Introduction to AGWA
The Automated Geospatial Watershed Assessment Tool

Land cover change and hydrologic response

Introduction:	In this exercise you will investigate the manner in which land cover changes over a 25 year period have affected runoff processes in SE Arizona.
Goal:	To familiarize yourself with AGWA and the various uses and limitations of hydrologic modeling for landscape assessment.
Assignment:	Run the SWAT model on a large watershed in the San Pedro River Basin and the KINEROS model on a small sub-basin using 1973 and 1997 NALC land cover.

A Short Introduction to Hydrologic Modeling for Watershed Assessment

The basic tenet of watershed management is that direct and powerful linkages exist among spatially distributed watershed properties and watershed processes. Stream water quality changes, especially due to erosion and sediment discharge, have been directly linked to land uses within a watershed. For example, erosion susceptibility increases when agriculture is practiced on relatively steep slopes, while severe alterations in vegetation cover can produce up to 90% more runoff than in watersheds unaltered by human practices.

The three primary watershed properties governing hydrologic variability in the form of rainfall-runoff response and erosion are soils, land cover, and topography. While topographic characteristics can be modified on a small scale (such as with the implementation of contour tillage or terracing in agricultural fields), variation in watershed-scale hydrologic response through time is primarily due to changes in the type and distribution of land cover.

Watershed modeling techniques are useful tools for investigating interactions among the various watershed components and hydrologic response (defined here as rainfall-runoff and erosion relationships). Physically-based models, such as the KINEmatic Runoff and EROSion model (KINEROS) are designed to simulate the physical processes governing runoff and erosion (and subsequent sediment yield) on a watershed. Lumped parameter models such as the Soil & Water Assessment Tool (SWAT) are useful strategic models for investigating long-term watershed response. These models can be useful for understanding and interpreting the various interactions among spatial characteristics insofar as the models are adequately representing those processes.

The percentage and location of natural land cover influences the amount of energy that is available to move water and materials. Forested watersheds dissipate energy associated with rainfall, whereas watersheds with bare ground and anthropogenic cover are less able to do so. The percentage of the watershed surface that is impermeable, due to urban and road surfaces, influences the volume of water that runs off and increases the amount of sediment that can be moved. Watersheds with highly erodible soils tend to have greater potential for soil loss and sediment delivery to streams than watersheds with non-erodible soils. Moreover, intense precipitation events may exceed the energy threshold and move large amounts of sediments across a degraded watershed (Junk et al., 1989; Sparks, 1995). It is during these events that human-induced landscape changes may manifest their greatest negative impact.

The Study Area

These exercises will use the Upper San Pedro River Basin from the Charleston USGS stream gage in Southern Arizona as the study area. The San Pedro River flows north from Sonora, Mexico into southeastern Arizona (Figure 1). With a wide variety of topographic, hydrologic, cultural, and political characteristics, the basin represents a unique study area for addressing a range of scientific and management issues. The area is a transition zone between the Chihuahuan and Sonoran deserts and has a highly variable climate with significant biodiversity. The study watershed is approximately 2886 km2 and is dominated by desert shrub-steppe, riparian, grasslands, agriculture, oak and mesquite woodlands, and pine forests. The basin supports one of the highest numbers of mammal species in the world and the riparian corridor provides nesting and migration habitat for over 400 bird species. Large changes in the socio-economic framework of the basin have occurred over the past 25 years, with a shift from a rural ranching economy to considerably greater urbanization. As the human population has grown, so too has groundwater withdrawal, which threatens the riparian corridor and the long-term economic, hydrologic, and ecological stability of the basin.

Significant land cover change occurred within the San Pedro Basin between 1973 and 1997. Satellite data were acquired for the San Pedro basin for a series of dates covering the past 25 years: 1973, 1986, 1992, and 1997. Landsat Multi-Spectral Scanner (MSS) and Thematic Mapper (TM) satellite images have been reclassified into 10 land cover types ranging from high altitude forested areas to lowland grasslands and agricultural communities with 60 meter resolution. The most significant changes were large increases in urbanized area, mesquite woodlands, and agricultural communities, and commensurate decreases in grasslands and desert scrub. This overall shift indicates an increasing reliance on groundwater (due to increased municipal water consumption and agriculture) and potential for localized large-scale runoff and erosion events (due to the decreased infiltration capacities and roughness associated with the land cover transition).

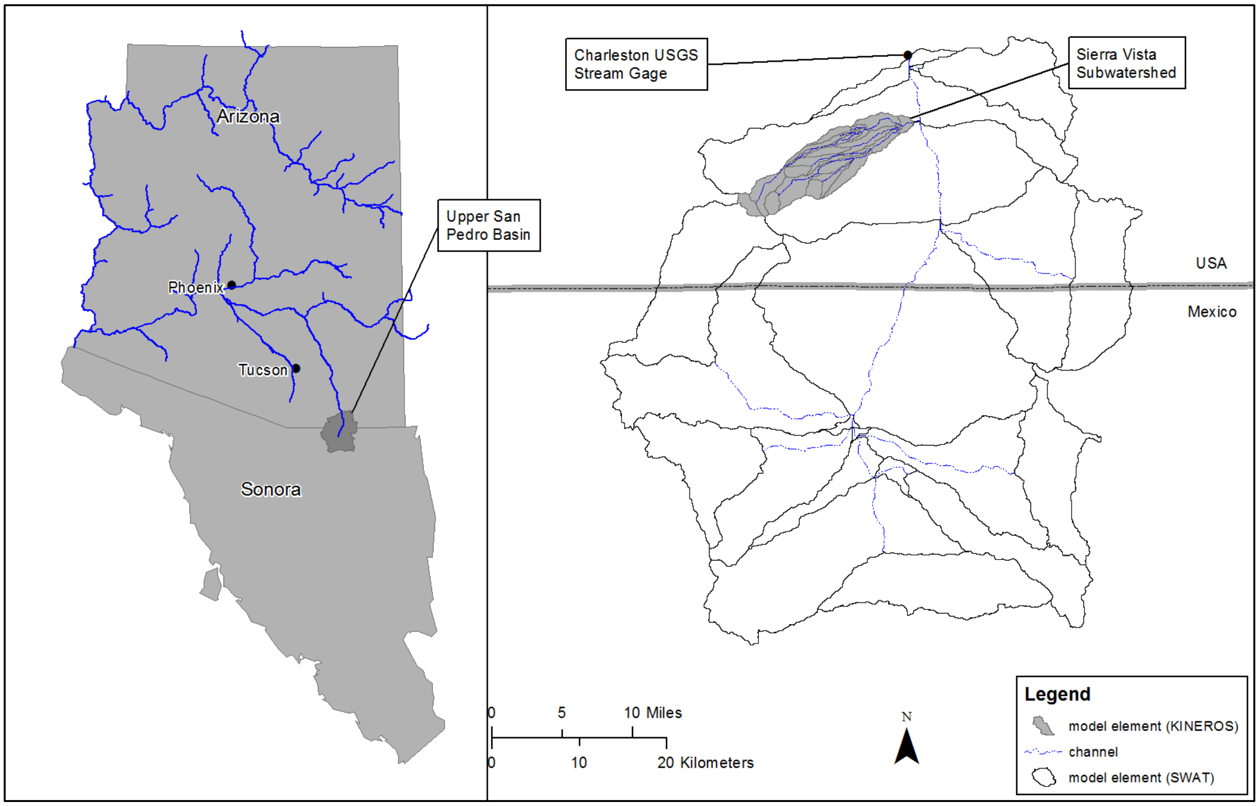
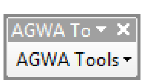
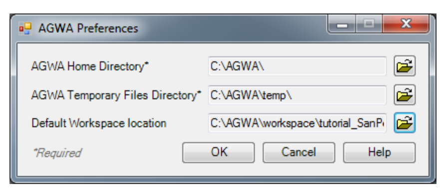


Figure 1. Locations of the two study areas within the Upper San Pedro River Basin you will be modeling today. The larger basin (2886 km2) will be modeled using SWAT and drains to the Charleston USGS runoff gaging station. This basin encompasses the smaller watershed (92 km2), labeled here as "Sierra Vista Subwatershed", to be modeled using KINEROS. Upland and channel elements are shown as they may be used in the SWAT simulations, and the upland and lateral elements (channels are withheld for clarity) used to parameterize KINEROS are outlined in the smaller watershed.

Getting Started

Start ArcMap with a new empty map. Save the empty map document as **tutorial_SanPedro** in the **C:\AGWA\workspace\tutorial_SanPedro** folder (The default workspace location will need to be created by clicking on *Create New Folder* button in the window that opens.). If the ***AGWA Toolbar*** is not visible, turn it on by selecting ***Customize > Toolbars > AGWA Toolbar*** on the ArcMap Main Menu bar. Once the map document is opened and saved, set the Home,





Temp, and Default Workspace folders by selecting ***AGWA Tools > Other Options > AGWA Preferences*** on the ***AGWA Toolbar***.

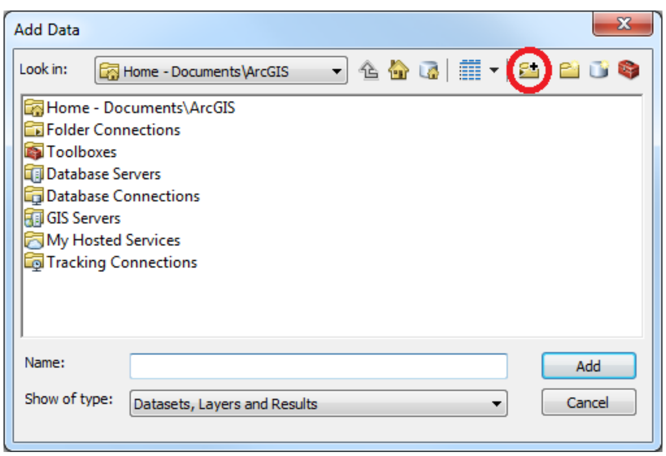
TIP Always use a meaningful name to help identify the map document. Map documents can be saved anywhere, but for project organization and to help navigate to the project workspace via the ArcCatalog window in ArcMap, we suggest saving the map document in the workspace location.

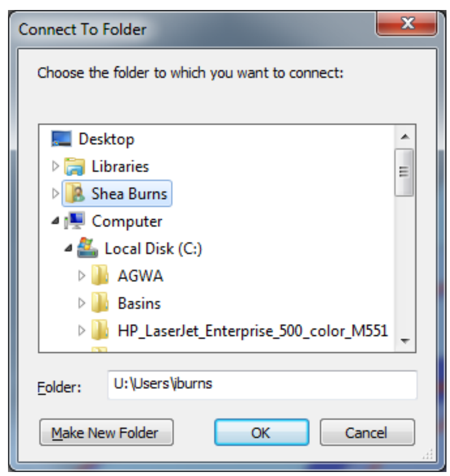
- Home: **C:\AGWA**
- Temp: **C:\AGWA\temp**
- Default Workspace: **C:\AGWA\workspace\tutorial_SanPedro**
  The default workspace location will need to be created by clicking on ***Make New Folder*** button in the window that opens.

> The Home directory contains all of the look-up tables, datafiles, models, and documentation required for AGWA to run. If this is set improperly or you are missing any files, you will be presented with a warning that lists the missing directories or files that AGWA requires.
>
> The Temp directory is where some temporary files created by AGWA will be placed. You may want to routinely delete files and directories in the Temp directory if you need to free up space or are interested in identifying the temporary files associated with your next AGWA use.
>
> The Default Workspace directory is where delineation geodatabases will be stored by default. This can be a helpful timesaver during the navigation process if you have a deeply nested directory structure where you store AGWA outputs.

GIS Data

Before adding data to the map, connections to drives and folders where your data is stored must be established if they have not been already. To establish folder connections if they don't already exist, click on the ***Add Data*** button below the menu bar at the top of the screen. In the Add Data form that opens, click the ***Connect To Folder*** button and select **Local Disk (C:)**.

