



2016

# Laboratory Exercise- Mapping the Risk of Structural Failure in Schools due to an Earthquake

Joel Barker

Kimberly Sowards

Casey Webb

Follow this and additional works at: <https://scholarsarchive.byu.edu/gislabs>

 Part of the [Civil Engineering Commons](#), and the [Geographic Information Sciences Commons](#)

---

## Recommended Citation

Barker, Joel; Sowards, Kimberly; and Webb, Casey, "Laboratory Exercise- Mapping the Risk of Structural Failure in Schools due to an Earthquake" (2016). *Engineering Applications of GIS - Laboratory Exercises*. 19.  
<https://scholarsarchive.byu.edu/gislabs/19>

This Article is brought to you for free and open access by the Civil and Environmental Engineering at BYU ScholarsArchive. It has been accepted for inclusion in *Engineering Applications of GIS - Laboratory Exercises* by an authorized administrator of BYU ScholarsArchive. For more information, please contact [scholarsarchive@byu.edu](mailto:scholarsarchive@byu.edu), [ellen\\_amatangelo@byu.edu](mailto:ellen_amatangelo@byu.edu).

# Laboratory Exercise- Mapping the Risk of Structural Failure in Schools due to an Earthquake

Created by Joel Barker, Kimberly Sowards, and Casey Webb

## Background

Utah's present geology has been greatly dictated by tectonic stresses that have occurred over the last 0.7 Ga. A determining factor in much of this Geology is the Hingeline that runs through Salt Lake County. Throughout the history of the western North America, this has been an important weak zone. It is no surprise that this same zone is now home to the Wasatch Fault System, which accommodates some of the extension of Western North America. The steep mountains facing west toward Salt Lake City were formed from the tectonic processes of the Fault. The Wasatch Fault is a normal fault, indicating that a hanging block (Salt Lake Valley) is moving downward along a hanging wall (Wasatch Mountains). The block's movement is considered 'stick slip', which refers to the build-up and release of strain along the fault.

## Problem Statement

Over one million citizens live within Salt Lake County. These citizens take for granted the immense pressures and stresses that created the beautiful geological features that surround them. The tectonic forces that have molded much of the Salt Lake area are still active. Modern calculations have estimated over 2 meters of strain have accumulated on the Fault. This could easily produce a 7.0 magnitude earthquake and a large fault scarp.

The possibility of an intense earthquake is something that the people of Salt Lake County have to live with every day. Although it is impossible to prevent the imminent earthquake, we can be better prepared for its occurrence. One of the main causes of injury or death from earthquakes is the structural failure of buildings. Modern building codes in the Salt Lake area require special building techniques and materials that can withstand the compressional and shear waves produced by earthquakes. However, earthquake resistant building codes were not strictly enforced until 1985.

Because of the high concentrations of children who gather in school buildings, we consider these buildings an especially high priority. As a way to prepare for the impending earthquake, schools that are at high risk of structural collapse should be identified and rebuilt/reinforced. This will be done by (1) locating schools that were built before the new building codes were emplaced and (2) predicting the areas that will experience the greatest force from the earthquake. You will use ModelBuilder to develop a model that will indicate the schools that are at highest risk for structural failure from an earthquake along the fault.

## Data

You can download the data from the following sources or create the data you need to complete this exercise.

<http://gis.utah.gov/data/boundaries/citycountystate/> Salt Lake County Shapefile: You can access the zipped shapefile through Utah's AGRC website. Move down the page until you see the link "County Boundaries: Shapefile." You can then unzip this file into your Arc folder.

<https://gis.utah.gov/data/geoscience/> Quaternary Faults: Once at the Utah AGRC website, scroll down and click on the 'Faults' button on the left. This file can then be unzipped into your arc folder.

<http://earthquake.usgs.gov/hazards/apps/vs30/predefined.php/> Shear Wave Velocity: Scroll down to the table labeled 'North America'. Find the row labeled 'Salt Lake City' and find the column 'ASCII.' Then download the file labeled 'ASCII.' This file will need to be georeferenced.

<https://gis.utah.gov/data/society-overview/schools-libraries/> Schools: This zipped shapefile can be found on Utah's AGRC website. Upon scrolling down, you will find the button 'Society.Schools: Shapfile.'

## ModelBuilder Tools

*Buffer:* The tool creates buffer polygons around lines, points, or polygons at a distance specified in the tool window.

*Select:* This tool allows you to extract certain features like lines or polygons from an input feature class or layer.

*Intersect:* Finds the geometric intersection between the features in two different shapefiles.

*Polygon to Raster:* Converts a Polygon shapefile into a raster.

