

Outcrop suitability analysis of blueschists within the Dry Lakes region of the Condrey Mountain Window, North-central Klamaths, Northern California

(1) Introduction:

This project proposes to assess the landscape of the Dry Lakes area within the Condrey Mountain Window in the Klamath Mountains of northern California and southern Oregon to find the most probable locations for blueschist outcrops within the region on the basis of slope analysis, road cuts, river cuts, and satellite imagery. The data collection and processing is documented below, and the final result will be a map of the Dry Lakes area within the Condrey Mountain Window highlighting the best localities to search for blueschist outcrops.

(2) Data collection:

Data for this project has been collected from a variety of sources which are listed below.

1. Vector data and shapefiles for the geologic map were generously provided by Dr. Mark Helper who helped to map the area and later digitize the files that were used for this project. Specific information that was used for the final product were the shapefiles for the mapped blueschist regions.
2. River and hydrologic data provided were obtained from the National Hydrography Dataset of the USGS (<http://nhd.usgs.gov/>). The specific dataset used for this project was for the Klamath region of northern California (NHD_1801_Klamath-Northern_California_Coastal_HU4).
3. Road data for the entirety of California was obtained via mapcruzin.com
4. Landsat 8 multispectral satellite imagery was obtained from the USGS (<http://landsatlook.usgs.gov/viewer.html>).
5. Digital Elevation Model data was also generously provided by Dr. Mark Helper who obtained it via the Bureau of Land Management (BLM) in California.

(3) Data preprocessing:

The first preprocessing step necessary was to download and obtain usable satellite imagery for analysis. The procedure below describes the process.

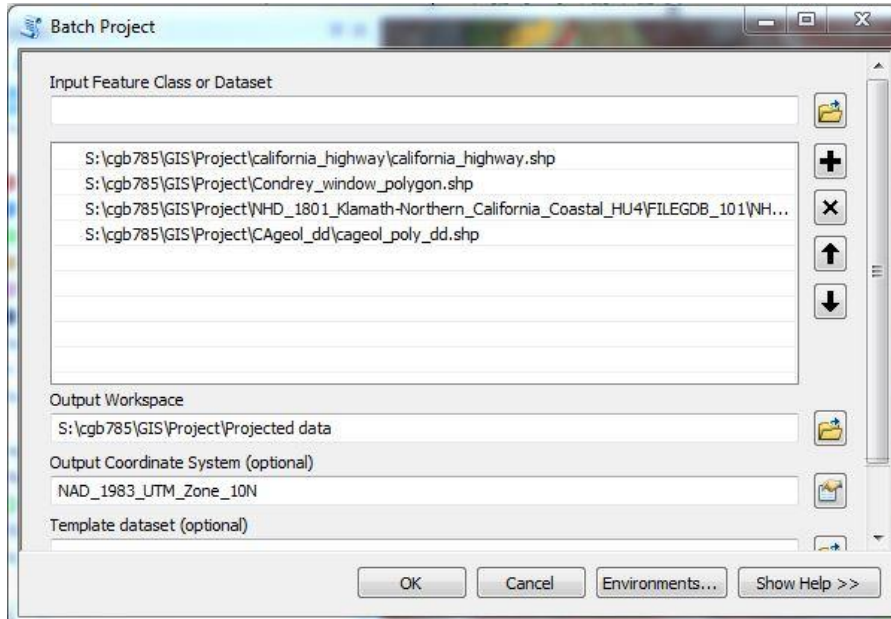
3.1 Landsat data preprocessing

Downloading: To download the Landsat 8 imagery the USGS Landsat Look explorer site linked above was utilized to zoom to the study area of northern California to search for recent imagery. The image used in this project was from the 23rd of November, 2015. Once an image was selected, it was added to a cart (you must register a free account with the USGS site to access the data), and downloaded as a compressed file. To access the actual data, the Bulk Download Application provided for free by the USGS was used to download the large file to a compressed format on local space on the computer, which was then unzipped to obtain the 9 GEOTIFF image bands.

(4) ArcGIS Processing:

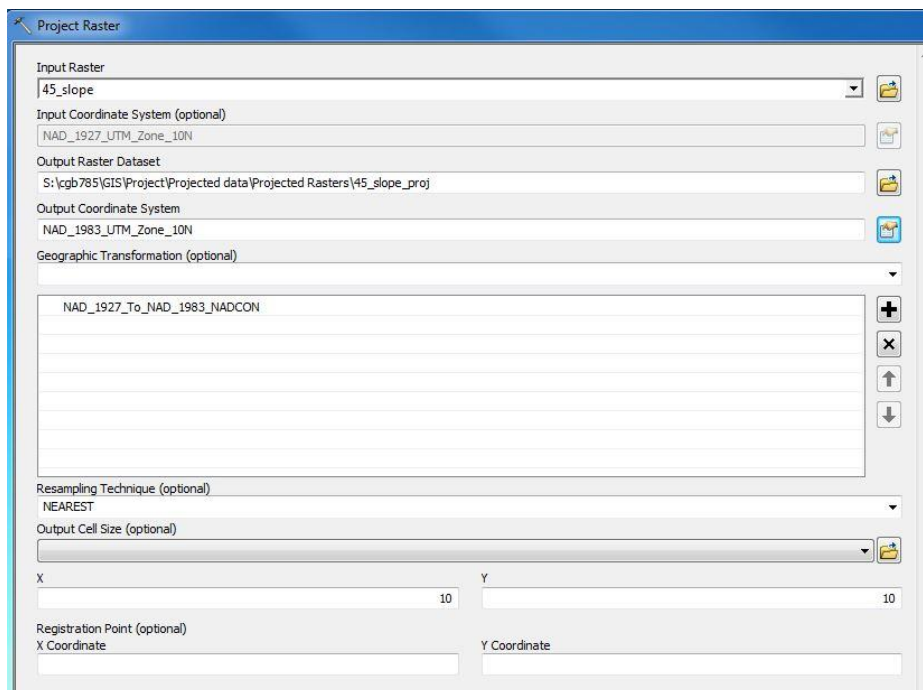
Next, the data was manipulated in several ways using various tools in ArcGIS to obtain the necessary data needed for outcrop suitability analysis. Major procedures are outlined below.

4.1 - Obtaining the same spatial reference for all data



The first step to obtain usable data was to format it such that the data could be useful when displayed on the same screen. This meant making sure all files (vector files, DEMs, satellite imagery, shapefiles, etc.) were in the same spatial reference and same projection so that there were no discrepancies or errors when displaying different data over the same area. For the vector

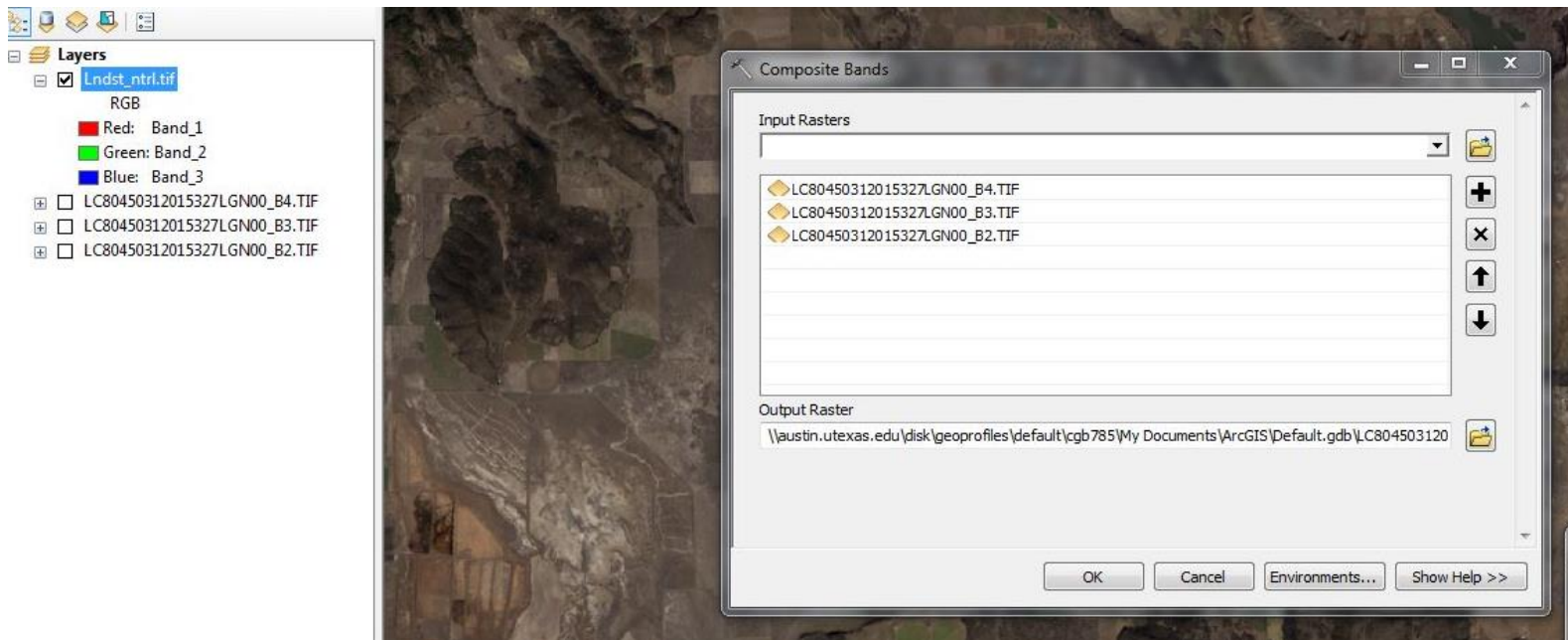
data, such as the rivers, roads, and polygons of rock units, the tool “Batch Project” under the “Data Management” toolbox was used. This tool takes vector data from varying spatial references and converts it to a spatial reference and projection that is specified. For this project, *all raster and vector data was projected and converted to NAD1983, UTM Zone 10N*.



