Graphical Policy Analysis Tool

CADSWES

Overview

The purpose of the Graphical Policy Analysis Tool is to allow users the ability to effectively visualize and analyze RiverWare model outputs as well as other data sets. This tool is designed to allow statistical comparisons and graphing of multiple modeling runs that may vary with respect to hydrology, operational policy, or other parameters. The Graphical Policy Analysis Tool utilizes the functionality of the Microsoft Excel spreadsheet environment and the programming capability of Microsoft Visual Basic for Applications (VBA).

To utilize the Microsoft Excel operating environment in which GPAT exists, the data must be resident in Excel workbooks. To generate graphs from the outputs of the RiverWare hydrologic modeling tool, data must be output to a readable Microsoft Excel (.xls) workbook format. This can be accomplished directly in RiverWare on the Windows platform by specifying an Excel output device through the Output Manager or by specifying the creation of Excel files in the Output panel of the Multiple Run Management Configuration dialog. RiverWare output files (.rdf) can be converted to Microsoft Excel files (.xls) using the RdfToExcel tool designed and distributed through CADSWES. Multiple RiverWare output files can be simultaneously analyzed by putting each into an independent Microsoft Excel (.xls) workbook. These multiple workbooks can represent different polices or separate single runs and still be compared and analyzed within GPAT.

In addition, GPAT now has considerable flexibility in handling time series data in Excel that did not originate from RiverWare. The requirements are that the rows represent time steps, the first column of a worksheet contains the time step names, and the first row of a worksheet contains the column names.

To generate graphs from the data contained in the workbooks, the user must specify their input data format and select a graph type. The resulting graphs and the corresponding graphed data are created in worksheets in a ***Destination Workbook*** which also must be specified by the user. A record of each graph generated is created in the ***Destination Workbook*** on a worksheet titled ***Log Sheet***. Graph configurations can be saved into a configuration file through the GPAT interface and reloaded later so that frequently used graphs don't need to be reconfigured each time they are generated.

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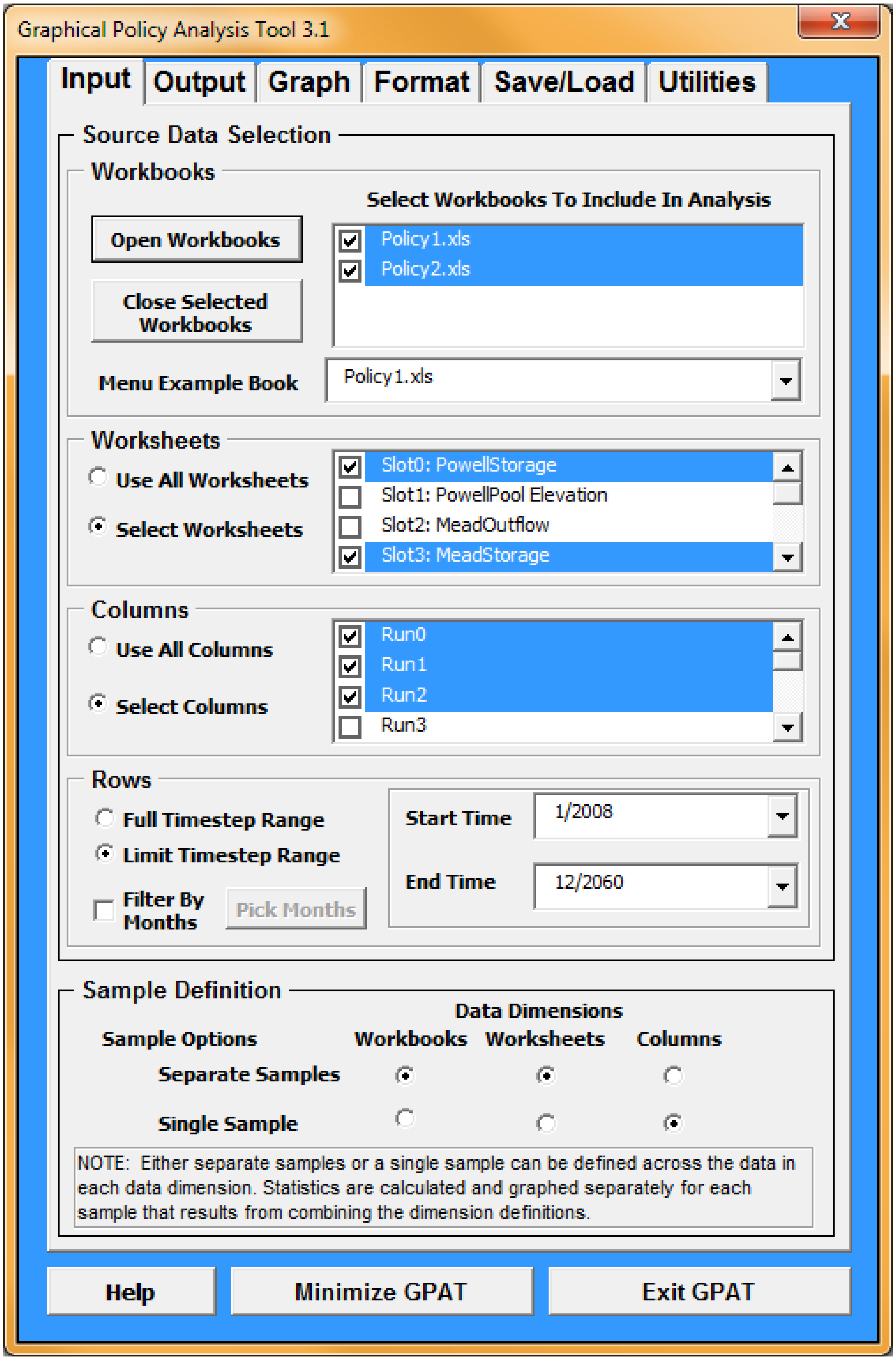
Graphical User Interface

Input Tab



Workbooks Frame

When GPAT is opened from the Microsoft Excel environment, each workbook that is currently open in Excel is listed on the Worksheet Frame of the Input tab of the form. Pressing the 'Open Workbooks' button on the Input tab of GPAT can open workbooks that are not already open in Excel, or currently open workbooks can be closed and removed from the list by selecting them and pressing the "Close Workbooks" button. GPAT will use the workbooks the user has selected in the workbook list when generating a graph.

An example workbook is automatically chosen by the program to populate worksheet, column, and row information in other parts of the user interface. The user can select a different workbook to be the example by reselecting in the Menu Example Book dropdown list. This example workbook does not necessarily have to be selected in the main workbook list for inclusion in the analysis. This allows the user flexibility in comparing between a number of similarly formatted workbooks without losing their worksheet, column, and row selections each time they select different books in the main workbook list.

Worksheets Frame

The user has a choice of using all the worksheets or selecting only particular ones to be used in the analysis. To select worksheets, the user presses the select worksheets button and chooses one or more from the given list generated from the example workbook. All worksheets chosen must appear in each of the selected workbooks, or the program will generate an error during analysis and graphing for the data set. If Use All Worksheets is selected, the worksheets may differ in number and name among the scenarios as long as worksheets are not used in defining samples across the workbooks (see Sample Definition Frame discussion below).

Columns Frame

Similarly, the user can use all columns or select particular ones. At least one worksheet must be selected in the worksheet frame in order to have a column list to select from. To select columns, the user presses the select columns button and chooses one or more from the given list. All of the columns selected must appear in all of the selected worksheets or the program will error during data analysis and graphing. If Use All Columns is selected, the columns may differ in number and name among the scenarios as long as columns are not used in defining samples across the workbooks (see Sample Definition Frame discussion below).

Rows Frame

The rows must represent the time dimension of the time series data. On the Input tab the user has the choice of using the full time step range of the data in the analysis or selecting a start and end time for a limited time step range. To select start and end times for a limited range, the user must first have at least one worksheet selected in the worksheet frame so the program can identify the available time steps for populating the start and end time lists. It is important to note that whether the time step range is full or limited, the specified time steps must be present in every worksheet included in the analysis or the analysis and graphing operation will fail with an error message.

In addition, under the rows frame of the Input tab the user can check the Filter By Months box to filter the data by one or more specified months. This activates the Pick Months button, which brings up a dialog where the user can selectively choose the months. This allows, for example, a user with monthly data to calculate a data distribution for June only, or for April through June.

Sample Definition Frame

The source data to use in generating a graph is specified by the selected workbooks, worksheets, and columns. However, the user also needs to specify how these data should be combined into samples. In the Sample Definition frame, there are buttons to specify if items in the workbook, worksheet, and column dimensions should go into a single sample or be in separate samples. The dimensions are then combined to define the samples in the data. For example, if two workbooks are selected and defined as separate samples, three worksheets are selected and defined as separate samples, and all columns are defined as a single sample, then combining the dimensions will result in six separate data samples. Analysis and graphing are performed separately for each sample defined in the data and result in different lines on the graph. This gives great latitude and flexibility in creating samples across the three available dimensions, and the user needs to experiment with the settings to get the configuration that they need for their particular data.

A data name needs to be created for each data sample to label the legend for the line created on the graph. A sample is labeled with the names of the dimensions that are specified as separate samples. For example, if workbooks are policies configured as separate samples, worksheets are slots configured as separate samples, and columns are runs configured as a single sample, then a separate sample is created for each workbook and specified worksheet combination, with all the applicable columns (runs) added into that sample. That sample would then be labeled on the graph with the workbook and worksheet names in the format "policy.slot". If the user is using only one workbook in this example, it does not matter for sample creation if the workbook dimension is selected as separate sample or a single sample since there is only one of them. If the user does not want the workbook (policy) name to appear in each sample label on the graph, the workbook dimension could be selected as single sample and the naming would then just be based on the worksheet name as "slot".

Another common example would be a case where the user has single runs from RiverWare in separate Excel workbooks, but wants to calculate statistics across the runs. In this case workbooks represent runs, there is probably one worksheet per workbook, and columns represent different slots. In the Sample Definition frame, the user would define workbooks as being in the same sample, worksheets could be configured as separate or a single sample since there is only one of them, and columns would be configured as separate samples. A sample would be created for each selected slot (column) and would contain the applicable time series from each workbook (run). Each sample would have the specified statistics calculated on it, and the resulting graph line would be labeled with the column (slot) name if worksheets are defined as a single sample, or the "worksheet.column" name if worksheets are defined as separate samples.

Sample Definition Example for Scenarios with Different Numbers of Runs

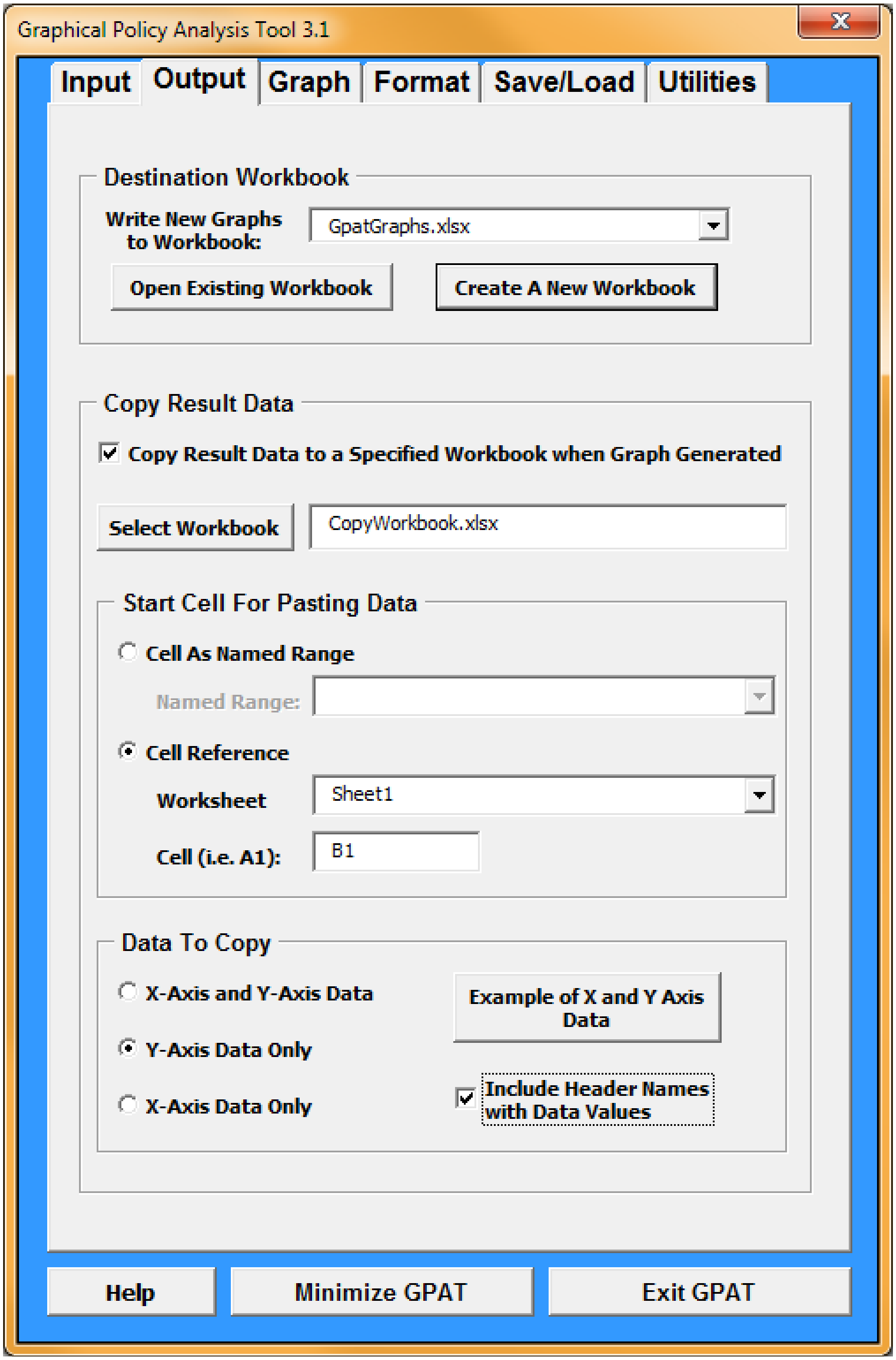
A study modeling potential future flows for a river basin may use various hydrologic ensembles as input for generating future flow data. Hydrologic ensembles, for example, could be based on the historic record of flows, a paleo record based on tree ring analysis, or an historic record modified for an assumed climate change in the future. Because these hydrologic sources could contain different numbers of years of data, the RiverWare multiple runs based on each could have different numbers of runs in them. GPAT can now handle comparing multiple runs containing different numbers of runs.

