The Automated Geospatial Watershed Assessment Tool

Assessing BMP’s for development mitigation at the small watershed scale

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Introduction to the AGWA/KINEROS2 study of development near Benson, Arizona

Residential and commercial development is occurring with unprecedented speed throughout the American Southwest. It is projected that from 1995 to 2025, the population in the six Southwestern states of California, Nevada, Arizona, New Mexico, Utah and Colorado will increase by more than 50%, while the remainder of the country is projected to grow only 10 to 15%. This scale and rapid pace of development presents special challenges to the review and permitting process as required under Section 404 of the Clean Water Act (CWA) and the National Environmental Policy Act (NEPA). Many of the areas undergoing rapid development are in arid and semi-arid regions whose watersheds and associated streams exhibit ephemeral or intermittent flow. The standard process for CWA permitting associated with new development rarely considers the special attributes and circumstances encountered in these environments. In addition, rapid urbanization can present a challenge in assessing the cumulative impacts of development on watersheds and landscapes when permitting is conducted piecemeal over multiple parcels in the same region.

The U.S. Environmental Protection Agency’s (EPA) 404(b)(1) Guidelines (Guidelines) are the substantive environmental criteria used in evaluating permit applications to the U.S. Army Corps of Engineers to discharge dredged or fill material into waters of the United States, including wetlands, under Section 404 of the Clean Water Act. No discharge of dredged or fill material shall be permitted if there is a practicable alternative which would have less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant adverse environmental consequences.

To determine the impact of a proposed project on the aquatic ecosystem, the Guidelines require an analysis of the direct, indirect, secondary and cumulative impacts to the aquatic ecosystem (40 CFR 230.11(g)(1)(h)). According to the Guidelines, “the terms aquatic environment and aquatic ecosystem mean waters of the United States, including wetlands, that serve as habitat for interrelated and interacting communities and populations of plants and animals” (Part 230.3(c)), and the definition of “waters of the United States” includes tributaries. The condition of an aquatic ecosystem may be better understood by examining the hydrology of the watershed. For example, communities of plants and animals depend on the aquatic environment for nutrients and shelter. Changes to the hydrology of that environment, such as increases or decreases in flow or sediment volumes, can have serious impacts on the aquatic ecosystem and the health of those communities.
The Study Area

The San Pedro River is nationally known as being one of the last free-flowing rivers in the Southwest. It is a critical migration corridor for hundreds of bird species and serves as important habitat for many other regionally-declining species of plants, fish, and wildlife. In 1988, nearly 40 miles of the river were designated as the first RNCA (Riparian National Conservation Area) in the country, to protect the river and riparian area, and its biological, educational, recreational and cultural resources. Just a few miles downstream from the San Pedro Riparian National Conservation Area (SPRNCA) is a proposed 8,200 acre development. Although not federally protected as an RNCA, the San Pedro River downstream (north) of the study area also contains many of the same highly valued attributes and is critical to maintaining the ecological integrity of upstream areas.

In this exercise, AGWA is applied as if the proposed development located near Benson, Arizona (Figure 1) has been built, and presents optional practices that may mitigate hydrologic changes resulting from the development. Post-development land cover conditions and proposed scenarios will be evaluated using KINEROS2 through the AGWA interface. Changes in runoff and sediment yield due to the proposed changes will be computed for one of five watersheds that encompass the study area and extends to the main-stem of the San Pedro River.

Figure 1. Location Map of the study area, near Benson, Arizona.
Getting Started

Start ArcMap with a new empty map. Save the empty map document as tutorial_Whetstone2 in the C:\AGWA\workspace\tutorial_whetstone2 folder (the workspace location will need to be created by clicking on the Make New Folder button in the window that opens).

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.

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.

