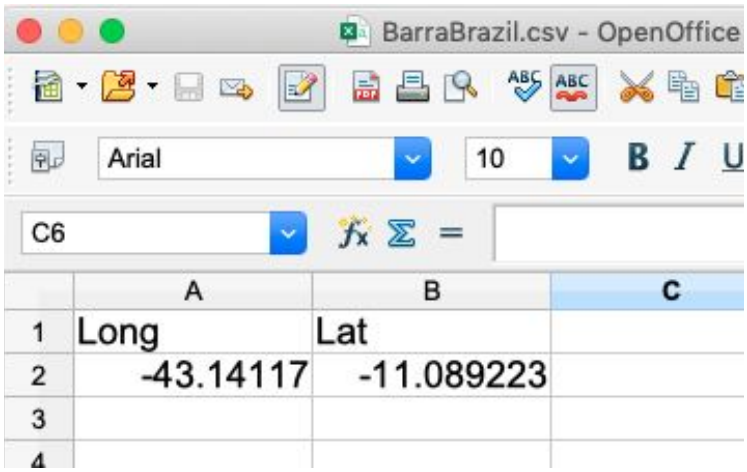
Tutorial: River Basin Delineation using HydroSHEDS

1. Create a working folder/directory on your Desktop to keep the data organized. Name the working folder “SFBasin” (We are using this name since the basin we are delineating is the San Francisco river basin in Brazil.)
2. Create sub-folders/directories in the “SFBasin” working folder with explicit names such as “SABasins”, “DEM”, “DrainageDirection”, “HydroBASINS”, and “RiverNetwork”
3. Convert the Longitude & Latitude of our study location as a georeferenced point file. **Long** refers to Longitude and **Lat** refers to Latitude. In this exercise we’ll be using the Long/Lat location for Barra, Brazil (-43.14117, -11.089223)
4. Using Apache OpenOffice (or Microsoft Office), create a new spreadsheet and enter the Long/Lat location for Barra, Brazil as shown in the example below

(Apache OpenOffice is an open-source office software suite. It is available in many languages and works on most operating systems.)



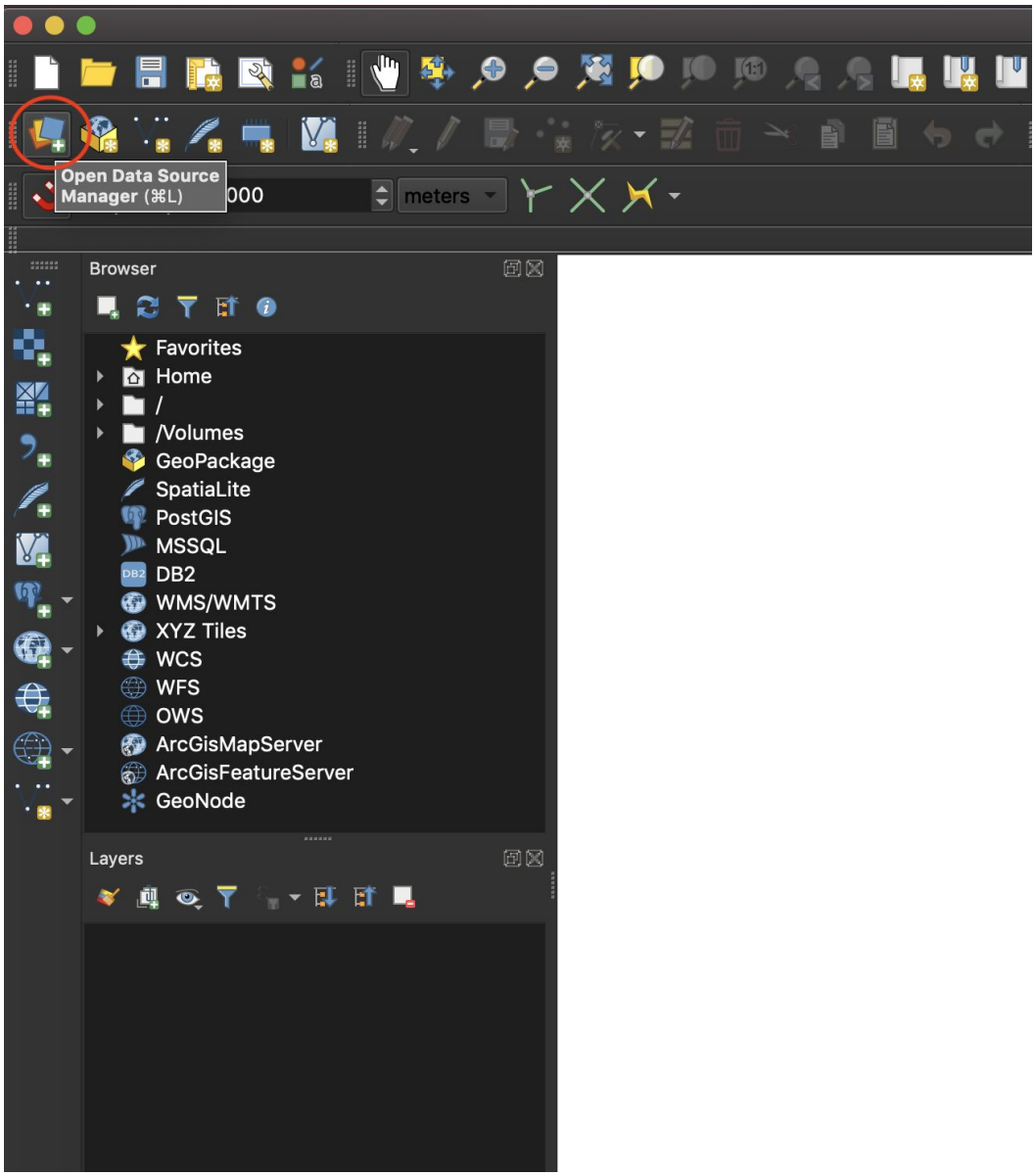
5. Save the spreadsheet as a CSV file named “BarraBrazil.csv” in the working folder, “SFBasin”
6. Launch the QGIS application