A typical arrangement for Excel workbooks containing RiverWare output from the multiple runs described above would be to have a workbook for each scenario, which would be a multiple run based on a certain hydrologic ensemble. Worksheets in each workbook would correspond to information for different RiverWare slots. Columns in a worksheet would correspond to individual runs in the multiple run, the number of which would vary between the scenarios. In this case, the sample definition in GPAT would have workbooks and worksheets specified as separate samples and columns specified as in the same sample. GPAT graphs comparing the multiple runs would have lines where each represents a particular slot in a particular scenario, and the statistic generating the line would be calculated across all of the runs in the scenario.

Specifying graphs in the GUI for cases like this where the number of columns may vary between workbooks does not require any special configuration - the user would just specify the Use All Columns option on the input tab and statistics for the graphs would be calculated across all the columns present in each workbook. The output data generated for any of the times series graphs would not look any different than in cases where the number of runs are the same across workbooks (i.e. for a graph of Data Value Statistics Over Time there would be a mean statistic generated for each timestep in the time series). However, for Cumulative Distribution Function (CDF) graphs where all of the data values across the runs are ordered and shown as a frequency distribution, the number of data points for a graph line will vary depending on the number of runs in the scenario. The output data for these graph types will look different than if all scenarios have the same number of runs. In the latter case of number of runs being equal, the output data is written with the first column being the frequency value of the data and subsequent columns containing the data values for each scenario. If numbers of runs are not equal, the number of values will not be equal, so each scenario will have its own frequency column resulting in paired columns of frequency then value for each scenario.

Other than this difference in how output data is written for CDF graphs, the analysis of multiple runs with different numbers of runs in GPAT is the same as for any other analysis. Note, however, if you use the Select Columns option to pick the calculation of statistics across particular runs, such as Runs 75 to 100, and those runs are not present in all of the workbooks, this will generate an error during graph generation.

Output Tab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Destination Workbook Frame

The user must select a ***Destination Workbook*** in the top frame of the Output tab of GPAT. This workbook is where the graphing data and the graphs that result from GPAT will be stored. For each graph created by the user there are two worksheets created in the destination workbook. The first sheet contains the graph itself and the second contains the result data that the graph was plotted from. A destination workbook is characterized by having a worksheet titled ***Log Sheet*** that appears after all of the graphing sheets. The log sheet contains a row entry for each graph that has been written into the destination workbook. The user can open an existing Destination Workbook, which must have the formatted Log Sheet in it, or can create a new Destination Workbook for their graphs.

Copy Result Data Frame

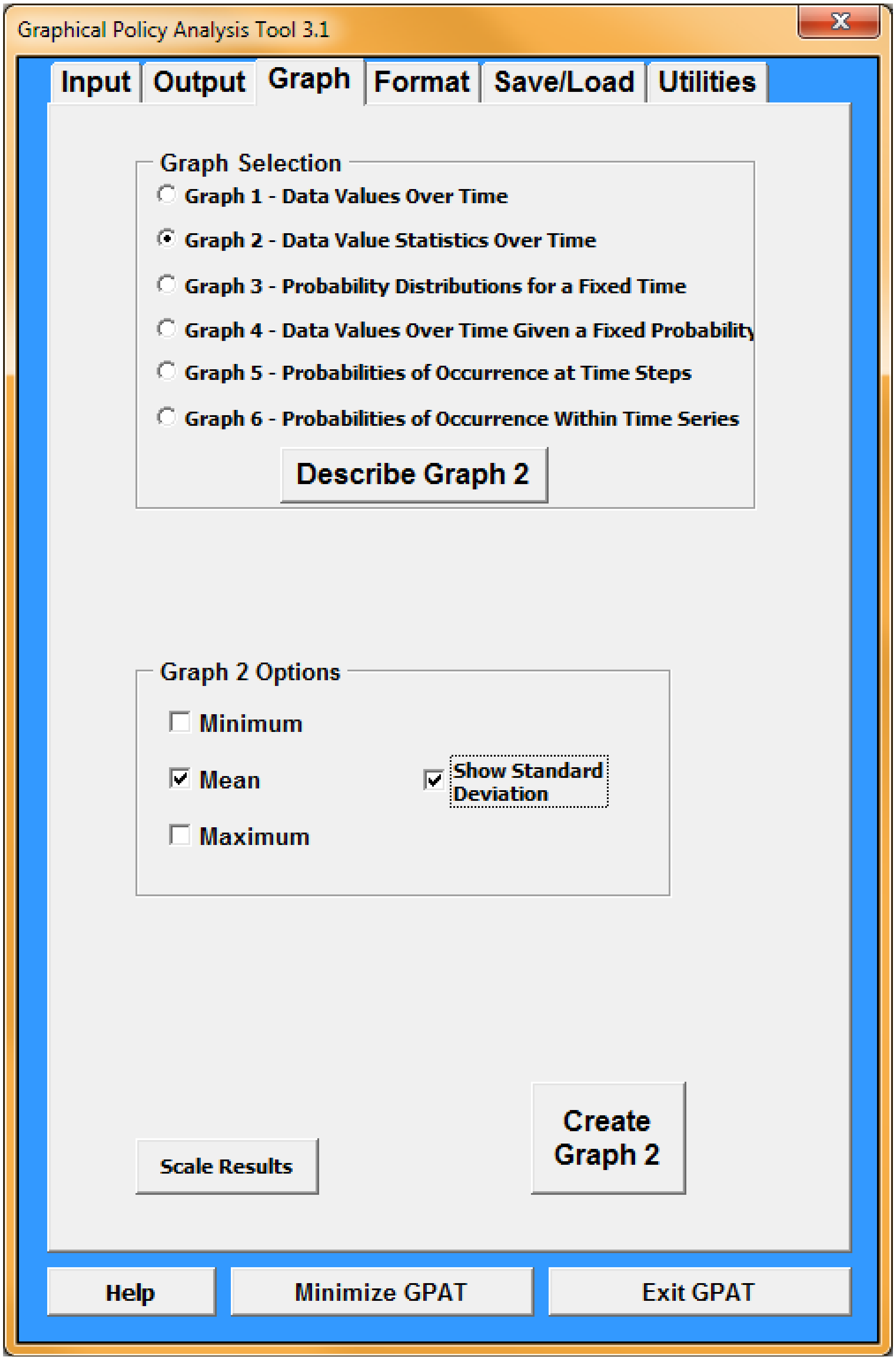
In addition to the Destination Workbook, the user has the option of also copying the result data calculated by GPAT into another workbook when a graph is created. This functionality accommodates a case where the user has pre-configured plots in an existing workbook that they would like to use to display the data, or a case where the user wants to do some other post-processing of the result data in their workbook.

The user selects the workbook to copy data into and then specifies the start cell for where the GPAT data will be copied. The start cell can be specified by choosing a named range that has been set up for the cell in the workbook, or by selecting a worksheet from the workbook and specifying a cell reference for the start cell.

Options are available to specify what data should be copied. In a plot of elevations on the y axis versus time on the x axis, for example, the X-Axis and Y-Axis Data option would copy both the time column and the elevation data columns from the GPAT results into the specified workbook. The Y-Axis Data Only option would copy only the elevation data columns, and the X-Axis Data Only option would copy only the time column. The Include Header Names with Data Values option, if checked, would copy the names of the data series as the first row of the copied data. A button is available in this dialog to bring up a sample plot that explains what data is copied under the various options.

If the Copy Result Data option is selected when a graph is created, the specified result data columns are copied into the indicated workbook using the start cell as the anchor point for the paste of the data. Note that after completion of a graph, the Copy Result Data option is automatically unchecked so that subsequent graph creations will not accidently overwrite the copied data. The user must recheck the Copy Result Data option to reactivate the copy feature for a future graph.

Graph Tab



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Graph Selection Frame

In the graph selection frame of the Graph Select page, the user is required to select a ***Graph Type*** for their graph. Each type of graph requires different inputs by the user, and thus the user interface is adjusted to accept all the required information. If the user does not provide each required piece of information, an error prompting the user to enter it is generated. A button is available to see an example graph as each Graph Type is selected. The Graph Types are discussed later in this document.

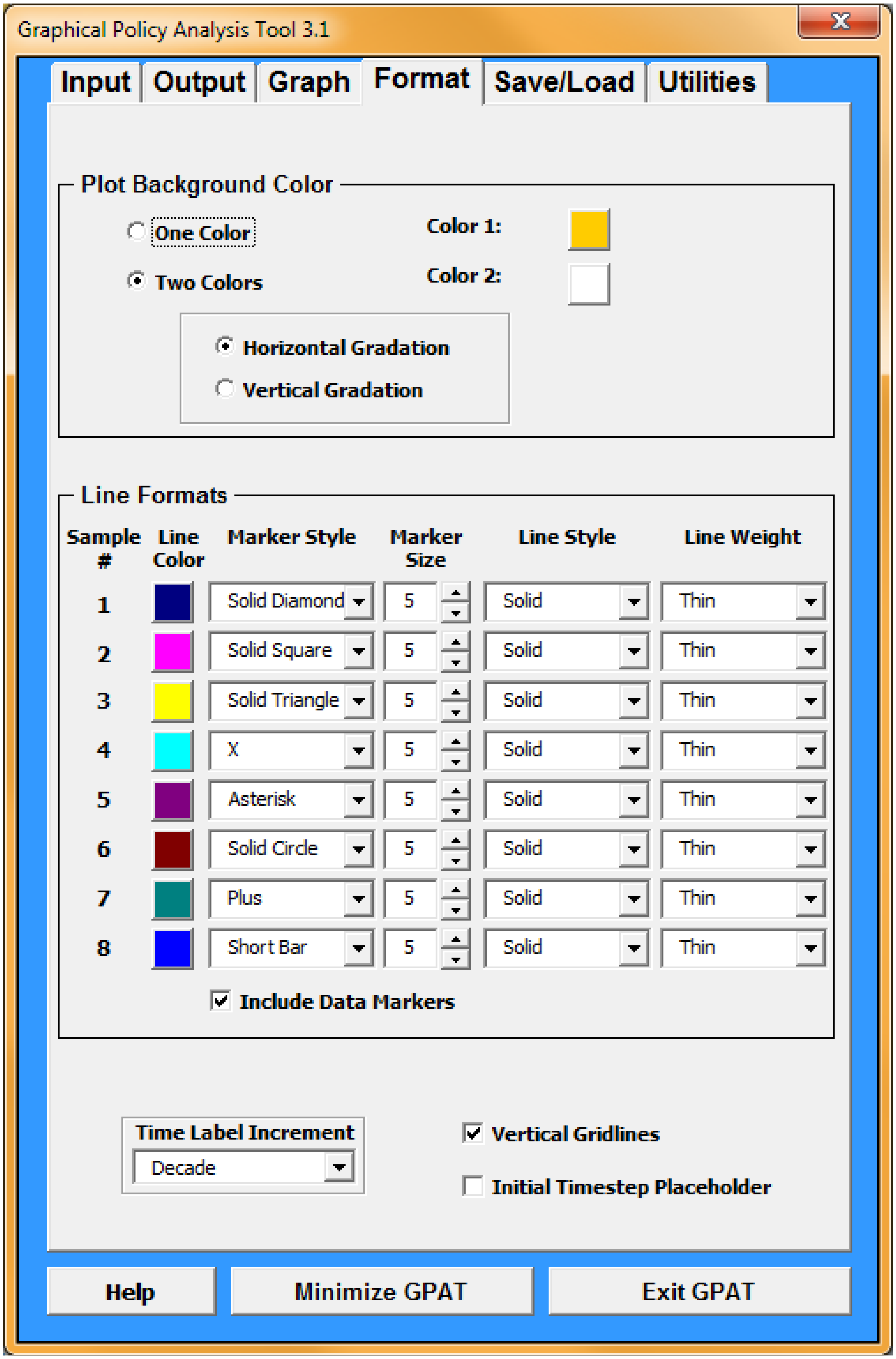
Scale Results

There is also a button on the Graph Select page for scaling the results. This button brings up a menu where the user can scale the results by a factor of from 0.000000001 to 1000000000. This factor is multiplied by all of the result values before plotting on the graph. The user can enter a new unit to appear on the graph that accounts for the scaling factor (such as thousands of acre-ft).

