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Activity Title: **Geographic Information Systems (GIS) and Water Resources**

Type of Activity: short-term project.

Brief description: Water is fundamental to the human life and the functioning of the natural environment. The scope and scale of water resources problems make GIS software a powerful tool for developing solutions. This activity will demonstrate how water quality and environmental health issues can be analyzed together, how hydrologic information can be built up, and how decisions can be made using GIS.

Context: This activity can be used in an undergraduate hydrogeology course, or in an introductory GIS class.

Briefly describe or list the skills and concepts that students must have mastered before beginning the activity: I have used this exercise in my undergraduate hydrogeology class. The very first session students were introduced to the basic concepts of GIS. This activity is self-explanatory and provides an opportunity for students to learn new concepts as well as apply known concepts. All this by way of saying, there is no single background required. Students apply the skills and concepts they know and learn new skills and concepts along the way.

Briefly describe how the activity is situated in your course:
I have used this activity as a short-term project (two classes per week).

Goals of the Activity or Assignment

- **Content or concepts:**
  - The students learn how to identify housing sites in relation to river access and types of nearby land use. The also learn about measurable water properties (specific conductance, amount of dissolved oxygen, pH) that indicate water quality.
- **Higher order thinking skills:**
  - The students use GIS tools such as buffering and MapTips to correlate water quality data and flood potential with home location.
- **Other skills:**
  - Depending on the availability of data, the approach and skills learned in this activity might be applicable to a real situation in the future.

Briefly describe the content/concepts goals for this activity:
The goal is for students to understand how the water quality is related to environmental health and to business decision, such as home purchasing.

Briefly describe the higher order thinking skills goals for this activity:
Use of a GIS-based software (ArcExplorer), performing specific GIS tasks (buffering, adding layers, using MapTips, modifying layer properties, etc.), assessing water quality, evaluating flood potential, choosing the house properties.

Briefly describe any other skills goals for this activity:
Other skills goals are pretty broadly based and dependent on the availability of data and level of individual students and classes.

Description
This activity is based on "Exercise 8: Water Quality and Environmental Health", by M. E. Stuart, M. A. Cunningham, J. S. Schneiderman, and L. Gold, "Exploring Environmental Science with GIS", 2005, McGraw Hill, used by permission

Getting Started
This exercise posits a hypothetical situation: you would like to purchase land that will provide your family with opportunities to fish and swim in a stream on your property. Additionally, you would like the land to

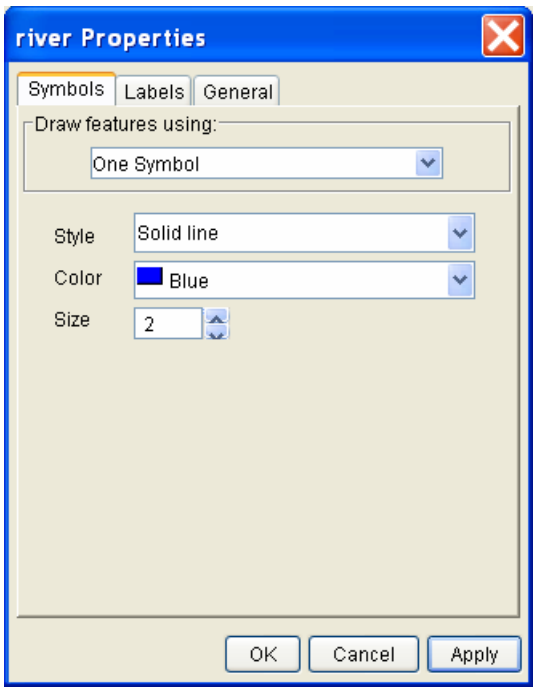
afford some privacy. In order to find such a place, you need to locate land for sale that has a stream running through it and you want to confirm that the stream water is clean. The following exercise illustrates how one can locate land with particular characteristics and also assess surface water quality for local bodies of water. The data you will use might pertain to any location where streams flow through residential areas.

IMPORTANT: You will need to download and install on your laptop the software (ArcExplorer 9.1 and JRE 1.4.2, free at http://www.esri.com/software/arcexplorer/download9.html#windows (only for Windows OS, sorry no Macs!). Then download the directory **Water_Quality_exercise** from this website and copy it on the desktop.


