

Introduction to SWAT+

Soil and Water Assessment Tool

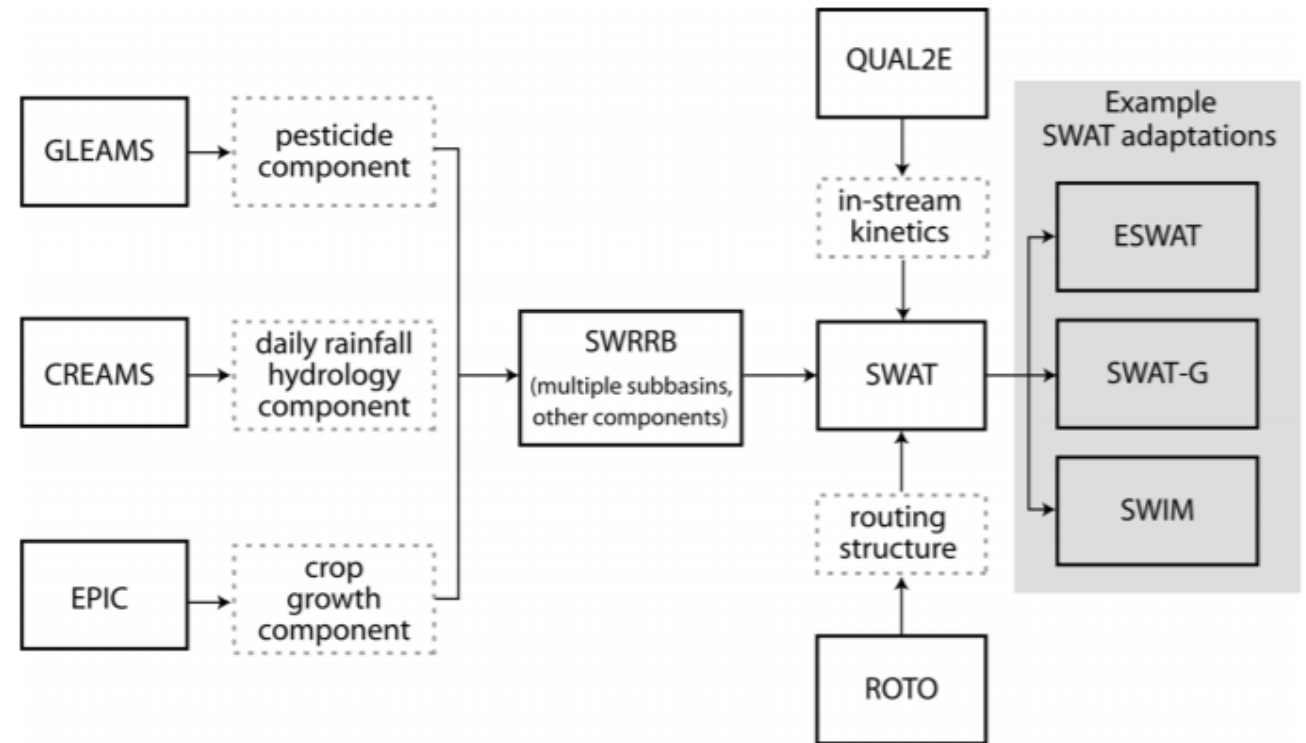
Katrin Bieger, Jeffrey G. Arnold, Chris George,
Jaclyn Tech, and Raghavan Srinivasan

1. Introduction to SWAT+
2. Constructing a model using QSWAT+
3. Running the model using the SWAT+ Editor
4. Visualizing model output using QSWAT+
5. Editing SWAT+ input files
6. Calibration of SWAT+ models

- Small watershed to river basin-scale model to simulate the quality and quantity of surface and ground water and predict the environmental impact of land use, land management practices, and climate change
- Daily time step
- Comprehensive simulation of land phase processes and in-stream routing
- Worldwide use of SWAT:
 - Applications at various temporal and spatial scales all around the globe
 - Annual international and regional conferences
 - Over 3200 peer-reviewed articles

History of SWAT+

- Product of over 45 years of U.S. Department of Agriculture and Texas A&M University model development

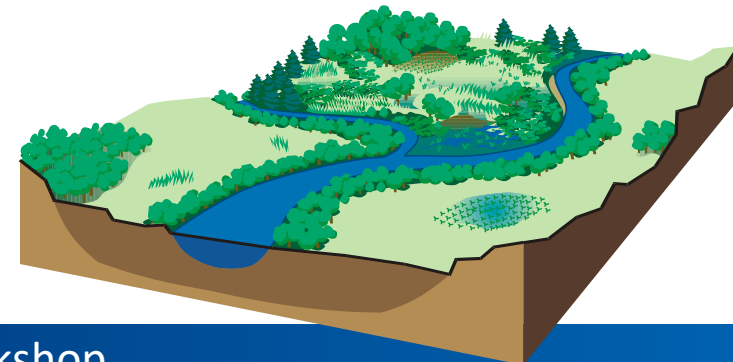


The climate of a watershed provides the moisture and energy inputs that control the water balance and relative importance of its components.

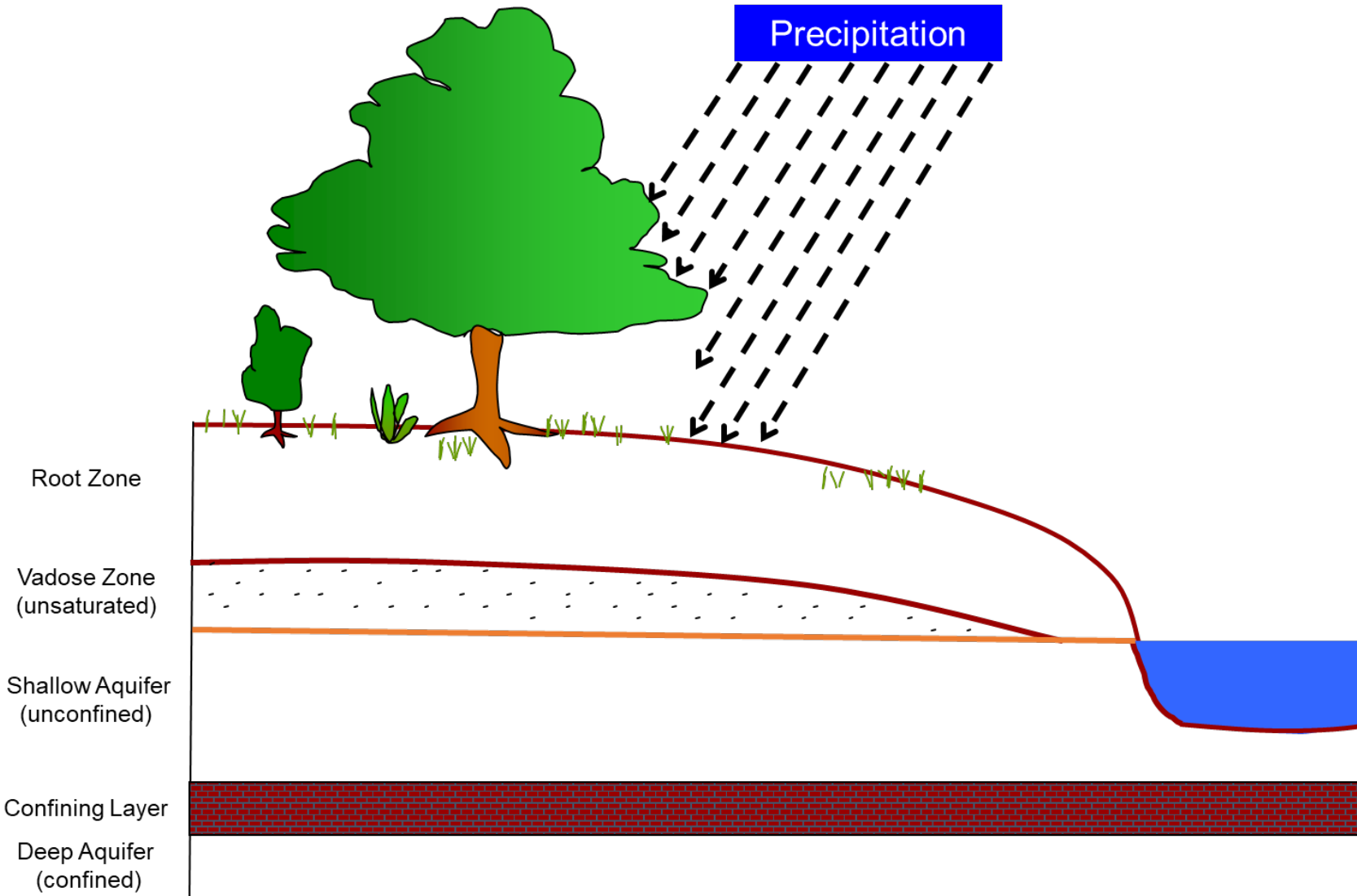
- Weather variables
 - Precipitation
 - Min./max. air temperature
 - Relative humidity
 - Solar radiation
 - Wind speed
- Observed data
- Weather generator
 - when observed data is not available
 - to fill in missing values in observed data
- Precipitation is classified as rain or snow depending on air temperature

Land and Water Phases

- Land phase processes
 - Hydrology
 - Plant growth
 - Erosion
 - Nutrient cycling
 - Pesticide, pathogen, heavy metal, and salt dynamics
 - Land management
- Control runoff and loads of sediment, nutrients, and constituents entering the streams of the watershed
- Water phase processes
 - In-stream routing
 - In-stream transport of sediment, nutrients, pesticides, pathogens, heavy metals, and salts
 - Reservoirs and ponds
- Control the amount of water and loads of sediment, nutrients, and constituents reaching the watershed outlet

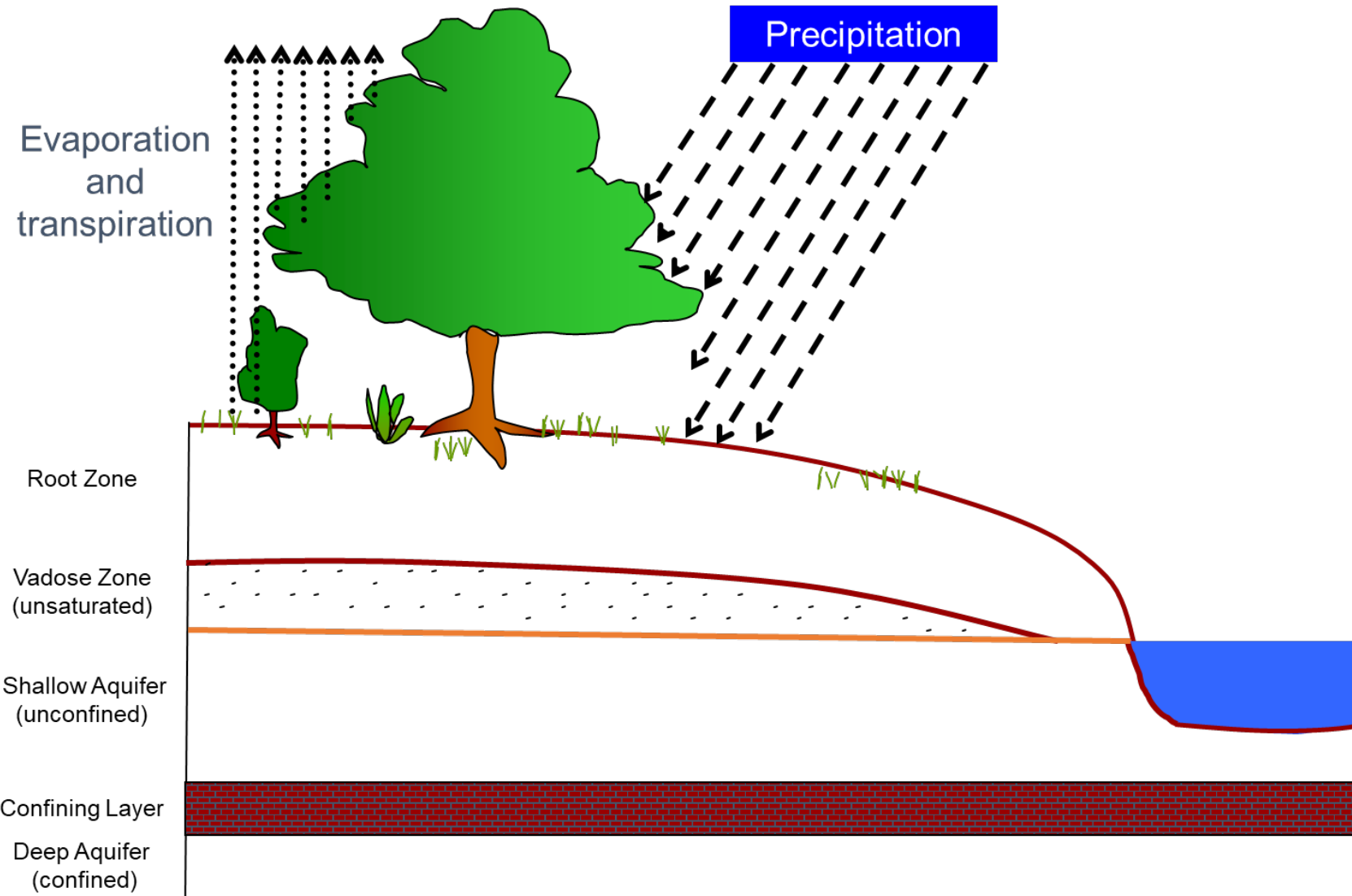


Hydrology – Moisture Inputs



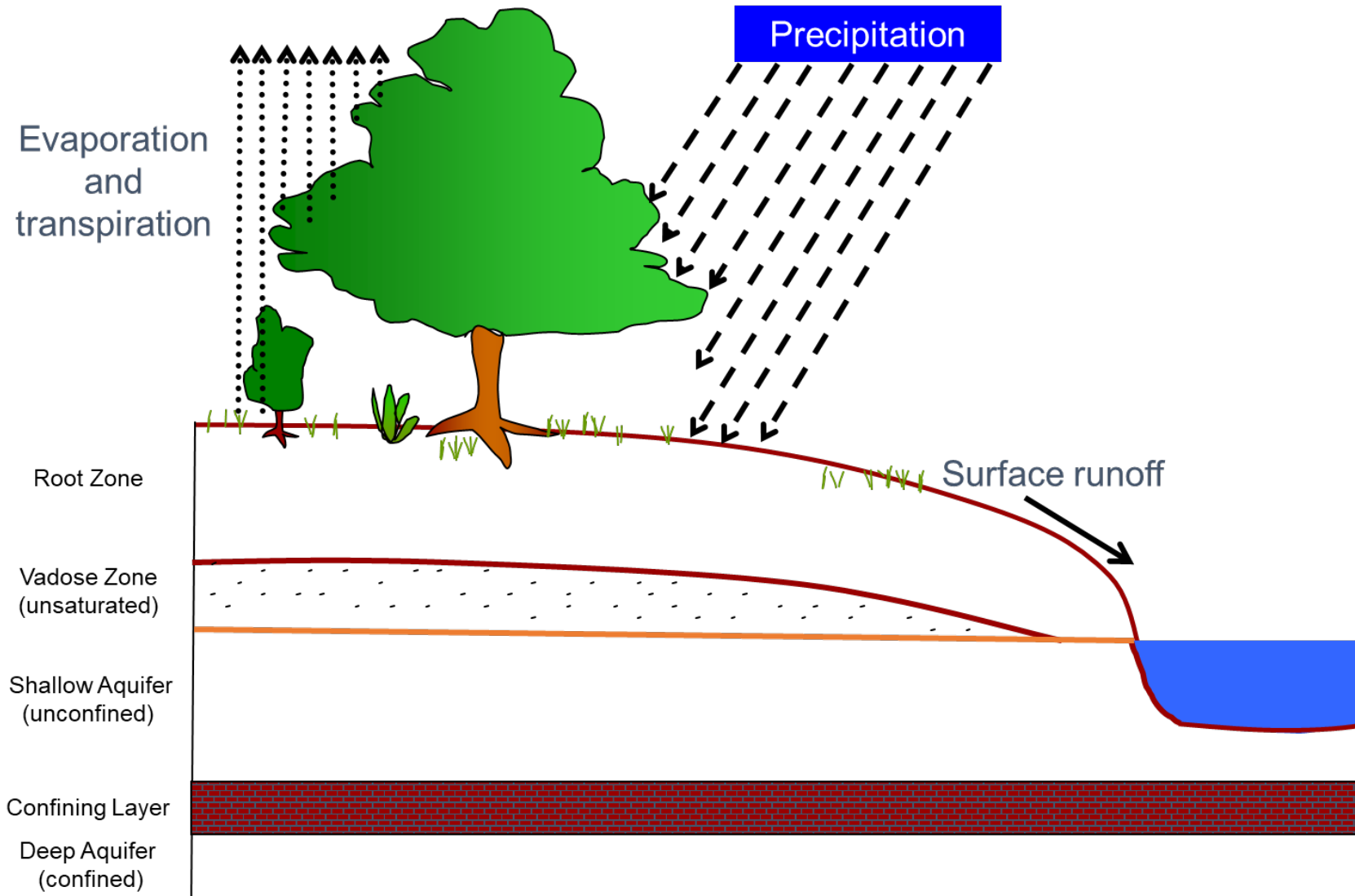
- Precipitation
 - Rain
 - Snow
- Snowmelt
- Irrigation

Hydrology – Evapotranspiration (ET)



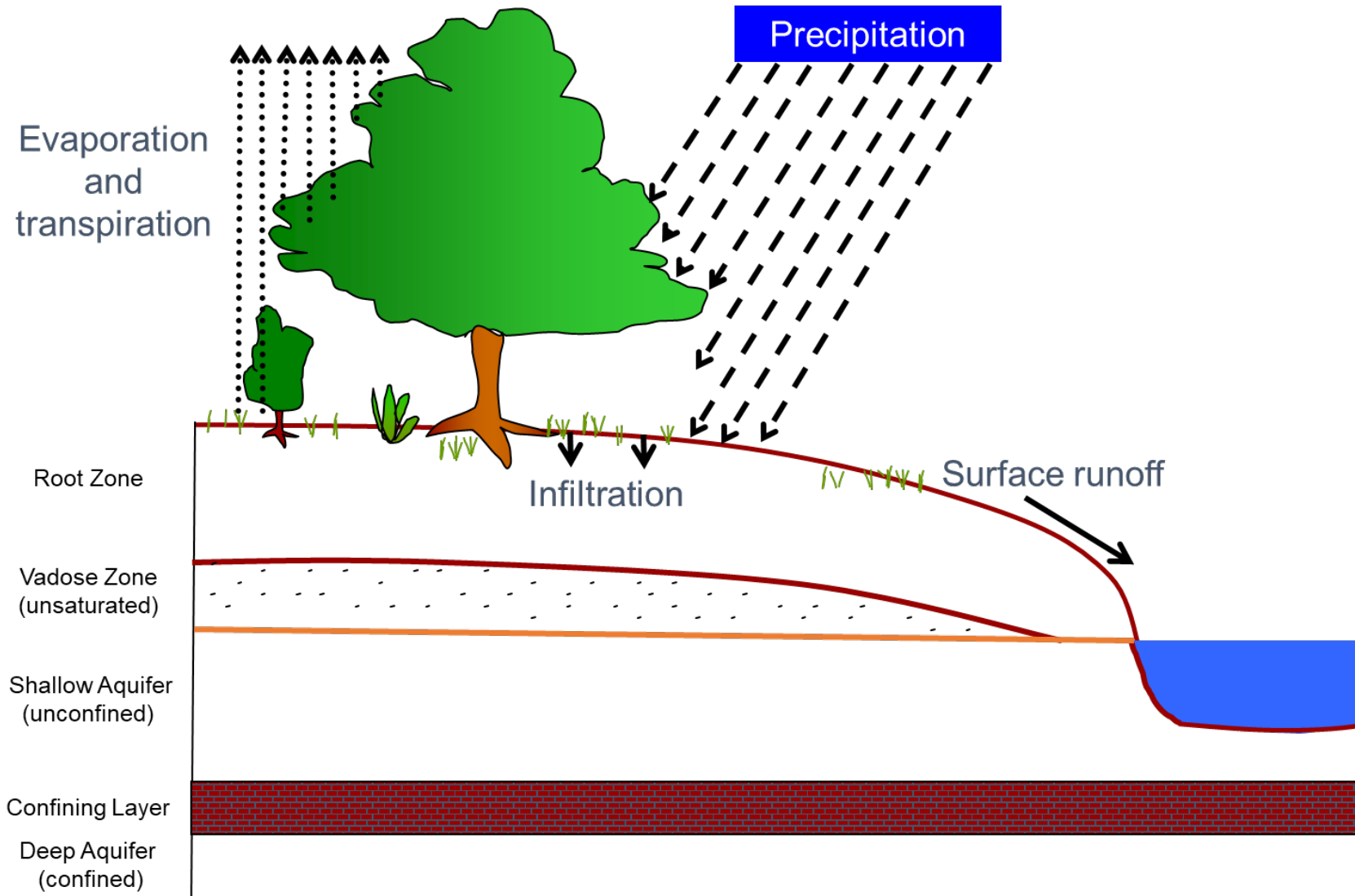
- Potential ET
 - Hargreaves
(Hargreaves et al., 1985)
 - Priestley-Taylor
(Priestley and Taylor, 1972)
 - Penman-Monteith
(Monteith, 1965)
- ET from soils and plants is computed separately

Hydrology – Surface Runoff



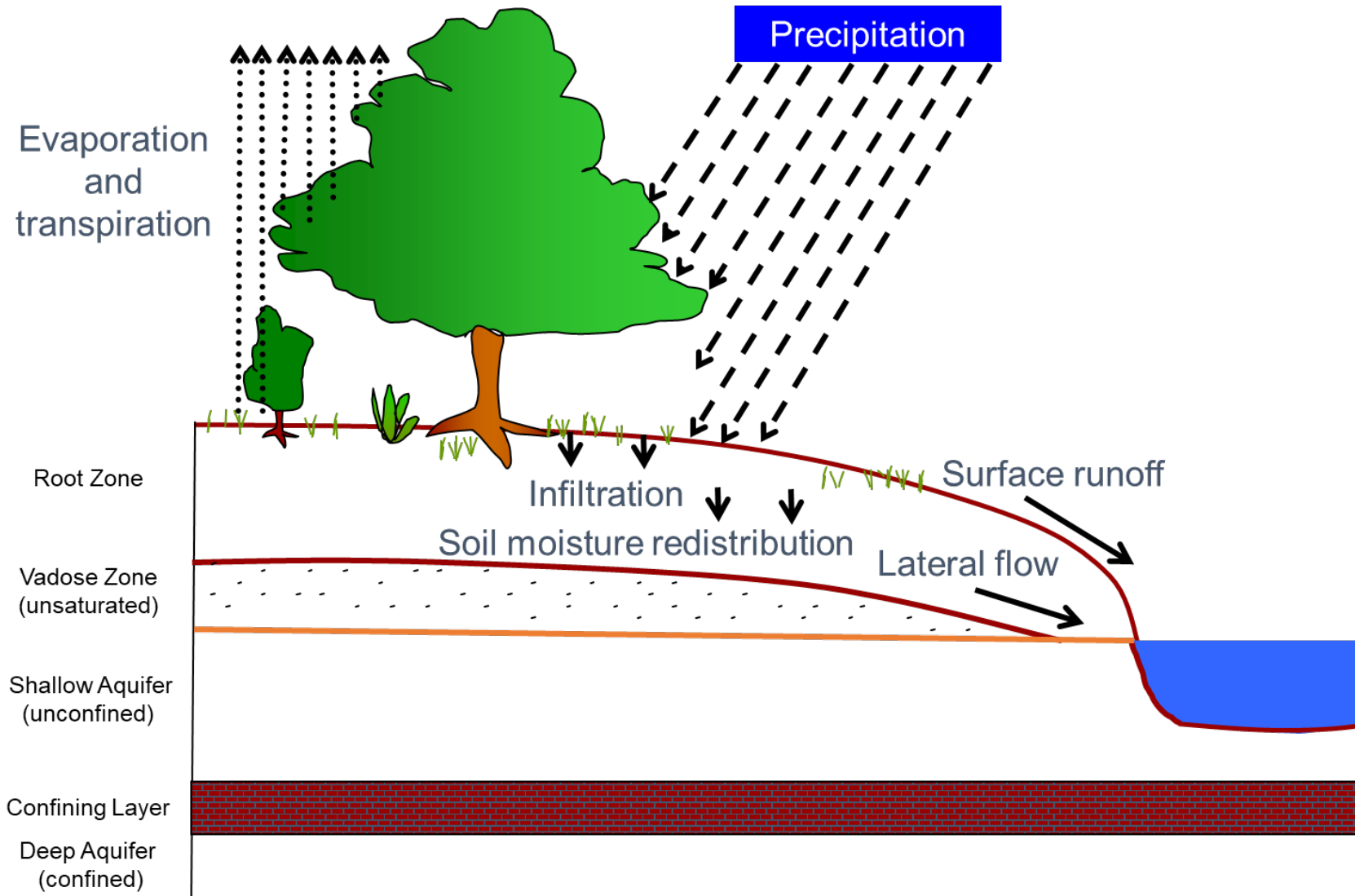
- SCS Curve Number (CN) method (USDA-SCS, 1972)
 - CN varies non-linearly with the soil moisture content
- Green & Ampt infiltration method (Green and Ampt, 1911)
 - Surface runoff calculated as difference between precip and infiltration
 - Requires sub-daily precip data

Hydrology – Infiltration



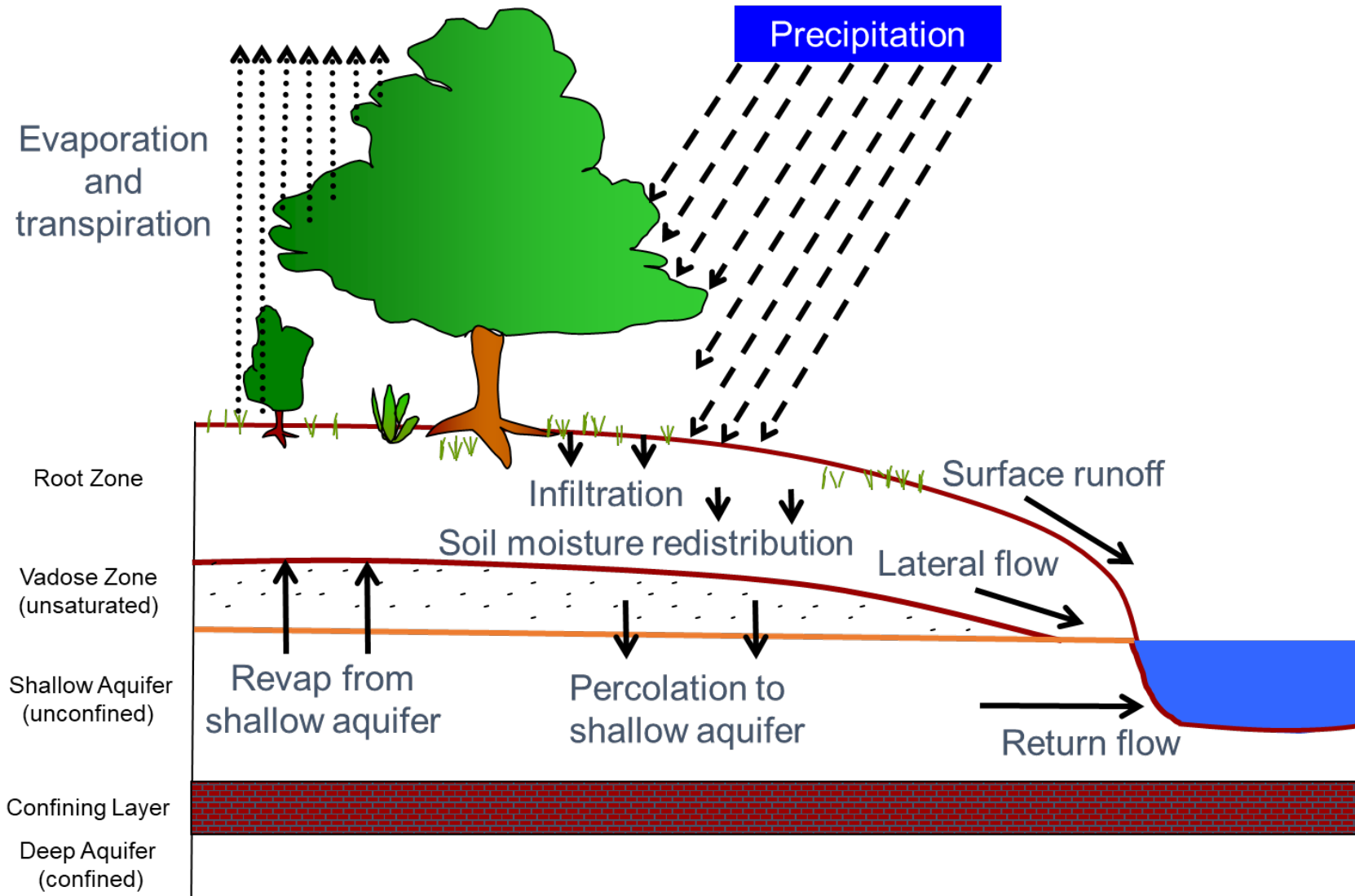
- Calculated as difference between precipitation and surface runoff when using CN method
- Calculated directly when using Green & Ampt method
- Rate of infiltration decreases as soil becomes wetter

Hydrology – Redistribution and Lateral Flow



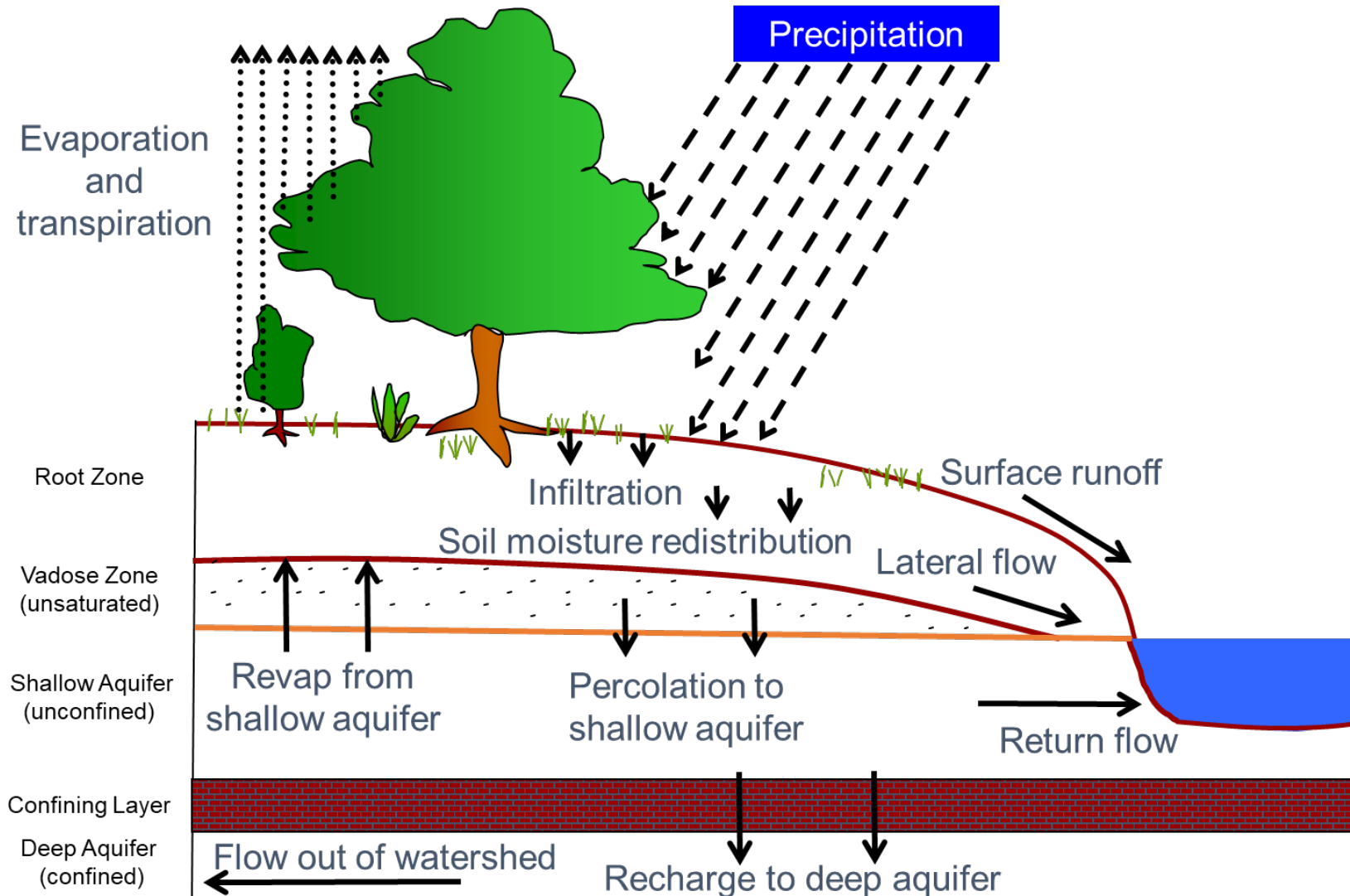
- Redistribution
 - Downward flow when field capacity of a soil layer is exceeded and the layer below is not saturated
 - Flow rate depends on saturated conductivity of soil layer
- Lateral flow
 - Depends on soil water content, conductivity, and slope

Hydrology – Shallow Aquifer



- Percolation
 - Water percolating past the bottom of the root zone recharges the shallow aquifer
- Revap
 - Replenishes soil moisture in very dry conditions
- Return flow
 - Groundwater contribution to streamflow

Hydrology – Deep Aquifer



- Percolation out of shallow aquifer recharges deep aquifer
- Deep aquifer flow is assumed to leave the watershed

- Stresses:

- Water
- Nitrogen
- Phosphorus
- Temperature
- Aeration

Yield Prediction

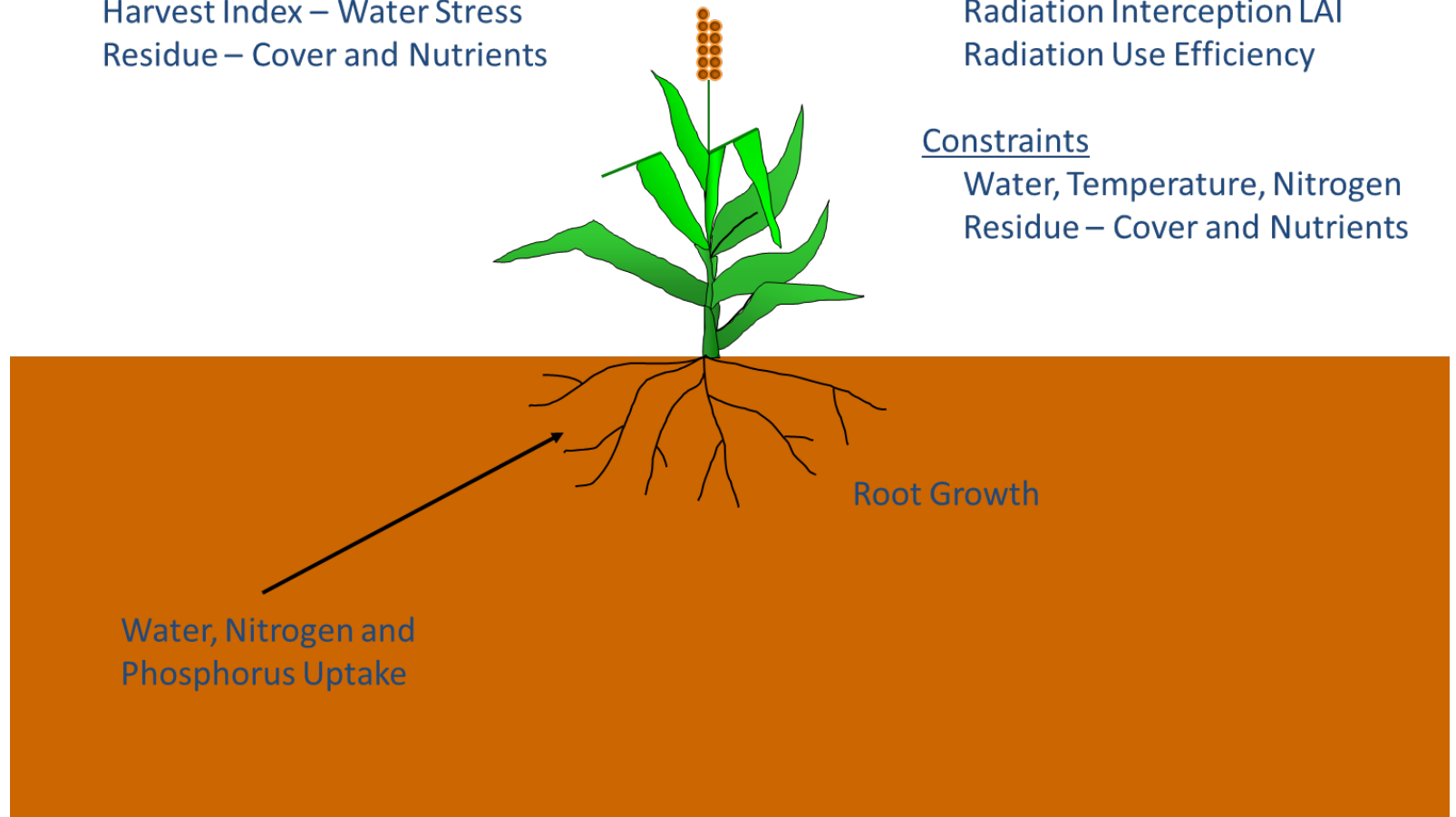
Harvest Index – Water Stress
Residue – Cover and Nutrients

Optimum Growth

Radiation Interception LAI
Radiation Use Efficiency

Constraints

Water, Temperature, Nitrogen
Residue – Cover and Nutrients

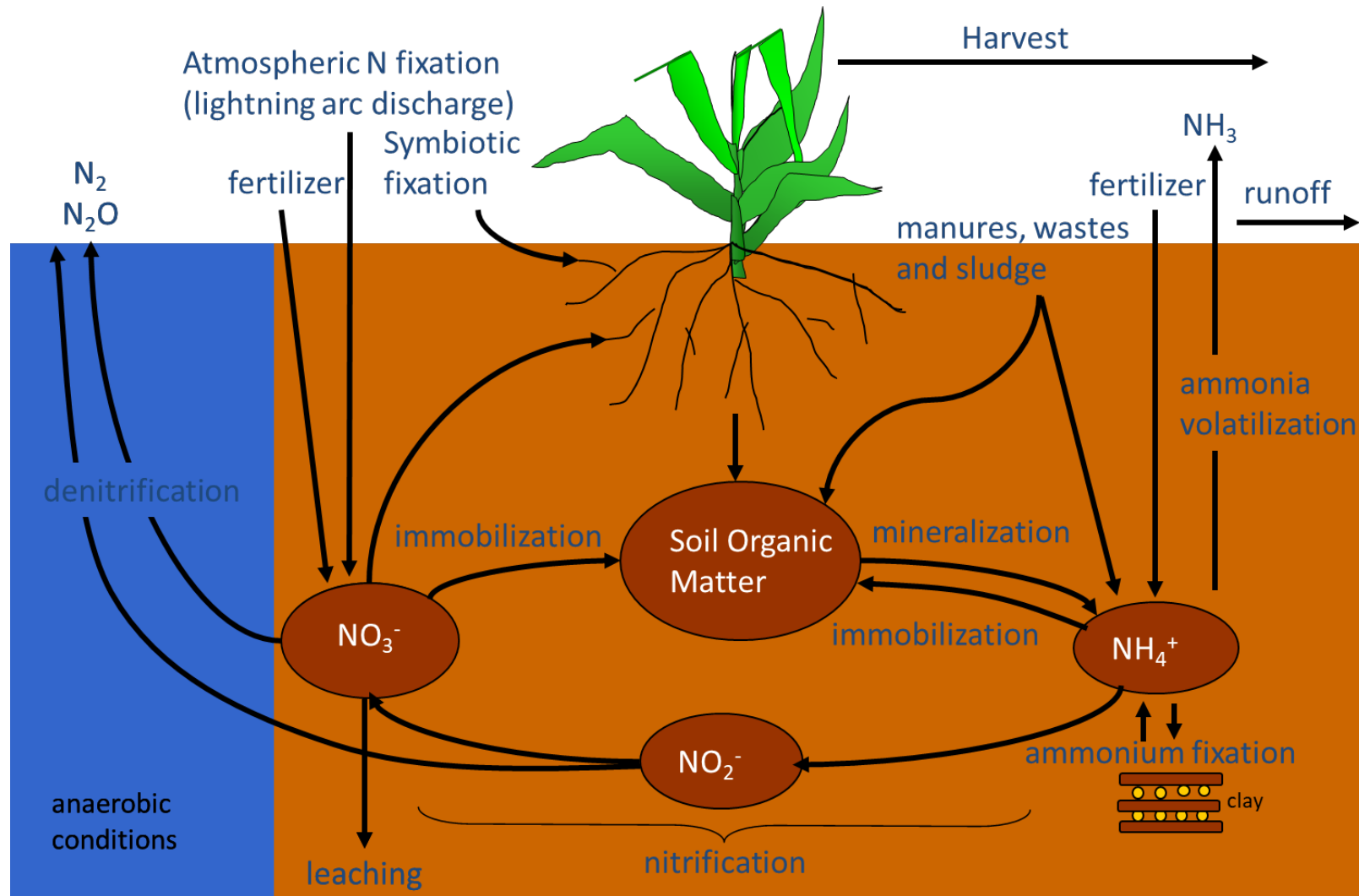


- Modified Universal Soil Loss Equation

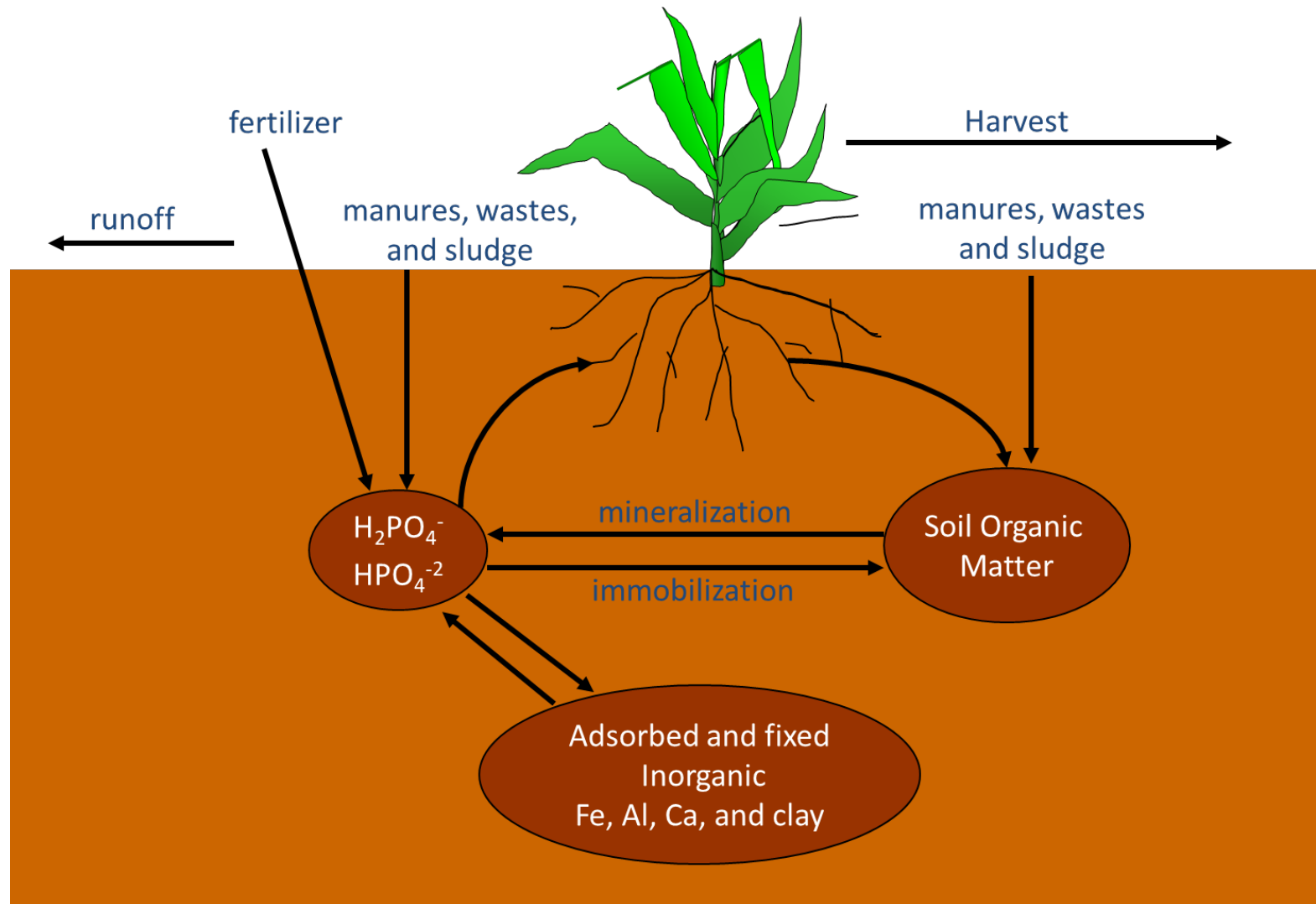
$$sed = 11.8 \cdot (Q_{surf} \cdot q_{peak} \cdot area_{hru})^{0.56} \cdot K_{USLE} \cdot C_{USLE} \cdot P_{USLE} \cdot LS_{USLE} \cdot CFRG$$

- sed = sediment yield on a given day (metric tons)
- Q_{surf} = surface runoff volume (mm/ha)
- Q_{peak} = peak runoff rate (m3/s)
- $area_{hru}$ = area of the HRU (ha)
- K_{USLE} = USLE soil erodibility factor
- C_{USLE} = USLE cover and management factor
- P_{USLE} = USLE support practice factor
- LS_{USLE} = USLE topography factor
- $CFRG$ = coarse fragment factor

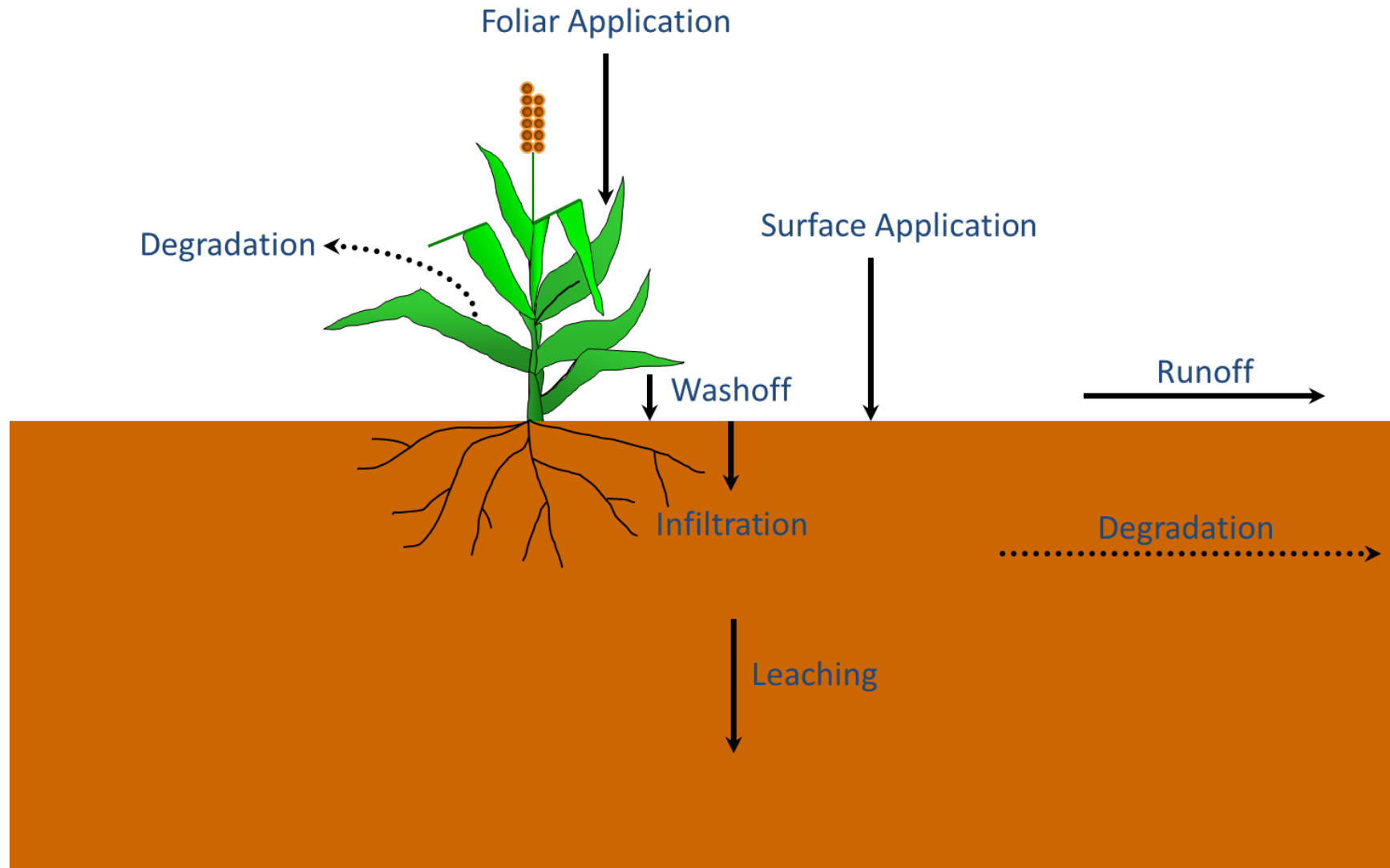
Nitrogen Cycle



Phosphorus Cycle



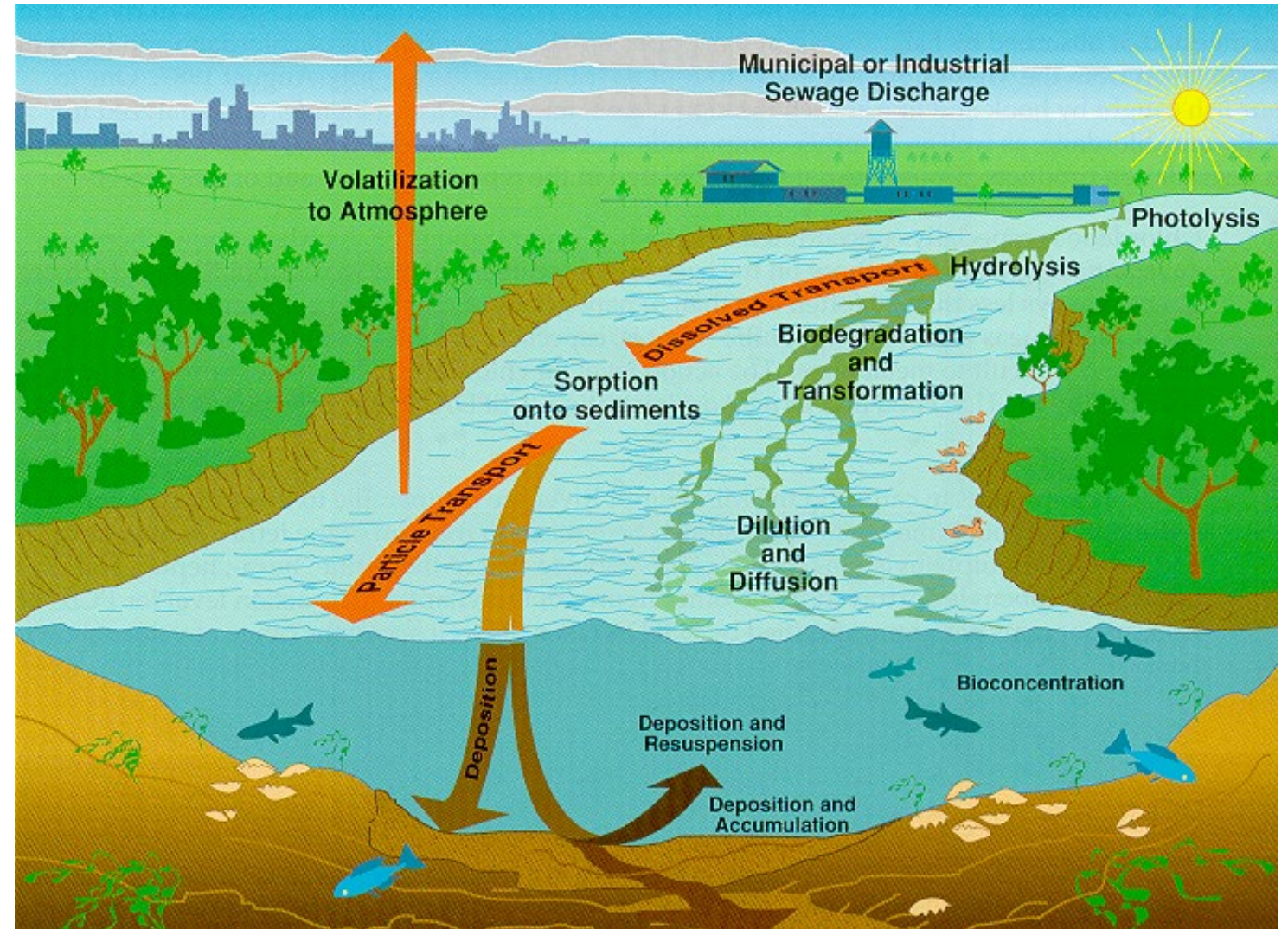
Pesticides



- Crop Rotations
- Removal of biomass as harvest / conversion of biomass to residue
- Tillage / biomixing of soil
- Fertilizer applications
- Grazing
- Pesticide applications
- Irrigation
- Subsurface (tile) drainage
- Water impoundment (e.g. rice)
- Conservation practices
- Structural practices
- Urban areas

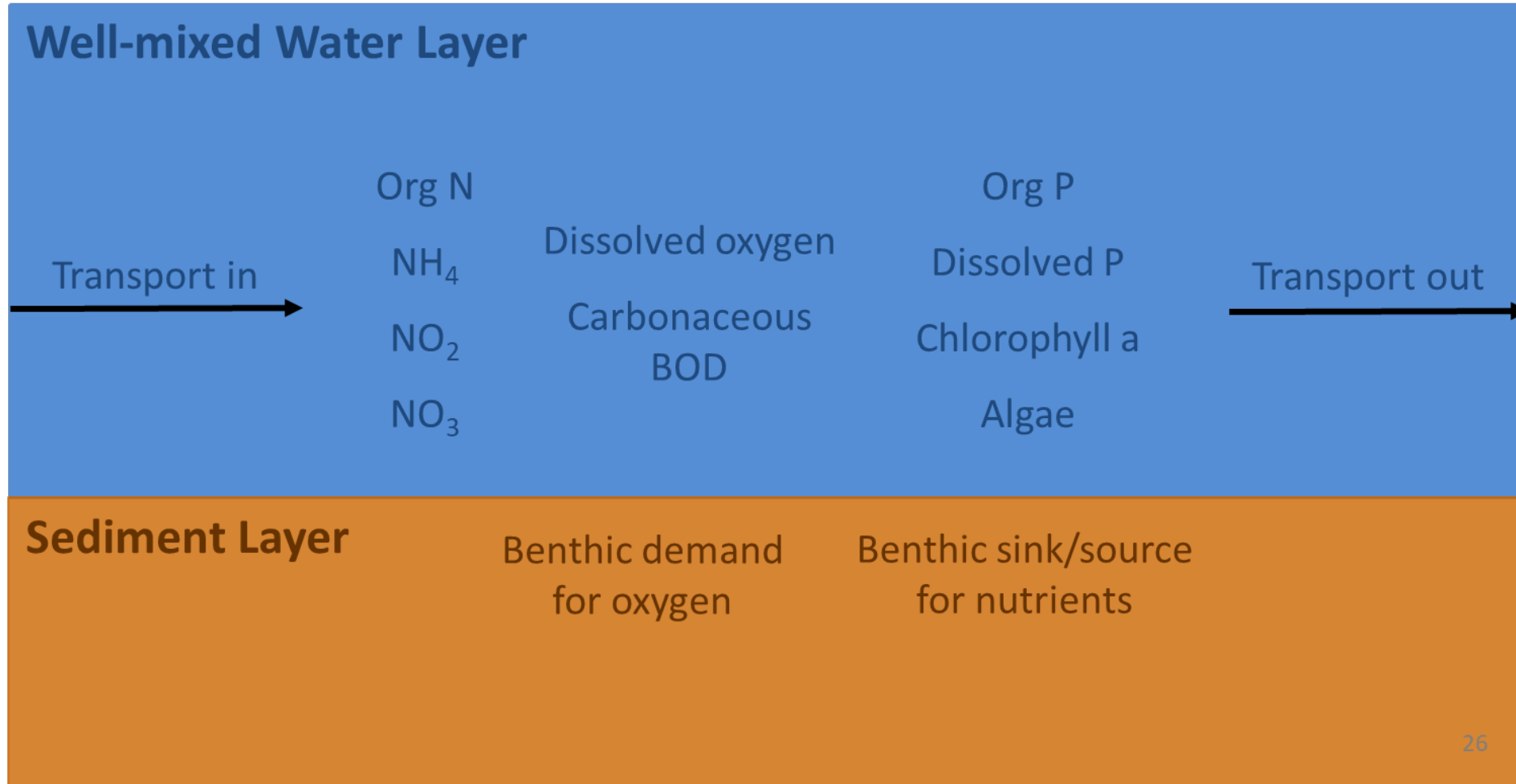
In-Stream Processes

- Flood routing
- Evaporation
- Transmission losses
- Down-cutting and widening
- Nutrients
- Constituents (pesticides, pathogens, heavy metals, salt)