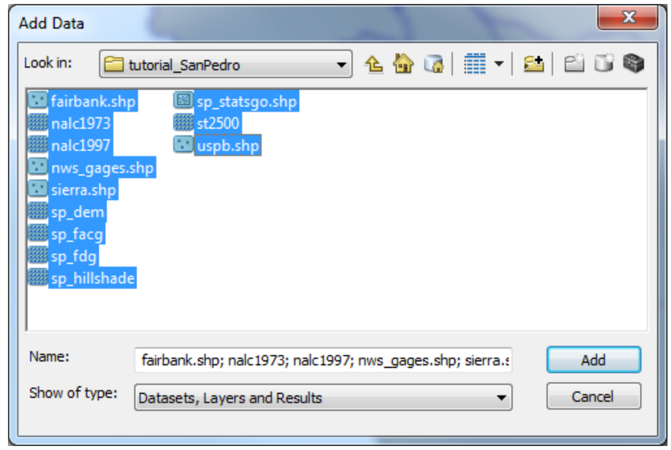




Once the folder connection is established, navigate to the **C:\AGWA\gisdata\tutorial_SanPedro** folder and add the following datasets and layers:

- **..\fairbank.shp** – National Weather Service Fairbank raingage
- **..\nalc1973** – NALC 1973 land cover classification (60m GRID)

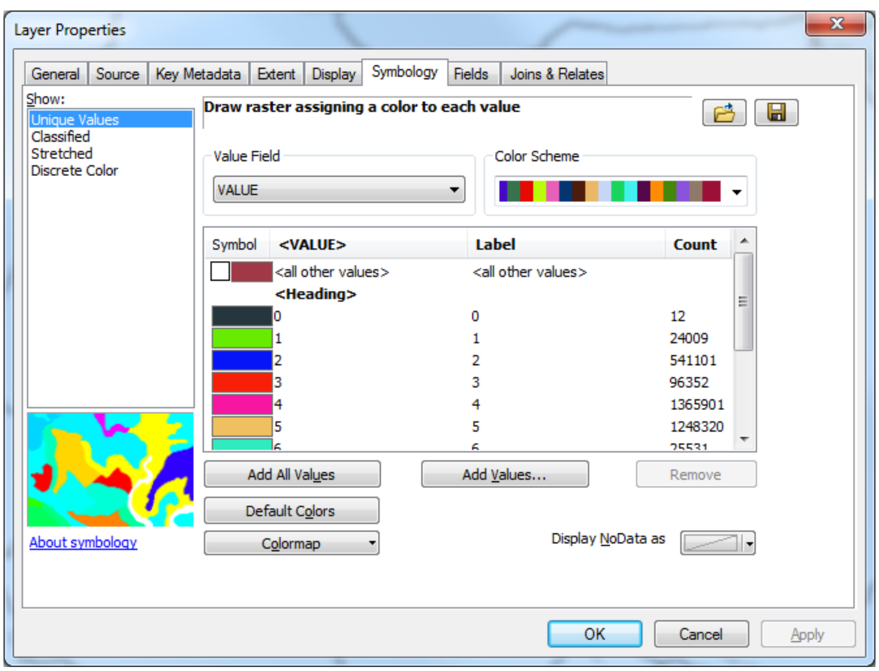
- **..\nalc1997** – NALC 1997 land cover classification (60m GRID)
- **..\nws_gages.shp** – Multiple raingages throughout the basin
- **..\Sierra.shp** – Outlet of the Sierra Vista watershed for KINEROS
- **..\sp_dem** – Digital elevation model (30m GRID)
- **..\sp_facg** – Flow accumulation grid (30m GRID)
- **..\sp_fdg** – Flow direction grid (30m GRID)
- **..\sp_statsgo.shp** – STATSGO soils
- **..\uspb.shp** – Outlet of the Upper San Pedro watershed for SWAT

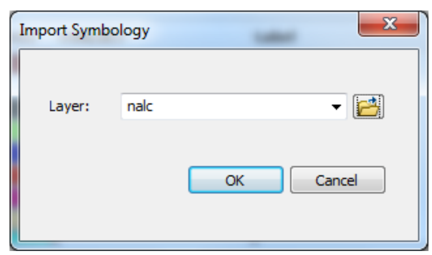


You will also need to add some other data to the project. To do this, again click on the ***Add Data*** button. Navigate to the **C:\AGWA\datafiles** folder and add the following files:

- **..\lc_luts\nalc_lut.dbf** – NALC look-up table for NALC land cover
- **..\precip\dsgnstrm.dbf** – return period rainfall for KINEROS
- **..\precip\sp60_73.dbf** – San Pedro rainfall from 1960-1973 for all the NWS gages in the basin
- **..\wgn\wgn_us83.shp**–weather generator stations for SWAT

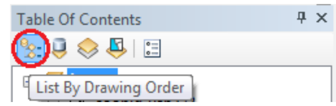
To better visualize the different land cover types and associate the pixels with their classification, load a legend into the ***nalc1973*** and ***nalc1997*** datasets. To do this, right click the layer name of the **nalc1973** dataset in the ***Table of Contents*** and select ***Properties*** from the context menu that appears. Select the ***Symbology*** tab from the form that opens. In the ***Show*** box on the left side of the form, select ***Unique Values*** and click the  button on the right. Click the file browser button, navigate to and select





C:\AGWA\datafiles\renderers\nalc.lyr and click on ***Add***, and click ***OK*** to apply the symbology and exit the ***Import Symbology*** form. Click on ***Apply*** in the ***Layer Properties*** form and then on ***OK*** to exit this form. The ***nalc1973*** and ***nalc1997*** datasets have the same legend and classification, so repeat the same procedure for the ***nalc1997*** dataset.

At this point we have all the data necessary to start modeling: topography, soils, land cover, and rainfall. Take a look at the data you have available to you to familiarize yourself with the area. Layers can be reordered, turned on/off, and their legends collapsed to suit your preferences and clean up the display. If you the layers cannot be reordered by clicking and dragging, the ***List By Drawing Order*** button may need to be selected at the top of the ***Table Of Contents***. Zoom back into the San Pedro region by right-clicking on the ***nalc1973*** grid in the list of layers and selecting ***Zoom To Layer***.



Save the map document and continue.

Part 1: Modeling Runoff at the Basin Scale Using SWAT

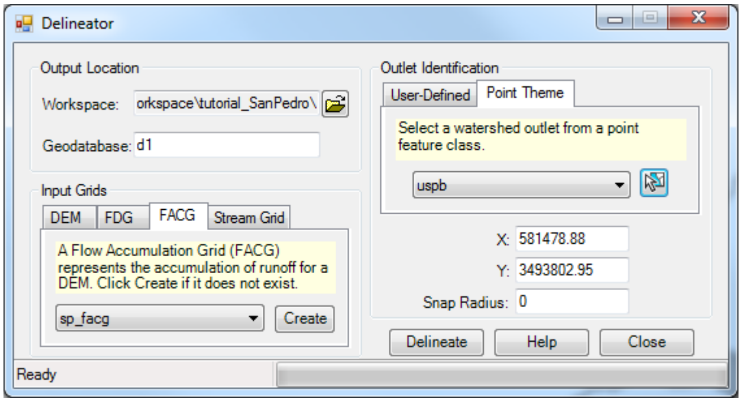
In this exercise you will create a large watershed in the San Pedro Basin, and use the SWAT model to determine where the impact of land use change over a 25 year period has been severe.

There are several steps involved in modeling a watershed using AGWA: delineation; discretization or subdividing into model elements; parameterization of topographic, land cover, and soil properties; precipitation definition; writing model input files; model execution; and importing results.

Step 1: Delineating the watershed

Delineating creates a feature class that represents all the area draining to a user-specified outlet.

1. Perform the watershed delineation by selecting ***AGWA Tools > Delineation Options > Delineate Watershed***.
   DESCRIPTION In the ***Delineator*** form, several parameters are defined including the output location, the name of the delineation, the digital elevation model (DEM), the flow direction grid (FDG), the flow accumulation grid (FACG), the watershed outlet location, and a search radius from the outlet location which AGWA will use to locate the most downstream location to use as the watershed outlet.



1.1. ***Output Location*** box

1.1.1. ***Workspace*** textbox: navigate to and select/create **C:\AGWA\workspace\tutorial_SanPedro**

DESCRIPTION The workspace specified is the location on your hard drive where the delineated watershed is stored as a feature class in a geodatabase.

1.1.2. ***Geodatabase*** textbox: enter **d1**

NOTE You will be required to change the name of the geodatabase if a geodatabase with the same name exists in the selected workspace.

1.2. ***Input Grids*** box

1.2.1. ***DEM*** tab: select **sp_dem** (do not click Fill)

1.2.2. ***FDG*** tab: select **sp_fdg** (do not click Create)

1.2.3. ***FACG*** tab: select **sp_facg** (do not click Create)

1.3. ***Outlet Identifcation*** box

1.3.1. ***Point Theme*** tab: select **uspb**

1.3.2. Click the ***Select Feature*** button  and click and drag to draw a rectangle around the point.

NOTE The selection is restricted to the selected point theme. If more than one point exists in the selected point theme and the drawn rectangle intersects multiple points, the first intersected point in the point theme attribute table will be selected.

1.4. Click ***Delineate***

1.5. Save the map document and continue.

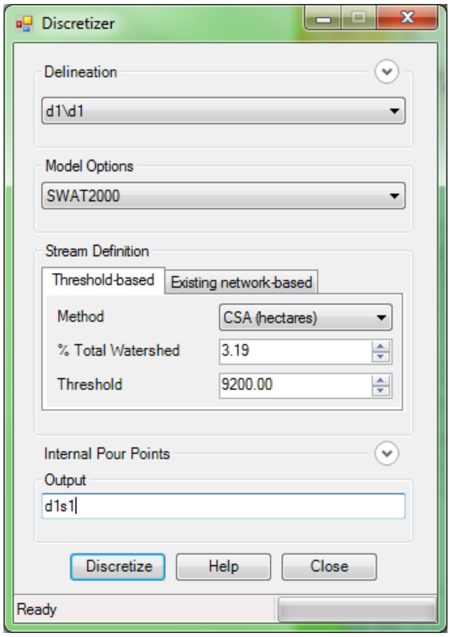
At this point, AGWA has delineated the watershed which generates a geodatabase named ***d1***. Inside the geodatabase, a feature class, also named ***d1***, that represents the delineated watershed has been created and the selected outlet point, whether user-defined or selected from an existing point theme, will be copied into a separate feature class named ***d1_point***.

Step 2: Discretizing or subdividing the watershed

Discretizing breaks up the delineated watershed into model specific elements and creates a stream feature class that drains the elements.

2. Perform the watershed discretization by selecting ***AGWA Tools > Discretization Options > Discretize Watershed.***

DESCRIPTION In the Discretizer form, several parameters are defined including the model to use, the complexity of the discretization, the name of the discretization, and whether additional pour points will be used to further control the subdivision of the watershed.