- Home: C:\AGWA\workspace\tutorial_whetstone2
- Temp: C:\AGWA\workspace\tutorial_whetstone2
- Default Workspace: C:\AGWA\workspace\tutorial_whetstone2

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 during various steps in 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_Whetstone\` folder and add the following datasets and layers:

- `demf`
- `development.tif`
- `developed`
- `facg`
- `fdg`
- `hillshade`
- `nldc2001`
- `outlets.shp`
- `San Pedro River.shp`
- `statsgo.shp`

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

- `lc_luts\mrlc2001_lut.dbf` – MRLC look-up table for 2001 and 2006 NLCD land cover
- `precip\dsgnstrm.dbf` – return period rainfall for KINEROS2

You may want to collapse the legends and rearrange the order of the layers to better see what is going on. Click on the minus box next to the layer name in the Table of Contents to collapse the legend, or right-click on the Layers dataframe and select **Collapse All Layers.** Click and drag the layers by their names in Table of Contents to rearrange layer order. If you cannot rearrange the layer order, you may need to select the **List By Drawing Order** button in the **Table Of Contents.**

To better visualize the different land cover types and associate the pixels with their classification, load a legend into the `nldc2001` and `developed` datasets. To do this, right click the layer name of the `nldc2001`
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 Import button on the right. Click the file browser button, navigate to and select C:\AGWA\datafiles\renderers\nlcd2001.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 nlcd2001 and developed datasets have the same legend and classification, so repeat the same procedure for the developed dataset.

**Part 1: Modeling Runoff in Study Area Using Developed Land Cover**

In Part 1, one of the watersheds intersecting the study area will be delineated. The watershed will be discretized into model elements and those elements will be parameterized using the developed land cover. Following the initial parameterization, the model will be executed.
Step 1: Delineating the watershed

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

1.1. **Output Location** box
   1.1.1. **Workspace** textbox: navigate to and select/create C:\AGWA\workspace\tutorial_Whetstone2
   1.1.2. **Geodatabase** textbox: enter d1

1.2. **Input Rasters** box
   1.2.1. **DEM** tab: select demf (do not click Fill)
   1.2.2. **FD** tab: select fdg (do not click Create)
   1.2.3. **FA** tab: select facg (do not click Create)
   1.2.4. **Stream Network** tab: do nothing

1.3. **Outlet Identification** box
   1.3.1. **Point Theme** tab
      1.3.1.1. **Outlets theme**: outlets
      1.3.1.2. Click the **Select Feature** button and draw a rectangle around one of the points. You may select any point in the outlets feature class. Screenshots and results presented hereafter reflect selection of the middle point.

1.4. Click Delineate.

1.5. Save the map document and continue to the next step.
Step 2: Discretizing or subdividing the watershed

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

2.1. **Delineation**: select \( d1 \times d1 \)

2.2. **Model**: select KINEROS

2.3. **Stream Definition Methodolgy**: select Threshold-based

   2.3.1. **Threshold-based**: select CSA (acres)

   2.3.2. **Threshold**: enter **137.99**

   2.3.3. **Percent Total Watershed**: do nothing (Note: this value will change when we change the threshold)

2.4. **Internal Pour Points Methodology**: select Default

2.5. **Discretization Name**: enter **d1k1**

2.6. Click **Discretize**

2.7. Save the map document and continue.

Step 3: Parameterizing the watershed elements for KINEROS2

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 \( d1 \times d1k1 \)

   3.1.2. **Parameterization Name**: enter **base**

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. **Flow Length Options**: select Geometric Abstraction

3.3.2. **Hydraulic Geometry Option**: select Default

3.3.3. **Channel Type**: select <Customize Channel Selections...> then click the **Customize Channel Selections** button. The **Customize Channel Selections** form will open.

3.3.4. In the **Customize Channel Selections** form

![Customize Channel Selections](image)

- **3.3.4.1.** Double click on the empty cell in the **Channel Type** column and select **Natural**. A second row is automatically added to the table.
- **3.3.4.2.** In the second row, click the `<Click to select>` cell in the **Select Channels** column. Use the mouse to drag a box over the channels running through the development to select them (see selection below).
- **3.3.4.3.** In the second row, click the empty cell in the **Channel Type** column and select **Developed**.
- **3.3.4.4.** Click **Continue**. You will be returned to the **Element Parameterizer** form.