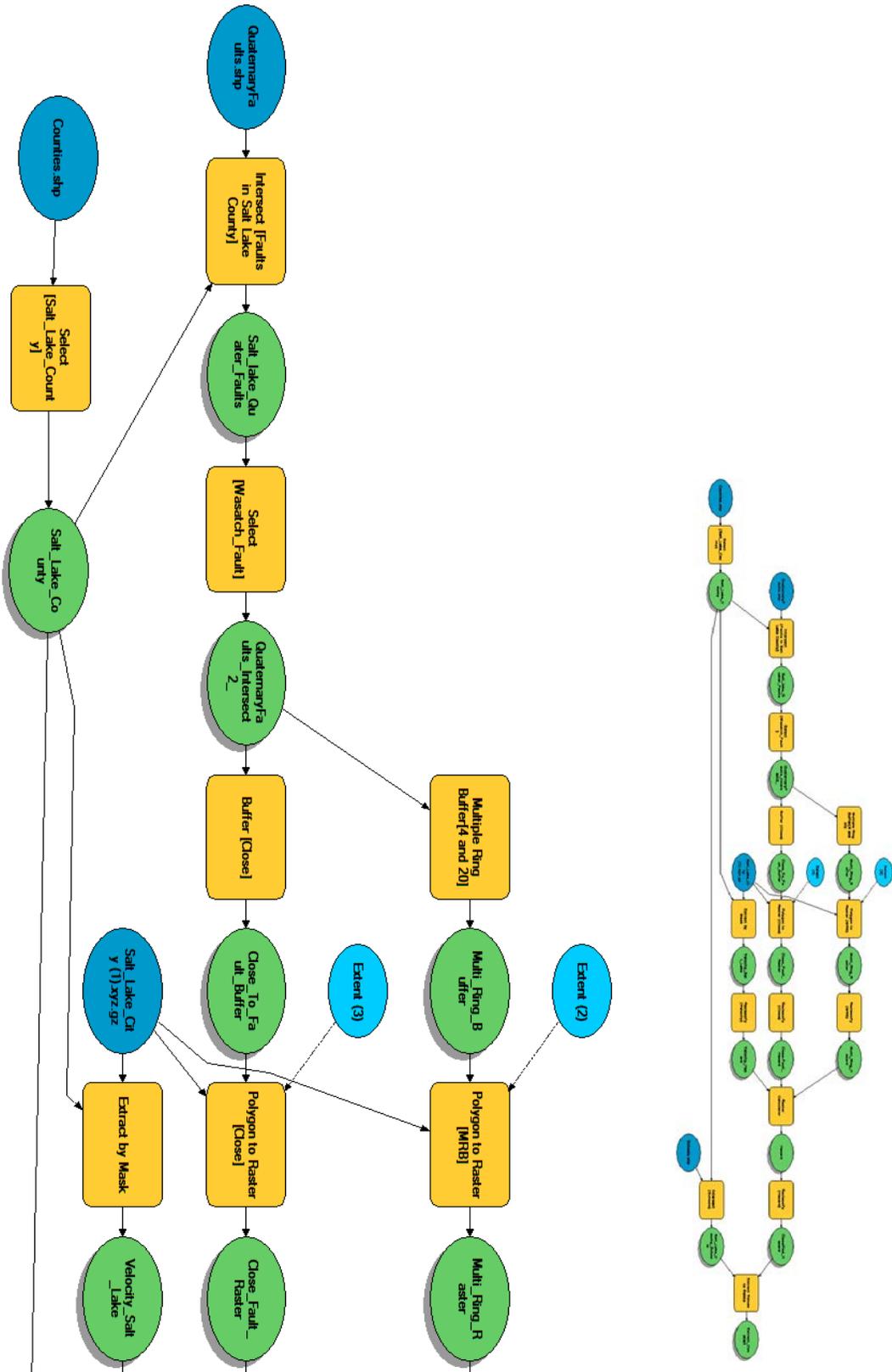
*Extract by Mask:* Extracts the cells of a raster that correspond to the areas defined by a mask.

