InfoSWMM

Introduction to InfoSWMM

Calibrator

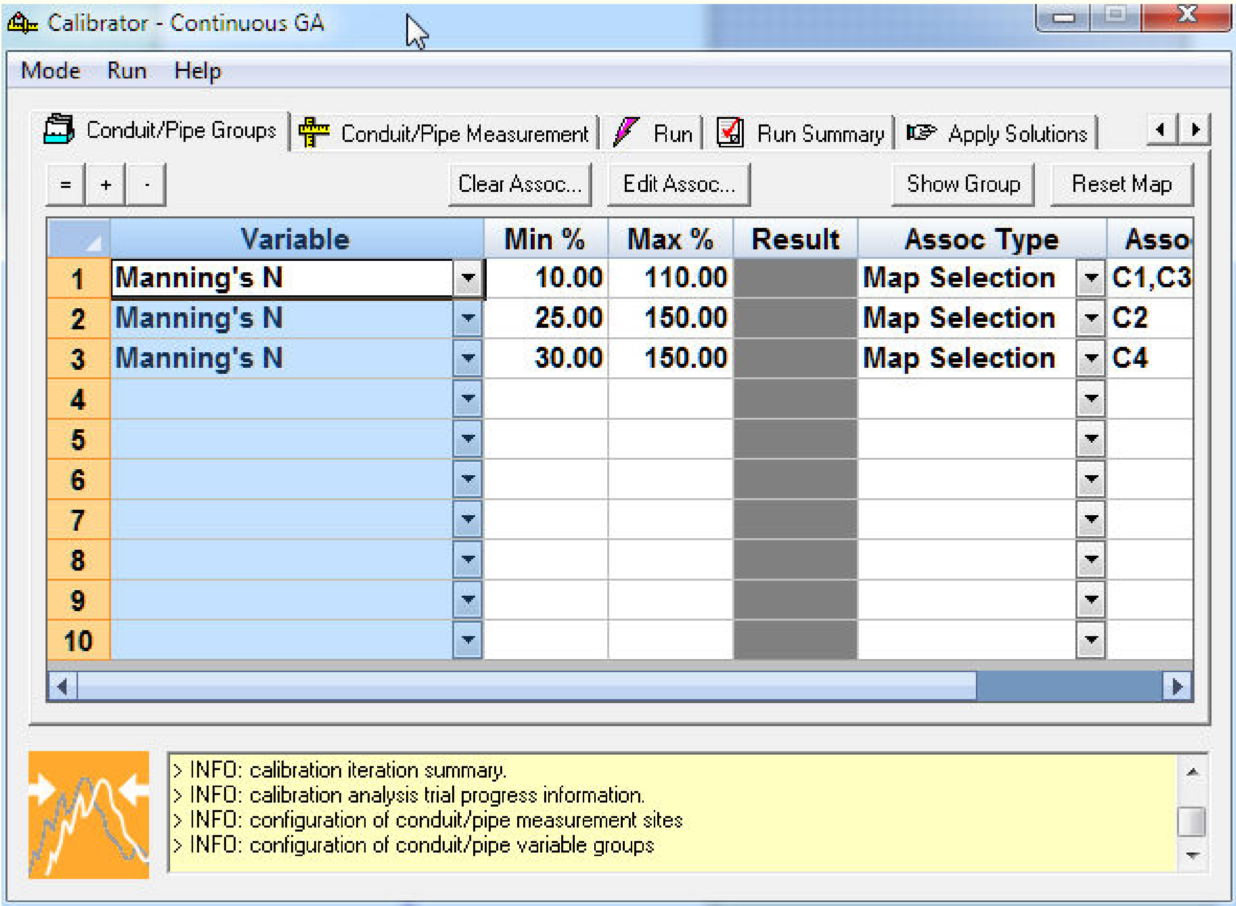
nfoSWMM Calibrator sets a new standard in automated Stormwater model calibration. It helps you build and validate the credibility and reliability of your urban stormwater collection system models. With point-and-click simplicity, you can command the latest advances in Genetic Algorithms and Global Search control strategies to optimally adjust Subcatchment parameters, infiltration parameters, groundwater parameters, aquifer parameters, RDII hydrograph parameters, and conduit parameters and best reflect what is actually occurring in the system. The program minimizes the difference between observed field data (such as flow, velocity, and/or depth) and model predictions considering all test data simultaneously to provide the best calibration possible.

You can even disaggregate the model into separate logical calibration groups (e.g., subcatchment, soil, aquifer, RDII, and conduit) based on the known physical characteristics of the associated elements (e.g., topographic condition, soil type, land use, conduit age, conduit material type, etc.) and seamlessly interface with nfoSWMM

to evaluate their fitness under various simulation options and operating conditions and to maximize efficiency. All in an integrated and extremely rich graphical presentation environment, making model calibration an enjoyable and friendly task.

Groups	Purpose	Running the Calibrator
Subcatchments	**Conduit** Measurement	Run
RDII Hydrographs	Calibration Methodology	Objective Functions
Soils	**Purpose of the Calibrator**	Run Summary

Conduits	Graphs	Apply Solutions
Aquifers		Calibration Methodology



nfoSWMM

Calibrator Empowers you to Make the Best Models *from* ***the Best Available Monitored Data***

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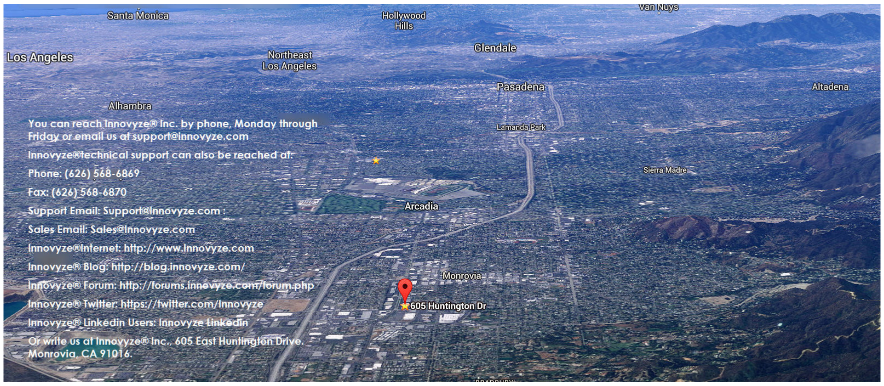

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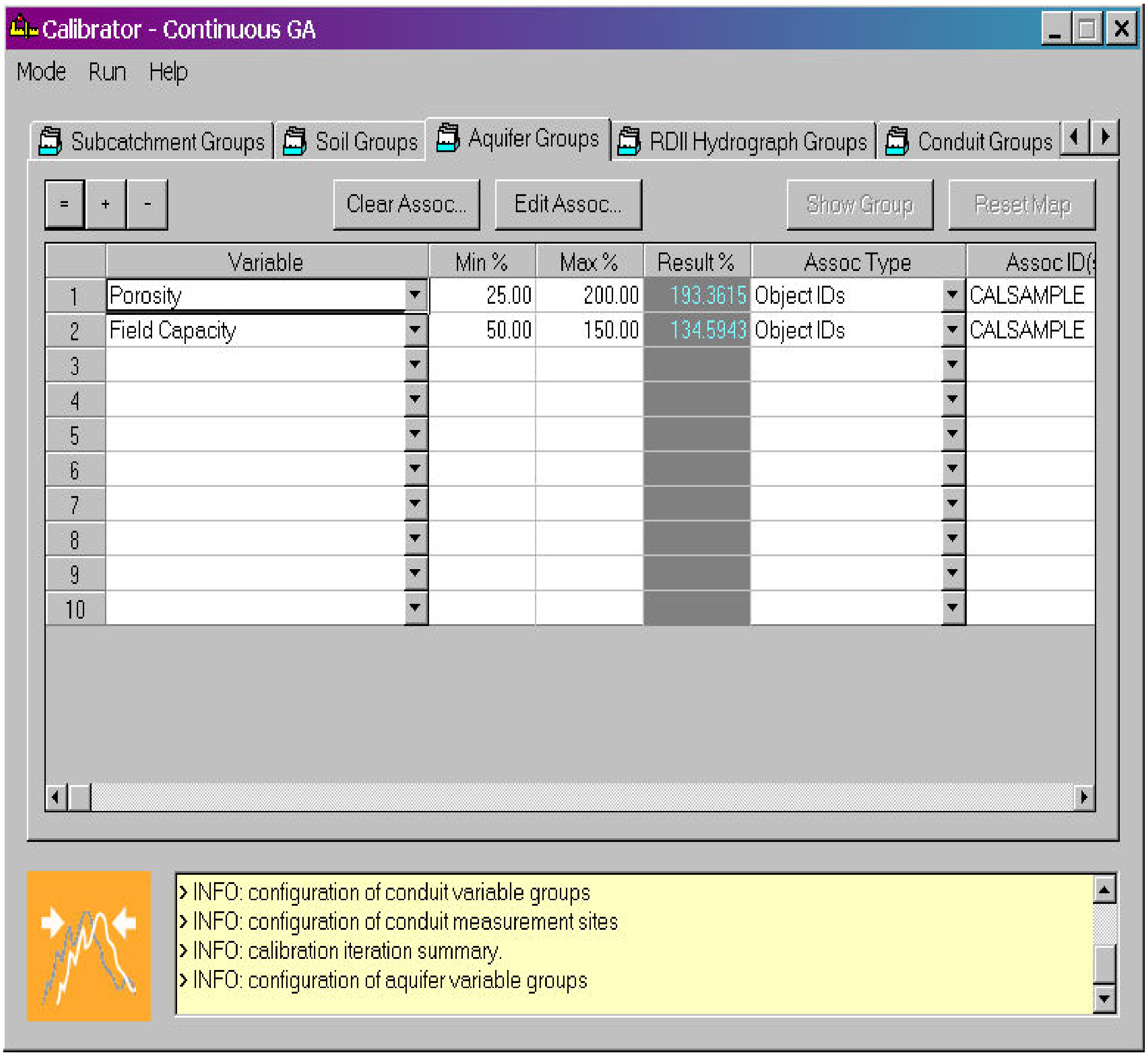
Aquifer Groups

The aquifer group consists of aquifer parameters that are required to model Subcatchment groundwater flow. Define the aquifer groups to be used in the calibration analysis, or modify any aquifer group previously identified, input ranges of acceptable aquifer parameters for each aquifer group, or color-code each aquifer group.

If invalid aquifer ID (e.g., non-existing aquifer) is associated with a group, the calibrator will issues an error message and will not run.

If irrelevant aquifer parameter (e.g., aquifer group is defined but groundwater is not simulated) is defined as calibrated, the calibrator will run, but as expected, the parameter will not play any role in the calibration process.



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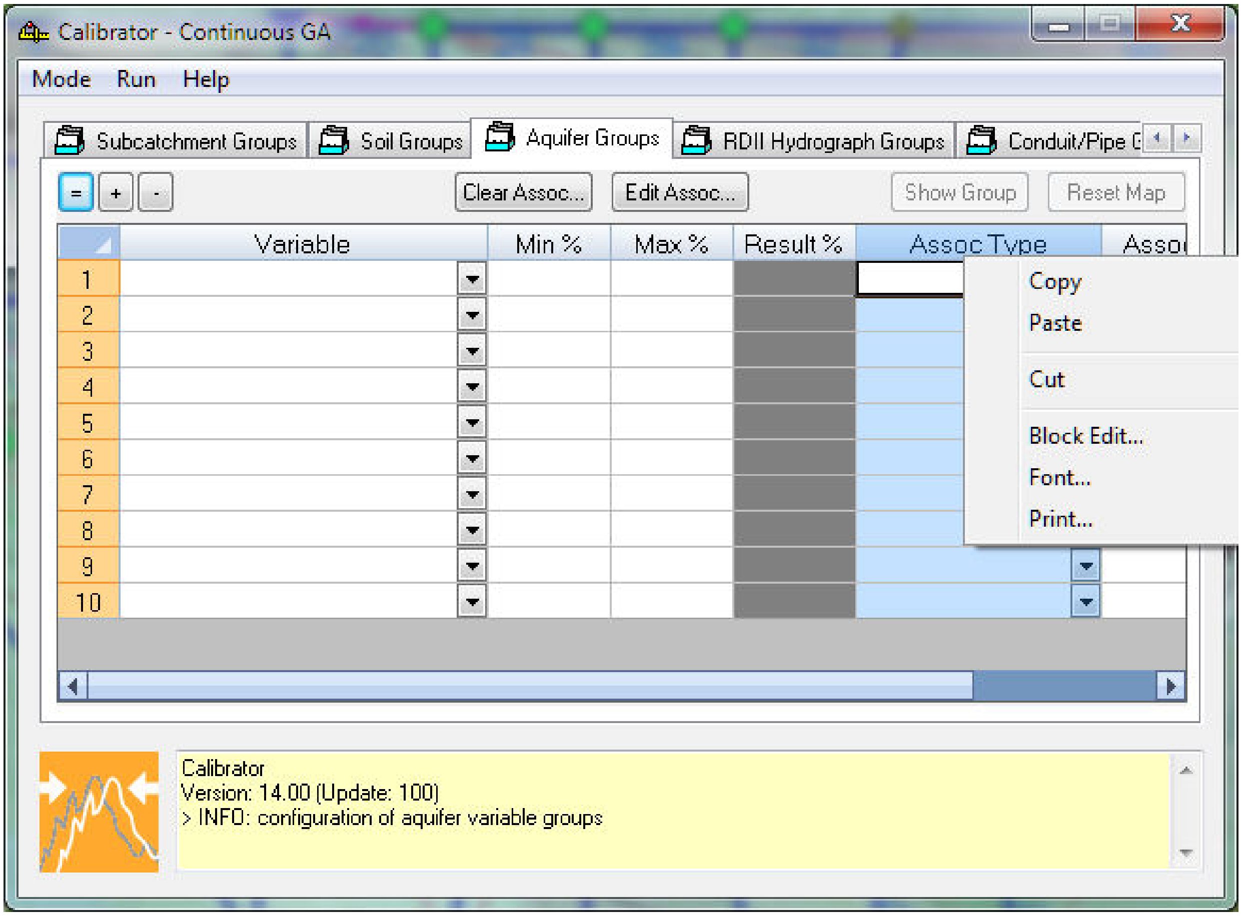

Click here for details on these options.

See Also

Calibration Options

Genetic Algorithm Options

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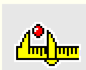
Calibration Groups

ThenfoSWMM

 Calibrator has five general calibration groups:

- **Aquifer Groups**
- **Conduit Groups**
- **RDII Hydrograph Groups**
- **Soil Groups**
- **Subcatchment Groups**

One or more nfoSWMM

parameters are associated with each of these calibration groups. Modelers can disaggregate their system into separate logical calibration groups based on characteristics of the associated elements that affect the parameters being calibrated (e.g., topographic conditions, soil type, land use, conduit age, conduit material type, etc.) to handle spatial heterogeneity of the parameters with maximum flexibility. Working mechanism of the five calibration groups and the required input information is similar. Therefore, these common features are described below before going into unique characteristics of the individual groups.

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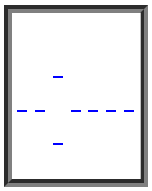
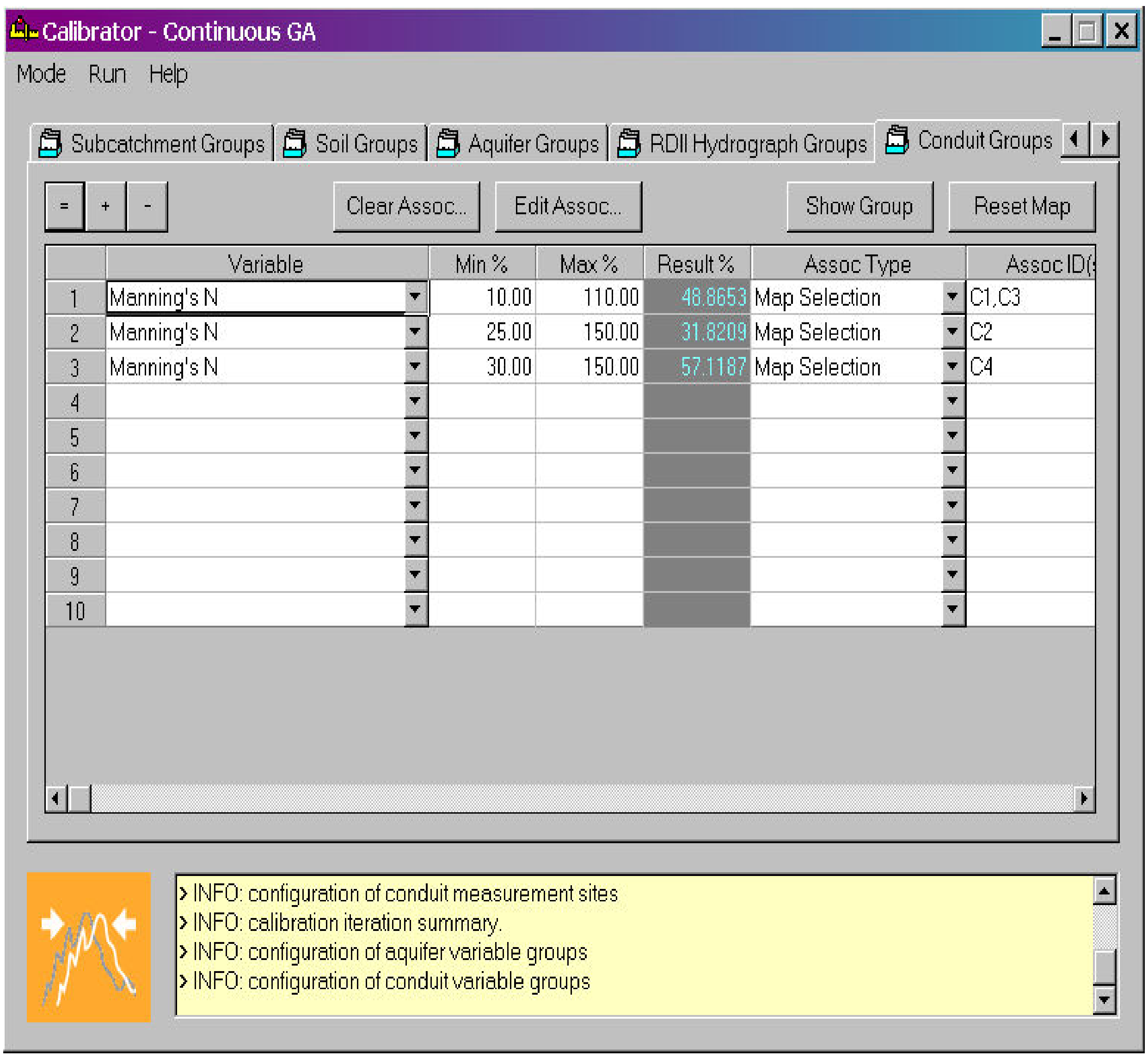


Conduit Groups

The conduit group enables the user to calibrate Manning's roughness coefficient for conduits. Define the conduit groups to be used in the calibration analysis. Modify any conduit group previously identified, input ranges of acceptable Manning's n for each conduit group, or color-code each conduit group.
If invalid Conduit ID (e.g., non-existing conduit) is associated with a group, the calibrator will issues an error message and will not run.



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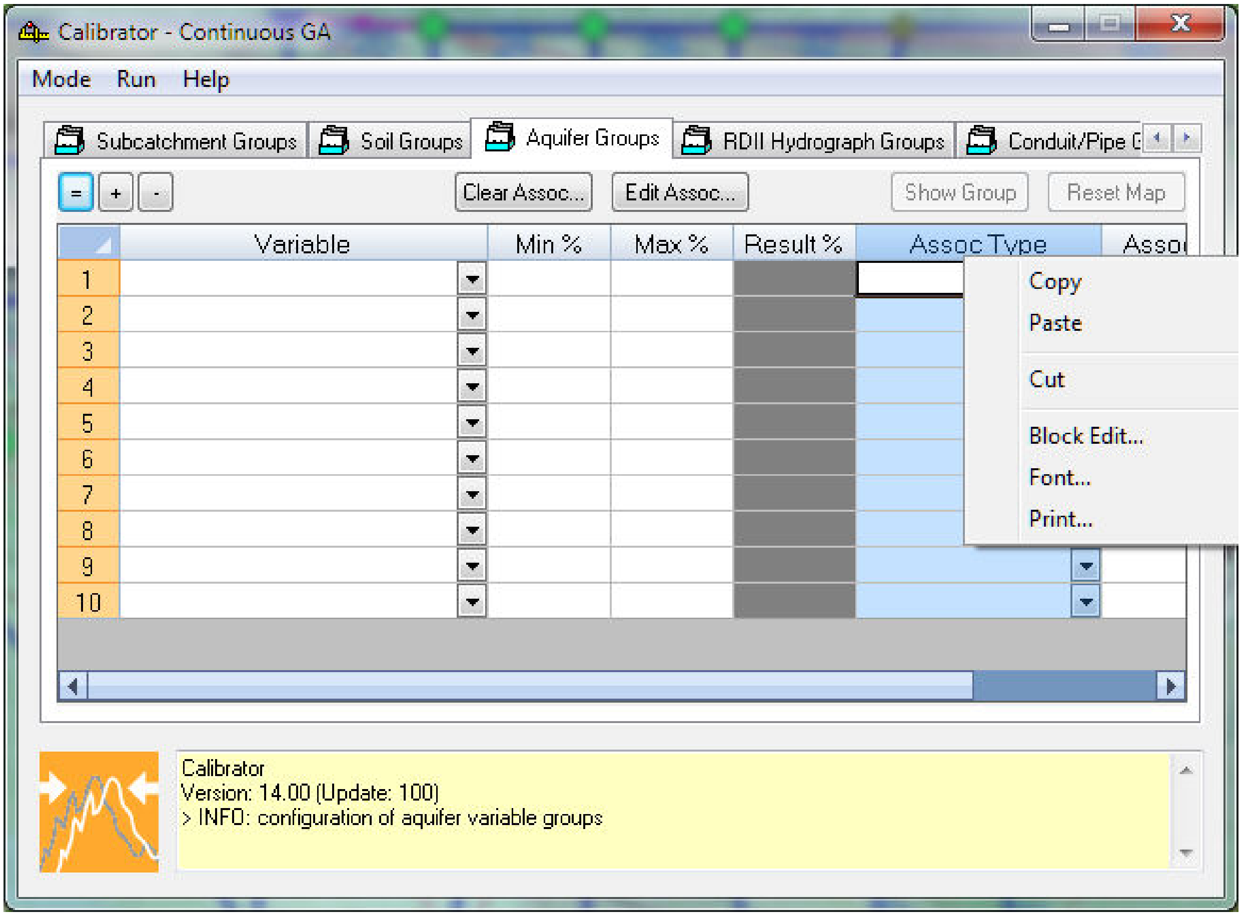

Click here for details on these options.

See Also

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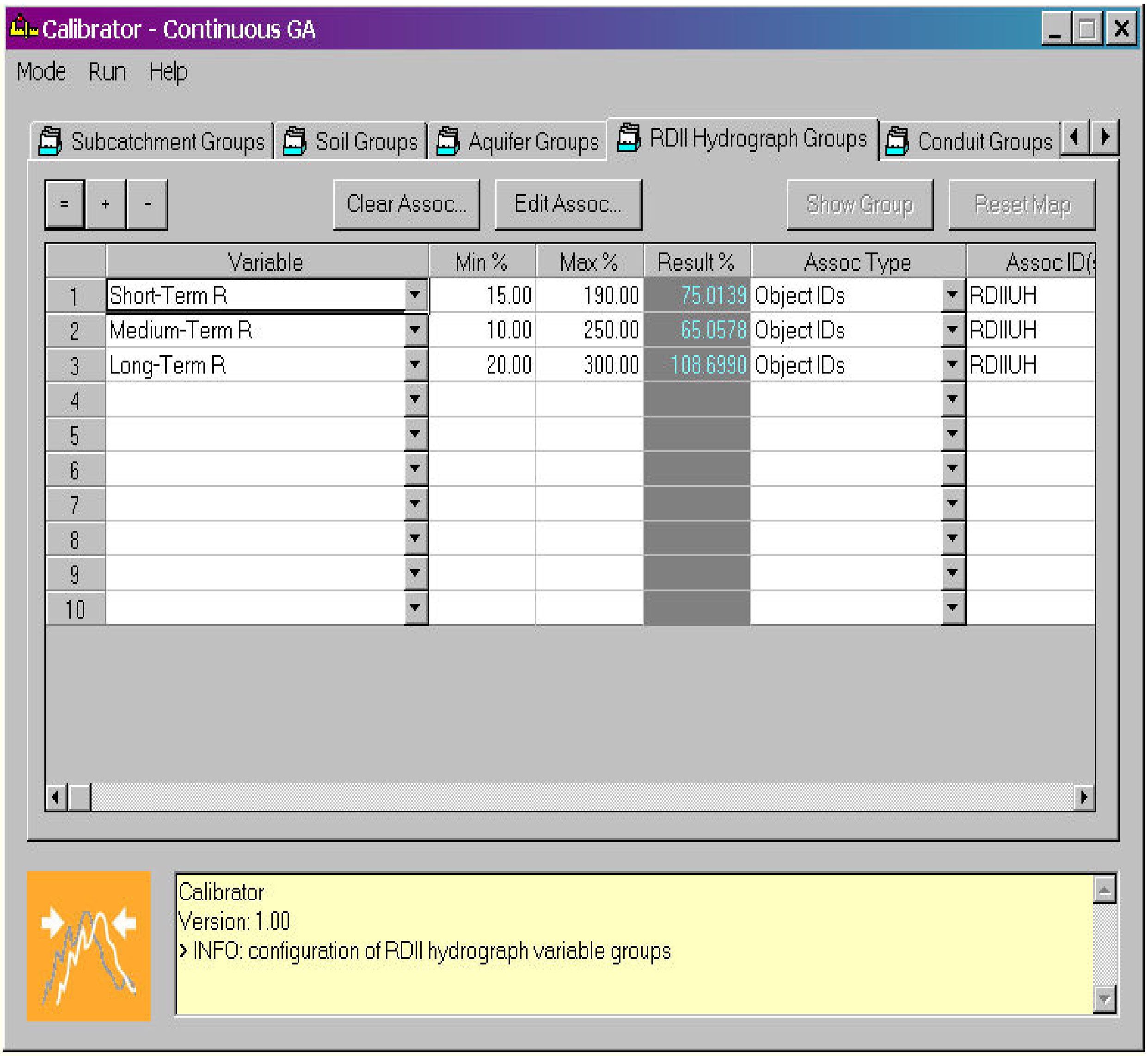
RDII Hydrograph Groups

The RDII group consists

of RDII unit hydrograph parameters that are required to model rainfall derived infiltration and inflow to junctions. Define the RDII groups to be used in the calibration analysis. Modify any RDII group previously identified, input ranges of acceptable RDII parameters for each RDII group, or color-code each RDII group.

If invalid RDII ID (e.g.,

non-existing RDII UH) is associated with a group, the calibrator will issues an error message and will not run.



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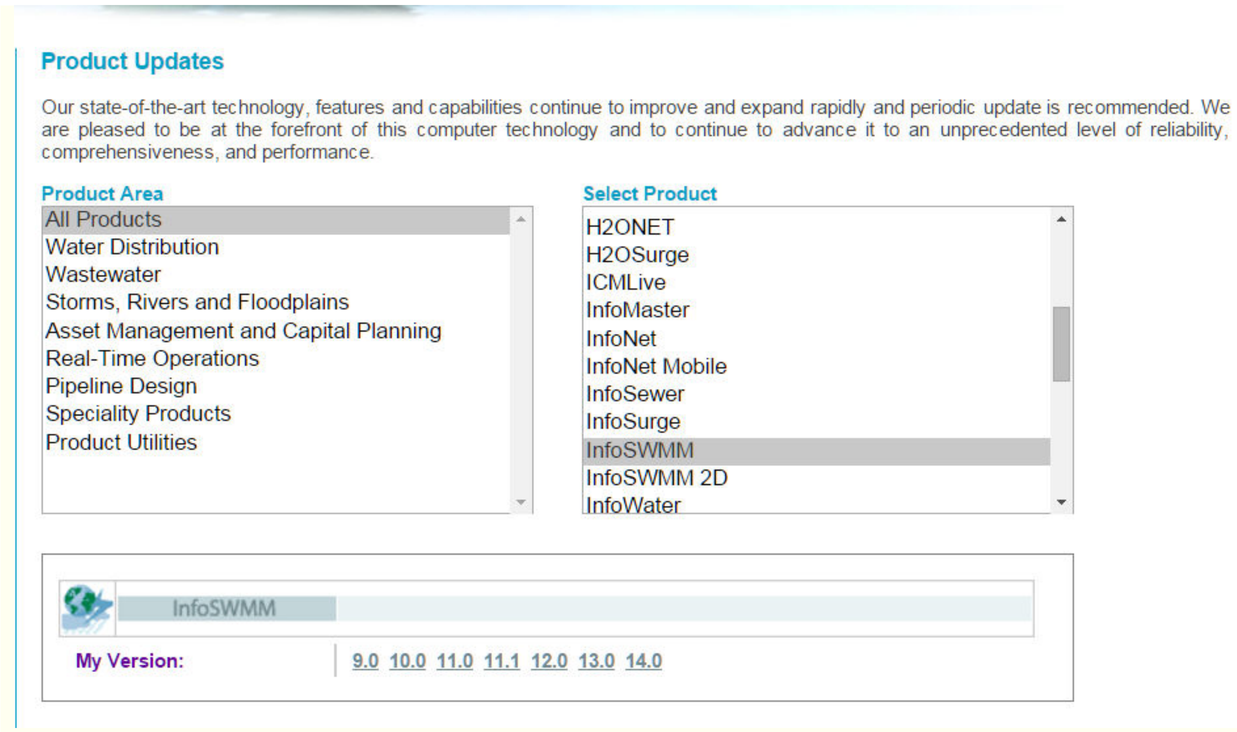

[Click here](#) for details on these options.

See Also

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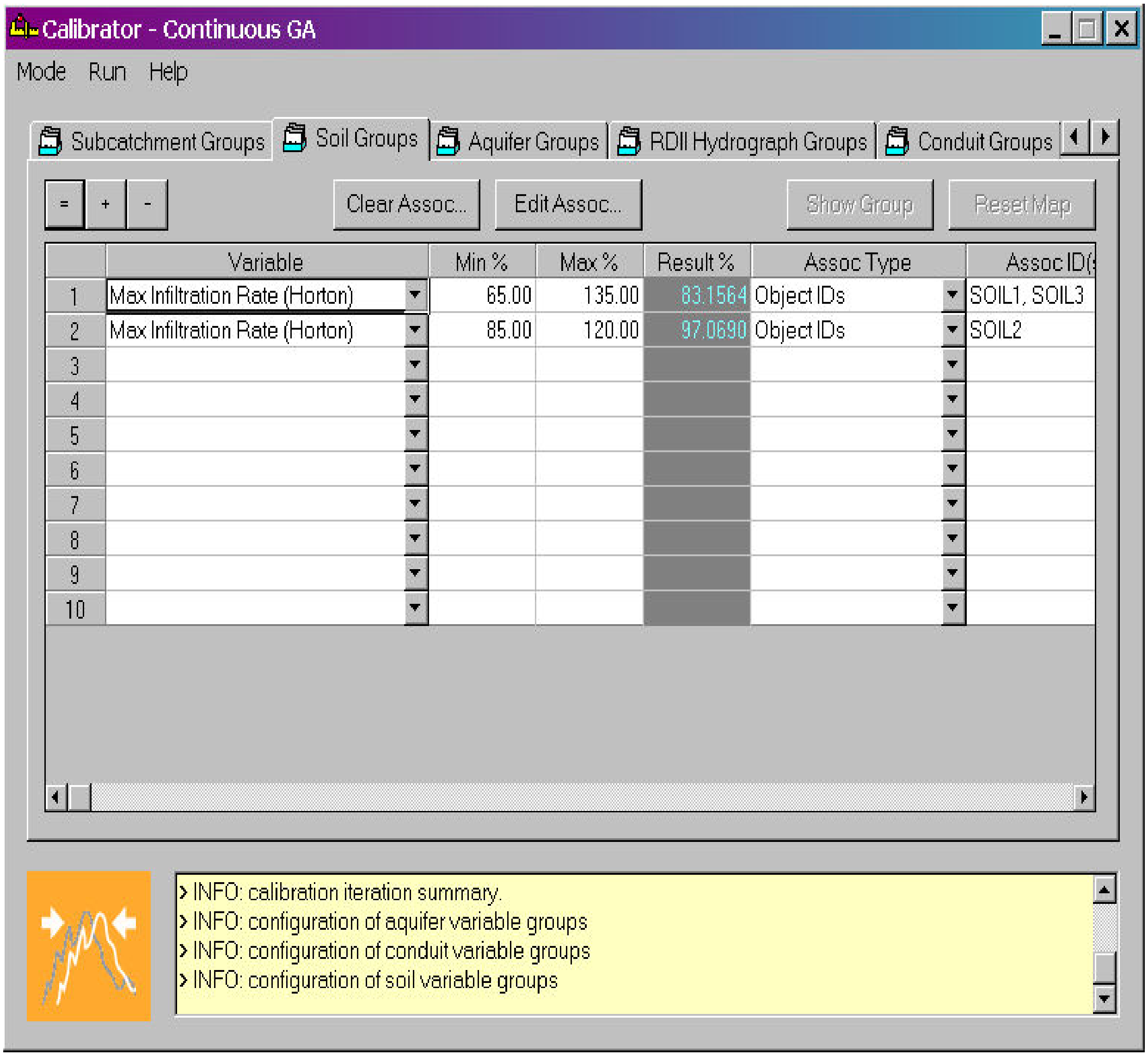
Soil Groups

The soil group contains InfoSWMM infiltration parameters. infoSWMM can model Subcatchment infiltration using the Horton method, Green-Ampt method, or Curve Number method. Depending on the infiltration model used, the following infiltration parameters can be calibrated and are all available from the soil group. ID of the soils that have similar infiltration characteristics should be listed in the Assoc ID(s) column.
If invalid soil ID (e.g., non-existing soil) is associated with a group, the calibrator will issue a warning message but it will run. However, if all IDs provided to a group are invalid the calibrator will issue an error message and will not run.
If irrelevant soil parameter (e.g., parameter that is not associated with the infiltration model being used) is defined as calibrated, the calibrator will run, but the parameter will not play any role in the calibration process.



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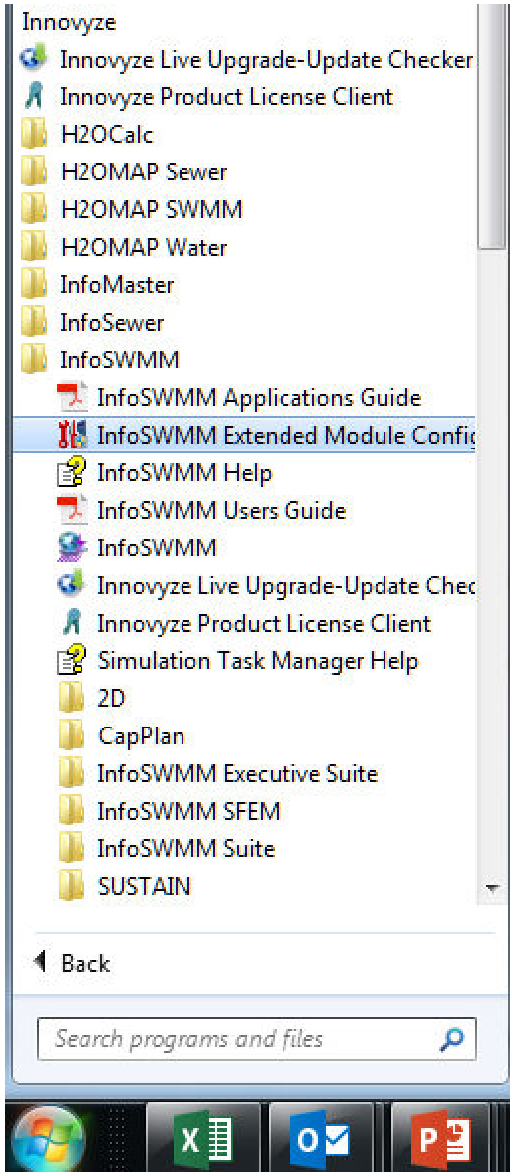

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[Apply Solutions]

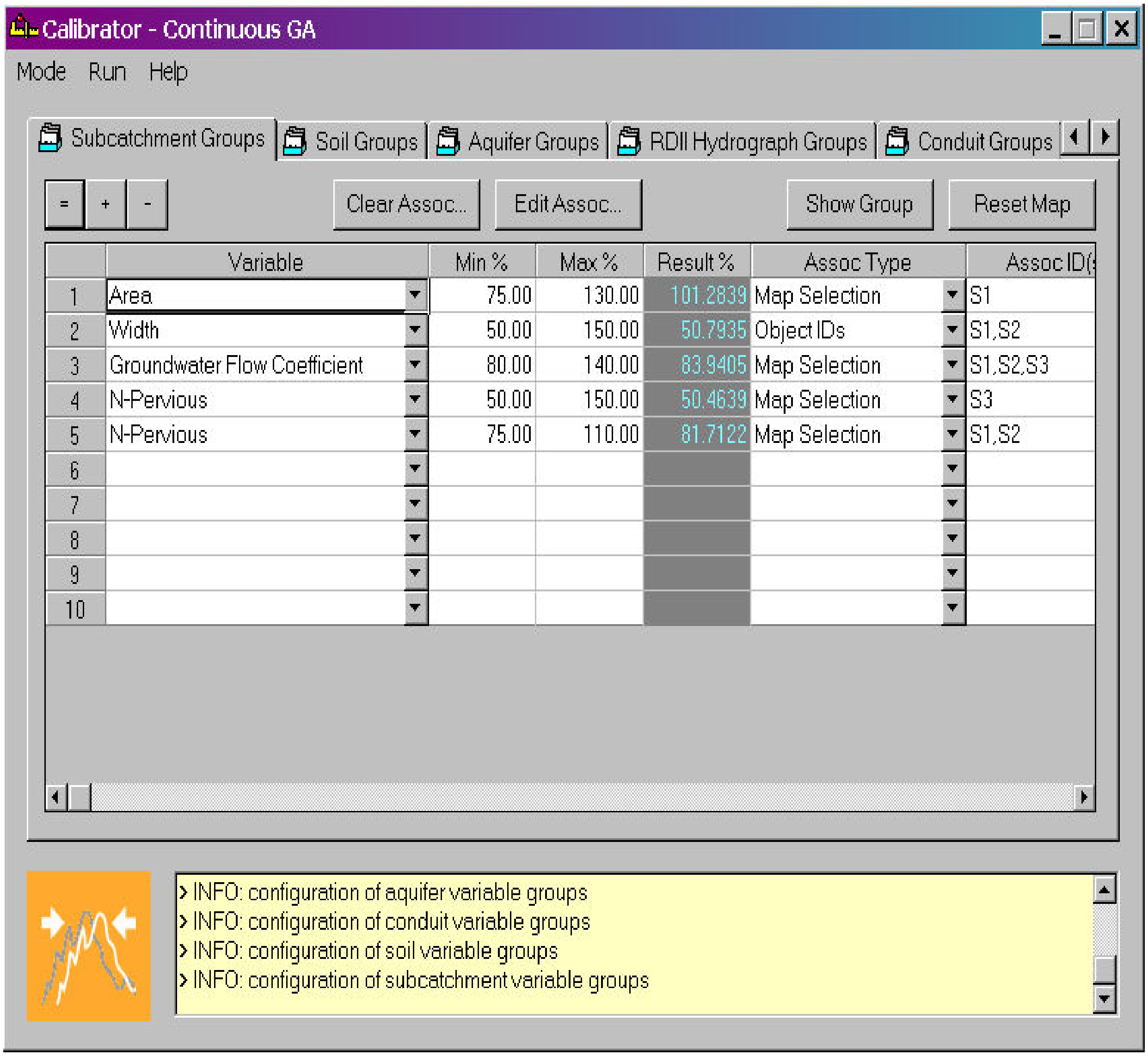
Subcatchment Groups

The Subcatchment group contains Subcatchment rainfall-runoff modeling parameters and groundwater parameters. nfoSWMM supports four different rainfall-runoff modeling methods:

- EPA SWMM's Non-Linear Reservoir Method
- Colorado Urban Hydrograph Procedure (CUHP)
- Natural Resources Conservation Service (NRCS) Dimensionless Unit Hydrograph
- NRCS Triangular Unit Hydrograph

Specify the parameters (variables) to calibrate. Selection of the parameters to calibrate depends on the rainfall-runoff modeling technique and if groundwater is being analyzed.
If invalid Subcatchment ID (e.g., non-existing Subcatchment) is associated with a group, the calibrator will issue a warning message but it will run. However, if all IDs provided to a group are invalid the calibrator will issue an error message and will not run.

If irrelevant Subcatchment parameter (e.g., parameter that is not associated with the rainfall-runoff model being used) is defined as calibrated, the calibrator will run, but the parameter will not play any role in the calibration process.



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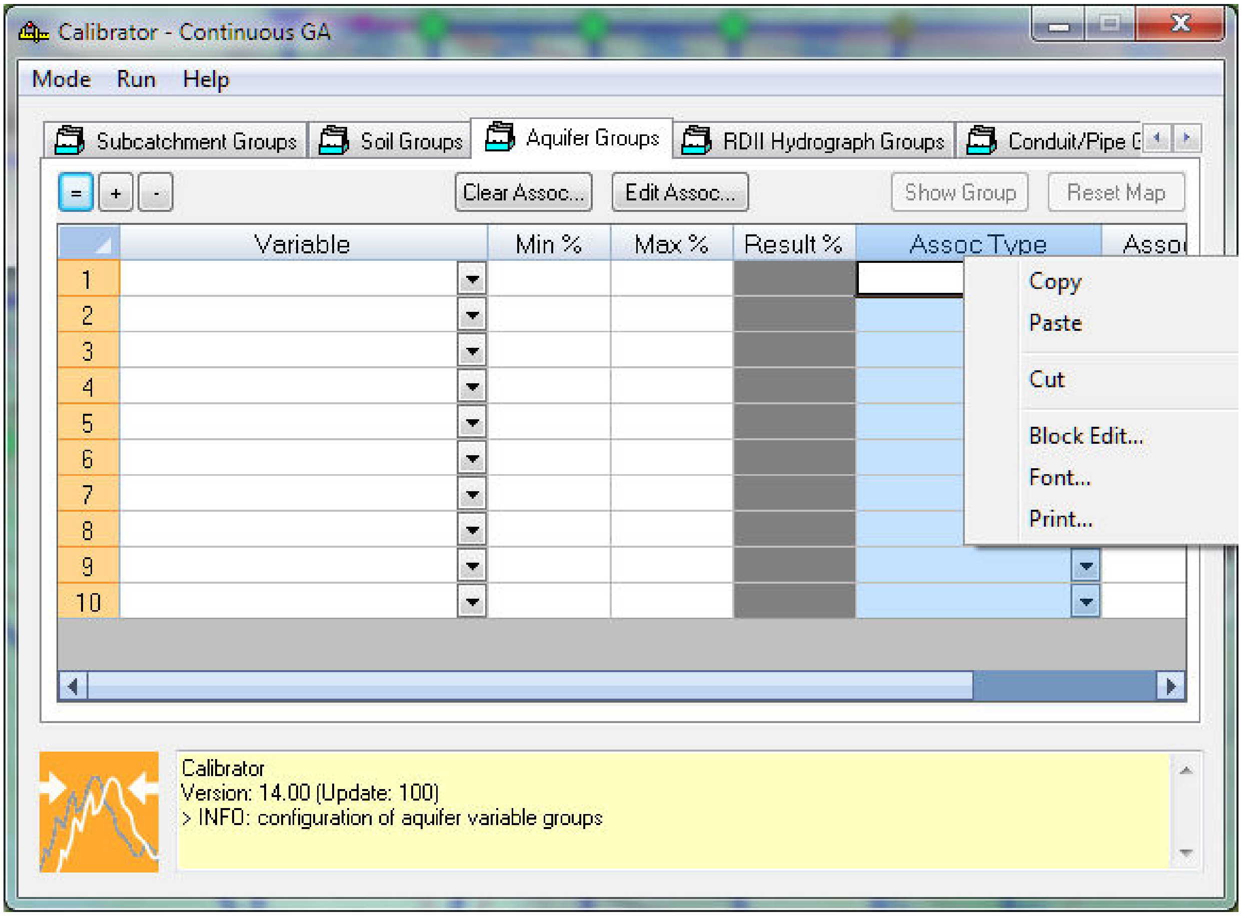

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See Also

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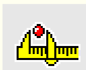
The Run Tab

The run tab is used to

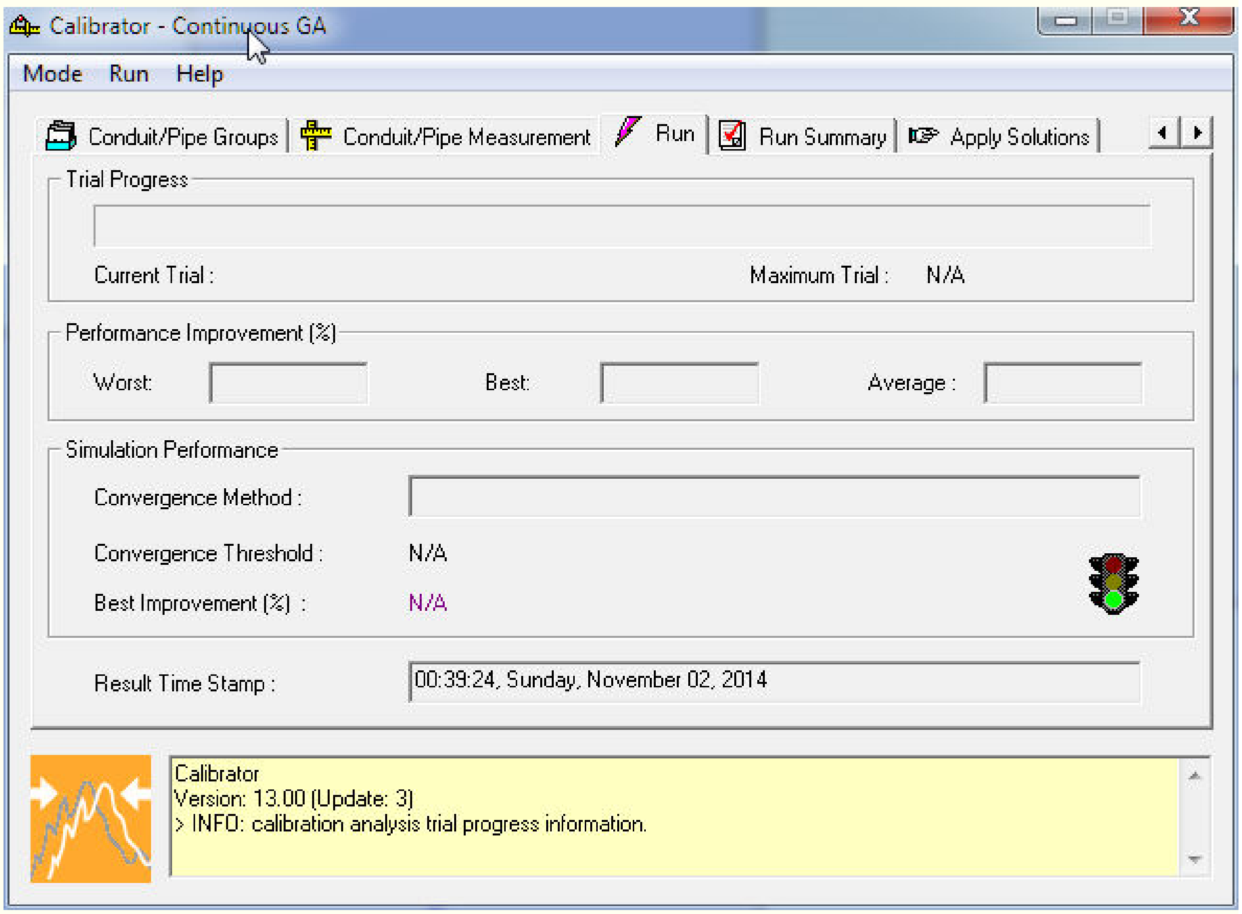
report calibration information while the InfoSWMM



Calibrator is running.

If the simulation run

was unsuccessful, a descriptive message will appear in the message area explaining what needs to be corrected in the input data.



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Objective Functions

The objective of the optimal calibration problem is to minimize the numerical discrepancy between the observed and predicted values of link flow, link depth, and/or link velocity at various locations in the system. Any of the following nine different mathematical objective functions can be used in InfoSWMM Calibrator.

Root Mean Square Error (RMSE)

$$\text{Minimize} \quad \sqrt{\frac{\left(\sum_{i=1}^{N}(Pobs_i - Psim_i)^2\right)}{N}}$$

In the ideal condition when corresponding observed and simulated values exactly match, value of RMSE will be zero.

Simple Least Square Error (SLSE)

$$\text{Minimize} \quad \sum_{i=1}^{N}(Pobs_i - Psim_i)^2$$

This performance evaluation function could assume values ranging from zero (best fit) to ∞ (poor fit), and it tends to favor large errors and large (i.e., peak) flows.

Mean Simple Least Square Error (MSLSE)

$$\text{Minimize} \quad \frac{\sum_{i=1}^{N}(Pobs_i - Psim_i)^2}{N}$$

This performance evaluation function could assume values ranging from zero (best fit) to ∞ (poor fit), and it tends to favor large errors and large (i.e., peak) flows.

Difference in Total Volume

$$Minimize \quad \left(\sum_{i=1}^{N} Pobs_i - \sum_{i=1}^{N} Psim_i \right)$$

Difference in total volume could range from -∞ (poor performance) to ∞ (poor performance), the ideal value being zero (i.e., exact match between total simulated volume and total observed volume).

Nash-Sutcliffe Efficiency Criterion

$$Maximize \quad \left(1 - \frac{\sum_{i=1}^{N} (Pobs_i - Psim_i)^2}{\sum_{i=1}^{N} (Pobs_i - \overline{P}obs)^2} \right)$$

This efficiency criterion could assume values from -∞ (poor performance) to 1 (perfect model).

R-Square (R2)

$$Maximize \quad \left(\frac{\sum_{i=1}^{N} (Pobs_i - \overline{P}obs)(Psim_i - \overline{P}sim)}{\left[\sum_{i=1}^{N} (Pobs_i - \overline{P}obs)^2 \right]^{0.5} \left[\sum_{i=1}^{N} (Psim_i - \overline{P}sim)^2 \right]^{0.5}} \right)^2$$

R2 value varies from zero (indicates worst fit) to unity (indicates perfect fit).

Modified Coefficient of Efficiency

$$Maximize \quad \left(1 - \frac{\sum_{i=1}^{N} \left|Pobs_i - Psim_i\right|}{\sum_{i=1}^{N} \left|Pobs_i - \overline{P}obs\right|}\right)$$

The modified coefficient of efficiency could assume values from -∞ (poor performance) to 1 (perfect model).

Dimensionless Root Mean Square Error (DRMSE)

$$Minimize \quad \frac{\sqrt{\dfrac{\left(\sum_{i=1}^{N} (Pobs_i - Psim_i)^2\right)}{N}}}{\overline{P}obs}$$

In the ideal condition when corresponding observed and simulated values exactly match, value of DRMSE will be zero.

Dimensionless Simple Least Square Error (DSLSE)

$$Minimize \quad \sum_{i=1}^{N} \left(\frac{Pobs_i - Psim_i}{Pobs_i}\right)^2$$

where N designates the total number of measurements available, Pobsi represents the observed measurement values at time i; Psimi is the model simulated values at time i; is mean of the measured values; is mean of the simulated values.

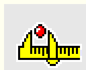
This performance evaluation function could assume values ranging from zero (best fit) to ∞ (poor fit), and it tends to be independent of length of records and it favor large errors and large (i.e., peak) flows.

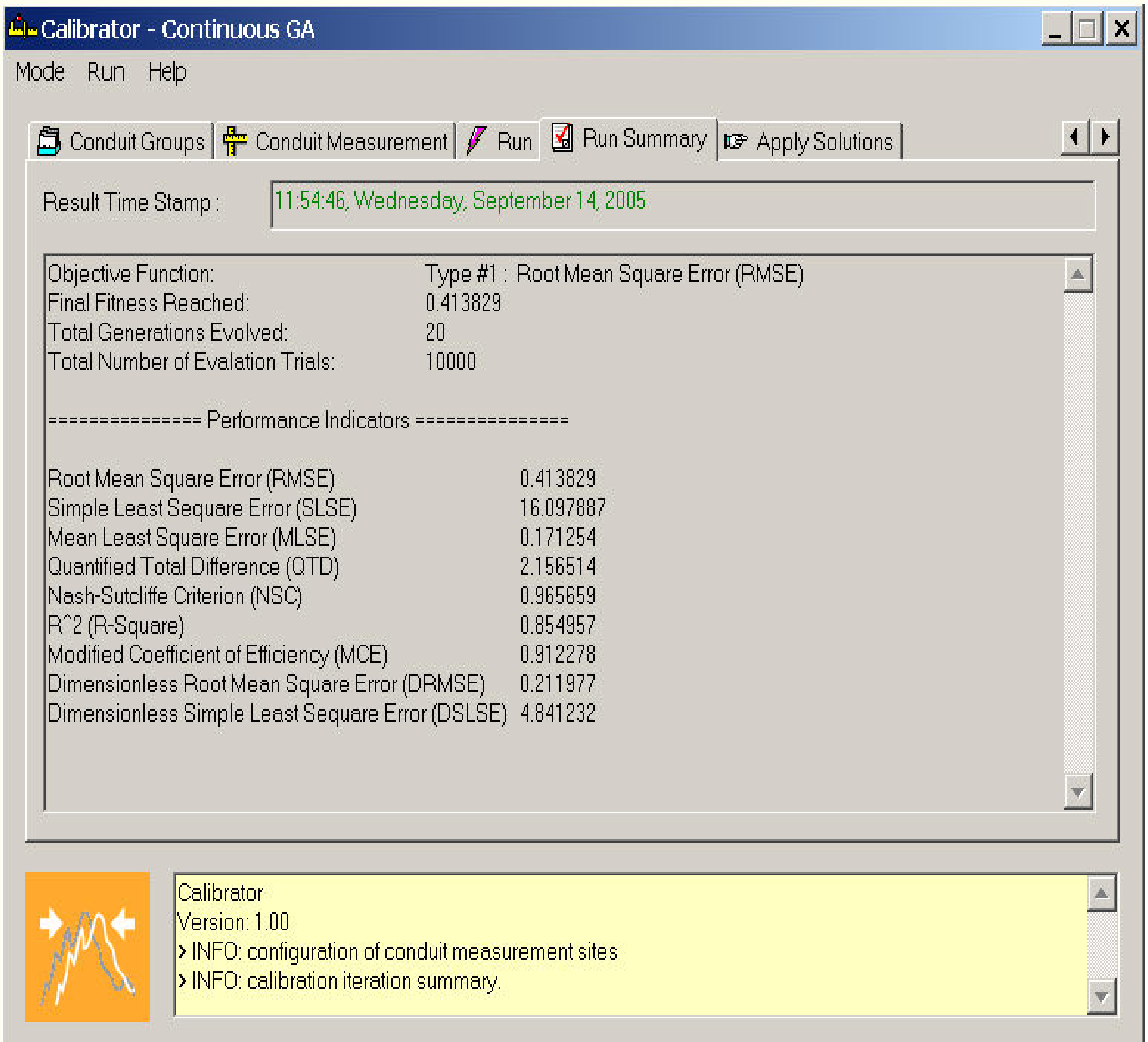
It is believed that complete assessment of model performance should include at least one relative error measure (e.g., modified coefficient of efficiency) and at least one absolute error measure (e.g., root mean square error) with additional supporting information (e.g., a comparison between the observed and simulated mean and standard deviation).

The number of field measurements defining the objective function must be greater than or equal to the number of calibration variables. It is expected that the accuracy of the model calibration would be increased by the use of a large number of field measurements. The decision variables could be any one or more of about fifty InfoSWMM parameters. These decision variables are automatically adjusted to minimize the objective function selected while satisfying a set of implicit and explicit constraints.

Run Summary

Then

InfoSWMM  Calibrator creates an ASCII calibration summary report detailing the results of the last calibration run



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Apply Solutions

Upon completion of a calibration

run, the Apply Solutions tab dialog box provides the ability to apply the optimal parameter values obtained by the calibrator to the elements and objects of any model scenario.

Because calibrator solutions

are stored as the percentages of the original values and not the actual values, multiple applications of results could lead to unwanted parameters.