Create Graph

The user then presses the Create Graph button in the lower right corner of the Graph Select page to generate the desired graph. It may take a short time for data processing before the graph is drawn into the Destination Workbook.

Format Tab



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The Graph Format tab allows the user to preselect the specified format items for their graphs. Each graph will then be generated with the selected formats so the user does not have to change the formats in Excel after the fact for each graph generated.

Plot Background Color Frame

The One Color button allows the user to specify a single solid color for the background area of their plot. To change the color, click on the color square and select a new one from the palette that comes up. The Two Colors button allows the user to select two colors to be used in the background area of their plot. If the Horizontal Gradation button is selected, the background will vary from color one at the bottom to color two at the top. The Vertical Gradation button varies the background from color 1 on the left to color 2 on the right.

Line Formats Frame

These options allow the user to select formats for the lines that will appear on their graphs. Line color, line style and line weight are selectable, as well as data point marker style and size. If the Include Data Markers checkbox at the bottom is unchecked, the marker format items will be grayed out and no data markers will appear on the graph lines.

Formats can be selected for the first eight samples shown on graphs. On graphs where multiple lines are plotted from the same sample, these lines will all be shown in the same format. For example, on Graph 2 where mean, minimum, and maximum can be plotted, or on Graph 4 where 10^{th}, 50^{th}, and 90^{th} percentiles for a sample can be plotted, these lines will all be shown in the format for the sample. If more than eight samples are plotted on a graph, the formats for the additional ones will be Excel default values.

Time Label Increment

The Time Label Settings Frame allows for changes in the formatting of the time axis depending on the selection here. If the time axis data is in a date format, the tick-marks and labels on the axis can be spaced by daily, weekly, monthly, semi-annual, annual, decade, or century depending on the time span of the modeling run. These settings simply provide an increment for Excel to initially graph, so if the resultant graph appearance is not exactly what the user intended, axis modifications can be made directly through the Excel graph formatting capabilities after the graph is made. It is recommended that other types of graphical formatting be done directly through Excel. See the Microsoft Excel help menu to assist with graph modifications.

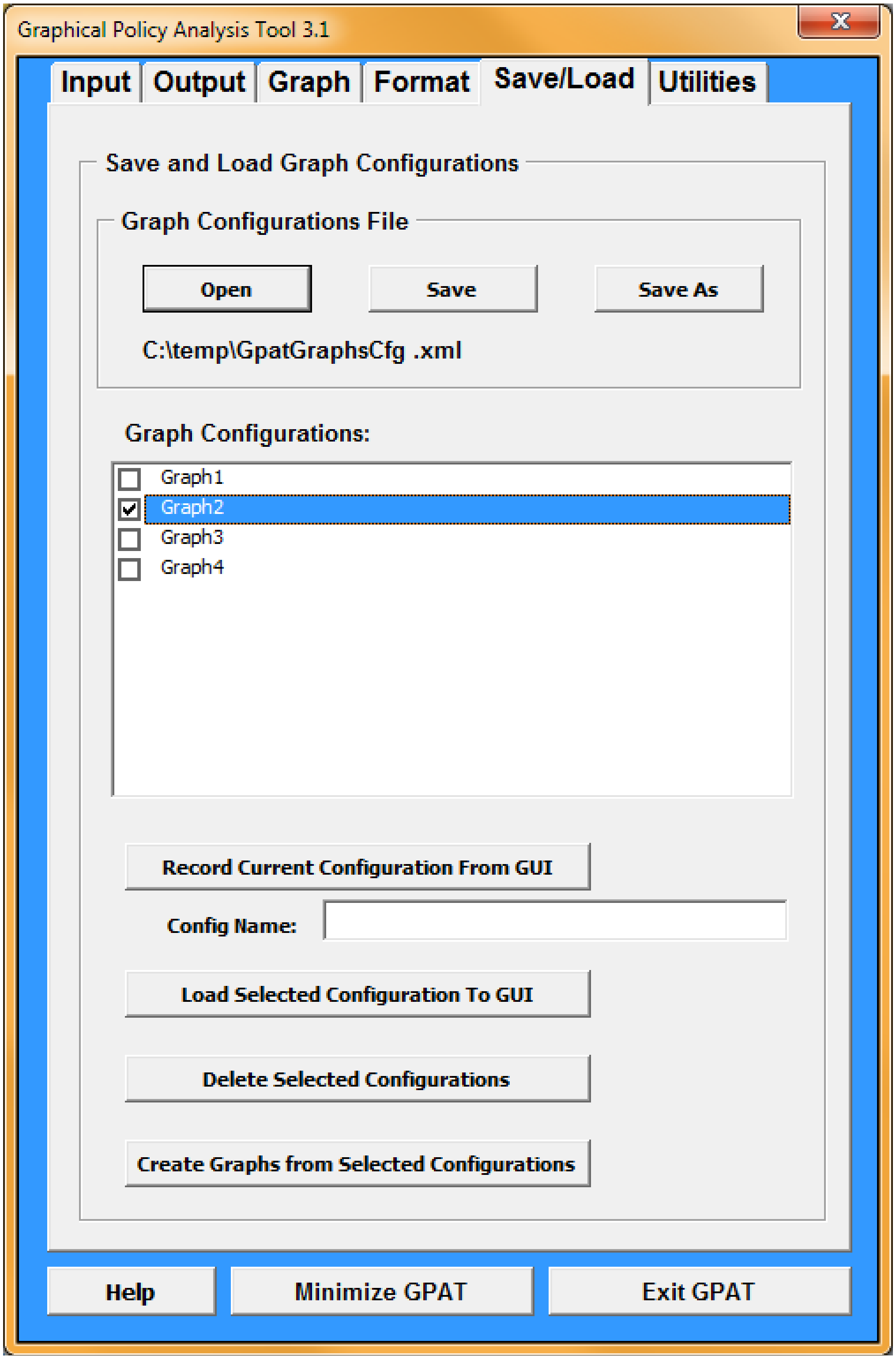
Vertical Gridlines

The Vertical Gridlines checkbox allows the user to optionally include or exclude vertical lines extending across the graph from the major divisions of the x-axis. These lines can help grid the data to more easily visualize the values of data points.

Initial Timestep Placeholder

This checkbox is only available if Graph Type 1, 2, or 4 is selected. Checking the box adds an initial timestep placeholder into the results data sheet. This placeholder has a time generated for it based on subtracting the length of a timestep from the time of the first data point. The initial timestep is part of the graphing range, so that if a user enters a data value into the initial timestep, the data point will automatically appear on the associated graph. This functionality allows a user, for example, to add the current real value in as a starting point for data that was modeled into the future.

Save/Load Tab



The Save/Load tab allows for saving of graph configurations into a file and then reloading them into GPAT. A configuration is written into the file using an XML format and consists of all of the information on the Input, Output, Graph, and Format tabs of the GPAT interface, except for the workbook names (source data workbooks, destination workbook, and the workbook for copying result data, if applicable). This allows a saved configuration to be used with different source workbooks and different result destinations. For example, a set of graphs could be created and saved for an Excel file of slot data output from a RiverWare model. The file and configurations could then be reused later with a different run or set of runs from the same model to generate graphs without having to reconfigure each graph in the interface. Note that worksheet and column names, if selected and specified, are saved into the configurations, so if a configuration file is used with a data workbook from a different model that has different object and slot names, for example, the selected worksheets or columns will not be set with the new workbook and the interface will be defaulted to use all worksheets or all columns.

Graph Configurations File Frame

An existing configurations file can be selected and loaded with the Open button. When loaded, the path and name of the file will be displayed below the button and the names of the graph configurations that are saved into the file will be loaded into memory and their names will be populated into the Graph Configurations list below. The Save button will save the graph configurations from the Graph Configurations list into the currently displayed file path, replacing any configurations that are currently in the file. The Save As button will present a file chooser where the user can enter a new file for saving the current graph configurations.

Graph Configurations

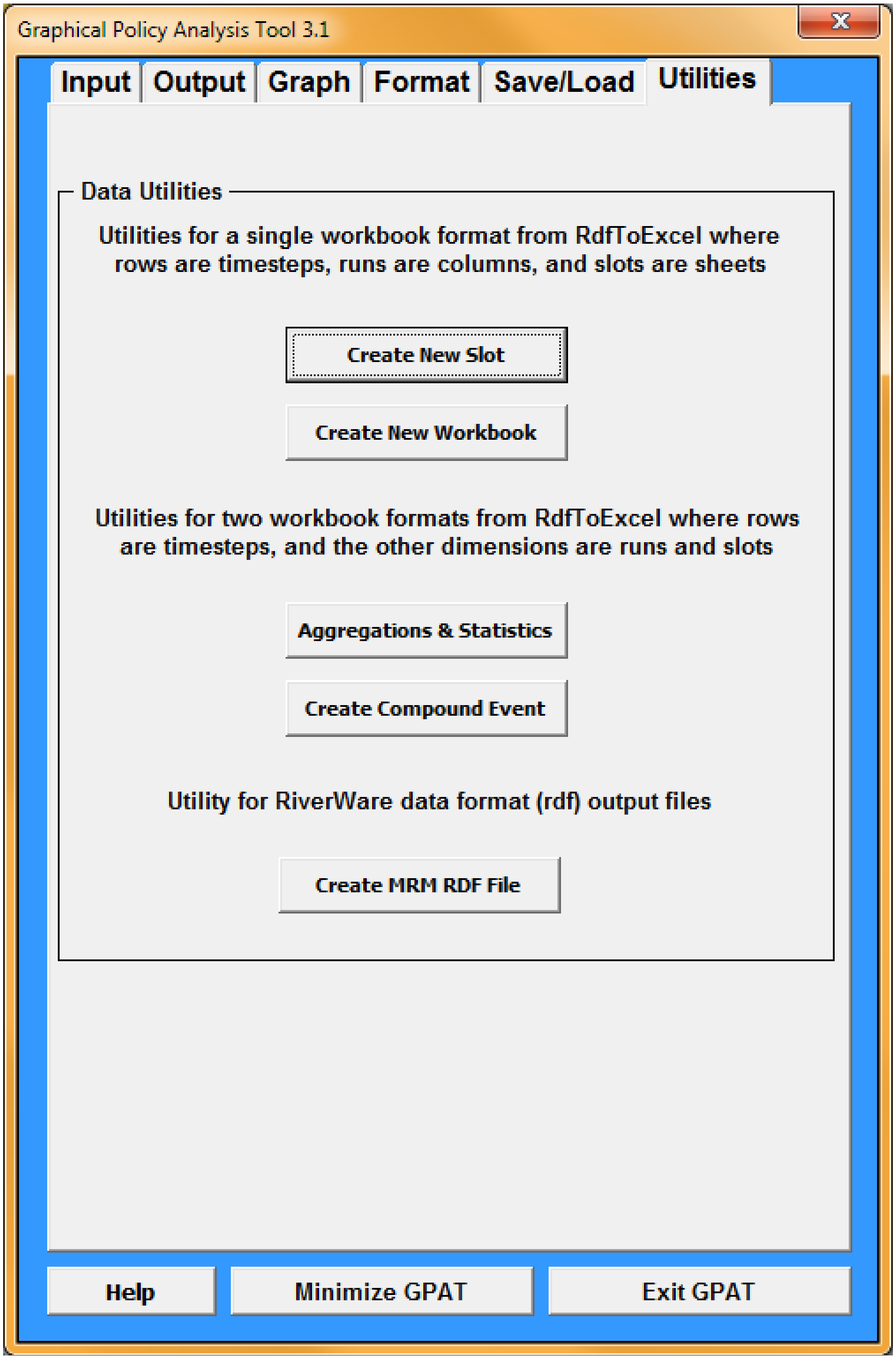
The list shows the graph configurations currently residing in memory. This list can be populated by loading a configuration file as described above. The listed configurations must be saved to a file as described above to be preserved after GPAT is closed.

The Record Current Configuration From GUI button allows adding a new configuration to the list by saving all of the current graph configuration information from the GPAT interface into an entry with the name as entered into the Config Name text box. The name must be unique within the list.

Selecting a graph configuration in the list and clicking the Load Selected Configuration to GUI button will load all of the configuration information for that graph into the GPAT interface. One or more graph configuration can be removed from the list by selecting them and clicking the Delete Selected Configurations button.

The Create Graphs from Selected Configurations button will, in turn, load all of the selected configurations from the list into the GUI and create their graphs using the current Source Data Workbooks, Destination Workbook, and Copy Result Workbook, if applicable.

