DECISION SUPPORT TUTORIAL
Creating and Running a Model with ArcGIS ModelBuilder

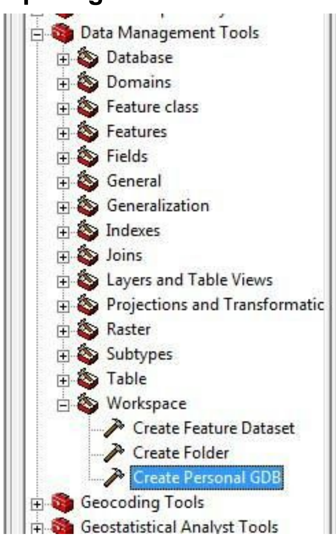
In this tutorial, we will revisit a decision mapping exercise used in the Introduction to GIS class. In that exercise we determined the suitable places for an environmental educational center based on criteria set forth by the Bronx River Watershed Alliance. Those criteria (decision support layers) were:

1. Vacant Lots
2. That are within a certain distance from the Greenway (0.5 kilometers),
3. And within a certain distance from Educational Facilities (0.5 kilometers).

Previously, we used a raster-based analysis (via the Spatial Analyst Extension) to create our decision support system. Here, we will perform the same analysis by creating a model with ArcGIS ModelBuilder. The advantage of generating a model is that the analysis can be run many times with different input data or parameters, without requiring alteration to the model itself. Once the model is developed, we can change parameters (such as the distance from Educational Facilities) without having to redo the entire analysis. We could also change the weights for what is important to us.

First, we will develop a simple model in ModelBuilder that accomplishes the minimum requirements of our suitability study. Once you are familiar with ModelBuilder, we will add to the model to perform a more advanced analysis.

Preparing for the Model



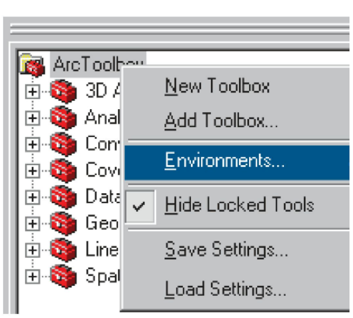
1. Before we begin building our model, we need to create two geodatabases: One to store the intermediate results of our model (the calculations that are performed along the way) and another to store our final outputs.

In ArcToolbox, navigate to **Data Management Tools > Workspace > Create Personal GDB**. Double-click on "Create Personal GDB."

In the dialogue box, navigate to where you would like to store your geodatabase (e.g.: E:\modelBuilderTutorial\dbase.) Name your output database "Intermediate."

Repeat this step to create another geodatabase called "Results." This will be where we store the final outputs of our model.

2. Next, we need to set our current workspace to point to our final output database "Results," and create a scratch workspace pointed to "Intermediate."



Right-click on "ArcToolbox" and select "Environments…"

Click on "Workspace" to drop down its options.

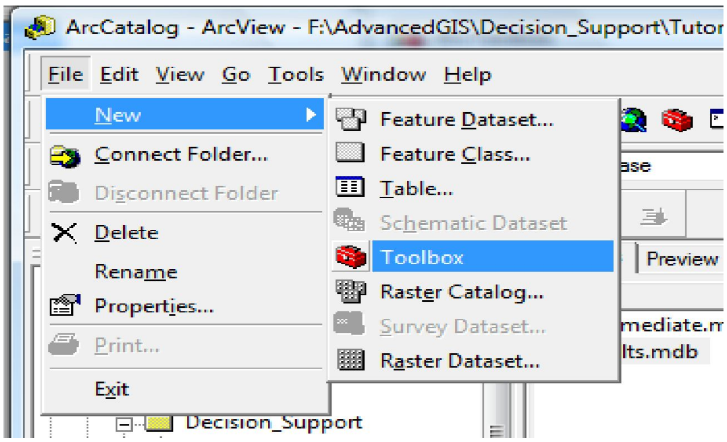
In "Current Workspace" browse to your "Results" geodatabase.

In "Scratch Workspace" browse to your "Intermediate" geodatabase.

Click **OK**.

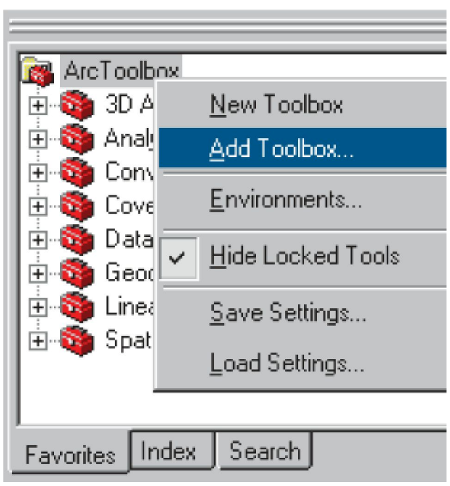
Although we haven't added any data yet, **save** your map project document to save your environment settings.

3. Next we need to create and add a custom toolbox. Here, we will create and store our model.



Open ArcCatalog. In ArcCatalog, navigate to your "Results" geodatabase. There, you will create your new toolbox. Go to **File > New > Toolbox.**

In the dialogue box, name your toolbox "MB_tutorial."



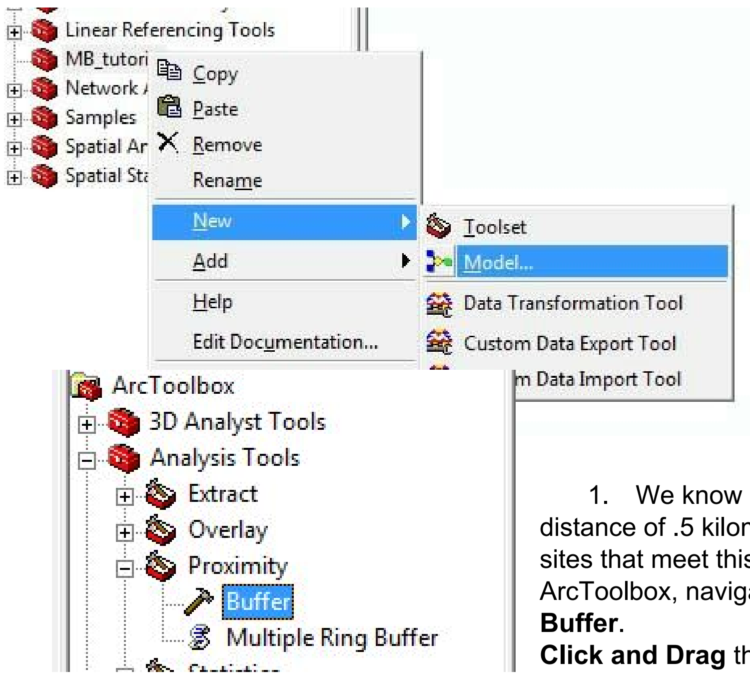
In ArcMap, right-click on "ArcToolbox" and select "Add Toolbox…" In the dialogue, navigate to your "MB_tutorial" and click Open.

Save your map project document. Saving your document will save the state of the ArcToolbox window.

Creating a New Model

Now that we are prepared to build our model, let's create one. We will do this by building processes and connections between processes that can automate our suitability analysis for potential sites for an environmental education facility. Simply, a model is a series of inputs and processes that give us a new output. In our case, the criteria we listed earlier will be the "inputs and processes," and the output will be potential sites for the facility.

1. First we will need to add the datasets our model needs to our map project. Add **greenway.shp**, **vacant_land_2004.shp**, and **educational_facilities_2004.shp** to your map project.

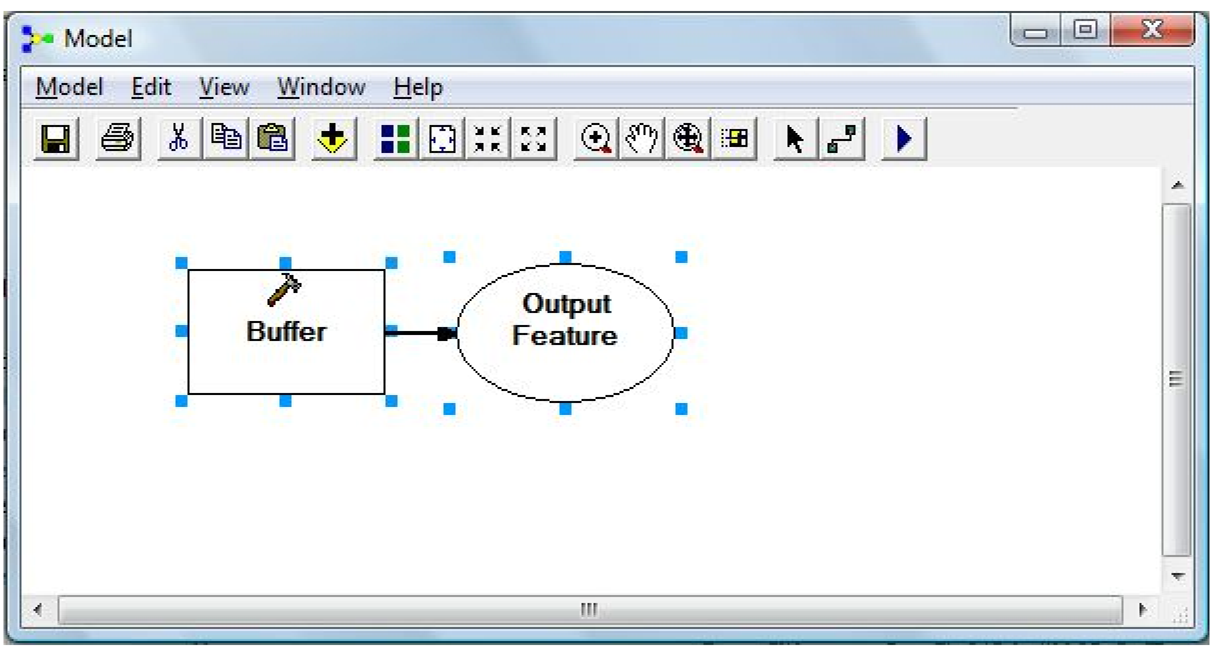


2. In the ArcToolbox window, right-click on your “MB_tutorial” toolbox, and select **New > Model.**

A new, empty ModelBuilder window will open.