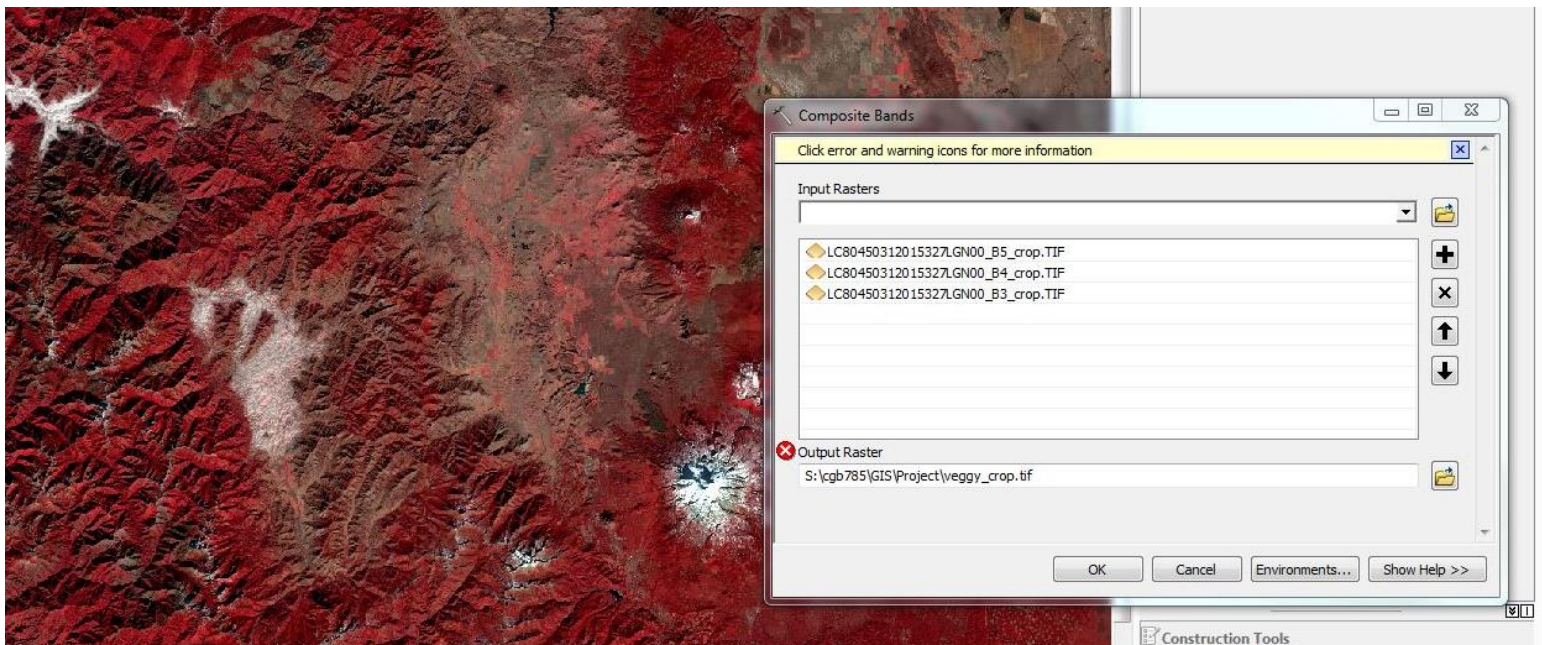
For raster data, a similar tool called “Project Raster” under the “Data Management” toolbox was used to project all raster data such as the individual Landsat 8 bands and the DEM to NAD1983 UTM Zone 10N, as shown in the picture to the left. All data used from this point on was used after projecting to the correct coordinate system.

4.2 - Compositing bands

Because Landsat imagery is multispectral, the data comes in 9 different bands that have to be combined in combinations of 3 bands to produce a color image. For Landsat 8 data, bands 4, 3, and 2 have to be combined to be displayed in the Red, Green, and Blue color channels within ArcMap respectively to obtain a “natural color” image. For this, the tool “Composite Bands” under “Data Management” tools was used.

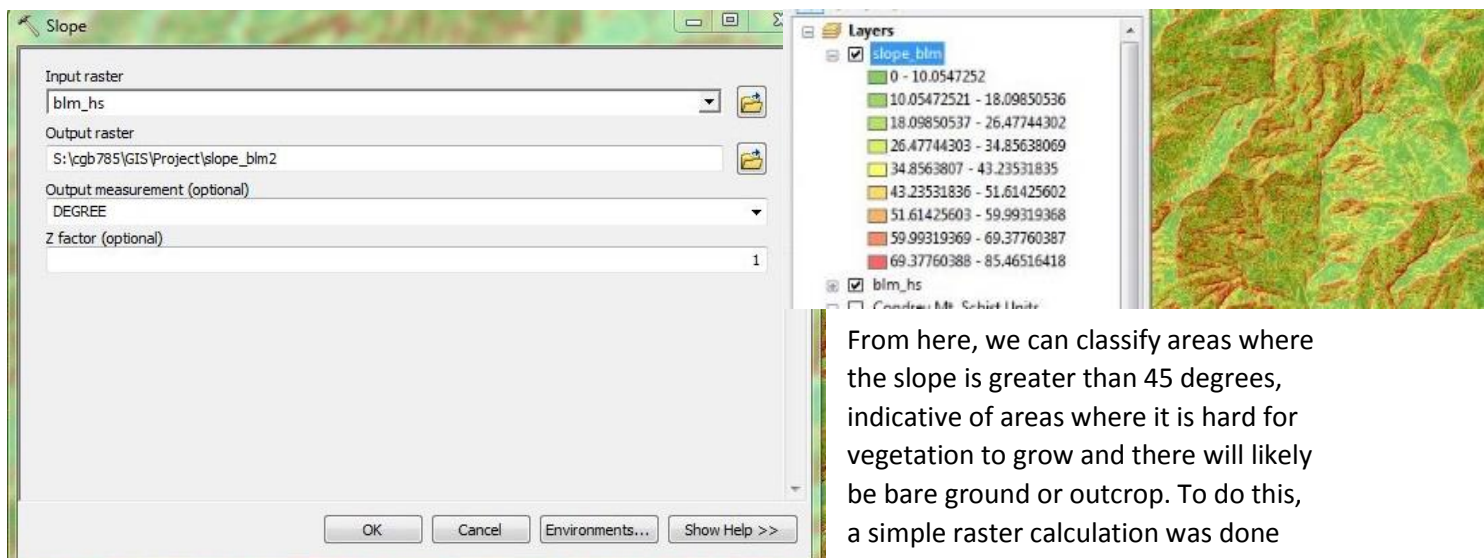
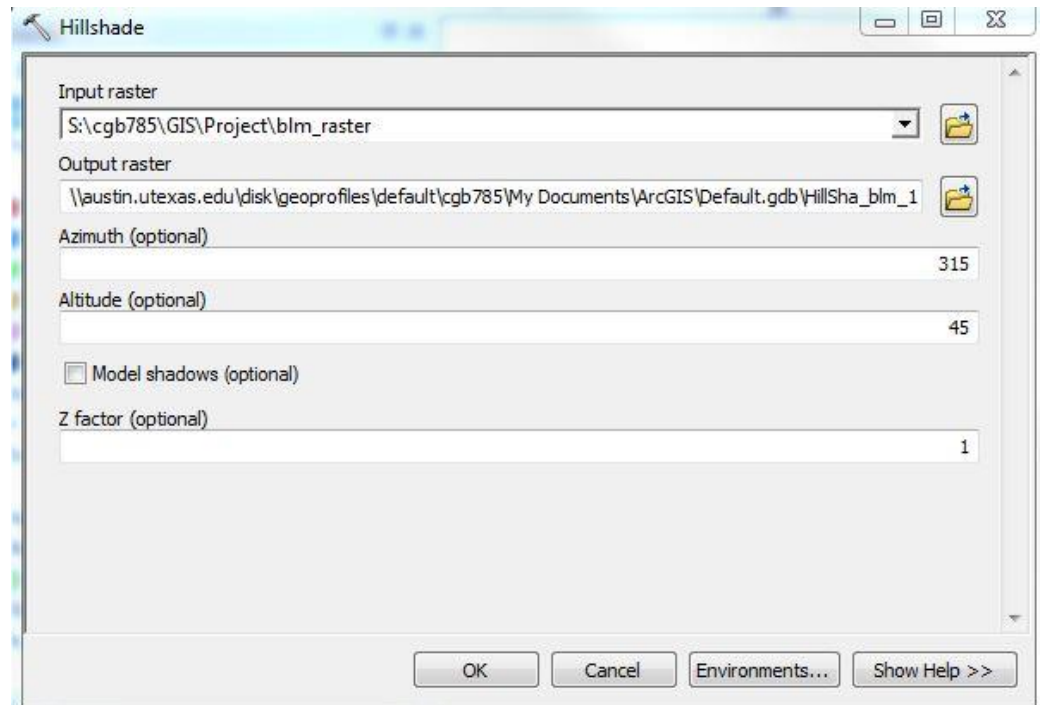


