Exercise 06
Spatial Databases
Assigned Feb. 23, 2018
Due Mar. 2, 2018

Part 1. Databases

We can avoid the proliferation of shapefiles, and all the auxiliary files, by storing our data in a databases. Unfortunately there are multiple different types of databases which can be used and not all GIS programs can read all the types created by other programs. ArcGIS uses "geodatabases" which cat at least partially be read by QGIS, with some restrictions. As of version 10.2, ArcGIS also added support for "spatiaLite" databases, which QGIS and a number of other programs CAN read. We'll use those for this exercise. SpatiaLite databases are a version of "sqlite" databases, with special geographic information added. Although we will not use them in this class, QGIS and ArcGIS can also store information in databases which resides on some central "database server" computer -- where many different uses all need to access the same database. For example both QGIS and ArcGIS can use "PostGIS", which is a spatial extension to the standard "PostgreSQL" database system.

In the first part of this exercise we'll simply move the `land_additions` shapes and the `gps_waypoints` and track from exercise 4 into a single database. While you can try this with your own files, to avoid any unexpected difficulties I've provided my own versions of the above two shapefiles for you to use instead. They, plus the Laramie map files and a pair of Digital Elevation Model (DEM) files, are all located in an `exercise_06_data.zip` file on the class website.

1) Start `QGIS`, open the Laramie map as before, and update the CRS for the map as you did previously. To be sure the "Project CRS" is set to that same updated datum right click on the map in the layers panel and select **Set Project Layer from CRS**.

2) **Creating the database.** There are a couple operations which will implicitly or explicitly create a new database. Let's do it explicitly. (That avoids occasional bugs which occur when trying to create them implicitly.)First open the `Browser` panel. Usually the `Layers` and the `Browsers` panel are both available, occupying the same space on the left, and you select one or the other using the tab on the bottom. If `Browsers` is not available, in Windows in the main menu go to `View/Panels` and make sure that `Browser` is checked. On the Linux and perhaps the Mac you will find that under `Setting/Panels`.

Within the `Browser` panel you should see various entries like `Home`, `PostGIS`, and `SpatiaLite`. Right click on `SpatiaLite` and select `Create database`. A dialog box will open letting you select a directory and a filename. If not already there, navigate to your own `exercise_06` folder, and type in `exercise_06.sqlite` as the name. Click `Save` to start the creation. On Linux it will be approximately 4.2 Mb in size when create is finished. It may be less on Windows. In that directory you might also see an **exercise_06.sqlite-journal** file come and go while QGIS initializes the file. You might wonder why an empty database occupies up to 4.2 MB. That is because while it doesn't contain any shapes yet, it does contain all the information about all the various EPSG coordinate reference frames. Note you do NOT want to create a spatiaLite database for each layer. With a minimum size of 4.2 MB that would be very inefficient. You want one database to hold all the (related) layers.

3) Importing an existing shapefile to the spatiaLite database. First load either my existing **rrh_land_additions** shapefile from exercise 3, or your own, into QGIS using the standard **Vector/ Add Vector Layer** command from the main menu. Next select **Database/DB Manager/DB Manager** from the main menu. Click on the **+** or **>** before **SpatiaLite** to expand the list of SpatiaLite databases -- you will probably have only one -- and you should see **exercise_06.sqlite**.

Just to understand what is already saved in it, double click on **exercise_06.sqlite** and it should expand into a long list of entries including **spatial_ref_sys**. *(Note -- in the most recent versions of QGIS they seem to have hidden the display of the spatial_ref_syst information, so this double-click method doesn't work. However later we'll see an alternate way to query this information. If you don't see the list after double-clicking, just skip to the next paragraph.)* The latter contains the various EPSG defined coordinate reference systems mentioned above. We'll return to the other entries later. Double clicking on **exercise_06.sqlite** should collapse the long list.