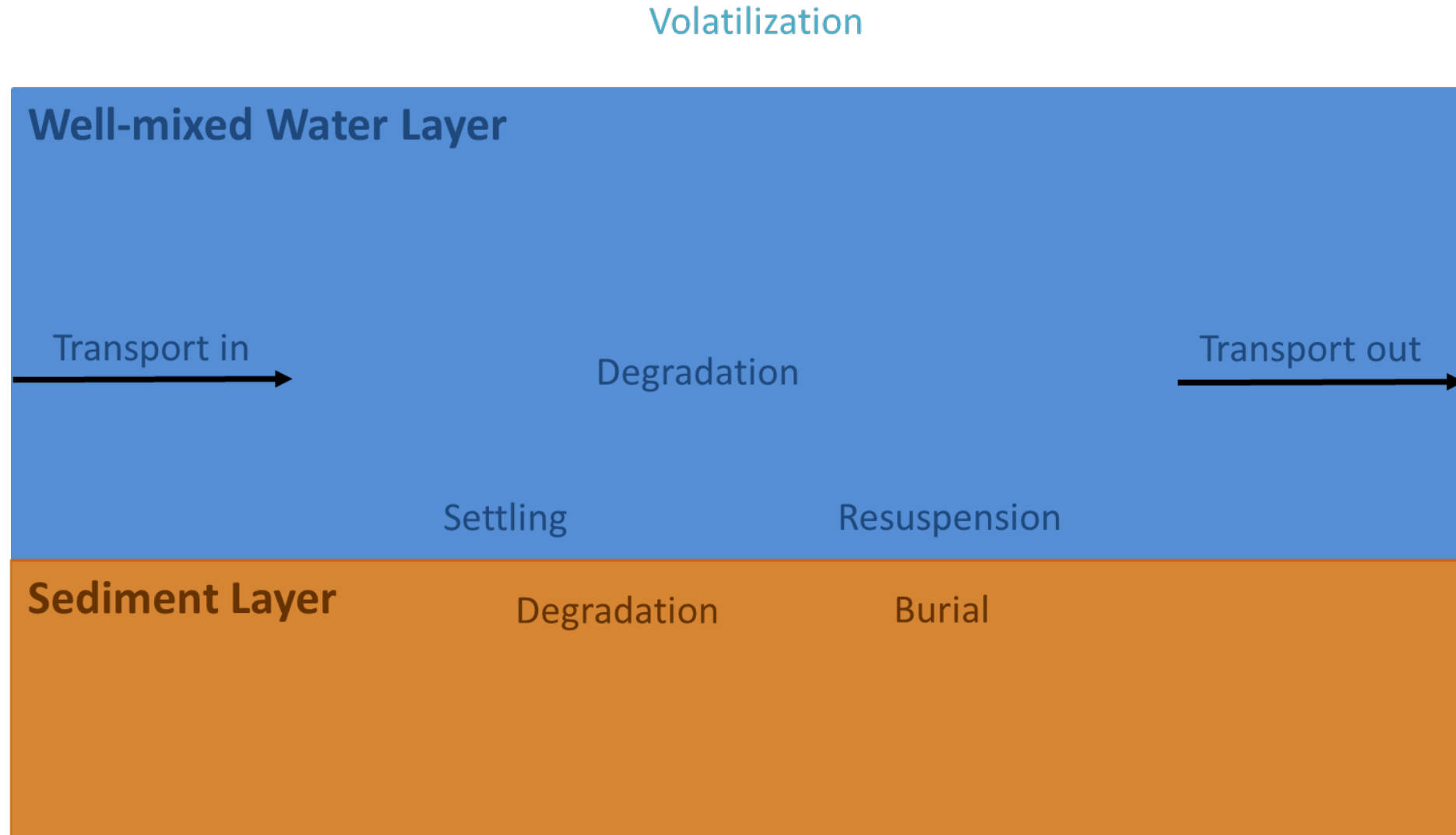


In-Stream Nutrient Processes

Atmospheric Aeration



In-Stream Pesticide Processes



- Water balance:
 - Inflow
 - Evaporation
 - Seepage
 - Withdrawals
 - Outflow
- Nutrient balance:
 - Well-mixed system
 - Nitrogen and phosphorus loss rates
 - 2 settling periods per year

- Upland processes

- Comprehensive hydrologic balance
- Physically-based inputs
- Plant growth and crop yields
- Nutrient cycling in soil
- Land management and agricultural BMPs
- Urban processes and BMPs

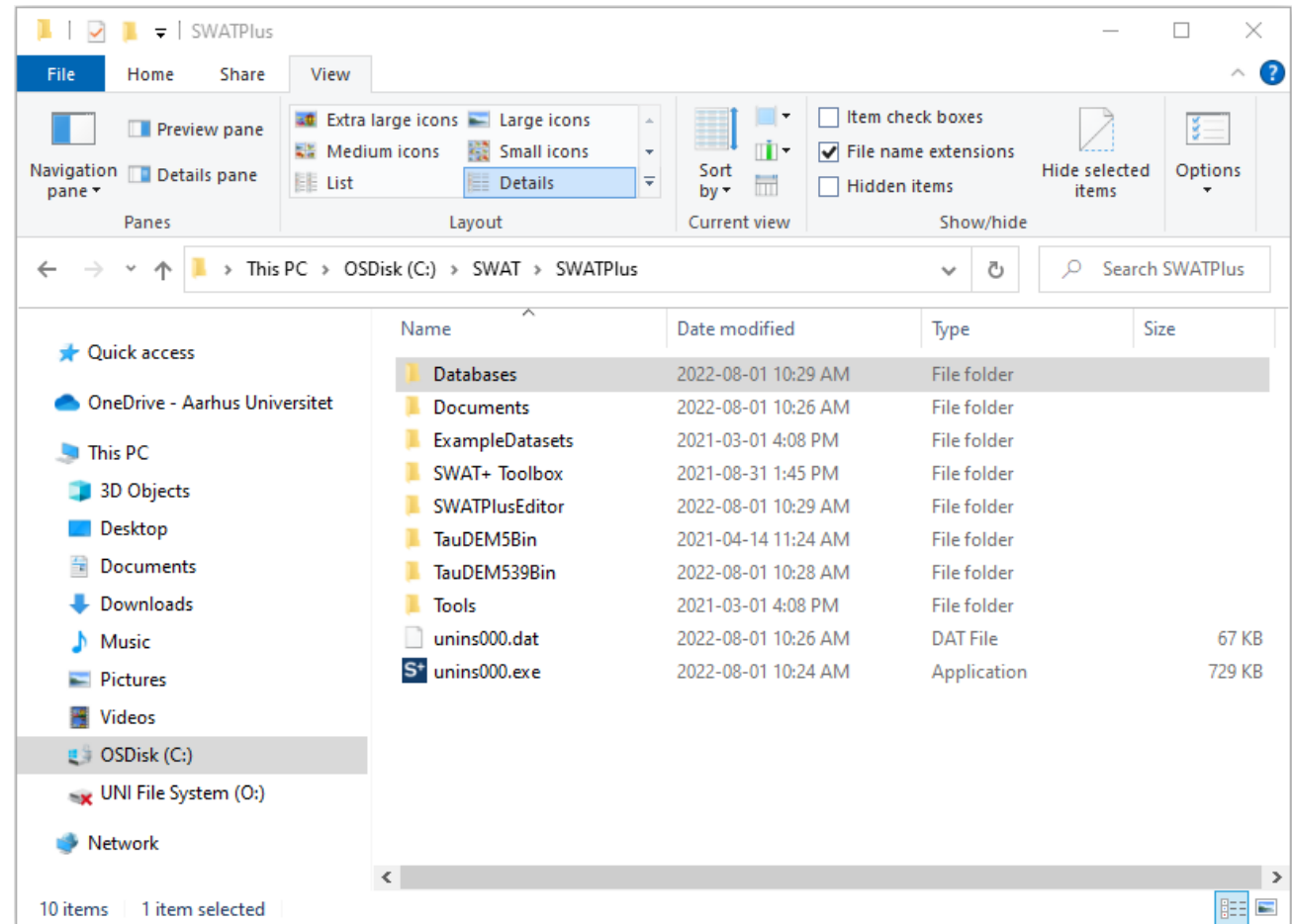
- Channel Processes

- Flexible Watershed Configuration
- Water Transfer—Irrigation Diversions
- Sediment Deposition/Scour
- Nutrient/Pesticide Transport
- Pond, Wetland and Reservoir Impacts

- Download and install QGIS and the SWAT+ Installer following the instructions on <https://swatplus.gitbook.io/docs/installation>.
- Download and install additional software:
 - Text Editor of your choice (e.g., Notepad++)
 - SQLite Studio (<https://sqlitestudio.pl>) or any other tool for viewing and editing SQLite databases

SWATPlus Directory

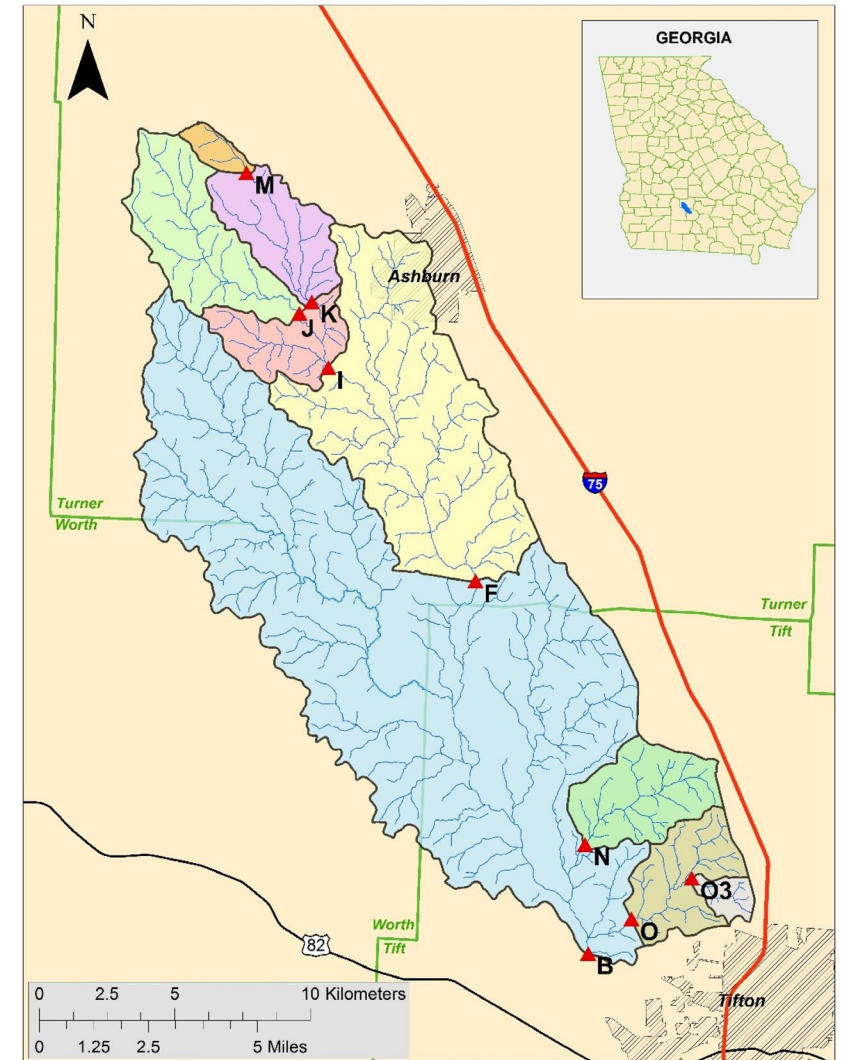
- Databases: project database template, reference database, project file template, global weather generator database and SSURGO/STATSGO soil database
- Documents: QSWAT+ manual
- ExampleDatasets: Robit data
- SWAT+ Toolbox: Software for sensitivity analysis, model calibration, evaluation, and validation (Windows only)
- SWATPlusEditor: Software for editing and running SWAT+ models
- TauDEM: TauDEM programs used for watershed delineation
- Tools: ConvertFromArc and SWATGraph



- QSWAT+:
 - Spatial setup of SWAT+ models (watershed delineation and HRU definition)
 - Visualization of SWAT+ output
- SWAT+ Editor:
 - Reading in of weather data
 - Editing of SWAT+ inputs
 - Writing of SWAT+ input files (SQLite databases to text files)
 - Running the model and saving outputs

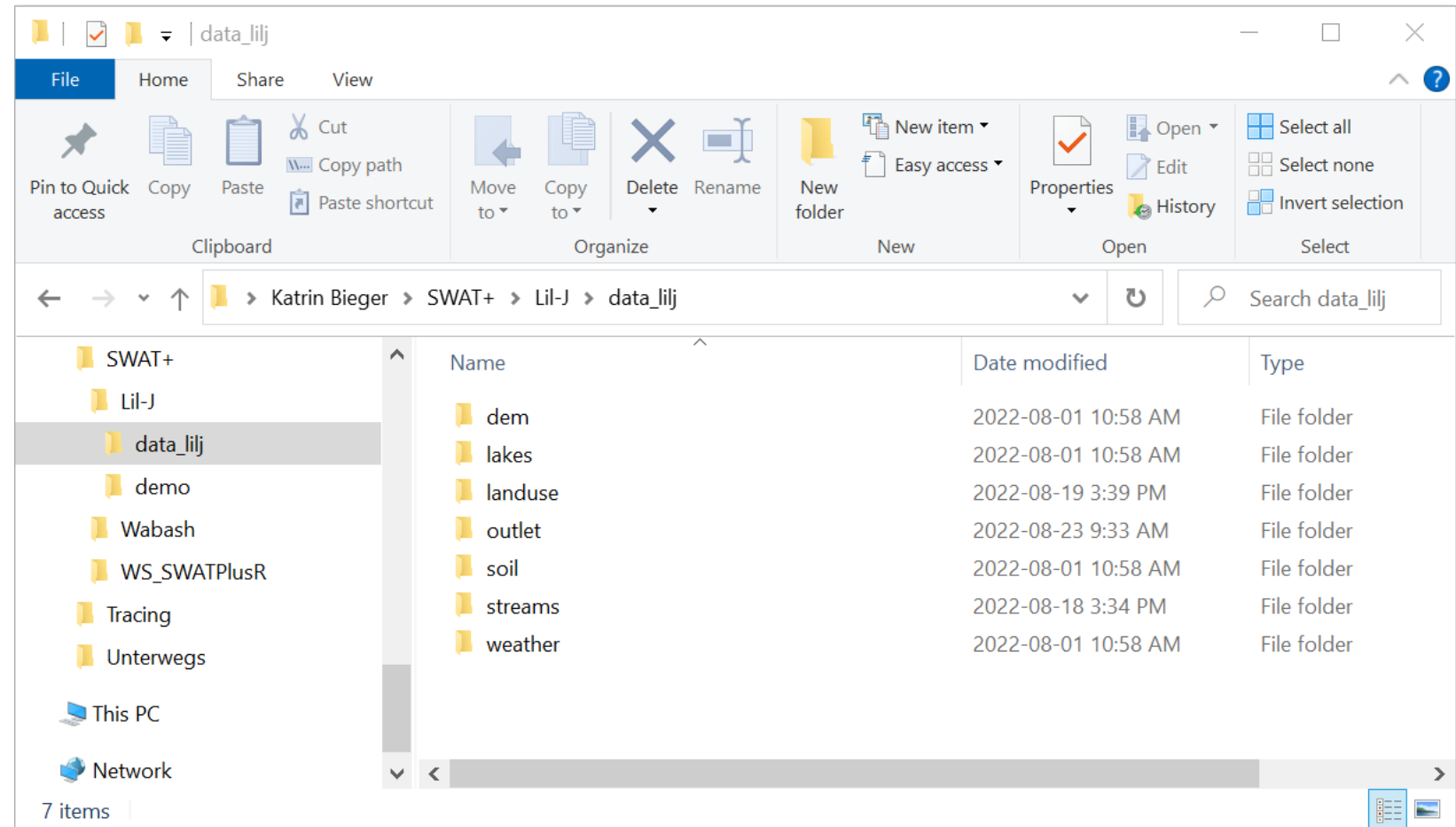
Example Watershed

- Little River Experimental Watershed, Georgia, USA
 - Area: 334 km²
 - Average annual precip: 1208 mm
 - Average temperature: 19.1°C
 - Average streamflow: 2.95 m³/s
 - Topography: Broad floodplains, gently sloping uplands
 - Land use: 50% forest, 41% ag land
 - Soils: loamy sands and sandy loams
- Subwatershed J -> Lil-J



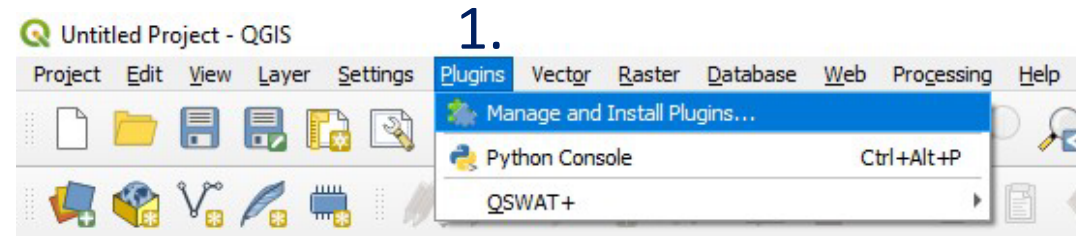
Input Data Directory

- This directory contains all the input data we need for setting up a SWAT+ model for the Lil-J watershed.



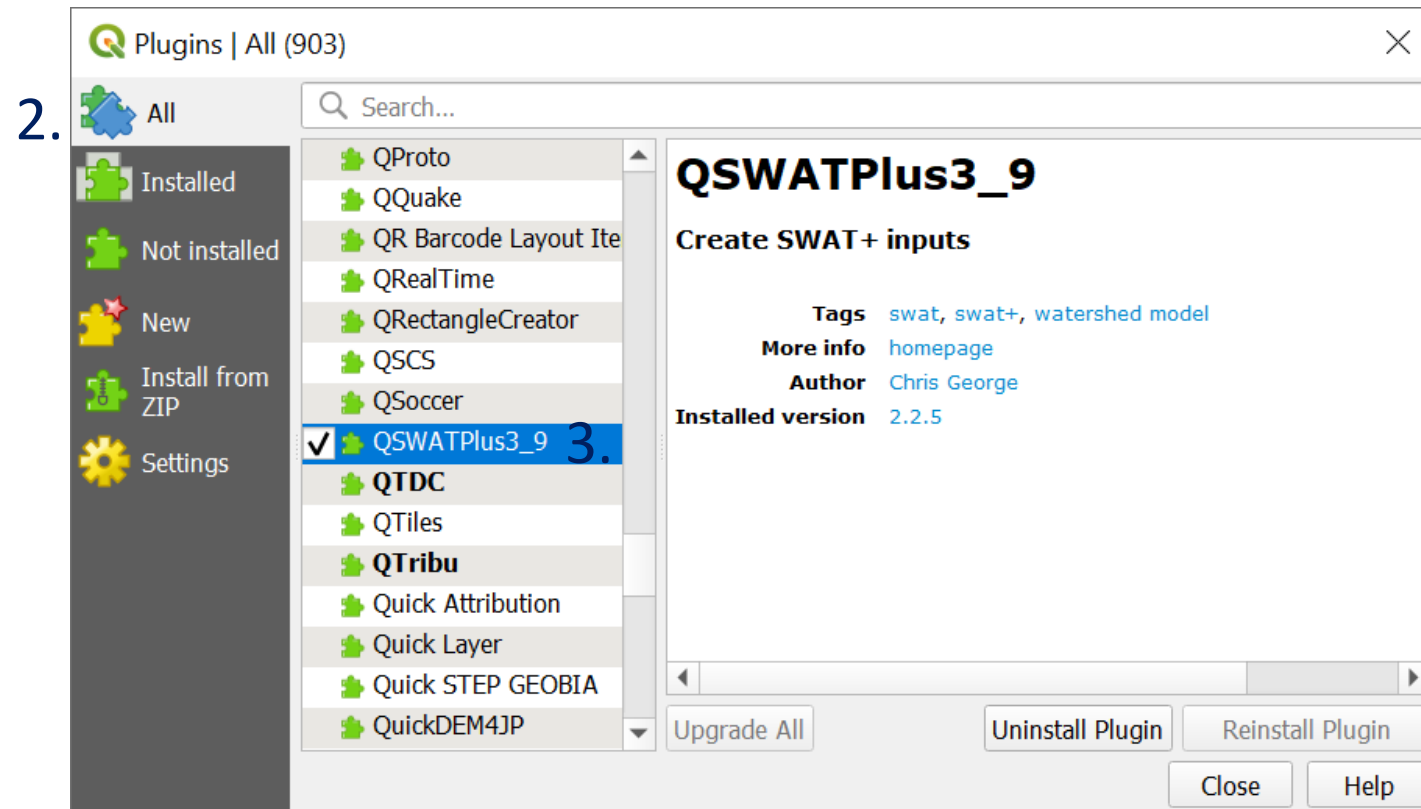
Installation of QSWAT+ Plugin

1. Go to Plugins > Manage and Install Plugins



2. Select All

3. Activate QSWATPlus3_64 by checking the box

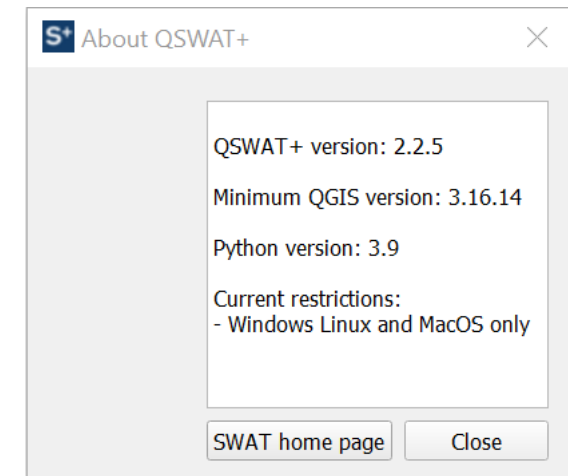
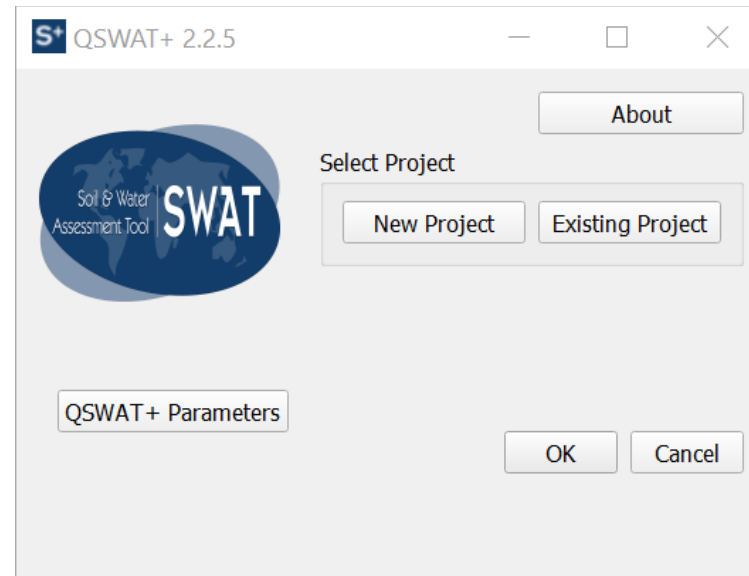


4. You should now see a SWAT+ button in the QGIS toolbar



QSWAT+ Main Window

1. Click the *SWAT+* button to open the QSWAT+ main window.
2. Click *About* to get information about which versions of QSWAT+, QGIS, and Python you are using.



QSWAT+ Parameters

1. Click *QSWAT+ Parameters* to see which parameters you can set to customize your model.
- MPI = Message Passing Interface
 - Can be used for watershed delineation if you have a multi-core processor to reduce processing time for large DEMs.
 - Please refer to Chapter 16 of the QSWAT+ Manual for instructions for installing and using MPI.
 - This setting will be applied to all QSWAT+ projects.
 - The remaining QSWAT+ parameters are project-specific.

The screenshot shows the 'QSWAT+ Parameters' dialog box. It contains the following settings:

- SWATPlus directory:** C:\SWAT\SWATPlus
- Use MPI:** ☒ (checked)
- MPI bin directory:** C:\Program Files\Microsoft MPI\Bin
- Channel widths and depths:**
 - Channel width multiplier: 1.29
 - Channel width exponent: 0.6
 - Channel depth multiplier: 0.13
 - Channel depth exponent: 0.4
- Slope and length multipliers:**
 - Reach slopes: 1.0
 - Tributary slopes: 1.0
 - Mean slopes: 1.0
 - Main channel length: 1.0
 - Tributary channel length: 1.0
- Stream burn-in depth:** 50
- Upslope HRU drain %:** 90
- Font point size:** 10
- Buttons:** Save, Cancel

- QSWAT+ uses standard formulae for estimating the widths and depths of channels:

$$\begin{aligned} \text{width} &= WM * DA^{WE} \\ \text{depth} &= DM * DA^{DE} \end{aligned}$$

where DA is the area draining into the channel in square km, WM is the channel width multiplier, DM the channel depth multiplier, WE the channel width exponent, and DE the channel depth exponent.

- The defaults are intended to provide typically appropriate values, but may not give good estimates in your area. Changing these values and clicking *Save* will cause the values to be used for calculating channel widths and depths and also saved in the project file for use in the future.

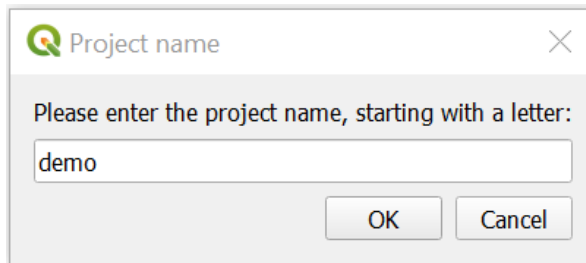
Slope and Length Multipliers

- Mean slopes and channel lengths are calculated as part of delineation. DEMs are obviously only small samples of the actual terrain elevations, and so these values may poorly estimated.
- They can be changed individually in the relevant project database tables, but it may also be useful to correct a persistent bias by multiplying the estimated figures by a constant.
- As with the width and depth parameters, when these values are changed and *Save* is clicked, they are immediately updated.

- Stream burn-in depth: This is the depth in meters by which elevations are decreased when streams are burned in. Changing this parameter and clicking *Save* only has effect the next time the watershed delineation is done (with the burn-in option selected).
- Upslope HRU drain %: When a floodplain is included in calculating LSUs and HRUs, HRUs in upslope LSUs have by default 90% of their outflowing water routed to the channel (or reservoir or pond) and 10% to the floodplain LSU.
- Font point size: This enables users to select a larger or smaller font size for QSWAT+. It only takes effect if *Save* is clicked and QGIS (and QSWAT+) restarted.

Starting a New Project

1. Click *New Project* to start setting up a new SWAT+ project
2. In the form for selecting a parent directory, navigate to the desired folder and click *Select Folder*
3. In the form for specifying the project name, type in «demo» and click *Save*

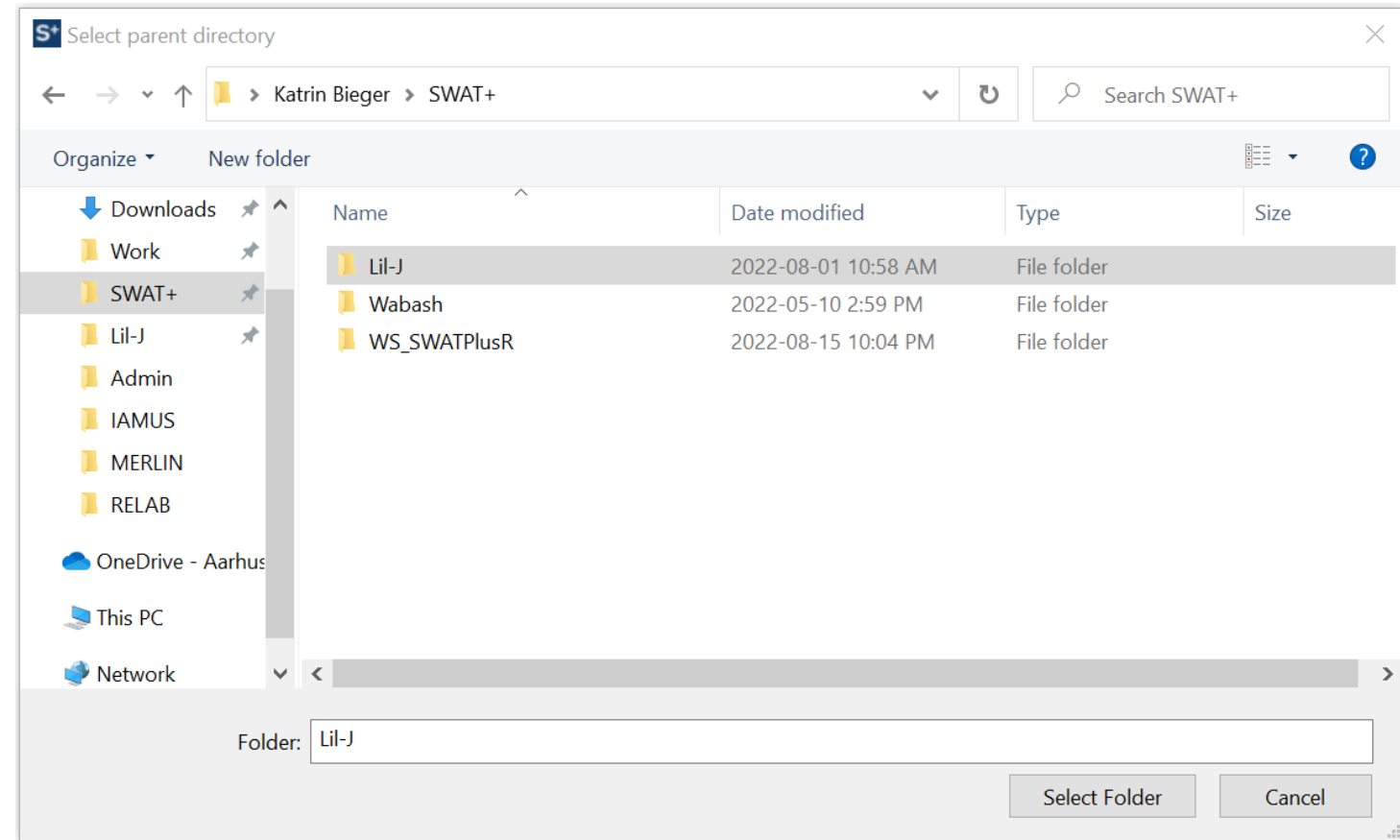


Project name

Please enter the project name, starting with a letter:

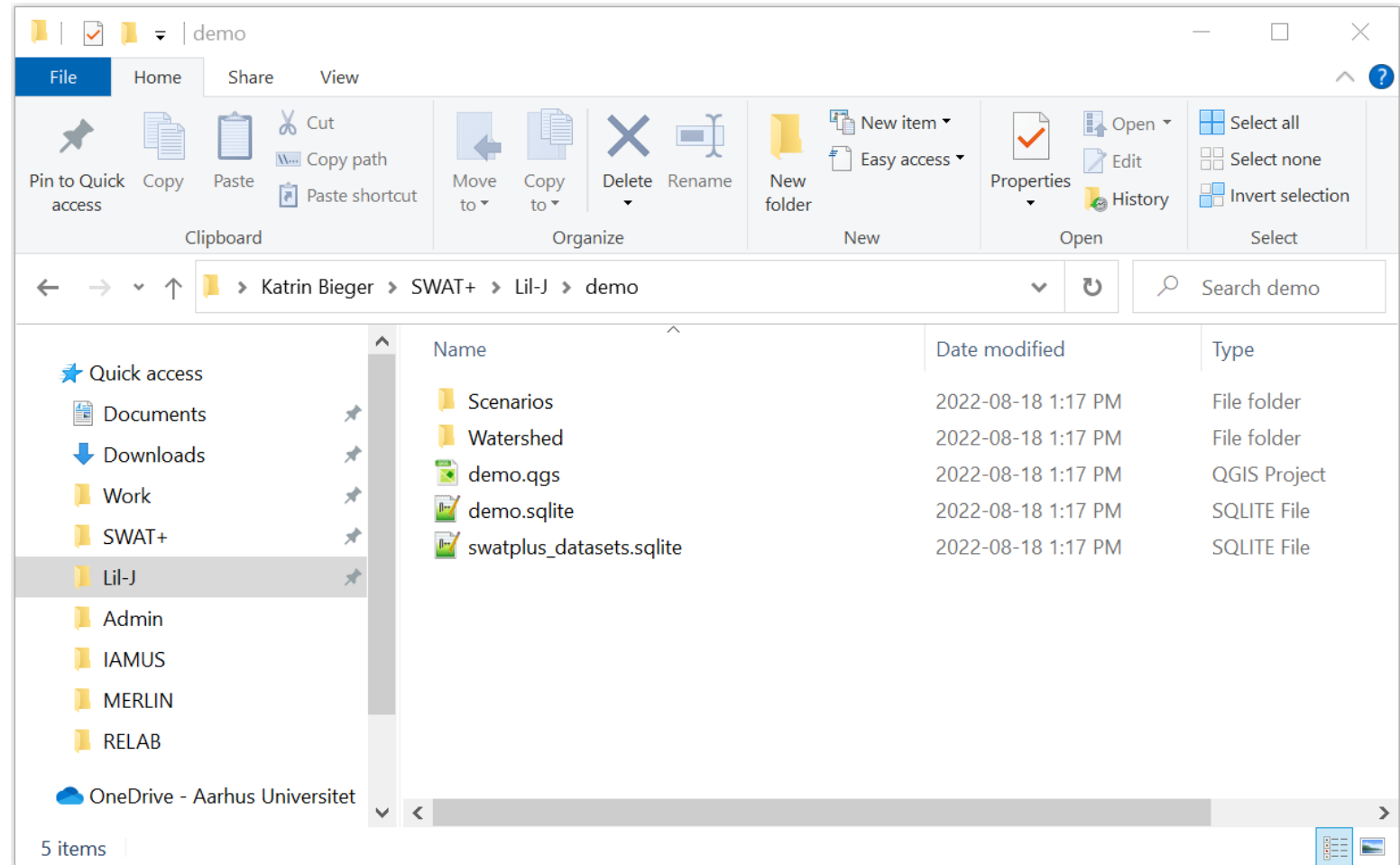
demo

OK Cancel



Project Folder

- QSWAT+ creates a folder containing
 - a project file (demo.qgs)
 - a project database (demo.sqlite)
 - a SWAT+ database (swatplus_datasets.sqlite)
 - two subdirectories (Scenarios and Watershed)



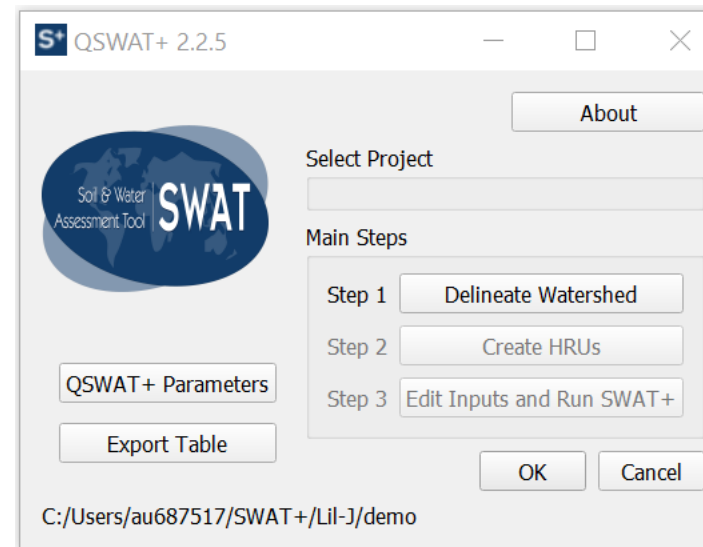
- SWAT+ database: Copy of a default value database stored as C:\SWAT\SWATPlus\Databases\swatplus_datasets.sqlite.
 - Contains default data that will be used later by the SWAT+ Editor.
- Project database: Copy of a default project database stored as C:\SWAT\SWATPlus\Databases\QSWATProj2018.sqlite.
 - QSWAT+ will extract watershed-specific data from the GIS maps and create tables in this database.
 - Based on the default data and the watershed-specific data, the SWAT+ Editor will write all data needed for a SWAT+ run into this database.

- The Scenarios folder contains a subdirectory Default with two folders:
 - Results: stores SWAT+ outputs that were extracted by the SWAT+ Editor for visualization in QSWAT+ and visualization results
 - TxtInOut: contains all SWAT+ input and output files
- If we later decide to save a SWAT+ run, it will also be saved in this folder

- The Watershed folder contains three subfolders:
 - Rasters: contains all raster files used or generated during the model setup
 - Shapes: contains all shapefiles used or generated during the model setup
 - Text: contains text files with information about land use, soils, slopes, and HRUs

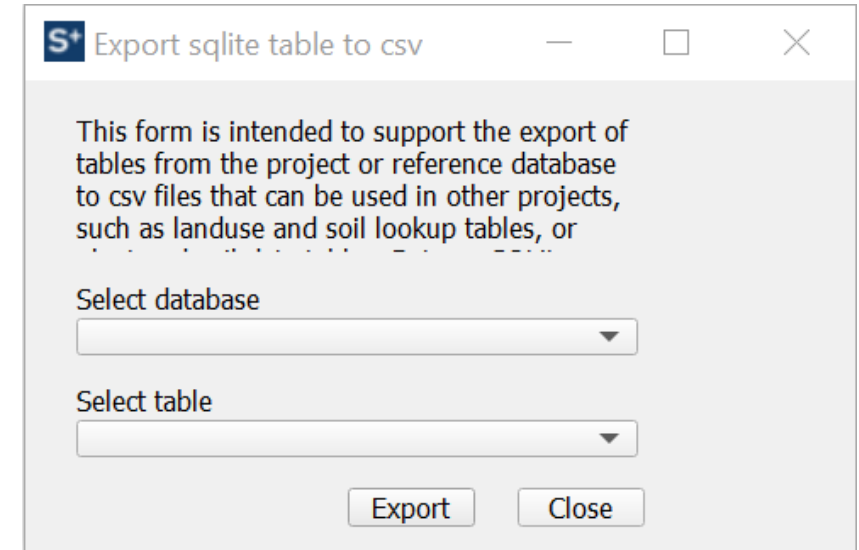
Changes to the QSWAT+ Main Window

- We can see that the QSWAT+ Main Window has changed now that we created a project.
 - There is a new button called Export Table.
 - There is a list of main steps of which only the first one, Delineate Watershed, is currently active.



Export Table

- Clicking the Export Table button on the main form opens the Export SQLite table to csv form. You can use this form to create a csv (comma separated value) file from any SQLite database table. Then, perhaps after editing, you can import the form into its original table or to another database. QSWAT+ supports the import of csv files for landuse lookup tables, soil lookup tables, usersoil tables, plant tables and urban landuse tables.



The screenshot shows a dialog box titled "Export sqlite table to csv". The dialog contains a text area with the following text: "This form is intended to support the export of tables from the project or reference database to csv files that can be used in other projects, such as landuse and soil lookup tables, or ...". Below the text area are two dropdown menus: "Select database" and "Select table". At the bottom right of the dialog are two buttons: "Export" and "Close".

Watershed Delineation

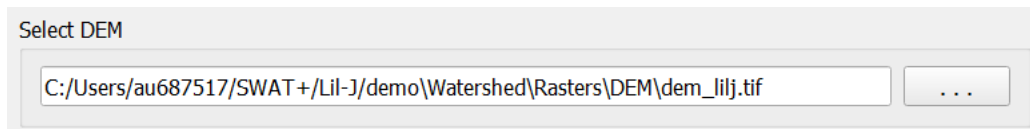
1. Click *Delineate Watershed* to open the watershed delineation form
 - In this form, we will delineate/define:
 - Stream network
 - Inlets/outlets
 - Subbasins
 - Landscape Units
 - Lakes
 - TauDEM options

The screenshot shows the 'Delineate Watershed' dialog box in the SWAT+ software. The window has a title bar with the SWAT+ logo and the text 'Delineate Watershed'. The main area is divided into several sections. At the top, there is a 'Select DEM' section with a text input field and a browse button (...). Below this is a tabbed interface with four tabs: 'Delineate watershed' (selected), 'Use existing watershed', 'DEM properties', and 'TauDEM output'. Under the 'Delineate watershed' tab, there is a checkbox for 'Burn in existing stream network'. Below that is another text input field with a browse button (...). Further down are two rows of input fields for 'Channel threshold' and 'Stream threshold', each with 'Cells' and 'Area' sub-inputs. A dropdown menu for 'Area' is set to 'sq. km'. To the right of these fields is a 'Create streams' button. Below these is a checked checkbox for 'Use an inlets/outlets shapefile' with a corresponding text input field and browse button (...). There are two buttons, 'Draw inlets/outlets' and 'Select inlets/outlets', below the shapefile field. A 'Snap threshold (metres)' input field is set to '300', with a 'Review snapped' button next to it. At the bottom of this section is a 'Make grid' checkbox, a 'Grid size' input field set to '1', and a 'Create watershed' button. The bottom section of the dialog has three tabs: 'Create landscape' (selected), 'Merge subbasins', and 'Add Lakes'. Under the 'Create landscape' tab, there is a large empty text area and a 'Create' button. At the very bottom, there is a 'Number of processes' input field set to '8', a 'Show Taudem output' checkbox, and 'OK' and 'Cancel' buttons.

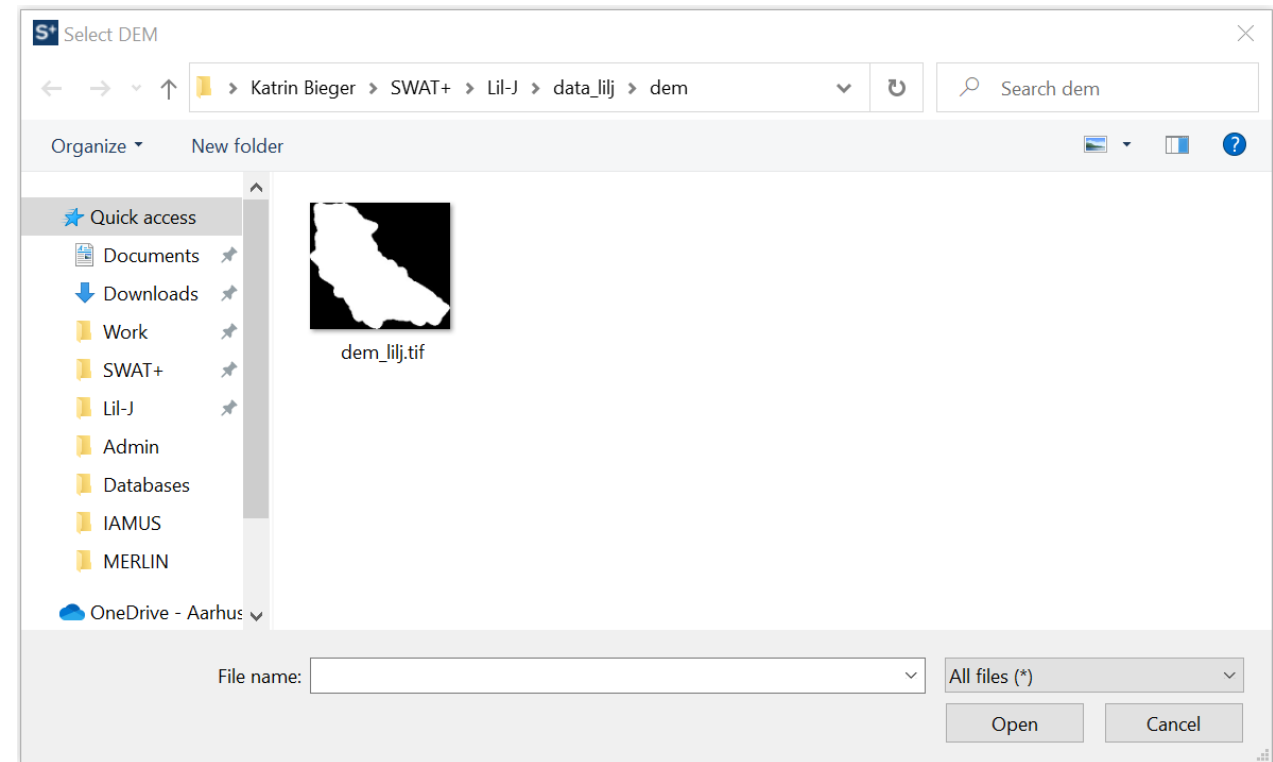
- QSWAT+ accepts a wide range of grid formats, in fact any format acceptable by the Geospatial Data Abstraction Library (GDAL).
- However, QSWAT+ uses TauDEM to do the watershed delineation, which requires DEMs to be in GeoTiff format, so if necessary QSWAT+ does a conversion to GeoTiff when it copies the DEM into the project folder.
- For watershed delineation, QSWAT+ assumes that each cell in the DEM grid represents the same area, so the DEM needs to be projected into an equal area projection or a conformal projection.

Loading the DEM

1. Click on the button with the three dots in the Select DEM box and navigate to the DEM folder in the input file directory.
2. Select dem_lilj.tif and click *Open*.

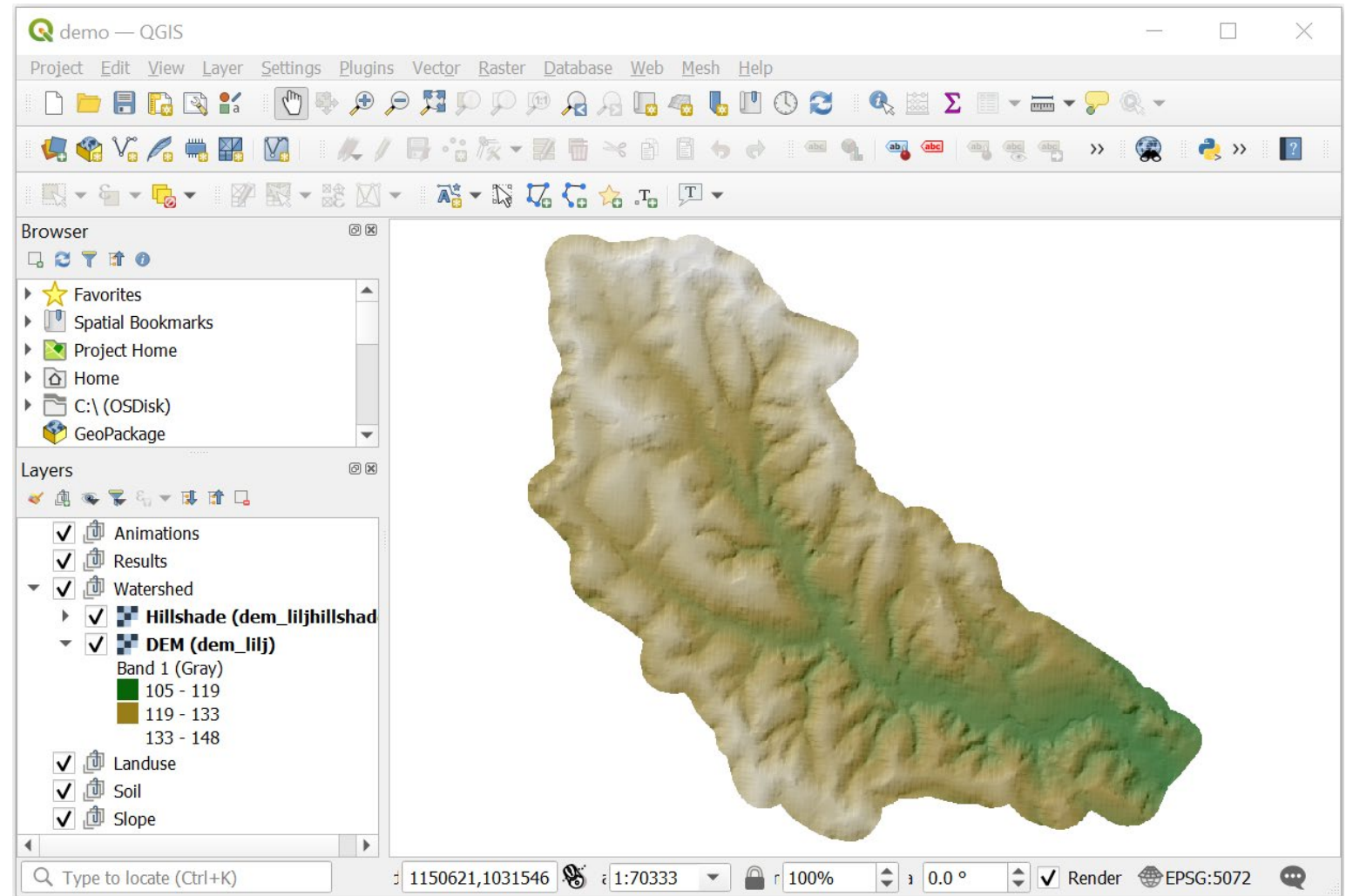


Note: If your DEM was in ESRI grid format, you would select the hdr.adf file as the one to load. You can pull down the list currently set to “All files (*)” to see the conventions for other grid formats.



DEM Load and Display

- As the DEM is converted to GeoTiff you may briefly see the shell window where GDAL is working.
- Then, the DEM is displayed in QGIS.
- A hillshade layer is also created to give a better impression of the terrain.



DEM Properties

1. Click the *DEM properties* tab in the Watershed Delineation form.
- This tab provides information about
 - the horizontal and vertical units,
 - the cell size and area,
 - the extent of the DEM, and
 - the projection of the DEM.
 - If your DEM has vertical units other than meters you need to change them here.

The screenshot shows the 'Delineate Watershed' dialog box with the 'DEM properties' tab selected. The 'Select DEM' field at the top contains the path 'C:/Users/au687517/SWAT+/Lil-J/demo/Watershed/Rasters/DEM/dem_lilj.tif'. Below this, the 'DEM properties' tab is active, displaying various settings: 'Horizontal units' is set to 'metr', 'Vertical units' is set to 'metr', 'Cell size (m)' is '10 x 10', and 'Cell area (ha)' is '0.01'. The 'Extent in degrees' section shows coordinates for North, West, East, and South. The 'Spatial reference' section displays the EPSG:5072 projection, including the PROJCRS, BASEGEOCRS, DATUM, ELLIPSOID, and LENGTHUNIT. At the bottom, there are buttons for 'Create landscape', 'Merge subbasins', and 'Add Lakes', along with a checkbox for 'Don't display lake messages' and a 'Number of processes' spinner set to 0. The 'Show Taudem output' checkbox is also present. 'OK' and 'Cancel' buttons are at the bottom right.

Delineate Watershed

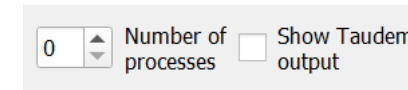
1. Click the *Delineate Watershed* tab in the Watershed Delineation form.
- Now, we will provide the information QSWAT+ needs to
 - burn in an existing stream network,
 - define channel and stream thresholds,
 - and place inlets/outlets on the stream network.

The screenshot shows the 'Delineate watershed' tab in the QSWAT+ Watershed Delineation form. The form has four tabs: 'Delineate watershed' (selected), 'Use existing watershed', 'DEM properties', and 'TauDEM output'. The 'Delineate watershed' tab contains the following options and fields:

- ☐ Burn in existing stream network
- Channel threshold: 548, Cells: 0.0548, Area: sq. km (dropdown)
- Stream threshold: 5483, Cells: 0.5483, Area: (dropdown)
- ☒ Use an inlets/outlets shapefile
- Snap threshold (metres): 300
- ☐ Make grid, 1 (dropdown), Grid size

Buttons include 'Create streams', 'Draw inlets/outlets', 'Select inlets/outlets', 'Review snapped', and 'Create watershed'.

- We can set a couple of options for TauDEM, which should be done before starting the stream network delineation.



A screenshot of the TauDEM options interface. It features a spinner control for 'Number of processes' with the value '0' displayed. To the right is a checkbox labeled 'Show Taudem output' which is currently unchecked.

- The *Number of processes* option sets the number of processes to use if we are using MPI. We recommend 8 on a dual core processor and 12 or more on a quad core processor, but feel free to experiment. Otherwise, this number should be set to 0.
- A series of TauDEM tools will be run to perform delineation. You can see their outputs as they are run by checking *Show Taudem output*. Alternatively, you can see their outputs after you have run them in the *TauDEM output* tab.

Burn in Existing Stream Network

- Burning in a stream network is optional, but useful when a suitable map is available and the area is relatively flat.
 - The burn in lowers the elevation of the DEM grid cells along the streams so that they are lower than the surrounding grid cells and identified as streams during stream network delineation.
1. Check *Burn in existing stream network*, click on the button with the three dots, and navigate to the streams folder in the input file directory.
 2. Select streams_lilj.shp and click *Open*.
- The shapefile is displayed in QGIS.

☒ Burn in existing stream network

C:/Users/au687517/SWAT+/Lil-J/demo/Watershed/Shapes/streams_lilj.shp

...

Channel and Stream Thresholds

- Delineation needs a number representing the minimum area needed to form a stream or channel.
 - These can be defined either as a number of cells or as an area, and you can choose the units to use for an area.
 - QSWAT+ provides default values. You can change these and create the channels and streams until the resulting stream network looks reasonable.
1. Change the units to hectares and put 10 ha as the area for a channel and 100 ha for a stream.

Channel threshold	<input type="text" value="1000"/>	Cells	<input type="text" value="10"/>	Area	<input type="text" value="hectares"/>	<input type="button" value="Create streams"/>
Stream threshold	<input type="text" value="10000"/>	Cells	<input type="text" value="100"/>	Area		

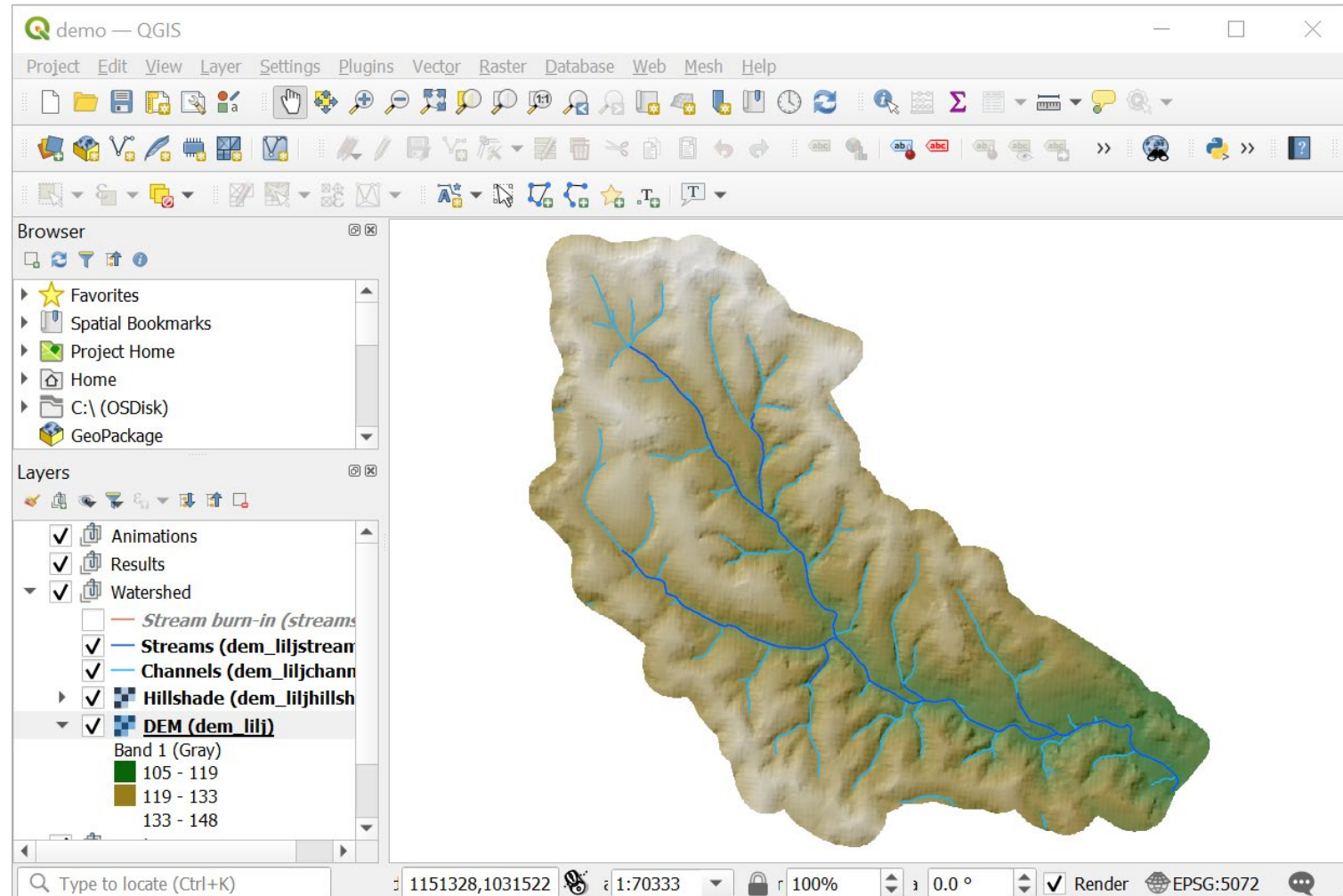
- The distinction between channels and streams is only used during model setup. In SWAT+, channels and streams will be the same spatial object.
- QSWAT+ will create a subbasin for each stream and a landscape unit for each channel. The subbasins will not be used in SWAT+. However, QSWAT+ will create one shallow aquifer per subbasin, so the stream threshold has an impact on the number and size of aquifers in the model setup.
- Outlets can only be placed on streams, not on channels, so make sure that the stream threshold is small enough for the streams to extend to the location of all gauges of interest.

