QSWAT+ Tutorial - Svratka River Catchment

2023 June 30

Prepared by: Jillian Greene, Sean Woznicki, and Jamshid Jalali
Annis Water Resources Institute
Grand Valley State University

QSWAT+ v 2.4.0
SWAT+ Editor v 2.3.0

Contents

I. Software Requirements & Setup

- Text editor (e.g. NotePad++, TextEdit, or getit)
- SQLite database editor (e.g. SQLiteStudio, DB Broswer for SQLite)
- QGIS 3.28 Long Term Release, 64-bit
  - Windows Installer
  - MacOS Installer
  - Linux Installer
- SWAT+ 2.3.0
  - Windows Installer
  - MacOS Installer
  - Linux Installer

Installation instructions: QGIS interface for SWAT+ QSWAT+ (Dile et al., 2023)

- SWAT+ Installation – pages 6-9
- QSWAT+ Plugin & Startup – pages 11-12

II. Source Data Structure

All spatial layers and respective lookup tables should be prepared according to the SWAT+ requirements found in the SWAT+ documentation. The required input files include a Digital Elevation Model (DEM), land use raster and lookup table, soil raster and lookup tables (unless using SSURGO/STATSGO in the USA, then lookup tables are built in), and daily weather data (minimum and maximum temperature, precipitation, wind speed, solar radiation, and relative humidity). Note that only precipitation and temperature data are required. Optional files include streams (polylines), inlets and outlets (points), and lake and reservoir waterbodies (polygons) shapefiles. All spatial layers should be in the same projected coordinate system with units of meters. For the Svratka River model, all input data is located in *Model_Inputs* as follows:

- DEM raster in *DEM*
- Landuse raster and lookup table in *Landcover*
- Soil raster and three lookup tables in *HWSD*
- Weather data in *Weather*
- Global Runoff Data Centre (GRDC) discharge data and locations shapefile in *GRDC_Stations*

III. Delineate Watershed

Once the plugin is installed (using Dile et al., 2023 pg. 11-12), create a **New Project** in a desired folder location named *svratka_model.* This will enable step 1; click **Delineate Watershed** to begin the delineation process. Under **Select DEM**, navigate to the DEM raster, *svratka_dem.tif* under *Model_Inputs/DEM.* This is a 100m DEM to decrease processing time; however, higher resolution DEMs are possible and will produce finer results.

Users can optionally burn in an existing stream network by inserting a shapefile (.shp), and checking the “Burn in existing stream network” box. For the Svratka River model, this step will be skipped.

Next, users can adjust the stream and channel threshold based on the number of cells or square area draining into the designated cell. The area units can be km^2, m^2, mi^2, ft^2, acres, or hectares. Stream reaches include stretches of the stream network between significant points, subbasins are designated by main divisions of the watershed, and channels are delineated as finer divisions of the stream network. For the Svratka River model, the Channel and Stream thresholds will be left as the default, seen in Figure 1 below. Click **Create Streams** to build the stream network; it should take ~1 minute to complete.

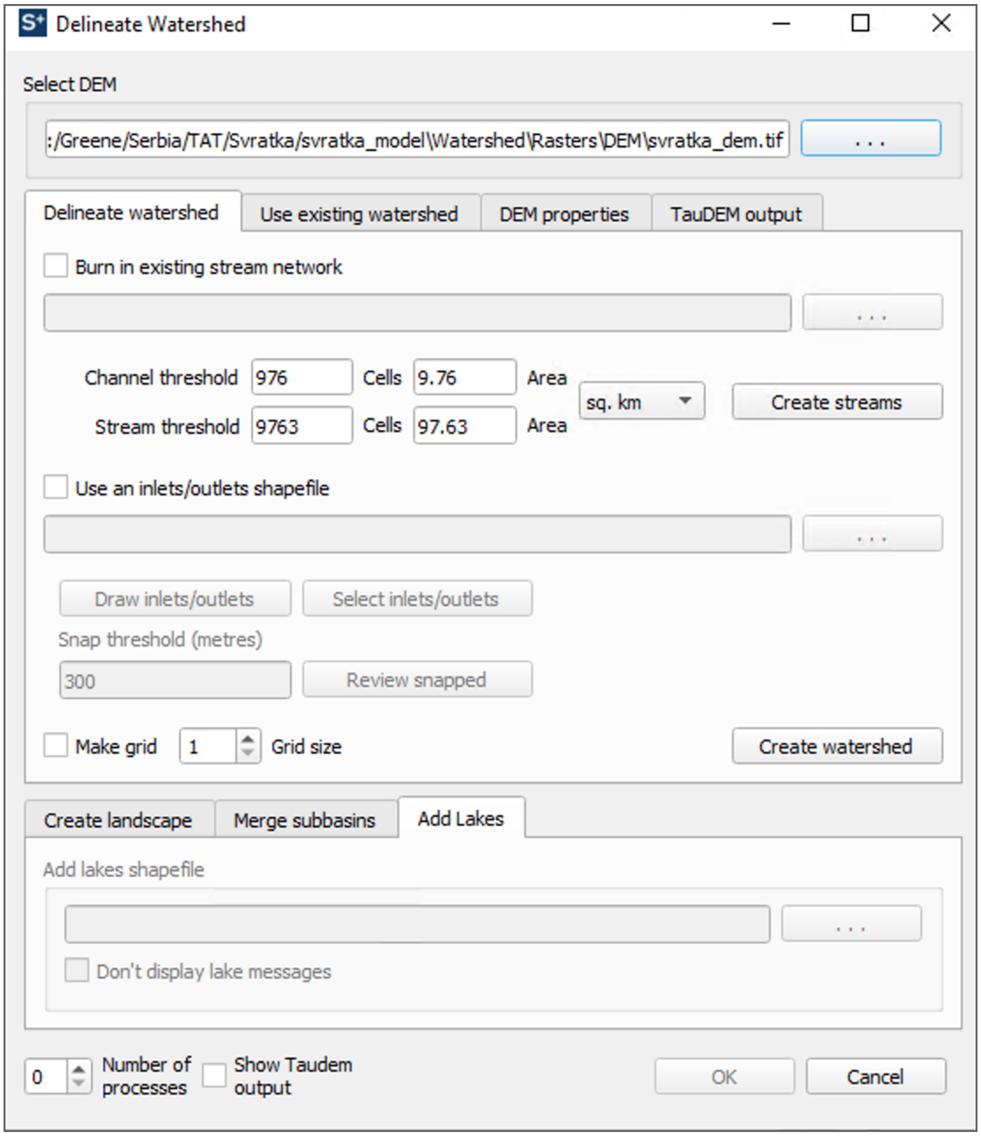

Figure 1. Delineate Watershed dialogue box, creating the stream network.

An inlets/outlets shapefile can be added or drawn to designate inlets, outlets, reservoirs, ponds, or point sources. For this model, this step will be skipped; uncheck the **Use an inlets/outlets shapefile** box.