Add Layers

Open ArcExplorer (Start > Programs > ESRI > ArcExplorer). Click on the Add Layers icon and navigate to the Water_Quality_exercise folder. Add the shapefiles **Homes_For_Sale, river,** and **Streets** to your ArcExplorer legend by double clicking on each shapefile and then close the Catalog window. Remember that if you see an error message while opening the shapefiles, just press Continue. Click on each box to make these data visible in your map window. To modify the display of the data, right click on the shapefile in the legend that you would like to change and open the Layer Properties dialog box, or use the Layer Properties tool on the toolbar. For example, for the **river** shapefile, change the line color for the river to blue and the size to 2 as shown below.


Layer Properties



Similarly, adjust the **Streets** file to show gray lines with a line size of 1 and switch the **Homes_For_Sale** point data to display brown squares in size 8.


Zoom to Full Extent

Your map window now displays a subset of a larger dataset of streets and rivers. These data were clipped—that is, extracted—from a larger dataset using another ESRI software called ArcGIS. The fact that they were clipped accounts for the circular shape of the map. If the circular shape of the map is not obvious, use the Zoom to Full Extent tool.

Locating Homes for Sale

Let's assume that given your desire for a home near a stream, you have narrowed your search to a particular area and have found an appealing region in which homes for sale might be located near a stream.

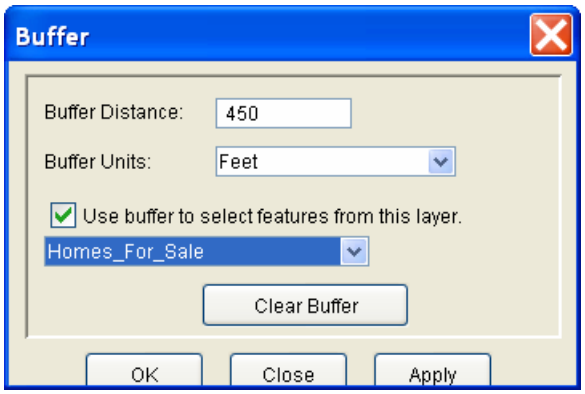
First, you need to identify homes for sale that meet the criterion of being along a stream. To do this you will buffer the **river** file and then select homes from the **Homes_For_Sale** file.

Click once on the **river** file to make it active. Using the Select Features tool from the toolbar, choose the circle shape. Place the cursor in the middle of the map and drag a circle shape so that all of the **river** lines are selected. The circle that you draw will be red and the **river** lines will turn bright yellow once they have been selected. With the **river** file selected, you can buffer the river to a distance of 450 feet. That is, assuming you desire a home no farther than 450 feet from the river, you will create a buffer of 450 feet around the river and see what homes fall within that buffer zone. The software will select the homes for you.


Select Features

With the **river** layer active, choose the Buffer tool from the toolbar. As illustrated below, in the Buffer window that opens, type in 450 for the Buffer Distance, choose "Feet" for the Buffer Units from the drop-down menu, check the box Use buffer to select features from this layer, and elect the **Homes_For_Sale** layer. Click OK.


Buffer



Notice that a red buffer line has been drawn around the river and that some homes have turned from brown squares to bright yellow ones. Since they are difficult to see, have the software locate them for you. To do so, click once on the **Homes_For_Sale** layer to make it active and choose the Attributes tool from the toolbar. The Attributes window lists twelve properties for sale within 450 feet of the river. Write down the addresses of these properties in column A of Table 1 at the end of this exercise.


Attributes

Though the selected homes lie within 450 feet of the river, some may have no river access. That is, a street may run between the house and the river. Use the Identify and Zoom In tools on the toolbar to identify each location by address and determine if the home has direct access to the river. For homes with river access, enter "yes" in column B of Table 1 and for those with no access enter "no."


Identify


Zoom In

If the Attributes window is still open, close it and use the Clear All Selection tool to clear the buffer and its accompanying selections.