Utilities Tab



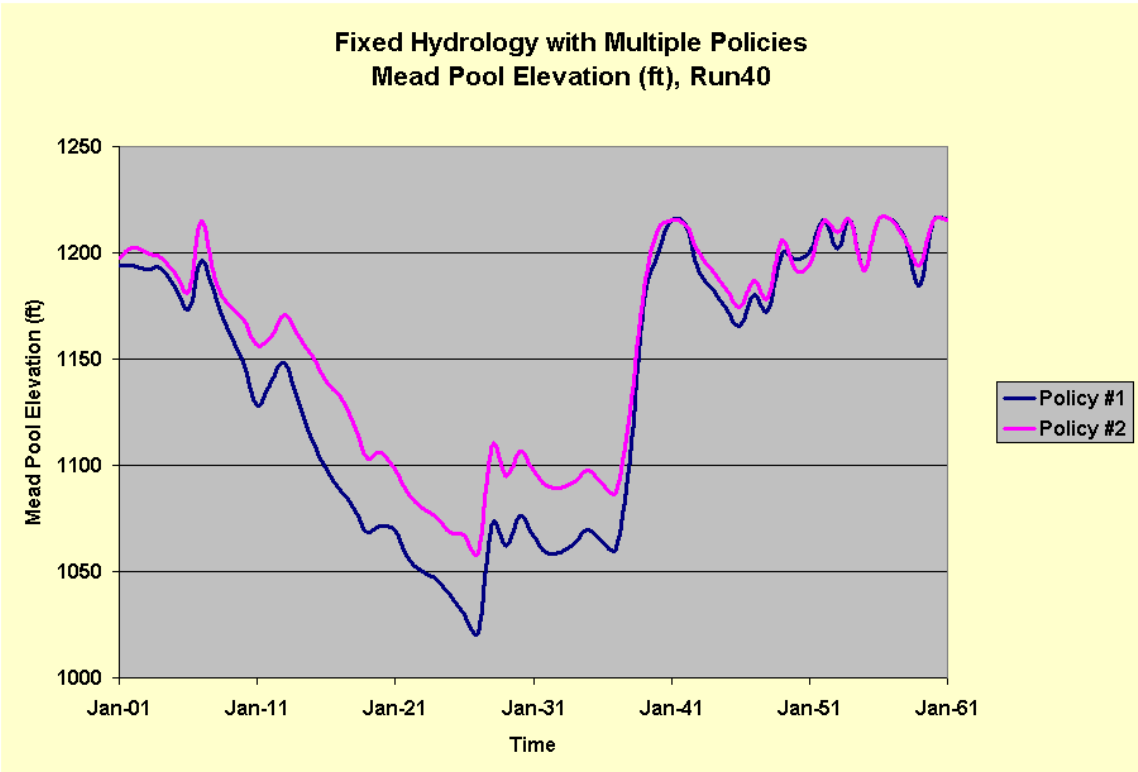
Data Utilities Frame

The Utilities tab contains utility programs that have been written for manipulating Excel workbooks and RiverWare data format (.rdf) files. The utilities are divided into groups depending on what type of files they work with. Each utility is discussed in detail later in this document.

Graph Types

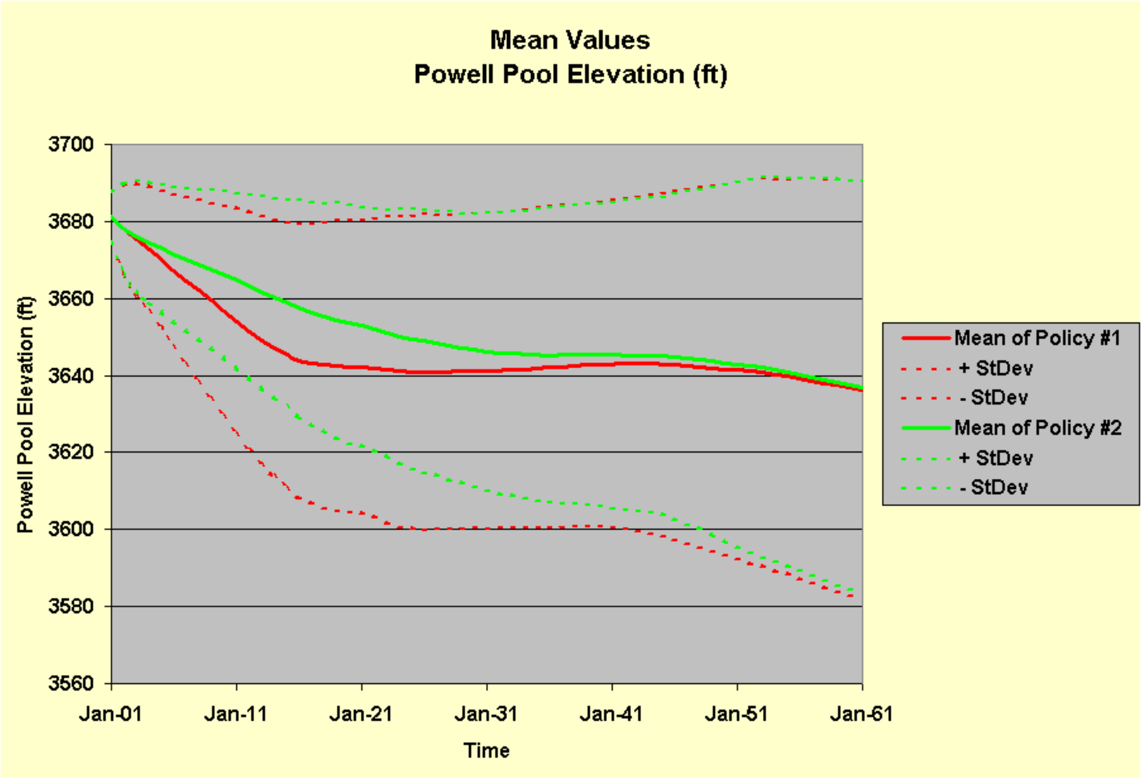
Graph 1 - Data Values over Time

The most basic type of graph available is to plot the actual values of a time series. For this graph type, the samples must be configured in such a way that there is only one time series in each sample. This time series is then graphed with time (independent variable) on the x-axis and value (dependent variable) on the y-axis. Separate samples show up as separate lines on the graph.



Graph 2 - Data Value Statistics over Time

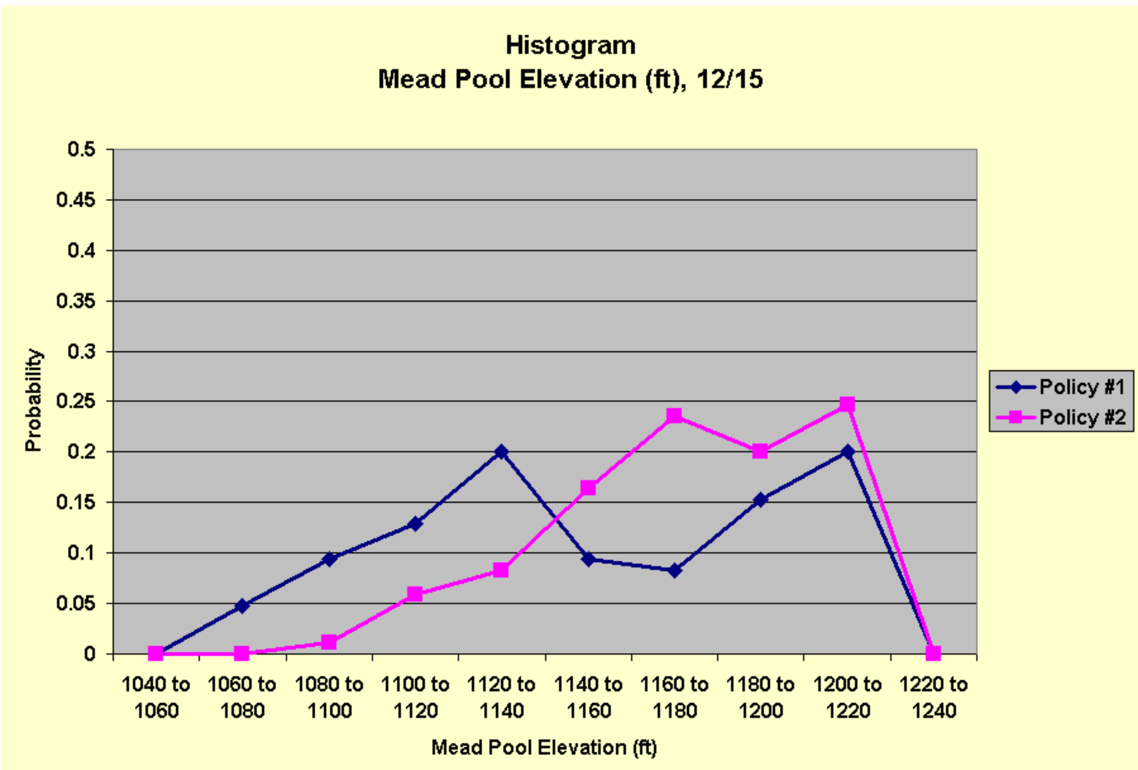
Generating various statistics of data values is based upon a multiple time series (run) analysis. This graphing option allow the user to compute and graphically display the mean, minimum and maximum slot values occurring over time across multiple time series. Therefore, a value is computed at each time step that represents the collective value of all the runs at that time step. Along with the derivation of the mean value, the user also has the option of graphing standard deviation bounds around the mean values representing the mean value plus the standard deviation and the mean value minus the standard deviation. The format of this graph is time (independent variable) on the x-axis and data value statistic (dependent variable) on the y-axis.



Graph 3 - Probability Distributions for a Fixed Time

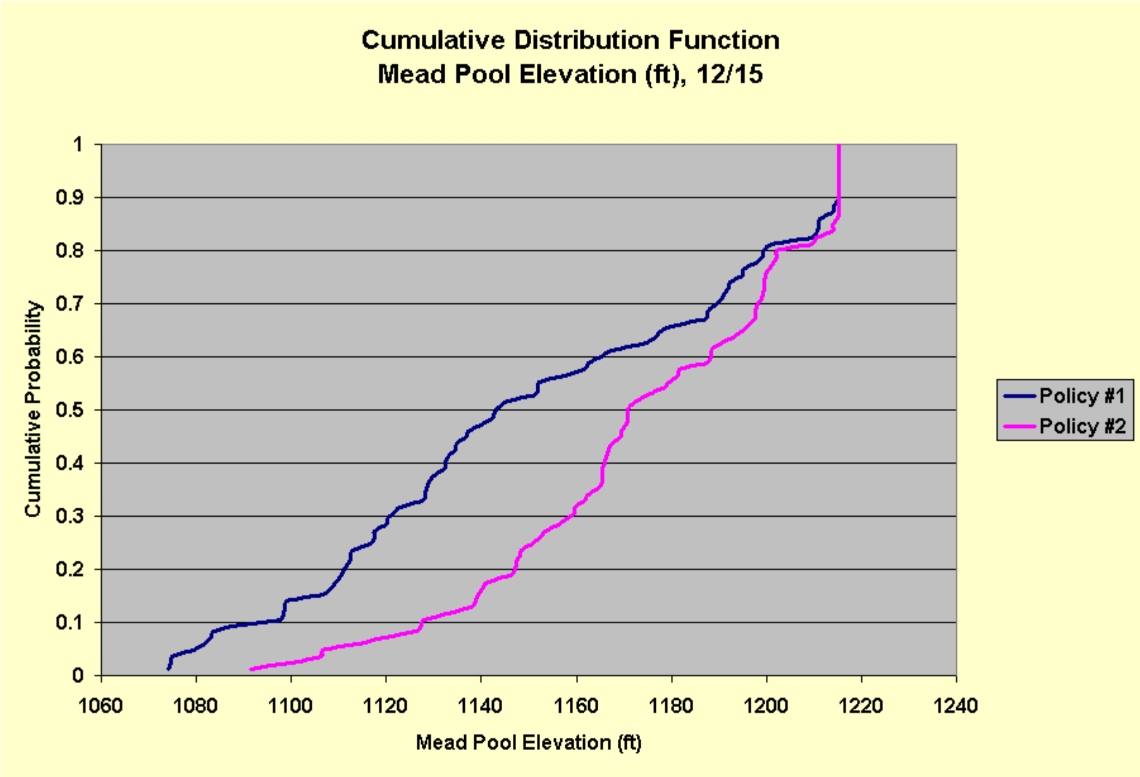
Multiple run analyses in RiverWare generate multiple slot values that can also be of interest to users when displayed in greater detail than simple statistics will allow. The requirement for this level of detail is provided by the Graphical Policy Analysis Tool functionality of generating histograms of slot values (to estimate probability density functions) and cumulative distribution functions (CDFs). These two types of graphing options allow the user to compare and contrast the resultant modeled slot values from multiple workbooks for a time frame. For the first two graphs, the user chooses exactly one time step from a list of time steps. For the last three graphs, the CDF is sampling across both time steps and runs. For all the CDF graphs, the user can show probability on the either the x or y axis via the option box at the bottom of the dialog.

- The Histogram function operates by grouping the slot values for the single selected time into discrete bins. The Graphical Policy Analysis Tool first uses all relevant slot values from the time series in the sample. Recommended values for the smallest bin number, bin size, and the number of bins are presented to the user. The user is given the option to manipulate these values and recalculate the highest bin value, which can be compared to the actual maximum slot value in the data. The recommended bin settings allow one empty bin



before and one empty bin after the range of actual data to create a more suitable display.

  - The Cumulative Density Function (Single Time) graphing option avoids the issues related to bins, yet is often more difficult for users to interpret. This graph is created by sorting the actual slot values for the single specified time into increasing order for each sample. Each value is then ranked from n = 1 to the total number of values. The cumulative density function is created by plotting the increasing slot values versus the ratio of n to the total number of values. The proper interpretation of this graph is that the probability associated with a point represents the statistical probability that the slot value will be less than or equal to the value associated with the point.



- The Cumulative Distribution Function (Throughout Time) graphing option produces a similar graph to the (Single Time) option discussed above, except the data is not for a single selected time step, but is for all time steps included in the sample.
- The Cumulative Distribution Function (Annual Peak Through Time) graphing option produces a CDF plot similar to the others, but the data that is included is only the annual peak value calculated for each year in each time series of the sample.
- The Cumulative Distribution Function (Annual Maximums of Sustained Values Over Duration) option has an adjacent box where the user enters a number of time steps for a duration. A “sustained value” over the duration is then calculated for each time step by finding the minimum from a window of time steps equal to the duration that starts on the current time step. The maximum of the sustained durations is then determined for each year. These maximum yearly sustained values are then used in generating the cumulative distribution function graph.

