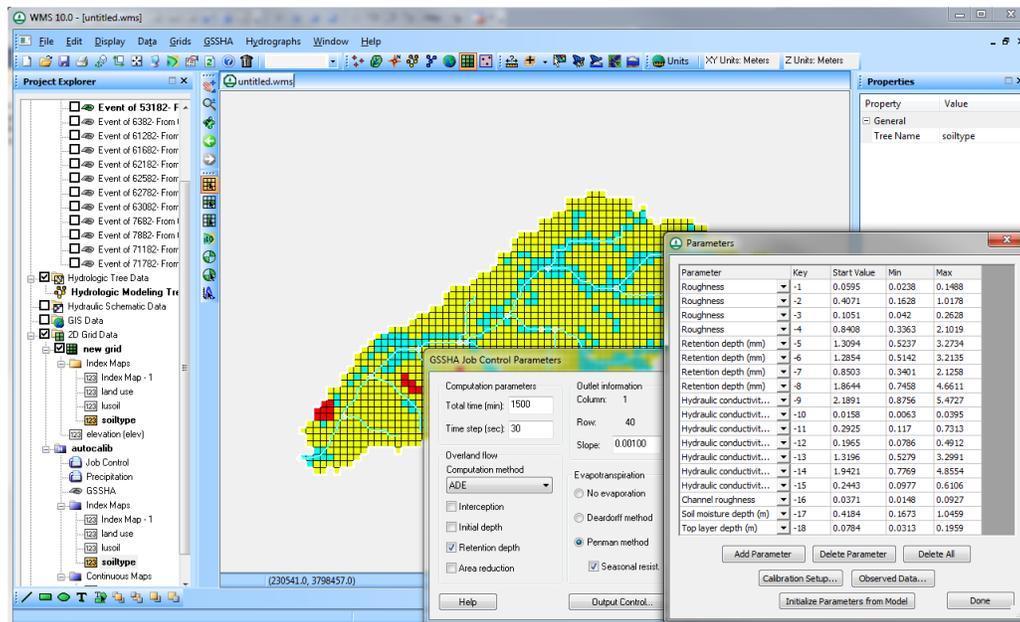


WMS 11.0 Tutorial

Automated Calibration of GSSHA Models

Define parameters to be specified as adjustable, the objective function to be used to support that estimation, and automatically calibrate a GSSHA model



Objectives

This tutorial shows how to set up and run a GSSHA model that automatically calibrates specified adjustable parameters using a documented efficient local search method.

Prerequisite Tutorials

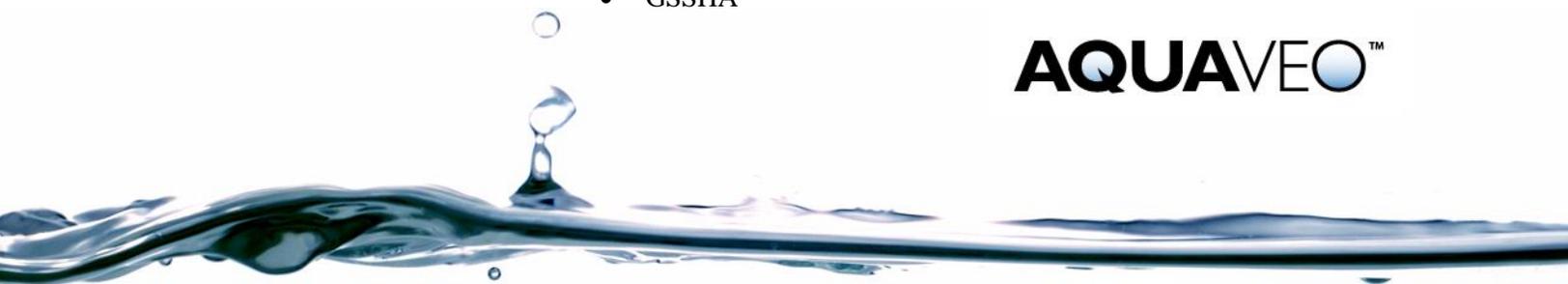
- Stochastic Simulations of GSSHA models

Required Components

- Data
- Drainage
- Map
- Hydrology
- 2D Grid
- GSSHA

Time

- 20–40 minutes



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1 Getting Started

To get started with the project:

1. Open WMS. If WMS is already open select *File* | **New** to reset to the default settings.
2. Select *File* | **Open** to bring up the *Open* dialog.
3. Navigate to the *GSSHACalibration3\Calibration\Automated* folder and select “goodwin.prj”.
4. Click **Open** to open the project and exit the *Open* dialog.
5. Turn off the display of all the coverages except the “ GSSHA” coverage.