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.
3.3.5. Back in the Element Parameterizer form, click Continue. You will be returned to the Parameterizer form to create the Land Cover and Soils parameterization.

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

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: developed

3.5.1.2. Look-up table: mrlc2001_lut

3.5.2. Soils tab

3.5.2.1. Soils layer: statsgo
3.5.2.2. **Soils database**: navigate to and select 
\[C:\AGWA\gisdata\tutorial_Whetstone2\soildb_US_2002.mdb\]

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

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

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**Step 4: Preparing rainfall files**

4. Write the KINEROS2 precipitation file for the watershed by selecting **AGWA Tools > Precipitation Options > Write KINEROS Precipitation**.

4.1.1. **Discretization**: select d2/d2k1

4.1.2. **Storm Source**: select Database

4.1.3. **Database**: select dsgnstrm

4.1.4. **Location**: select San Pedro

4.1.5. **Frequency (years)**: select 10

4.1.6. **Duration (hours)**: select 1

4.1.7. **Time Steps**: enter 13

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

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

4.1.10. **Storm Location**: select Apply to entire watershed

4.1.11. **Precipitation filename**: enter 10yr1hr
4.1.12. Click Write.

4.1.13. AGWA KINEROS Precipitation window: Click Yes

Step 5: Writing KINEROS2 input files

5. Write the KINEROS2 input files by selecting AGWA Tools > Simulation Options > KINEROS Options > Write KINEROS Input Files.

5.1. Basic Info tab:
   5.1.1. Select the discretization: select d1\d1k1
   5.1.2. Select the parameterization: select base
   5.1.3. Select the precipitation file: select 10yr1hr
   5.1.4. Select the multiplier file: leave blank
   5.1.5. Select a name for the simulation: enter base_10yr1hr
   5.1.6. Click Write.
Depending on which outlet you selected in the delineation step earlier, you may be presented with a series of warnings. Where the watersheds meet the San Pedro River, the topography becomes very flat, and combined with the resolution, accuracy, and precision of the DEM, several stream reaches have calculated slopes of zero. A warning message in AGWA is shown when this occurs and informs you that a nominal slope value will be used to prevent the model from crashing. Although not the case in this example, the warnings could indicate an underlying problem with the discretization, a particularly flat study area not well-suited to the application of AGWA, or a large sink feature in the DEM that when filled created a large low slope area.

**Step 6: Executing the KINEROS2 model**

6. Execute the KINEROS2 model for the Sierra Vista watershed by selecting **AGWA Tools > Simulation Options > KINEROS Options > Execute KINEROS Model**.

   6.1. **Select the discretization**: select *d1\d1k1*
   
   6.2. **Select the simulation**: select *base_10yr1hr*
   
   6.3. Click **Run**.

   A command window will open and show the execution of KINEROS2 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.
6.4. Close the Run KINEROS form.
At this point, the developed conditions have been simulated with developed concrete channels in the development; in part 2, a what if scenario is simulated where the developed channels are replaced with natural channels, and rainwater harvesting equivalent to capturing approximately 1500 gallons of rainfall (1” of rainfall on a 2500 square foot) has been added at a housing density of 10 houses per acre.

Part 2: Modeling Runoff in Study Area Using Natural Channels and Rainwater Harvesting

Step 7: Repeat the parameterization with natural channels
7. Rerun the element parameterization of your watershed to create a parameterization representing all natural channels by selecting AGWA Tools > Parameterization Options > Parameterize.

7.1. Input box
   7.1.1. Discretization: select d1\d1k1
   7.1.2. Parameterization Name: enter scenario1

7.2. Elements box
   7.2.1. Parameterization: select Create new parameterization
   7.2.2. Click Select Options. The Element Parameterizer form opens.

7.3. In the Element Parameterizer form
   7.3.1. Flow Length Options: select Geometric Abstraction
   7.3.2. Hydraulic Geometry Options: select Default
   7.3.3. Channel Type: select Natural
   Because the channel selection is not being customized, all the channels in the watershed will be set to the Natural channels type.
7.3.4. Click **Continue**. You will be returned to the **Parameterizer** form to copy the Land Cover and Soils parameterization.