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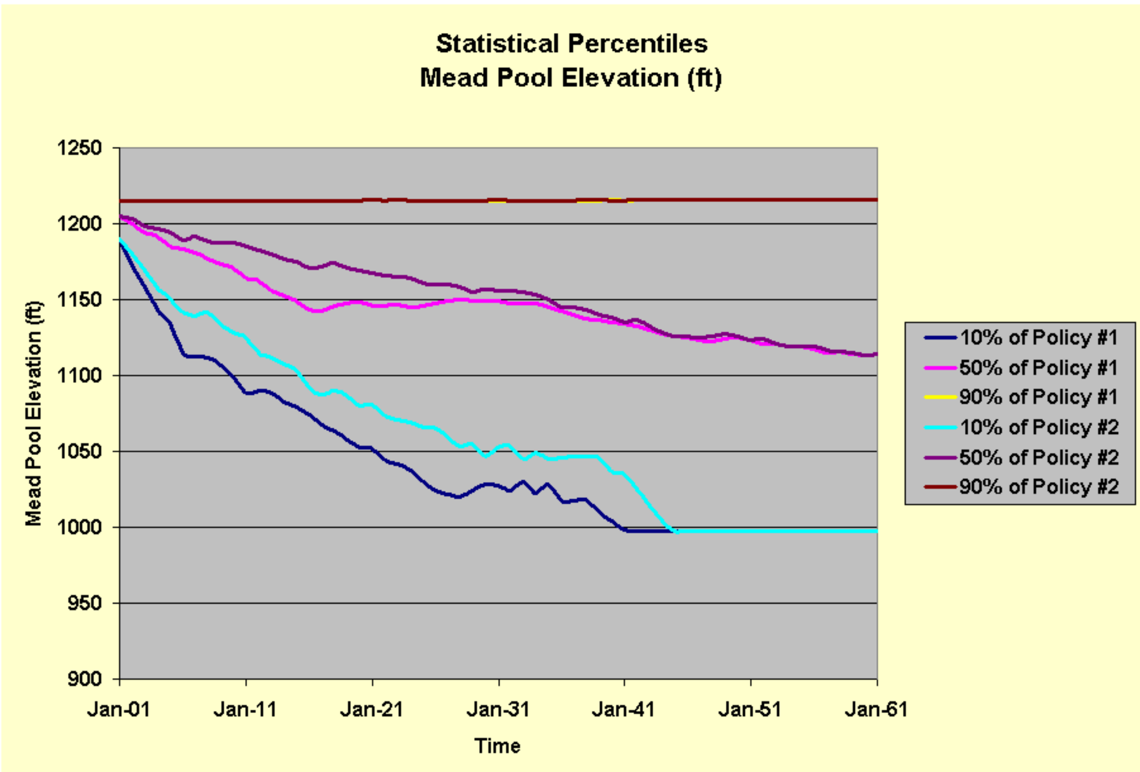
Graph 4 - Data Values over Time Given a Fixed Probability

Ordered ranking at each time step of slot values resulting from multiple time series (runs) gives the user the ability specify statistical percentiles of interest and return the slot values that correspond with these percentiles for each time step. In general, a 10th percentile would indicate that the slot values resulting from 10% of the runs in a sample at a time step fell less than or equal to the indicated slot value. Similarly, the 50th percentile would indicate that half of the runs resulted in a slot value less than the indicated slot value, and half the runs resulted in a slot value greater than the indicated slot value for a time step. The user is allowed selection of any integer percentile to graph between 1% and 99%. The format of this graph is time (independent variable) on the x-axis and slot value (dependent variable) and the y-axis. Each line on the graph represents a percentile chosen by the user.



Perhaps it is surprising that there is no single generally accepted method for calculating percentiles ([1]). For relatively large samples most methods will generate similar answers. However, for small samples there can be noticeable differences. For example, the smallest value in a 3 number sample can be assigned a percentile ranging from 0% to 33% depending on the method. For a larger 100 number sample, the smallest value can be assigned a percentile ranging from only 0% to 1%.

In this section we will describe some accepted guidelines for percentile calculation, several alternative methods that fit within these guidelines and are included in GPAT, and an example demonstrating that each method generates different percentiles.

There are two generally accepted guidelines that limit the approaches to calculating percentiles. The first guideline is that the percentile of an observation must be at least as great as the percentage of values that are less than this value. The second guideline is that the percentile of an observation can be no greater than 100 minus the percentage of larger values. These guidelines limit the range of percentiles that can be assigned to each value, and most methods are consistent with these ranges.

Percentile Methods in GPAT

The most commonly used methods can be divided in to two general approaches. The first is to assign a single percentile to each observed value and interpolate between these values for other percentiles. In general, the minimum observed value is also associated with any percentile below the percentile assigned to this minimum value. Similarly, the maximum observed value is associated with any percentile above the percentile assigned to this maximum value. GPAT has five methods that use this first approach. The second approach is to assign a range of percentiles to each observed value. GPAT has one method that uses the second approach.

The following notation is useful for describing the alternative methods:
n = the number of observations,
t = a percentile,
p = t/100, a proportion of the values,
x_j = the observed value for the j^{th} observation ordered from small to large, and
y(p) = the value associated with proportion p.

The first approach, "Least", is to generate the lowest acceptable value within the guidelines for each observed value, and interpolate between these values. The proportion p associated with x_j is

$p = (j-1) / n$.

The second approach, "Greatest", is to generate the largest acceptable value within the guidelines for each observed value, and interpolate between these values. The proportion p associated with x_j is

$p = j/n$.

The third approach, "Split", is the previous method in GPAT which splits the difference between Least and Greatest. The proportion p associated with x_j is

$p = (j-1/2) / n$.

We call the fourth approach, "CRC". This method is presented in the CRC Standard Math Tables ([2]), is recommended at NIST ([3]), and is one of several methods (PCTLDEF=4) available in the statistical software, SAS ([4]). The proportion p associated with x_j is

$p = j / (n + 1)$.

The fifth method, "Excel", has been popularized by its use in Microsoft Excel. One feature of this method is that the minimum is the 0^{th} percentile and the maximum is the 100^{th} percentile. The proportion p associated with x_j is

$p = (j - 1) / (n - 1)$.

The last three approaches have the advantage that they assign the 50^{th} percentile to the standard definition of the median value:

x_j with $j = (n + 1) / 2$ if n is odd and
$(x_j + x_{j+1}) / 2$ with $j = n / 2$ if n is even.

The sixth approach, "Range", is based on the SAS "Empirical Distribution Method" ([4]). This method assigns a percentile to each observation using the same method as Greatest. Instead of interpolating, the entire range of percentiles between Least and Greatest are also assigned to this observed value. Here is an alternative description of the method in terms of mapping from percentiles to observed values. For a given proportion p, define j and g as:

j = integer portion of n * p
g = fractional portion of n * p

Then, the value, y, associated with proportion p is

$y = x_j$ if $g = 0$
$y = x_{j+1}$ if $g > 0$

Numerical Example

An example may help to illustrate the differences between the methods. Suppose we have 4 observations with values of: 1, 2, 3, and 4. The proportions p are shown in the following table.

	Proportion(s) p					
Observation	Least	Greatest	Split	CRC	Excel	Range
1	0	0.25	0.125	0.2	0	$0.00 \le p \le 0.25$
2	0.25	0.5	0.375	0.4	0.333	$0.25 < p \le 0.50$
3	0.5	0.75	0.625	0.6	0.667	$0.50 < p \le 0.75$
4	0.75	1	0.875	0.8	1	$0.75 < p \le 1$

Similarly, the 50^{th} percentile values are shown in the next table. For this example, the median is 2.5.

	Least	Greatest	Split	CRC	Excel	Range
50^{th} percentile value	3	2	2.5	2.5	2.5	2

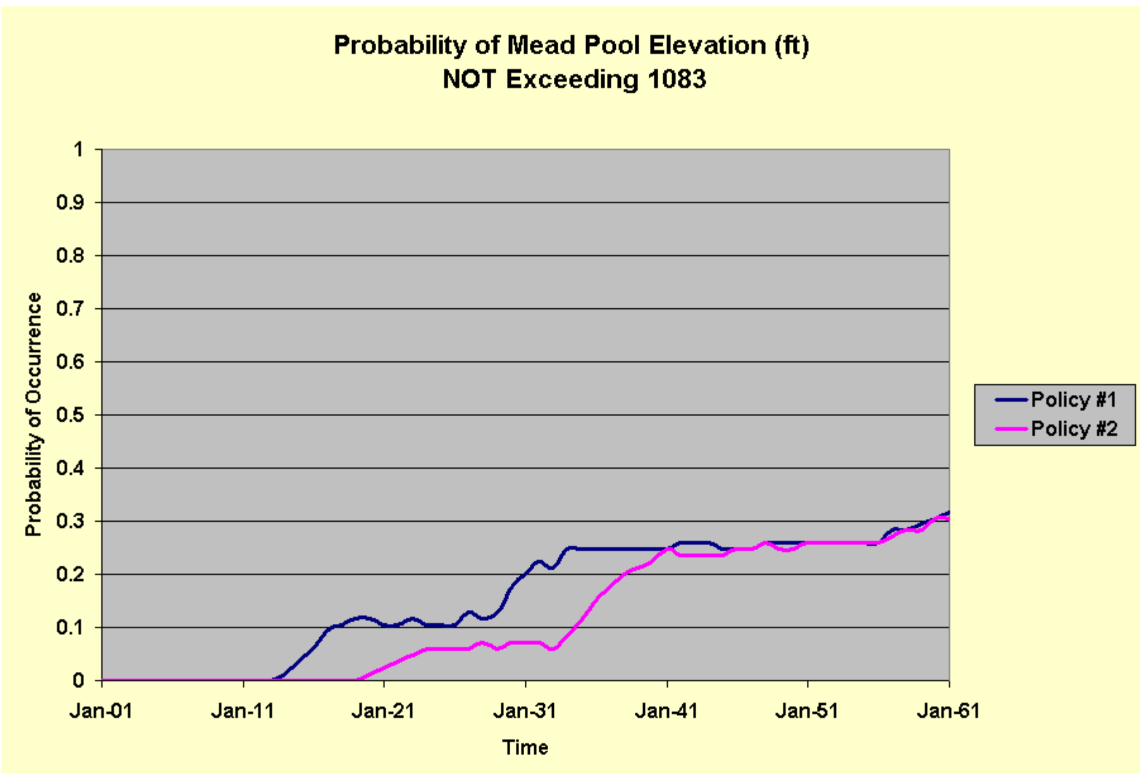
References:

([1]) http://www.pbarrett.net/percentile.pdf
([2]) Beyer, William H., CRC Standard Math Tables, 26th Edition, CRC Press, 1981.
([3]) http://www.itl.nist.gov/div898/handbook/prc/section2/prc252.htm
([4]) http://www.id.unizh.ch/software/unix/statmath/sas/sasdoc/stat/chap18/sect12.htm

Graph 5 - Probabilities of Occurrence at Time Steps

Several graphs of interest are available in the Graphical Policy Analysis Tool that can be grouped into a single category. These graphs represent various probabilities of slot values occurring at each time step based on all the runs performed. The interface presents the user with the three primary types of probability graphs and the required information to generate the probabilities.

- The first probability graph allows the user to specify a particular slot value of interest and determine the probability of **exceeding** or **not exceeding** that value at each time step. The probabilities generated in this option are the result of the ratio of runs that generate a slot value that satisfies the exceedence or non-exceedence criteria to the total number of runs. This option is essentially the inverse problem of the fixed probability option described above, where the slot value is determined from a user specified probability of non-



exceedence.

- The second option expands the functionality of the previous option by allowing the user to specify a **bounded range** of slot values for which the slot may either occur within or outside of. Again, this computationally determines the ratio of the number of runs that generate slot values that fit the criteria to the total number of runs performed for each time step.

- The third probability option is designed specifically for slot values that indicate **binary occurrence** of events. Three options are encountered in RiverWare output files: 1, 0, and NaN (an acronym for Not a Number). This probability function first checks that all the data in the slot values are of these forms, and then a ratio is generated of the total number of runs that result in a slot value of 1 to the total number of runs for each time step. The user is also allowed to specify the proper procedure for handling NaN values. The default option is to treat a NaN as if is a zero value. The user can also select the NaN to represent a value of 1, or to not consider NaN values at all in the ratio. This last alternative produces an error message if the slot value for all runs is NaN during any time step and therefore a ratio can not be generated. The format of each of these types of types of graphs is time (independent variable) on the x-axis and a probability of occurrence (dependent variable) an the y-axis with a bounded range from zero to one.