Clear All Selection

Evaluating Land Use

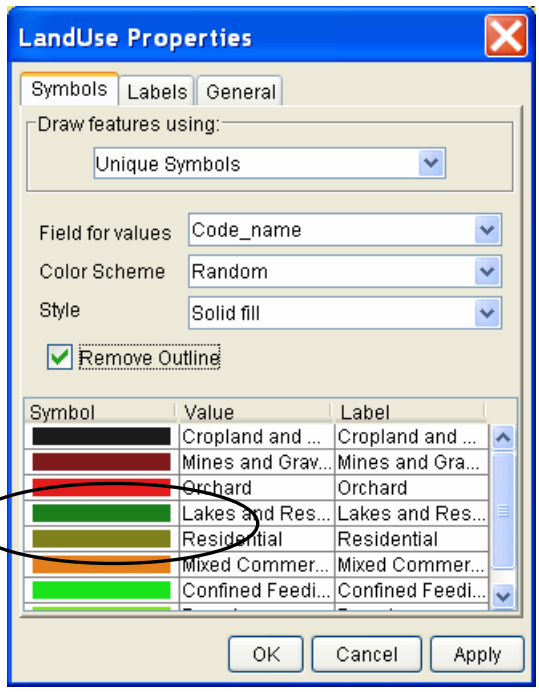
The houses you have identified will be of interest as potential homes if they are on land zoned for residential use or categorized as forested land or cropland. Properties zoned for mixed commercial use are not ones you would like to purchase. Therefore, in this portion of the exercise, you will determine the local land use for each of the properties for sale.


Add Layers

Using the Add Layers tool, add to your map the **LandUse** shapefile from the Water_Quality_exercise folder. This layer contains categories of land uses that you can view easily using multiple colors. Right click on the **LandUse** layer to open the Layer Properties window or choose Layer Properties from the toolbar. As shown below, click the Symbols tab. Draw features using Unique Symbols, choose Code_name for the Field for values, select the Random Color Scheme, and use Solid fill for Style. The software colorizes the values randomly. Change the colors by double clicking on the color symbol so that Lakes and Reservoirs are blue and Forest is green. Also, check the Remove Outline box to blend together the land use polygons of similar value and thus make the **LandUse** layer most readable.

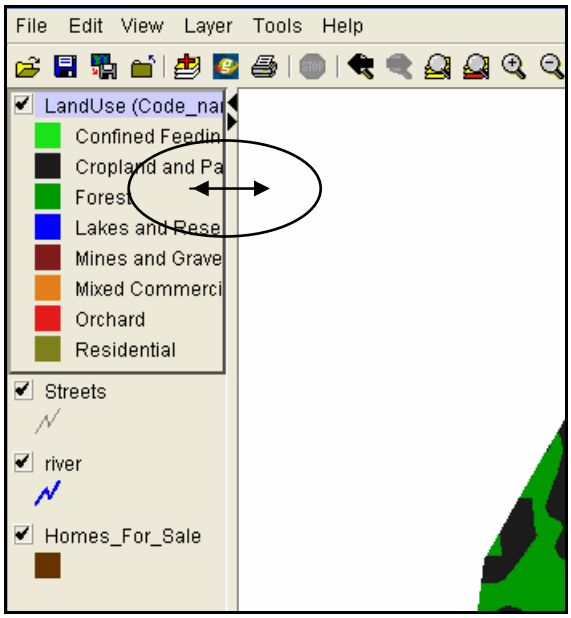

Layer Properties

Change Lakes and Reservoirs to blue, Forest to green



With **LandUse** as the topmost layer, you can determine the primary land uses in this area by observing which colors dominate the **LandUse** layer. If it is difficult to read the types of land uses from the legend, widen the legend area as follows: place the cursor between the legend and the map area, look for the horizontal line with arrows at both ends and drag the legend to expand it as shown below.

To make the legend area larger drag from the area between the legend and the map region (circled)



What are the two predominant land uses in this area?

Answer:_____


Map Tips


Identify

Next, you will determine the type of land use for each of the properties you have listed in Table 1. Drag the **LandUse** layer to the bottom and turn on all layers. Once again buffer the river to a distance of 450 feet as you did in a previous section of this exercise. Use the MapTips and Identify tools, to determine the address and land use type for each selected house denoted in yellow. Note that when you choose MapTips from the

toolbar, a dialog box will open. Choose the **Homes_For_Sale** layer and the ADDRESS field, click Set MapTips, and OK. You will need to toggle between **Homes_For_Sale** and **LandUse** in the legend to read the address and the land use type in the Identify Results dialog box. Write the land use code name for each of the properties under column C in Table 1.

When you are finished checking land use, turn off or remove the **LandUse** layer and click Clear All Selection

Clear All Selection

Assessing Water Quality

In this portion of the exercise you will analyze water quality in the river and tributaries that flow through the region in which you may purchase a home.