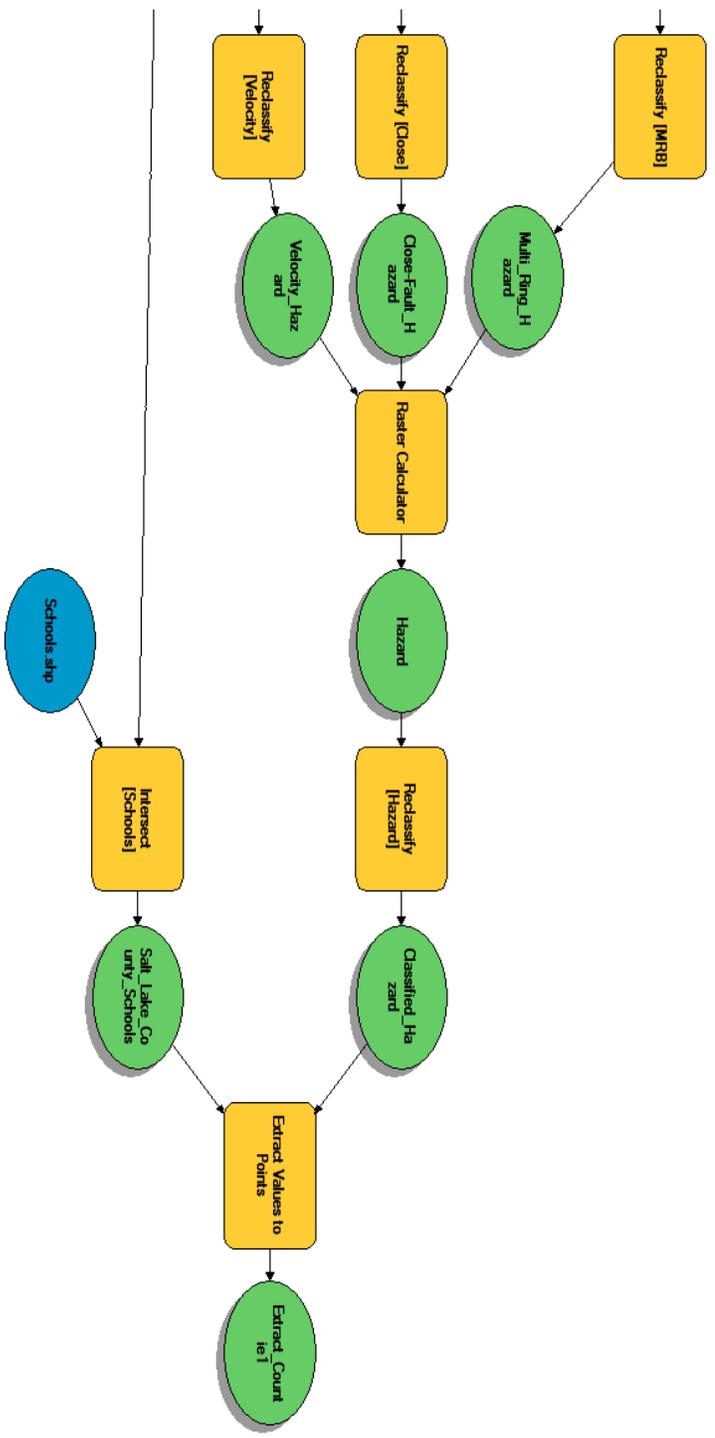
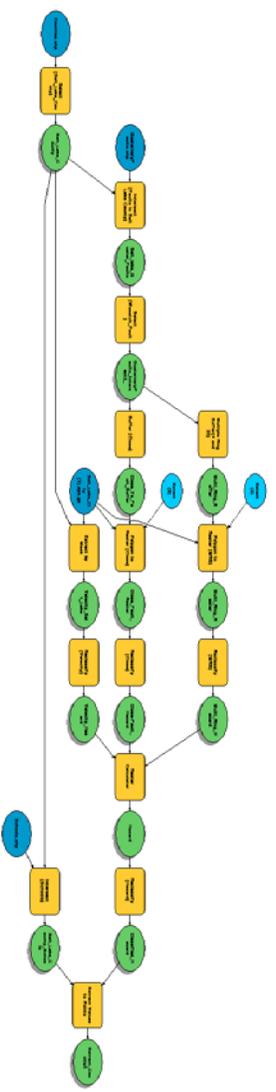
*Reclassify:* This tool lets you identify ranges of old values in a raster, and then change those values to new values that you can put into the tool.

*Multiple Ring Buffer:* Creates multiple buffers at specified distances around the input features.

*Raster Calculator:* Builds and executes a single Map Algebra expression using Python syntax in a calculator-like interface

# Example Model





## Step by Step Solution

### Step 1

One of the data sets that you have downloaded does not have a projection associated with it. The Shear Wave Velocity raster needs to be georeferenced so you can use it in your model. Georeferencing was explained in Lab 2. We found that the easiest way to place sites was to find the shore and Islands of Utah Lake.

### Step 2

Your project will be focused on the Salt Lake County area within Utah. Using the Select tool, we can use our Counties shapefile as the input. The Expression should be filled out as **"NAME" = 'SALT LAKE'** to extract Salt Lake County.

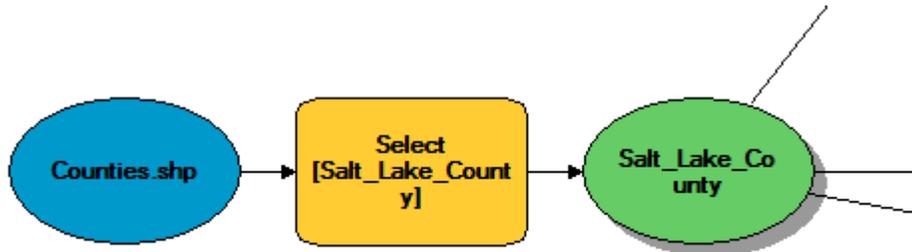


Figure 1 Using the Select tool in ModelBuilder

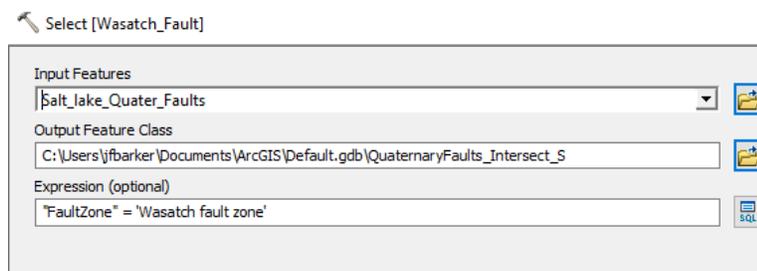


Figure 2 Inputs and expression used in the Select tool

### Step 3

In this step, we will use the intersect tool to show the mapped faults found in the county. Make sure that the quaternary faults shapefile and the newly selected county shapefile appear as inputs in the Intersect tool. This process will decrease the time it will take to run the model.

