Introduction to AGWA2
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 AGWA2 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.
Keywords:	Watershed assessment, Hydrologic model, Rainfall interpolation, Continuous vs. event-based modeling

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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 km^2 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).

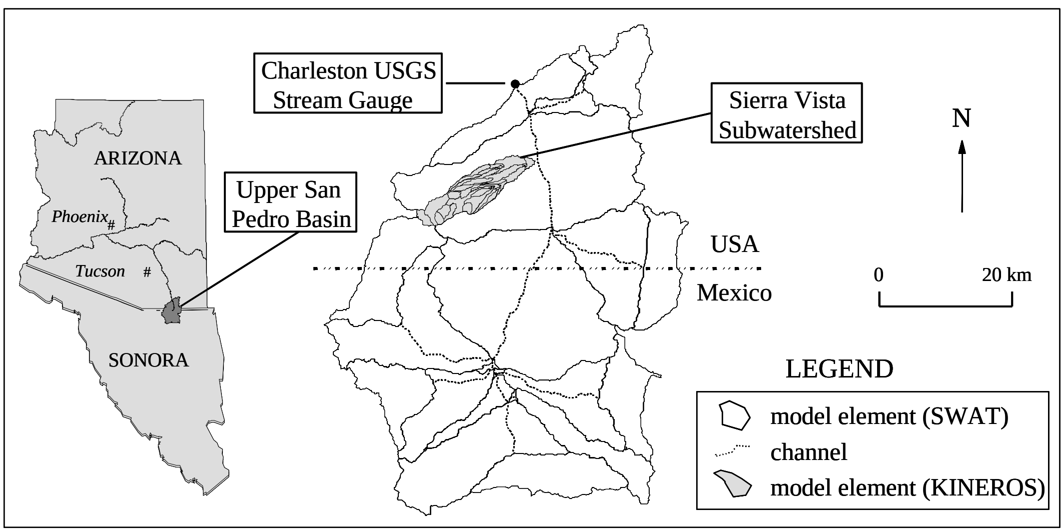
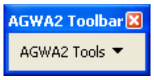


Figure 1. Locations of the two study areas within the Upper San Pedro River Basin you will be modeling today. The larger basin (2886 km^2) will be modeled using SWAT and drains to the Charleston USGS runoff gaging station. This basin encompasses the smaller watershed (92 km^2), labeled here as "Sierra 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.

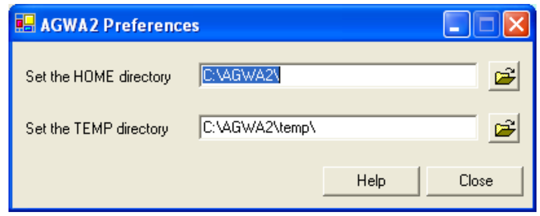
Getting Started

Open ArcMap and start with a new empty map. Save the empty map document with a meaningful name to help identify it and save it in a location of your choice; for this tutorial use **tutorial_SanPedro** as the name. If you wish to organize all of your AGWA2 map documents in one location, we suggest using the **C:\AGWA2\mxds** directory. Turn on the *AGWA2 Toolbar* by right-clicking on an empty space on a toolbar and clicking *AGWA2 Toolbar* if it is not already on. You may also turn on the toolbar by clicking the *Tools* menu and selecting the *Customize* menu item, then checking the *AGWA2 Toolbar* checkbox in the *Toolbars* tab.



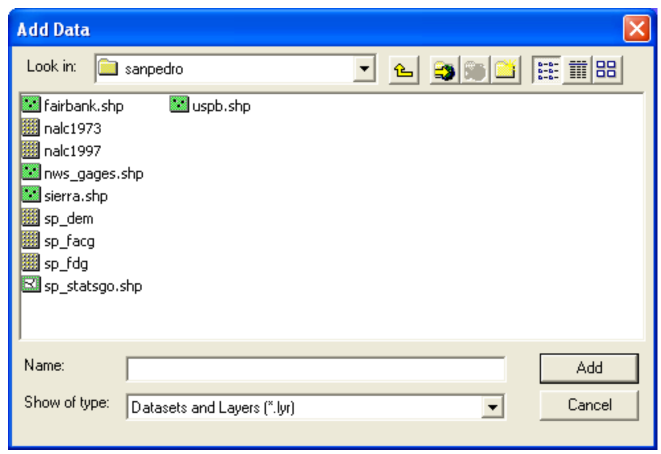
Setting Up the Home and Temp Directory

Once the map document is opened and saved, you must set the *HOME* and *TEMP* directories before using AGWA2. These directories must be set for each new map document you plan to use AGWA2 with.



To set the *HOME* and *TEMP* directories, open the *AGWA2 Preferences* form by selecting the *Preferences* menu item from the *AGWA2 Tools -> Other Options* menu. Once the form is open, click the folder buttons corresponding to the *HOME* and *TEMP* directories. The *HOME* directory must be the location where the *AGWA2* folder was extracted from the *AGWA2 files.zip* file in the *Installation* section above, typically **C:\AGWA2**.

GIS Data



Add data to the map by clicking on the *Add Data* button below the menu bar at the top of the screen. Navigate to the *C:\AGWA2\gisdata\tutorial_SanPedro* folder extracted above and add the following datasets and layers:

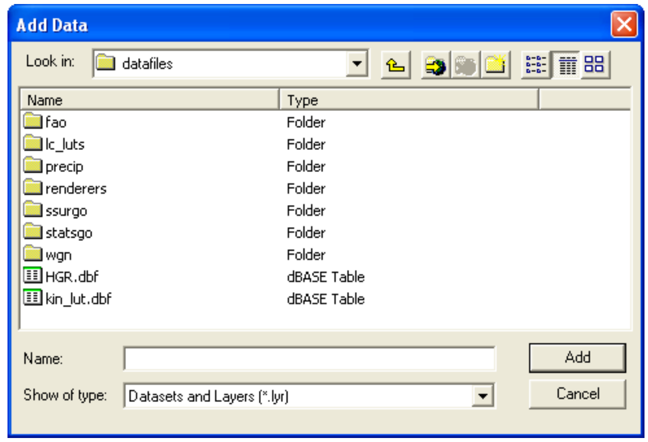
- *Fairbank.shp* – National Weather Service Fairbank raingage
- *Nalc1973* – NALC 1973 land cover classification (60m GRID)
- *Nalc1997* – NALC 1997 land cover classification (60m GRID)
- *NWS_gages.shp* – Multiple raingages throughout the basin
- *Sierra.shp* – Outlet of the Sierra Vista watershed for 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

A Note About Moving Spatial Data: It is important to remember that when dealing with spatial data (coverages, themes, shapefiles, and grids) should not be moved from one directory into another using Microsoft Windows Explorer. This can create errors within the spatial data files; to avoid potential problems please use **ArcCatalog** to manage spatial data.

For the nalc1973 and nalc1997 datasets, one at a time, right click their layer name 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 **Import** button on the right. Click the file browser button and navigate to and select **C:\AGWA2\datafiles\renderers\nalc.lyr**.

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:\AGWA2\datafiles* subdirectory 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



At this point we have all the data necessary to start modeling: **topography, soils, land cover, and rainfall**. Zoom back into the San Pedro region by right-clicking on the *nalc1973* grid in the list of layers and selecting *Zoom To Layer*. To clean up the display, layers can be toggled on or off by clicking their checkboxes and legends can be collapsed or expanded by clicking on the plus or minus next to the layer. Save the map document and continue to the next step.