2 Selecting Rainfall Events

The first step in an automated calibration is to select the rainfall event simulation to calibrate, and run an initial simulation to ensure the simulation is set up correctly. To do this:

1. Switch to the **2-D Grid Module** .
2. Select *GSSHA* | **Precipitation** to bring up the *GSSHA Precipitation* dialog.
3. Make sure the first three events are turned on (Event 52282, 52482, and 53182) and the rest are turned off.
4. Click **OK** to exit the *GSSHA Precipitation* dialog.

The simulation should be run once in the forward simulation mode to make sure the model runs. A model that cannot run cannot be calibrated.

5. Select *GSSHA* / **Run GSSHA...** to open the *GSSHA Run Options* dialog.
6. Click **OK** to accept the default run parameters. This will exit the *GSSHA Run Options* dialog and open the *Model Wrapper* dialog.
7. After the run is completed, click **Close** to exit the *Model Wrapper* dialog and read in the solution.

2.1 Assigning keys to map tables and other parameters

The next step is to use the WMS GSSHA interface to indicate which parameters should be adjustable calibration parameters. Generally, the calibration parameters are those which involve uncertainty in measurement or the ones that affect the outflow hydrograph the most. This is done by defining negative “key” values for each of the parameters needing calibration.

1. Select *GSSHA / Map Tables...* to open the *GSSHA Map Table Editor* dialog.
2. The dialog should automatically open to the *Roughness* tab. Enter the keys -1, -2, -3 and -4 for the roughness values shown below. Entering negative numbers tells WMS that these are the calibration parameters. WMS then associates the values that will be defined in the calibration dialog (in a future step) with these parameters.

Roughness					
ID	1	2	3	4	5
Description1	pine 27% ...	water 0.3% ...	cotton 14% ...	pasture 42%...	gullied land ...
Description2	...	...	...	...	...
Surface roughness	-1.000000	0.358000	-2.000000	-3.000000	-4.000000

3. In the *Retention* tab, enter the following keys:

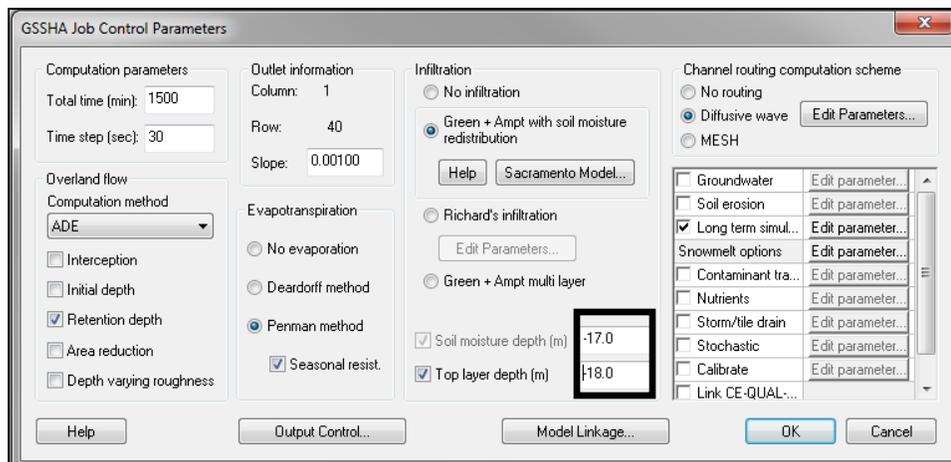
Retention					
ID	1	2	3	4	5
Description1	Pine 27% ...	Water 0.3% ...	Cotton 14% ...	Pasture 42%...	Gullied land ...
Description2	...	...	...	...	...
Retention depth (mm)	-5.000000	1.300000	-6.000000	-7.000000	-8.000000