Next click on the **Import layer/file** icon near the top of the **DB Manager** window. (If you get a **No Database selected** . . . error, go back and right click on the **exercise_06.sqlite** file and select **re-connect**.) At the top of the dialog which opens, select **land_additions**. Click on the **Update Options** button and it will fill in a Table name based on your shapefile name. You could alter it if desired. Finally click **OK**. In some versions of QGSI you will then see an **Import was successful** window. If it does appear, just click **OK** to close it.

We'll next add the **gps_waypoints** shapefile to the database. But this time, instead of adding that layer first to QGIS then adding the layer to the database, we'll directly add the shapefile from disk. Open **DB Manager** again if it has been closed, and again click on **Import layer/file**. Click on the "..." icon at the upper left and in the dialog which opens, select the **gps_waypoints** file. Again click on **Update Options** then click **OK**. **If the Import was successful** appears, just click **OK** to close it.

Note that so far none of the database layers have actually been added to the QGIS canvas. Before adding them, to avoid confusion remove the old **land_additions** shapefile based layer from the project by right clicking on it in the layers panel and selecting **Remove**. We could at this point delete all the **gps_waypoint.*** and **land_addition.*** files as the actual data is nowcontained within **exercise_06.sqlite**, but you don't need to actually do that. Unfortuntaely QGIS doesn't let you save the map raster file within sqlite although some types of databases can store rasters.

To add the two database layer, from the main menu select `Layer / Add Layer / Add SpatiaLite Layer` and a dialog box will open. At the top of the box you can select among various SpatialLite database files. If it isn't already shown, click on that to select your `exercise_06.sqlite file`. then click `Connect` to be sure that QGIS and spatiaLite are using that particular database. In the next lower panel there should appear a "tree" with `gps_waypoint` and `land_addition` branches. Select both by clicking on the first, then holding the `CTRL` key and clicking on the second. Finally, click on `Add`. Both should now appear in the QGIS layers panel.

4) Labels First adjust the `Style` of the `land_additions` so the different polygons have different colors and are transparent enough to see the map underneath. Next let's add labels showing the addition date for each label. In the `Properties` dialog for the layer, select the **Labels** tab. In the dropdown box at the top change the default `No Labels` to `Show labels for this layer`. In the next row set `Label with` to `year_added`. If you are using my `rrh_land_additions` most of the labels will be reasonably located but the main Laramie 1963 label will be located partly outside the actual polygon. That is because the default placement is based on the polygon centroid, and this strangely shaped polygon has “bay” carved out of its center. To fix that select `Placement` in the panel on the left of the dialog box and experiment with the options to move the labels to reasonable locations. You could for example set X and Y offsets from that centroid, but these woud apply to ALL labels in the layer. You could also (using the small icon to the right of the X,Y offset boxes) change offsets on a feature-by-feature basis using columns from the attributre table. But the simplest option is just to check the `Force point inside polygon` box. Note than any changes do not take effect till you click `Apply`. Finally, select `Text` in the panel on the left and adjust the size of the text. As you can see there are multiple possible adjustments in labels, and you can control most of them using fields in the attribute table.

5) Save an image of this map: Zoom to the land_additions layer size then save an image of the map as `db_layers.jpg` using `Project / Save as image`.

Part 2. DEM's, and more operations on rasters

In the layers panel turn off the display of the `land_additions` and `gps_waypoints`.

In the exercise_06_data set there is a raster file `laramie_elevation_0_3_arcsec` which gives the elevation on an 0.3 arcsecond grid. (I've clipped this to a relatively small region compared to the original to limit the size of the file.) The aux.xml file contains information about the location of this Digital Elevatoin Model (DEM) raster.

6) Loading the DEM. Using `Layer / Add Layer / Add Raster Layer` or the equivalent icon  add the elevation file. Once it is added in the layer panel right click on it and select `Zoom to layer`. You should see a gray scale elevation profile showing the Laramie range east of town. Right click on it in the layer panel again, select Properties, and look at the Style tab. By default when this was loaded QGIS found the (approximate) minimum value of 2168.85 (meters), the maximum of 2626.95, and set the Contrast enhancement mode as `Stretch to MinMax`, which displays that minimum as black and the maximum as white. Try adjusting that Min and Max then clicking `Apply` to see how the display changes.as black and the highest as white. Experiment with changing the `Rendering type` from the default `Singleband gray` to `Singleband pseudocolor` then changing the color map to `Spectral` (or some other choice of your own), clicking `Classify`, then `Apply`.