2.1. ***Delineation*** box: select **d1\d1**

2.2. ***Model Options*** box: select **SWAT2000**

2.3. ***Stream Definition*** box

2.3.1. ***Threshold-based*** tab page

2.3.1.1. ***Method***: select **CSA (Hectares)**

2.3.1.2. ***% Area***: do nothing (Note: this value will change when we change the CSA)

2.3.1.3. ***Threshold***: enter **9200**

2.4. ***Internal Pour Points*** dropdown: do nothing

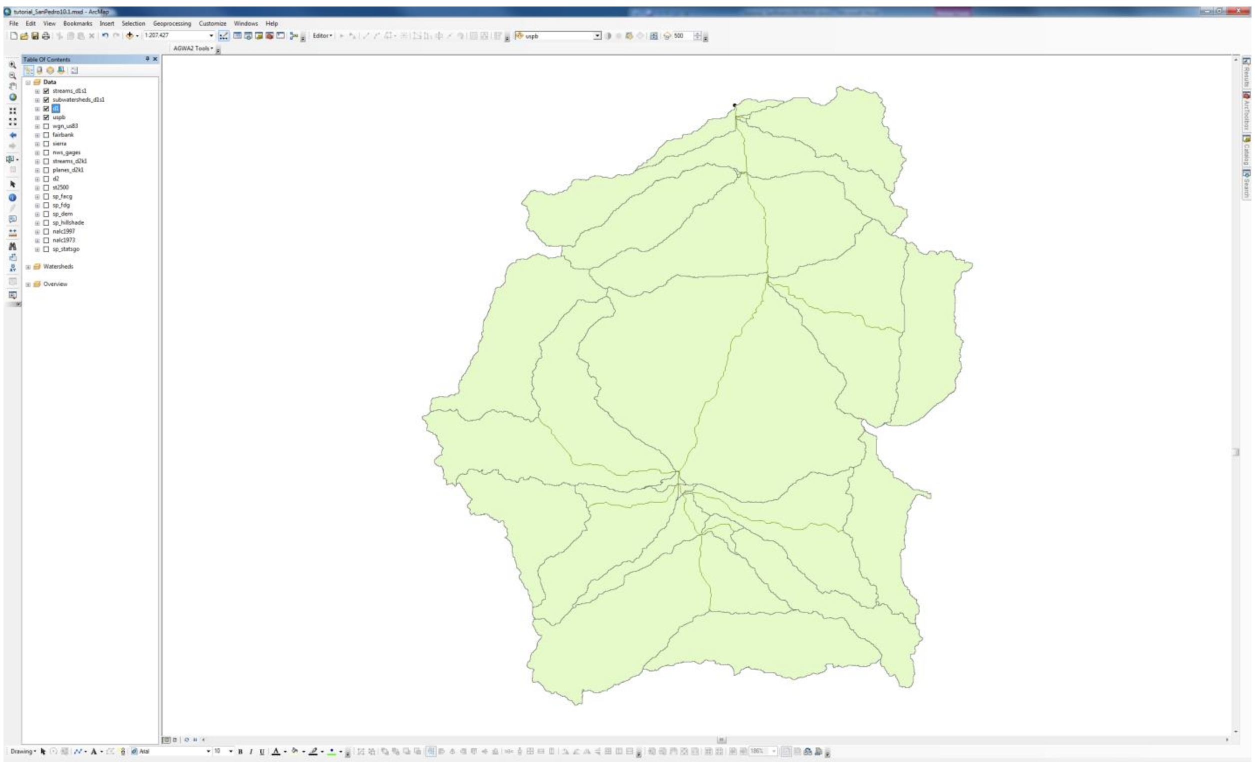
2.5. ***Output*** box

2.5.1. ***Name***: **d1s1**

2.6. Click ***Discretize***

2.7. Save the map document and continue.

Discretizing breaks up the delineation/watershed into model specific elements and creates a stream feature class that drains the elements. The CSA, or Contributing/Channel Source Area, is a threshold value which defines first order channel initiation, or the upland area required for channelized flow to begin. Smaller CSA values result in a more complex watershed, and larger CSA values result in a less complex watershed. The default CSA in AGWA is set to 2.5% of the total watershed area. The discretization process created a subwatersheds layer with the name subwatersheds_d1s1 and a streams map named streams_d1s1. In AGWA discretizations, are referred to with their geodatabase name as a prefix followed by the discretization name given in the Discretizer form, e.g. d1\d1s1.

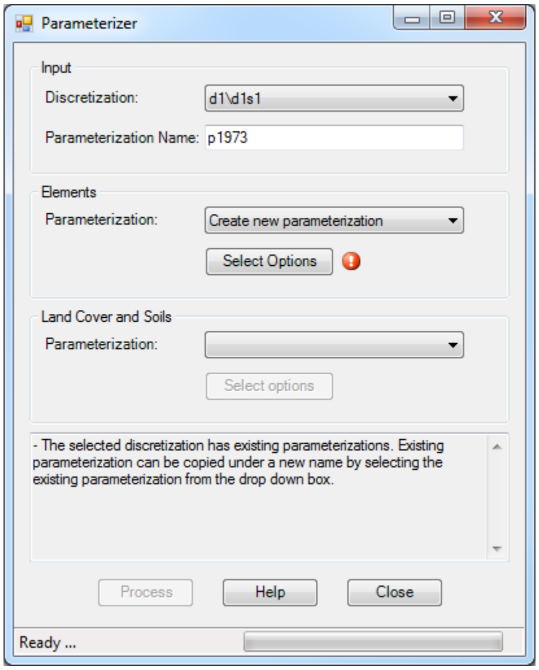


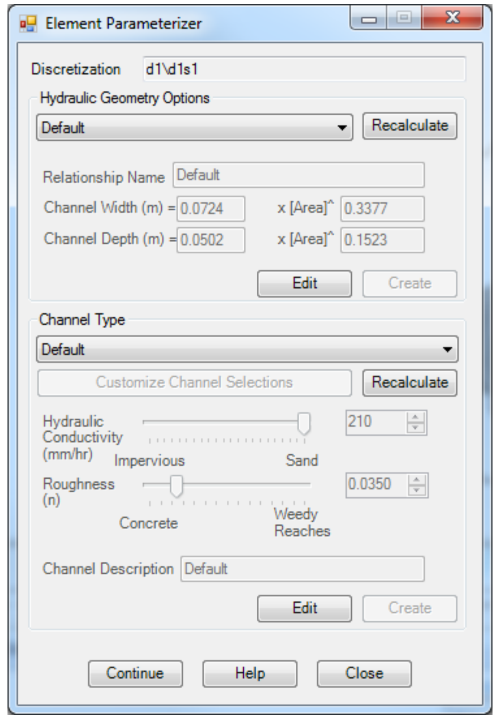
Step 3: Parameterizing the watershed elements for SWAT

Parameterizing defines model input parameters based on topographic, land cover, and soils properties. Model input parameters represent the physical properties of the watershed and used to write the model input files.

3. Perform the element, land cover, and soils parameterization of the watershed by selecting ***AGWA Tools > Parameterization Options > Parametrize***.
    3.1. ***Input*** box
        3.1.1. ***Discretization***: select **d1\d1s1**
        3.1.2. ***Parameterization Name***: enter **p1973**
    3.2. ***Elements*** box
        3.2.1. ***Parameterization***: select **Create new parameterization**

3.2.2. Click ***Select Options***. The Element Parameterizer form opens.





3.3. In the ***Element Parameterizer*** form

3.3.1. ***Hydraulic Geometry Options*** box

3.3.1.1. Select the **Default** item.

Do not click the ***Recalculate*** button.

Do not click the ***Edit*** button.

3.3.2. ***Channel Type*** box

3.3.2.1. Select the **Default** item.

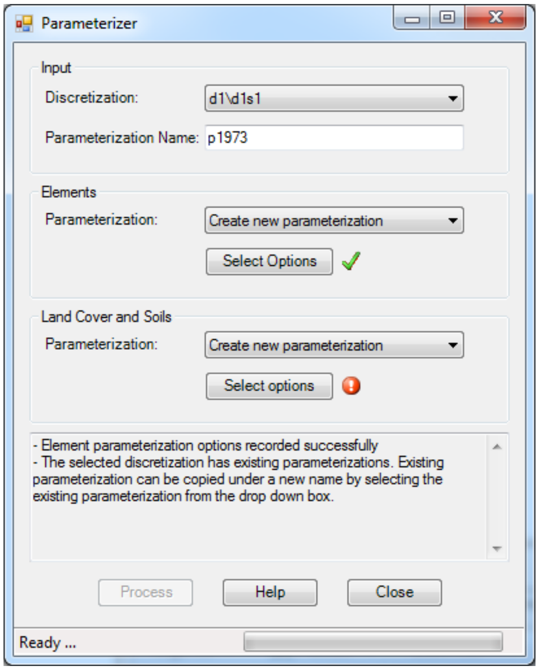
There are three channel types available by default: Default, Natural, and Developed. The Default channel type is equivalent to the Natural channel type. The Natural channel type reflects a sandy channel bottom with high infiltration and a winding but clean channel with roughness set to 0.035 Manning's n. The Developed channel type reflects a concrete channel with zero infiltrability, very low roughness set to 0.010 Manning's n, and fraction of channel armored against erosion equal to 1. These values may be edited on the fly when not customizing a channel selection. If modified parameter values are desired with a custom channel selection, use the Edit and Create buttons with the trackbars or numeric textboxes to create a new channel type before customizing the channel selection.

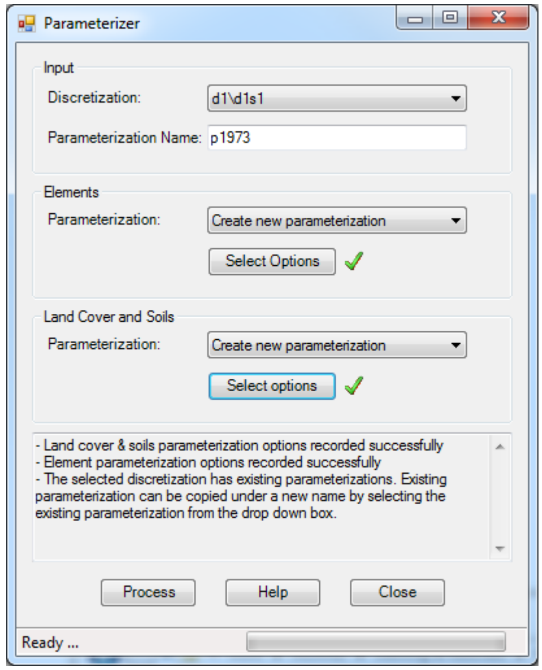
3.3.3. Click ***Continue***. You will be returned to the ***Parameterizer*** form to create the Land Cover and Soils parameterization.

3.4. Back in the ***Land Cover and Soils*** box of the ***Parameterizer*** form

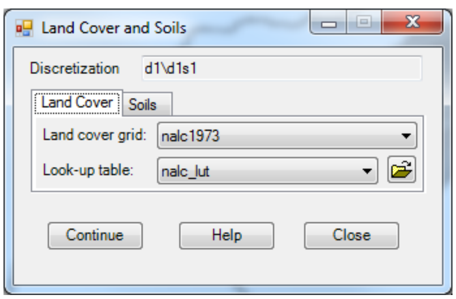
3.4.1. ***Parameterization***: select **Create new parameterization**

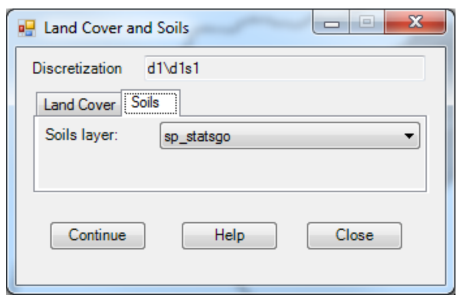
3.4.2. Click ***Select Options***. The ***Land Cover and Soils*** form opens.





3.5. In the ***Land Cover and Soils*** form





3.5.1. ***Land Cover*** tab

3.5.1.1. ***Land cover grid***: select **nalc1973**

3.5.1.2. ***Look-up table***: select **nalc_lut**

NOTE If the ***nalc_lut*** table is not present in the combobox, you may have forgotten to add the table to the map earlier. If this is the case, click on the ***Add Data*** button and browse to the **C:\AGWA\datafiles\lc_luts** folder and select the **nalc_lut.dbf**, then select the **nalc_lut** table from the combobox.

3.5.2. ***Soils*** tab

3.5.2.1. ***Soils*** layer: select **sp_statsgo**

3.6. Click ***Continue***. You will be returned to the ***Parameterizer*** form where the ***Process*** button will now be enabled.

3.7. In the ***Parameterizer*** form, click ***Process***.

In the last step, parameterization look-up tables for the overland flow elements and stream elements have been created to store the model input parameters representing the physical properties of the watreshed.

Step 4: Repeat for 1997 land cover

AGWA can store multiple parameterizations in the parameterization look-up tables. Running the parameterization with a different set of options (element, soils, or land cover) will append data to the existing look-up tables instead of overwriting them, so the parameterization can be accessed again at a later time. In a new parameterization, if only one part is different from an existing parameterization, AGWA can copy the parameters from an existing parameterization to save time.

4. Rerun the land cover and soils parameterization of the watershed with the 1997 land cover by selecting ***AGWA Tools > Parameterization Options > Parameterize***.
   4.1. ***Input*** box
      4.1.1. ***Discretization***: select **d1\d1s1**
      4.1.2. ***Parameterization Name***: enter **p1997**
   4.2. ***Elements*** box
      4.2.1. ***Parameterization***: select **p1973**
      Land cover change is the emphasis of this exercise and no other changes will be made; because no other options are changing, the element parameterization parameters can be copied from an existing parameterization.
   4.3. ***Land Cover and Soils*** box
      4.3.1. ***Parameterization***: select **Create new parameterization**
      4.3.2. Click ***Select Options***. The ***Land Cover and Soils*** form opens.
   4.4. In the ***Land Cover and Soils*** form
      4.4.1. ***Land Cover*** tab
         4.4.1.1. ***Land cover grid***: select **nalc1997**
         4.4.1.2. ***Look-up table***: select **nalc_lut**
      4.4.2. ***Soils*** tab
         4.4.2.1. ***Soils*** layer: select **sp_statsgo**
   4.5. Click ***Continue***. You will be returned to the ***Parameterizer*** form where the ***Process*** button will now be enabled.
   4.6. In the ***Parameterizer*** form, click ***Process***.