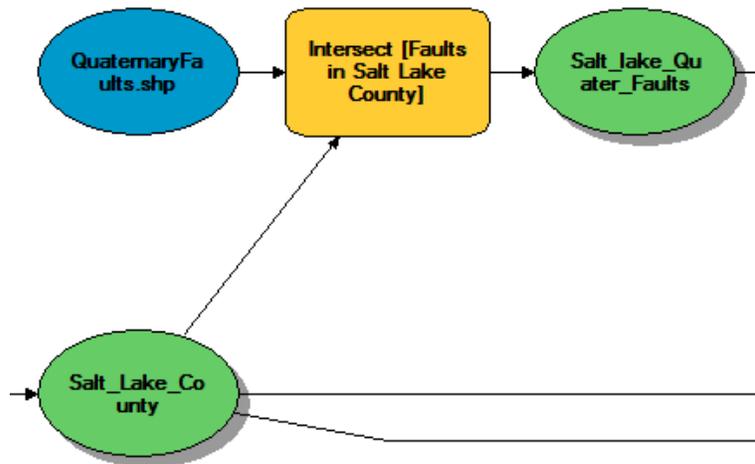


Figure 3 Using the Intersect tool

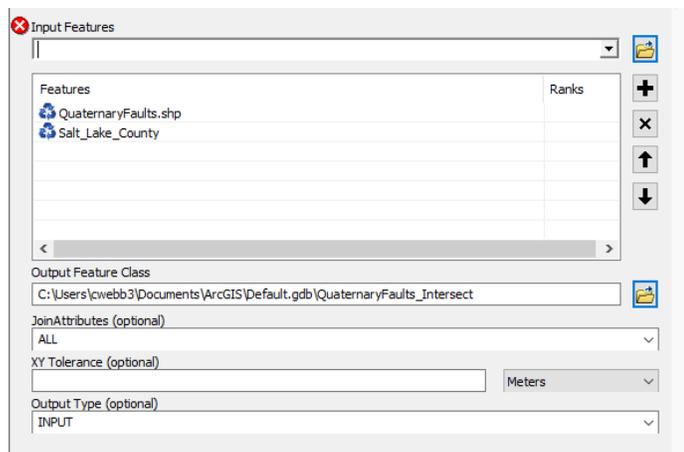


Figure 4 How to access the Intersect tool window and input shapefiles

### Step 4

There are many minor faults that have formed as a result of extensional stresses along the Wasatch Front. The fault that would provide the most slip and destruction would be the Wasatch Fault. We will use the select tool to extract only this fault. The SQL expression should be typed into the Expression box as "**FaultZone**" = '**Wasatch fault zone**'.

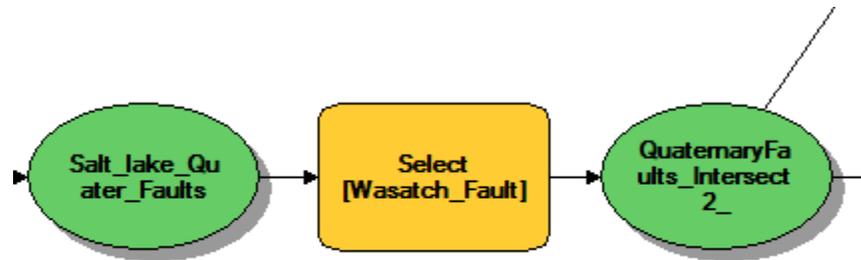


Figure 5 Using the Select tool on the faults

### Step 5

We will create two buffers using the new Wasatch Fault Line shapefile. The first is a buffer is the closest at only .5 miles. Make sure to select 'Round' End Type and 'ALL' in the Dissolve Type. This small buffer is used to represent the fault scarp. The fault scarp is an offset on the ground surface indicating that one side of the fault has violently moved vertically with respect to the other side. The scarp could destroy houses, rupture major water, sewer, power, and electrical lines.

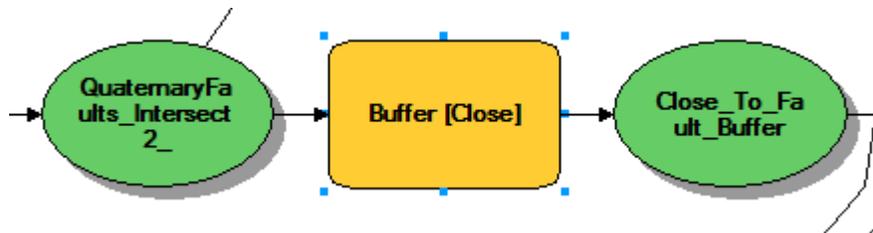


Figure 6 Using the Buffer tool in ModelBuilder

### Step 6

You will then need to create a second, Multiple Ring, Buffer around the fault. In the Box labeled distances, we want to add distances every 4 miles from 4 to 20 miles. Make sure that Miles are selected and that Dissolve is turned on.