To delineate the watershed, users can create the standard model, which will create subbasins based on the DEM (Figure 2, left), or using the grid model (Figure 2, right). The grid model creates a grid based on the user-set number of cells to execute subsequent analyses. For the Svratka model, we will use the grid model with 2 km grid cells. Check the box next to **Make Grid** and set the **Grid Size** to 20. Click **Create Watershed.**

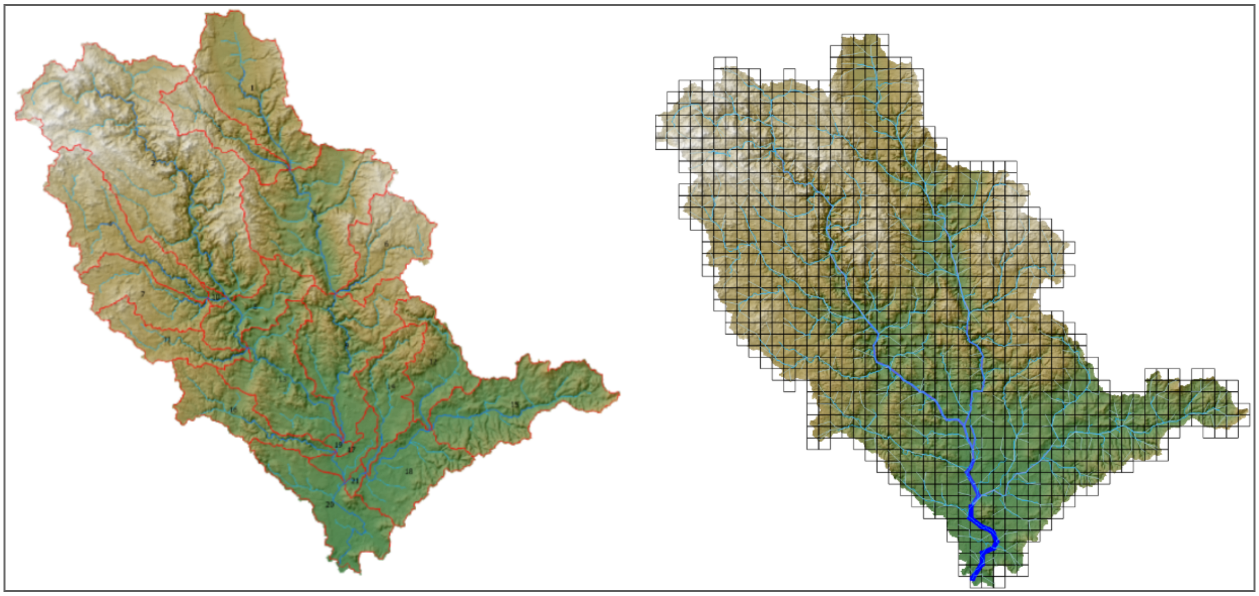

Figure 2. Standard SWAT Model (left), Gridded SWAT Model (right).

Users can create a floodplain using the landscape units created by SWAT. To do this, select the **Create Landscape** tab and then **Create.** There are three ways to create a floodplain map in SWAT: using a buffer around the channels, using an inverted DEM, or using stream branch lengths. Each method's performance varies depending on the characteristics of the watershed being modeled. For this project, we will be using the DEM Inversion with the same threshold from the Create Streams step (Figure 3). Select **Create** on the DEM Inversion tab, and **Done** when the process has completed.

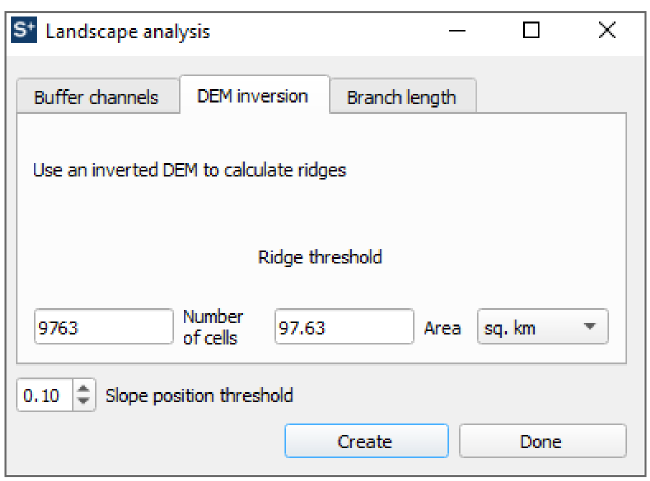

Figure 3. Landscape analysis: creating a floodplain raster via DEM inversion.

Finally, users have the option to merge subbasins or add a lakes shapefile to further fine tune the watershed delineation. The merge subbasins tab is disabled with the grid model, and there are no lakes to add to the Svratka example. To complete the Watershed Delineation, click **OK.** Now step 2, **Create HRUs,** is enabled.

IV. Create HRUs

SWAT creates Hydrological Response Units (HRUs) that divide subbasins into finer aspatial units based on soil, land use, and slope. To begin click **Create HRUs** which will populate a dialogue box with two tabs: Landuse and Soil, and HRUs. On the first tab, load in the **landuse map** and **soil map** (*Landcover/svratka_landcover.tif* and *HWSD/svratka_soils.tif,* respectively). The **landuse and soil database** file path will be left as is.

Landuse and soil lookup tables need to be imported to assign meaning to the numeric values found in the rasters. For landuse, under Tables, select **Use CSV file** in the **landuse lookup** dropdown, and enter *Landcover/landuse_lookups.csv.* This file contains the numeric landuse ID with its corresponding four-letter SWAT code for different landuse/cover types.

For soil, we need to enter a soil lookup table as well as usersoil tables that correspond to soil properties. In the **Soil Data** box on the left, leave the **usersoil** option selected. If the SWAT project is using STATSGO or SSURGO (USA) data, lookup tables are built-in to the file directory and soil tables are not needed. This project uses data from the Harmonized World Soil Database; therefore, usersoil tables are necessary. Under Tables, select **Use CSV file** under the **soil lookup** dropdown, and enter *HWSD/svratka_soils.csv.* This will attribute the numeric raster value to a type of soil. Subsequently, soil properties will be defined with two additional CSVs, one for the main soil type, and one for soil types that have multiple layers. Under the **Usersoil** table, select **Use CSV file**, and enter *HWSD/svratka_usersoil_main.csv.* The file lookup will remain open; secondly, enter *HWSD/svratka_usersoil_layers.csv.* Now both CSVs are loaded; the usersoil table label will read *svratka_usersoil_main*. When defining soil properties with layers in this manner, the file names must contain the string *usersoil* and be extended with *_main* and *_layers* to be properly read by SWAT+.

