Downloading DEM and Performing Raster Operations using ArcGIS Spatial Analyst

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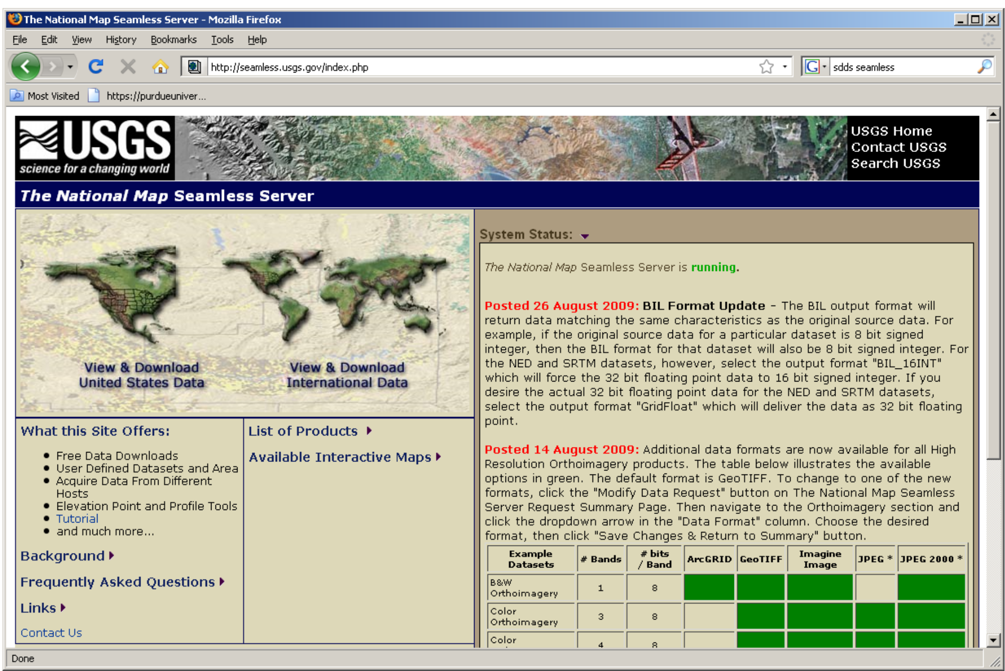
1.0 Purpose

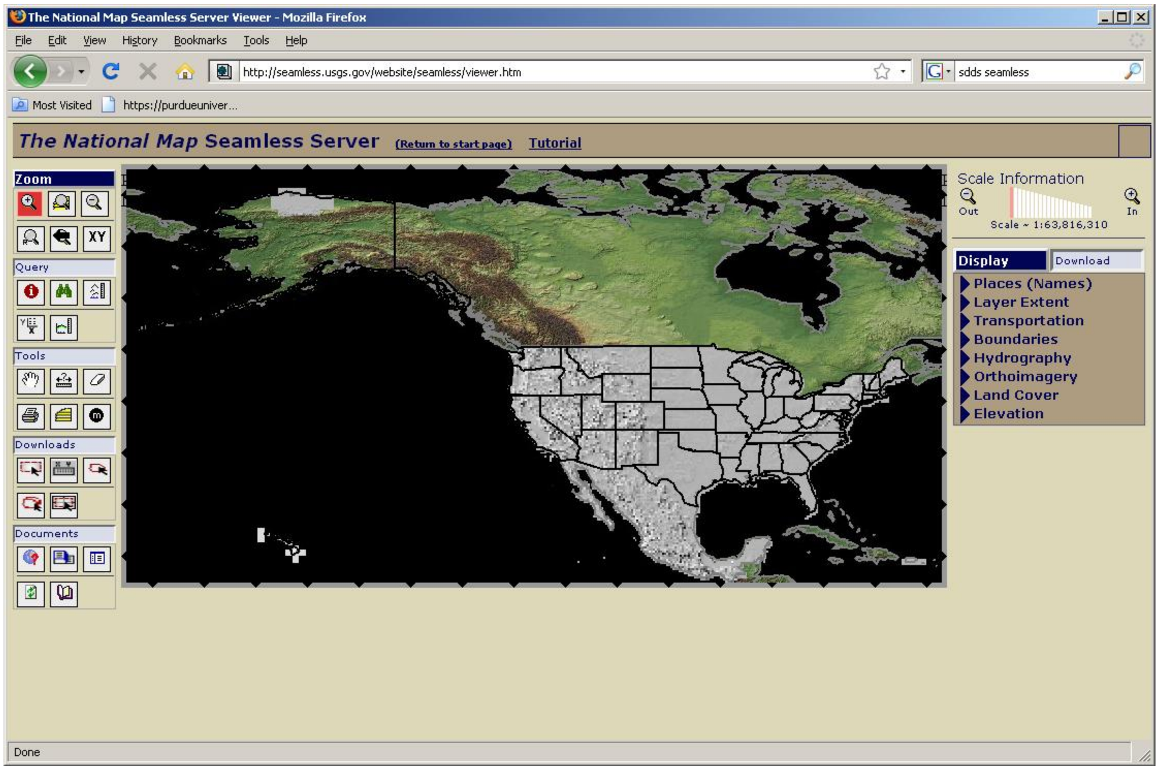
The purpose of this exercise to demonstrate the steps involved in downloading the elevation and land cover data USGS Seamless Data Distribution System.