Water quality samples were collected at twelve sampling stations along the river and the data are included in the GIS software. Water quality parameters that were analyzed include temperature, stream flow, specific conductance, dissolved oxygen, and pH. These are standard water quality indicator parameters that reveal the suitability of water for purposes such as swimming and fishing as well as drinking. Ideally, an interested person would monitor water quality data for at least a year to evaluate seasonal effects. In this instance, we will examine data for only one sampling event. Thus the data reflect water quality at one moment rather than over an extended period of time.

Parameters such as temperature and stream flow rates for the twelve sampling sites in this exercise appear to be uniform across each of the water collection stations. Therefore, these parameters provide little insight into variations in water quality along the properties you might purchase. Rather, variations in specific conductance, dissolved oxygen, and pH may reveal useful information about water quality on the properties.

Specific conductance measures the flow of electricity through water over a set distance of water sampled, in this case 25 centimeters. High specific conductance indicates high salt content (salinity) of water. The presence of dissolved salts in freshwater streams negatively impacts freshwater aquatic life.

Oxygen is essential for aerobic aquatic life. Therefore, for a stream to support such life, it must contain a relatively high amount of *dissolved oxygen.* Dissolved oxygen levels of 6 milligrams per liter or higher indicate good quality water.

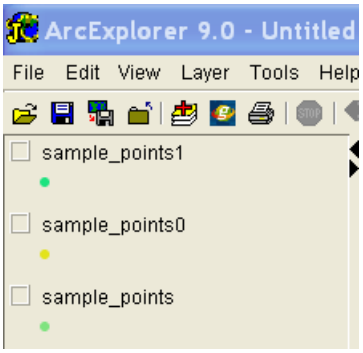
Water acidity or alkalinity is measured by *pH*—a scale that runs from greater than 0 to less than 14. pH values less than 7 indicate acidic water and those greater than 7 are basic. Extreme values of pH limit the ability of aquatic plants and animals to thrive.

In this section, you will make maps that display the specific conductance, dissolved oxygen, and pH in order to assess water quality. The following table shows the units of measurement and ArcExplorer Field Names for each of the water quality parameters:

Water Quality Parameters Units of Measurement and ArcExplorer Field Names in Parentheses

Temperature (TEMP)	degrees Celsius
Stream flow (STREAMFLOW)	cubic feet per second
Specific Conductance (CONDUC)	microsiemens per square centimeter
Dissolved Oxygen (DIS_OXY)	milligrams per liter
pH (pH)	standard units

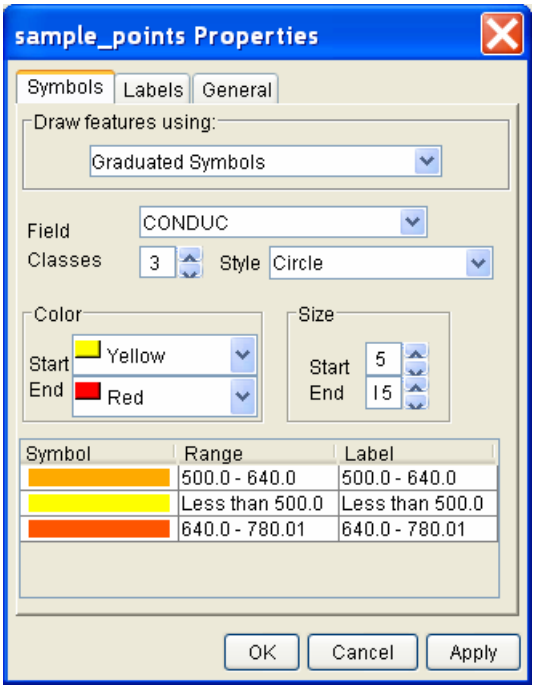
Click the Add Layers button from the toolbar and choose the sample_points shapefile from the Catalog window. Double click on the sample_points shapefile three times in order to add three **sample_points** layers to the map legend and then close the Catalog window.The three **sample_points** layers will appear in the legend as shown below.



Note that two of the **sample_points** layers will have the numbers "0" and "1" after them and the third will have no numerical designation.

Let's begin by mapping specific conductance. Right click on one of the **sample_points** layers and choose Layer Properties. Guided by the figure below, Draw features using Graduated Symbols, select the Field CONDUC, choose 3 Classes and Circle for Style, use start and end default colors (yellow and red), and change the size ranges to start at 5 and end at 15. Click OK.