Additional settings include slope bands, elevation bands, reservoir threshold, and selecting a floodplain map. For the Svratka model, we will add a slope band at 5% and 10% to divide HRUs into those that have slopes from 0-5%, 5-10% and >10%. Under Set Slope Bands (%), type 5 in the box and hit **Insert**, and repeat with 10. The reservoir threshold will be left as the default (101% water), no elevation bands will be defined, and the floodplain map from step 1 (*invflood0_10.tif)* should be entered under **Select floodplain map.**

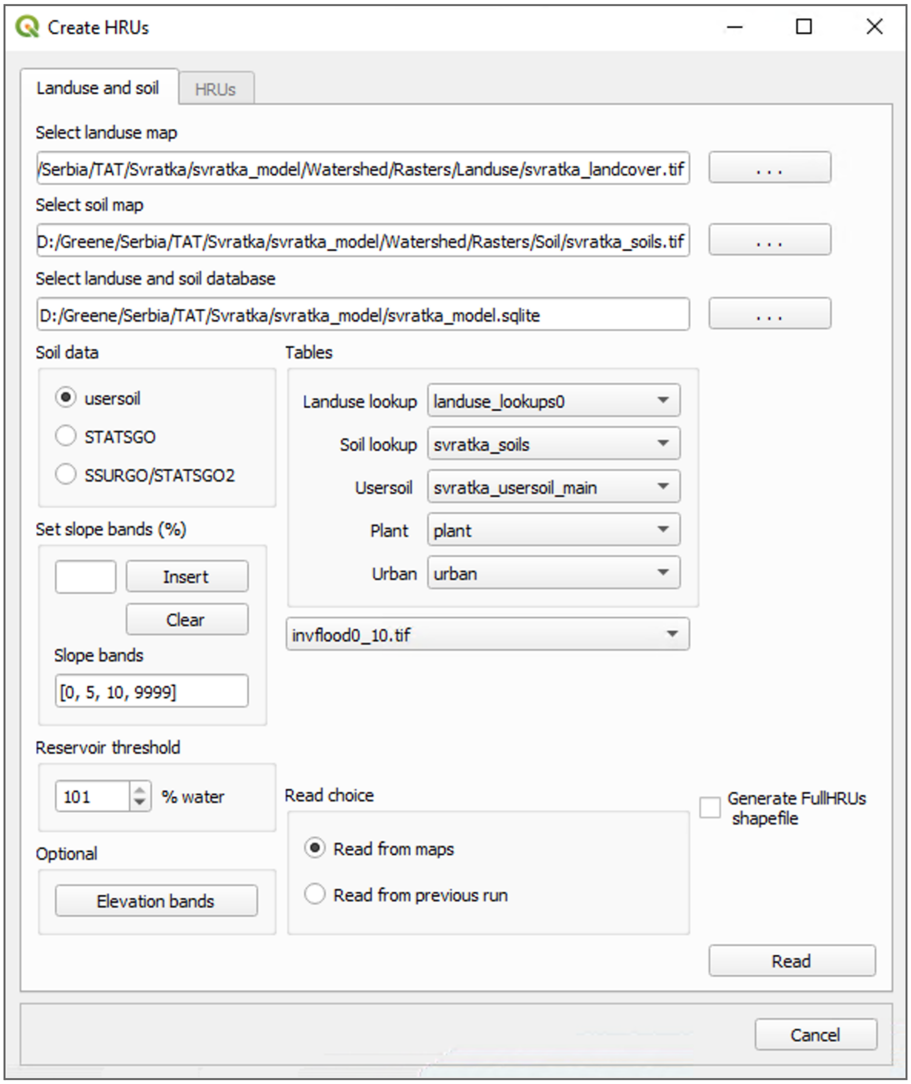

Figure 4. Ready to run landuse and soil files for creating HRUs.

When all parameters are set, select the box next to Generate Full HRUs shapefile, and click **Read**. The HRUs tab will become enabled.

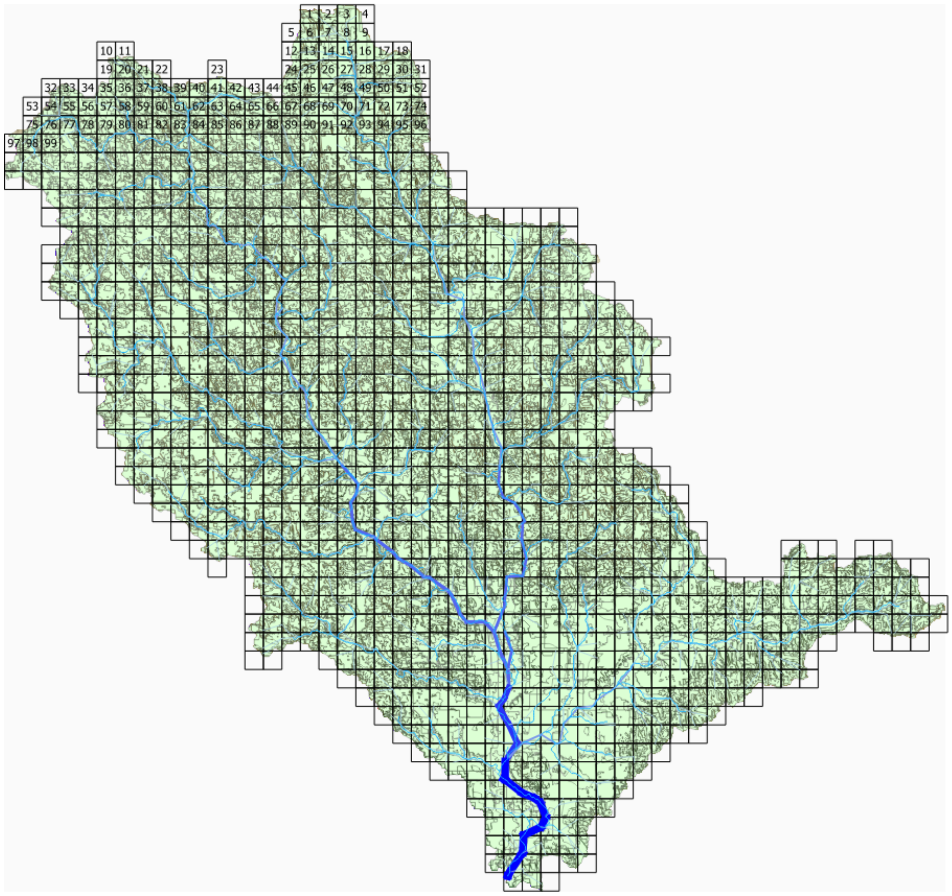

Figure 5. After reading maps.

Under the HRUs tab, users have the option to split or exempt landuses. Commonly, agricultural land will be split by crop type. For example, users could define that 30% of agricultural land is under maize, 40% for wheat, and 30% for soybeans. Exempting landuses could be used to ensure that a specific landuse is retained in HRU calculations. For this project, we will not split or exempt any landuses for the sake of simplicity.

Finally, the HRU creation method is enabled under **Single/Multiple HRUs**. For single HRUs, they can be created based on the dominant landuse, soil, and slope within a subbasin or simply the dominant HRU by area within a subbasin. Alternatively, multiple HRUs can be created within a subbasin defined by user-set thresholds of either % landuse/soil/slope, % area, or a target number of HRUs per subbasin. For the Svratka project, select **Filter by landuse, soil, and slope** and set the landuse % to 10; click **Go.** Now set the soil % to 10, click **Go,** and slope % to 10 and click **Create HRUs**.