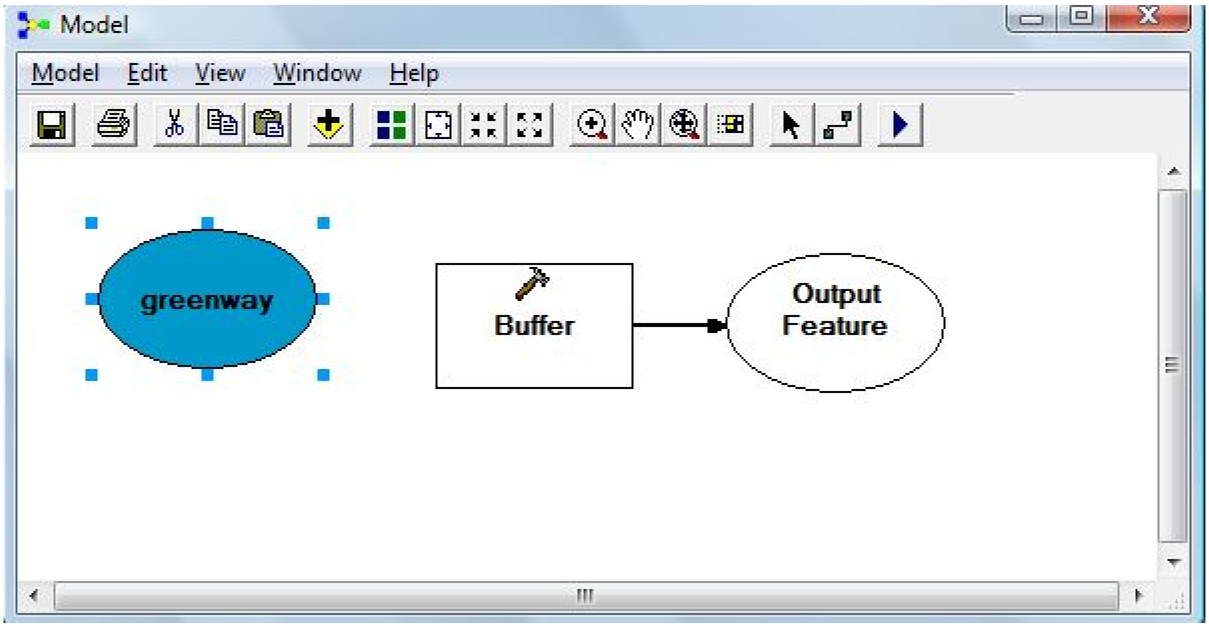
Building the Model

1. We know that our first decision criterion is a distance of .5 kilometers from the greenway. To find suitable sites that meet this criterion, we will create a buffer. In the ArcToolbox, navigate to **Analysis Tools > Proximity > Buffer**.
Click and Drag the buffer tool into the ModelBuilder window. It should look like the image below.



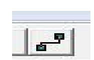
The Buffer tool and its output will appear in the window. Right now, both are white to indicate that the tool is not ready-to-run because it lacks input and parameters. The input for this tool will be the greenway.shp file and its distance parameter will be 1640 feet (approximately 0.5 kilometers).

2. To give the Buffer tool its input, **click-and-drag** the greenway.shp file from the Table of Contents into the ModelBuilder.



Notice that the greenway file is blue. That is because it requires no additional input or parameters to be a valid element of the model.

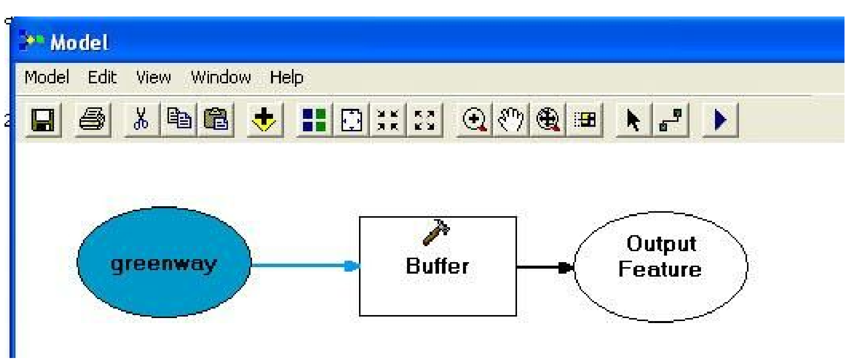
3. Next, we will link the greenway file to the buffer tool to indicate that this shapefile should be used as the input data for the buffer.

Click on the Line Connector Tool in the ModelBuilder window. It looks like this:  . Your cursor should now look like a wand.

With the Line Connector, **first click on the Greenway** in the ModelBuilder. Notice that an arrow is now based on the greenway and points away from it.

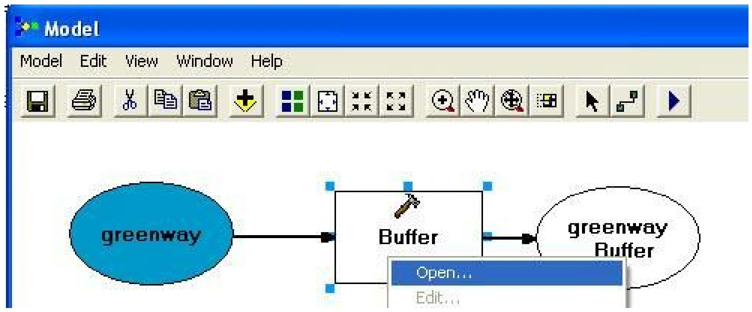
Next click on the Buffer.

Your Model should now look like this:



4. We still haven't assigned a distance parameter for the Buffer Tool. **Right-click on the Buffer Tool** and select **Open.**

5.

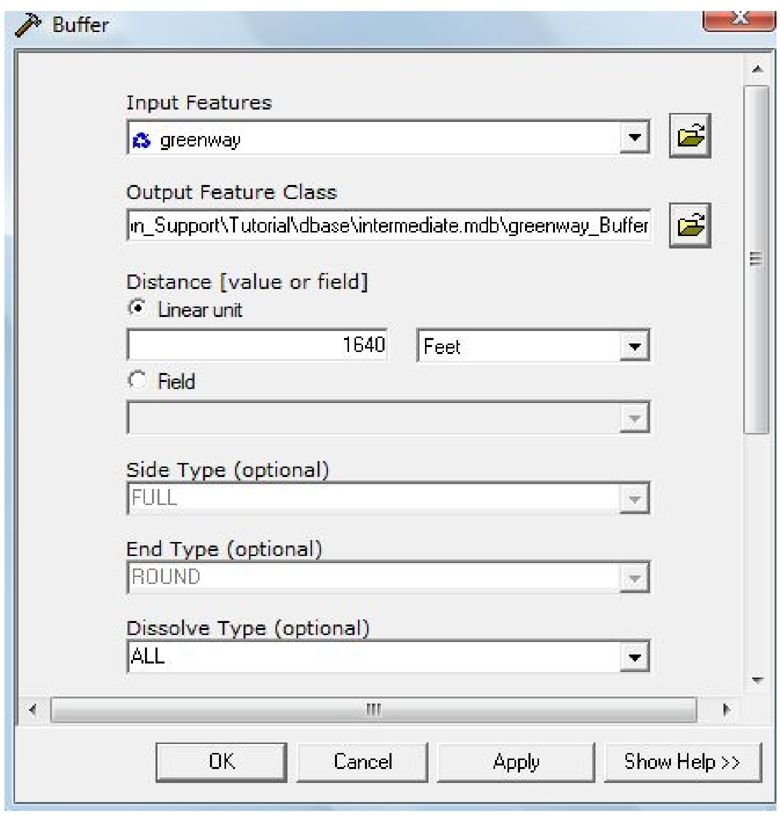


The standard Buffer dialogue box will open.

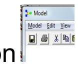
Notice that the greenway file is your input feature. Notice also that the output feature class is already pointed to your "intermediate" geodatabase. This is because we set the Scratch Workspace to this database.

Under "Distance," select **Linear Unit**, and type **1640 Feet**. (1640 feet is approximately equal to .5 kilometers. We will use feet because our data is in feet.)

Lastly, under "Dissolve Type (optional)," select **All**. The greenway shapefile has several features, and we do not want a buffer around each of them. To avoid that, we will dissolve those features and create a single buffer around the greenway.



Click OK.

6. **Save** your Model, by clicking the Save button  in the ModelBuilder window. Or by clicking **Model>Save**.

7. Let's repeat this process (Steps 1 through 5) to create an educational_facilities_2004.shp buffer.

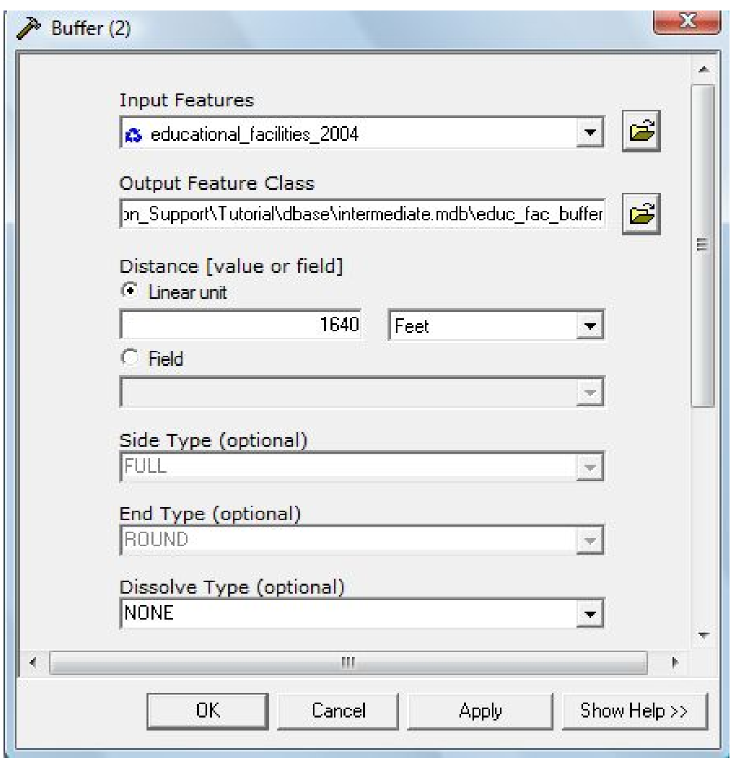
Drag and drop the educational_facilities_2004.shp from the Table of Contents to the ModelBuilder window.