Please note the following when applying solutions to datasets:

- For each calibration run,

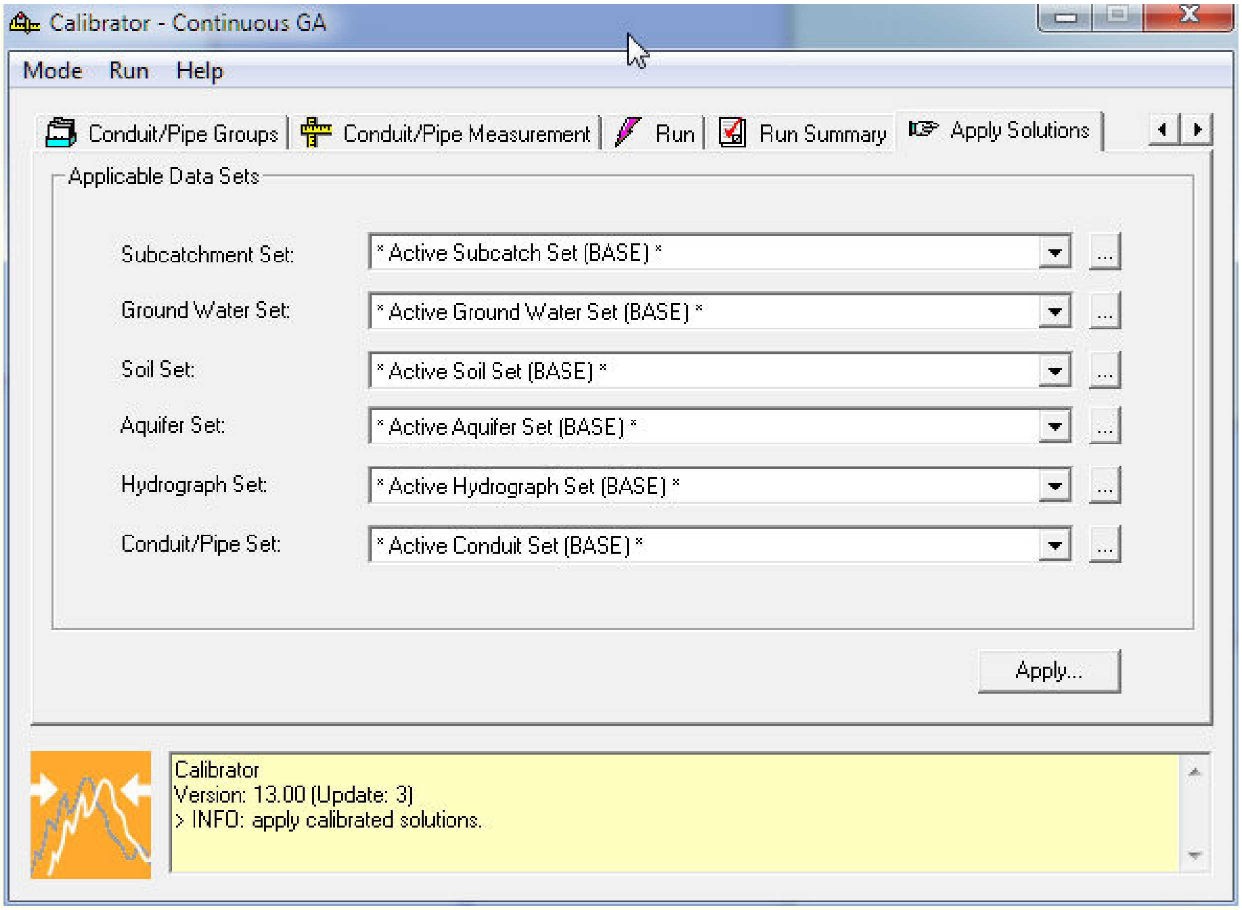
  solutions can be applied toward the active data set ONCE. The second application will do nothing.

- The solutions can be applied

  to non-active data sets as many times as the user desires until the solutions are applied to the active data set. Once the active data set is updated with the solutions, any further application toward a non-active data set will be disallowed.

- Before a non-active data

  set is about to be updated with the new solutions, it will be replicated from the active data set.



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Conduit Measurement

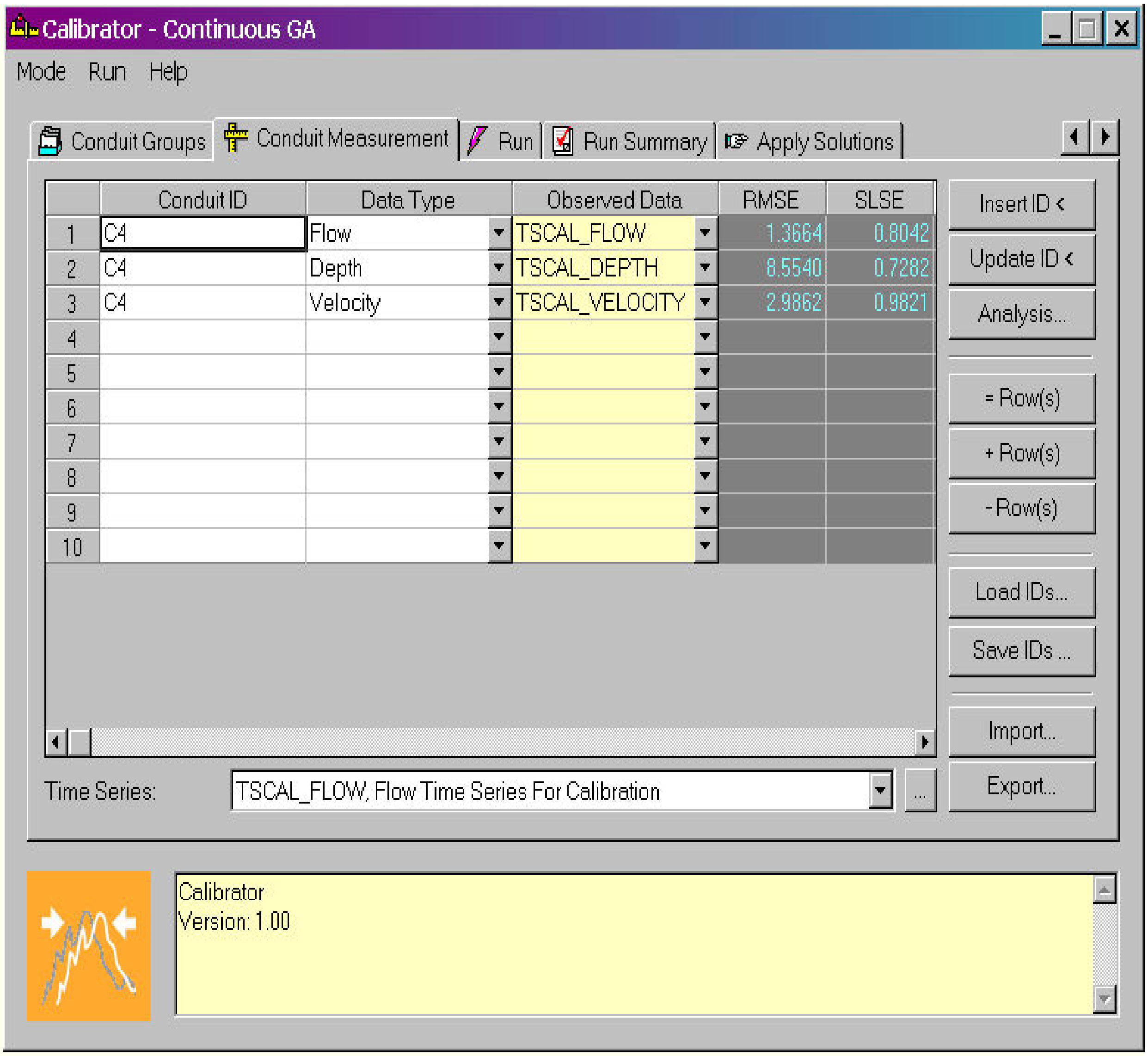
Specify observed data

or measurements or review the statistics of the calibration run. The measurements could be flow, depth, and/or velocity taken at one or more conduits. InfoSWMM

calibrator accepts time series measurement information.

Once the calibration is

executed, the conduit measurement dialog editor displays values of the goodness-of-fit evaluation criteria including root mean square error (RMSE), Nash-Sutcliffe efficiency criterion, modified coefficient of efficiency, R-square, and deviation in total volume of the measured and the simulated values.



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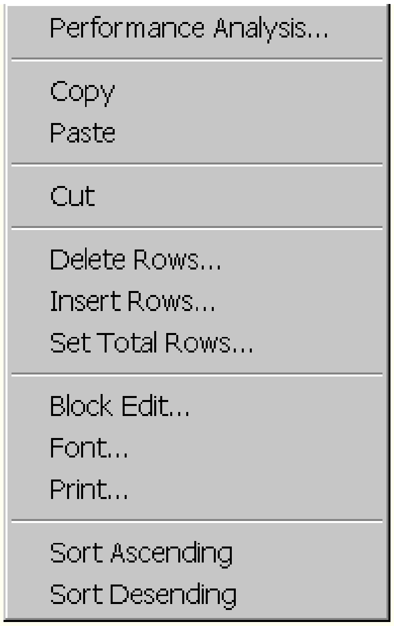

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See Also

Run

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Calibration Methodology

The successful application of a sewer collection system model to the planning, design, and management of urban Stormwater systems is highly dependent upon how well the model is calibrated and how well the model mimics the reality. Model calibration consists of fine tuning of model parameters until the model simulates field conditions to an established degree of accuracy. Fine-tuning of the model entails making adjustments to the model parameters to obtain the desired output data. The degree of accuracy refers to the difference between simulated and actual values and is used to establish a level of confidence in the model. It is normally expressed as a percent difference (typically 10 percent) between model predictions and actual measurements. Calibration is important to establish model credibility, create a benchmark, produce a predictive tool, increase knowledge and understanding of the system and its operations, and to discover errors or unknown conditions in the field.

Periodic re-calibration of models is also necessary not only when major new facilities are added to the system or when system operations change, but also to learn more about the system so that informed decisions can be effectively made to improve system operations and performance.

InfoSWMM Calibrator provides a fully automated approach to

accurate and efficient stormwater management model calibration. The program makes use of a variation of the genetic algorithm optimization technology enriched with global search control strategies and closely coupled with InfoSWMM for maximum efficiency, performance and reliability.

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Calibration Formulation

When calibrating a Stormwater management model, the goal is to determine the best set of nfoSWMM model parameters which produces the lowest overall deviation between the numerically simulated model results and the observed field data at user specified locations in the system. Observed field data can include link flow, link depth, and link velocity measurements. These measurements could be taken at one or more links in the system.

Grouping is very useful in the calibration process. nfoSWMM calibrator has five group types: Subcatchment group, soil group, aquifer group, RDII group, and conduit group. Grouping has to be made accounting for similarity in the characteristics of the elements. For example, if the modeler is interested in calibrating subcatchment width s/he may need to group subcatchments depending on their similarity in shape/size so that subcatchments in the group may use the same multiplying factor during the calibration. To calibrate Manning's roughness parameter for conduits, one may need to group conduits together depending on similarity in their characteristics such as material, date of installation, location, and diameter. It is assumed that all elements within a group will have an identical multiplying factor for the parameter being calibrated. The multiplying factor would be multiplied by the original parameter value assigned to each of the individual elements to determine actual value of parameter to be used during the calibration process.

nfoSWMM Calibrator casts the calibration problem as an implicit nonlinear optimization problem, subject to explicit inequality and equality constraints. It computes optimal model parameters within user-specified bounds, such that the deviation between the model predictions and field measurements is minimized. The optimal model calibration problem is thus governed by an objective function and its associated set of constraints.

1.1 OBJECTIVE FUNCTIONS

The objective of the optimal calibration problem is to minimize the numerical discrepancy between the observed and predicted values of link flow, link depth, and/or link velocity at various locations in the system. Any of the following nine different mathematical objective functions can be used in InfoSWMM Calibrator.

Root Mean Square Error (RMSE)

$$Minimize \quad \sqrt{\frac{\left(\sum_{i=1}^{N}(Pobs_i - Psim_i)^2\right)}{N}}$$

In the ideal condition when corresponding observed and simulated values exactly match, value of RMSE will be zero.

Simple Least Square Error (SLSE)

$$Minimize \quad \sum_{i=1}^{N}(Pobs_i - Psim_i)^2$$

This performance evaluation function could assume values ranging from zero (best fit) to ∞ (poor fit), and it tends to favor large errors and large (i.e., peak) flows.

Mean Simple Least Square Error (MSLSE)

$$Minimize \quad \frac{\sum_{i=1}^{N}(Pobs_i - Psim_i)^2}{N}$$

This performance evaluation function could assume values ranging from zero (best fit) to ∞ (poor fit), and it tends to favor large errors and large (i.e., peak) flows.

Difference in Total Volume

$$Minimize \quad \left(\sum_{i=1}^{N} Pobs_i - \sum_{i=1}^{N} Psim_i \right)$$

Difference in total volume could range from -∞ (poor performance) to ∞ (poor performance), the ideal value being zero (i.e., exact match between total simulated volume and total observed volume).

Nash-Sutcliffe Efficiency Criterion

$$Maximize \quad \left(1 - \frac{\sum_{i=1}^{N} (Pobs_i - Psim_i)^2}{\sum_{i=1}^{N} (Pobs_i - \overline{P}obs)^2} \right)$$

This efficiency criterion could assume values from -∞ (poor performance) to 1 (perfect model).

R-Square (R2)

$$Maximize \quad \left(\frac{\sum_{i=1}^{N} (Pobs_i - \overline{P}obs)(Psim_i - \overline{P}sim)}{\left[\sum_{i=1}^{N} (Pobs_i - \overline{P}obs)^2 \right]^{0.5} \left[\sum_{i=1}^{N} (Psim_i - \overline{P}sim)^2 \right]^{0.5}} \right)^2$$

R2 value varies from zero (indicates worst fit) to unity (indicates perfect fit).

Modified Coefficient of Efficiency

$$Maximize \quad \left(1-\frac{\sum_{i=1}^{N}\left|Pobs_i - Psim_i\right|}{\sum_{i=1}^{N}\left|Pobs_i - \overline{P}obs\right|}\right)$$

The modified coefficient of efficiency could assume values from -∞ (poor performance) to 1 (perfect model).

Dimensionless Root Mean Square Error (DRMSE)

$$Minimize \quad \frac{\sqrt{\dfrac{\left(\sum_{i=1}^{N}(Pobs_i - Psim_i)^2\right)}{N}}}{\overline{P}obs}$$

In the ideal condition when corresponding observed and simulated values exactly match, value of DRMSE will be zero.

Dimensionless Simple Least Square Error (DSLSE)

$$Minimize \quad \sum_{i=1}^{N}\left(\frac{Pobs_i - Psim_i}{Pobs_i}\right)^2$$

where N designates the total number of measurements available, Pobsi represents the observed measurement values at time i; Psimi is the model simulated values at time i; is mean of the measured values; is mean of the simulated values.

This performance evaluation function could assume values ranging from zero (best fit) to ∞ (poor fit), and it tends to be independent of length of records and it favor large errors and large (i.e., peak) flows.

It is believed that complete assessment of model performance should include at least one relative error measure (e.g., modified coefficient of efficiency) and at least one absolute error measure (e.g., root mean square error) with additional supporting information (e.g., a comparison between the observed and simulated mean and standard deviation).

The number of field measurements defining the objective function must be greater than or equal to the number of calibration variables. It is expected that the accuracy of the model calibration would be increased by the use of a large number of field measurements. The decision variables could be any one or more of about fifty nfoSWMM parameters. These decision variables are automatically adjusted to minimize the objective function selected while satisfying a set of implicit and explicit constraints.

1.2 IMPLICIT SYSTEM CONSTRAINTS

The implicit constraints on the system correspond to equations that govern/simulate the underlying hydrologic, hydraulic and water quality processes including conservation of mass and conservation of momentum at various scales such as node, and/or link, and/or the entire system. Each function call to nfoSWMM with a set of decision variables returns the simulated values for link flow, link depth, and link velocity that will be compared with corresponding measured data.

1.3 EXPLICIT CONSTRAINTS

The explicit bound constraints are used to set minimum (lower) and maximum (upper) limits on the calibrated nfoSWMM parameters. For example, for each conduit group G (where a single conduit may constitute a group) Manning's roughness coefficient for a conduit in the group may be bound by an explicit inequality constraint as follows:

$$k_{\min} \times n_i \leq n_i \leq k_{\max} \times n_i \qquad \forall G$$

where kmin designates the lower bound multiplier (minimum value of a multiplier) for roughness coefficient of conduits in conduit group G; kmax represents the upper bound multiplier (maximum value of a multiplier) for roughness coefficient of conduits in conduit group G; and n is roughness coefficient value for conduit i in group G. Please note that each of the conduits in group G could take different values of n. The only value that is same for all conduits in the group is the multiplier k.

It should be noted that the choice of grouping may greatly affect the calculated parameter values as well as the convergence accuracy. It is also expected that the final calculated parameters, will be close to the actual values (i.e., optimal/near optimal values) although they may not be "exact" or absolute optima.

Genetic Algorithms

Genetic algorithms (GA) are an adaptation procedure based on the mechanics of natural genetics and natural selection1. They are designed to perform search procedures of an artificial system by emulating the evolution process (Darwin's evolution principle) observed in nature and biological organisms.

The evolution process is based on the preferential survival and reproduction of the fittest member of a population with direct inheritance of genetic information from parents to offspring and the occasional mutation of genes.

The principal advantages of genetic algorithms are their ability to converge expeditiously on an optimal or near-optimal solution without having to analyze all possible solutions available and without requiring derivatives or other auxiliary knowledge.

2.1 OVERVIEW OF GENETIC ALGORITHMS

Genetic algorithms are fundamentally different from traditional optimization methods in terms of the search process. While traditional routines track only a single pathway to the optimal solution, genetic algorithms search from an entire population of possible solutions (individuals). In addition, genetic algorithms use randomized and localized operators as opposed to deterministic rules. Each individual in the population is represented by either a string or a set of real numbers encoding one possible solution.

The performance of each individual in the population is measured by its fitness (goodness), which quantifies the degree of optimality of the solution.

Based on their fitness values, individuals are selected for reproduction of the next generation. Each new generation maintains its original size.

The selected individuals reproduce their offspring by mimicking gene operations of crossover and mutation. After a number of generations, the population is expected to evolve artificially, and the optimal or near optimal solution is ultimately reached.

2.2 COMPONENTS OF GENETIC ALGORITHMS

Standard genetic algorithms involve three basic functions: selection, crossover, and mutation. Each function is briefly described below.

Selection – Individuals in a population are selected for reproduction according to their fitness values. In biology, fitness is the number of offspring that survive to reproduction. Given a population consisting of individuals identified by their chromosomes, selecting two chromosomes to represent parents to reproduce offspring is guided by a probability rule that the higher the fitness an individual has, the more likely the individual will survive. There are many selection methods available including weighted roulette wheel, sorting schemes, proportionate reproduction, and tournament selection.

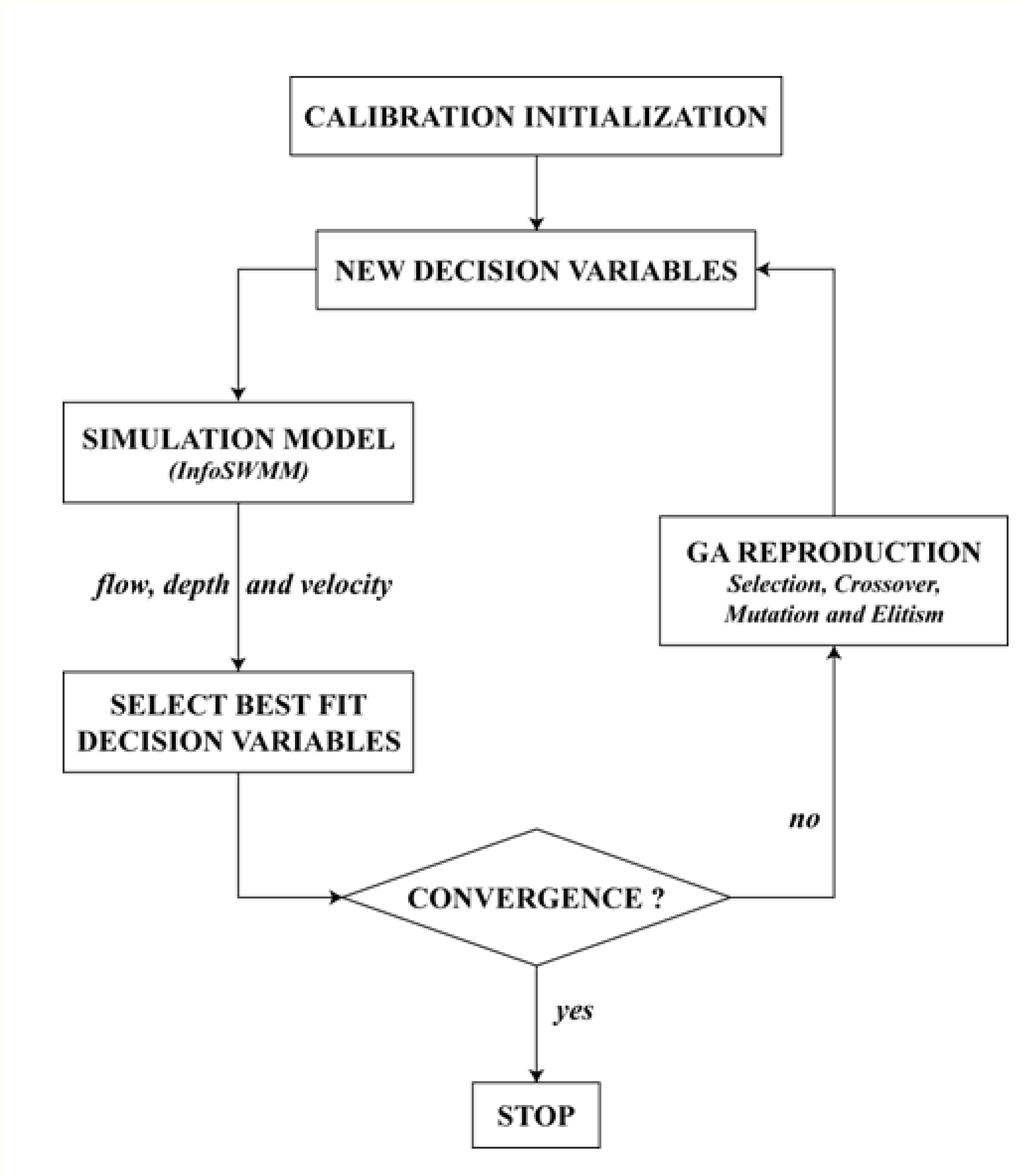
Crossover - Selected parents reproduce the offspring by performing a crossover operation on the chromosomes (cut and splice pieces of one parent to those of another). In nature, crossover implies two parents exchange parts of their corresponding chromosomes. In genetic algorithms, a crossover operation makes two strings swap their partial strings. Since more fit individuals have a higher probability of producing offspring than less fit ones, the new population will possess, on average, an improved fitness level. The basic crossover is a one-point crossover. Two selected strings create two offspring strings by swapping the partial strings, which is cut by one randomly sampled breakpoint along the chromosome. The one-point crossover can easily be extended to k-point crossover. It randomly samples k breakpoints on chromosomes and then exchanges every second corresponding segments of two parent strings.

Mutation - Mutation is an insurance policy against lost genes. It works on the level of string genes by randomly altering gene value. With small probability, it randomly selects one gene on a chromosome then replaces the gene by a randomly selected value. The operation is designed to prevent GA from premature termination namely converging to a solution too early.

Elitism - The selection and crossover operators will tend to ensure that the best genetic material and the components of the fittest chromosomes will be carried forward to the next generation. However, the probabilistic nature of these operators implies that this will not always be the case.

An elitist strategy is therefore required to ensure that the best genetic material will not be lost by chance. This is accomplished by always carrying forward the best chromosome from one generation to the next.

The flowchart below illustrates the optimal calibration process.



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Expanded Graphing Help

The following functions are available for customizing the graph display in the Calibrator. If you do not see one or more of the following buttons while a graph is being displayed, that function is not available for the currently displayed graph type. All functions may not be available for all graph types.

 Pan - After zooming in on a portion of the graph, use the Pan feature to shift the graph left and right and up and down.

 Zoom In - Drag and drop the outline around a portion of the graph to zoom in.

 Zoom Out - Click on the graph to zoom out by a fixed amount.

 Horizontal Lock - Locks the graph horizontally so that the pan function will only allow movement in the left and right direction.

 Vertical Lock - Locks the Vertically so that the pan function will only allow movement in the up and down direction.

 Previous Extents - Returns the graph view to the previous extent.

Next Extents - Returns the graph view to the next extent after the previous extent has been used.

Full Extent - Returns the graph view to the full extent.

Auto Pan Left - Automatically pans the zoomed view left. Press Stop Auto Pan to stop.

Auto Pan Right - Automatically pans the zoomed view right. Press Stop Auto Pan to stop.

Auto Pan Stop - Stops the Auto Pan Right or Left.

Copy - Copy Graph - Copies

the current graph image to the Clipboard. The contents of the clipboard can be pasted into other applications such as MS Word or Excel.

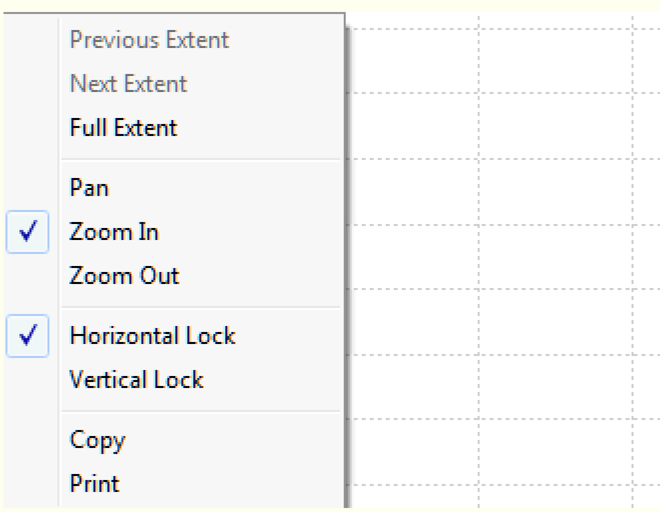
Print - Prints the current graph. You may indicate print margins, whether or not the graphs will be printed in color, and whether or not a border will be included on the graph printout. Click here to learn more.

Properties - Allows the user to adjust the Graph Style and Axis properties of the current graph. See Graph Properties below for details.

Help -

Opens the graph help or Press F1

A Right Mouse Click - Opens up the same set of menu commands.



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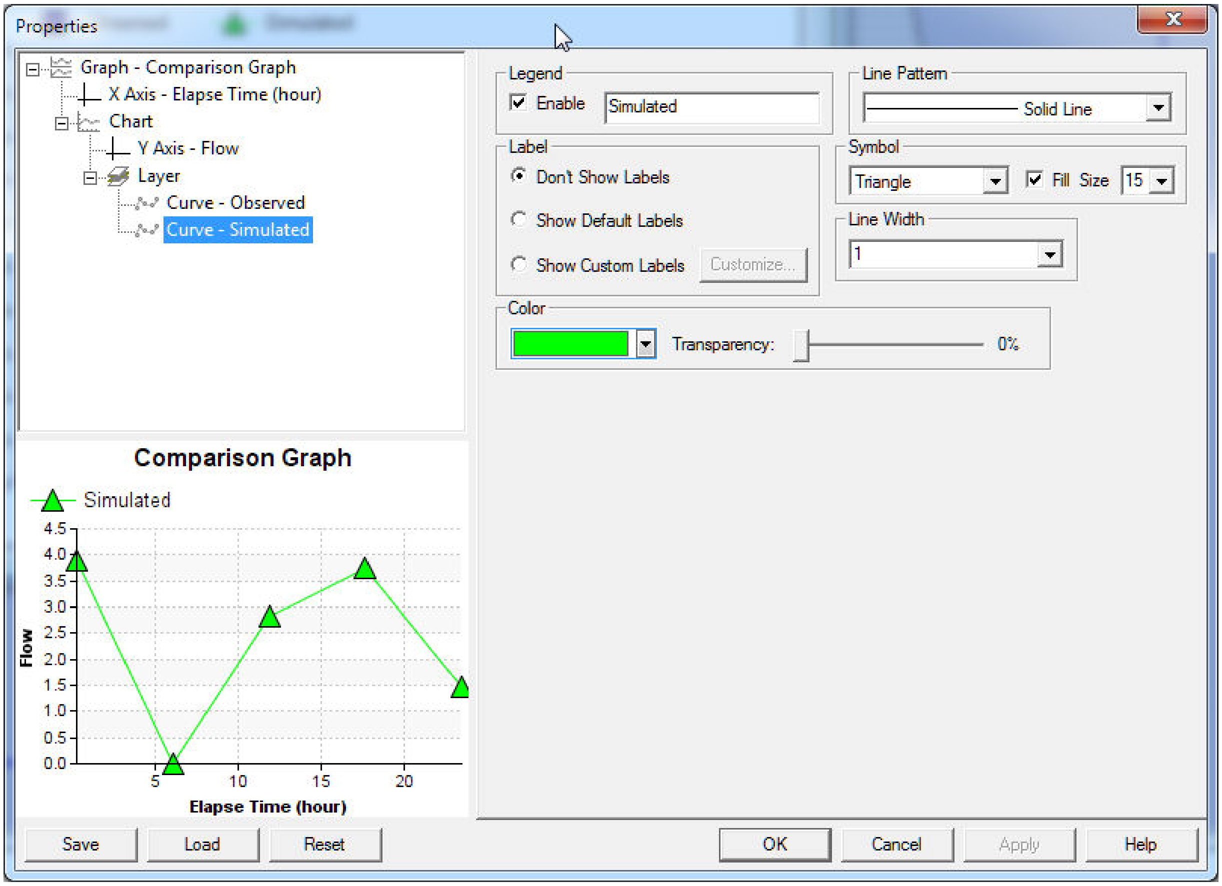
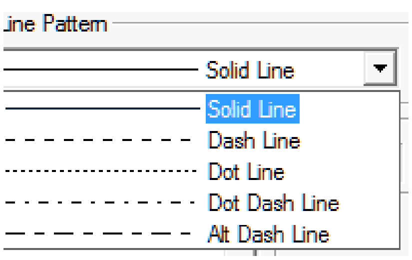
Graphing Properties

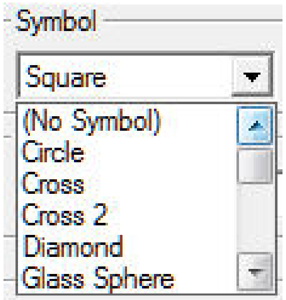
The Graph Property Dialog



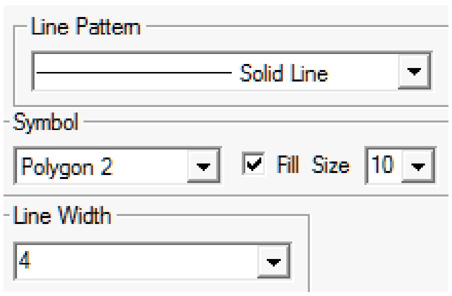
Layer Curve Line Pattern allows you to choose a different line pattern for the data curves.



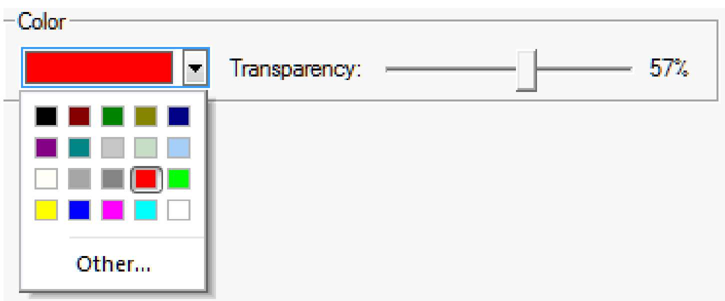
Layer Curve Symbols allows you to choose a different symbol for the data curves.



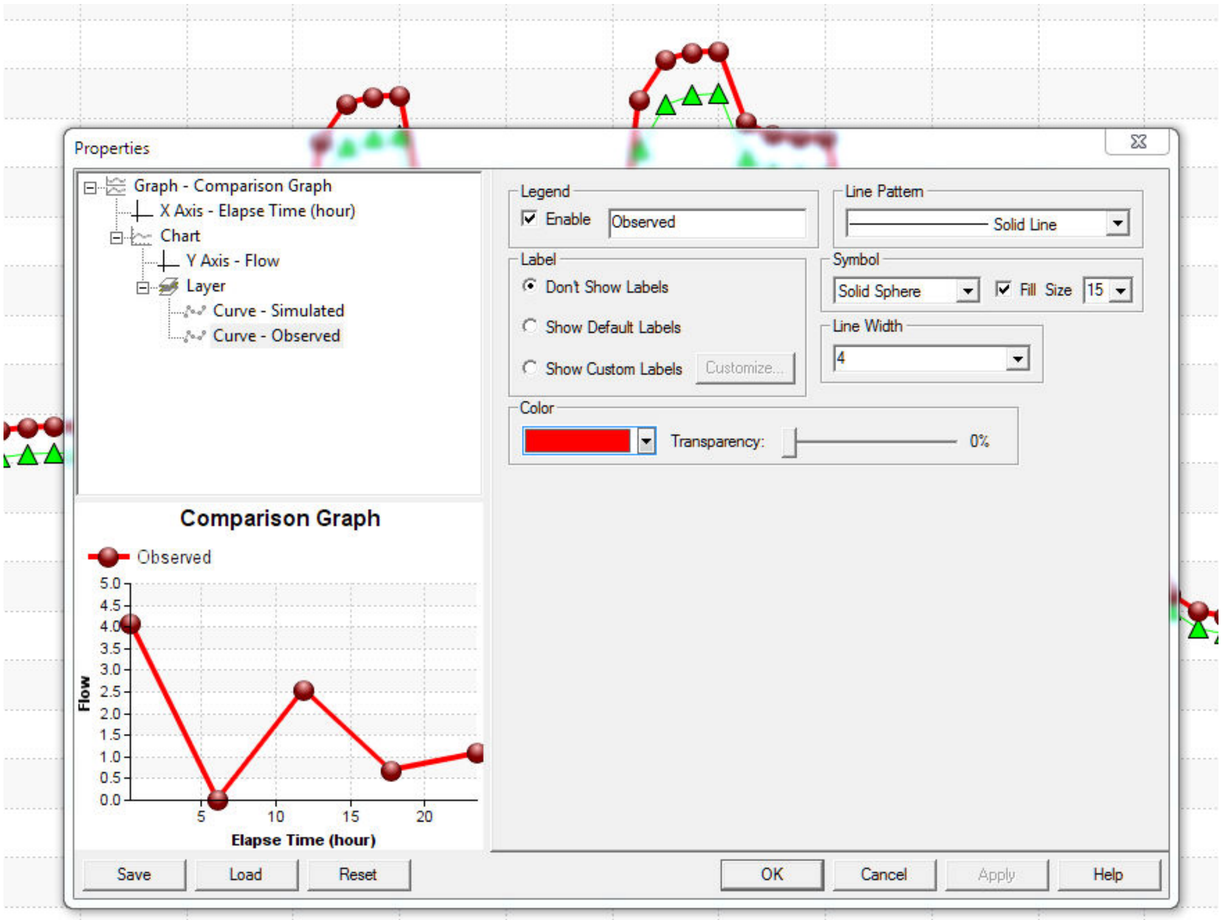
Other options are Fill Size and Line Width



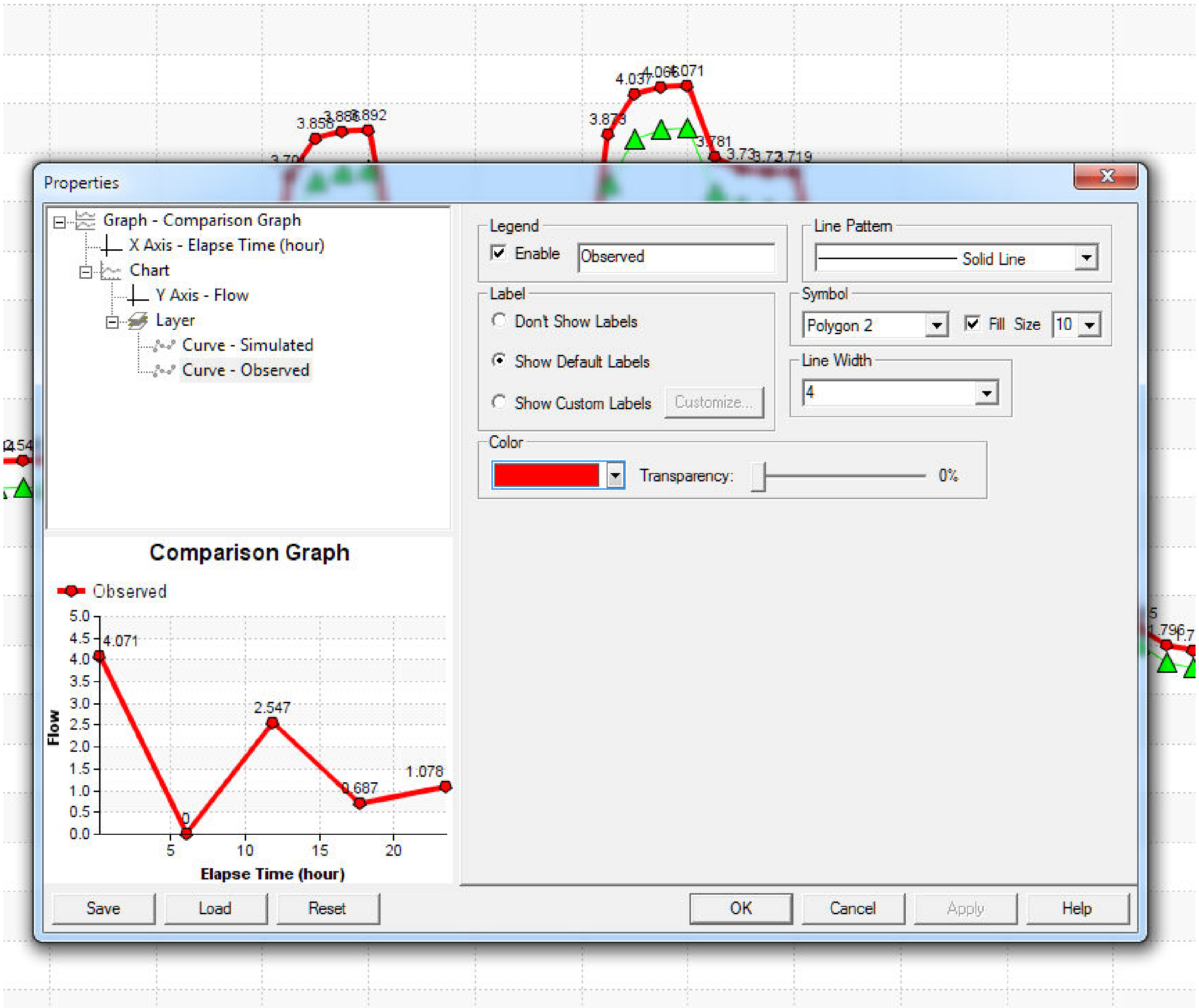
Color and Transparency apply to both the symbols and lines/bars/area.



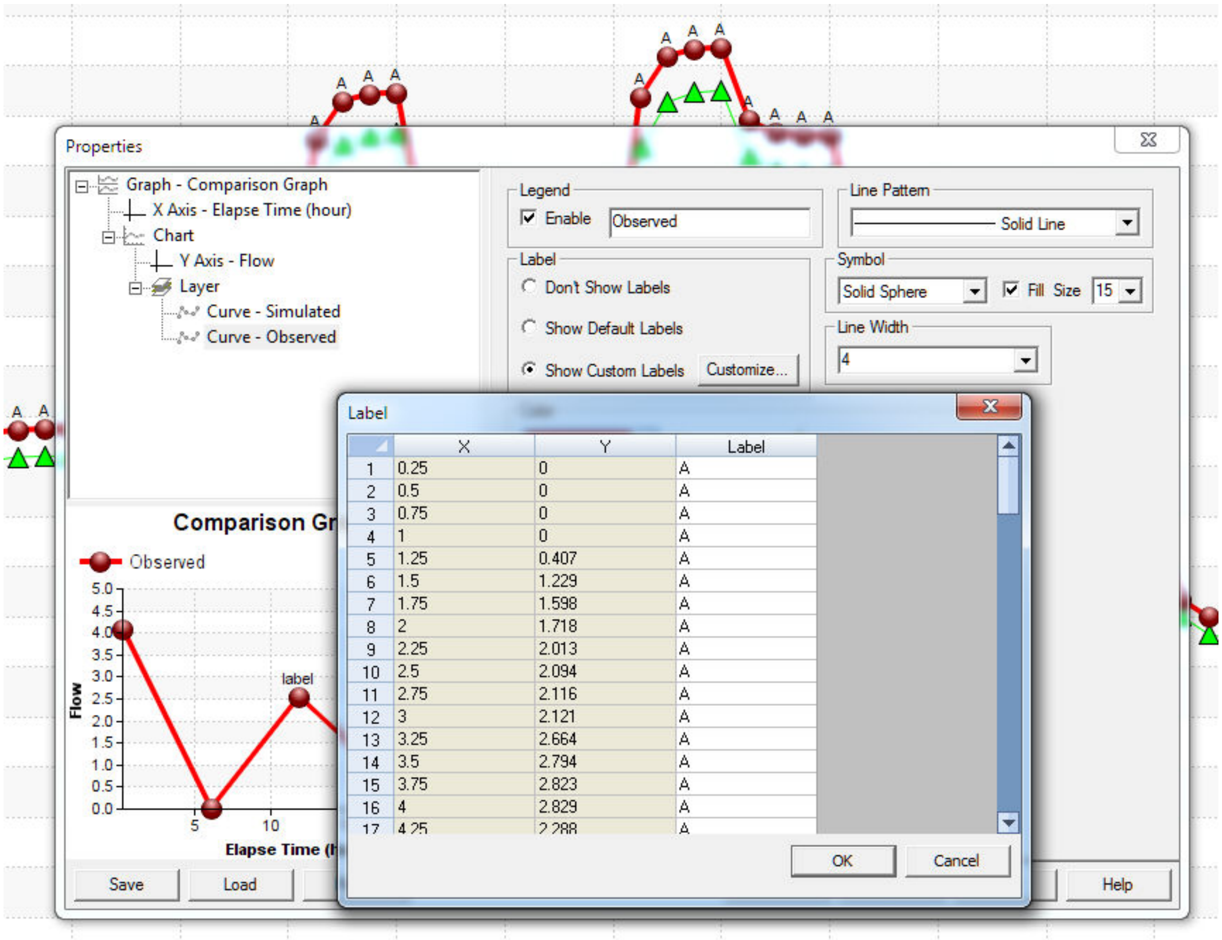
Don't Show the Default Labels



Show the Default Labels

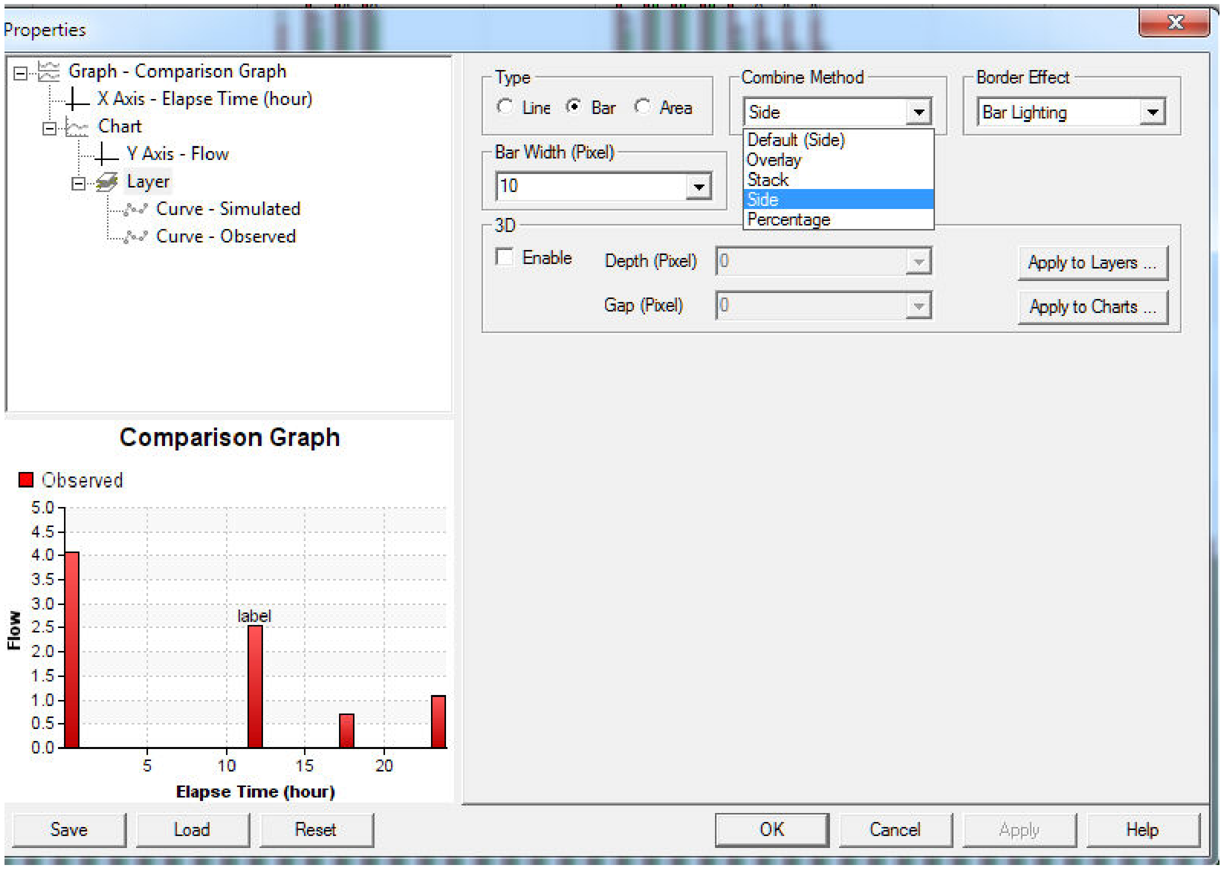


Show the User Defined Labels

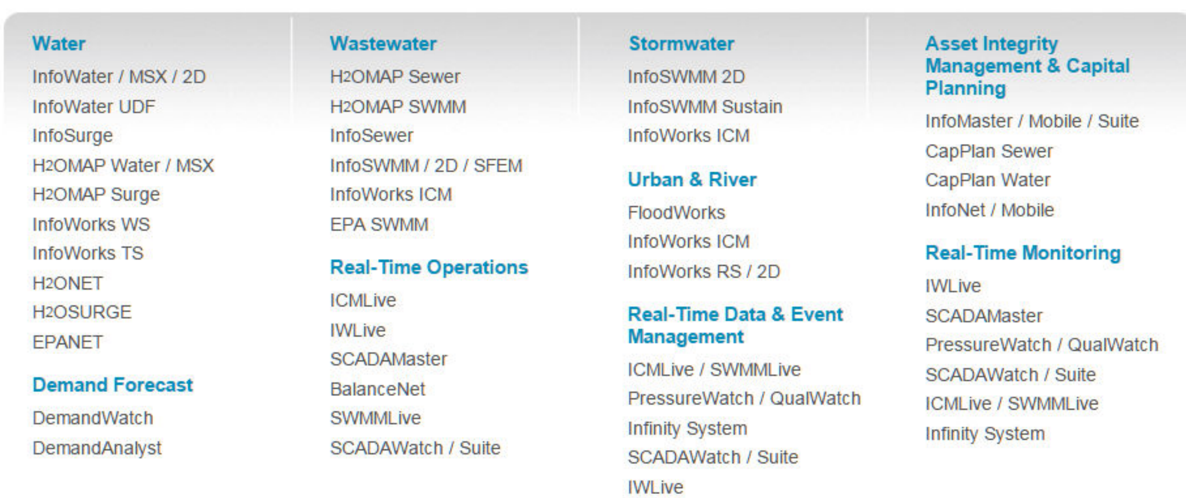


	X	Y	Label
1	0.25	0	A
2	0.5	0	A
3	0.75	0	A
4	1	0	A
5	1.25	0.407	A
6	1.5	1.229	A
7	1.75	1.598	A
8	2	1.718	A
9	2.25	2.013	A
10	2.5	2.094	A
11	2.75	2.116	A
12	3	2.121	A
13	3.25	2.664	A
14	3.5	2.794	A
15	3.75	2.823	A
16	4	2.829	A
17	4.25	2.288	A

You can define the Combine Method as well as the Border Effects and change the graphs to Line, Bars and Areas



The options for Bar Combine Effects include:



and for the border effects

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Innovyze Calibrator User Guide

Innovyze Contact Information

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Innovyze® Blog: http://blog.innovyze.com/

Innovyze® Forum: http://forums.innovyze.com/forum.php

Innovyze® Twitter: https://twitter.com/Innovyze

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Or write us at Innovyze® Inc., 605 East Huntington Drive. Monrovia, CA 91016.

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InfoSWMM

Introduction

Stormwater models are particularly useful decision support tools in that they enable us to investigate many practical and pressing issues that arise during planning, design, operation, and management of urban stormwater collection systems. These models are, however, simplifications of reality, and no matter how sophisticated they may be, they undergo some aspect of conceptualization or empiricism, and their results are only as realistic as model assumptions and algorithms, detail and quality of inputs, and parameter estimates. Einstein commented that models should be “as simple as possible and no simpler.” Therefore, it is imperative that a mechanism that improves accuracy of model predictions, based on observed field information, be implemented before using the models for their intended purposes. The common approach to accomplishing this useful task is to adjust sensitive model parameters so that the model results coincide with observed field conditions, a process commonly referred to as calibration.

Before any stormwater management model can be adequately used to analyze the performance of an existing sewer system, the model must first be calibrated. Calibration of stormwater models is not only an essential component of the initial model building process, it is also important to periodically re-calibrate a model to reflect the physical changes in both operations and facilities in the system so that model predictions can be interpreted with confidence.

The price for neglecting calibration is basing decisions on a model that may be seriously in error and thus, advising the implementation of ill-engineered capital improvement projects.

InfoSWMM

is a comprehensive and advanced hydrologic, hydraulic,

and water quality simulation model. The hydrologic simulation component of InfoSWMM performs rainfall-runoff computation through proper description of surface runoff generation and routing, infiltration processes and groundwater flow processes accounting for spatial and temporal heterogeneity of climate, soil, land use, and topographic conditions of the watershed.

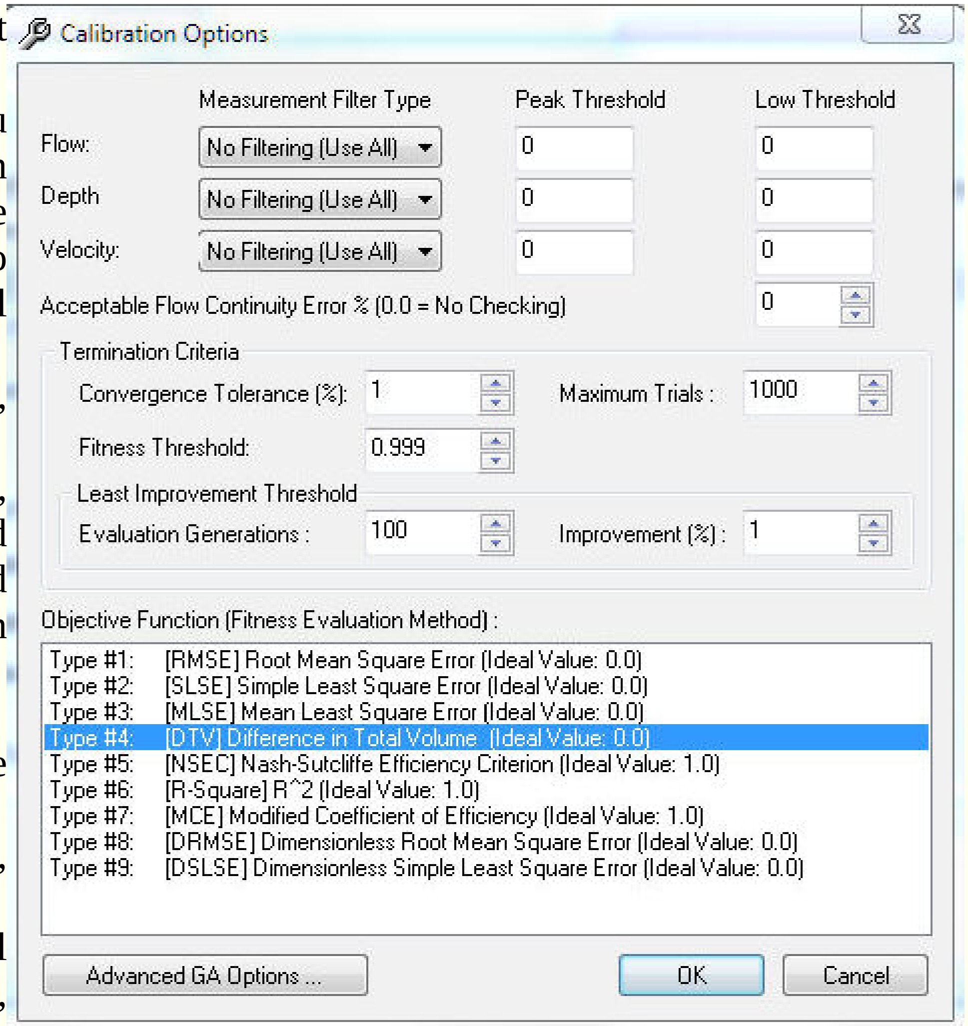
Modeling of these processes demands determination of proper values for large number of model parameters (e.g., subcatchment parameters, infiltration parameters, aquifer parameters, groundwater parameters, etc). Unfortunately, it is hardly possible to obtain values of these parameters from measurements alone due to lack of data at the desired degree of quality and quantity.

Therefore, calibration is the only viable solution to determine optimal values of these InfoSWMM parameters.

Manual calibration and automatic calibration are two types of parameter estimation approaches.

Manual calibration is by far the most widely used method for advanced models like InfoSWMM . Manual calibration, however, is time consuming and very subjective, and its success highly depends on budget availability and the experience of the modelers and their knowledge of the study watershed, along with model assumptions and its algorithms. Automatic calibration involves the use of optimization algorithm to determine best-fit parameters, and it offers a number of advantages over the manual approach. Automatic calibration is fast, it is less subjective, and since it makes an extensive search of the existing parameter combinations, it is highly likely that the computed results would be better than those obtained using the traditional manual approach. InfoSWMM Calibrator is a fully automated calibration module that uses highly advanced, reliable and robust optimization methods such as genetic algorithms.

InfoSWMM Calibrator sets a new standard in automated stormwater model calibration. It helps you build and validate the credibility and reliability of your urban stormwater collection system models. With point-and-click simplicity, you can command the latest advances in Genetic Algorithms and Global Search control strategies to optimally adjust subcatchment parameters, infiltration parameters, groundwater parameters, aquifer parameters, RDII hydrograph parameters, and conduit parameters and best reflect what is actually occurring in the system. The program minimizes the difference between observed field data (such as flow, velocity, and/or depth) and model predictions considering all test data simultaneously to provide the best calibration possible. You can even disaggregate the model into separate logical calibration groups (e.g., subcatchment, soil, aquifer, RDII, and conduit) based on the known physical characteristics of the associated elements (e.g., topographic condition, soil type, land use, conduit age,



conduit material type, etc.) and seamlessly interface with the InfoSWMM to evaluate their fitness under various simulation options and operating conditions and to maximize efficiency. All in a seamlessly integrated and extremely rich graphical presentation environment, making model calibration an enjoyable and friendly task.

Now you can consistently build and analyze more complete, accurate and reliable models than ever before and in record time. Without that credibility, the most complex and theoretically sound model that could be developed would not be effective in helping plan a sound system.

A well calibrated model will not only result in more accurate predictions but will also greatly assist you in operating and managing stormwater collection systems and in making sound and cost-effective engineering decisions for system design, rehabilitation, replacement, strengthening, and expansion.

We are happy to bring you the state-of-the-art in optimized stormwater calibration technology to provide the best possible calibration with a minimum effort to help you obtain better information on your sewer system and significantly improve and simplify your model representation process.

Colby T. Manwaring, P.E.

Chief Executive Officer, Innovyze Inc.

Portland, Oregon USA January 30, 2019

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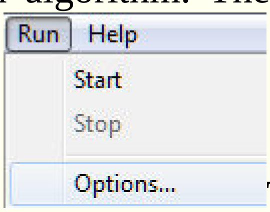
2.1 Menu Overview

nfoSWMM

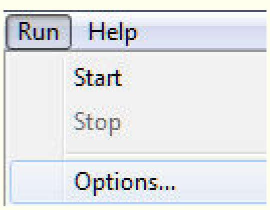
Calibrator

commands are logically organized into menu pillars (drop-down menus with multiple choices). The module has three menus: Mode, Run, and Help menu.

- **Mode Menu:** The mode command enables the user to select optimization method of her/his choice. At the moment only continuous (i.e., real-coded) Genetic Algorithms (GA) is supported. Additional optimization algorithms will be added in the near future.

- **Run Menu:** Contains commands that are used to launch calibration run, to stop a run before completion, and to specify parameters of the optimization algorithm. The following commands are available from the Run Menu: 

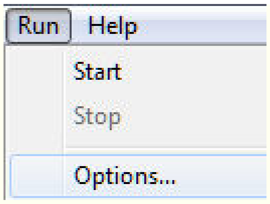
The "Start" command launches the calibration run.



The "Stop" command interrupts the calibration run. Please note that nfoSWMM

Calibrator can stop the optimization at any time

and yet enables you to review the results obtained up to the point of interruption.