4. Switch to the *Infiltration* tab and enter the following keys for *Hydraulic Conductivity*.

Infiltration									
ID	1	2	3	4	5	6	7	8	9
Description1	gullied-land-...	gullied-land-...	water-.3% ...	pasture-clay-...	cotton-clay+...	pine-clay-loa...	pine-silt-loa...	cotton-silt-lo...	pasture-silt-...
Description2	...	...	...	...	...	...	...	...	...
Hydraulic conductivity (cm/hr)	-9.000000	1.410000	0.003000	-10.000000	-11.000000	-12.000000	-13.000000	-14.000000	-15.000000
Capillary head (cm)	16.680000	4.950000	0.003000	20.880000	20.880000	20.880000	16.680000	16.680000	16.680000
Porosity (m ³ /m ³)	0.486000	0.437000	0.582000	0.464000	0.464000	0.464000	0.486000	0.486000	0.486000
Pore distribution index (cm/cm)	0.234000	0.694000	0.001000	0.242000	0.242000	0.242000	0.234000	0.234000	0.234000
Residual saturation (m ³ /m ³)	0.015000	0.020000	0.015000	0.075000	0.075000	0.075000	0.015000	0.015000	0.015000
Field capacity (m ³ /m ³)	0.330000	0.091000	0.436500	0.318000	0.318000	0.318000	0.330000	0.330000	0.330000
Wilting point (m ³ /m ³)	0.133300	0.033000	0.133300	0.133300	0.133300	0.133300	0.197000	0.133000	0.133000

5. The last column in the *Hydraulic Conductivity* field should be -15. Click **Done** to close the *GSSHA Map Table Editor* dialog.
6. In the **Map Module** , click on the **Select feature line branch**  tool and double click on the downstream most channel arc (the one closest to the watershed outlet) which will open the *Properties* dialog.
7. Enter “-16” in the *All* row for *Manning’s n*.
8. Click **OK** to exit the *Properties* dialog.

9. Select the **2-D Grid Module** .
10. Select **GSSHA / Job Control** to open the *GSSHA Job Control Parameters* dialog.
11. Enter “-17” for *Soil moisture depth (m)* and “-18” for *Top layer depth (m)*.
12. Select **OK** to close the *GSSHA Job Control Parameters* dialog.

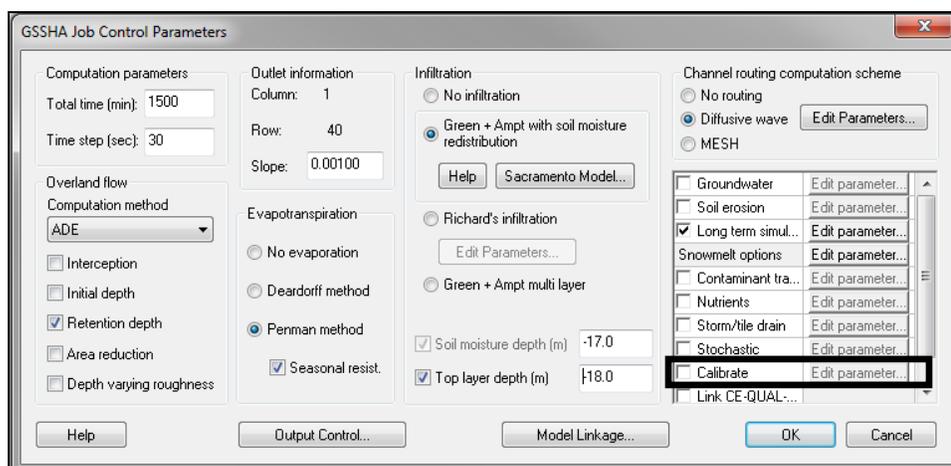


So, altogether there are 18 parameters that will be used in the automated calibration for this tutorial example problem.

2.2 Defining calibration parameters

The next step in this tutorial involves defining the upper and lower boundary parameters which have values that can vary during the calibration run.