Part I: 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.

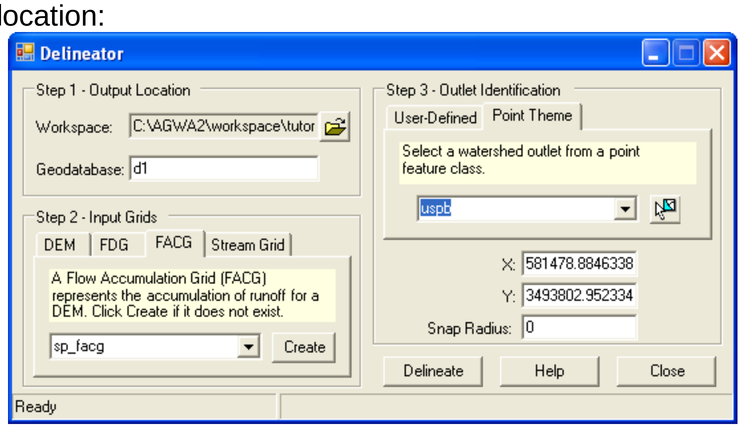
Step 1: Subdividing the watershed

Before modeling can begin on a watershed, the watershed must be delineated and subdivided into model elements. Delineating creates a feature class that represents all the area draining to a user-specified outlet. Discretizing breaks up the delineation/watershed into model specific elements and creates a stream feature class that drains the elements

1. Take a look at the data you have available to you to familiarize yourself with the area. You can reorder, change the legend of, collapse the legend of, and turn on/off the different layers to suit your preferences.

2. Make sure the *uspb* point feature layer is turned on (checked) and is located at the top of the list of available layers. The uppermost layers are displayed on top of the other layers, and moving the *uspb* layer to the top will enable us to see the location of this point, which is the watershed outlet for our first modeling exercise.

3. Perform the watershed delineation by selecting the *Delineate New Watershed* menu item from the *AGWA2 Tools -> Delineation Options* menu. In the *Delineator* form, you must define several parameters including the output location and name, the input grids, and the watershed outlet location:



A. *Output Location* box

   I. Define the workspace location by clicking on the folder button and navigating to and creating **C:\AGWA2\workspace\tutorial_SanPedro**.

   II. Name the geodatabase **d1**; note that you will be required to change the name of the geodatabase if a geodatabase with the same name exists in the workspace location you have chosen.

> **Notes on File Management:** Geodatabases provide a logical organizational structure to store output data. AGWA2 creates a unique geodatabase for each delineation and stores subsequent discretizations in that geodatabase. Discretizations are stored as two feature classes (polygon and polyline) within a feature dataset.
>
> Geodatabases do not store flat ASCII files well, so model inputs and outputs for simulations are stored in a subfolder located and named in line with the geodatabase. Each discretization contains its own *precip* folder and *simulations* folder. This logically organizes inputs and outputs to help prevent inadvertently mixing them up, and also allows in more flexibility in naming precipitation inputs and model simulations.

B. *Input Grids* box

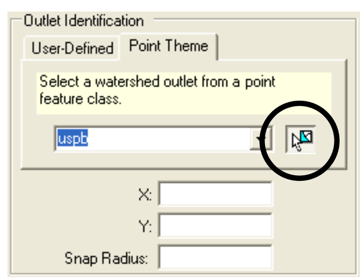
   I. On the DEM tab, select the **sp_dem** layer from the combobox

   II. On the FDG tab, select the **sp_fdg** layer from the combobox

   III. On the FACG tab, select the **sp_facg** layer from the combobox

> **Time Savings:** To save time in this tutorial, you are provided with a filled DEM and the flow direction (FDG) and flow accumulation (FACG) grids have already been created. Filling a DEM ensures it is hydrologically correct by filling isolated depressions, called sinks, in the elevation surface that can cause flow routing problems, and are common in USGS DEMs that have not been corrected. When working with a new DEM, you will also need to create both flow direction and flow accumulation grids before during the delineation process.

C. *Outlet Identification* box



   I. Select the *Point Theme* tab

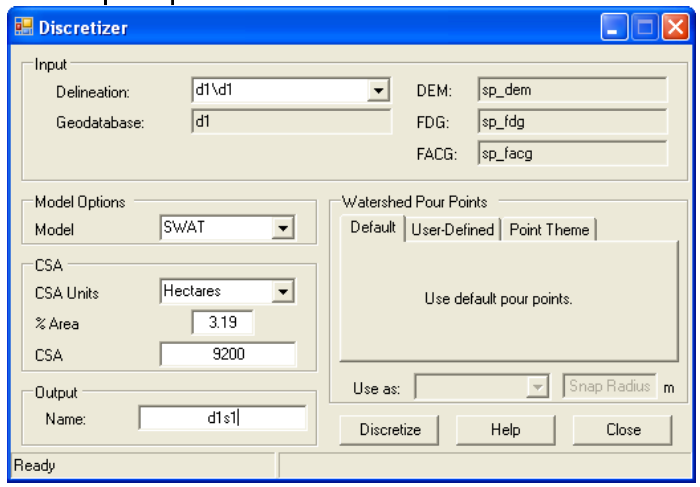
   II. Select the **uspb** layer from the combobox

   III. Click the *Select Feature* button and draw a rectangle around the point (you may need to drag the *uspb* layer to the top of the list of layers and turn other layers off to find the outlet), thereby selecting it. This will automatically populate the *X*, *Y*, and *Snap Radius* textboxes with the coordinates and search radius that will be used to identify the outlet of the stream. The snap radius is the distance in meters used to find the lowest elevation surrounding the coordinates, and consequently the most likely to be located on a stream. This feature is typically only used in combination with the *User-Defined* option for selecting the outlet location and will be left at 0 since the point theme is already located on the stream.

D. Click the **Delineate** button.

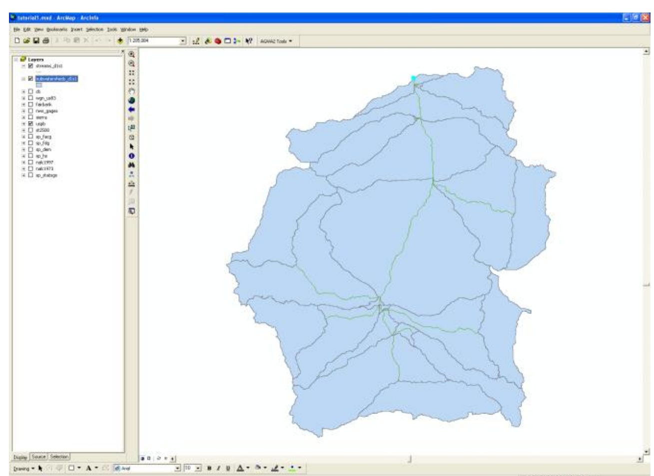
AGWA2 will generate a feature class named according to what was specified in the *Delineator* form that delineates the outline of the watershed contributing runoff to the upper San Pedro River Basin from the point marked by the *uspb* feature class.