Before moving to the next step, go back to the `Singleband gray mode`. To make the Laramie map visible underneath this raster, in the `Properties` dialog select the `Transparency` tab and set to roughly 50%. You should be able to see the canyons just east of town. If not, adjust the Min and Max or other display properties of the raster.

7) Histograms of raster data

Let's save a histogram giving the number of pixels at each elevation. Once again right click on the elevation layer, select properties, then select the Histogram "tab". Click on `Compute Histogram` if a histogram is not already visible. You should see one main peak -- the elevation of the Laramie Valley, plus a broad range of elevations which corresponds to the long eastern slope of the Laramie Range. There are also a few pixels at even higher elevations which represents the highest "peaks. The oscillation in the histogram is an artifact of how the Digital Elevation Model (DEM) or the histogram was constructed. Use the "floppy" icon at the lower right to save a copy of the histogram plot as `elevation_histogram.jpg` in your main data folder. (As usual QGIS will probably want to put it in some non-optimum folder.)

8) Raster Algebra

From the main menu use `Raster / Raster calculator` to convert this meter DEM to a FOOT one named `laramie_elevation_0_3_arcsec_foot`. There are 3.28084 feet per meter. To create a formula to convert, in the `Raster calculator` dialog double click on the elevation entry in the `Raster bands` list to add that to the `Raster calculator expression` panel at the bottom of the dialog, then add `* 3.28084` . Select an output layer with the original layer name, but with `_feet` appended. With all the parameters set, click **`OK`** to do the calculation. With the "feet" layer now in the project, remove the original meter layer. Adjust the transparency of the elevation feet layer so again you can see the Laramie map.

9) Reading Raster Values

If it isn't already present, use the menu `Plugins / Manage Plugins` to activate the value tool -- clicking to add a checkbox next to its name. If you can't see the value tool present, use the `Search` field to find an intall it. A value tool panel should now appear underneath the layers panel. Check the `Enable` checkbox in that panel and watch the values displayed change as you move around the map. Verify the reported elevations vs. what is shown on the map -- especially at a few critical contours. When you are finished uncheck the `Enable` checkbox to avoid later complications.

10) Profiles

Repeat the above process to find and install the `Profile` plugin. Select the foot elevation layer in the `Layers Panel` then click on the green Profile icon  which should have been added to your toolbars when you installed Profile. A new panel should appear at the bottom of the QGIS window. (You may need to click on `Add Layer` in that new panel to add the foot elevation layer.) By default it lets you draw a temporary line. Start one by single clicking on your map, then click to add additional points, and double click to add the final one. An elevation profile should appear in the panel. Explore some of the options in the profile plot panel. For example you can obtain a list of elevations values along the profile, then copy it to the clipboard. You could also have told it to find the profile along a selected line in a previously created shapefile. Once done, close the profile panel by clicking on the close button at the top right of the panel.

11) Contours (and other GDAL tools)

A series of Geospatial Data Abstraction Library (GDAL) tools were installed along with QGIS and can be called from within QGIS. See `<http://www.gdal.org/>` for more details on the operations they can perform. From the main menu select `Raster / Extraction / Contour` and in the dialog which appears choose as an output file `contour_50ft`. (You will probably have to browse to the right exercise_06 directory as the gdal tools don't remember the QGIS "current" directory.) Change the interval to `50`, and check the `Attribute name` box so that the output shapefile will have an attribute named the default **`ELEV`**. Also check `Load into canvas when finished`. The text shown at the bottom of the window is the actual gdal command which is about to be run. If you wanted to change options for it, you could click the Edit (pencil) icon. But for now, just click **`OK`** and when it finishes, after what may be several tens of seconds, close any completion message boxes which appear (sometimes showing output from the gdal command) and also close the main contour dialog. Zoom in on the area of Laramie, and compare the location and shape of the just-created contours and the original map 50-foot contours. You may need to adjust the Style Properties of the contours layer, and perhaps adjust various layers' transparency. Once you have a good display, save this image as a `contour_comparison.jpg` file.