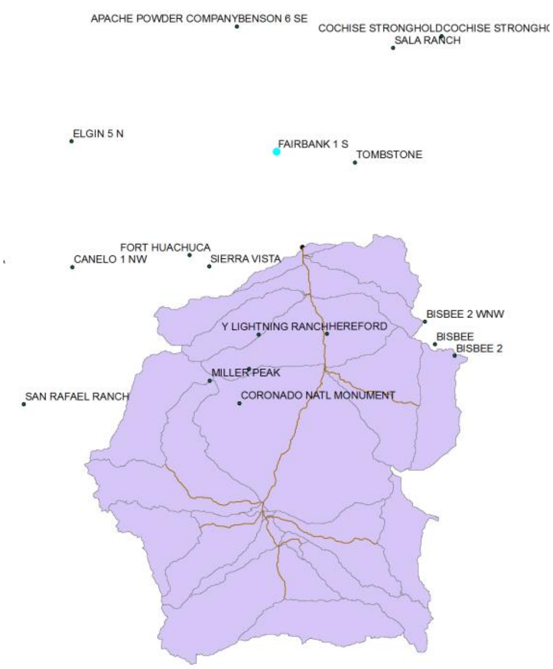
The parameterization look-up tables now have two parameterizations stored in them. When writing the simulation input files later, you will select which parameterization to write the files for.

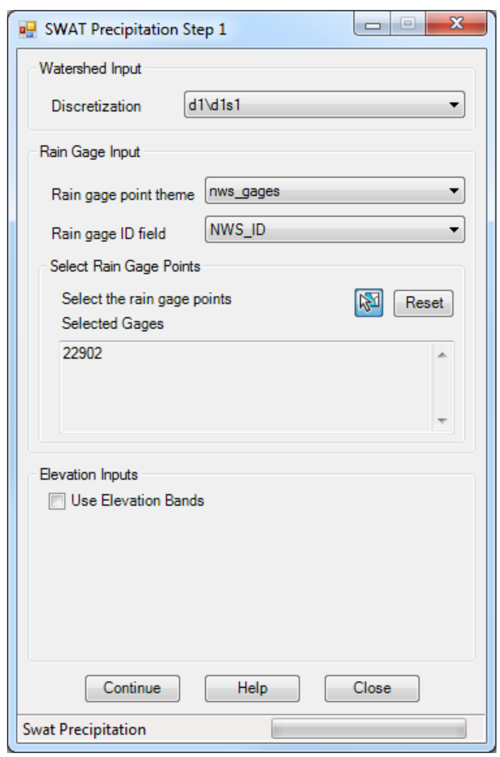
Step 5: Preparing rainfall files

AGWA provides a means for preparing rainfall files in SWAT- or KINEROS-ready format. For SWAT, the user must have a dbf file containing the continuous, daily estimates of rainfall for the rain gages within the study area. Daily rainfall data for gages within and/or surround the watershed are provided to you in the sp60_73.dbf file.

When AGWA is used expressly as a hydrologic modeling tool it is critical that the rainfall data be spatially distributed across the watershed. A large body of literature exists regarding the crucial nature of spatially distributed rainfall data. In this exercise however, we will use a single rain gage to generate a uniform rainfall file across all the model elements. This is clearly a huge deviation from using distributed, observed data, but there is a sound reason for doing so in change detection work. We are interested in the impacts of land cover change on hydrologic response, but the spatial variability in rainfall can have confounding effects on the analysis, overwhelming the isolated changes within the subwatershed elements. Using uniform rainfall serves to isolate the effects of land cover change independent of the rainfall.

5. Write the SWAT precipitation file for the watershed by selecting ***AGWA Tools > Precipitation Options > Write SWAT Precipitation***.
   5.1. ***SWAT Precipitation Step 1*** form
      5.1.1. ***Watershed Input*** box:
         5.1.1.1. ***Discretization***: **d1\d1s1**
      5.1.2. ***Rain Gage Input*** box:
         5.1.2.1. ***Rain gage point theme***: **nws_gages**
         5.1.2.2. ***Rain gage ID field***: **NWS_ID**
      5.1.3. ***Select Rain Gage Points*** box





5.1.3.1. Click the ***Select Feature*** button to select the ***Fairbank*** raingage in the view (the figure, above left, displays the location of the gage). The id number, ***22902***, of the selected gage will be displayed in the ***Selected Gages*** textbox.

5.1.4. ***Elevation Inputs*** box:

5.1.4.1. ***Use Elevations Bands*** checkbox: leave unchecked.

5.1.5. Click ***Continue***.

5.2. ***SWAT Uniform Precipitation*** form

5.2.1. ***Write the *.pcp file*** box:

5.2.1.1. ***Selected discretization theme***: ***d1\d1s1***

5.2.1.2. ***Selected rain gage point theme***: ***nws_gages***

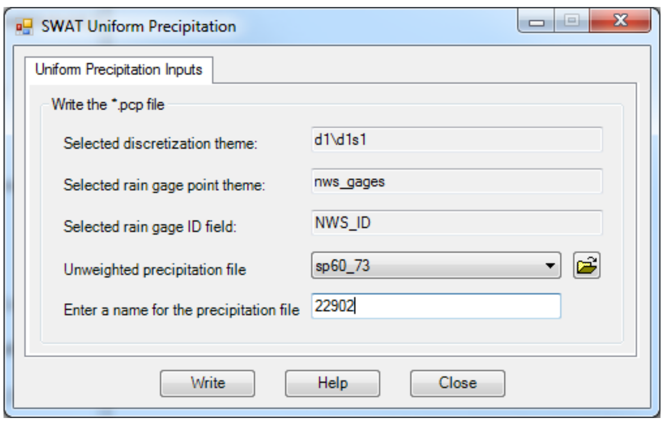
5.2.1.3. ***Selected rain gage ID field***: ***NWS_ID***

5.2.1.4. ***Unweighted precipitation file***: **sp60_73.dbf**

5.2.1.5. ***Enter a name for the precipitation file***: **22902**

TIP Using the gage ID of the selected gage as the filename can help keep track of the precipitation files in case other files are used to compare to in different simulations.

5.2.1.6. Click ***Write***.



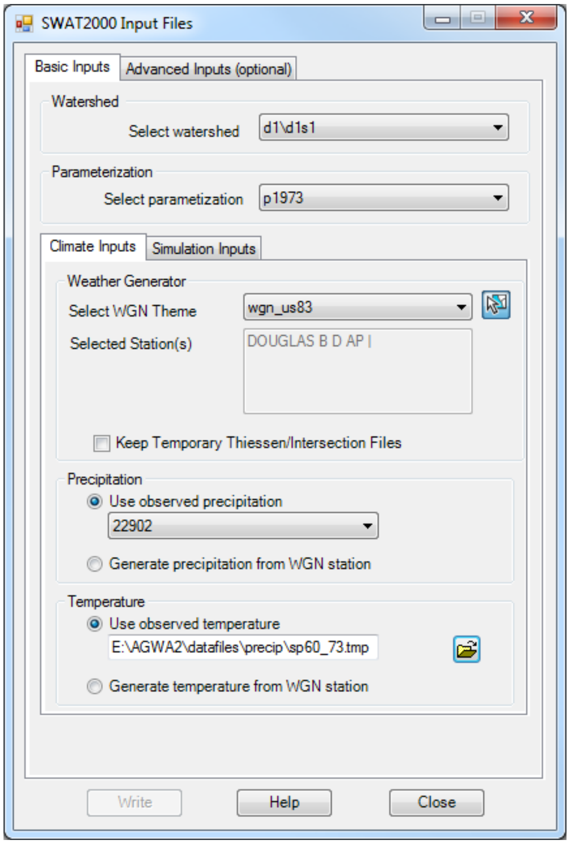
** Optional ** Given a number of rain gages scattered throughout the study area, AGWA will generate a Thiessen rainfall map and distribute observed rainfall on the various watershed elements using an area-weighting scheme. You can try using two different sources of rainfall data for SWAT: uniform and distributed. In this example you will use a single gage (uniform), but you could also try running SWAT with multiple gages (distributed). In this way you can investigate the impacts of rainfall input on hydrologic modeling.

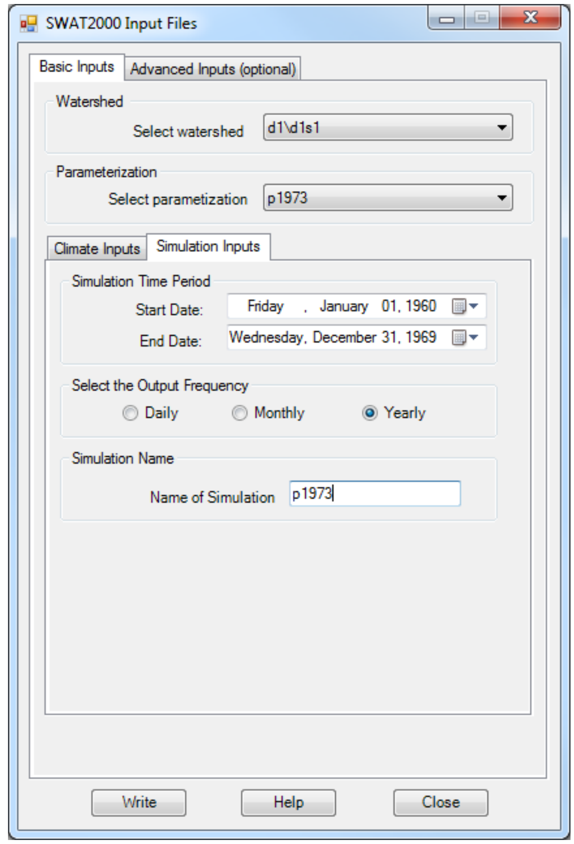
The ***22902.pcp*** file will be written to the ***C:\AGWA\workspace\tutorial_SanPedro\d1\d1s1\precip***. AGWA will look in this folder for available precipitation files when writing the model input files.

Step 6: Writing SWAT input files

Writing the model input files creates a simulation directory and writes all required input files for the model. When writing the input files, AGWA loops through features of the selected discretization and reads the model parameters from the parameterization look-up tables to write into the input files for the model.

6. Write the SWAT input files by selecting ***AGWA Tools > Simulation Options > SWAT2000 Options > Write SWAT2000 Input Files***.





6.1. ***Basic Inputs*** tab:

6.1.1. ***Watershed*** box: **d1\d1s1**

6.1.2. ***Parameterization*** box: **p1973**

6.1.3. ***Climate Inputs*** tab:

6.1.3.1. ***Weather Generator*** box:

6.1.3.1.1. ***Select WGN Theme***: **wgn_us83**

6.1.3.1.2. ***Selected Station***: **DOUGLAS B D AP** (due east of the watershed)

6.1.3.1.3. ***Keep Temporary Thiessen/Intersection Files***: leave unchecked

6.1.3.2. ***Precipitation*** box:

6.1.3.2.1. ***Use observed precipitation***: **22902**

6.1.3.3. ***Temperature*** box:

6.1.3.3.1. ***Use observed temperature***: click the Folder Browser button to browse to **C:\AGWA\datafiles\precip** folder and select the temperature file **sp60_73.tmp**.

6.1.4. ***Simulation Inputs*** tab:

6.1.4.1. ***Simulation Time Period*** box:

6.1.4.1.1. ***Start Date***: **Friday, January 1, 1960**

6.1.4.1.2. ***End Date***: **Wednesday, December 31, 1969**

6.1.4.2. ***Select the Output Frequency*** box: **Yearly**

6.1.4.3. ***Simulation Name*** box: **p1973**

This is the simulation name and consequently, if you set names and locations as specified thus far, will also be the folder name the SWAT results are placed in within the ***C:\AGWA\workspace\tutorial_SanPedro\d1\d1s1\simulations*** folder.