1. Select **GSSHA | Job Control...** to reopen the *GSSHA Job Control Parameters* dialog. It is necessary to close and reopen the dialog so that the *Soil moisture depth* and *Top layer depth* parameters can be internalized and later used as calibration parameters.
2. Turn “Calibrate” on. (See the following figure).



- Click **Edit parameter...** to the right of “Calibrate” to open the *Parameters* dialog.
- Select the **Initialize Parameters from Model** button so that there will be 18 parameters in the list.

Parameter	Key	Name	Start Value	Min	Max	Parameter Type	Tied
Roughness	-1	R_1	0.0595	0.0238	0.1488	Log	
Roughness	-2	R_2	0.4071	0.1628	1.0178	Log	
Roughness	-3	R_3	0.1051	0.042	0.2628	Log	
Roughness	-4	R_4	0.8408	0.3363	2.1019	Log	
Retention depth (mm)	-5	RE_5	1.3094	0.5237	3.2734	Log	
Retention depth (mm)	-6	RE_6	1.2854	0.5142	3.2135	Log	
Retention depth (mm)	-7	RE_7	0.8503	0.3401	2.1258	Log	
Retention depth (mm)	-8	RE_8	1.8644	0.7458	4.6611	Log	
Hydraulic conductiv...	-9	HC_9	2.1891	0.8756	5.4727	Log	
Hydraulic conductiv...	-10	HC_10	0.0158	0.0063	0.0395	Log	
Hydraulic conductiv...	-11	HC_11	0.2925	0.117	0.7313	Log	
Hydraulic conductiv...	-12	HC_12	0.1965	0.0786	0.4912	Log	
Hydraulic conductiv...	-13	HC_13	1.3196	0.5279	3.2991	Log	
Hydraulic conductiv...	-14	HC_14	1.9421	0.7769	4.8554	Log	
Hydraulic conductiv...	-15	HC_15	0.2443	0.0977	0.6106	Log	
Channel roughness	-16	CR_16	0.0371	0.0148	0.0927	Log	
Soil moisture depth (m)	-17	SMD_17	0.4184	0.1673	1.0459	Log	
Top layer depth (m)	-18	TLD_18	0.0784	0.0313	0.1959	Log	

Buttons: Add Parameter, Delete Parameter, Delete All, Calibration Setup..., Observed Data..., Initialize Parameters from Model, Help, Done

- Enter the *Start Value*, *Min* and *Max* values as shown in the figure above by copying and pasting the values from the file `\Calibration\Automated\InitialParams.txt`, found in the data files for this tutorial. Guidance for starting parameter estimates can be found on <http://gsshawiki.com>.

2.3 Defining the Observed Data for Model Calibration

A quantitative measure of closeness of fit is called an objective function, and it is an important component of the automatic calibration process. For this example GSSHA problem, the objective function will be defined by comparing observed flow data at the Goodwin Creek watershed outlet with the model simulated counterparts. The best set of parameters corresponds to the lowest objective function value.

For this example problem, the GSSHA model is calibrated for a long term event where there are multiple storm events.

- In the *Parameters* dialog, click on the **Observed Data...** button to bring up the *GSSHA Observations* dialog.

2. Click the **Add** button.
3. Change the *Observation Type* to “Outlet Hydrograph”.
4. Click on the **Define** button under the *Observed Data* column to bring up the *Define GSSHA Observation* dialog.
5. Select **Define Series...** to open the *XY Series Editor* dialog.
6. With *Show Dates* turned off, copy and paste the values from the file `\Calibration\Automated\observed.txt` into the *XY Series Editor*.
7. Change the *Curve Name* to “hydro”.
8. Select **OK** to exit the *XY Series Editor* dialog.
9. Click **Done** to exit the *Define GSSHA Observation* dialog.
10. Under the *Weights* column, click **Define** to open the *XY Series Editor* dialog. Notice an XY series has been defined to correspond to the observation data. These weights could be edited to put a greater emphasis on peak values if desired.
11. Select **Cancel** to exit the *XY Series Editor* dialog and then **OK** to close the *GSSHA Observations* dialog.