Channel and Stream Definition

1. Click *Create Streams*.

- A series of TauDEM tools are run*. You can examine their output in the *TauDEM output* tab if you wish.
- The channel and stream network is added to QGIS.
- Delineation can take some time, so be patient!

*PitRemove, D8FlowDir, DInfFlowDir, Area D8, AreaDinf, GridNet, Threshold, and StreamNet



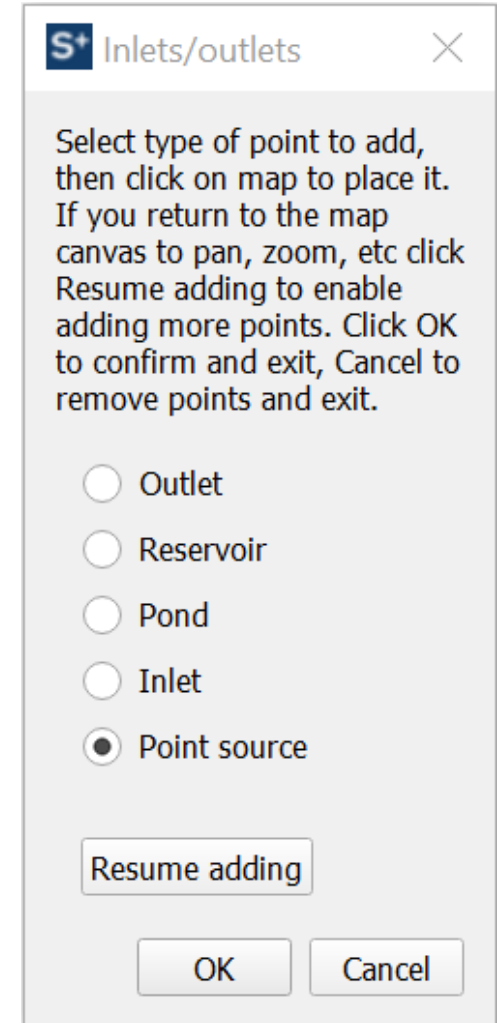
- Main outlet
 - Main outlets do not have an outlet downstream from them.
- Upstream outlets
 - These should be placed at locations where observed streamflow data is available to make sure the model produces a simulated time series.
- Inlets
 - QSWAT+ will exclude the area upstream from an inlet from the model setup.
- Each inlet or outlet point you define will create a subbasin boundary.

Defining Outlets

- You can define inlets/outlets
 - by using an existing shapefile
 - or by drawing them interactively
- Drawing them interactively will create a shapefile that can be in future setups for the same watershed.
- It is also possible to draw on an existing shapefile to create additional points, or to select only a subset of points in an existing shapefile.
- All inlet or outlet points must be placed on a stream, so if we want to draw any outlets, we need to display the stream network.
- If you don't use an inlets/outlets shapefile, main outlets will be defined where the streams cross the edges of the DEM.

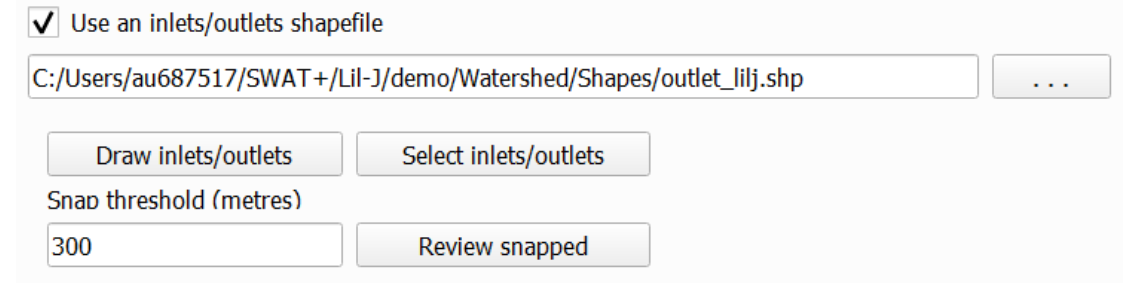
Defining Other Types of Points

- You can also define reservoirs, ponds, and point sources.
- Reservoir and pond points will be snapped to channels and will divide channels in two. Areas of land use WATR in the adjacent LSU of the upper channel will be allocated to the pond or reservoir. The adjacent LSU is the floodplain if used, else the channel's single LSU. Users are warned if there is no land use WATR.
- QSWAT+ will automatically add a point source to every channel. However, defining point sources manually is a good option if you want to place them more precisely.



Using an Existing Outlet Shapefile

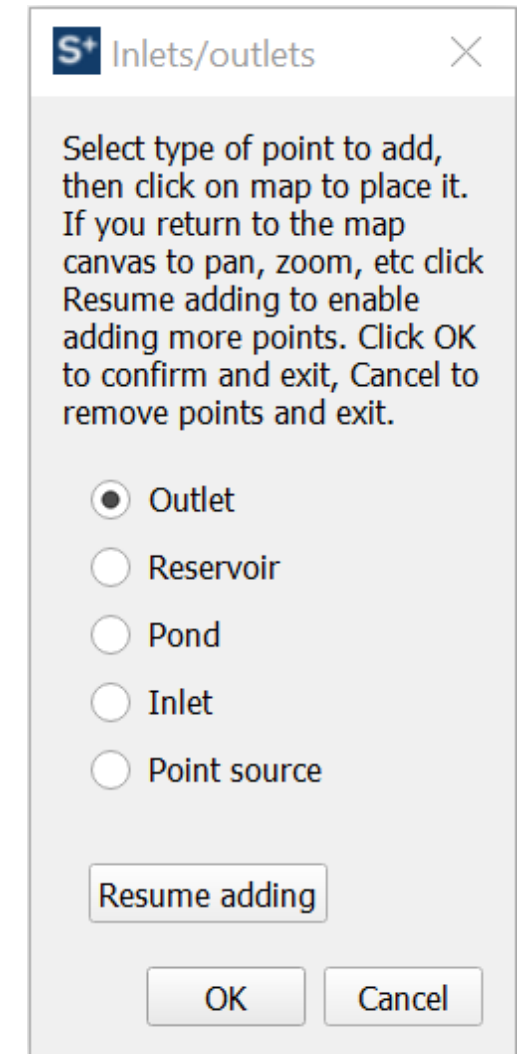
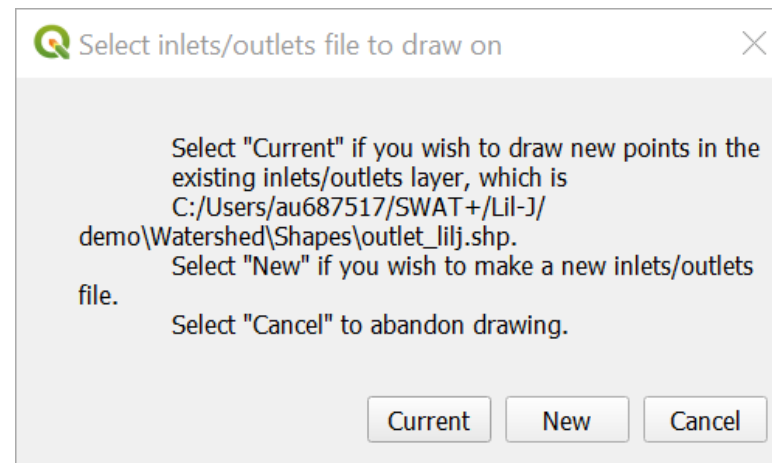
- For the example watershed, we will use an existing shapefile containing the main outlet.
1. Make sure that *Use an inlets/outlets shapefile* is checked, click on the button with the three dots, and navigate to the outlet folder in the input file directory.
 2. Select *outlet_lilj.shp* and click *Open*.



The screenshot shows a dialog box in the SWAT+ software. At the top, there is a checked checkbox labeled "Use an inlets/outlets shapefile". Below this, a text field contains the file path "C:/Users/au687517/SWAT+/Lil-J/demo/Watershed/Shapes/outlet_lilj.shp", followed by a button with three dots "...". Below the text field, there are two buttons: "Draw inlets/outlets" and "Select inlets/outlets". Under these buttons, the text "Snap threshold (metres)" is displayed, with a text field containing the value "300" and a button labeled "Review snapped".

Drawing Outlets

1. Click *Draw inlets/outlets*.
2. In the Select inlets/outlets file to draw on form, click *Current*.
3. In the Inlets/outlets form make sure that *Outlet* is selected.
4. Click on the map where you want the outlet to be located (try to get the point on the stream).
5. Click *OK*.



- If you zoom in, you can see the point is almost certainly not exactly on the stream.
- QSWAT+ will snap points to the nearest channel or stream provided they are within the snap threshold, which defaults to 300 m.
- When we create the watershed, the form will say how many points were snapped. If this is less than intended, we can move them closer or try increasing the threshold. If we have several points and some were not snapped, click *Review snapped* to see which ones have been snapped successfully.

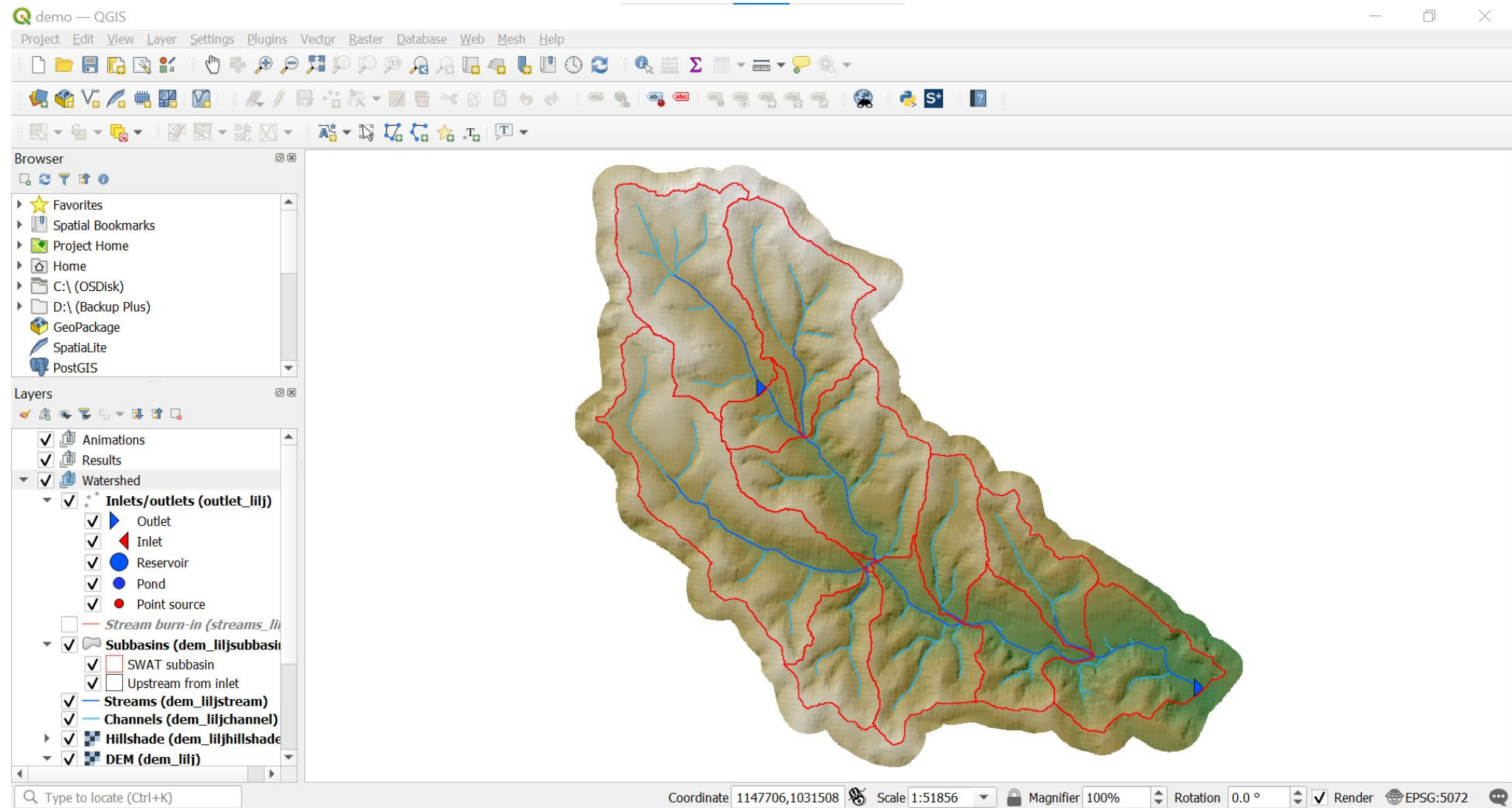
Creating the Watershed

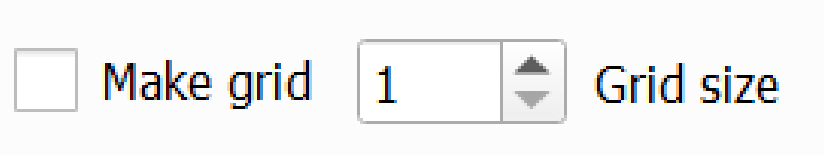
1. Click *Create watershed*, and check that 2 snapped is reported on the Watershed Delineation form.

The screenshot shows the 'Delineate watershed' tab of the SWAT+ Watershed Delineation form. The form is divided into several sections:

- Stream Network:** A checkbox labeled 'Burn in existing stream network' is checked. Below it is a text field containing the path 'C:/Users/au687517/SWAT+/Lil-J/demo/Watershed/Shapes/streams_lilj.shp' and a browse button '...'.
Channel threshold: 1000
Stream threshold: 10000
- Thresholds and Units:** Two rows of input fields for 'Cells' and 'Area'.
Row 1: Cells = 0.1, Area = sq. km (dropdown menu)
Row 2: Cells = 1, Area = sq. km (dropdown menu)
A 'Create streams' button is located to the right of the second row.
- Inlets/Outlets:** A checkbox labeled 'Use an inlets/outlets shapefile' is checked. Below it is a text field containing the path 'C:/Users/au687517/SWAT+/Lil-J/demo/Watershed/Shapes/outlet_lilj.shp' and a browse button '...'.
Below the path field are two buttons: 'Draw inlets/outlets' and 'Select inlets/outlets'.
- Snapping:** A text field labeled 'Snap threshold (metres)' contains the value '300'. To its right is a 'Review snapped' button, and further right, the text '2 snapped' is displayed.
- Grid:** A checkbox labeled 'Make grid' is unchecked. Next to it is a spinner box set to '1' and the text 'Grid size'. A 'Create watershed' button is located at the bottom right of the form.

Watershed Display

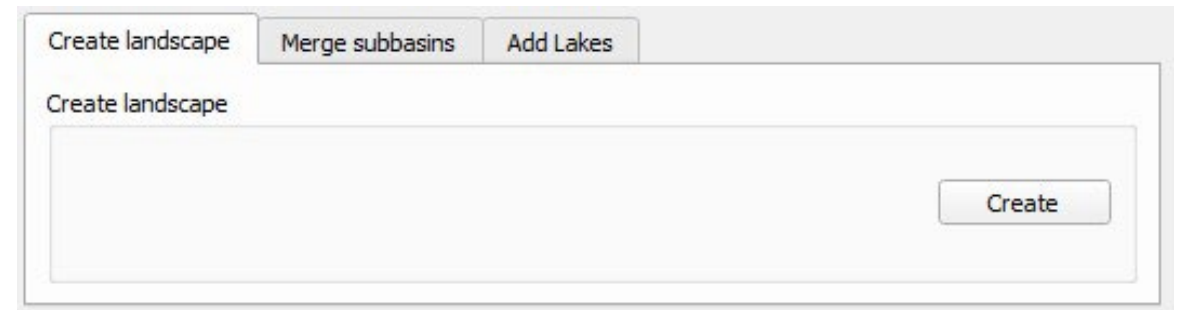


A screenshot of the 'Make Grid' option in the SWAT+ software. It features a checkbox labeled 'Make grid' which is currently unchecked. To its right is a numeric input field containing the value '1', followed by a vertical double-headed arrow icon. Further right is the text 'Grid size'.

- QSWAT+ provides the option to construct a grid-based SWAT+ model. You can create a grid in the *Watershed delineation* tab or use an existing grid in the *Use existing watershed* tab.
- We will not explore this option in this workshop. Please refer to Chapter 9 in the QSWAT+ Manual for a detailed description of how to set up a grid-based SWAT+ model.

Creating Landscape Units

- There is an option to distinguish between floodplain and upland areas. HRUs will be defined per landscape unit.
 - If we create floodplain and upland landscape units then each channel will have two, otherwise each channel will have a single landscape unit.
1. Make sure the *Create landscape* tab is selected
 2. Click *Create* to open the Landscape analysis form



- There are three methods of creating floodplains:
 - Buffering channels is a simple method of creating a strip on both sides of the channel that is a multiple of its width (which QSWAT+ estimates from the area draining into it).
 - DEM inversion involves finding ridges by effectively turning the DEM inside out and identifying ridges as if they were streams. The floodplain consists of those points for which the ratio of their height to the ridge's height above the stream is smaller than or equal to the slope position threshold, which defaults to 0.1.
 - Branch length defines ridge points as those for which the length of flow path for an adjacent point to where the flow paths of the two points meet exceeds a threshold. It then uses slope position like DEM inversion. Branch length typically gives similar results to DEM inversion but is perhaps an order of magnitude slower to compute.

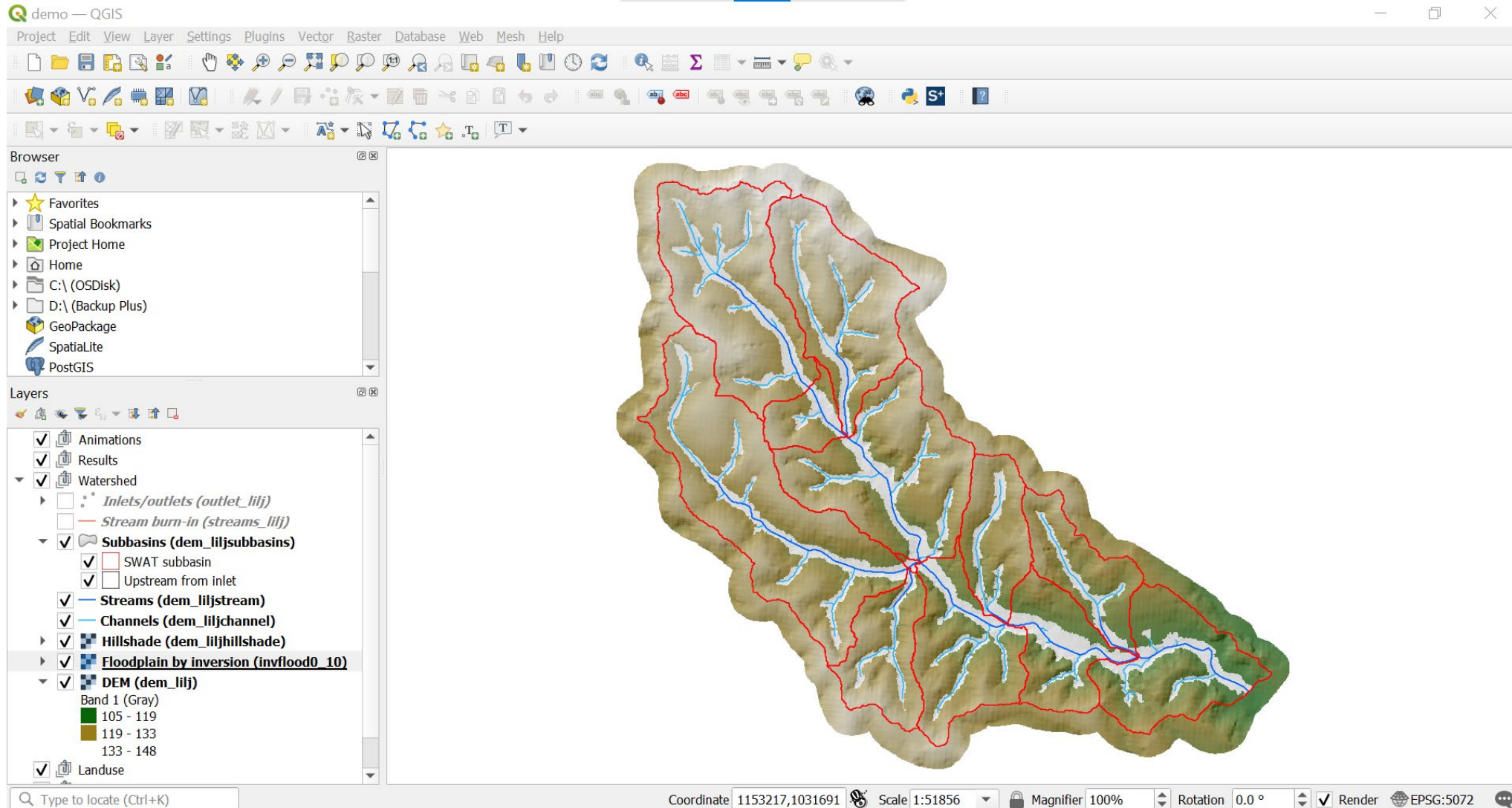
DEM Inversion

- We will generate a floodplain map using DEM inversion with default thresholds.
 1. Make sure the *DEM inversion* tab is selected.
 2. Use the default values for Number of cells, Ridge Threshold, and Slope position threshold.
 3. Click *Create* to generate the floodplain map.
 4. Click *Done* to close the Landscape analysis form.
- You can generate several floodplain maps with different methods and/or thresholds and later select the most appropriate one.

The screenshot shows the 'Landscape analysis' dialog box with the 'DEM inversion' tab selected. The dialog contains the following elements:

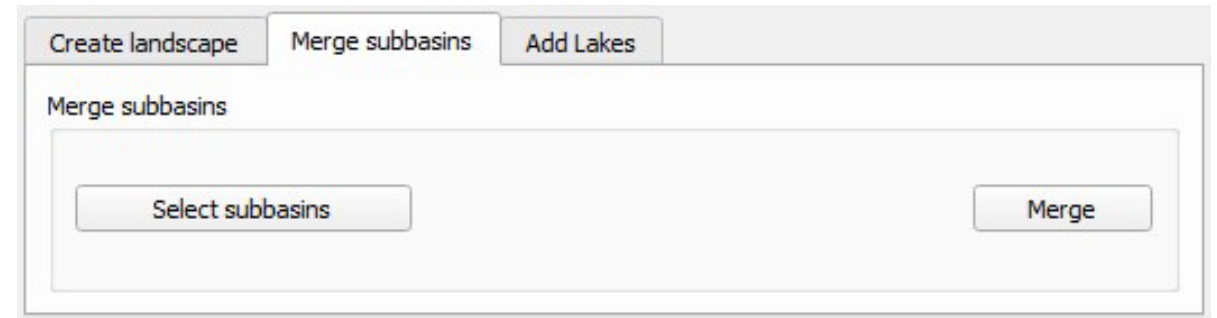
- Buffer channels** (selected tab)
- DEM inversion** (selected tab)
- Branch length** (tab)
- Use an inverted DEM to calculate ridges
- Ridge threshold
- 10000 (input field)
- Number of cells (input field)
- 1 (input field)
- Area (input field)
- sq. km (dropdown menu)
- 0.10 (input field)
- Slope position threshold (input field)
- Create (button)
- Done (button)

Floodplain Display



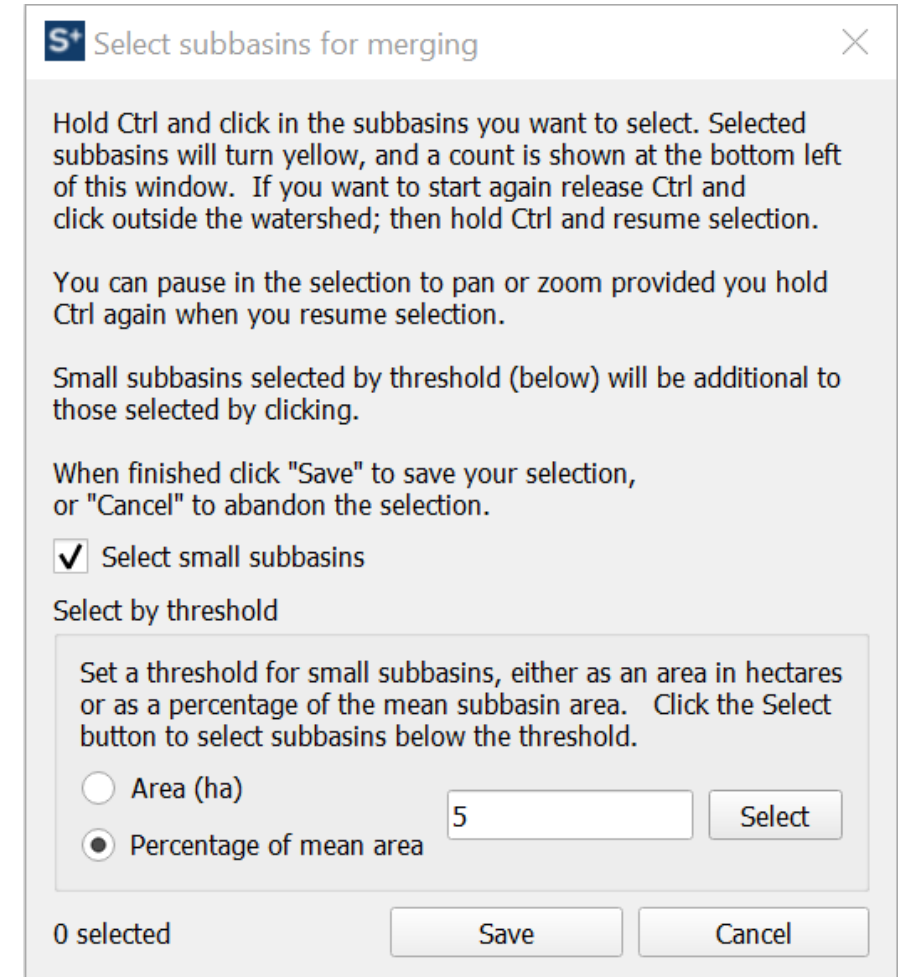
Merging Subbasins

- Delineation often produces very small subbasins where there are small distances between stream junctions. These can distort SWAT+ results and it is a good idea to remove them.
- Three options:
 - Manual selection by clicking in the subbasins that are to be merged.
 - Selection of small subbasins by setting a threshold.
 - Combination of both.
- Merging is always with the subbasin downstream, so if you want to merge two subbasins, only select the upstream one.
- Subbasins cannot be merged if
 - there is no subbasin downstream and/or
 - the subbasin has an inlet or outlet.



Selecting Subbasins for Merging

1. Select the *Merge subbasins* tab and click *Select subbasins*.
 2. On the Select subbasins for merging form that appears, check *Select small subbasins*, click *Select* and then click *Save*.
 3. Click *Save*.
- If you do not like the results, you can click *Create watershed* again to restore the original subbasins.



S* Select subbasins for merging

Hold Ctrl and click in the subbasins you want to select. Selected subbasins will turn yellow, and a count is shown at the bottom left of this window. If you want to start again release Ctrl and click outside the watershed; then hold Ctrl and resume selection.

You can pause in the selection to pan or zoom provided you hold Ctrl again when you resume selection.

Small subbasins selected by threshold (below) will be additional to those selected by clicking.

When finished click "Save" to save your selection, or "Cancel" to abandon the selection.

☒ Select small subbasins

Select by threshold

Set a threshold for small subbasins, either as an area in hectares or as a percentage of the mean subbasin area. Click the Select button to select subbasins below the threshold.

☐ Area (ha)

☒ Percentage of mean area

5

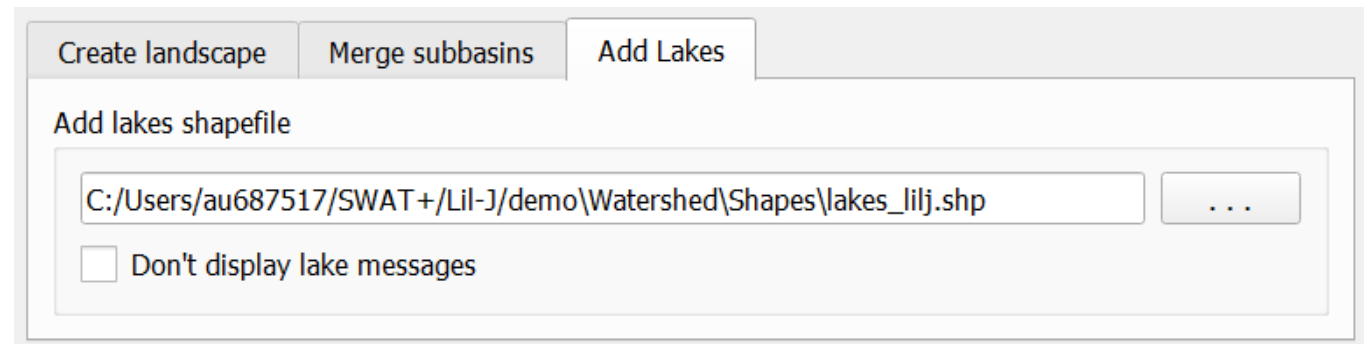
Select

0 selected

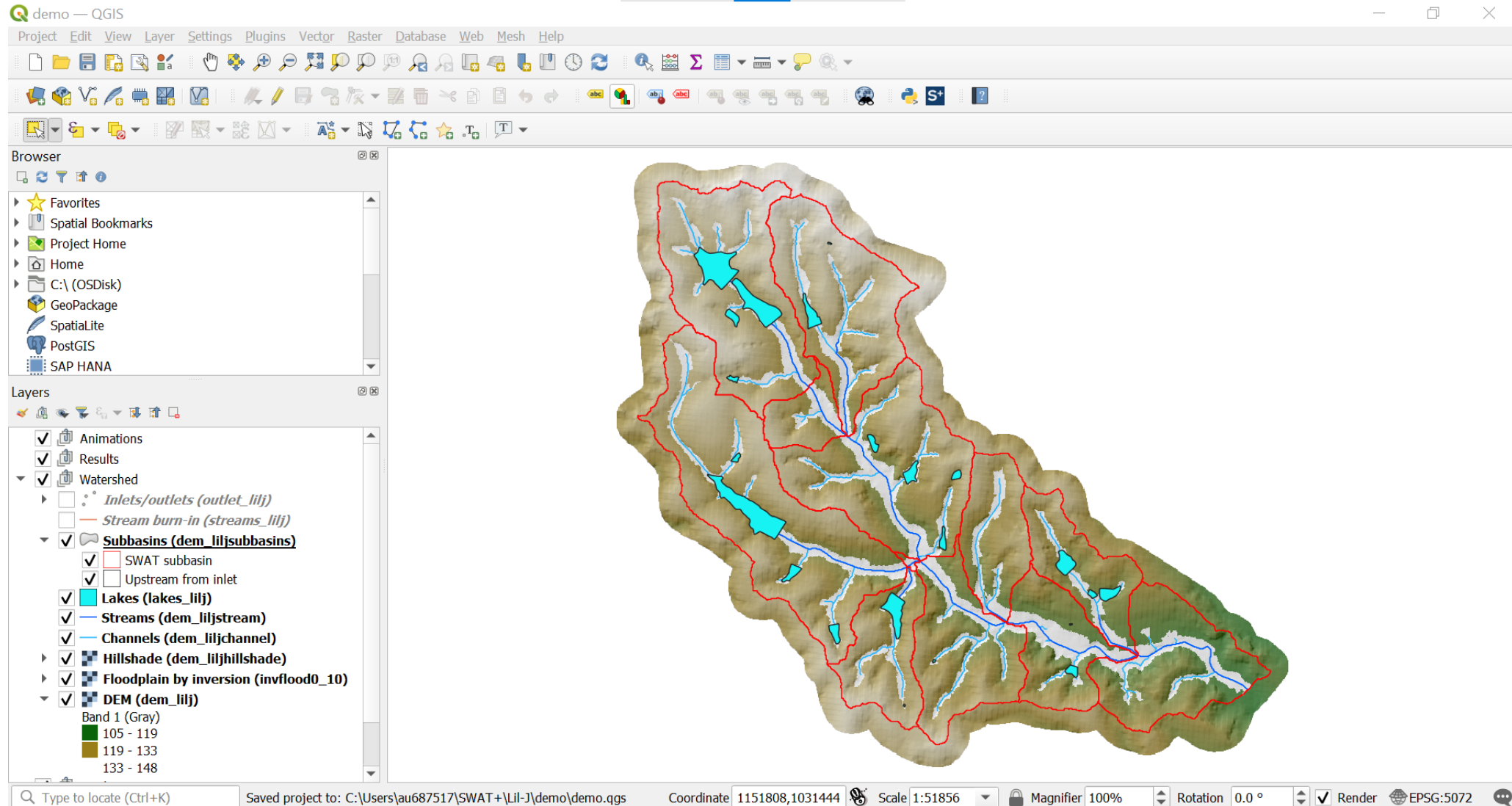
Save Cancel

Adding Lakes

- We will add lakes to the example watershed using a lake shapefile.
 1. Select the *Add lakes* tab, click on the button with the three dots, and navigate to the lakes folder in the input file directory.
 2. Select lakes_lilj.shp and click *Open*.



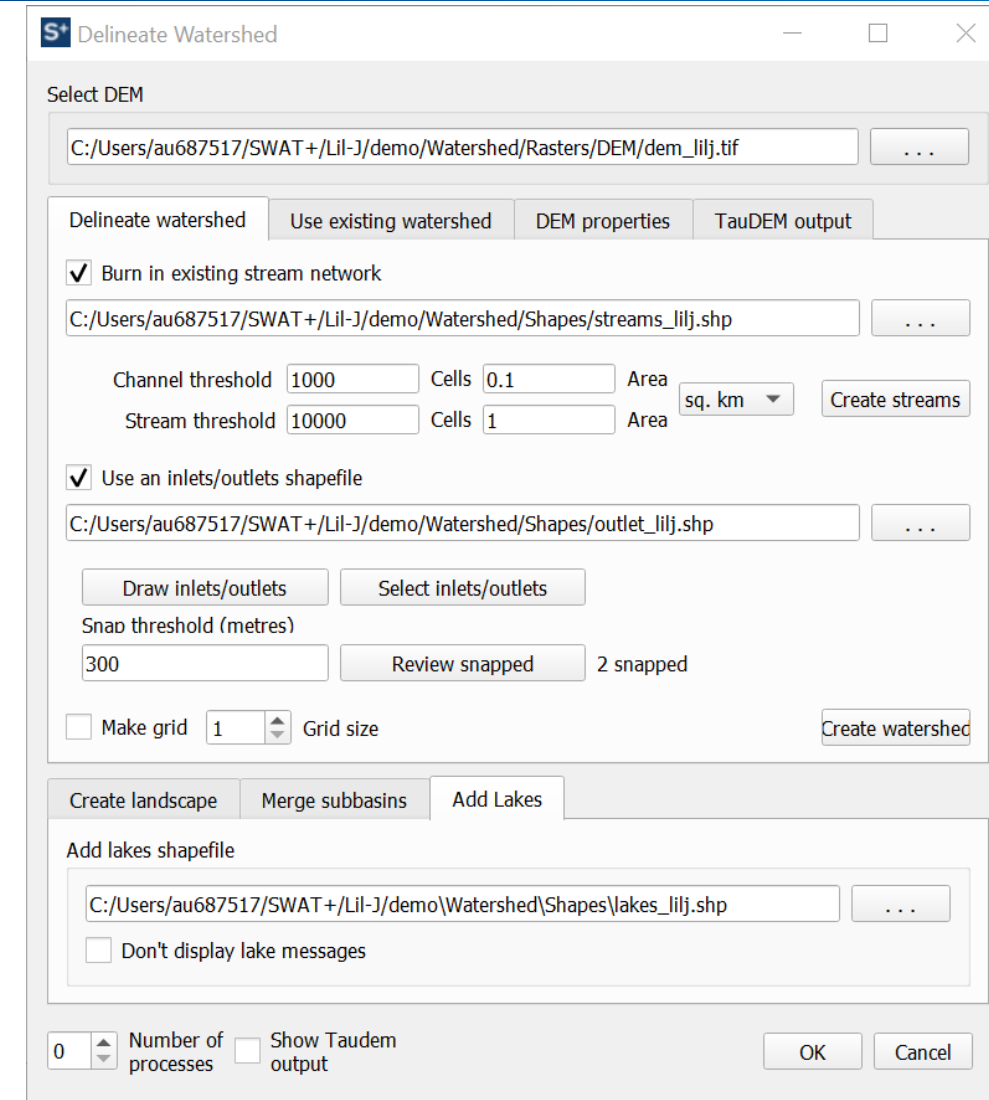
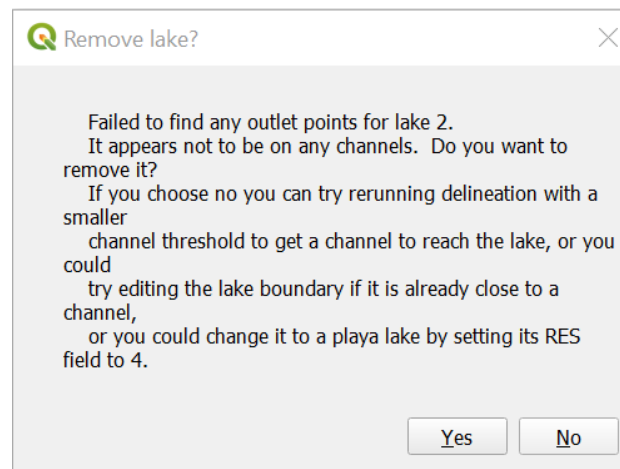
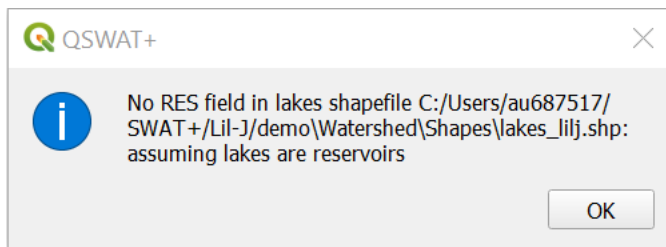
Lake Display



Completing the Watershed Delineation

1. Click *OK* to complete watershed delineation.

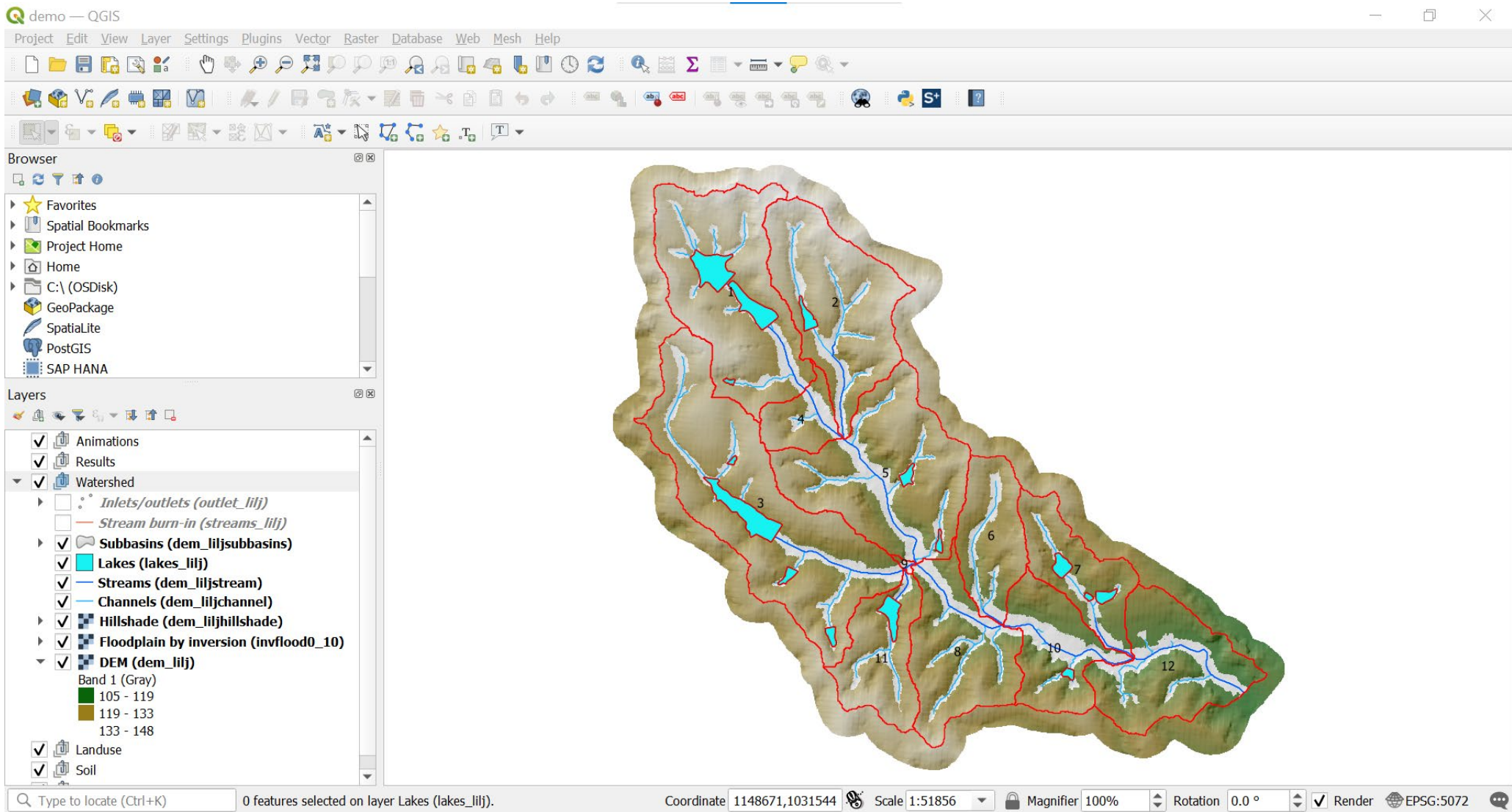
- For several lakes, we will get a message, that they are not located on a channel. We will click *Yes* to agree to removing those lakes.
- Finally, we will be notified that QSWAT+ assumes all lakes to be reservoirs.



- There are other possible lake messages, which you may encounter when setting up a SWAT+ model for a different watershed, for example when a channel enters and leaves a reservoir multiple times.

- There are 4 different lake types that can be assigned to the polygons in the lake shapefile:
 - Reservoirs
 - Ponds
 - Wetlands
 - Playas
- Please refer to Chapter 10 in the QSWAT+ Manual for a detailed description of the required format of the lake shapefile, how water is routed into and out of lakes, and issues that may arise when including lakes.

Watershed Display



Use Existing Watershed

- The delineation form allows you to opt for a predefined watershed and channel network by selecting the *Use existing watershed* tab.
- Please refer to Chapter 15 of the QSWAT+ Manual for a detailed instructions on how to prepare the required shapefiles.

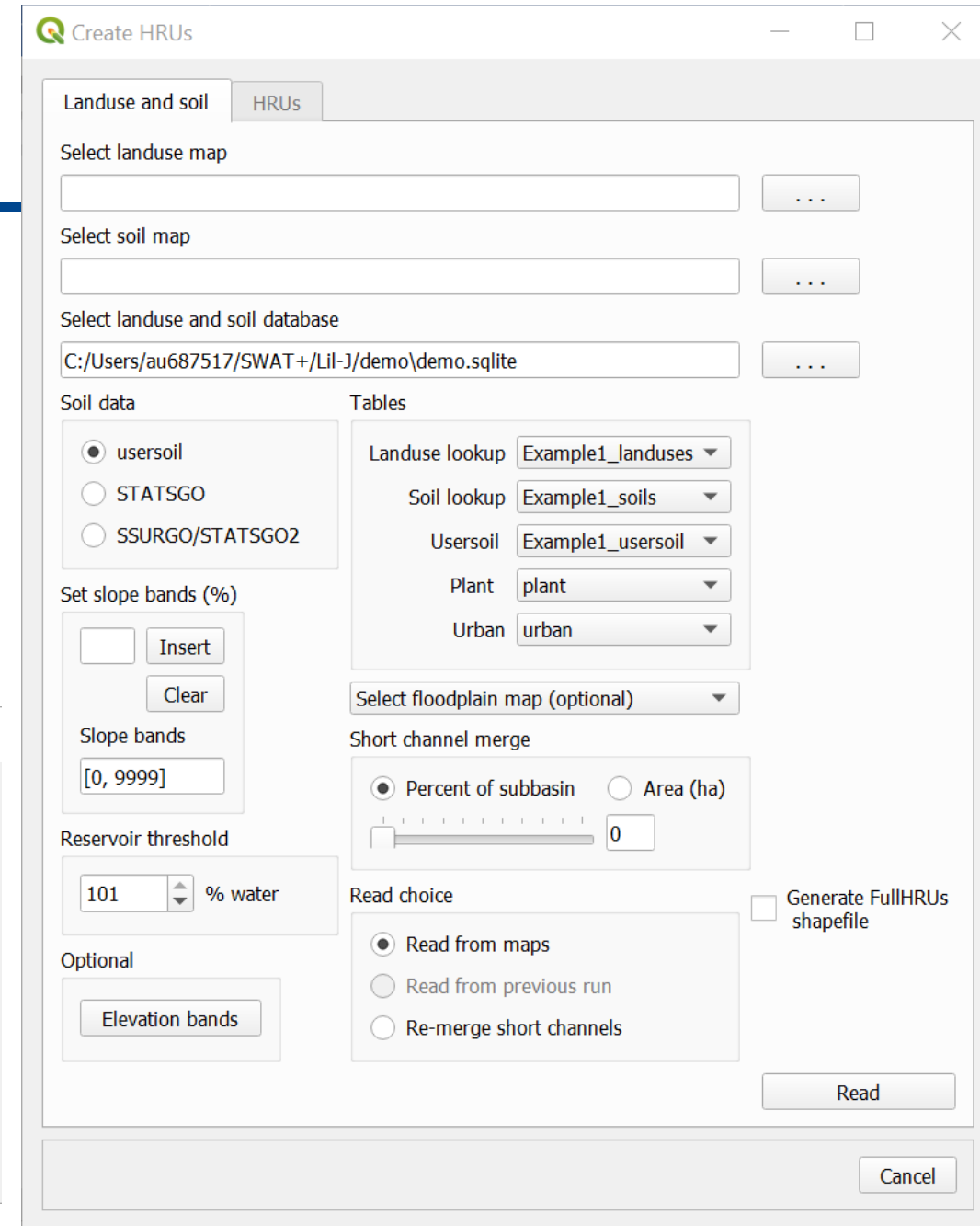
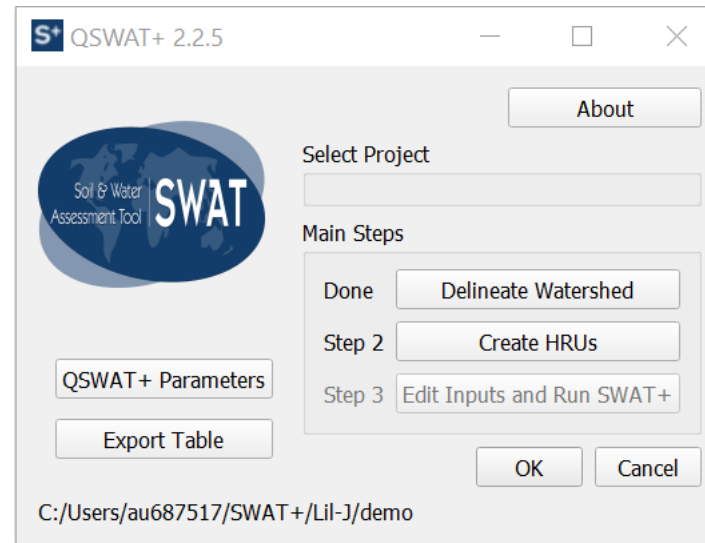
The screenshot shows the 'Delineate watershed' dialog box with the 'Use existing watershed' tab selected. The dialog contains the following fields and options:

- ☐ Use grid model
- Subbasins shapefile: C:/Users/au687517/SWAT+/Lil-J/demo/Watershed/Shapes/dem_liljsubbasins.shp
- Watershed shapefile: C:/Users/au687517/SWAT+/Lil-J/demo/Watershed/Shapes/dem_liljwshed.shp
- Channels shapefile: C:/Users/au687517/SWAT+/Lil-J/demo/Watershed/Shapes/dem_liljchannel/dem_liljchannel.shp
- Inlets/outlets shapefile (optional): C:/Users/au687517/SWAT+/Lil-J/demo/Watershed/Shapes/outlet_lilj.shp
- Existing calculated fields policy: ☒ Reuse, ☐ Recalculate and overwrite existing
- Run button

Create HRUs

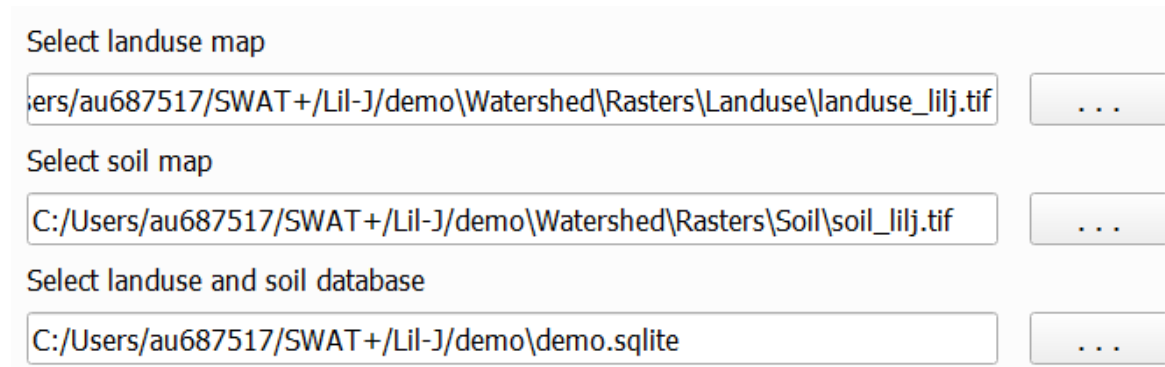
- Our main form shows that Step 1 (*Delineate Watershed*) is done.
- The next step is to add land use and soil information and define the HRUs.

1. Click *Create HRUs* to open the *Create HRUs* form.



Adding Land Use and Soil Data

1. To select a land use map, navigate to the landuse folder in the input file directory. Select landuse_lilj.tif and click *Open*.
2. To select a soil map, navigate to the soil folder in the input file directory. Select soil_lilj.tif and click *Open*.



The screenshot shows a dialog box with three sections for selecting input files. Each section has a text input field and a button with three dots (indicating a file explorer). The first section, 'Select landuse map', has the path 'ers/au687517/SWAT+/Lil-J/demo\Watershed\Rasters\Landuse\landuse_lilj.tif'. The second section, 'Select soil map', has the path 'C:/Users/au687517/SWAT+/Lil-J/demo\Watershed\Rasters\Soil\soil_lilj.tif'. The third section, 'Select landuse and soil database', has the path 'C:/Users/au687517/SWAT+/Lil-J/demo\demo.sqlite'.

Select landuse map	ers/au687517/SWAT+/Lil-J/demo\Watershed\Rasters\Landuse\landuse_lilj.tif	...
Select soil map	C:/Users/au687517/SWAT+/Lil-J/demo\Watershed\Rasters\Soil\soil_lilj.tif	...
Select landuse and soil database	C:/Users/au687517/SWAT+/Lil-J/demo\demo.sqlite	...

- By default, the land use and soil databases will be stored in the project SQLite database.

- The land use and soil maps are just grids of numbers. We have to relate these numbers to landuse codes and soil names, which we do by defining lookup tables in the project database.
- In QSWAT+, we can import pre-defined comma-separated value (csv) files.
 1. In the Landuse table pull-down menu select *Use csv file*. Navigate to the landuse folder in the input file directory and select landuse_lookup.csv.
 2. In the Soil table pull-down menu select *Use csv file*. Navigate to the soil folder in the input file directory and select soil_lookup.csv.
- We only need to read the csv files once. Next time we run the project, they will be available and selected when we start this form. We can change and import them again though.

Usersoil Table

- We also need a table of soil properties, called a usersoil table.
 1. In the Usersoil table pull-down menu select *Use csv file*. Navigate to the soil folder in the input file directory and select usersoil_lrew.csv.
- STATSGO and SSURGO are soil databases for the United States and can therefore only be used for U.S. watersheds.
- The plant and urban tables are included in the reference database.

Soil data

☒ usersoil

☐ STATSGO

☐ SSURGO/STATSGO2

Tables

Landuse lookup landuse_lookup ▼

Soil lookup soil_lookup ▼

Usersoil usersoil_lrew ▼

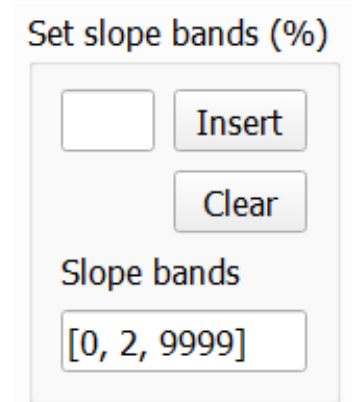
Plant plant ▼

Urban urban ▼

- By default, QSWAT+ only defines one slope band for the entire watershed.
- We can define additional slope bands to be included in HRU definition by specifying the upper limit of the bands in %.

1. Type “2” in the white field in the *Set slope bands* box and click *Insert*.

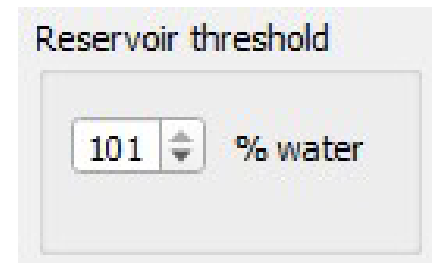
- You will see [0, 2, 9999] in the Slope bands box. You can insert as many intermediate points as you wish by repeating the procedure. Click Clear if you are unhappy with the results and need to start again.



The screenshot shows a dialog box titled "Set slope bands (%)". It contains a small white input field with the number "2" entered. To the right of the input field are two buttons: "Insert" and "Clear". Below these buttons, the text "Slope bands" is displayed above a text box containing the array "[0, 2, 9999]".

Reservoir threshold

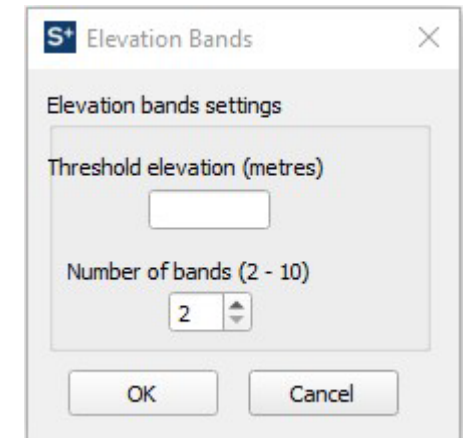
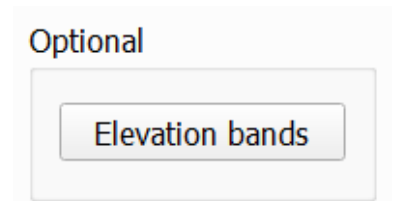
- Besides adding pond or reservoir points to the inlets/outlets shapefile during watershed delineation and adding a lake shapefile during watershed delineation, ponds and reservoirs may be added by setting a reservoir threshold during HRU definition.
- The *Reservoir threshold* is the percentage of land use WATR in the adjacent LSU of each channel needed to form a reservoir. For example, if this is set to 20%, then any channel for which land use WATR is 20% or more of the adjacent LSU will become a reservoir. If the downstream channel is also a reservoir by this method, they are combined into a single reservoir. The default threshold is 101%, effectively turning this mechanism off.
- Otherwise, areas of land use WATR will form wetland HRUs.



The image shows a software interface for setting the 'Reservoir threshold'. It features a text label 'Reservoir threshold' at the top. Below it is a control element consisting of a text box containing the number '101', a small up/down arrow button, and the text '% water'.


Elevation Bands

- At this point, we can also define elevation bands. These are bands used for subbasins at high elevation affected by snow and ice.
- Elevation bands are set in QSWAT+ by defining a minimum elevation (slope bands are only defined in subbasins whose maximum elevation exceeds this), and by defining how many bands to use.
- The *Elevation bands* form appears when you click the *Elevation Bands* button in the *Optional* box at the bottom of the *Create HRUs* form.
- We will not define elevation bands for the example watershed.



Selecting a Floodplain Map

- If we wish to delineate upland areas and floodplains, we can now choose which of the floodplain maps we created during watershed delineation we would like to use.
1. In the *Select floodplain map (optional)* pull-down menu select the floodplain map by inversion we made earlier (invflood0_10.tif).