2.0 Downloading Elevation and Land Cover Data

Elevation and land cover data can be downloaded from the USGS website http://seamless.usgs.gov/. Before you proceed, make sure you change your internet options to allow "pop-ups" for this website. To download the data, **click** on *View and Download United States Data* as shown below.



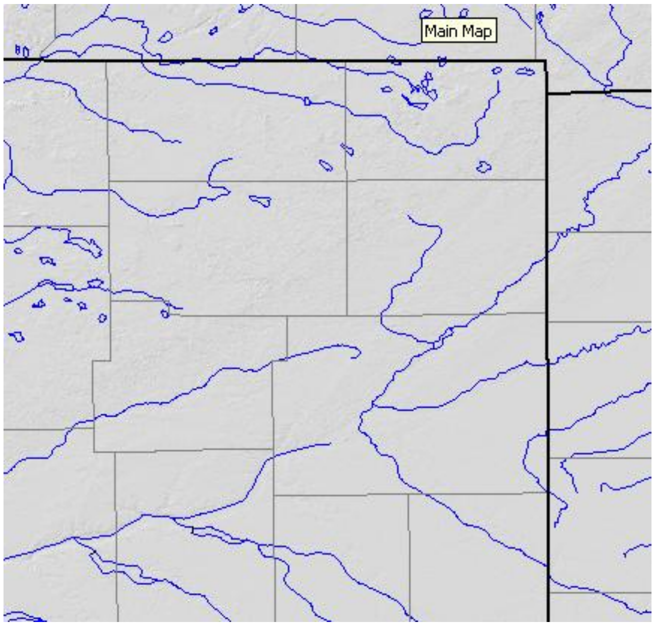
This will lead you to the National Map Seamless Data Distribution System (SDDS) Viewer as shown below:



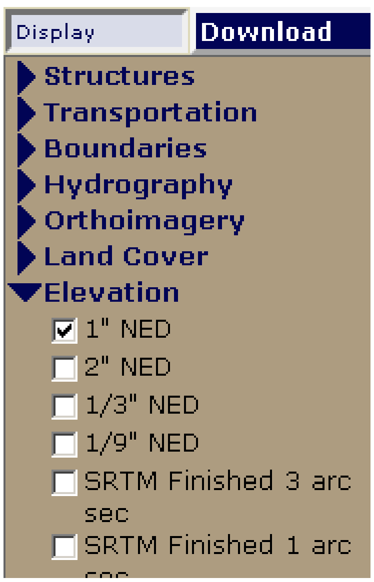
The SDDS viewer has three components: visualization and download tools (on the left), the data viewer (middle part), and table of contents of downloadable data and legend layers (on the right)

Using the zoom-in button , **zoom-in** to the area of interest (north east Indiana) as shown below:

If the exact location of the area of interest is unknown, additional display layers from the right-bottom corner (such as counties layer, streams etc.) can be used to find out the approximate location of the area of interest. **Click** on the *Display* tab, and add/remove layers from Places/Transportation/Hydrography to select the area of interest. For example, the following figure shows the display with counties, streams and state boundaries.

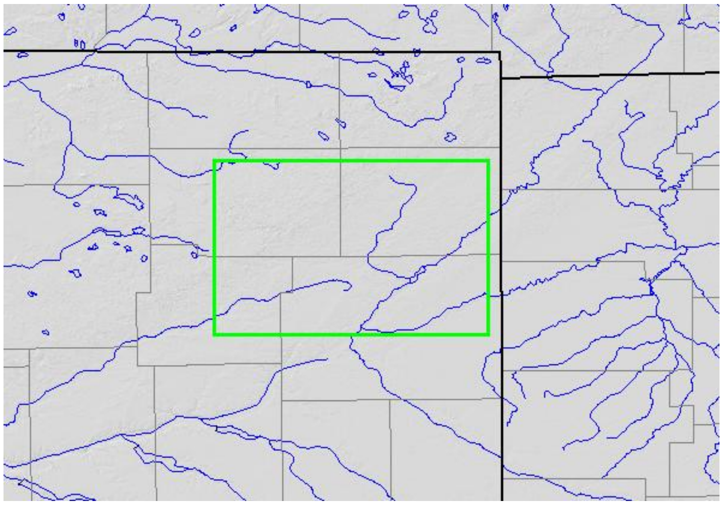


Next **press** the *Download* tab to select the data you want to download. For this exercise, we will select the default 1" NED (1" is approximately 30m):