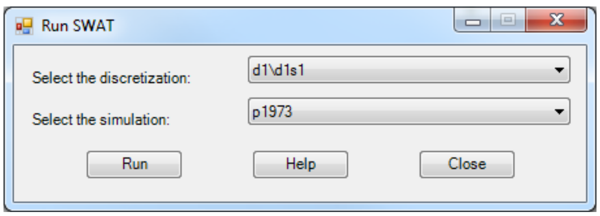
6.1.5. Click ***Write***.

7. Repeat ***Part 1, Step 6: Writing SWAT input files*** with the **p1997** parameterization and name the simulation **p1997**.

Step 7: Executing the SWAT model

Executing the SWAT model opens a command window where the model is executed. By default, the command window stays open so that success or failure of the simulation can be verified.

8. Execute the SWAT model for the Upper San Pedro watershed by selecting ***AGWA Tools > Simulation Options > SWAT2000 Options > Execute SWAT2000 Model***.

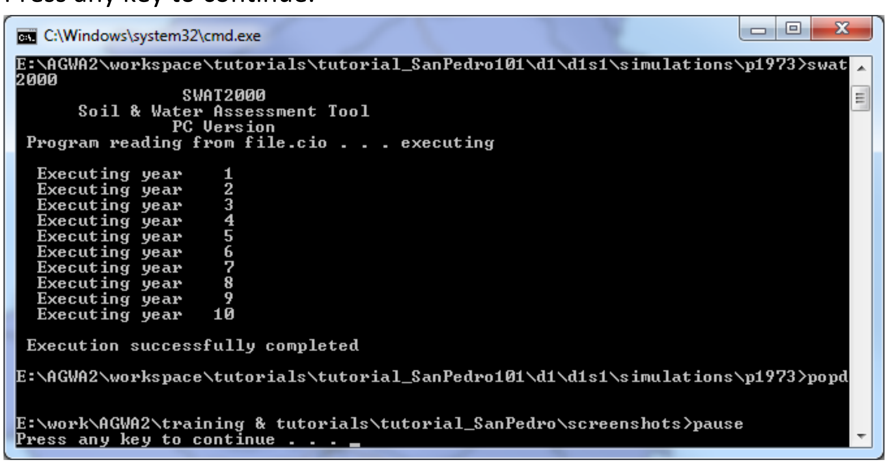


8.1. ***Select the discretization***: select **d1\d1s1**

8.2. ***Select the simulation***: select **p1973**

8.3. Click ***Run***.

A command window will open and show the execution of SWAT for the 10 year simulation period. The command window will stay open so that successful completion can be verified. Press any key to continue.



8.4. Close the ***Run SWAT*** form.

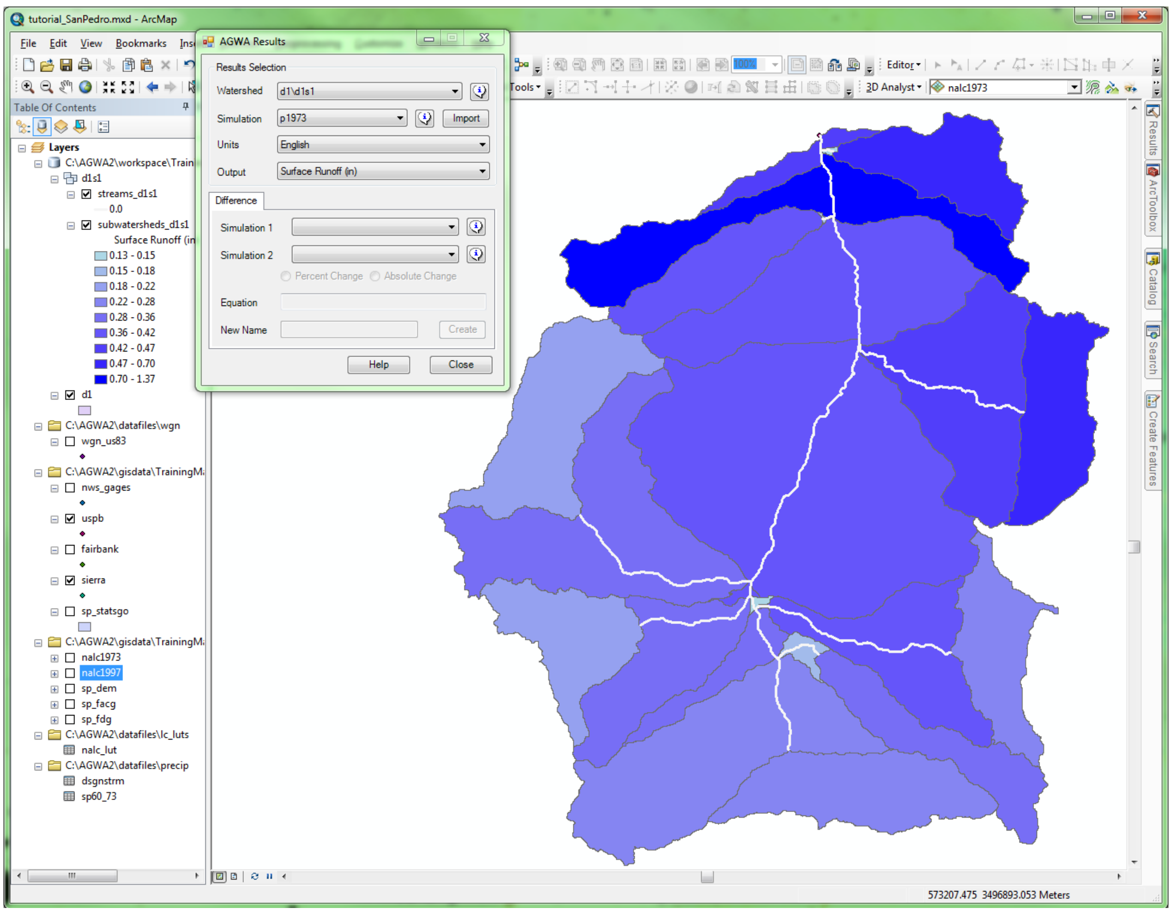
8.5. Repeat ***Part 1, Step 7: Executing the SWAT model*** with the **p1997** simulation.

Step 8: Viewing the results

After SWAT execution is complete, the SWAT output files must be imported into AGWA before displaying the spatially distributed results, such as runoff, infiltration, and other water balance results.

9. Import the SWAT results from the 1973 and1997 simulations by selecting ***AGWA Tools > View Results > SWAT Results > View SWAT2000 Results***.
    9.1. ***Results Selection*** box
        9.1.1. ***Watershed***: select **d1\d1s1**
        9.1.2. ***Simulation***: click ***Import***
            9.1.2.1. **Yes** to importing ***p1973***
            9.1.2.2. **Yes** to importing ***p1997***
10. Experiment with the results visualization by choosing different results to display.
    10.1. ***Results Selection*** box
        10.1.1. ***Watershed***: select **d1\d1s1**
        10.1.2. ***Simulation***: select **p1973** or **p1997**
        10.1.3. ***Units***:select **English**
        10.1.4. ***Output***: select **Surface Runoff (in)**

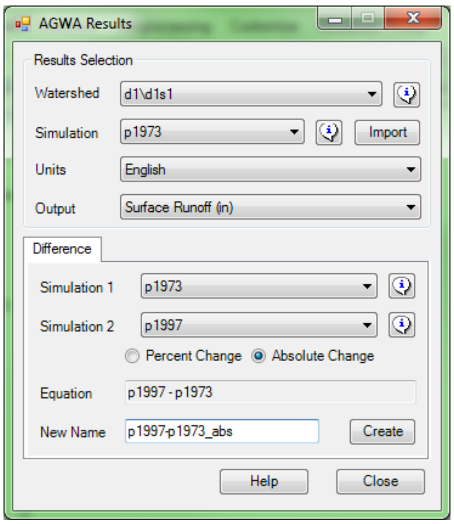
The results for the ***p1973*** simulation with the ***Surface Runoff (in)*** output should look like the image below.

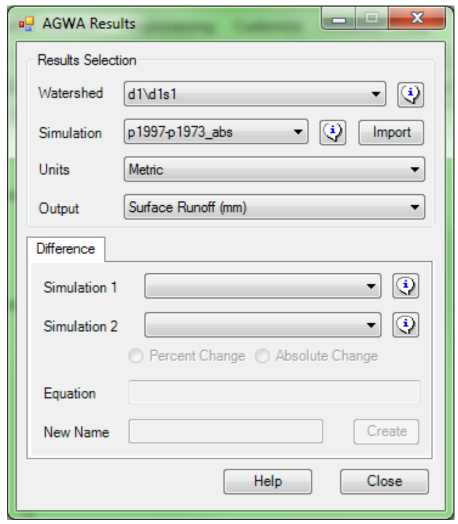


Step 9: Comparing 1973 and 1997 results

In this step, a new set of results representing the differences in SWAT outputs between the 1997 and 1973 land cover classes will be created. Differencing involves simple subtraction that can be normalized or left as absolute change.

11. If the AGWA Results form is closed, reopen it by selecting ***AGWA Tools > View Results > SWAT Results > View SWAT2000 Results***.
  11.1. ***Results Selection*** box
    11.1.1. ***Watershed***: select **d1\d1s1**
  11.2. ***Difference*** tab
    11.2.1. ***Simulation1***: select **p1973**
    11.2.2. ***Simulation2***: select **p1997**
    11.2.3. Select **Absolute Change** radiobutton
      Note the formula used to calculate the new results.
    11.2.4. ***New Name***: **p1997-p1973_abs**

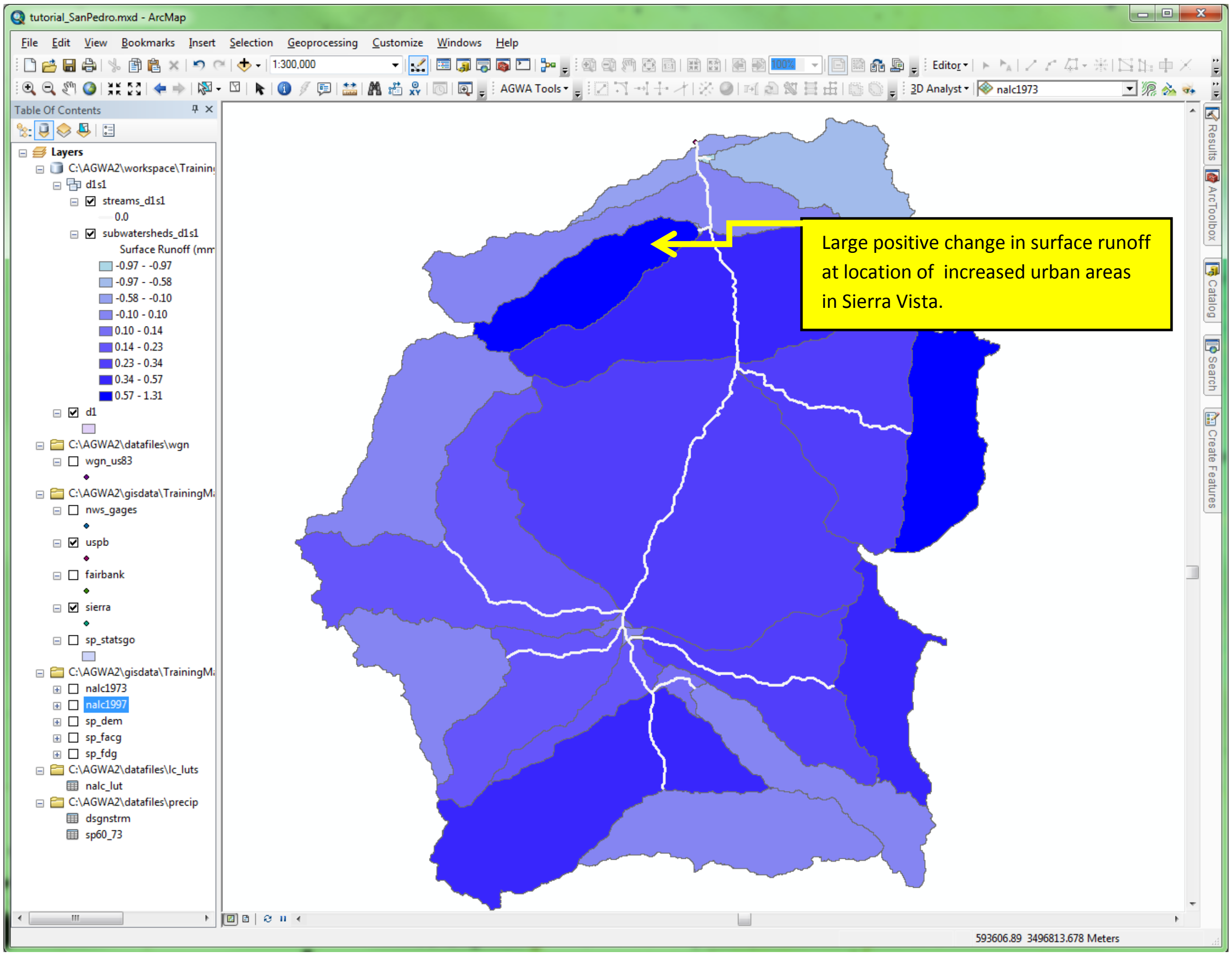




    11.2.5. Click ***Create***
      The Import button does not need to be clicked to import the differenced results, they are added (but not selected) to the ***Simulation*** combobox automatically.
  11.3. ***Results Selection*** box
    11.3.1. ***Watershed***: select **d1\d1s1**
    11.3.2. ***Simulation***: select **p1997-p1973_abs**
    11.3.3. ***Units:*** select **Metric**
    11.3.4. ***Output***: select **Surface Runoff (mm)**

Negative values indicate where the selected output is predicted to decrease and positive values indicate where the selected output is predicted to increase. In this example, any increases or decreases in any of the selected outputs is due to changes in land cover.