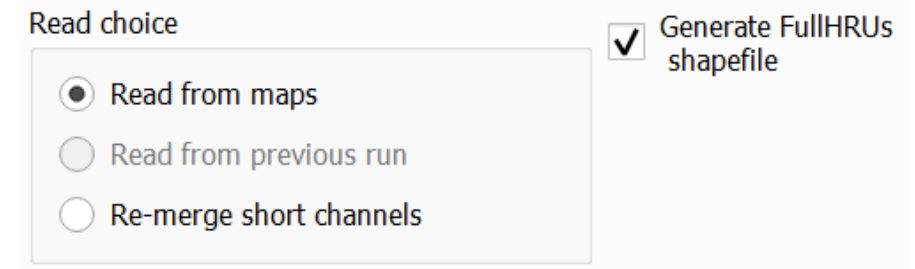
A screenshot of a software interface showing a pull-down menu. The menu is open, and the text 'invflood0_10.tif' is visible within the selection box. A small downward-pointing arrow is located at the right end of the box.

invflood0_10.tif

Creating Potential HRUs

- We are now ready to create the potential HRUs.

1. Check the box next to *Generate FullHRUs shapefile*.
2. Click Read.



Read choice

☒ Read from maps

☐ Read from previous run

☐ Re-merge short channels

☒ Generate FullHRUs shapefile

- The *Read choice* is set to *Read from maps*, which is currently the only choice. In future runs of the example, we will be able to Read from previous run, provided we don't change the watershed delineation, the soil and land use files, or the slope bands. This reads data stored in the project database and is much faster than re-reading the maps.
- When the rasters are all read and the full (or potential) HRUs created, the form reports that there are 11 subbasins, 144 channels, and 3398 potential HRUs.

Merging Channels

- Channels with small LSUs (typically short channels) generate HRUs that contribute strongly to the processing time of SWAT+ but make little difference to the results, and so it is common to merge them.

1. Set the threshold in the *Short channel merge* box to 5% of the subbasin.

2. Click *Read* again.

- We see that the channel and HRU counts have changed.

Short channel merge

☒ Percent of subbasin ☐ Area (ha)

Subbasins count: 11
Channels count: 144
Full HRUs count: 3398

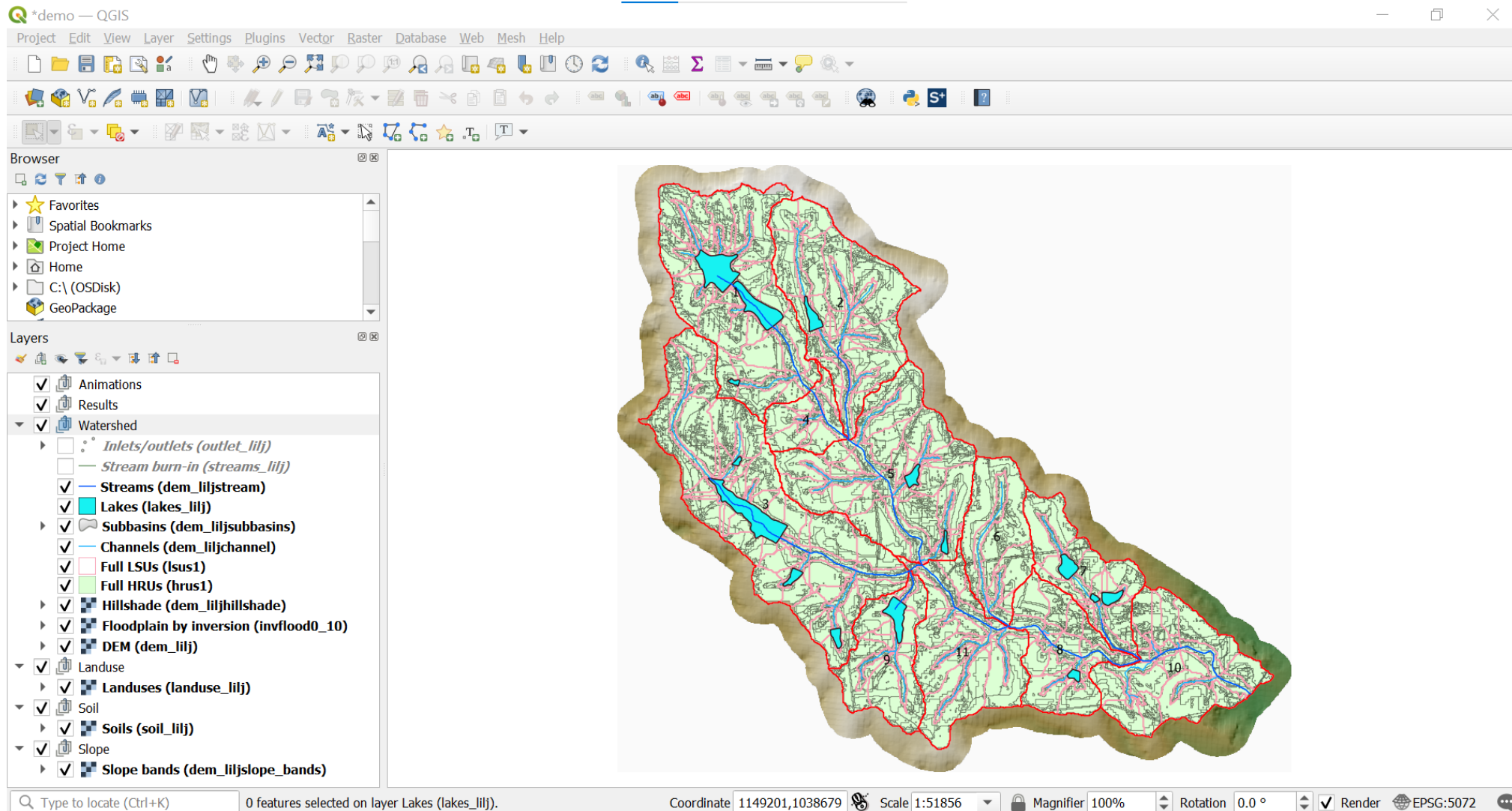


Subbasins count: 11
Channels count: 104
Full HRUs count: 3035

- You can change the threshold and repeat the merge as many times as you like.

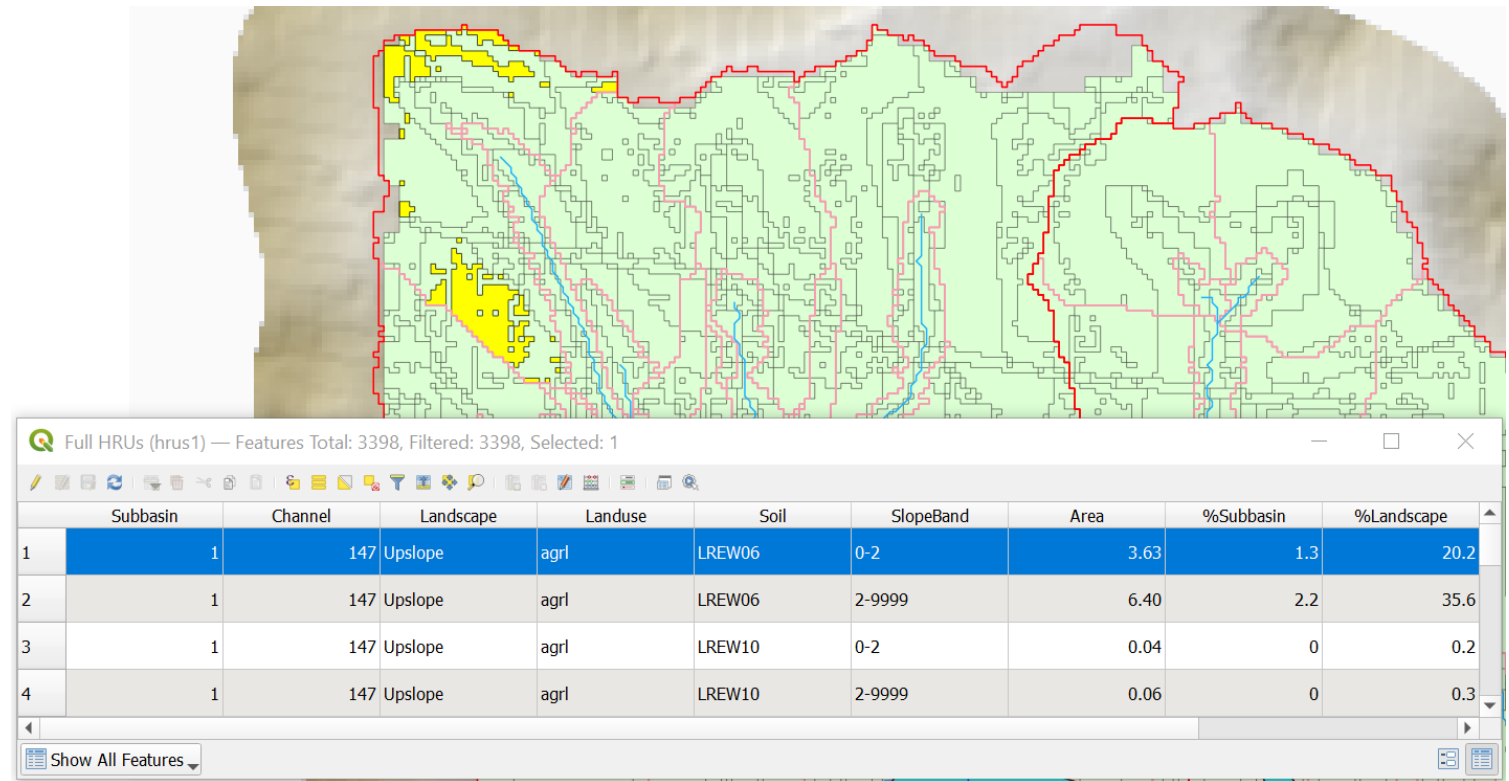
- At this point we can see in the QGIS Layers panel
 - a Full HRUs map showing the HRU boundaries,
 - a Full LSUs map showing the LSU boundaries,
 - the landuse and soil maps labelled with landuse codes and soil names, and
 - a slope bands map that is colored according to slope bands.
- Each cell in the watershed has been categorized according to the LSU it is in and its landuse, soil, and slope band. Points that share the same four values are grouped into potential HRUs.

Potential HRUs Display



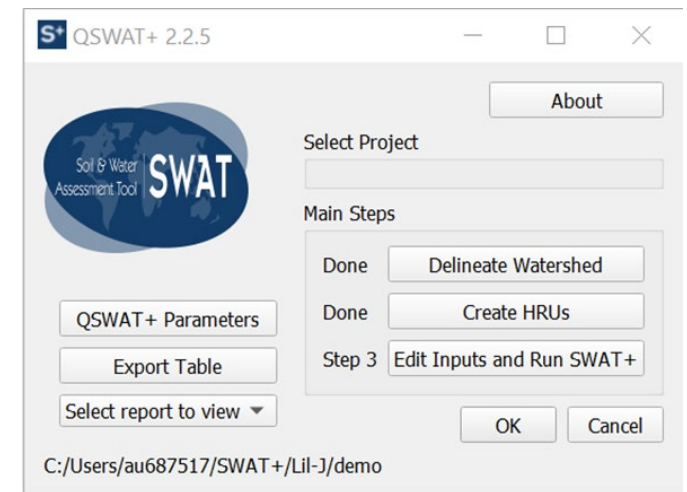
Examining Potential HRUs

- We can use the Full HRUs shapefile to see our potential HRUs.
- The cells marked in yellow share
 - subbasin 1,
 - channel 147,
 - landscape Upslope,
 - landuse agri,
 - soil LREW06, and
 - slope band 0-2.
- Collectively they have an area of 3.63 ha and comprise 1.3% of subbasin 1 and 20.2% of the upslope LSU of channel 147.



Reports

- If we look at the main QSWAT+ form, we see that two reports are now available: “Elevation” and “Landuse and Soil”. Each can be opened by selecting it in the pull-down menu.
- The Elevation report shows the area and percentage distribution of elevation for the whole watershed and for each subbasin.
- The Landuse and Soil report shows the area and percentage distribution of each landuse, soil, and slope band for the whole basin and for each subbasin and channel.



Editing the Potential HRUs

- In the HRUs tab of the Create HRUs form, we have some options available to edit the potential HRUs to make them more detailed or to simplify them:
 - We can apply thresholds to exclude small HRUs that are not expected to impact the model output.
 - Exempting landuses means marking them as not to be removed when we remove small HRUs. For example, the FRST (forest) landuse could be exempted.
 - Splitting landuses allows us to divide existing landuses, e.g., if we know that 50% of the landuse AGRL (generic agriculture) in this area is CORN and 50% is SOYB.

The screenshot shows the 'Create HRUs' dialog box with the 'HRUs' tab selected. The 'Optional' section contains 'Split landuses' and 'Exempt landuses' buttons. The 'Single/Multiple HRUs' section has radio buttons for 'Dominant landuse, soil, slope', 'Dominant HRU' (selected), 'Filter by landuse, soil, slope', 'Filter by area', and 'Target number of HRUs'. The 'Threshold method' section has radio buttons for 'Percent of landscape unit' (selected) and 'Area (Ha)'. The 'Landuse, soil, slope thresholds' section features three sliders for 'Landuse (%)', 'Soil (%)', and 'Slope (%)', each with a 'Go' button. At the bottom right are 'Create HRUs' and 'Cancel' buttons.

Splitting Landuses

1. Click *Split landuses*.
2. The *Split Landuses* form appears. In the *Select landuse to split* pull-down menu, select *AGRL*.
3. In the *Select sub-landuse* form, select “*CORN (corn)*” and click *OK*.
4. Click *Add sub-landuse*.
5. In the *Select sub-landuse* form, select “*SOYB (soybean)*” and click *OK*.
6. Change the percentages in the table to 50 each.
7. Click *Save edits*.
8. Click *Save splits*.

S+ Split Landuses

Select landuse to split:

Select split landuse to edit:

landuse	sub-landuse	percent
agrl	CORN	50
	SOYB	50

Buttons: Add sub-landuse, Delete sub-landuse, Delete split landuse, Cancel edits, Save edits, Save splits, Cancel

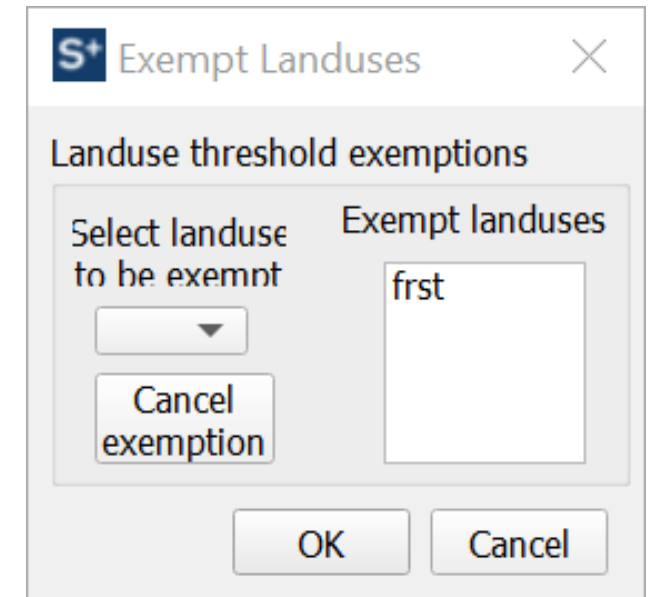
S+ Select sub-landuse

List of sub-landuses: BROS (smooth_bromegrass), BSVG (barren_or_sparsley_vegetated), CABG (cabbage), CANA (spring_canola_argentine), CANG (canary_grass), CANP (spring_canola_polish), CANT (cantaloupe), CASH (cashews), CASS (cassava), CAUF (cauliflower), CEDR (cedar), CELR (celery), CLVA (alsike_clover), CLVR (red_clover), CLVS (sweetclover), CNGR (canada_grass), COCB (cockle_burr), COCO (coconut_tree), COCT (cocoa_tree), COFF (coffee), CONT (unknown), CORN (corn), CORN100 (corn), CORN110 (corn).

Buttons: OK, Cancel

Exempting Landuses

1. Click *Exempt landuses*.
2. The *Exempt Landuses* form appears. In the *Select landuse* to split pull-down menu, select *frst*.
3. Click *OK*.



The screenshot shows the 'Exempt Landuses' dialog box. It has a title bar with the SWAT+ logo and a close button. The main area is titled 'Landuse threshold exemptions'. Inside, there are two columns: 'Select landuse to be exemnt' and 'Exempt landuses'. The 'Select landuse to be exemnt' column has a dropdown menu with a downward arrow and a 'Cancel exemption' button below it. The 'Exempt landuses' column has a text box containing the value 'frst'. At the bottom of the dialog are 'OK' and 'Cancel' buttons.

- In the *Single/Multiple HRUs* box, the user has a choice between defining just one HRU per LSU or dividing the LSU into multiple HRUs.
- The first two choices define just one HRU for each LSU:
 - *Dominant HRU* will choose the landuse, soil and slope combination of the largest potential HRU in the LSU.
 - *Dominant landuse, soil, slope* will give to the single HRU the landuse with the largest area of the LSU's landuses, and similarly for soil and slope.
- The other three choices are multiple choices. If one of these are chosen it is possible to reduce the number of HRUs by eliminating small ones and redistributing their area proportionately amongst the larger ones. Small HRUs may be eliminated by
 - defining thresholds for landuse, soil, and slope bands (*Filter by landuse, soil, slope*),
 - using area thresholds (*Filter by area*), or
 - targeting the number of HRUs to be formed (*Target number of HRUs*) .

Single/Multiple HRUs

- ☐ Dominant landuse, soil, slope
- ☒ Dominant HRU
- ☐ Filter by landuse, soil, slope
- ☐ Filter by area
- ☐ Target number of HRUs

Filtering by Area

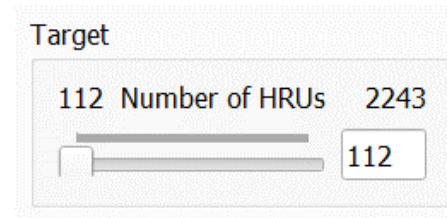
- If Filter by area is chosen, there is then a choice of threshold method and a choice of threshold value.
 - If the method chosen is *Percent of landscape unit* and the value (set by moving the slider or typing in the box) is 10, then HRUs that are less than 10% of their LSUs will be removed.
 - If the method chosen is *Area (ha)* and the value set is 5, then HRUs that are less than 5 ha will be removed.

The image displays two side-by-side screenshots of the SWAT+ software interface, specifically the 'Filter by area' settings. Each screenshot shows a 'Threshold method' section with two radio buttons: 'Percent of landscape unit' and 'Area (Ha)'. The left screenshot has 'Percent of landscape unit' selected, and the right screenshot has 'Area (Ha)' selected. Below the radio buttons is a slider bar labeled 'Area (%)' or 'Area (ha)' with a numerical input box. In the left screenshot, the slider is set to 10% and the input box contains '10'. In the right screenshot, the slider is set to 5 ha and the input box contains '5'.

- The percent or area method makes a difference when subbasins vary considerably in size. Suppose, for example, that LSU A has a size of 50 hectares and LSU B has a size of 5 hectares. Suppose potential HRU A1 has a size of 5 hectares, and so is 10% of its LSU, and potential HRU B1 has a size of 2.5 hectares, and so is 50% of its LSU. When selecting by ha area, A1 is bigger than B1, but by percent B1 is bigger than A1. With an area threshold of 10% and a ha threshold of 5, A1 would (just) be retained by both. B1 would be retained by percent but eliminated by ha.

Setting a Target Number of HRUs

- If *Target number of HRUs* is chosen there is a choice of threshold method, and a choice of target value.
- Suppose, for example, we set a target of 2000 HRUs, out of the current 2243.
 - If the method chosen is *Percent of landscape unit* then the HRUs will be sorted in order of their percentages of their subbasins, and the smallest 243 will be eliminated.
 - If the method chosen is *Area (ha)* then the HRUs will be sorted in order of their areas in hectares, and the smallest 243 will be eliminated.



Target

112 Number of HRUs 2243

112

- Targets are typically exceeded when exemptions for some landuses have been chosen, or landuses are split, as splitting is done after elimination. If the result has too many HRUs you can always run again with a lower target.

Filtering by Landuse, Soil, and Slope

- For the example watershed, we will use *Filter by landuse, soil, slope*.
- 1. Select *Filter by landuse, soil, slope* and choose *Percent of landscape unit* as the method.
- 2. Set *Landuse (%)* to 10 and click *Go* to exclude any landuse for which the percentage area in the LSU is less than 10.
- 3. Set *Soil (%)* to 10 and click *Go* to exclude any soils for which the percentage area per landuse in the LSU is less than 10.
- 4. Set *Slope (%)* to 10 to exclude any slope bands for which the percentage area per landuse and soil combination in the LSU is less than 10.
- The number at the end of the sliders indicates that this is the lowest percentage for a dominant landuse, soil, or slope band across all the LSUs. Trying to set the percentage higher than this would mean trying to remove all HRUs from at least one LSU.

Landuse, soil, slope thresholds

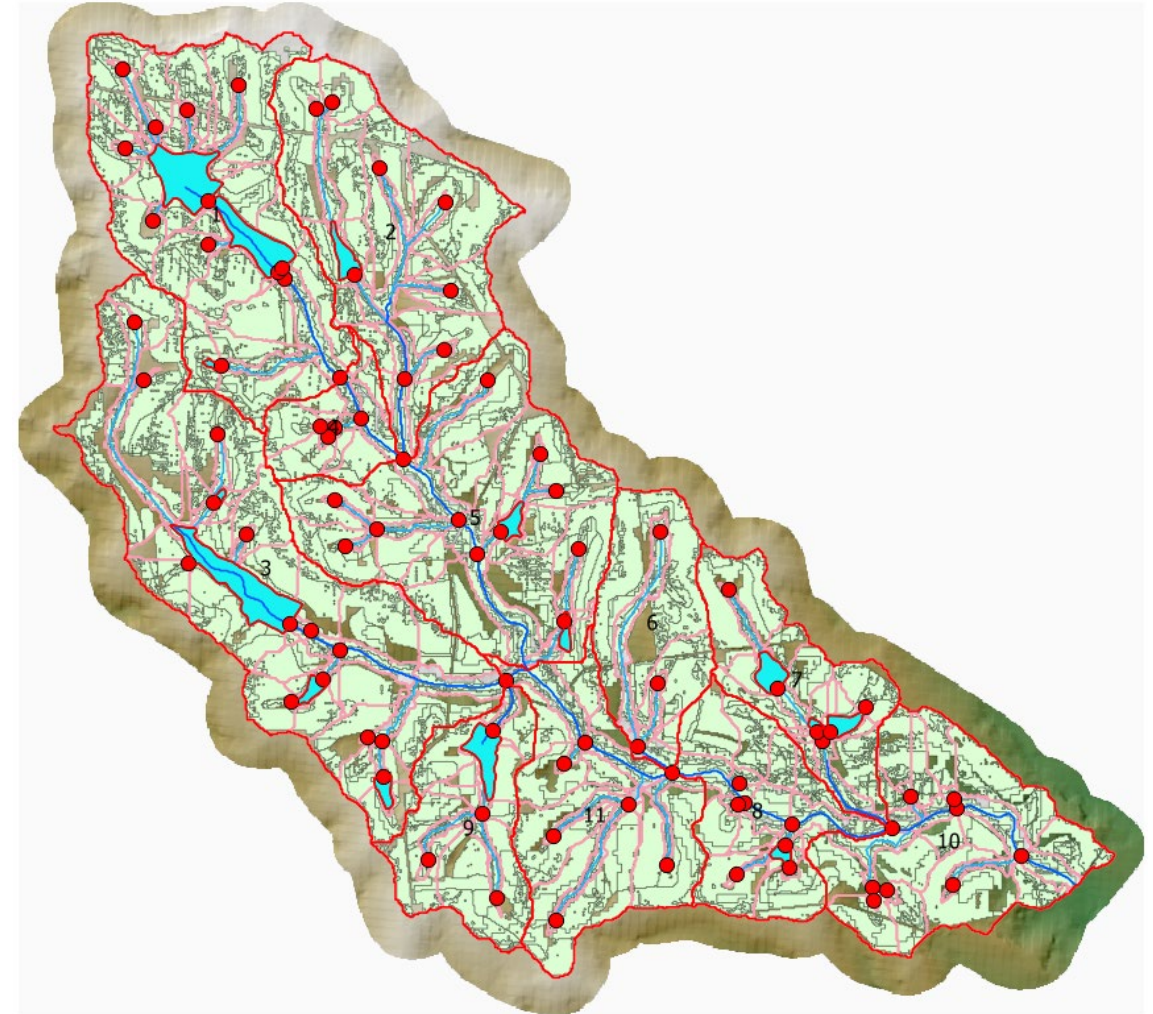
0	Landuse (%)	24	10
			Go
0	Soil (%)	30	10
			Go
0	Slope (%)	50	10

1. Click *Create HRUs*.

- We see in the main QSWAT+ form, in the *Select report to view* pull-down menu, that there is a new report available: *HRUs*.
- This report shows the detailed actual and percentage areas for the watershed and each subbasin, for each landuse and soil, before and after HRU creation, and for each HRU.
- We can see that we ended up with 1310 HRUs.
- If you want to change the HRU selection, click on *Create HRUs* in the main QSWAT+ form to reopen the *Create HRUs* form. *Read choice* will be set to *Read from previous run*, and you can click *Read* and redo the HRU selection.

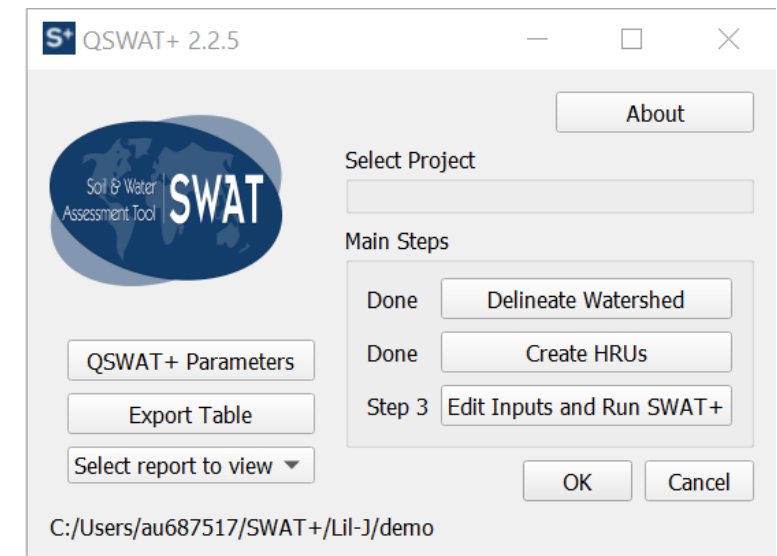
Actual HRUs

- A new shapefile (Actual HRUs) has been created. This is the Full HRUs file with the eliminated HRUs removed.
- It appears that there are holes in the watershed, but the retained HRUs were proportionately increased in size so that in each LSU their total area is the area of the LSU.



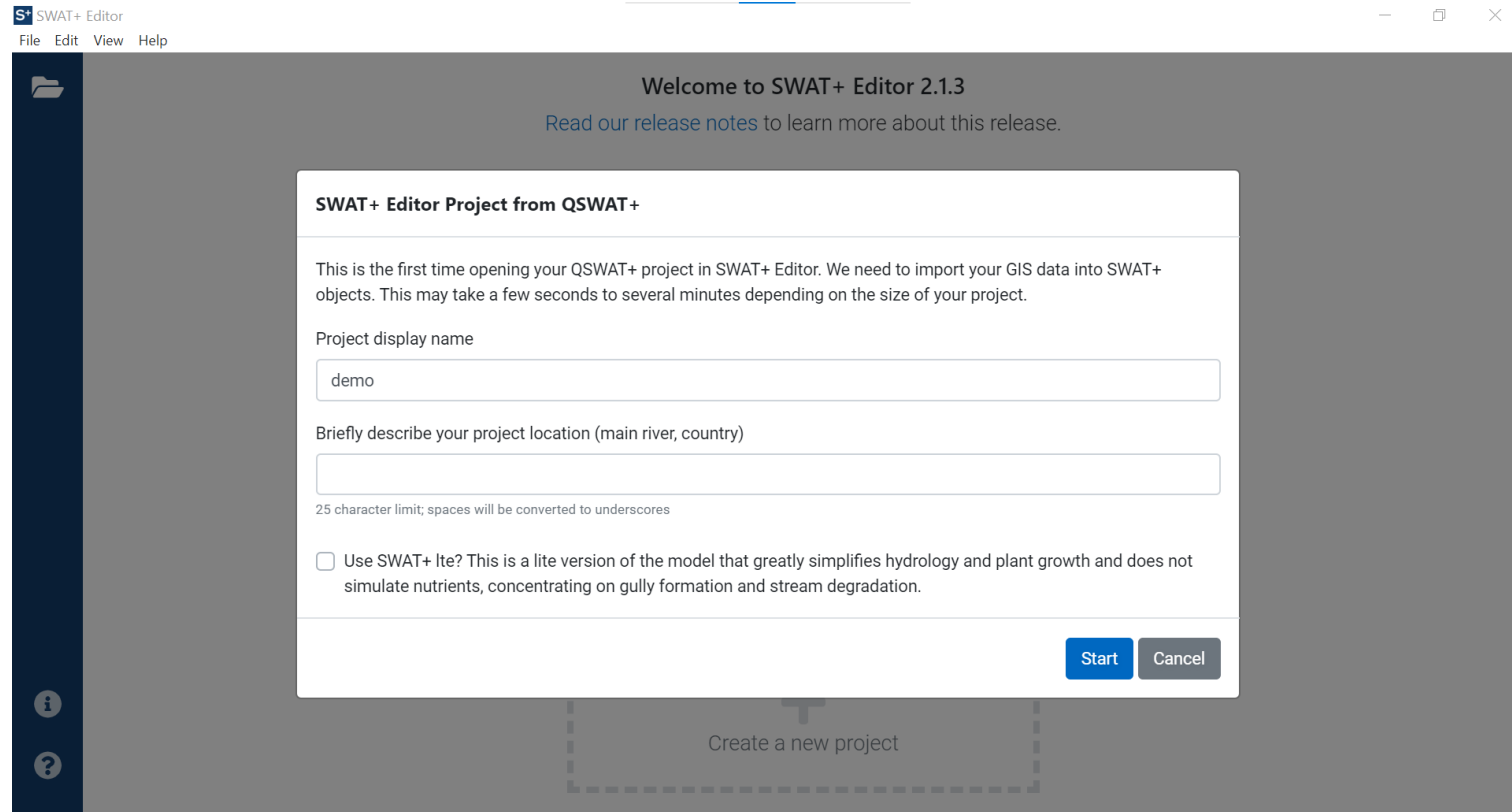
Edit Inputs and Run SWAT

- Our main form shows that Step 2 (*Create HRUs*) is done.
 - The next steps are to edit SWAT+ inputs and run the model.
1. Click *Edit Inputs and Run SWAT* to open the *SWAT+ Editor*.



Import QSWAT+ Project

- This is the first time we are opening our QSWAT+ project in the SWAT+ Editor, so we have to import it.
 - The editor should already have selected the appropriate SQLite database file, project name, and SWAT+ database file.
1. Type *Lilj Georgia* in the field for the description of the project location.
 2. Click *Start*.



Project Setup and Information

- Basic information about the current project
- Buttons to Get Started and Change Name/Description.
- Link to SWAT+ Editor release notes
- Buttons to open a different project and to create a new project from scratch.
- List of current and recent projects
- SWAT+ Editor navigation buttons.

The screenshot displays the SWAT+ Editor 2.1.3 interface. On the left is a dark blue sidebar with navigation icons: a folder (Projects), a pencil (Edit), a play button (Run), a checkmark (Save), and an information/question mark icon at the bottom. The main area is titled 'SWAT+ Editor 2.1.3' and includes a link to 'Read our release notes'. Below this are two buttons: 'Open another project' and 'Create a new project'. A 'RECENT PROJECTS' list shows 'demo', 'Wabash01', 'X_1', and 'test01', each with a close button. The 'Current project: demo' section shows the path 'C:/Users/au687517/SWAT+/Lil-J/demo'. The 'Project information' table lists 'Total area' (2,133.21 ha), 'Simulation period' (1980 - 1985), 'Software' (SWAT+ Editor 2.1.3, QSWAT+ 2.2.5), and 'Last saved' (Mon, Aug 22, 2022 3:41 PM). The 'Object totals' table lists: 11 Subbasins, 1747 HRUs, 85 Channels, 23 Aquifers, 15 Reservoirs, 207 Routing Units, 207 Landscape Units, 88 Recall (point source/inlet data), and 0 Export Coefficients. At the bottom are 'Get started' and 'Change Name/Description' buttons. On the right, the 'Land use distribution' section features a pie chart with five segments in blue, yellow, green, orange, and black.

Total area	2,133.21 ha	Software	SWAT+ Editor 2.1.3, QSWAT+ 2.2.5
Simulation period	1980 - 1985	Last saved	Mon, Aug 22, 2022 3:41 PM

11	Subbasins
1747	HRUs
85	Channels
23	Aquifers
15	Reservoirs
207	Routing Units
207	Landscape Units
88	Recall (point source/inlet data)
0	Export Coefficients

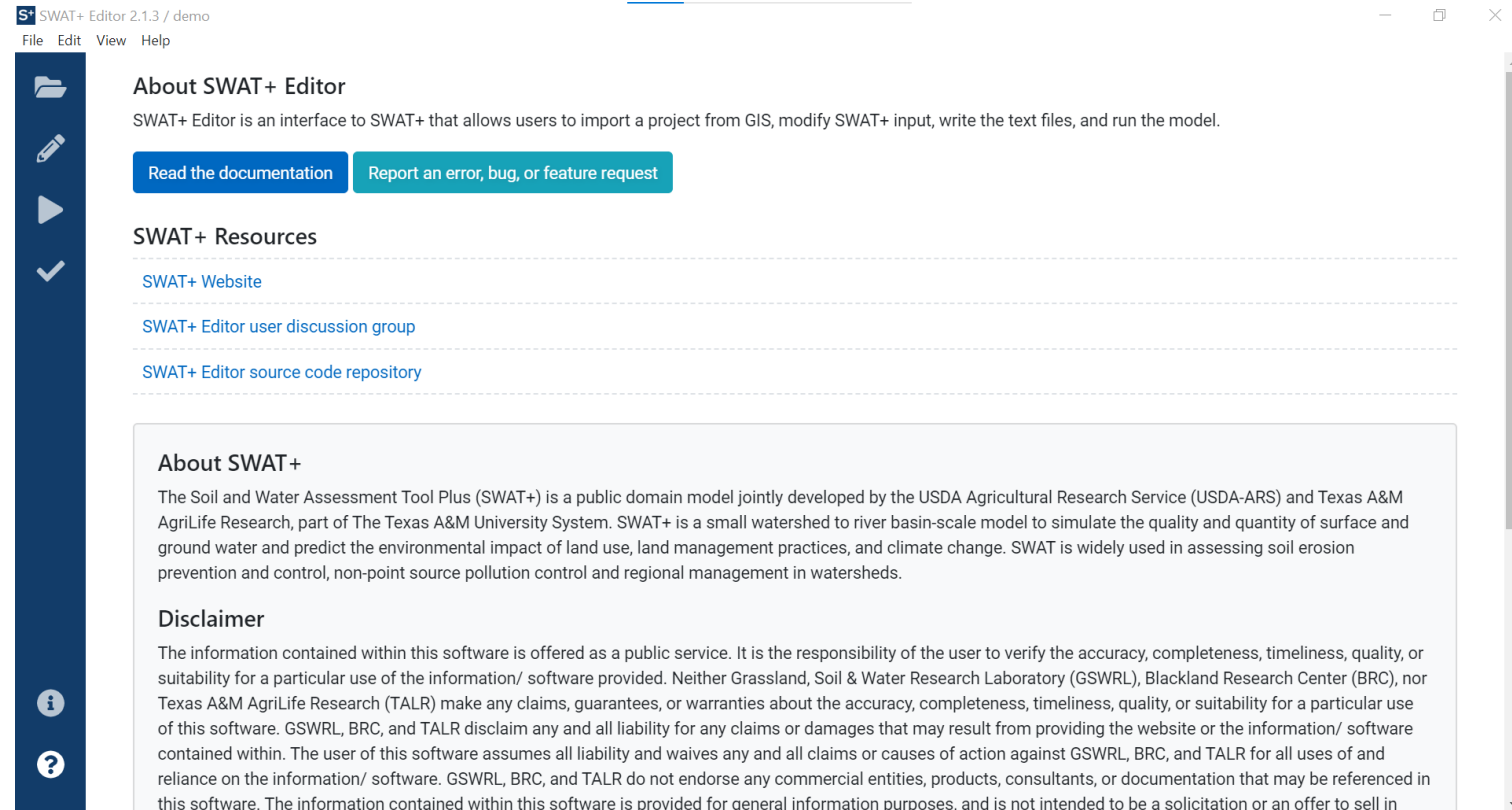
Navigation Buttons



- Project setup and information
 - Edit SWAT+ inputs
 - Run SWAT+
 - SWAT+ Check
-
- Project information (return to Project Information or open project directory)
 - Help and documentation

Help and Documentation

- Information about SWAT+ Editor
- Links to
 - SWAT+ documentation,
 - Bitbucket site to report an error or bug or make a feature request,
 - SWAT+ website,
 - SWAT+ Editor user group, and
 - SWAT+ Editor source code repository.



Start editing SWAT+ Inputs

1. Click *Get started* in the main window (or the *Edit SWAT+ inputs* icon).

The screenshot displays the SWAT+ Editor 2.1.3 interface. On the left is a dark blue sidebar with icons for file management, editing, and project management. The main window is titled 'Current project: demo' and shows the project path 'C:/Users/au687517/SWAT+/LiJ-3/demo'. Below this, 'Project information' is displayed in a table:

Project information	
Total area	2,133.21 ha
Simulation period	1980 - 1985
Software	SWAT+ Editor 2.1.3, QSWAT+ 2.2.5
Last saved	Mon, Aug 22, 2022 3:41 PM

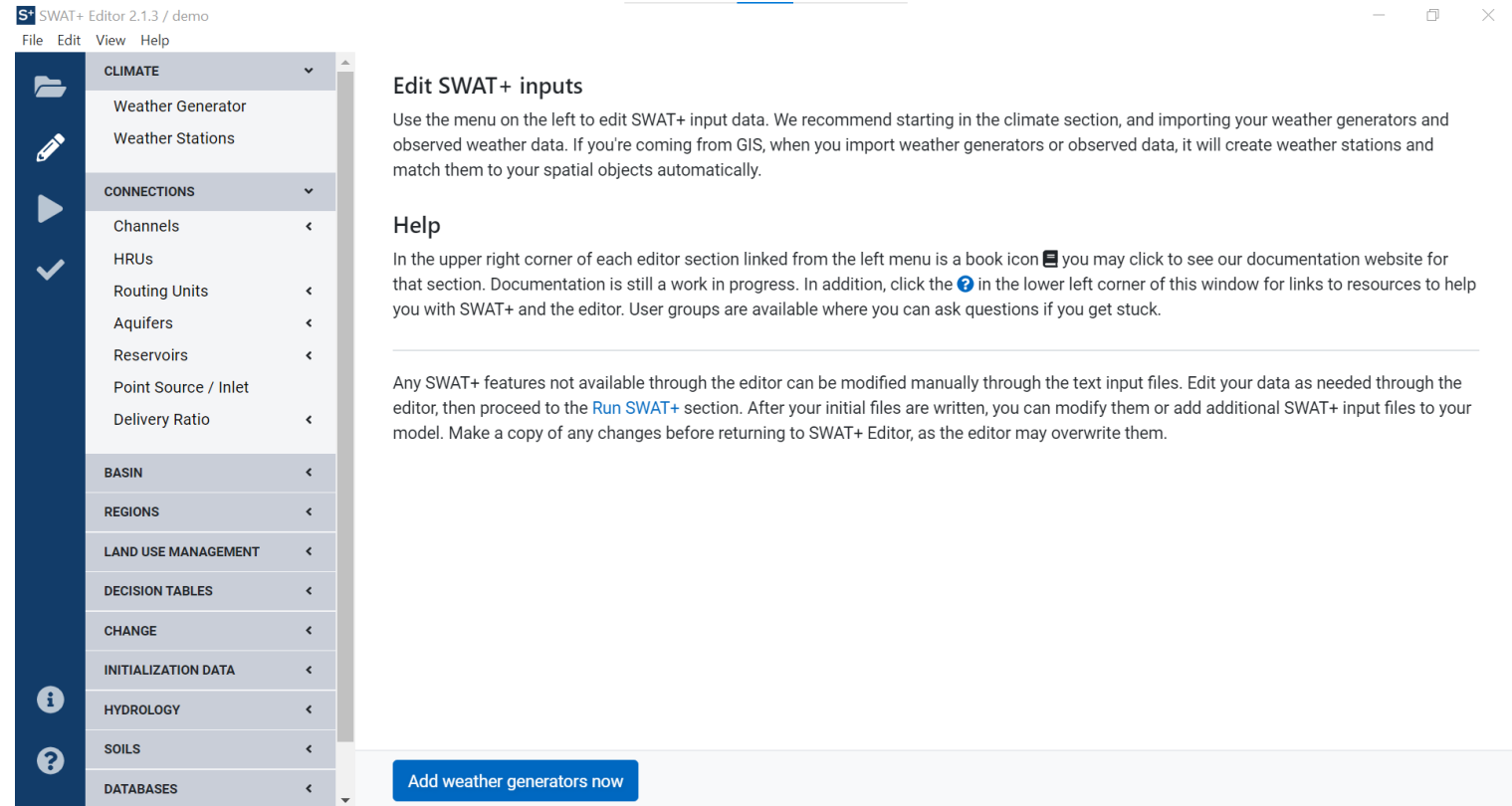
Below the project information is a table of 'Object totals':

Object totals	
11	Subbasins
1747	HRUs
85	Channels
23	Aquifers
15	Reservoirs
207	Routing Units
207	Landscape Units
88	Recall (point source/inlet data)
0	Export Coefficients

On the right side of the main window, there is a 'Land use distribution' section featuring a pie chart. The pie chart is divided into several colored segments representing different land use types. At the bottom of the main window, there are two buttons: 'Get started' and 'Change Name/Description'.

Edit SWAT+ Inputs

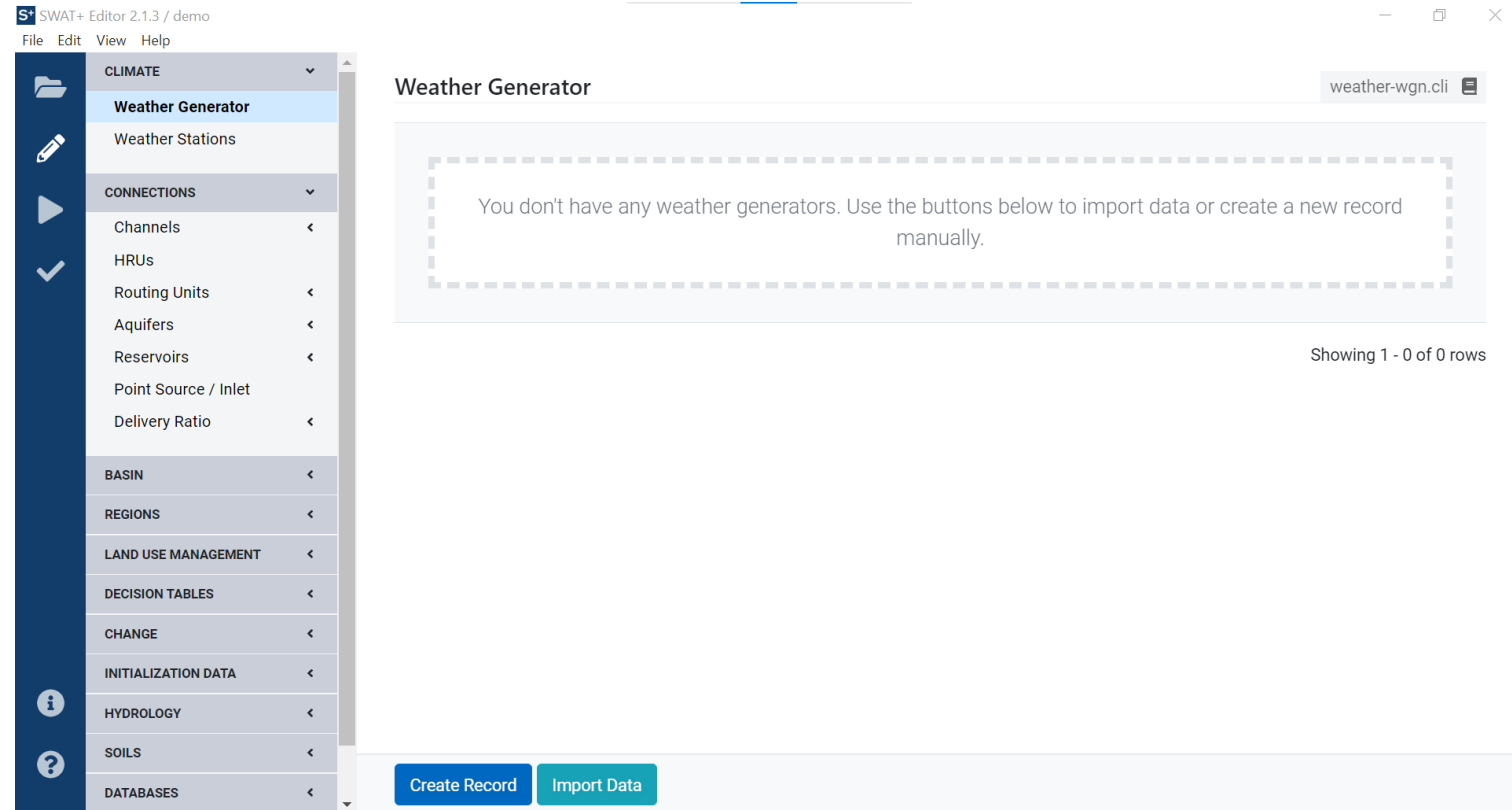
- The menu lists the editor sections, which correspond loosely to SWAT+ input file names.
 - First, we need to import weather generator and observed weather data.
1. Click *Add weather generators now* in the main window (or *Weather Generator* in the menu on the left).



Weather Generator

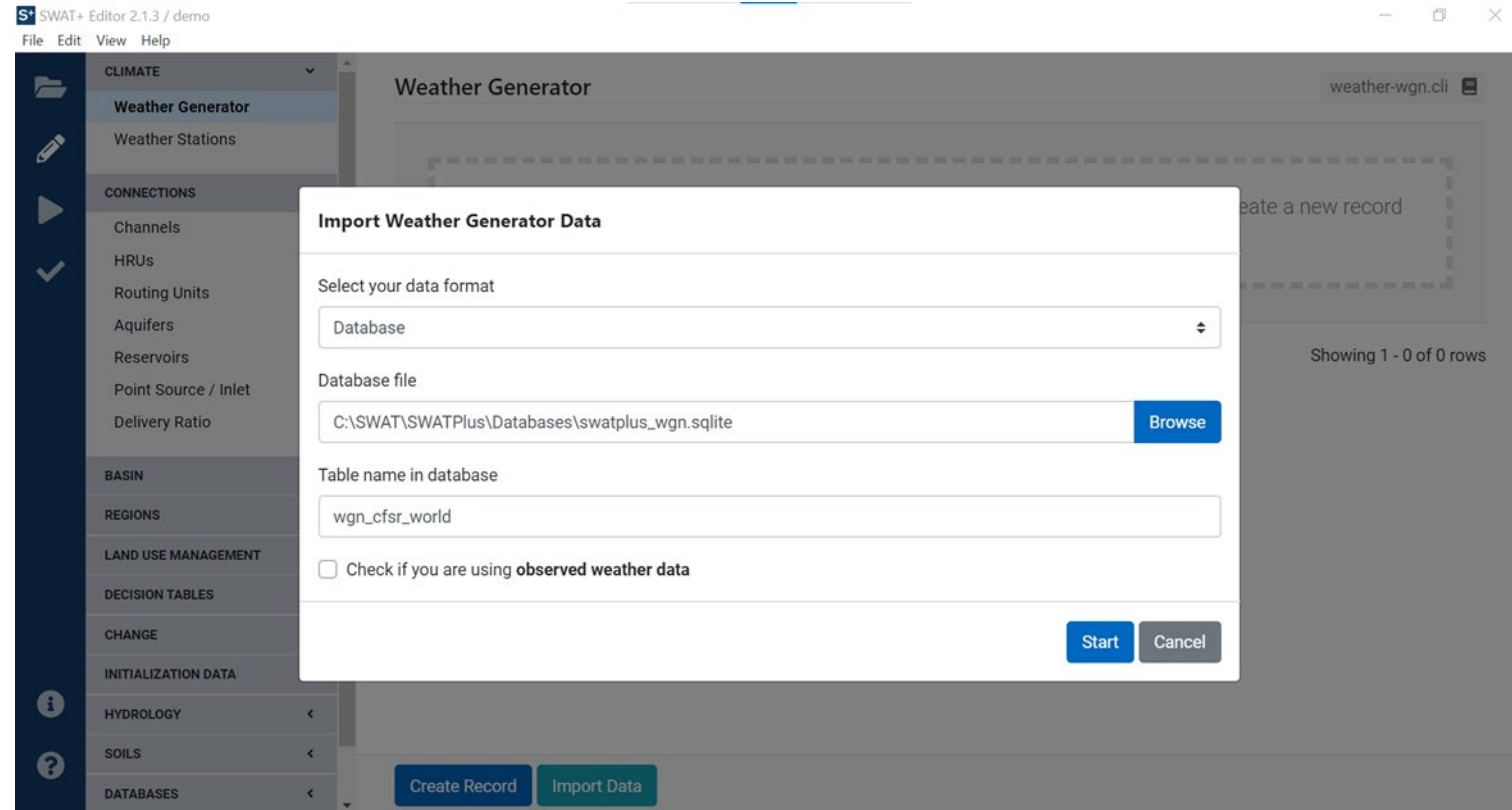
- You can add weather generators manually by clicking *Create new record* or import weather generator data from an external database, which is what we will do in this case.

1. Click *Import Data*.



Import Weather Generator Data

- The SWAT+ Editor should already have selected the appropriate data format, database file, and table name in the database.
1. Check the box at the bottom to indicate that you are using observed weather data.
 - Checking this box will prevent the SWAT+ Editor from creating stations based on the weather generators as we prefer to create them based on the observed weather data.
 2. Click *Start*.



List of Weather Generators

- The SWAT+ Editor should now show a list of weather generators that are located in or near the catchment.
 - Next, we will import observed weather data and define weather stations.
1. Click *Weather Stations* in the menu on the left.

SWAT+ Editor 2.1.3 / demo

File Edit View Help

CLIMATE

Weather Generator

Weather Stations

CONNECTIONS

Channels

HRUs

Routing Units

Aquifers

Reservoirs

Point Source / Inlet

Delivery Ratio

BASIN

REGIONS

LAND USE MANAGEMENT

DECISION TABLES

CHANGE

INITIALIZATION DATA

HYDROLOGY

SOILS

DATABASES

Weather Generator

Search...

NAME	LATITUDE	LONGITUDE	ELEVATION (M)	RAIN YEARS
314n834w	31.38	-83.44	86.00	32
314n838w	31.38	-83.75	92.00	32
314n841w	31.38	-84.06	71.00	32
317n834w	31.69	-83.44	104.00	32
317n838w	31.69	-83.75	122.00	32
317n841w	31.69	-84.06	79.00	32
320n834w	32.00	-83.44	86.00	32
320n838w	32.00	-83.75	84.00	32
320n841w	32.00	-84.06	99.00	32

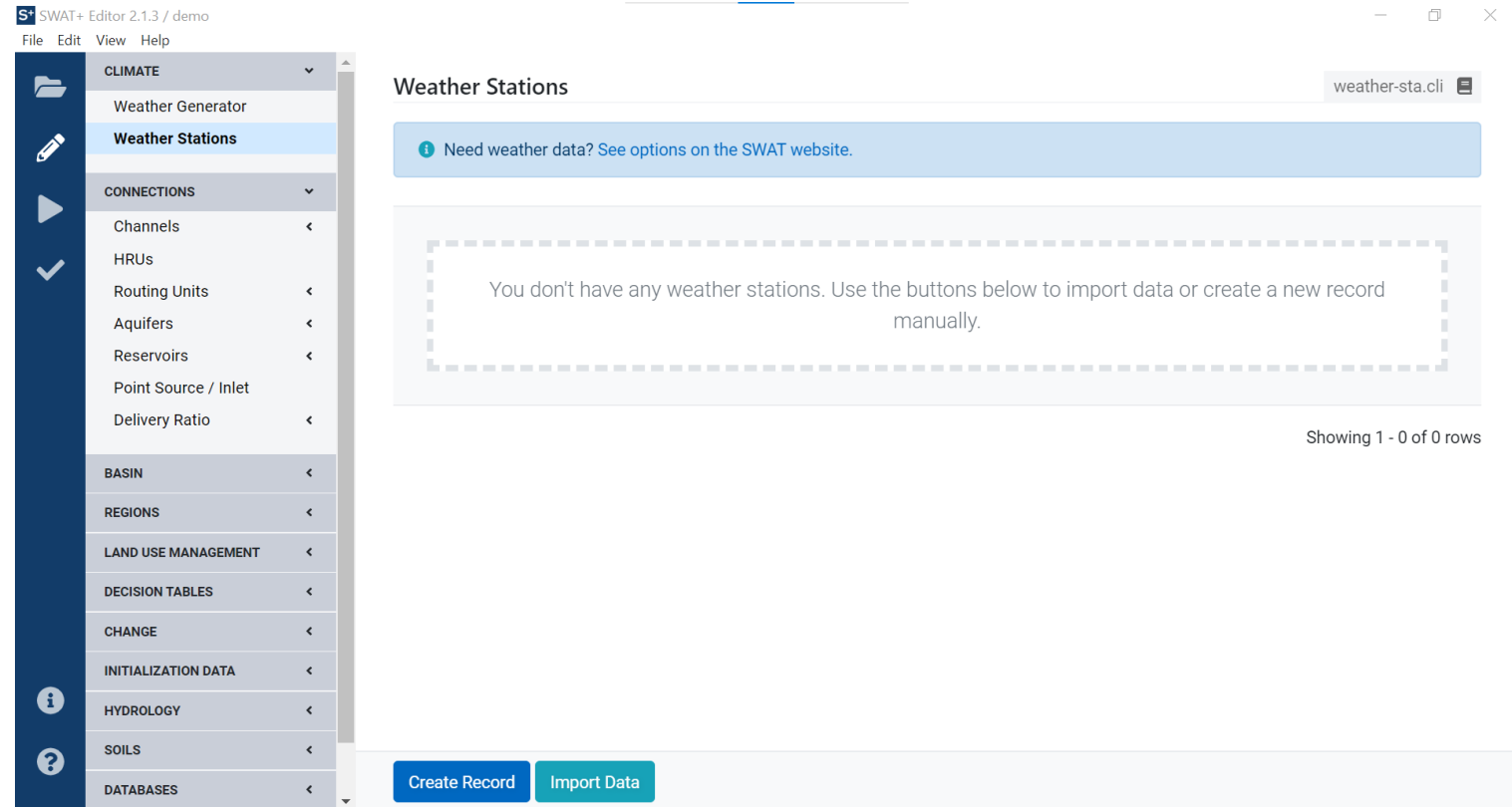
Showing 1 - 9 of 9 rows

Create Record Import Data

Weather Stations

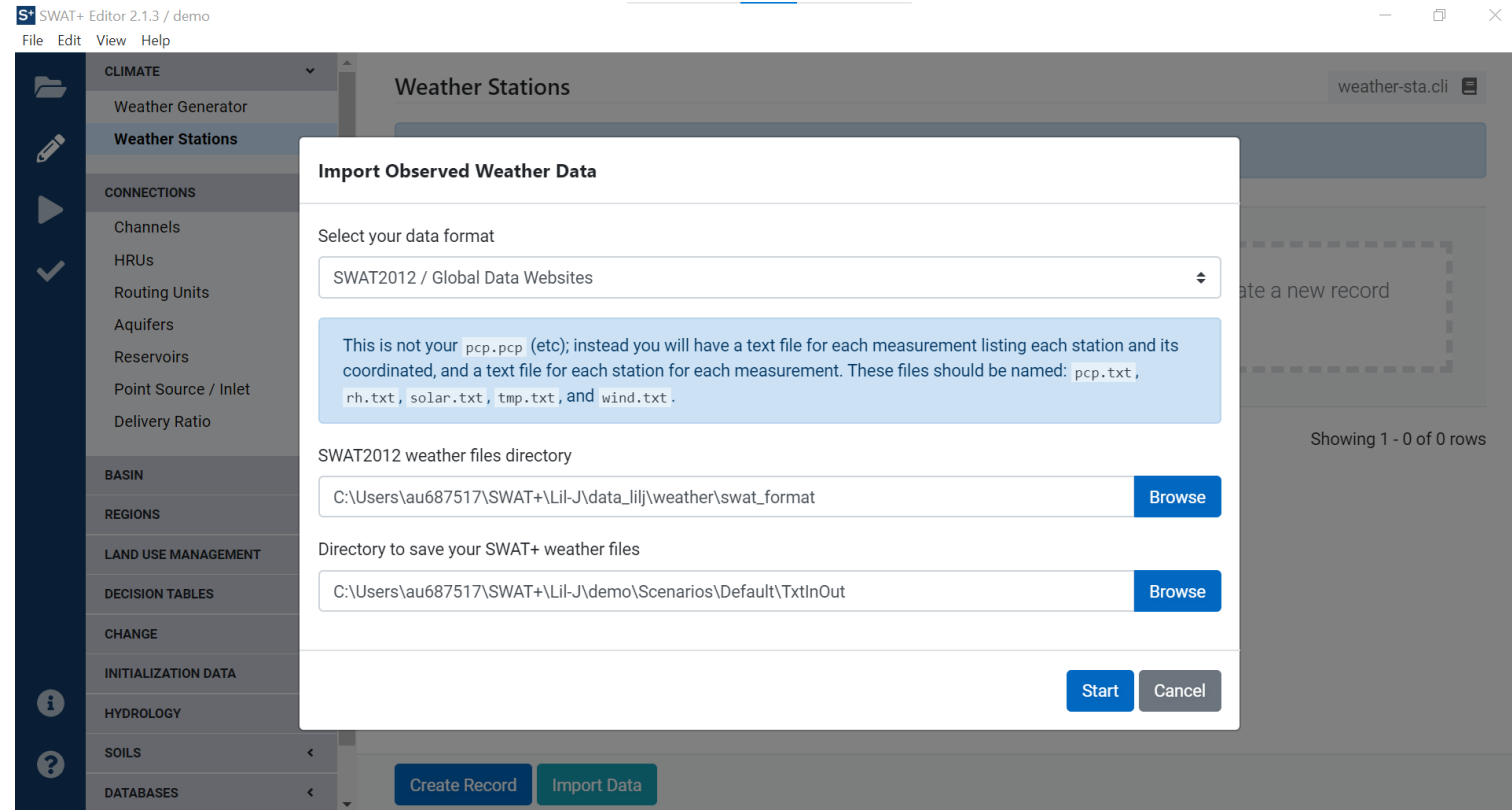
- If you need weather data for your watershed, you can click the provided link to see options on the SWAT website.