Layer Properties



Make sure the **sample_points** layer is active and checked so that you can inspect the data on your map.

Also, identify the sample station numbers as follows. Once again choose Layer Properties, go to the Labels tab and label features by Station.

Layer Properties

On the Water Quality Worksheet, Table 2, at the end of this exercise, mark an X in the Specific Conductance column (B) for the stations that have the highest values of conductivity. If you followed the steps above and used three classes, the high values for specific conductance will appear on the map as large orange or red circles.

Now follow the same steps for dissolved oxygen (DIS_OXY) and pH. Use three graduated symbols as you did for specific conductance but choose different styles for these parameters such as triangles and stars, respectively. When you evaluate each of these parameters, you may want to turn off the other two water quality maps. On Table 2, mark with an X those stations that have low levels of dissolved oxygen and pH values higher than 7.5.

Examine your data as reported in Table 2. Water monitoring stations with two or more Xs in columns B, C, and D indicate lower water quality than is preferable for recreational purposes such as swimming and fishing. In column E of Table 2, write the word "poor" for stations that have two or more Xs in columns B, C, and D.
Note that the stream in your area flows from north to south. For example, water flows from Stations 9, 12, and 8 past the other stations and ultimately down to Station 1.

Now that you have assessed water quality at stations in the watershed, use these data to narrow your choices of possible home purchases. Houses adjacent to or downstream from sampling stations with low water quality should be eliminated from the list of desirable properties.

With the **Homes_For_Sale** layer active, choose the MapTips tool. Using **Homes_For_Sale** for the layer and ADDRESS for the field, click the Set MapTips button and click OK. Now use the Identify tool to locate addresses of houses downstream or adjacent to water stations with poor water quality. Write "poor" in the Water Quality Evaluation column (D) on Table 1 for these addresses.


Map Tips


Identify

Turn off or remove the three **sample points** layers. Keep the **river, Streets,** and **HomesFor_Sale** layers turned on.

Evaluating Flood Potential
Add to your map the **100_year_flood** shapefile from the **Water_Quality_exercise** folder. Place the **100_year_flood** layer below the other layers. The **100_year_flood** layer is a polygon that shows land area in the region that will be impacted in the event of a major flood, also known as a 100-year flood. Any homes located within the 100-year flood zone will be undesirable properties.


Add Layers


Select Features

With the **100_year_flood** layer active, use the Select Features tool and draw a large circle around the flood zone polygon. When selected properly, it will turn yellow.

Using the Buffer tool, select a buffer distance of 1 foot and choose features from the **Homes_For_Sale** layer. Make the **Homes_For_Sale** layer active and examine the attributes. Properties listed in the Attributes box are located within the 100-year flood zone. Determine which property addresses on Table 1 appear in the Attributes box. For those addresses, write "yes" in the Flood Potential column (E) of Table 1.


Buffer


Attributes

Choose the Properties
You have now investigated the characteristics of properties for sale in the area you wish to purchase a home in terms of river access, land use, water quality, and flood potential. On Table 1, circle the addresses of properties that are suitable for purchase according to the evaluation criteria. To do this, eliminate those properties that have no river access, land use that is something other than residential, cropland, or forest, poor water quality, and vulnerability to major floods.

Table 1: Homes Within 450 Feet of the River

A	B	C	D	E
Address	River Access	Land Use	Water Quality Evaluation	Flood Potential

Table 2: **Water Quality Worksheet**

A	B	C	D	E
Station ID	Specific Conductance	Dissolved Oxygen	pH	Water Quality Evaluation
Station 1				
Station 2				
Station 3				
Station 4				
Station 5				
Station 6				
Station 7				
Station 8				
Station 9				
Station 10				
Station 11				
Station 12				

What Have You Learned?

In this exercise you have identified housing sites in relation to river access and types of nearby land use. You have also learned about measurable water properties that indicate water quality. You have used GIS tools such as buffering and MapTips to correlate water quality data and flood potential with home locations. Depending on the availability of data, the approach and skills that you have employed in this exercise are ones that might be applicable to a real situation in the future.

Evaluation

I have evaluated the utility of this exercise through grading the solutions (Table1 and Table2) and through exams (the standard way).

Documentation

To be handed out at the workshop.