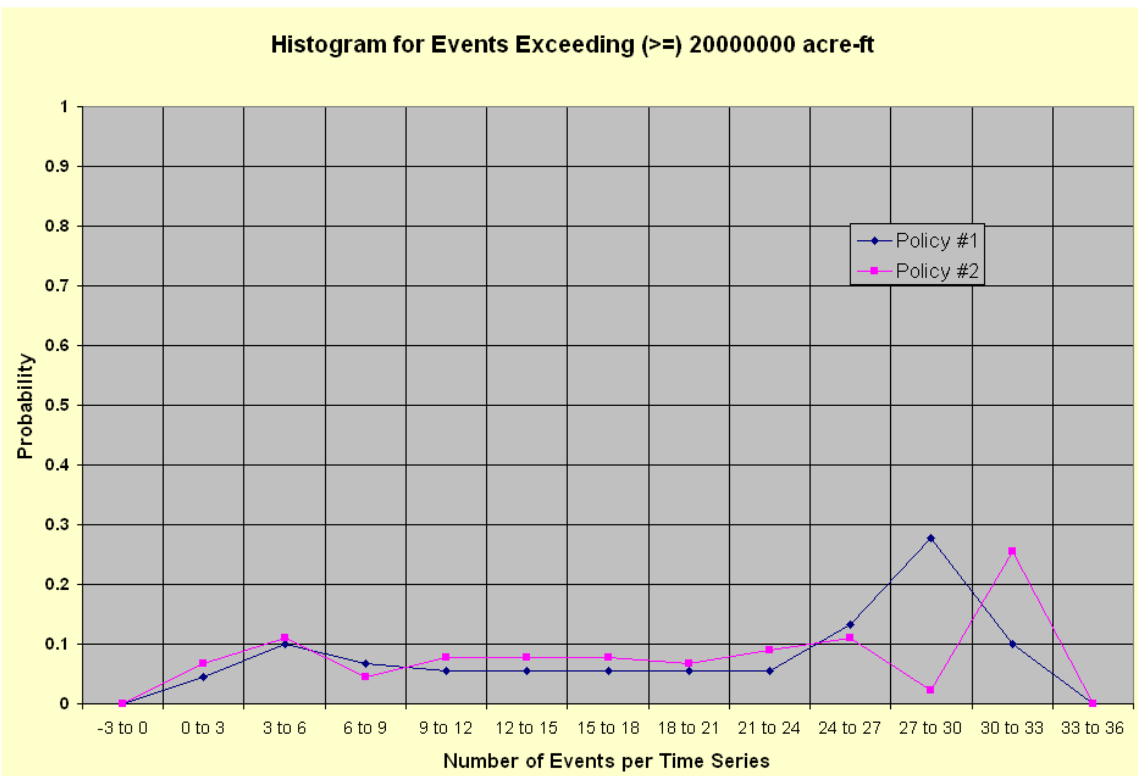
Graph 6 - Probabilities of Occurrence Within Time Series

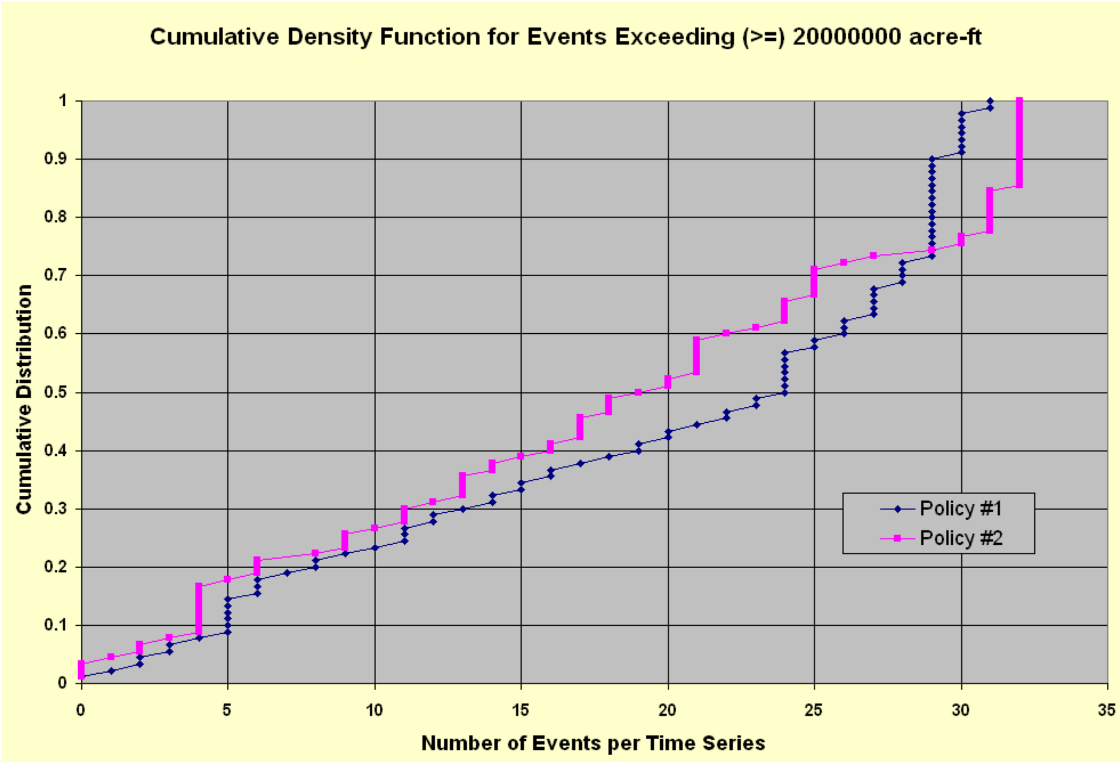
Graph # 5 – Probabilities of Occurrence At Time Steps calculates an event statistic for each time step in the data and generates a time series of statistics for the resulting graph. Graph # 6 - Probabilities of Occurrence Within Time Series was added to allow the tabulation of event occurrences across all the time steps in each time series to create an event count total for each time series in a sample.

Events are defined in the interface exactly as they are for Graph #5 described above. Events can include exceeding or not exceeding a value, occurrence in a bounded range of values, or a binary occurrence.

The results data sheet reports the event count for each time series in the sample. A statistics table is generated that shows number of series with events, number of series without events, total number of series, probability of series having an event, mean number of events per series, mean number of events per series with events, and maximum number of events in a series with events.

The user also selects whether to graph the event data as a histogram or a cumulative density function. The histogram shows the probability of an event count for a series falling into a particular range of event counts. The ranges are defined by default or can be explicitly defined by the user. The cumulative density function shows the cumulative probability that an event count for a series is less than or equal to the particular event count shown on the x axis.





Cumulative Density Function for Events Exceeding (>=) 20000000 acre-ft
Cumulative Distribution
Number of Events per Time Series
Policy #1
Policy #2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
5
10
15
20
25
30
35

Data Utilities

Utility - Create New Slot

This data utility is written to only apply to workbooks that are output from the Excelwriter program, and only those output with the configuration of rows as time steps, worksheets as slots, and columns as runs. This utility provides the user with the ability to generate new slots based upon arithmetic operations on existing slots. Selecting this option through the primary user interface displays another interface to prompt the user for the needed information to generate the new slot. A list of available workbooks is displayed, based on all the open workbooks.. Double clicking on one of the workbooks that has the appropriate format generates a list of available slots in two pull-down menus on the interface. Each workbook in which the new slot is to be generated is selected in the list (including the workbook that was used to generate the slot list). The user then selects the two existing slots and the arithmetic operation to do with the slots. The interface also accepts a long descriptive name (less than 31 characters) for the new slot and a short slot code (less than 6 characters) to identify the new slot by worksheet. A prompt displaying the units of the two existing slots is shown and the user is prompted to enter the units for the new slot. The resulting slot is generated in each of the specified workbooks and the header files are updated to incorporate the new slot information.

Various errors are possible during this slot generation process. Foremost are the problems related to the existence and format of both original slots in each workbook selected. Not only must both the slots exist, but the descriptions and slot codes must also match exactly. If there is any discrepancy between the slot correspondence, an error message will be generated indicating the particular workbook and slot in error. Another potential error is if the newly defined slot code is already in use in one of the workbooks. Under this circumstance, the user will be notified and the slot creation will not occur.

Utility – Create New Workbook

This data utility is written to only apply to workbooks that are output from the Excelwriter program, and only those output with the configuration of rows as time steps, worksheets as slots, and columns as runs. This utility provides the ability to create an entire new workbook based on arithmetic operations of existing workbooks. A primary example of the usefulness of such an operation is to determine the actual differences in various slot values between two workbooks. The procedure that is invoked upon selecting the ***Create New Workbook*** button displays a user interface to enter the required information. Two lists of available workbooks are generated with identical contents. The user selects which workbooks to include in the workbook generation procedure and which arithmetic operation to do between the workbooks. This procedure scans the header files and identifies which runs, times and slots have common descriptions (slot codes, slot names, and units). If these attributes are found to not coincide, the user is prompted to discard this item, include them anyway, or exit the entire procedure.

Utility - Aggregations and Statistics

The Aggregation and Summary Statistics functionality in GPAT can be used on workbooks created by ExcelWriter to aggregate data from shorter timesteps to longer timesteps and/or to generate a list of summary statistics for slot data.

1. Before using the aggregation and summary statistics tools, make sure that the Excel workbook that you intend to analyze is in an acceptable format. The aggregation and statistics tools will support two types of ExcelWriter orientations: the ExcelWriter default orientation, and an alternate orientation, shown in Figures 1 and 2. **Note: After processing the rdf file with ExcelWriter, do not make any changes to the workbook as these changes may interfere with reading information in the workbook.**

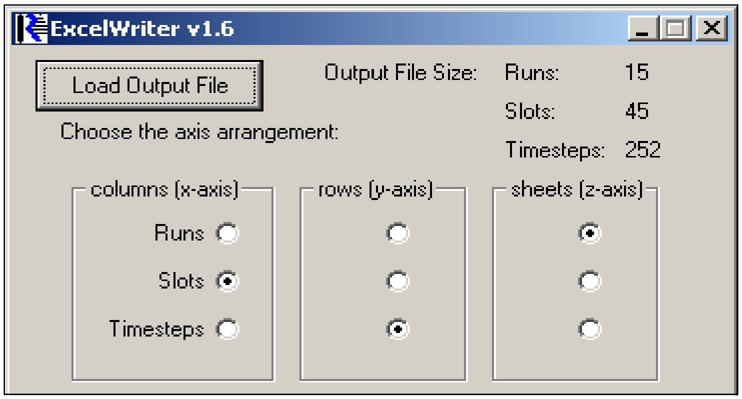


Figure 1 - ExcelWrite Default Orientation

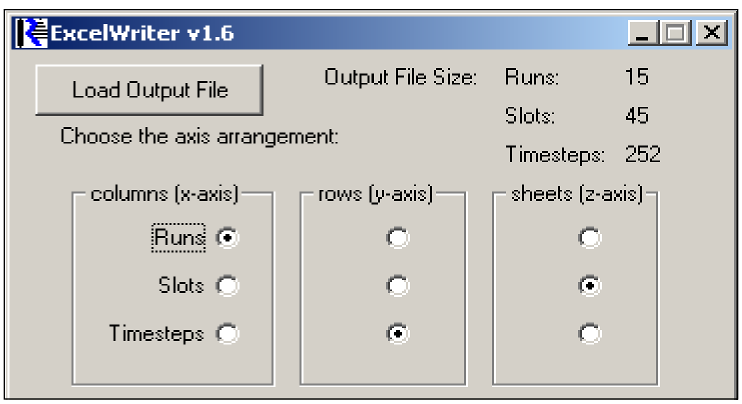


Figure 2 - Alternate Orientation

2. Click on the Aggregations and Statistics button on the GPAT interface to view the options menu. Choose one of the three options available from the menu shown in Figure 3 below: Aggregations, Summary Statistics, or Aggregations & Summary Statistics.

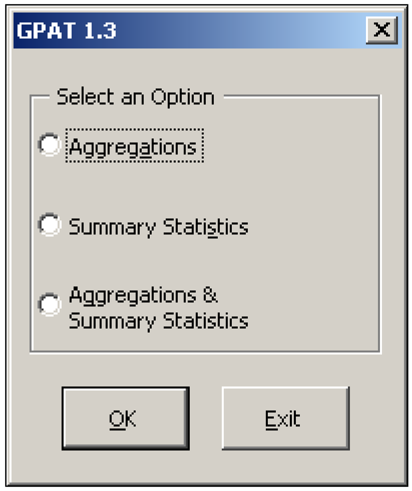


Figure 3 - Aggregations & Statistics Menu

Aggregations:
GPAT will prompt the user to select an Excel workbook to analyze. Once a workbook has been selected, the GPAT will open the workbook. As GPAT is opening the workbook, it will check to make sure that the selected workbook is in the proper format. If the workbook format is not supported , an error message will display and the user will be redirected to the GPAT interface.

Once the selected workbook has been opened and verified, the aggregation menu (See Figure 4 on the following page) will appear. Because GPAT will not disaggregate workbooks, any new timestep options that would lead to a disaggregation will be disabled. Choose the new timestep, and click on the OK button to complete the aggregation.