4. Perform the watershed discretization by selecting the *Discretize Watershed* menu item from the *AGWA2 Tools -> Discretization Options* menu. In the *Discretizer* form, you must define several parameters including the model to parameterize for, the level of detail of the discretization, the name of the discretization, and whether additional pour points will be used to further control the subdivision of the watershed.



   A. In the *Input* box, select the **d1\d1** geodatabase\delineation pair.
   B. In the *Model* combobox, select the **SWAT** item.
   C. You may ignore the *Watershed Pour Points* box. 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 optionally as reservoir inputs for SWAT or pond inputs for KINEROS.
   D. In the *CSA* box, change the *CSA Units* to **Hectares** and enter a *CSA* of **9200** or a *% Area* of **3.2**.
   E. In the *Output* box, enter **d1s1** as the discretization name.

> **Contributing Source Area:** AGWA subdivides watersheds into hydrologic elements based on the contributing source area (CSA) approach, where channels are defined as a function of the contributing area, or the total area required for channelized flow to occur. Smaller CSA values results in a more complex watershed. The default CSA is set to 2.5% of the watershed.



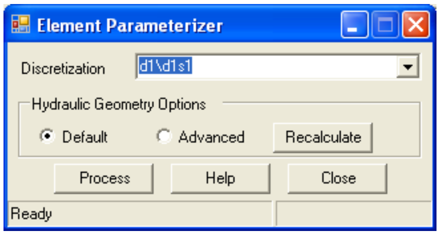
   F. Click the **Discretize** button. The final watershed discretization should look like the one at right. The actual color may be different, but the configuration of the elements should be the same. If it is very different, you may want to start again to make sure the values were entered correctly.

   Note that in the discretization process AGWA2 created a subwatersheds layer with the name *subwatersheds_d1s1* name and a streams map named *streams_d1s1*. In AGWA2 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 2: Parameterizing the watershed elements for SWAT

Each of the watershed elements needs to be characterized by its hydraulic geometry, its flow length, and according to its unique properties of land cover and soils. These properties are used by AGWA2 to create input parameters for either SWAT or KINEROS.

1. Open the *Element Parameterizer* form by selecting the *Element Parameterization* menu item from the *AGWA2 Tools ->Parameterization Options* menu.
   A. For the *Discretization*, select the **d1\d1s1** geodatabase\discretization pair.
   B. In the *Hydraulic Geometry Options* box, select the **Default** radio button.
   C. Click the **Process** button.



2. Open the *Land Cover and Soils* form by selecting the *Land Cover and Soils Parameterization* menu item from the *AGWA2 Tools ->Parameterization Options* menu.
   A. On the *Watershed* tab, select the **d1\d1s1** geodatabase\discretization pair from the *Discretization* combobox.
   B. On the *Land Cover* tab,
      I. Select the **nalc1973** layer from the *Land Cover Grid* combobox.
      II. Select the **nalc_lut** table from the *Look-up table* combobox. 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 *\agwa2\datafiles\lc_luts* folder and select the *nalc_lut.dbf*, then select the *nalc_lut* table from the combobox.
   C. In the *Soils* tab, select the **sp_statsgo** layer from the *Soils layer* combobox.
   D. Click the **Continue** button; after a short period of time, the progress bar will begin updating. AGWA2 will now prepare the *d1s1* discretization for running SWAT by intersecting the watershed with the 1973 land cover map and STATSGO soils data.

At this point the watershed has been subdivided into model elements and these elements have been characterized according to their hydraulic geometry, flow length, land cover, and soil properties. AGWA2 has added a few items to the attribute table of the subwatersheds and streams layers that will be used to provide input to the SWAT model. You can see these changes by right-clicking the subwatersheds or streams theme in the list of layers and selecting *Open Attribute Table*.

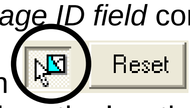
Step 3: Prepare rainfall files

AGWA2 provides a means for preparing rainfall files in SWAT- or KINEROS-ready format. For SWAT, the user must have a dbf file containing the daily estimates of rainfall for the rain gages within the study area. Rainfall data for gages within the San Pedro are provided to you in the *sp60_73.dbf* file.

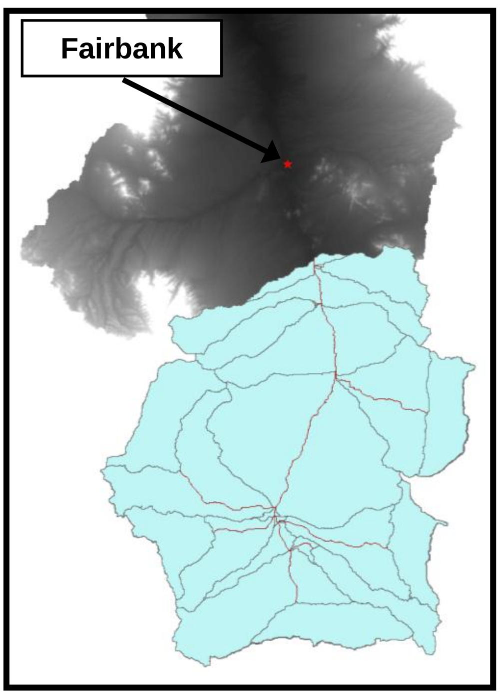
When AGWA2 is used expressly as a hydrologic modeling tool it is critical that the rainfall data be spatially distributed across the watershed. A large body of literature exists regarding the crucial nature of spatially distributed rainfall data. Given a number of rain gages scattered throughout the study area (see the *nws_gages* data layer), AGWA2 will generate a Thiessen rainfall map and distribute observed rainfall on the various watershed elements using an area-weighting scheme. Feel free to use the *nws_gages* file in concert with the *sp60_73.dbf* file to generate rainfall data, but we are NOT using this option right now.

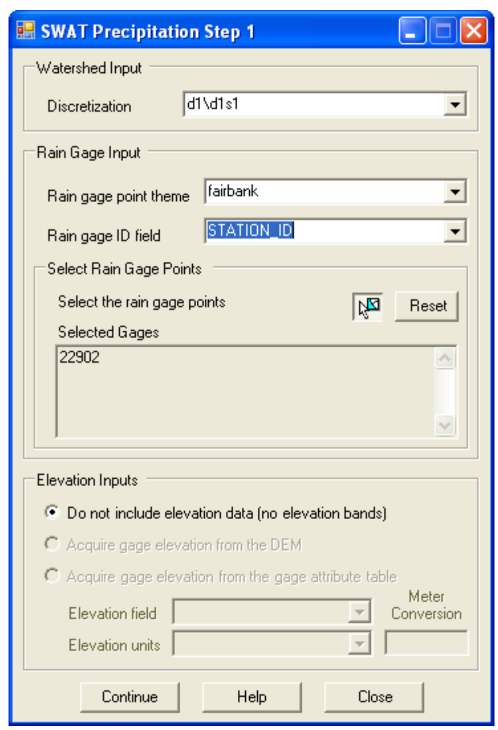
Note on rainfall input: In this exercise, we will use a single rain gage to generate a uniform rainfall file across all the model elements. This is clearly a huge deviation from using observed data, but there is a sound reason for doing so in change detection work. We are interested in the impacts of 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 homogeneous rainfall serves to isolate the effects of land cover change independent of the rainfall.

** Optional ** You can try using 2 different sources of rainfall data for SWAT: uniform and distributed rainfall. In this example you will use a single gage (uniform), but you could also try running SWAT with the *nws_gages* layer (distributed) and use all available gages for the same time period. In this way you can investigate the impacts of rainfall input on hydrologic modeling.