1. Click *Import Data*.



Import Observed Weather Data

- In this case we will use the weather data that is included in the example dataset.
 - 1 station
 - SWAT2012 format
1. Click *Browse* to navigate to the weather folder in the input file directory and click *Select Folder*.
 2. Click *Start*.



List of Weather Stations

- The SWAT+ Editor should now show a list of weather stations for the watershed.
 - We only had observed data for one station, but two weather generators were selected, so two weather stations were defined.
 - Next, we will prepare our first SWAT+ run.
1. Click the *Run SWAT+* icon.

The screenshot shows the SWAT+ Editor 2.1.3 / demo interface. On the left is a vertical sidebar with a menu. The 'CLIMATE' section is expanded, showing 'Weather Generator' and 'Weather Stations' (which is selected). Below this are 'CONNECTIONS' (Channels, HRUs, Routing Units, Aquifers, Reservoirs, Point Source / Inlet, Delivery Ratio), 'BASIN', 'REGIONS', 'LAND USE MANAGEMENT', 'DECISION TABLES', 'CHANGE', 'INITIALIZATION DATA', 'HYDROLOGY', 'SOILS', and 'DATABASES'. The main window is titled 'Weather Stations' and has a file icon labeled 'weather-sta.cli'. Below the title is a blue banner with an information icon and the text 'Need weather data? See options on the SWAT website.' Below this is a search bar labeled 'Search...'. A table lists two weather stations:

	NAME	WGN	PRECIPITATION	TEMPERATURE	SOLAR RADIATION	REL. HUMIDITY	WIND SPEED	WIND DIRECTION	ATMO. DEP.	
<input checked="" type="checkbox"/>	s31494n83526w	314n834w	pcp144.pcp	lrew_tmp.tmp	lrew_slr.slr	lrew_hmd.hmd	lrew_wnd.wnd	null	null	3
<input checked="" type="checkbox"/>	s31727n83738w	317n838w	pcp144.pcp	lrew_tmp.tmp	lrew_slr.slr	lrew_hmd.hmd	lrew_wnd.wnd	null	null	3

Showing 1 - 2 of 2 rows

At the bottom of the main window are two buttons: 'Create Record' and 'Import Data'.

Simulation Settings and Run SWAT+

- In the Run SWAT+ window, we can define our simulation settings and start the SWAT+ run.

1. Click *Set your simulation period*.

The screenshot shows the SWAT+ Editor 2.1.3 / demo window. The interface includes a menu bar (File, Edit, View, Help) and a sidebar with icons for file operations, editing, running, and saving. The main content area is divided into two sections: 'Confirm Simulation Settings' and 'Run SWAT+'.

Confirm Simulation Settings

Choose where to write your input files	C:\Users\au687517\SWAT+\Lil-J\demo\Scenarios\Default\TxtInOut
Set your simulation period	1988 - 2012
Choose output to print	

Run SWAT+

Before running the model, we must write the input files used by the model. If you have modified your inputs via the edit section since last running the model, be sure to keep this box checked. Check the third box to read your output files into a SQLite database. This will be used by the visualization tool in QSWAT+. If you do not intend to use this feature, you may uncheck this box to save time.

<input checked="" type="checkbox"/> Write input files
<input checked="" type="checkbox"/> Run SWAT+ rev. 60.5.4 <input type="checkbox"/> Use debug version?
<input checked="" type="checkbox"/> Analyze output for visualization

At the bottom, there are three buttons: 'Save Settings & Run Selected', 'Save Scenario', and 'Exit SWAT+ Editor'.

Simulation - Time

- Starting and ending date of the simulation
 - You can change the simulation time step to sub-daily by clicking *Advanced user options*.
1. Change the starting date to January 1, 2005.

The screenshot shows the 'Confirm Simulation Settings' dialog box in the SWAT+ Editor 2.1.3 / demo. The dialog has a dark blue sidebar on the left with icons for file management, editing, simulation, and help. The main area contains the following sections:

- Choose where to write your input files:** C:\Users\lau687517\SWAT+\Lib-J\demo\Scenarios\Default\TxtInOut
- Set your simulation period:** 1988 - 2012
- Make sure your simulation dates fall within the dates in your [observed weather files](#). Simulation dates outside this range will result in simulated weather.**
- Starting date of simulation:** January 1, 2005
- Ending date of simulation:** December 31, 2012
- Advanced user options...** (button)
- Choose output to print:** (empty field)
- Run SWAT+**
 - Before running the model, we must write the input files used by the model. If you have modified your inputs via the edit section since last running the model, be sure to keep this box checked. Check the third box to read your output files into a SQLite database. This will be used by the visualization tool in QSWAT+. If you do not intend to use this feature,

At the bottom, there are three buttons: 'Save Settings & Run Selected', 'Save Scenario', and 'Exit SWAT+ Editor'.

Simulation - Print

- Number of years to skip when printing output
- Starting and ending date for printing daily output
- Print interval
- Print objects

1. Change the warm-up period to 3.

SWAT+ Editor 2.1.3 / demo

File Edit View Help

Choose output to print

Warm-up period

 Number of years to skip printing output

	Daily	Monthly	Yearly	Average	Outputs
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Model Components					
Channel	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	channel_sd channel_sdmorph
Aquifer	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	aquifer
Reservoir	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	reservoir
Point Source (Recall)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	recall
Routing Unit	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	ru
Hydrology	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	hyd
Basin Model Components					
Channel	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	basin_sd_cha basin_sd_chamorph

Advanced user options...

☐ Soil nutrients carbon output file ☐ Management output file
☐ Hydrograph connect output file ☐ Flow duration curve output file
☐ Print output files in CSV format

Date to start printing output

 Leave blank to print entire simulation period

Date to stop printing output

 Leave blank to print entire simulation period

Daily print within the period (e.g., interval=2 will print every other day)

Save Settings & Run Selected Save Scenario Exit SWAT+ Editor

Simulation - Print Objects

- List of output files that can be printed for spatial objects in SWAT+.
- Each file can be printed at a daily, monthly, yearly, and average annual time step.

1. Check the boxes as shown in the screenshots to the right.

	Daily	Monthly	Yearly	Average	Outputs
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
Model Components					
Channel	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	channel_sd channel_sdmorph
Aquifer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	aquifer
Reservoir	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	reservoir
Point Source (Recall)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	recall
Routing Unit	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	ru
Hydrology	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	hyd
Basin Model Components					
Channel	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	basin_sd_cha basin_sd_chamorph
Aquifer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	basin_aqu
Reservoir	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	basin_res
Point Source (Recall)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	basin_psc
Nutrient Balance					
Basin	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	basin_nb
Landscape Unit	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	lsunit_nb
HRU	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	hru_nb
Water Balance					
Basin	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	basin_wb
Landscape Unit	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	lsunit_wb
HRU	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	hru_wb
Plant Weather					
Basin	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	basin_pw
Landscape Unit	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	lsunit_pw
HRU	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	hru_pw
Losses					
Basin	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	basin_ls
Landscape Unit	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	lsunit_ls
HRU	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	hru_ls

Run the Model

- We are now ready to start the first model run.
- You must write the input files every time you changed any parameters within the SWAT+ Editor.
- We will not use the debug version of the code as it is much slower than the release version and we do not anticipate any problems.

1. Click *Save Settings & Run Selected*.

- A window is displayed showing the progress of the simulation.

The screenshot shows the SWAT+ Editor 2.1.3 / demo window. The 'Confirm Simulation Settings' dialog box is open, displaying the following settings:

- Choose where to write your input files:** C:\Users\au687517\SWAT+\Lil-J\demo\Scenarios\Default\TxtInOut
- Set your simulation period:** 1988 - 2012
- Choose output to print:** (empty field)

Below the settings, the 'Run SWAT+' section contains the following instructions and options:

Before running the model, we must write the input files used by the model. If you have modified your inputs via the edit section since last running the model, be sure to keep this box checked. Check the third box to read your output files into a SQLite database. This will be used by the visualization tool in QSWAT+. If you do not intend to use this feature, you may uncheck this box to save time.

- ☒ Write input files
- ☒ Run SWAT+ rev. 60.5.4
 - ☐ Use debug version?
- ☒ Analyze output for visualization

At the bottom of the window, there are three buttons: 'Save Settings & Run Selected', 'Save Scenario', and 'Exit SWAT+ Editor'.

Post-Run Options

- When the model run is completed, a window is displayed offering us some options:

- Run SWAT+ Check
- Save Scenario
- Open Results Directory
- Back to Editor
- Exit SWAT+ Editor

1. Click *Save Scenario* and enter run01 as the scenario name and click *Save Scenario*.

All selected tasks have completed. ×

Run SWAT+ Check

Save Scenario

Open Results Directory

Back to Editor Exit SWAT+ Editor

Save Scenario

Saving a scenario will make a copy your project database as well as all model input and output text files. We recommend running the model before saving your scenario. After saving completes, any additional changes made to your project will not affect the saved scenario. You may load the saved scenario back to the editor from the [project setup screen](#).

Give your scenario a unique name

run01

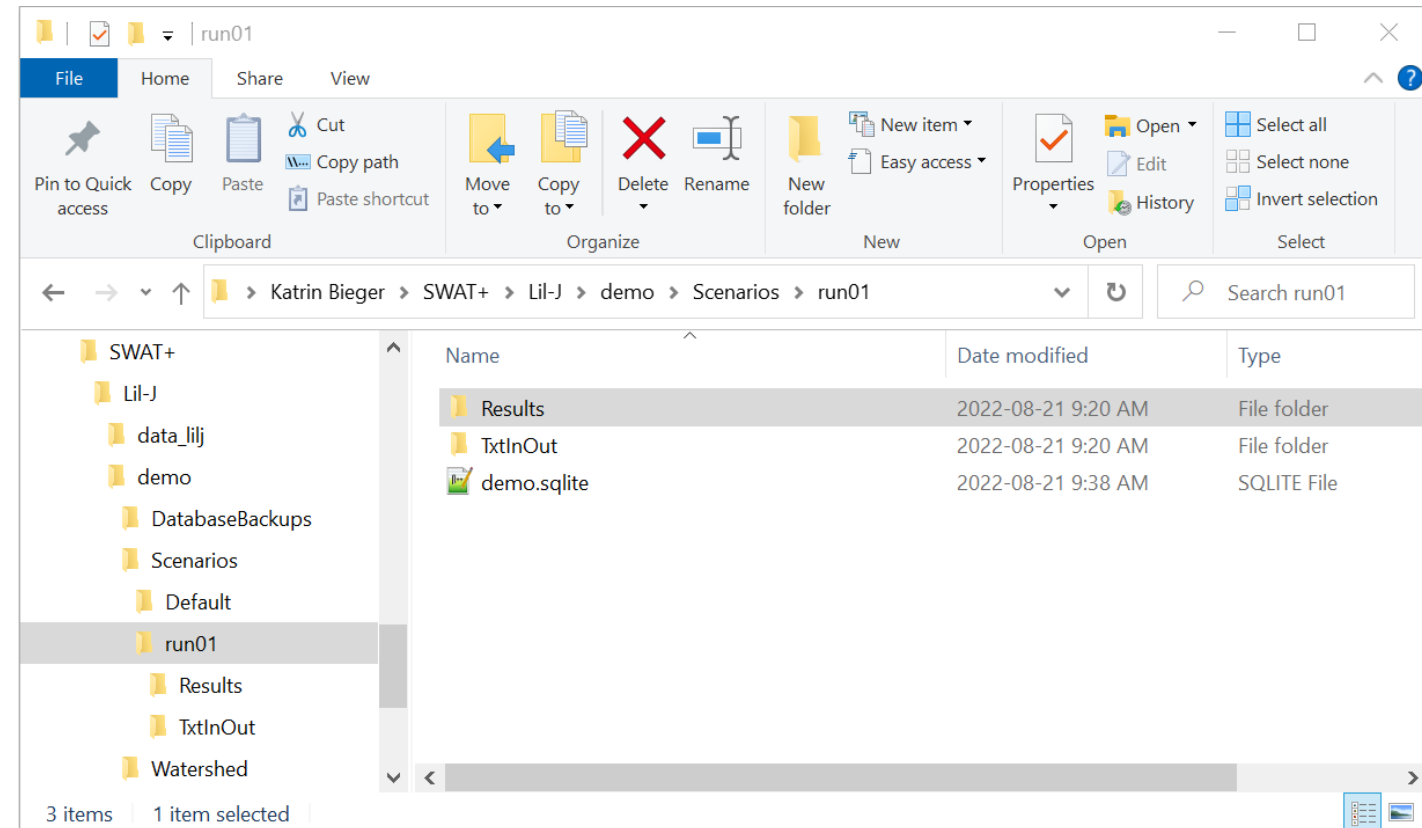
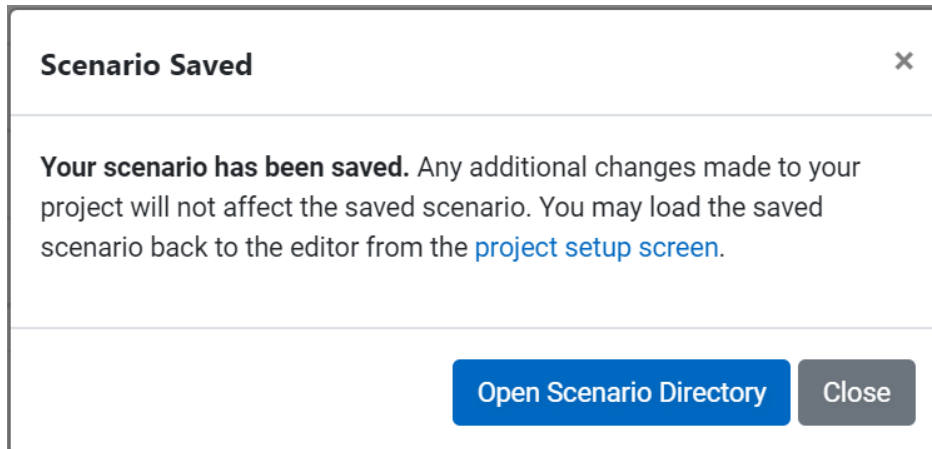
Will create a new folder with this name under your project's Scenarios directory. Cannot be the same name as an existing scenario.

Save Scenario Cancel

Saved Scenarios

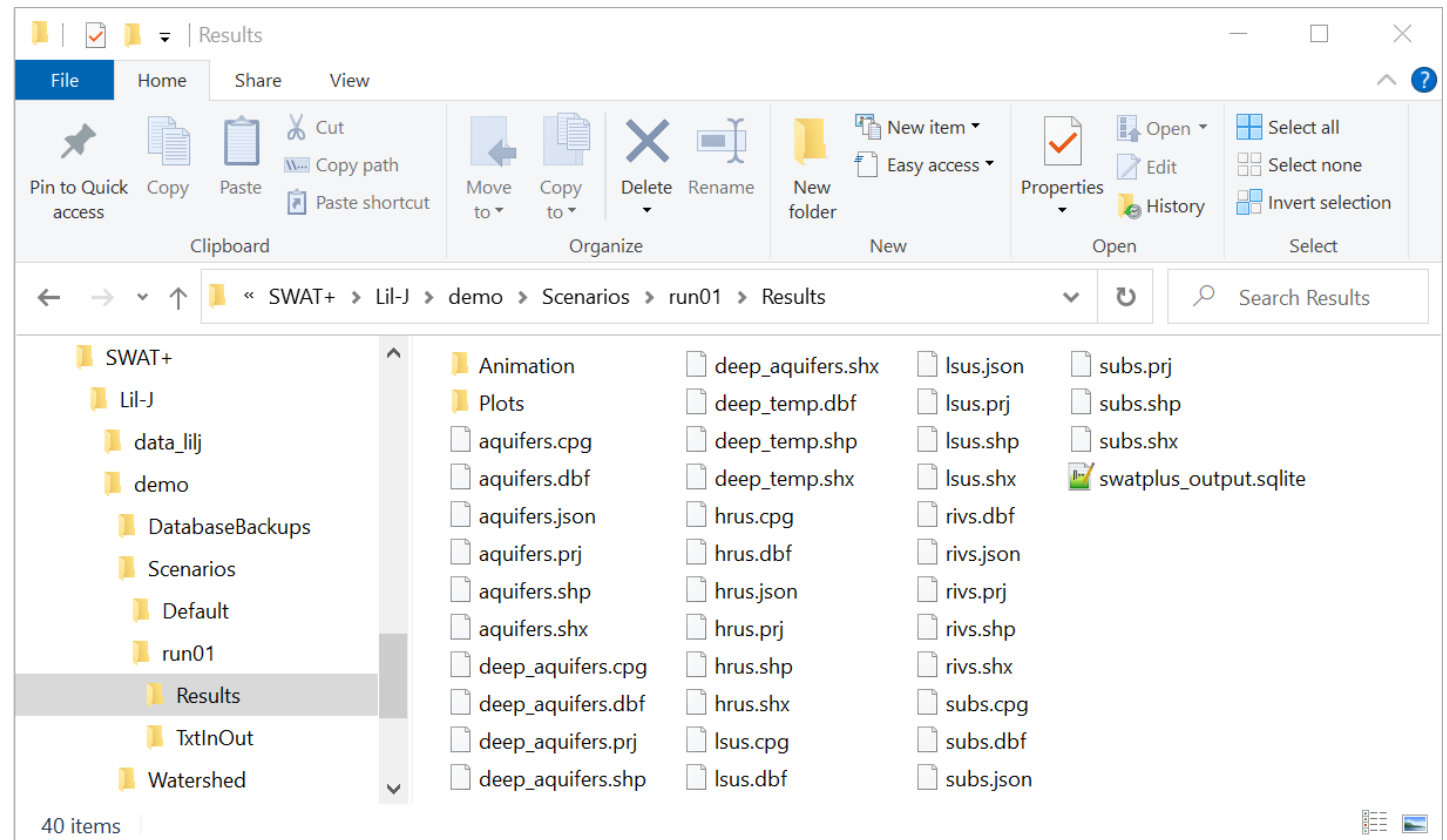
- A window is displayed informing us that the scenario has been saved and that additional changes made to our project will not affect the saved scenario.

- Click *Open Scenario Directory*.
- In the SWAT+ Editor, click *Close* to close the Scenario Saved form.



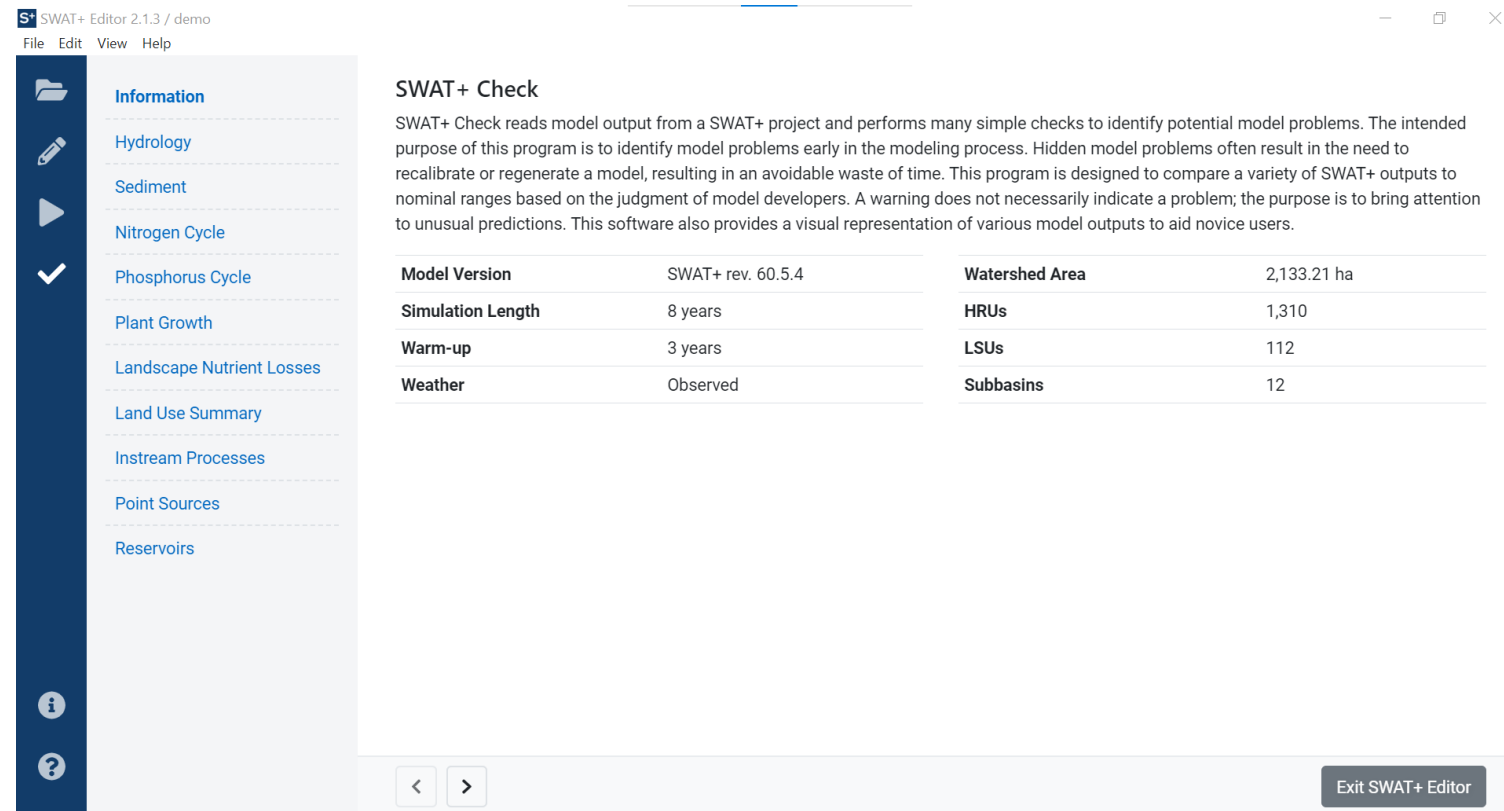
Results Folder

- Several files have been copied to the results folder:
 - SQLite database containing SWAT+ output
 - Shapefiles that we may need to map model output
- Also, folders have been created for saving some of the animations and plots we will create shortly.



SWAT+ Check

- SWAT+ Check reads model output from a SWAT+ project and performs many simple checks to identify potential model problems.
- You can access SWAT+ Check at any time by clicking the SWAT+ check icon.
- You can navigate to different processes/model components using the menu on the left.



The screenshot shows the SWAT+ Editor 2.1.3 / demo interface. On the left is a vertical menu with icons for Information, Hydrology, Sediment, Nitrogen Cycle, Phosphorus Cycle (highlighted with a checkmark), Plant Growth, Landscape Nutrient Losses, Land Use Summary, Instream Processes, Point Sources, and Reservoirs. At the bottom of the menu are information and help icons. The main window is titled 'SWAT+ Check' and contains a descriptive paragraph about the tool's purpose. Below the text are two tables. The first table lists model parameters: Model Version (SWAT+ rev. 60.5.4), Simulation Length (8 years), Warm-up (3 years), and Weather (Observed). The second table lists watershed characteristics: Watershed Area (2,133.21 ha), HRUs (1,310), LSUs (112), and Subbasins (12). At the bottom of the window are navigation arrows and an 'Exit SWAT+ Editor' button.

SWAT+ Editor 2.1.3 / demo

File Edit View Help

SWAT+ Check

SWAT+ Check reads model output from a SWAT+ project and performs many simple checks to identify potential model problems. The intended purpose of this program is to identify model problems early in the modeling process. Hidden model problems often result in the need to recalibrate or regenerate a model, resulting in an avoidable waste of time. This program is designed to compare a variety of SWAT+ outputs to nominal ranges based on the judgment of model developers. A warning does not necessarily indicate a problem; the purpose is to bring attention to unusual predictions. This software also provides a visual representation of various model outputs to aid novice users.

Model Version	SWAT+ rev. 60.5.4
Simulation Length	8 years
Warm-up	3 years
Weather	Observed

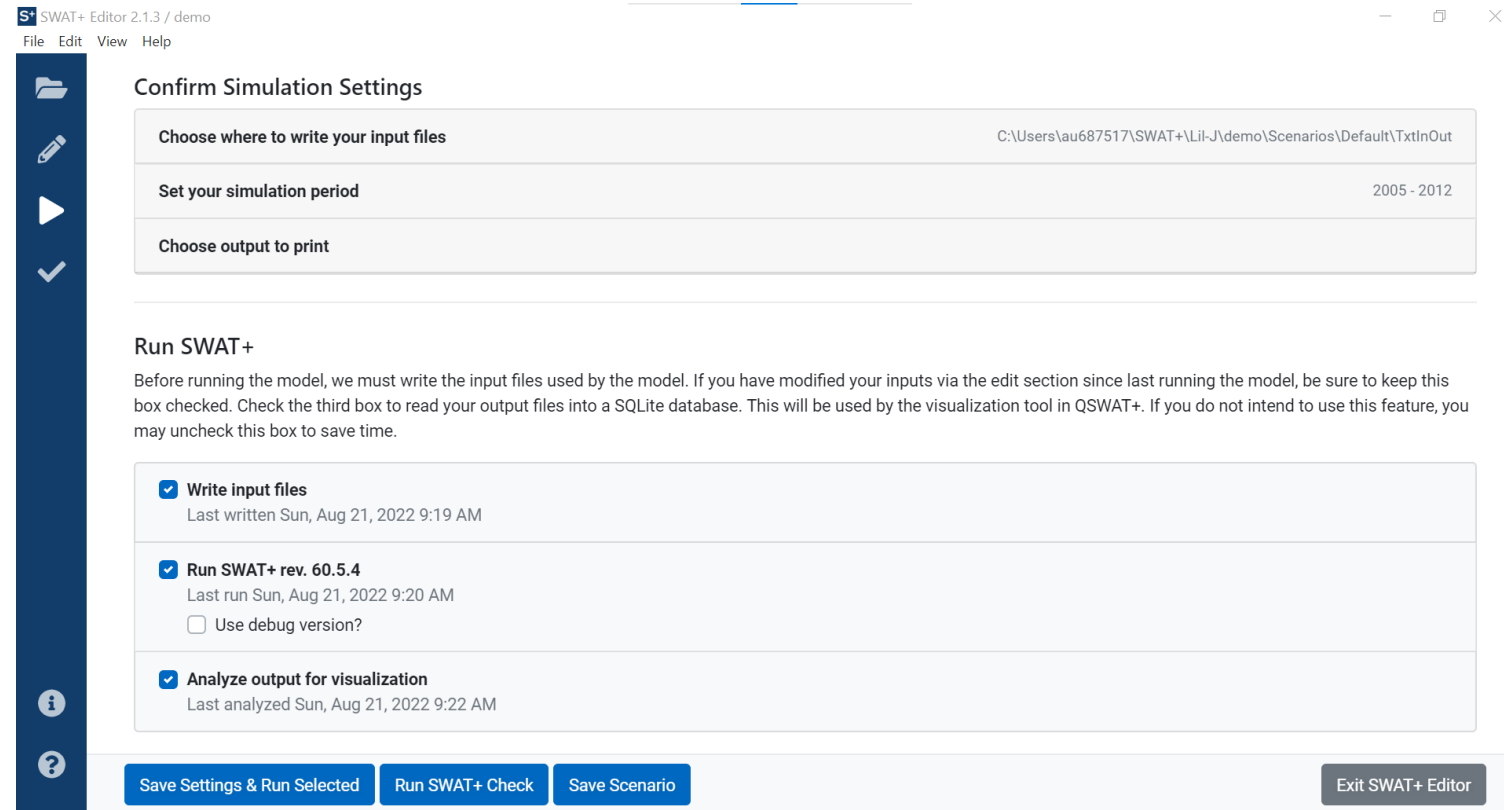
Watershed Area	2,133.21 ha
HRUs	1,310
LSUs	112
Subbasins	12

< >

Exit SWAT+ Editor

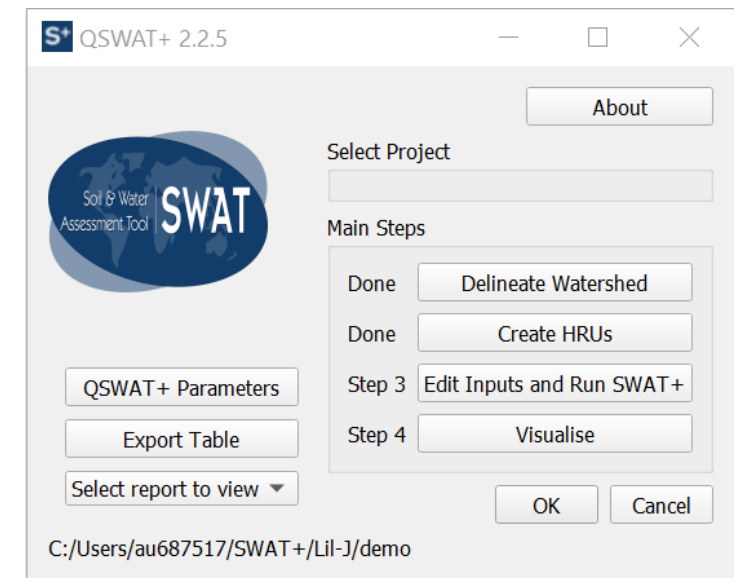
Closing the SWAT+ Editor

- We are now ready to analyze model output. This will be done in QSWAT+.
1. Click *Exit SWAT+ Editor* to return to QSWAT+.



Visualize SWAT+ Output

- Our main form now shows an additional Step 4 (*Visualise*). This becomes available when there is an output database in the Results folder.
1. Click *Visualise* to open the *Visualise Results* form.
- In this workshop, we will only take a quick look at the options provided by QSWAT+ for visualizing SWAT+ output. Please refer to Chapters 7 and 8 in the QSWAT+ Manual for a more detailed description.



Visualize Results Form

- At this point, we have only the scenario called *Default* that the SWAT+ Editor generated and *run01*, which is simply a copy of *Default*.
- The SWAT+ output tables available are the ones we saved, restricted to those that can be visualized.
- The period defaults to the period we ran the model for, excluding the warm-up period.
- There are 4 options available:
 - Static data
 - Animation
 - Plot
 - Post Processing
- There is also a Print section, which we will use to compose print layouts.

The screenshot shows the 'Visualise Results' window in SWAT+. It features a top section with 'Choose scenario' (set to 'Default') and 'Choose SWAT+ output table'. Below this is the 'Choose period' section with 'Start date' (1 January 2008) and 'Finish date' (31 December 2012). The main area has four tabs: 'Static data', 'Animation', 'Plot', and 'Post processing'. The 'Static data' tab is active, showing a 'Choose results shapefile' field, a 'Choose variables' list with 'Add', 'All', 'Del', and 'Clear' buttons, and a 'Choose summary' dropdown set to 'Totals'. A 'Create' button is at the bottom right of this section. At the very bottom, there is a 'Print' section with radio buttons for 'Landscape' (selected) and 'Portrait', a 'Number of maps' spinner set to 1, and a 'Print' button. A 'Close' button is located at the bottom right of the window.

Visualizing Static Data

1. Select the *lsunit_pw_mon* output table.
2. Select the *Static data* tab.
 - The pull-down menu under *Choose variables* contains all the outputs in the *lsunit_pw_mon* table. You can select them one at a time using *Add*, but it is easier to select all of them using *All*.
3. Click *All* and then highlight *bioms*.
 - There are several options available under *Choose summary* (note that not all summaries make sense for all outputs):
 - Totals: Total value for entire simulation period.
 - Daily, monthly, and annual means: Total value divided by number of days, months, or years, respectively, in the simulation.
 - Maxima and minima: Maximum and minimum values of the variable in the simulation.
4. Select *Monthly means* and click *Create*.

S+ Visualise Results

Choose scenario: Default

Choose SWAT+ output table: lsunit_pw_mon

Choose period:

Start date: 1 January 2008

Finish date: 31 December 2012

Static data | Animation | Plot | Post processing

Choose results shapefile: mo\Scenarios\Default\Results\lsunit_pw_monresults.shp

Choose variables:

lai

Add | All | Del | Clear

bioms
yld
residue
sol_tmp
strsw
strsa
strstmp
strsn
strsp

Choose summary: Monthly mea

Create

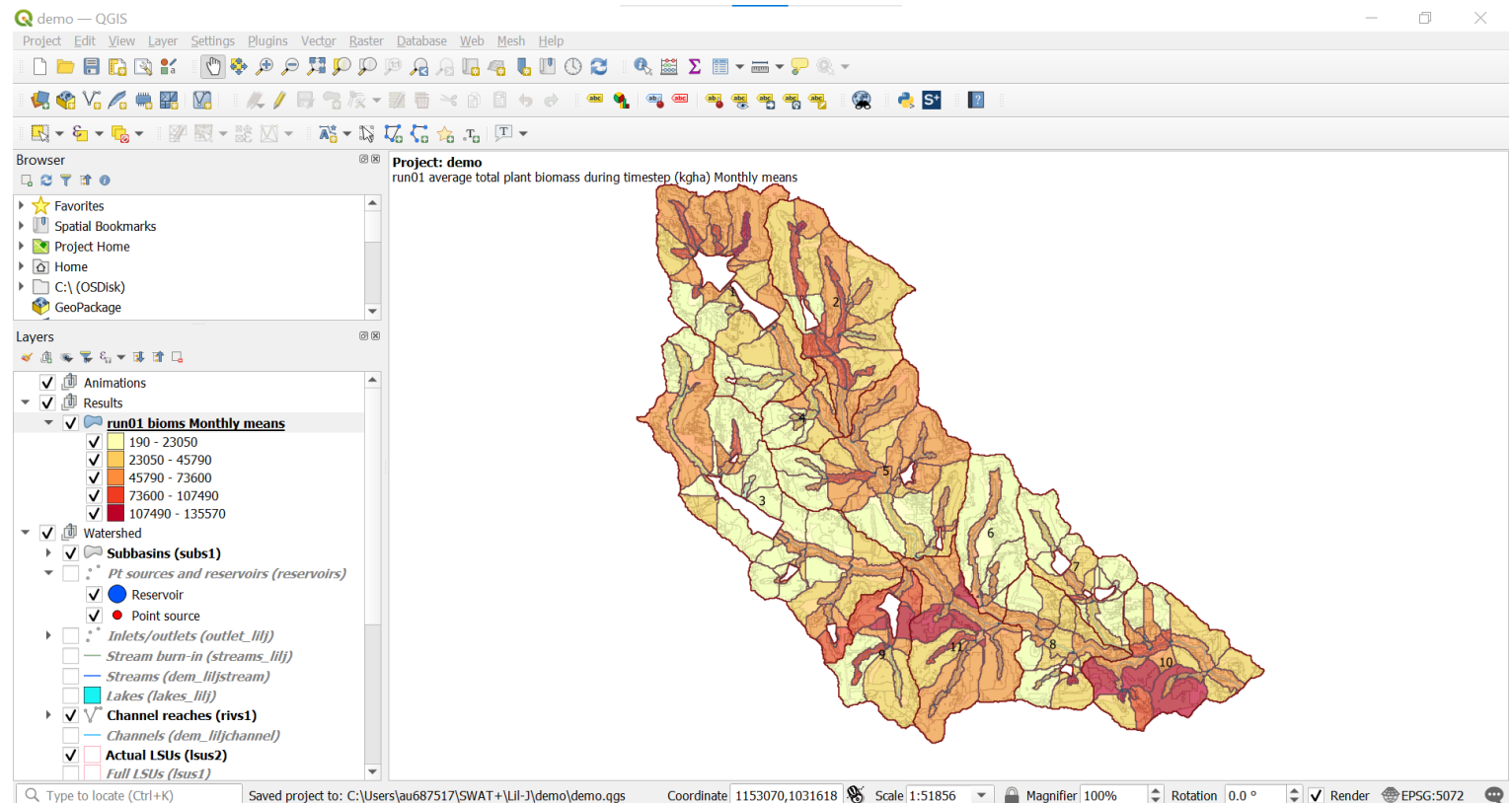
Print:

☐ Landscape ☒ Portrait Number of maps: 1 Print

Close

Visualizing Static Data

- A file named *lsunit_pw_monresults.shp* is created in the Results directory and a map showing the monthly means of biomass per Landscape Unit is displayed in QGIS.
- Now you can
 - change the file name and/or location,
 - change the variable to display or the summary,
 - examine the data being displayed by opening the attribute table of the results shapefile, and
 - create and display new data as a function of existing data using the QGIS Field Calculator.



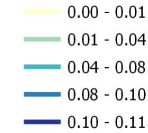
Printing

SWAT+ results: demo

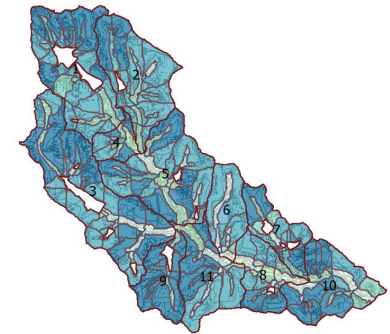
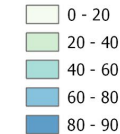


- QSWAT+ provides templates to create a composition of 1, 2, 3, 4, or 6 results maps laid out in either landscape or portrait mode.
 - The templates are not expected to provide final compositions. You can edit them to change text, change the size and position of maps, etc.
 - We will make a 3-map display.
1. Switch to the *lsunit_wb_mon* output table and create a map of the monthly means of *et*.
 2. Switch to the *channel_sdmorph_mon* output table and create a map of the monthly means of *flo_out*.
 3. Under Print, select *Portrait* and 3 as the *Number of maps* and click *Print*.
 4. Save it as a PDF or image (*Layout > Export as Image*).

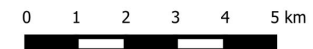
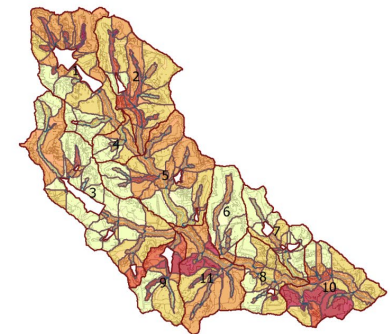
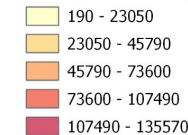
run01 flo_out Monthly means



run01 et Monthly means



run01 bioms Monthly means



Rules for Creating Print Layouts

- If n maps are requested, the first n maps in the Results group of the Layers panel are used, regardless of current visibility.
- Layers in the Watershed group are included as background if they are currently visible. The Watershed layer is commonly used to provide subbasin boundaries. Results layers have transparency set to 35% so that background layers are visible.
- If you want to include another map, for example a landuse map, drag it into the Results group before clicking Print.
- The map layers in the composition are set locked. Otherwise, they would only show whatever the canvas shows, but they can still be resized or moved.
- The scale bar is attached to the top left map. If you change its size the scale bar will adjust, but you need to change the others manually to match.
- Hint: maximize the watershed size in the map canvas before you start to set up the composition.

Animation

1. Select the *Animation* tab.
 2. Under *Set up animation*, select *New*.
 3. Under *Animation mode*, select *Map canvas*.
 4. Select *flo_out* as the *Variable*.
- We can only select one variable at a time, since animation continuously rewrites a shapefile and we do not want it to run too slowly.
 - QSWAT+ uses 5 classes and calculates suitable breaks using the Jenks natural breaks algorithm. This calculation involves all the *flo_out* values for all the channels for the whole period and can take some time.
3. Set the *Speed* to 5 and click the *Play* button.

The screenshot shows the 'Visualise Results' window in QSWAT+. The 'Animation' tab is selected. Under 'Set up animation', the 'New' radio button is chosen, and 'flo_out' is selected as the variable. Under 'Animation mode', the 'Map canvas' radio button is selected. The 'Start date' is set to 1 January 2008, and the 'Finish date' is set to 31 December 2012. The 'Speed' is set to 5. The 'Play' button is visible. The 'Close' button is at the bottom right.

Visualise Results

Choose scenario: run01

Choose SWAT+ output table: channel_sdmorph_mon

Choose period

Start date: 1 January 2008

Finish date: 31 December 2012

Static data | Animation | Plot | Post processing

Set up animation

☒ New ☐ Current Variable: flo_out

Animation mode

☒ Map canvas ☐ Print composer

December 2012

Speed: 5

Start recording Play Play recording

Close

Additional Animation Options

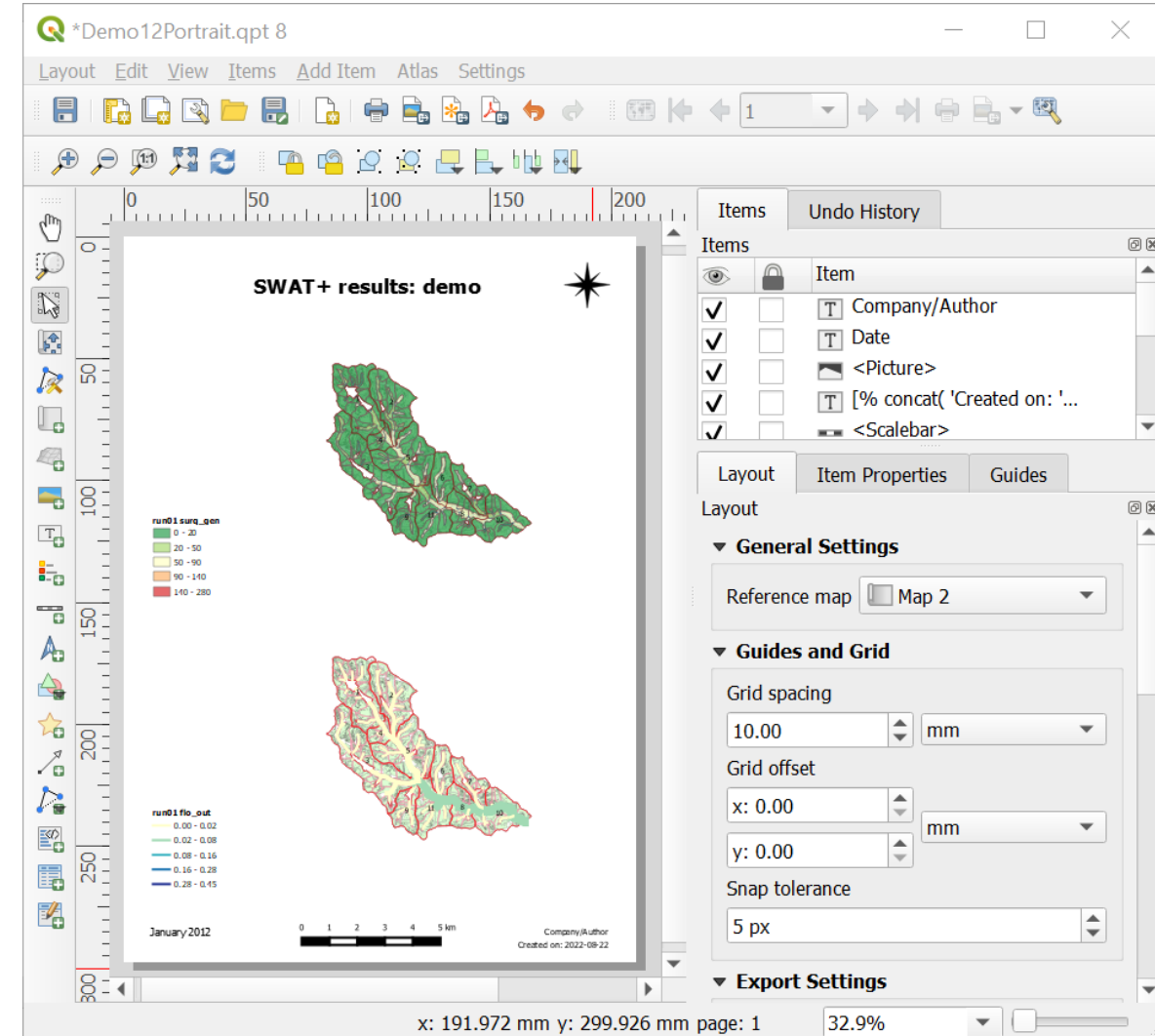
- You can pause with the pause button and rewind to the start.
- You can drag the slider or use the left and right arrow keys to step through the animation.
- At each point the map canvas shows the values of flo_out for each channel at the date shown above the slider. We chose earlier to print monthly output, so the animation proceeds in monthly steps.
- Animation is done by changing the attribute values of a shapefile, rivs0.shp in this case, in the current scenario's Results\Animation directory. You can save this file, but remember it only contains values for the time point currently shown.

1. Rewind the animation by dragging the slider or using the rewind button.
 2. Click the green *Start recording* button and click the Play button to run the animation again.
 3. When it reaches the end (or whenever you like) click *Stop recording*.
- Each step in the recording has been saved as a PNG file. When you stop recording the PNG files are assembled into an animated GIF.
 - After recording, clicking *Play* will play the animated GIF using whatever is the default tool on your machine.
 - The speed of the recording is according to the speed setting when *Stop recording* is clicked. It may play faster than the animation itself, so you may want to remake it with a different speed setting.
 - Stop recording deletes the PNG files for the individual time steps in the recording. If you want to use them, e.g., to use GIMP to make a more elaborate animation, pause the animation or wait for it to finish, do not click Stop recording, and find them in Results\Animation folder.

- If we want to animate more than one variable at once the map canvas is not very suitable as the animations will overlay each other. Instead, we can use a print composition.
1. Change the table to *lsunit_wb_mon*.
 2. Keep the *New* setting (if you choose *Current* the next animation will replace the old one).
 3. Select *surq_gen* as the *Variable*.
 4. Select *Print Composer* as the *Animation mode*.
 5. Under *Composer options* select *Portrait* and *2* as the *Number of maps*. This selects the first 2 maps in the Animation group, regardless of visibility.
 6. Move the slider by hand towards the end of the period, e.g., January 2012, to reduce the number of images.
 7. Click *Start recording*. A form explains that the composer will start and gives instructions how you can modify it.
 8. Click *OK* and the QGIS Layout window appears.

Print Animation cont'd

1. We are not going to make any changes right now, so close the Layout window.
 2. The red start/stop button indicates that recording is ready to start. Click *Play*.
 3. The composer is used to generate an image for each time step. When it finishes, click the red *Stop recording* button.
- A message tells you that the recording is stored as *Videon.gif* (n is a number) in the Results folder.
6. Click *Play* to see the saved animation.



- To visually analyze model output, we can produce a graph of one or more variables against time. We might, for example, compare
 - the same variables from different LSUs, channels or HRUs,
 - the same variables from different scenarios, or
 - simulated variables to observed values.
- We are going to compare simulated output from our main outlet with observed data.
 1. Set the SWAT+ output table to `channel_sdmorph_day` and select the *Plot* tab.
 2. Under *Choose observed data file* navigate to the outlet folder in the input file directory, select `qobs_lilj.csv` and click *Open*.
 3. Click *Add plot* to create a plot entry.
 4. Set the Unit to 1, which is the main outlet channel and the Variable to `flow_out`.

Plotting Results cont'd

- We could now copy this plot using *Copy plot*, add new plots using *Add Plot*, remove plots using *Delete plot*, and move plots using *Move up* and *Move down*.
- Click *Add observed* to add an entry from our observed data file.
 - Click *Plot*.
- We are first asked to provide a name for the output file, which will be a comma separated value file. It is created so that you can afterwards use other tools to display or analyze your model output.
- Choose a suitable name, e.g., flow, and click *Save*.

The screenshot shows the 'Visualise Results' window with the 'Plot' tab selected. The configuration includes:

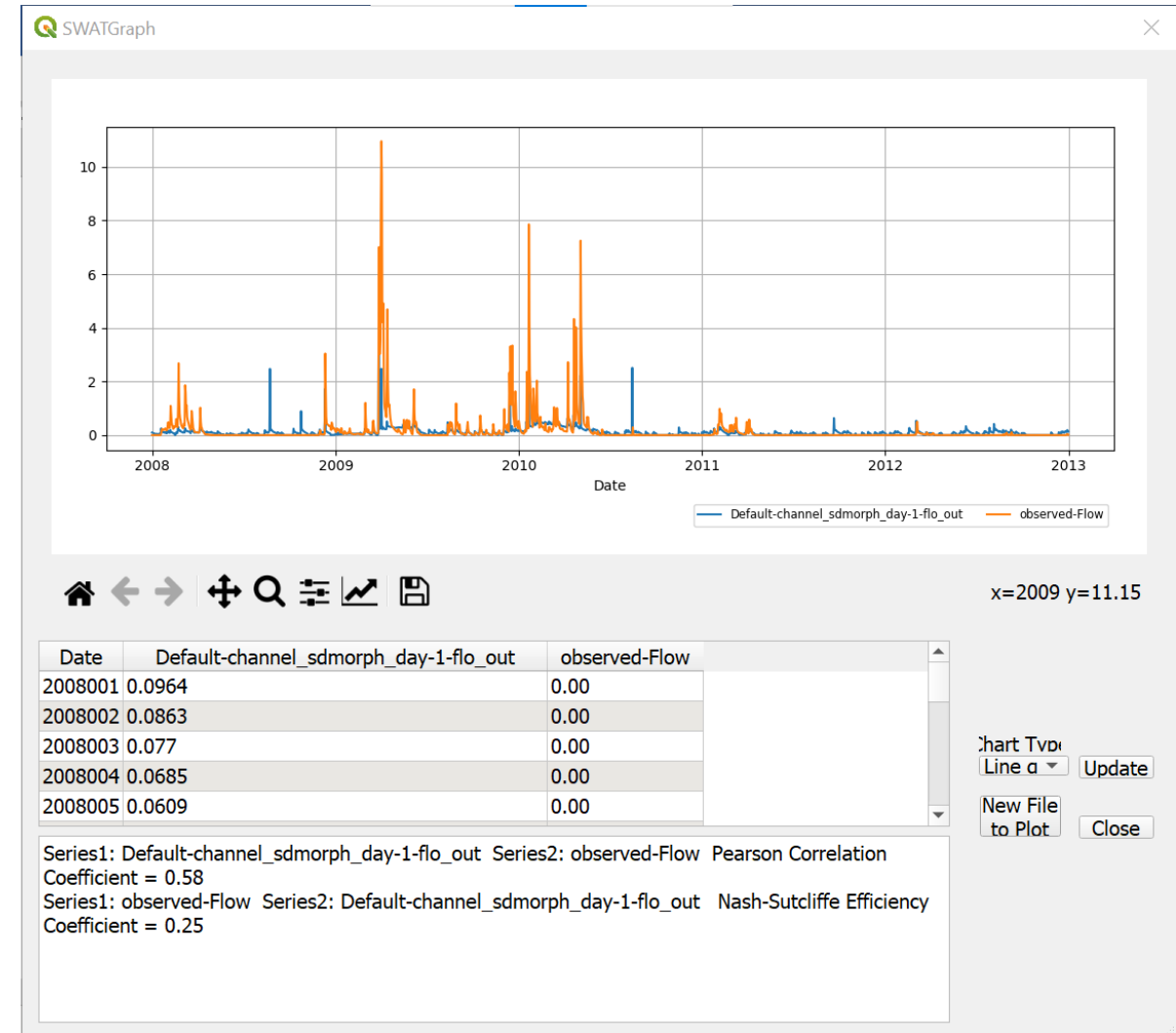
- Choose scenario:** Default
- Choose SWAT+ output table:** channel_sdmorph_day
- Choose period:** Start date (1 January 2008) to Finish date (31 December 2012)
- Choose observed data file (optional):** 17/SWAT+/Lil-1/data_lilj/outlet/qobs_lilj.csv
- Unit:** 1
- Variable:** Flow

On the left side of the 'Plot' tab, there are buttons: Add plot, Delete plot, Copy plot, Move up, Move down, and Add observed.

Scenario	Table	Unit	Variable
Default	channel_sd...	1	flo_out
observed	-	-	Flow

At the bottom right of the 'Plot' tab is a 'Plot' button, and at the bottom right of the entire window is a 'Close' button.

- SWATGraph will be opened, showing
 - a line plot of the data,
 - the data used,
 - the correlation between all pairs of plots, and
 - the Nash-Sutcliffe-Efficiency for all pairs involving an observed plot.
- You can
 - change the line graph to a bar chart using *Chart Type*,
 - pan and zoom to examine parts of the graph in more detail,
 - provide a title and label the axes, and
 - save the plot as an image file for use in documents.



- In the *Post processing* tab, QSWAT+ can calculate several environmental flows if daily channel output was printed.
 - Qq provides for each calendar month the flow in m³/s that is exceeded by q% of the flows in that month. For example, if you set q to be 95%, and set the subbasin to 7, and the August result is 0.03, then 95% of the time the average daily flow from subbasin 7 in August is at least 0.03 m³/s.
 - dQp provides a single flow statistic for a selected subbasin, where d is the number of days for creating moving averages, p is a threshold percentage. Users also need to set a start month (which should not be in a low flow period) and choose between Percentile and Mean. The flow for each year is calculated as the minimum of the moving average flows for that year. Then if Percentile is selected, and p is, say, 95 and d is 21, then 21D95 will be calculated as the flow which is exceeded for 95% of the flows for each year. If Mean is selected then 21Qm is calculated as the mean of the flows for each year and d is ignored.
 - Qb provides annual and monthly statistics for a selected subbasin. A rate of flow for each year is calculated as the minimum moving average for a year, where the length of the moving average is chosen as the one that gives the highest rate of change between the minimum and the previous moving average. The annual result is then the mean of these flows for each year. The values for each month are the annual result multiplied by the variation factor for the month. The variation factor is calculated as the square root of a ratio, the ratio of mean daily flow for days in that month to the minimum such figure for all months.
- Results can be saved, either in separate files or combined into a single file, allowing results of different statistics and different parameters to be retained and compared.
- Note that the example watershed is much smaller than would normally be used for calculating environmental flows.

1. Click *Close* to close the *Visualise Results* form.
- There are several input files that we have not looked at in the SWAT+ Editor yet.
2. Click *Edit Inputs and Run SWAT* in the main QSWAT+ form to open the SWAT+ Editor.
- We will now go through the files that can be edited in the SWAT+ Editor to learn what they are used for by SWAT+ and how we can edit them.
- You can always edit individual records, but for many files you can also export your existing data to CSV or import a CSV file of new values by clicking the *Import/Export Data* button.

Navigating the SWAT+ Editor - Tables

- Sort by a column in the table by clicking on the heading name. It will toggle ascending or descending direction as indicated by the arrows next to the name.
- Tables with many records can be scrolled and then paged by clicking the page number or arrow links at the bottom of the table.
- Each row may contain an edit/view icon on the far left to access the data in the row, and a delete icon on the far right (may need to scroll to access the far right of the table).
- In the search box up top, start typing the name of the objects you want to find. Matching options will appear in the table. Remove the text from the search box to remove the filter.
- In the action bar at the bottom, click create new record to add an item to the table. The import/export data button allows you to quickly access your data in CSV (comma-separated values spreadsheet) format, in most cases.

The screenshot shows the SWAT+ Editor 2.1.3 / demo interface. On the left is a sidebar with a tree view of project components: CLIMATE, CONNECTIONS, BASIN, REGIONS, LAND USE MANAGEMENT, DECISION TABLES, CHANGE, INITIALIZATION DATA, HYDROLOGY (expanded), Topography (selected), Fields, SOILS, DATABASES, and STRUCTURAL. The main window displays the 'Topography' table for the 'topography.hyd' dataset. At the top of the table is a search box and a status indicator 'Showing 1 - 20 of 1954 rows'. The table has columns: NAME, SLP, SLP_LEN, LAT_LEN, DIST_CHA, and DEPOS. Each row represents a topography record with a unique ID (e.g., topohru0001) and numerical values for the other columns. Each row has an edit/view icon on the left and a delete icon on the right. At the bottom of the table is an action bar with 'Create Record' and 'Import/Export' buttons, and a pagination control showing page 1 of 1954.

NAME	SLP	SLP_LEN	LAT_LEN	DIST_CHA	DEPOS
topohru0001	0.03457	60	60	121	0
topohru0002	0.01532	90	90	121	0
topohru0003	0.03251	60	60	121	0
topohru0004	0.02780	90	90	121	0
topohru0005	0.01780	90	90	121	0
topohru0006	0.01526	90	90	121	0
topohru0007	0.03201	60	60	121	0
topohru0008	0.01526	90	90	121	0
topohru0009	0.03201	60	60	121	0
topohru0010	0.02568	90	90	121	0
topohru0011	0.01219	90	90	121	0
topohru0012	0.00791	121	121	121	0
topohru0013	0.03091	60	60	121	0

Navigating the SWAT+ Editor - Editing

- Most objects in SWAT+ have a name field and are identified using this name. Names should be unique and not contain spaces (spaces will be automatically converted to underscores).
- Each edit form will have a save changes button at the bottom. Be sure to click this button after making any changes and before leaving the form.
- Press the back button to return to the previous screen.
- Click copy to make a copy of the current object you are viewing. You will be asked to give the copied object a unique name. Note: the copy function is not available for all object types, including connection objects.