Next, a false color vegetation image was created using the same process above, but using the 5, 4, and 3 bands for the R, G, and B color channels respectively. With this band combination, vegetation is easily shown in shades of red while non-vegetated areas maintain their natural colors.



4.3 - Creating a hillshade and slope map

Next, a hillshade was created from the Digital Elevation Model (DEM) using the “Hillshade” tool under the “Spatial Analyst” toolbox, as shown. Along with the hillshade, a slope map was also created from the DEM to obtain a raster of slope values ranging from 0-90 degrees. This was done using the “Slope” tool under the “Spatial Analyst” toolbox as shown below.



From here, we can classify areas where the slope is greater than 45 degrees, indicative of areas where it is hard for vegetation to grow and there will likely be bare ground or outcrop. To do this, a simple raster calculation was done using the “Raster Calculator” tool



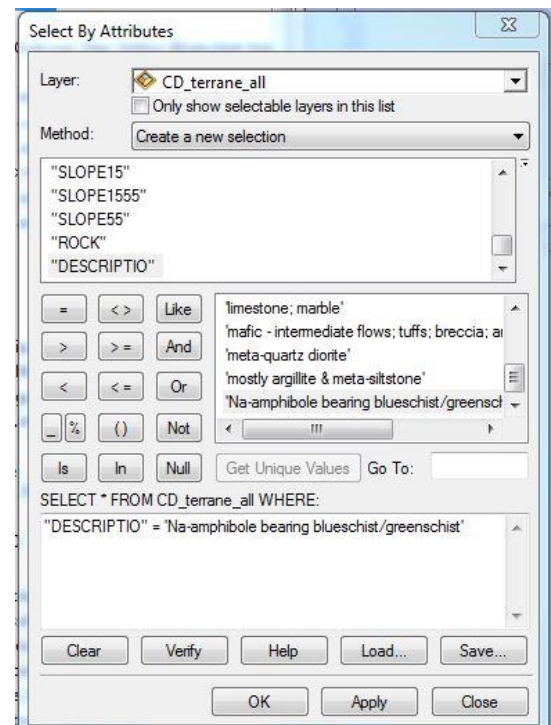
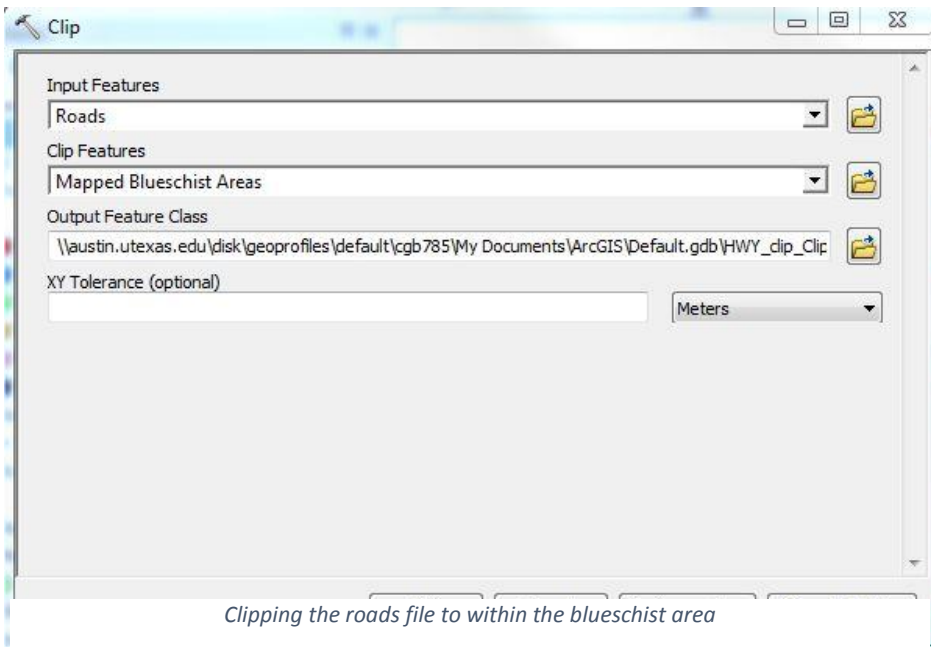
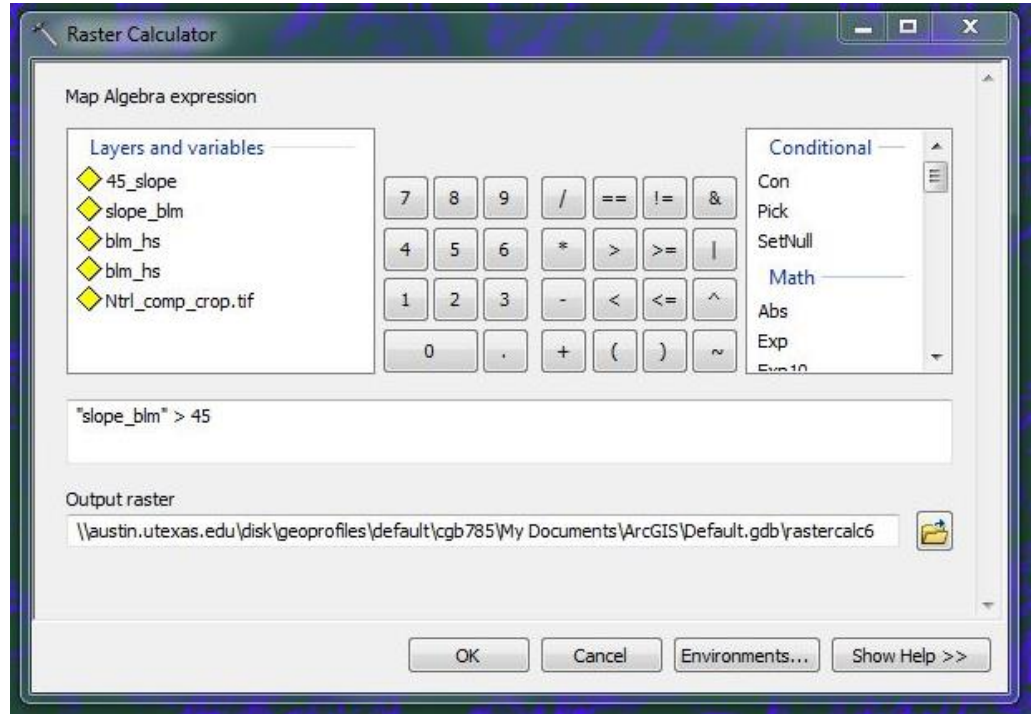
Slope map showing areas that have slopes greater than 45 degrees

under the “Spatial Analyst” toolbox, which was instructed to produce a new simple raster (of only 1s and 0s) showing where the slope was greater than 45 degrees.