1. To generate uniform rainfall data, open the *SWAT Precipitation Step 1* form by selecting the *SWAT* menu item from the *AGWA2 Tools -> Precipitation Options* menu.
   A. In the *Watershed Input* box, select the **d1\d1s1** geodatabase\discretization pair from the *Discretization* combobox.
   B. In the *Rain Gage Input* box,
      I. Select **fairbank** from the Rain gage point theme combobox
      II. Select **STATION_ID** from the *Rain Gage ID field* combobox
      III. In the Select Rain Gage Points box,
         a. Click the *Select Feature* button 

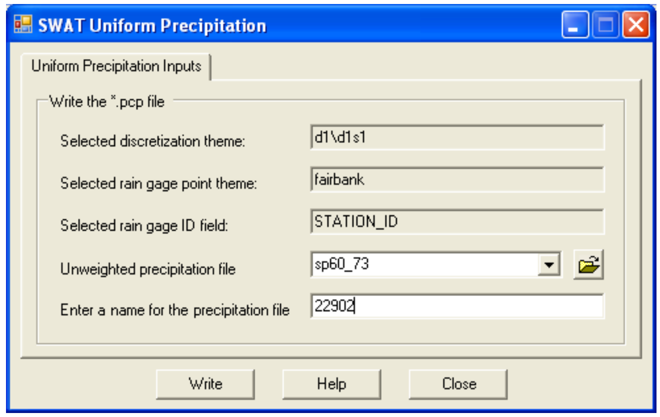
to select the raingage in the view (the figure to the left displays the location of the gage). The id number of the selected gage will be displayed in the *Selected Gages* textbox.
   C. In the Elevation Inputs box,
      I. Select the ***Do not include elevation data (no elevation bands)*** radio button. Click the **Continue** button.





2. The *SWAT Uniform Precipitation* form will automatically open since only one gage was selected.
   A. In the *Write *.pcp file* box,
      I. Select the **sp60_73** table from the *Unweighted precipitation file* combobox.

II. Enter **22902**, indicating the number of the selected raingage, as the filename in the *Enter a name for the precipitation file* textbox.

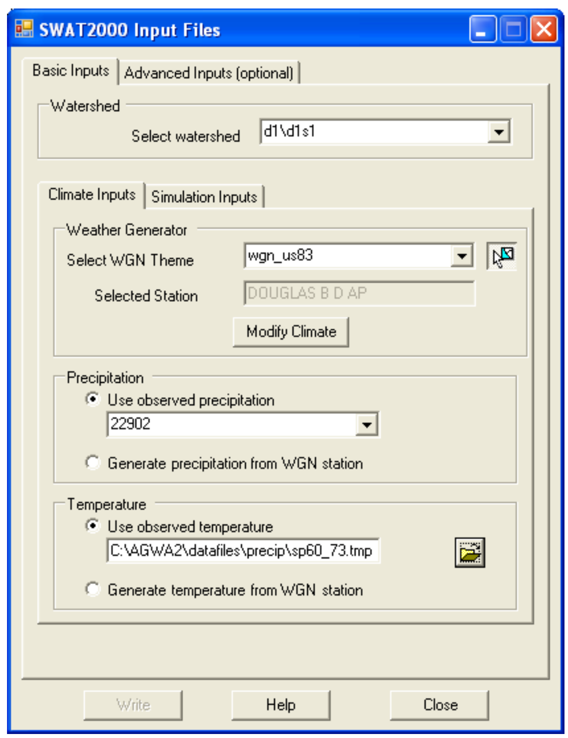


III. Click the **Write** button. If you set the same names and locations as specified thus far, the *22902.pcp* file will be written to the *C:\AGWA2\workspace\tutuorial1\d1\d1s1\precip* folder according to the hierarchy outlined in the *Notes on File Management* box above.

Step 4: Write input files and run SWAT

The watershed has been delineated, discretized, and parameterized and rainfall files created. The next step is to write the model input files and then run the model. AGWA loops through the attributes of the selected watershed discretization and creates text files used to run the model. Once the text files are written, it is time to run the model.

1. To write the input files, open the *SWAT2000 Input Files* form by selecting the *Write Input Files* menu item from the *AGWA2 Tools -> Simulation Options -> SWAT2000* menu.
   A. In the *Watershed* box,
      I. Select the **d1\d1s1** geodatabase\discretization pair from the *Select watershed* combobox.
   B. On the *Climate Inputs* tab,



      I. In the *Weather Generator* box,
         a. Select the **wgn_us83** layer from the *Select WGN Theme* combobox.
         b. Click the *Select Feature*  button to select the *DOUGLAS B D AP* point feature (due east of the watershed when zoomed out).
      II. In the Precipitation box,
         a. Select the **Use observed precipitation** radiobutton.
         b. Select the **22902** precipitation file from the combobox.
      III. In the Temperature box,
         a. Select the **Use observed temperature** radiobutton
         b. Click the *Folder Browser* button to browse to the *AGWA2\datafiles\precip* directory and select the temperature file **sp60_73.tmp**.

   C. On the *Simulation Inputs* tab,
      I. In the Simulation Time Period box,
         a. Enter **01/01/1960** in the *Start Date of Simulation (mm/dd/yyyy)* textbox.
         b. Enter **10** in the *Number of years to simulate* textbox.

There are 14 years of data in the rainfall record created earlier. You can change the start and end dates for the simulation so long as they fall between January 1, 1960 and Dec 31, 1973.

II. In the *Select Output Frequency* box,

a. Select the **Yearly** radiobutton.

III. In the *Simulation Name* box,

a. Enter **s73** in the *Name of Simulation* textbox.

This is the simulation name and consequently, if you set names and locations as specified thus far, will also be the directory name the SWAT results are placed in within the *C:\AGWA2\workspace\tutorial_SanPedro\d1\d1s1\simulations* directory according to the hierarchy outlined in the *Notes on File Management* box above.

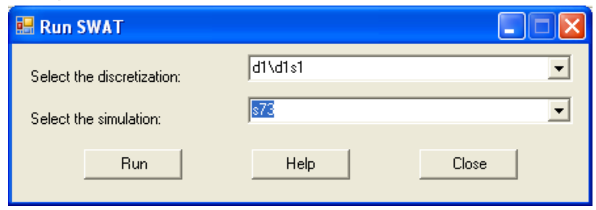
D. Click **Write** to write the SWAT input files.

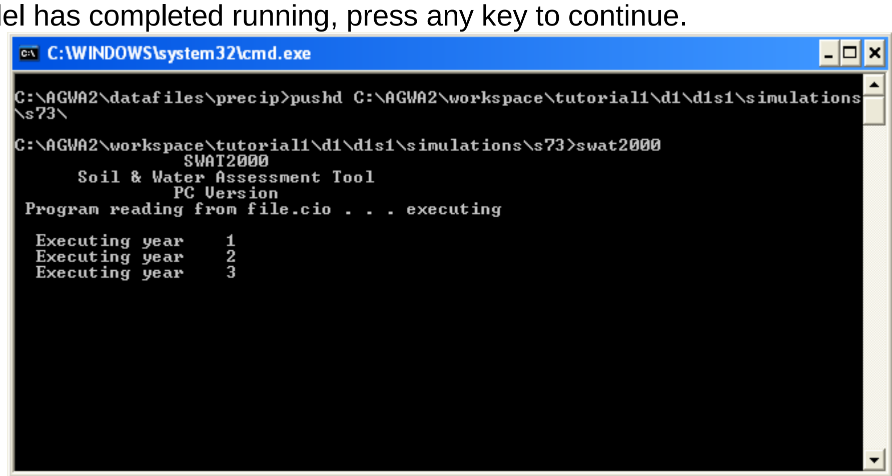
2. To run the model, open the *Run SWAT* form by selecting the *Run SWAT* menu item from the *AGWA2 Tools -> Simulations Options -> SWAT2000* menu.