Results of the simulated change in surface runoff resulting from land cover changes are shown below:



Part II: Modeling Runoff at the Small Watershed Scale Using KINEROS

In the previous section we identified regions that have undergone significant changes both in terms of their landscape characteristics and their hydrology. These basin scale assessments are quite useful for detecting large patterns of change, and we will use the results to zoom in on a subwatershed to investigate the micro-scale changes and how they may affect runoff from simulated rainfall events.

SWAT is a continuous simulation model, and in the last exercise we simulated runoff for 10 years on a yearly basis. KINEROS is termed an event model, and we will use design storms to simulate the runoff and sediment yield resulting from a single storm. In this case, we will use the estimated 10-year, 1-hour return period rainfall.

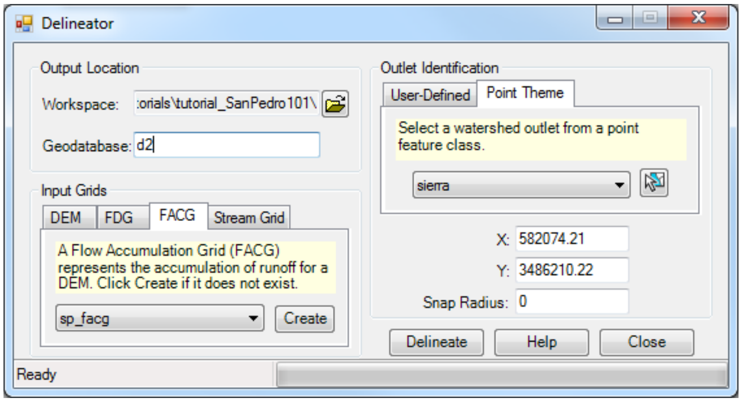
A quick review of the spatial distribution of changes in surface runoff predicted by SWAT shows that one of the larger increases occurred in a small watershed draining an area near Sierra Vista that underwent significant urban growth from 1973 to 1997. The area near Sierra Vista is highlighted in red.

In this exercise, we are going to zoom in temporally and spatially to investigate large-scale changes within the watershed.

Step 1: Delineating the watershed

As we did in Part 1 for SWAT, the first step is to delineate the watershed of interest. The geodatabase and feature class created during watershed delineation is model independent.

12. Perform the watershed delineation by selecting ***AGWA Tools > Delineation Options > Delineate Watershed***.



12.1. ***Output Location*** box

12.1.1. ***Workspace*** textbox: navigate to and select/create **C:\AGWA\workspace\tutorial_SanPedro**

DESCRIPTION The workspace specified is the location on your hard drive where the delineated watershed is stored as a feature class in a geodatabase.

12.1.2. ***Geodatabase*** textbox: enter **d2**

NOTE You will be required to change the name of the geodatabase if a geodatabase with the same name exists in the selected workspace.

12.2. ***Input Grids*** box

12.2.1. ***DEM*** tab: select **sp_dem** (do not click Fill)

12.2.2. ***FDG*** tab: select **sp_fdg** (do not click Create)

12.2.3. ***FACG*** tab: select **sp_facg** (do not click Create)

12.3. ***Outlet Identifcation*** box

12.3.1. ***Point Theme*** tab:select **sierra**

12.3.2. Click the ***Select Feature*** button and click and drag to draw a rectangle around the point.

NOTE The selection is restricted to the selected point theme. If more than one point exists in the selected point theme and the drawn rectangle intersects multiple points, the first intersected point in the point theme attribute table will be selected.

12.4. Click ***Delineate***

12.5. Save the map document and continue.

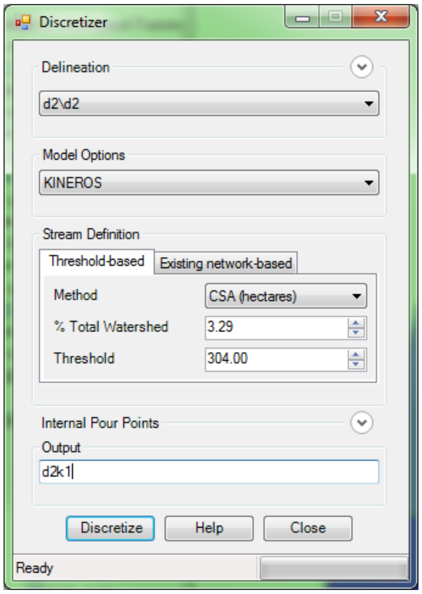
The delineation can be used for multiple discretizations and with any of the included models.

Step 2: Discretizing or subdividing the watershed

Discretizing breaks up the delineated watershed into model specific elements and creates a stream feature class that drains the elements. KINEROS model elements differ from SWAT model elements in that planes are split into lateral elements by the stream feature class.

13. Perform the watershed discretization by selecting ***AGWA Tools > Discretization Options > Discretize Watershed.***

DESCRIPTION In the Discretizer form, several parameters are defined including the model to use, the complexity of the discretization, the name of the discretization, and whether additional pour points will be used to further control the subdivision of the watershed.



13.1. ***Delineation*** box: select **d2\d2**

13.2. ***Model Options*** box: select **KINEROS**

NOTE SWAT and KINEROS require significantly different watershed subdivisions and their watershed topology is not interchangeable, so be sure that the KINEROS model is selected and not SWAT.

13.3. ***Stream Definition*** box

13.3.1. ***Threshold-based*** tab

13.3.1.1. ***Method***: select **CSA (Hectares)**

13.3.1.2. ***% Area***: do nothing (Note: this value will change when we change the CSA)

13.3.1.3. ***Threshold***: enter **304**

13.4. ***Internal Pour Points*** dropdown: do nothing

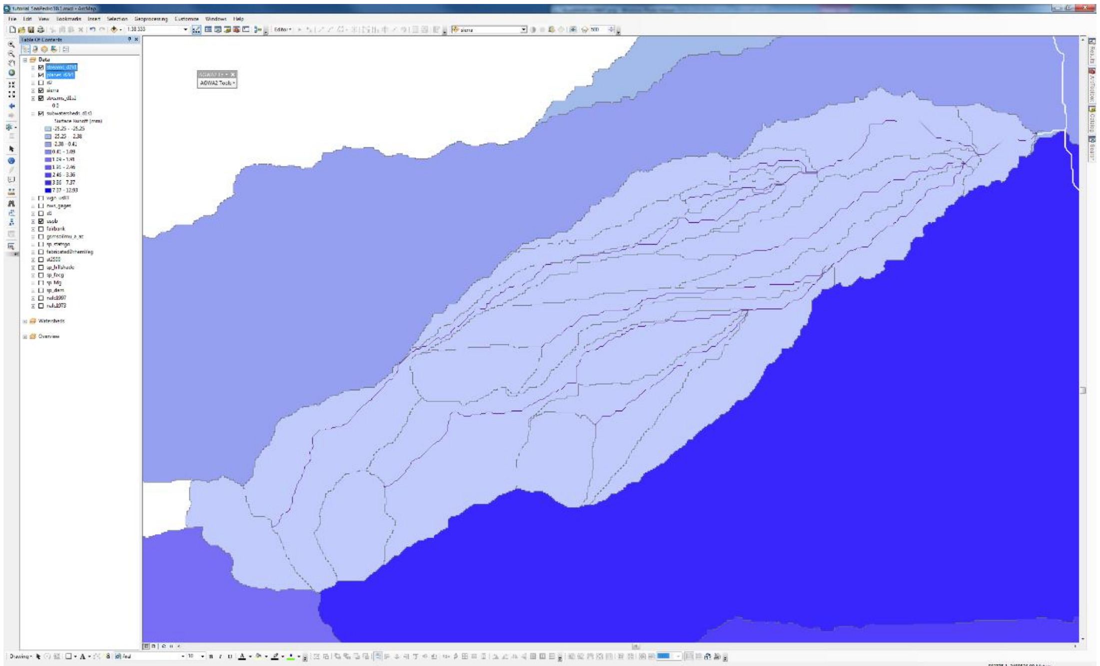
DESCRIPTION Pour points can be used to force the subdivision of watershed elements at user-supplied points, either by clicking on the map or selecting points from a point theme. User-supplied pour points can simply be used to help subdivide the watershed or later serve as a location to define reservoir inputs for SWAT or pond inputs for KINEROS.

13.5. ***Output*** box

13.5.1. ***Name***: enter **d2k1**

13.6. Click ***Discretize***

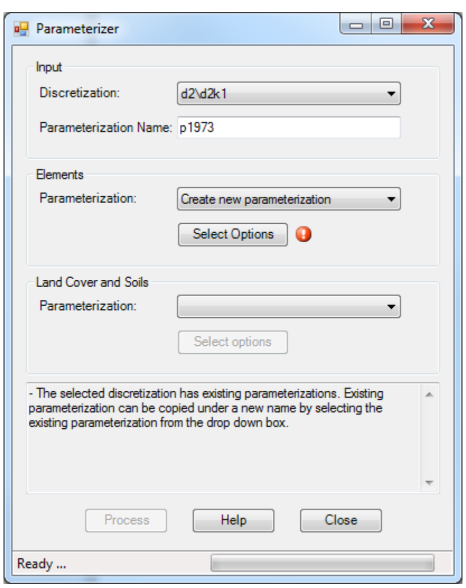
13.7. Save the map document and continue.

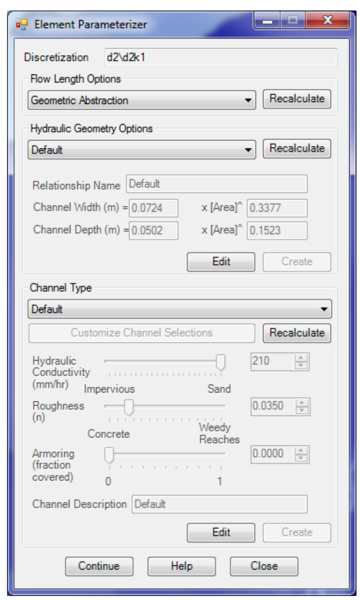


Step 3: Parameterizing the watershed elements for KINEROS

As with SWAT, each of the watershed elements needs to be characterized by its topographic, hydraulic geometry, flow length, land cover and soils properties.

14. Perform the element, land cover, and soils parameterization of the watershed by selecting ***AGWA Tools > Parameterization Options > Parametrize***.





14.1. ***Input*** box

14.1.1. ***Discretization***: select **d2\d2k1**

14.1.2. ***Parameterization Name***: enter **p1973**

14.2. ***Elements*** box

14.2.1. ***Parameterization***: **Create new parameterization**

14.2.2. Click ***Select Options***. The Element Parameterizer form opens.

14.3. In the ***Element Parameterizer*** form

14.3.1. ***Flow Length Options*** box

14.3.1.1. Select the **Geometric Abstraction** item.

14.3.2. ***Hydraulic Geometry Options*** box

14.3.2.1. Select the **Default** item.

Do not click the ***Recalculate*** button.