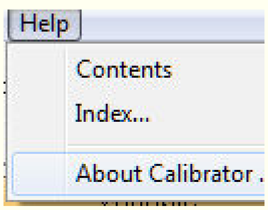
The “Options” command launches the *CALIBRATION OPTIONS* dialog box, which allows specifying optimization parameters and simulation options.

With this command the user specifies available measurement types and data filtering criteria, convergence criteria, advanced GA options, the objective function type (i.e., goodness-of-fit criterion), etc.

- **Help Menu:** Contains commands that are used to access nfoSWMM

Calibrator

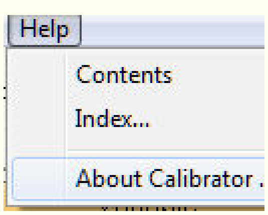
online help and its version information. InfoSWMM Calibrator Help is available from within nfoSWMM Calibrator. The following commands are available from the Help menu:



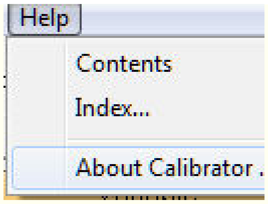
The “Contents” command opens contents page of the online help. You may also press the F1 key to see documentation on the command or tool you are currently using. For example, you can open the *CALIBRATION*

OPTIONS dialog box and while the dialog box is open, press the F1

key. The *CALIBRATION OPTIONS* command help topic appears on the screen. You may click on any portion of the dialog box in the help topic for more information.



The “Index” command lets you search for online help topics of your interest using keywords.



Launches the About InfoSWMM Calibrator dialog box which summarizes the version properties and some other information about your InfoSWMM

model.

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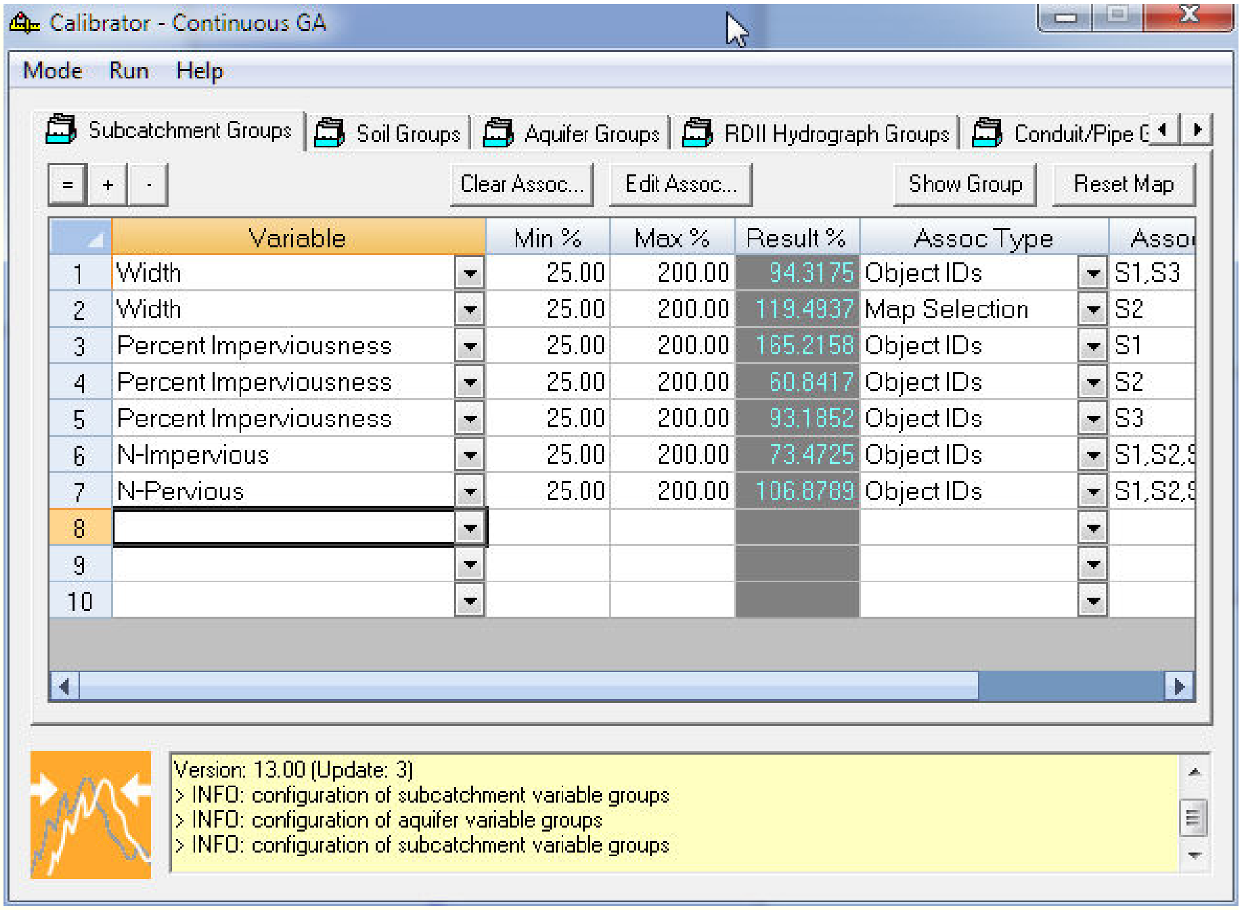
2.2 Calibration Groups

As mentioned above InfoSWMM

Calibrator has five general calibration groups:

Subcatchment group, Soil group, Aquifer group, RDII group, and Conduit group. One or more InfoSWMM parameters are associated with each of these calibration groups. Modelers can disaggregate their system into separate logical calibration groups (e.g., Subcatchment, soil, aquifer, RDII, and conduit) based on characteristics of the associated elements that affect the parameters being calibrated (e.g., topographic conditions, soil type, land use, conduit age, conduit material type, etc.) to handle spatial heterogeneity of the parameters with maximum flexibility. Working mechanism of the five calibration groups and the required input information is similar.

Therefore, these common features are described below before going into unique characteristics of the individual groups.



As illustrated

using the Subcatchment dialog box shown above each of the five calibration groups demand the following input information; provide the result column indicated below; and has the following buttons to enable the operations described below.

- **Variable** – Enables specification of the parameter(s) to be calibrated among the list of potential calibratable parameters for the group.

- **Min%**

and Max% – Refers to the minimum multiplier value and maximum multiplier value, respectively, that could be applied to the calibrated parameter.

During calibration process, InfoSWMM

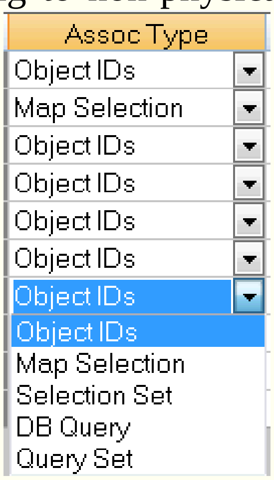
Calibrator identifies optimal value of multiplier within the Min% and Max% range provided for the parameter. These parameter uncertainty limits should be specified cautiously taking into account conditions specific to the collection system being modeled.

Result – Once the calibrator is run, optimal value (i.e., percent multiplier) determined for each calibrable parameter is provided in this column.

Assoc Type – This column lets you choose how to specify the InfoSWMM

physical/non-physical objects belonging to the

group being created. Content and application of this column varies with group type depending on whether the object type is physical (i.e., can be displayed on the map) or non-physical. For groups that refer to physical objects (i.e., subcatchment group and conduit group) the following options are available: *Map Selection*, *Object IDs*, *Selection Set*, *DB Query*, and *Query Set*. Only *Object IDs* option is available for the other three groups referring to non-physical objects (i.e., soil group, aquifer group, and RDII group)



- Ø Object

  IDs - if this option is selected, the element IDs has to be typed manually. The IDs should be comma separated.

- Ø Map Selection - lets you select the elements graphically.

- Ø Selection

  Set - lets you specify object IDs from existing selection set

- Ø DB Query

  - allows you specify the object based on existing DB Query

- Ø Query

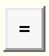
  Set - enables you specify the object IDs from existing Query Set

Assoc ID(s) – List of elements in the group is provided in this column.

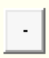
One the **Assoc Type** is selected, the modeler has to specify the Object IDs in this column.

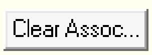
In

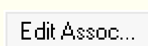
addition to the input information specification columns described above, the calibration group pages do have one or more of the following buttons that assist in simplifying usage of the above described group information specification columns.

- 

 - Allows you to set the number of groups (i.e., number of rows).
- 

 - Lets you add a row above the highlighted (i.e. currently active) row.
- 

 - Deletes the highlighted row.
- 

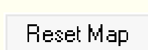
 - Clears list of IDs provided in the **Assoc ID(s)** column.
- 

 -

  Enables you to edit (i.e., specify, change, add or delete) one otr more object IDs in the **Assoc ID(s)** column.
- 

 -

  This button is active only for subcatchment group and conduit group.

  It graphically displays element in the group.
- 

 -

  This button is active only for subcatchment group and conduit group.

  It resets the graphic display back to its original form. Once the *Show Group* feature is used to display elements that belong to a group, if the user wants to graphically display elements belonging to another group, s/he must use the *Reset Map* feature to undo the previous display and then click on the *Show Group* button.

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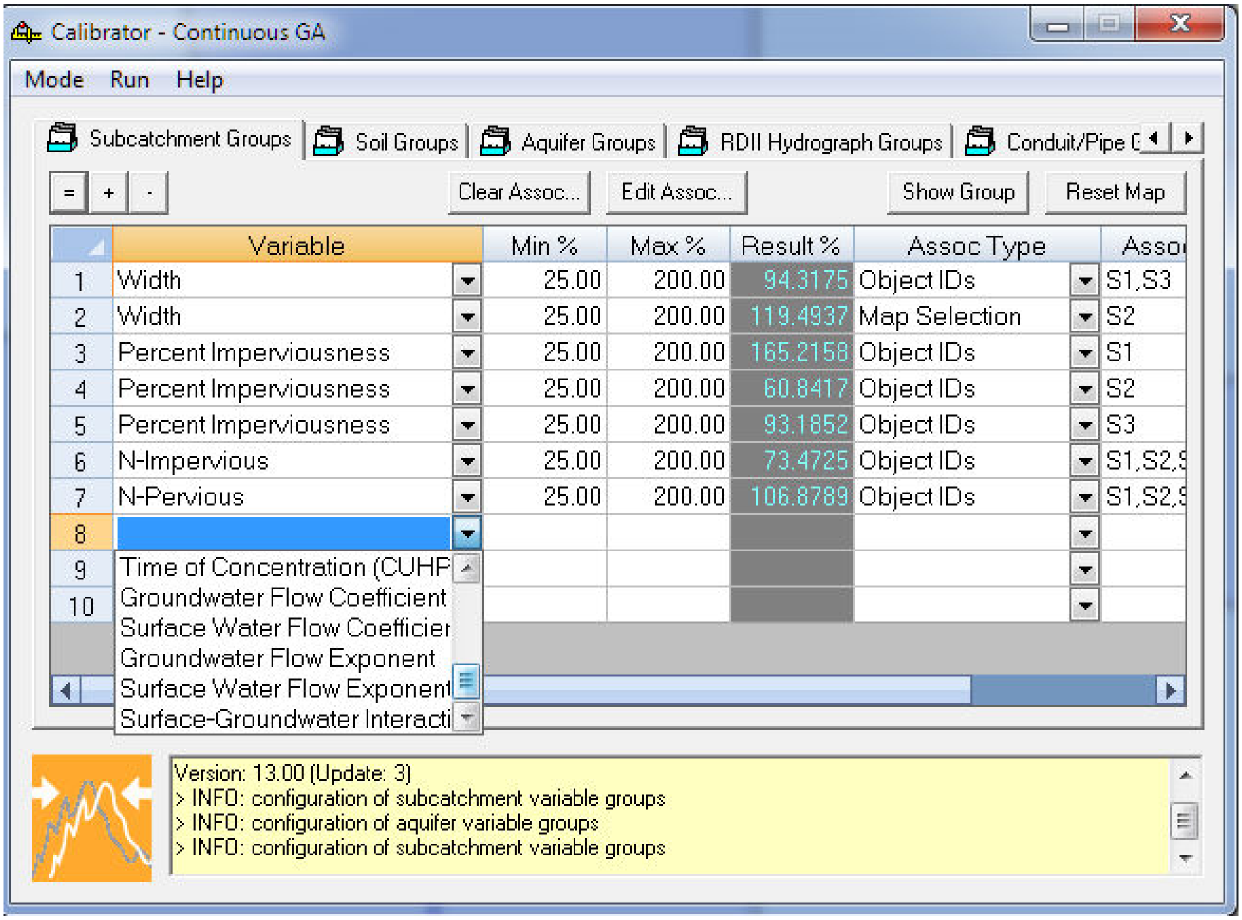
2.2.1 Subcatchment Group

The Subcatchment group contains Subcatchment rainfall-runoff modeling parameters and groundwater parameters. InfoSWMM supports four different rainfall-runoff modeling methods: EPA SWMM's Non-Linear Reservoir Method, Colorado Urban Hydrograph Procedure (CUHP), Natural Resources Conservation Service (NRCS) Dimensionless Unit Hydrograph, and NRCS Triangular Unit Hydrograph method. Using the Subcatchment group, the modeler can select the specific parameters s/he wants to calibrate. Selection of the parameters to calibrate depends on the rainfall-runoff modeling technique utilized and also on the interest of the user to model groundwater. InfoSWMM parameters available for various rainfall-runoff modeling approaches and groundwater parameters are listed below.

- EPA SWMM's Non-Linear Reservoir Method
- Area
- Width
- Percent Imperviousness
- Slope
- N-Impervious
- N-Pervious
- Impervious Depression Storage
- Pervious Depression Storage
- CUHP Method
- Area
- Percent Imperviousness
- Slope
- Impervious Depression Storage
- Pervious Depression Storage
- Length

- Centroid Distance
- CIA Fraction
- RPA Fraction
- NRCS Dimensionless and NRCS Triangular Methods
- Area
- Slope
- Length
- Lag Time
- If Groundwater is Simulated
- Groundwater Flow Coefficient
- Surface water flow Coefficient
- Groundwater Flow Exponent
- Surface Water Flow Exponent
- Surface-Groundwater Interaction



Once the parameters to be calibrated are known, the user has to decide the *Min%* and *Max%* value of each parameter, and the Subcatchments that could be clustered in to one calibration group.

NOTE: *If invalid Subcatchment ID (e.g., non-existing Subcatchment) is associated with a group, the calibrator will issue a warning message but it will run. However, if all IDs provided to a group are invalid the calibrator will issue an error message and will not run.*

NOTE: *If irrelevant Subcatchment parameter (e.g., parameter that is not associated with the rainfall-runoff model being used) is defined as calibrable, the calibrator will run, but as expected, the parameter will not play any role in the calibration process.*

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2.2.2

Soil Group

The soil group, shown below, contains nfoSWMM

infiltration

parameters. nfoSWMM can

model subcatchment infiltration using Horton method, Green-Ampt method, or Curve Number method. Depending on the infiltration model used, the following infiltration parameters can be calibrated and are all available from the soil group. ID of the soils that have similar characteristics from the perspective of the calibrated infiltration/soil parameters should be listed in the **Assoc ID(s)** column.

- Horton

  Method and Modified Horton
- Maximum Infiltration Rate
- Minimum Infiltration Rate
- Decay Rate
- Drying Time
- Maximum Infiltration Volume
- Green-Ampt

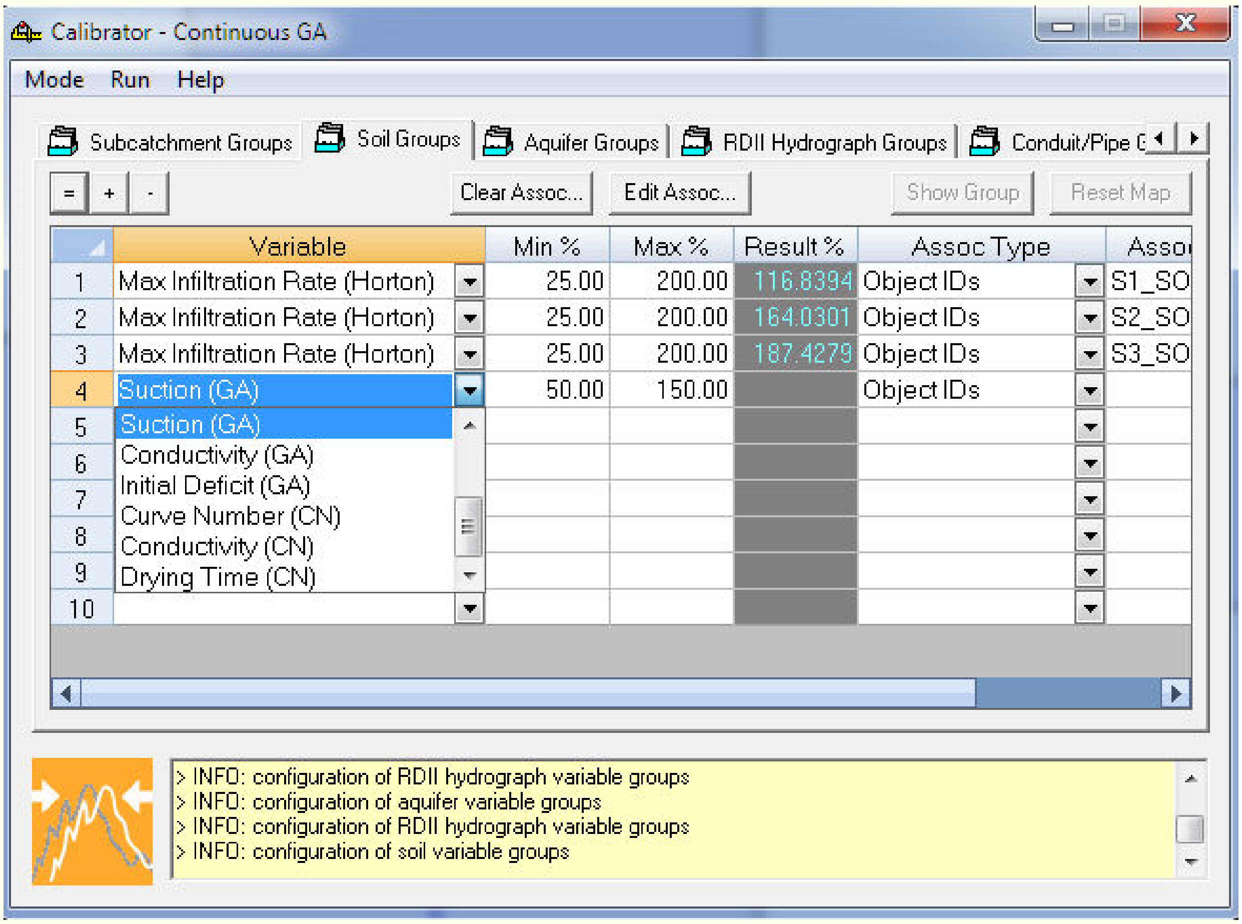
  Method and Modified Green-Ampt Method
- Suction
- Conductivity
- Initial Deficit
- Curve

  Number Method
- Curve Number

- Conductivity
- Drying Time

NOTE: *If invalid soil ID (e.g., non-existing soil) is associated with a group, the calibrator will issue a warning message but it will run. However, if all IDs provided to a group are invalid the calibrator will issue an error message and will not run.*

NOTE: *If irrelevant soil parameter (e.g., parameter that is not associated with the infiltration model being used) is defined as calibrable, the calibrator will run, but as expected, the parameter will not play any role in the calibration process.*



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2.2.3

Aquifer Group

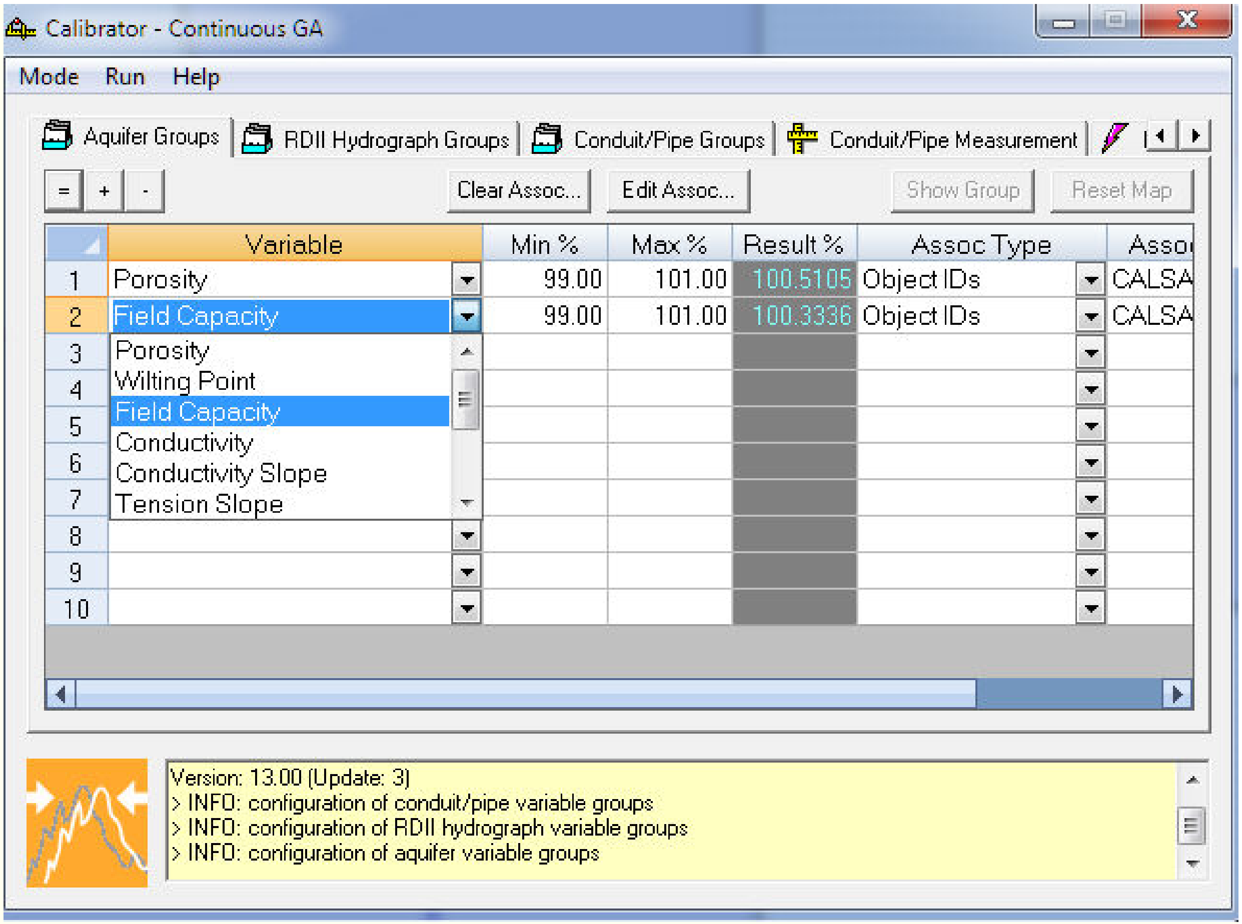
The aquifer

group, shown below, consists of aquifer parameters that are required to model Subcatchment groundwater flow. Using aquifer group tab, the user can define the aquifer groups to be used in the calibration analysis.

The user can also modify any aquifer group previously identified, input ranges of acceptable aquifer parameters for each aquifer group, or color-code each aquifer group. The aquifer parameters that are available for calibration are: porosity, wilting point, field capacity, conductivity, conductivity slope, tension slope, upper evaporation fraction, lower evaporation depth, bottom elevation, water table elevation, and unsaturated zone moisture.

NOTE: *If invalid aquifer ID (e.g., non-existing aquifer) is associated with a group, the calibrator will issues an error message and will not run.*

NOTE: *If irrelevant aquifer parameter (e.g., aquifer group is defined but groundwater is not simulated) is defined as calibrable, the calibrator will run, but as expected, the parameter will not play any role in the calibration process.*



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2.2.4

RDII Group

The RDII

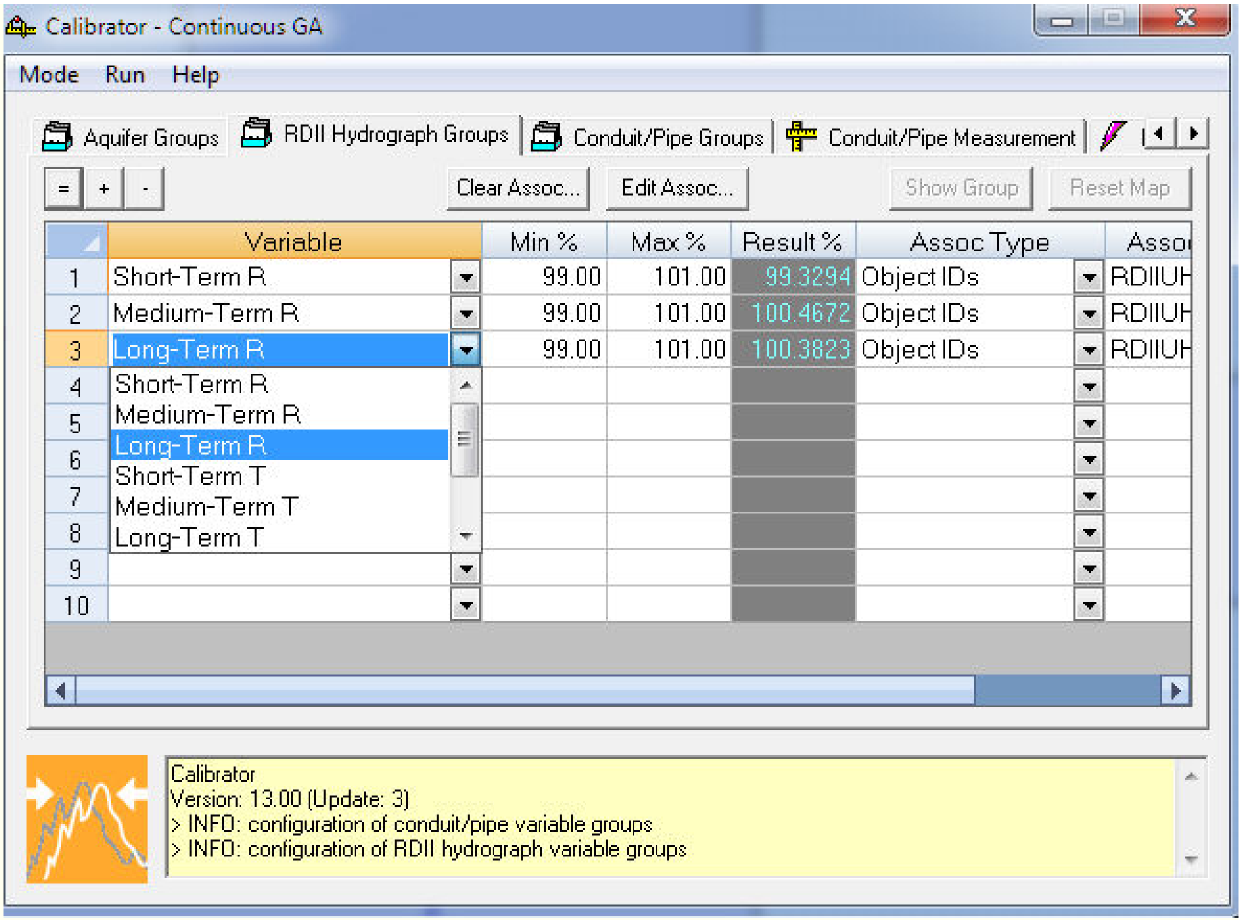
group, shown below, consists of RDII unit hydrograph parameters that are required to model rainfall driven infiltration and inflow to nodes. Using RDII group tab, the user can define the RDII groups to be used in the calibration analysis. The user can also modify any RDII group previously identified, input ranges of acceptable RDII parameters for each RDII group, or color-code each RDII group. The RDII parameters that are available for calibration are short-term, medium-term, and long-term R, T, and K

parameters.

NOTE: *If*

invalid RDII ID (e.g., non-existing RDII UH) is associated with a

group, the calibrator will issues an error message and will not run.



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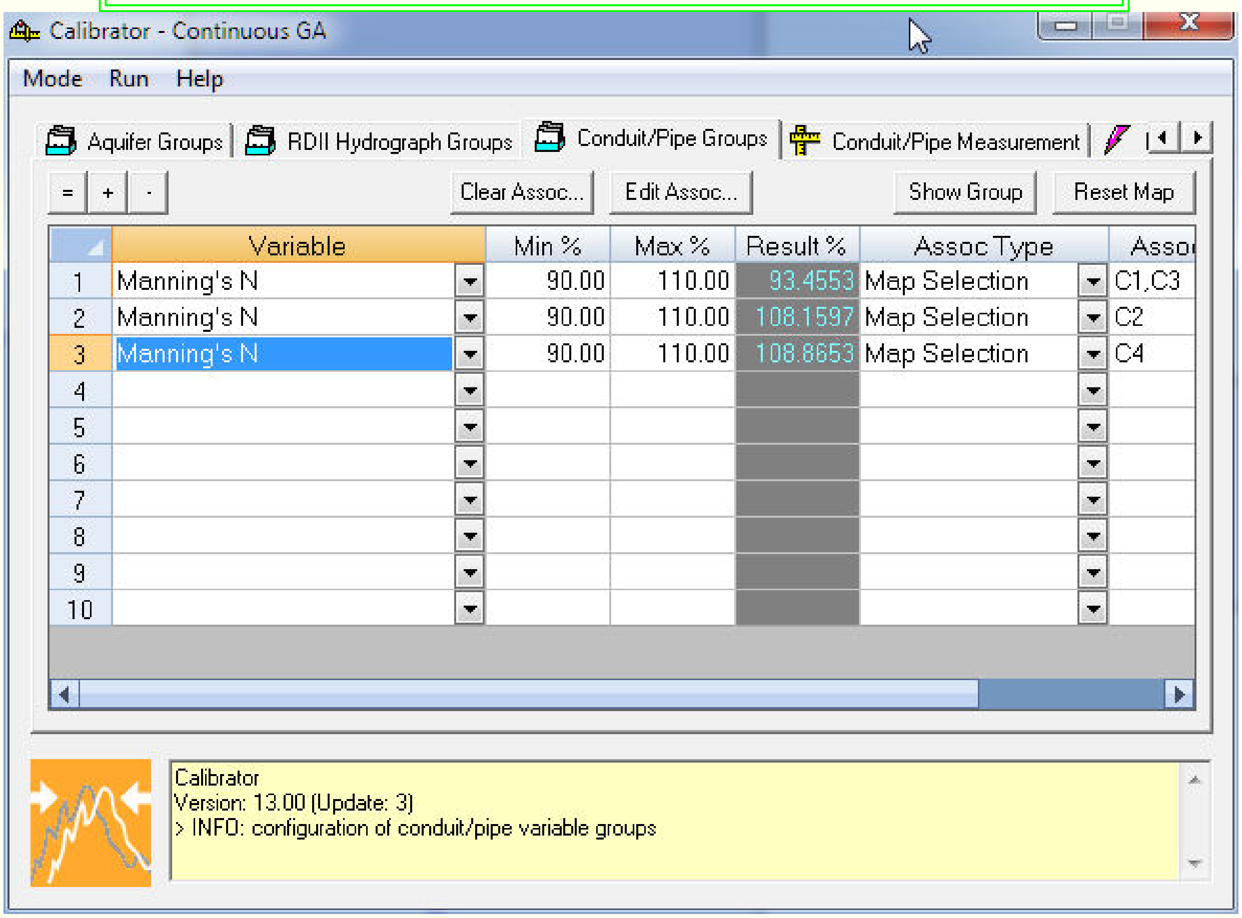
2.2.5

Conduit Group

The conduit group, shown below, enables the user to calibrate Manning's roughness coefficient for conduits. Using conduit group tab, the user can define the conduit groups to be used in the calibration analysis. The user can also modify any conduit group previously identified, input ranges of acceptable Manning's n for each conduit group, or color-code each conduit group.

> **NOTE:**
>
> *If invalid Conduit ID (e.g., non-existing conduit) is associated with a group, the calibrator will issues an error message and will not run.*



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2.3 Conduit Measurement

This

tab allows the user to specify observed data or measurements and also to review performance of the calibration run. The measurements could be flow, depth, and/or velocity taken at one or more conduits. nfoSWMM

calibrator

accepts measurement information in the form of time series.

Once

the calibration model is executed, the conduit measurement dialog editor displays values of the goodness-of-fit evaluation criteria including root mean square error, Nash-Sutcliffe efficiency criterion, modified coefficient of efficiency, r-square, and deviation in total volume of the measured and the simulated values. Calibration result analysis page could also be launched from conduit measurement dialog editor.

The

conduit measurement dialog editor consists of the following input/output columns.

- **Conduit**

  ID - ID of the conduit where the measurement is taken is given in this column.

- **Data**

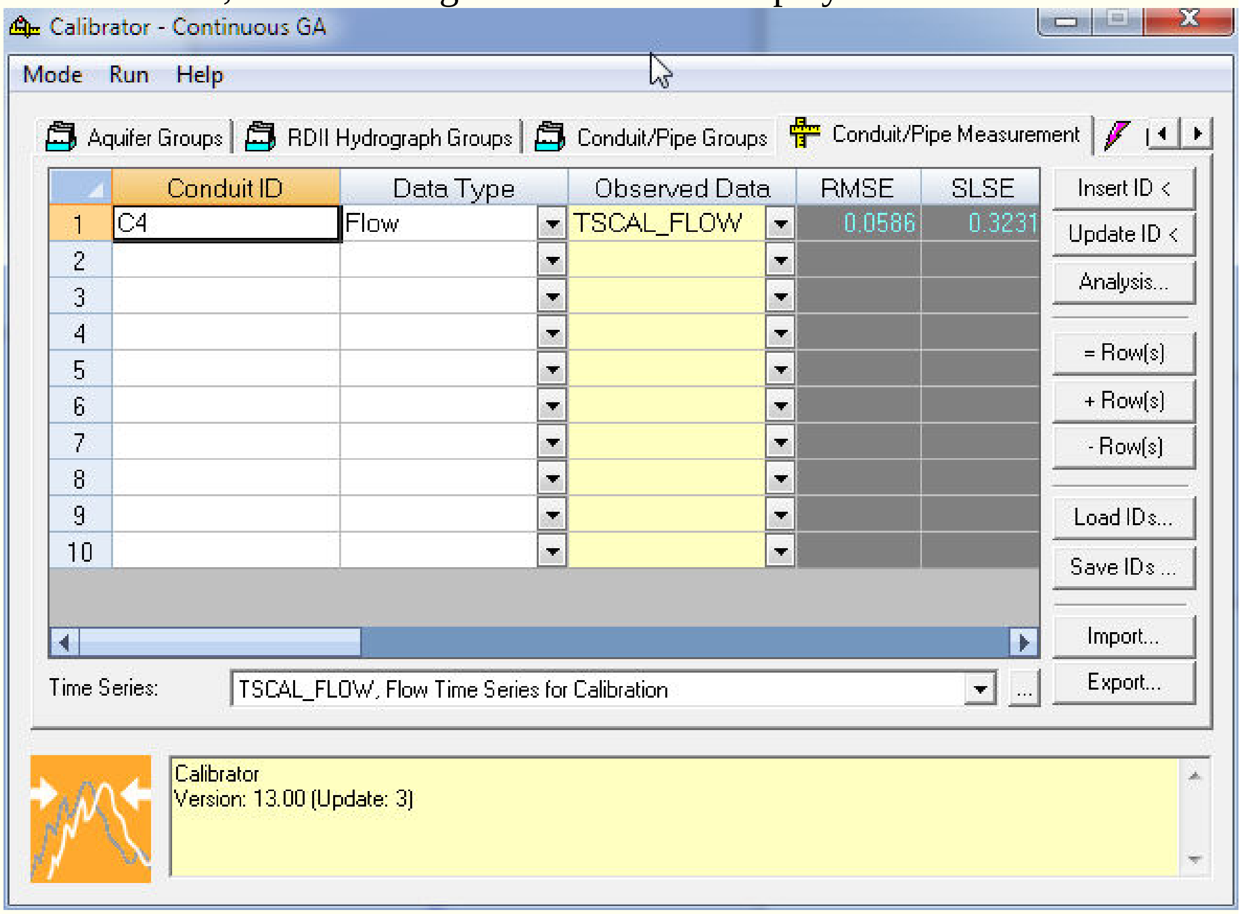
  Type - Type of the measurement (i.e., flow, depth, or velocity) is specified in this column.

- **Observed**

  Data – ID of the time series that contains the observed data is specified in this column.

- **Goodness-of-fit**

Evaluation Criteria Columns - Once the calibration model is executed, value of the goodness-of-fit is displayed in these columns.



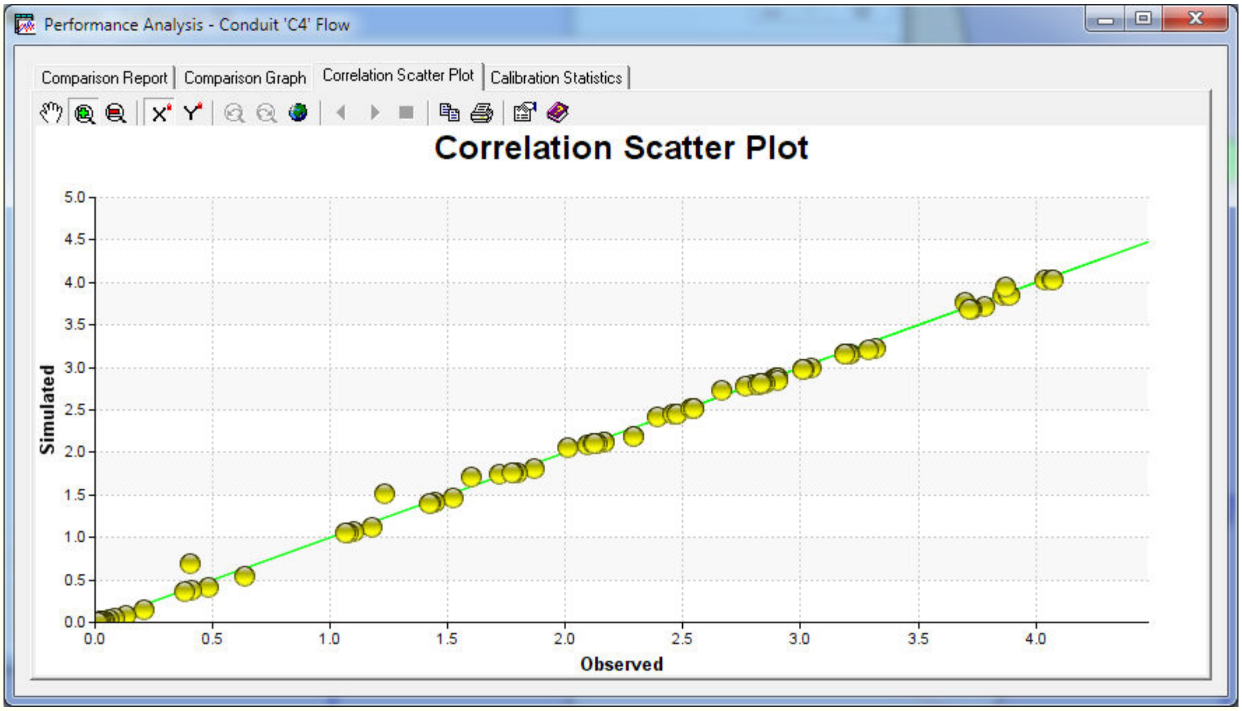
In

addition, the conduit measurement dialog editor has the following buttons to facilitate assignment of input information and reviewing output results.

- Insert ID < - Graphically selects measurement conduit ID and inserts into the Conduit ID column as additional measurement site.
- Update ID < -

  Graphically selects measurement conduit ID and replaces an existing Conduit ID with the new ID.
- Analysis... -

  Launches the *Performance Analysis* page indicated below where the user reviews performance of the calibrator graphically and statistically.



- = Row(s) -

Lets you set the number of rows.

- + Row(s) -

  Enables you to add a row above the selected row.

- - Row(s) - Lets you remove the selected row.

- Load IDs... -

  Loads conduit IDs from a selection set.

- Save IDs ... -

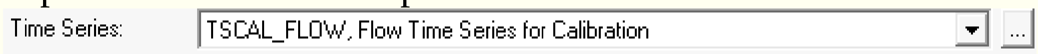
  Saves existing measurement conduit IDs to a selection set.

- Import... -

  Imports and populates the Conduit ID, Data Type, and Observed Data columns.

- Export... -

Exports the Conduit ID, Data Type, and Observed Data columns. The exported file could be imported back.

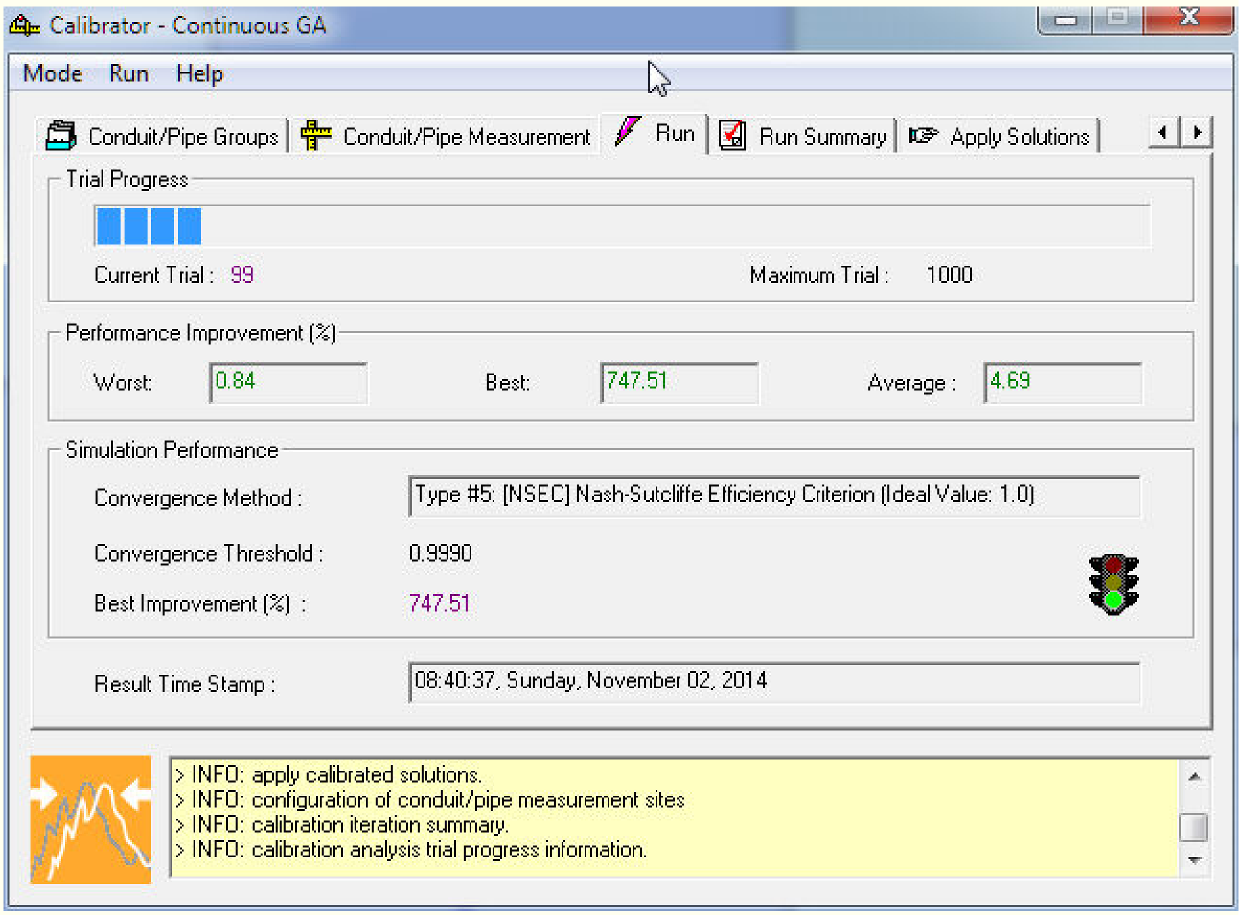
- 

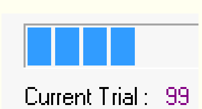
The Time Series drop down box allows you to choose the time series to be used, or you could also create a new time series and specify it to a conduit ID of your choice.

2.4 Run TAB

The

run tab is used to report calibration information while the calibrator is running. If the simulation run was unsuccessful, a descriptive message will appear in the message area explaining what needs to be corrected in the input data. The following information is reported in the *Run* tab dialog box.





– The current iteration number in the optimization routine. Each trial represents a new calculated set of parameters.

– The maximum number of solution iterations that nfoSWMM

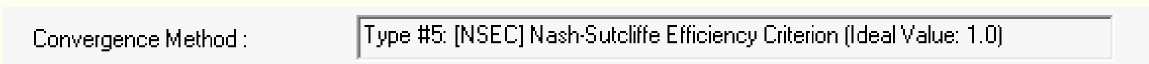
Calibrator

should employ when determining the model parameters. This criterion is checked after each computed generation.

– The maximum value of the objective function in the current set of solutions (generation).

– The minimum value of the objective function in the current set of solutions (generation).

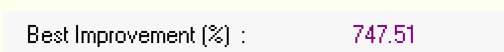
– The average value of the objective function in the current set of solutions (generation).



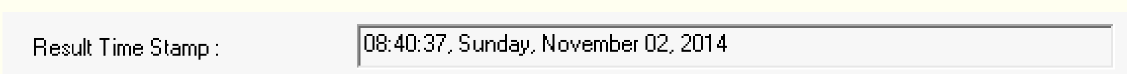
– Define the objective (fitness) function type and the optimization convergence criteria. Three options for the objective function are available as defined later in this guide.

– Prescribe a convergence criterion for the optimization routine used to minimize the selected fitness function. The iterations end when the fitness threshold is reached. nfoSWMM Calibrator

will not allow a value smaller than one (0.01) percent to be used.



– The best value of the objective function reached based on the user selected convergence criteria.



– Time corresponding to the GA optimization completion.

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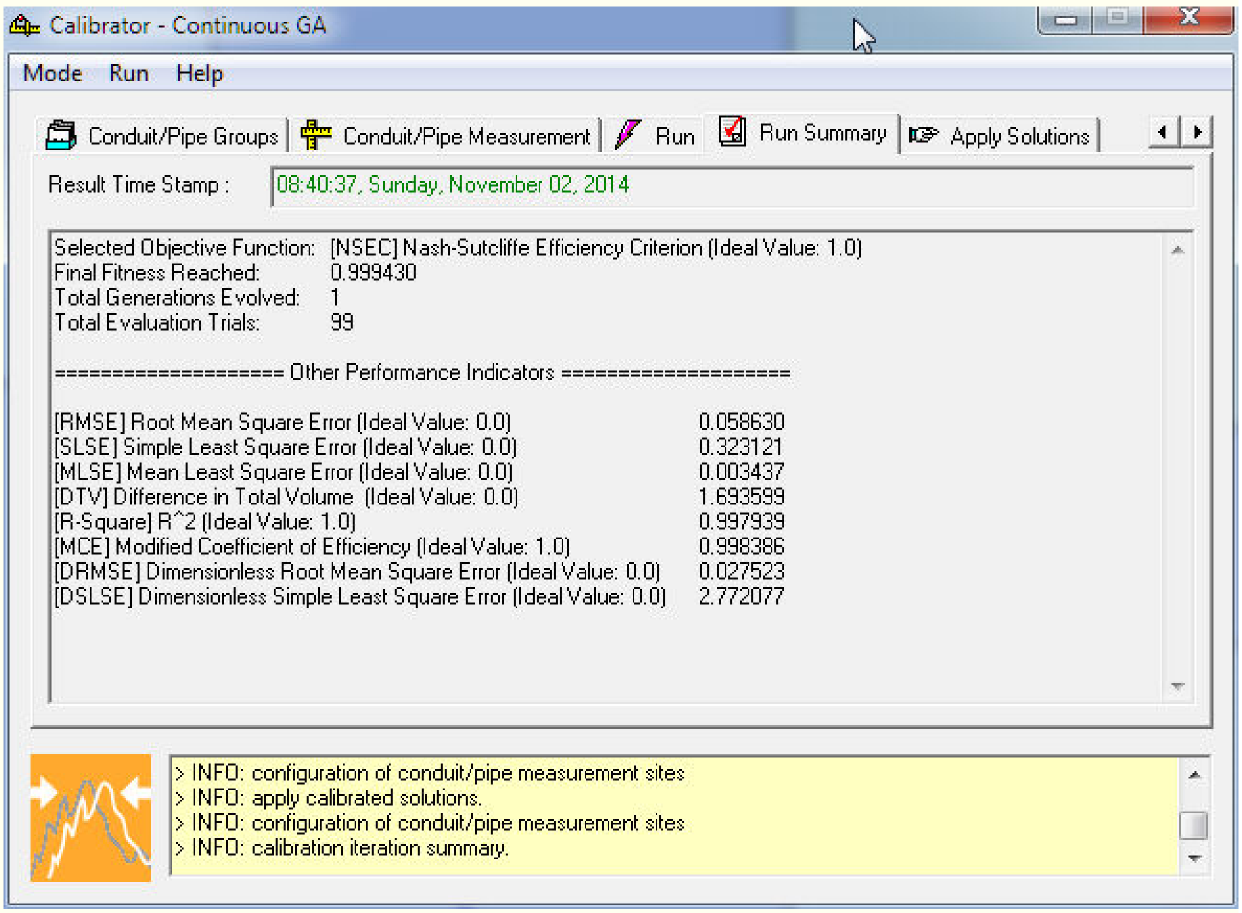
2.5 Run Summary Tab

The following dialog box appears for the *Run Summary* tab. InfoSWMM Calibrator creates an ASCII calibration summary report in the *Run Summary* tab.



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2.6 Apply Solutions

Upon completion

of a calibration run, the *Apply Solutions* tab dialog box provides the user with the means to apply the optimal parameter values obtained by the calibrator to the elements and objects of the model overwriting the original nominal values. The modeler can apply the optimal parameters to the desired scenario among the existing ones. The dialog box has the following items.

- **Subcatchment**

  Set – Applies the final values of the calibrable parameters to the subcatchments.

- **Groundwater**

  Set – Applies final values of the groundwater parameters to the subcatchments.

- **Soil**

  Set – Applies the soil parameters to the soils objects.

- **Aquifer**

  Set – Applies the aquifer parameters to the appropriate aquifer.

- **Hydrograph**

  Set – Applies RDII parameters to the appropriate unit hydrograph.

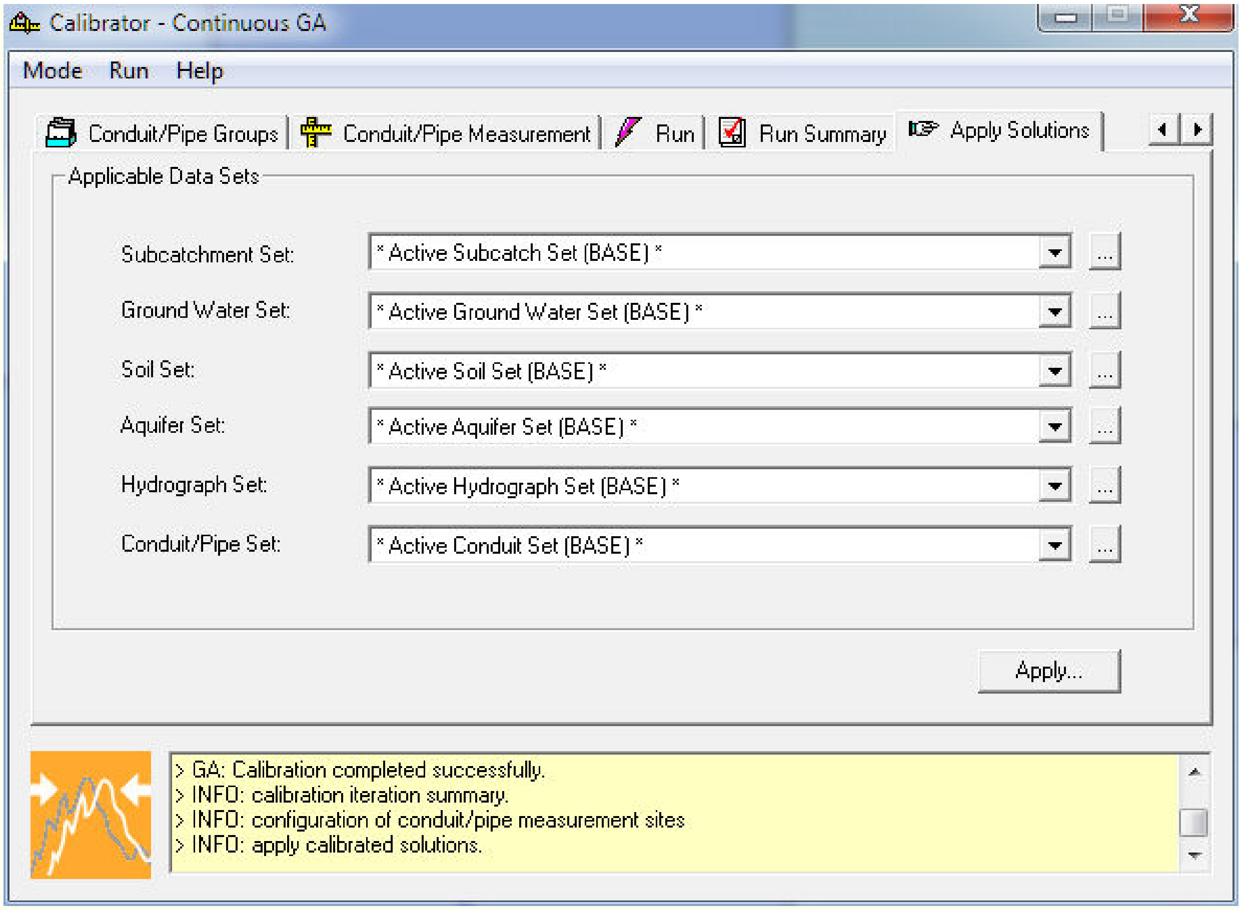
- **Conduit**

  Set – Applies optimal value of Manning’s N to conduits.

– Click this button to finalize parameter application process.

The drop

down box lets you choose the appropriate element set. You could also create new element set.



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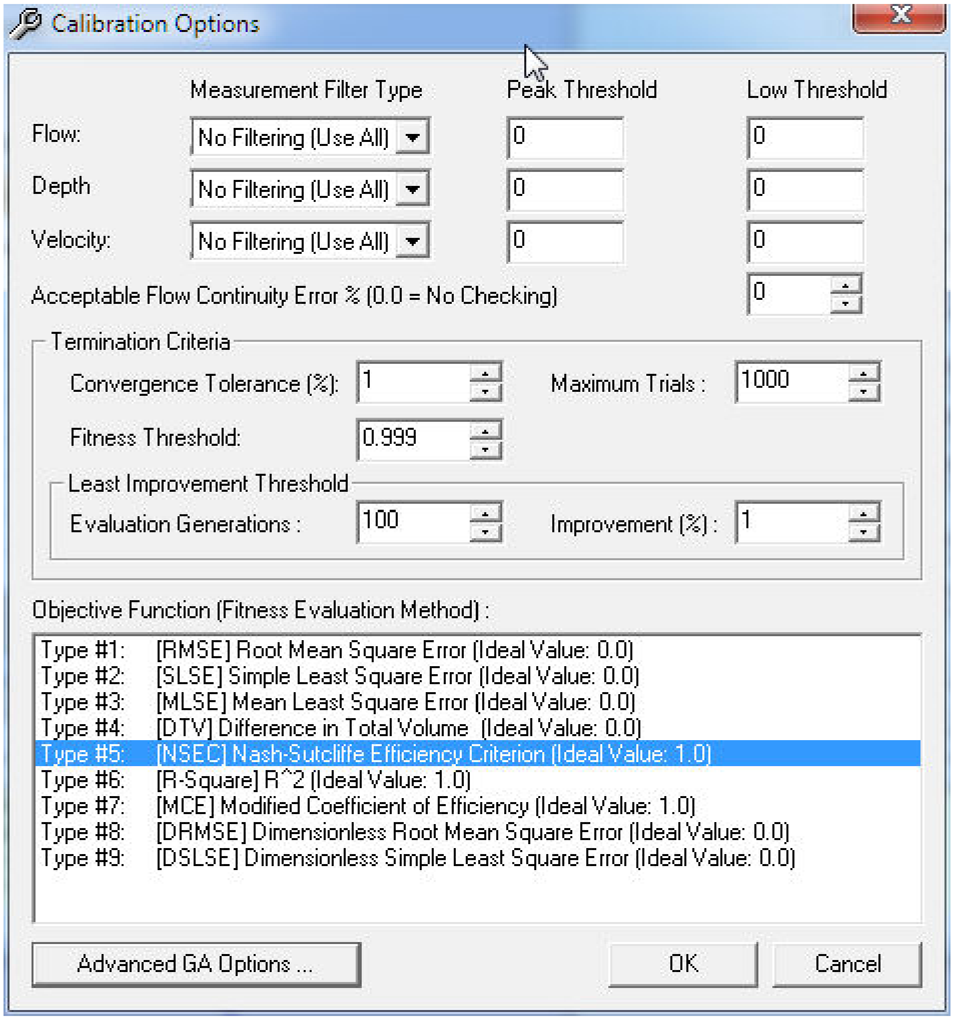
2.7 Calibration Options Dialog Box

The Calibration Options dialog box controls optimization properties and simulation options that are utilized during a model calibration simulation. Within this dialog box, the user specifies the type of measurement to be used to evaluate fitness function (i.e. entire time series, peak flows along with the peak threshold, or low values along with low threshold), convergence criteria (e.g., fitness threshold, least fitness improvement, and least improvement generation), maximum number of trials, advanced GA options, and the objective function type. The following items appear for the *Calibration Options* dialog box.

