TECHNICAL MEMORANDUM
Virginia Rainwater Harvesting

DATE: March 25, 2013
First Draft: February 23rd, 2013

SUBJECT: Virginia Cistern Design Spreadsheet,
Documentation of Updates

FROM: Alex Forasté, P.E.

TO: Joe Battiata, P.E.

This memorandum provides documentation of the changes made to the March 2012 Virginia Cistern Design Spreadsheet, v. 2.0 to create the updated v. 2.1, March 2013 version.
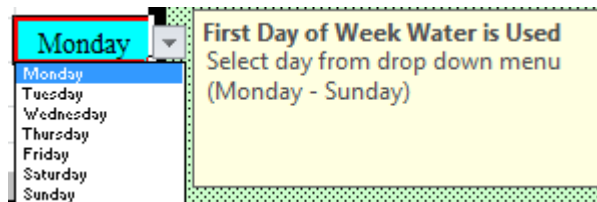
- ***Input Tab – Monthly Inputs, Smart Control option, and Formatting***

  o The input cells for Irrigation, Cooling Towers (CT), and Additionally Daily Use (ADU) were modified to allow for monthly inputs. Previously, there were only year-round entry options, with Monday to Friday start/stop entry for CT and ADU.

  o The Irrigation category was moved to the section immediately below the Laundry category. The Secondary Runoff Reduction Drawdown practice category was moved to the section immediately below Irrigation.

  o An option for the Secondary Runoff Reduction Drawdown practice to be used in conjunction with irrigation to create an equivalent year-round use has been provided. This option will allow the user to achieve credit for both practices by supplementing non-irrigation months with the secondary practice. If this option is selected, the manual entry cells are hidden and the Designer is provided with a minimum gallon/day application rate that must be applied during non-irrigation months. Below is a visual with the option selected.

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The Designer is provided with a beginning and ending month that coincides with the irrigation entries ending and beginning months, respectively. The Secondary Practice daily application rate is derived from the smallest User defined monthly irrigation rate. If the option is not selected, the Designer may manually enter an application rate for a specified period of time, similar to the original version, with a beginning and ending date. See visual below.

SECONDARY RUNOFF REDUCTION DRAWDOWN

If stored water is directed to secondary practice.
NOTE: The permissible flow to be directed is dependent upon the storage volume and surface area of the receiving

Will the Secondary Drawdown practice be used in conjunction with a seasonal irrigation use to achieve an equivalent year-round use? This assumes that the practice will begin when irrigation ends and vice versa at the minimum irrigation application rate. If no, leave box unchecked.		☐ Yes
How many gallons of water will be directed to the secondary practice? (gallons/day)		500
What month and day of the year does the secondary practice start?	March	1
What month and day of the year does secondary practice end?	November	30

- o The beginning and ending dates for the Secondary Runoff Reduction Drawdown practice are now in a Month and Day format. Previously, it was necessary to enter the Julian day associated with these dates (e.g. 1-365), referring to the Julian Day Calendar tab. In addition, the units for this category have been changed from cf/day to gallons/day.

- o The cell that the User adjusts to select the day of the week is now a drop down menu with days of the week (e.g. "Monday") for all entries. Previously there was a number coding ("e.g. 1=Monday).