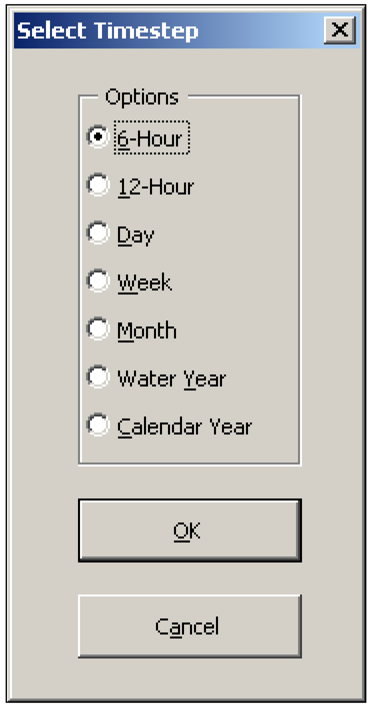


Figure 4 - Aggregation Menu

For workbooks in the ExcelWriter default format, GPAT will identify the workbook as either a multiple or single run file. When aggregating multiple run files, GPAT creates a new workbook, including a new Header sheet to match the new data. GPAT aggregates single run workbooks by creating a new worksheet within the same workbook, creating a new workbook, or by re-writing the existing workbook, depending on the user's preference (See Figure 5). If the user chooses to add a worksheet, the new worksheet will be labeled according to the new timestep. If a worksheet for that timestep already exists, it will be re-written. For the new workbook option, GPAT will create a new workbook with a Header page that corresponds to the new data. If the user decides to re-write the current workbook, GPAT will replace the original data with the aggregated data and will make the necessary updates to the Header.

For workbooks in the alternate orientation, GPAT will create a new workbook and Header sheet. GPAT supports 1-hour, 6-hour, 12-hour, daily, weekly, and monthly input data and will aggregate data to the following time steps: 6-hour, 12-hour, day, week, month, water year, and calendar year.

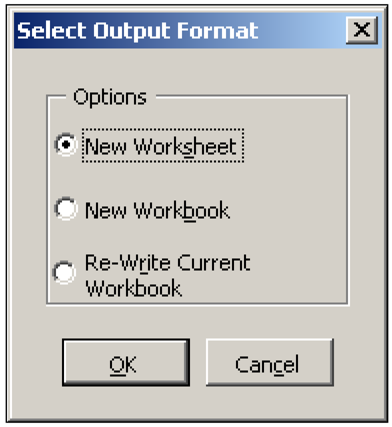


Figure 5 - Single Run Output Options

DUT performs four aggregation types: end of period (i.e. end of day, end of month, etc), average, summation, and a cfs to acre-feet conversion. DUT determines which aggregation to perform for each slot by reading the units from the Header. A table showing which aggregation DUT executes for each slot is located at the end of this section. If a cfs to acre-feet conversion takes place, the change in units will be reflected in the Header if the user creates a new workbook. If, however, the user performs the aggregation within the same workbook by creating a new sheet, the Header will not show any change in units. Use caution, therefore, when aggregating a single run within the same workbook. Note that for large files and smaller timesteps, DUT may take several minutes to perform aggregations. Option menus and dialog boxes will disappear only once the aggregation and/or statistical report is complete.

Summary Statistics:
This option generates a statistical report in a new worksheet within the current workbook. The report includes the following statistics: mean, median, mode, standard deviation, kurtosis, skewness, minimum, date of min, maximum, and date of max. For single run workbooks, summary statistics are always generated from the original data set, not from worksheets containing aggregated data.

Aggregations & Summary Statistics:
This option performs both of the actions described above in one step. If the user stores the aggregated data in a new workbook or re-writes the current workbook, the statistical report will be based upon the newly aggregated data.

GPAT Aggregation By Unit

The table below lists each of the units recognized by GPAT and their respective aggregation functions. Any unit not recognized by GPAT will, by default, be averaged.

Unit		**Aggregation**
m	Length	End of Period
cm	Length	End of Period
km	Length	End of Period
in	Length	End of Period
ft	Length	End of Period
feet	Length	End of Period
yd	Length	End of Period
mi	Length	End of Period
m1/2	SqrtLength	Average

ft1/2	SqrtLength	Average
feet1/2	SqrtLength	Average
m2	Area	End of Period
ft2	Area	End of Period
feet2	Area	End of Period
mi2	Area	End of Period
acre	Area	End of Period
ha	Area	End of Period
cfs-day/ft	Area	End of Period
m3	Volume	End of Period unless labeled as Evaporation slot (Summation)
ft3	Volume	End of Period unless labeled as Evaporation slot (Summation)
feet3	Volume	End of Period unless labeled as Evaporation slot (Summation)
acre-ft	Volume	End of Period unless labeled as Evaporation slot (Summation)
acre-feet	Volume	End of Period unless labeled as Evaporation slot (Summation)
cfs-day	Volume	End of Period unless labeled as Evaporation slot (Summation)
liters	Volume	End of Period unless labeled as Evaporation slot (Summation)
ML	Volume	End of Period unless labeled as Evaporation slot (Summation)
GL	Volume	End of Period unless labeled as Evaporation slot (Summation)
cms	Flow	Average
cfs	Flow	Average up to daily timestep; Converts to acre-ft for month, year
acre-ft/day	Flow	Summation to acre-ft/month or acre-ft/yr
acre-feet/day	Flow	Summation to acre-ft/month or acre-ft/yr
acre-ft/month	Flow	Summation to acre-ft/yr
acre-feet/month	Flow	Summation to acre-ft/yr
acre-ft/year	Flow	Summation
acre-feet/year	Flow	Summation
mgd	Flow	Average
ML/day	Flow	Average
s/m	TimePerLength	Average
hr/m	TimePerLength	Average
day/m	TimePerLength	Average
year/m	TimePerLength	Average
hr/ft	TimePerLength	Average
s/ft	TimePerLength	Average
day/ft	TimePerLength	Average
year/ft	TimePerLength	Average
acre-s/ft3	TimePerLength	Average
cms2	FlowSquared	Average
cfs2	FlowSquared	Average
acre-ft2/day2	FlowSquared	Average
acre-feet2/day2	FlowSquared	Average
acre-ft2/month2	FlowSquared	Average
acre-feet2/month2	FlowSquared	Average

acre-ft2/year2	FlowSquared	Average
1/cms	PerFlow	Average
1/cfs	PerFlow	Average
1/acre-ft/day	PerFlow	Average
1/acre-feet/day	PerFlow	Average
cms/m1/2	FlowPerSqrtLength	Average
cfs/ft1/2	FlowPerSqrtLength	Average
cfs/feet1/2	FlowPerSqrtLength	Average
MW	Power	Average
GW	Power	Average
KW	Power	Average
KVA	Power	Average
HP	Power	Average
MW/cms	PowerPerFlow	Average
MW/cfs	PowerPerFlow	Average
MWH/m3	PowerPerFlow	Average
MWH/cms-day	PowerPerFlow	Average
MWH/cfs-day	PowerPerFlow	Average
KWH/acre-ft	PowerPerFlow	Average
KWH/acre-foot	PowerPerFlow	Average
MWH	Energy	Average
KWH	Energy	Average
GWH	Energy	Average
hour	Time	Average
sec	Time	Average
min	Time	Average
day	Time	Average
hr	Time	Average
month	Time	Average
year	Time	Average
MWH/MW	Time	Average
hour2	TimeSquared	Average
sec2	TimeSquared	Average
min2	TimeSquared	Average
day2	TimeSquared	Average
hr2	TimeSquared	Average
g	Mass	Average
kg	Mass	Average
mg	Mass	Average
metric_tons	Mass	Average

tons	Mass	Average
J	Heat	Average
KJ	Heat	Average
cal	Heat	Average
J/m2sec	EnergyFlux	Average
J/m2day	EnergyFlux	Average
cal/cm2day	EnergyFlux	Average
kcal/m2hr	EnergyFlux	Average
g/m2sec	MassFlux	Average
g/m2hr	MassFlux	Average
g/m2day	MassFlux	Average
g/ft2day	MassFlux	Average
g/m3sec	VolFlux	Average
g/m3hr	VolFlux	Average
g/m3day	VolFlux	Average
g/ft3day	VolFlux	Average
g/m3	Concentration	Average
kg/m3	Concentration	Average
mg/m3	Concentration	Average
mg/l	Concentration	Average
tons/acre-ft	Concentration	Average
tons/acre-feet	Concentration	Average
lb/ft3		Average
m2/s	AreaPerTime	Average
m2/day	AreaPerTime	Average
ft2/s	AreaPerTime	Average
ft2/day	AreaPerTime	Average
1/sec	PerTime	Average
1/hr	PerTime	Average
1/day	PerTime	Average
cms/m3	PerTime	Average
C	Temperature	Average
m/C	LengthPerTemperature	Average
cm/C	LengthPerTemperature	Average
m/F	LengthPerTemperature	Average
ft/F	LengthPerTemperature	Average
in/F	LengthPerTemperature	Average
F	Temperature	Average

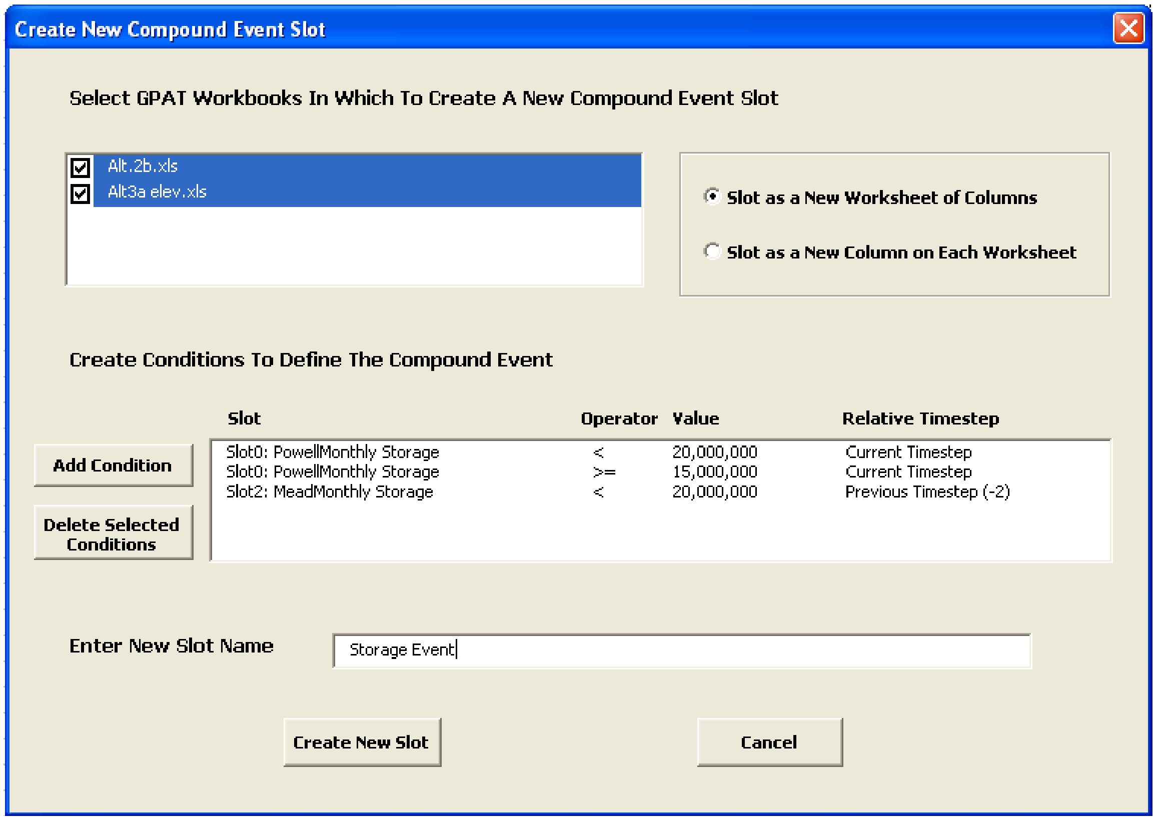
J/gC	SpecificHeat	Average
J/kgC	SpecificHeat	Average
m/s	Velocity	Average
cm/s	Velocity	Average
km/hour	Velocity	Average
ft/s	Velocity	Average
feet/s	Velocity	Average
mi/hour	Velocity	Average
in/month	Velocity	Average
ft/month	Velocity	Average
feet/month	Velocity	Average
ft/day	Velocity	Average
feet/day	Velocity	Average
in/day	Velocity	Average
in/hour	Velocity	Average
cm/month	Velocity	Average
cm/day	Velocity	Average
cm/hour	Velocity	Average
m/year	Velocity	Average
ft/year	Velocity	Average
feet/year	Velocity	Average
in/year	Velocity	Average
m/month	Velocity	Average
kg/m3_dens	Density	Average
g/m3_dens	Density	Average
#this	needs	Average
#$/MWh	EnergyCost	Average
$/MWh	PowerCost	Average
$	Value	Average
$/cms	ValuePerFlow	Average
$/cfs	ValuePerFlow	Average
$/m3	ValuePerVolume	Average
$/cfs-day	ValuePerVolume	Average
m/m3	LengthPerVolume	Average
ft/cfs-day	LengthPerVolume	Average
m/cms	LengthPerFlow	Average
ft/cfs	LengthPerFlow	Average

