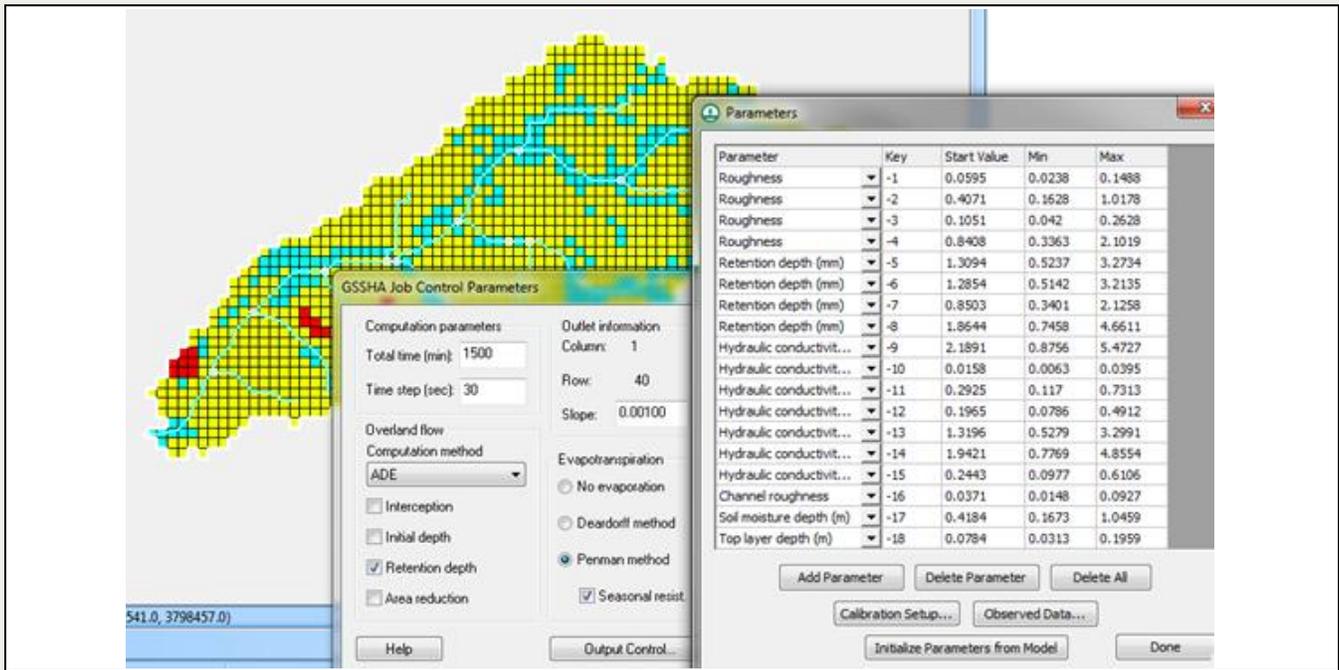




WMS 11.4 Tutorial

### Automated Calibration of GSSHA Models

Define parameters 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

- WMS Core
- GSSHA Model

### Time

- 20–40 minutes

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## 1 Introduction

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 Events 52282, 52482, and 53182 are turned on 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, check *Read solution on exit* and 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. On the *Roughness* tab, in the *Surface Roughness* row, enter the following values (see Figure 1):
  - For column 1, enter “-1”.
  - For column 3, enter “-2”.
  - For column 4, enter “-3”.
  - For column 5, enter “-4”.

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

Figure 1 Roughness tab showing negative values in Surface roughness row.

3. On the *Retention* tab, in the *Retention depth (mm)* row, enter the following values (See Figure 2):
  - For column 1, enter “-5”.
  - For column 3, enter “-6”.
  - For column 4, enter “-7”.
  - For column 5, enter “-8”.