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

7.4.1. **Parameterization**: select **base**

The emphasis of this exercise is installation of rooftop rainwater harvesting and conversion of developed channels to a more natural channel, so land cover is held constant by copying it from the **base** simulation.

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

### Step 8: Add rainwater harvesting to the developed areas of the watershed

8. Add rainwater harvesting to the watershed where the **Developed, Medium Intensity** land cover class of the **developed** land cover occurs by selecting **AGWA Tools > Other Options > Rainwater Harvesting**.

![Rainwater Harvesting Parameterization](image)

8.1. **Discretization**: d1/d1k1

8.2. **Parameterization**: scenario1

8.3. **Land cover grid**: developed

8.4. **Look-up table**: mrlc2001_lut

8.5. **Land cover class**: Developed, Medium Intensity

8.6. **Parameters for selected land cover class** box

8.6.1. **Housing Density**: 10.0

8.6.2. **Roof Size**: 2500

8.6.3. **Depth Collected**: 1.0

8.7. Click **Process**. The form remains open to facilitate adding rainwater harvesting to multiple land cover classes in the watershed or to multiple parameterizations.

8.8. Click **Close**.
Step 9: Writing the KINEROS2 input files for the new scenario

9. Write the KINEROS2 simulation input files for your watershed by selecting **AGWA Tools > Simulation Options > KINEROS Options > Write KINEROS Input Files.**

![KINEROS Simulation Information](image)

9.1. **Basic Info** tab:
   9.1.1. **Select the discretization**: select `d1\d1k1`
   9.1.2. **Select the parameterization**: select `scenario1`
   9.1.3. **Select the precipitation file**: select `10yr1hr`
   9.1.4. **Select the multiplier file**: leave blank
   9.1.5. **Select a name for the simulation**: enter `scenarios1_10yr1hr`
   9.1.6. Click **Write**.

Step 10: Executing the KINEROS2 model for the new scenario

10. Run the KINEROS2 model for your watershed by selecting **AGWA Tools > Simulation Options > KINEROS Options > Execute KINEROS Model.**

![Run KINEROS](image)

10.1. **Select the discretization**: select `d1\d1k1`
10.2. **Select the simulation**: select `scenario1_10yr1hr`
10.3. Click **Run**.
    
    A command window will open and show the execution of KINEROS2 for the 10-year, 1-hour storm. The command window will stay open so that successful completion can be verified.
Part 3: Comparing Results from Developed and the “What If” Scenario

In Part 3, the results from the base_10yr1hr and scenario1_10yr1hr simulations will be imported into AGWA. These results will then be differenced to visually see how the what if scenario affects the hydrology of the watersheds in the study area.

Part 11: Viewing and comparing the developed and “what if” scenarios

11. Import the results from the two simulations by selecting AGWA Tools > KINEROS2 Results > View KINEROS2 Results.

11.1. Discretization: select d2\d2k1

11.2. Simulation tab:

11.2.1. Check boxes for base_10yr1hr and scenario1_10yr1hr
11.2.2. Click **Import/Update**

11.3. Difference the **base_10yr1hr** and **scenario1_10yr1hr** simulation results.

11.3.1. **Create Difference** tab

11.3.1.1. **Base Simulation**: select **base_10yr1hr**

11.3.1.2. **Alternative Simulation**: select **scenario1_10yr1hr**

11.3.1.3. **Change Type**: select **Absolute**

11.3.1.4. **New Name**: enter **scenario1_10yr1hr-base_10yr1hr_abs**

11.3.1.5. Click **Create**
11.4. View the differenced results.

11.4.1. View Results (Map) tab
   11.4.1.1. Simulation: select scenario1_10yr1hr -base_10yr1hr_abs
   11.4.1.2. Units: select Metric
   11.4.1.3. Output: select Runoff (mm)
   11.4.1.4. Click View.