First Day of Week Water is Used
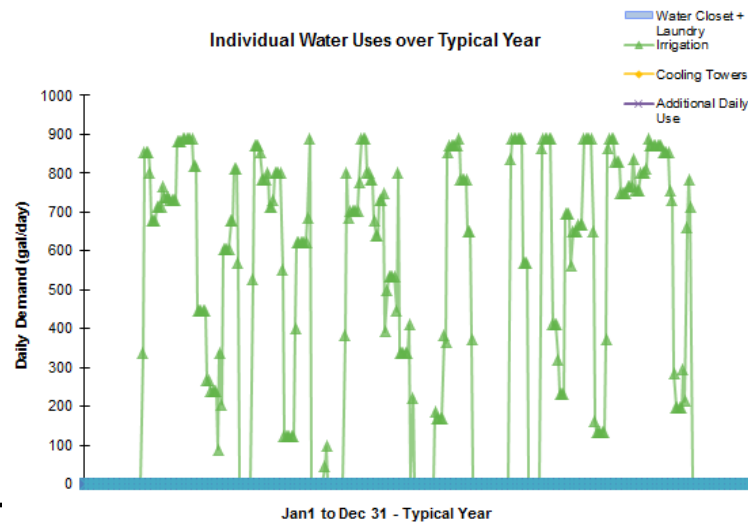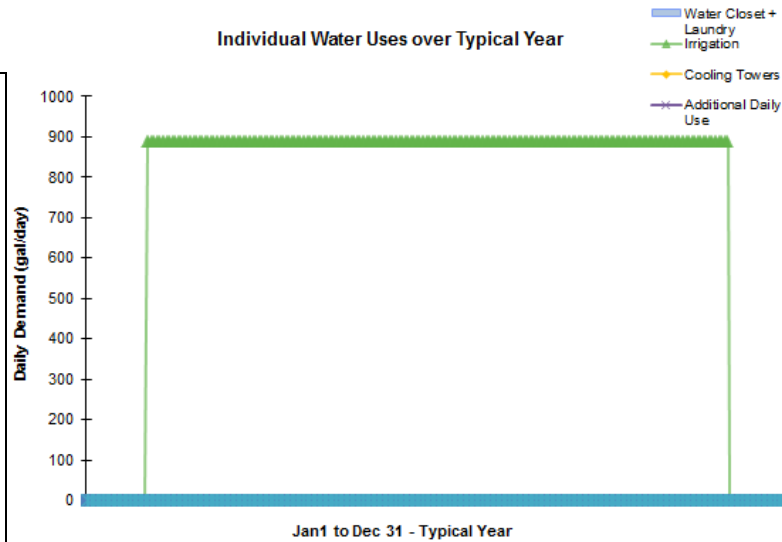Select day from drop down menu
(Monday - Sunday)

- o The Laundry and Toilets/Urinal calculations were adjusted in the Input tab so that a demand is included only for one of the following: a.) the turquoise cells which provide reasonable assumptions of use, OR b.) the dark blue "Alternate Input Cell" entry. In other words, if a value is present in the Alternate cell, that value is used. If the value in the Alternate cell is set to '0', then the other turquoise cells are used. This change was made to reduce potential User input errors.

- o A Smart Control option for Irrigation has been included. Previously, irrigation was applied regardless of precipitation events. Now, with the smart control option, soil sensors, precipitation sensors, and manual shut-off can be simulated on a daily basis. If selected, the sum of the precipitation depths during the 7

previous days is calculated. If it is found to be equal to or greater than the User specified irrigation rate (inches/week), then the irrigation is not applied. If precipitation did occur, but was less than the User specified irrigation rate, then a supplemental irrigation volume is applied, but only up to the specified irrigation rate. If no precipitation occurred, then the full irrigation rate is applied.

IRRIGATION WITH SMART CONTROL OPTION

The top figure shows the Irrigation demand, as entered from February 1st to November 30th , without the smart control option selected. The bottom figure shows the same date selection and irrigation demand entry, but with the smart control option selected. Irrigation is only applied during non-rainfall days and only as needed to meet the specified irrigation rate.