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

Figure 2 Retention tab showing negative values in Retention depth (mm) row

4. On the *Infiltration* tab, enter the following values for *Hydraulic Conductivity (cm/hr)* (See Figure 3):
  - For column 1, enter “-9”.
  - For column 4, enter “-10”.
  - For column 5, enter “-11”.
  - For column 6, enter “-12”.
  - For column 7, enter “-13”.
  - For column 8, enter “-14”.
  - For column 9, enter “-15”.

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-l...
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 <sup>3</sup> /m <sup>3</sup> )	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 <sup>3</sup> /m <sup>3</sup> )	0.015000	0.020000	0.015000	0.075000	0.075000	0.075000	0.015000	0.015000	0.015000
Field capacity (m <sup>3</sup> /m <sup>3</sup> )	0.330000	0.091000	0.436500	0.318000	0.318000	0.318000	0.330000	0.330000	0.330000
Wilting point (m <sup>3</sup> /m <sup>3</sup> )	0.133300	0.033000	0.133300	0.133300	0.133300	0.133300	0.197000	0.133000	0.133000

Figure 3 Infiltration tab showing negative values in the Hydraulic conductivity (cm/hr) row

5. Click **Done** to close the *GSSHA Map Table Editor* dialog.
6. Switch to the **Map Module** .
7. Select the **Select feature line branch**  tool then double-click the most downstream channel arc (the one closest to the watershed outlet) to open the *Properties* dialog.
8. Enter “-16” in the *All* row for *Manning’s n*.
9. Click **OK** to exit the *Properties* dialog.
10. Select the **2-D Grid Module** .
11. Select *GSSHA | Job Control* to open the *GSSHA Job Control Parameters* dialog.
12. Under *Infiltration*, enter “-17” for *Soil moisture depth (m)* (See Figure 4)
13. Enter “-18” for *Top layer depth (m)*.
14. Select **OK** to close the *GSSHA Job Control Parameters* dialog.

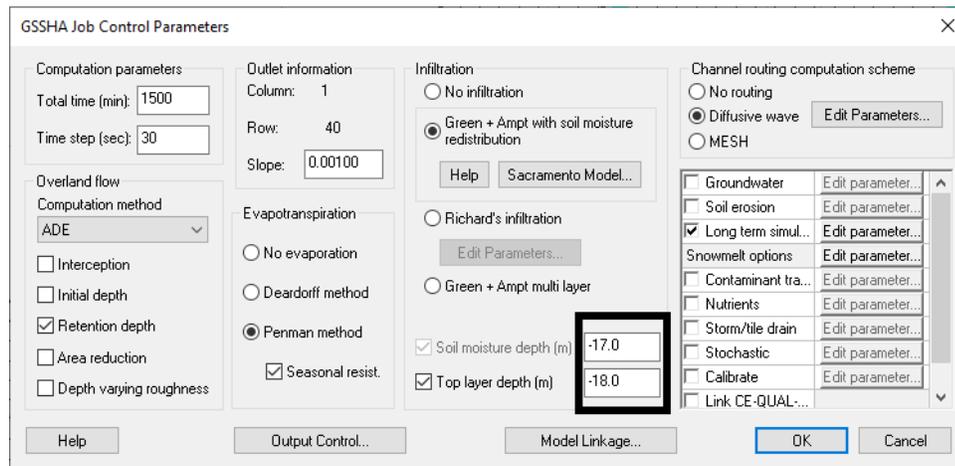


Figure 4 GSSHA Job Control Parameters dialog showing negative values entered under Infiltration section.

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. On the right side, turn on “Calibrate”. (Figure 5.)