Drag and drop the Buffer Tool from ArcToolbox to the ModelBuilder window.

Create a directional link between "educational_facilities_2004" and "Buffer(2)" in the ModelBuilder, by using the line connector tool.

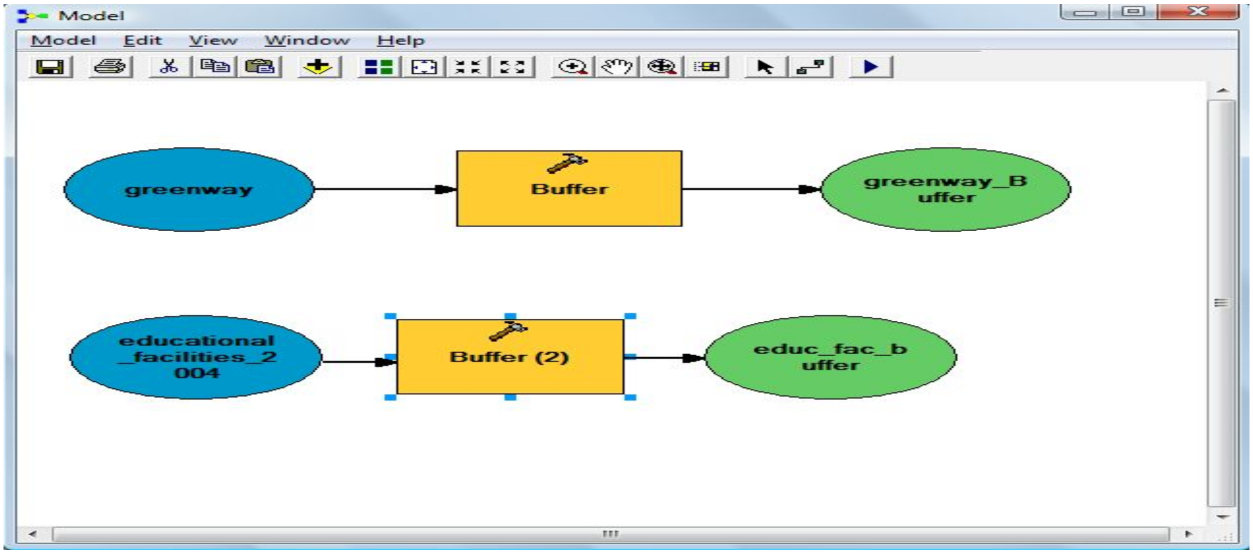
Right-click on the "Buffer(2)" tool and select **Open**. In the dialogue box, specify **1640 feet** as the buffer's linear distance.

Under "Dissolve Type" select **NONE**. This is different from the buffer we dissolved for the greenway, because we want individual buffers surrounding each individual educational facility. Your Buffer (2) dialogue box should look like the image below:



Click OK.

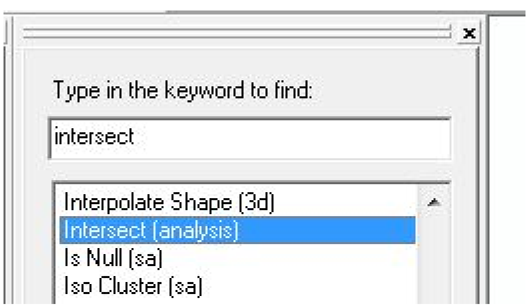
Your ModelBuilder window should now look like this:



Save your model.

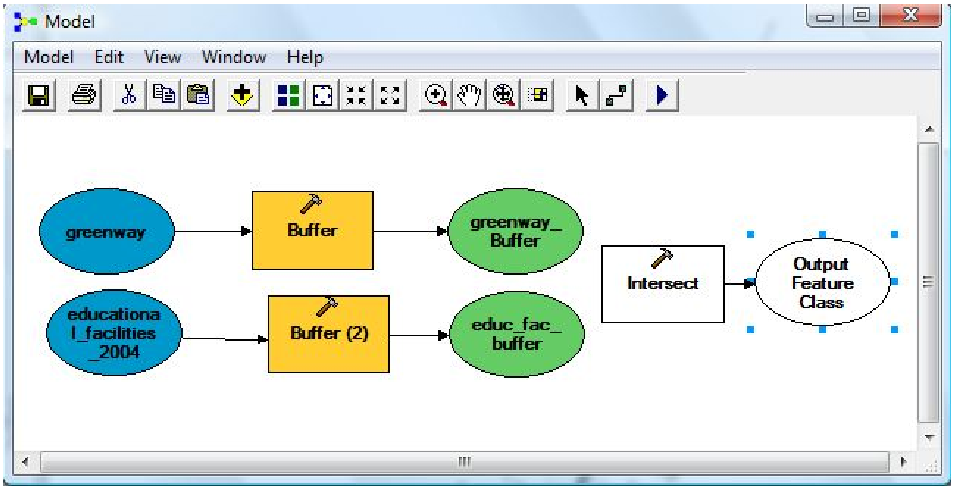
8. Next, we want to intersect our two buffers. We want to know which areas in the Bronx are within 1640 feet of the greenway and within 1640 feet of an educational facility.

   It is not necessary to know where a specific tool is located within ArcToolbox to drag and drop it into the ModelBuilder window. If you prefer to use the "Index" or "Search" functions of the ArcToolbox, the drag-and-drop function works the same way.

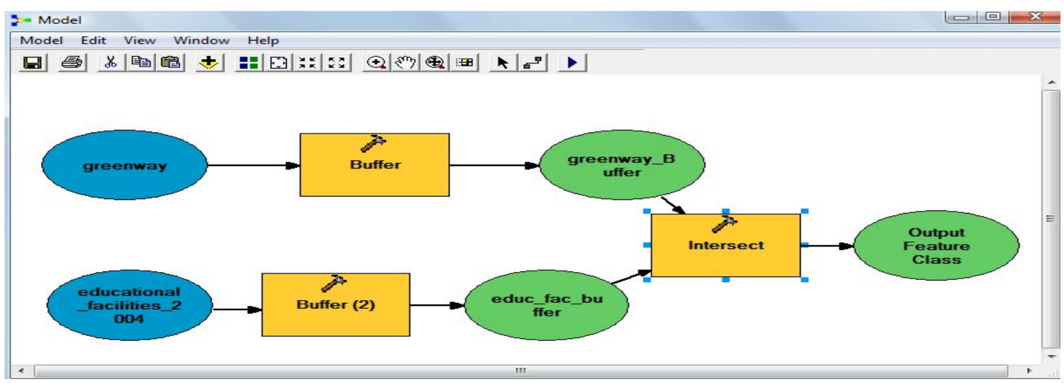


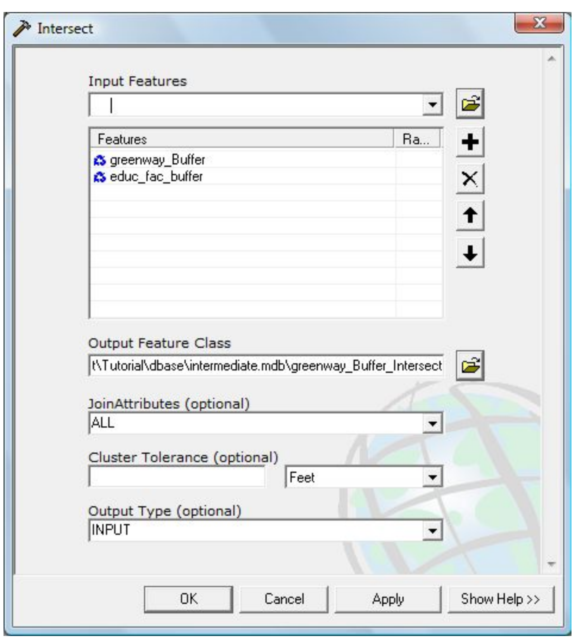
When you've found the tool, **drag and drop "Intersect (analysis)" into the ModelBuilder window**.

As before, it will be white when it appears in the window:



9. Use the directional line connector tool to connect the Greenway Buffer to the Intersect Tool. Do the same for the Educational Facilities Buffer. The result should look like this:





10. **Right-click** on the Intersect tool and select **Open**. The Intersect dialogue box will appear.

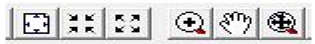
Notice that the two buffers are now listed as the input features to be intersected.

Notice also that the output feature class will, once again, be stored in the “intermediate” geodatabase.

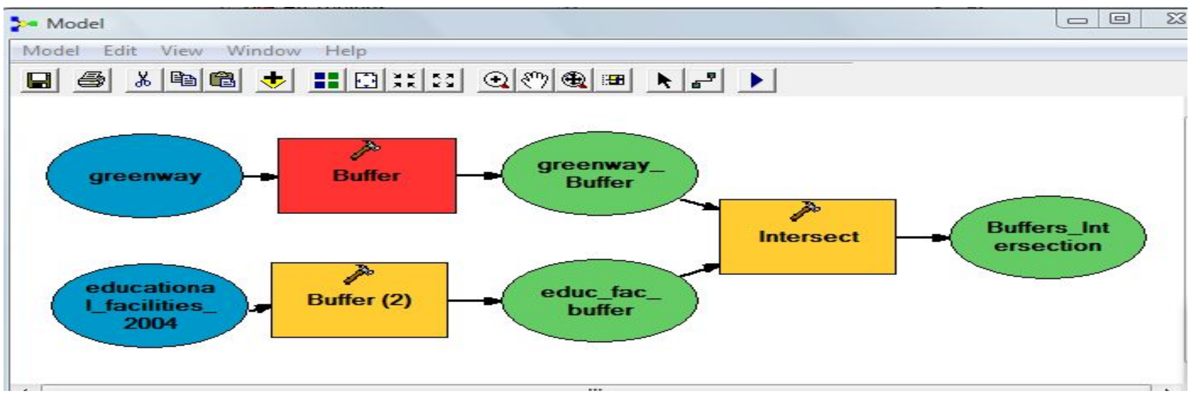
Click OK.

By default, the Intersection Output Feature will be labeled “Output Feature” in your model diagram. You can rename it by **Right-clicking** on it in the ModelBuilder window and selecting **Rename**. Rename this Output Feature “Buffers_Intersection.”

Save your model.