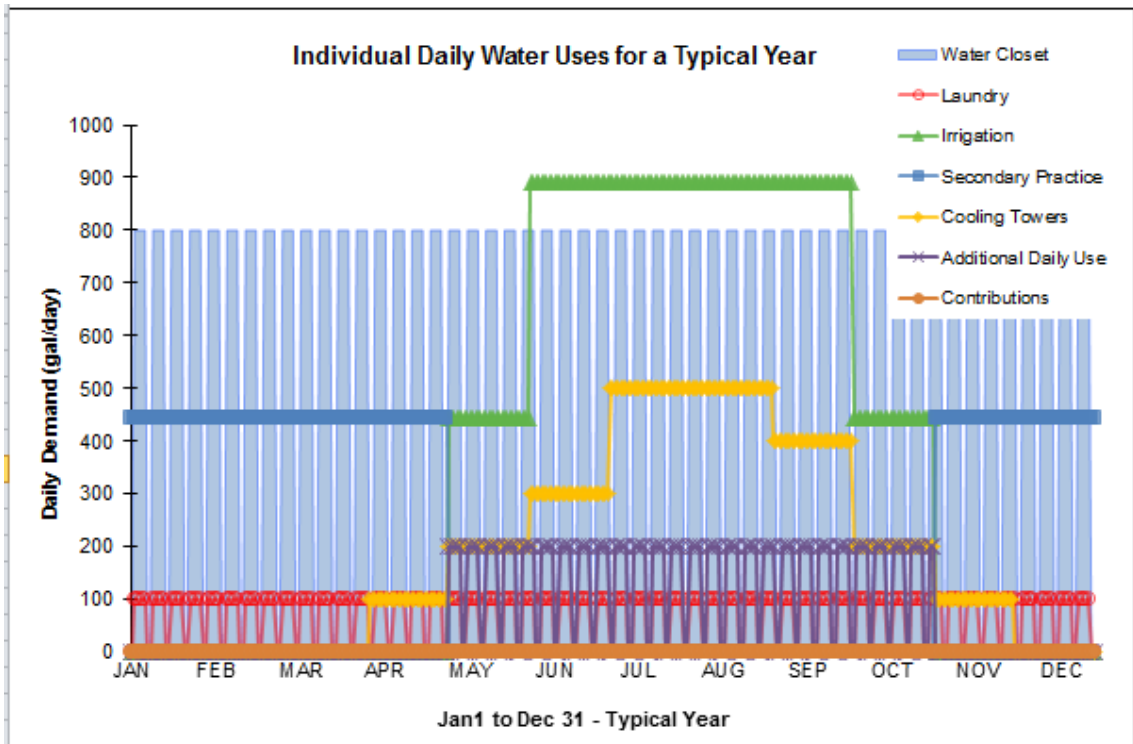
o   A category for "Contributions from Other Sources" has been added. Entries are in a monthly format with a weekly start/stop option (e.g. Monday – Friday, etc.). This category captures any additional contributions that may be added to the cistern, excluding municipal backup supplies, such as condensate from air handling units. It is treated as a 'negative' demand in the spreadsheet model.

- o An option has been added to allow Users to model a system that will be hooked up to a Municipal Backup Supply. This option is only intended for municipal backups that dump water directly into the cistern (e.g. air gap). It should not be used for those that connect to the supply line between the cistern and building (e.g. pressure regulator or otherwise) and do not dump municipal water directly into the cistern. If selected, the User may specify the low and high water level triggers as a percent of the cistern volume (from bottom of cistern to overflow invert). Using a percent format allows application to all cistern sizes in the results section. Visual of the input is below:
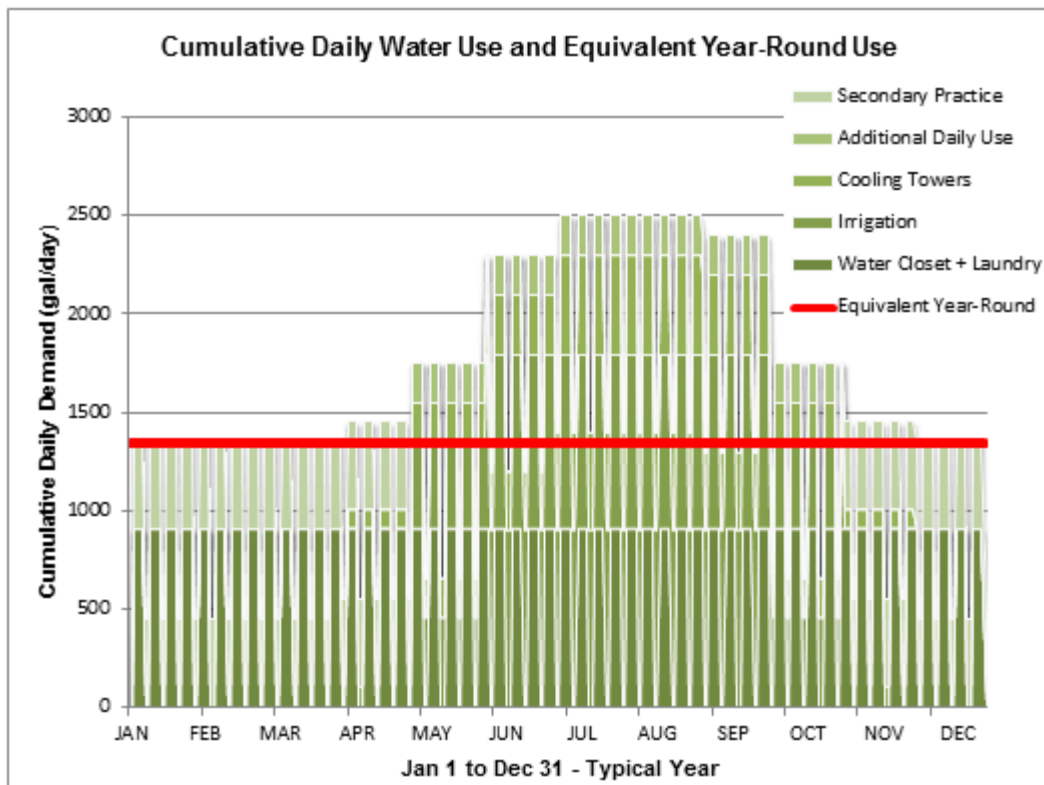
MUNICIPAL BACKUP SUPPLY		
If the system is to be connected to a municipal water backup supply, complete this section.		
Will a municipal backup be used to augment water levels in the cistern?		☐ Yes
Note: If the municipal water does not directly fill the cistern, do not check this box.		
At what point will a low water level trigger the municipal backup to begin adding water? (as % of cistern volume)		35%
At what point will a high water level trigger the municipal backup to stop adding water? (as % of cistern volume)		70%