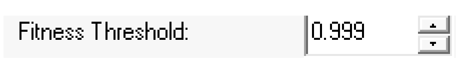
- **Measurement Filter Type** – Lets the modeler specify the measurements to be used to evaluate the fitness value. This could be done for flow, velocity, or depth. One of the following three options could be selected: *No Filtering (ALL)*, *>= Peak Threshold*, *<= Low Threshold.*

- **Peak Threshold** – Required only if the >= *Peak Threshold* is chosen for *Measurement Filter Type* and it enables specifying the threshold for peak values. Measurement values >= the assigned threshold will be considered during fitness evaluation.

- **Low Threshold** – Required only if the <= *Low Threshold* is chosen for *Measurement Filter Type* and it enables specifying the threshold for low values. Measurement values less than or equal to the assigned threshold will be considered during fitness evaluation.

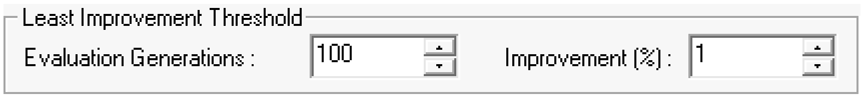


The optimization module will terminate its iterative solution refinement process when one of the following four criteria is satisfied.

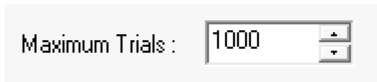


– Prescribes a convergence criterion for the optimization routine used to minimize the selected fitness function. The iterations ends when the fitness threshold is reached.

– Prescribes another convergence criterion for the optimization routine used to minimize the selected fitness function. The optimization ends if it fails to improve the total fitness better than the Least Fitness Improvement ratio (%) over the *Least Improvement Generation*.

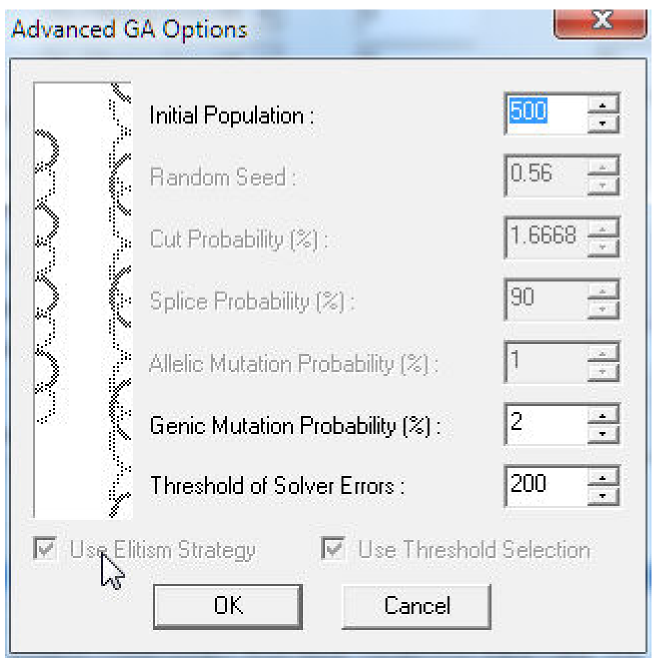


– Specifies the maximum number of consecutive generations with improvements of the fitness function not greater than the Least Fitness Improvement ratio.



– The maximum number of solution iterations that InfoSWMM Calibrator should employ when determining improved sets of model parameters. This criterion is checked after each computed generation.

– Launches the Advanced GA Options dialog box as shown below. The user is able to specify advanced GA parameters such as initial population and mutation rate to improve convergence and accuracy.



- **Initial Population** – Refers to the initial number of solution candidates used.
- **Mutation Probability (%)** – This rate gives the expected number of genes to be mutated every iteration.

- 

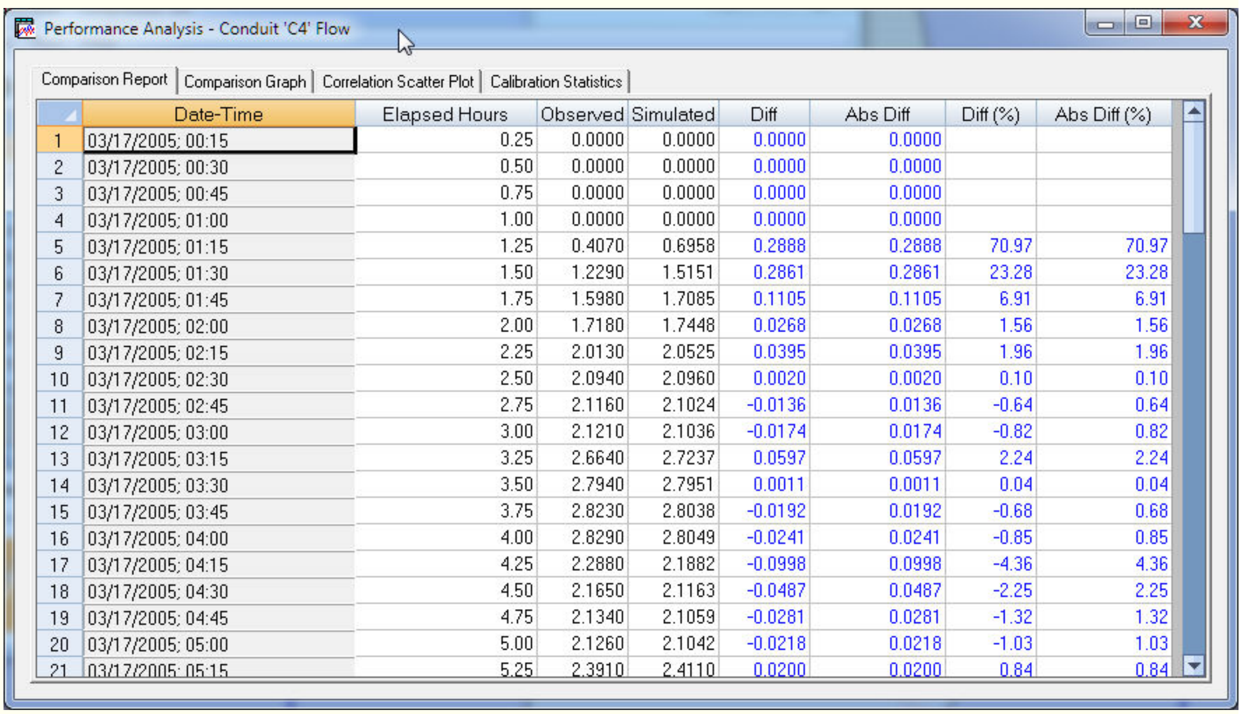
– Defines the objective function type or fitness evaluation criterion. Nine options are available. Mathematical formulation of these fitness evaluation methods may be reviewed from the methodology section of the users guide.
- Simple Least Square Error
- First Dimensionless Form of Simple Least Square Error
- Mean Least Square Error
- Root Mean Square Error
- Dimensionless Form of Root Mean Square Error
- R^2 (R-Square)
- Nash-Sutcliffe Criterion
- Modified Coefficient of Efficiency
- Quantified Total Difference

2.8 Performance Analysis Dialog

The *Performance Analysis* dialog editor is launched by clicking on the *Analysis* button (Analysis...) from the *Conduit Measurement* dialog editor. nfoSWMM

Calibrator allows you to compare results of a simulation against measured field data using one or more of the four buttons given on the *Performance Analysis* page: *Comparison Report*, *Comparison Graph*, *Correlation Scatter Plot*, and *Calibration Statistics*.

- **Comparison Report** – At every time that has the measurement data, the comparison report presents observed data and corresponding simulated values side-by-side along with differences between the two values.

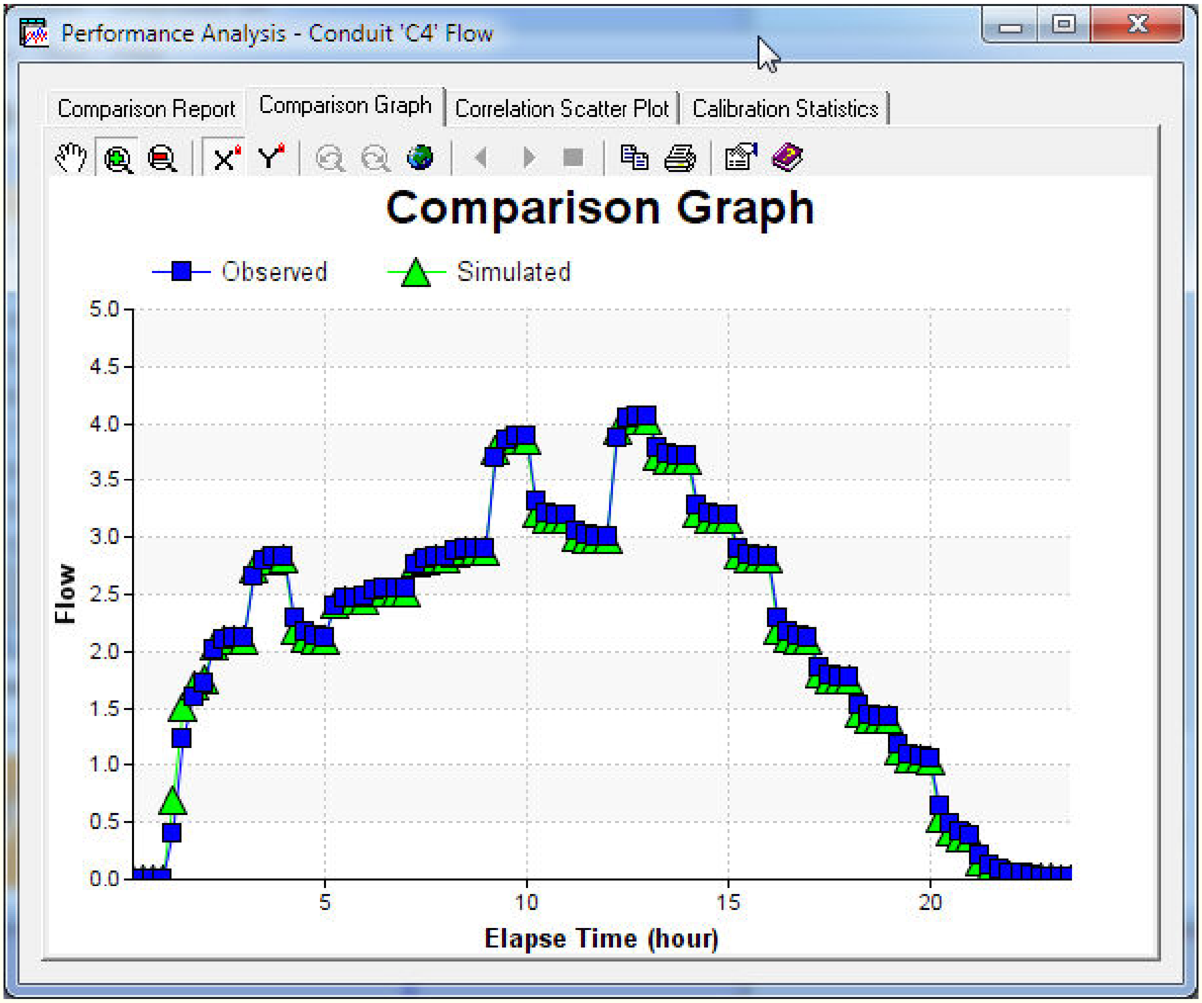


	Date-Time	Elapsed Hours	Observed	Simulated	Diff	Abs Diff	Diff (%)	Abs Diff (%)
1	03/17/2005; 00:15	0.25	0.0000	0.0000	0.0000	0.0000		
2	03/17/2005; 00:30	0.50	0.0000	0.0000	0.0000	0.0000		
3	03/17/2005; 00:45	0.75	0.0000	0.0000	0.0000	0.0000		
4	03/17/2005; 01:00	1.00	0.0000	0.0000	0.0000	0.0000		
5	03/17/2005; 01:15	1.25	0.4070	0.6958	0.2888	0.2888	70.97	70.97
6	03/17/2005; 01:30	1.50	1.2290	1.5151	0.2861	0.2861	23.28	23.28
7	03/17/2005; 01:45	1.75	1.5980	1.7085	0.1105	0.1105	6.91	6.91
8	03/17/2005; 02:00	2.00	1.7180	1.7448	0.0268	0.0268	1.56	1.56
9	03/17/2005; 02:15	2.25	2.0130	2.0525	0.0395	0.0395	1.96	1.96
10	03/17/2005; 02:30	2.50	2.0940	2.0960	0.0020	0.0020	0.10	0.10
11	03/17/2005; 02:45	2.75	2.1160	2.1024	-0.0136	0.0136	-0.64	0.64
12	03/17/2005; 03:00	3.00	2.1210	2.1036	-0.0174	0.0174	-0.82	0.82
13	03/17/2005; 03:15	3.25	2.6640	2.7237	0.0597	0.0597	2.24	2.24
14	03/17/2005; 03:30	3.50	2.7940	2.7951	0.0011	0.0011	0.04	0.04
15	03/17/2005; 03:45	3.75	2.8230	2.8038	-0.0192	0.0192	-0.68	0.68
16	03/17/2005; 04:00	4.00	2.8290	2.8049	-0.0241	0.0241	-0.85	0.85
17	03/17/2005; 04:15	4.25	2.2880	2.1882	-0.0998	0.0998	-4.36	4.36
18	03/17/2005; 04:30	4.50	2.1650	2.1163	-0.0487	0.0487	-2.25	2.25
19	03/17/2005; 04:45	4.75	2.1340	2.1059	-0.0281	0.0281	-1.32	1.32
20	03/17/2005; 05:00	5.00	2.1260	2.1042	-0.0218	0.0218	-1.03	1.03
21	03/17/2005; 05:15	5.25	2.3910	2.4110	0.0200	0.0200	0.84	0.84

- **Comparison Graph** – Displays a plot of observed and simulated values against time.

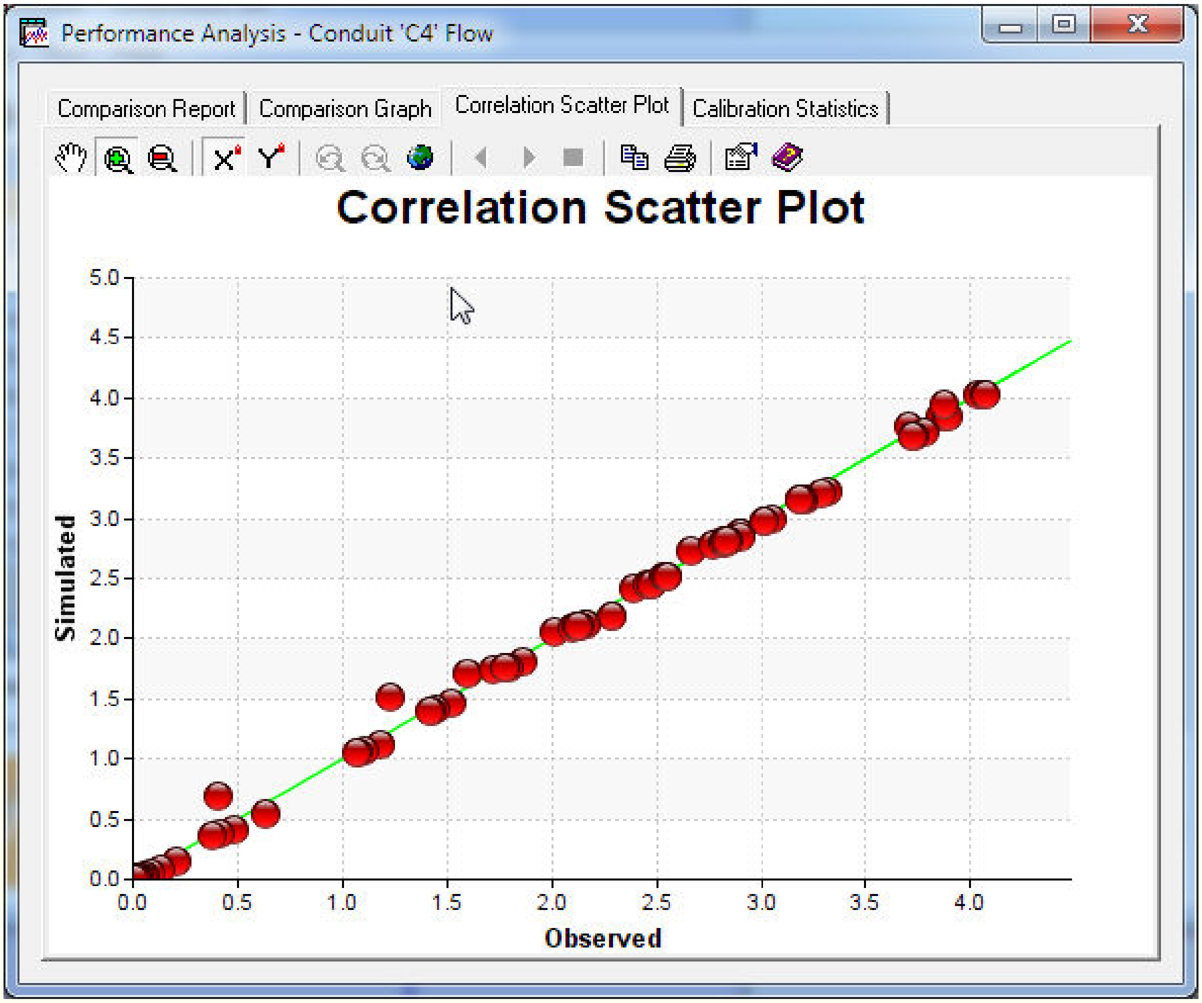
The

user has the options to modify appearance of the graph using icons on the top of the window.

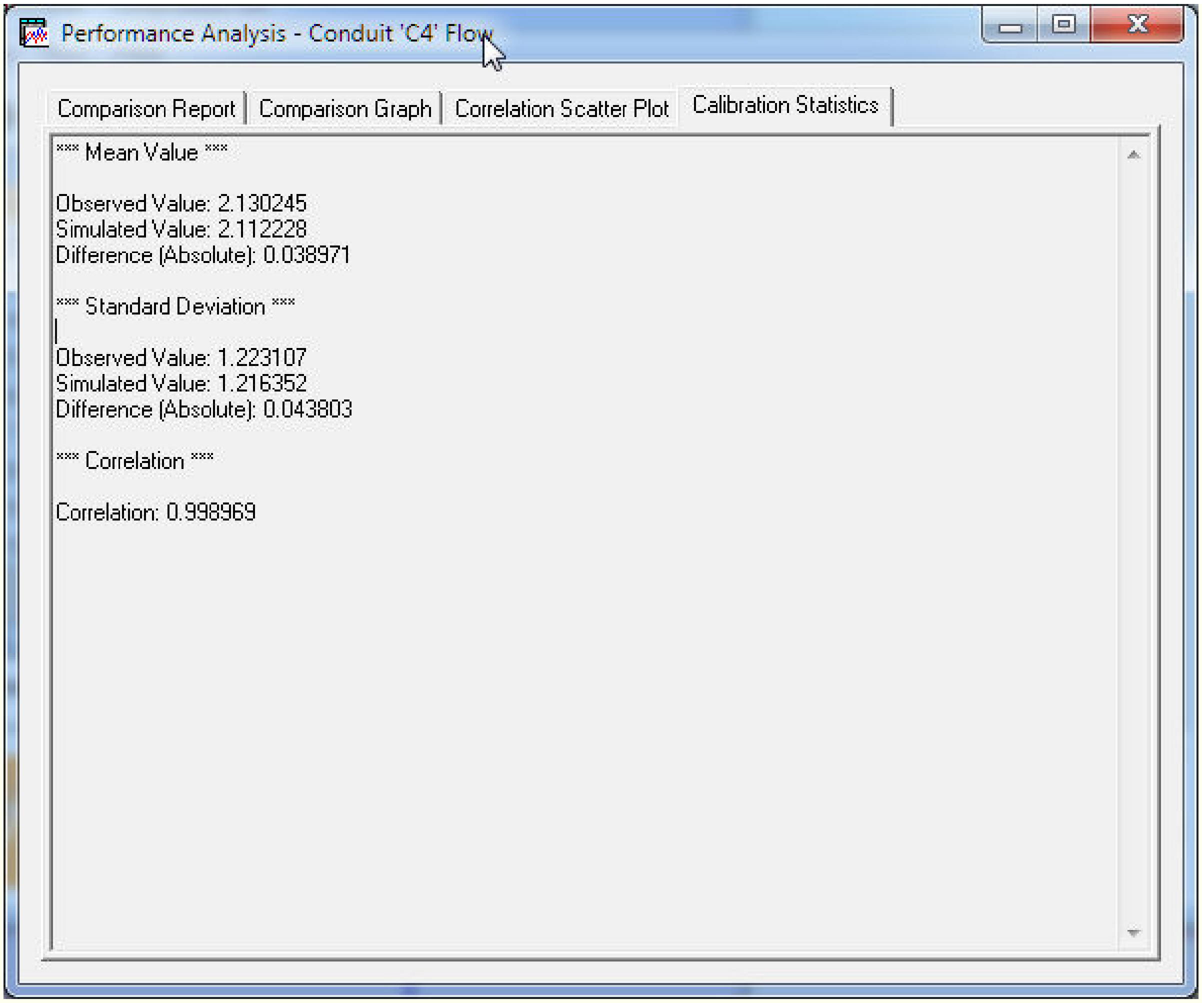


Correlation

Scatter Plot – The correlation scatter plot displays simulated values against observed values. The closer that the points come to the 45-degree angle line on the plot the closer is the match between observed and simulated values.



● **Calibration Statistics** – In this tab, nfoSWMM Calibrator creates an ASCII calibration statistics report.



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InfoSWMM

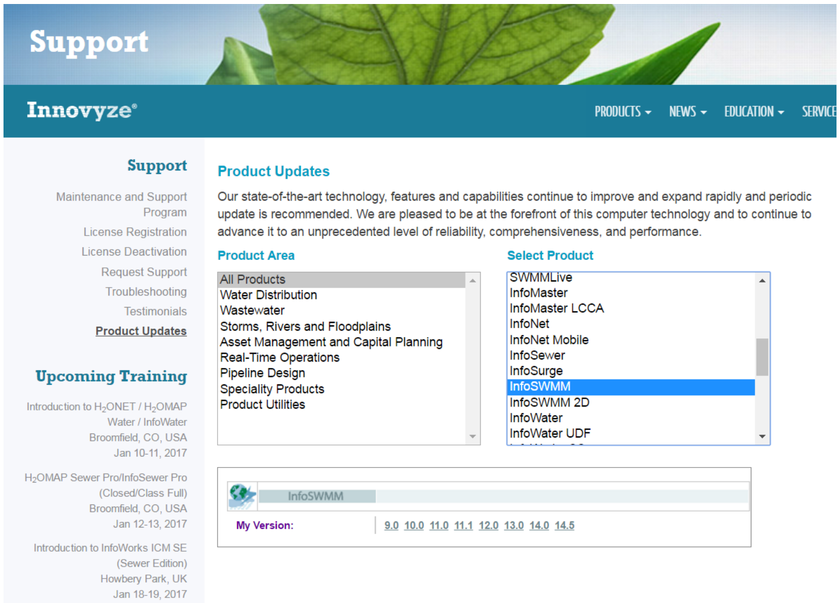
Installation Guide

System Requirements for InfoSWMM w ArcGIS, H2OMap SWMM does not need ArcGIS	
Compatible 32-bit OS:	Windows Server 2008 R2, Windows Server 2012 R2, Windows 7/8/8.1/10 pro or above
Compatible 64-bit OS:	Windows Server 2008 R2, Windows Server 2012 R2, Windows 7/8/8.1/10 pro or above
Compatible ArcGIS:	10.0, 10.1, 10.2, 10.3, 10.4, and 10.5 (**Check your PC ability to run ArcG**
Prerequisites:	**Microsoft Visual C++ 2008 Redistributable - x64 v9.0.30729.17**/**Microsoft Visual C++ 2008 x86 v9.0.30729.17**, **Microsoft Visual C++ 2010 Redistributable - x86 v10.0.40219.1**/**Microsof Redistributable - x64 v10.0.40219.1** and **Windows Internet Explorer 7 or later**
Hardware Requirements:	CPU Speed: 2.2 GHz minimum or higher; Hyper-threading (HHT) or Multi-core recommended Processor: Intel Pentium 4, Intel Core Duo, or Xeon Processors; SSE2 (or greater) Memory/RAM: 2 GB or higher Screen Resolution: 1024 x 768 recommended or higher at Normal size (96dpi) Disk Space: 500 MB of free space to accommodate a full setup installation and additional di much free disk space available as possible. Its virtual memory system needs additional fre working on large projects Video/Graphics Adapter: 64 MB RAM minimum, 256 MB RAM or higher recommended. INTEL chipsets supported Networking Hardware: Simple TCP/IP, Network Card or Microsoft Loopback Adapter is requi Manager **Language:** Support Multiple Languages (English, French: Menu, German: Menu & Dialogu Spanish: Menu, and Turkish: Menu) - To change display languages: Control Pa Language -> Formats tab -> select [Language] from the Format select box. **(For the display of InfoSWMM Language Setting)**

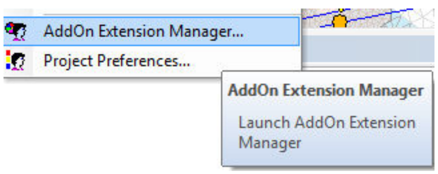
Installing Innovyze Software Add On's and Extensions

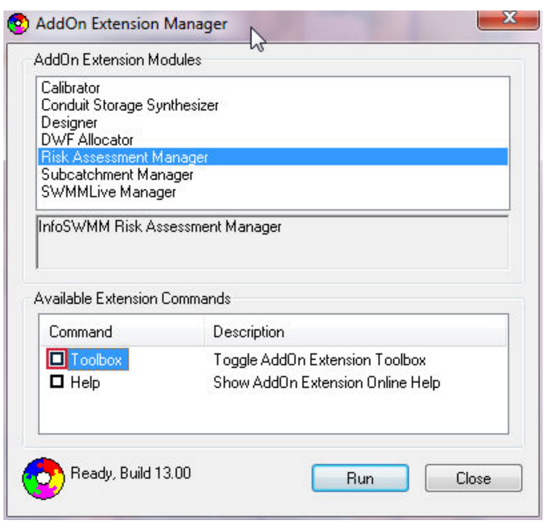
Innovyze programs can only be installed from our Internet website. To install this program or a single user, perform the following procedure:

- Turn on your computer and start Windows. Close any other applications that are currently running.
- Start your Internet Browser software and go to http://www.Innovyze.com. Once on Innovyze® Inc's homepage, please go to http://www.innovyze.com/updates/ Choose the *program* tab and click on the link. This will launch the File Download dialogue box.
- Choose the *SAVE THIS PROGRAM TO A Directory* option and follow the on-screen instructions. When saved on your hard drive run the Execute (*.exe) file from the folder that was downloaded and follow the on-screen instructions.



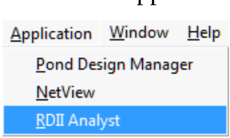
Upon successful installation of the program, the program is initialized from inside InfoSWMM by using the “AddOn Extension Manager” tool. From the Tool Menul, select an Add On as shown below.

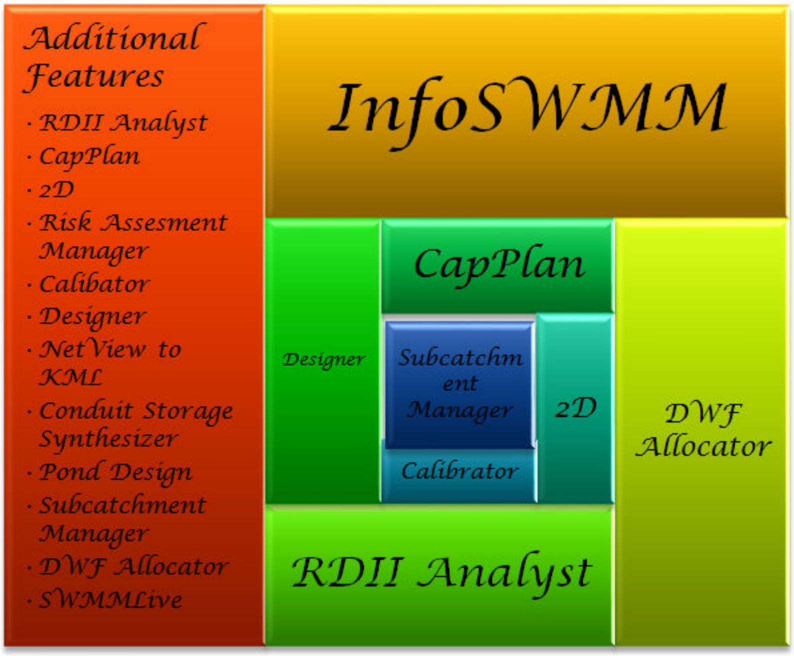




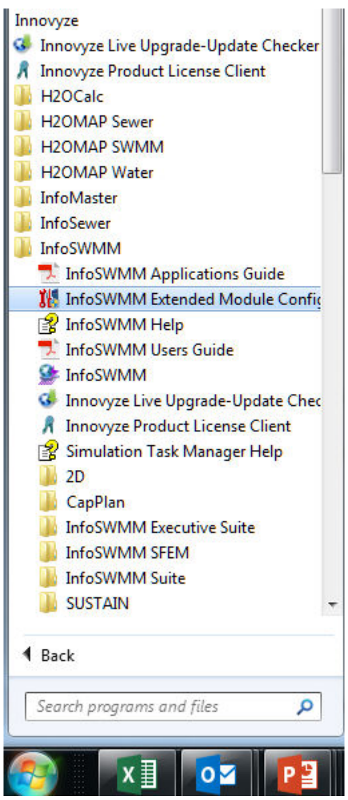
The selected run dialog appears, and it is now available for use. Section 2 discusses each icon and the menu shown below in detail. This program is part of the InfoSWMM Suite.

Or use the Application Window where there are additional AddOns for InfoSWMM





If you do not see the AddON's or Applications for the InfoSWMM Suite version of then you can use the InfoSWMMExtended Module Configuration from Windows Start.



Using the On Line Help

Innovyze provides on-line Help with extensive information about modeling features and capabilities. The documentation includes numerous topics, each including narrative descriptions, illustrations, and diagrams describing the features of each program.

The on-line Help offers the ability to search for a desired topic rapidly or to move between related topics in a fast, efficient manner. An extensive index is available allowing you to search on any number of words, phrases, or commands. Innovyze Help includes several major sections, each identified by a magenta book in the Help Contents. Each section contains numerous related topics.

StartingInnovyze Help

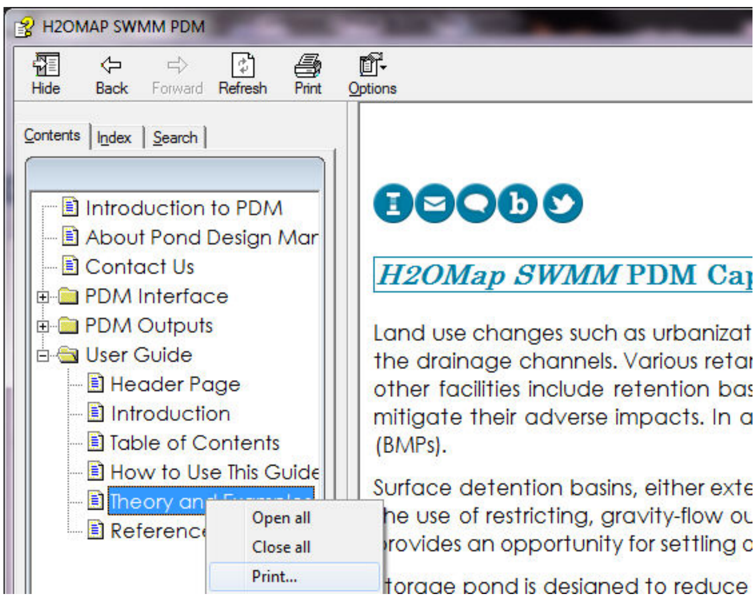
Innovyze Help is available by opening any Innovyze dialog box and pressing the F1 key. You may click on any portion of the dialog box in the help topic for more information.

Navigating the On Line Help

Use either Innovyze Help Contents or the Index to navigate to the desired topic. Choose the Help Topic button in the upper left-hand corner of the Help window to access the Help contents and index. Embedded in the text of each topic are numerous *links*, identified as underlined blue text, to related topics. Simply click on the desired link text with the mouse to move immediately to the related topic.

Printing the OnLine Help

You may print any Innovyze Help topics you desire. To do so, navigate to the desired Help topic and then choose the Print Topic command from the Help window File menu.



Instructions to Renew the CD and License Keys for the Innovyze (MWH Soft) Floating License Server

Below are instructions to renew the CD and License Keys for the Innovyze (MWH Soft) Floating License Server and the floating licenses to reflect the current expiration date.

1. Open the Innovyze (MWH Soft) Floating License Server.
2. Go to the **Help** -> **About** menu in the upper left corner.
3. Go to the Request License Key On-line for dropdown menu and select Renewal. Press the **Go** button. This will open our On-Line License Registration page.

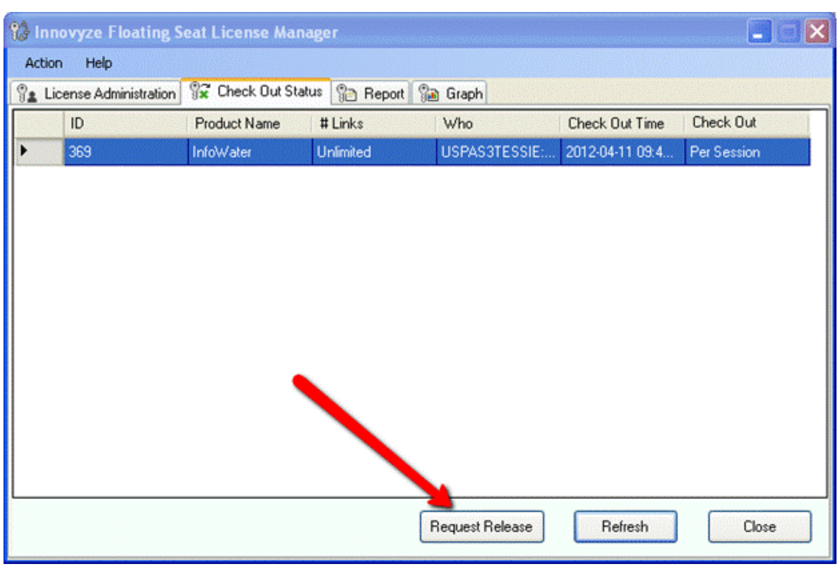
4. Complete the requested information and press the **Submit** button. This should return to you a new CD Key and License Key.
5. Copy and paste the new keys into the appropriate boxes in the **About** dialog box.
6. Press the **Apply License Changes** button. A new Subscription Expiration Date should appear.
7. Close the **About** box and the Innovyze (MWH Soft) Floating License Server.
8. Download and run the update for the Innovyze (MWH Soft) Floating License Server from the attached link:
   - Innovyze Floating License Server 5.0 Update 020 (22.03 MB), 12/10/2015
9. Open the Innovyze (MWH Soft) Floating License Server.
10. If your FLM is installed on a virtual server, go to the upper left corner and select **Action** -> **Register Virtual Environment …**
11. Select the License Administration tab.
12. Go to the Request License Key On-Line for dropdown menu and select **Renewal**. Press the **Go** button. This will open our On-Line License Registration page.
13. Complete the requested information and press the **Submit** button. This should return to you a new CD Key and License Key.
14. Copy and paste the new keys into the appropriate boxes in the License Administration tab.
15. Press the **Apply** button. A new Expiration Date should appear.

Press the Close button

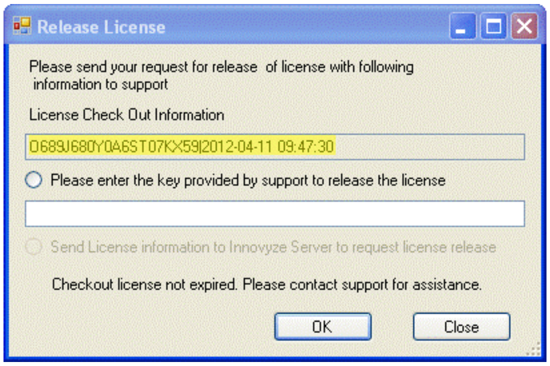
Please follow the instructions below to request a license release key for a floating license.

Please follow the instructions below to request a license release key for a floating license. Most likely this will need to be forwarded to someone who has access to the Innovyze Floating Seat License Manager on a server.

- Open the Innovyze Floating Seat License Manager and select the Check Out Status tab.
- Select the license to release and press the Request Release button.



Copy the License Check Out Information generated and paste into an email to support@innovyze.com



- We will return to you a code to enter in to the second field.
- Once both fields are populated in the Release License dialog box, press the OK button to release the license.

Technical Support On the Web and by Email

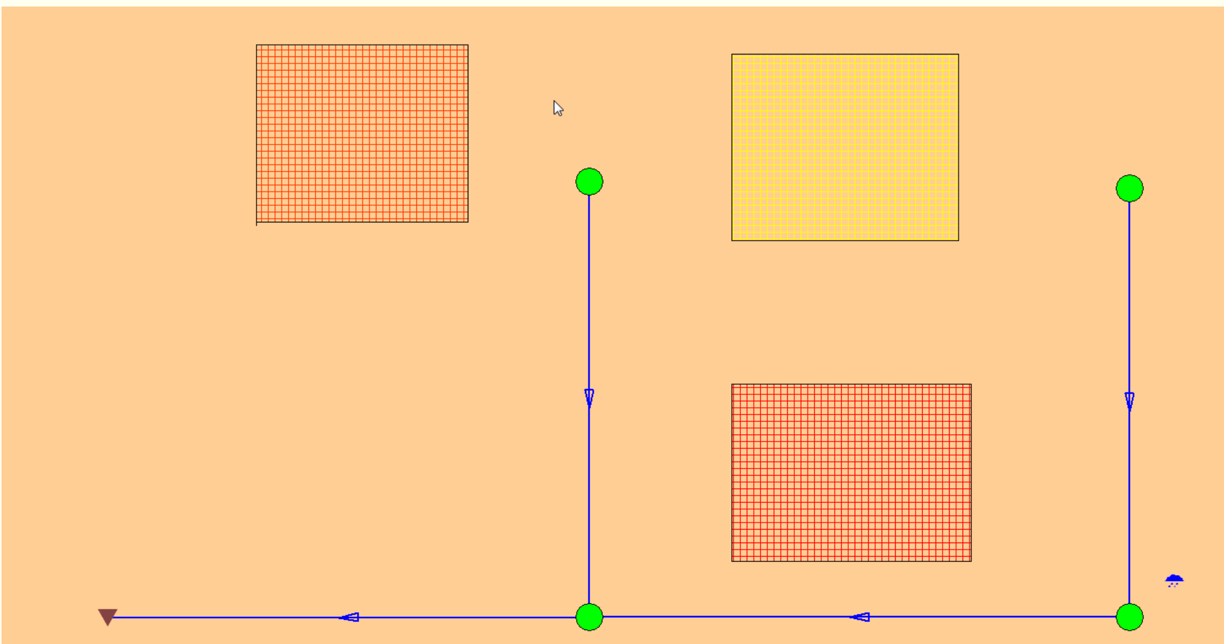
See the Help file Topic Contact Us for detailed Innovyze Technical Support information.

Conventions for InfoSWMM

This guide uses the following typographic conventions: *ITALIC CAPS* InfoSWMM menu titles, menu choices, and commands: Choose *OPEN* from the *FILE* menu.

Dialog box and window titles, and specific areas within a dialog box or window (InfoSWMM and InfoSWMM Calibrator): Choose the “Subcatchment” button from theInfoSWMM *CALIBRATOR* dialog box.

Bold Name ofInfoSWMM Calibrator project: The tutorial makes use of a sample InfoSWMM project named “**Yourcitycal**”.



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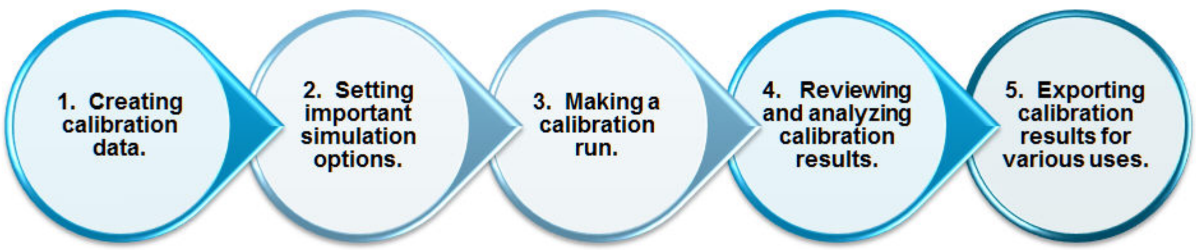
Step 1: Start of Tutorial One

The Quick-Start tutorial is designed for first-time users of InfoSWMM Calibrator and provides a guided tour to core commands and functions used to create and execute a calibration run in InfoSWMM . As such, it should be used as a launching point to a more comprehensive understanding of the program.

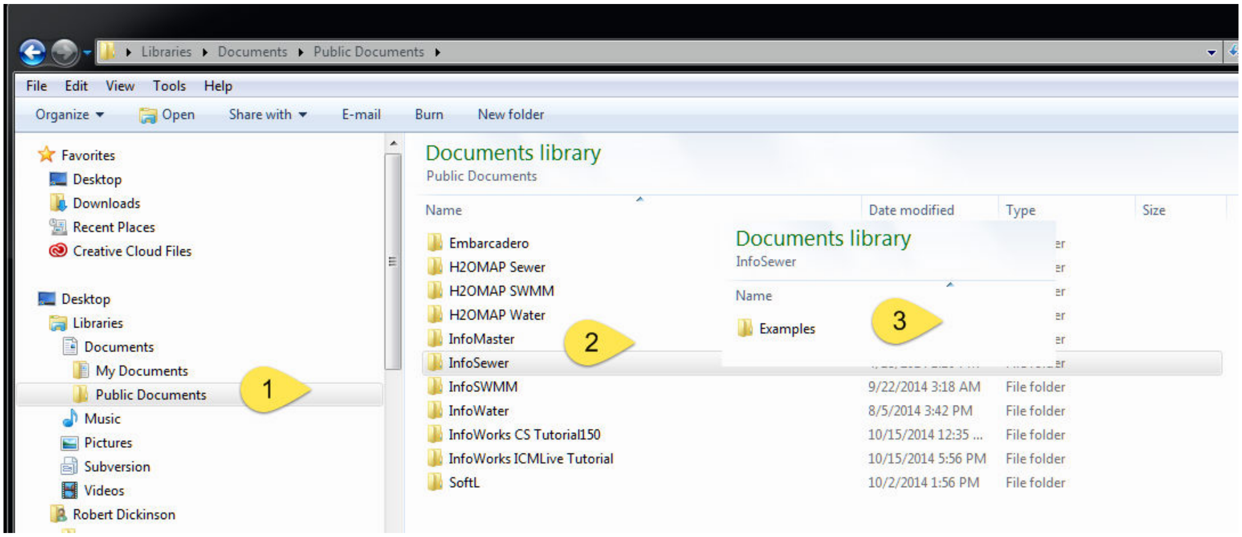
The estimated time to complete the Quick Start tutorial is approximately one hour.

The Quick Start tutorial will help first-time users become familiar with the following:

- 1. Creating calibration data.
- 2. Setting important simulation options.
- 3. Making a calibration run.
- 4. Reviewing and analyzing calibration results.
- 5. Exporting calibration results for various uses.



All of the @innovzye sample files are in the Public Documents/ Name of Software / Examples folder

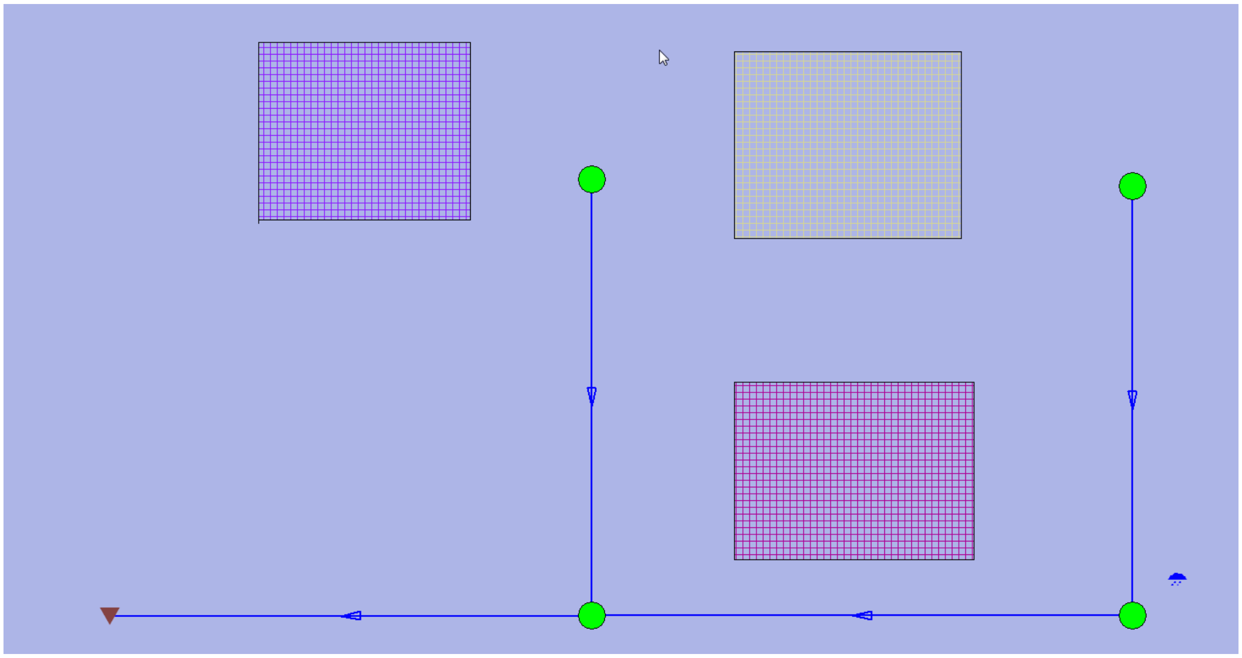


During the Quick Start tutorial, the user will modify an existing project called “**Yourcitycal**”. This project is provided with the typical InfoSWMM Calibrator software installation and can be found in the InfoSWMM Examples directory:

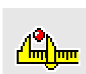
C:\Program Files\INFOSWMM Version X\Examples\ **Yourcitycal.mxd**

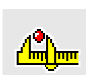
(May be different for custom installations).

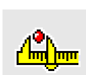
The “**Yourcitycal**” project modified in this tutorial illustrates how the module adjusts some of InfoSWMM parameters to best match field measurements to model simulation results. Note that the calibrable parameters used here are only to demonstrate how to use the calibration module. InfoSWMM Calibrator has the capability to optimize more than fifty different parameters. The “**Yourcitycal**” model schematic is shown below.

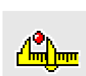


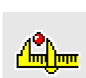
The model consists of the following network components:

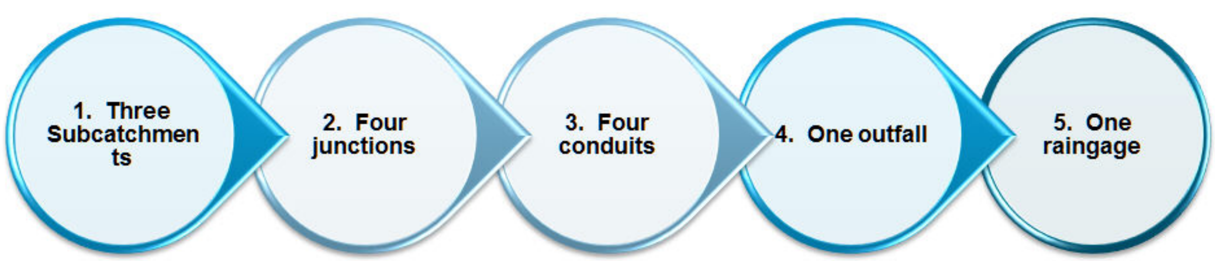
 **1. Three subcatchments**

 **2. Four junctions**

 **3. Four conduits**

 **4. One outfall**

 **5. One raingage**



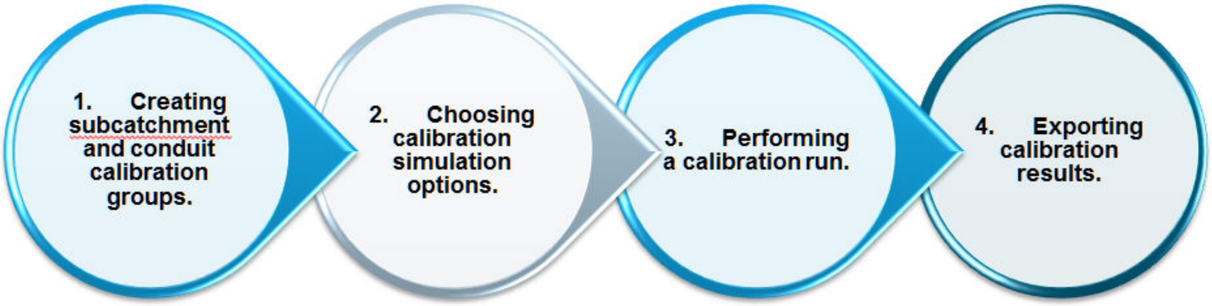
During the tutorial, you will be guided through:

1. Creating Subcatchment and conduit calibration groups.

2. Choosing calibration simulation options.

3. Performing a calibration run.

4. Exporting calibration results.



The first step is to open the InfoSWMM project.

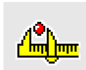
1. From the "Start" menu, select Programs, choose the InfoSWMM program group, and then choose InfoSWMM .

2. Select *OPEN* from the *FILE* menu. On the *SPECIFY AN EXISTING InfoSWMM PROJECT FILE* dialog box, navigate to the directory containing the "**Yourcitycal**" project and choose that InfoSWMM project.

C:\Program Files\INFOSWMM Version X\Examples\
Yourcitycal.mxd

(May be different for custom installations)

3. Click on the *PURPLE DOWN ARROW* icon to initialize InfoSWMM. Click on the "Close" button on the initiated *LIVE UPGRADE/UPDATE CHECKER* dialog. When InfoSWMM is initialized, the icons on the InfoSWMM toolbars will be enabled for use.

 4. Before continuing, save the “**Yourcitycal**” project to a new project name. If you wish to restart the tutorial, the original project will be available. Choose the *SAVE AS* command from the *FILE* menu. On the dialog box, enter the new project name “**Tutorial**”. This becomes the active project.

Step 2: Select Subcatchment Calibration Groups

Rainfall-runoff modeling involves a number of parameters and is subject to a great deal of uncertainty. As such it is the best candidate for calibration to achieve uncertainty reduction through parameter optimization. In this tutorial you will define ten subcatchment parameters (e.g., subcatchment width, percent Imperviousness, etc), and three infiltration parameters (Horton's maximum infiltration rate, Horton's minimum infiltration rate).

Therefore, you will create ten subcatchment calibration groups and three soil calibration groups in this tutorial. Using InfoSWMM

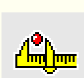
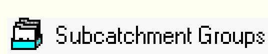
Calibrator, the modeler can optimize many more model parameters. Please note that subcatchments in the same group may or may not have the same parameter value. InfoSWMM

Calibrator optimizes a multiplying factor (not the

actual parameter value) that is multiplied by the original value assigned to the parameter for the individual element (e.g., width is 400 ft in this case for all the three subcatchments) to determine the actual value used to simulate runoff during the calibration process. All subcatchments in the same group use the same multiplying factor, but the original parameter value assigned to the subcatchments may or may not be the same. This approach offers the flexibility to handle variation in the characteristics of subcatchments and other objects.

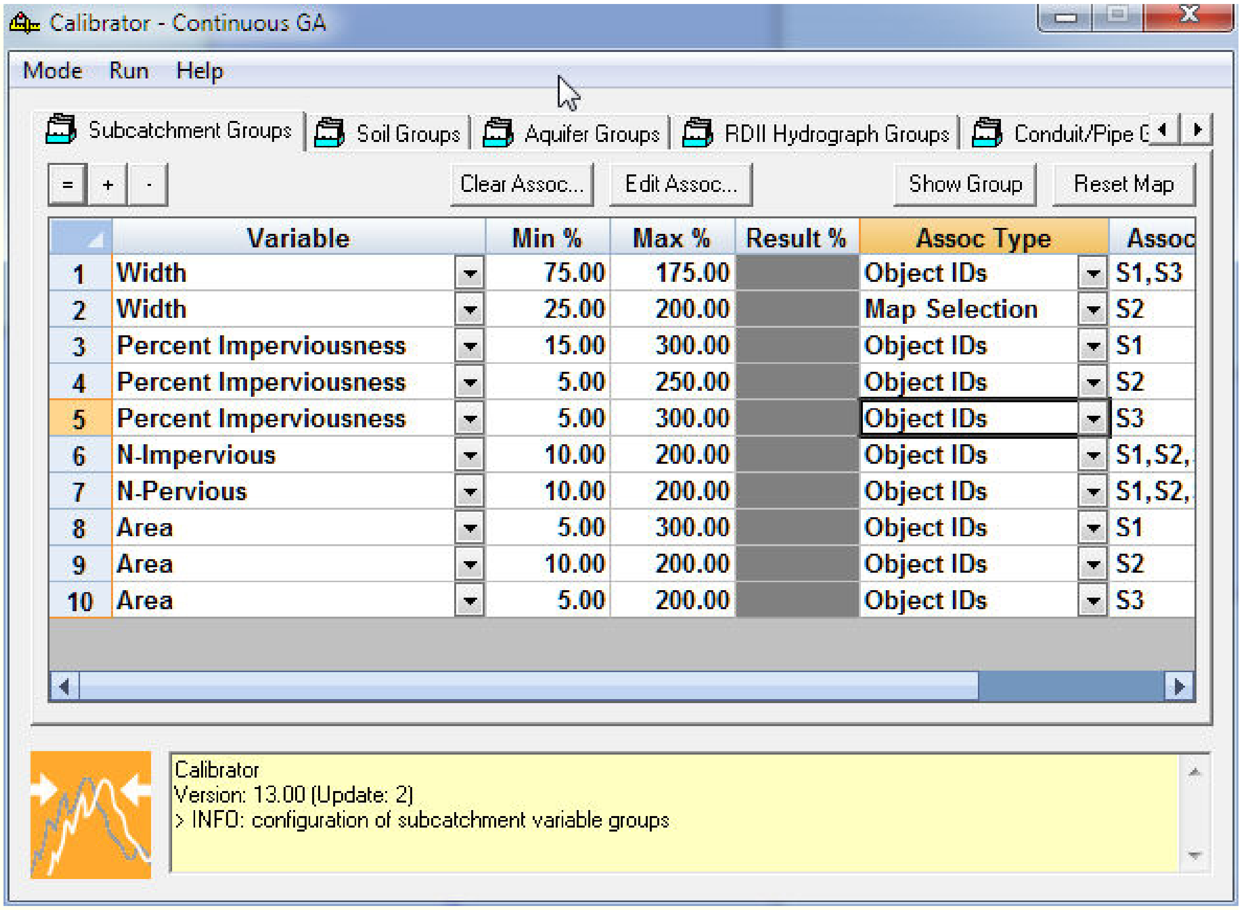
For this example,

ten subcatchment groups have already been created. However, to create different subcatchments groups, the following steps would be required.

 Select the "Subcatchment Group" button 

and select the parameter to be calibrated (e.g., Width) for the *VARIABLE*

field.



Choose the Object ID for the *ASSOC TYPE* field, and type ID of the subcatchment (s) to be part of the group in the *ASSOC ID* column. Please note that you could choose how to assign subcatchment IDs using any one of the available options (i.e., Object ID, Map Selection, Selection Set, DB Query, or Query Set).