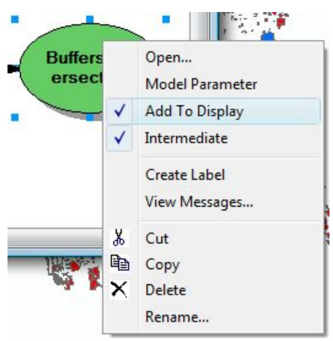
As we add processes and datasets to our model, it may be necessary or helpful to resize and reorganize the model diagram. These buttons  on the ModelBuilder toolbar operate the same as those in ArcMap do. If necessary, you can zoom in, out, or to the extents of your model to see all of the model’s elements.

11. Let’s test what we’ve done thus far by running our model. In the ModelBuilder window, go to **Model>Run Entire Model**. A model progress dialogue will appear, showing the progress of your processes. Also, as the model runs, the current process will be highlighted in red.

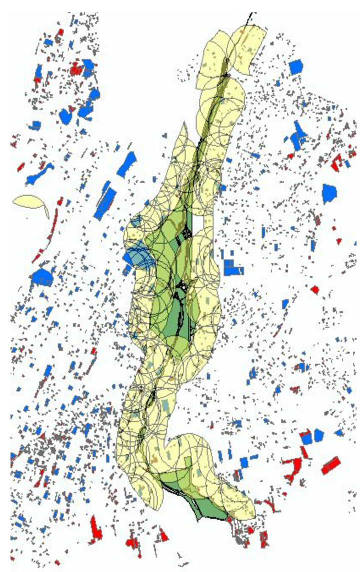


After the model has run, note that the processes and output layers are now displayed with a shadow behind them. This indicates that the processes have been performed and that the output files have been created. Close the Model progress dialogue.

12. If your Buffers_Intersection feature does not automatically add itself to the Table of Contents, you can add it to the display by **Right-clicking** on it in the ModelBuilder window and **selecting “Add to Display.”**

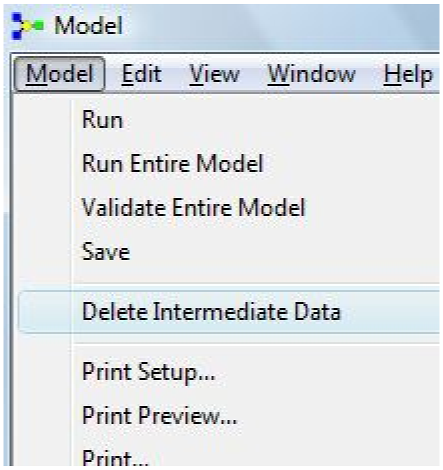


We can confirm that our map looks as we would expect at this point. Your map should look like the image at the right:



After you’ve confirmed that our model is operating as you expect, **remove “Buffers_Intersection” from the Table of Contents**.

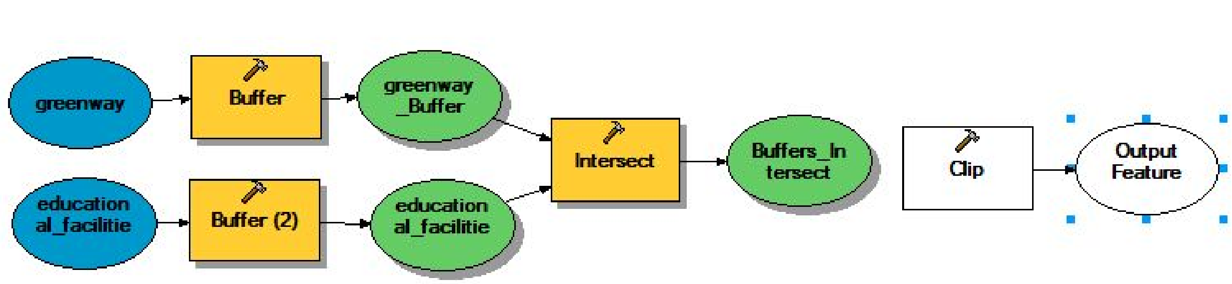
13. In the ModelBuilder window, **go to Model>Delete Intermediate Data**. This will remove the output layers we just created from the “Intermediate” geodatabase (our scratch workspace).



Notice that the shadows in our ModelBuilder window disappear. The model is now returned to its state before we ran our test.

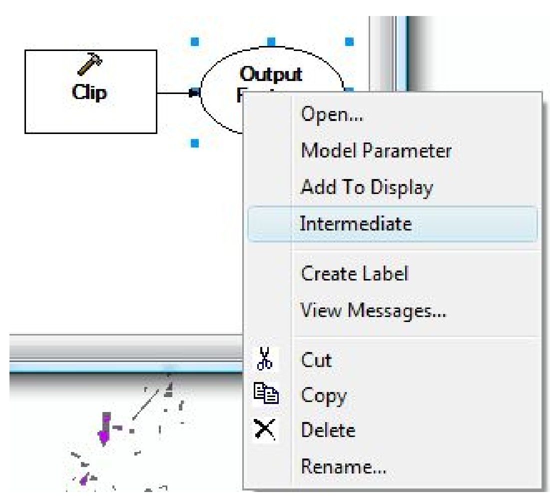
14. Next we want to find the vacant parcels that satisfy our distance decision criteria. We will do that by performing a clip. (Of course, this could also be done with a number of other processes – e.g. selection or intersection – all of which could also be incorporated into the model.)

Drag and drop the Clip tool from the ArcToolbox to the ModelBuilder Window.

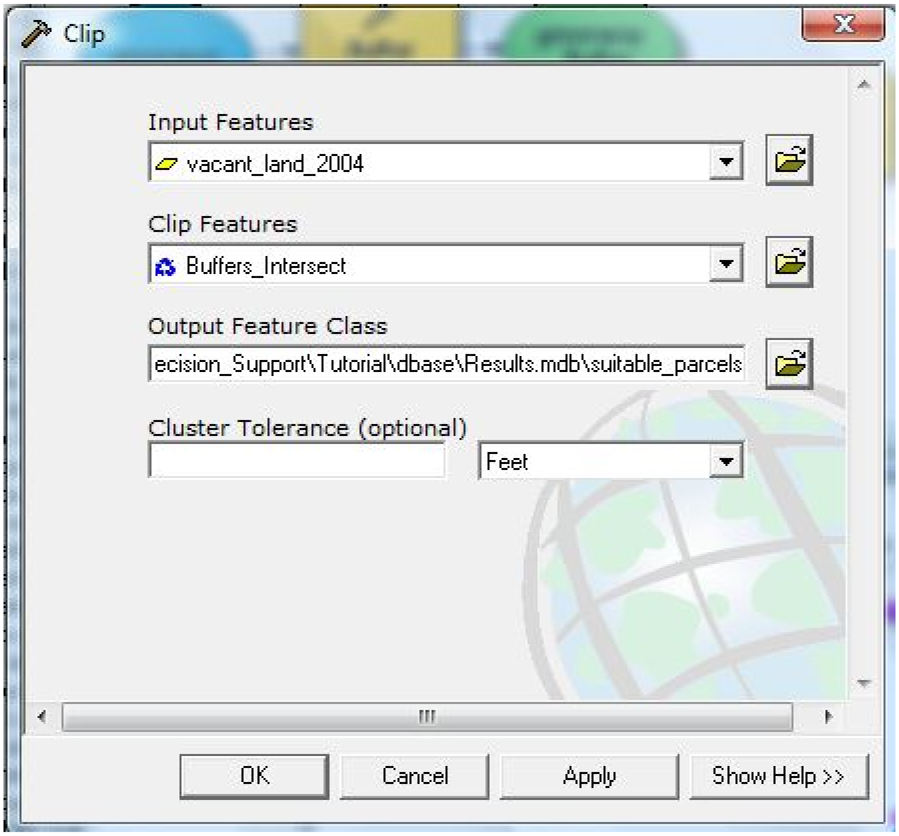


Before we assign input data to the clip tool, **Right-click on the Clip’s Output Feature, and un-check “Intermediate.”**
The clip output is the final result of our model and should not be stored in the scratch workspace.

Next, **right-click on the Clip tool and select Open.**

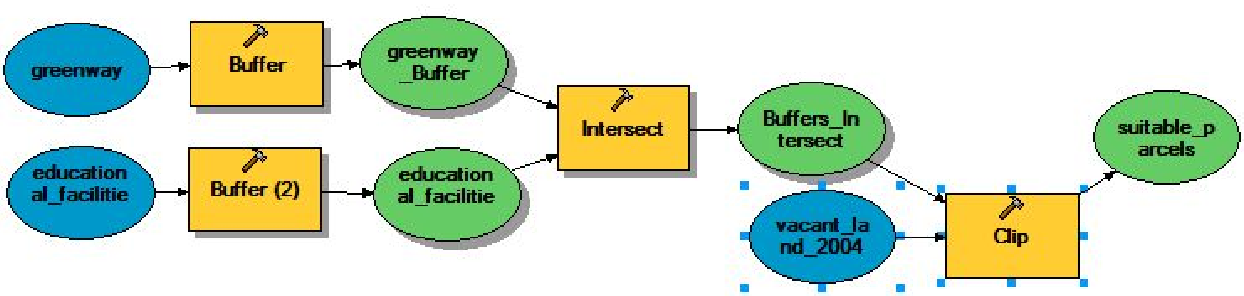


In the Clip dialogue box, choose the vacant_land_2004.shp file as the Input Layer and the Buffers_Intersect as the Clip Layer. **Save the Output Feature Class in the "Results" geodatabase and name it suitable_parcels. You will need to specify this**



Click OK.

Notice that "vacant_land_2004" has been added to the model diagram as an input layer for the Clip tool.



15. **Run your model.** (Again, if your suitable_parcels result layer does not appear in your map, right-click and make sure "Add to Display" is checked.)