  Low water level triggers are limited to 5% and greater, as it is assumed that low water cut-off volumes will be required for pumps. High water levels are limited to at least 5% more than low water triggers and up to 100%. In the spreadsheet, this is modeled by filling the cistern up to the high water level mark as soon as water levels reach the low water level trigger.

- o Some Narrative Descriptions were revised for clarity.

- o Bubble descriptions that hover over input cells to assist and guide Users were updated to reflect changes.

- o General appearance and formatting of Input tab was updated to accommodate new monthly input formats.

- *Julian Day Tab* – Previously, the Julian Day calendar was provided in a separate tab so that Users could reference it when choosing the annual start and end date to begin and end irrigation (as well as for other entries). Now that monthly inputs, month/day formats, and drop down menu day formats are used, this tab no longer needs to be visible to the User.

- *Results – RR Volume Credit Tab – Additional Graphs*

- o A new graph was added to display individual water uses. This provides the User with a visual representation of the values they entered in the Input tab and can help to better understand the relative magnitudes of each use to one another. Only one year is plotted, as each year is identical.

Individual Daily Water Uses for a Typical Year

- o The spreadsheet was adapted so that a Runoff Reduction Volume Credit is granted for year-round uses, even when a seasonal use exists. Previously, the credit was set to zero if any seasonal use was entered. In addition, credit can be received for two non-concurrent seasonal uses, so long as they create an equivalent year-round use together. See below for more information.