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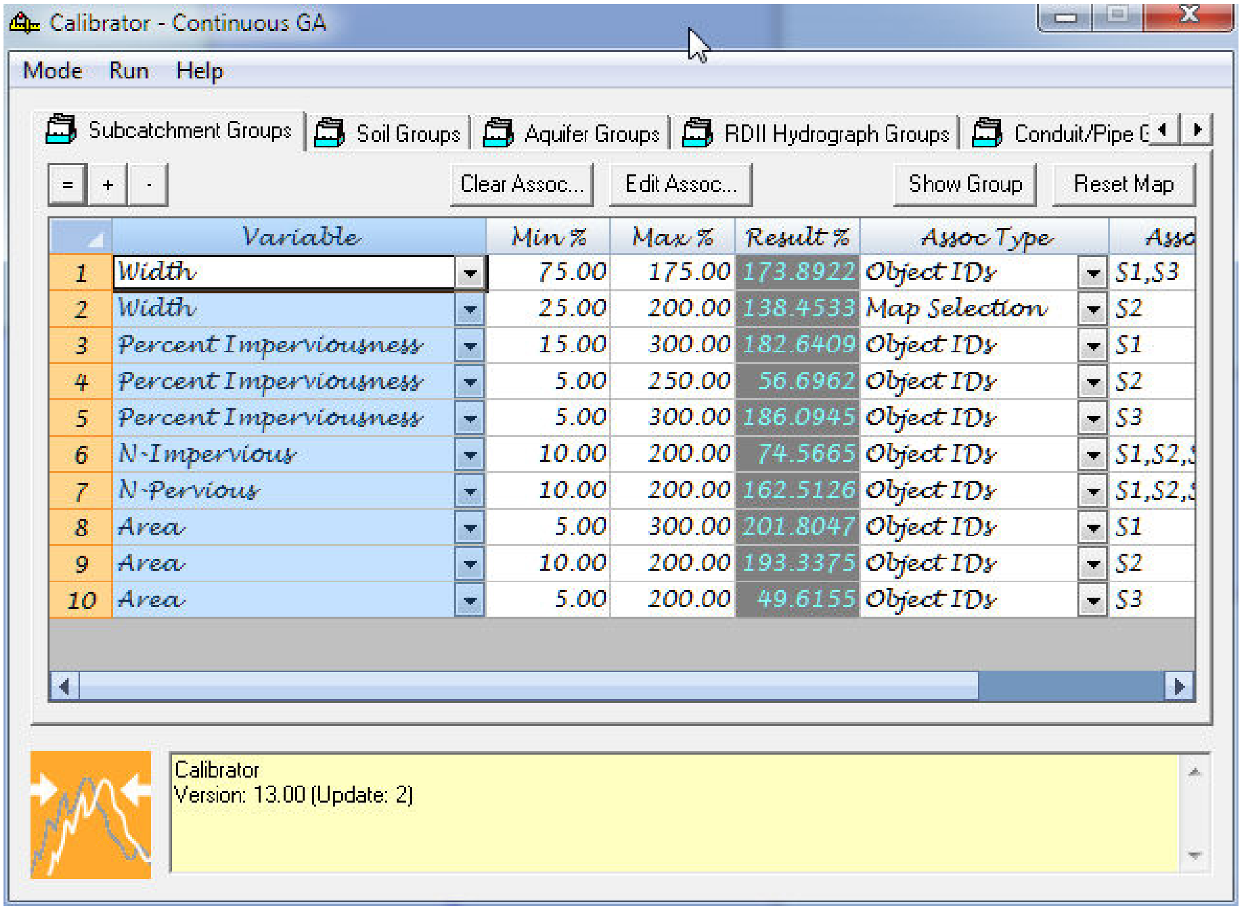
Step 3: Define Bounds for Subcatchment Parameters Multipliers

The next step is to define the desired minimum and maximum limits (in percent) for the multiplier of Subcatchment parameters for each of the ten calibration groups. Use the table below as a guide when entering this data.

GROUP ID	MIN (%)	MAX (%)
1	50	175
2	25	200
3	15	300
4	5	250
5	5	300
6	10	200
7	10	200
8	5	300
9	10	200
10	5	200

Based on the multiplier percentages specified above, for example, the Subcatchment width in group 1 will vary within 50 to 175% of the original width assigned to the Subcatchments in the group (i.e., 400 ft for both Subcatchments). Width of Subcatchment S2 could vary within 25% to 200% of the original width assigned to the Subcatchment (i.e., 400 ft).



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Step 4: Select Soil Calibration Groups

In this tutorial, you also need to calibrate two of Horton's infiltration parameters. The next step is therefore, to define the soil calibration groups. Soils should be grouped together based on their similarity in infiltration property such as soil type and texture.

For this example, three soil calibration groups have already been created. However, to create different soil groups, the following steps would be required.

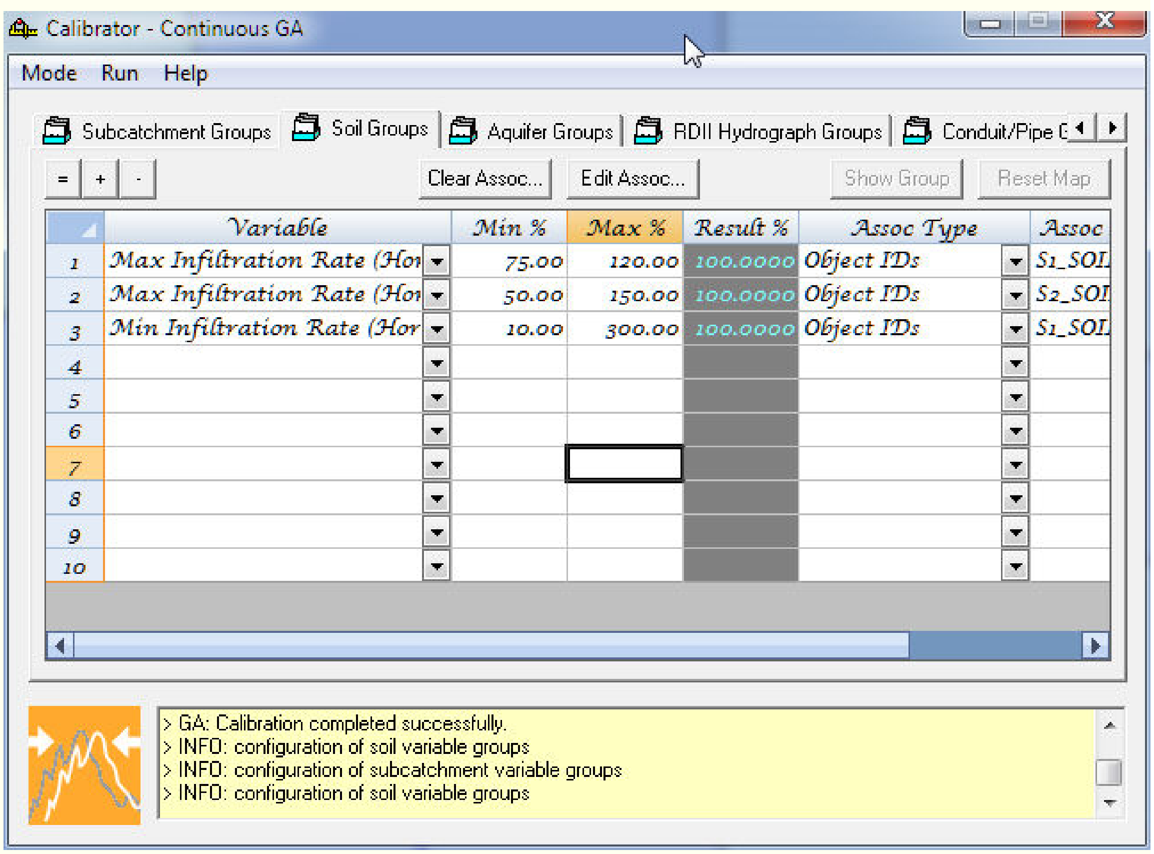
- Select the

  "Soil Group" button 

  and select the parameter to be calibrated (e.g., maximum infiltration rate) for the *VARIABLE* field.

- Choose the

  Object ID for the *ASSOC TYPE* field, and type ID of the soils (s) to be part of the group in the *ASSOC ID* column.



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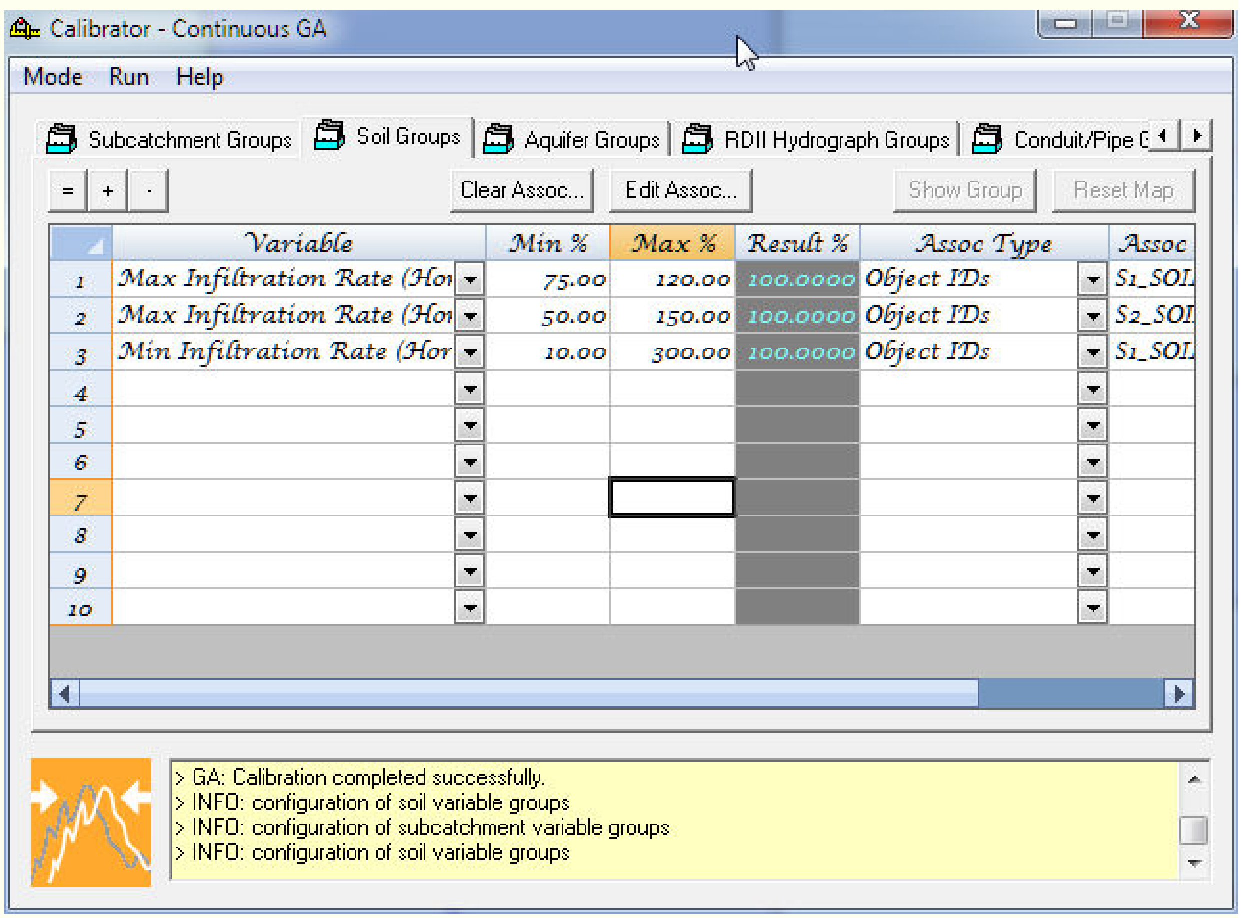
Step 5: Define Bounds for Infiltration Rate Multipliers

The next step is to define the desired minimum and maximum limits for the infiltration rate parameters for each group. Use the table below as a guide when entering this data.

GROUP ID	MIN %	MAX %
1	75	120
2	50	150
3	10	300

The *Soil Group* page should now appears as follows.



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Step 6: Specify Measurement Data

You will now specify the measurements at target conduits to which the system needs to be calibrated. The measurements could be flow, depth, or velocity. In this tutorial you will specify and use a 24-hour flow data measured at intervals of 15-munite at conduit C4. The measurement data is specified in the form of Time Series. A time series has three columns: date (contains month, day, and year information), time of the day, and value columns.

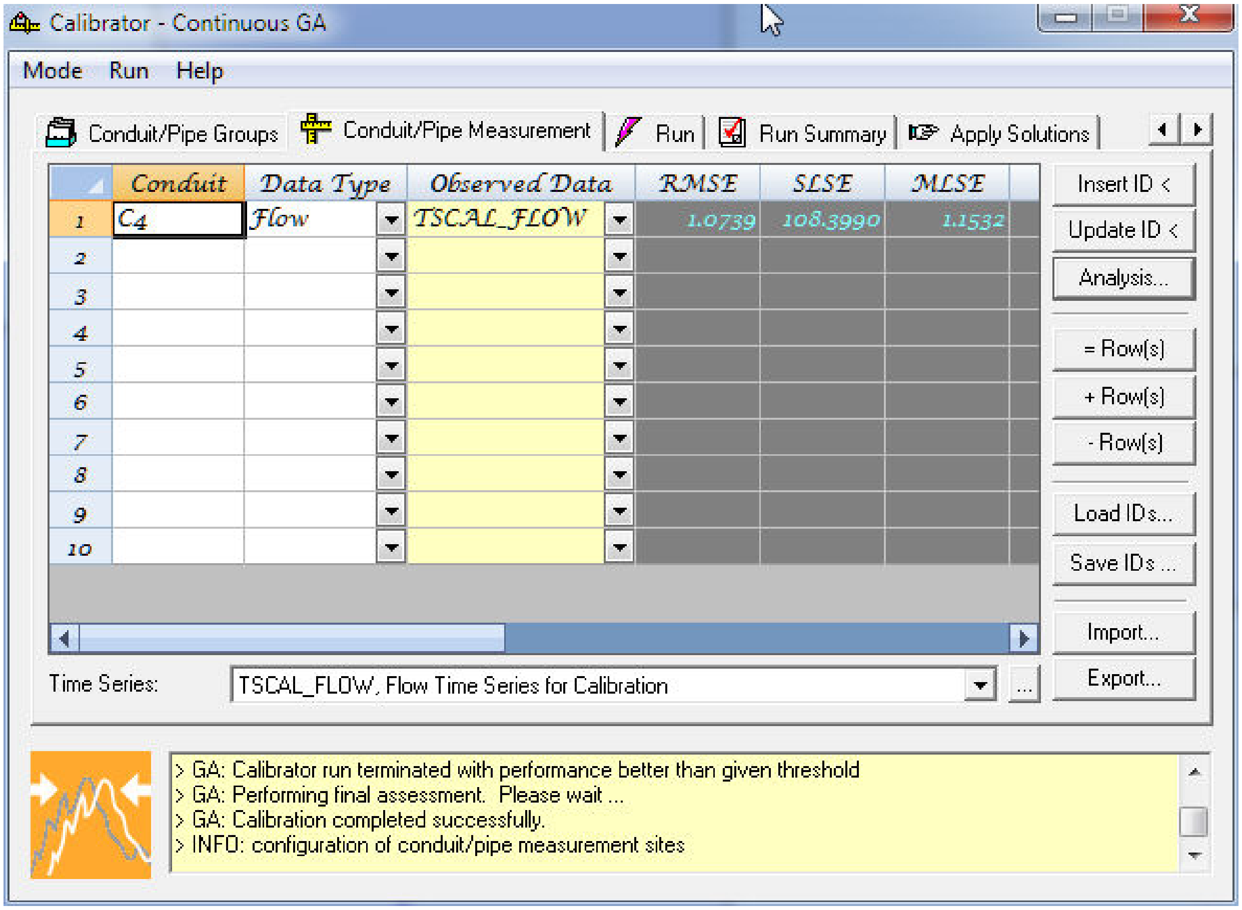
To define the measurement data,

- Select the "Conduit Measurement Group" button 

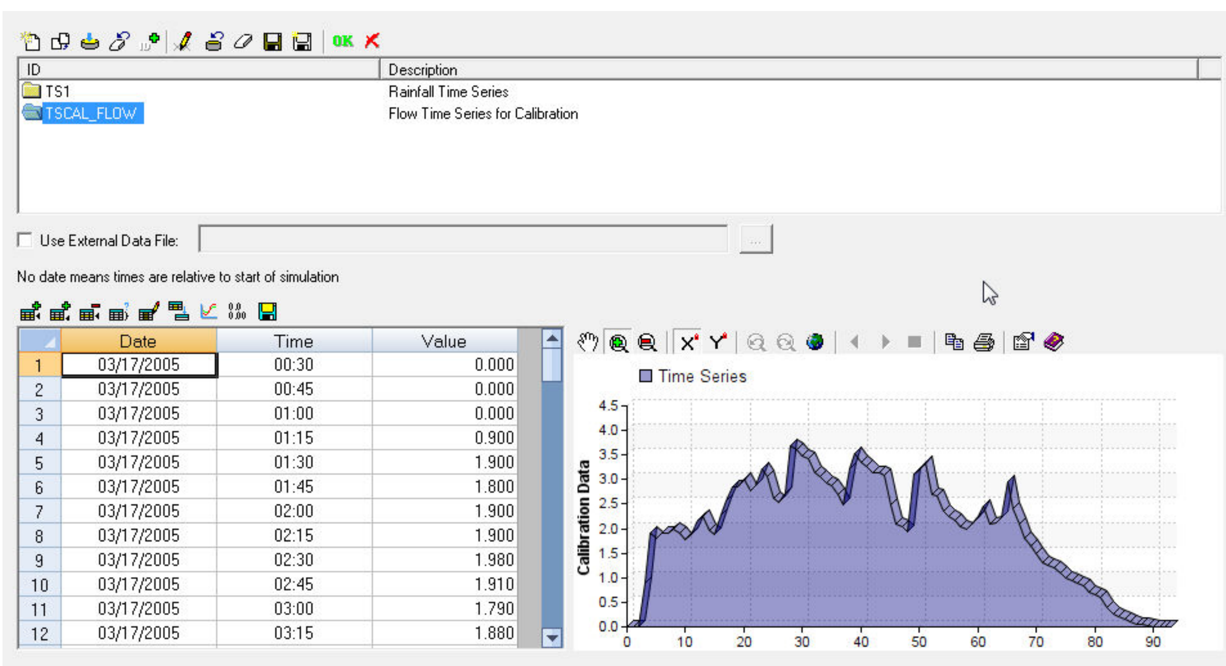
 and insert the conduit ID (i.e., C4) where the measurement is taken to the *CONDUIT ID* field. You could also click on the 

 button and graphically select the conduit.
- Choose *Flow* for the *DATA TYPE* field.
- Specify "TSCAL_FLOW" time series for the *OBSERVED DATA* field.

The *Conduit Measurement* dialog editor should now appears as follows.



- What the Calibration data looks like as a time series in the Operation Tab of the Attribute Browser (AB).



- What the Calibration data looks like as a Calibration data file. The calibration data file has the format (as described in the SWMM5 Help file)

Calibration Files contain measurements of variables at one or more locations that can be compared with simulated values in Time Series Plots. Separate files can be used for each of the following:

- Subcatchment Runoff
- Subcatchment Groundwater Flow
- Subcatchment Groundwater Elevation
- Subcatchment Snow Pack Depth
- Subcatchment Pollutant Washoff
- Node Depth
- Node Lateral Inflow
- Node Flooding
- Node Water Quality
- Link Flow
- Link Velocity
- Link Depth

Calibration files are registered to a project by selecting **Project** >> **Calibration Data** from the Main Menu(see Registering Calibration Data).

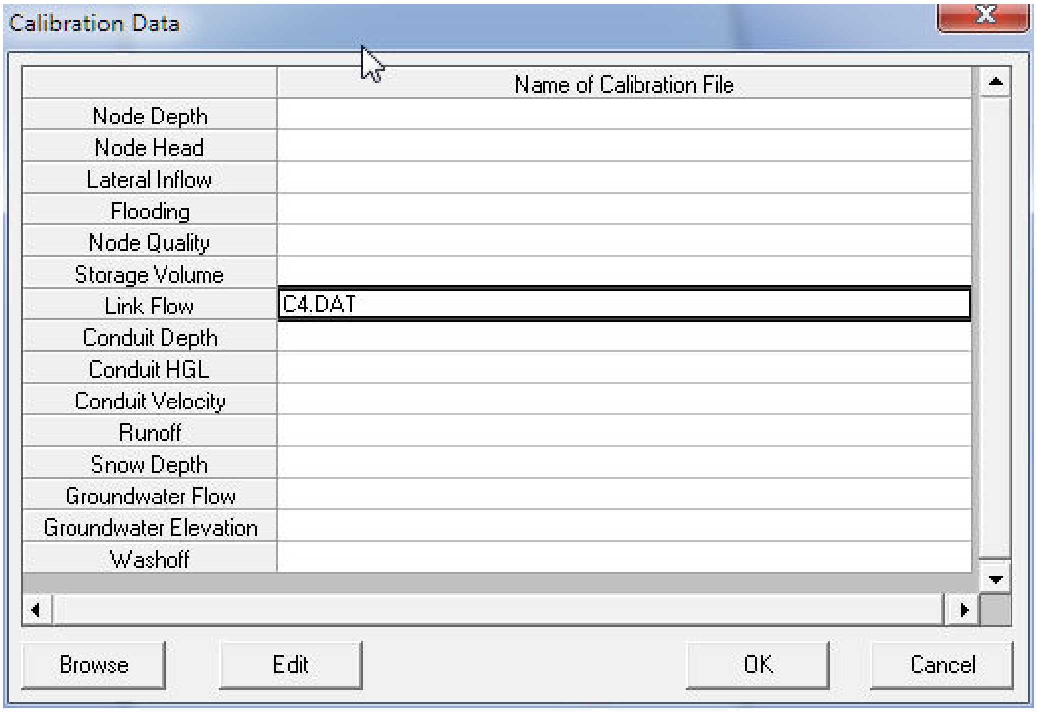
The format of the file is as follows:

1. The name of the first object with calibration data is entered on a single line.
2. Subsequent lines contain the following recorded measurements for the object:
   - measurement date (month/day/year, e.g., 6/21/2004) or number of whole days since the start of the simulation
   - measurement time (hours:minutes) on the measurement date or relative to the number of elapsed days
   - measurement value (for pollutants, a value is required for each pollutant).
3. Follow the same sequence for any additional objects.

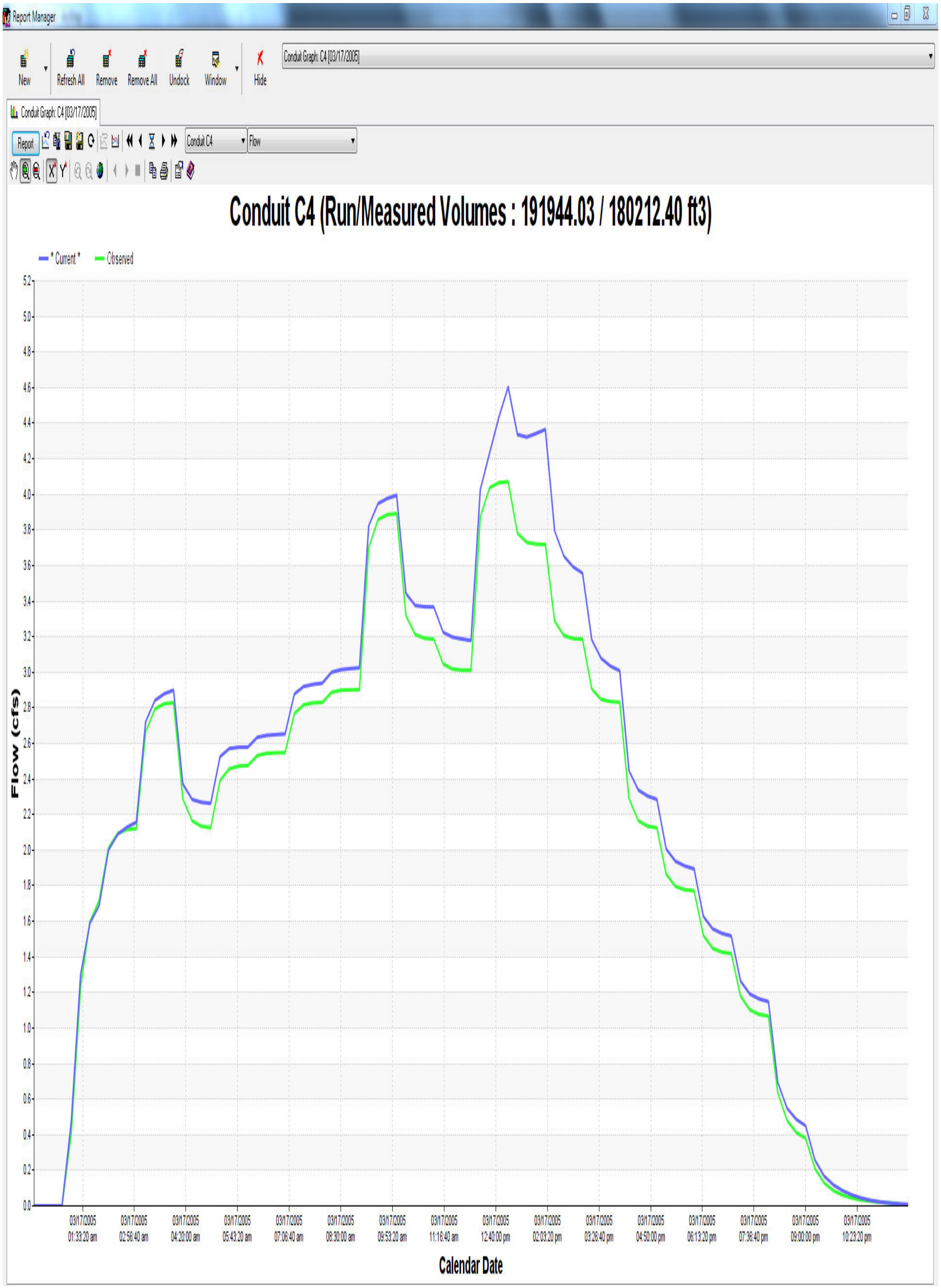
An excerpt from an example calibration file is shown below. It contains flow values for two conduits: 1030 and 1602.Note that a semicolon can be used to begin a comment. In this example, elapsed time rather than the actual measurement date was used.

```
;Flows for Selected Conduits
;Conduit Days Time Flow
;-----------------------------
1030
si 0 0:15 0
  0 0:30 0
  0 0:45 23.88
  0 1:00 94.58
  0 1:15 115.37
1602
  0 0:15 5.76
  0 0:30 38.51
  0 1:00 67.93
  0 1:15 68.01
```

- It is used or accessed using the Calibration Data Dialog.



- if you plot a node, link or Subcatchment with Calibration data it shows both Run (Simulated) and Observed from the Calibration File on the same graph.


Report Manager
New
Refresh All
Remove
Remove All
Undock
Window
Hide
Conduit Graph: C4 [03/17/2005]
Report
Conduit C4
Flow
Conduit C4 (Run/Measured Volumes : 191944.03 / 180212.40 ft3)
* Current *
Observed
Flow (cfs)
Calendar Date
03/17/2005 01:33:20 am
03/17/2005 02:56:40 am
03/17/2005 04:20:00 am
03/17/2005 05:43:20 am
03/17/2005 07:06:40 am
03/17/2005 08:30:00 am
03/17/2005 09:53:20 am
03/17/2005 11:16:40 am
03/17/2005 12:40:00 pm
03/17/2005 02:03:20 pm
03/17/2005 03:26:40 pm
03/17/2005 04:50:00 pm
03/17/2005 06:13:20 pm
03/17/2005 07:36:40 pm
03/17/2005 09:00:00 pm
03/17/2005 10:23:20 pm

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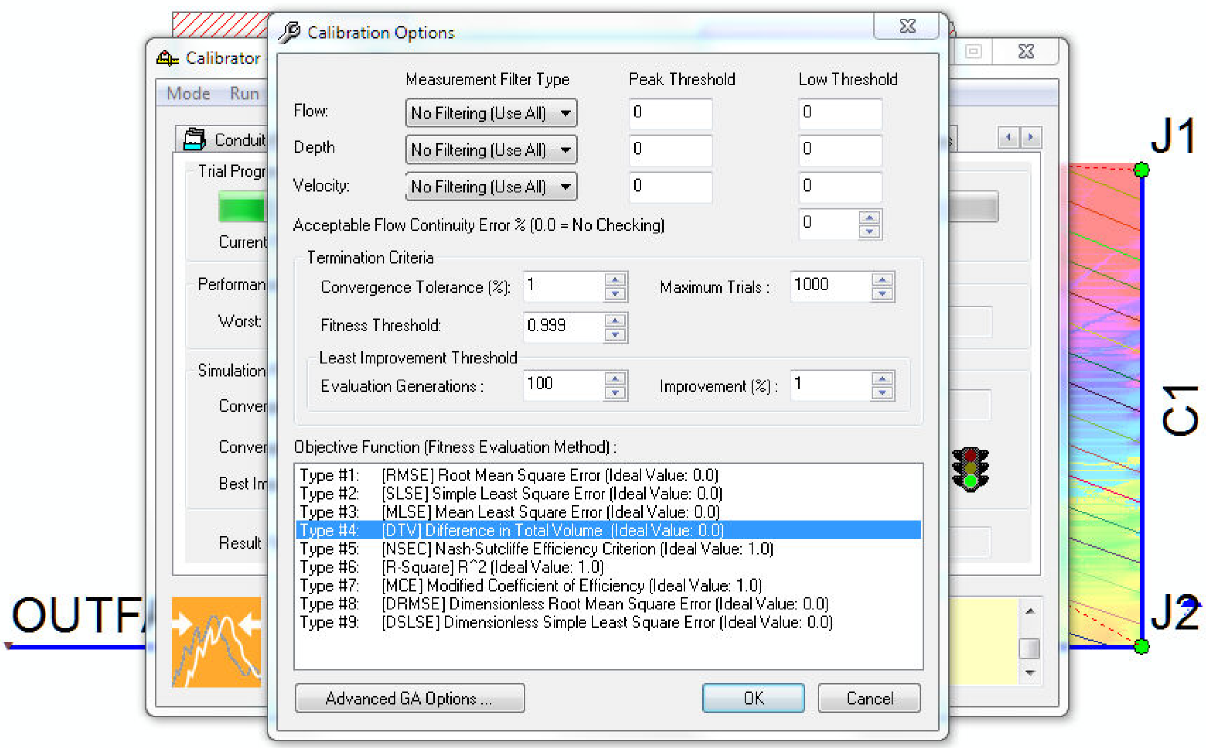
Step 7: Select Calibration Run Options

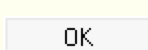
Now that you have completed the process of creating a calibration run, the next step is to define your calibration run options. You will specify a Type 6 objective function (R-Square), a "Convergence Toleraance" of 1%, a "Fitness Threshold"

of 95 % or 0.95

- Choose the "Options" command from the Run menu and enter the data shown below in the *Calibration Options* dialog box.



- Press

  the "OK" button 

 to close the dialog box.

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Step 8 - Starting Data for the Subcatchments

- This is the starting

  data for the Subcatchments

Subcatchment ID (Char) Raingage ID (Char) Receiving Node ID (Char) Subcatchment Area (ac) Subcatch. Imperviousness(%) (Double) Subcatchment Width (ft) Subcatchment Slope (Double) Subcatchment Curb Length (Double) Snow Pack ID (Char) Manning's N for Imperv. Portion (Double) Manning's N for Pervios Portion (Double) Depression Stor. for Imp. Portion (in) Depression Stor. for Perv. Portion (in) % of Imperv.

Part w/o Dep. Stor. (Double) Runoff Routing Destination (Int) S1 GAGE1 J1 4.000 22.520 191.570 0.500 0.000

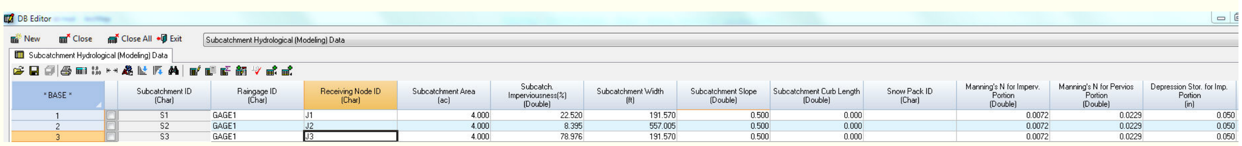
0.0072 0.0229 0.050 0.050 25.000 0: Outlet

S2 GAGE1 J2 4.000 8.395 557.005 0.500 0.000

0.0072 0.0229 0.050 0.050 25.000 0: Outlet

S3 GAGE1 J3 4.000 78.976 191.570 0.500 0.000

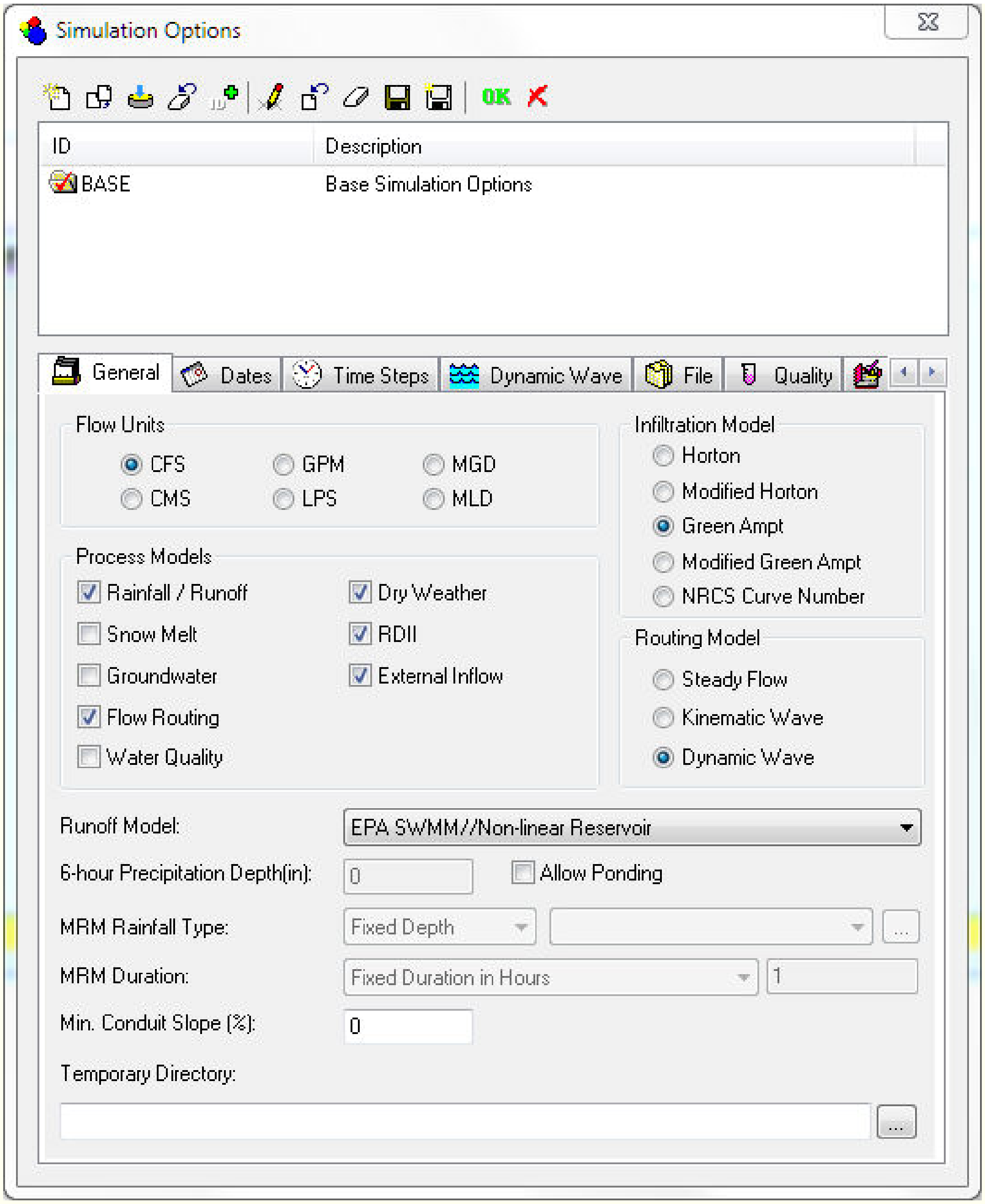
0.0072 0.0229 0.050 0.050 25.000 0: Outlet



* BASE *		Subcatchment ID (Char)	Raingage ID (Char)	Receiving Node ID (Char)	Subcatchment Area (ac)	Subcatch. Imperviousness(%) (Double)	Subcatchment Width (ft)	Subcatchment Slope (Double)	Subcatchment Curb Length (Double)	Snow Pack ID (Char)	Manning's N for Imperv. Portion (Double)	Manning's N for Pervios Portion (Double)	Depression Stor. for Imp. Portion (in)
1		S1	GAGE1	J1	4.000	22.520	191.570	0.500	0.000		0.0072	0.0229	0.050
2		S2	GAGE1	J2	4.000	8.395	557.005	0.500	0.000		0.0072	0.0229	0.050
3		S3	GAGE1	J3	4.000	78.976	191.570	0.500	0.000		0.0072	0.0229	0.050

- This is the process

  flags used in the model at the start


Simulation Options
ID
Description
BASE
Base Simulation Options
General
Dates
Time Steps
Dynamic Wave
File
Quality
Flow Units
CFS
GPM
MGD
CMS
LPS
MLD
Infiltration Model
Horton
Modified Horton
Green Ampt
Modified Green Ampt
NRCS Curve Number
Process Models
Rainfall / Runoff
Dry Weather
Snow Melt
RDII
Groundwater
External Inflow
Flow Routing
Water Quality
Routing Model
Steady Flow
Kinematic Wave
Dynamic Wave
Runoff Model:
EPA SWMM//Non-linear Reservoir
6-hour Precipitation Depth(in):
0
Allow Ponding
MRM Rainfall Type:
Fixed Depth
MRM Duration:
Fixed Duration in Hours
1
Min. Conduit Slope (%):
0
Temporary Directory:

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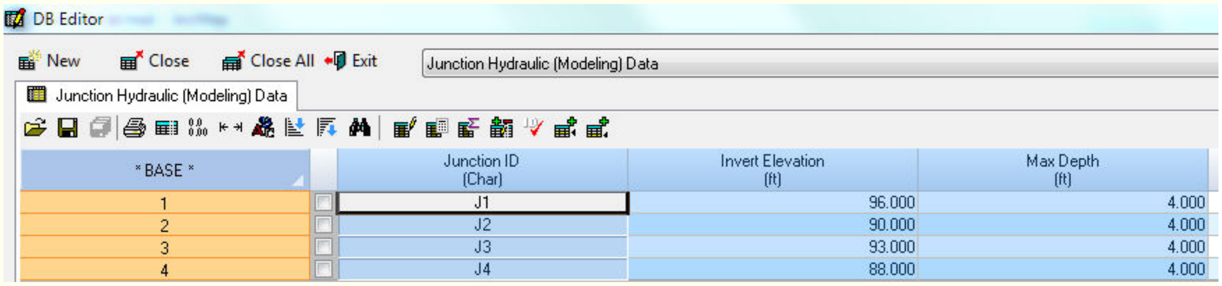
Step 9 - Starting Data for the Links and Nodes



* BASE *		Junction ID (Char)	Invert Elevation (ft)	Max Depth (ft)
1		J1	96.000	4.000
2		J2	90.000	4.000
3		J3	93.000	4.000
4		J4	88.000	4.000

Junction

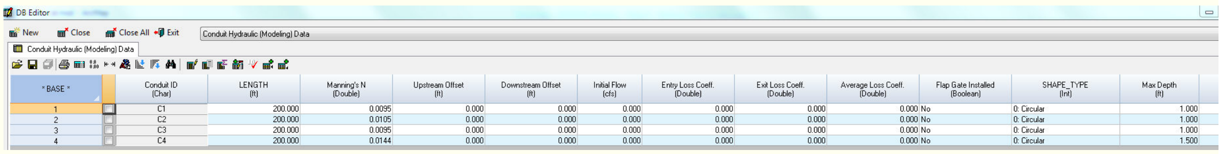
ID (Char) Invert Elevation (ft) Max Depth (ft)

J1 96.000 4.000

J2 90.000 4.000

J3 93.000 4.000

J4 88.000 4.000


DB Editor

New | Close | Close All | Exit | Conduit Hydraulic (Modeling) Data

Conduit Hydraulic (Modeling) Data

* BASE *		Conduit ID (Char)	LENGTH (ft)	Manning's N (Double)	Upstream Offset (ft)	Downstream Offset (ft)	Initial Flow (cfs)	Entry Loss Coeff. (Double)	Exit Loss Coeff. (Double)	Average Loss Coeff. (Double)	Flap Gate Installed (Boolean)	SHAPE_TYPE (Int)	Max Depth (ft)
1		C1	200.000	0.0095	0.000	0.000	0.000	0.000	0.000	0.000	No	0: Circular	1.000
2		C2	200.000	0.0105	0.000	0.000	0.000	0.000	0.000	0.000	No	0: Circular	1.000
3		C3	200.000	0.0095	0.000	0.000	0.000	0.000	0.000	0.000	No	0: Circular	1.000
4		C4	200.000	0.0144	0.000	0.000	0.000	0.000	0.000	0.000	No	0: Circular	1.500

Conduit

ID (Char) LENGTH (ft) Manning's N (Double) Upstream Offset (ft) Downstream Offset (ft) Initial Flow (cfs) Entry Loss Coeff. (Double) Exit Loss Coeff.

(Double) Average Loss Coeff. (Double) Flap Gate Installed (Boolean) SHAPE_TYPE

(Int) Max Depth (ft)

C1 200.000 0.0095 0.000 0.000 0.000 0.000 0.000 0.000 No 0: Circular 1.000

C2 200.000 0.0105 0.000 0.000 0.000 0.000 0.000 0.000 No 0: Circular 1.000

C3 200.000 0.0095 0.000 0.000 0.000 0.000 0.000 0.000 No 0: Circular 1.000

C4 200.000 0.0144 0.000 0.000 0.000 0.000 0.000 0.000 No 0: Circular 1.500

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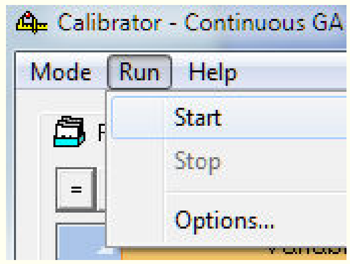
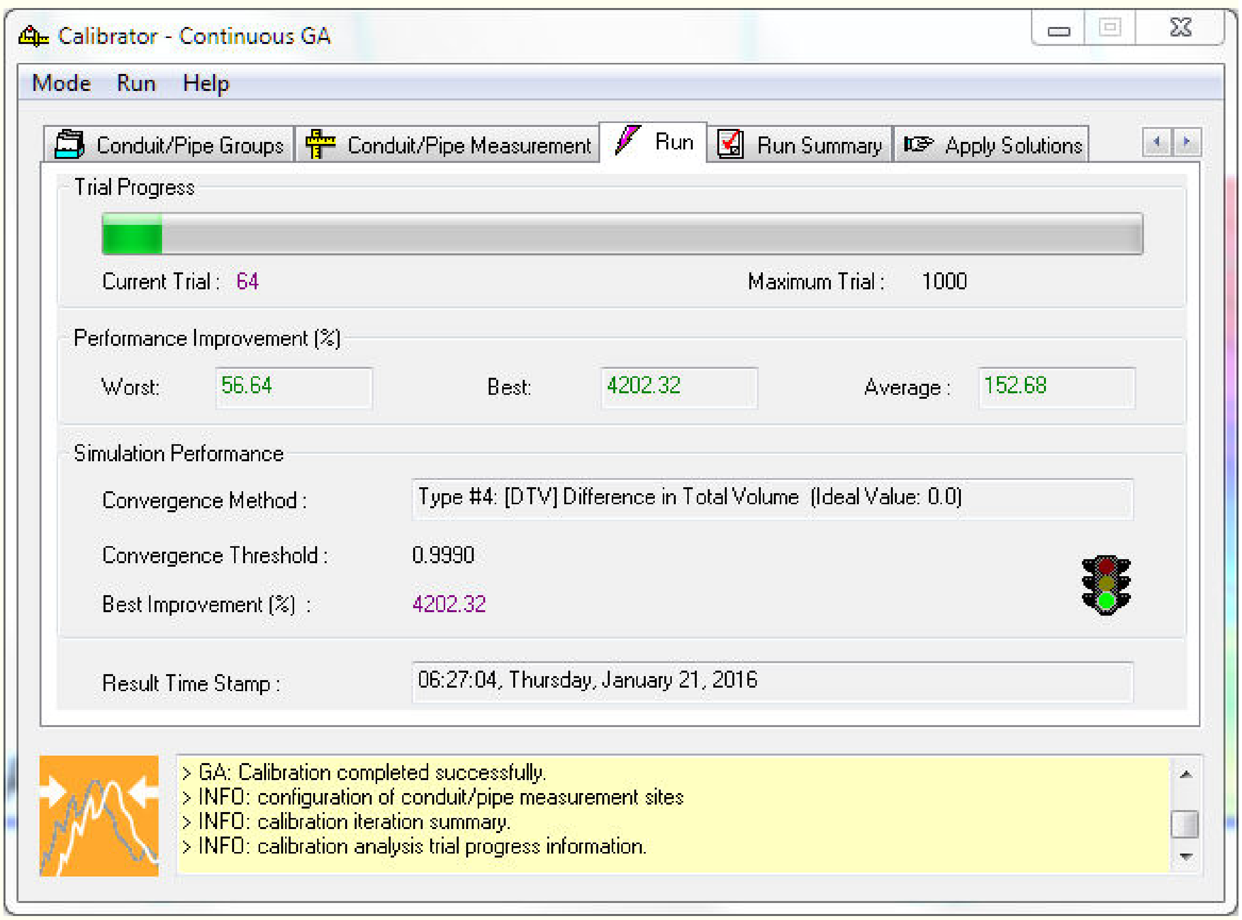
Step 10: Run the Calibration Model

You have now entered all required information for calibration model. To run the calibration model, choose the “Start” command from the Run menu. The *Run* tab appears on the screen.





As shown in the *Run* tab, a fitness of 0.856646 was reached after 1735 trials for the type 2 fitness function specified.

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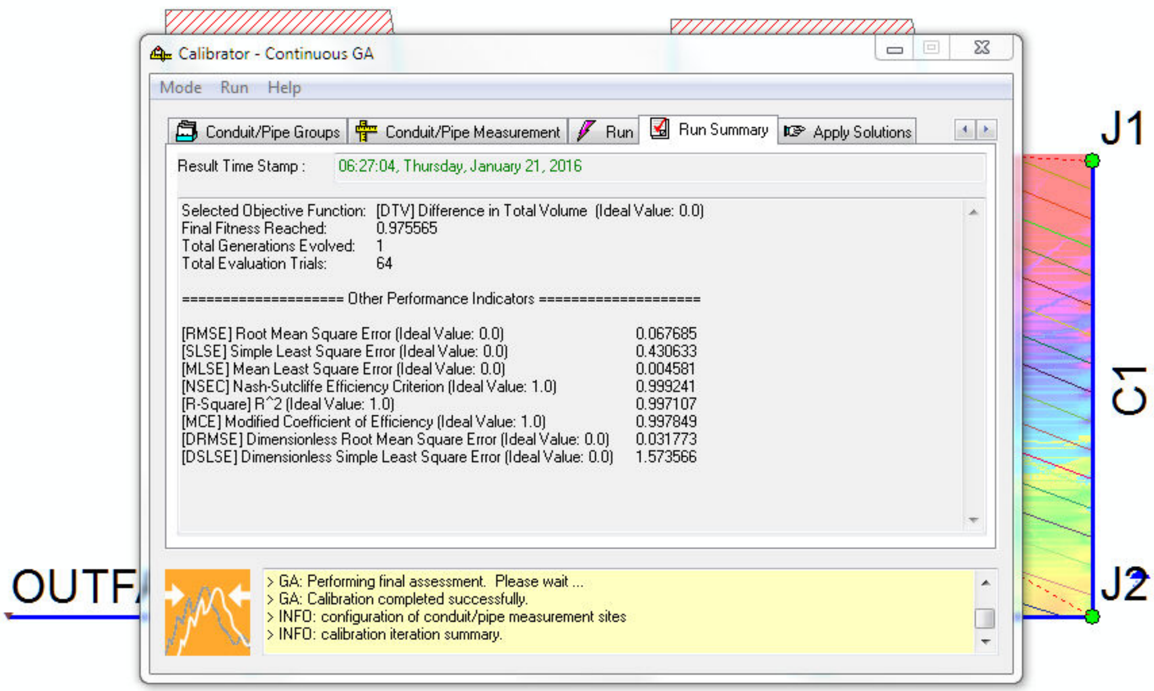
Step 11: Review Calibration Results

The calibration results can be reviewed by choosing the Analysis... tab from the Conduit/Pipe Measurement dialog box and/or using the Run Summary window.

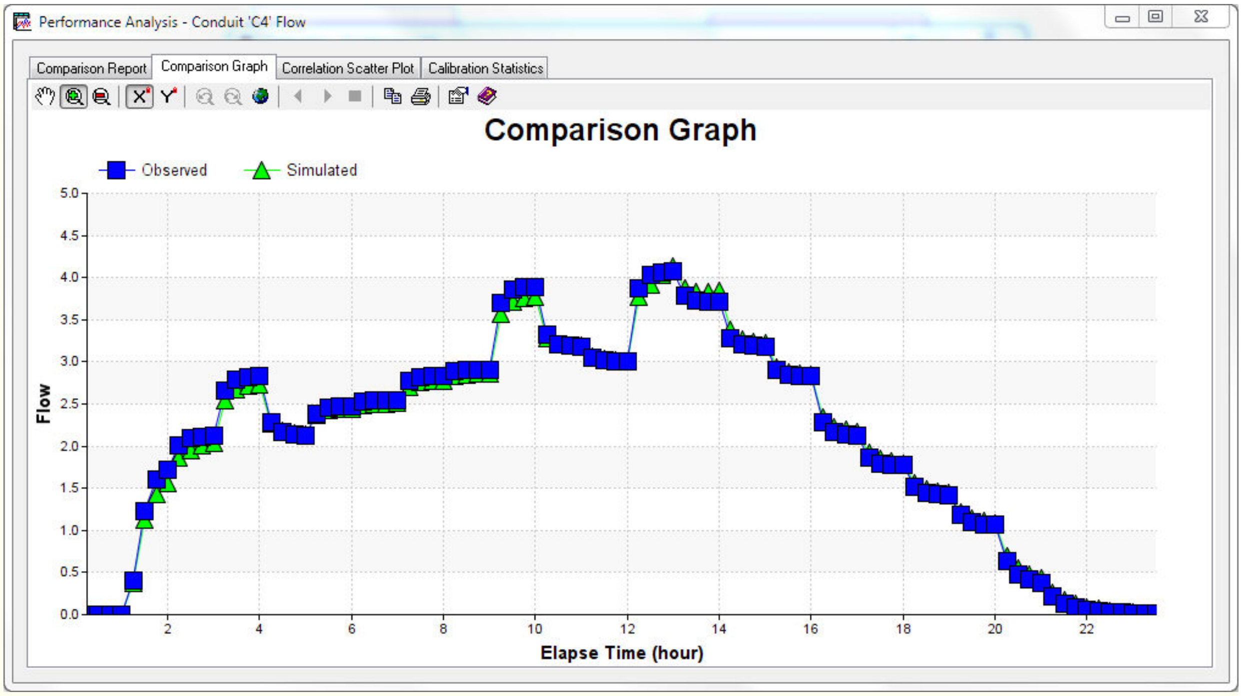
Tabular comparison of observed and

simulated values is given on the comparison report page.



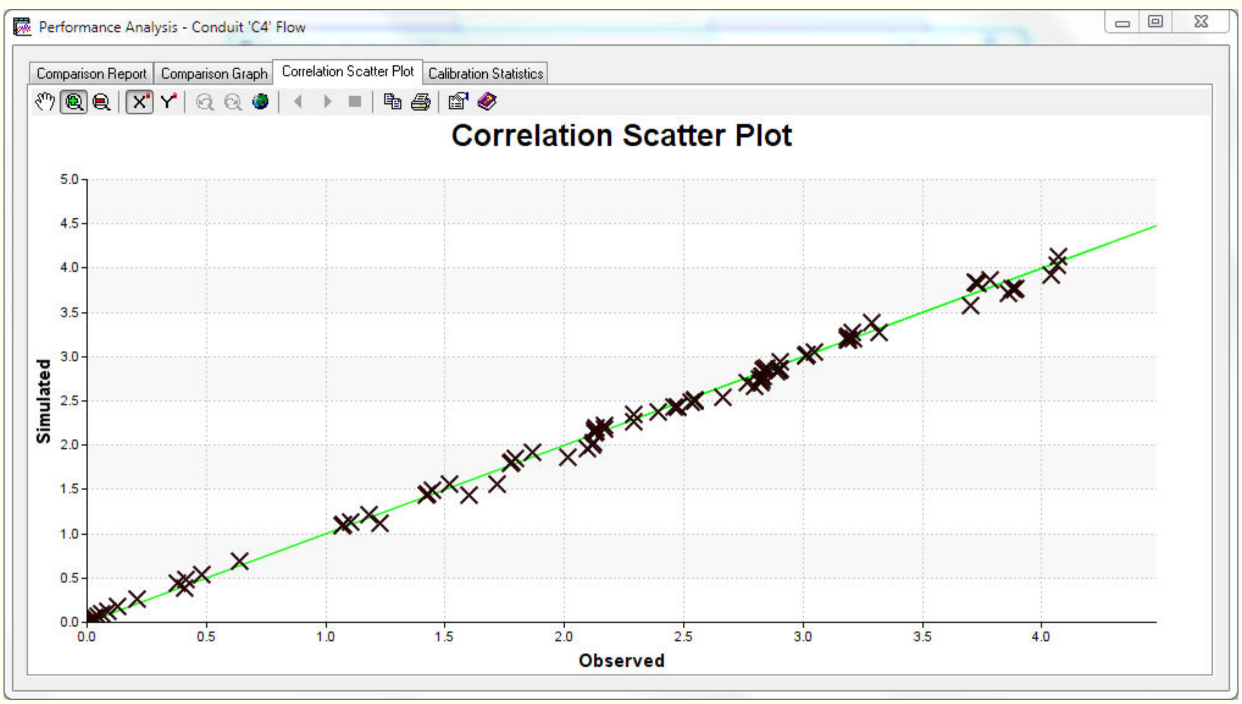
The Comparison Graph page presents

graphical comparison of observed and simulated values.



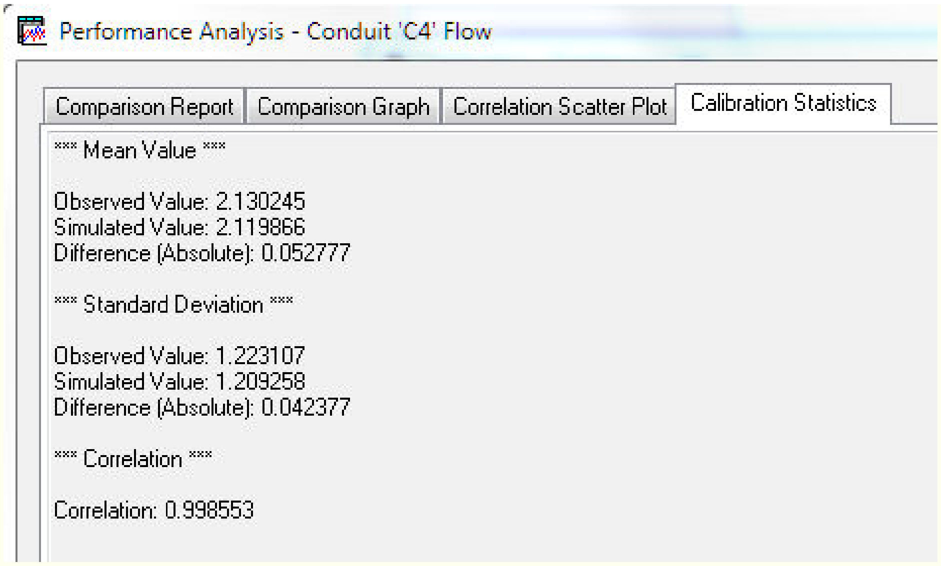
The Correlation Scatter Plot page plots

simulated results against observed value as shown below.



Statistical summary of the performance

of the calibrator is given on the Calibration Statistics page.



The Run Summary page presents summary of basic performance indicators (e.g., basic goodness-of-fit criteria) and summary of the optimization run (e.g., number of simulations, generation number, etc).

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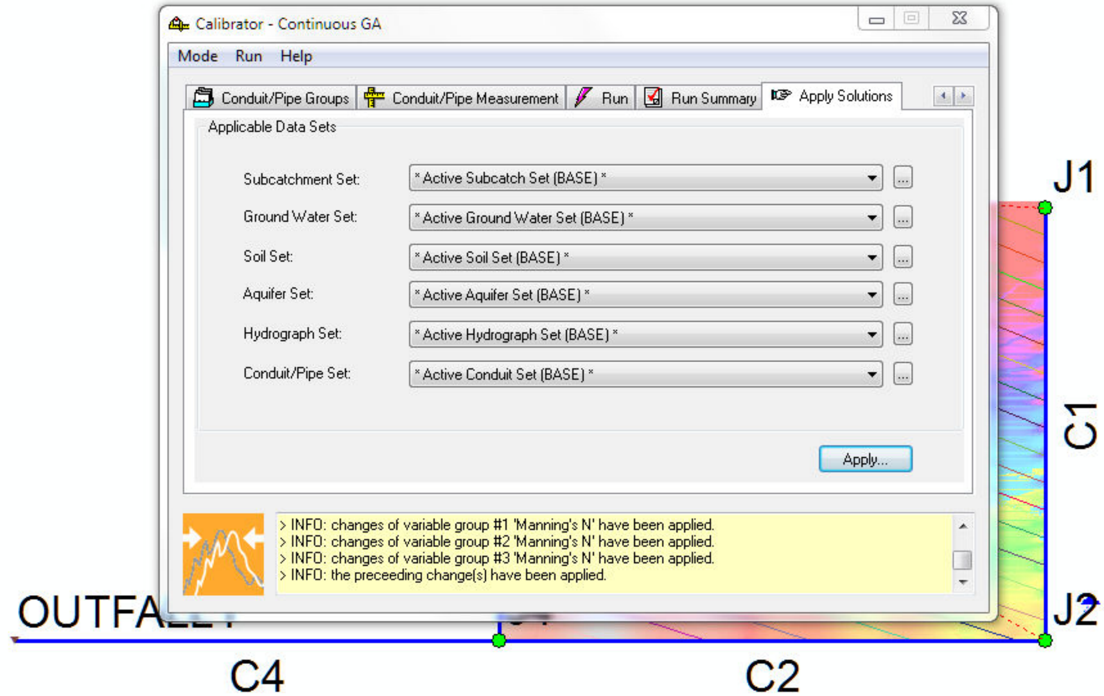
Step 12: Apply Solutions

You can apply the calibration result to the model using the Apply Solutions page. You could select the scenario of your choice to which the calibration result has to be applied.