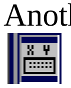


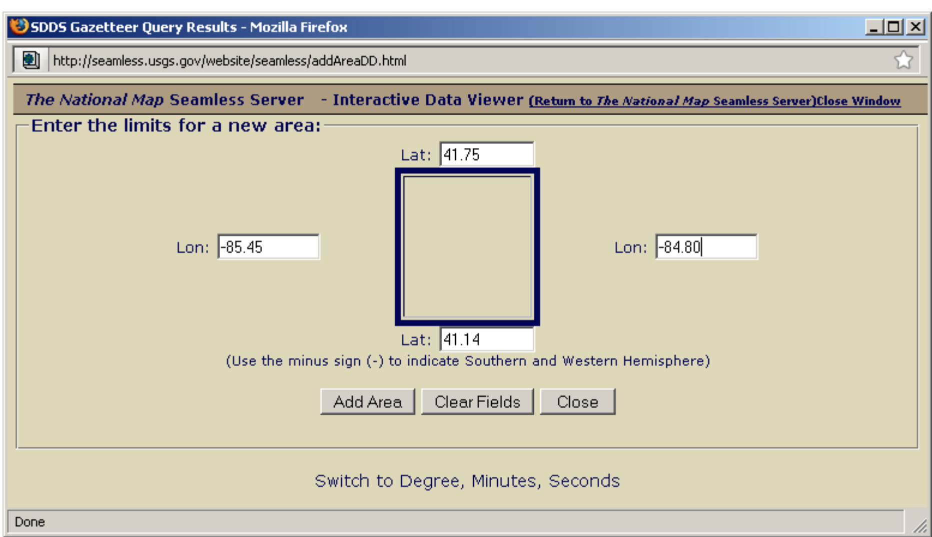
You can select the area of interest by using any of the following three buttons (interactive selection):

Use the rectangle selection option to choose the area of interest as shown below:

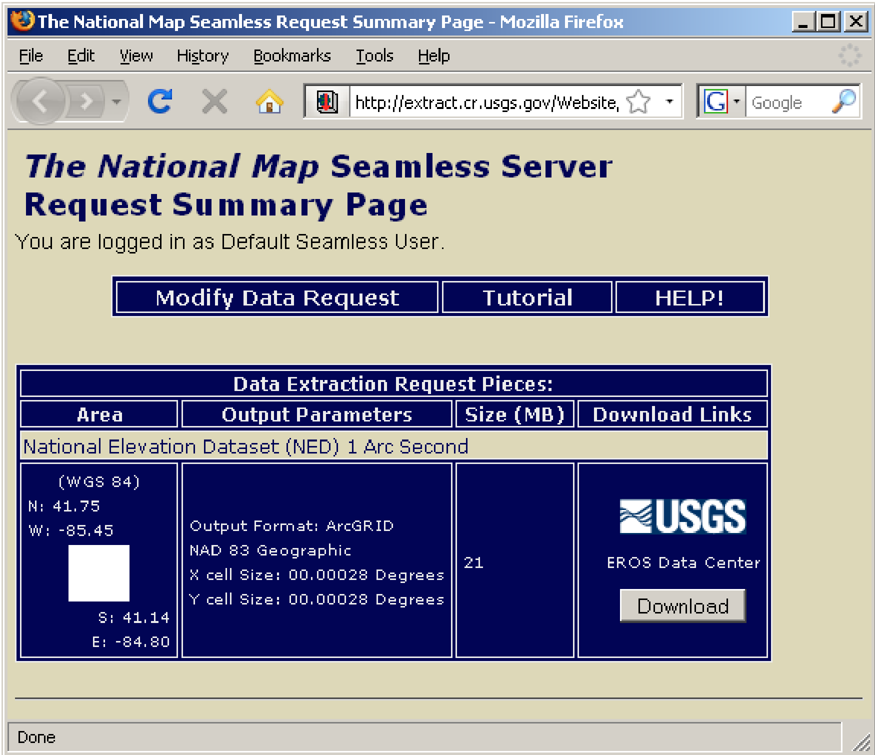


When using the interactive section for downloading the data, a green rectangle means the data can be downloaded through the internet, and the red rectangle means the data is too large for downloading, and can be ordered through CD only. You can download a file so long as it is less than 100MB in size.