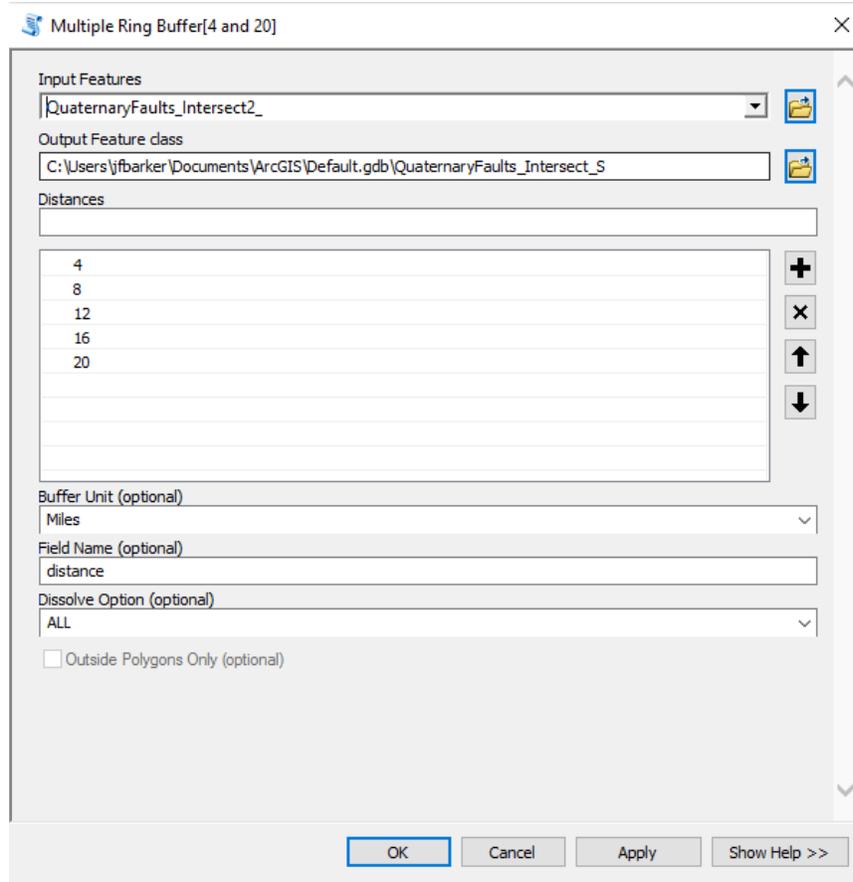


Figure 7 Accessing the Multiple Ring Buffer window

### Step 7

The next steps involve getting the raster ready for the Raster Calculator tool. First, we need to convert the polygon we created through the buffer into a Raster output. In order to be safe, you may want to add your georeferenced Shear Wave Velocity shapefile into the cell size box. Once you have your raster, you can now reclassify each of the buffers as shown in the figure below. The range 8-12 should have the highest number, 10. (See figure 9) This range is where the predicted epicenter is located. Normal faults rupture 8-12 km below the Earth's surface. The fault dips 45\*, projecting the epicenter into the valley.

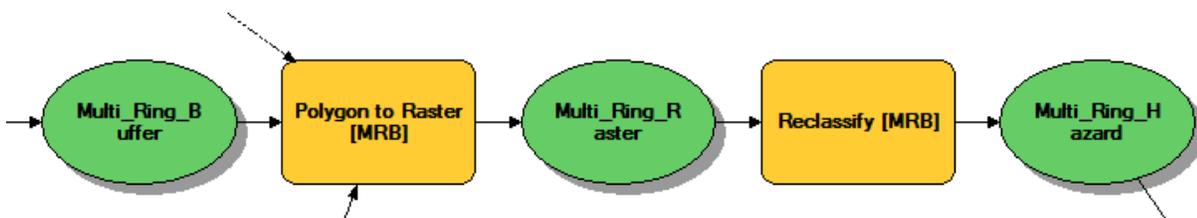


Figure 8 Using the Polygon to Raster and Reclassify tool in ModelBuilder

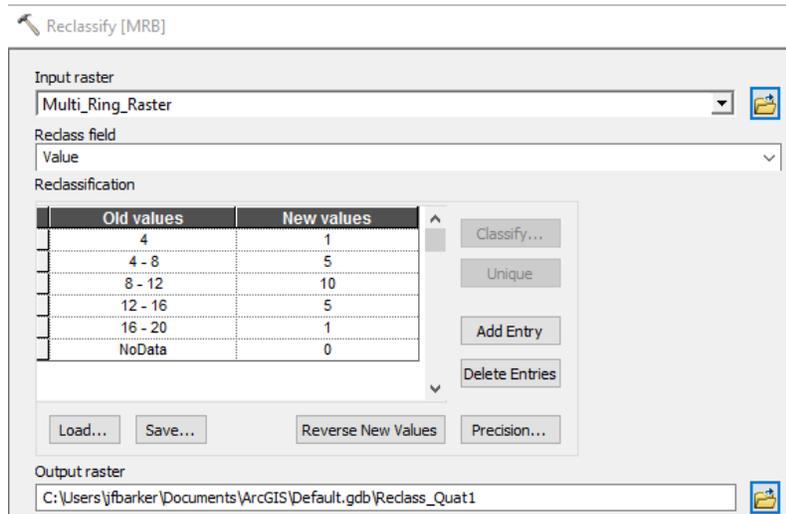


Figure 9 Reclassify window in ModelBuilder

### Step 8

The same process needs to happen to the Polygon output formed from the closer buffer. It is a good idea to use the same cell size, such as the Shear Wave shapefile. The reclassification tool is much easier to set up in this step. The reclass field should read 'Value' and the Reclassification should only have two lines. One stating old values of 1 are now 10 and another stating that NoData should now equal 1. This gives the area directly on the fault scarp high priority.