A. Select the **d1\d1s1** geodatabase\discretization pair from the *Select the Discretization* combobox.

B. Select the **s73** simulation from the *Select the simulation* combobox

C. Click **Run** and AGWA2 will run SWAT for the 10 year simulation period and you should see the black command window as shown below running SWAT. When the model has completed running, press any key to continue.





Step 5: View the results

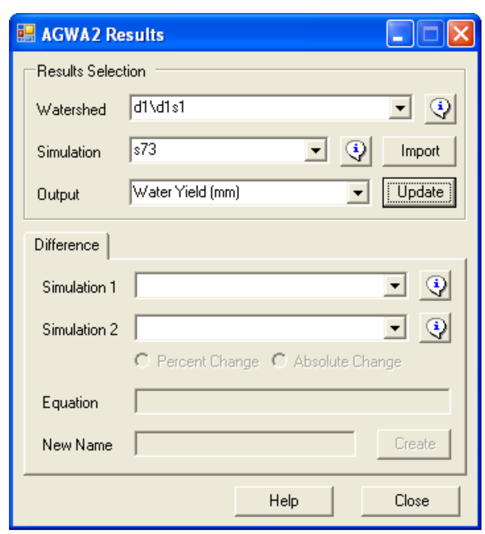
After SWAT runs to completion, the SWAT output files must be imported into AGWA2 before displaying the spatially distributed results, such as runoff, infiltration, and other water balance results.

1. Open the *AGWA2 Results* form by selecting the *View SWAT Results* menu item from the *AGWA2 Tools -> View Results* menu.

A. In the *Results Selection* box,

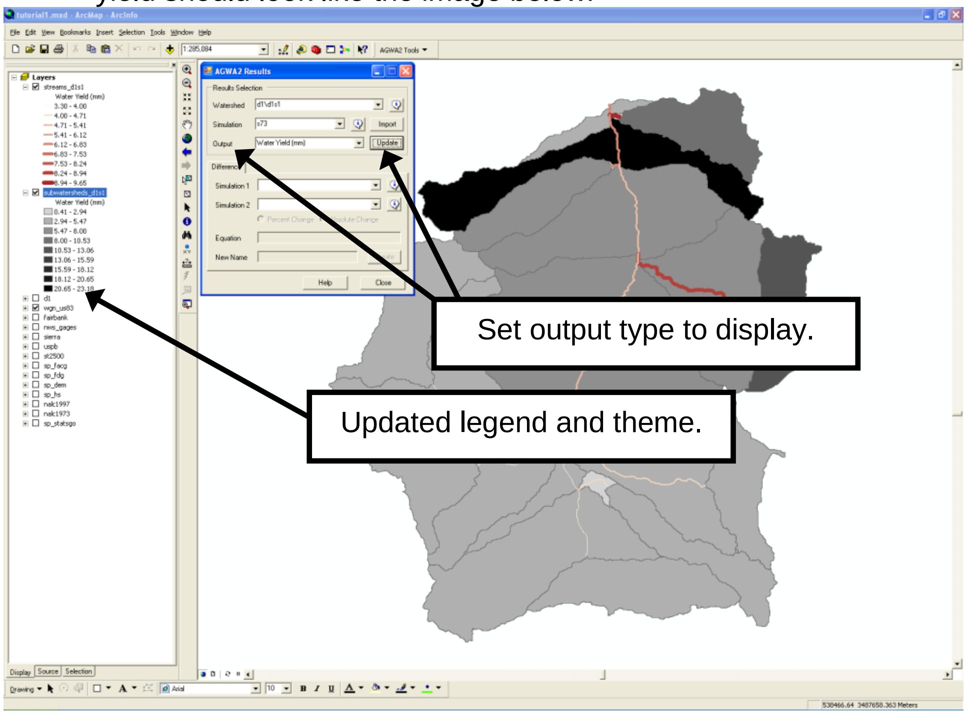
I. Select the **d1\d1s1** geodatabase\discretization pair from the *Watershed* combobox.

II. Click the **Import** button to import the simulation results. Say yes if asked to



import simulation *s73*. Once the results are imported, the Simulation combobox will be updated.

III. Experiment with the results visualization by choosing different results to display from the *Output* combobox and clicking the **Update** button. The results for water yield should look like the image below:



Step 6: Repeat for 1997 land cover

You do not have to re-delineate, re-discretize, or re-configure the watershed to run the simulation with the 1997 land cover. Start the process at Step 2: Parameterizing the watershed elements for SWAT, from above. You do not need to rerun the *Element Parameterization* as we are not changing the hydraulic geometry or flow length options.

1. Rerun the *Land Cover and Soils Parameterization* choosing the **nalc1997** land cover data this time.

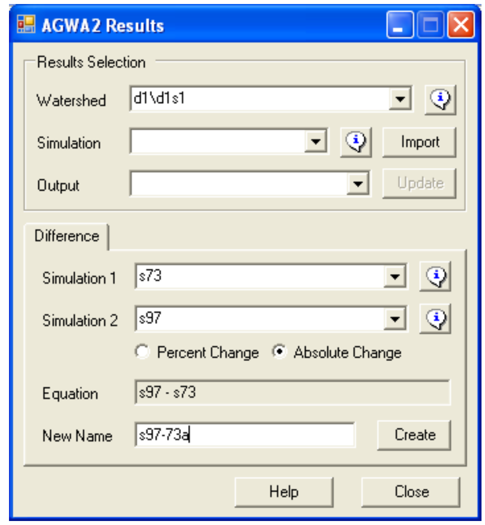
2. You do not have to re-produce rainfall data since the geometric watershed configuration is exactly the same, so skip Step 3: Prepare rainfall files.

3. Repeat Step 4: Write input files and run SWAT using the same precipitation, temperature, and weather generator data and simulation duration of 10 years. The difference this time is that the discretization is parameterized with the 1997 land cover instead of the 1973 land cover. Use the simulation name **s97**.

Step 7: Compare 1997 and 1973 results

In this step, we will create a new set of results representing the differences in SWAT outputs between the 1997 and 1973 land cover classes. Differencing involves simple subtraction that can be normalized or left as absolute change. Negative values indicate where the selected output is predicted to decrease and positive values indicate an increased prediction of the selected output, in this case due to changes in the land cover.

1. Open the *AGWA2 Results* form by selecting the *View SWAT Results* menu item from the *AGWA2 Tools -> View Results* menu.
   A. In the *Results Selection* box,
      I. Select the **d1\d1s1** geodatabase\discretization pair from the *Watershed* combobox.



II. Click the **Import** button to import the *s97* results. View your results. Note that the patterns are similar in display, but the regional magnitudes are different.