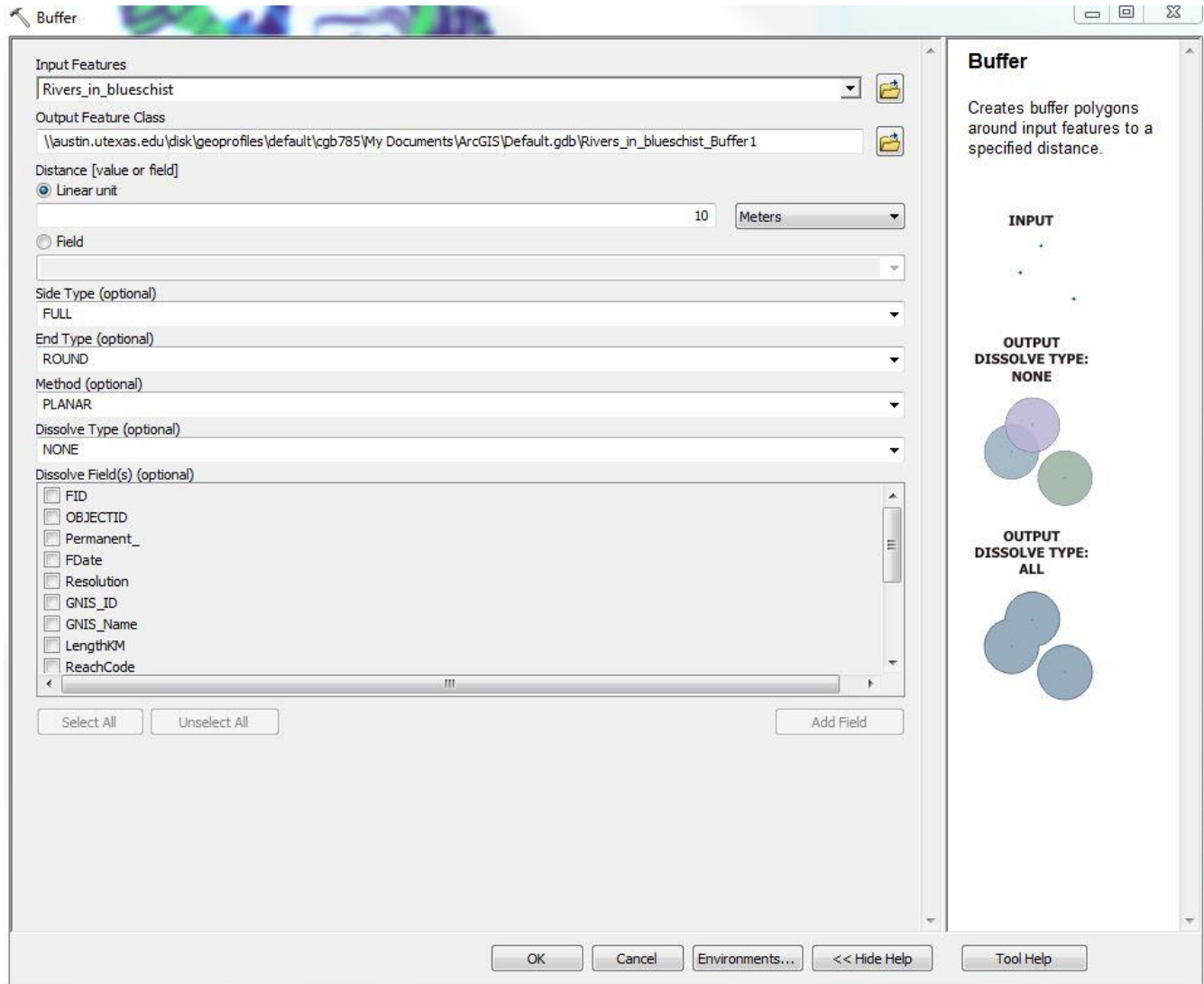
4.4 - Finding intersections of roads and streams with blueschist areas

Next, we wanted to find areas where there are roads or rivers within the mapped blueschist area in hopes of finding roadcuts or river cuts where outcrops will be exposed. To do this, we first had to extract only the polygons for the blueschists from the geologic map. This was done by simply selecting "Select by attributes", specifying the geologic map polygon file as the source layer, and selecting where "DESCRIPTION" = "Na-amphibole bearing blueschists/greenschists." This allowed us to only select the blueschist polygons, from which we then right clicked the geology polygon layer > "Selection" > "Create layer from selected features." We now have a layer file of only the blueschist outcrops.

Now in order to find roads that are within this blueschist polygon, the tool "Clip" under the "Analysis" toolbox was used to clip the roads file to only roads that are within the boundaries of the blueschists, as shown below. The same process was done for the Rivers file to extract river sections that were within the blueschist area.

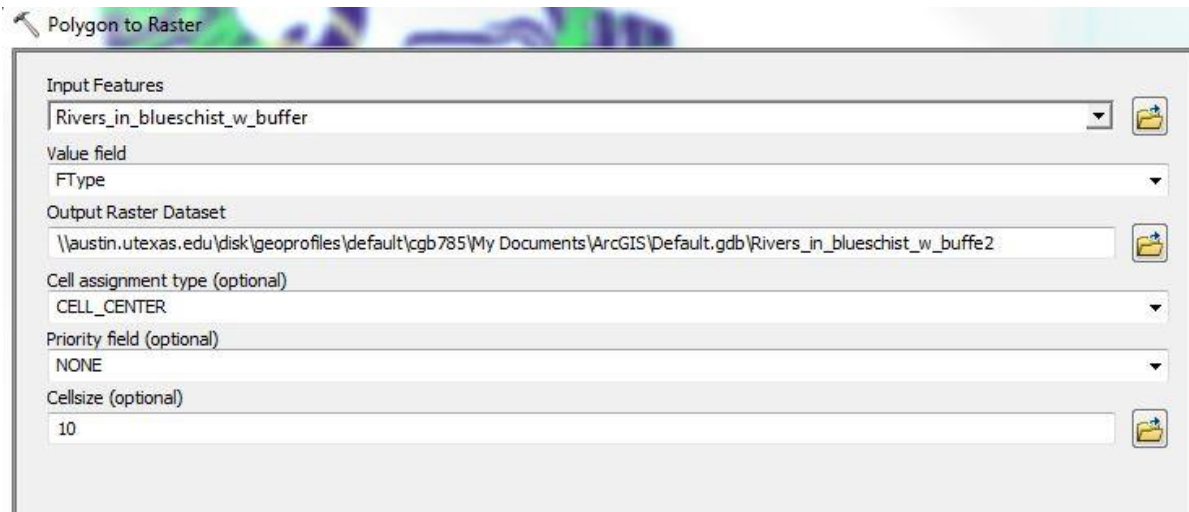


Roads and rivers within the blueschist areas were then buffered with a 10m radius on either side using the “Buffer” tool under the “Analysis” toolbox.