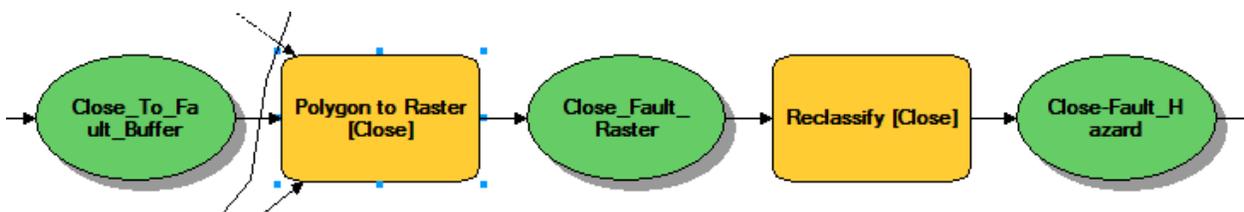


Figure 10 Using the Polygon to Raster and Reclassify tools in ModelBuilder

### Step 9

Next, we need to extract out the portion of the Shear Wave Velocity raster that is located within Salt Lake County. This is done by using the Extract by Mask tool. You should make sure to select the Salt Lake County shapefile in the Input Raster or Feature Mask Data box.

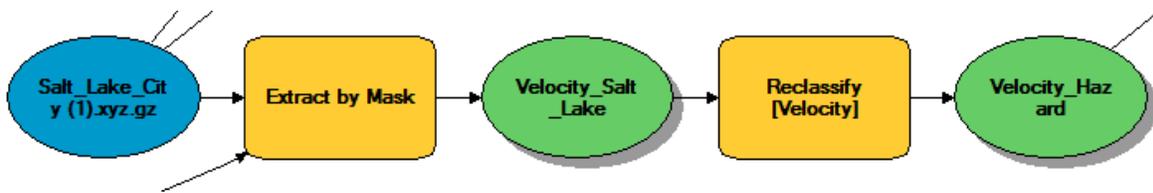


Figure 11 Using the Extract by Mask and Reclassify tool in ModelBuilder

You will then need to use the Reclassify tool for the third time in order to prioritize the risk associated with shear wave velocity differences. These values are shown in the figure below. Notice that the lower shear wave velocities have higher associated risk levels. This is due to the unconsolidated nature of sediments with lower Shear Wave Velocities. (See figure 12)

Old values	New values
150 - 220	10
220 - 290	9
290 - 360	8
360 - 430	7
430 - 500	6
500 - 570	5
570 - 640	4
640 - 710	3
710 - 760	2
NoData	NoData

Figure 12 The values inputted into the Reclassification box of the Reclassify window

## Step 10

You will then need to use the Raster calculator to multiply all three of the Reclassified outputs. These multiplied rasters will form an output called Hazard that you will reclassify.

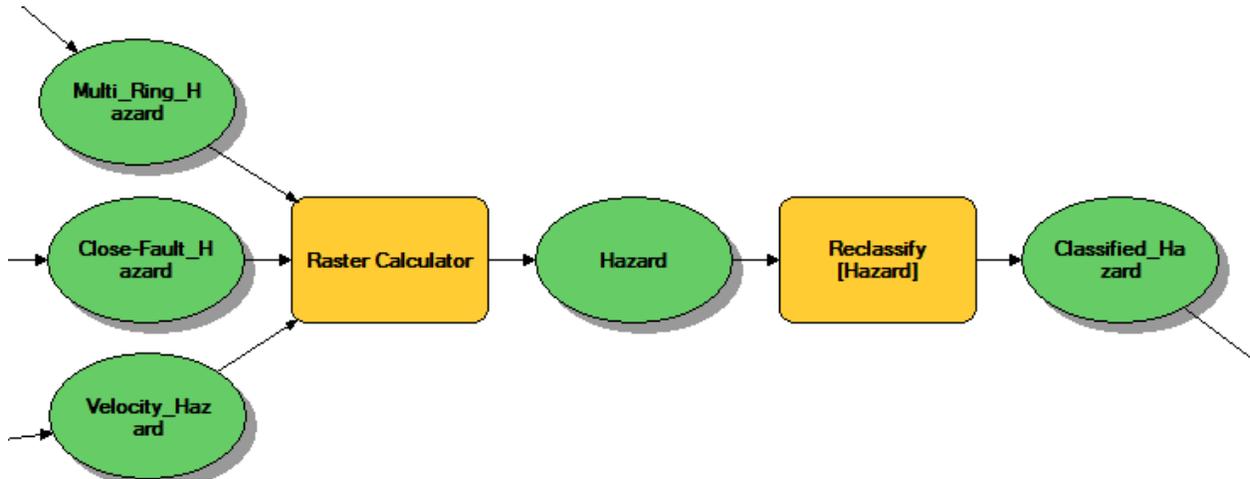


Figure 13 Combining reclassified outputs in Raster Calculator and reclassifying the Hazard Raster