2.4 Defining Levenberg-Marquardt (LM)/Secant LM (SLM) data

1. In the *Parameters* dialog, click on the **Calibration Setup...** button which will open the *Calibration Setup* dialog.

Notice that there are several calibration methods from which to choose. The default LM/SLM methods are recommended for routine use. However, if sufficient time is available for a more exhaustive exploration, then of the three global optimization methods (Multistart, TR, and MLSL), the MLSL method is recommended. The SLM calibration option will compute a set of optimum values using a local search. If the model can be run for several hours, select *MLSL* for the calibration method. The *MLSL* option computes a set of optimum values using a global search, but will require more time than the SLM method. Do not modify any of the calibration setup parameters at this time.

2. Click **OK** to accept the default settings and close the *Calibration Setup* dialog.
3. Click **Done** to close the *Parameters* dialog.
4. Click **OK** to close the *GSSHA Job Control Parameters* dialog.

3 Save and Run the Model

1. Select *GSSHA* | **Save Project File...** to open the *Save GSSHA Project File* dialog.
2. **Save** the GSSHA project as “autocalib.prj” to exit the *Save GSSHA Project File* dialog. Notice that WMS runs an initial forward simulation before saving so it can compare the observed with computed values and prepare the necessary calibration input files.
3. Select *GSSHA* / **Run GSSHA...** to open the *GSSHA Run Options* dialog.

- Select **OK** to close the *GSSHA Run Options* dialog and open the *Model Wrapper* dialog.

This run will take some time to finish. It is recommended to run the calibration overnight or in the background while working on other tasks.

- When the model has finished running, click **Close** to exit the *Model Wrapper* dialog. This will open the *GSSHA Calibration Output* dialog.

4 Run the Forward Simulation with the Optimized Parameters

Once the calibration completes, GSSHA writes the best set of parameters (the set of parameters which produce minimum cost function). WMS can read the best parameters, and then save the project file using a new filename so the original calibration input file is not overwritten. Some of the input or output control data can be modified in order to run a new forward simulation with the calibrated parameters.

The GSSHA model wrapper displays an evolution of the automatic calibration. It indicates if the maximum number of specified optimization iterations was met or if the local (global, if such a method is chosen) search terminated by virtue of other specified stopping criteria.

The *GSSHA Calibration Output* dialog shows the starting and optimized parameter values along with the starting and optimized objective function values.

Parameter	Key	Run 1 Start Value	Run 1 Optimized...	Run 2 Start Value	Run 2 Optimized...	Run 3 Start Value	Run 3 Optimized...
Roughness	-1	0.024232	0.0238	0.138213	0.145604	0.100701	0.135923
Roughness	-2	0.612553	0.1628	0.272938	0.175709	0.535988	0.794389
Roughness	-3	0.246821	0.215002	0.145116	0.059807	0.191757	0.042
Roughness	-4	1.872044	0.508565	1.135772	0.869548	0.818591	2.1019
Retention depth (mm)	-5	2.238294	3.229525	2.514518	2.032373	2.863888	1.186688
Retention depth (mm)	-6	3.052274	3.003409	3.004393	3.2135	1.814126	3.2135
Retention depth (mm)	-7	1.931991	2.1258	0.526688	0.807784	1.105863	1.607553
Retention depth (mm)	-8	4.549659	2.144612	0.85371	0.7458	1.63603	1.171599
Hydraulic conductivity (c...	-9	3.19313	2.766227	3.033175	1.290824	5.184704	5.4727
Hydraulic conductivity (c...	-10	0.016982	0.036764	0.009449	0.013186	0.014208	0.0063
Hydraulic conductivity (c...	-11	0.470615	0.117	0.334035	0.340773	0.291542	0.226794
Hydraulic conductivity (c...	-12	0.135703	0.0786	0.275779	0.231718	0.454422	0.312254
Hydraulic conductivity (c...	-13	0.579316	0.87127	0.638216	0.911188	1.634862	1.120367
Hydraulic conductivity (c...	-14	3.604531	4.244902	2.988436	3.056922	1.940332	0.7769
Hydraulic conductivity (c...	-15	0.136463	0.220284	0.182198	0.212216	0.500159	0.169622
Channel roughness	-16	0.028635	0.037733	0.041768	0.037682	0.029819	0.038445
Soil moisture depth (m)	-17	0.772132	1.0459	0.648765	0.768461	0.24339	0.559093
Top layer depth (m)	-18	0.072497	0.070582	0.068163	0.081468	0.085263	0.085661
Starting Objective Value:		145.573393		161.988497		245.25658	
Optimized Objective Value:			36.505748		23.489611		23.477539
Select an Optimization:			<input type="checkbox"/> Select		<input type="checkbox"/> Select		<input checked="" type="checkbox"/> Select