- o A Cumulative Daily Water Use graph was added to the Results-RR Volume Credit tab. This plot 'stacks' each individual daily water use over the course of a year allowing the User to identify periods of high and low cumulative use. It also provides a way to identify the lowest period of cumulative use over the year – or a minimum threshold – which exists year-round. This lowest cumulative use over the course of the year is described herein as the "Equivalent Year-Round Use". This method accounts for both the traditional year-round uses, as well as seasonal uses in an equitable way and is used to calculate the Runoff Reduction Volume Credit. See below for an example of the chart.
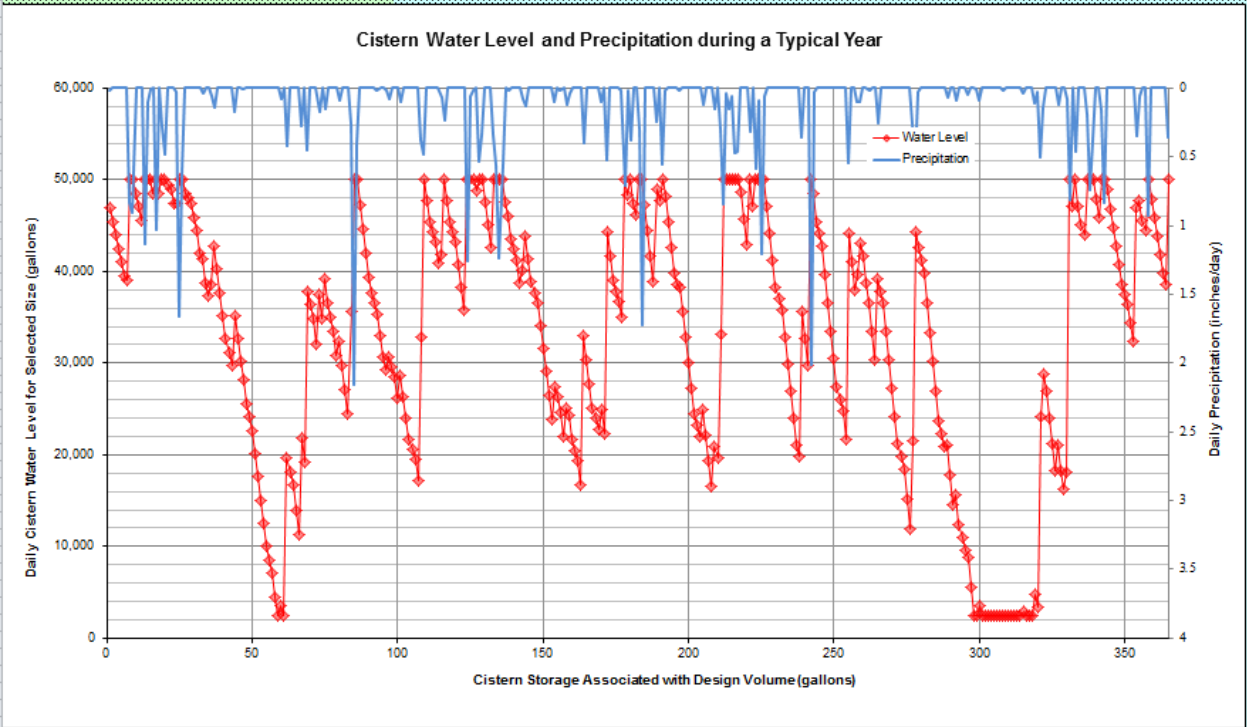
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Cumulative Daily Water Use and Equivalent Year-Round Use

The red line in the chart above identifies the lowest cumulative water use over the course of a year for the same scenario shown in the "Individual Daily Water Uses for a Typical Year" chart in this Memo. The Equivalent Year-Round Use is used to calculate the Runoff Reduction Volume Credit and informs the Designer how they may adjust their design to affect their credit value.

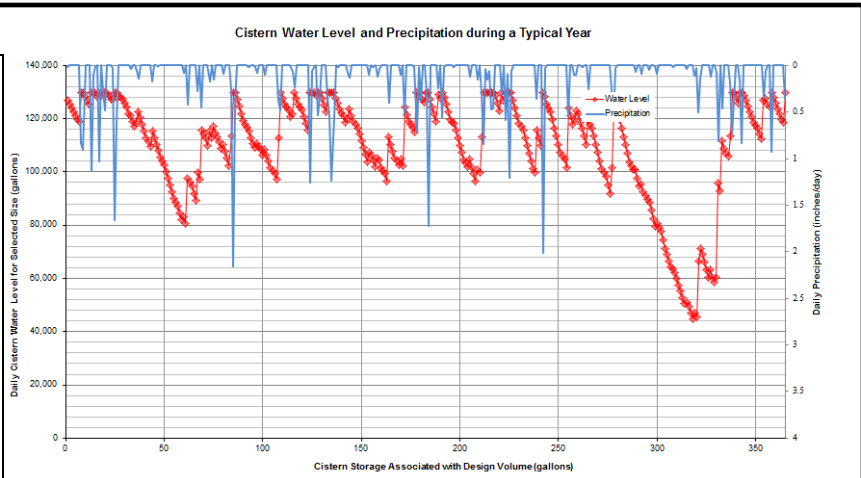o Figures were checked and units verified.

- *Results – Additional Graph*

  o The Units on the Y-axis of the Average Water Level in Cistern graph have been modified so that it reads in gallons, not 1000's gallons. All other figures were checked and units verified.

  o A new graph was added to display the daily cistern water levels and 24 hour precipitation events over the course of a year. The User must select a cistern size from a drop down menu. Only one cistern size is displayed at a time. This chart allows the User to see how the cistern is reacting to various water use scenarios and precipitation events. It also provides the User with a 'gut check' and makes the model more transparent. The plot below is for a 50,000 gallon cistern.