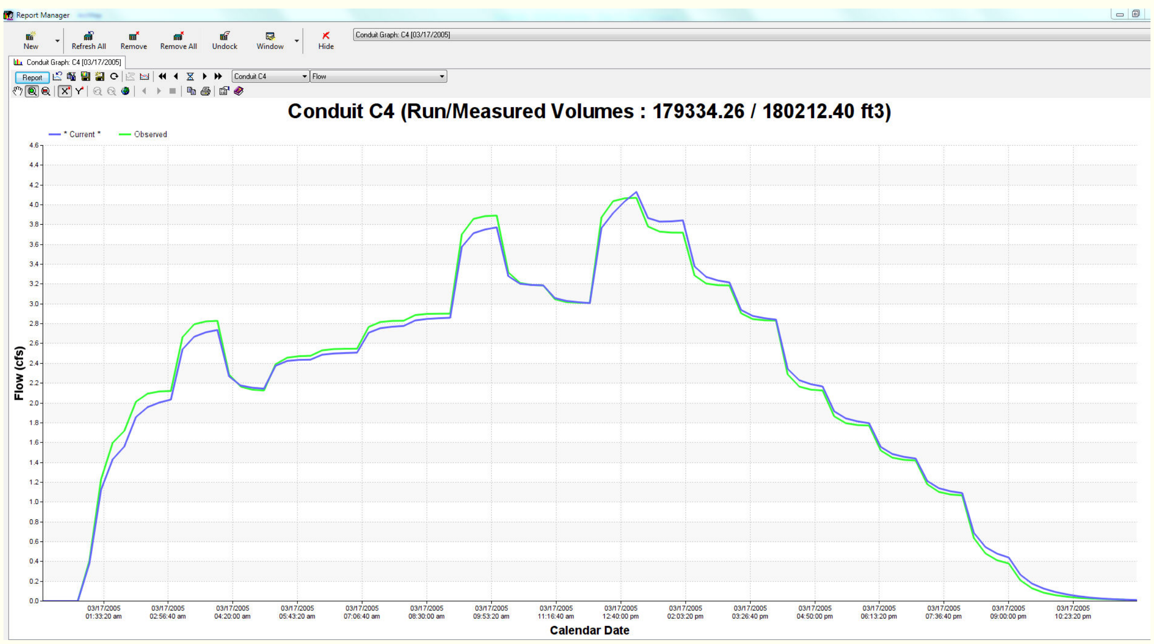
- **1.** Choose the Apply Solutions tab and launch the dialog editor.
- **2.** Choose the desired Data Set IDs for the available groups. You could click on the "…" button to create "New" data set as well.
- **3.** Choose the "Apply" button Apply... to execute the apply command.

  The calibration results are now saved to the appropriate data sets.

  The *Apply Solutions* tab should appear as follows. It should be noted that the apply solution command multiplies the optimal values of the multipliers identified by the calibrator with the original parameter values given to the corresponding elements (e.g., subcatchment); determines actual parameter values; and saves it to the selected data set. If used with the active scenario, the apply button could be used only once. Subsequent usage will have no effect. If used with non-active scenarios, every usage of the apply button will keep on multiplying the current parameter value by the optimal multiplier. Therefore, the user needs to be cautious not to make undesired usage of this essential functionality.



Run the Model and Graph Link C4 Again



Congratulations! You have now completed the calibration tutorial.

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INFOSWMM CALIBRATOR

USERS GUIDE

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TABLE OF CONTENTS

SECTION 4 - METHODOLOGY

PREFACE

INTRODUCTION

Stormwater models are particularly useful decision support tools in that they enable us to investigate many practical and pressing issues that arise during planning, design, operation, and management of urban stormwater collection systems. These models are, however, simplifications of reality, and no matter how sophisticated they may be, they undergo some aspect of conceptualization or empiricism, and their results are only as realistic as model assumptions and algorithms, detail and quality of inputs, and parameter estimates. Einstein commented that models should be “as simple as possible and no simpler.” Therefore, it is imperative that a mechanism that improves accuracy of model predictions, based on observed field information, be implemented before using the models for their intended purposes. The common approach to accomplishing this useful task is to adjust sensitive model parameters so that the model results coincide with observed field conditions, a process commonly referred to as calibration.

Before any stormwater management model can be adequately used to analyze the performance of an existing sewer system, the model must first be calibrated. Calibration of stormwater models is not only an essential component of the initial model building process, it is also important to periodically re-calibrate a model to reflect the physical changes in both operations and facilities in the system so that model predictions can be interpreted with confidence. The price for neglecting calibration is basing decisions on a model that may be seriously in error and thus, advising the implementation of ill-engineered capital improvement projects.

InfoSWMM is a comprehensive and advanced hydrologic, hydraulic, and water quality simulation model. The hydrologic simulation component of InfoSWMM performs rainfall-runoff computation through proper description of surface runoff generation and routing, infiltration processes and groundwater flow processes accounting for spatial and temporal heterogeneity of climate, soil, land use, and topographic conditions of the watershed. Modeling of these processes demands determination of proper values for large number of model parameters (e.g., subcatchment parameters, infiltration parameters, aquifer parameters, groundwater parameters, etc). Unfortunately, it is hardly possible to obtain values of these parameters from measurements alone due to lack of data at the desired degree of quality and quantity. Therefore, calibration is the only viable solution to determine optimal values of these InfoSWMM parameters.

Manual calibration and automatic calibration are two types of parameter estimation approaches. Manual calibration is by far the most widely used method for advanced models like InfoSWMM. Manual calibration, however, is time consuming and very subjective, and its success highly depends on budget availability and the experience of the modelers and their knowledge of the study watershed, along with model assumptions and its algorithms. Automatic calibration involves the use of optimization algorithm to determine best-fit parameters, and it offers a number of advantages over the manual approach. Automatic calibration is fast, it is less subjective, and since it makes an extensive search of the existing parameter combinations, it is highly likely that the computed results would be better than those obtained using the traditional manual approach. InfoSWMM Calibrator is a fully automated calibration module that uses highly advanced, reliable and robust optimization methods such as genetic algorithms.

InfoSWMM Calibrator sets a new standard in automated stormwater model calibration. It helps you build and validate the credibility and reliability of your urban stormwater collection system models. With point-and-click simplicity, you can command the latest advances in Genetic Algorithms and Global Search control strategies to optimally adjust subcatchment parameters, infiltration parameters, groundwater parameters, aquifer parameters, RDII hydrograph parameters, and conduit parameters and best reflect what is actually occurring in the system. The program minimizes the difference between observed field data (such as flow, velocity, and/or depth) and model predictions considering all test data simultaneously to provide the best calibration possible. You can even disaggregate the model into separate logical calibration groups (e.g., subcatchment, soil, aquifer, RDII, and conduit) based on the known physical characteristics of the associated elements (e.g., topographic condition, soil type, land use, conduit age, conduit material type, etc.) and seamlessly interface with the InfoSWMM to evaluate their fitness under various simulation options and operating conditions and to maximize efficiency. All in a seamlessly integrated and extremely rich graphical presentation environment, making model calibration an enjoyable and friendly task.

Now you can consistently build and analyze more complete, accurate and reliable models than ever before and in record time. Without that credibility, the most complex and theoretically sound model that could be developed would not be effective in helping plan a sound system. A well calibrated model will not only result in more accurate predictions but will also greatly assist you in operating and managing stormwater collection systems and in making sound and cost-effective engineering decisions for system design, rehabilitation, replacement, strengthening, and expansion.

We are happy to bring you the state-of-the-art in optimized stormwater calibration technology to provide the best possible calibration with a minimum effort to help you obtain better information on your sewer system and significantly improve and simplify your model representation process.

Paul F. Boulos, Ph.D.

President

September, 2005

HOW TO USE THIS GUIDE

The Users Guide is designed to accompany the InfoSWMM Calibrator program and is organized in four sections as follows:

SECTION 1 – INSTALLATION AND CONFIGURATION

Section 1 of the Users Guide contains instructions for software installation and configuration, and for using the extensive on-line help documentation, as well as information on how to get additional help and technical support.

SECTION 2 – INFOSWMM CALIBRATOR INTERFACE

Section 2 of the Users Guide provides description of the functions and capabilities of InfoSWMM Calibrator.

SECTION 3 – QUICK START TUTORIAL

Section 3 of the Users Guide illustrates the use of the InfoSWMM Calibrator program. Through a tutorial using a sample project, the reader is given a guided tour to core commands and functions used to create and execute a calibration run and display the calibration results.

SECTION 4 – METHODOLOGY

Section 4 of the Users Guide presents discussion of the theory and methodology behind the optimal stormwater model calibration employed by InfoSWMM Calibrator.

CONVENTIONS

This guide uses the following typographic conventions:

ITALIC CAPS InfoSWMM menu titles, menu choices, and commands:

Choose *OPEN* from the *FILE* menu.

Dialog box and window titles, and specific areas within a dialog box or window (InfoSWMM and InfoSWMM Calibrator):

Choose the “Subcatchment” button from the *INFOSWMM CALIBRATOR* dialog box.

Bold Name of InfoSWMM Calibrator project:

The tutorial makes use of a sample InfoSWMM project named “**Yourcitycal**”.

SECTION 1

INSTALLATION AND CONFIGURATION

1.1 MINIMUM SYSTEM REQUIREMENTS

The following is a minimum computer configuration necessary to install and run InfoSWMM Calibrator:

IBM-compatible 700 MHz, Pentium III CPU personal computer with math coprocessor.

2. 256 megabytes of Random Access Memory (RAM).

3. 400 megabytes of free disk space to accommodate a full InfoSWMM installation.

4. Microsoft Windows NT 4.0 SP 5 or later, 2000 Professional SP 3 or later, 2002 Professional, XP Professional (WIN32 operating system).

5. ArcView 8.2 or above.

6. Microsoft Internet Explorer 5.

7. InfoSWMM.

8. VGA graphics adapter and monitor.

1.2 RECOMMENDED SYSTEM CONFIGURATION

The following is a list of recommendations for taking full advantage of InfoSWMM:

1. IBM-compatible 1.2 GHz (or higher), Pentium IV CPU personal computer.

2. 512 Mb RAM - The more RAM available on your system, the better.

3. Additional disk space - Keep as much free disk space available as possible. The InfoSWMM virtual memory system needs additional free disk space when working on large projects

1.3 INSTALLING InfoSWMM calibrator

InfoSWMM Calibrator can only be installed from our Internet website. To install InfoSWMM Calibrator for a single user, perform the following procedure:

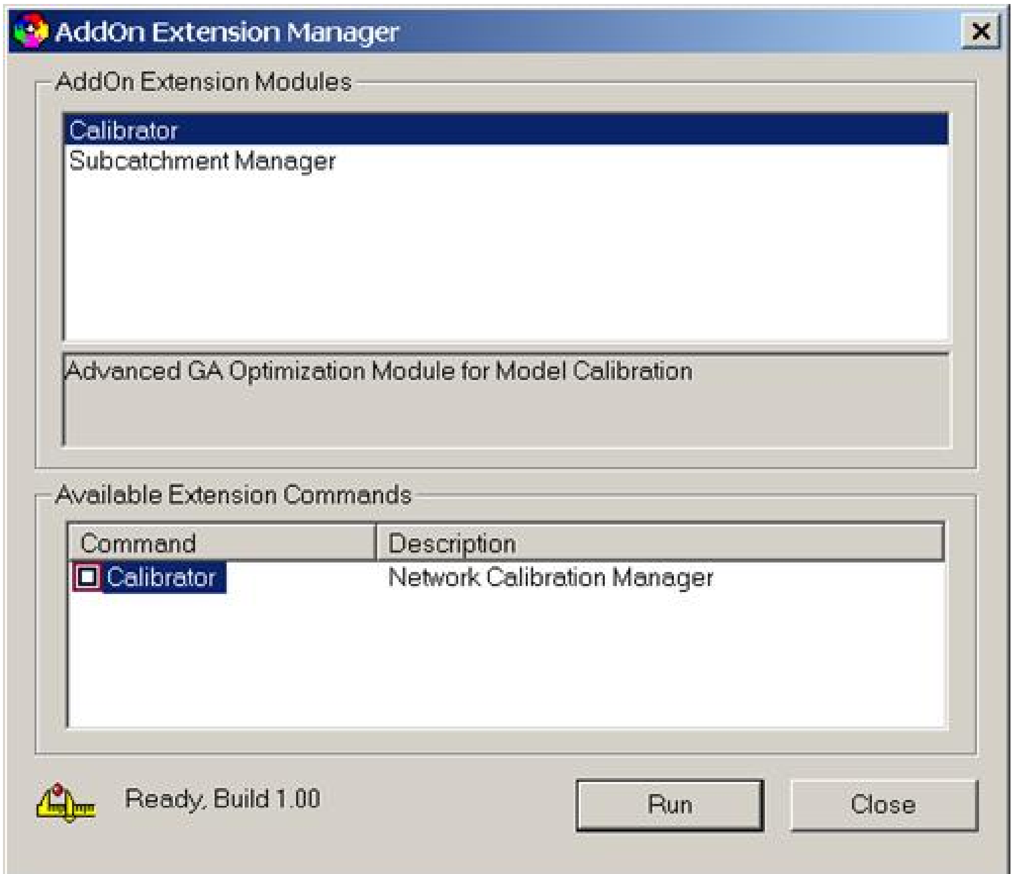
1. Turn on your computer and start Windows. Close any other applications that are currently running.

2. Start your Internet browser software and go to http://www.Innovyze.com. Once on Innovyze® Inc's homepage, please go to the DOWNLOAD link. Go to the InfoSWMM area.

3. Choose the Calibrator extension and click on the link. This will launch the File Download dialogue box.

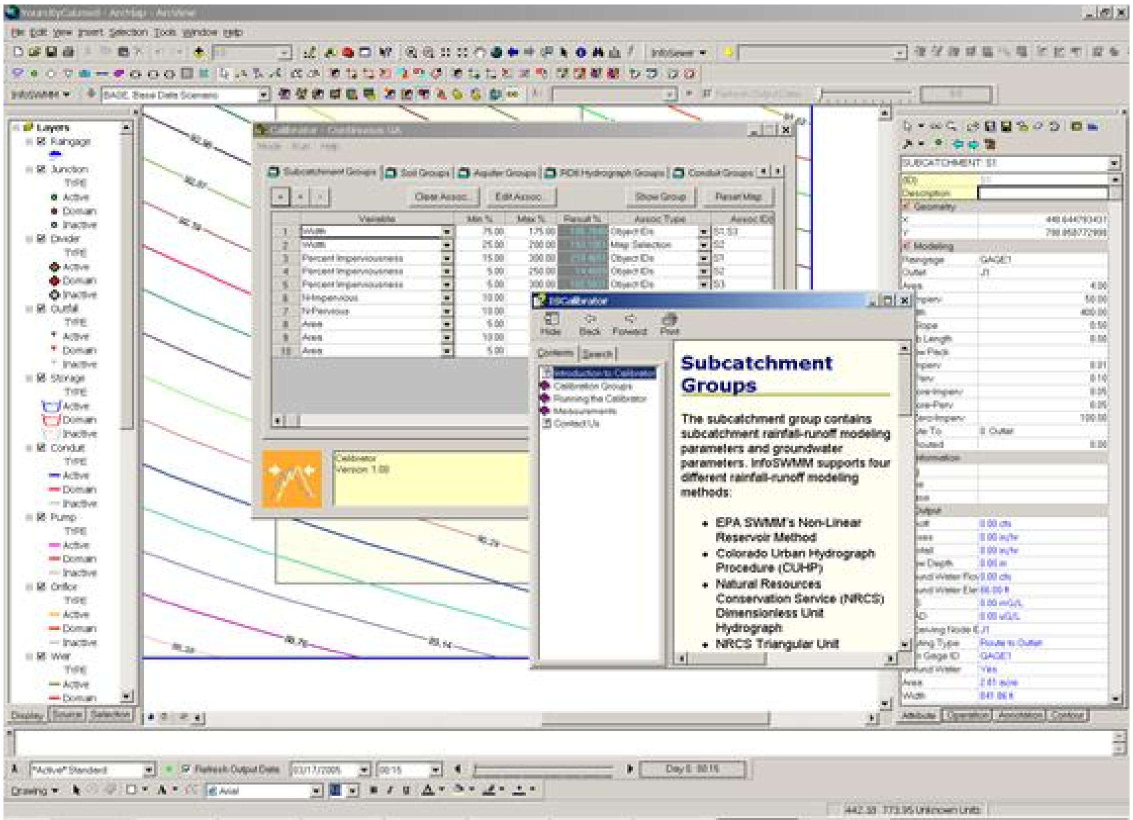
4. Choose the SAVE THIS PROGRAM TO DISK option and follow the on-screen instructions. When saved on your hard drive run the Execute (*.exe) file from the folder that was downloaded and follow the on screen instructions.

Upon successful installation of InfoSWMM Calibrator, the program is initialized from inside InfoSWMM by selecting the *ADD-ON MANAGER* command from the *TOOLS* menu. With the Add-On Manager dialog box open, select Calibrator from the drop down list as shown below and click the "Run" button.


AddOn Extension Manager
AddOn Extension Modules
Calibrator
Subcatchment Manager
Advanced GA Optimization Module for Model Calibration
Available Extension Commands
Command
Description
Calibrator
Network Calibration Manager
Ready, Build 1.00
Run
Close

1.4 USING INFOSWMM Calibrator ON-LINE help

InfoSWMM Calibrator provides very comprehensive and easy to use on-line help capabilities. You may press the F1 key to see documentation on the command or tool you are currently using. For example, you can select the *Subcatchment Group* tab and while the dialog box is open, press the F1 key. The *Subcatchment Group* tab help topic appears on the screen. You may click on any portion of the dialog box in the help topic for more information as shown in the illustration below:



1.5 TECHNICAL SUPPORT

We are committed to quality software and superior customer support. If you need assistance beyond the *InfoSWMM Calibrator Users Guide*, please contact us:

Technical Support Line: (626) 568-6869

Fax: (626) 568-6870

E-Mail: Innovyze@Innovyze.com : support@Innovyze.com

Internet: http://www.Innovyze.com

Or write us at Innovyze® Inc, 618 Michillinda Avenue, Suite 200, Arcadia, California 91007 USA. We will seriously consider your suggestions for future versions of InfoSWMM Calibrator. For international support, please contact your local Innovyze® Inc Certified Representative.

We will occasionally create interim updates that contain fixes and/or new features. These interim updates will be available as patches, free of charge, on our Internet Web site with complete instructions for applying them. To get to our home page, just point your Web browser to our Internet address listed above.

NOTE: *Do not forget to renew your Annual Maintenance Agreement to take full advantage of future enhancements, updates, upgrades, and technical support.*

SECTION 2

INFOSWMM Calibrator Interface

InfoSWMM Calibrator provides sophisticated micro level hydrologic and hydraulic calibration capabilities. It casts the calibration problem as an implicit nonlinear optimization problem subject to explicit inequality and equality constraints. InfoSWMM Calibrator provides the user with an efficient, flexible and easy to use vehicle for accurate and reliable model calibration and validation.

The optimization problem consists of determining model parameters broadly categorized into five general groups: subcatchment group (i.e., subcatchment runoff parameters and groundwater parameters), soil group (i.e., infiltration parameters), aquifer group (i.e., aquifer parameters), RDII group (i.e., RDII unit hydrograph parameters), and conduit group (i.e., conduit parameters) that produce the minimum overall difference between the observed measurements (i.e., flow, velocity, and/or depth measurements) and corresponding model predicted results. Unlimited number of subgroups could be defined for each of the five calibration groups described above. The subgroups represent modeling elements (e.g., subcatchments) that have identical properties and that may be adjusted by the same scale during the calibration process.

Optimal values of the calibrable parameters are determined from a user-specified range of minimum and maximum values associated with their respective group (e.g., subcatchment, soil, aquifer, etc). It is assumed that parameter values of all elements (e.g., subcatchments) within the group will be scaled (i.e., multiplied) by the same factor from the original parameter value assigned to each of the elements in the group. As such, the user should lump elements and objects together in separate groups based on their similarity from the perspective of the characteristics that affect the specific parameter being considered. It should be emphasized that there is no limitation regarding the number of elements assigned to a group (i.e., it could be one or more) thus providing the modeler the flexibility to accommodate heterogeneity.

Unlimited number of measurements and measurement sites could be defined using InfoSWMM Calibrator thus offering tremendous flexibility. The measurements could be flow, depth, and/or velocity. It is an obvious reality that quality of calibration exercise depends on the number as well as quality of measurements. If one uses large number of good quality measurements, it is more likely that the parameter values determined by the calibrator better reflect reality. Regarding number of measurements, the general guideline is that the number of field measurements must be greater than or equal to the number of decision variables, the more measurements the better the accuracy of the calibration.

InfoSWMM Calibrator is initialized from inside InfoSWMM by selecting the *ADD-ON MANAGER* command from the *TOOLS* menu. With the Add-On Manager dialog box open, select Calibrator from the drop down list and click the “Run” button.

In this chapter of the Users Guide, you will be introduced to InfoSWMM Calibrator Interface. The purpose of the available commands will be described.

2.1 MENU OVERVIEW

InfoSWMM Calibrator commands are logically organized into menu pillars (drop-down menus with multiple choices). The module has three menus: Mode, Run, and Help menu.

Mode Menu: The mode command enables the user to select optimization method of her/his choice. At the moment only continuous (i.e., real-coded) Genetic Algorithms (GA) is supported. Additional optimization algorithms will be added in the near future.

Run Menu: Contains commands that are used to launch calibration run, to stop a run before completion, and to specify parameters of the optimization algorithm. The following commands are available from the Run Menu:

- 

The "Start" command launches the calibration run.
- 

The "Stop" command interrupts the calibration run. Please note that InfoSWMM Calibrator can stop the optimization at any time and yet enables you to review the results obtained up to the point of interruption.
- 

The "Options" command launches the *CALIBRATION OPTIONS* dialog box, which allows specifying optimization parameters and simulation options. With this command the user specifies available measurement types and data filtering criteria, convergence criteria, advanced GA options, the objective function type (i.e., goodness-of-fit criterion), etc.

Help Menu: Contains commands that are used to access InfoSWMM Calibrator online help and its version information. InfoSWMM Calibrator Help is available from within InfoSWMM Calibrator. The following commands are available from the Help menu:

- 

The "Contents" command opens contents page of the online help. You may also press the F1 key to see documentation on the command or tool you are currently using. For example, you can open the *CALIBRATION OPTIONS* dialog box and while the dialog box is open, press the F1 key. The *CALIBRATION OPTIONS* command help topic appears on the screen. You may click on any portion of the dialog box in the help topic for more information.

- 

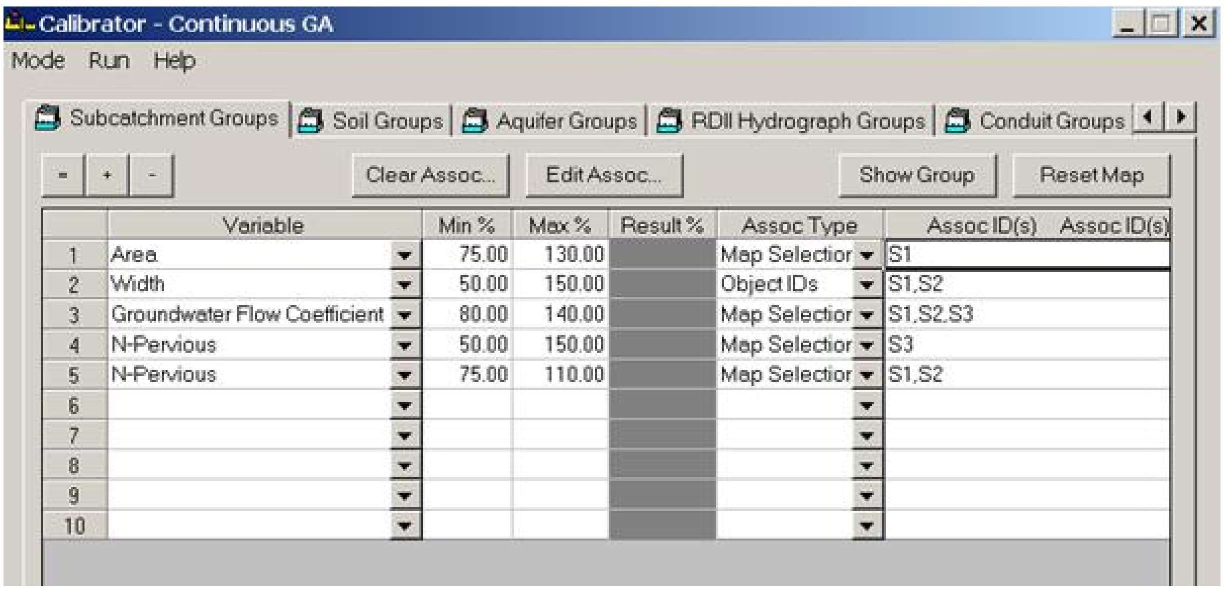
The “Index” command lets you search for online help topics of your interest using keywords.

- 

Launches the About InfoSWMM Calibrator dialog box which summarizes the version properties and some other information about your InfoSWMM model.

2.2 CALIBRATION Groups

As mentioned above InfoSWMM Calibrator has five general calibration groups: Subcatchment group, Soil group, Aquifer group, RDII group, and Conduit group. One or more InfoSWMM parameters are associated with each of these calibration groups. Modelers can disaggregate their system into separate logical calibration groups (e.g., subcatchment, soil, aquifer, RDII, and conduit) based on characteristics of the associated elements that affect the parameters being calibrated (e.g., topographic conditions, soil type, land use, conduit age, conduit material type, etc.) to handle spatial heterogeneity of the parameters with maximum flexibility. Working mechanism of the five calibration groups and the required input information is similar. Therefore, these common features are described below before going into unique characteristics of the individual groups.



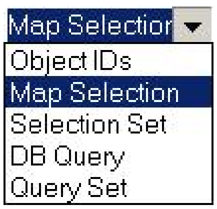
As illustrated using the subcatchment dialog box shown above each of the five calibration groups demand the following input information; provide the result column indicated below; and has the following buttons to enable the operations described below.

- **Variable** – Enables specification of the parameter(s) to be calibrated among the list of potential calibrable parameters for the group.

- **Min% and Max%** – Refers to the minimum multiplier value and maximum multiplier value, respectively, that could be applied to the calibrable parameter. During calibration process, InfoSWMM Calibrator identifies optimal value of multiplier within the Min% and Max% range provided for the parameter. These parameter uncertainty limits should be specified cautiously taking into account conditions specific to the collection system being modeled.

- **Result** – Once the calibrator is run, optimal value (i.e., percent multiplier) determined for each calibrable parameter is provided in this column.

- **Assoc Type** – This column lets you choose how to specify the InfoSWMM physical/non-physical objects belonging to the group being created. Content and application of this column varies with group type depending on whether the object type is physical (i.e., can be displayed on the map) or non-physical. For groups that refer to physical objects (i.e., subcatchment group and conduit group) the following options are available: *Map Selection*, *Object IDs*, *Selection Set*, *DB Query*, and *Query Set*. Only *Object IDs* option is available for the other three groups referring to non-physical objects (i.e., soil group, aquifer group, and RDII group)



Ø Object IDs - if this option is selected, the element IDs has to be typed manually. The IDs should be comma separated.

Ø Map Selection - lets you select the elements graphically.

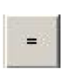
Ø Selection Set - lets you specify object IDs from existing selection set

Ø DB Query - allows you specify the object based on existing DB Query

Ø Query Set - enables you specify the object IDs from existing Query Set

- **Assoc ID(s)** – List of elements in the group is provided in this column. One the **Assoc Type** is selected, the modeler has to specify the Object IDs in this column.

In addition to the input information specification columns described above, the calibration group pages do have one or more of the following buttons that assist in simplifying usage of the above described group information specification columns.

· 

- Allows you to set the number of groups (i.e., number of rows).

· 

- Lets you add a row above the highlighted (i.e. currently active) row.

· 

- Deletes the highlighted row.

· 

- Clears list of IDs provided in the **Assoc ID(s)** column.

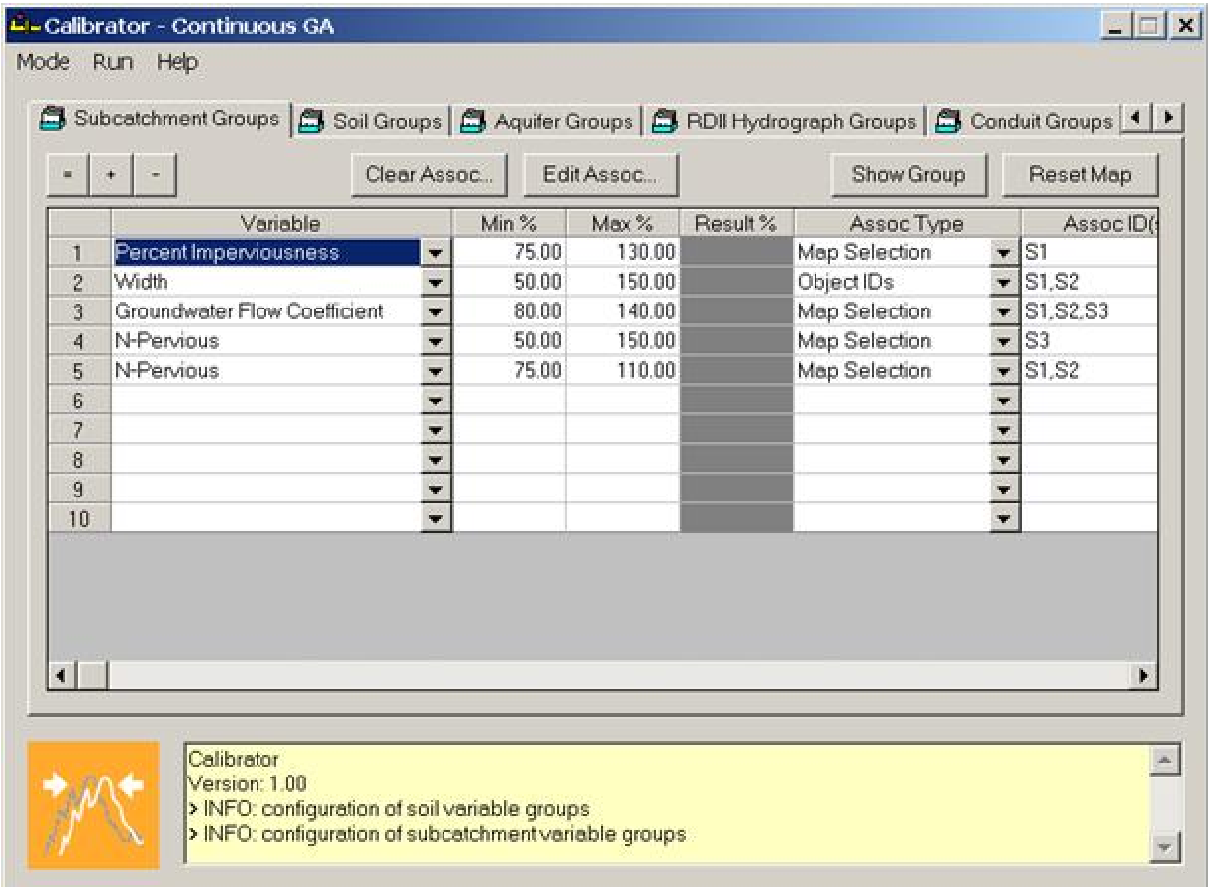
- Edit Assoc... - Enables you to edit (i.e., specify, change, add or delete) one otr more object IDs in the **Assoc ID(s)** column.
- Show Group - This button is active only for subcatchment group and conduit group. It graphically displays element in the group.
- Reset Map - This button is active only for subcatchment group and conduit group. It resets the graphic display back to its original form. Once the *Show Group* feature is used to display elements that belong to a group, if the user wants to graphically display elements belonging to another group, s/he must use the *Reset Map* feature to undo the previous display and then click on the *Show Group* button.

2.2.1 SUBCATCHMENT GROUP

The subcatchment group contains subcatchment rainfall-runoff modeling parameters and groundwater parameters. InfoSWMM supports four different rainfall-runoff modeling methods: EPA SWMM's Non-Linear Reservoir Method, Colorado Urban Hydrograph Procedure (CUHP), Natural Resources Conservation Service (NRCS) Dimensionless Unit Hydrograph, and NRCS Triangular Unit Hydrograph method. Using the Subcatchment group, the modeler can select the specific parameters s/he wants to calibrate. Selection of the parameters to calibrate depends on the rainfall-runoff modeling technique utilized and also on the interest of the user to model groundwater. InfoSWMM parameters available for various rainfall-runoff modeling approaches and groundwater parameters are listed below.

- EPA SWMM's Non-Linear Reservoir Method
  - Area
  - Width
  - Percent Imperviousness
  - Slope
  - N-Impervious
  - N-Pervious
  - Impervious Depression Storage
  - Pervious Depression Storage
- CUHP Method

    - Area
    - Percent Imperviousness
    - Slope
    - Impervious Depression Storage
    - Pervious Depression Storage
    - Length
    - Centroid Distance
    - CIA Fraction
    - RPA Fraction
- NRCS Dimensionless and NRCS Triangular Methods
    - Area
    - Slope
    - Length
    - Lag Time
- If Groundwater is Simulated
    - Groundwater Flow Coefficient
    - Surface water flow Coefficient
    - Groundwater Flow Exponent
    - Surface Water Flow Exponent
    - Surface-Groundwater Interaction



Once the parameters to be calibrated are known, the user has to decide the *Min%* and *Max%* value of each parameter, and the subcatchments that could be clustered in to one calibration group.

NOTE: *If invalid subcatchment ID (e.g., non-existing subcatchment) is associated with a group, the calibrator will issue a warning message but it will run. However, if all IDs provided to a group are invalid the calibrator will issue an error message and will not run.*

NOTE: *If irrelevant subcatchment parameter (e.g., parameter that is not associated with the rainfall-runoff model being used) is defined as calibrable, the calibrator will run, but as expected, the parameter will not play any role in the calibration process.*

2.2.2 SOIL GROUP

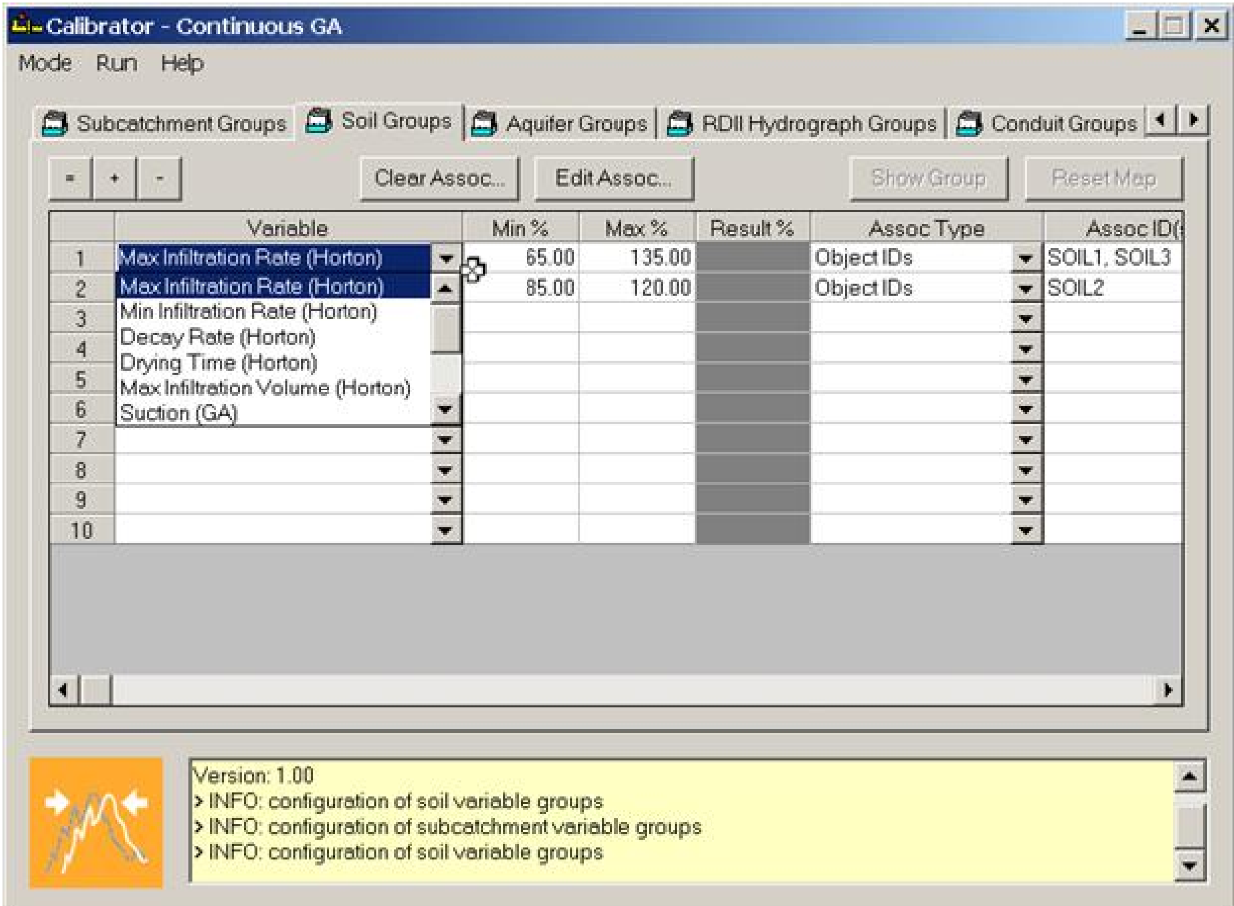
The soil group, shown below, contains InfoSWMM infiltration parameters. InfoSWMM can model subcatchment infiltration using Horton method, Green-Ampt method, or Curve Number method.

Depending on the infiltration model used, the following infiltration parameters can be calibrated and are all available from the soil group. ID of the soils that have similar characteristics from the perspective of the calibrable infiltration/soil parameters should be listed in the **Assoc ID(s)** column.

- Horton Method
    - Maximum Infiltration Rate
    - Minimum Infiltration Rate
    - Decay Rate
    - Drying Time
    - Maximum Infiltration Volume
- Green-Ampt Method
    - Suction
    - Conductivity
    - Initial Deficit
- Curve Number Method
    - Curve Number
    - Conductivity
    - Drying Time

NOTE: *If invalid soil ID (e.g., non-existing soil) is associated with a group, the calibrator will issue a warning message but it will run. However, if all IDs provided to a group are invalid the calibrator will issue an error message and will not run.*

NOTE: *If irrelevant soil parameter (e.g., parameter that is not associated with the infiltration model being used) is defined as calibrable, the calibrator will run, but as expected, the parameter will not play any role in the calibration process.*

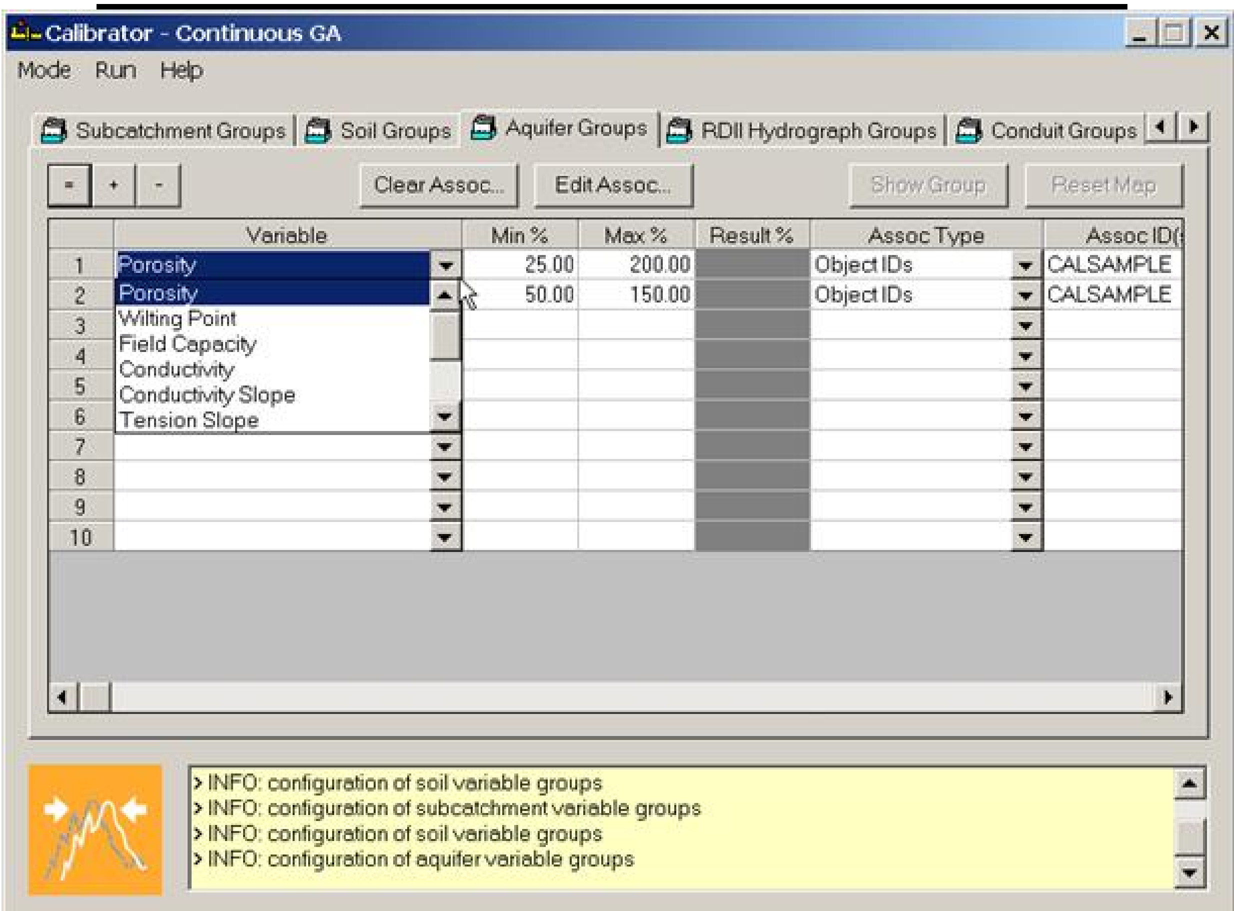


2.2.3 AQUIFER GROUP

The aquifer group, shown below, consists of aquifer parameters that are required to model subcatchment groundwater flow. Using aquifer group tab, the user can define the aquifer groups to be used in the calibration analysis. The user can also modify any aquifer group previously identified, input ranges of acceptable aquifer parameters for each aquifer group, or color-code each aquifer group. The aquifer parameters that are available for calibration are: porosity, wilting point, field capacity, conductivity, conductivity slope, tension slope, upper evaporation fraction, lower evaporation depth, bottom elevation, water table elevation, and unsaturated zone moisture.

NOTE: *If invalid aquifer ID (e.g., non-existing aquifer) is associated with a group, the calibrator will issues an error message and will not run.*

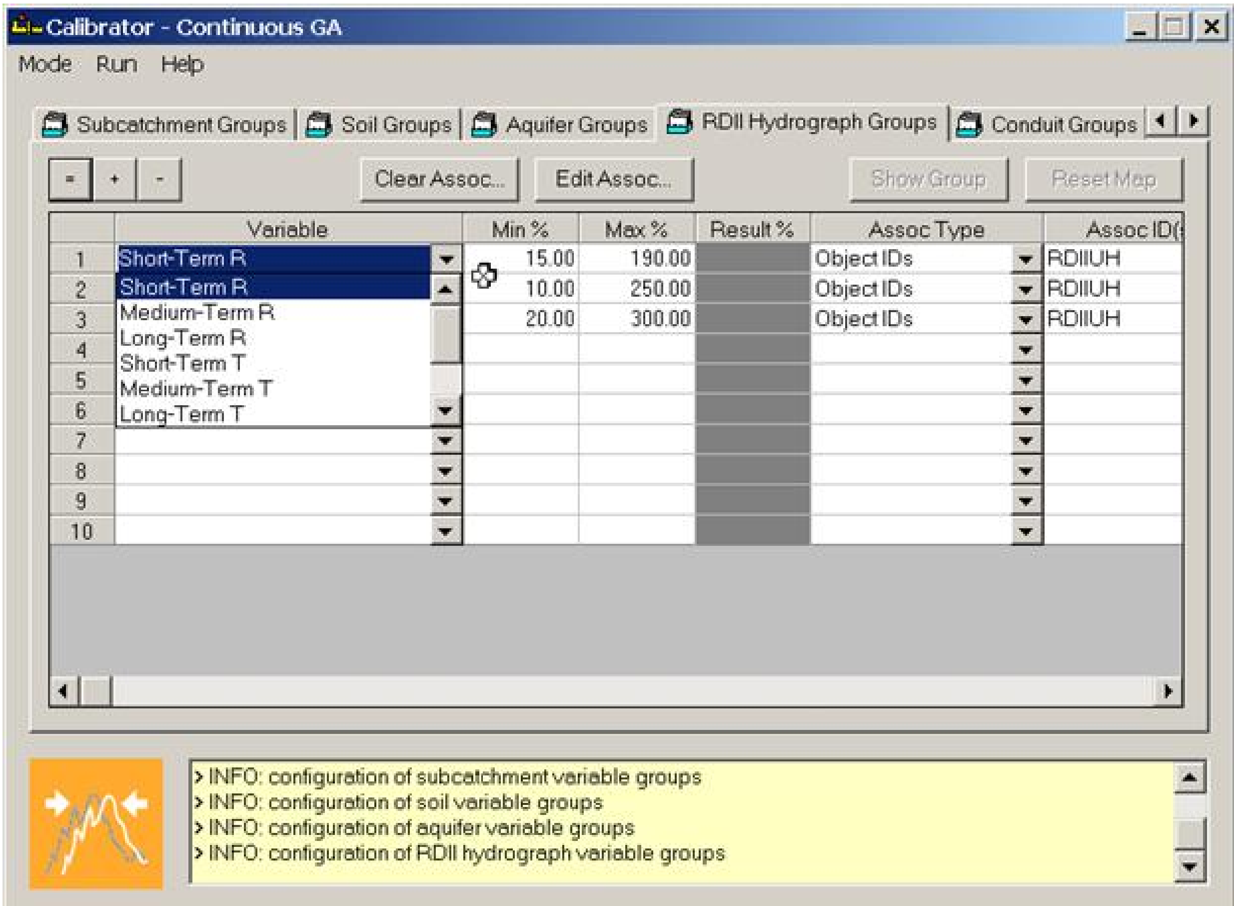
NOTE: *If irrelevant aquifer parameter (e.g., aquifer group is defined but groundwater is not simulated) is defined as calibrable, the calibrator will run, but as expected, the parameter will not play any role in the calibration process.*



2.2.4 RDII GROUP

The RDII group, shown below, consists of RDII unit hydrograph parameters that are required to model rainfall driven infiltration and inflow to nodes. Using RDII group tab, the user can define the RDII groups to be used in the calibration analysis. The user can also modify any RDII group previously identified, input ranges of acceptable RDII parameters for each RDII group, or color-code each RDII group. The RDII parameters that are available for calibration are short-term, medium-term, and long-term R, T, and K parameters.

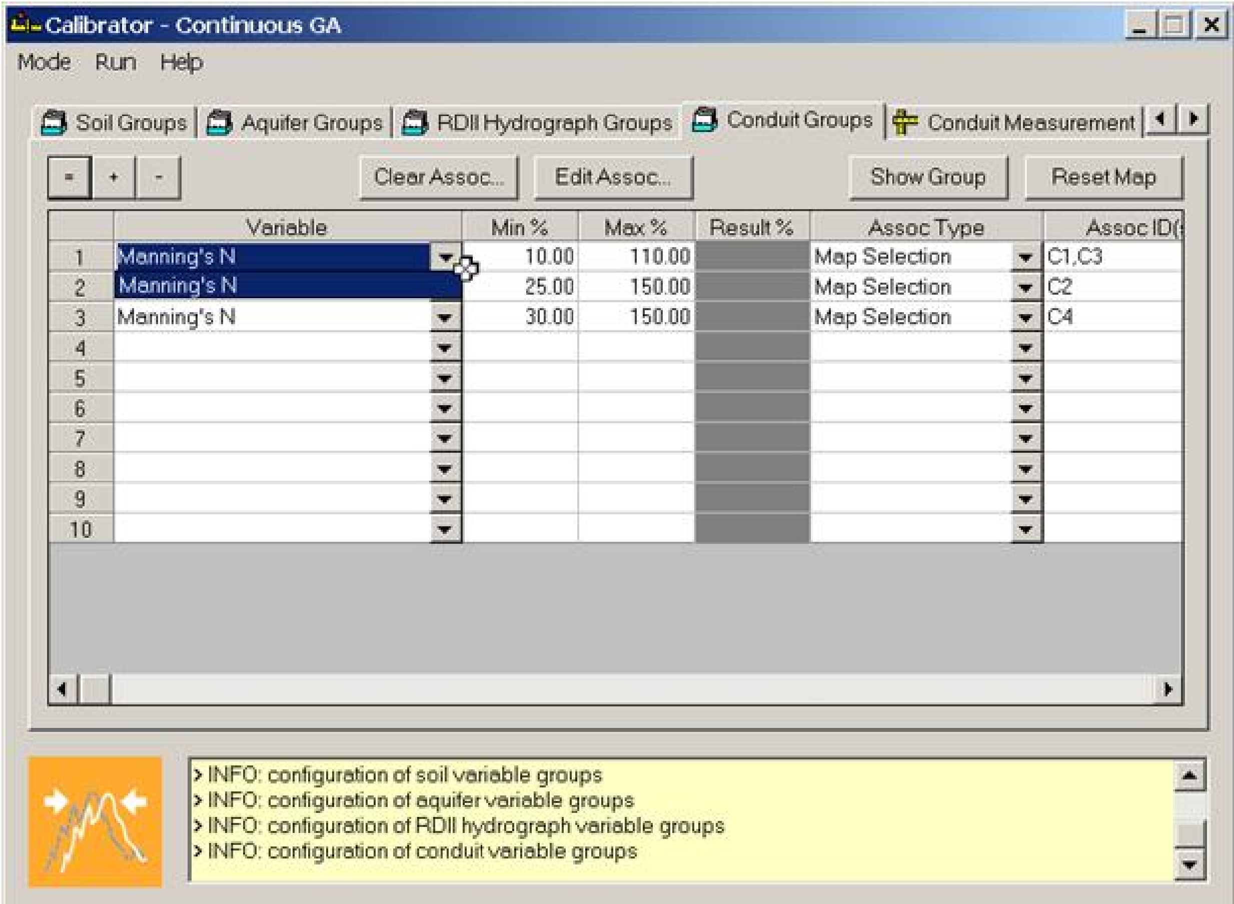
NOTE: *If invalid RDII ID (e.g., non-existing RDII UH) is associated with a group,* *the calibrator will issues an error message and will not run.*



2.2.5 CONDUIT GROUP

The conduit group, shown below, enables the user to calibrate Manning's roughness coefficient for conduits. Using conduit group tab, the user can define the conduit groups to be used in the calibration analysis. The user can also modify any conduit group previously identified, input ranges of acceptable Manning's n for each conduit group, or color-code each conduit group.

NOTE: *If invalid Conduit ID (e.g., non-existing conduit) is associated with a group, the calibrator will issues an error message and will not run.*


Calibrator - Continuous GA
Mode Run Help
Soil Groups
Aquifer Groups
RDII Hydrograph Groups
Conduit Groups
Conduit Measurement
Clear Assoc...
Edit Assoc...
Show Group
Reset Map
Variable
Min %
Max %
Result %
Assoc Type
Assoc ID(
Manning's N 10.00 110.00 Map Selection C1,C3
Manning's N 25.00 150.00 Map Selection C2
Manning's N 30.00 150.00 Map Selection C4
> INFO: configuration of soil variable groups
> INFO: configuration of aquifer variable groups
> INFO: configuration of RDII hydrograph variable groups
> INFO: configuration of conduit variable groups

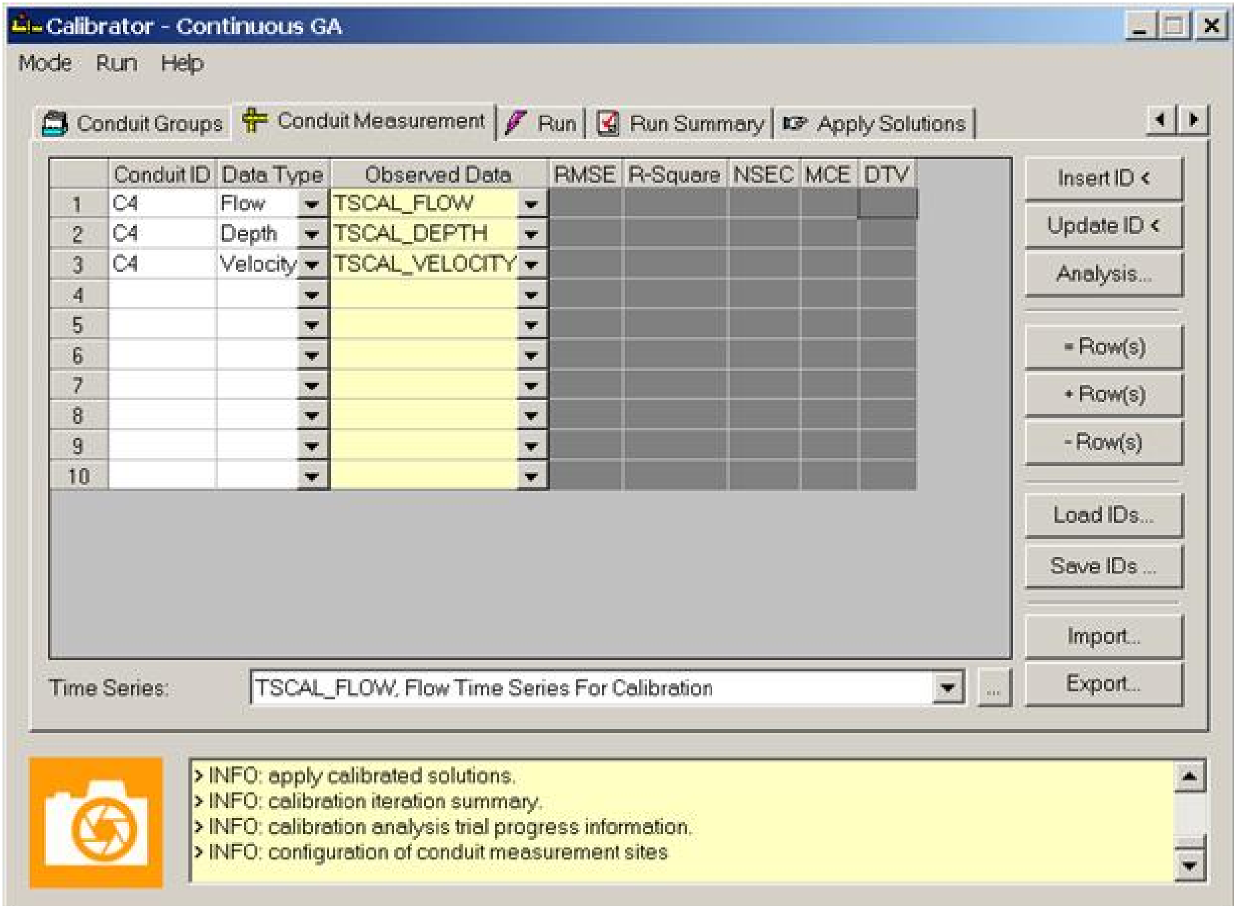
2.3 conduit measurement

This tab allows the user to specify observed data or measurements and also to review performance of the calibration run. The measurements could be flow, depth, and/or velocity taken at one or more conduits. InfoSWMM calibrator accepts measurement information in the form of time series.

Once the calibration model is executed, the conduit measurement dialog editor displays values of the goodness-of-fit evaluation criteria including root mean square error, Nash-Sutcliffe efficiency criterion, modified coefficient of efficiency, r-square, and deviation in total volume of the measured and the simulated values. Calibration result analysis page could also be launched from conduit measurement dialog editor.

The conduit measurement dialog editor consists of the following input/output columns.

