.S. Geological Survey Scientific Investigations Report 2011-5125, 49 p., plus CD-ROM. (Also available at http://pubs.usgs.gov/sir/2011/5125/)

Waldron, M.C., and Archfield, S.A., 2006, Factors affecting firm yield and the estimation of firm yield for selected streamflow-dominated drinking-water-supply reservoirs in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2006-5044, 39 p.