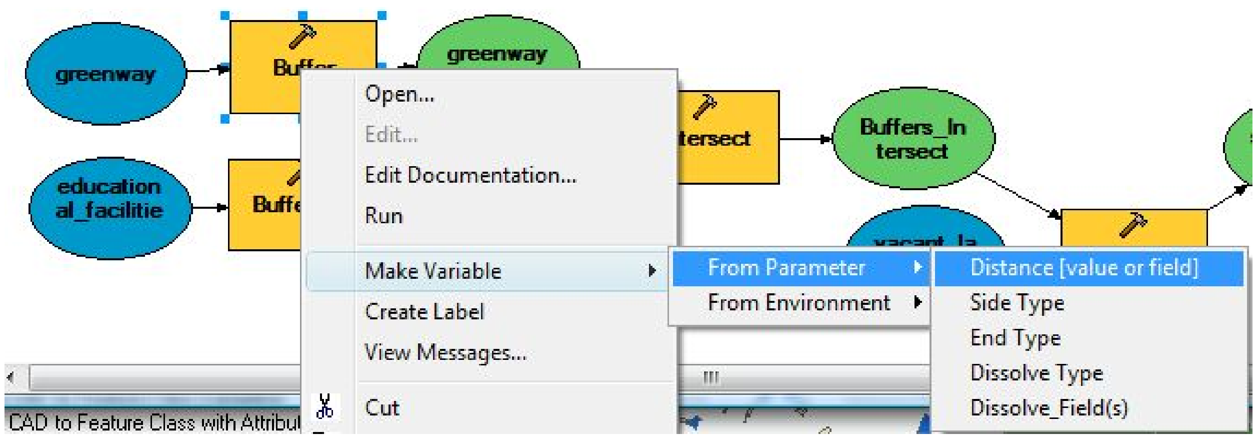
We now have a layer called “suitable_parcels” with 642 features, each of them a vacant lot within 1640 feet of the greenway and an educational facility.Obviously, this is far too many possible locations to help with decision-making. Let’s try changing some of the parameters of our model.

Adding and Editing Model Parameters

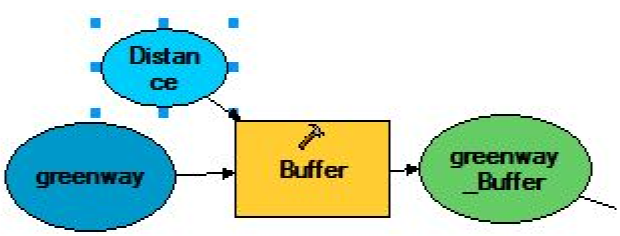
1. First, **delete the intermediate data** from your model (Model>Delete Intermediate Data). Remember that the result from our model is not “Intermediate,” and therefore will not be deleted. This is convenient if we want to compare results after we have changed the model parameters.

2. Let’s first try to modify our model by modifying the distance to the greenway we consider.

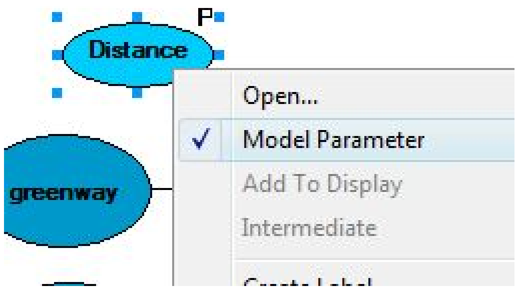
Right-click on the greenway Buffer tool. Select Make Variable > From Parameter.



Notice that the options that appear are all the parameter options from the Buffer Tool. **Select “Distance [value or field].”** We are selecting “distance” because this is the parameter we would like to modify each time we run the model.



A light-blue Distance Variable icon will appear in your model diagram. If you open the variable (Right-click > Open), you will see that it contains the same parameter fields in the Buffer Tool.

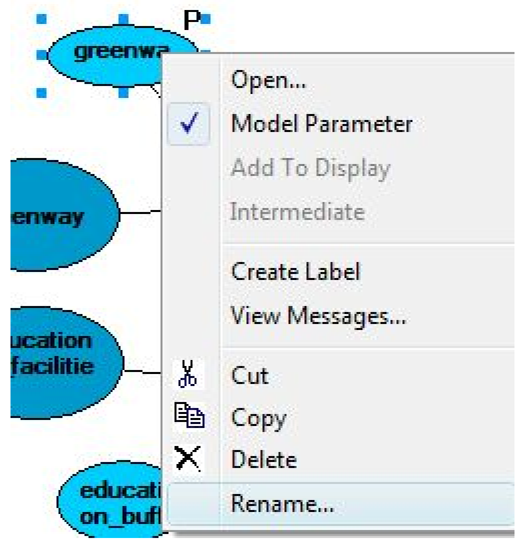


3. **Right-click on the Distance Variable, and check "Model Parameter."** A black "P" will appear in the upper right corner of the variable icon. This indicates that the variable is not only a parameter for the buffer, but a parameter of the whole model.

4. Repeat steps 2 and 3 for the Educational Facilities Buffer. First, make the distance parameter a variable. Then, make the variable a model parameter.

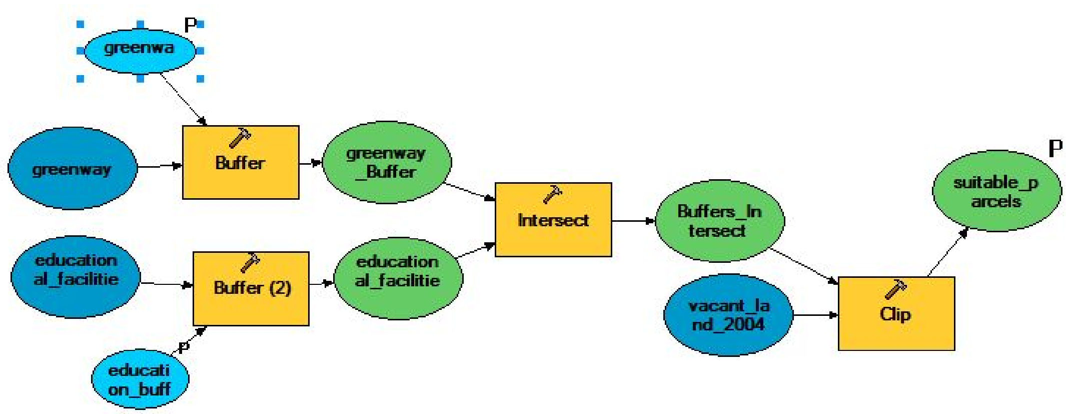
5. Next, we want to rename these model parameters so we can tell them apart later. **Right-click on the greenway buffer distance variable and select "Rename."** Rename this variable "greenway_buffer_distance."

   Rename the educational facilities buffer distance variable "Education_buffer_distance."



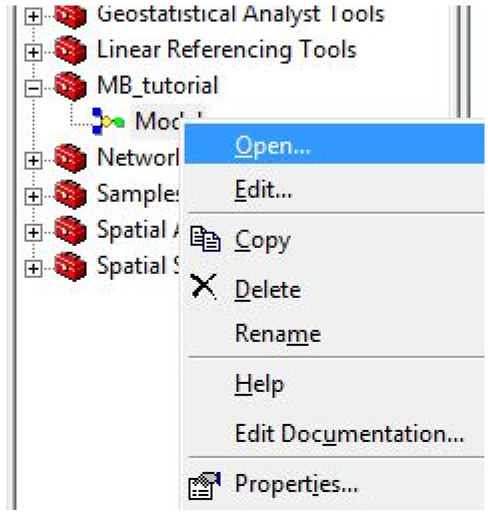
6. **Right-click on the Clip Output layer "suitable_parcels," and check "Model Parameter."** Just as it did for the Distance variable, a black "P" will appear. This will let us change the name of our result before we run the model.

   Your model should now look like this:

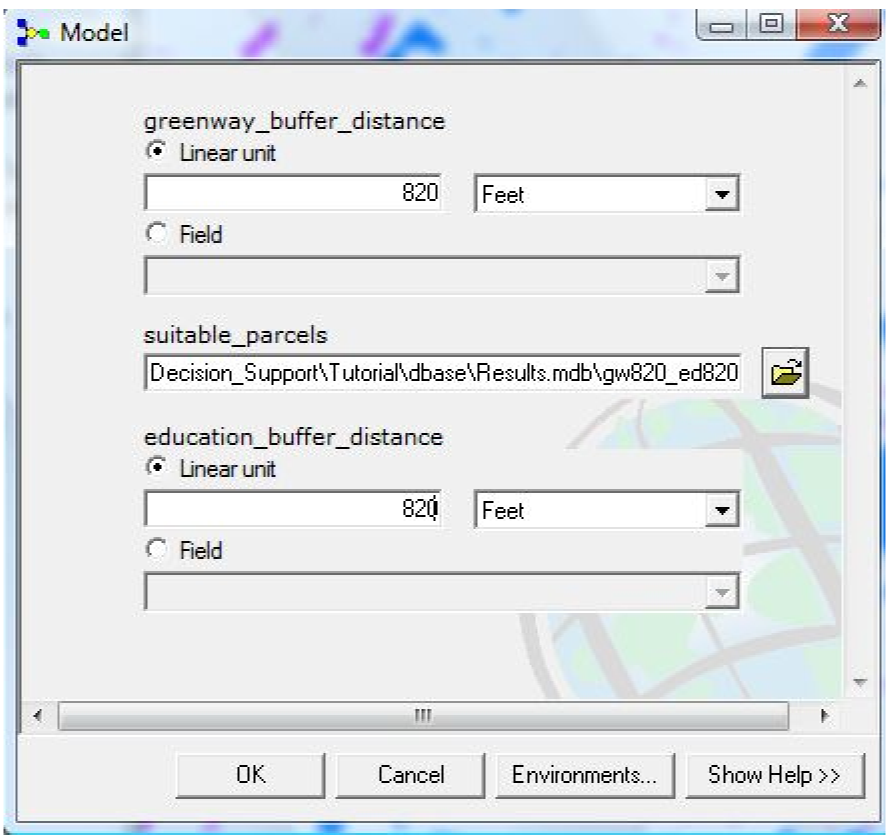


7. **Save** your model, and **Close** the ModelBuilder window.

8. In ArcToolbox, **Right-Click on your Model and select “Open.”**



9. A dialogue box containing the three model parameters will open. Any variable you declare a “model parameter” will appear in this dialogue box each time you open a model to run.

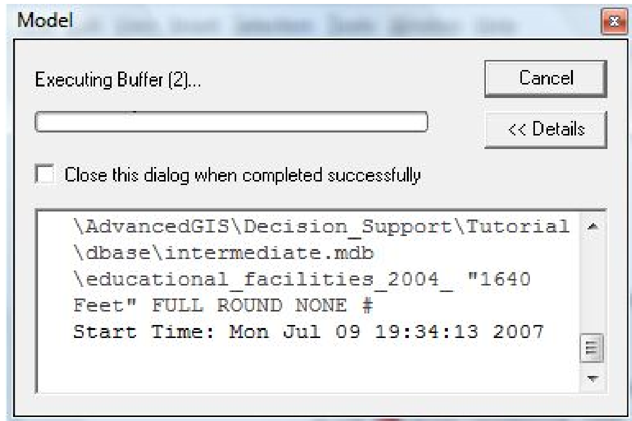


Let’s re-run our model with buffers that are half the distance of the original. We will now only be choosing vacant lots within 820 feet of the greenway and educational facilities.