- **Conduit ID** - ID of the conduit where the measurement is taken is given in this column.
- **Data Type** - Type of the measurement (i.e., flow, depth, or velocity) is specified in this column.
- **Observed Data** – ID of the time series that contains the observed data is specified in this column.
- **Goodness-of-fit Evaluation Criteria Columns** - Once the calibration model is executed, value of the goodness-of-fit is displayed in these columns.



In addition, the conduit measurement dialog editor has the following buttons to facilitate assignment of input information and reviewing output results.

- 

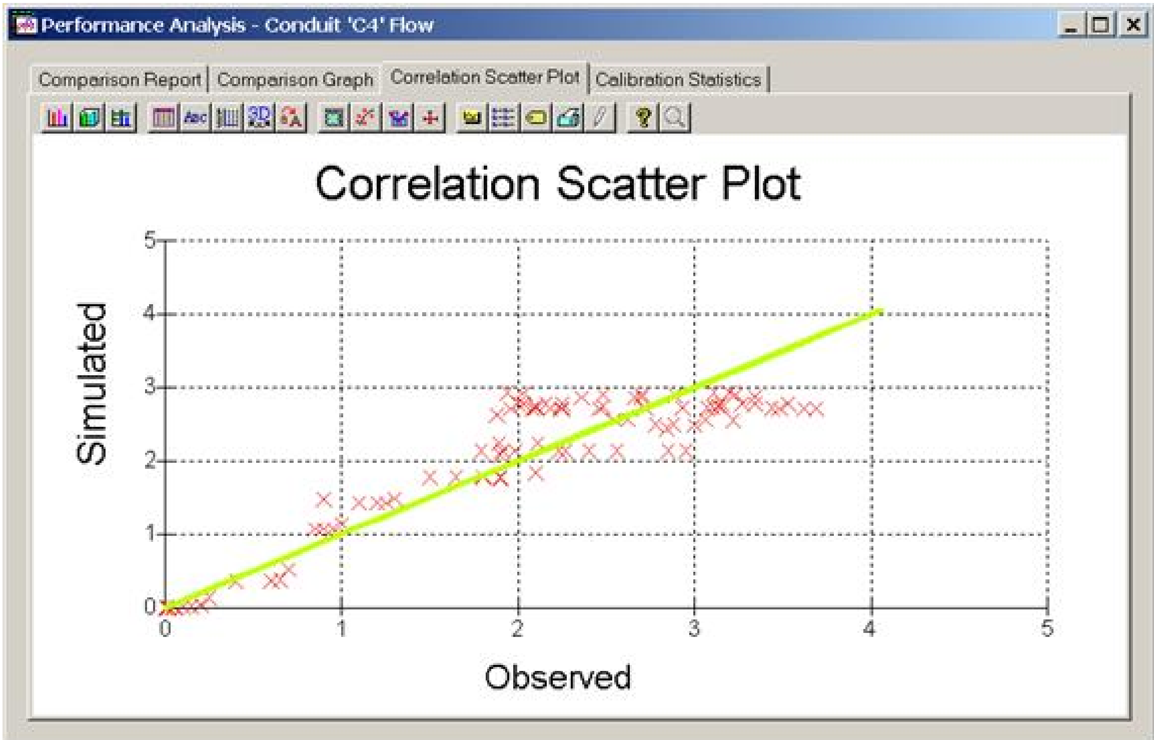
- Graphically selects measurement conduit ID and inserts into the Conduit ID column as additional measurement site.

- 

- Graphically selects measurement conduit ID and replaces an existing Conduit ID with the new ID.

- 

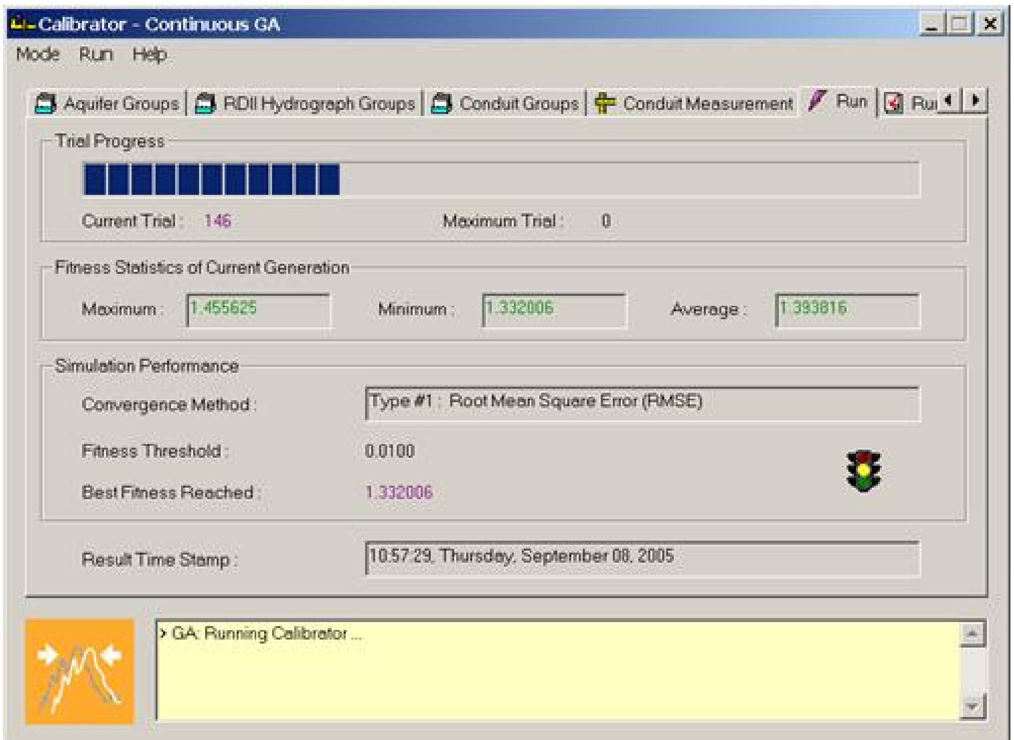
- Launches the *Performance Analysis* page indicated below where the user reviews performance of the calibrator graphically and statistically.



- [= Row(s)] - Lets you set the number of rows.
- [+ Row(s)] - Enables you to add a row above the selected row.
- [- Row(s)] - Lets you remove the selected row.
- [Load IDs...] - Loads conduit IDs from a selection set.
- [Save IDs ...] - Saves existing measurement conduit IDs to a selection set.
- [Import...] - Imports and populates the Conduit ID, Data Type, and Observed Data columns.
- [Export...] - Exports the Conduit ID, Data Type, and Observed Data columns. The exported file could be imported back.
- Time Series: - The Time Series drop down box allows you to choose the time series to be used, or you could also create a new time series and specify it to a conduit ID of your choice.

2.4 Run TAB

The run tab is used to report calibration information while the calibrator is running. If the simulation run was unsuccessful, a descriptive message will appear in the message area explaining what needs to be corrected in the input data. The following information is reported in the *Run* tab dialog box.



Current Trial: – The current iteration number in the optimization routine. Each trial represents a new calculated set of parameters.

Maximum Trial: – The maximum number of solution iterations that INFOSWMM Calibrator should employ when determining the model parameters. This criterion is checked after each computed generation.

Maximum: – The maximum value of the objective function in the current set of solutions (generation).

Minimum: – The minimum value of the objective function in the current set of solutions (generation).

Average: – The average value of the objective function in the current set of solutions (generation).

Convengence Method: – Define the objective (fitness) function type and the optimization convergence criteria. Three options for the objective function are available as defined later in this guide.

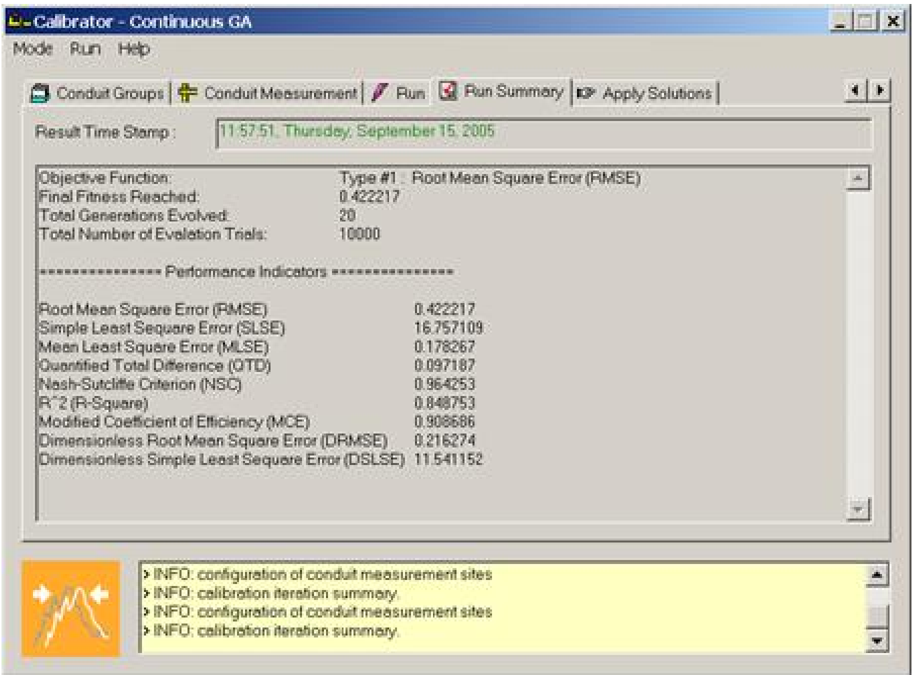
Fitness Threshold: – Prescribe a convergence criterion for the optimization routine used to minimize the selected fitness function. The iterations end when the fitness threshold is reached. INFOSWMM Calibrator will not allow a value smaller than one (0.01) percent to be used.

Best Fitness Reached: – The best value of the objective function reached based on the user selected convergence criteria.

Result Time Stamp: – Time corresponding to the GA optimization completion.

2.5 RUN SUMMARY TAB

The following dialog box appears for the *Run Summary* tab. INFOSWMM Calibrator creates an ASCII calibration summary report in the *Run Summary* tab.



2.6 apply solutions

Upon completion of a calibration run, the *Apply Solutions* tab dialog box provides the user with the means to apply the optimal parameter values obtained by the calibrator to the elements and objects of the model overwriting the original nominal values. The modeler can apply the optimal parameters to the desired scenario among the existing ones. The dialog box has the following items.

Subcatchment Set – Applies the final values of the calibrable parameters to the subcatchments.

Groundwater Set – Applies final values of the groundwater parameters to the subcatchments.

Soil Set – Applies the soil parameters to the soils objects.

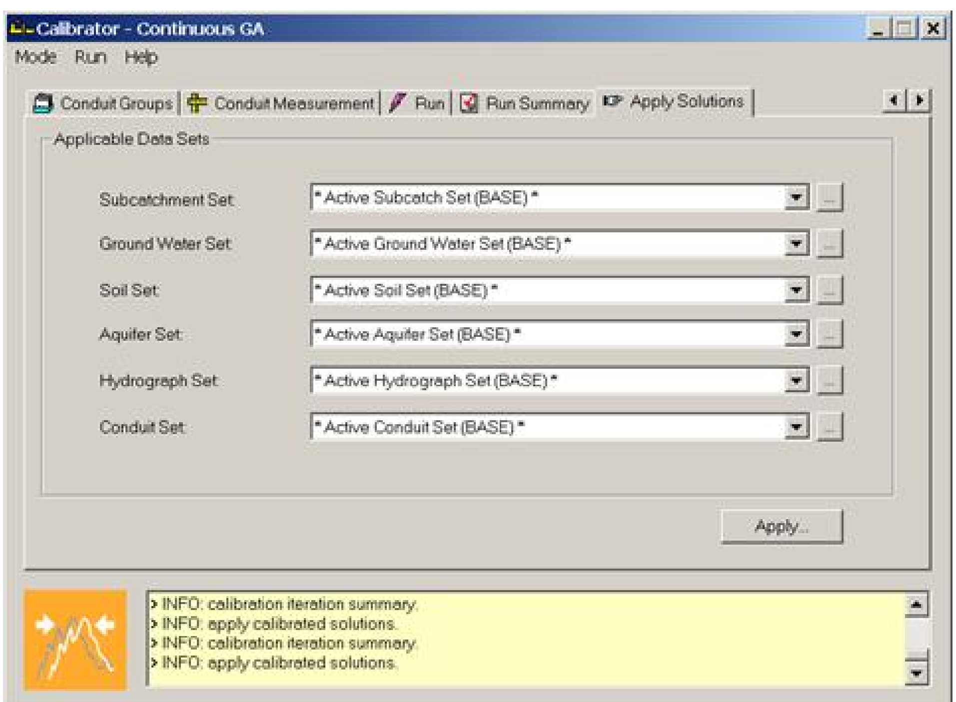
Aquifer Set – Applies the aquifer parameters to the appropriate aquifer.

Hydrograph Set – Applies RDII parameters to the appropriate unit hydrograph.

Conduit Set – Applies optimal value of Manning's N to conduits.

– Click this button to finalize parameter application process.

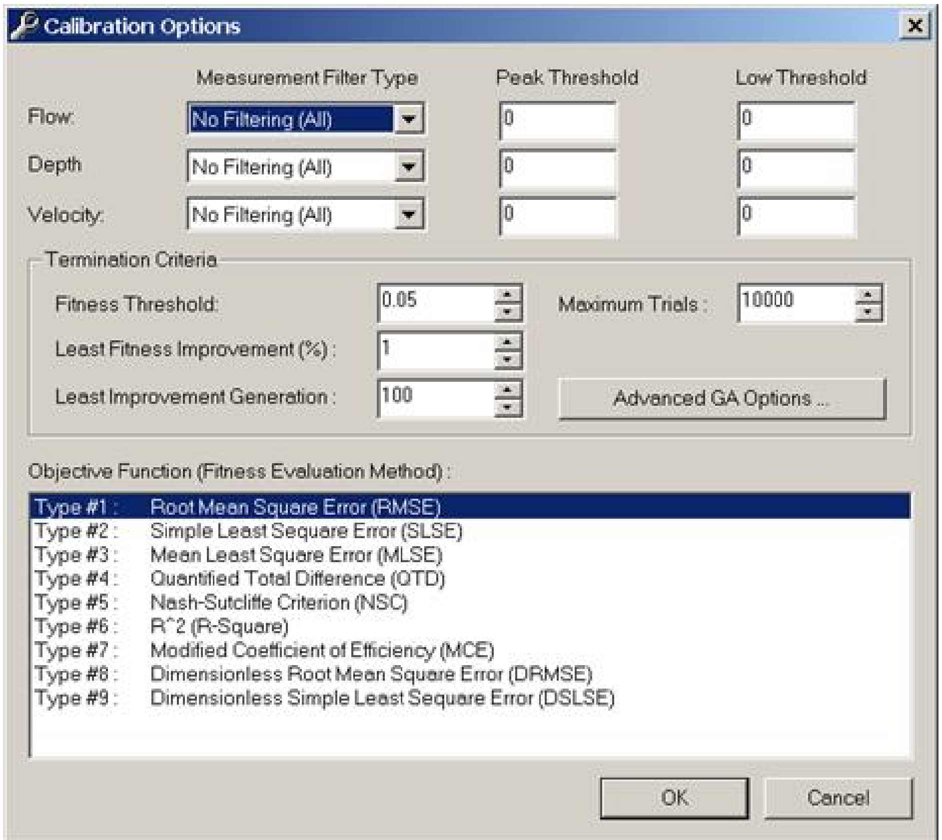
The drop down box lets you choose the appropriate element set. You could also create new element set.



2.7 CALIBRATION OPTIONS DIALOG BOX

The Calibration Options dialog box controls optimization properties and simulation options that are utilized during a model calibration simulation. Within this dialog box, the user specifies the type of measurement to be used to evaluate fitness function (i.e. entire time series, peak flows along with the peak threshold, or low values along with low threshold), convergence criteria (e.g., fitness threshold, least fitness improvement, and least improvement generation), maximum number of trials, advanced GA options, and the objective function type. The following items appear for the *Calibration Options* dialog box.

- **Measurement Filter Type** – Lets the modeler specify the measurements to be used to evaluate the fitness value. This could be done for flow, velocity, or depth. One of the following three options could be selected: *No Filtering (ALL)*, *>= Peak Threshold*, *<= Low Threshold.*
- **Peak Threshold** – Required only if the >= *Peak Threshold* is chosen for *Measurement Filter Type* and it enables specifying the threshold for peak values. Measurement values >= the assigned threshold will be considered during fitness evaluation.
- **Low Threshold** – Required only if the <= *Low Threshold* is chosen for *Measurement Filter Type* and it enables specifying the threshold for low values. Measurement values less than or equal to the assigned threshold will be considered during fitness evaluation.



The optimization module will terminate its iterative solution refinement process when one of the following four criteria is satisfied.

- 

– Prescribes a convergence criterion for the optimization routine used to minimize the selected fitness function. The iterations ends when the fitness threshold is reached.
- 

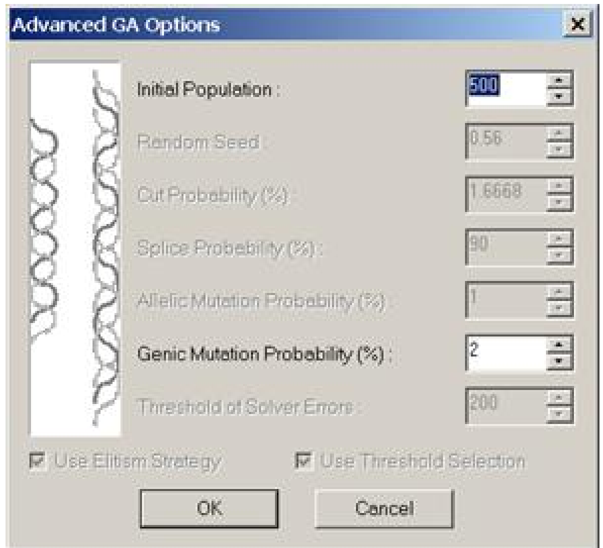
– Prescribes another convergence criterion for the optimization routine used to minimize the selected fitness function. The optimization ends if it fails to improve the total fitness better than the Least Fitness Improvement ratio (%) over the *Least Improvement Generation*.
- 

– Specifies the maximum number of consecutive generations with improvements of the fitness function not greater than the Least Fitness Improvement ratio.
- 

– The maximum number of solution iterations that InfoSWMM Calibrator should employ when determining improved sets of model parameters.

This criterion is checked after each computed generation.

- Advanced GA Options ... – Launches the Advanced GA Options dialog box as shown below. The user is able to specify advanced GA parameters such as initial population and mutation rate to improve convergence and accuracy.



- **Initial Population** – Refers to the initial number of solution candidates used.

- **Mutation Probability (%)** – This rate gives the expected number of genes to be mutated every iteration.

- Objective Function (Fitness Evaluation Method) : – Defines the objective function type or fitness evaluation criterion. Nine options are available. Mathematical formulation of these fitness evaluation methods may be reviewed from the methodology section of the users guide.

  · Simple Least Square Error

  · First Dimensionless Form of Simple Least Square Error

  · Mean Least Square Error

  · Root Mean Square Error

  · Dimensionless Form of Root Mean Square Error

  · R^2 (R-Square)

  · Nash-Sutcliffe Criterion

· Modified Coefficient of Efficiency

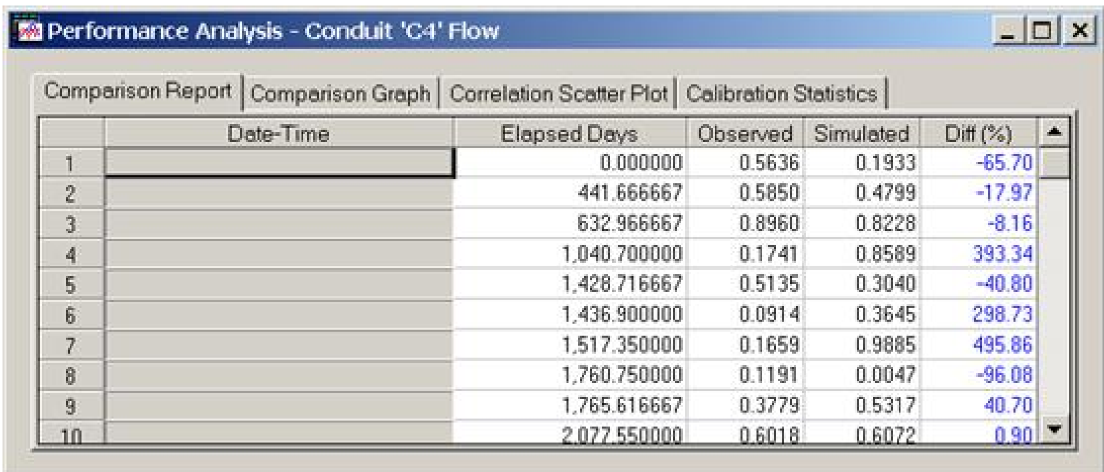
· Quantified Total Difference

2.8 PerformaNce ANALYSIS Dialog

The *Performance Analysis* dialog editor is launched by clicking on the *Analysis* button (

) from the *Conduit Measurement* dialog editor. InfoSWMM Calibrator allows you to compare results of a simulation against measured field data using one or more of the four buttons given on the *Performance Analysis* page: *Comparison Report*, *Comparison Graph*, *Correlation Scatter Plot*, and *Calibration Statistics*.

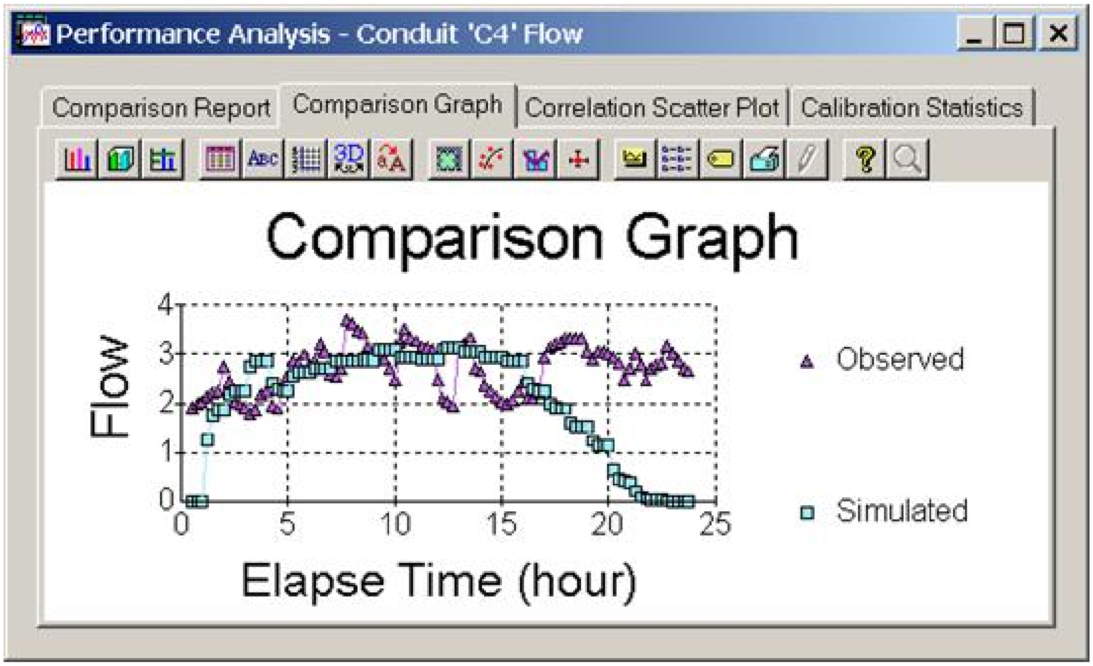
- **Comparison Report** – At every time that has the measurement data, the comparison report presents observed data and corresponding simulated values side-by-side along with differences between the two values.



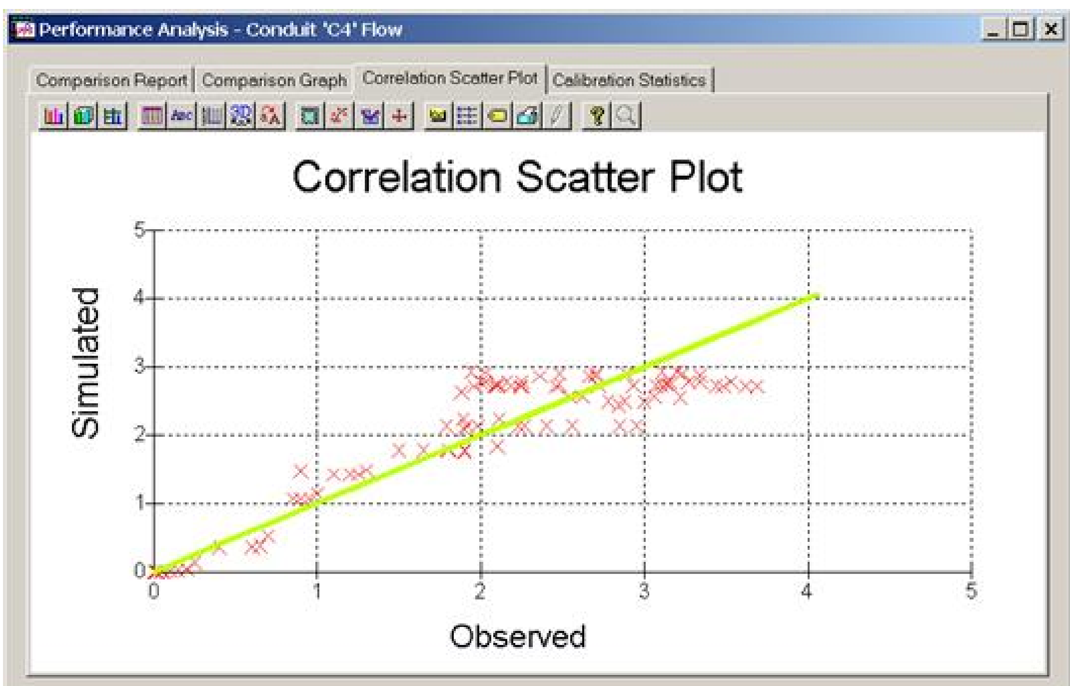
	Date-Time	Elapsed Days	Observed	Simulated	Diff (%)
1		0.000000	0.5636	0.1933	-65.70
2		441.666667	0.5850	0.4799	-17.97
3		632.966667	0.8960	0.8228	-8.16
4		1,040.700000	0.1741	0.8589	393.34
5		1,428.716667	0.5135	0.3040	-40.80
6		1,436.900000	0.0914	0.3645	298.73
7		1,517.350000	0.1659	0.9885	495.86
8		1,760.750000	0.1191	0.0047	-96.08
9		1,765.616667	0.3779	0.5317	40.70
10		2,077.550000	0.6018	0.6072	0.90

- **Comparison Graph** – Displays a plot of observed and simulated values against time.

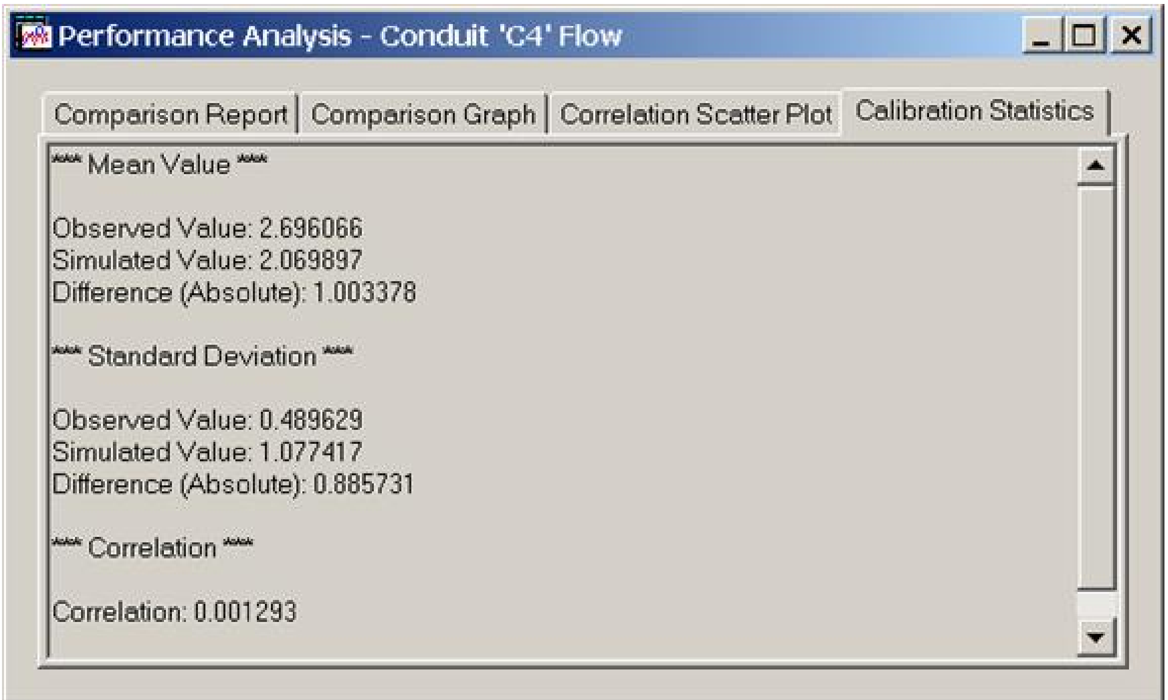
  The user has the options to modify appearance of the graph using icons on the top of the window.



· **Correlation Scatter Plot** – The correlation scatter plot displays simulated values against observed values. The closer that the points come to the 45-degree angle line on the plot the closer is the match between observed and simulated values.



- **Calibration Statistics** – In this tab, InfoSWMM Calibrator creates an ASCII calibration statistics report.



SECTION 3

QUICK START TUTORIAL

The Quick-Start tutorial is designed for first-time users of InfoSWMM Calibrator and provides a guided tour to core commands and functions used to create and execute a calibration run in InfoSWMM. As such, it should be used as a launching point to a more comprehensive understanding of the program.

The estimated time to complete the Quick Start tutorial is approximately one hour.

The Quick Start tutorial will help first-time users become familiar with the following:

1. Creating calibration data.

2. Setting important simulation options.

3. Making a calibration run.

4. Reviewing and analyzing calibration results.

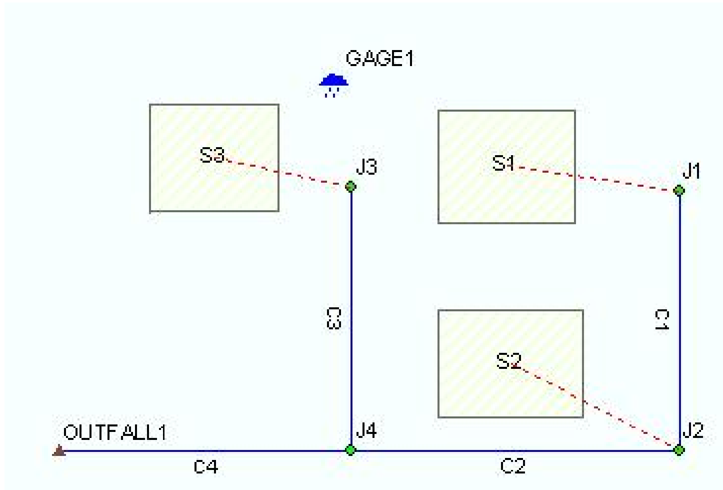
5. Exporting calibration results for various uses.

During the Quick Start tutorial, the user will modify an existing project called "**Yourcitycal**". This project is provided with the typical InfoSWMM Calibrator software installation and can be found in the InfoSWMM Examples directory:

C:\Program Files\INFOSWMM Version X\Examples\ **Yourcitycal.mxd**

(May be different for custom installations).

The "**Yourcitycal**" project modified in this tutorial illustrates how the module adjusts some of InfoSWMM parameters to best match field measurements to model simulation results. Note that the calibrable parameters used here are only to demonstrate how to use the calibration module. InfoSWMM Calibrator has the capability to optimize more than fifty different parameters. The "**Yourcitycal**" model schematic is shown below.



The model consists of the following network components:

1. Three subcatchments

2. Four junctions

3. Four conduits

4. One outfall

5. One raingage

During the tutorial, you will be guided through:

1. Creating subcatchment and conduit calibration groups.

2. Choosing calibration simulation options.

3. Performing a calibration run.

4. Exporting calibration results.

The first step is to open the InfoSWMM project.

1. From the “Start” menu, select Programs, choose the *INFOSWMM* program group, and then choose *INFOSWMM*.

2. Select *OPEN* from the *FILE* menu. On the *SPECIFY AN EXISTING INFOSWMM PROJECT FILE* dialog box, navigate to the directory containing the “**Yourcitycal**” project and choose that InfoSWMM project.

C:\Program Files\INFOSWMM Version X\Examples**Yourcitycal.mxd**

(May be different for custom installations)

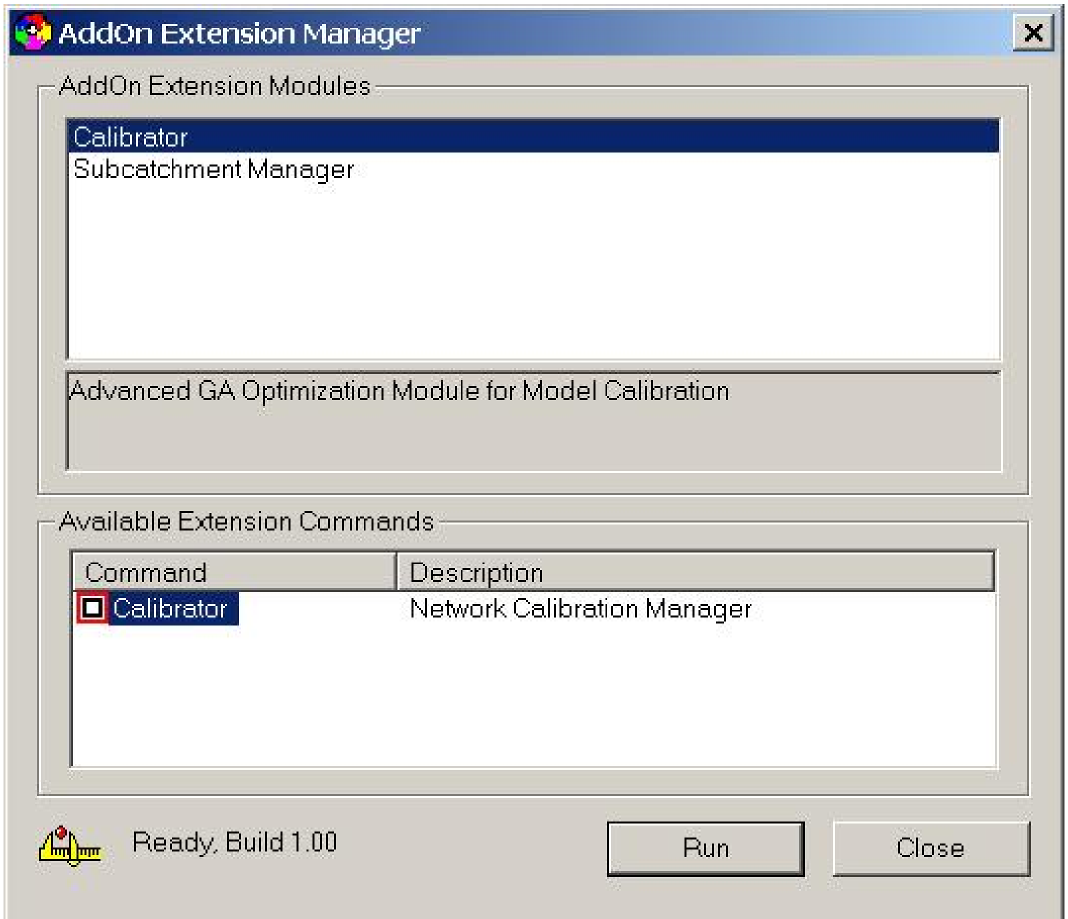
3. Click on the *PURPLE DOWN ARROW* icon  to initialize InfoSWMM. Click on the "Close" button on the initiated *LIVE UPGRADE/UPDATE CHECKER* dialog. When InfoSWMM is initialized, the icons on the InfoSWMM toolbars will be enabled for use.

4. Before continuing, save the "**Yourcitycal**" project to a new project name. If you wish to restart the tutorial, the original project will be available. Choose the *SAVE AS* command from the *FILE* menu. On the dialog box, enter the new project name "**Tutorial**". This becomes the active project.

STEP 1: Launch The Calibrator

The first step is to launch INFOSWMM Calibrator dialog box.

1. From the *TOOLS* menu choose Add-On Manager (or click on the Add-On Manager icon ). With the Add-On Manager Dialog box open, select Calibrator from the drop down list and click the "Run" button from the dialog box shown below. This will load the INFOSWMM Calibrator, and the dialog box appears on the screen.



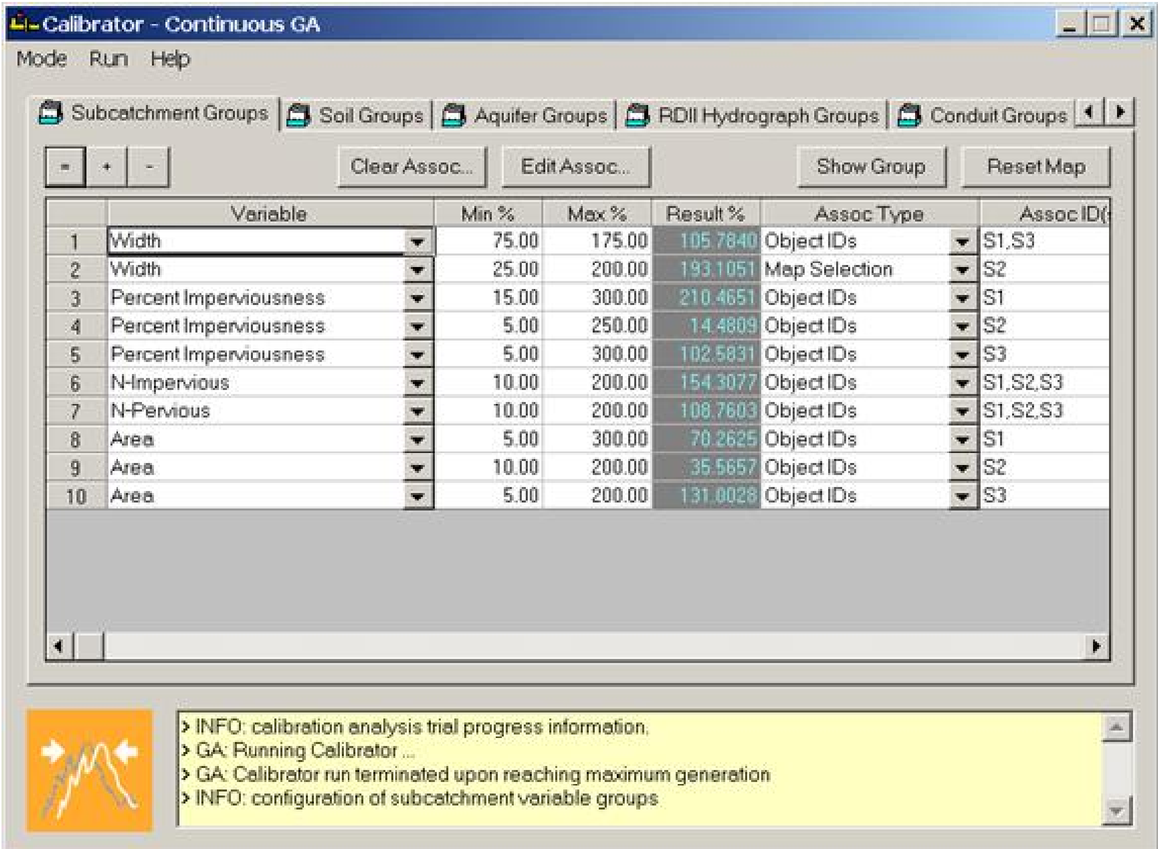
STEP 2: Select Subcatchment CALIBRATION GROUPS

Rainfall-runoff modeling involves a number of parameters and is subject to a great deal of uncertainty. As such it is the best candidate for calibration to achieve uncertainty reduction through parameter optimization. In this tutorial you will define ten subcatchment parameters (e.g., subcatchment width, percent Imperviousness, etc), and three infiltration parameters (Horton’s maximum infiltration rate, Horton’s minimum infiltration rate). Therefore, you will create ten subcatchment calibration groups and three soil calibration groups in this tutorial. Using InfoSWMM Calibrator, the modeler can optimize many more model parameters. Please note that subcatchments in the same group may or may not have the same parameter value. InfoSWMM Calibrator optimizes a multiplying factor (not the actual parameter value) that is multiplied by the original value assigned to the parameter for the individual element (e.g., width is 400 ft in this case for all the three subcatchments) to determine the actual value used to simulate runoff during the calibration process. All subcatchments in the same group use the same multiplying factor, but the original parameter value assigned to the subcatchments may or may not be the same. This approach offers the flexibility to handle variation in the characteristics of subcatchments and other objects.

For this example, ten subcatchment groups have already been created. However, to create different subcatchments groups, the following steps would be required.

1. Select the “Subcatchment Group” button 

and select the parameter to be calibrated (e.g., Width) for the *VARIABLE* field.



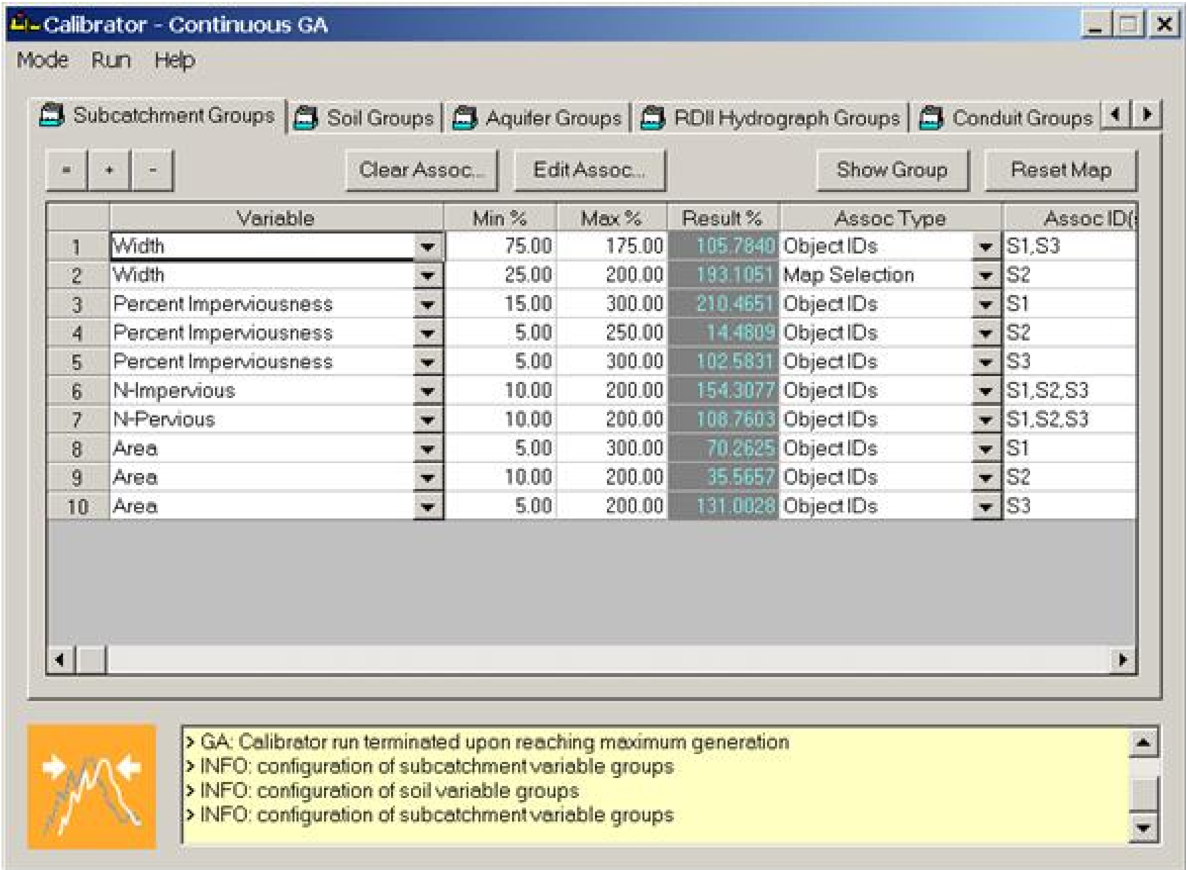
2. Choose the Object ID for the *ASSOC TYPE* field, and type ID of the subcatchment (s) to be part of the group in the *ASSOC ID* column. Please note that you could choose how to assign subcatchment IDs using any one of the available options (i.e., Object ID, Map Selection, Selection Set, DB Query, or Query Set).

STEP 3: define BOUNDS for Subcatchment Parameters Multipliers

The next step is to define the desired minimum and maximum limits (in percent) for the multiplier of subcatchment parameters for each of the ten calibration groups. Use the table below as a guide when entering this data.

GROUP ID	MIN (%)	MAX (%)
1	50	175
2	25	200
3	15	300
4	5	250
5	5	300
6	10	200
7	10	200
8	5	300
9	10	200
10	5	200

Based on the multiplier percentages specified above, for example, the subcatchment width in group 1 will vary within 50 to 175% of the original width assigned to the subcatchments in the group (i.e., 400 ft for both subcatchments). Width of subcatchment S2 could vary within 25% to 200% of the original width assigned to the subcatchment (i.e., 400 ft).


Calibrator - Continuous GA
Mode Run Help
Subcatchment Groups
Soil Groups
Aquifer Groups
RDII Hydrograph Groups
Conduit Groups
Clear Assoc...
Edit Assoc...
Show Group
Reset Map
Variable
Min %
Max %
Result %
Assoc Type
1 Width 75.00 175.00 105.7840 Object IDs S1,S3
2 Width 25.00 200.00 193.1051 Map Selection S2
3 Percent Imperviousness 15.00 300.00 210.4651 Object IDs S1
4 Percent Imperviousness 5.00 250.00 14.4809 Object IDs S2
5 Percent Imperviousness 5.00 300.00 102.5831 Object IDs S3
6 N-Impervious 10.00 200.00 154.3077 Object IDs S1,S2,S3
7 N-Pervious 10.00 200.00 108.7603 Object IDs S1,S2,S3
8 Area 5.00 300.00 70.2625 Object IDs S1
9 Area 10.00 200.00 35.5657 Object IDs S2
10 Area 5.00 200.00 131.0028 Object IDs S3
> GA: Calibrator run terminated upon reaching maximum generation
> INFO: configuration of subcatchment variable groups
> INFO: configuration of soil variable groups
> INFO: configuration of subcatchment variable groups

STEP 4: Select Soil CALIBRATION GROUPS

In this tutorial, you also need to calibrate two of Horton's infiltration parameters. The next step is therefore, to define the soil calibration groups. Soils should be grouped together based on their similarity in infiltration property such as soil type and texture.

For this example, three soil calibration groups have already been created. However, to create different soil groups, the following steps would be required.

1. Select the "Soil Group" button 

and select the parameter to be calibrated (e.g., maximum infiltration rate) for the *VARIABLE* field.

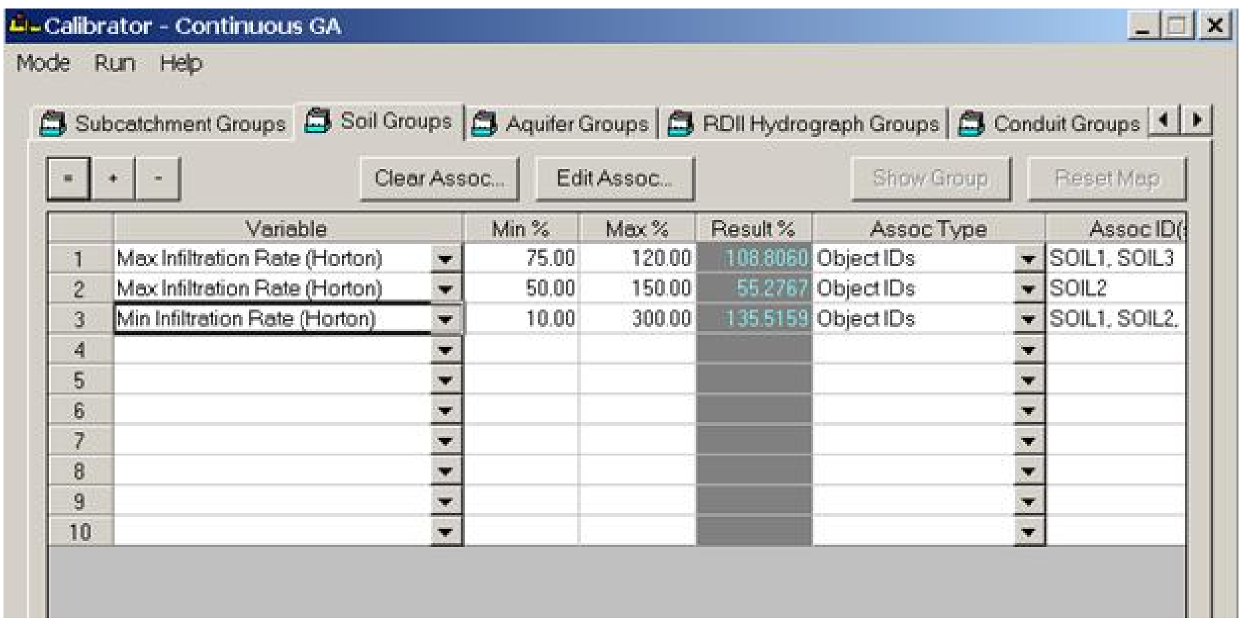
2. Choose the Object ID for the *ASSOC TYPE* field, and type ID of the soils (s) to be part of the group in the *ASSOC ID* column.

STEP 5: define BOUNDS for Infiltration Rate Multipliers

The next step is to define the desired minimum and maximum limits for the infiltration rate parameters for each group. Use the table below as a guide when entering this data.

GROUP ID	MIN %	MAX %
1	75	120
2	50	150
3	10	300

The *Soil Group* page should now appears as follows.



STEP 6: sPecify Measurement Data

You will now specify the measurements at target conduits to which the system needs to be calibrated. The measurements could be flow, depth, or velocity. In this tutorial you will specify and use a 24-hour flow data measured at intervals of 15-munite at conduit C4. The measurement data is specified in the form of Time Series. A time series has three columns: date (contains month, day, and year information), time of the day, and value columns.

To define the measurement data,

1. Select the "Conduit Measurement Group" button 

and insert the conduit ID (i.e., C4) where the measurement is taken to the *CONDUIT ID* field.

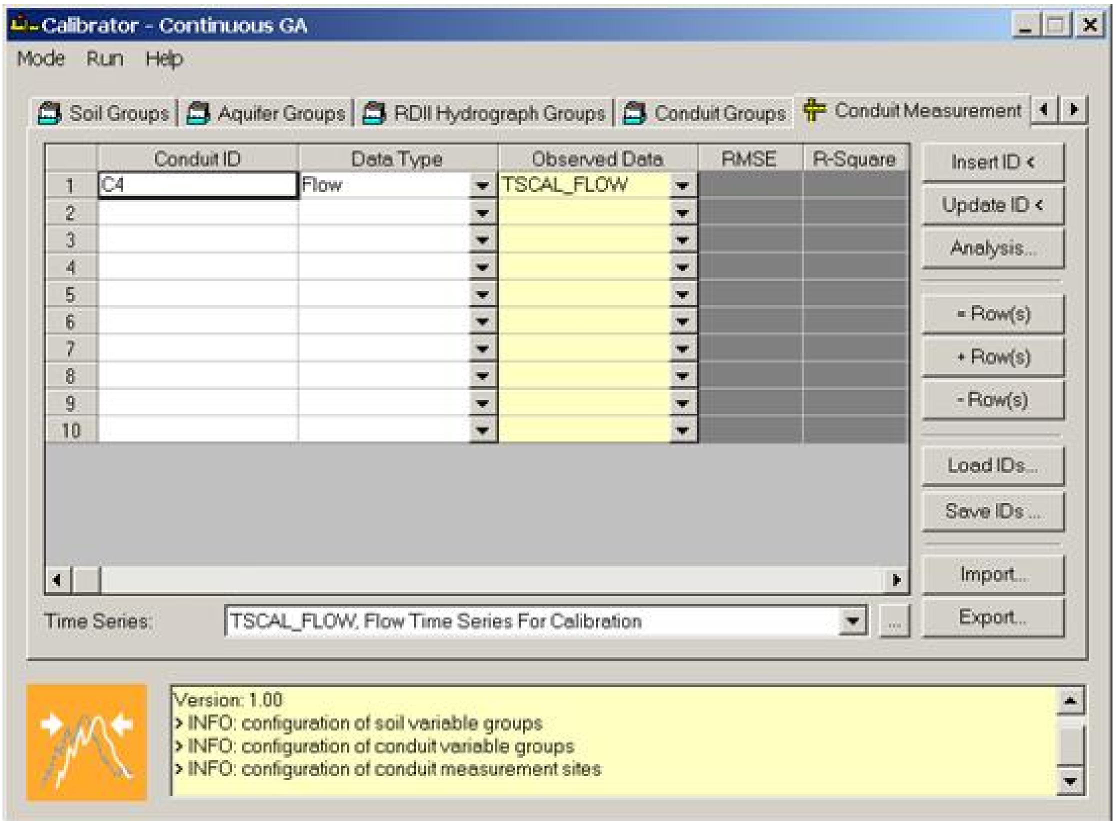
You could also click on the 

button and graphically select the conduit.

2. Choose *Flow* for the *DATA TYPE* field.

3. Specify "TSCAL_FLOW" time series for the *OBSERVED DATA* field.

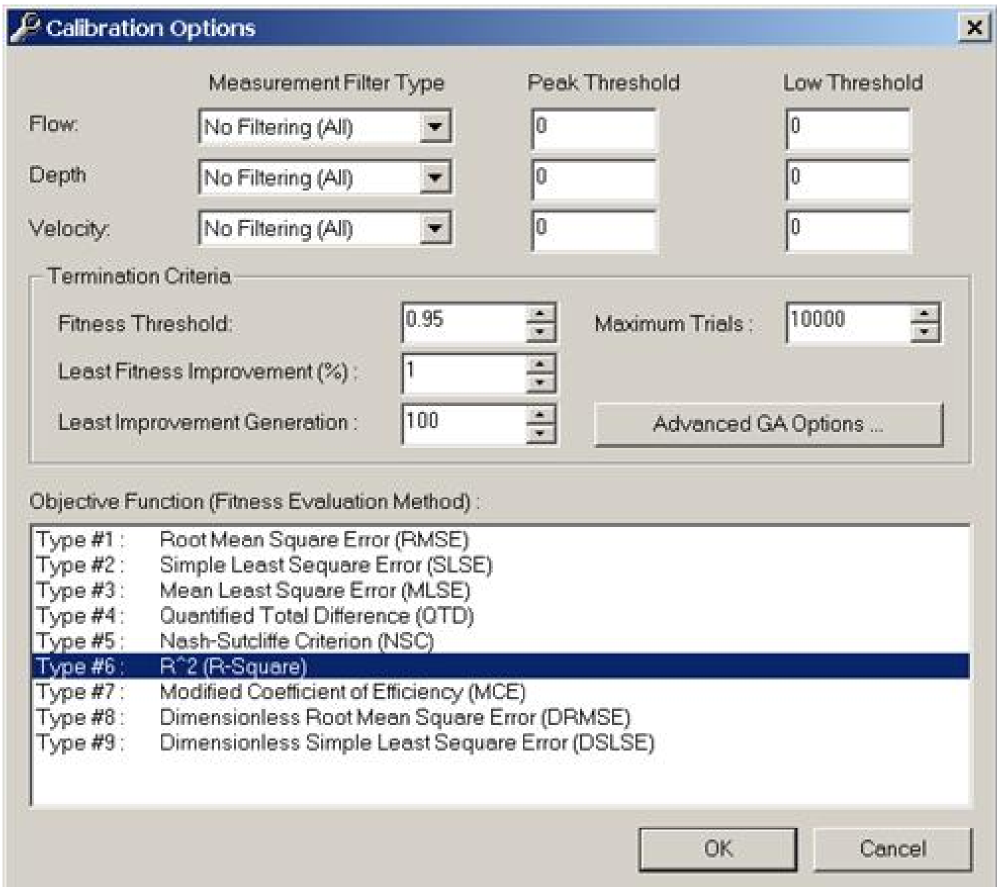
The *Conduit Measurement* dialog editor should now appears as follows.


Calibrator - Continuous GA
Mode
Run
Help
Soil Groups
Aquifer Groups
RDII Hydrograph Groups
Conduit Groups
Conduit Measurement
Conduit ID
Data Type
Observed Data
RMSE
R-Square
C4
Flow
TSCAL_FLOW
Insert ID <
Update ID <
Analysis...
= Row(s)
+ Row(s)
- Row(s)
Load IDs...
Save IDs ...
Import...
Export...
Time Series:
TSCAL_FLOW, Flow Time Series For Calibration
Version: 1.00
> INFO: configuration of soil variable groups
> INFO: configuration of conduit variable groups
> INFO: configuration of conduit measurement sites

STEP 7: select CALIBRATION RUN options

Now that you have completed the process of creating a calibration run, the next step is to define your calibration run options. You will specify a Type 2 objective function (R-Square), a “Fitness Threshold” of 0.95, a “Least Fitness Improvement” of 1 percent, a “Least Improvement Generation” of 20, and a maximum number of trials of 500 (default value).