The screenshot shows the SWAT+ Editor 2.1.3 / demo interface. On the left is a sidebar with a tree view of project components: CLIMATE, CONNECTIONS, BASIN, REGIONS, LAND USE MANAGEMENT, DECISION TABLES, CHANGE, INITIALIZATION DATA, and HYDROLOGY. The HYDROLOGY section is expanded, showing sub-items: Hydrology, Topography (selected), and Fields. Below these are SOILS, DATABASES, and STRUCTURAL. The main panel is titled 'Topography / Edit' and shows the 'Name' field with the value 'topohru0001'. Below this is a table with parameters for the selected object.

Value	Description	SWAT+ Variable	Default	Recommended Range
0.03456676	Average slope steepness in HRU	s1p	0.02	
60	Average slope length in HRU	s1p_len	50	
60	Slope length for lateral subsurface flow	lat_len	50	
121	Average distance to stream	dist_cha	100	0 - 100000

At the bottom of the form are three buttons: 'Save Changes' (with a dropdown arrow), 'Back', and 'Copy'.

Navigating the SWAT+ Editor – Bulk Editing

- If you want to apply changes to a field for multiple objects at once, you can use bulk edit mode.
- From the object's edit form page, click the arrow on the right side of the *Save Changes* button and then click *Make changes to multiple records...* to enter bulk edit mode.
- First, select the objects to which you want to make changes.
- Next, choose which fields you want to edit by clicking the check box to the left of the field.
- Enter the value you want and click *Save Bulk Changes*.

The screenshot shows the SWAT+ Editor 2.1.3 / demo interface. The left sidebar contains a tree view with categories: BASIN, REGIONS, LAND USE MANAGEMENT, DECISION TABLES, CHANGE, INITIALIZATION DATA, HYDROLOGY (selected), Topography, Fields, SOILS, DATABASES, and STRUCTURAL. The main panel is titled 'Hydrology / Edit' and shows a table of parameters for 'hyd0001'. The table has columns: Value, Description, SWAT+ Variable, and Default. The parameters listed are: lat_ttime (0 days), lat_sed (0 g/L), can_max (1 mm), esco (0.95), and two rows for Organic N and P enrichment (both 0). A blue tooltip message states: 'You are in bulk edit mode. Select the objects you want to edit then check the fields to which you want to apply to the selected.' Below the table, there are two lists: 'Select Subbasins' (with Subbasin 1 checked) and 'Select Land Use' (with frst, frse, CORN, SOYB, wetf, and utrn listed). At the bottom, there are buttons for 'Save Bulk Changes' and 'Exit Bulk Edit Mode'.

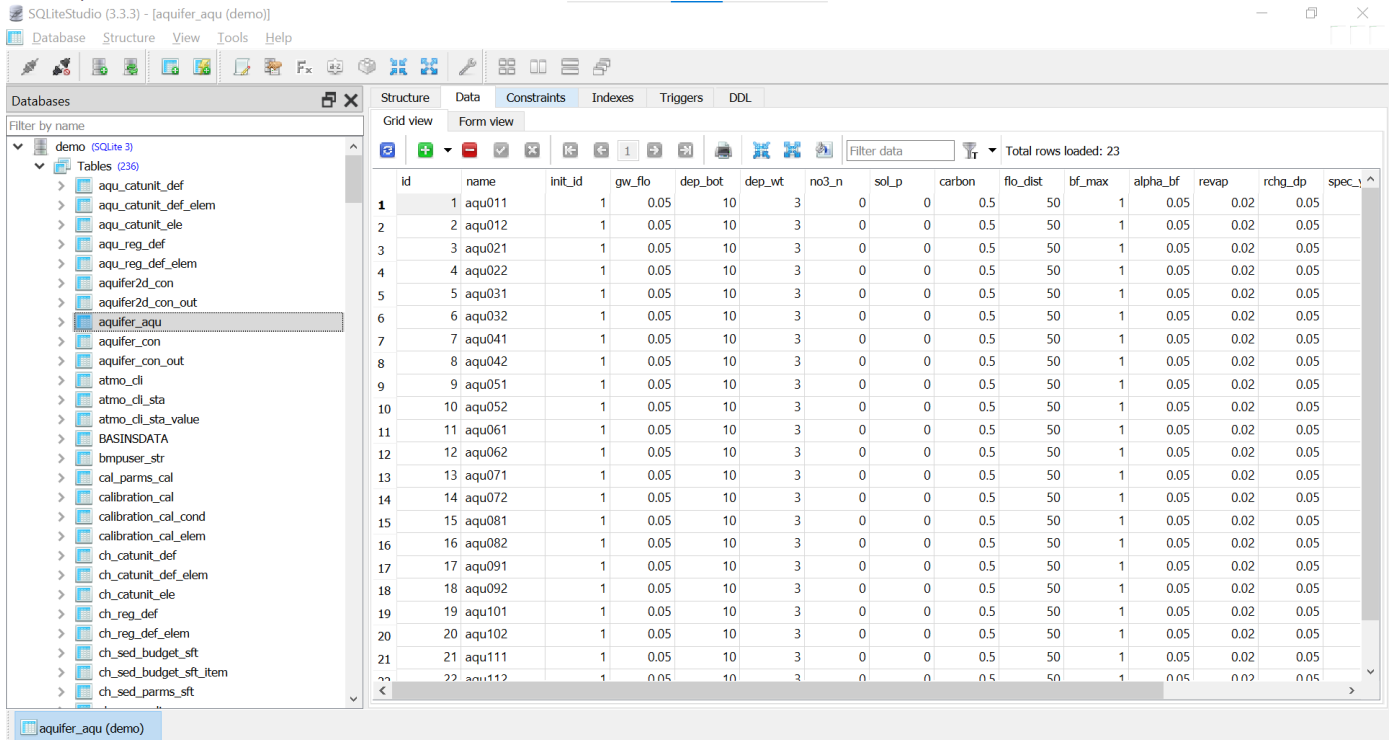
Value	Description	SWAT+ Variable	Default	
0	days	Exponential of the lateral flow travel time	lat_ttime	0
0	g/L	Sediment concentration in lateral flow	lat_sed	0
1	mm	Maximum canopy storage	can_max	1
0.95		Soil evaporation compensation factor	esco	0.95
1		Plant water uptake compensation factor		
0		Organic N enrichment		
0		Organic P enrichment		

SQLite Tables vs. SWAT+ Input Files

- The SWAT+ Editor writes changes into the SQLite database.
- Whenever you made changes in the Editor, the SWAT+ input files need to be re-written to reflect those changes.
- Whenever you made changes in the SWAT+ input files, you must be careful not to overwrite them accidentally when you re-write the files from the Editor.

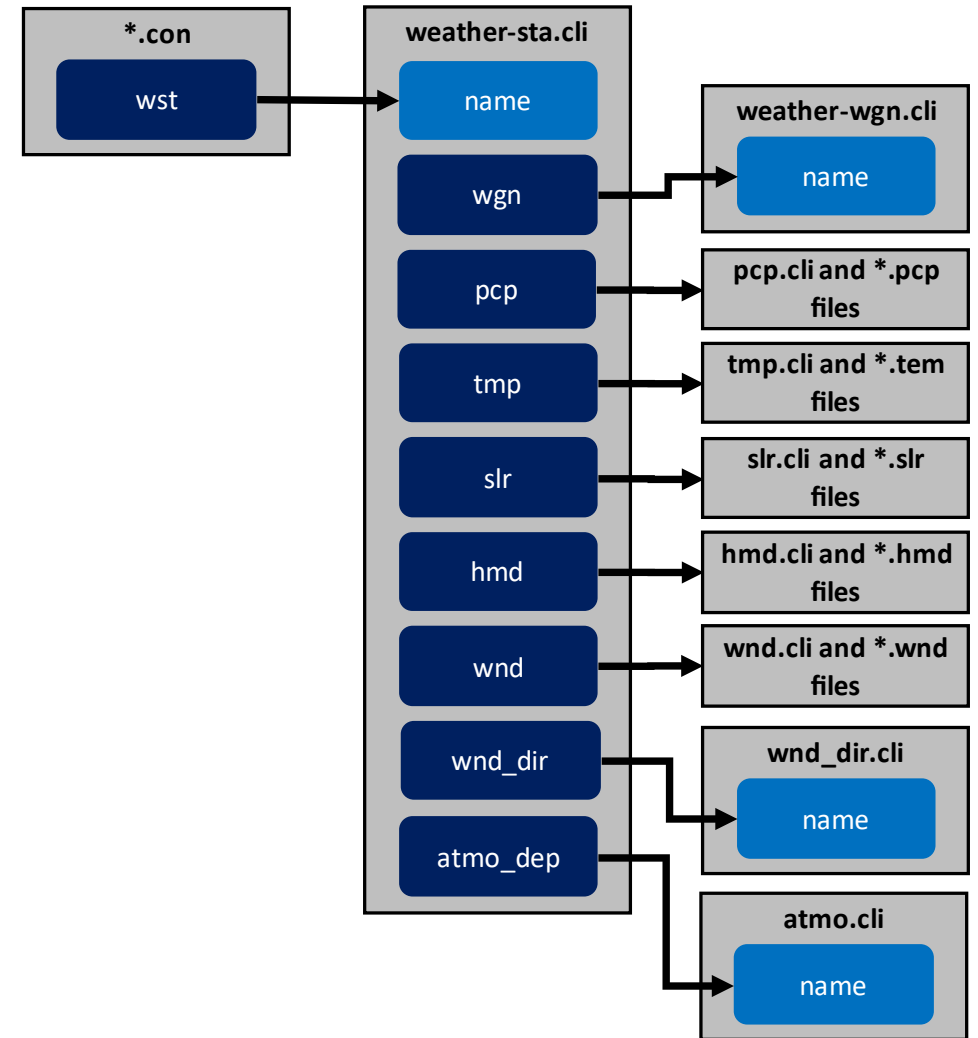
aquifer.aqu: written by SWAT+ editor v2.1.3 on 2022-08-22 15:45 for SWAT+ rev.60.5.4

id	name	init	gw_flo	dep_bot	dep_wt	no3_n	sol_p	carbon	flo_dist	bf_max	alpha_bf	revap	rchg_dp
1	aqu011	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
2	aqu012	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
3	aqu021	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
4	aqu022	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
5	aqu031	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
6	aqu032	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
7	aqu041	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
8	aqu042	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
9	aqu051	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
10	aqu052	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
11	aqu061	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
12	aqu062	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
13	aqu071	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
14	aqu072	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
15	aqu081	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
16	aqu082	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
17	aqu091	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
18	aqu092	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
19	aqu101	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
20	aqu102	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
21	aqu111	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
22	aqu112	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000
23	aqu_deep010	initaqu1	0.05000	10.00000	3.00000	0.00000	0.00000	0.50000	50.00000	1.00000	0.05000	0.02000	0.05000



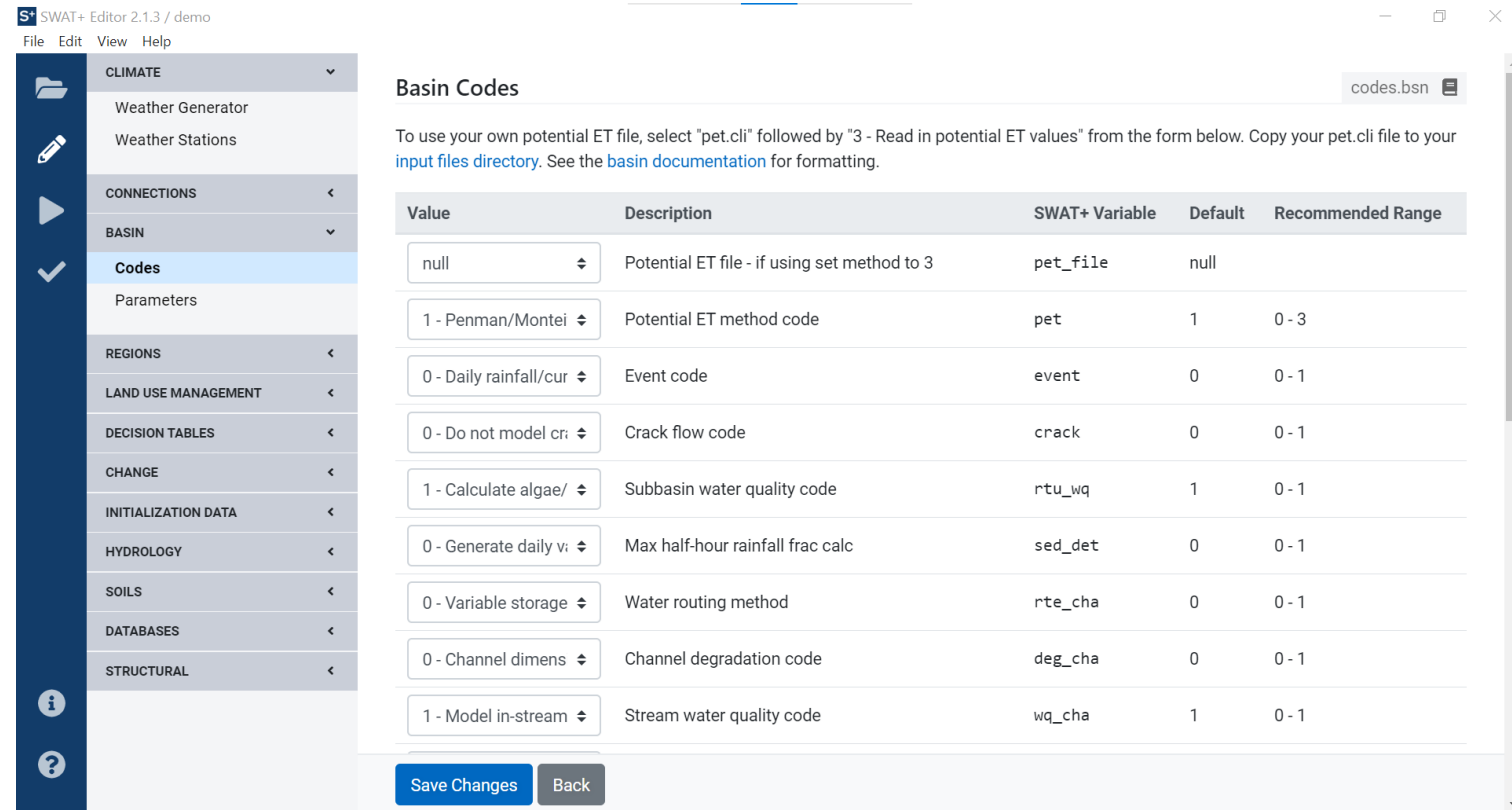
Weather Files

- From each connect file, SWAT+ points to a weather station file, which then points to the weather generator file and the climate data files (as well as a wind direction file, and an atmospheric deposition file).
- For each climate variable, the model needs one data file per station and one file listing the names of all data files.



Basin - Codes

- The basin codes determine which methods to use for calculation of PET, surface runoff, etc.
- The methods selected here will be used for the entire basin.
- The SWAT+ Editor lists the values, a short description of the variable, the SWAT+ variable name, the default value, and a recommended range.
- All codes can be changed directly in this form.



SWAT+ Editor 2.1.3 / demo

File Edit View Help

Basin Codes

To use your own potential ET file, select "pet.cli" followed by "3 - Read in potential ET values" from the form below. Copy your pet.cli file to your [input files directory](#). See the [basin documentation](#) for formatting.

Value	Description	SWAT+ Variable	Default	Recommended Range
null	Potential ET file - if using set method to 3	pet_file	null	
1 - Penman/Monteir	Potential ET method code	pet	1	0 - 3
0 - Daily rainfall/cur	Event code	event	0	0 - 1
0 - Do not model cr	Crack flow code	crack	0	0 - 1
1 - Calculate algae/	Subbasin water quality code	rtu_wq	1	0 - 1
0 - Generate daily v	Max half-hour rainfall frac calc	sed_det	0	0 - 1
0 - Variable storage	Water routing method	rte_cha	0	0 - 1
0 - Channel dimens	Channel degradation code	deg_cha	0	0 - 1
1 - Model in-stream	Stream water quality code	wq_cha	1	0 - 1

Save Changes Back

Basin - Parameters

- Basin parameters do not vary within the watershed and can therefore be set at basin level.

SWAT+ Editor 2.1.3 / demo
File Edit View Help

CLIMATE
Weather Generator
Weather Stations

CONNECTIONS

BASIN
Codes
Parameters

REGIONS

LAND USE MANAGEMENT

DECISION TABLES

CHANGE

INITIALIZATION DATA

HYDROLOGY

SOILS

DATABASES

STRUCTURAL

parameters.bsn

Basin Parameters

Value	Description	SWAT+ Variable	Default	Recommended Range
<input type="text" value="3"/>	Leaf area index at which no evaporation occurs from water surface	lai_noevap	3	0 - 10
<input type="text" value="0"/>	Initial soil water storage expressed as a fraction of field capacity water content	sw_init	0	0 - 1
<input type="text" value="4"/>	Surface runoff lag coefficient	surq_lag	4	1 - 24
<input type="text" value="1"/>	Peak rate adjustment factor for sediment routing in the subbasin (tributary channels)	adj_pkrt	1	0.5 - 2
<input type="text" value="1"/>	Peak rate adjustment factor for sediment routing in the main channel	adj_pkrt_sed	1	0 - 2
<input type="text" value="0"/>	Linear parameter for calculating the maximum amount of sediment that can be reentrained during channel sediment routing	lin_sed	0.0001	0.0001 - 0.01
<input type="text" value="1"/>	Exponent parameter for calculating sediment reentrained in channel sediment routing	exp_sed	1	1 - 1.5
<input type="text" value="0"/>	Rate factor for humus mineralization of active organic nutrients (N and P)	orgn_min	0.0003	0.001 - 0.003
<input type="text" value="20"/>	Nitrogen uptake distribution parameter	n_uptake	20	0 - 100

Save Changes Back

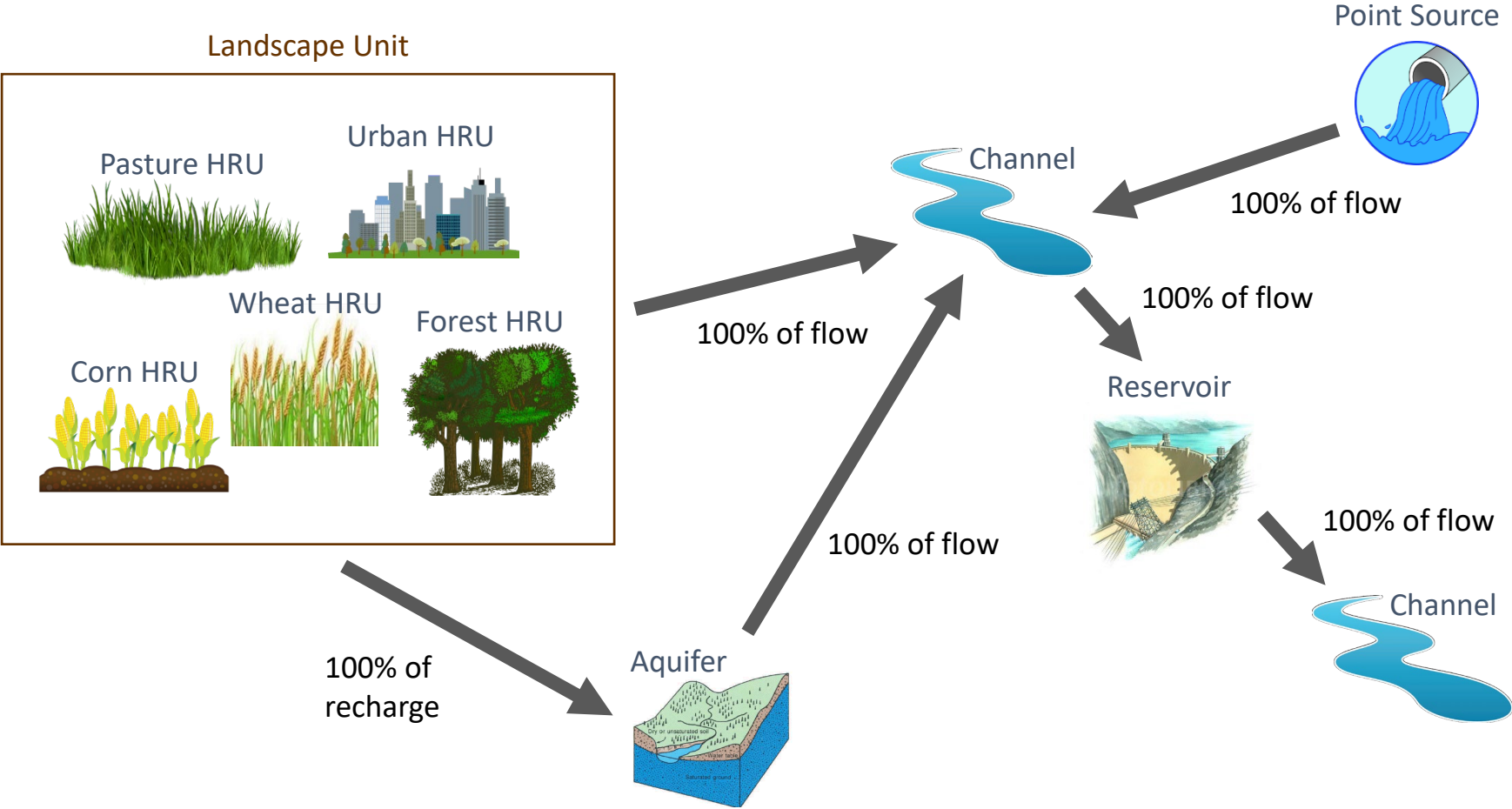
Connections

- Connect files define the interaction between different spatial objects within a watershed.
- You can
 - add records by clicking *Create Record*,
 - edit existing records by clicking the edit icon at the beginning of each line, and
 - delete existing records by clicking the red x at the end of each line.

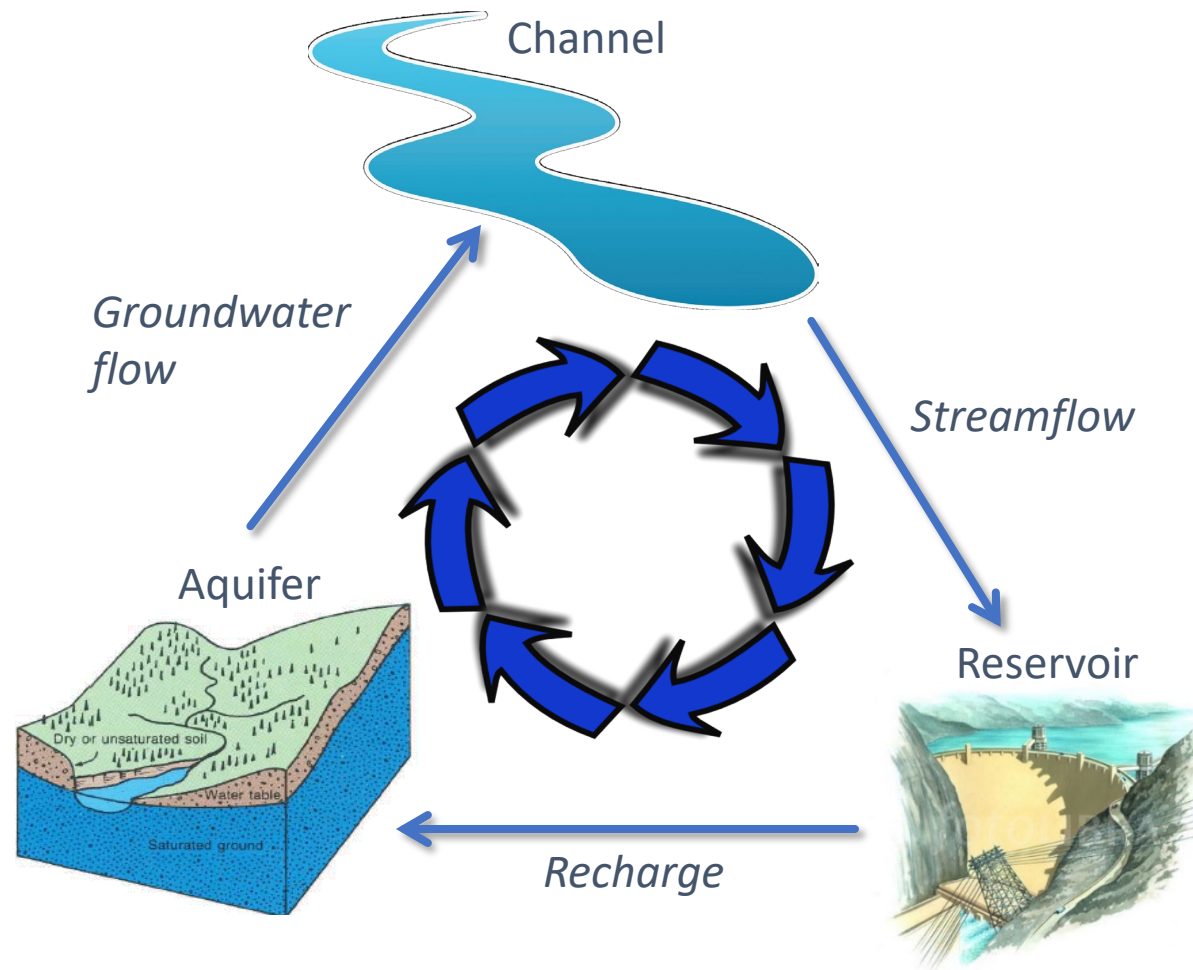
The screenshot displays the SWAT+ Editor 2.1.3 / demo interface. On the left is a vertical sidebar with a tree view containing categories like CLIMATE, CONNECTIONS, BASIN, REGIONS, LAND USE MANAGEMENT, DECISION TABLES, CHANGE, INITIALIZATION DATA, HYDROLOGY, SOILS, and DATABASES. The 'CONNECTIONS' category is expanded, showing 'Channels' as the selected item. The main window is titled 'Channels' and features a search bar and a table with 20 rows of data. Each row includes an edit icon, a name (e.g., cha001), area, coordinates, elevation, weather station, and various parameters. A 'Create Record' button is at the bottom left, and a pagination control at the bottom right shows '1' of 20 rows.

	NAME	AREA (HA)	LAT	LON	ELEV (M)	WEATHER STATION	INITIAL	HYD./SED.	NUTRIENTS	# OUTFLOW
	cha001	2,203.33	31.69	-83.70	null	s31727n83738w	initcha1	hydcha001	nutch1	0
	cha002	2,146.82	31.70	-83.71	null	s31727n83738w	initcha1	hydcha002	nutch1	1
	cha003	2,097.33	31.70	-83.71	null	s31727n83738w	initcha1	hydcha003	nutch1	1
	cha006	1,887.08	31.70	-83.72	null	s31727n83738w	initcha1	hydcha006	nutch1	1
	cha007	1,828.19	31.70	-83.72	null	s31727n83738w	initcha1	hydcha007	nutch1	1
	cha008	1,797.54	31.70	-83.73	null	s31727n83738w	initcha1	hydcha008	nutch1	1
	cha010	1,638.89	31.70	-83.73	null	s31727n83738w	initcha1	hydcha010	nutch1	1
	cha013	1,483.16	31.71	-83.74	null	s31727n83738w	initcha1	hydcha013	nutch1	1
	cha014	914.19	31.71	-83.74	null	s31727n83738w	initcha1	hydcha014	nutch1	1
	cha015	541.39	31.71	-83.74	null	s31727n83738w	initcha1	hydcha015	nutch1	1
	cha017	765.11	31.72	-83.74	null	s31727n83738w	initcha1	hydcha017	nutch1	1
	cha018	417.28	31.71	-83.75	null	s31727n83738w	initcha1	hydcha018	nutch1	1
	cha019	689.58	31.72	-83.75	null	s31727n83738w	initcha1	hydcha019	nutch1	1
	cha021	323.11	31.71	-83.75	null	s31727n83738w	initcha1	hydcha021	nutch1	1

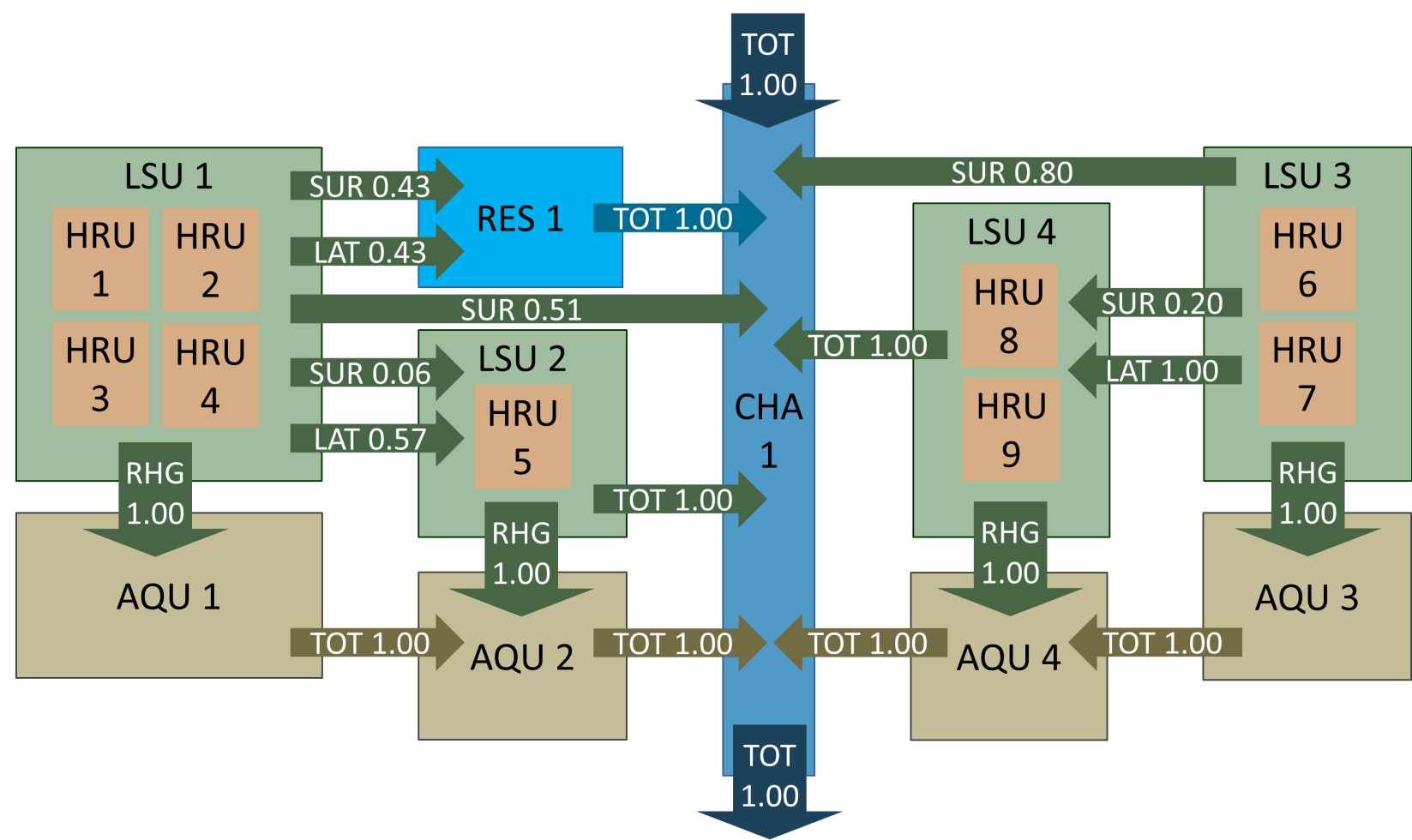
Spatial Objects and Connections



Infinite Loop



Connectivity Example



Legend: LSU connect file Reservoir connect file Aquifer connect file Channel connect file

- All connect files are structured the same way:
 - The first few columns specify the name of the object, its area, latitude, longitude, and weather station, and a pointer to the object properties.
 - The following columns define which spatial objects are receiving flow from this spatial object, what kind of flow, and how much.

Column name	Description
OUT_TOT	Total number of objects receiving runoff from this object. The following four columns are repeated accordingly.
OBJ_TYP	Type of the receiving object (e.g., LSU, channel, reservoir, aquifer).
OBJ_ID	ID of the receiving object.
HYDRO_TYP	Type of hydrograph to be sent to the receiving object (e.g., surface runoff, lateral flow, recharge).
FRAC	The fraction of the hydrograph to be sent to the receiving object. Fractions of the same hydrographs can be sent to multiple receiving objects as long as the fractions add up to 1.

Editing Connect Files

- Name, Latitude, Longitude, Area, and Elevation can be edited directly in the form.
- Object Properties, Weather Station, and Outflow can be edited in separate forms that open when clicking the respective edit icon.
- Also, new outflows can be added by clicking the *Add outflow* button.
- Any unsaved changes will be lost when you click any edit icon or *Back*.

SWAT+ Editor 2.1.3 / demo
File Edit View Help

CLIMATE <
CONNECTIONS v
 Channels v
 Initial
 Hydrology & Sediment
 Nutrients
 HRUs
 Routing Units <
 Aquifers <
 Reservoirs <
 Point Source / Inlet
 Delivery Ratio <
BASIN <
REGIONS <
LAND USE MANAGEMENT <
DECISION TABLES <
CHANGE <
INITIALIZATION DATA <
HYDROLOGY <
SOILS <
DATABASES <

Channels / Edit

Name
cha002

Weather Station ?
s31727n83738w

Latitude
31.696226649629814

Longitude
-83.70816259184755

Area (ha)
2146.82

Elevation (m)

Location
chandeg.con

Leaflet | © OpenStreetMap contributors

Outflow

ORDER	TYPE	NAME	HYDROGRAPH	FRACTION
1	sdc	cha001	tot	1

Add Outflow

Initial Properties ?
initcha1

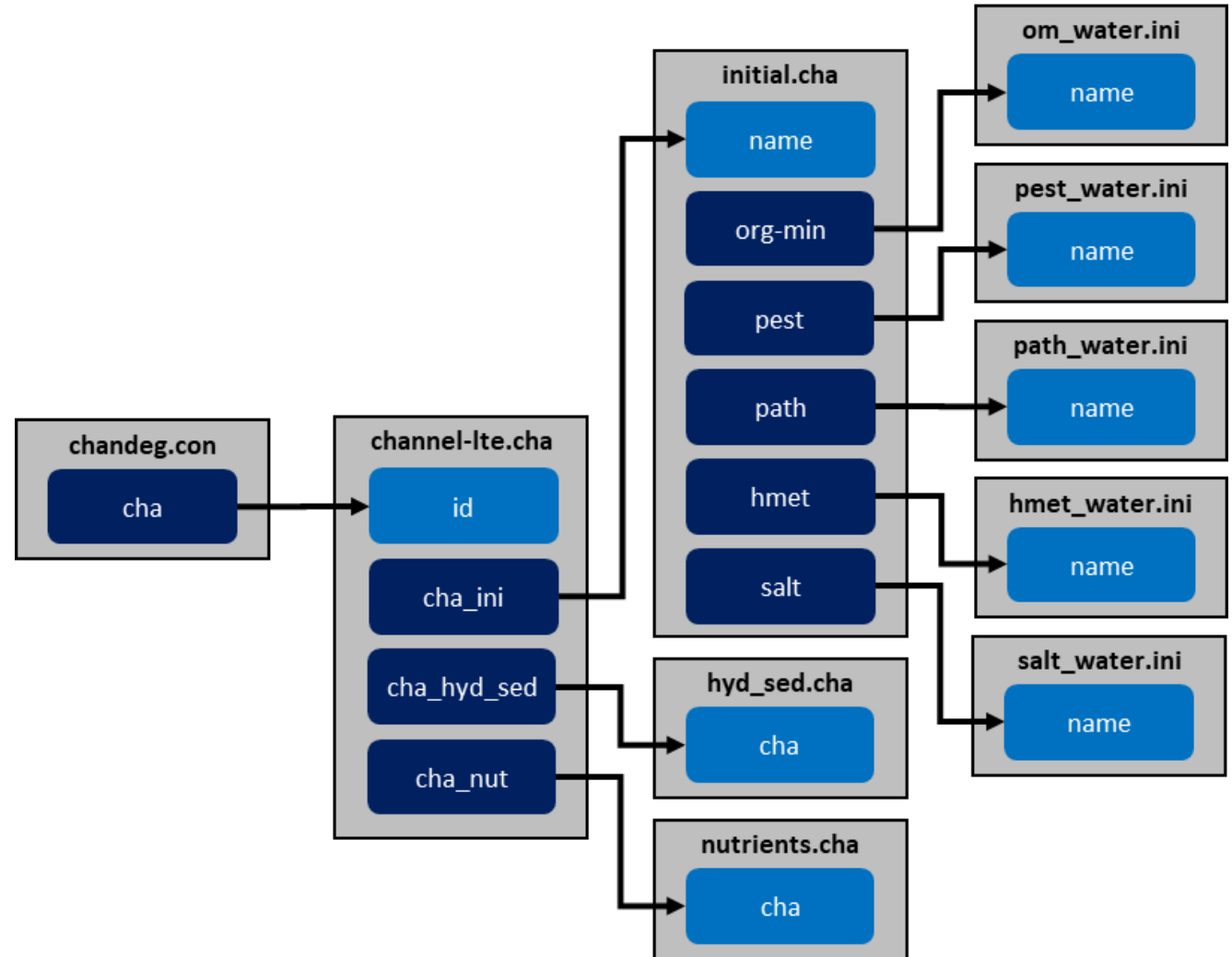
Hydrology/Sediment Properties ?
hydcha002

Nutrients Properties ?
nutcha1

Save Changes Back














Channel Properties

- For the channel properties, SWAT+ points from the channel connect file to a main channel file, which then points to files defining initial conditions, hydrology and sediment, and nutrients.
- The channel initialization file points to five files containing the initial concentrations of nutrients, pesticides, pathogens, heavy metals and salts in the water.



Channel Connections and Properties

chandeg.conchannel-lte.cha

NAME	AREA (HA)	LAT	LON	ELEV (M)	WEATHER STATION	INITIAL	HYD./SED.	NUTRIENTS	# OUTFLOW
 cha001	2,203.33	31.69	-83.70	null	s31727n83738w	initcha1	hydcha001	nutcha1	0 ❌
 cha002	2,146.82	31.70	-83.71	null	s31727n83738w	initcha1	hydcha002	nutcha1	1 ❌
 cha003	2,097.33	31.70	-83.71	null	s31727n83738w	initcha1	hydcha003	nutcha1	1 ❌
 cha006	1,887.08	31.70	-83.72	null	s31727n83738w	initcha1	hydcha006	nutcha1	1 ❌
 cha007	1,828.19	31.70	-83.72	null	s31727n83738w	initcha1	hydcha007	nutcha1	1 ❌
 cha008	1,797.54	31.70	-83.73	null	s31727n83738w	initcha1	hydcha008	nutcha1	1 ❌
 cha010	1,638.89	31.70	-83.73	null	s31727n83738w	initcha1	hydcha010	nutcha1	1 ❌
 cha013	1,483.16	31.71	-83.74	null	s31727n83738w	initcha1	hydcha013	nutcha1	1 ❌
 cha014	914.19	31.71	-83.74	null	s31727n83738w	initcha1	hydcha014	nutcha1	1 ❌
 cha015	541.39	31.71	-83.74	null	s31727n83738w	initcha1	hydcha015	nutcha1	1 ❌
 cha017	765.11	31.72	-83.74	null	s31727n83738w	initcha1	hydcha017	nutcha1	1 ❌
 cha018	417.28	31.71	-83.75	null	s31727n83738w	initcha1	hydcha018	nutcha1	1 ❌
 cha019	689.58	31.72	-83.75	null	s31727n83738w	initcha1	hydcha019	nutcha1	1 ❌

- Channels usually only have one outflow to the downstream channel or reservoir.

Name

cha002

Weather Station ?

s31727n83738w

Latitude

31.696226649629814

Longitude

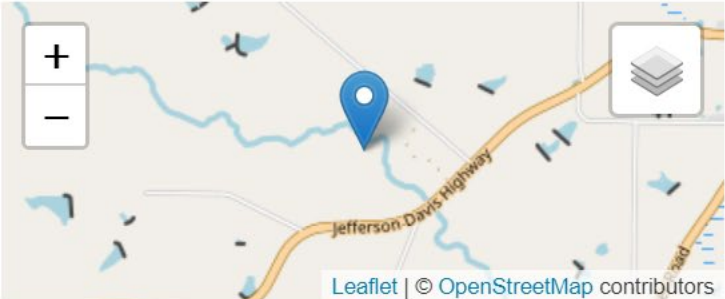
-83.70816259184755

Area (ha)

2146.82

Elevation (m)

Location



Outflow

	ORDER	TYPE	NAME	HYDROGRAPH	FRACTION	
	1	sdc	cha001	tot	1	

Add Outflow

Channel Initialization

SWAT+ Editor 2.1.3 / demo

File Edit View Help

CLIMATE

CONNECTIONS

Channels

Initial

Hydrology & Sediment

Nutrients

HRUs

Routing Units

Aquifers

Reservoirs

Point Source / Inlet

Delivery Ratio

BASIN

REGIONS

LAND USE MANAGEMENT

DECISION TABLES

CHANGE

INITIALIZATION DATA

HYDROLOGY

SOILS

DATABASES

Channels / Initial

initial.cha

Search...

Showing 1 - 1 of 1 rows

NAME	ORGANIC MINERAL	PESTICIDE	PATHOGEN	HEAVY METAL	SALT	DESCRIPTION
initcha1	no_init	null	null	null	null	

Create Record

2022-10-20

SWAT+ Introductory Workshop

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SWAT+

SOIL & WATER ASSESSMENT TOOL

2022-10-20

Channel Nutrients

SWAT+ Editor 2.1.3 / demo

File Edit View Help

CLIMATE

CONNECTIONS

Channels

Initial

Hydrology & Sediment

Nutrients

HRUs

Routing Units

Aquifers

Reservoirs

Point Source / Inlet

Delivery Ratio

BASIN

REGIONS

LAND USE MANAGEMENT

DECISION TABLES

CHANGE

INITIALIZATION DATA

HYDROLOGY

SOILS

DATABASES

Channels / Nutrients

nutrients.cha

Search...

Showing 1 - 1 of 1 rows

NAME	PLT_N	PTL_P	ALG_STL	BEN_DISP	BEN_NH3N	PTLN_STL	PTLP_STL	CST_STL	BEN_CST	CBN_BOD_CO	AIR_RT	CBN_BOD_STL	BEN_F
nutch1	0	0	1	0.050	0.500	0.050	0.050	2.500	2.500	1.710	50	0.360	

Create Record Import/Export

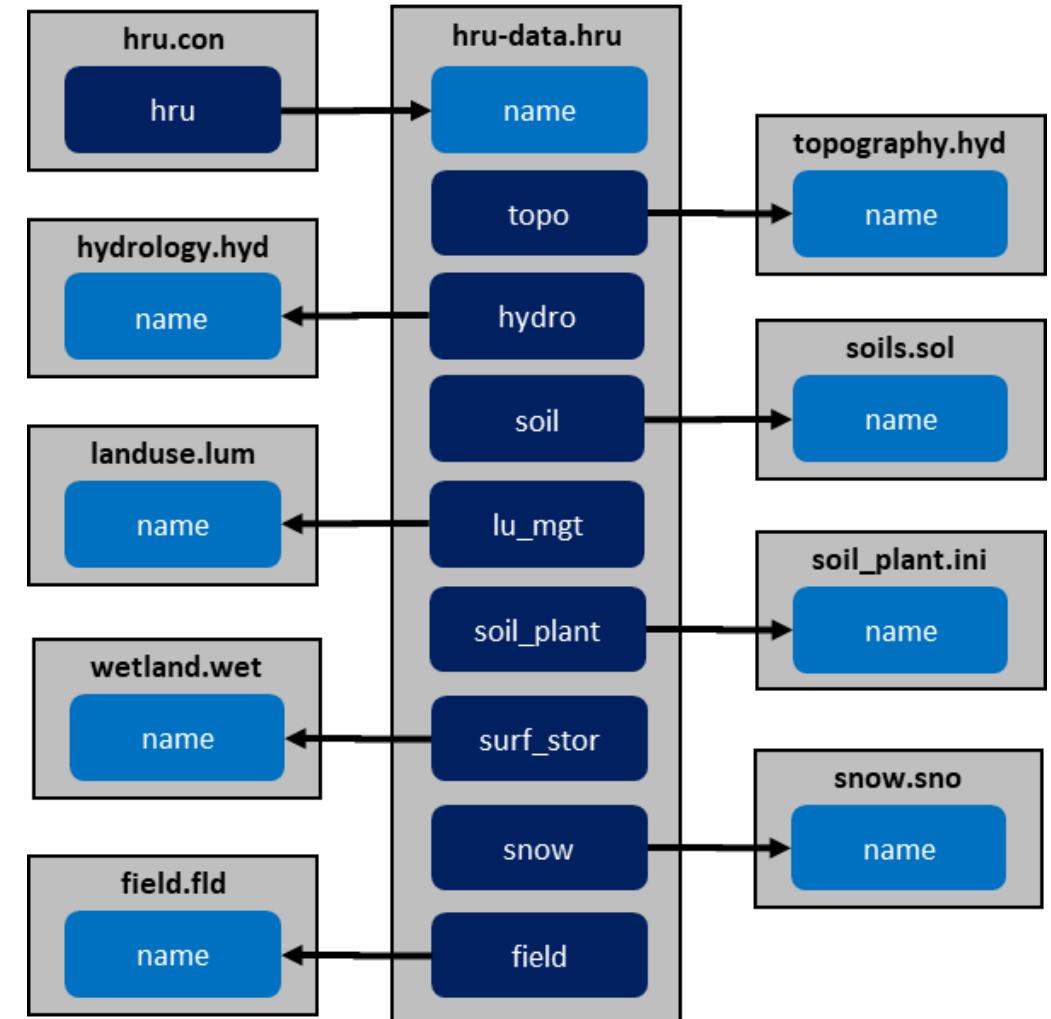
2022-10-20

SWAT+ Introductory Workshop

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HRU Properties

- For the HRU properties, SWAT+ points from the HRU connect file to a main HRU properties file, which then points to files defining topography, hydrology, soils, land use, soil nutrients, surface storage, snow and fields.



- While HRUs can be directly connected to other spatial objects, they are typically summed at Routing Unit level. Therefore, they have a connect file, but no outflow.

CLIMATE <

CONNECTIONS v

Channels <

HRUs

Routing Units <

Aquifers <

Reservoirs <

Point Source / Inlet <

Delivery Ratio <

BASIN <

REGIONS v

Landscape Units <

LAND USE MANAGEMENT <

DECISION TABLES <

CHANGE <

INITIALIZATION DATA <

HYDROLOGY <

SOILS <

DATABASES <

HRUs / Edit

Name

hru0001

Weather Station ?

s31727n83738w

Latitude

31.750600663866585

Longitude

-83.76407263023216

Area (ha)

2.8543221781055017

Elevation (m)

138.6551724137931

Location

hru.con

Outflow

This object does not have any outflow.

Add Outflow

Topography Properties ?

topohru0001

Hydrology Properties ?

hyd0001

Soil Properties ?

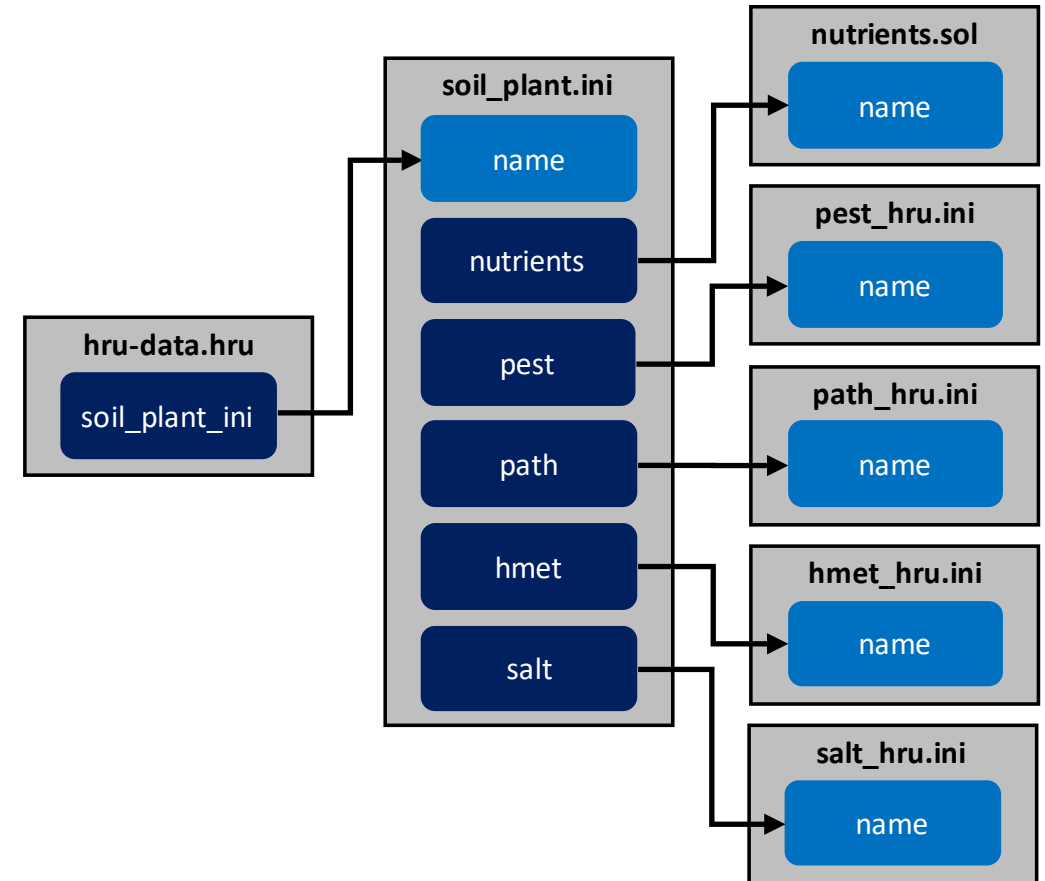
LREW06

Land Use Management Properties ?

frst_lum

HRU Initialization

- For the HRU initialization, SWAT+ points from the HRU data file to a soil and plant initialization file, which then points to files defining the initial values of organic material and pesticides (as well as pathogens, heavy metals, and salt).



Soil and Plant Initialization

- From the soil and plant initialization, SWAT+ points to the soil nutrient file and to files specifying the initial amounts pesticides (as well as pathogens, heavy metals, and salts) on the plants and in the soil.

SWAT+ Editor 2.1.3 / demo

File Edit View Help

CLIMATE

CONNECTIONS

BASIN

REGIONS

LAND USE MANAGEMENT

DECISION TABLES

CHANGE

INITIALIZATION DATA

Plant Communities

Soil Plant

Organic Mineral

Constituents

HYDROLOGY

SOILS

DATABASES

STRUCTURAL

i

?

Soil Plant

soil_plant.ini

Search...

Showing 1 - 1 of 1 rows

NAME	SOIL WATER FRACTION	NUTRIENTS	PESTICIDES	PATHOGENS	HEAVY METALS	SALT
soilplant1	0	soilnut1	null	null	null	null

Create Record

Initialization of Constituents

- You need to tell the SWAT+ Editor that you want to include constituents before you can specify the initial values in the HRUs and in the water bodies.

The screenshot shows the SWAT+ Editor 2.1.3 / demo interface. The left sidebar contains a navigation menu with categories: CLIMATE, CONNECTIONS, BASIN, REGIONS, LAND USE MANAGEMENT, DECISION TABLES, CHANGE, and INITIALIZATION DATA. Under INITIALIZATION DATA, the 'Constituents' sub-category is expanded, showing options for Pesticides (HRU), Pesticides (Water), Pathogens (HRU), and Pathogens (Water). The main panel is titled 'Constituents' and contains a file 'constituents.cs'. It includes a message: 'The constituents file enables pesticides and pathogens used in your model. Do you want to include and configure these in your model?' with buttons 'No, do not use' and 'Yes, include'. Below this are sections for 'Pesticides' and 'Pathogens', each with an 'Add a pesticide/pathogen' button and a search input field. At the bottom are 'Save Changes' and 'Back' buttons.

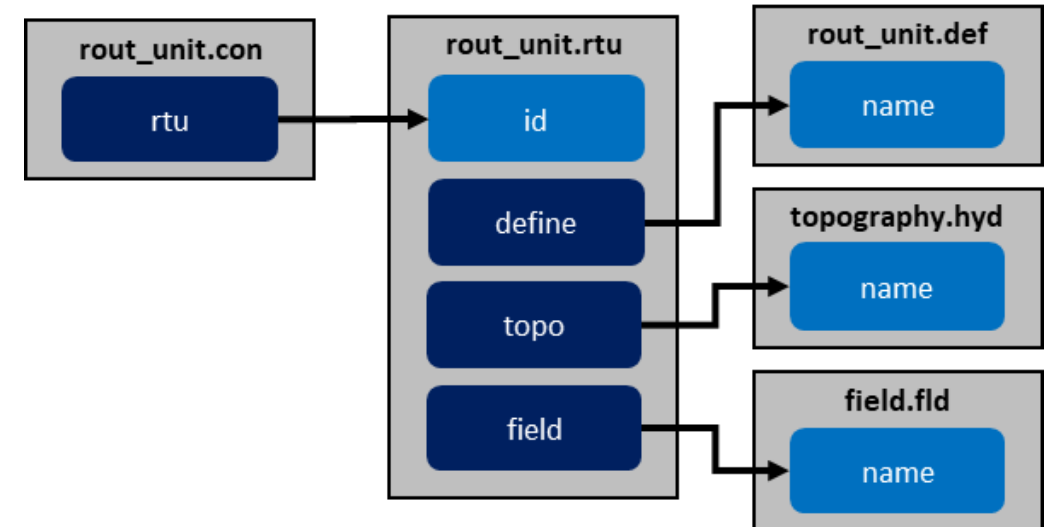
The screenshots show the configuration screens for pesticides in HRUs and water bodies. The top screen is 'Pesticides (HRU)' with a file 'pest_hru.ini'. It shows a table with the pesticide 'aatrex' and its initial values: 'Amount of pesticide on plant at start of simulation (kg/ha)' set to 1, and 'Amount of pesticide in soil at start of simulation (kg/ha)' set to 2. The bottom screen is 'Pesticides (Water)' with a file 'pest_water.ini'. It shows a table with the pesticide 'aatrex' and its initial values: 'Amount of pesticide in water at start of simulation (kg/ha)' set to 0.5, and 'Amount of pesticide in the benthic zone at start of simulation (kg/ha)' set to 1.2.

Pesticides (HRU)	
aatrex	
Amount of pesticide on plant at start of simulation (kg/ha)	1
Amount of pesticide in soil at start of simulation (kg/ha)	2














Pesticides (Water)	
aatrex	
Amount of pesticide in water at start of simulation (kg/ha)	0.5
Amount of pesticide in the benthic zone at start of simulation (kg/ha)	1.2

Routing Unit Properties

- Routing units do not have very many properties as they mostly serve the purpose of summing up HRUs.
- The rout_unit.rtu file points to 3 files:
 - RTU Define
 - Topography
 - Field







Routing Unit Connections and Properties

rou_t_unit.con						rou_t_unit.rtu				
NAME	AREA (HA)	LAT	LON	ELEV (M)	WEATHER STATION	TOPOGRAPHY	DEL. RATIO	FIELD	# OUTFLOW	
 rtu0012	25.65	31.69	-83.70	109.40	s31727n83738w	toportu0012	null	f1d0012	2	✖
 rtu0022	38.61	31.70	-83.71	111.18	s31727n83738w	toportu0022	null	f1d0022	2	✖
 rtu0032	23.37	31.70	-83.71	113.08	s31727n83738w	toportu0032	null	f1d0032	2	✖
 rtu0062	18.63	31.70	-83.72	111.85	s31727n83738w	toportu0062	null	f1d0062	2	✖
 rtu0072	20.42	31.70	-83.72	114.86	s31727n83738w	toportu0072	null	f1d0072	2	✖
 rtu0082	25.67	31.70	-83.73	117.41	s31727n83738w	toportu0082	null	f1d0082	2	✖
 rtu0102	21.01	31.70	-83.73	115.16	s31727n83738w	toportu0102	null	f1d0102	2	✖
 rtu0132	27.58	31.71	-83.74	117.78	s31727n83738w	toportu0132	null	f1d0132	2	✖
 rtu0142	56.19	31.71	-83.74	121.01	s31727n83738w	toportu0142	null	f1d0142	2	✖
 rtu0152	2.54	31.71	-83.74	115.71	s31727n83738w	toportu0152	null	f1d0152	2	✖
 rtu0172	19.53	31.72	-83.74	122.97	s31727n83738w	toportu0172	null	f1d0172	2	✖
 rtu0182	59.75	31.71	-83.75	124.06	s31727n83738w	toportu0182	null	f1d0182	2	✖
 rtu0192	32.83	31.72	-83.75	123.36	s31727n83738w	toportu0192	null	f1d0192	2	✖



Routing Unit Connections

- Upland RTUs have 4 default outflows:
 - a fraction of surface runoff to its channel,
 - the remaining surface runoff to its floodplain,
 - Lateral flow to its floodplain, and
 - recharge to an aquifer.
- Floodplain RTUs have 2 default outflows:
 - total flow (surface runoff + lateral flow (+ tile flow)) to its channel and
 - recharge to an aquifer.