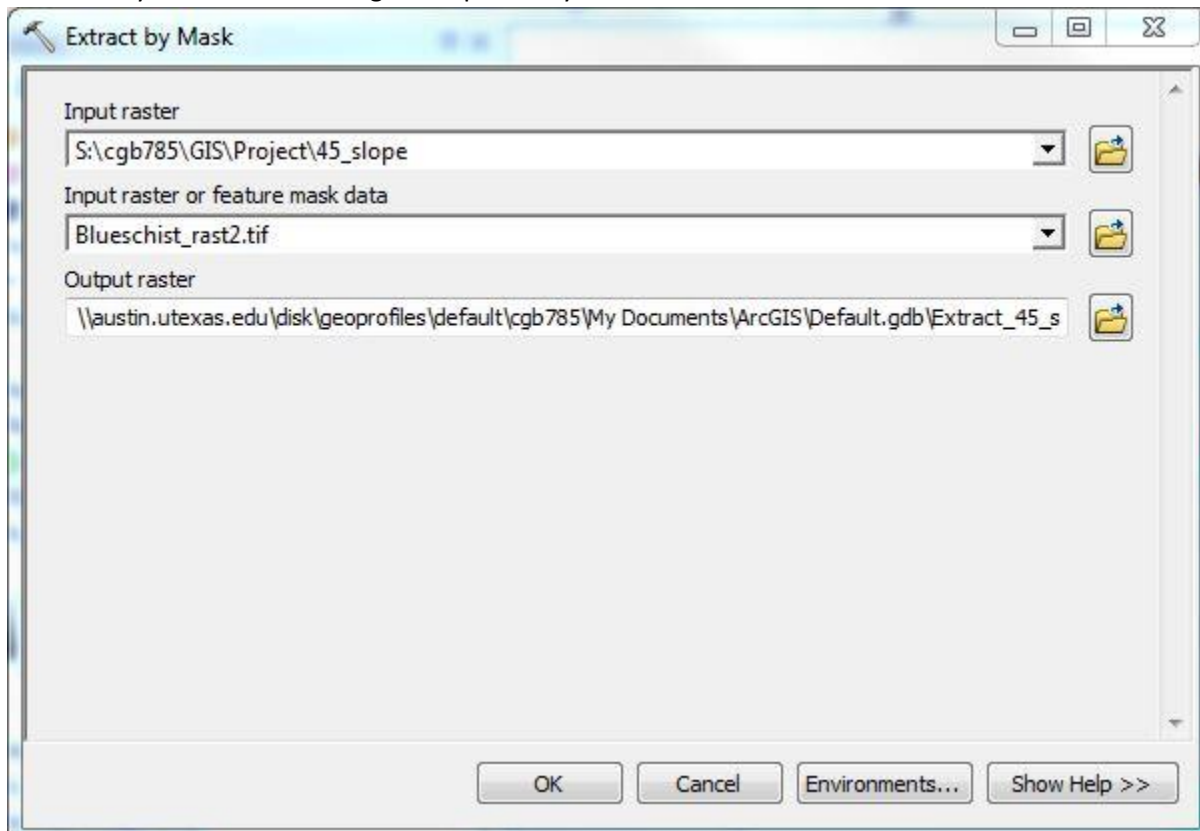
4.5 - Creating rasters from vector data

The next step necessary perform raster calculations was to get all data in raster form, which at this point was only the clipped roads and rivers within the blueschist areas and the blueschist polygon. To do this, the tool “Polygon to Raster” under the “To raster” toolset was used to convert the blueschist polygon to a raster with a cell size of 10m (the same resolution as the DEM and slope map). The same process was done with the buffered river and road layers also using a 10m resolution (if you remember, there was a 10m buffer on either side of the polyline, so using 10m resolution we expect a raster to be created with one 10m cell on either side of the polyline).

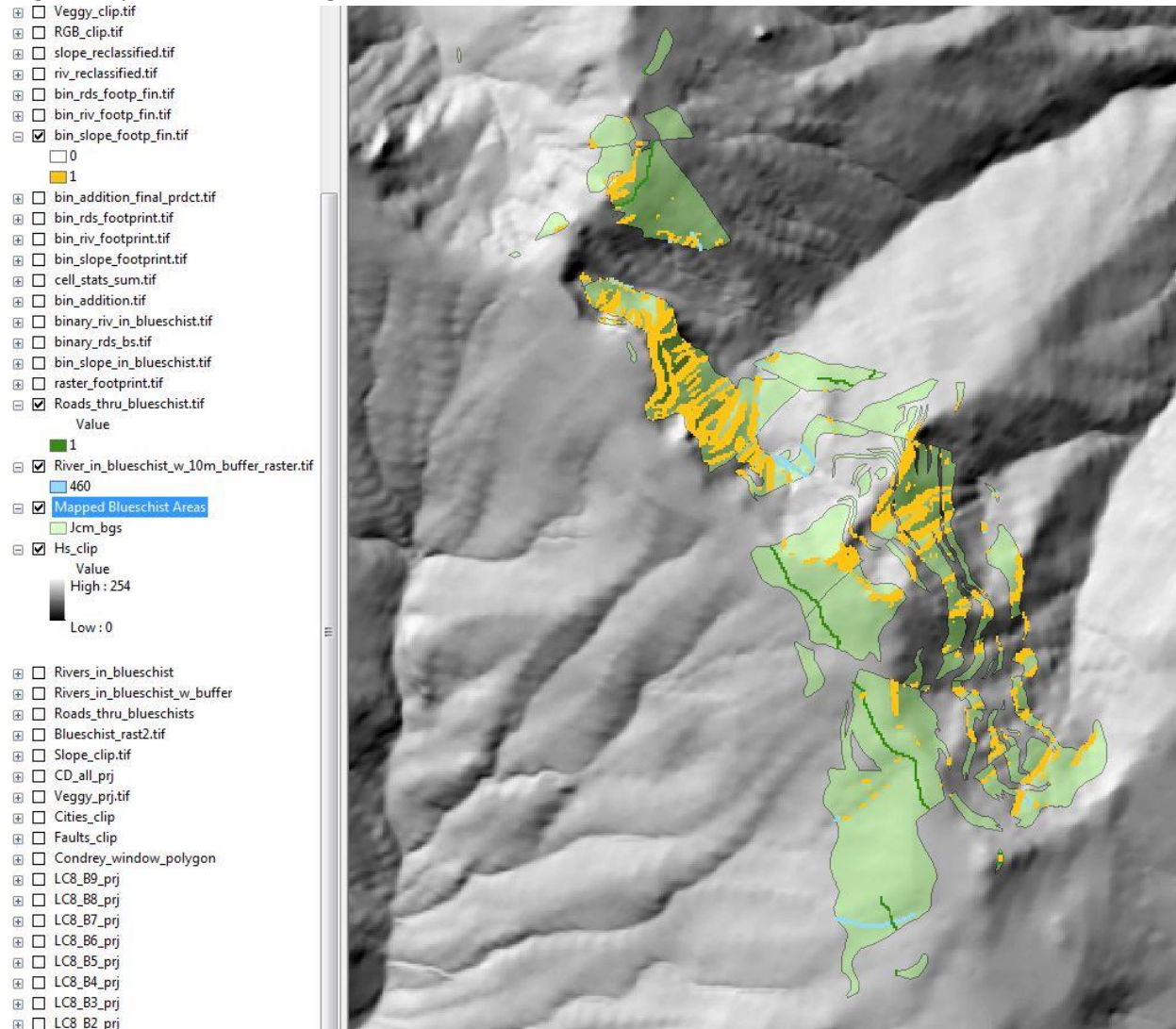


4.6 – Extracting > 45 degree slope areas within blueschist region

Up to this point we have created 2 simple rasters consisting of 1s and 0s which are the 10m buffered roads and rivers that are within the blueschist region. We need one more simple raster before we can continue, which is the areas where slope is greater than 45 degrees. Now that we have a raster of the blueschist area as well, we can use the “Extract by Mask” tool under the “Spatial Analyst” toolbox to extract only areas of the 45 degree slope binary raster that lie within the blueschist raster.



Once this has been done, we now have 3 simple binary rasters that tell us where roads, rivers, and >45 degree slopes exist within regions of blueschist!

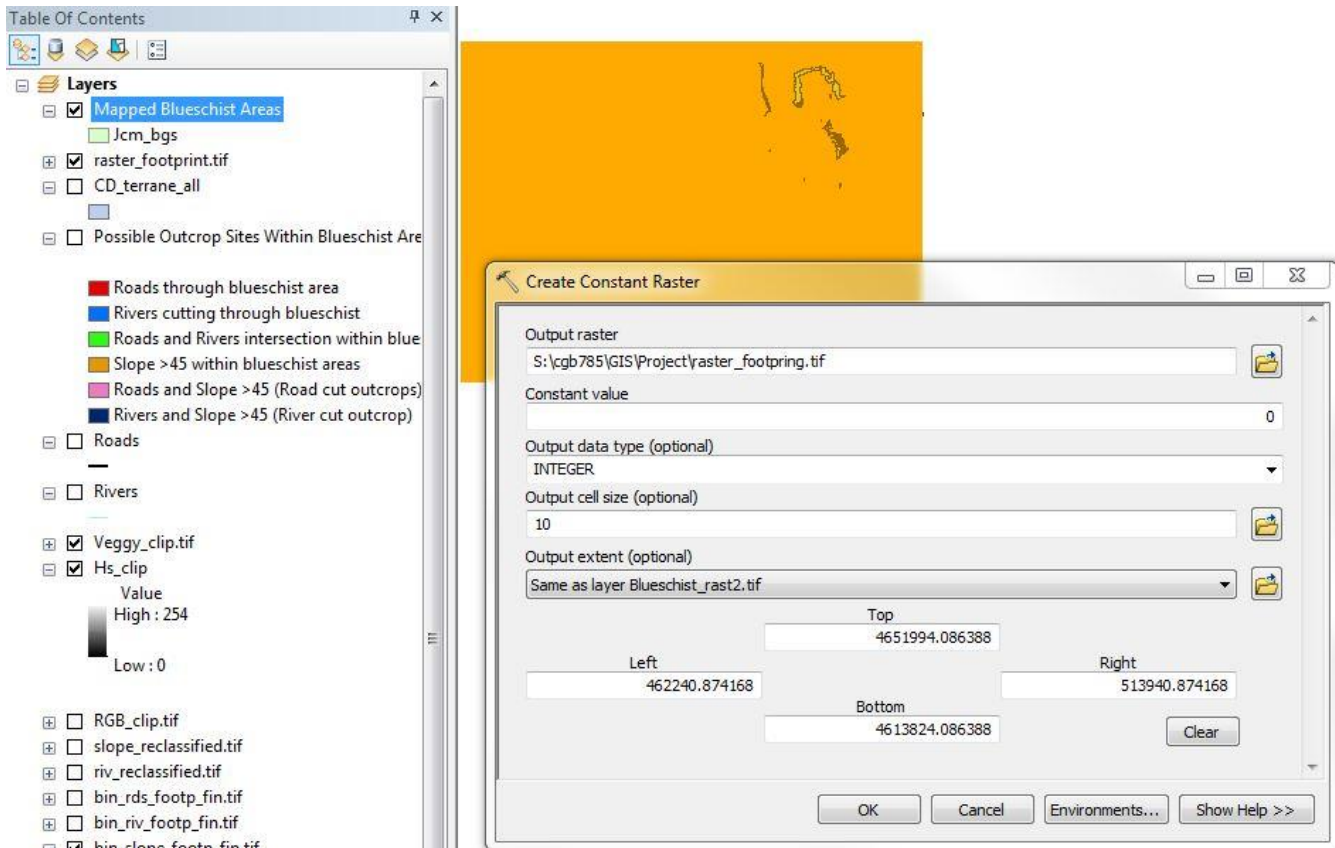


Screenshot showing areas of possible blueschist outcrops. Orange is >45 degree slope, Blue is rivers, and Dark green is roads