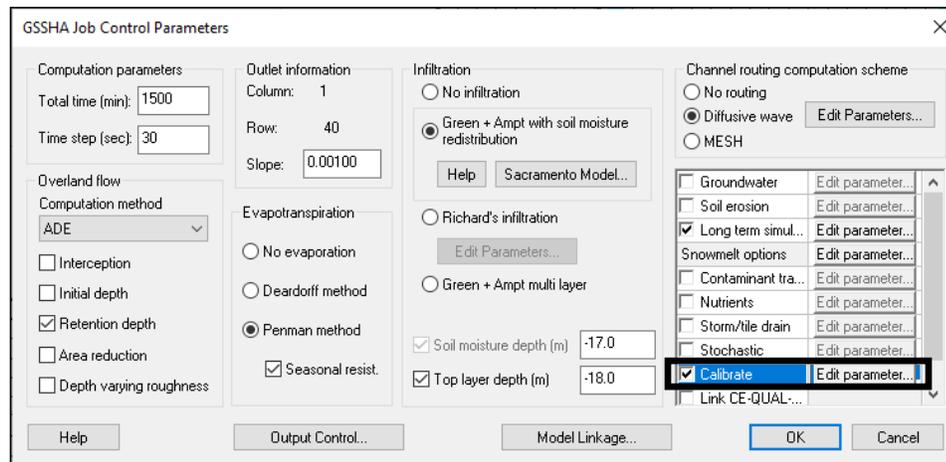


Figure 5 *GSSHA Job Control Parameters* dialog with “Calibrate” selected in right-most column.

3. Click **Edit parameter...** to the right of “Calibrate” to open the *Parameters* dialog.
4. Click **Initialize Parameters from Model**

It will show all 18 parameters in the list.

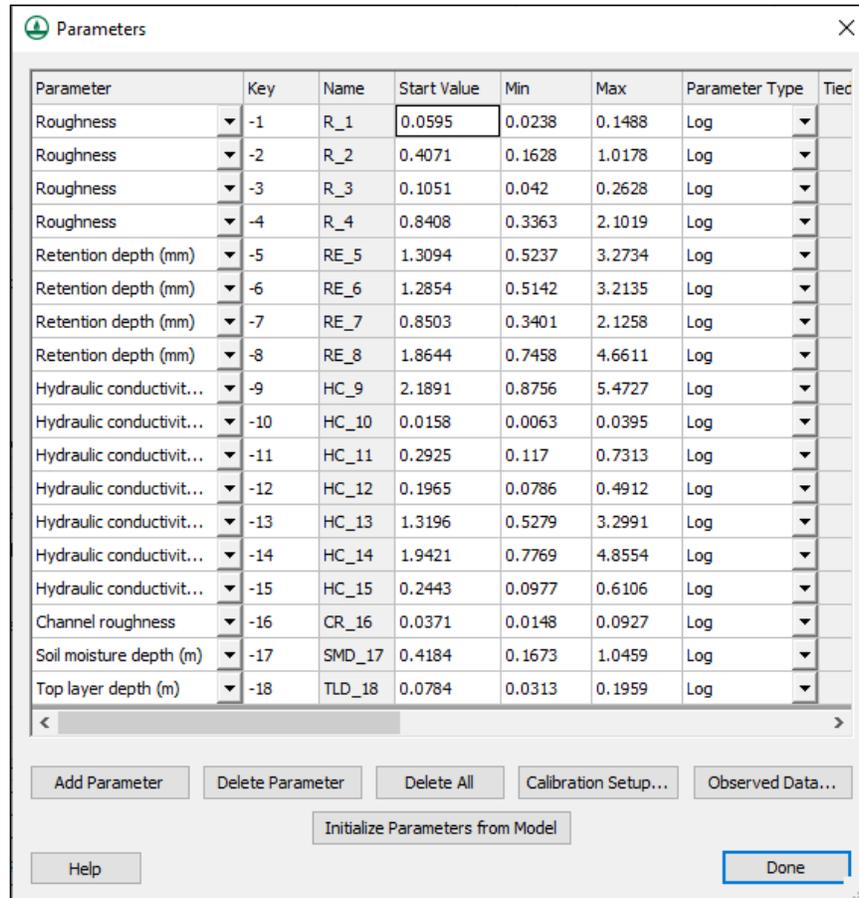


Figure 6 Parameters dialog showing the 18 parameters selected for calibration.