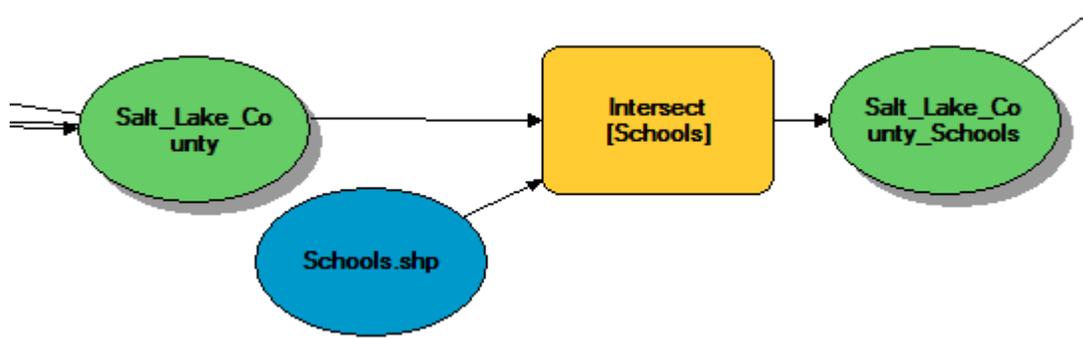
You will reclassify the hazard raster into 9 categories to relatively separate the risk from 1 (low risk) to 9 (high risk). Each of these categories should be separated as seen in Figure 14.

2 - 10	1
10 - 20	2
20 - 30	3
30 - 40	4
40 - 50	5
50 - 60	6
60 - 70	7
70 - 85	8
85 - 100	9
NoData	NoData

Figure 14 The values for the reclassification of the Hazard raster

### Step 11

You need to bring in the locations of the schools within Utah county. To accomplish this, you will intersect the Salt Lake County polygon with the Schools shapefile to identify only those schools that reside in Salt Lake County.



### Step 12

You will use the Extract Values to Points tool in this step of the Model.

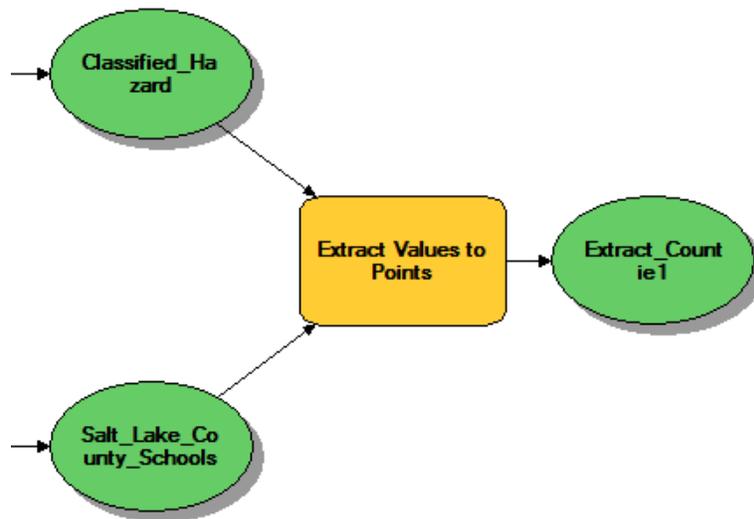


Figure 15 The Extract Values to Points tool in ModelBuilder

In this tool, you will input the point features, Schools, and input the raster that you created after reclassifying the Hazard raster.

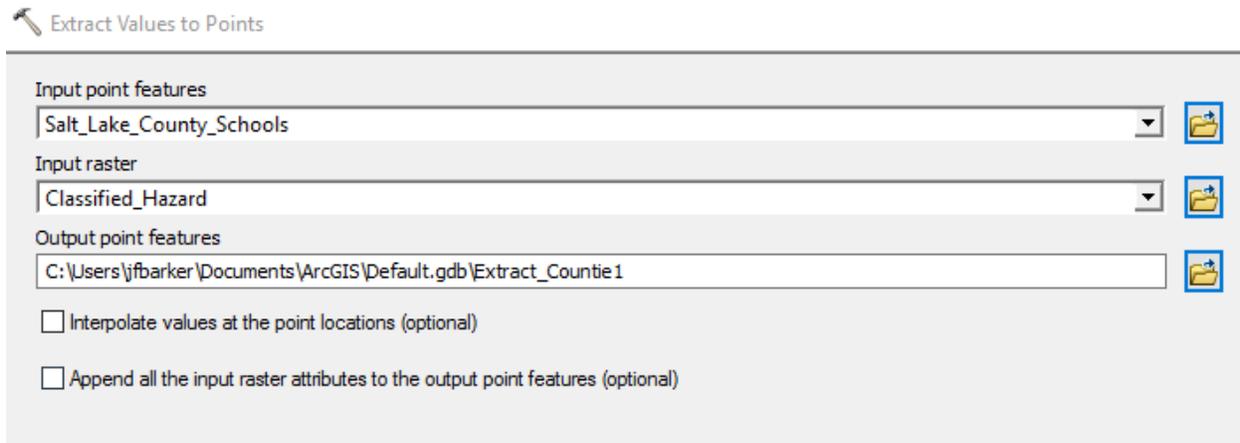


Figure 16 Accessing the Extract Values to Points window

### *Step 13*

In this step, you will create a hazard assessment based on the age of the school. Open the attributes table and start an editing session. Create a new field in the school shapefile for the hazard values. Manually enter 1, 2, or 3 into the table indicating what year the school was built. Label “1” for school built since 1985, “2” for schools built from 1950 to 1985, and a “3” for schools older than 1950.