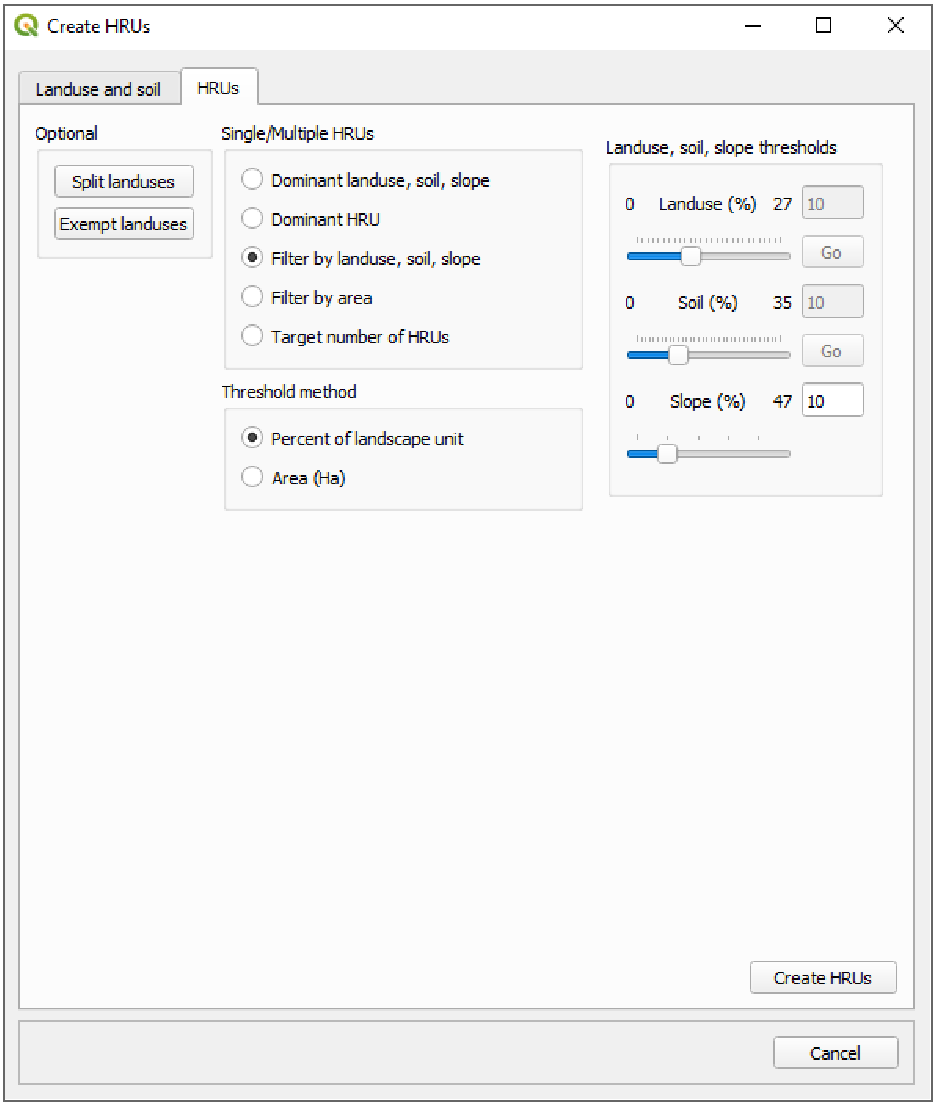

Figure 6. Ready to run HRUs.

V. Edit Inputs and Run SWAT+

Now the model is ready to run in the SWAT Editor. Click **Edit Inputs and Run SWAT+.** The project will automatically populate a display name; ensure that it is correct and click **Start** (Figure 7).

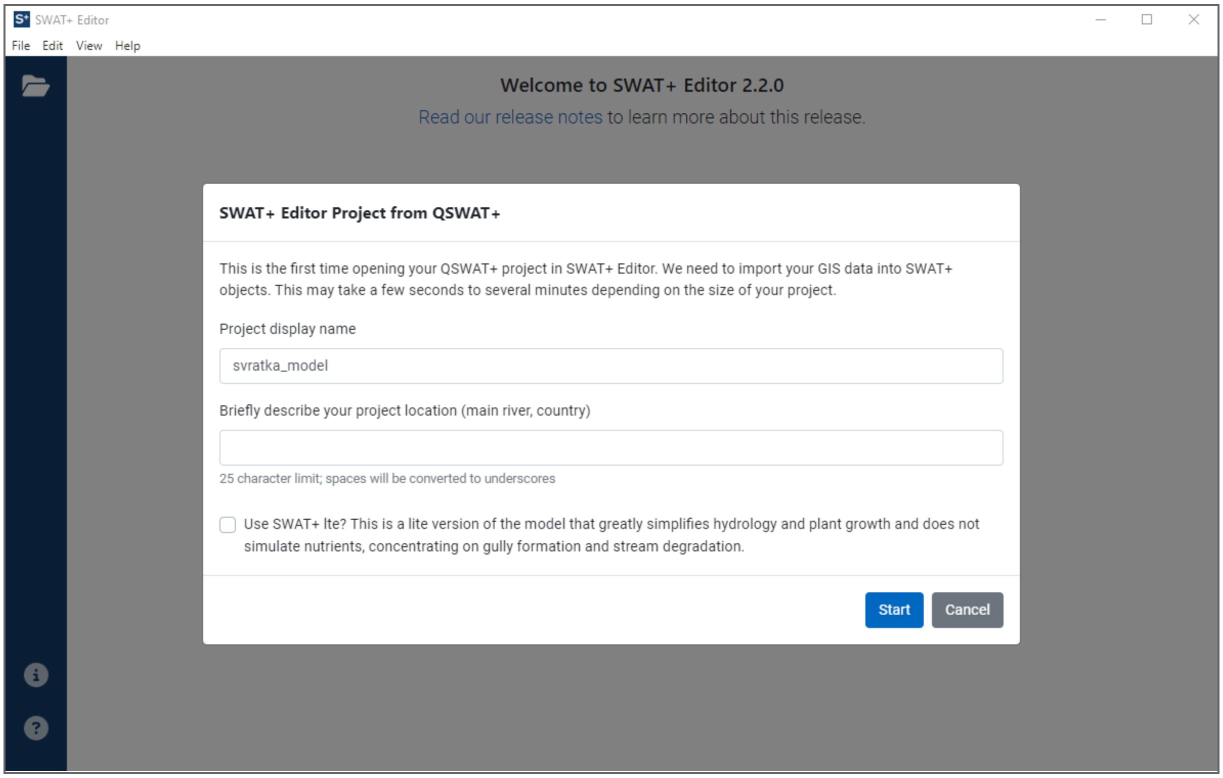

Figure 7. SWAT Editor start screen.

The project page will show some watershed overview statistics including total area, simulation period, object totals, and landuse distribution.

The last data that needs to be imported is the climate data. To do this, click the pencil icon in the top left (**Edit SWAT+ inputs**), and navigate to the **Weather Generator** tab, and **Import Data.** This data is created from the *swatplus_ wgn.sqlite* built-in to SWAT. Therefore, leave all the defaults as is, and click **Start**.