1/m	PerLength	Average
1/ft	PerLength	Average
m2/m3	PerLength	Average
cms/m	FlowPerLength	Average
cfs/ft	FlowPerLength	Average
m3/cms	VolumePerFlow	Average
ft3/cfs	VolumePerFlow	Average
cfs-day/cfs	VolumePerFlow	Average
decimal	Fraction	Average
percent	Fraction	Average
m/m	noDimension	Average
cms/cms	noDimension	Average
ft/ft	noDimension	Average
MWH/m	energyPerLength	Average
MWH/ft	energyPerLength	Average
MW/m	powerPerLength	Average
MW/ft	powerPerLength	Average
pct_StdDev	PercentUncertainty	Average
pct_95%CI	PercentUncertainty	Average
stdDev_m3	VolumeUncertainty	Average
stdDev_ft3	VolumeUncertainty	Average
stdDev_feet3	VolumeUncertainty	Average
stdDev_acre-ft	VolumeUncertainty	Average
stdDev_acre-feet	VolumeUncertainty	Average
stdDev_cfs-day	VolumeUncertainty	Average
95%CI_m3	VolumeUncertainty	Average
95%CI_ft3	VolumeUncertainty	Average
95%CI_feet3	VolumeUncertainty	Average
95%CI_acre-ft	VolumeUncertainty	Average
95%CI_acre-feet	VolumeUncertainty	Average
95%CI_cfs-day	VolumeUncertainty	Average
stdDev_CMS	FlowUncertainty	Average
stdDev_CFS	FlowUncertainty	Average
stdDev_acre-ft/day	FlowUncertainty	Average
stdDev_acre-feet/day	FlowUncertainty	Average
stdDev_acre-ft/month	FlowUncertainty	Average
stdDev_acre-feet/month	FlowUncertainty	Average
stdDev_acre-ft/year	FlowUncertainty	Average
stdDev_acre-	FlowUncertainty	Average

feet/year		
95%CI_CMS	FlowUncertainty	Average
95%CI_CFS	FlowUncertainty	Average
95%CI_acre-ft/day	FlowUncertainty	Average
95%CI_acre-feet/day	FlowUncertainty	Average
95%CI_acre-ft/month	FlowUncertainty	Average
95%CI_acre-feet/month	FlowUncertainty	Average
95%CI_acre-ft/year	FlowUncertainty	Average
95%CI_acre-feet/year	FlowUncertainty	Average
stdDev_m	LengthUncertainty	Average
stdDev_cm	LengthUncertainty	Average
stdDev_km	LengthUncertainty	Average
stdDev_in	LengthUncertainty	Average
stdDev_ft	LengthUncertainty	Average
stdDev_feet	LengthUncertainty	Average
stdDev_yd	LengthUncertainty	Average
stdDev_mi	LengthUncertainty	Average
95%CI_m	LengthUncertainty	Average
95%CI_cm	LengthUncertainty	Average
95%CI_km	LengthUncertainty	Average
95%CI_in	LengthUncertainty	Average
95%CI_ft	LengthUncertainty	Average
95%CI_feet	LengthUncertainty	Average
95%CI_yd	LengthUncertainty	Average
95%CI_mi	LengthUncertainty	Average
stdDev_hour	TimeUncertainty	Average
stdDev_sec	TimeUncertainty	Average
stdDev_min	TimeUncertainty	Average
stdDev_day	TimeUncertainty	Average
stdDev_hr	TimeUncertainty	Average
95%CI_hour	TimeUncertainty	Average
95%CI_sec	TimeUncertainty	Average
95%CI_min	TimeUncertainty	Average
95%CI_day	TimeUncertainty	Average
95%CI_hr	TimeUncertainty	Average
m6	VolumeSquared	Average
m6/t	FlowVolume	Average
cmshour	FlowTime	Average

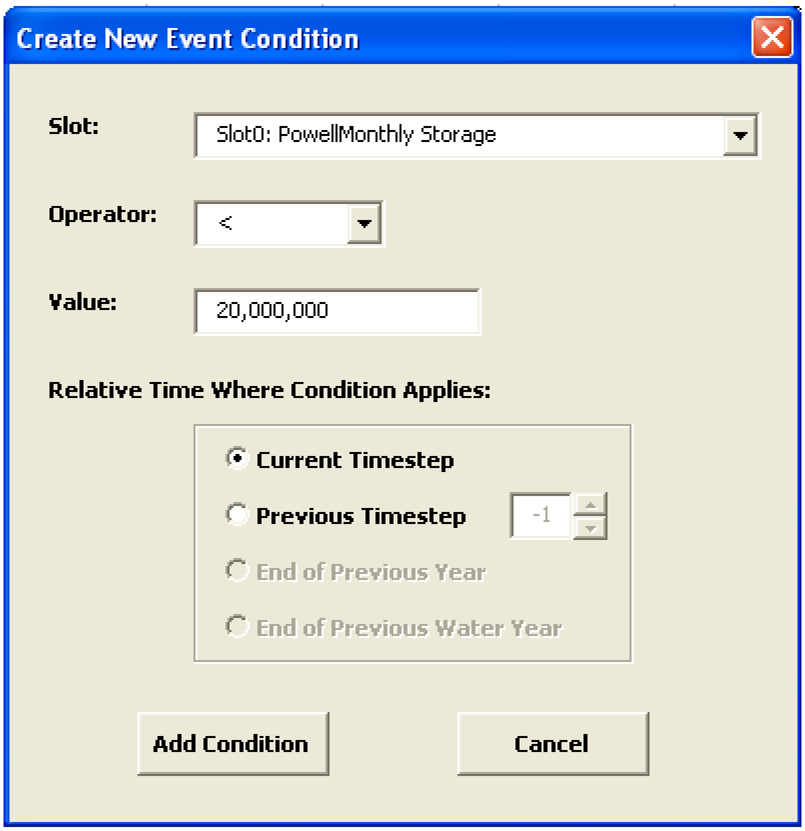
Utility – Create Compound Event

The purpose of this utility is to create a new slot that contains a binary 1 or 0 value reflecting if a specified event occurred or not at that time. The event can be compound, meaning that a number of conditions on a number of different slots can be used to define the event. Depending on the orientation of their data, the user can choose to add the new slot as a new worksheet of columns or as a new column on each data worksheet in their workbook. The new slot can then be analyzed and graphed in the main GPAT interface the same as any other binary slot.



The workbook list shows all workbooks that are currently open in GPAT. The user can select the ones in which they want to create the new slot. The default selection to create the new slot as a new worksheet of columns is appropriate for a data orientation where worksheets in a workbook are slots and columns on the worksheets are runs. The other selection would be for an orientation where worksheets in a workbook represent runs and columns on the worksheets are slots.

The list in the middle of the dialog displays the conditions that will be used to define the event. Conditions are all treated with an “AND” logic so that all conditions must apply for the defined event to be true. Selected conditions can be deleted from the list with the Delete Selected Conditions button. Conditions can be added through the following dialog brought up by the Add Condition button.



The Create New Event Condition dialog presents a pick list of available slots to let the user specify which one the condition should apply to. There is a list of 6 operators for the user to choose from (<, <=, =, <>, >, >=) to show how the slot value should relate to the value entered by the user in the Value text box. Finally there is a list of relative time selections to specify when the condition should apply relative to the time being evaluated for the new compound event slot. The default is the current timestep. The previous timestep selection allows the user to specify the number of timesteps prior to the event timestep being evaluated that the condition will be applied (such as this event will be true if PowellMonthly Storage was < 20,000,000 two timesteps ago). The End of Previous Year and End of Previous Water Year buttons are available if the timestep of the data is monthly or less. End of Previous Year means the event will be true if the last data value in the previous calendar year meets the condition. End of Previous Water Year is evaluated similarly to calendar year except the water year runs from October through September instead of January through December. After selections are complete, the condition is added to the overall event definition by pressing the Add Condition button.

After a condition is added, the main Create Compound Event dialog is brought back and will show the new condition in the condition list. A new slot name must be entered into the text box at the bottom of this dialog before the new slot can be created with the Create New Slot button. After creation, the new slot will appear either as a new worksheet or a new column, depending on the orientation, in the appropriate workbooks in the Input tab of the main GPAT interface.

Utility – Create MRM RDF File

The purpose of this data utility is to create a multiple run rdf file from a set of single run rdf files from RiverWare. The resulting file can then be used to create a multiple run Excel spreadsheet. Click on the "Create MRM RDF File" button to see the multiple run rdf interface as shown on Figure 6. Follow the steps below to add and remove single traces and to create a multiple run rdf file. Click on the "Exit" button to return to the main interface. Note that the slots of the single run files must correspond exactly.

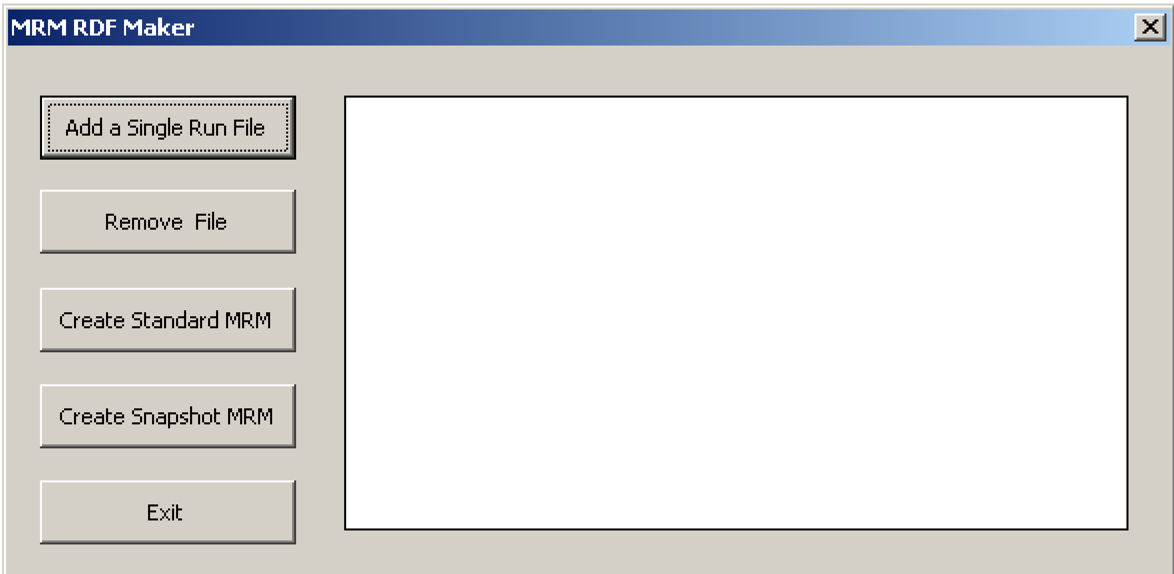


Figure 6. Make Multiple Run RDF Interface.

Select/Remove Single Trace RDF Files

Too add single trace files, click on the "Add Single Run File" button, and navigate to the desired rdf file and the file will appear on the interface as shown on Figure 7. To remove a file, select the desired file and click on the "Remove File" button.

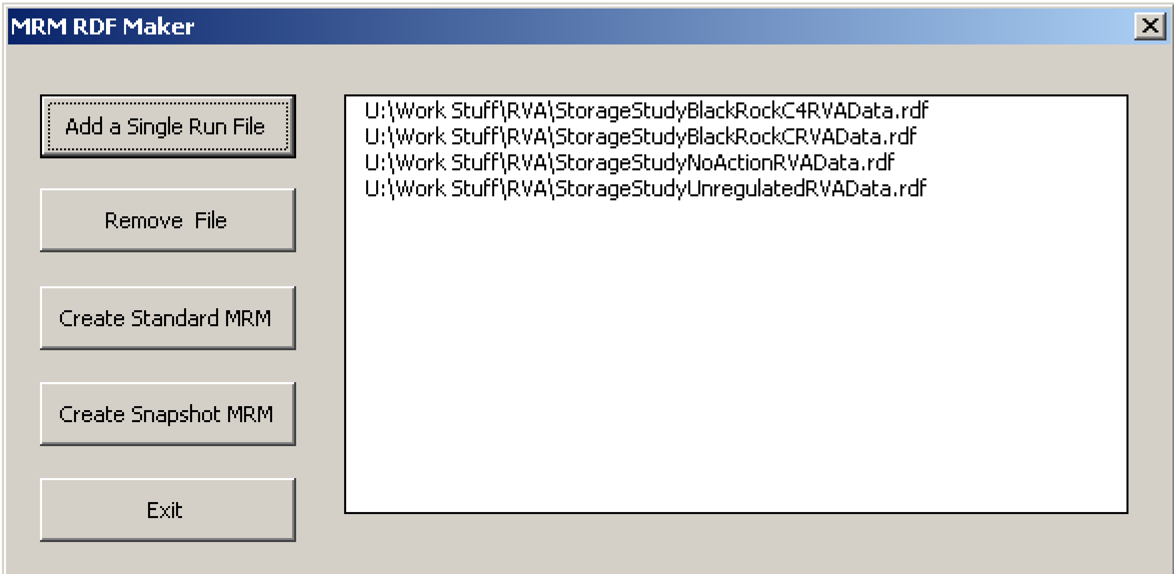


Figure 7. MRM Maker Interface with Files Added.

Create Standard MRM RDF File

Click on the “Create Standard MRM” button to create a standard multiple run management rdf file from the list of files displayed in the interface. A prompt will appear to confirm that the user wants to create a file. After confirmation, the user is prompted for a description of the project, and of each of the single run files. After the descriptions have been entered, a multiple run rdf file will be created. Following the creation of the file, the user has the option of running ExcelWriter to convert the file to an Excel workbook. Rdf files must be converted to Excel format before using with GPAT.

Create Snapshot MRM RDF File

Use “Create Snapshot MRM” button to create a multiple run management rdf file from the list of single run snapshot rdf files. The slots of the snapshots must be identical but the snapshot names (object names in the rdf) can vary. The process of creating the multiple run file is the same as the standard multiple run rdf creation. The program attempts to create object and slot names equivalent to those from a standard run. The program created names may be edited by selecting an entry and clicking on the “Edit” button. All entries must have a period between the object name and the slot name (e.g. Gage.Outflow). The user should only have to edit the default names when spaces exist in the original object and slot names.