5. Outside of WMS, navigate to the `\Calibration\Automated\` directory and open "InitialParams.txt" in a text editor.
6. Copy the values from the file.
7. In the *Parameters* dialog, select the first cell under *Start Value* and paste the values into the *Start Value*, *Min* and *Max* columns in the *Parameters* dialog.

Do not close the *Parameters* dialog.

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.

1. In the *Parameters* dialog, click on the **Observed Data...** button to bring up the *GSSHA Observations* dialog.
2. Click the **Add** button.

3. In the *Observation Type* column, select “Outlet Hydrograph” from the dropdown menu.
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. Make sure *Show Dates* is turned off.
7. Navigate to the `\Calibration\Automated\` directory.
8. Open “observed.txt ”in a text editor.
9. Copy the values from the text file.
10. Select the cell directly under *Time (min)* and paste the values from the text file into the *XY Series Editor*.
11. Change the *Curve Name* to “hydro”.
12. Select **OK** to exit the *XY Series Editor* dialog.
13. Click **Done** to exit the *Define GSSHA Observation* dialog.
14. Under the *Weights* column (scroll right, if necessary), 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.

15. Select **Cancel** to exit the *XY Series Editor* dialog.
16. Click **OK** to close the *GSSHA Observations* dialog.

Do not close the *Parameters* dialog.

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

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1. In the *Parameters* dialog, click on the **Calibration Setup...** button to 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

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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.
4. 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.

5. 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

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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

Figure 7 GSSHA Calibration Output dialog showing starting and optimized values, and starting and optimized objective function values.

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.

1. Select the desired set of optimized values from the dialog.
2. Turn off both *Run simulation with optimized values* and *Replace key values....*
3. 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.

4. Select **GSSHA | Read Solution...** to open the *Read GSSHA Solution* dialog.
5. 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\_ch1\_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. Enter “autocalibMult.prj” as the new file name and click **Save** 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 it active.
4. Select the **Select Feature Point/Node**  tool.

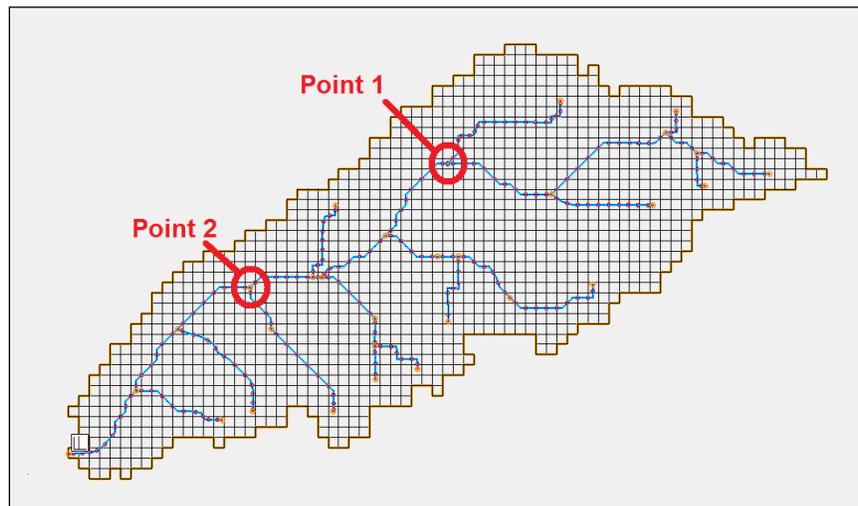


Figure 8 Locations of two additional observation points

5. Double-click on Point 1 as shown in Figure 8 to bring up the *Properties* dialog.
6. In the *Observations* column (scroll right if necessary), click on the  button to bring up the *GSSHA Observations* dialog.