Type 820 feet for the greenway_buffer_distance and for the education_buffer_distance parameters, and name the resulting suitable_parcels output feature “gw820_ed820.”

Click OK.

Your model will now run. Although you cannot see the progress in the ModelBuilder window, the processes being run will be documented in the progress dialogue. (See example below.)

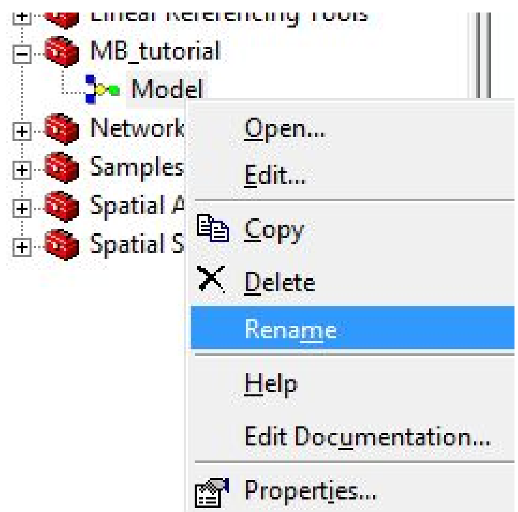


The resulting output of your model should add itself to the map display. If you open its attribute table, you will find that we now have only 161 possible sites.

While 161 sites is considerably less than 642, it is probably still too many to sufficiently narrow down the options. At this point, you could continue to run your model with different distance parameters or go back into your model and edit it, adding steps to select only lots of certain other criteria, e.g. square footages. While we can create a good decision support system by slowly adding decision criteria, we cannot weight these criteria with this method.

In the Introduction to GIS exercises, we used raster decision layers and weighted criteria modeling to create a decision map. Now that we are familiar with the ModelBuilder, let's recreate that analysis in a more automated way.

Weighted Criteria Models with the ModelBuilder



1. First, rename the model you have. **Right-click** on the "Model" in the ArcToolbox and **select "Rename."** Rename your model "Simple_Model."

2. We do not want to start over completely with a new model, so **Copy Simple_Model** and **Paste** a copy of it into the MB_tutorial toolbox. "Simple_Model(2)" should appear.

   Rename the copy. Call it "Weighted_Model."

3. Next, make sure your Spatial Analyst extension is turned on, because we will be using these tools. (Tools > Extensions > check Spatial Analyst.)

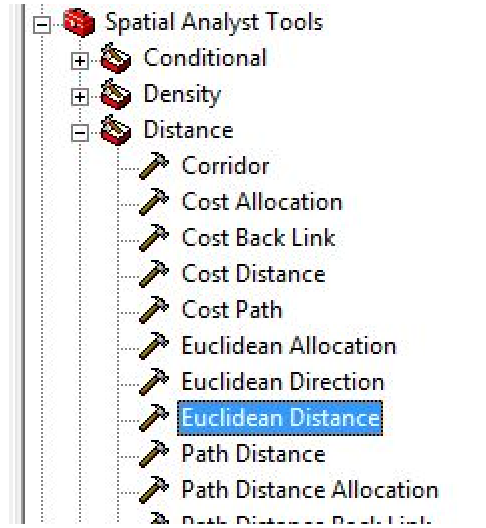
4. Open the ModelBuilder window for the "Weighted_Model" by **Right-Clicking** it in the ArcToolbox and selecting **Edit.**

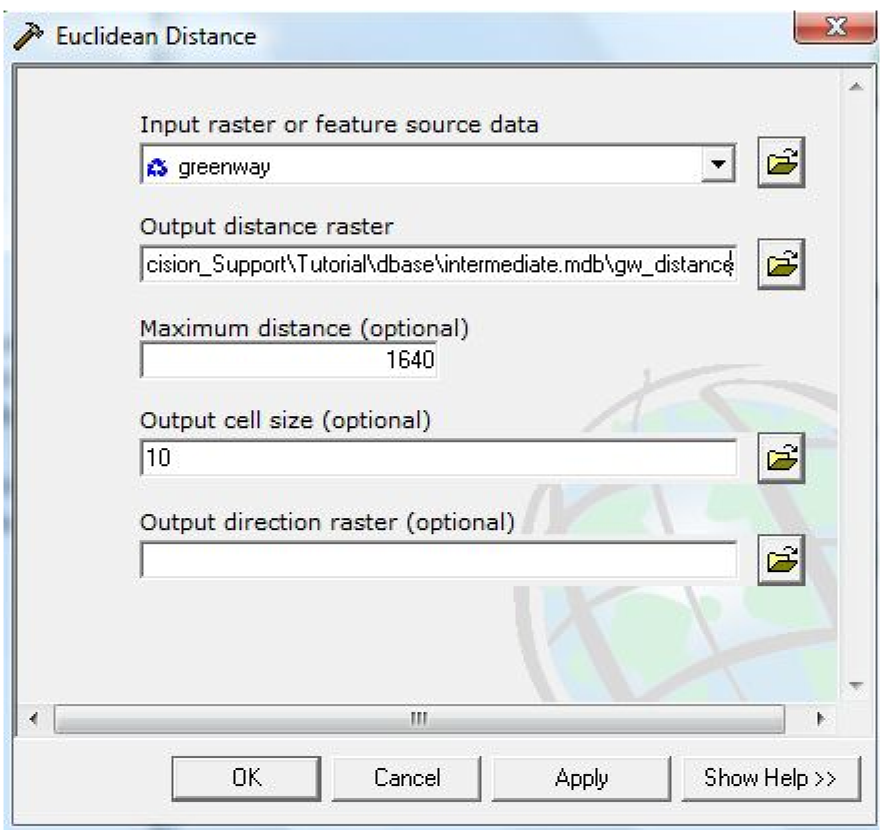
   We are going to follow the logic of the model we built, but change the tools to conform with the raster-based weighted criteria model.

First, **delete the two model parameter distance variables.**

5. Next, we are going to replace our Buffer tools with Straight Line Distance calculations from the Spatial Analyst. In the ArcToolbox, this tool is called “Euclidean Distance.” **Drag and Drop the Euclidean Distance Tool** from the Arc Toolbox to the ModelBuilder window.

Note that the tool has two possible outputs. Both are not required to make the tool operate. We will ignore the “Output direction raster” because it is an option our analysis will not use. It might be useful to position it away from the rest of your flow-chart diagram.





Right-Click on the Euclidean Distance Tool and **Select Open.** In the dialogue box, select the Greenway as the input data source.

Make sure that the output distance raster is set to the “intermediate” database, and name it “gw_distance.”

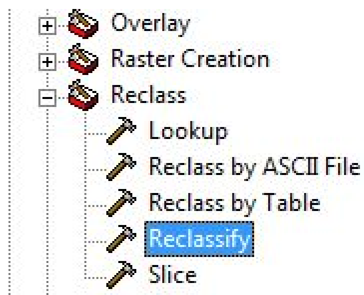
Make the maximum distance 1640 (this is in feet because the dataset is in feet).

Leave the Output direction raster option empty.

Click OK.

6. Repeat Step 5 for the Educational Facilities layer. Name the Euclidean Distance output raster "educ_distance."

7. Next, we need to reclassify the distance rasters. **Drag and drop the Reclassify Tool** into the ModelBuilder window.



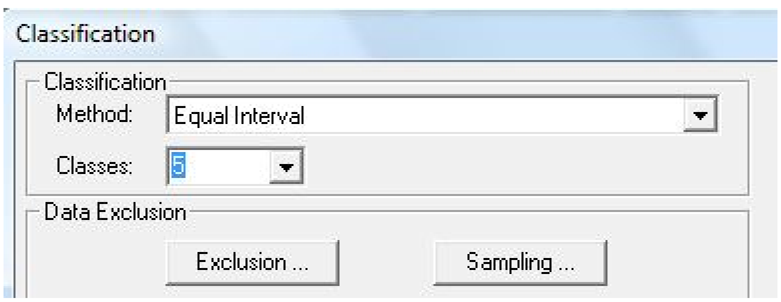
With the Line Connector Tool, **link** the gw_distance output raster to the Reclassify tool, designating this raster as the one to be reclassified. **Open the Reclassify dialogue box** (Right-click > Open).

Normally, we would expect to see the values of the input raster listed in this dialogue box. Likewise, we would be able to choose a new classification method by clicking "classify." This is not the case, because the input raster has not yet been created. We set up the Euclidean distance tool, but we have not run it.

We can run individual tools within a model without running the entire model. In addition to generating intermediate output needed to continue, this is useful for testing small portions of large models. Note that when you select a single operation to run, any earlier steps that are necessary for that operation will also be run.

Click Cancel to close the Reclassify Dialogue box. **Right-click on the Euclidean Distance tool** and **Select Run.** This will run only the tool operation, so that we can continue.

When the distance tool has finished running, once again **open the Reclassify dialogue**. This time, things should look as we had expected.