Outflow

	ORDER	TYPE	NAME	HYDROGRAPH	FRACTION	
	1	sdh	cha141	sur	0.99	✗
	2	ru	rtu1411	sur	0.01	✗
	3	ru	rtu1411	lat	1	✗
	4	aqu	aqu012	rhg	1	✗

Outflow

	ORDER	TYPE	NAME	HYDROGRAPH	FRACTION	
	1	sdh	cha141	tot	1	✗
	2	aqu	aqu011	rhg	1	✗

Routing Unit Define and Elements

- SWAT+ needs two files to define which elements are part of which Routing Unit.
- In the SWAT+ Editor, there is only one table for these two files.

The screenshot shows the SWAT+ Editor 2.1.3 / demo interface. On the left is a sidebar with a tree view of project components. The 'Routing Units / Elements' component is selected and highlighted in blue. The main area displays a table titled 'Routing Units / Elements' with a search bar and a 'Showing 1 - 20 of 1747 rows' indicator. The table has columns for NAME, TYPE, OBJECT, FRACTION, ROUTING UNIT, and DELIVERY RATIO. The first 14 rows are visible, showing hru0001 through hru0014, all of type 'hru', with various fraction values and routing unit assignments (rtu1472 or rtu1471). The delivery ratio is 'null' for all, and each row has a red 'X' icon in the final column. At the bottom of the table is a 'Create Record' button. Below the table is a pagination bar showing page 1 of 1747 rows.

NAME	TYPE	OBJECT	FRACTION	ROUTING UNIT	DELIVERY RATIO
hru0001	hru	hru0001	0.152502	rtu1472	null
hru0002	hru	hru0002	0.019892	rtu1472	null
hru0003	hru	hru0003	0.104280	rtu1472	null
hru0004	hru	hru0004	0.089793	rtu1472	null
hru0005	hru	hru0005	0.022926	rtu1472	null
hru0006	hru	hru0006	0.110494	rtu1472	null
hru0007	hru	hru0007	0.194810	rtu1472	null
hru0008	hru	hru0008	0.110494	rtu1472	null
hru0009	hru	hru0009	0.194810	rtu1472	null
hru0010	hru	hru0010	0.076726	rtu1471	null
hru0011	hru	hru0011	0.194373	rtu1471	null
hru0012	hru	hru0012	0.228069	rtu1471	null
hru0013	hru	hru0013	0.191368	rtu1471	null
hru0014	hru	hru0014	0.061381	rtu1471	null

Landscape Unit Define and Elements

- SWAT+ needs two files to define which HRUs belong to which Landscape Unit.

SWAT+ Editor 2.1.3 / demo

File Edit View Help

CONNECTIONS

Channels

HRUs

Routing Units

Aquifers

Reservoirs

Point Source / Inlet

Delivery Ratio

BASIN

REGIONS

Landscape Units

Elements

LAND USE MANAGEMENT

Land Use Management

Management Schedules

Operations Databases

Curve Numbers

Conservation Practices

Manning's n

DECISION TABLES

CHANGE

Landscape Units

Is_unit.def

Showing 1 - 20 of 207 rows

NAME	AREA	NUMBER OF ELEMENTS
rtu0011	6.580	6
rtu0012	19.070	12
rtu0021	9.820	6
rtu0022	28.790	18
rtu0031	6.370	7
rtu0032	17.000	17
rtu0061	10.590	8
rtu0062	8.040	23
rtu0071	8.760	12
rtu0072	11.660	19
rtu0081	9.340	6
rtu0082	16.330	5
rtu0101	10.270	8
rtu0102	10.740	2

Create Record

« < 1 2 3 4 ... > »

Landscape Units / Elements

Is_unit.ele

Showing 1 - 20 of 1747 rows

NAME	TYPE	OBJECT	BASIN FRACTION	SUBBASIN FRACTION	REGION FRACTION	LANDSCAPE UNIT
hru0001	hru	hru0001	0.001287	0.152502	0.000000	rtu1472
hru0002	hru	hru0002	0.000168	0.019892	0.000000	rtu1472
hru0003	hru	hru0003	0.000880	0.104280	0.000000	rtu1472
hru0004	hru	hru0004	0.000758	0.089793	0.000000	rtu1472
hru0005	hru	hru0005	0.000193	0.022926	0.000000	rtu1472
hru0006	hru	hru0006	0.000932	0.110494	0.000000	rtu1472
hru0007	hru	hru0007	0.001644	0.194810	0.000000	rtu1472
hru0008	hru	hru0008	0.000932	0.110494	0.000000	rtu1472
hru0009	hru	hru0009	0.001644	0.194810	0.000000	rtu1472
hru0010	hru	hru0010	0.000147	0.076726	0.000000	rtu1471
hru0011	hru	hru0011	0.000373	0.194373	0.000000	rtu1471
hru0012	hru	hru0012	0.000437	0.228069	0.000000	rtu1471
hru0013	hru	hru0013	0.000367	0.191368	0.000000	rtu1471
hru0014	hru	hru0014	0.000119	0.061381	0.000000	rtu1471

Create Record

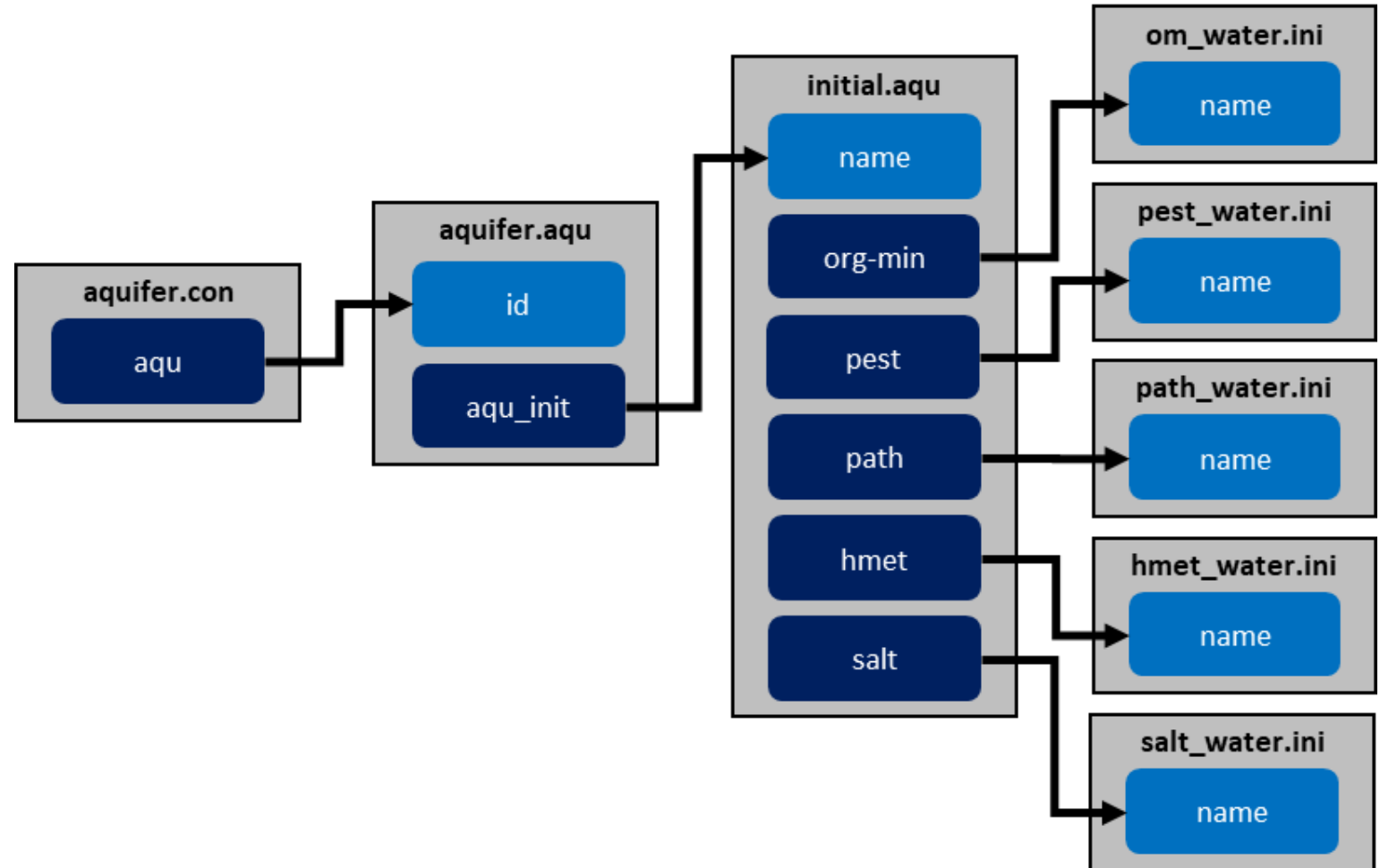
« < 1 2 3 4 ... > »

Routing Unit vs Landscape Unit

- A landscape unit (LSU) is defined as a collection of HRUs and can be defined as a subbasin, or it could be a flood plain or upland unit, or it could be a grid cell with multiple HRUs. The landscape unit is not routed, it only used for output.
- The routing unit is the spatial unit SWAT+ that allows us to lump outputs and route the outputs to any other spatial object. In default setups, routing units will be the same as landscape units, but unlike landscape units, routing units can contain spatial objects other than HRUs.

Aquifer Properties














- The aquifer connect file points to the main aquifer file, which contains the parameters describing the aquifer properties and a pointer to the aquifer initialization file.
- The aquifer initialization file points to five files containing the initial concentrations of nutrients, pesticides, pathogens, heavy metals and salts in the water.



Aquifer Connections and Properties

aquifer.con

aquifer.aqu

NAME	AREA (HA)	LAT	LON	ELEV (M)	WEATHER STATION	INITIAL	GW FLO	DEP BOT	DEP WT	NO3 N	SOL P	CARBON	FLO DIST	BF MAX	ALPHA BF	REVAP	RCHG DP	SPEC YLD	HL NO3N	FLO MIN	REVAP MIN	# OUTFLOW
 aqu011	3.90	31.74	-83.76	129.50	s31727n83738w	initaqu1	0.050	10.000	3.000	0.000	0.000	0.500	50.000	1.000	0.050	0.020	0.050	0.050	0.000	3.000	5.000	2
 aqu012	283.07	31.74	-83.76	135.24	s31727n83738w	initaqu1	0.050	10.000	3.000	0.000	0.000	0.500	50.000	1.000	0.050	0.020	0.050	0.050	0.000	3.000	5.000	2
 aqu021	0.64	31.74	-83.75	133.44	s31727n83738w	initaqu1	0.050	10.000	3.000	0.000	0.000	0.500	50.000	1.000	0.050	0.020	0.050	0.050	0.000	3.000	5.000	2
 aqu022	242.75	31.74	-83.75	134.04	s31727n83738w	initaqu1	0.050	10.000	3.000	0.000	0.000	0.500	50.000	1.000	0.050	0.020	0.050	0.050	0.000	3.000	5.000	2
 aqu032	394.80	31.72	-83.76	129.94	s31727n83738w	initaqu1	0.050	10.000	3.000	0.000	0.000	0.500	50.000	1.000	0.050	0.020	0.050	0.050	0.000	3.000	5.000	2
 aqu042	56.69	31.73	-83.75	127.08	s31727n83738w	initaqu1	0.050	10.000	3.000	0.000	0.000	0.500	50.000	1.000	0.050	0.020	0.050	0.050	0.000	3.000	5.000	2
 aqu052	294.63	31.72	-83.74	126.43	s31727n83738w	initaqu1	0.050	10.000	3.000	0.000	0.000	0.500	50.000	1.000	0.050	0.020	0.050	0.050	0.000	3.000	5.000	2
 aqu062	118.30	31.71	-83.73	125.33	s31727n83738w	initaqu1	0.050	10.000	3.000	0.000	0.000	0.500	50.000	1.000	0.050	0.020	0.050	0.050	0.000	3.000	5.000	2
 aqu072	111.75	31.71	-83.72	123.26	s31727n83738w	initaqu1	0.050	10.000	3.000	0.000	0.000	0.500	50.000	1.000	0.050	0.020	0.050	0.050	0.000	3.000	5.000	2
 aqu082	183.31	31.70	-83.74	122.76	s31727n83738w	initaqu1	0.050	10.000	3.000	0.000	0.000	0.500	50.000	1.000	0.050	0.020	0.050	0.050	0.000	3.000	5.000	2
 aqu092	2.54	31.71	-83.74	115.71	s31727n83738w	initaqu1	0.050	10.000	3.000	0.000	0.000	0.500	50.000	1.000	0.050	0.020	0.050	0.050	0.000	3.000	5.000	2
 aqu102	128.56	31.70	-83.72	118.31	s31727n83738w	initaqu1	0.050	10.000	3.000	0.000	0.000	0.500	50.000	1.000	0.050	0.020	0.050	0.050	0.000	3.000	5.000	2
 aqu112	115.16	31.70	-83.75	129.60	s31727n83738w	initaqu1	0.050	10.000	3.000	0.000	0.000	0.500	50.000	1.000	0.050	0.020	0.050	0.050	0.000	3.000	5.000	2

Aquifer Connections

- Upland Aquifers have 2 default outflows:
 - total flow to the floodplain aquifer and
 - recharge to the deep aquifer.
- Floodplain Aquifers also have 2 default outflows:
 - total flow to the channel, and
 - recharge to the deep aquifer.

Name

aqu012

Weather Station ?

s31727n83738w

Latitude

31.74064009826512

Longitude

-83.75867979153853

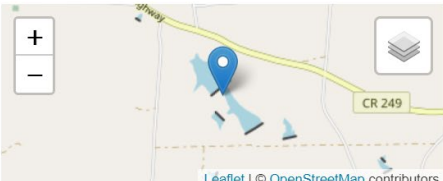
Area (ha)

283.07

Elevation (m)

135.23672589818773

Location



Outflow

ORDER	TYPE	NAME	HYDROGRAPH	FRACTION
1	aqu	aqu011	tot	1
2	aqu	aqu_deep012	rhg	1

Add Outflow

Name

aqu011

Weather Station ?

s31727n83738w

Latitude

31.74064009826512

Longitude

-83.75867979153853

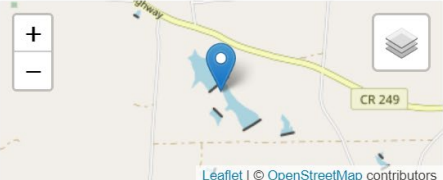
Area (ha)

3.9

Elevation (m)

129.50088500976562

Location



Outflow

ORDER	TYPE	NAME	HYDROGRAPH	FRACTION
1	sdh	cha025	tot	1
2	aqu	aqu_deep012	rhg	1

Add Outflow

SWAT+



SOIL & WATER ASSESSMENT TOOL

Aquifers / Initial

initial.aqu

Search...

Showing 1 - 1 of 1 rows



NAME	ORGANIC MINERAL	PESTICIDE	PATHOGEN	HEAVY METAL	SALT	DESCRIPTION
 initaqu1	no_init	null	null	null	null	

GWflow Module

- Developed by Ryan Bailey at Colorado State University
- Based on MODFLOW
- <https://swat.tamu.edu/software/plus/>

Article

A New Physically-Based Spatially-Distributed Groundwater Flow Module for SWAT+

Ryan T. Bailey^{1,*}, Katrin Bieger² , Jeffrey G. Arnold³ and David D. Bosch⁴ 

¹ Dept. of Civil and Environmental Engineering, Colorado State University, Fort Collins, CO 80523, USA

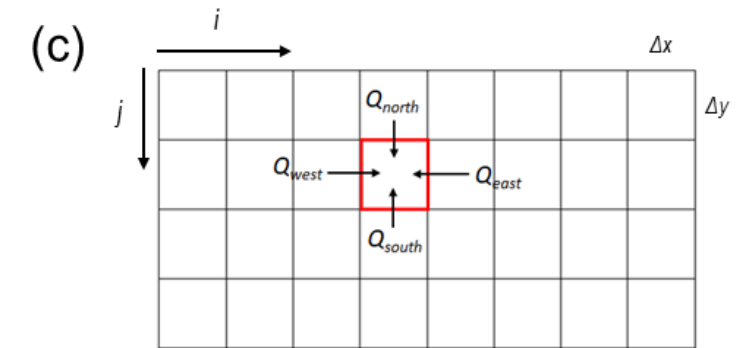
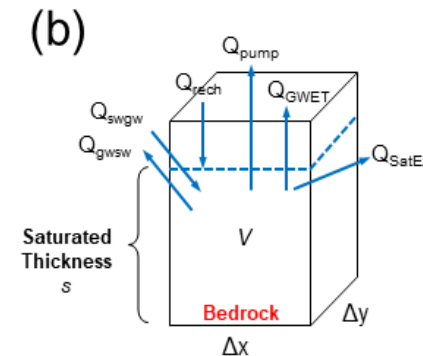
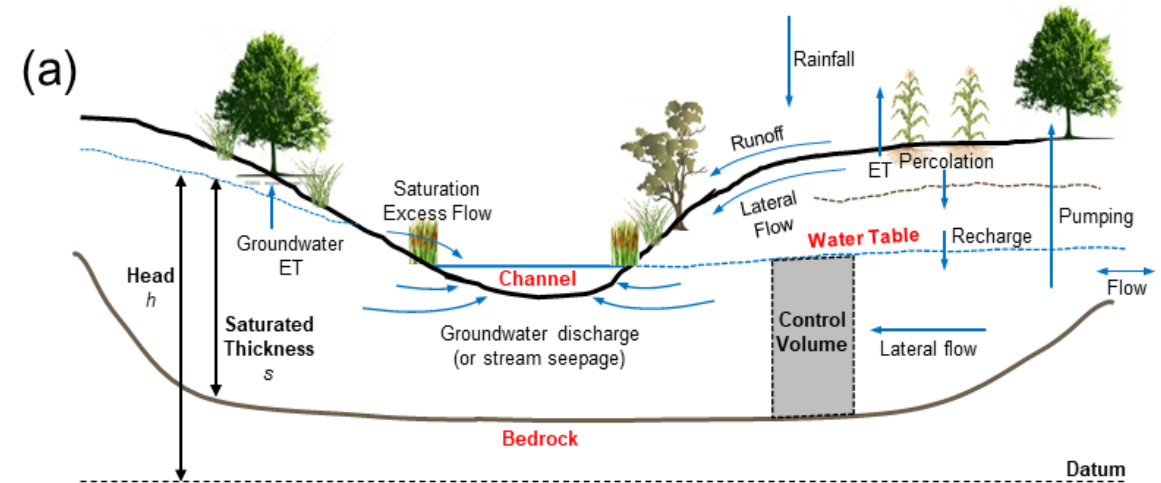
² Blackland Research & Extension Center, Texas A&M AgriLife, Temple, TX 76502, USA; kbieger@brc.tamus.edu

³ Grassland Soil and Water Research Laboratory, USDA-ARS, Temple, TX 76502, USA; jeff.arnold@usda.gov

⁴ Southeast Watershed Research, USDA-ARS, Tifton, GA 31794, USA; david.bosch@usda.gov

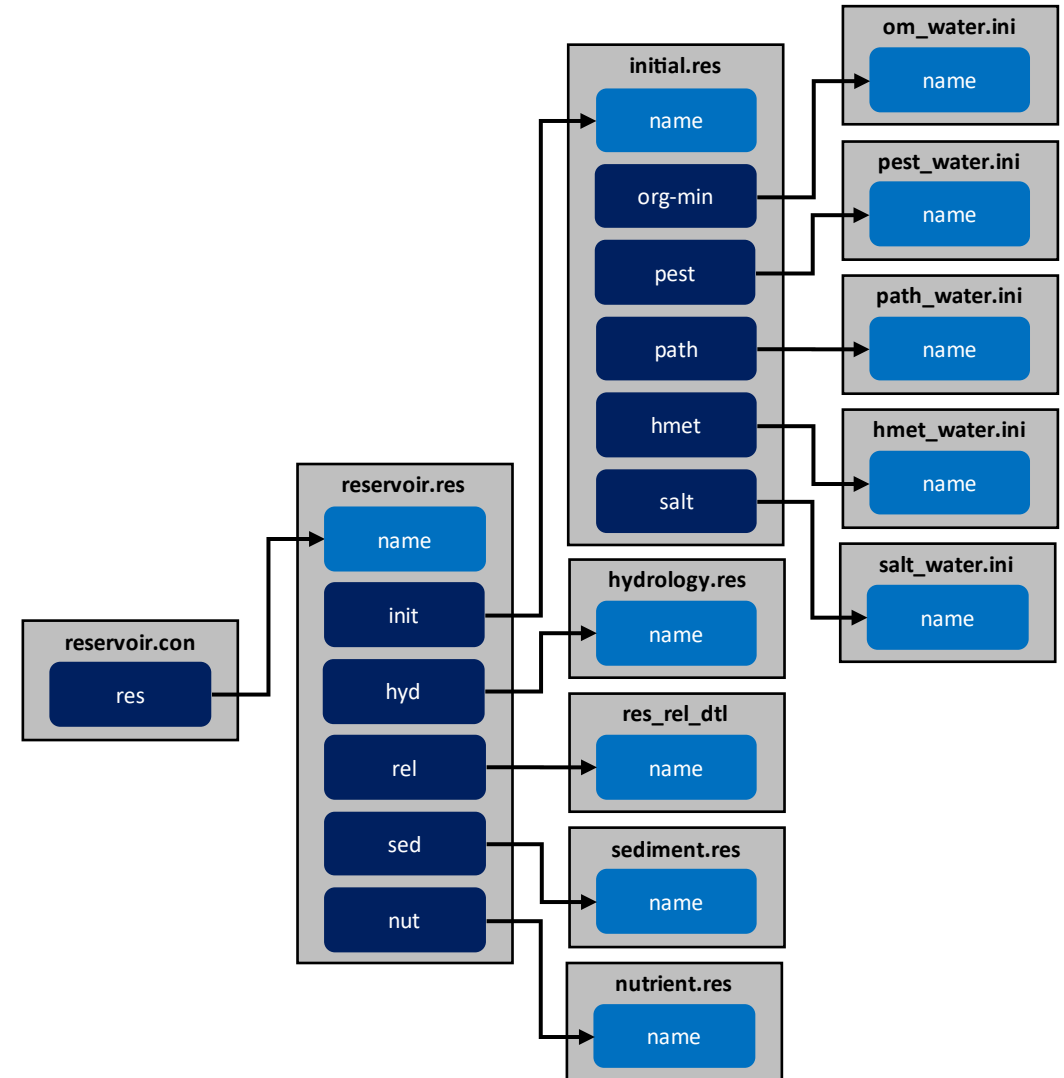
* Correspondence: rtbailey@colostate.edu

Hydrology 2020, 7, 75; doi:10.3390/hydrology7040075



Reservoir Properties

- For the reservoir properties, SWAT+ points from the reservoir connect file to a main reservoir file, which then points to files defining initial conditions, hydrology, release, sediment, and nutrients.
- The reservoir initialization file points to five files containing the initial concentrations of nutrients, pesticides, pathogens, heavy metals and salts in the water.



Reservoir Connections and Properties

reservoir.con

reservoir.res

NAME	AREA (HA)	LAT	LON	ELEV (M)	WEATHER STATION	INITIAL	RELEASE	HYDROLOGY	SEDIMENT	NUTRIENTS	#	OUTFLOW
 res01	14.10	31.74	-83.76	132.67	s31727n83738w	initres1	drawdown_days	res01	sedres1	nutres1	1	✖
 res03	10.61	31.74	-83.76	128.92	s31727n83738w	initres1	drawdown_days	res03	sedres1	nutres1	1	✖
 res04	3.49	31.74	-83.75	130.93	s31727n83738w	initres1	drawdown_days	res04	sedres1	nutres1	1	✖
 res06	0.61	31.73	-83.76	130.67	s31727n83738w	initres1	drawdown_days	res06	sedres1	nutres1	1	✖
 res08	2.49	31.72	-83.74	122.25	s31727n83738w	initres1	drawdown_days	res08	sedres1	nutres1	1	✖
 res10	1.34	31.71	-83.74	121.04	s31727n83738w	initres1	drawdown_days	res10	sedres1	nutres1	1	✖
 res11	4.04	31.71	-83.72	121.44	s31727n83738w	initres1	drawdown_days	res11	sedres1	nutres1	1	✖
 res12	0.64	31.70	-83.72	117.71	s31727n83738w	initres1	drawdown_days	res12	sedres1	nutres1	1	✖
 res13	2.68	31.70	-83.72	118.29	s31727n83738w	initres1	drawdown_days	res13	sedres1	nutres1	1	✖
 res14	1.34	31.70	-83.72	114.78	s31727n83738w	initres1	drawdown_days	res14	sedres1	nutres1	1	✖
 res18	6.43	31.71	-83.74	122.65	s31727n83738w	initres1	drawdown_days	res18	sedres1	nutres1	1	✖
 res19	1.89	31.70	-83.75	128.20	s31727n83738w	initres1	drawdown_days	res19	sedres1	nutres1	1	✖
 res20	1.94	31.71	-83.76	124.42	s31727n83738w	initres1	drawdown_days	res20	sedres1	nutres1	1	✖

Reservoir Connections

- Reservoirs usually only have one outflow to the downstream channel or reservoir.

Name

res01

Weather Station ?

s31727n83738w

Latitude

31.74315777836756

Longitude

-83.76057207904881

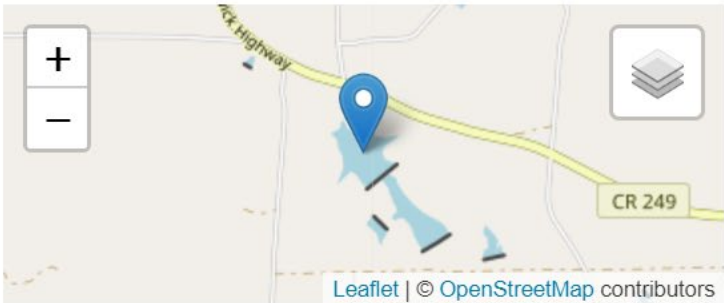
Area (ha)

14.101442027688963

Elevation (m)

132.6699422200521

Location



Outflow

	ORDER	TYPE	NAME	HYDROGRAPH	FRACTION	
	1	sdc	cha044	tot	1	

Add Outflow

2022-10-20

SWAT+ Introductory Workshop

175

SWAT+

SOIL & WATER ASSESSMENT TOOL

Create Record

SWAT+ Editor 2.1.3 / demo

File Edit View Help

- CLIMATE <
- CONNECTIONS v
 - Channels <
 - HRUs
 - Routing Units <
 - Aquifers <
 - Reservoirs** v
 - Reservoir Hydrology**
 - Initial
 - Sediment
 - Nutrients
 - Wetlands
 - Wetland Hydrology
 - Point Source / Inlet
 - Delivery Ratio <
 - BASIN <
 - REGIONS <
 - LAND USE MANAGEMENT <
 - DECISION TABLES <
 - CHANGE <
 - INITIALIZATION DATA <
 - HYDROLOGY <

Reservoirs / Hydrology

hydrology.res

Search...

Showing 1 - 15 of 15 rows

NAME	YR_OP	MON_OP	AREA_PS	VOL_PS	AREA_ES	VOL_ES	K	EVAP_CO	SHP_C01	SHP_C02
res01	1	1	14.101	141.014	16.217	162.167	0	0.600	0	0 ✖
res03	1	1	10.612	106.120	12.204	122.038	0	0.600	0	0 ✖
res04	1	1	3.485	34.855	4.008	40.083	0	0.600	0	0 ✖
res06	1	1	0.614	6.142	0.706	7.063	0	0.600	0	0 ✖
res08	1	1	2.492	24.917	2.865	28.654	0	0.600	0	0 ✖
res10	1	1	1.339	13.387	1.539	15.395	0	0.600	0	0 ✖
res11	1	1	4.044	40.445	4.651	46.511	0	0.600	0	0 ✖
res12	1	1	0.645	6.447	0.741	7.414	0	0.600	0	0 ✖
res13	1	1	2.679	26.791	3.081	30.810	0	0.600	0	0 ✖
res14	1	1	1.344	13.445	1.546	15.461	0	0.600	0	0 ✖
res18	1	1	6.426	64.260	7.390	73.899	0	0.600	0	0 ✖
res19	1	1	1.894	18.936	2.178	21.777	0	0.600	0	0 ✖
res20	1	1	1.937	19.372	2.228	22.278	0	0.600	0	0 ✖
res21	1	1	18.003	180.025	20.703	207.020	0	0.600	0	0 ✖

Create Record Import/Export

Reservoir Sediment

SWAT+ Editor 2.1.3 / demo

File Edit View Help

CLIMATE

CONNECTIONS

Channels

HRUs

Routing Units

Aquifers

Reservoirs

Reservoir Hydrology

Initial

Sediment

Nutrients

Wetlands

Wetland Hydrology

Point Source / Inlet

Delivery Ratio

BASIN

REGIONS

LAND USE MANAGEMENT

DECISION TABLES

CHANGE

INITIALIZATION DATA

HYDROLOGY

Reservoirs / Sediment

sediment.res

Search...

Showing 1 - 2 of 2 rows

NAME	SED_AMT	D50	CARBON	BD	SED_STL	STL_VEL
sedres1	1	10	0	0	1	1
sedwet1	1	10	0	0	1	1

Create Record

Import/Export

SWAT+





SOIL & WATER ASSESSMENT TOOL

Reservoirs / Nutrients

nutrients.res 

Search...

Showing 1 - 2 of 2 rows

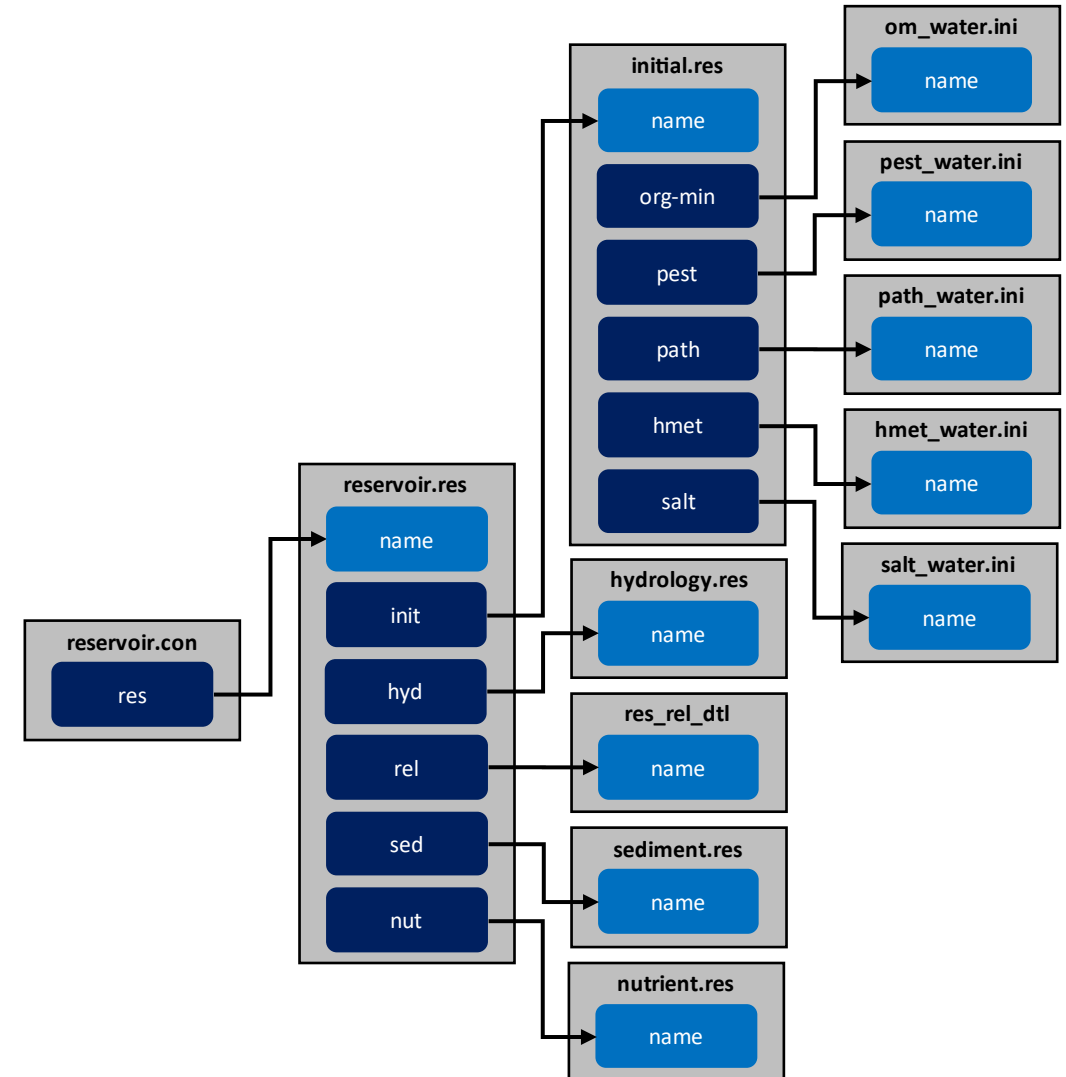
	NAME	MID_START	MID_END	MID_N_STL	N_STL	MID_P_STL	P_STL	CHLA_CO	SECCHI_CO	THETA_N	THETA_P	N_MIN_STL	P_MIN_STL	
	 nutres1	5	10	5.500	5.500	10	10	1	1	1	1	0.100	0.010	
	 nutwet1	5	10	5.500	5.500	10	10	1	1	1	1	0.100	0.010	

Create Record

Import/Export

Wetland Properties

- For the wetland properties, SWAT+ points from the HRU data file to a main wetland file, which then points to files defining initial conditions, hydrology, release, sediment, and nutrients.
- There is a wetland hydrology file, but for the initial conditions, release, sediment, and nutrients, SWAT+ uses the reservoir files.
- The wetland initialization file points to five files containing the initial concentrations of nutrients, pesticides, pathogens, heavy metals and salts in the water.



SWAT+

SOIL & WATER ASSESSMENT TOOL

2022-10-20

SWAT+

SOIL & WATER ASSESSMENT TOOL

Reservoirs / Wetlands Hydrology

Point source / Inlet

- By default, one point source has been added to each channel.
- Point source or inlet data can be added at daily, monthly, or yearly time steps using recall files.
- Constant values can be added using the export coefficient file.

The screenshot displays the SWAT+ Editor 2.1.3 / demo interface. On the left is a sidebar with a tree view containing categories like CLIMATE, CONNECTIONS, BASIN, REGIONS, LAND USE MANAGEMENT, DECISION TABLES, CHANGE, INITIALIZATION DATA, HYDROLOGY, SOILS, DATABASES, and STRUCTURAL. The 'Point Source / Inlet' option is selected under the CONNECTIONS category. The main window is titled 'Point Source / Inlet Data' and contains a table of data for 89 rows (showing 1-20). The table has columns: NAME, AREA (HA), LAT, LON, ELEV (M), WEATHER STATION, TIME STEP, and # OUTFLOW. Below the table are input fields for Name, Weather Station, Latitude, Longitude, Area (ha), and Elevation (m). There are buttons for 'Create Record' and 'Import/Export Data'. On the right, there is a map showing the location of the point source and an 'Outflow' section with a table for outflow data and an 'Add Outflow' button. At the bottom, there is a 'Time Step' dropdown set to 'Constant' and a 'Data' section with a table for data input.

Point Source / Inlet Data

In SWAT+, constant values for point sources and inlets are stored in the export coefficients properties file, exco.exc, while time series data are stored entirely in the recall section. However, in the editor, we keep both time series and constant recall and export coefficients in the same section. When you write input files, the editor will write to the appropriate files.

QSWAT+ automatically generates an empty point source location for each channel in your model. We recommend keeps all of these points in your model. They will not be used unless you update the data yourself. If keeping constant point source data, flow will need to be greater than 0 in order to be read by the model. Click a point below to modify its data, or use the import/export button at the bottom of the page.

Search...

Showing 1 - 20 of 89 rows

NAME	AREA (HA)	LAT	LON	ELEV (M)	WEATHER STATION	TIME STEP	# OUTFLOW
pt043	0.00	31.69	-83.71	106.44	s31727n83738w	Constant	1
pt045	0.00	31.70	-83.71	108.77	s31727n83738w	Constant	1
pt051	0.00	31.70	-83.72	109.00	s31727n83738w	Constant	1
pt053	0.00	31.70	-83.72	111.32	s31727n83738w	Constant	1
pt055	0.00	31.7					
pt059	0.00	31.7					
pt065	0.00	31.7					
pt067	0.00	31.7					
pt071	0.00	31.7					

Create Record Import/Export Data

Location

Outflow

Time Step

Constant

Data

JDAY	MO	DAY_MO	YR	OB_TYP	OB_NAME	FLO	SED	ORGN	SEDP	NO3	SOLP	CHLA	NH3	NO2	CBOD	DOX	SAND	SILT	CLAY
1	1	1	1	pt_const	pt043	0	0	0	0	0	0	0	0	0	0	0	0	0	0

<https://swatplus.gitbook.io/docs/user/editor/inputs/connections/recall>

<https://swatplus.gitbook.io/docs/user/editor/inputs/connections/export-coefficients>

Regions

- Regions are used to summarize SWAT+ output.
- Currently, Landscape Units are the only regions that are defined in SWAT+. They are composed of HRUs. For each Landscape Unit, the HRUs located in it and their area fractions are listed.

The screenshot displays the SWAT+ Editor 2.1.3 / demo interface. The left sidebar shows a navigation menu with categories: CLIMATE, CONNECTIONS, BASIN, REGIONS, Landscape Units (selected), LAND USE MANAGEMENT, DECISION TABLES, CHANGE, INITIALIZATION, HYDROLOGY, SOILS, DATABASES, and STRUCTURAL. The 'Landscape Units' window shows a table of units with columns: NAME, AREA, and NUMBER OF ELEMENTS. The 'Landscape Units / Edit' window shows the details for unit 'rtu0012', including its name, area (25.65 ha), and a table of elements (HRUs) with columns: NAME, TYPE, OBJECT, BASIN FRACTION, SUBBASIN FRACTION, and REGION FRACTION.

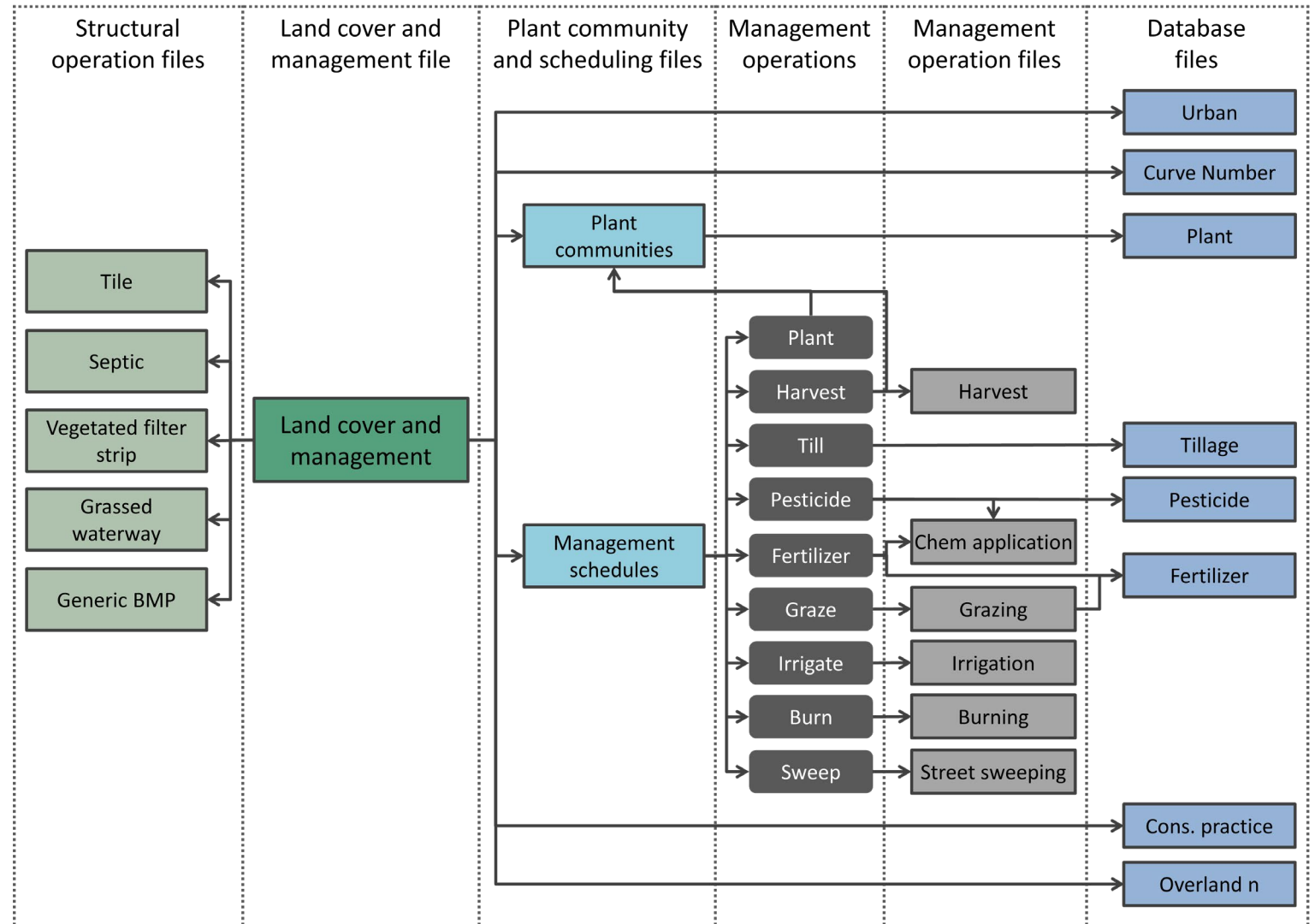
NAME	AREA	NUMBER OF ELEMENTS
rtu0012	25.650	11
rtu0022	38.610	20
rtu0032	23.370	21
rtu0062	18.630	26
rtu0072	20.420	20

NAME	TYPE	OBJECT	BASIN FRACTION	SUBBASIN FRACTION	REGION FRACTION
hru1254	hru	hru1254	0.000469	0.039014	0.000000
hru1255	hru	hru1255	0.003250	0.270277	0.000000
hru1256	hru	hru1256	0.001318	0.109581	0.000000
hru1257	hru	hru1257	0.001616	0.134384	0.000000
hru1258	hru	hru1258	0.000423	0.035174	0.000000
hru1259	hru	hru1259	0.000857	0.071250	0.000000
hru1260	hru	hru1260	0.001648	0.137089	0.000000
hru1261	hru	hru1261	0.001003	0.083426	0.000000
hru1262	hru	hru1262	0.000867	0.072127	0.000000
hru1263	hru	hru1263	0.000167	0.013855	0.000000
hru1264	hru	hru1264	0.000407	0.033822	0.000000

Land Use and Management

- For land use and management there is a main land use file, which points to several other files:

- Plant communities
- Management schedules
- Urban database
- Curve Number table
- Conservation practice table
- Overland Manning's n table
- Structural operation files



- Main landuse file with pointers to several other input files.

SWAT+ Editor 2.1.3 / demo

File Edit View Help

CLIMATE

CONNECTIONS

BASIN

REGIONS

LAND USE MANAGEMENT

Land Use Management

Management Schedules

Operations Databases

Curve Numbers

Conservation Practices

Manning's n

DECISION TABLES

CHANGE

INITIALIZATION DATA

HYDROLOGY

SOILS

DATABASES

STRUCTURAL

Land Use Management

landuse.lum

Search...

Showing 1 - 10 of 10 rows

NAME	CALIBRATION GROUP	PLANT COMM.	MANAGEMENT SCH.	CN2	CONS. PRAC.	URBAN	URBAN RUNOFF	MANNING'S N	T
corn_lum	corn_comm	corn_rot	rc_strow_g	cross_slope	null			convtill_res	n
frse_lum	frse_comm	null	wood_f	up_down_slope	null			forest_heavy	n
frst_lum	frst_comm	null	wood_f	up_down_slope	null			forest_med	n
past_lum	past_comm	null	pastg_f	up_down_slope	null			densegrass	n
rngb_lum	rngb_comm	null	brush_f	up_down_slope	null			range_20cover	n
shrb_lum	shrb_comm	null	rc_strow_g	up_down_slope	null			convtill_nores	n
soyb_lum	soyb_comm	soyb_rot	legr_strow_g	cross_slope	null			convtill_res	n
urml_lum	null	null	urban	up_down_slope	urml	buildup_washoff	urban_asphalt		n
utrn_lum	null	null	urban	up_down_slope	utrn	buildup_washoff	urban_asphalt		n
wetf_lum	wetf_comm	null	wood_p	up_down_slope	null			forest_med	n

Create Record

TILE DRAIN	SEPTIC TANK	FILTER STRIP	GRASSED WATERWAY	BMPS	DESCRIPTION
null	null	null	null	null	✗
null	null	null	null	null	✗
null	null	null	null	null	✗
null	null	null	null	null	✗
null	null	null	null	null	✗
null	null	null	null	null	✗
null	null	null	null	null	✗
null	null	null	null	null	✗
null	null	null	null	null	✗

Plant Communities

- For our example watershed, each community has only 1 plant.
- You can edit the parameters of existing plants and add plants to a community in the form that opens when clicking the edit icon.

SWAT+ Editor 2.1.3 / demo
File Edit View Help

CLIMATE <

CONNECTIONS <

BASIN <

REGIONS <

LAND USE MANAGEMENT <

DECISION TABLES <

CHANGE <

INITIALIZATION DATA ▾

Plant Communities

Soil Plant

Organic Mineral

Constituents <

HYDROLOGY <

SOILS <

DATABASES <

STRUCTURAL <

plant.ini

Search...

Showing 1 - 8 of 8 rows

NAME	INITIAL ROTATION YEAR	NUMBER OF PLANTS	DESCRIPTION
corn_comm	1	1	
frse_comm	1	1	
frst_comm	1	1	
past_comm	1	1	
mrgb_comm	1	1	
shrb_comm	1	1	
soyb_comm	1	1	
wetf_comm	1	1	

Create Record

SWAT+ Editor 2.1.3 / demo
File Edit View Help

CLIMATE <

CONNECTIONS <

BASIN <

REGIONS <

LAND USE MANAGEMENT <

DECISION TABLES <

CHANGE <

INITIALIZATION DATA ▾

Plant Communities

Soil Plant

Organic Mineral

Constituents <

HYDROLOGY <

SOILS <

DATABASES <

STRUCTURAL <

plant.ini

Plant Communities / Edit

Name
corn_comm

Initial Rotation Year
1

Description (optional)

Plants

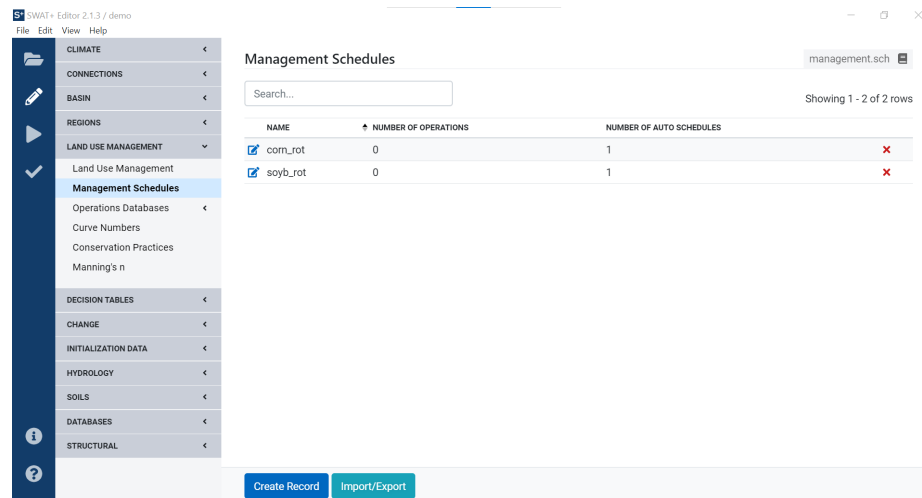
Plant	Land Cover	Init. LAI	Init. Biomass	Init. PHU Frac.	Plant Pop.	Age (yrs)	Init. Residue Cover
corn	No	0.000	0.000	0.000	0.000	0.000	10000.000

Save Changes Add Plant to Community Back

Plant	Land Cover	Init. LAI	Init. Biomass	Init. PHU Frac.	Plant Pop.	Age (yrs)	Init. Residue Cover
frse	Yes	2.000	50000.000	0.000	0.000	1.000	10000.000

Management Schedules

- For our example watershed, we are using very simple management schedules, which are defined by a Decision Table.
- However, it is also possible to define management operations based on dates or heat units by clicking the *Add an operation* button in the Advanced tab.



SWAT+ Editor 2.1.3 / demo

File Edit View Help

CLIMATE <
CONNECTIONS <
BASIN <
REGIONS <
LAND USE MANAGEMENT >
Land Use Management
Management Schedules
Operations Databases <
Curve Numbers
Conservation Practices
Manning's n
DECISION TABLES <
CHANGE <
INITIALIZATION DATA <
HYDROLOGY <
SOILS <
DATABASES <
STRUCTURAL <

Management Schedules

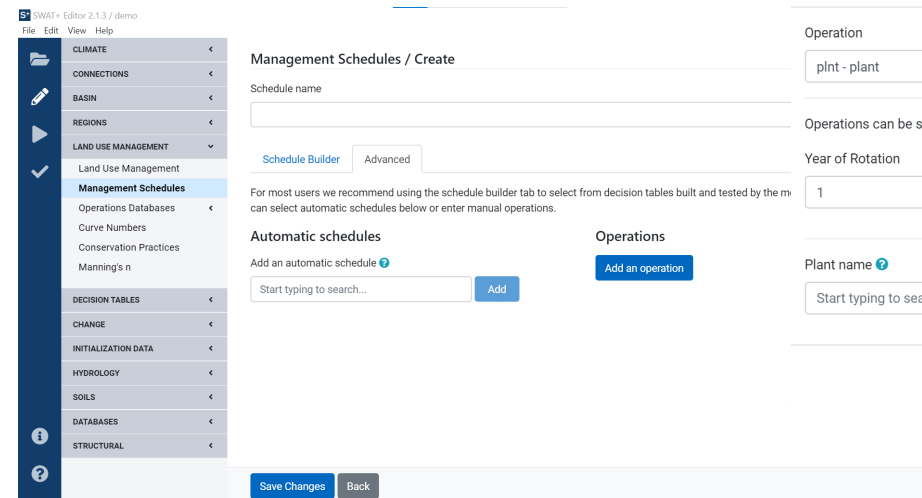
management.sch

Search...

Showing 1 - 2 of 2 rows

NAME	NUMBER OF OPERATIONS	NUMBER OF AUTO SCHEDULES
corn_rot	0	1
soyb_rot	0	1

Create Record Import/Export



SWAT+ Editor 2.1.3 / demo

File Edit View Help

CLIMATE <
CONNECTIONS <
BASIN <
REGIONS <
LAND USE MANAGEMENT >
Land Use Management
Management Schedules
Operations Databases <
Curve Numbers
Conservation Practices
Manning's n
DECISION TABLES <
CHANGE <
INITIALIZATION DATA <
HYDROLOGY <
SOILS <
DATABASES <
STRUCTURAL <

Management Schedules / Create

Schedule name

Schedule Builder Advanced

For most users we recommend using the schedule builder tab to select from decision tables built and tested by the m can select automatic schedules below or enter manual operations.

Automatic schedules

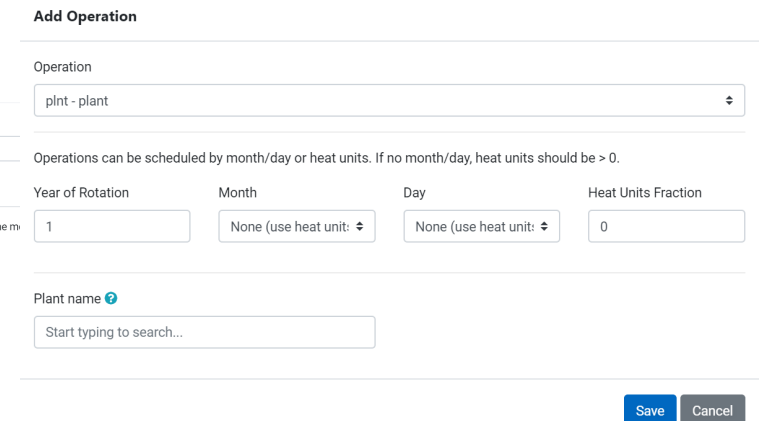
Add an automatic schedule ?

Start typing to search... Add

Operations

Add an operation

Save Changes Back



Add Operation

Operation

plnt - plant

Operations can be scheduled by month/day or heat units. If no month/day, heat units should be > 0.

Year of Rotation Month Day Heat Units Fraction

1 None (use heat unit: Day) None (use heat unit: Day) 0

Plant name ?

Start typing to search...

Save Cancel

Operation Databases

- Pre-defined parameter sets for:
 - Harvest
 - Grazing
 - Irrigation
 - Chemical Applications
 - Fire
 - Street sweeping

SWAT+ Editor 2.1.3 / demo

File Edit View Help

CLIMATE <

CONNECTIONS <

BASIN <

REGIONS <

LAND USE MANAGEMENT ▾

Land Use Management

Management Schedules

Operations Databases ▾

Harvest

Graze

Irrigation

Chemical Applications

Fire

Sweep

Curve Numbers

Conservation Practices

Manning's n

DECISION TABLES <

CHANGE <

INITIALIZATION DATA <

HYDROLOGY <

SOILS <

Operations / Harvest

Search...

Showing 1 - 14 of 14 rows

NAME	HARV_TYP	HARV_IDX	HARV_EFF	HARV_BM_MIN	DESCRIPTION
forest_cut	tree	0.950	0.990	0	
grain	grain	0	0.950	0	
grass_bag	biomass	0.500	1	2000	
grass_mulch	biomass	0.500	0	2000	
hay_cut_high	biomass	0.800	1	3000	
hay_cut_low	biomass	0.800	1	1000	
orchard	biomass	0.010	1	0	
peanuts	tuber	1.100	0.950	0	
silage	biomass	0.900	0.950	0	
stover_high	residue	0.900	1	1000	
stover_low	residue	0.300	1	3000	
stover_med	residue	0.600	1	2000	
tuber	tuber	1.100	0.950	0	
vegetables	biomass	0.500	1	2000	

Create Record Import/Export

Curve Numbers

- Pre-defined CN values for a range of land use types.

SWAT+ Editor 2.1.3 / demo
File Edit View Help

CLIMATE

CONNECTIONS

BASIN

REGIONS

LAND USE MANAGEMENT

Land Use Management

Management Schedules

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Conservation Practices

Manning's n

DECISION TABLES

CHANGE

INITIALIZATION DATA

HYDROLOGY

SOILS

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STRUCTURAL

Curve Numbers

Search...

Showing 1 - 20 of 52 rows

NAME	CN_A	CN_B	CN_C	CN_D	DESCRIPTION	TREAT	COND_COV
brush_f	35	56	70	77	Brush-brush-weed-grass_mixture_with_brush_the_major_element	----	Fair
brush_g	30	48	65	73	Brush-brush-weed-grass_mixture_with_brush_the_major_element	----	Good
brush_p	48	67	77	83	Brush-brush-weed-grass_mixture_with_brush_the_major_element	----	Poor
dirtroad	72	82	87	89	Dirt_streets_and_roads_(including_right-of-way)	----	----
fal_bare	77	86	91	94	Fallow	Bare_soil	----
fal_res_g	74	83	88	90	Fallow	Crop_residue_cover	Good
fal_res_p	76	85	90	93	Fallow	Crop_residue_cover	Poor
farm	59	74	82	86	Farmsteads-buildings_lanes_driveways_and_surrounding_lots	----	----
gravroad	76	85	89	91	Gravel_streets_and_roads_(including_right-of-way)	----	----
legr_cont_g	55	69	78	83	Close-seeded_or_broadcast_legumes_or_rotation	Contoured	Good

Create Record Import/Export

« < 1 2 3 > »

Conservation Practices

- Pre-defined values of USLE_P and slope length for several agricultural conservation practices.

SWAT+ Editor 2.1.3 / demo

File Edit View Help

CLIMATE

CONNECTIONS

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Land Use Management

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CHANGE

INITIALIZATION DATA

HYDROLOGY

SOILS

DATABASES

STRUCTURAL

Conservation Practices

cons_practice.lum

Search...

Showing 1 - 20 of 38 rows

NAME	USLE_P	SLP_LEN_MAX	DESCRIPTION
contour_1-2	0.300	121	Contour_tillage_1-2%_slopes
contour_13-16	0.700	24	Contour_tillage_13-16%_slopes
contour_17-20	0.800	18	Contour_tillage_17-20%_slopes
contour_21-25	0.900	15	Contour_tillage_21-25%_slopes
contour_3-5	0.500	91	Contour_tillage_3-5%_slopes
contour_6-8	0.500	61	Contour_tillage_6-8%_slopes
contour_9-12	0.600	36	Contour_tillage_9-12%_slopes
contour_farming	0.500	121	Contour_tillage
cross_slope	0.750	121	Cross_slope_tillage
strip17-20_past	0.400	36	Strip_cropping_17-20%_slopes_with-pasture
strip_1-2_past	0.300	244	Strip_cropping_1-2%_slopes_with-pasture
strip_1-2_row	0.600	244	Strip_cropping_1-2%_slopes_with-rowcrops
strip_13-16_past	0.350	49	Strip_cropping_13-16%_slopes_with-pasture
strip_13-16_row	0.700	49	Strip_cropping_13-16%_slopes_with-rowcrops

Create Record

Import/Export

«

<

1

2

>

»

Manning's n

- Pre-defined values of Manning's n for overland flow.