1. Choose the “Options” command from the Run menu and enter the data shown below in the *Calibration Options* dialog box.

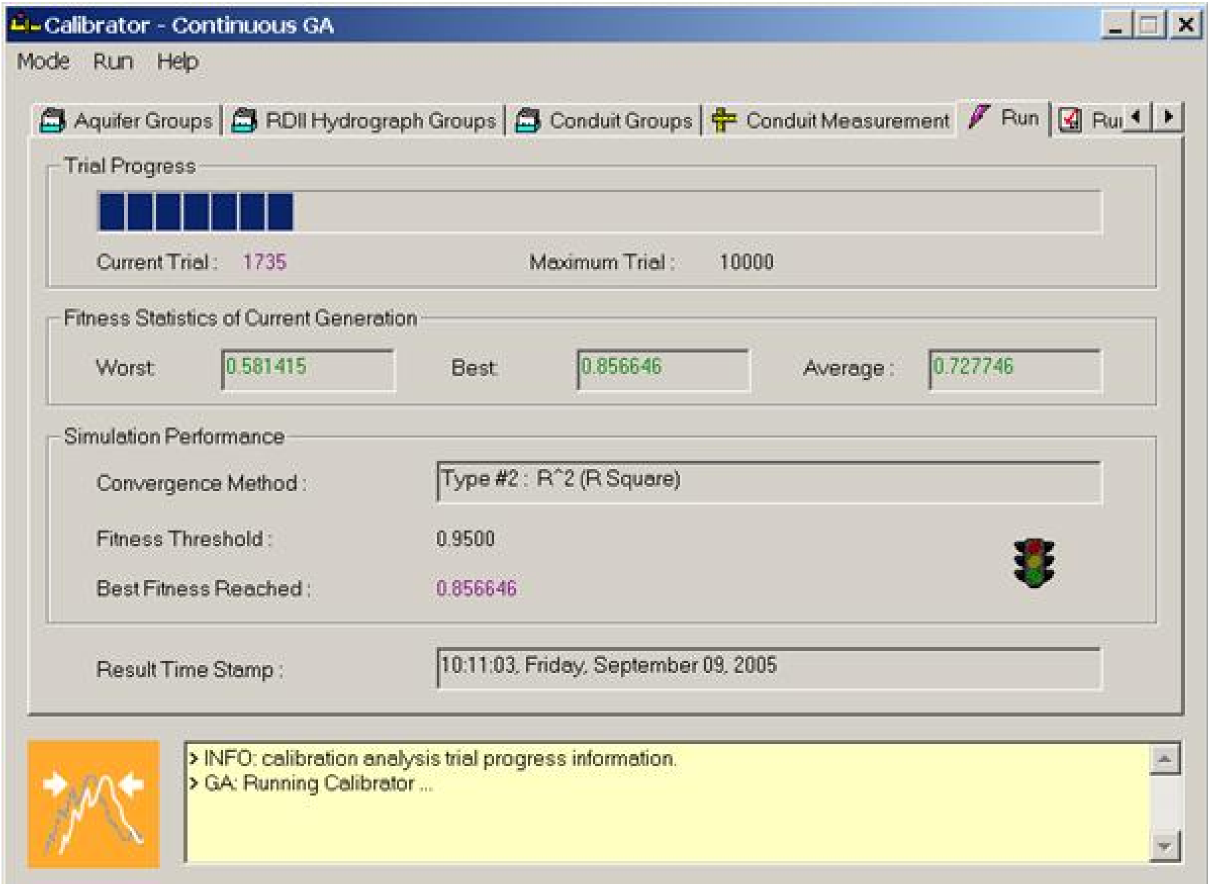


2. Press the “OK” button 

to close the dialog box.

STEP 10: run the calibration Model

You have now entered all required information for calibration model. To run the calibration model, choose the “Start” command from the Run menu. The *Run* tab appears on the screen.

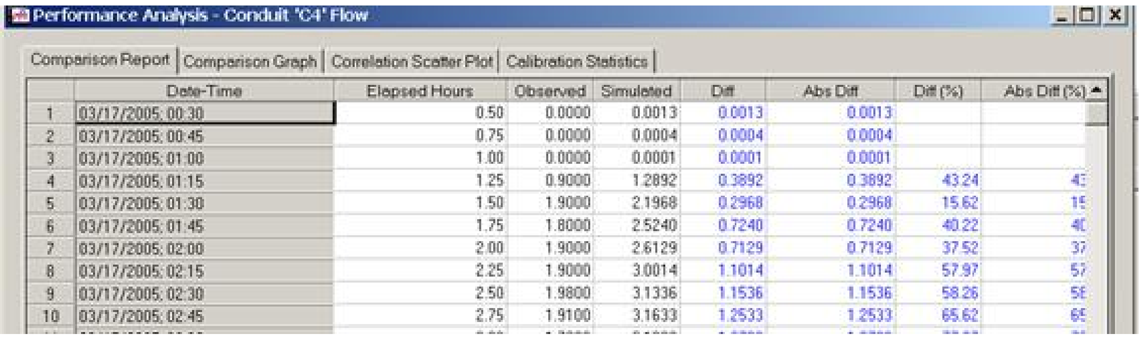


As shown in the *Run* tab, a fitness of 0.856646 was reached after 1735 trials for the type 2 fitness function specified.

STEP 11: REVIEW CALIBRATION RESULTS

The calibration results can be reviewed by choosing the Analysis... tab from the Conduit Measurement dialog box and/or using the Run Summary window.

Tabular comparison of observed and simulated values is given on the comparison report page.

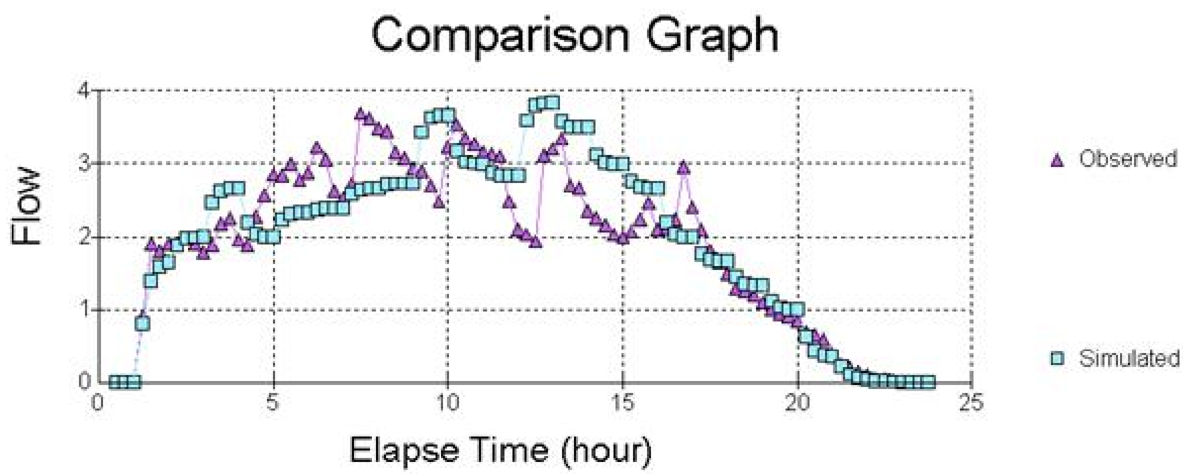


Performance Analysis - Conduit 'C4' Flow

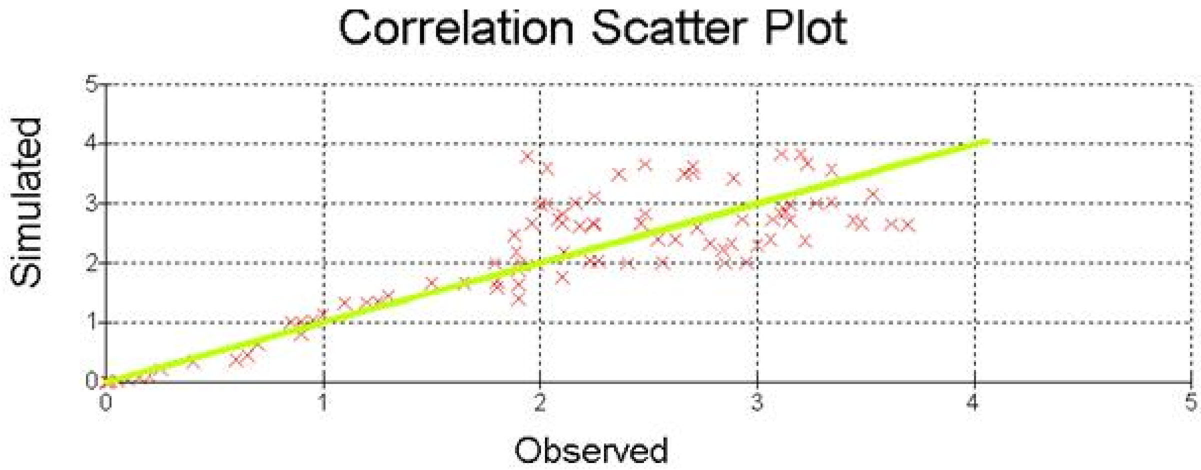
Comparison Report | Comparison Graph | Correlation Scatter Plot | Calibration Statistics

	Date-Time	Elapsed Hours	Observed	Simulated	Diff	Abs Diff	Diff (%)	Abs Diff (%)
1	03/17/2005; 00:30	0.50	0.0000	0.0013	0.0013	0.0013		
2	03/17/2005; 00:45	0.75	0.0000	0.0004	0.0004	0.0004		
3	03/17/2005; 01:00	1.00	0.0000	0.0001	0.0001	0.0001		
4	03/17/2005; 01:15	1.25	0.9000	1.2892	0.3892	0.3892	43.24	43
5	03/17/2005; 01:30	1.50	1.9000	2.1968	0.2968	0.2968	15.62	15
6	03/17/2005; 01:45	1.75	1.8000	2.5240	0.7240	0.7240	40.22	40
7	03/17/2005; 02:00	2.00	1.9000	2.6129	0.7129	0.7129	37.52	37
8	03/17/2005; 02:15	2.25	1.9000	3.0014	1.1014	1.1014	57.97	57
9	03/17/2005; 02:30	2.50	1.9800	3.1336	1.1536	1.1536	58.26	58
10	03/17/2005; 02:45	2.75	1.9100	3.1633	1.2533	1.2533	65.62	65

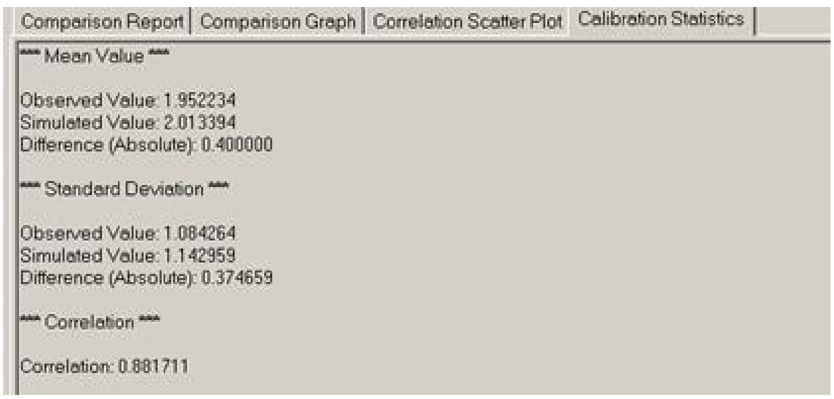
The Comparison Graph page presents graphical comparison of observed and simulated values.



The Correlation Scatter Plot page plots simulated results against observed value as shown below.



Statistical summary of the performance of the calibrator is given on the Calibration Statistics page.



The 

page presents summary of basic performance indicators (e.g., basic goodness-of-fit criteria) and summary of the optimization run (e.g., number of simulations, generation number, etc).

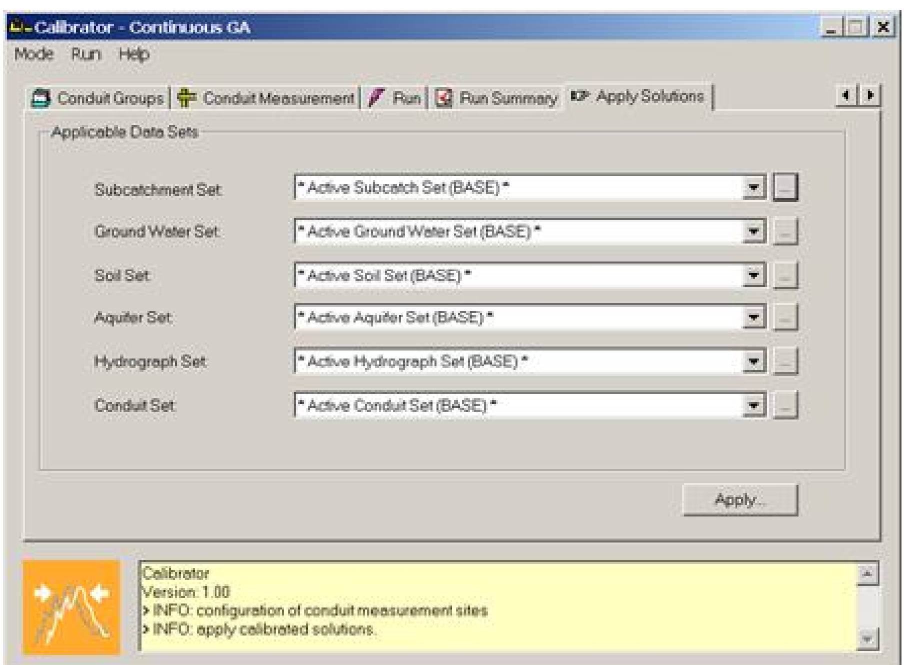
STEP 12: APPLY SOLUTIONS

You can apply the calibration result to the model using the Apply Solutions page. You could select the scenario of your choice to which the calibration result has to be applied.

1. Choose the Apply Solutions tab and launch the dialog editor.

2. Choose the desired Data Set IDs for the available groups. You could click on the "…" button to create "New" data set as well.

3. Choose the "Apply" button Apply... to execute the apply command. The calibration results are now saved to the appropriate data sets. The *Apply Solutions* tab should appear as follows. It should be noted that the apply solution command multiplies the optimal values of the multipliers identified by the calibrator with the original parameter values given to the corresponding elements (e.g., subcatchment); determines actual parameter values; and saves it to the selected data set. If used with the active scenario, the apply button could be used only once. Subsequent usage will have no effect. If used with non-active scenarios, every usage of the apply button will keep on multiplying the current parameter value by the optimal multiplier. Therefore, the user needs to be cautious not to make undesired usage of this essential functionality.



Congratulations! You have now completed the calibration tutorial.

SECTION 4

METHODOLOGY

The successful application of a sewer collection system model to the planning, design, and management of urban stormwater systems is highly dependent upon how well the model is calibrated and how well the model mimics the reality. Model calibration consists of fine tuning of model parameters until the model simulates field conditions to an established degree of accuracy. Fine-tuning of the model entails making adjustments to the model parameters to obtain the desired output data. The degree of accuracy refers to the difference between simulated and actual values and is used to establish a level of confidence in the model. It is normally expressed as a percent difference (typically [10 percent) between model predictions and actual measurements. Calibration is important to establish model credibility, create a benchmark, produce a predictive tool, increase knowledge and understanding of the system and its operations, and to discover errors or unknown conditions in the field.

Periodic re-calibration of models is also necessary not only when major new facilities are added to the system or when system operations change, but also to learn more about the system so that informed decisions can be effectively made to improve system operations and performance.

InfoSWMM Calibrator provides a fully automated approach to accurate and efficient stormwater management model calibration. The program makes use of a variation of the genetic algorithm optimization technology enriched with global search control strategies and closely coupled with InfoSWMM for maximum efficiency, performance and reliability.

4.1 CALIBRATION FORMULATION

When calibrating a stormwater management model, the goal is to determine the best set of InfoSWMM model parameters which produces the lowest overall deviation between the numerically simulated model results and the observed field data at user specified locations in the system. Observed field data can include link flow, link depth, and link velocity measurements. These measurements could be taken at one or more links in the system.

Grouping is very useful in the calibration process. InfoSWMM calibrator has five group types: subcatchment group, soil group, aquifer group, RDII group, and conduit group. Grouping has to be made accounting for similarity in the characteristics of the elements. For example, if the modeler is interested in calibrating subcatchment width s/he may need to group subcatchments depending on their similarity in shape/size so that subcatchments in the group may use the same multiplying factor during the calibration. To calibrate Manning's roughness parameter for conduits, one may need to group conduits together depending on similarity in their characteristics such as material, date of installation, location, and diameter. It is assumed that all elements within a group will have an identical multiplying factor for the parameter being calibrated. The multiplying factor would be multiplied by the original parameter value assigned to each of the individual elements to determine actual value of parameter to be used during the calibration process.

InfoSWMM Calibrator casts the calibration problem as an implicit nonlinear optimization problem, subject to explicit inequality and equality constraints. It computes optimal model parameters within user-specified bounds, such that the deviation between the model predictions and field measurements is minimized. The optimal model calibration problem is thus governed by an objective function and its associated set of constraints.

4.1.1 OBJECTIVE FUNCTION

The objective of the optimal calibration problem is to minimize the numerical discrepancy between the observed and predicted values of link flow, link depth, and/or link velocity at various locations in the system. Any of the following five different mathematical objective functions can be used in InfoSWMM Calibrator.

Root Mean Square Error (RMSE)

$$\text{Minimize} \quad \sqrt{\frac{\left(\sum_{i=1}^{N}(Pobs_i - Psim_i)^2\right)}{N}}$$

In the ideal condition when corresponding observed and simulated values exactly match, value of RMSE will be zero.

Simple Least Square Error (SLSE)

$$Minimize \quad \sum_{i=1}^{N} (Pobs_i - Psim_i)^2$$

This performance evaluation function could assume values ranging from zero (best fit) to ∞ (poor fit), and it tends to favor large errors and large (i.e., peak) flows.

Mean Simple Least Square Error (MSLSE)

$$Minimize \quad \frac{\sum_{i=1}^{N} (Pobs_i - Psim_i)^2}{N}$$

This performance evaluation function could assume values ranging from zero (best fit) to ∞ (poor fit), and it tends to favor large errors and large (i.e., peak) flows.

Difference in Total Volume

$$Minimize \quad \left(\sum_{i=1}^{N} Pobs_i - \sum_{i=1}^{N} Psim_i \right)$$

Difference in total volume could range from -∞ (poor performance) to ∞ (poor performance), the ideal value being zero (i.e., exact match between total simulated volume and total observed volume).

Nash-Sutcliffe Efficiency Criterion

$$Maximize \quad \left(1 - \frac{\sum_{i=1}^{N} (Pobs_i - Psim_i)^2}{\sum_{i=1}^{N} (Pobs_i - \overline{P}obs)^2} \right)$$

This efficiency criterion could assume values from -∞ (poor performance) to 1 (perfect model).

R-Square (R^2)

$$Maximize \quad \left(\frac{\sum_{i=1}^{N}(Pobs_i - \overline{P}obs)(Psim_i - \overline{P}sim)}{\left[\sum_{i=1}^{N}(Pobs_i - \overline{P}obs)^2\right]^{0.5}\left[\sum_{i=1}^{N}(Psim_i - \overline{P}sim)^2\right]^{0.5}} \right)^2$$

R^2 value varies from zero (indicates worst fit) to unity (indicates perfect fit).

Modified Coefficient of Efficiency

$$Maximize \quad \left(1 - \frac{\sum_{i=1}^{N}\left|Pobs_i - Psim_i\right|}{\sum_{i=1}^{N}\left|Pobs_i - \overline{P}obs\right|} \right)$$

The modified coefficient of efficiency could assume values from -∞ (poor performance) to 1 (perfect model).

Dimensionless Root Mean Square Error (DRMSE)

$$Minimize \quad \frac{\sqrt{\dfrac{\left(\sum_{i=1}^{N}(Pobs_i - Psim_i)^2\right)}{N}}}{\overline{P}obs}$$

In the ideal condition when corresponding observed and simulated values exactly match, value of DRMSE will be zero.

Dimensionless Simple Least Square Error (DSLSE)

$$Minimize \quad \sum_{i=1}^{N}\left(\frac{Pobs_i - Psim_i}{Pobs_i}\right)^2$$

This performance evaluation function could assume values ranging from zero (best fit) to ∞ (poor fit), and it tends to be independent of length of records and it favor large errors and large (i.e., peak) flows.

where N designates the total number of measurements available, $Pobs_i$ represents the observed measurement values at time i; $Psim_i$ is the model simulated values at time i; $\tilde{P}obs$ is mean of the measured values; $\tilde{P}sim$ is mean of the simulated values.

It is believed that complete assessment of model performance should include at least one relative error measure (e.g., modified coefficient of efficiency) and at least one absolute error measure (e.g., root mean square error) with additional supporting information (e.g., a comparison between the observed and simulated mean and standard deviation)[2].

The number of field measurements defining the objective function must be greater than or equal to the number of calibration variables. It is expected that the accuracy of the model calibration would be increased by the use of a large number of field measurements. The decision variables could be any one or more of about fifty InfoSWMM parameters. These decision variables are automatically adjusted to minimize the objective function selected while satisfying a set of implicit and explicit constraints.

4.1.2 IMPLICIT SYSTEM CONSTRAINTS

The implicit constraints on the system correspond to equations that govern/simulate the underlying hydrologic, hydraulic and water quality processes including conservation of mass and conservation of momentum at various scales such as node, and/or link, and/or the entire system. Each function call to InfoSWMM with a set of decision variables returns the simulated values for link flow, link depth, and link velocity that will be compared with corresponding measured data.

4.1.3 EXPLICIT CONSTRAINTS

The explicit bound constraints are used to set minimum (lower) and maximum (upper) limits on the calibrable InfoSWMM parameters. For example, for each conduit group G (where a single conduit may constitute a group) Manning's roughness coefficient for a conduit in the group may be bound by an explicit inequality constraint as follows:

$$k_{min} \times n_i \leq n_i \leq k_{max} \times n_i \qquad \forall G$$

where k_{min} designates the lower bound multiplier (minimum value of a multiplier) for roughness coefficient of conduits in conduit group G; k_{max} represents the upper bound multiplier (maximum value of a multiplier) for roughness coefficient of conduits in conduit group G; and n is roughness coefficient value for conduit i in group G. Please note that each of the conduits in group *G* could take different values of *n*. The only value that is same for all conduits in the group is the multiplier *k*.

It should be noted that the choice of grouping may greatly affect the calculated parameter values as well as the convergence accuracy. It is also expected that the final calculated parameters, will be close to the actual values (i.e., optimal/near optimal values) although they may not be “exact” or absolute optima.

4.2 GENETIC ALGORITHMS

Genetic algorithms (GA) are an adaptation procedure based on the mechanics of natural genetics and natural selection[1]. They are designed to perform search procedures of an artificial system by emulating the evolution process (Darwin's evolution principle) observed in nature and biological organisms. The evolution process is based on the preferential survival and reproduction of the fittest member of a population with direct inheritance of genetic information from parents to offspring and the occasional mutation of genes. The principal advantages of genetic algorithms are their ability to converge expeditiously on an optimal or near-optimal solution without having to analyze all possible solutions available and without requiring derivatives or other auxiliary knowledge.

4.2.1 OVERVIEW OF GENETIC ALGORITHMS

Genetic algorithms are fundamentally different from traditional optimization methods in terms of the search process. While traditional routines track only a single pathway to the optimal solution, genetic algorithms search from an entire population of possible solutions (individuals). In addition, genetic algorithms use randomized and localized operators as opposed to deterministic rules. Each individual in the population is represented by either a string or a set of real numbers encoding one possible solution. The performance of each individual in the population is measured by its fitness (goodness), which quantifies the degree of optimality of the solution. Based on their fitness values, individuals are selected for reproduction of the next generation. Each new generation maintains its original size. The selected individuals reproduce their offspring by mimicking gene operations of crossover and mutation. After a number of generations, the population is expected to evolve artificially, and the optimal or near optimal solution is ultimately reached.

4.2.2 COMPONENTS OF GENETIC ALGORITHMS

Standard genetic algorithms involve three basic functions: selection, crossover, and mutation. Each function is briefly described below.

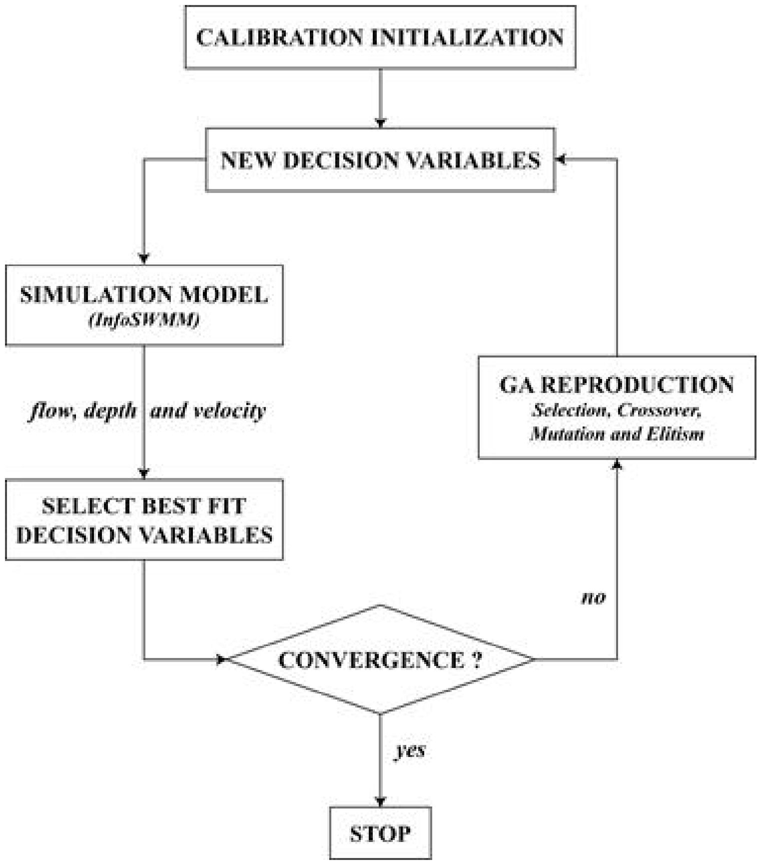
Selection – Individuals in a population are selected for reproduction according to their fitness values. In biology, fitness is the number of offspring that survive to reproduction. Given a population consisting of individuals identified by their chromosomes, selecting two chromosomes to represent parents to reproduce offspring is guided by a probability rule that the higher the fitness an individual has, the more likely the individual will survive. There are many selection methods available including weighted roulette wheel, sorting schemes, proportionate reproduction, and tournament selection.

Crossover - Selected parents reproduce the offspring by performing a crossover operation on the chromosomes (cut and splice pieces of one parent to those of another). In nature, crossover implies two parents exchange parts of their corresponding chromosomes. In genetic algorithms, a crossover operation makes two strings swap their partial strings. Since more fit individuals have a higher probability of producing offspring than less fit ones, the new population will possess, on average, an improved fitness level. The basic crossover is a one-point crossover. Two selected strings create two offspring strings by swapping the partial strings, which is cut by one randomly sampled breakpoint along the chromosome. The one-point crossover can easily be extended to *k*-point crossover. It randomly samples *k* breakpoints on chromosomes and then exchanges every second corresponding segments of two parent strings.

Mutation - Mutation is an insurance policy against lost genes. It works on the level of string genes by randomly altering gene value. With small probability, it randomly selects one gene on a chromosome then replaces the gene by a randomly selected value. The operation is designed to prevent GA from premature termination namely converging to a solution too early.

Elitism - The selection and crossover operators will tend to ensure that the best genetic material and the components of the fittest chromosomes will be carried forward to the next generation. However, the probabilistic nature of these operators implies that this will not always be the case. An elitist strategy is therefore required to ensure that the best genetic material will not be lost by chance. This is accomplished by always carrying forward the best chromosome from one generation to the next.

The flowchart below illustrates the optimal calibration process.


CALIBRATION INITIALIZATION
NEW DECISION VARIABLES
SIMULATION MODEL
(InfoSWMM)
flow, depth and velocity
SELECT BEST FIT DECISION VARIABLES
CONVERGENCE ?
no
yes
STOP
GA REPRODUCTION
Selection, Crossover, Mutation and Elitism

4.3 REFERENCES

1. Goldberg, D.E. (1989). *Genetic Algorithms in Search, Optimization and Machine Learning*. Addison Wesley, Reading, MA.

2. Legates, D.R. and McCabe, G.J. (1999). "Evaluating the Use of Goodness of Fit Measures in Hydrologic and Hydroclimatic Model Validation," Water Resources Research, Vol. 35, pp. 233-241.

Methodology for InfoSWMM

The successful application of a sewer collection system model to the planning, design, and management of urban stormwater systems is highly dependent upon how well the model is calibrated and how well the model mimics the reality. Model calibration consists of fine tuning of model parameters until the model simulates field conditions to an established degree of accuracy. Fine-tuning of the model entails making adjustments to the model parameters to obtain the desired output data. The degree of accuracy refers to the difference between simulated and actual values and is used to establish a level of confidence in the model. It is normally expressed as a percent difference (typically [10 percent) between model predictions and actual measurements. Calibration is important to establish model credibility, create a benchmark, produce a predictive tool, increase knowledge and understanding of the system and its operations, and to discover errors or unknown conditions in the field.

Periodic re-calibration of models is also necessary not only when major new facilities are added to the system or when system operations change, but also to learn more about the system so that informed decisions can be effectively made to improve system operations and performance.

InfoSWMM Calibrator provides a fully automated approach to accurate and efficient stormwater management model calibration. The program makes use of a variation of the genetic algorithm optimization technology enriched with global search control strategies and closely coupled with InfoSWMM for maximum efficiency, performance and reliability.

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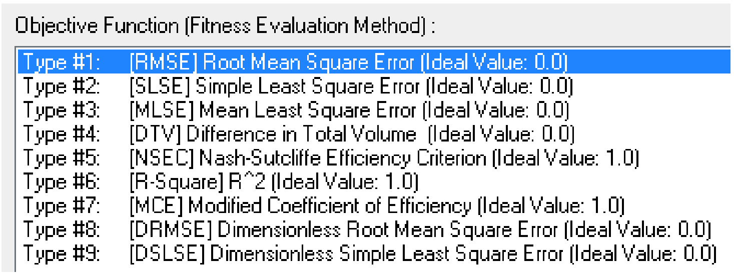
Objective

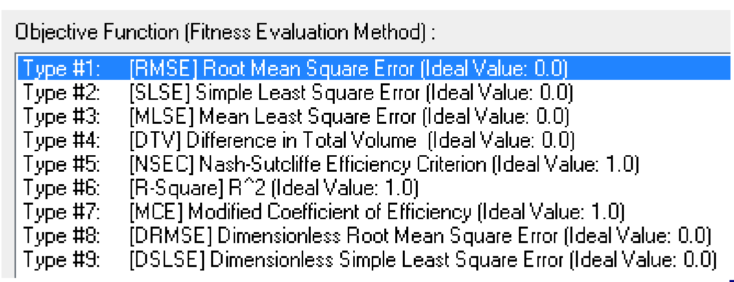
The objective of the optimal calibration problem is to minimize the numerical discrepancy between the observed and predicted values of link flow, link depth, and/or link velocity at various locations in the system. Any of the following five different mathematical objective functions can be used in InfoSWMM Calibrator.



Root Mean Square Error (RMSE)

$$Minimize \quad \sqrt{\frac{\left(\sum_{i=1}^{N}(Pobs_i - Psim_i)^2\right)}{N}}$$

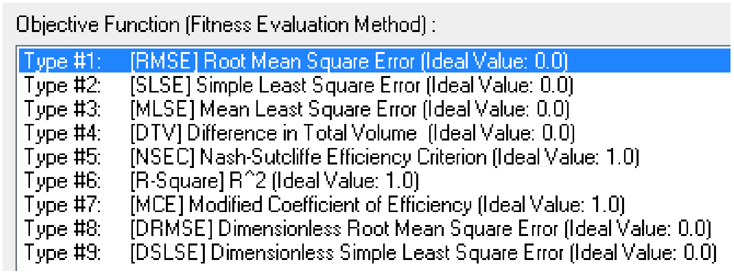
In the ideal condition when corresponding observed and simulated values exactly match, value of RMSE will be zero.



Simple Least Square Error (SLSE)

$$Minimize \quad \sum_{i=1}^{N}(Pobs_i - Psim_i)^2$$

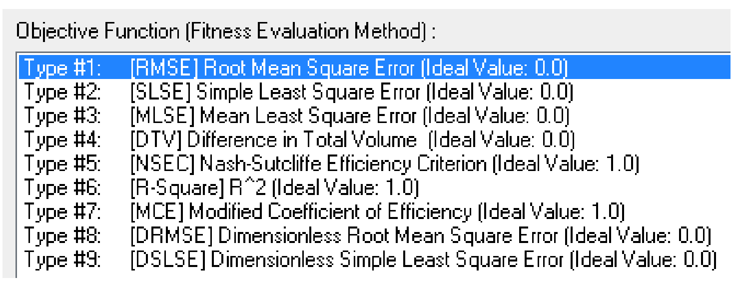
This performance evaluation function could assume values ranging from zero (best fit) to ∞ (poor fit), and it tends to favor large errors and large (i.e., peak) flows.



Mean Simple Least Square Error (MSLSE)

$$Minimize \quad \frac{\sum_{i=1}^{N}(Pobs_i - Psim_i)^2}{N}$$

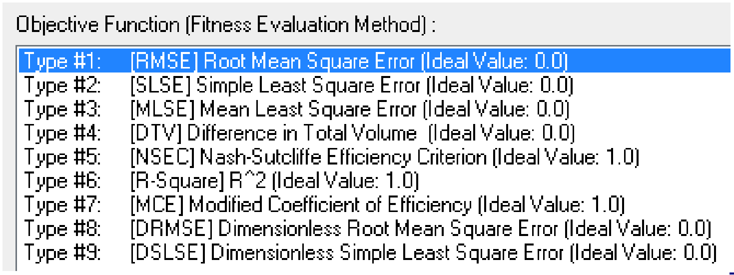
This performance evaluation function could assume values ranging from zero (best fit) to ∞ (poor fit), and it tends to favor large errors and large (i.e., peak) flows.



Difference in Total Volume

$$Minimize \quad \left(\sum_{i=1}^{N} Pobs_i - \sum_{i=1}^{N} Psim_i \right)$$

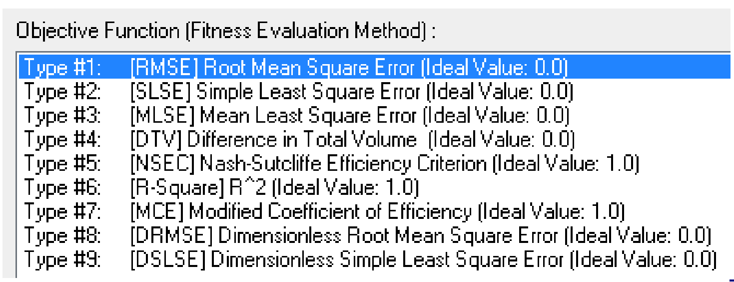
Difference in total volume could range from -∞ (poor performance) to ∞ (poor performance), the ideal value being zero (i.e., exact match between total simulated volume and total observed volume).



Nash-Sutcliffe Efficiency Criterion

$$Maximize \quad \left(1 - \frac{\sum_{i=1}^{N} (Pobs_i - Psim_i)^2}{\sum_{i=1}^{N} (Pobs_i - \overline{P}obs)^2} \right)$$

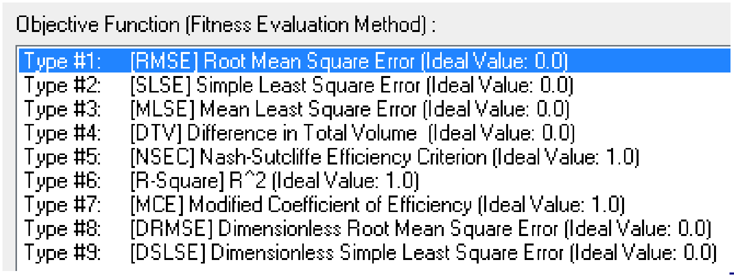
This efficiency criterion could assume values from -∞ (poor performance) to 1 (perfect model).



R-Square (R^2)

$$Maximize \quad \left(\frac{\sum_{i=1}^{N} (Pobs_i - \overline{P}obs)(Psim_i - \overline{P}sim)}{\left[\sum_{i=1}^{N} (Pobs_i - \overline{P}obs)^2 \right]^{0.5} \left[\sum_{i=1}^{N} (Psim_i - \overline{P}sim)^2 \right]^{0.5}} \right)^2$$

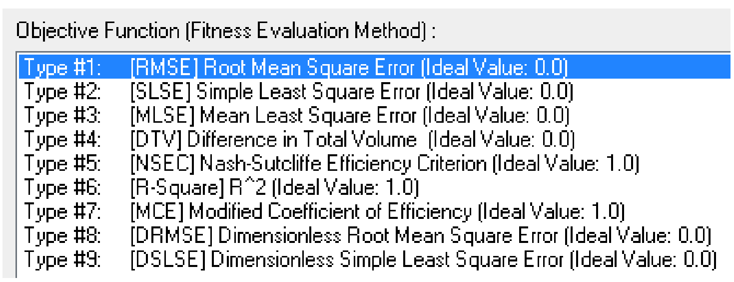
R^2 value varies from zero (indicates worst fit) to unity (indicates perfect fit).



Modified Coefficient of Efficiency

$$Maximize \quad \left(1 - \frac{\sum_{i=1}^{N} \left| Pobs_i - Psim_i \right|}{\sum_{i=1}^{N} \left| Pobs_i - \overline{P}obs \right|} \right)$$

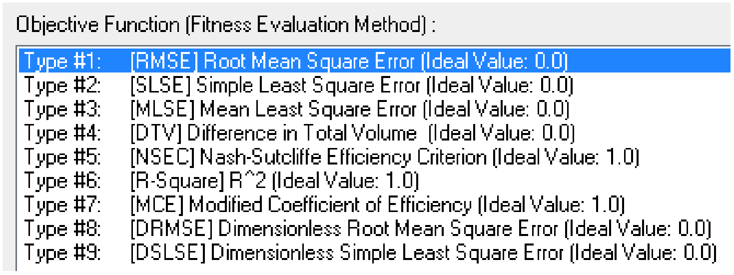
The modified coefficient of efficiency could assume values from -∞ (poor performance) to 1 (perfect model).



Dimensionless Root Mean Square Error (DRMSE)

$$Minimize \quad \frac{\sqrt{\frac{\left(\sum_{i=1}^{N} (Pobs_i - Psim_i)^2 \right)}{N}}}{\overline{P}obs}$$

In the ideal condition when corresponding observed and



Dimensionless Simple Least Square Error (DSLSE)

Simulated values exactly match, value of DRMSE will be zero.

$$Minimize \qquad \sum_{i=1}^{N}\left(\frac{Pobs_i - Psim_i}{Pobs_i}\right)^2$$

This performance evaluation function could assume values ranging from zero (best fit) to ∞ (poor fit), and it tends to be independent of length of records and it favor large errors and large (i.e., peak) flows.

where N designates the total number of measurements available, $Pobs_i$ represents the observed measurement values at time i; $Psim_i$ is the model simulated values at time i;$Pobs$ is mean of the measured values; $Psim$ is the mean of the simulated values.

It is believed that complete assessment of model performance should include at least one relative error measure (e.g., modified coefficient of efficiency) and at least one absolute error measure (e.g., root mean square error) with additional supporting information (e.g., a comparison between the observed and simulated mean and standard deviation)[2].

The number of field measurements defining the objective function must be greater than or equal to the number of calibration variables. It is expected that the accuracy of the model calibration would be increased by the use of a large number of field measurements. The decision variables could be any one or more of about fifty nfoSWMM parameters. These decision variables are automatically adjusted to minimize the objective function selected while satisfying a set of implicit and explicit constraints.

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4.1.2 Implicit System Constraints

The implicit constraints on the system correspond to equations that govern/simulate the underlying hydrologic, hydraulic and water quality processes including conservation of mass and conservation of momentum at various scales such as node, and/or link, and/or the entire system. Each function call to InfoSWMM with a set of decision variables returns the simulated values for link flow, link depth, and link velocity that will be compared with corresponding measured data.

4.1.3 Explicit Bound Constraints

The explicit bound constraints are used to set minimum (lower) and maximum (upper) limits on the calibrable InfoSWMM

parameters. For example, for each conduit group *G*

(where a single conduit may constitute a group) Manning's roughness coefficient for a conduit in the group may be bound by an explicit inequality constraint as follows:

$$k_{\min} \times n_i \leq n_i \leq k_{\max} \times n_i \qquad \forall G$$

where k_{min} designates the lower bound multiplier (minimum value of a multiplier) for roughness coefficient of conduits in conduit group *G*; k_{max} represents the upper bound multiplier (maximum value of a multiplier) for roughness coefficient of conduits in conduit group *G*; and *n* is roughness coefficient value for conduit *i* in group *G*. Please note that each of the conduits in group *G* could take different values of *n*. The only value that is same for all conduits in the group is the multiplier *k*.

It should

be noted that the choice of grouping may greatly affect the calculated parameter values as well as the convergence accuracy. It is also expected that the final calculated parameters, will be close to the actual values (i.e., optimal/near optimal values) although they may not be "exact" or absolute optima.

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4.2.1 Overview Of Genetic Algorithms

Genetic algorithms (GA) are an adaptation procedure based on the mechanics of natural genetics and natural selection[1].

They are designed to perform search procedures of an artificial system by emulating the evolution process (Darwin's evolution principle) observed in nature and biological organisms. The evolution process is based on the preferential survival and reproduction of the fittest member of a population with direct inheritance of genetic information from parents to offspring and the occasional mutation of genes. The principal advantages of genetic algorithms are their ability to converge expeditiously on an optimal or near-optimal solution without having to analyze all possible solutions available and without requiring derivatives or other auxiliary knowledge.

Genetic algorithms are fundamentally different

from traditional optimization methods in terms of the search process.

While traditional routines track only a single pathway to the optimal solution, genetic algorithms search from an entire population of possible solutions (individuals). In addition, genetic algorithms use randomized and localized operators as opposed to deterministic rules. Each individual in the population is represented by either a string or a set of real numbers encoding one possible solution. The performance of each individual in the population is measured by its fitness (goodness), which quantifies the degree of optimality of the solution. Based on their fitness values, individuals are selected for reproduction of the next generation. Each new generation maintains its original size. The selected individuals reproduce their offspring by mimicking gene operations of crossover and mutation.

After a number of generations, the population is expected to evolve artificially, and the optimal or near optimal solution is ultimately reached.

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4.2.2 Components Of Genetic Algorithms

Standard genetic algorithms involve

three basic functions: selection, crossover, and mutation. Each function is briefly described below.

- **Selection –** Individuals

  in a population are selected for reproduction according to their fitness values. In biology, fitness is the number of offspring that survive to reproduction. Given a population consisting of individuals identified by their chromosomes, selecting two chromosomes to represent parents to reproduce offspring is guided by a probability rule that the higher the fitness an individual has, the more likely the individual will survive. There are many selection methods available including weighted roulette wheel, sorting schemes, proportionate reproduction, and tournament selection.

- **Crossover -** Selected parents

  reproduce the offspring by performing a crossover operation on the chromosomes (cut and splice pieces of one parent to those of another).

  In nature, crossover implies two parents exchange parts of their corresponding chromosomes. In genetic algorithms, a crossover operation makes two strings swap their partial strings. Since more fit individuals have a higher probability of producing offspring than less fit ones, the new population will possess, on average, an improved fitness level.

  The basic crossover is a one-point crossover. Two selected strings create two offspring strings by swapping the partial strings, which is cut by one randomly sampled breakpoint along the chromosome. The one-point crossover can easily be extended to *k*-point crossover.

  It randomly samples *k* breakpoints on chromosomes and then exchanges every second corresponding segments of two parent strings.

- **Mutation -** Mutation is an

insurance policy against lost genes. It works on the level of string genes by randomly altering gene value. With small probability, it randomly selects one gene on a chromosome then replaces the gene by a randomly selected value. The operation is designed to prevent GA from premature termination namely converging to a solution too early.

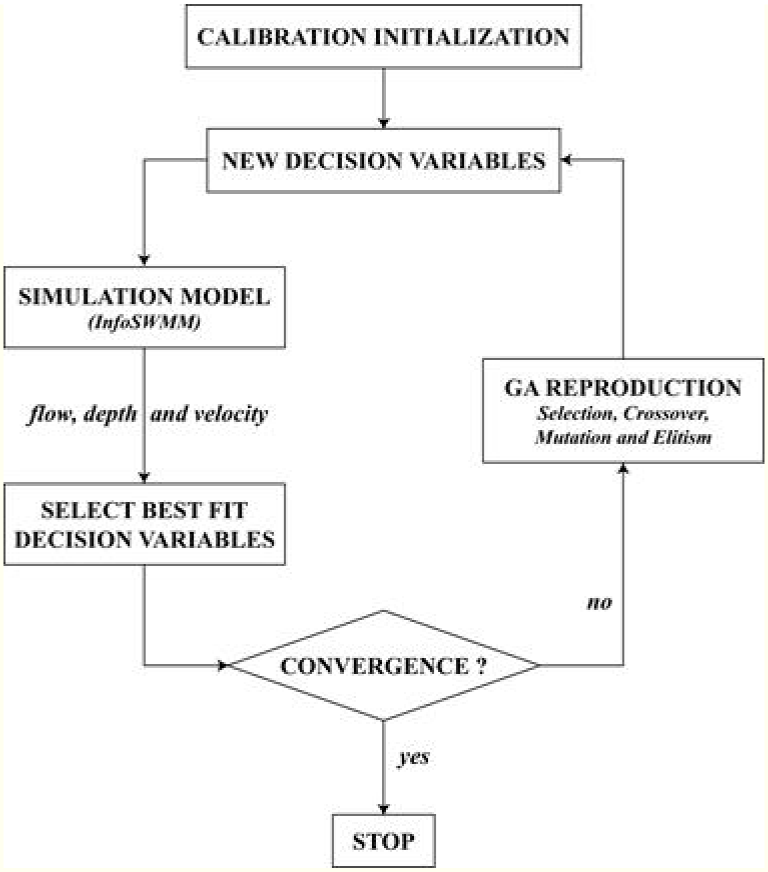
- **Elitism -** The selection

  and crossover operators will tend to ensure that the best genetic material and the components of the fittest chromosomes will be carried forward to the next generation. However, the probabilistic nature of these operators implies that this will not always be the case.

  An elitist strategy is therefore required to ensure that the best genetic material will not be lost by chance. This is accomplished by always carrying forward the best chromosome from one generation to the next.

The flowchart

below illustrates the optimal calibration process.



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Calibration Options

This dialog box controls optimization properties and simulation options that are utilized during a model calibration. Specify the type of measurement to be used to evaluate fitness function , convergence criteria, maximum number of trials, advanced GA options, and the objective function type.

The optimization module will terminate its iterative solution refinement process when one of the termination criteria is sa

$$Maximize\left(1-\frac{\sum_{i=1}^{N}\left|Pobs_i - Psim_i\right|}{\sum_{i=1}^{N}\left|Pobs_i - \overline{Pobs}\right|}\right)$$

tisfied.

Note - Click on any portion of the dialog box above for information on any item.

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Genetic Algorithm Options

These potions should only be modified when the user understands how genetic algorithms work.

$$Maximize\left(\frac{\sum_{i=1}^{N}\left(Pobs_i-\bar{P}obs\right)\left(Psim_i-\bar{P}sim\right)}{\left[\sum_{i=1}^{N}\left(Pobs_i-\bar{P}obs\right)^2\right]^{0.5}\left[\sum_{i=1}^{N}\left(Psim_i-\bar{P}sim\right)^2\right]^{0.5}}\right)^2$$

Note - Click on any portion of the dialog box above for information on any item.

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Subcatchment Variables

Specify the parameter(s) to be calibrated among the list below.

EPA SWMM’s Non-Linear Reservoir Method

- Area
- Width
- Percent Imperviousness
- Slope
- N-Impervious
- N-Pervious
- Impervious Depression Storage
- Pervious Depression Storage

CUHP Method

- Area
- Percent Imperviousness
- Slope
- Impervious Depression Storage
- Pervious Depression Storage
- Length
- Centroid Distance
- CIA Fraction
- RPA Fraction

NRCS Dimensionless and NRCS Triangular Methods

- Area
- Slope

- Length
- Lag Time

Groundwater Simulations

- Groundwater Flow Coefficient
- Surface water flow Coefficient
- Groundwater Flow Exponent
- Surface Water Flow Exponent
- Surface-Groundwater Interaction

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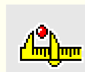
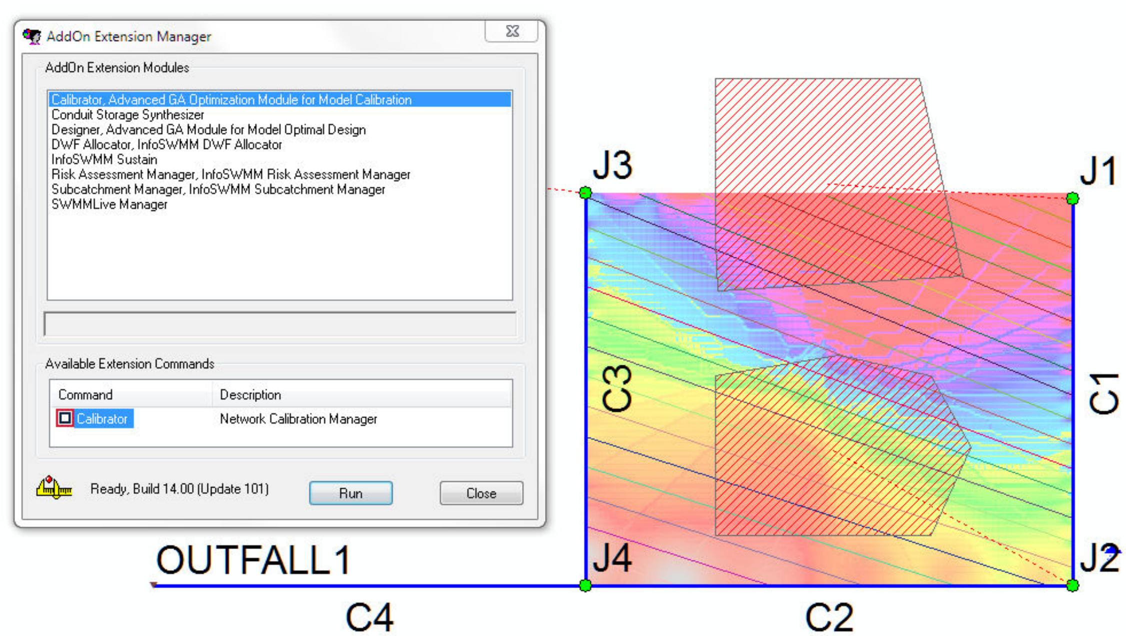
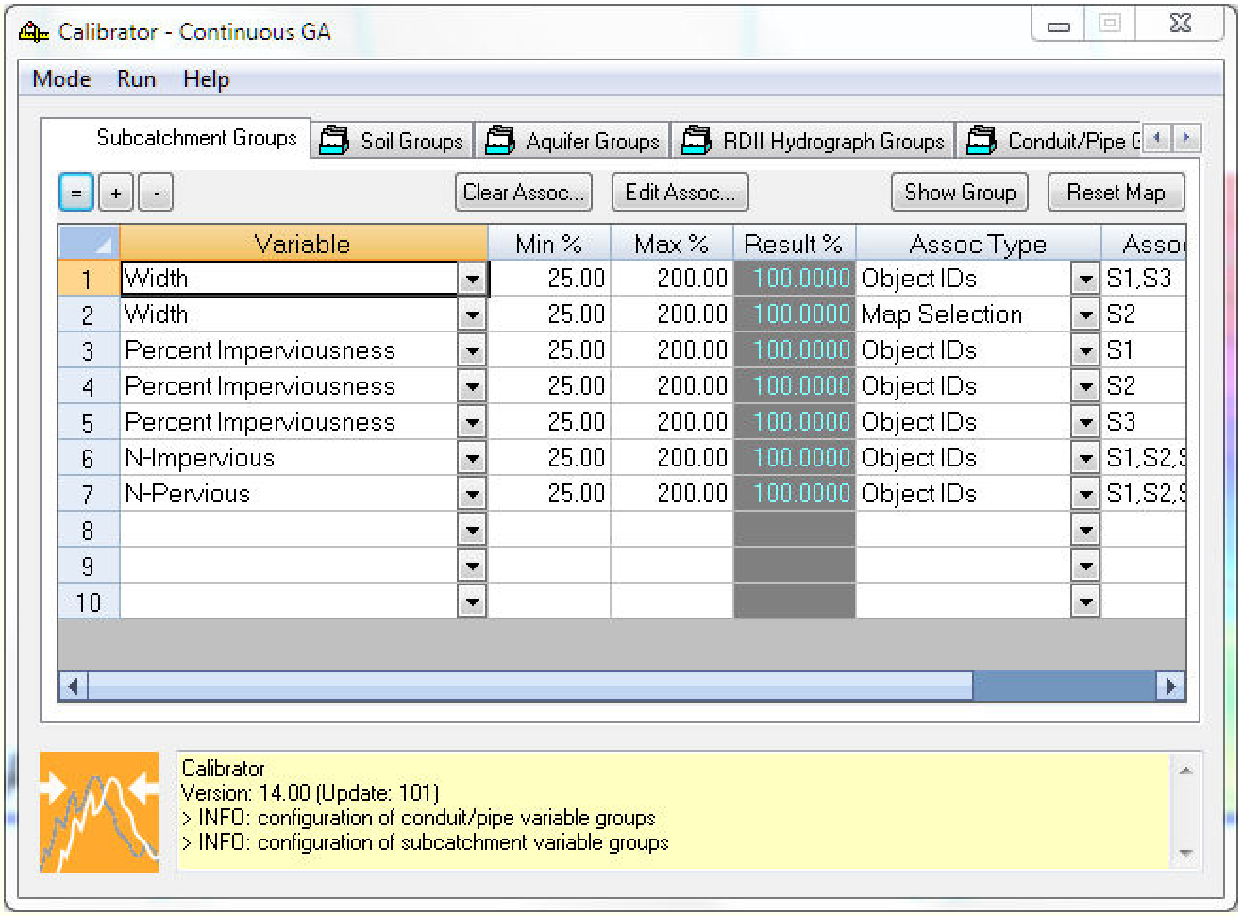
2 – InfoSWMM Calibrator interface

Section 2 of the Users Guide provides description of the functions and capabilities of InfoSWMM  Calibrator.





InfoSWMM

Calibrator provides sophisticated micro level

hydrologic and hydraulic calibration capabilities. It casts the calibration problem as an implicit nonlinear optimization problem subject to explicit inequality and equality constraints. InfoSWMM

Calibrator provides the user with an efficient, flexible and easy to use vehicle for accurate and reliable model calibration and validation.

The optimization problem consists of determining model parameters broadly categorized into five general groups: Subcatchment group (i.e., Subcatchment runoff parameters and groundwater parameters), soil group (i.e., infiltration parameters), aquifer group (i.e., aquifer parameters), RDII group (i.e., RDII unit hydrograph parameters), and conduit group (i.e., conduit parameters) that produce the minimum overall difference between the observed measurements (i.e., flow, velocity, and/or depth measurements) and corresponding model predicted results. Unlimited number of subgroups could be defined for each of the five calibration groups described above.

The subgroups represent modeling elements (e.g., subcatchments) that have identical properties and that may be adjusted by the same scale during the calibration process.

Optimal values of the calibrated parameters are determined from a user-specified range of minimum and maximum values associated with their respective group (e.g., subcatchment, soil, aquifer, etc). It is assumed that parameter values of all elements (e.g., subcatchments) within the group will be scaled (i.e., multiplied) by the same factor from the original parameter value assigned to each of the elements in the group.

As such, the user should lump elements and objects together in separate groups based on their similarity from the perspective of the characteristics that affect the specific parameter being considered. It should be emphasized that there is no limitation regarding the number of elements assigned to a group (i.e., it could be one or more) thus providing the modeler the flexibility to accommodate heterogeneity.

Unlimited number of measurements and measurement sites could be defined using InfoSWMM

Calibrator thus offering tremendous flexibility.

The measurements could be flow, depth, and/or velocity. It is an obvious reality that quality of calibration exercise depends on the number as well as quality of measurements. If one uses large number of good quality measurements, it is more likely that the parameter values determined by the calibrator better reflect reality. Regarding number of measurements, the general guideline is that the number of field measurements must be greater than or equal to the number of decision variables, the more measurements the better the accuracy of the calibration.

InfoSWMM

Calibrator is initialized from inside InfoSWMM

by selecting the *ADD-ON MANAGER* command

from the *TOOLS* menu. With the Add-On Manager dialog box open, select Calibrator from the drop down list and click the “Run” button.

In this chapter of the Users Guide, you will be introduced to InfoSWMM Calibrator Interface. The purpose of the available commands will be described.

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