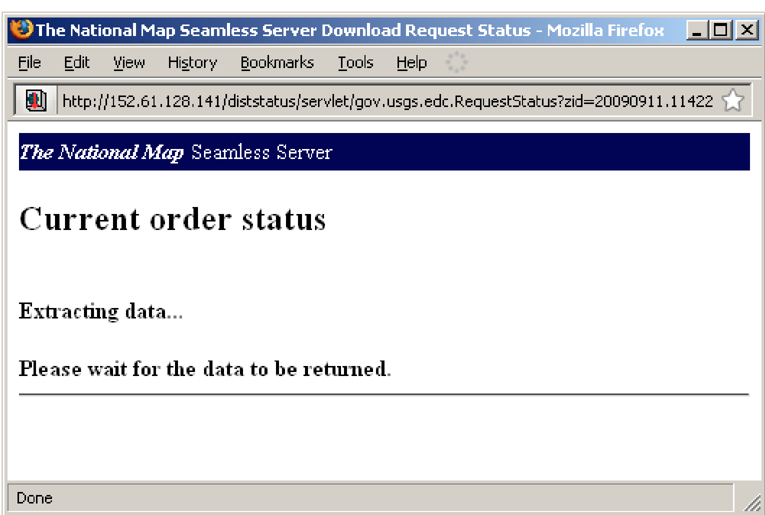
Another option for defining the area of interest is through *Define Area By Coordinates*  button in the downloads section. The define area by coordinates option will prompt you to enter the geographic coordinates of the extent of the area of interest as shown below. You can switch between decimal degrees or degrees/minutes/seconds option by using the link at the bottom. You can get your coordinates from a geographic layer in GIS or other sources. For Cedar Creek DEM, the following coordinates will work, if you choose to download data by using the co-ordinates option. **Click** the *Add Area* button to download the data.



After the area is selected, the following page is displayed summarizing the data:



Click on each *Download* button to download the elevation and land cover data for the selected area. If the area of interest is large, the data may be broken down into pieces for downloading through the internet. Depending on the order status and the internet speed, downloading process may take a while to complete. Be patient and kind to your computer and keyboard!! (Note: the data are extracted from another server that does not have seamless.usgs.gov address so make sure pop-ups are not blocked. If you are using IE you can press the control button during this process.)



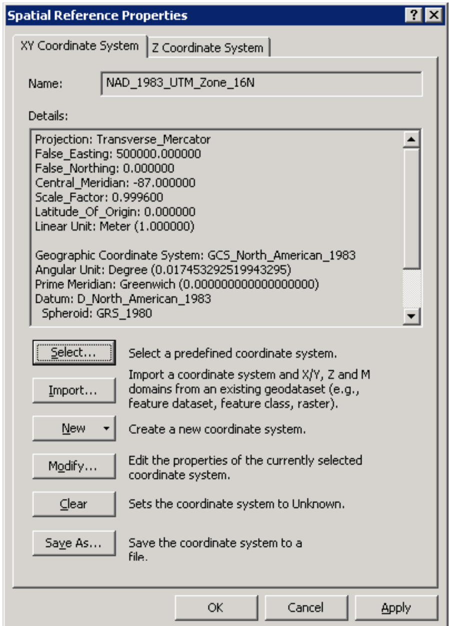
The data are supplied in a zipped format. Save the files on your local drive, unzip them, and you are ready to use the data. If you want you can clip the data to the study area to avoid redundant data during GIS analysis.

3.0 Exploring a DEM

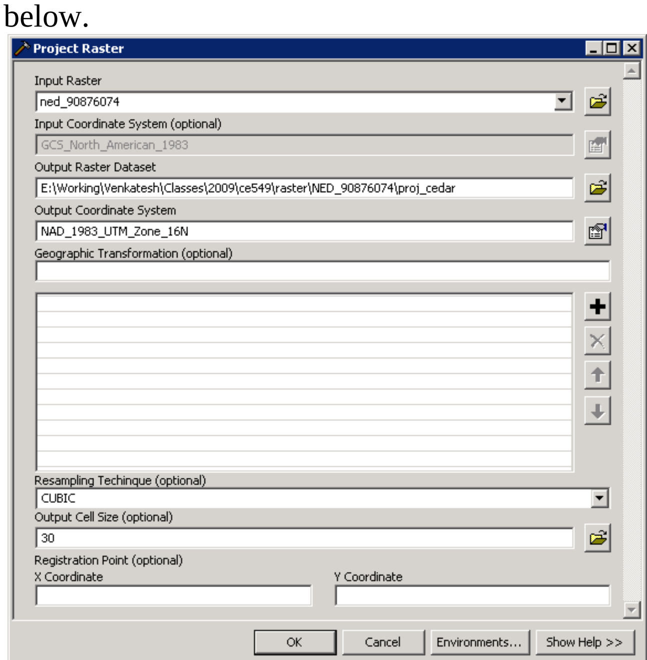
Things that we need to know about a DEM are its projections, cell size, type (integer or float), format, number of bands and size. These can be found by **right-clicking** on the DEM and then selecting *Properties*. Within the Properties window, **select** the *Source* tab, and you will get all the information that you need about the dataset. However, if the DEM is in geographic coordinates, the cell size will be in decimal degrees which will make no sense to most people. Similarly processing such a raster (with geographic coordinates) for hydrologic applications will yield attributes such as river length and flow accumulation area in units that are non conventional to many hydrologists. Therefore, the first step is to project a raster in appropriate coordinate system.