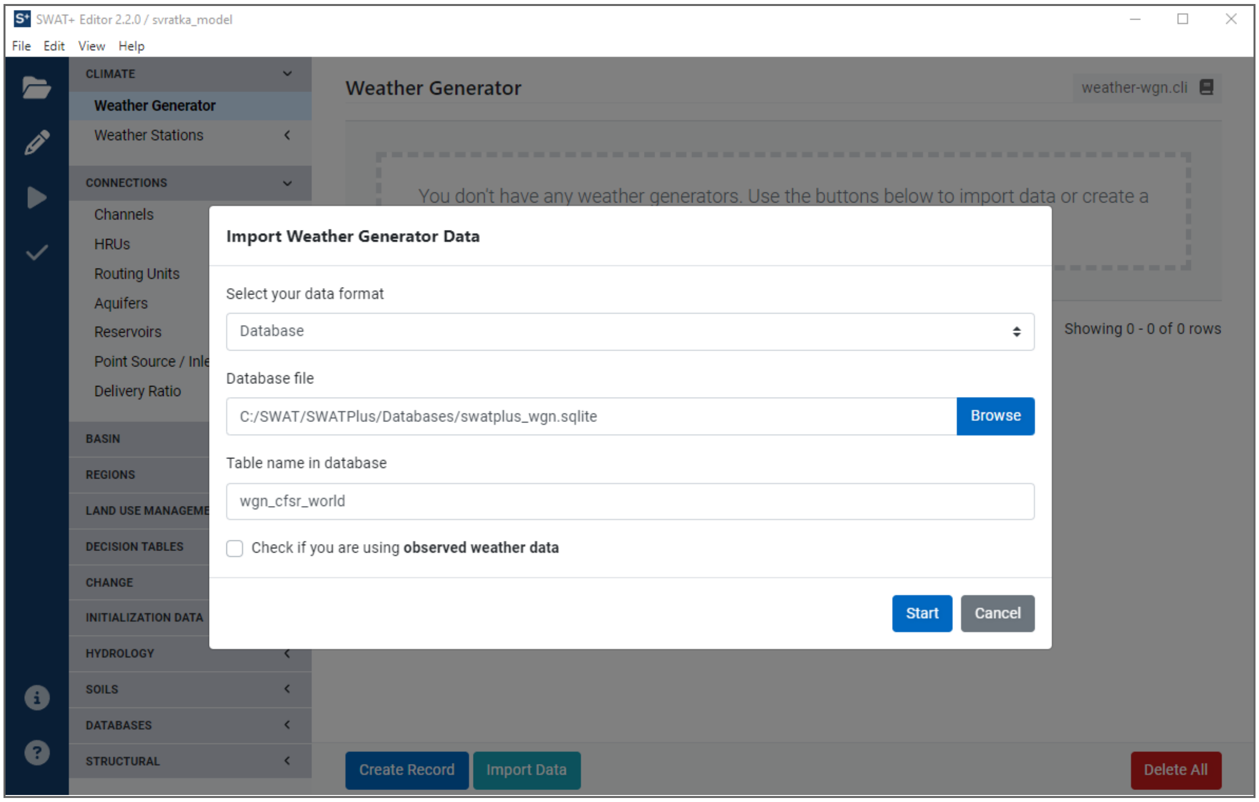

Figure 9. Weather Generator defaults, ready to start.

Now, to import the observed climate data, click on the **Weather Stations** tab. Select **Import Data** and leave the data format type as SWAT2012 / Global Data Websites. Enter the weather files directory in the SWAT2012 (*~Model_Inputs/Weather*). The SWAT Editor searches this directory for the station files; therefore, they need to be named according to the SWAT requirements (pcp.txt, rh.txt, solar.ext, etc). Leave the directory to save your SWAT+ weather files as the default. Click **Start**. For the Svratka project, there are 7 stations of observed climate data.

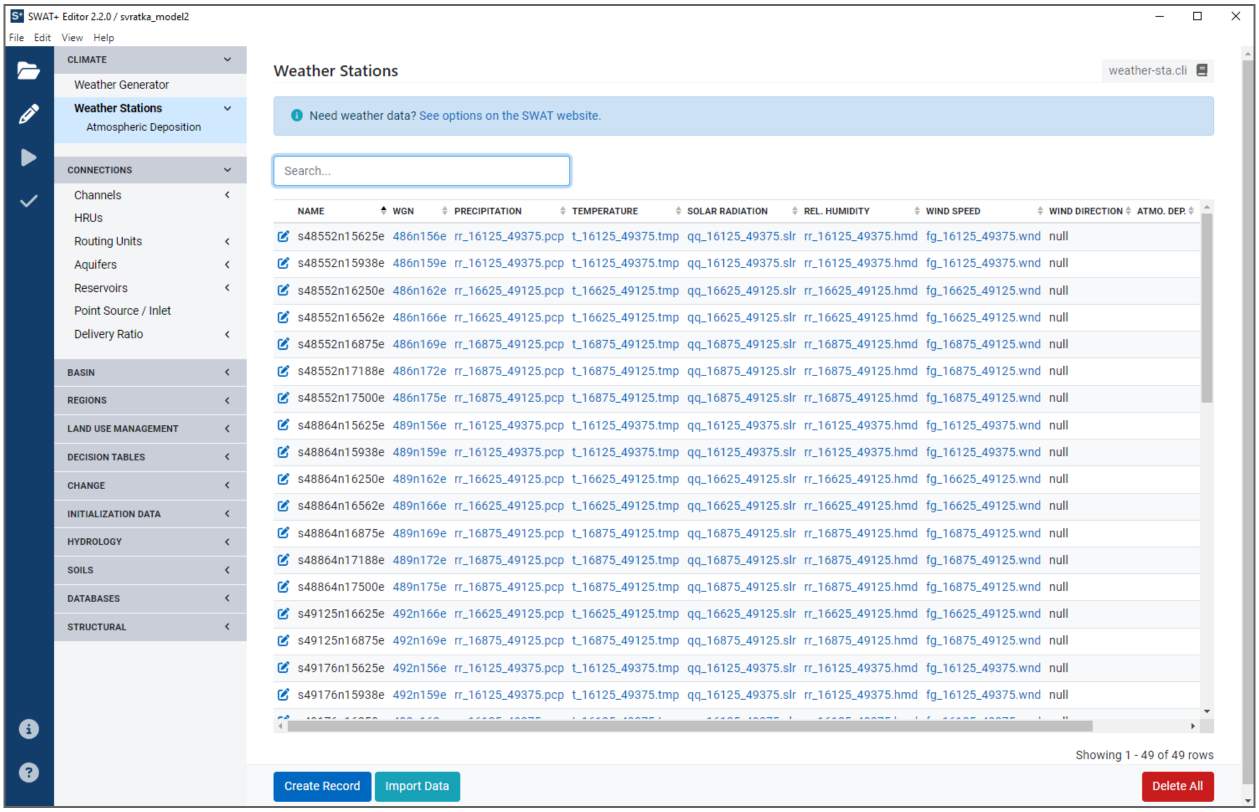

Figure 9. Imported observed climate data stations.

Click the triangle (play) symbol in the top left (Run SWAT+) to set the simulation period and outputs to write. The simulation period will automatically be set based on the observed weather data imported in the previous step (1950-2022); alter the simulation period to 2018-2022 to reduce the runtime. Click **Choose output to print** to expand the options. The default warm-up period will be 1 year, for the Svratka project, change this to 2 years. Select the **Monthly, Yearly** and **Average** boxes for **Channel** under **Model Components,** and **Yearly and Average** for **Landscape Units** under **Water Balance** and **Losses** (Figure 10). For the sake of runtime and file size within this tutorial, all other rows can be unchecked. In this project, we are interested in streamflow; however, other projects may take interest in other variables and select alternative outputs.