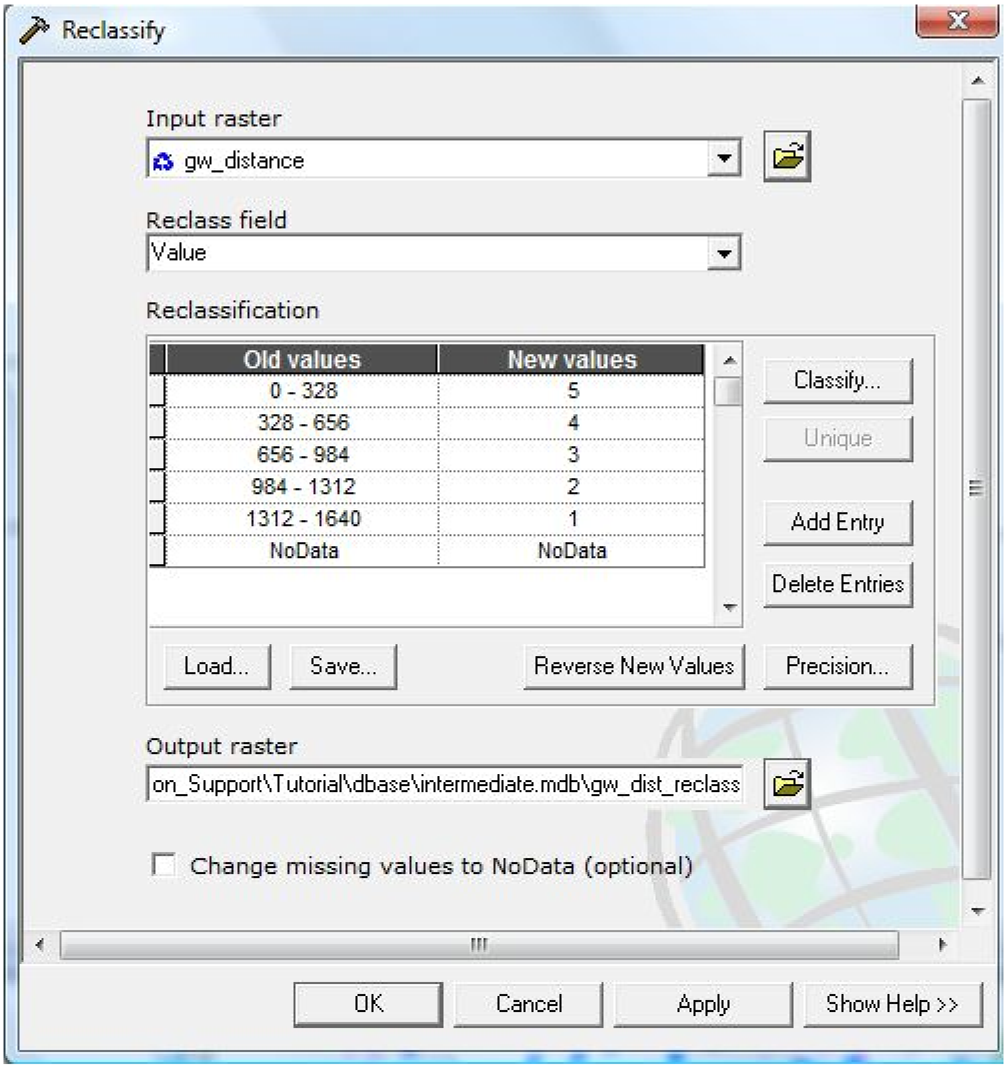
Click Classify. In the Classification dialogue, select **Equal Interval** as your classification method and create **5 classes.**

Click OK.

Back in the Reclassify dialogue, **Click Reverse New Values** so the higher reclass values correspond with the shortest distances from the greenway (i.e. the old values).

Name your output raster "gw_dist_reclass."

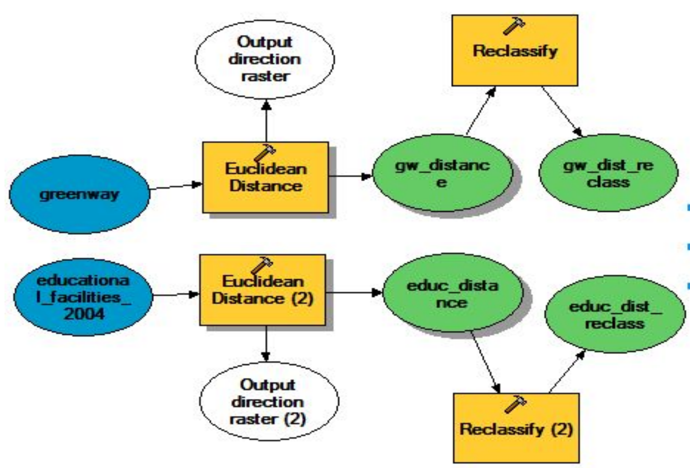
The Reclassify dialogue should look like the one on the next page. **Click OK.**

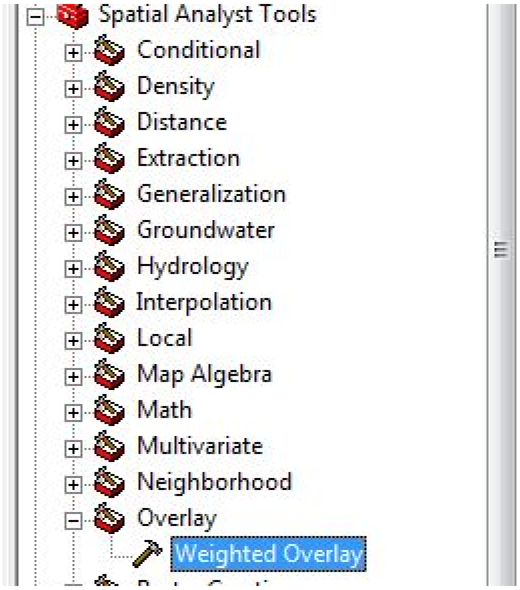


8. Repeat Step 7 for the educ_distance output raster. Name its reclassified raster "educ_dist_reclass."

The updated part of your ModelBuilder window should now look like this:

If you haven't already, you can delete the parts of the model that we have replaced.





The next step of our simple model to address is the Intersection. Typically, this step would be replaced by adding the rasters using the Spatial Analyst Raster Calculator. Any weights we would want to assign to the decision layers would have to be written as calculator expression. In the ModelBuilder, we will streamline this step by using the "Weighted Overlay" tool.

9. **Drag and Drop the Weighted Overlay Tool** from the ArcToolbox to the ModelBuilder window.

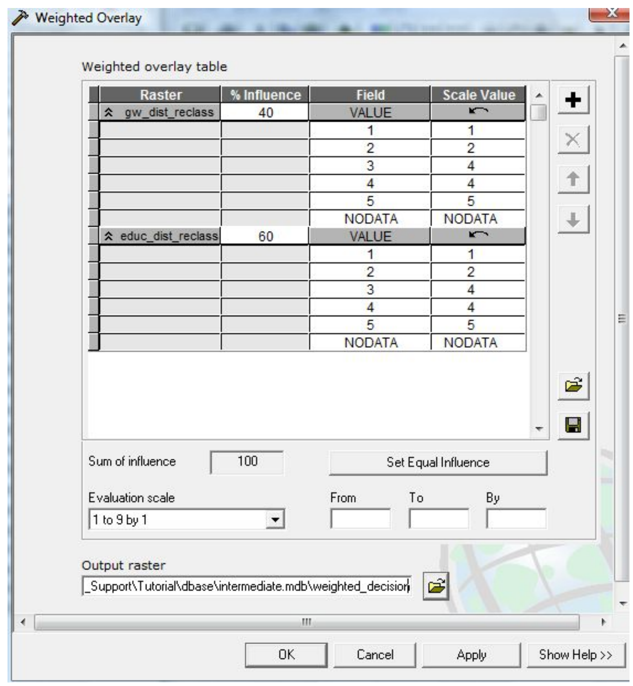
Connect the two reclassified distance rasters to the Overlay Tool, designating them as the Overlay's input layers.

Open the Weighted Overlay Tool's dialogue box (Right-click > Open). Notice that by default, the first decision layer is assigned 100% influence.

We know that the distance to educational facilities is slightly more important than the distance to the greenway. In the Weighted Overlay Table, **assign the gw_dist_reclass layer 40% influence**. Also, **assign the educ_dist_reclass layer 60% influence.**

Name the Output Layer "weighted_decision."

Click OK.



[NOTE: Thinking ahead, we might want to be able to change the weights of our decision criteria layers and possibly run this model several times. Unfortunately, the weighted overlay tool cannot generate variables from its parameters the way the buffer tool did. If you plan to run multiple weighted overlays, then the Map Algebra tools can be used instead.]
We have replaced the "intersect" step in our model, so **delete the intersect tool.**

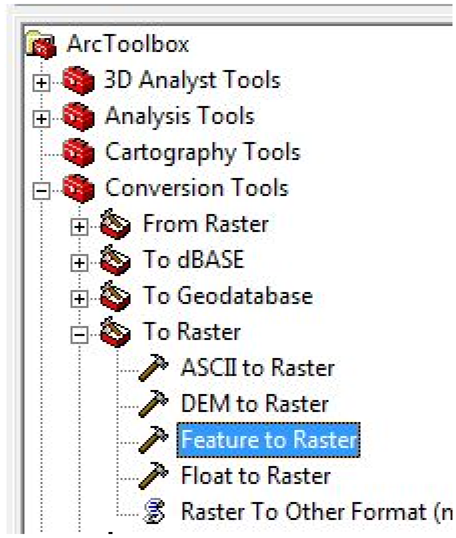
10. Finally, we want to include the vacant land into our decision support system. Previously, we did this by clipping all the vacant parcels within the combined decision layer. This time, we will use a raster-based method to find the weighted value of each vacant lot.

    First, we will need to convert the vacant_land_2004.shp into a raster file. **Drag and drop the Feature to Raster tool into the ModelBuilder window.** (ArcToolbox > Conversion Tools > To Raster > Feature to Raster.)

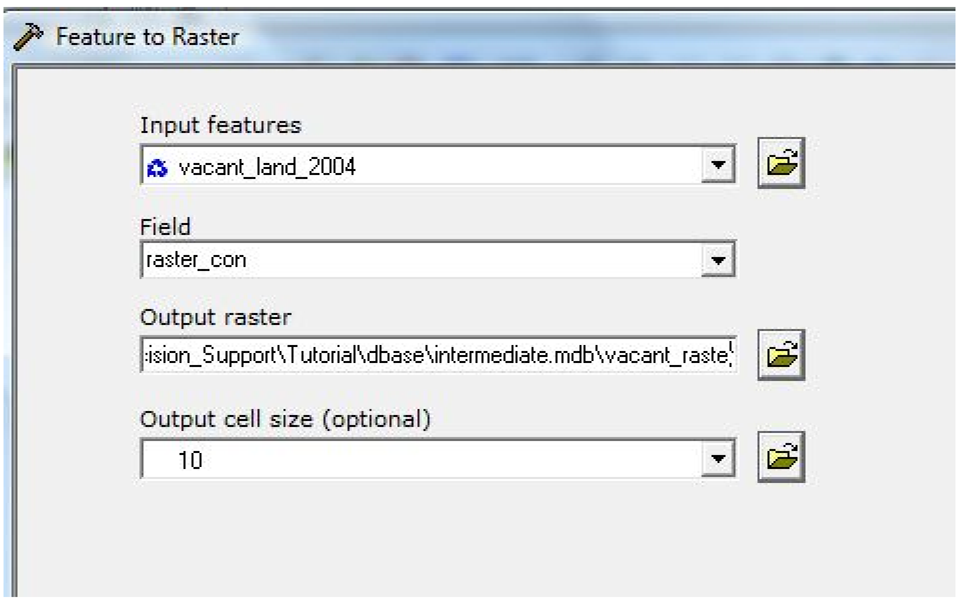
Then **make vacant_land_2004 the input for the Feature to Raster tool.**

Open the Feature to Raster dialogue (right-click > Open).