4.0 DEM Projection

Any datasets in ArcMap is projected by using ArcGIS Toolbox. If the toolbox is not already added to your map document, click on the red toolbox button  in ArcMap toolbar to open the toolbox in ArcMap. As you seen in the raster properties, the geographic projection is already defined for this dataset. In the ArcToolbox, **Select** *Data Management Tools*→*Projections and Transformations*→*Raster*→*Project Raster*. (Note: If there is no projection defined for the raster, the first step is to first define the projection by selecting the Define Projection toolbar, and then project it using Project Raster tool). In the project raster window, **select** your input raster and name the projected output raster as *cedar_proj*. Unless you want your output as image (.img) or TIFF (.tiff), do not provide any extension to the output raster. This will create the output in default GRID format. Define the coordinate system by **pressing** the spatial reference properties button . **Click** on *Select..*→ *Projected Coordinate Systems*→*UTM*→*NAD1983*→*NAD1983 UTM Zone 16N.prj*. **Click** *Add* and then OK as shown below.



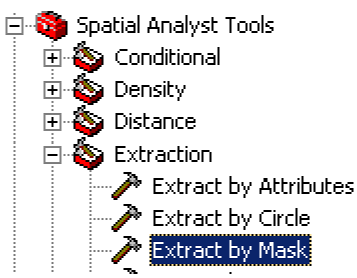
UTM Zone 16N is used because the dataset used in this tutorial falls in this zone. It is not applicable to any other dataset that is outside this zone. A user must choose the coordinate system after careful thinking, and as long as you know what you are doing, you can choose any other coordinate system even for this dataset. Also note that when a raster is projected, the whole dataset is re-sampled (or you can think of it as interpolated or recreated). Therefore, the re-sampling technique can play a role in the quality of your projected output. If you want, you can leave the default re-sampling technique unchanged. In this case, we will use the CUBIC interpolation technique for re-sampling. Also note that the cell size should be close to what the data source says it should be. In this case, we know the DEM is 30m and so put the output cell size as 30m as shown below.



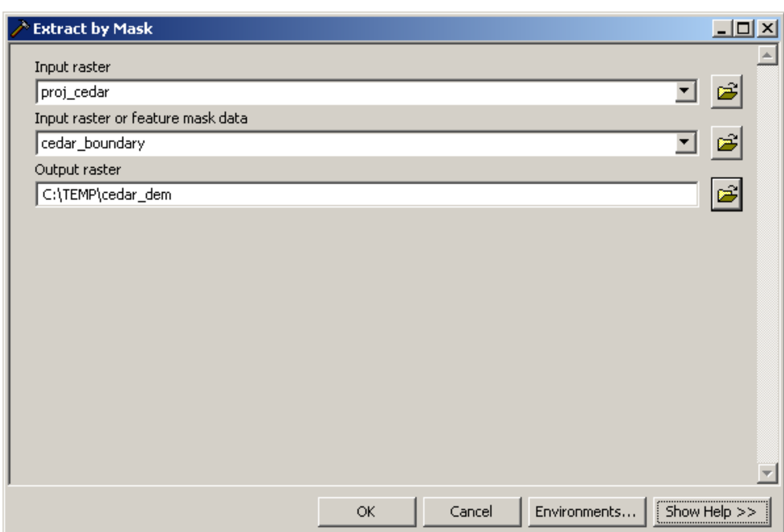
Click *OK*. The new projected raster (*cedar_proj*) will be added to the map document after the process is complete. **Change** the coordinates system of the Data Frame to see the data in projected coordinates. Now lets see what we can do with this DEM by using Spatial Analyst Extension in ArcMap. If you have purchased Spatial Analyst extension (which is the case for Purdue University), then you should be able to load the extension by **selecting** *View→Toolbars→Spatial Analyst*.