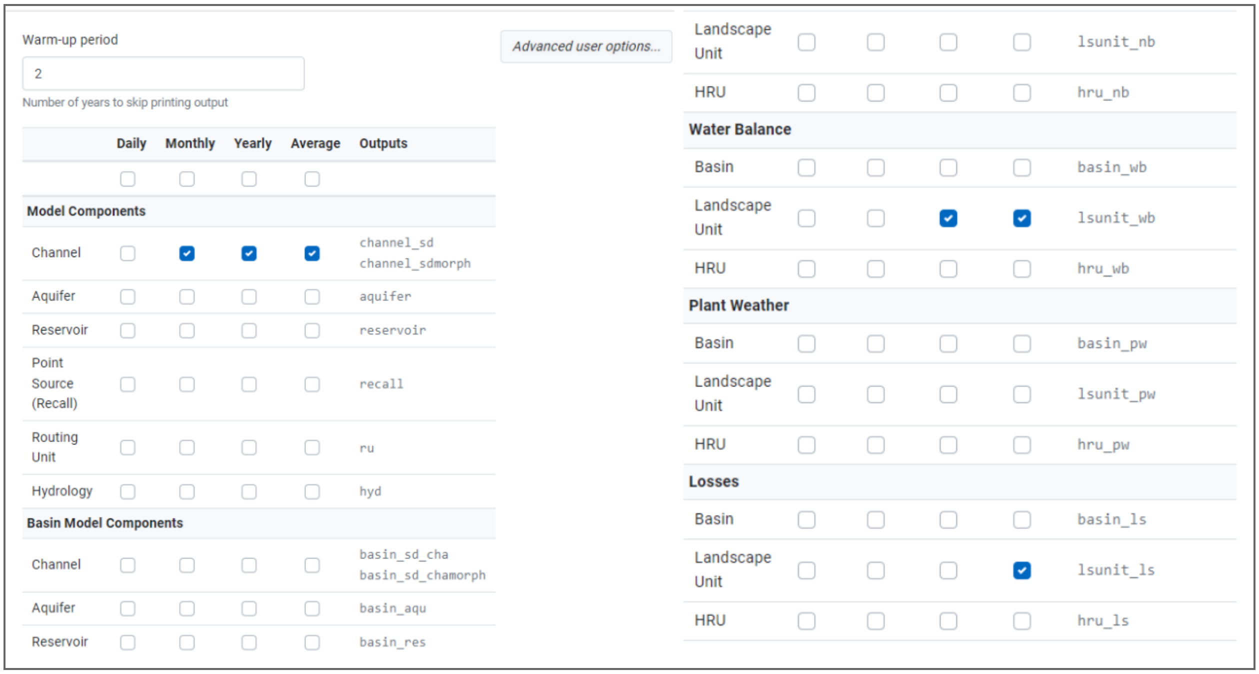

Figure 10. Selected outputs to print.

Finally, ensure that **Write input files, Run SWAT+**, and **Analyze output for visualization** are all selected. Click **Save Settings & Run Selected**, and users can see files as they are being written. This step may take several minutes. All results will be written to *Scenarios/Default.* Upon completion, **Exit SWAT+ Editor.**

VI. Visualize Results

A. Mapping Results

When the SWAT+ Editor completes, a 4th step for visualization appears in the QSWAT+ box. To begin, click **Visualize.** The scenario can be left as **Default**, and the SWAT+ output table drop down box will display the outputs selected in the previous step. For now, select **lsunit_wb_aa.** The period can be left as the default (2019-2021). For this tutorial, we will create a static map of the annual mean surface runoff from the landscape.

Under the static maps tab, use the drop down box to view the variable options; hover over the variable names for descriptions. Select **surq_gen,** surface runoff generated from the landscape, and click **add.** Highlight the variable in the box and click **Create** (Figure 11).

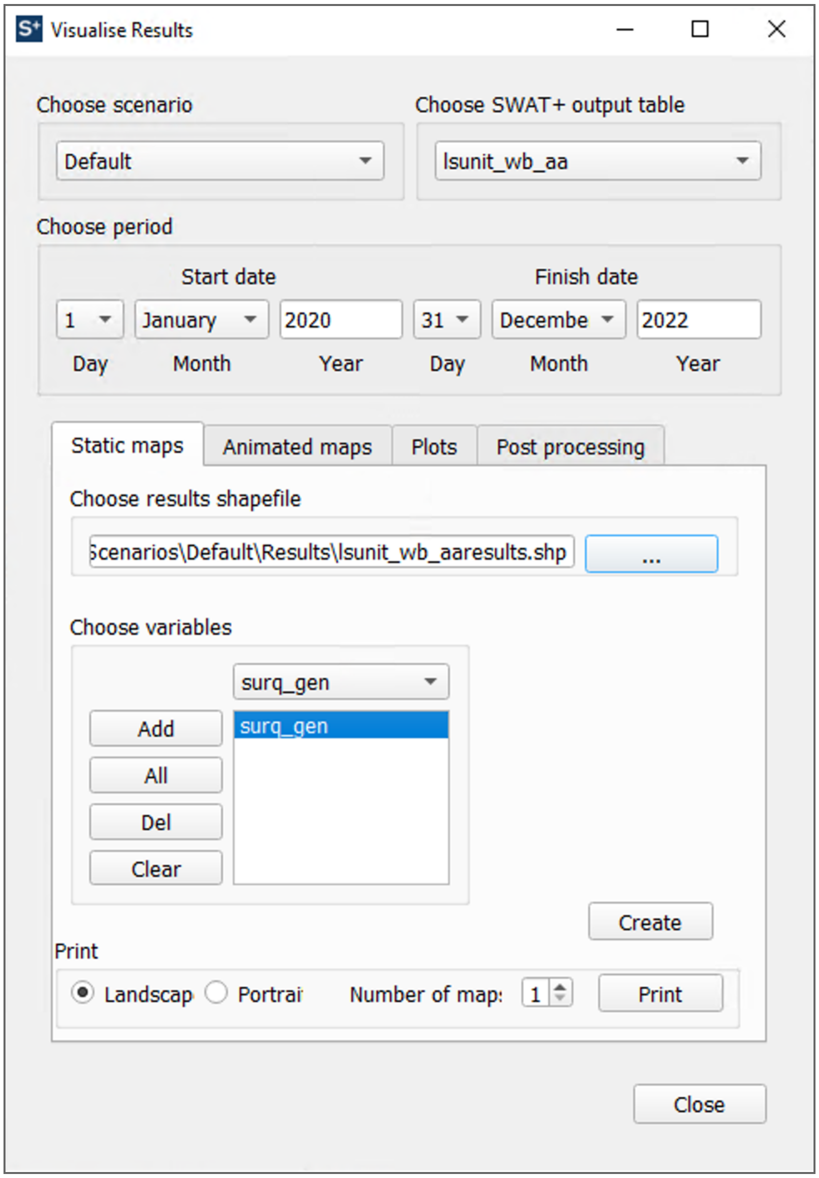

Figure 11. Visualize Results settings.