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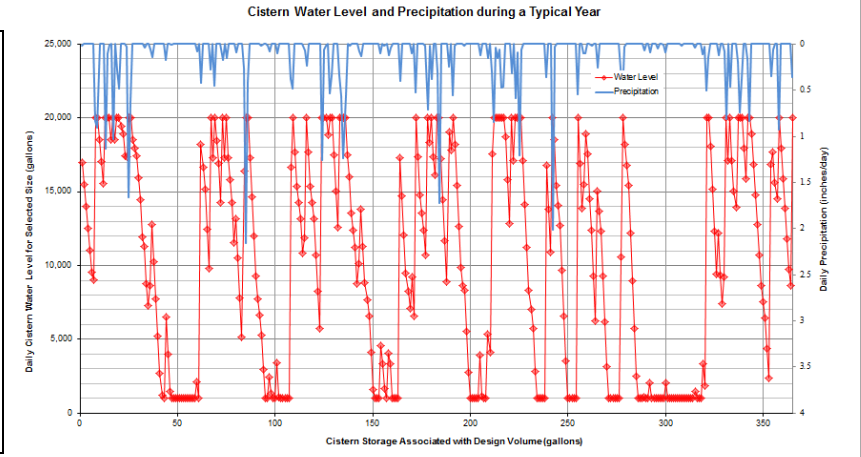Cistern Water Level and Precipitation during a Typical Year

In the plot above, it can be seen that after several storm events, the cistern becomes full, after which it steadily declines to empty (low-water cutoff level).

Larger cisterns hold larger quantities of water and may never run dry during a typical year. This chart shows that there is sufficient supply to span a prolonged dry spell (~45 days) without running dry.

This chart shows the same conditions as the chart above, but with a smaller cistern size. The water levels are much more volatile with the cistern frequently overflowing and running dry.

- o The cistern water levels can be shown in the above Cistern Water Level and Precipitation plot for a normal, wet, and dry year.

Year	Annual Avg
1978	43.65
1979	52.21
1980	35.02
1981	35.04
1982	42.88
1983	45.04
1984	44.58
1985	42.39
1986	34.74
1987	39.63
1988	33.12
1989	52.29
1990	45.04
1991	34.47
1992	40.55
1993	42.15
1994	42.44
1995	40.16
1996	55.19
1997	35.98
1998	43.13
1999	41.54
2000	42.28
2001	32.28
2002	40.15
2003	60.77
2004	46.85
2005	41.48
2006	47.33
MIN	32.28
MAX	60.77
AVERAGE	42.49
MEDIAN	42.28

Normal, Wet, and Dry Rainfall Years:

The Cistern Design Spreadsheet offers four geographic locations from which the Designer may choose in the Input tab: Richmond International Airport, Reagan National, Harrisonburg, and Lynchburg. To determine the normal, wet, and dry rainfall years, the following process was used:

The total annual precipitation for each of these locations was summed for the years 1978 – 2006. The four were then averaged by year to calculate the Annual Average in the table shown to the left here. The minimum, maximum, average, and median values were then calculated for all years and found to be 32.28 in/yr, 60.77 in/yr, 42.49 in/yr, and 42.28 in/yr, respectively as show to the bottom left. The years associated with the minimum, maximum, and annual average rainfall values were selected as the dry, wet, and normal rainfall years, respectively. These were 2001, 2003, and 1994.

Therefore, when the User selects a cistern size for a wet rainfall year on the Results tab, and Richmond in the Input tab, the Cistern Water Level and Precipitation chart plots daily 24 hour rainfall in Richmond for the year 2003 and the resulting daily water levels for the specified cistern size.

For comparison, the annual average rainfall depths by region from 1978-2006 for Richmond, Reagan, Harrisonburg, and Lynchburg were 44.19 in/yr, 39.48 in/yr, 44.49 in/yr, and 41.82 in/yr, respectively.

- **Increased File size** – The file size has increased from 15 MB to approximately 25 MB. This is due to the increased capabilities and enhancements made to the spreadsheet, the second embedded model necessary to calculate the Runoff Reduction Volume Credit for the Equivalent Year-Round Use concept in addition to the pre-existing model necessary to calculate the "actual" results with all of the inputs. Efforts were made to keep file size down during development, so that it would not be larger than it's current state. However, it may be possible to reduce file size more.

Sincerely,

Alex Forasté, P.E.