5.0 Clipping a DEM

Most often (or always), we need to "clip" a raster to a study area that is smaller than the entire domain of the raster dataset. A smaller dataset in turn reduces processing time, thus increasing efficiency. In order to clip a raster, you should have the boundary of your study area. The boundary for the Cedar Creek watershed is provided in the Data geodatabase at the ftp site. Copy this file in your working directory and add it to the map document. There are several ways of clipping a raster to a polygon mask. In this exercise will be clip the raster by using the Analysis Tools in ArcToolbox. In the ArcToolbox, **select** *Spatial Analyst Tools →Extraction →Extract by Mask* as shown below



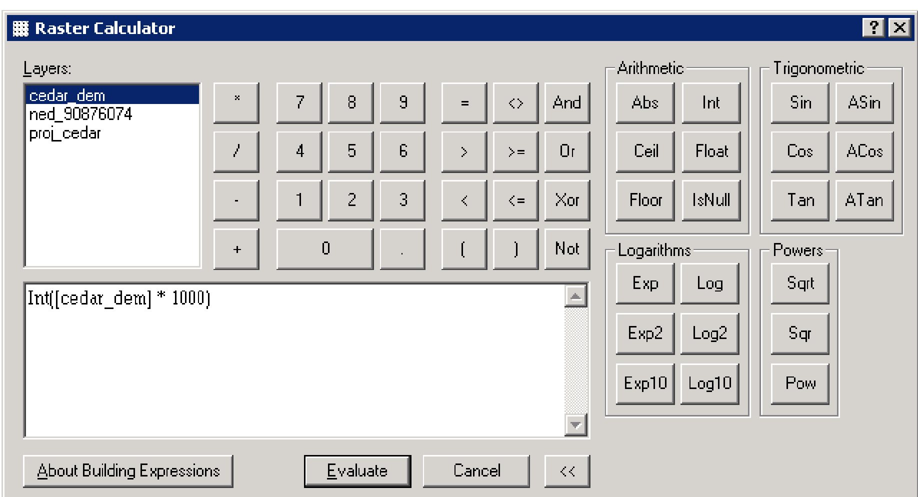
In the Extract by Mask window, **set** the input raster as *proj_cedar*, feature mask data as *cedar_boundary* and save the output raster as *cedar_dem* in your working directory as shown below. **Click** *OK*.



If everything goes well, a new raster called *cedar_dem* will be created and added to the map document. Check the size of *cedar_dem* and compare it with *proj_cedar* or the original raster. You can see there is more than 60% reduction in size.

6.0 Raster Conversion from Float to Integer

Another way of reducing the size of a DEM is by converting it to an integer type. In addition some of the spatial analyst tools (such as converting raster to features) work only with integer type rasters. Therefore, having an integer raster is desirable under certain circumstances. A float type raster can be converted to an integer type by using the Int function in raster calculator, but this will chop off all the decimals compromising the quality of the dataset. This issue, however, can be resolved by using other functions in the raster calculator before using the Int function. Cedar Creek DEM contains elevations in meters, and depending on how much accuracy is desired in the dataset, this DEM can be converted into integer type without compromising any information. For example, the elevation data in the Cedar Creek DEM is stored with up to six significant digits (micrometer level). If you want to restore the data at this accuracy level, you can multiply your DEM by 1000000, and then convert it to integer. In our case, we do not need that much accuracy for most applications, and therefore, we will keep our data up to one millimeter accurate. Use the raster calculator, to multiply cedar_dem by 1000 and then convert it to an integer grid as shown below (if you want, you can perform this operation in two steps by first multiplying it and then converting it to an integer grid).



Click Evaluate. After successful completion of the process, another raster named calculation will be added to the map document. Make this raster permanent by **saving** it as *int_cedar* by following the same procedure you performed for saving *cedar_dem* earlier. **Remove** calculation and **add** *int_cedar* to the map document. Depending on the accuracy of the final output, this step also reduces the size of the dataset by significant amount. For example, an accuracy of cm will reduce cedar_dem by approximately 50%.

Most operations in Raster Calculator are self-explanatory, and you should be able to use them without any problem.