### *Step 14*

Add another field called “total\_risk” to the School attributes table. Right click on the new field and select field calculator. Multiply the fields in columns created in steps 12 and 13. Order the new values into ascending order to locate the schools at highest risk for structural failure. Select the schools with total risks of higher than 15.

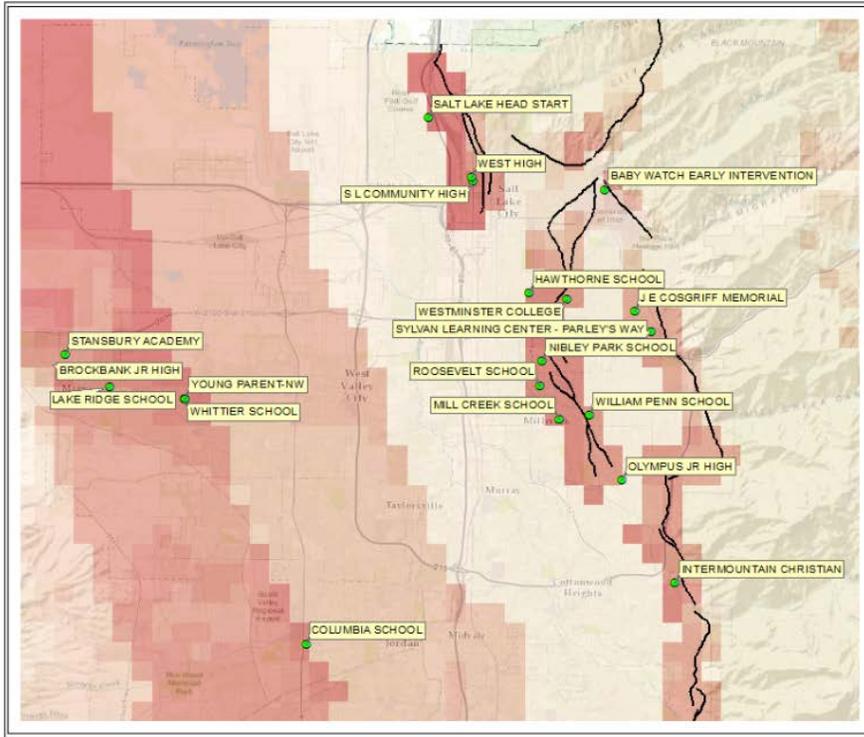
## **Deliverables**

For schools in Salt Lake County, construct a single ArcGIS ModelBuilder model that will prepare all of fault, schools, shear wave, and county data for an earthquake hazard analysis. You may need to prepare the school fields, map coloring/symbology, and shear wave georeferencing outside of ModelBuilder.

Prepare a report in the form of a document that presents your final model and clearly shows all elements of the model. Describe the steps and tools in your model and present your final map. Also include any changes you made to the reclassifications or analysis and why you chose those methods. Make sure to review over the rubric at the end of this chapter for the full requirements for the laboratory exercise.

# Example Map

Earthquake Hazards and at Risk Schools



**Legend**

- At Risk Schools
- Wasatch Fault

**Hazard Level**

1 (Lower Hazard)
2
3
4
5
6
7
8
9 (Greater Hazard)



Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS

Map Name \_\_\_\_\_  
 Date \_\_\_\_\_  
 Projection \_\_\_\_\_

## Rubric

Item	Points
Assignment Title, Author Name, Date, Course Name	/5
Brief summary of the requirements of the project	/5
Describe your model <ul style="list-style-type: none"> <li>• List each of the tools used: (2 pts)</li> <li>• List tool settings applied for the analysis (could someone repeat the assignment using your lab report?): (2 pts)</li> <li>• List all input, intermediate, and output datasets: (2 pts)</li> <li>• Describe each input dataset including type (point, line, polygon, raster) and the source of the data: (2 pts)</li> <li>• Describe each output dataset (point, line, polygon, raster): (2 pts)</li> </ul>	/10
<ul style="list-style-type: none"> <li>• One full page (<b>8.5x11</b>) showing your model (5 pts)</li> <li>• All text is readable (<b>10 point font minimum</b>) (3 pts)</li> <li>• All tools and data sets are shown (2 pts)</li> </ul>	/10
Make a full page ( <b>8.5x11</b> ) map showing the results of your avalanche hazard study of the Snowbird Ski Resort area. <ul style="list-style-type: none"> <li>• Map Title: (1 pt)</li> <li>• Neat Line: (1 pt)</li> <li>• North Arrow: (1 pt)</li> <li>• Scale Bar: (1 pt)</li> <li>• Text box with author name, date, map projection: (1 pt)</li> <li>• Each risk category clearly symbolized: (1 pt)</li> <li>• Labeled roads or other reference data: (1 pt)</li> <li>• Labeled points indicating location of ski resorts in the study area: (1 pt)</li> <li>• Zoomed to an appropriate scale for viewing analysis results: (1 pt)</li> <li>• All text is legible on printed map: (1 pt)</li> </ul>	/15