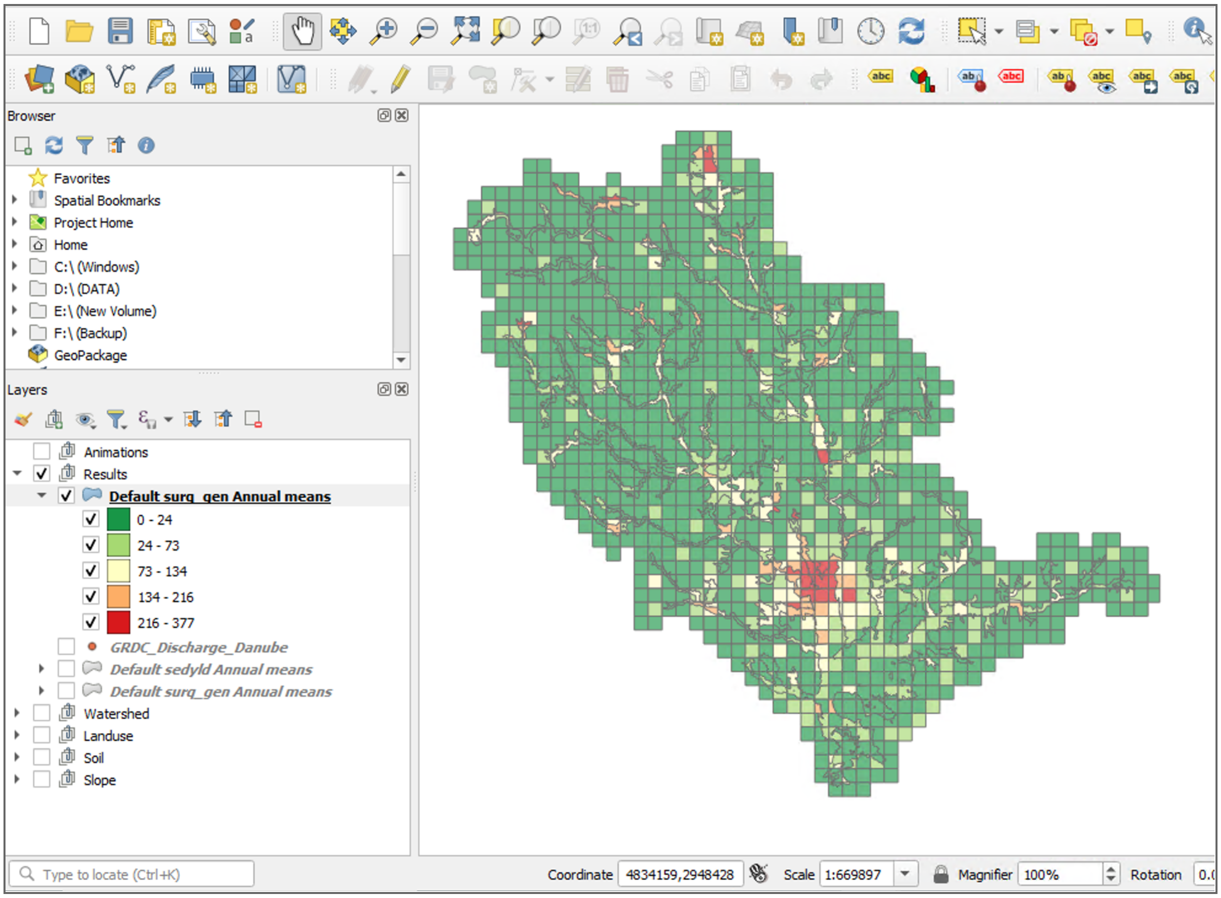

Figure 12. Default surface runoff generated from the landscape (mm), annual mean.

B. Plotting Results

Another visualization option is to create time-series plots of the different variables. Users can optionally add observed datasets to create comparison plots. For this tutorial, we will create a time-series of the flow out of one of the channels along the Svratka with modeled and observed flow data.

To begin, click **Visualize Results** and the **Plots** tab. Select *channel_sd_mon* under the SWAT+ output table dropdown box. In **Choose observed data file,** navigate to *GRDC_Stations/6142260_observedFlow.csv.* Optionally, add the *GRDC_Stations.tif* to the project by dragging it from a file explorer into the QGIS Window. Use this shapefile and the *Grid streams* shapefile from SWAT+ to determine the GRDC Station ID (6142260) and the Stream ID (270) using the Identify tool.

Select Graph/bar chart under the **Plot Type** dropdown, and 270 under the **Unit** dropdown box. The **Variable** selected will be *flo_out.* Click **Add plot** as well as **Add observed** to enter both scenarios into the plot (Figure 13). Click **Plot,** and create a filename for the CSV where the data will be written, for example, *svratka_flow_plot.* Click **Save** and the SWATGraph box will populate with a line graph displaying the modeled versus observed streamflow (Figure 14).