B. In the *Difference* box,

I. Select **s73** from the *Simulation 1* combobox

II. Select **s97** from the *Simulation 2* combobox

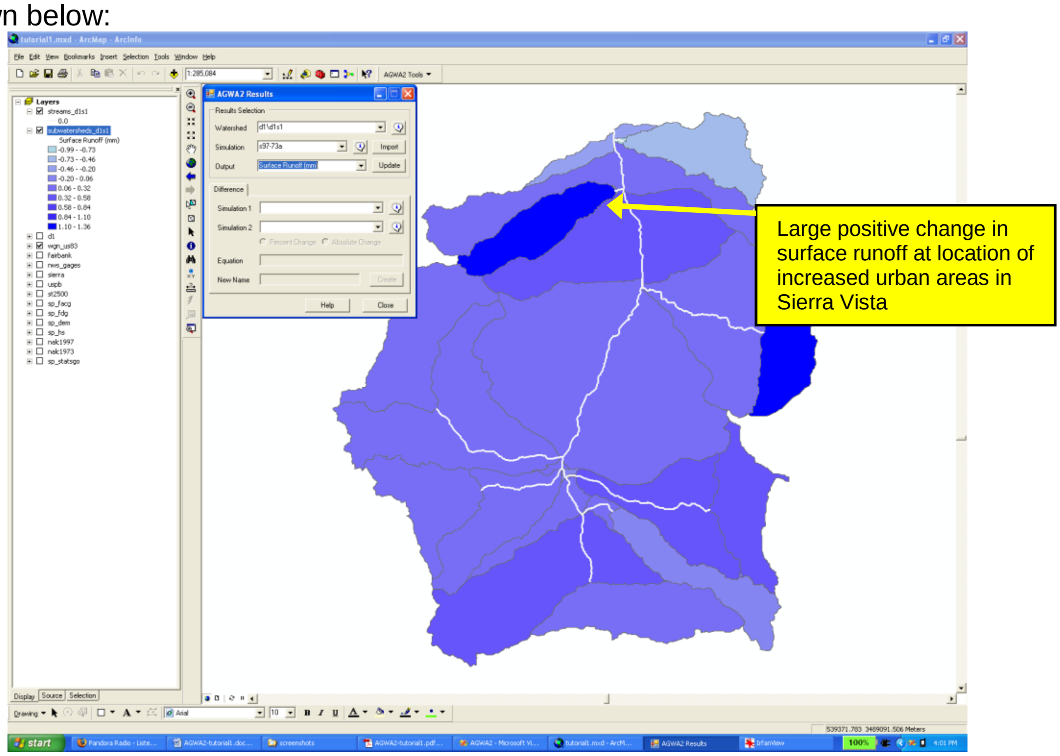
III. Select the **Absolute Change** radio button. Note the formula used to calculate the new results.

IV. Enter ***s97-73a*** for the new results name to indicate the direction of subtraction and type of change.

V. Click the **Create** button to create the differenced results. You do <u>not</u> need to click the *Import* button to add differenced results to the simulation combobox, they are added automatically.

C. Select a new output to visualize the difference caused by the change in land cover and click **Update**.

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



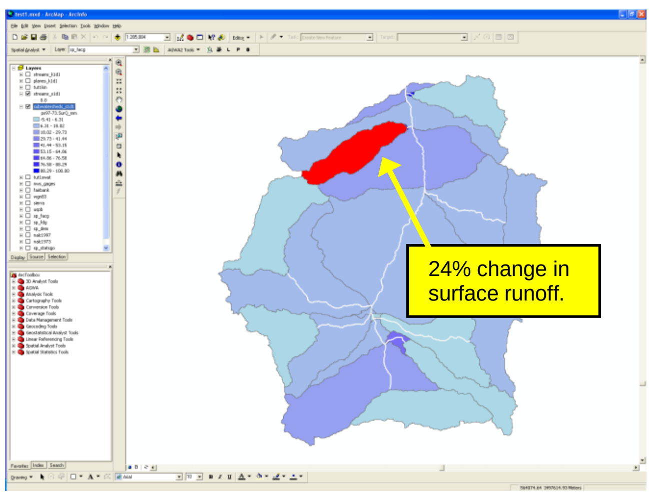
Part II: Modeling Runoff at the Small Watershed Scale Using KINEROS

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.



<u>Step 1: Subdividing the watershed</u>
Before modeling can begin on a watershed, the watershed must be delineated and subdivided into model elements. Delineating creates a feature class representing all the area draining to a user-specified outlet. Discretizing breaks up the delineation/watershed into model specific elements and creates a stream feature class to drain the elements. KINEROS model elements differ from SWAT model elements in that planes are split into lateral elements by the stream feature class.

1. As we did for SWAT, the first step is to generate an outline for the watershed in question. You might want to clean up the view a bit by turning off and/or collapsing theme layers that are not useful and making sure that the *Sierra* layer is enabled and at the top of the list of layers. This point will serve as the watershed outlet for the next exercise.

2. Open the *Delineator* form by selecting the *Delineate New Watershed* menu item from the *AGWA2 Tools -> Delineation Options* menu.
   A. In the *Output Location* box,

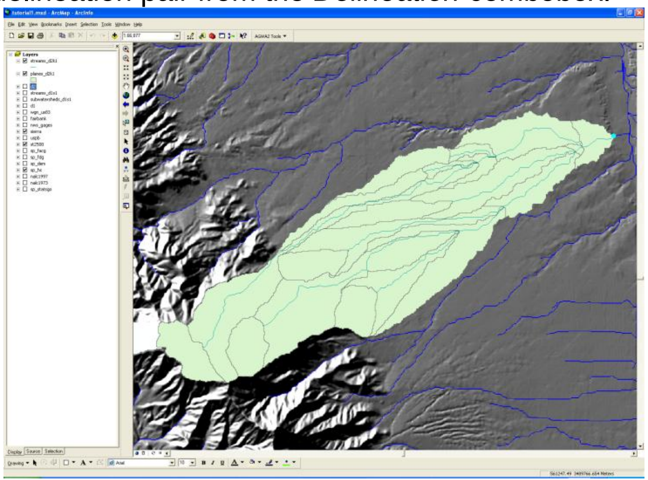
I. Use the same workspace location as in the SWAT delineation, **C:\AGWA2\workspace\tutorial_SanPedro**.
II. Name the geodatabase **d2**.

B. In the *Input Grids* box, fill in the comboboxes with the same layers as before:
   I. On the *DEM* tab, select the **sp_dem** layer
   II. On the *FDG* tab, select the **sp_fdg** layer
   III. On the *FACG* tab, select the **sp_facg** layer

C. In the *Outlet Identification* box,
   I. Select the *Point Theme* tab
   II. Select the **sierra** layer from the combobox
   III. Click the *Select Feature* button and draw a rectangle around the point.

D. Click the **Delineate** button.

3. Once the new watershed is delineated, open the *Discretizer* by selecting the *Discretize Watershed* menu item from the *AGWA2 Tools -> Discretization Options* menu.
   A. In the *Input* box,
      I. Select the **d2/d2** geodatabase/delineation pair from the *Delineation* combobox.
   B. In the *Model Options* box,
      I. Select the **KINEROS** item in the *Model* combobox
      SWAT and KINEROS require significantly different watershed subdivisions and will not work on each others' watershed geometry, so be sure that the KINEROS model is selected and not SWAT.