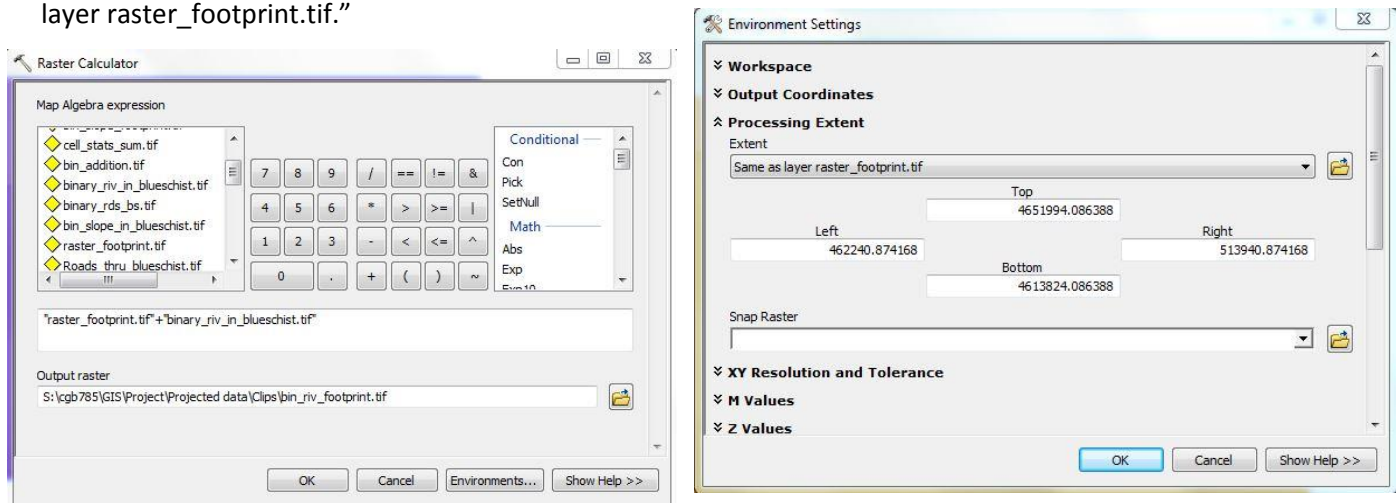
4.7 - Adding and reclassifying simple rasters

The next step in the process is to add the 3 simple rasters together to create one unique raster that has all localities present on it. However, since the simple rasters we created only have values with data within the extent of the specified area and not necessarily over the entire blueschist outcrop area, we need to make sure each simple raster has the same footprint. The first step to doing this was to use the tool "Create constant raster" under the "Spatial Analyst" toolbox to create a raster where all cell values are 0 and that has the extent of the entire region of interest. We can then add the smaller extent binary rasters to this constant raster to obtain a new binary raster that has the extent of the whole region of interest. When creating the constant raster, we select the "Output cell size" to be 10m (the same as our

binary rasters) and the “Output extent” to “Same as layer Blueschist_rast2.tif”, which is our previously created raster of the blueschist areas and fully encompasses the study area.

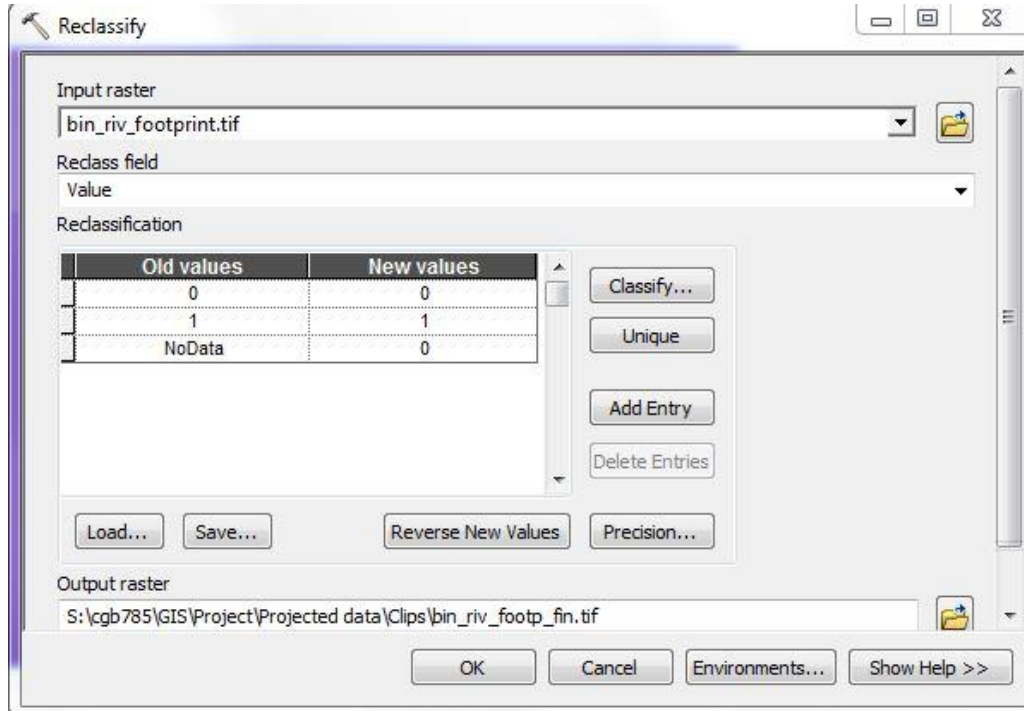


We are now ready to add our binary rasters to this. To do this we again use the “Raster Calculator” tool to add each binary raster to the constant raster footprint. An example is shown below adding the rivers binary raster to the footprint. Important step: You MUST click on “Environments” > “Processing extent” and change the extent to the same as the extent of the constant footprint raster, in this case “Same as layer raster_footprint.tif.”

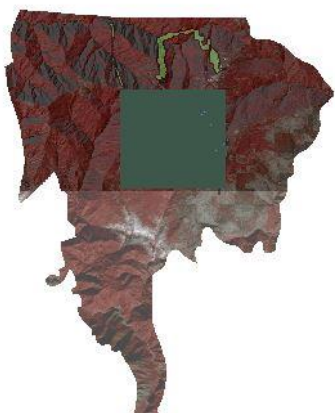


You can double-check to see if the new raster created has the same extent as the footprint by checking under “source” after clicking “properties” on the layer and checking the number of rows and columns.

At first the new simple raster will not appear to have the same footprint as the constant footprint raster, but this is because the areas where the two rasters do not overlap has been classified as "No data." We now need to reclassify the new raster so that "No data" cells are 0s instead of "No data." We now open up the "Reclassify" tool under the "Spatial Analyst" toolbox and select our new raster as the input. We want to keep 0 and 1 values as 0 and 1 but change "NoData" to 0, as shown below.



We now have a new binary raster of where the rivers are within the blueschist outcrops that has the spatial extent of the whole study area. The previous steps were done for the roads and slope binary rasters to obtain 3 binary rasters with the same spatial extent, which are now almost ready to be added together to form our final raster!