Run simulation with optimized values
 Replace key values in project with optimized values (save the project to a new filename or overwrite original project name)

OK Cancel

If using the SLM local optimization method, only a single set of optimized values will be visible. If using the MLSL method described above, there will be multiple sets of optimized values. Select the desired set of optimized values from the dialog.

1. Turn off both options: *Run simulation with optimized values* and *Replace key values....*
2. Click **OK** to close the *GSSHA Calibration Output* dialog. This dialog can be accessed at any time to replace the key values in the simulation by selecting the *GSSHA / Read Calibration Output...* menu command.
3. Select *GSSHA / Read Solution...* to open the *Read GSSHA Solution* dialog.
4. Click **OK** to accept the defaults, exit the *Read GSSHA Solution* dialog, and read in the solution.

5 Observe the Full Calibration Results

GSSHA writes several calibration files during and after a calibration run. Here are a couple of files to view. The *.rec file shows detailed results for the calibration run. The *.par and *.sen files show additional parameter information about the calibration run. When running the model using MLSL, the slm_chl_msl.rec file contains information about the global optimization method.

6 Automated Calibration to Additional Observation Points

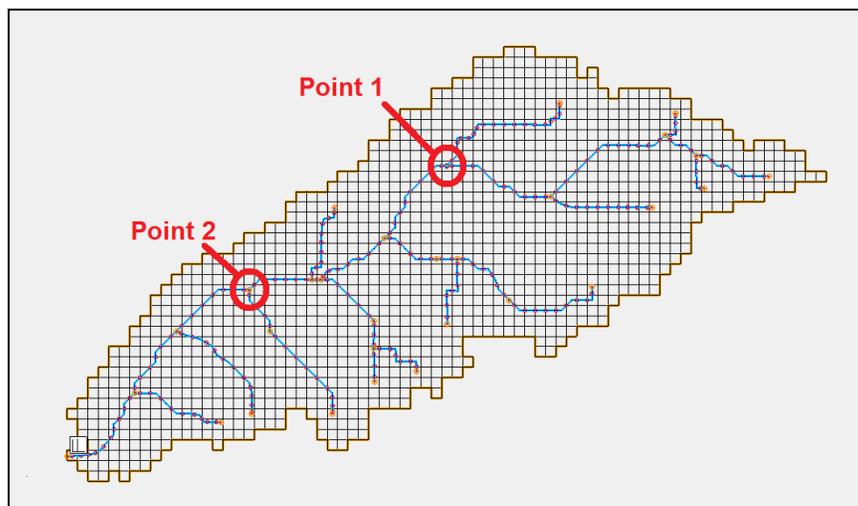
There will frequently be stream gages or other measured data at locations other than the outlet point that can be used to calibrate the model. The model can easily be calibrated to include these additional data values. The following data types can be calibrated at any applicable point in the watershed:

- Overland Depth
- Infiltration Depth
- Surface Moisture
- Channel Depth
- Channel Flow
- Groundwater Head
- Outlet Hydrograph (Only at the watershed outlet point)
- Snow Water Equivalent
- Tile Drain Discharge (In a GSSHA Storm Drain coverage)

This section describes how to add additional observation points to the model.