   C. Again, ignore the *Watershed Pour Points* box.
   D. In the *CSA* box, change the *CSA Units* to **Hectares** and enter a *CSA* of **304** or a *% Area* of **3.29**.
   E. In the *Output* box, enter **d2k1** as the discretization name.
   F. Click the **Discretize** button.

<u>Step 2: Parameterizing the watershed elements for KINEROS</u>

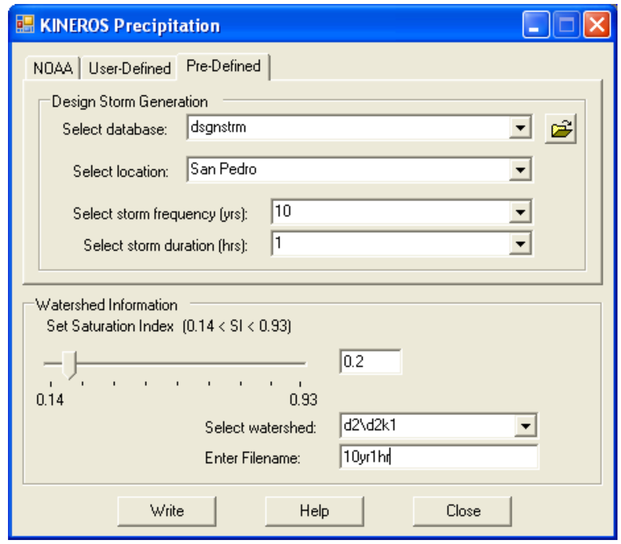
As in SWAT, each of the watershed elements needs to be characterized by its hydraulic geometry, its flow length, and according to its unique properties of land cover and soils.

1. Select the *Element Parameterization* menu item from the *AGWA2 Tools -> Parameterization Options* menu.
   A. Select the **d2/d2k1** geodatabase/discretization pair from the *Discretization* combobox.
   B. In the Flow Length Options box, select the **Geometric Abstraction** radiobutton
   C. In the Hydraulic Geometry Options box, select the **Default** radiobutton.
   D. Click the **Process** button.

2. Select the *Land Cover and Soils Parameterization* menu item from the *AGWA2 Tools -> Parameterization Options* menu.
   A. On the Watershed tab, select the **d2/d2k1** geodatabase/discretization pair from the *Discretization* combobox.
   B. On the Land Cover tab,
      i. Select the **nalc1973** layer from the *Land cover grid* combobox.
      ii. Select the **nalc_lut** table from the *Look-up table* combobox..
   C. On the Soils tab, select the **sp_statsgo** layer in the *Soils* tab.
   D. Click the **Continue** button.

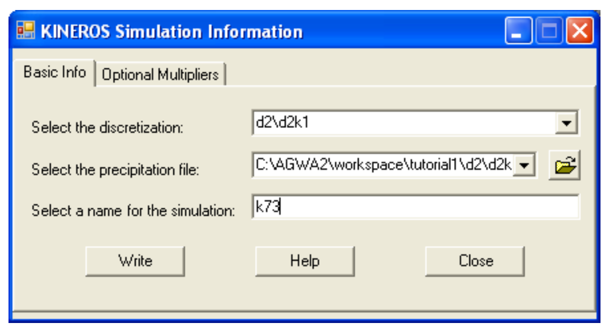
Step 3: Prepare rainfall files

KINEROS is designed to be run on rainfall events as opposed to the daily rainfall totals SWAT uses. AGWA2 has a number of return period events for southeast Arizona stored in its database. We are going to use one of the pre-defined storms, though AGWA2 allows you to create rainfall data for KINEROS in 5 ways:



- Homogeneous design storm from the database (our technique).
- Homogeneous design storm based on precipitation frequency maps.
- Homogeneous rainfall input by the user.
- Homogeneous rainfall input by the user based on a single return-period depth.
- Heterogeneous rainfall input by the user using multiple gage locations.

1. Write the KINEROS precipitation file by selecting the *Write KINEROS Precipitation* menu item from the *AGWA2 Tools -> Precipitation Options* menu.
   A. Select the *Pre-Defined* tab
      I. In the Design Storm Generation box,
         1. Select the **dsgnstrm** table from the *Select database* combobox.
         2. Select **San Pedro** from the *Select location* combobox.
         3. Select **10** from the *Select storm frequency (yrs)* combobox. Increasing the return period will increase the runoff since longer return period storms have greater rainfall depths.
         4. Select **1** from the *Select storm duration (hrs)* combobox.
   B. In the *Watershed Information* box,
      I. Leave the saturation index at 0.2. Increasing the watershed saturation index will increase the simulated runoff since losses to infiltration will be lessened.
      II. Select the **d2/d2k1** geodatabase/discretization pair from the *Select watershed* combobox.
      III. Enter **10yr1hr** in the *Enter Filename* textbox.
   C. Click the **Write** button.

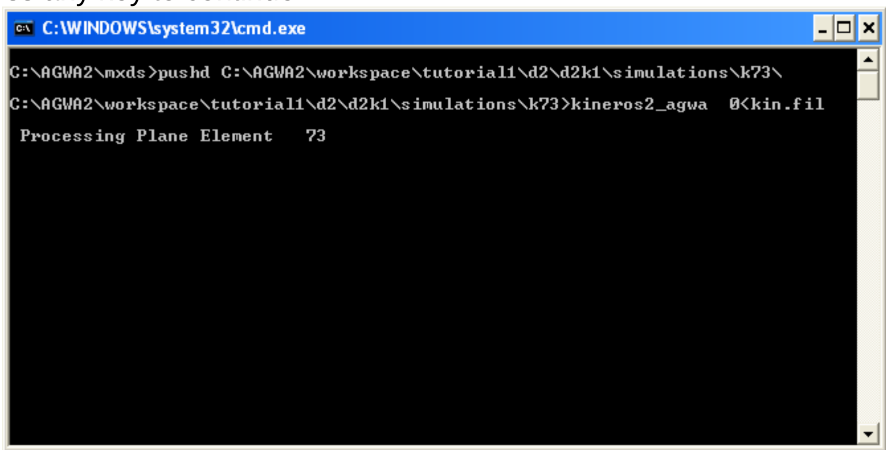


Step 4: Write input files and run KINEROS

Again you are at the point where the watershed has been delineated, discretized, and parameterized and rainfall files created. The next step is to write the model input files and run the model. As with SWAT, AGWA loops through the attributes of the selected watershed discretization and creates text files used to run the model. Once the text files are written, it is time to run the model.

1. To write the input files, open the *KINEROS Run Information* form by selecting the *KINEROS* menu item from the *AGWA2 Tools -> Simulation Options* menu.
   a. Select the **d2/d2k1** geodatabase/discretization pair from the *Select the discretization combobox*.
   b. Select the **10yr1hr** precipitation file from the *Select the precipitation file* combobox.
   c. Enter **k73** in the *Select a name for the simulation* textbox.

    d. Ignore the *Optional Multipliers* tab. AGWA2 allows for the use of parameter multipliers in the development of input parameter files for KINEROS. The multipliers can be very useful for calibration and validation studies but are not necessary for our purposes.
    e. Click the **Run** button. Once KINEROS starts running, you will see a black DOS screen like the one shown below.
2. To run the model, open the *Run KINEROS* form by selecting *Run KINEROS* menu item from the *AGWA2 Tools -> Simulations Options -> KINEROS* menu.
    a. Select the **d2\d2k1** geodatabase\discretization pair from the *Select the discretization* combobox.
    b. Select the **k73** simulation from the *Select the simulation* combobox
    c. Click the **Run** button and AGWA2 will run KINEROS and you should see the black command window like the one shown below. When the model has completed running, press any key to continue.