Select "raster_con" as the Field to assign values to the new output raster. This is a field made for this exercise. The value is 1 for each vacant lot. Name **the Output raster "vacant_raster,"** and **make the output cell size 10.**



The dialogue should look like this:



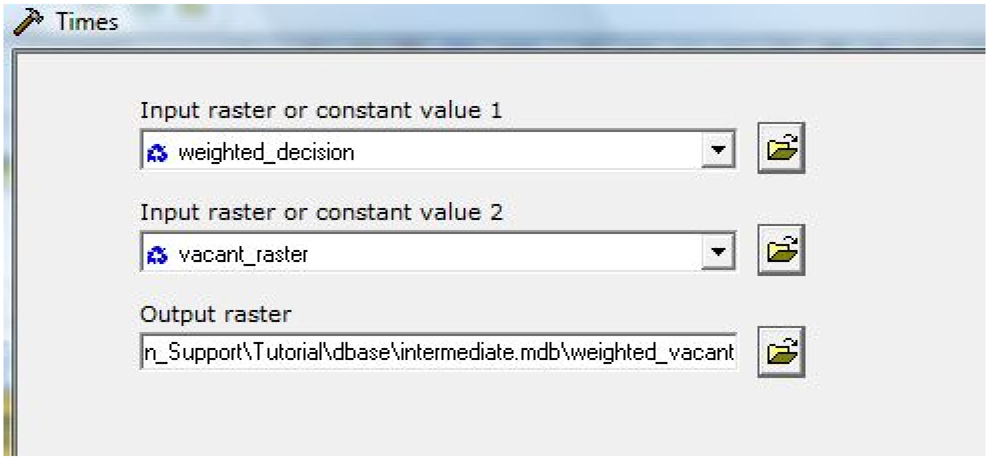
Click OK.

11. Lastly, we will multiply the weighted_decision raster layer by the vacant_raster layer. Because the vacant_raster layer is equal to 1 everywhere there is a vacant lot, the product will yield the decision values for only the vacant sites.

In the ArcToolbox, **find the "Times" tool** (Spatial Analyst Tools > Math > Times) **and place it in your model**.

Assign vacant_raster and weighted_decision as the tool's input values.

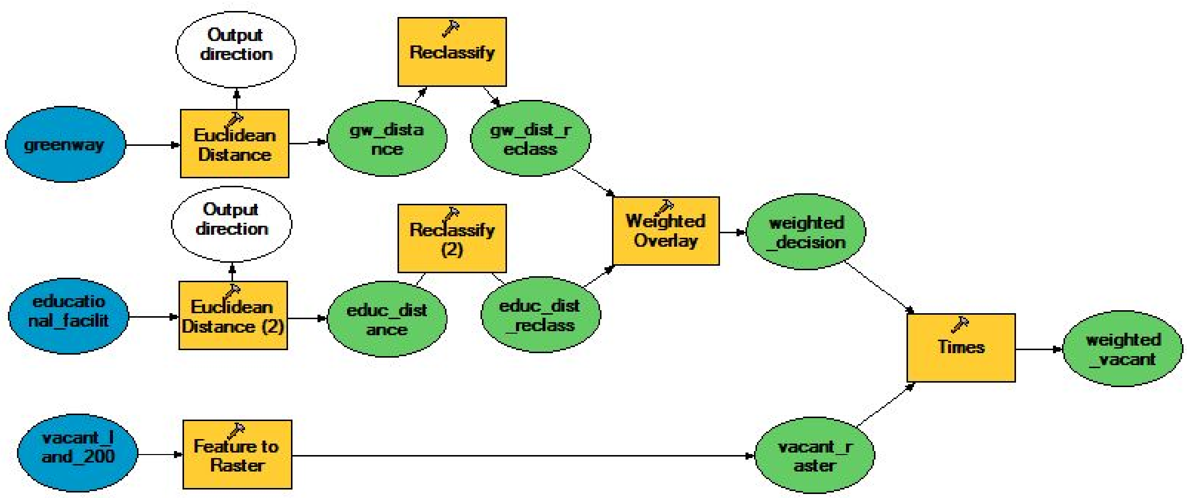
Open the Times Tool (right-click > Open) and **Name the Output Raster "weighted_vacant."**



Click OK.

Add the weighted_vacant output to your map display (right-click > check Add to Display).

Delete any remaining parts of the original "simple" model. The model should look something like this:

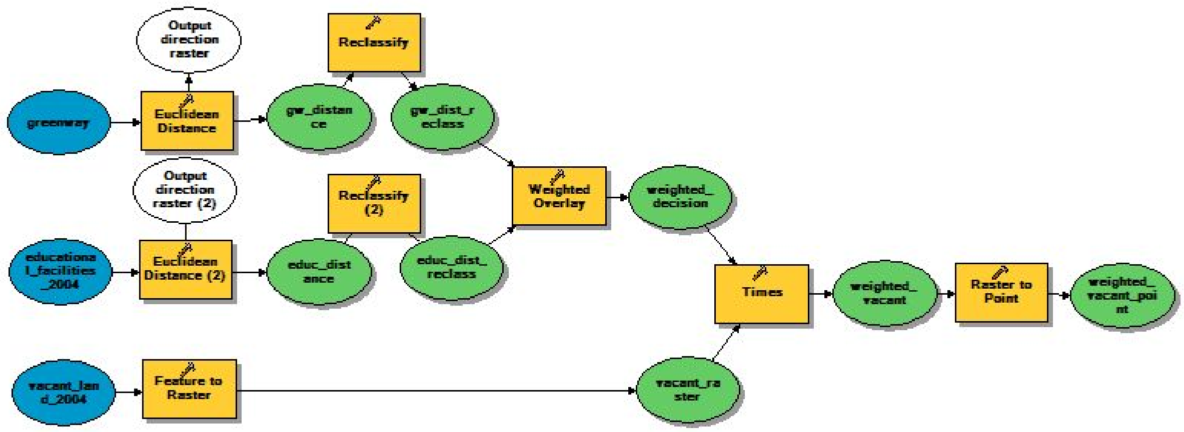


The weighted_vacant raster will visually show us vacant lots and their weighted suitability scores, but will not be able to count them for us, because the data is divided into cells. We must convert the raster back into a feature and aggregate the scores to see the final tally of potential sites.

Drag the Raster to Point tool into the ModelBuilder window. (Conversion Tools > from Raster > Raster to Point.)
Open the Raster to Point tool (right-click > Open). **Select "weighted_vacant"** as the input layer, **Choose "value"** as the field, and **Name the output feature "weighted_vacant_points."** This is your final result output; be sure to put it in the Results database.

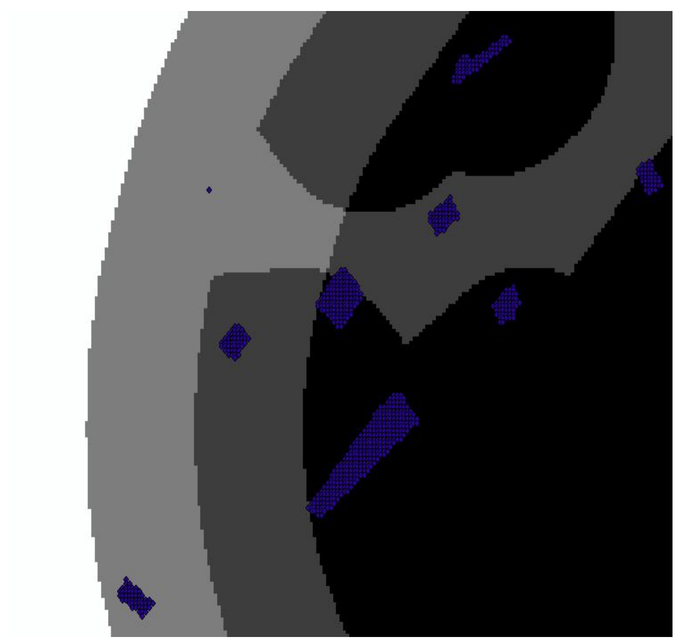
Add the "weighted_vacant_points" feature to the map display (right-click > Add to Display) and make sure that it is not "intermediate" (right-click > uncheck "Intermediate").

Your model should look like this:



Save your model (Model > Save).
Delete Intermediate Data (Model > Delete Intermediate Data).
Run your model (Model > Run Entire Model). This may take a few minutes.

Understanding our results



The resulting weighted_vacant_points will be displayed on your map. Zoomed in, it should look like this:

We converted the final decision raster to points (rather than polygons) because some of the lots span across different decision criteria bands. (On the right, the grey -> black scale are the weighted_decision raster.)

The final step of the analysis is the same from the original Intro to GIS exercise: a spatial join, averaging the decision score of the points as they are joined back to the original vacant_land_2004 shapefile.

After performing this join, you will find 30 lots with a score of 4.5 or higher and 27 vacant lots with a decision score of 5. (This is considerably less than the 161 sites we were able to find without using a weighted analysis.) You could then further narrow that number by looking at additional quantitative data (e.g. lot size) or qualitative data such as ownership and zoning.

Don't forget to save your model as it might be used later in the semester.

Deliverables: Due before the end of Monday, November 30th.

Use the ModelBuilder to further develop a decision support system from either of the two models created in the tutorial. In other words add a parameter. Consider the objective: to find suitable sites for a non-profit organization's environmental educational facility.

Upload one 11x17 board to Courseworks, containing the following:

- your final map
- data about your final selection (graphs and charts)
- an explanation on how you developed your model (your criteria and your process)
- and a diagram showing your model (do not just copy and paste a screenshot from GIS, instead, use illustrator or some other graphic software to create a clear and interesting diagram).