Extent shown in green before reclassifying "NoData" as zero

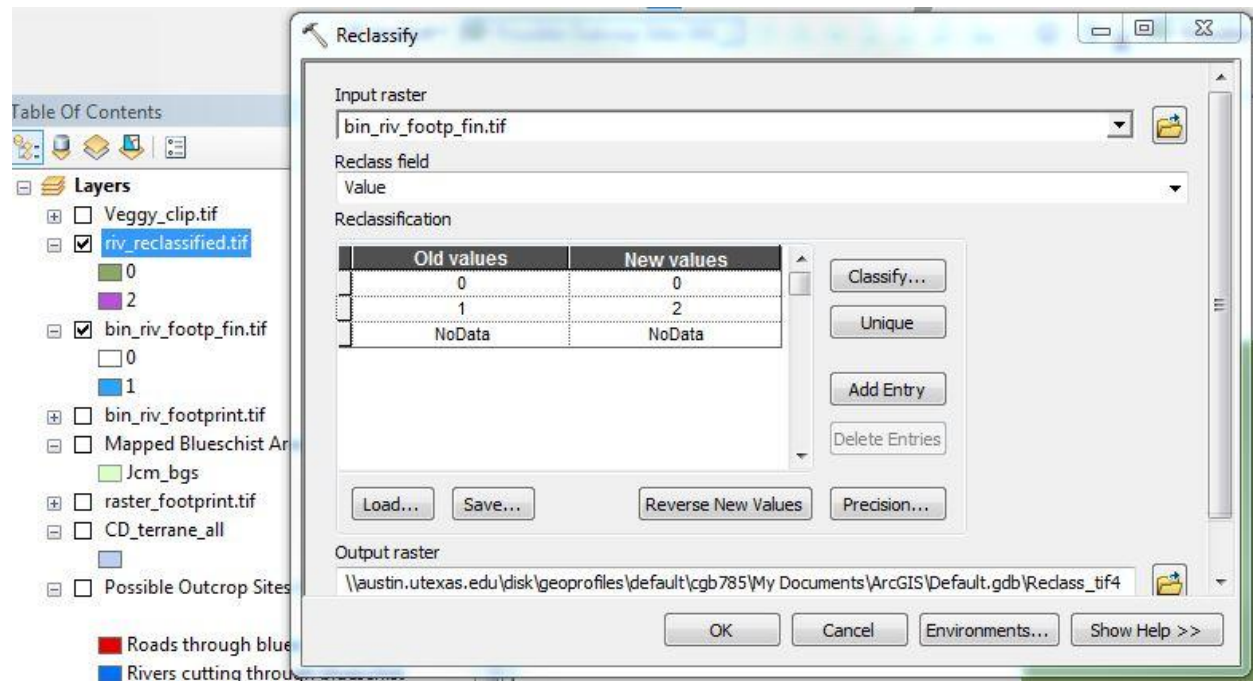


Extent after reclassifying "NoData" as zero

4.8 – Adding simple rasters...Again!

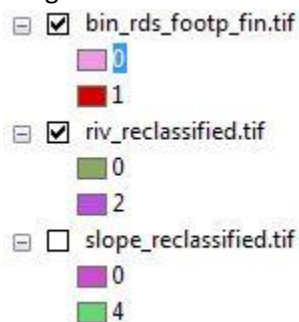
We are now almost ready to add our 3 simple rasters with the same extent together to create one final raster with all of our information. However, if we keep all rasters as 1s and 0s, how will we tell the difference between spots that are River + Road and River + Slope? To solve this, we first need to reclassify two of the rasters so that values of 1 are reclassified to either 2s or 4s. These numbers are arbitrarily chosen so that when 1s, 2s and 4s are added in various combination there are no new created values that overlap with old values, i.e. the possible new values will be 3, 5, 6 and 7, which do not overlap with 1, 2, or 4.

Again using the “Reclassify” tool we reclassify all 1 values in the slope raster to 4 and all of the 1 values in the river raster to 2.



Reclassifying 1 values in the river binary raster to 2s

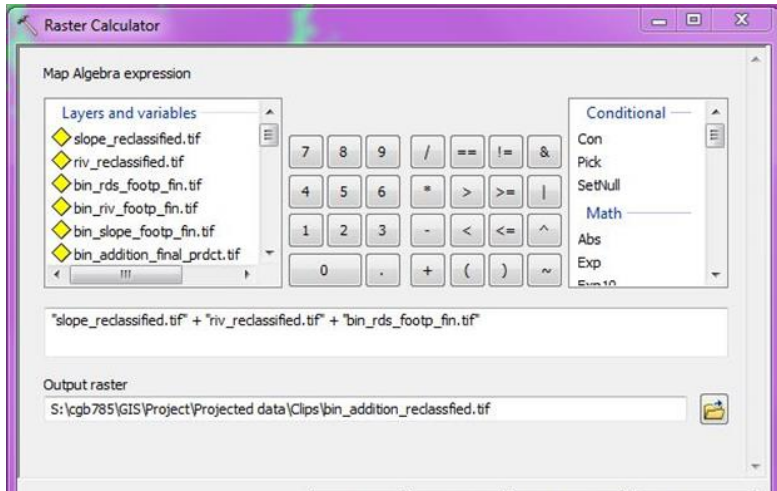
Once this has been done for binary slope raster as well, all that’s left to do is add the three together using the “Raster calculator” tool!



Newly reclassified binary rasters and their cell values

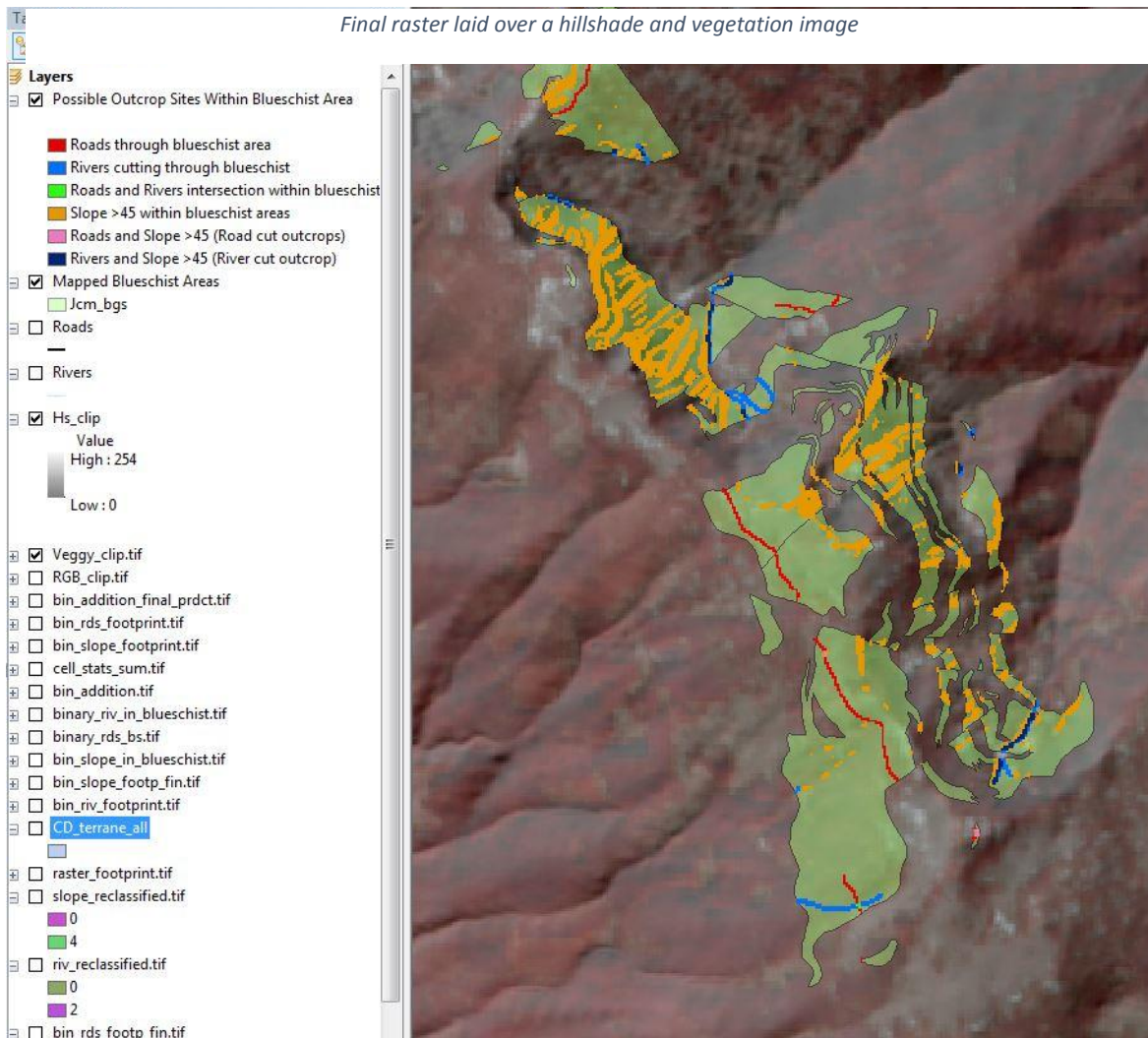
We know that roads within the blueschist have values of 1, rivers within have values of 2, and slopes greater than 45 degree have values of 4. Once the rasters have been added together and overlapping cells with values add, get unique solutions for areas that meet more than once criteria for possible outcrop locations. All of the possible values for the newly created raster addition are shown below.