7. Select the **Add** button to add an observation.
8. Under *Observation Type*, select “Channel Flow” from the dropdown menu.
9. Under *Observed Data*, click the **Define** button to open the *Define GSSHA Observation* dialog.
10. Click **Define Series** to open the *XY Series Editor* dialog.
11. Make sure *Show Dates* is turned off.
12. Navigate to the *GSSHACalibration3\Calibration\Automated\* directory.
13. Open “Pt1.txt” in a text editor.
14. Copy the values from the file.
15. Selecting the cell under *Time (min)* in the *XY Series Editor* dialog, right-click and select paste to copy the values into the appropriate columns.
16. Change the *Curve Name* to “Point1”.

The XY Series Editor should appear as in Figure 9.

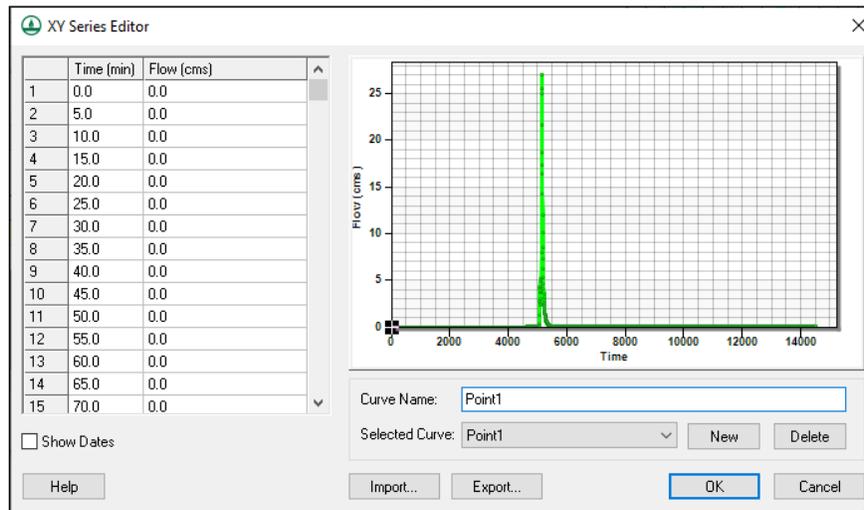


Figure 9 XY Series Editor showing imported values

17. Select **OK** to close the *XY Series Editor* dialog.
18. Click **Done** to close the *Define GSSHA Observation* dialog.
19. Select **OK** to close the *GSSHA Observations* dialog.
20. Select **OK** to close the *Properties* dialog.
21. Repeat steps 5 through 20 for Point 2, using data from the file named “Pt2.txt” and naming the curve “Point2”.

Now to save and run the model with the new observation points added.

22. In the **2D Grid Module** , select **GSSHA | Save Project File** to open the *Save GSSHA Project File* dialog.
23. **Save** the modified GSSHA project as “autocalibMult.prj” to save the project and exit the *Save As* dialog.
24. If asked to replace the file, select **Yes**.
25. Make sure the **2-D Grid Module**  is active.

26. Select *GSSHA* | **Run GSSHA...** to open the *GSSHA Run Options* dialog.
27. 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.

28. Click **Close** once the simulation is complete to exit the *Model Wrapper* dialog and open the *GSSHA Calibration Output* dialog.
29. Select **OK** to close the *GSSHA Calibration Output* dialog and open the *Save GSSHA Project File* dialog.
30. **Save** the project as “autocalibmultopt.prj” to save the project and exit the *Save GSSHA Project File* dialog.

Now that it has been calibrated and run, the new saved project can be run a final time.

31. Select *GSSHA* | **Run GSSHA** to open the *GSSHA Run Options* dialog.
32. Click **OK** to exit the *GSSHA Run Options* dialog and open the *Model Wrapper* dialog.
33. When the simulation is finished, click **Close** to exit the *Model Wrapper* dialog and read in the solution.
34. Feel free to compare the results of this simulation to the simulated values obtained earlier.

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## 7 Conclusion

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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.