7.0 Calculating Slope

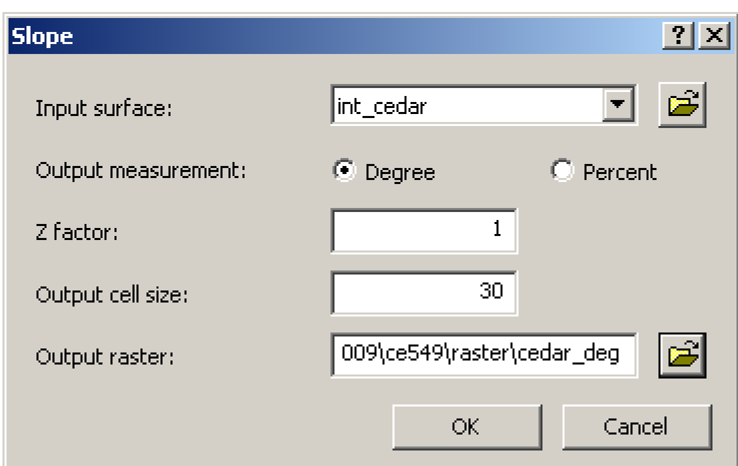
There are two options for computing slope grid in Spatial Analyst from elevation data. These include slope in percent and in degrees. The slope function in Spatial Analyst calculates the maximum rate of change in value from that cell to its neighbors (steepest downhill descent from the cell). ArcMap uses the following algorithm to compute the slope in degrees:

$$\text{slope\_degrees} = \text{ATAN}\left(\sqrt{ [dz/dx]^2 + [dz/dy]^2 } \right) * 57.29578$$

where [dz/dx] = ((c + 2f + i) - (a + 2d + g) / (8 * cell size) in the figure below and [dz/dy] = ((g + 2h + i) - (a + 2b + c)) / (8 * cell_size)

a	b	c
d	e	f
g	h	i

Slope in percent is then the tangent of the angle obtained by converting slope_degrees to radians (= slope_degree*π/180) times 100. So a 45 degree slope will give a 100% slope and a 75 degree slope will give a 374% slope. To compute the slope for *int_cedar*, Select *Spatial Analyst→Surface Analysis→Slope*. **Select** the default *Degree* option for output measurement, and name the output as *cedar_deg*.

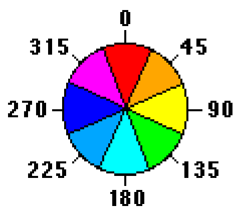


Similarly, **create** a percent slope grid and name it as *cedar_pct*. With cedar_deg and cedar_pct, visible in the map document, use the identify tool to get the slopes from these two grids at any point and see if you can verify the relation between degree and percent slope grids.

8.0 Calculating Aspect

In the previous step, steepest slope for each cell was calculated. The aspect is the direction of this steepest slope in x-y plane.

Aspect is calculated as aspect = 57.29578 * atan2 ([dz/dy], -[dz/dx]), where dz/dy and dz/dx have the same meaning as explained earlier in slope calculations. The output is then a compass direction (0 – 360 degrees shown below) of the aspect.

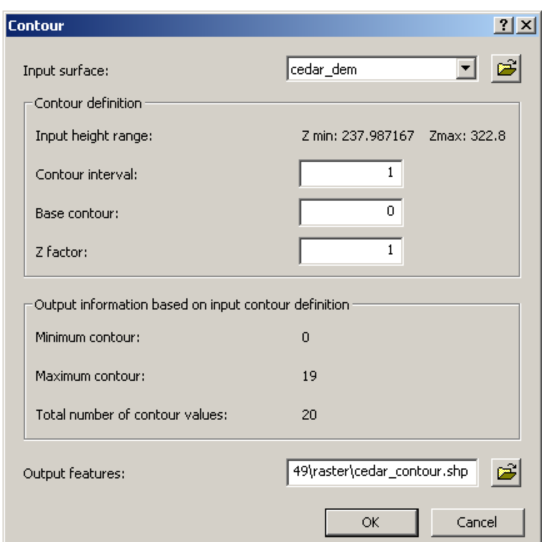


The compass direction (0 – 360 degrees) is computed according to the following rules:

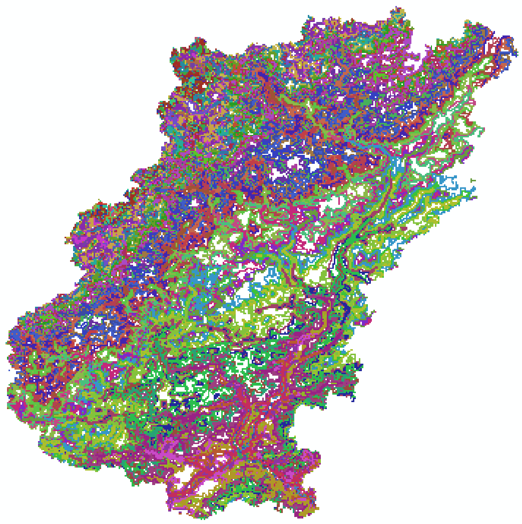
Aspect	Cell Value
< 0	90 - aspect
> 0	360 – aspect +90

9.0 Extracting Contours from DEM

Contours can be created from a DEM by using the Contour… function in surface analysis. **Select** *Spatial Analyst→Surface Analysis→Contour*.. Use *cedar_dem* as the input surface and provide a contour interval of 1. Name the output as cedar_contour.shp and **Click** *OK*.