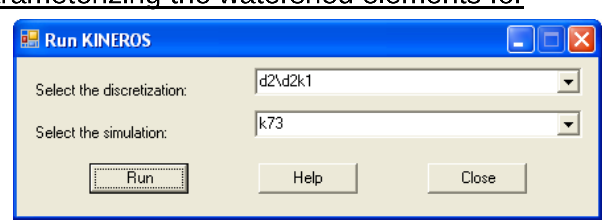
Step 5: View the results

Viewing the KINEROS results is identical to looking at SWAT results. After KINEROS runs to completion, the KINEROS output files must be imported into AGWA2 before displaying the spatially distributed results, such as runoff, infiltration, and other water balance results.

1. Open the *AGWA2 Results* form by selecting the KINEROS menu item from the *AGWA2 Tools -> View Results* menu.
    A. In the Results Selection box,
        I. Select the **d2\d2k1** geodatabase/discretization pair from the *Watershed* combobox.
        II. Click the **Import** button to import the simulation results for *k73*.
        III. Select the **k73** simulation from the *Simulation* combobox
        IV. Select the **Runoff (mm)** output from the *Output* combobox.
    B. Click the **Update** button.

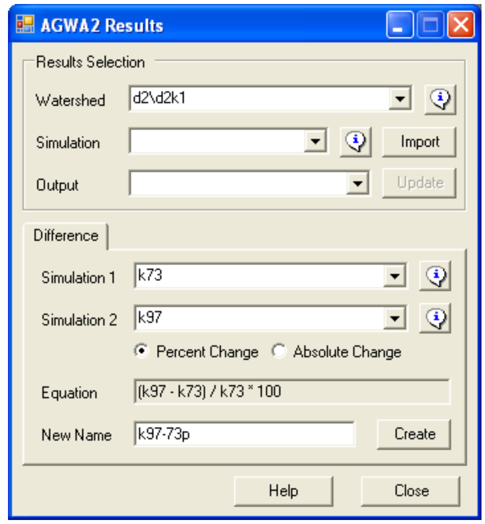
Step 6: Repeat for 1997 land cover

Again, you do not have to re-delineate, re-discretize, or re-configure the watershed to run the simulation with the 1997 land cover. Start the process at Step 2: Parameterizing the watershed elements for KINEROS, from above. You do not need to rerun the *Element Parameterization* as we are not changing the hydraulic geometry or flow length options.



1. Rerun the *Land Cover and Soils Parameterization* choosing the **nalc1997** land cover data this time.

2. You do not have to re-produce rainfall data since the geometric watershed configuration is exactly the same, so skip Step 3: Prepare rainfall files.



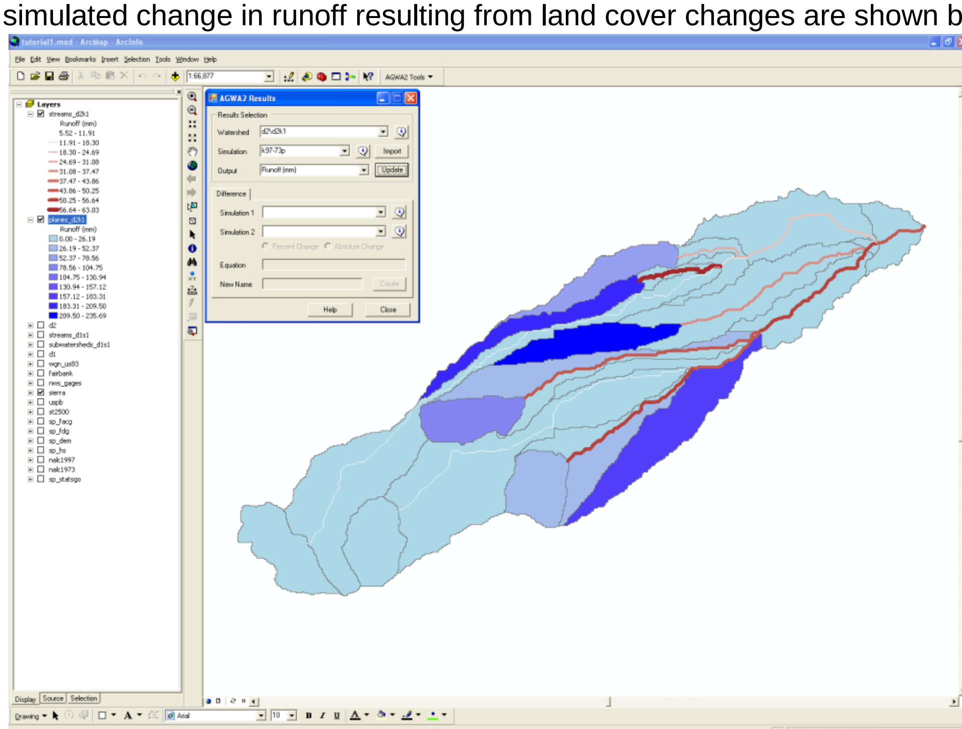
3. Repeat <u>Step 4: Write input files and run KINEROS</u> using the same precipitation file. Use the simulation name **k97**.

<u>Step 7: Compare 1997 and 1973 results</u>

In this step, we will create a new set of results representing the differences in KINEROS outputs between the 1997 and 1973 land cover classes. Differencing involves simple subtraction that can be normalized or left as absolute change. Negative values indicate where the selected output is predicted to decrease and positive values indicate an increased prediction of the selected output, in this case due to changes in the land cover.

1. Open the *AGWA2 Results* form by selecting the *View KINEROS Results* menu item from the *AGWA2 Tools -> View Results* menu.
   A. In the *Results Selection* box,
      i. Select the **d2\d2k1** geodatabase\discretization pair from the *Watershed* combobox.
      ii. Click the **Import** button to import the *k97* results. View your results. Note that the patterns are similar in display, but the regional magnitudes are different.
   B. In the *Difference* box,
      i. Select **k73** from the *Simulation 1* combobox
      ii. Select **k97** from the *Simulation 2* combobox.
      iii. Select the **Percent Change** radio button. Note the formula used to calculate the new results.
      iv. Enter **k97-73p** for the new results name to indicate the direction of subtraction and type of change.
      v. Click the **Create** button to create the differenced results. You do <u>not</u> need to click the *Import* button to add the new results to the simulation combobox, they are added automatically
   C. Select a new output to visualize the difference caused by the change in land cover and click **Update**.

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:

1. What regions of the basin have undergone significant change in their landscape characteristics?

2. How have these changes in the spatial variability impacted runoff, water quality, and the water balance?

3. 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?

4. How may these tools be used in a forecasting model or land cover simulation scenario to identify “at-risk” or sensitive areas?

5. 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

1. Change the CSA to see how altering the geometric complexity impacts the simulation of hydrology and landscape statistics.

2. 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.

3. 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.

4. 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?