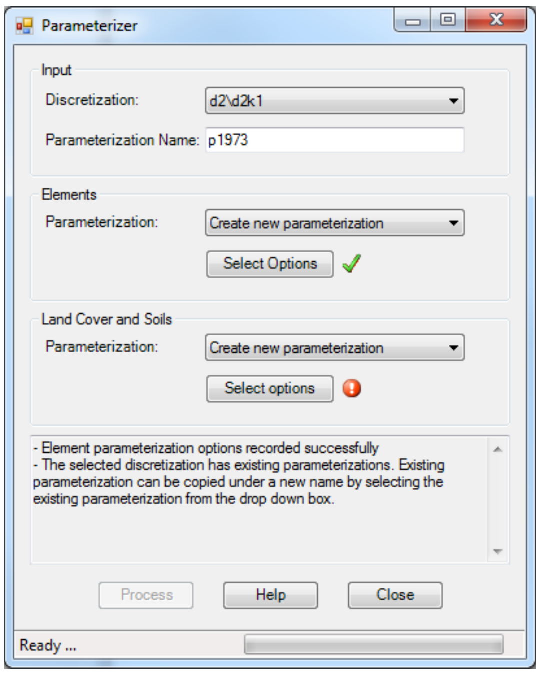
Do not click the ***Edit*** button.

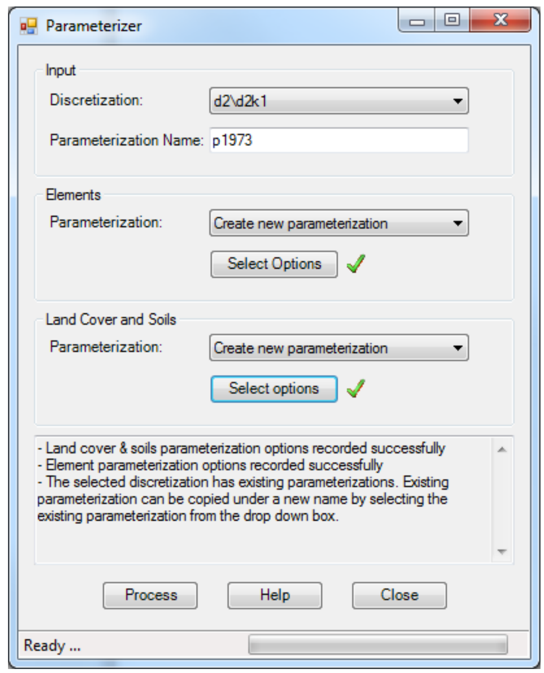
14.3.3. ***Channel Type*** box

14.3.3.1. Select the **Default** item.

14.3.4. Click ***Continue***. You will be returned to the ***Parameterizer*** form to create the Land Cover and Soils parameterization.

14.4. Back in the ***Land Cover and Soils*** box of the ***Parameterizer*** form

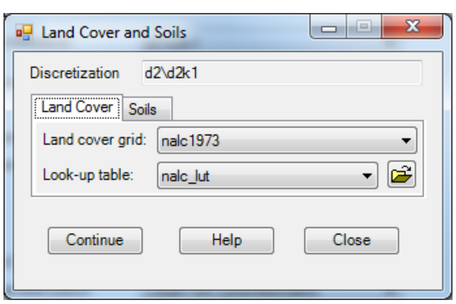


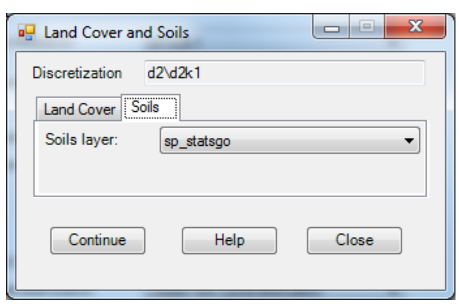


14.4.1. ***Parameterization***: select **Create new parameterization**

14.4.2. Click ***Select Options***. The ***Land Cover and Soils*** form opens.

14.5. In the ***Land Cover and Soils*** form





14.5.1. ***Land Cover*** tab

14.5.1.1. ***Land cover grid***: select **nalc1973**

14.5.1.2. ***Look-up table***: select **nalc_lut**

14.5.2. ***Soils*** tab

14.5.2.1. ***Soils*** layer: select **sp_statsgo**

14.6. Click ***Continue***. You will be returned to the ***Parameterizer*** form where the ***Process*** button will now be enabled.

14.7. In the ***Parameterizer*** form, click ***Process***.

Step 4: Repeat for 1997 land cover

15. Rerun the land cover and soils parameterization of the watershed with the 1997 land cover by selecting ***AGWA Tools > Parameterization Options > Parameterize***.

15.1. ***Input*** box

15.1.1. ***Discretization***: select **d2\d2k1**

15.1.2. ***Parameterization Name***: enter **p1997**

15.2. ***Elements*** box

15.2.1. ***Parameterization***: select **p1973**

Land cover change is the emphasis of this exercise and no other changes will be made; because no other options are changing, the element parameterization parameters can be copied from an existing parameterization.

15.3. ***Land Cover and Soils*** box

15.3.1. ***Parameterization***: select **Create new parameterization**

15.3.2. Click ***Select Options***. The ***Land Cover and Soils*** form opens.

15.4. In the ***Land Cover and Soils*** form

15.4.1. ***Land Cover*** tab

15.4.1.1. ***Land cover grid***: select **nalc1997**

15.4.1.2. ***Look-up table***: select **nalc_lut**

15.4.2. ***Soils*** tab

15.4.2.1. ***Soils*** layer: select **sp_statsgo**

15.5. Click ***Continue***. You will be returned to the ***Parameterizer*** form where the ***Process*** button will now be enabled.

15.6. In the ***Parameterizer*** form, click ***Process***.

Step 5: Preparing rainfall files

KINEROS is designed to be run on rainfall events as opposed to the daily rainfall totals used in SWAT. AGWA has a number of return period events for southeast Arizona and a few other locations stored in a design storm database. In this exercise, a storm from the design storm database will be used, though AGWA allows you to create rainfall data for KINEROS in a number of ways:

- Design storm depth and duration from the database (our technique).
- Design storm depth and duration based on precipitation frequency maps.
- User-defined hyetograph.

- User-defined depth and duration.

All rainfall events may be applied uniformly across the watershed. Alternatively, the storm center and radius can be defined to apply the rainfall event on a specific part of the watershed.

16. Write the KINEROS precipitation file for the watershed by selecting ***AGWA Tools*** > ***Precipitation Options*** > ***Write KINEROS Precipitation***.

16.1. ***KINEROS Precipitation*** form

16.1.1. ***Select discretization***: select **d2/d2k1**

16.1.2. ***Storm Depth*** box:

16.1.2.1. ***Database*** tab:

16.1.2.1.1. ***Select database***: select **dsgnstrm**

16.1.2.1.2. ***Select location***: select **San Pedro**

16.1.2.1.3. ***Select storm frequency (yrs)***: select **10**

16.1.2.1.4. ***Select storm duration (hrs)***: select **1**

16.1.3. ***Storm Location*** box

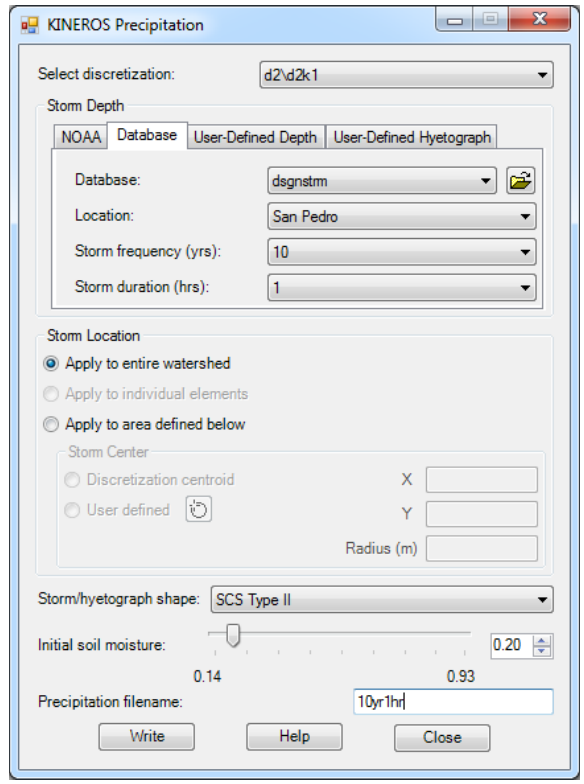
16.1.3.1. Select ***Apply to entire watershed*** radio button

16.1.4. ***Storm/hyetograph shape:*** select **SCS Type II**

16.1.5. ***Initial soil moisture:*** select **0.2**

16.1.6. ***Precipitation filename:*** enter **10yr1hr**

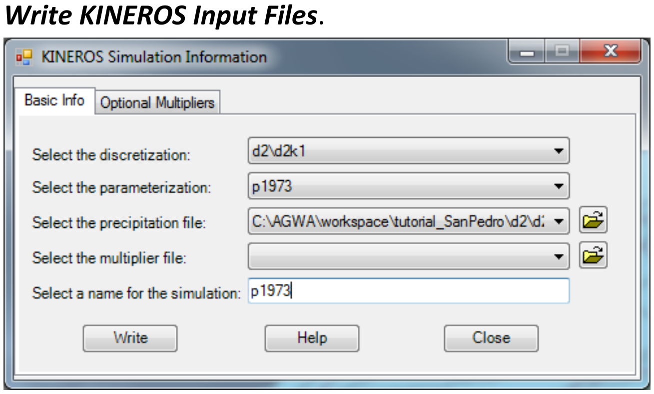
16.1.7. Click ***Write***.



Step 6: Writing KINEROS input files

Like with SWAT, AGWA loops through features of the selected discretization and reads the model parameters from the parameterization look-up tables to write into the input files for the model.

17. Write the KINEROS input files by selecting ***AGWA Tools > Simulation Options > KINEROS Options > Write KINEROS Input Files***.



17.1. ***Basic Info*** tab:

17.1.1. ***Select the discretization***: **d2\d2k1**

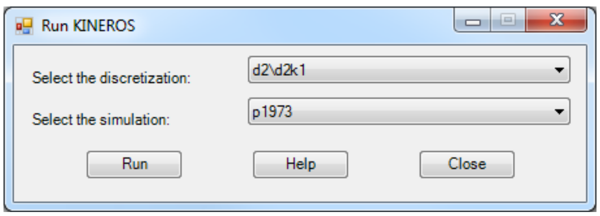
17.1.2. ***Select the parameterization***: select **p1973**
17.1.3. ***Select the precipitation file***: select **10yr1hr**
17.1.4. ***Select the multiplier file***: leave blank
17.1.5. ***Select a name for the simulation***: enter **p1973**
17.1.6. Click ***Write***.

17.2. Repeat ***Part 2, Step 6: Writing KINEROS input files*** with the **p1997** parameterization and name the simulation **p1997**.

Step 7: Executing the KINEROS model

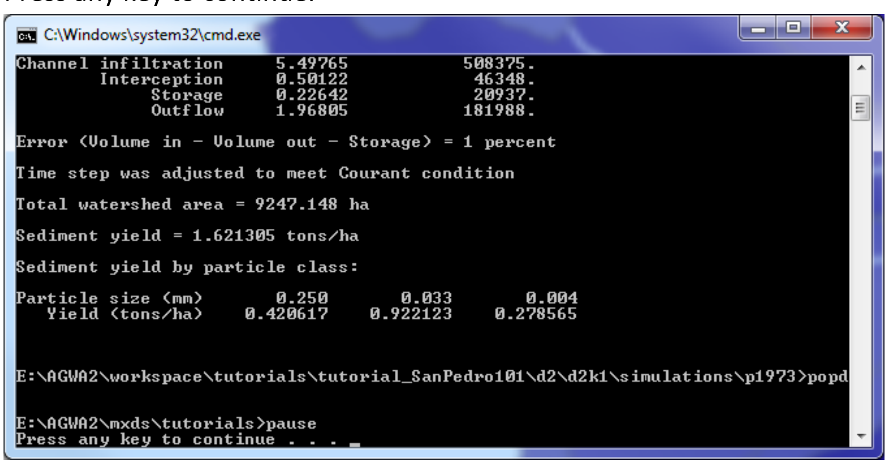
Executing the KINEROS model opens a command window where the model is executed. By default, the command window stays open so that success or failure of the simulation can be verified.