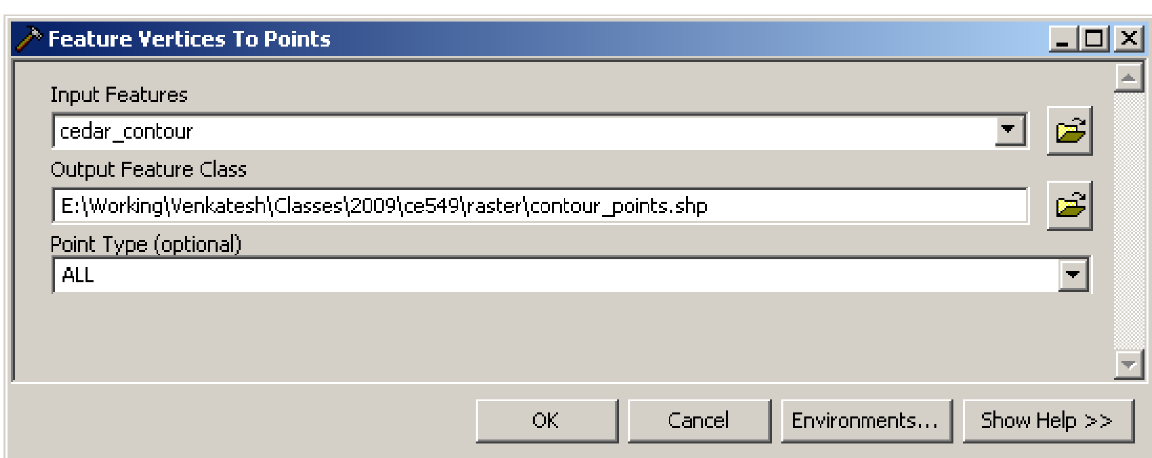


After the process is complete, a shapefile named cedar_contour will be added to the map document. If you open the attribute table of cedar_contour, you will see that the contour value associated with each line is stored as its attribute. You can change the symbology and use the values to produce a nice colorful contour map for Cedar Creek as shown below.



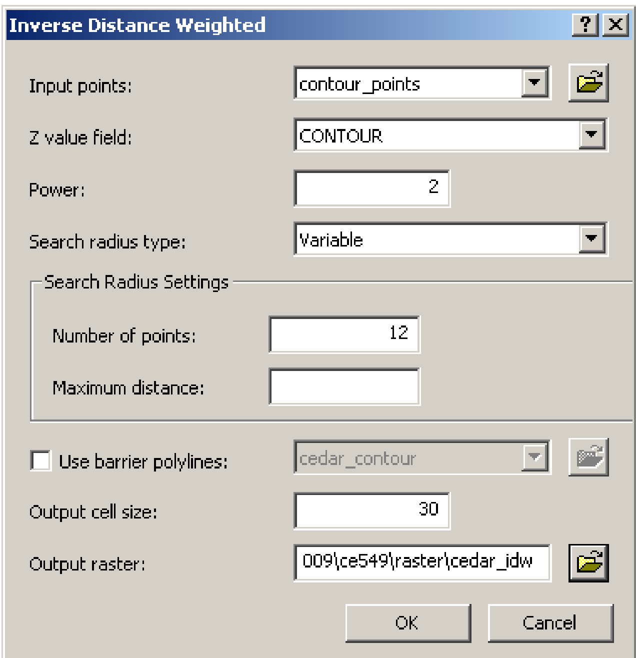
10.0 Creating a DEM from Contour Lines

Creating a DEM from contour lines can be done in multiple ways, and in most cases it is a two-step process. If a DEM is created through interpolation, then the first step is converting the lines to points, and then interpolating these points to create a DEM. When lines are converted to points, it is important to maintain the attributes (contour value in this case) so these can be used for the subsequent interpolation. Converting a polyline to points basically involves converting its vertices to individual points. In the Arc Toolbox, select Data Management Tools→Features→Feature Vertices to Points. Use cedar_contour for the Input Features, and name the output shapefile as contour_points.shp as shown below. Click OK.



Because of huge number of contour lines, this process takes a while. After the conversion, a point shapefile named contour_points will be added to the map document.

A DEM can be created by interpolating contour_points by using any interpolation technique. In this tutorial, inverse distance weighted will be used. Select Spatial Analyst→Interpolate to Raster→Inverse Distance Weighted.. Choose the contour_points as the Input points, contour for Z value field, change the output cell size to 30m, and name the output raster as cedar_idw. Leave the search type radius and number of points unchanged as shown below.



Compare cedar_idw with cedar_dem. OK, you are done!