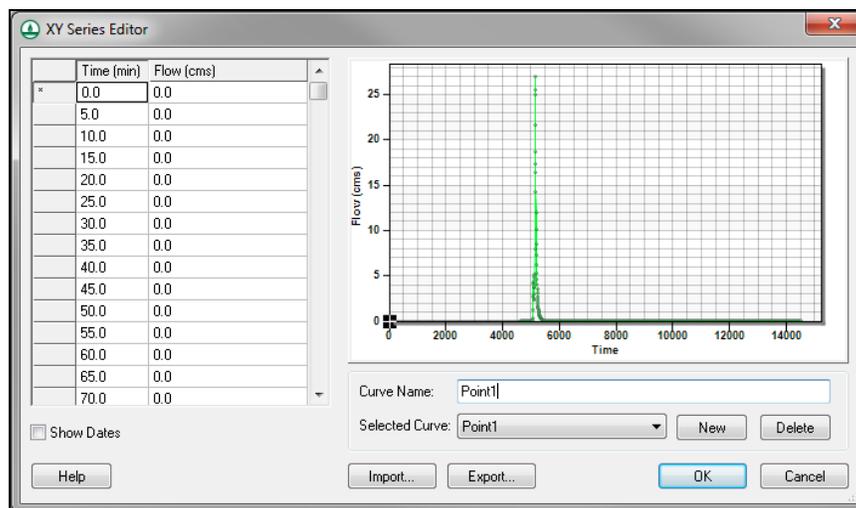
1. In the **2D Grid Module** , select *GSSHA / Save Project File* to open the *Save GSSHA Project File* dialog.
2. **Save** the project as “autocalibMult.prj” to save the project under a new name and exit the *Save GSSHA Project File* dialog. The *Model Wrapper* will appear for a brief moment and then close itself.
3. In the Project Explorer, select the “ GSSHA” coverage to make this the active coverage.

4. Select the **Select Feature Point/Node** tool .



5. Double-click on Point 1 as shown in the figure above to bring up the *Properties* dialog.
6. Click on the **...** button under the *Observations* column to bring up the *GSSHA Observations* dialog.
7. Select the **Add** button to add an observation.
8. Change the *Observation Type* to “Channel Flow”.
9. Click on the **Define** button under the *Observed Data* column to open the *Define GSSHA Observation* dialog.
10. Click **Define Series** to open the *XY Series Editor* dialog.
11. With *Show Dates* turned off, copy and paste the values from the file *GSSHACalibration3\Calibration\Automated\Pt1.txt* into the appropriate columns in the *XY Series Editor* dialog.
12. Change the *Curve Name* to “Point1”.

The XY Series Editor should appear as in the figure below.



13. Select **OK** to close the *XY Series Editor* dialog.
14. Click **Done** to close the *Define GSSHA Observation* dialog.
15. Select **OK** to close the *GSSHA Observations* dialog.
16. Select **OK** to close the *Properties* dialog.
17. Repeat steps 5 through 16 for Point 2, using data from the file named *Pt2.txt* and naming the curve “Point2”.
18. Select *File* | **Save** to open the *Save As* dialog.
19. **Save** the modified GSSHA project as “autocalibMult.prj” to save the project and exit the *Save As* dialog.
20. Select *GSSHA* / **Run GSSHA...** to open the *GSSHA Run Options* dialog.
21. Click **OK** to accept the defaults, exit the *GSSHA Run Options* dialog, and open the *Model Wrapper* dialog. Once again, this run will take some time to finish.
22. Click **Close** once the simulation is complete to exit the *Model Wrapper* dialog. This will open the *GSSHA Calibration Output* dialog.
23. Select **OK** to close the *GSSHA Calibration Output* dialog and open the *Save GSSHA Project File* dialog.
24. **Save** the project as “autocalibmultopt.prj” to save the project and exit the *Save GSSHA Project File* dialog.
25. Select *GSSHA* | **Run GSSHA** to open the *GSSHA Run Options* dialog.
26. Click **OK** to exit the *GSSHA Run Options* dialog and open the *Model Wrapper* dialog.
27. When the simulation is finished, click **Close** to exit the *Model Wrapper* dialog and read in the solution.
28. Feel free to compare the results of this simulation to the simulated values obtained earlier.

7 Conclusion

This concludes the “Automated Calibration of GSSHA Models” tutorial. This tutorial covered how to set up and execute the automated calibration of a GSSHA model.