18. Execute the KINEROS model for the Sierra Vista watershed by selecting ***AGWA Tools > Simulation Options > KINEROS Options > Execute KINEROS Model***.



18.1. ***Select the discretization***: select **d2\d2k1**
18.2. ***Select the simulation***: select **p1973**
18.3. Click ***Run***.

A command window will open and show the execution of KINEROS for the 10-year, 1-hour storm. The command window will stay open so that successful completion can be verified. Press any key to continue.



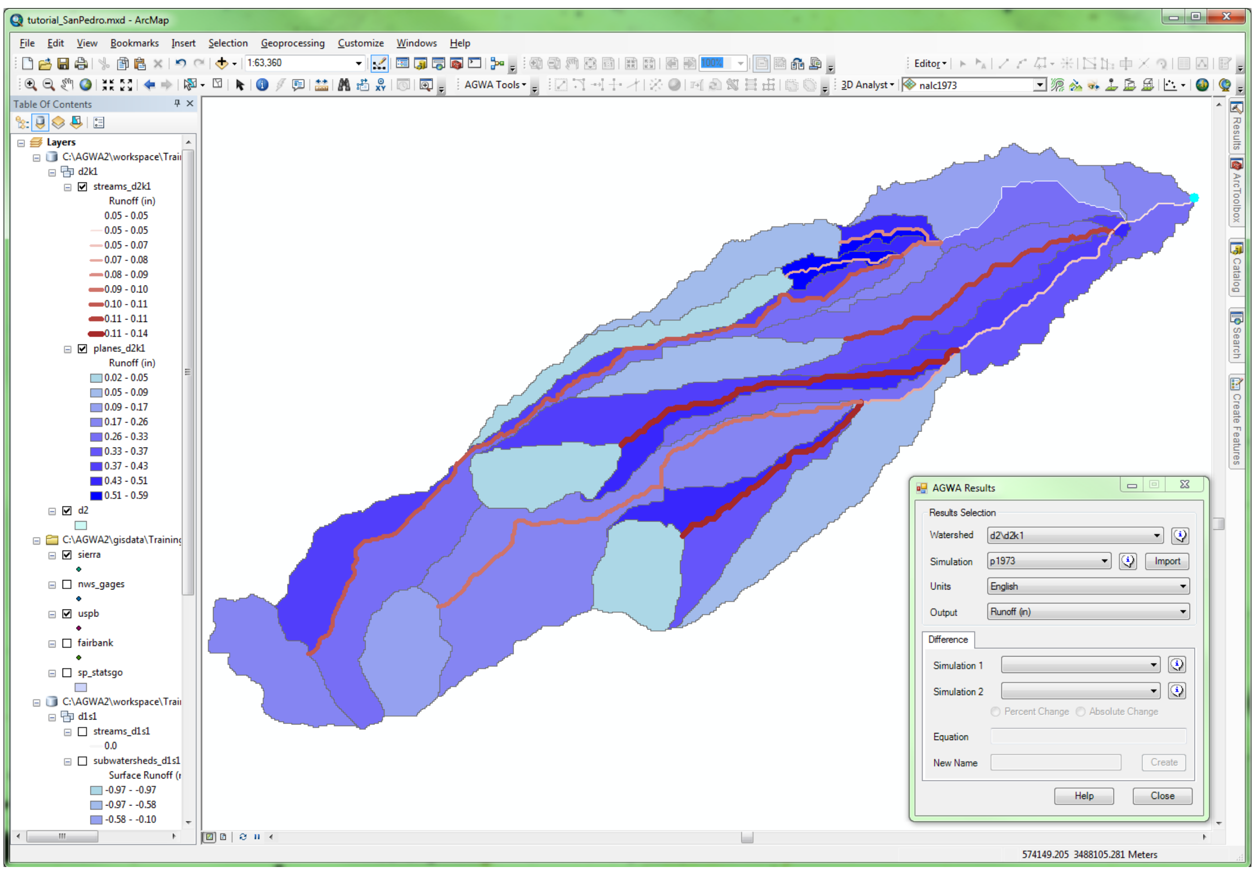
18.4. Repeat ***Part 2, Step 7: Executing the KINEROS model*** with the **p1997** simulation.

Step 8: Viewing the results

Viewing the KINEROS results is identical to looking at SWAT results. After KINEROS execution is complete, the KINEROS output files must be imported into AGWA before displaying the spatially distributed results, such as runoff, infiltration, and other water balance results. In addition to spatially distributed results, AGWA can also display hydrographs for the different discretization elements.

19. Import the KINEROS results from the 1973 and1997 simulations by selecting ***AGWA Tools > View Results > KINEROS Results > View KINEROS Results***.
    19.1. ***Results Selection*** box
        19.1.1. ***Watershed***: select **d2\d2k1**
        19.1.2. ***Simulation***: click ***Import***
            19.1.2.1. **Yes** to importing ***p1973***
            19.1.2.2. **Yes** to importing ***p1997***
20. Experiment with the results visualization by choosing different results to display.
    20.1. ***Results Selection*** box
        20.1.1. ***Watershed***: select **d2\d2k1**
        20.1.2. ***Simulation***: select **p1973** or **p1997**
        20.1.3. ***Units:*** select **English**
        20.1.4. Output: select **Runoff (in)**

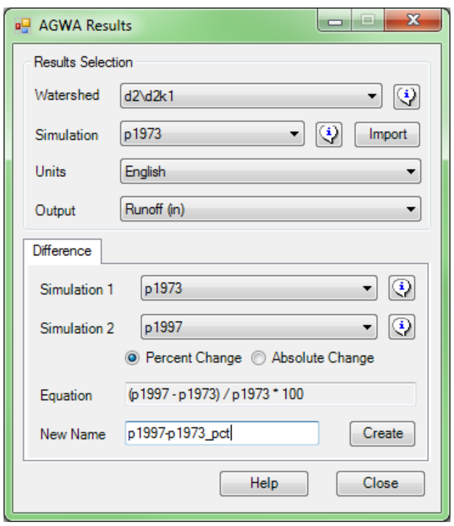
The results for the ***p1973*** simulation with the ***Runoff (in)*** output should look like the image below.

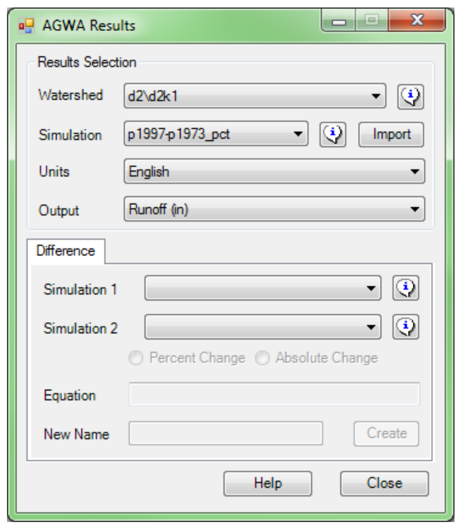


Step 9: Comparing 1973 and 1997 results

In this step, a new set of results representing the differences in KINEROS outputs between the 1997 and 1973 land cover classes will be created. Differencing involves simple subtraction that can be normalized or left as absolute change.

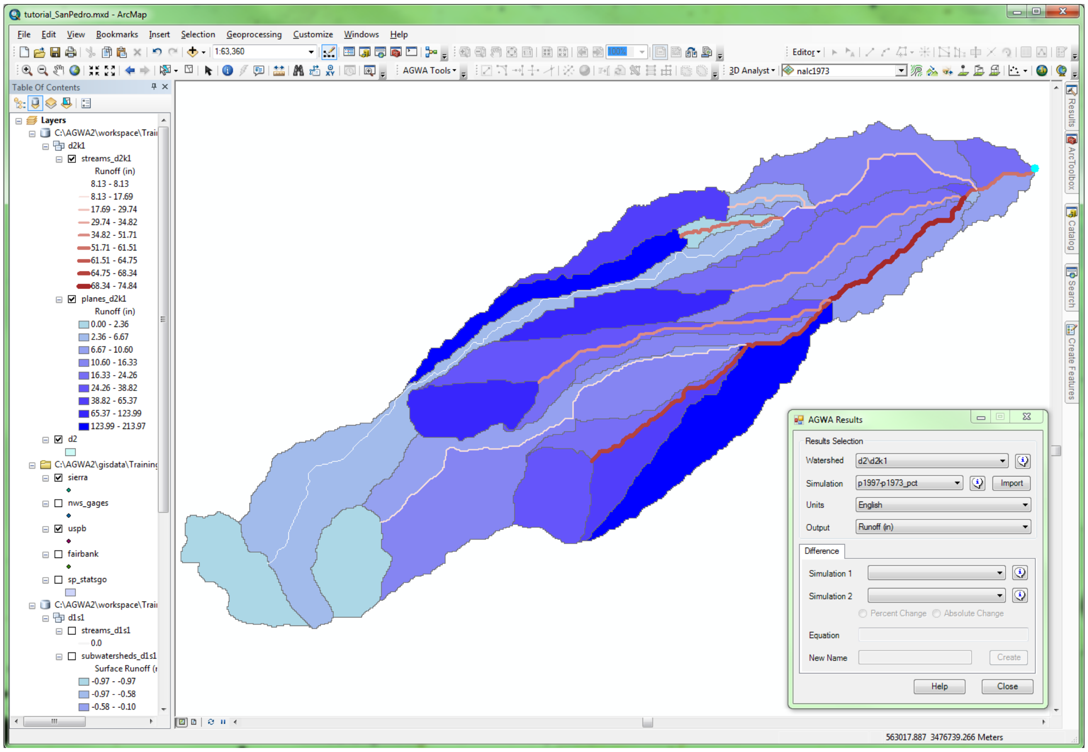
21. If the AGWA Results form is closed, reopen it by selecting ***AGWA Tools > View Results > KINEROS Results > View KINEROS Results***.
    21.1. ***Results Selection*** box
        21.1.1. ***Watershed***: select **d2\d2k1**
    21.2. ***Difference*** tab
        21.2.1. ***Simulation1***: select **p1973**
        21.2.2. ***Simulation2***: select **p1997**
        21.2.3. Select **Percent Change** radiobutton
            Note the formula used to calculate the new results.
        21.2.4. ***New Name***: enter **p1997-p1973_pct**
        21.2.5. Click ***Create***





    21.3. ***Results Selection*** box
        21.3.1. ***Watershed***: select **d2\d2k1**
        21.3.2. ***Simulation***: select **p1997-p1973_pct**
        21.3.3. ***Units:*** select **English**
        21.3.4. ***Output***: select **Runoff (in)**

Results of the simulated change in runoff resulting from land cover changes are shown below. What is driving this change in runoff? You can inspect the changes in the underlying land cover and make some correlations. The driving forces behind the change are primarily decreases in cover, surface roughness and infiltration.



Some question to think about that may be answered using this multi-faceted approach

- What regions of the basin have undergone significant change in their landscape characteristics?
- How have these changes in the spatial variability impacted runoff, water quality, and the water balance?
- Given spatially distributed changes in the water balance, what stresses (or benefits) are placed on the plant community or habitat? Can we identify regions of susceptibility or especially sensitive areas?
- How may these tools be used in a forecasting model or land cover simulation scenario to identify "at-risk" or sensitive areas?
- How do the spatial patterns of change affect runoff response? How can we optimize landscape and hydrologic assessment as a function of temporal and spatial scaling?

Some additional exercises to try on the San Pedro

- Change the CSA to see how altering the geometric complexity impacts the simulation of hydrology and landscape statistics.
- Use the MRLC from the early 1990s to simulate runoff and compare it with the commensurate 1992 NALC data to see how different land cover classifications affect the results.
- Use the nws_gages coverage to generate spatially-distributed rainfall for input to SWAT. This approach will create a Thiessen map across the watershed and you will notice a distinct south to north gradient in rainfall depths that affects the generation of runoff and also impacts the change statistics.

- Generate a variety of rainfall events for KINEROS and investigate the relative impacts of land cover change on small vs. large return period storms. You should see a drop in percent change with increasing rainfall. Why?