- 1 = Road in blueschist
- 2 = River in blueschist
- 3 = Road and river in blueschist
- 4 = Slope >45
- 5 = Slope >45 and road in blueschist (road cut)
- 6 = Slope >45 and river in blueschist (river cut)



Adding together the reclassified binary rasters

After the raster addition has been created and appropriate color schemes chosen for each category, the final raster is displayed over the vegetation image and hillshade, and is shown below.

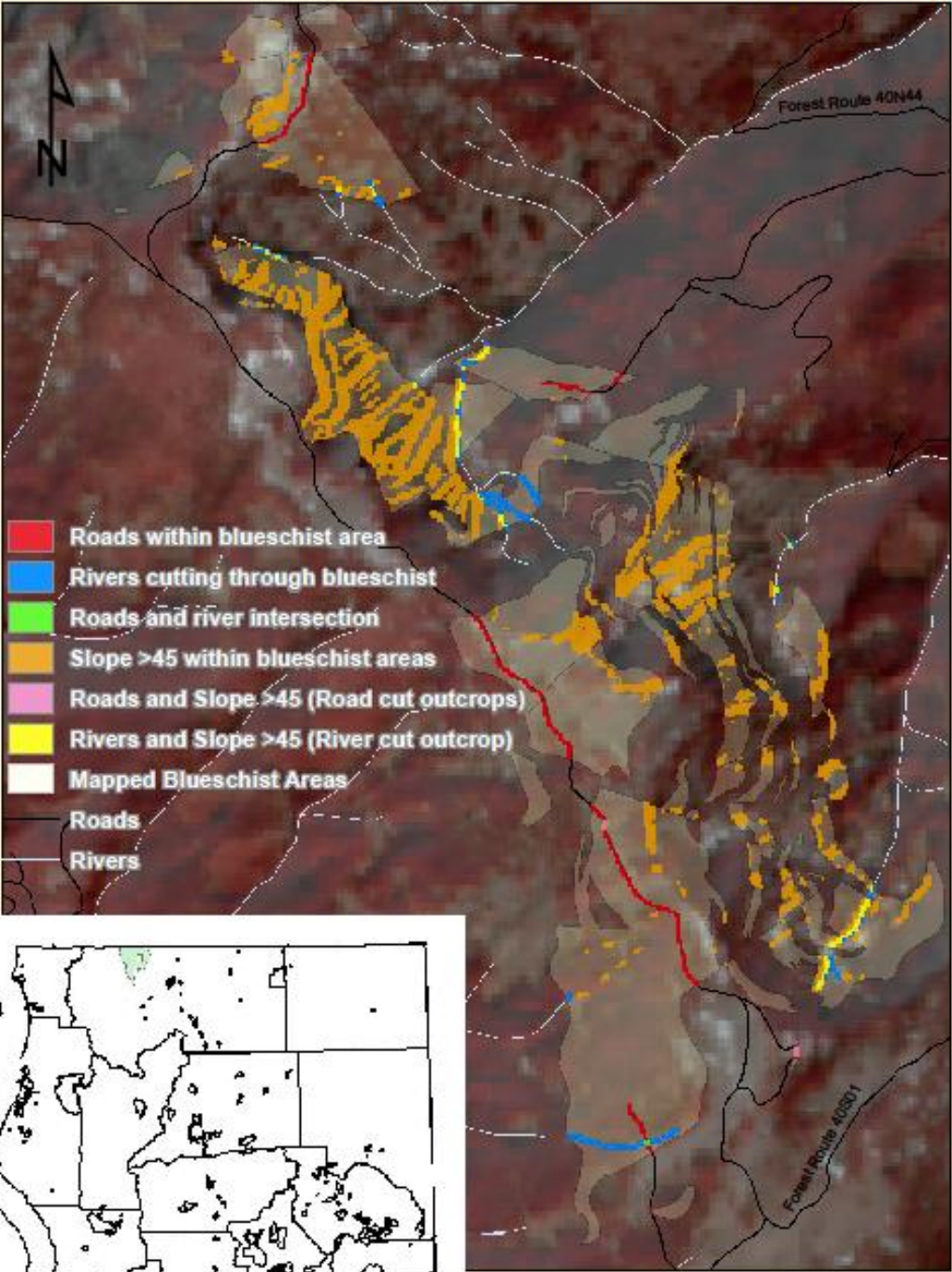


Final raster laid over a hillshade and vegetation image

The final product map is shown below! The vegetation map below helps to distinguish areas that aren't heavily forested which will also help when searching for outcrops.

Outcrop suitability analysis of blueschists within the Dry Lakes region of the Condrey Mountain Window, northern California

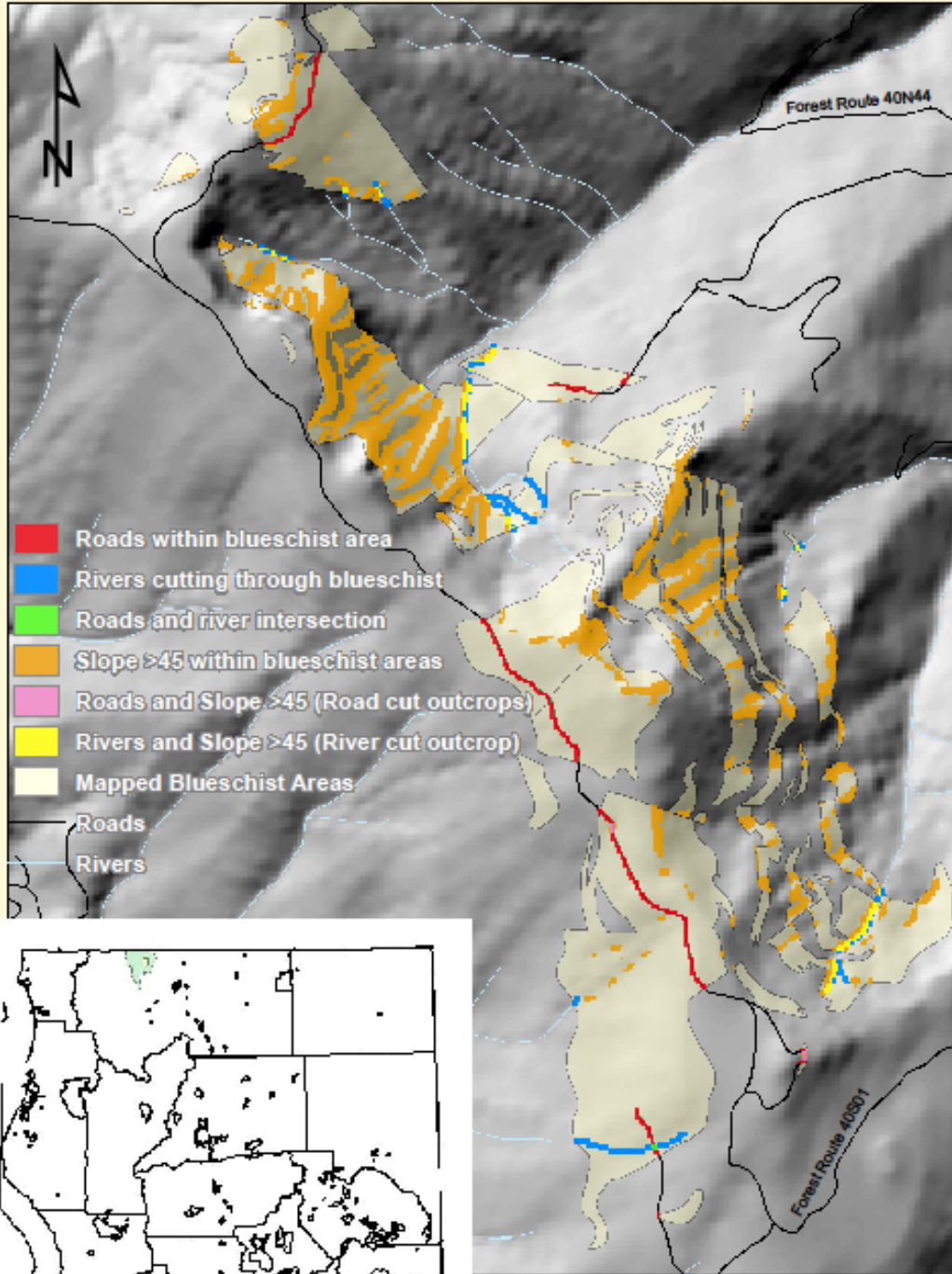
Christian Black 12/02/2015



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Outcrop suitability analysis of blueschists within the Dry Lakes region of the Condrey Mountain Window, northern California

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