12) Project Coordinate Reference System (CRS)
To reduce the size of the elevation file, we will create a version limited to roughly the extent of the Laramie map. However to specify the size of that extent we first need to understand how the different CRS's produce different coordinate values.

The QGIS display is using a CRS which matches the Laramie map, because that was the first layer loaded. The projection used in the display is called the `Project CRS`. If you move the cursor around the canvas, you can see X,Y coordinates at the bottom of the window change with location. For the Laramie Map CRS which you entered manually you specified `proj=poly`, `lat_0=0`, `long_0=105.562`, and `units=m`. The coordinates being shown are meters east of the 105.562^{O} meridian, north of the equator (0^{O} latitude) as measured in a polyconic projection.

The elevation file actually uses a different (plate carrée) CRS based on degrees latitude and longitude rather than projected linear distances. You can tell that by right-clicking on the layer, selecting `Properties`, and looking at the **CRS** under the **General** tab. QGIS is using "on-the-fly projection" to reproject that longitude-latitude gridded data onto the `Project CRS`, which as mentioned above, is the same polyconic projection used by the Laramie map.

When in the next step we clip the elevation data to a smaller region, QGIS will feed the size of that region to the GDAL clipper tool. However that tool needs coordinates in the same CRS used by the elevation file. While it would be ideal if QGIS was smart enough to convert coordinates to that file's CRS, unfortunately it isn't. The solution is to temporarily switch the QGIS `Project CRS` to that of the elevation file, run the gdal tool, then switch back after we are done. To do this, right click on the elevation layer and select `Set Project CRS from Layer`. (To go back to the original, right click on the map layer then once again select `Set Project CRS from Layer`.) Note how the coordinates shown at the bottom of QGIS change. The width of the region also appears to change, as the meters per degree of latitude is only $\cos(41^{O})=0.76$ times the meters per degree of longitude.

13) Clipping the Raster data to a smaller region
With the `Project CRS` set to match the elevation layer right click on the Laramie map and select zoom to layer extent. From the main menu select `Raster / Extraction / Clipper`. In the dialog which appears choose as an output file `map_elevation_feet.tiff`. Make sure the clipping mode is set to `Extent` then drag a box (i.e. click and hold the mouse) across the extent of the Laramie map. The size of the box you just created is entered into the $(x,y)_1$ and $(x,y)_2$ textboxes in the dialog window. Note that these numbers are now in degrees of longitude and latitude. Make sure that `Load into canvas when finished` is checked, and click `OK`. The operation may take several tens of seconds. Once finished,

close the various dialogs which have opened. You will probably want to remove the original elevation layer from the map, adjust the transparency of the new elevation layer, and finally, switch the **Project CRS** back to that of the original Laramie map.

14) Other raster operations

From the main menu select `Raster/Analysis/DEM`. In the dialog which opens be sure the elevation layer (not the Laramie map) is selected as input. Select an output file named `laramie_hillshade.tiff`. Be sure the standard `Hillshade` operation is selected, and for now just accept the default parameters. Be sure `Load into canvas when finished` is checked, then click `OK`. If necessary in the layers panel drag the contours layer up so it is displayed on top of the hillslope raster you just created. Finally, save an image of the display, naming it `hillshade_image.jpg`.

15) Submitting the results

Save your project file then create a zip file containing your project file and your four saved jpg images (the histogram, the map and new contours, and the hillshade). Do NOT include the large elevation files, the Laramie map, or the various contour shapefiles you created. Submit the zip file in class next Friday to the Homework Drop folder.