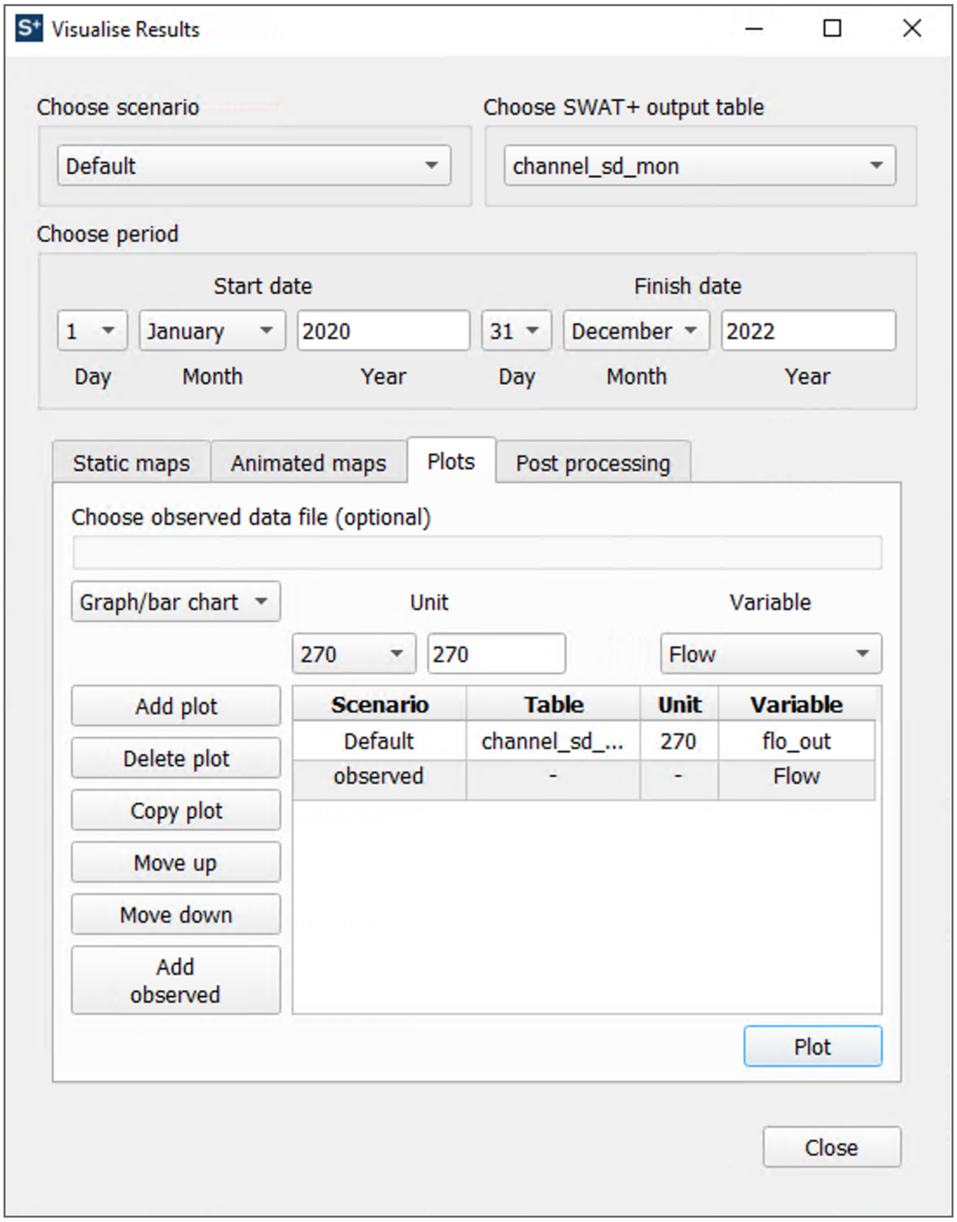

Figure 13. Visualize Results Plot tab with both model and observed data added.

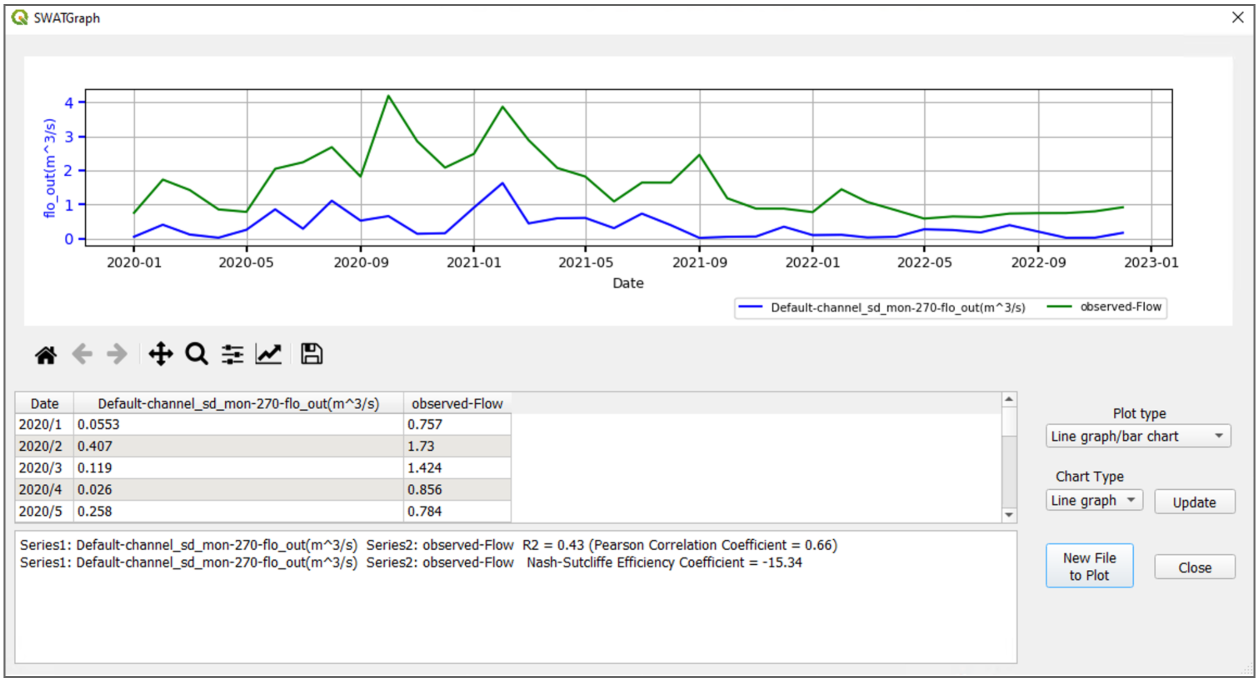

Figure 14. SWATGraph results displaying the modeled flow through channel 270 (blue) versus observed flow through the channel (green).

VII. Example Landuse Change Model

To illustrate a potential landuse change scenario within the watershed, a secondary landuse raster, *landcover_change.tif*, has been created in which the northeastern region of the watershed undergoes reforestation. In essence, the agricultural land was recoded to forest land. To show the effect of these land changes on the watershed model, create a new SWAT+ project with the same parameters as the previous one, but enter the *landcover_change.tif* map in place of the *svratka_landcover.tif* map in step 2, creating HRUs.

Upon running SWAT+, exit the editor and **Visualize Results.** To assess the impacts of landuse changes, we will analyze the sediment yield leaving the landscape via water erosion. Under **Choose SWAT+ output table,** select *lsunit_ls_aa* in the dropdown box. Choose **sedyld** (sediment yield in Mg/ha) under **Choose variables**, and click **Add, Create.** Recreate this map in the original SWAT+ model, and take note of the changes in the northeast corner (Figure 13).

Figure 15. Annual average sediment yield (Mg/ha) with reforestation (left) and "baseline" landuse (right). The synthetic landuse change observes agriculture to forest changes in the Northeast.

VIII. SWAT+ Resources

A. SWAT+ Input & Output Data Documentation
B. QSWAT+ User Group
C. SWAT+ Editor User Group
D. SWAT+ Model User Group
E. LUCST: A novel toolkit for Land Use Land Cover change assessment in SWAT+ to support flood management decisions
F. Upcoming NASA ARSET: Assessing the Impacts of Fires on Watershed Health

IX. Data Sources

A. Soil
   1. FAO Harmonized World Soil Database (HWSD) v1.2
      a) For ready-to-read, SWAT+ formatted HWSD data, contact Sean Woznicki, Jillian Greene, or Jamshid Jalali (contact information below)

B. Landcover
   1. CORINE Land Cover (CLC) 2018
   2. Sentinel-2 10m Land Use/Land Cover (Kontgis et al., 2021)
   3. User-generated

C. DEM
   1. EU Copernicus DEM v1.1
D. Weather
   1. E-OBS v26.0e (1950-2022)
   2. EuroCordex CMIP5 - Climate Projections
      a) For processed and ready-to-read European climate data, contact Sean Woznicki, Jillian Greene, or Jamshid Jalali (contact information below)
E. GRDC Data
   1. German Federal Institute of Hydrology (BfG) Global Runoff Data Centre

X. Contact Information

Emails:

- Sean Woznicki: woznicse@gvsu.edu
- Jillian Greene: greeneji@mail.gvsu.edu
- Jamshid Jalali: jalalij@mail.gvsu.edu

XI. References

Dile, Y., Srinivasan, R., & George, C. (2023, June). QGIS Interface for SWAT+: QSWAT+.

Karra, Kontgis, et al. "Global land use/land cover with Sentinel-2 and deep learning." IGARSS 2021-2021 IEEE International Geoscience and Remote Sensing Symposium. IEEE, 2021.