SWAT+ Editor 2.1.3 / demo
File Edit View Help

CLIMATE <
CONNECTIONS <
BASIN <
REGIONS <
LAND USE MANAGEMENT ▾
Land Use Management
Management Schedules
Operations Databases <
Curve Numbers
Conservation Practices
Manning's n
DECISION TABLES <
CHANGE <
INITIALIZATION DATA <
HYDROLOGY <
SOILS <
DATABASES <
STRUCTURAL <

Manning's n Tables

Search...

Showing 1 - 20 of 20 rows

NAME	OVN_MEAN	OVN_MIN	OVN_MAX	DESCRIPTION	
bermudagrass	0.410	0.300	0.480	Bermudagrass	✗
chisplow_nores	0.090	0.060	0.120	Chisel_plow_no_residue	✗
chisplow_res	0.130	0.100	0.160	Chisel_plow_residue	✗
convtill_nores	0.090	0.060	0.120	Conventional_tillage_no_residue	✗
convtill_res	0.190	0.160	0.220	Conventional_tillage_residue	✗
densegrass	0.240	0.170	0.300	Dense_grass	✗
falldisk_res	0.400	0.300	0.500	Fall_disking_residue	✗
fallow_nores	0.010	0.008	0.012	Fallow_no_residue	✗
forest_heavy	0.800	0.700	0.900	Forest_heavy	✗
forest_light	0.400	0.300	0.500	Forest_light_fair	✗
forest_med	0.600	0.500	0.700	Forest_medimum_good	✗
notill_0.5-1res	0.120	0.070	0.170	No_till_0.5-1_t/ha_residue	✗
notill_2-9res	0.300	0.170	0.470	No_till_2-9_t/ha_residue	✗
notill_nores	0.070	0.040	0.100	No_till_no_residue	✓

Create Record Import/Export

- Pre-defined parameter sets for:
 - Tile drains
 - Septic systems
 - Filter strips
 - Grassed waterways
 - User BMPs

SWAT+ Editor 2.1.3 / demo

File Edit View Help

CLIMATE <

CONNECTIONS <

BASIN <

REGIONS <

LAND USE MANAGEMENT <

DECISION TABLES <

CHANGE <

INITIALIZATION DATA <

HYDROLOGY <

SOILS <

DATABASES <

STRUCTURAL ▾

Tile Drains

Septic Systems

Filter Strips

Grassed Waterways

User BMPs

Grassed Waterways

grassedww.str

Search...

Showing 1 - 3 of 3 rows

NAME	FLAG	MANN	SED_CO	DP	WD	LEN	SLP	DESCRIPTION
grwway_high	0	0.050	0.020	1	4	0.500	0.100	Slope_>8
grwway_low	0	0.050	0.020	0.500	2	1	0.010	Slope_0-2
grwway_med	0	0.050	0.020	0.750	3	0.750	0.035	Slope_2-5

Create Record Import/Export

- Decision tables are a precise, compact way to model complex rule sets and their corresponding actions to represent real world decision making.
- Current uses in SWAT+
 - Land management
 - Reservoir release
 - Land use change
 - Flow conditions
- SWAT+ comes with a large number of pre-defined decision tables. The user can use those, modify them, or add new ones.

SWAT+

SOIL & WATER ASSESSMENT TOOL

Decision Tables / Land Use Management

If you want to create a new table, please select a similar table from the list below, and use the copy function. You may then edit the copy to suit your needs. You may also modify or add decision tables offline and import them into SWAT+ Editor using the import/export button below. Please export first to get your existing tables, and adhere to the formatting of the file.

This section is for advanced decision table management. We recommend most users use the [management schedule builder](#).

Project Tables

Datasets Library

The following tables are available in your project. Click the datasets library tab to see additional examples you can copy to your project.

Search...

Showing 1 - 40 of 40 rows

NAME	CONDITIONS	ACTIONS
 EnlistDuo_app	3	2
 cn2_update	2	2
 control_drainage	6	4
 fall_plow	3	2
 fert_rot_1	5	2
 fert_sprg_side	5	3
 fert_stess_test	4	2

Import/Export

SWAT+

SOIL & WATER ASSESSMENT TOOL

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SWAT+

SOIL & WATER ASSESSMENT TOOL

Decision Tables / Scenario Land Use

If you want to create a new table, please select a similar table from the list below, and use the copy function. You may then edit the copy to suit your needs. You may also modify or add decision tables offline and import them into SWAT+ Editor using the import/export button below. Please export first to get your existing tables, and adhere to the formatting of the file.

Any land use scenarios added to your project tables below will be applied to your model. Browse the datasets library tab and copy a scenario to your project as needed.







Project Tables

Datasets Library

The following tables are available in your datasets library. Select a table below to view it and copy to your project if desired.

Search...

Showing 1 - 13 of 13 rows

NAME	CONDITIONS	ACTIONS
 1800's_channel	7	4
 1800's_landuse	8	5
 1930's_channel	7	4
 1930's_consprac	7	4
 CEAP_scenarios	7	3
 CEAP_surf_vuln_index	9	4

Import/Export

SWAT+

SOIL & WATER ASSESSMENT TOOL

Decision Tables / Flow Conditions

If you want to create a new table, please select a similar table from the list below, and use the copy function. You may then edit the copy to suit your needs. You may also modify or add decision tables offline and import them into SWAT+ Editor using the import/export button below. Please export first to get your existing tables, and adhere to the formatting of the file.

We recommend not using flow condition tables at this time unless you are an advanced user who has already been in touch with the SWAT+ model development team to discuss your needs.







Project Tables

Datasets Library

The following tables are available in your datasets library. Select a table below to view it and copy to your project if desired.

Search...

Showing 1 - 14 of 14 rows

NAME	CONDITIONS	ACTIONS
 aqu_only	2	1
 ch_div_high_dmd	3	3
 ch_div_high_right	3	3
 ch_div_part_dmd	3	3
 ch_div_part_right	3	3
 ch_diver_min_flo	2	3

Import/Export

Decision Table Quadrants

- Decision Tables are divided into four quadrants:
 - Conditions
 - Alternatives
 - Outcomes
 - Actions

Conditions

Var	Obj	Obj Num	Lim Var	Lim Op	Lim Const	Alts
phu_base0	hru	0	null	-	0.15	> - - - -
phu_base0	hru	0	null	-	0.3	- - - - >
phu_plant	hru	0	phu_plant	-	1.15	- > Alternatives
soil_water	hru	0	fc	*	2	< < - - -
jday	hru	0	null	-	350	- - = - -
year_rot	hru	0	null	-	1	- - - > -

Actions

Act Typ	Obj	Obj Num	Name	Option	Const	Const2	Fp	Outcomes
plant	hru	0	plant	crop	0	1	null	y n n n y
harvest_kill	hru	0	grain_harv	crop	0	1	grain	n y y n n
rot_reset	hru	0	reset_1	null	1	1	null	n n n y n

Decision Table Example

name	conds	alts	acts							
pl_hv_corn	6	4	3							
var	obj	obj_num	lim_var	lim_op	lim_const					
soil_water	hru	0	fc	*	1.05		alt1	alt2	alt3	alt4
phu_base0	hru	0	null	-	0.15		<	<	-	-
phu_plant	hru	0	phu_mat	-	1.15		>	-	-	-
year_rot	hru	0	null	-	1		-	>	-	-
jday	hru	0	null	-	350		=	=	=	-
year_rot	hru	0	null	-	1		-	-	=	-
act_typ	obj	obj_num	name	option	const	const2	fp			
plant	hru	0	plant_corn	corn	0	1	null	outcome		
harvest_kill	hru	0	grain_harv	corn	0	1	grain	y	n	n
rot_reset	hru	0	reset_1	null	1	0	null	n	y	n

- For each Decision Table, the SWAT+ Editor provides a description and a tab for editing its plain text version.

SWAT+ Editor 2.1.3 / demo

File Edit View Help

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Decision Tables / Edit

Name

cn2_update

Description

Description

Advanced Editing

If potential heat units (plant based) > phu_mat 0.1 then cn_update abschg (lower_cn_grow)

If days since last harvest = 1 then cn_update abschg (increase_cn_harv)

This table isn't being using in your project. Use the [management schedule builder](#) to include and/or edit this table.

Back

Copy

Delete

Description

Advanced Editing

Warning: advanced users only. If you are comfortable with the decision table format, you may edit in plain text below.

name	conds	alts	acts					
cn2_update	2	2	2					
var	obj	obj_num	lim_var	lim_op	lim_const	alt1	alt2	
phu_plant	hru	0	phu_mat	-	0.1	>	-	
days_harv	hru	0	null	-	1	-	=	
act_typ	obj	obj_num	name	option	const	const2		
cn_update	hru	0	lower_cn_grow	abschg	-3	1		
cn_update	hru	0	increase_cn_harv	abschg	6	1		

Editing Decision Tables cont'd

- For editing Land Use and Management DTs, it is recommended to use the Management Schedule Builder.

SWAT+ Editor 2.1.3 / demo

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Decision Tables / Edit

lum.dtl

Name

pl_hv_summer1

Description

plant and harvest for continuous summer crop

Description Plain Text

This decision table is reserved in the model and cannot be modified.
To change any values in this table, we recommend making a copy and editing the copy instead.

Conditions

Var	Obj	Obj Num	Lim Var	Lim Op	Lim Const	Alts
phu_base0	hru	0	null	-	0.15	> - - - -
phu_base0	hru	0	null	-	0.3	- - - - >
phu_plant	hru	0	phu_mat	-	1.15	- > - - -
soil_water	hru	0	fc	*	2	< < - - -
jday	hru	0	null	-	350	- - = - -
vear_rot	hru	0	null	-	1	- - - > -

Back Copy

- Parameters describing the hydrologic properties of the HRUs.
- Each HRU has its own record in the hydrology file to allow users to calibrate the hydrology of individual HRUs, but the default values are the same for all HRUs.

SWAT+ Editor 2.1.3 / demo
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SOILS <
DATABASES <
STRUCTURAL <

Hydrology hydrology.hyd

Search...

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NAME	LAT_TTIME	LAT_SED	CAN_MAX	ESCO	EPCO	ORGN_ENRICH	ORGP_ENRICH	CN3_SWF	BIO_MIX	PERCO	LAT_ORGN	LAT_ORGP
hyd0001	0	0	1	0.950	1	0	0	0.950	0.200	0.900	0	0
hyd0002	0	0	1	0.950	1	0	0	0.950	0.200	0.050	0	0
hyd0003	0	0	1	0.950	1	0	0	0.950	0.200	0.050	0	0
hyd0004	0	0	1	0.950	1	0	0	0.950	0.200	0.900	0	0
hyd0005	0	0	1	0.950	1	0	0	0.950	0.200	0.900	0	0
hyd0006	0	0	1	0.950	1	0	0	0.950	0.200	0.050	0	0
hyd0007	0	0	1	0.950	1	0	0	0.950	0.200	0.050	0	0
hyd0008	0	0	1	0.950	1	0	0	0.950	0.200	0.900	0	0
hyd0009	0	0	1	0.950	1	0	0	0.950	0.200	0.900	0	0
hyd0010	0	0	1	0.950	1	0	0	0.950	0.200	0.900	0	0
hyd0011	0	0	1	0.950	1	0	0	0.950	0.200	0.900	0	0
hyd0012	0	0	1	0.950	1	0	0	0.950	0.200	0.050	0	0
hyd0013	0	0	1	0.950	1	0	0	0.950	0.200	0.050	0	0

Create Record Import/Export

« < 1 2 3 4 ... > »

Topography

- Parameters describing the topographic properties of HRUs and RTUs.
- Each HRU and RTU has its own record in the topography file as the slope is calculated based on the DEM and varies by HRU/RTU.
- The records for HRUs are listed first, followed by the records for RTUs.

SWAT+ Editor 2.1.3 / demo
File Edit View Help

topography.hyd

Topography

Search...

Showing 1 - 20 of 1422 rows

NAME	SLP	SLP_LEN	LAT_LEN	DIST_CHA	DEPOS	
topohru0001	0.03457	60	60	121	0	✗
topohru0002	0.01532	90	90	121	0	✗
topohru0003	0.03251	60	60	121	0	✗
topohru0004	0.02746	90	90	121	0	✗
topohru0005	0.01797	90	90	121	0	✗
topohru0006	0.01603	90	90	121	0	✗
topohru0007	0.02954	90	90	121	0	✗
topohru0008	0.01526	90	90	121	0	✗
topohru0009	0.03201	60	60	121	0	✗
topohru0010	0.01526	90	90	121	0	✗
topohru0011	0.03201	60	60	121	0	✗
topohru0012	0.02568	90	90	121	0	✗
topohru0013	0.01219	90	90	121	0	✗
topohru0014	0.00624	121	121	121	0	✓

Create Record Import/Export

« < 1 2 3 4 ... > »

Fields

- Parameters defining the dimensions and angle of a field.
- Fields are currently only used for routing sediment across floodplains.

SWAT+ Editor 2.1.3 / demo
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field.fld

Fields

Search...

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NAME	LEN	WD	ANG
fld0012	500	100	30 ✖
fld0022	500	100	30 ✖
fld0032	500	100	30 ✖
fld0062	500	100	30 ✖
fld0072	500	100	30 ✖
fld0082	500	100	30 ✖
fld0102	500	100	30 ✖
fld0132	500	100	30 ✖
fld0142	500	100	30 ✖
fld0152	500	100	30 ✖
fld0172	500	100	30 ✖
fld0182	500	100	30 ✖
fld0192	500	100	30 ✖
fld0212	500	100	30 ✖

Create Record Import/Export

« < 1 2 3 4 ... > »

Soil Physical Properties

- Parameters describing the physical properties of the soils in the watershed.

SWAT+ Editor 2.1.3 / demo
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Soils

Nutrients

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Soils

soils.sol

Showing 1 - 9 of 9 rows

NAME	HYD_GRP	DP_TOT	ANION_EXCL	PERC_CRK	TEXTURE	DESCRIPTION
LREW02	A	2160	0.500	0.500	S-S	
LREW03	B	1520	0.500	0.500	LS-SCL-SCL	
LREW04	B	1930	0.500	0.500	SL-SC-C	
LREW05	B	1650	0.500	0.500	LS-SL-SCL	
LREW06	B	1650	0.500	0.500	LS-SL-SCL-SCL	
LREW08	C	1650	0.500	0.500	SL-SCL-SCL	
LREW09	C	1650	0.500	0.500	LS-SL-SCL	
LREW10	D	1780	0.500	0.500	LS-SCL-SCL	
LREW12	D	25.400	0.500	0.500	water	

Create Record

Soil Layers

	Layer_num	Dp	Bd	Awc	Soil_k	Carbon	Clay	Silt	Sand	Rock	Alb	Usle_k	Ec	Caco3	Ph
	1	1520	1.500	0.070	331.200	0.435	5	1.400	93.600	6	0.300	0.100	0	0	5.300
	2	2160	1.550	0.050	331.200	0.145	3.500	1.500	95	6	0.300	0.100	0	0	5.300

Soil Nutrients

- Parameters describing the initial nutrient contents in the soils.
- The *Soils* column in the main HRU file points to the *Name* column in the soil and plant initialization file, which then points to the *Name* column in this file.

SWAT+ Editor 2.1.3 / demo

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Soils

Nutrients

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Soil Nutrients

Search...

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NAME	EXP_CO	LAB_P	NITRATE	FR_HUM_ACT	HUM_C_N	HUM_C_P	INORGP	WATERSOL_P	H3A_P	MEHLICH_P	BRAY_STRONG_P	DESCRIPTIC
soilnut1	0.001	5	7	0.020	10	80	3.500	0.150	0.250	1.200	0.850	

Create Record Import/Export

Databases

- SWAT+ includes the following databases:
 - Plants
 - Fertilizer
 - Tillage
 - Pesticides
 - Urban
 - Septic
 - Snow

SWAT+ Editor 2.1.3 / demo
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Plants plants.plt

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NAME	PLNT_TYP	GRO_TRIG	NFIX_CO	DAYS_MAT	BM_E	HARV_IDX	LAI_POT	FRAC_HU1	LAI_MAX1	FRAC_HU2	LAI_MAX2	HU_LAI_D
agrc	cold_annual	temp_gro	0	110	30	0.400	4	0.050	0.050	0.450	0.950	0
agrl	warm_annual	temp_gro	0	110	33.500	0.450	3	0.150	0.050	0.500	0.950	0
agrr	warm_annual	temp_gro	0	110	39	0.500	3	0.150	0.050	0.500	0.950	0
alfa	perennial	temp_gro	0.500	0	20	0.900	4	0.150	0.010	0.500	0.950	0
almd	perennial	temp_gro	0	0	16.100	0.050	1.200	0.050	0.050	0.400	0.950	0
appl	perennial	temp_gro	0	0	15	0.100	4	0.100	0.150	0.500	0.750	0
aspn	perennial	temp_gro	0	0	30	0.760	5	5	0.050	40	0.950	0
aspr	perennial	temp_gro	0	0	90	0.800	4.200	0.250	0.230	0.400	0.860	0
bana	perennial	temp_gro	0	0	30	0.440	4.500	0.050	0.050	0.400	0.950	0
barl	cold_annual	temp_gro	0	105	35	0.540	4	0.150	0.010	0.450	0.950	0
barl100	cold_annual	temp_gro	0	100	35	0.540	4	0.150	0.010	0.450	0.950	0
barl105	cold_annual	temp_gro	0	105	35	0.540	4	0.150	0.010	0.450	0.950	0
bbbs	perennial	temp_gro	0	0	14	0.900	3	0.050	0.100	0.250	0.700	0

Create Record Import/Export

<< < 1 2 3 4 ... > >>

Plant Database

- Parameters controlling plant growth under ideal conditions and quantifying the impact of some stresses in SWAT+.
- Includes a number of generic land cover types to facilitate linkage between the land use map and SWAT+ plants/crops.
- The list is by no means exhaustive and users may need to add plants to the database.

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Plants plants.plt

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NAME	PLNT_TYP	GRO_TRIG	NFIX_CO	DAYS_MAT	BM_E	HARV_IDX	LAI_POT	FRAC_HU1	LAI_MAX1	FRAC_HU2	LAI_MAX2	HU_LAI_D
agrc	cold_annual	temp_gro	0	110	30	0.400	4	0.050	0.050	0.450	0.950	0
agrl	warm_annual	temp_gro	0	110	33.500	0.450	3	0.150	0.050	0.500	0.950	0
agrr	warm_annual	temp_gro	0	110	39	0.500	3	0.150	0.050	0.500	0.950	0
alfa	perennial	temp_gro	0.500	0	20	0.900	4	0.150	0.010	0.500	0.950	0
almd	perennial	temp_gro	0	0	16.100	0.050	1.200	0.050	0.050	0.400	0.950	0
appl	perennial	temp_gro	0	0	15	0.100	4	0.100	0.150	0.500	0.750	0
aspn	perennial	temp_gro	0	0	30	0.760	5	5	0.050	40	0.950	0
aspr	perennial	temp_gro	0	0	90	0.800	4.200	0.250	0.230	0.400	0.860	
bana	perennial	temp_gro	0	0	30	0.440	4.500	0.050	0.050	0.400	0.950	0
barl	cold_annual	temp_gro	0	105	35	0.540	4	0.150	0.010	0.450	0.950	0
barl100	cold_annual	temp_gro	0	100	35	0.540	4	0.150	0.010	0.450	0.950	0
barl105	cold_annual	temp_gro	0	105	35	0.540	4	0.150	0.010	0.450	0.950	0
bbls	perennial	temp_gro	0	0	14	0.900	3	0.050	0.100	0.250	0.700	0

Create Record Import/Export

« < 1 2 3 4 ... > »

Fertilizer Database

- Parameters that describe the nutrient contents in various fertilizers and manure.

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Fertilizer fertilizer.frt

Search...

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NAME	MIN_N	MIN_P	ORG_N	ORG_P	NH3_N	PATHOGENS	DESCRIPTION
00_06_00	0	0.026	0	0	0		00_06_00
00_15_00	0	0.066	0	0	0		00_15_00
02_09_00	0.020	0.040	0	0	0		02_09_00
03_06_00	0.030	0.026	0	0	0		03_06_00
04_08_00	0.040	0.035	0	0	0		04_08_00
05_10_05	0.050	0.044	0	0	0		05_10_05
05_10_10	0.050	0.044	0	0	0		05_10_10
05_10_15	0.050	0.044	0	0	0		05_10_15
06_24_24	0.060	0.106	0	0	0		06_24_24
07_00_00	0.070	0	0	0	0		07_00_00
07_07_00	0.070	0.031	0	0	0		07_07_00
08_08_00	0.080	0.035	0	0	0		08_08_00
08_15_00	0.080	0.066	0	0	0		08_15_00
10_10_10	0.100	0.100	0	0	0		10_10_10

Create Record Import/Export

« < 1 2 3 > »

Tillage Database

- Parameters describing the redistribution of nutrients due to tillage operations.
- The list was summarized from a farm machinery database maintained by the USDA Economic Research Service.

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Tillage

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NAME	MIX_EFF	MIX_DP	ROUGH	RIDGE_HT	RIDGE_SP	DESCRIPTION
bedderd	0.550	150	35	0	0	bedder(disk)
bedders	0.550	150	30	0	0	beddershaper
beddhipr	0.650	150	35	0	0	bedderdisk-hipper
beddkrow	0.850	100	40	0	0	bedderdisk-row
bedrollr	0.250	50	5	0	0	bedroller
beetcult	0.250	25	15	0	0	beetcultivator
blade10	0.250	75	13	0	0	blade10ft
cchplow	0.500	150	20	0	0	coulter-chiselplow
chisplow	0.300	150	20	0	0	chiselplow
cltiweed	0.300	100	15	0	0	cultiweeder
constill	0.250	100	40	0	0	genericconservationtillage
crustbst	0.100	60	10	0	0	crustbuster
culmulch	0.250	25	5	0	0	culti-mulchroller
cultmul	0.250	40	5	0	0	culti-mulchroller

Create Record Import/Export

« < 1 2 3 4 > »

- Parameters that describe the properties of various pesticides.

SWAT+ Editor 2.1.3 / demo

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Pesticides

pesticide.pes

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NAME	SOIL_ADS	FRAC_WASH	HL_FOLIAGE	HL_SOIL	SOLUB	AQ_HLIFE	AQ_VOLAT	MOL_WT	AQ_RESUS	AQ_SETTLE	BEN_ACT_DEP	BEN
1sutan	400	0.300	1	13	44	0.007	0.000	0.100	0.002	0.500	0.300	
245-tp	2600	0.400	5	20	2.500	0.007	0.000	0.100	0.002	0.500	0.300	
2plus2	20	0.950	10	21	660000	0.007	0.000	0.100	0.002	0.500	0.300	
a-rest	120	0.500	30	120	650	0.007	0.000	0.100	0.002	0.500	0.300	
aatrex	171	0.450	5	60	33	0.007	0.000	0.100	0.002	0.500	0.300	
abate	100000	0.650	5	30	0	0.007	0.000	0.100	0.002	0.500	0.300	
acaraben	2000	0.050	10	20	13	0.007	0.000	0.100	0.002	0.500	0.300	
accelera	20	0.900	7	7	100000	0.007	0.000	0.100	0.002	0.500	0.300	
acclaim	9490	0.200	5	9	0.800	0.007	0.000	0.100	0.002	0.500	0.300	
alanap	20	0.950	7	14	231000	0.007	0.000	0.100	0.002	0.500	0.300	
alar	10	0.950	4	7	100000	0.007	0.000	0.100	0.002	0.500	0.300	
aldrin	300	0.050	2	28	0.100	0.007	0.000	0.100	0.002	0.500	0.300	

Create Record Import/Export

« < 1 2 3 4 ... > »

- Parameters that control the hydrologic behavior of urban areas.

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Septic

Snow

STRUCTURAL

Urban

urban.urb

Search...

Showing 1 - 9 of 9 rows

NAME	FRAC_IMP	FRAC_DC_IMP	CURB_DEN	URB_WASH	DIRT_MAX	T_HALFMAX	CONC_TOTN	CONC_TOTP	CONC_NO3N	URB_CN	DESCRIPTION
ucom	0.670	0.620	0.280	0.180	200	1.600	420	240	5.500	98	Commercial
uidu	0.840	0.790	0.140	0.180	400	2.350	430	104	5.600	98	Industrial
uins	0.510	0.470	0.120	0.180	340	3.900	480	212	6.300	98	Institutional
urnb	0.380	0.300	0.240	0.180	225	0.750	550	223	7.200	98	Residential
urhd	0.600	0.440	0.240	0.180	225	0.750	550	223	7.200	98	Residential-High Density
urld	0.120	0.100	0.240	0.180	225	0.750	460	196	6	98	Residential-Low Density
urmd	0.380	0.300	0.240	0.180	225	0.750	550	223	7.200	98	Residential-Medium Density
urml	0.200	0.170	0.240	0.180	225	0.750	460	196	6	98	Residential-Med/Low Density
utrn	0.980	0.950	0.120	0.180	340	3.900	480	212	6.300	98	Transportation

Create Record Import/Export

- Parameters for different septic systems.

SWAT+ Editor 2.1.3 / demo

File Edit View Help

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SOILS

DATABASES

Plants

Fertilizer

Tillage

Pesticides

Pathogens

Urban

Septic

Snow

STRUCTURAL

Septic

septic.sep

Search...

Showing 1 - 20 of 26 rows

NAME	Q_RATE	BOD	TSS	NH4_N	NO3_N	NO2_N	ORG_N	MIN_P	ORG_P	FCOLI	DESCRIPTION
bfl1	0.227	28.500	18.500	0	0	0	0	0	0	0	22Waterloo
bfl2	0.227	16.800	5	10.200	5.700	0	0	2.600	0.450	945	23Peat
cond	0.227	170	75	58	0.200	0	14	9	1	10000000	3Conventional
cwt1	0.227	26.500	12	0	0	0	0	0.600	0.110	968	17Septic
cwt2	0.227	27	15	0	0	0	0	0	0	0	18Municipad
cwt3	0.227	0	4.200	0.860	0	0	0	0.204	0.040	77	19Municipad
cwt4	0.227	7.500	14	3.290	0	0	0	0	0	0	20Municipal
cwt5	0.227	1.700	9.500	1.980	0	0	0	0	0	0	21Municipawetla
gadv	0.227	22	14	18.900	9.600	0	3	5.100	0.900	543	2Generic
gcon	0.227	170	75	42.400	0	0	10	6	1	10000000	1Generic
gfl1	0.227	25	220	25	0	0	25	10	2	10000000	26Untreated
rcf1	0.227	3.500	3.500	0	0	0	0	0	0	2920	14At
rcf2	0.227	5	6.500	0	0	0	0	0	0	3030	15Maryland
rcf3	0.227	11.500	13.500	5.500	20	0	0	5.100	0.900	57000	16Recirculating

Create Record Import/Export

« < 1 2 > »

- Parameters controlling snow fall, snow accumulation, and snow melt.
- There is currently only 1 record in the database.
- In watersheds with large variations in topography it can be useful to use more than one snow record (e.g., for mountainous headwater areas vs flat downstream areas).

The screenshot shows the SWAT+ Editor 2.1.3 / demo interface. On the left is a sidebar with a tree view of the database structure. The 'Snow' database is selected, showing a list of parameters: CLIMATE, CONNECTIONS, BASIN, REGIONS, LAND USE MANAGEMENT, DECISION TABLES, CHANGE, INITIALIZATION DATA, HYDROLOGY, SOILS, DATABASES (expanded), Plants, Fertilizer, Tillage, Pesticides, Pathogens, Urban, Septic, Snow (selected), and STRUCTURAL. The main window displays the 'Snow' table with a search bar and a table of data. The table has 10 columns: NAME, FALL_TMP, MELT_TMP, MELT_MAX, MELT_MIN, TMP_LAG, SNOW_H2O, COV50, and SNOW_INIT. There is one row with the name 'snow001' and values: 1, 0.500, 4.500, 4.500, 1, 1, 0.500, and 0. The status bar at the bottom shows 'Showing 1 - 1 of 1 rows' and buttons for 'Create Record' and 'Import/Export'.

NAME	FALL_TMP	MELT_TMP	MELT_MAX	MELT_MIN	TMP_LAG	SNOW_H2O	COV50	SNOW_INIT
snow001	1	0.500	4.500	4.500	1	1	0.500	0

- Hard Data
 - Long term, measured time series, typically at a point in the watershed (e.g. the outlet).
 - Typically used for visual comparison of hydrographs and model evaluation statistics.
- Problem:
 - A model can show excellent statistical agreement with measured stream gauge data, while misrepresenting processes (water balance, nutrient balance, sediment source/sinks) within a field or watershed.
 - This will cause errors when running management and climate scenarios.
- Soft Data
 - Information on individual processes within a budget. May not be directly measured within a study area. May be an average annual estimate and entail considerable uncertainty.

- Instead of changing the parameter values in the input files, SWAT+ uses a calibration file that overrides the original values.
- Change types:
 - replace value (absval)
 - absolute addition to or subtraction from of value (abschg)
 - percent addition to or subtraction from value (pctchg)
- Can be conditioned on land use, soil, etc.
- Calibration parameters can be added by selecting *Hard Calibration* and clicking the *Create Record* button.

Adding a Calibration Record

SWAT+ Editor 2.1.3 / demo

File Edit View Help

CLIMATE

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DECISION TABLES

CHANGE

Hard Calibration

Parameters

Soft Calibration

INITIALIZATION DATA

HYDROLOGY

SOILS

DATABASES

STRUCTURAL

?

Hard Calibration / Edit

calibration.cal

Calibration Parameter ?

esco

Type of Change

Change the value of the parameter (absval)

Value of Change

0.5

Select Objects to Calibrate

All will be calibrated if none are selected.

☐ hru0001

☐ hru0002

☐ hru0003

☐ hru0004

☐ hru0005

☐ hru0006

☐ hru0007

☐ hru0008

☐ hru0009

☐ hru0010

☐ hru0011

☐ hru0012

Save Changes

Add Condition

Back

Calibration Conditions

This calibration does not have any conditions. Add now.

Add Condition

Type of Condition

Land use

Condition Operator

=

Value

frst

Save Changes

Cancel

Calibration Conditions

	TYPE	OPERATOR	VALUE	
	landuse	=	frst	

Calibration Parameters

- List of parameters you can use for calibration, their object type, minimum and maximum value, and units.

SWAT+ Editor 2.1.3 / demo
File Edit View Help

CLIMATE <
CONNECTIONS <
BASIN <
REGIONS <
LAND USE MANAGEMENT <
DECISION TABLES <
CHANGE v
Hard Calibration Parameters v
Soft Calibration <
INITIALIZATION DATA <
HYDROLOGY <
SOILS <
DATABASES <
STRUCTURAL <

Hard Calibration / Parameters cal_parms.cal

You cannot add new parameters because they are determined by the model; however, you may edit the absolute minimum and maximum values by selecting a row below.

Search...

NAME	OBJ_TYP	ABS_MIN	ABS_MAX	UNITS
alpha	aqu	0	1	days
bf_max	aqu	0.100	2	mm
deep_seep	aqu	0.001	0.400	m/m
sp_yld	aqu	0	0.500	fraction
flo_min	aqu	0	50	m
revap_co	aqu	0.020	0.200	
revap_min	aqu	0	50	m
plaps	bsn	0	200	
tlaps	bsn	-10	10	
surlag	bsn	0.050	24	days
adj_pkr	bsn	0.500	2	
prf	bsn	0	2	
spcon	bsn	0.000	0.010	
snxyn	bsn	1	1	500

- Simple heuristic procedure for soft calibration of water balance in SWAT+
 - One or two variables for each process
 - Calibrates within 15 simulations
- Procedures for soft calibration of sediment and nutrient budgets are currently being added.

Including a Soft Calibration

- First, you need to tell the SWAT+ Editor to include a soft calibration and specify what you would like to calibrate.

The screenshot shows the SWAT+ Editor 2.1.3 / demo interface. On the left is a dark blue sidebar with a menu. The menu items are: CLIMATE, CONNECTIONS, BASIN, REGIONS, LAND USE MANAGEMENT, DECISION TABLES, CHANGE, Hard Calibration, Soft Calibration (expanded), Water Balance, Water Balance Parameters, Channel Sediment Budget, Channel Parameters, Plant Growth, Plant Parameters, INITIALIZATION DATA, HYDROLOGY, SOILS, DATABASES, and STRUCTURAL. The 'Soft Calibration' option is highlighted in light blue. The main window is titled 'Soft Calibration' and contains a text box with the following text: 'The soft calibration codes file contains the input variables for the characteristics of the calibration update properties. Do you want to include and configure these codes in your model?'. Below this text are two buttons: 'No, do not use' and 'Yes, include'. The 'Yes, include' button is selected. Below the buttons is a list of calibration options, each with a checkbox:

- ☒ Calibrate hydrologic balance for hru by land use in each region
- ☐ Calibrate hydrologic balance for hru_lte by land use in each region
- ☐ Calibrate plant growth by land use (by plant) in each region
- ☐ Calibrate sediment yield by land use in each region
- ☐ Calibrate nutrient balance by land use in each region
- ☐ Calibrate channel widening and bank accretion by stream order
- ☐ Calibrate channel nutrient balance by stream order
- ☐ Calibrate reservoir budgets by reservoir

 At the bottom of the window are two buttons: 'Save Changes' and 'Back'.

Defining the Soft Calibration Goals

- Here, you specify the average annual percentages of different water balance components that you want SWAT+ to simulate as closely as possible.

SWAT+ Editor 2.1.3 / demo

File Edit View Help

CLIMATE

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CHANGE

Hard Calibration

Soft Calibration

Water Balance

Water Balance Parameters

Channel Sediment Budget

Channel Parameters

Plant Growth

Plant Parameters

INITIALIZATION DATA

HYDROLOGY

SOILS

DATABASES

STRUCTURAL

?

Soft Calibration / Water Balance

water_balance.sft

Search...

Showing 1 - 1 of 1 rows

NAME	ITEMS
frst	0

Create Record

Add Item

Land Use Management

Start typing to search...

Value	Description	SWAT+ Variable	Default	
<input type="text"/>	Surface runoff ratio	surq_rto	0	
<input type="text"/>	Lateral flow ratio	latq_rto	0	
<input type="text"/>	Percolation ratio	perc_rto	0	
<input type="text"/>	ET ratio	et_rto	0	
<input type="text"/>	Tile flow ratio	tileq_rto	0	
<input type="text"/>	Potential evapotranspiration	pet	0	
<input type="text"/>	t/ha or t	Sediment yield	sed	0

Save Changes Cancel

Defining the Soft Calibration Parameters

- Here, the parameters to be used for the soft calibration and the ranges should be defined.

SWAT+ Editor 2.1.3 / demo

File Edit View Help

CLIMATE <

CONNECTIONS <

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REGIONS <

LAND USE MANAGEMENT <

DECISION TABLES <

CHANGE >

Hard Calibration <

Soft Calibration >

Water Balance

Water Balance Parameters

Channel Sediment Budget

Channel Parameters

Plant Growth

Plant Parameters

INITIALIZATION DATA <

HYDROLOGY <

SOILS <

DATABASES <

STRUCTURAL <

Soft Calibration / Water Balance Parameters / Create

wb_parms.sft

Parameter name

Type of change

Value	Description	SWAT+ Variable
	Negative limit of change	neg
	Positive limit of change	pos
	Lower limit of parameter	lo
	Upper limit of parameter	up

Save Changes Back

Hints for Calibration of SWAT+ Models

- Plant growth/crop yields
- Average annual/seasonal/monthly water balance
- Hydrology first, then sediment and finally nutrients
- Hydrograph:
 - Timing and magnitude of storm events
 - Recession
 - Baseflow
- Flow Duration Curves
- Sediment and nutrients:
 - Loadings from HRUs/Subbasins
 - Channel degradation/deposition
- Model Evaluation Statistics:
 - Nash-Sutcliffe Efficiency
 - Kling-Gupta Efficiency
 - Coefficient of Determination (R^2)
 - Percent bias (PBIAS)
 - Root Mean Square Error (RMSE)

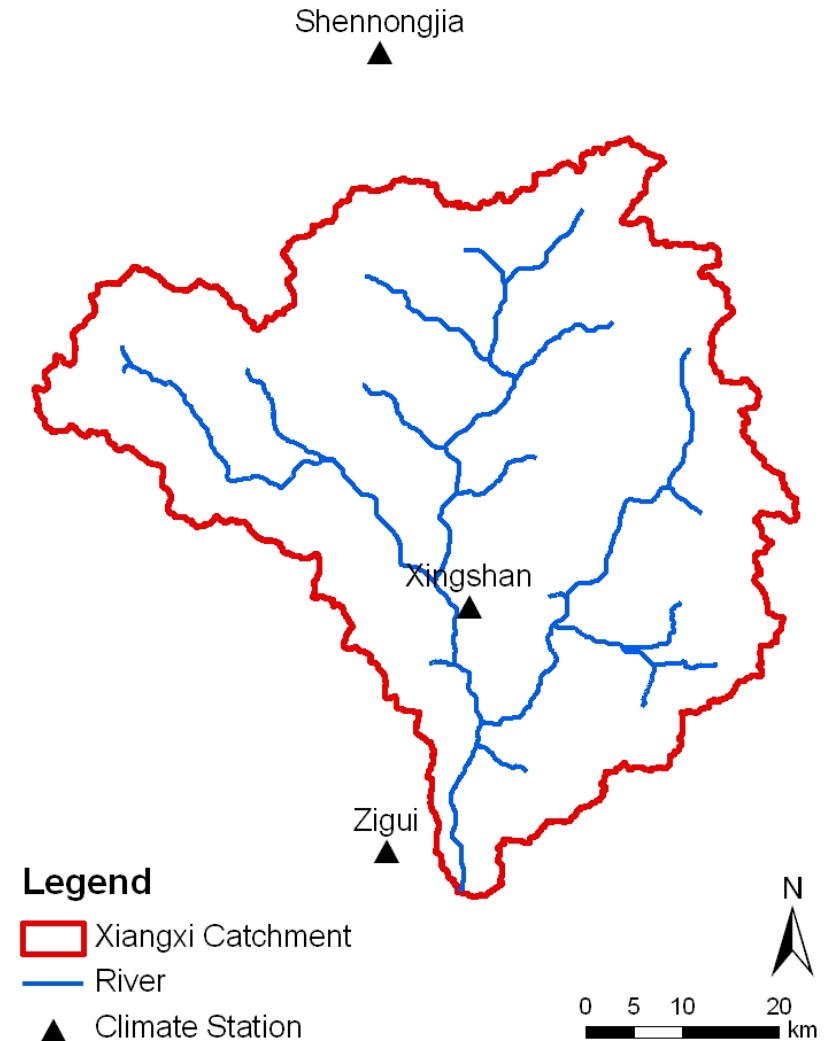
Common Calibration Problems

- Too little data - monitoring period too short
- Small range of conditions
- Prediction of future conditions which are outside the model conditions
- Calibration/validation does not adequately test separate pieces of model
- Calibration adjustments destroy physical representation of system by model
- Adjustment of the wrong parameters

- Be aware of the uncertainties associated with the model output (and be honest about this in publications and project reports).
- If you have the chance, go to the watershed and do some field work.

Sources of Uncertainty I

- Spatial resolution of climate data
- Implementation of elevation bands in order to account for increase in precipitation with elevation
- But spatial rainfall variability still not captured by climate stations



Sources of Uncertainty II

Missing information on growth of natural vegetation and/or agricultural management (crop rotations, tillage, time of planting, time of harvest, fertilization, irrigation)



Sources of Uncertainty III

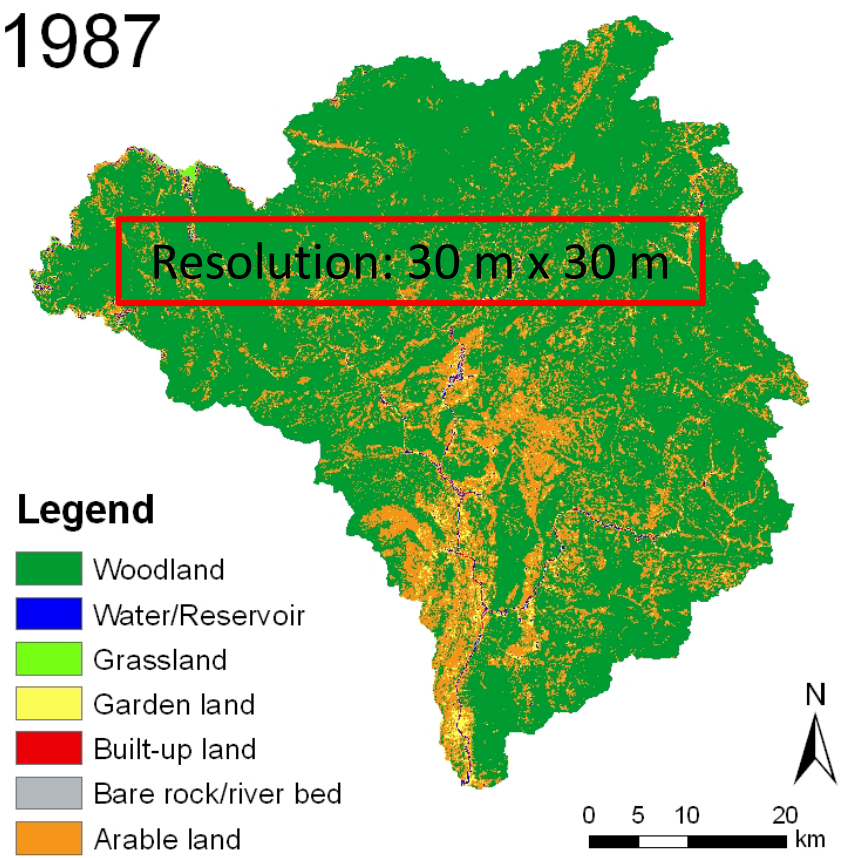
- Are the parameters in the SWAT databases adequate for my study area?
 - Plant/crop
 - Fertilizer
 - Pesticide
 - Urban
 - Tillage
- What is the quality of the parameter sets I added, e.g., soil properties?



Sources of Uncertainty IV

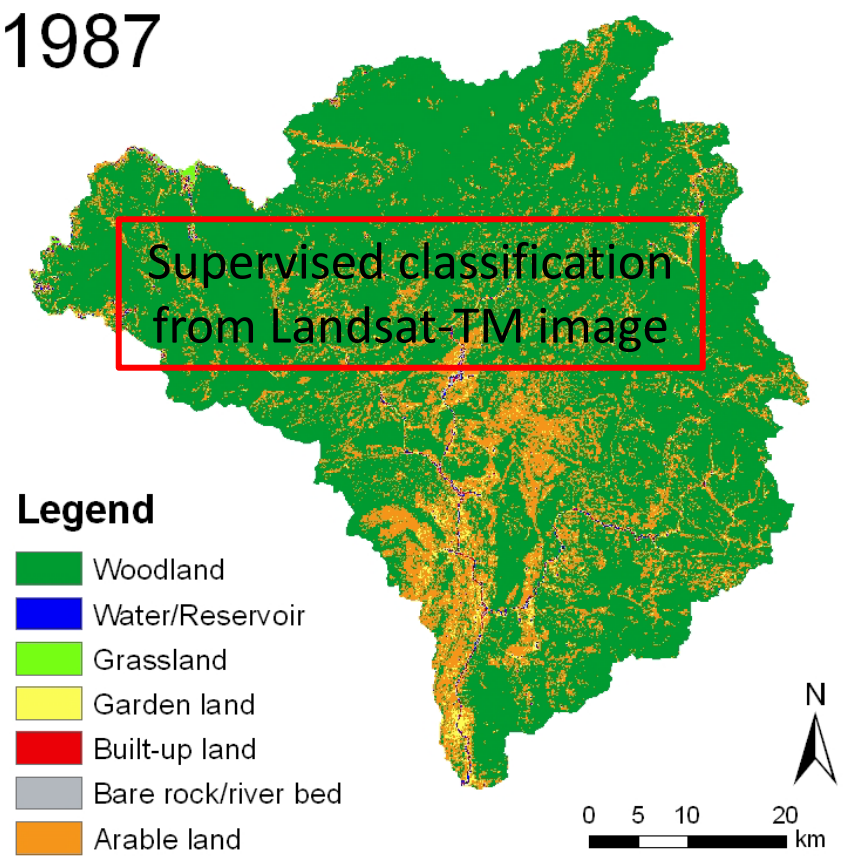
Spatial resolution of landuse map

1987



Quality of landuse classification

1987



Sources of Uncertainty VI

Condition of terraces

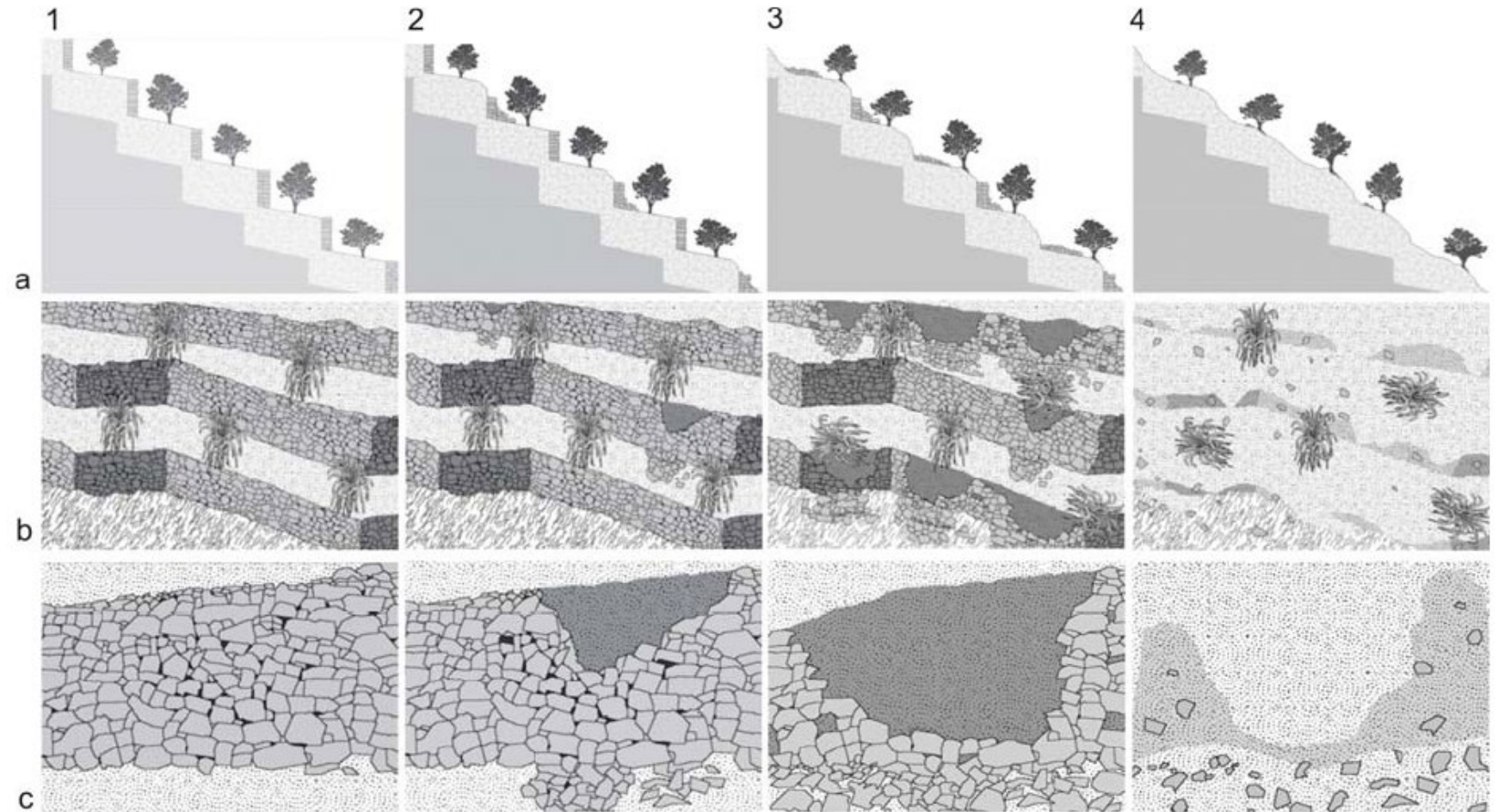


Figure: Schönbrodt-Stitt et al. 2012

Sources of Uncertainty VII

Missing information on reservoir volumes and release



Sources of Uncertainty VIII

Hydropower



Sources of Uncertainty IX

Landslides



Sources of Uncertainty X

Sediment dredging

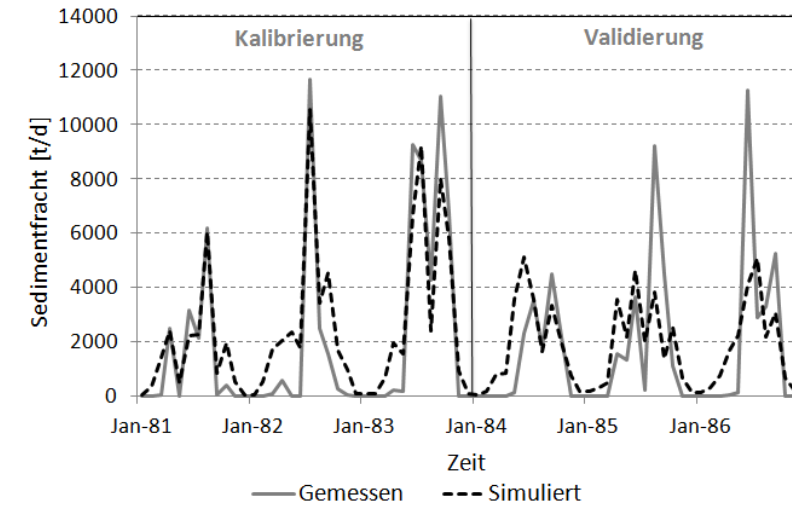
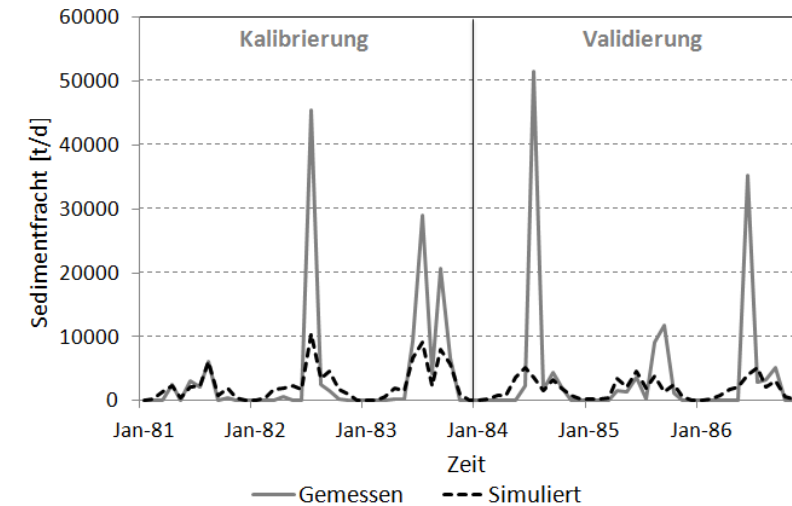


- Transferability of model algorithms
- Some of the SWAT algorithms are empirical, e.g., the MUSLE (Modified Universal Soil Loss Equation), which was developed for 18 watersheds in the southern United States

$$sed = 11.8 \cdot (Q_{surf} \cdot q_{peak} \cdot area_{hru})^{0.56} \cdot K_{USLE} \cdot C_{USLE} \cdot P_{USLE} \cdot LS_{USLE} \cdot CFRG$$

Sources of Uncertainty XII

- Uncertainty in observed data
 - Sampling technique
 - Sampling location
 - Quality of laboratory analyses



- **SWAT+ Toolbox:** SWAT+ Toolbox is designed to work with the SWAT+ model. You can use it for sensitivity analysis, model calibration, evaluation, and validation. The software is currently only available on Windows.
- **SWATplusR:** The SWATplusR package integrates SWAT+ and SWAT2012 models in modeling workflows in R. Taking advantage of the powerful R environment SWATplusR provides a large toolset for parameter sensitivity analysis, model calibration and the analysis of SWAT model results.
- **SWATplus-CUP:** SWATplus-CUP is a Calibration and Uncertainty Program for SWAT+. The purchase of a license is required.
- <https://swat.tamu.edu/software/plus/>

- All spatial input data should have the same projection.
- Generally, it is a good idea to create copies of the Lil-J input files where possible (e.g., for the lookup tables, the usersoil table, and observed flow that you will use for visualization) and adapting the file contents to your catchment. That way, they will be in the correct format and have the correct headers.

- Chapter 14 in the QSWAT+ Manual provides detailed instructions for:
 - Obtaining SRTM DEM data
 - Clipping and merging DEM rasters
 - Reprojecting the DEM
 - Masking a DEM

- Where/how can I get a land use map for my study area?
 - Agencies
 - Mapping in the field
 - Land use classification from satellite imagery
- Does the land use map represent land use to an adequate level of detail?

Landuse Lookup Table

- Maps LANDUSE_ID values (values found in the land use map you will use) to SWAT_CODE values (SWAT+ land use codes found in the plant or urban database).
- Should have the word “landuse” in its name.
- All landuse types/plants used in your lookup table must be found in either the plant or the urban database.

```
value,label
1,agrl
2,agrl
3,agrl
4,agrl
5,frsd
6,frse
7,frst
8,past
9,rngb
10,shrb
11,urml
12,utrn
13,wetf
14,wehb
```

- Contains the plant parameters for a large number of landuse types/plants.
- If a landuse type/crop occurs in your watershed (and thus in your landuse lookup table) that is not included in the SWAT+ plant database, you need to add it before creating your HRUs.
- Where can I find information about the plant properties required by SWAT?
 - Literature
 - Own measurements
 - Use properties of a similar crop
 - Contact SWAT+ developers for support

- Where/how can I get a soil map for my study area?
 - Agencies
 - Mapping in the field
 - Harmonized World Soil Database
 - FAO Digital Soil Map of the World

- maps SOIL_ID values (values found in the soil map you will use) to SNAM values (soil names found in the usersoil database).
- should have the word “soil” in its name.
- All soils used in your lookup table must be found in the usersoil database.

```
SOIL_ID, SNAM
1, LREW01
2, LREW02
3, LREW03
4, LREW04
5, LREW05
6, LREW06
7, LREW07
8, LREW08
9, LREW09
10, LREW10
11, LREW11
12, LREW12
```

- Contains the catchment-specific soil properties.
- Should have the word “usersoil” in its name.
- Where can I find information about the soil properties required by SWAT+?
 - Literature
 - Own measurements
 - Pedotransfer functions

- For each climate variable, a location file should be created. The header should have the columns ID (station ID), NAME, LAT (latitude), LONG (longitude) and ELEVATION.
- The actual climate data should have the same file name as the station NAME in the location file. There should be one file per station. The first line should be the date of the first observation in the format yyyyymmdd followed by the daily climatic data values.
- The units for precipitation, temperature, solar radiation, wind speed and relative humidity should be mm, degree centigrade, MJ/m², m/s, and decimal fraction, respectively.
- For temperature, the maximum and minimum temperature need to be listed separated by a comma.
- Missing values will be replaced by -99.
- All climate files should be saved in the same folder.

```
ID,NAME,LAT, LONG,ELEVATION
1,pcp144,31.72651,-83.73763,137.5
19880101
5.08
20.32
22.86
0.00
0.00
0.00
7.62
2.54
5.08
0.00
```

- If you wish, you can prepare your own weather generator data.
- For this, you need a few years of data for at least 1 station in/near your study area.
- There is a tool available for download from the SWAT website that helps you calculate the weather generator data (<https://swat.tamu.edu/software/>).

- Observed data is essentially a comma separated value file with
 - headings on the first line, separated by commas,
 - as many data values as there are headings on each succeeding line, separated by commas, and
 - ideally as many data lines as there are dates in the SWAT+ output.
- If the first heading is DATE (or date, Date, or the same 4 letters in any cases) then the first column is ignored. It is assumed (and not checked) that the dates correspond to the dates in the SWAT+ output.
- Leave blanks for missing data or put any text which cannot be parsed as a number, e.g. 'missing'. Missing data will be omitted from graph.

- https://www.card.iastate.edu/swat_articles/



The screenshot displays the SWAT Literature Database website. At the top, there is a header with the SWAT logo (Soil & Water Assessment Tool), the title "SWAT Literature Database for Peer-Reviewed Journal Articles", and logos for CARD (Center for Agricultural and Rural Development) and Iowa State University of Science and Technology. Below the header is a navigation bar with links: Search Database, Add an Article, Readme, Contact Database Staff, Citations List, SWAT Special Issues & Sections, SWAT Models, and CARD. The main content area features a section titled "Narrow down the articles shown" with several dropdown menus for filtering: Journals, Models, Broad Application Categories, Primary Application Categories, Secondary Application Categories, and Languages. Below these is a "Years" section with dropdowns for "2019" and "2022" separated by "to". A search input field is provided with the placeholder text "(search on any word or phrase)". At the bottom of the filter section are two buttons: "Submit" and "Reset Selections".

Questions? Comments? Suggestions? Complaints?

Need help with your SWAT+ model?

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You can also find me on ResearchGate and LinkedIn (I'm doing a terrible job at keeping my profiles up to date though).