(QGIS is a free and open-source desktop geographic information system (GIS) application. This demo uses QGISv3.8 [Zanzibar])

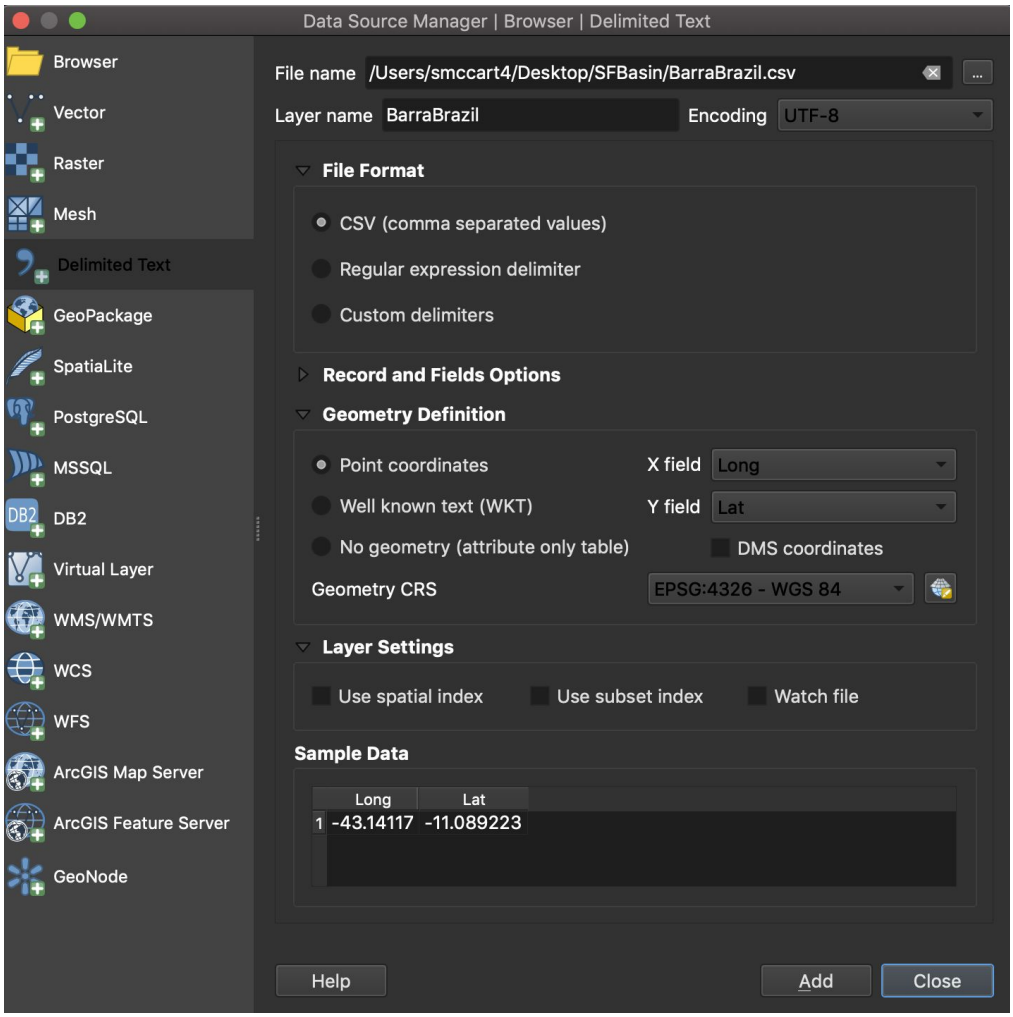
7. Save your QGIS project as “SFBasin” in the working folder

Project —> Save As —> Desktop —> SFBasin —> SFBasin.qgz

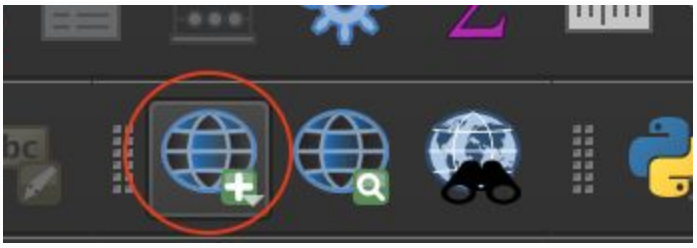
8. Click the Open Data Source Manager button on the Data Source Toolbar. You can also use the Ctrl + L keyboard shortcut



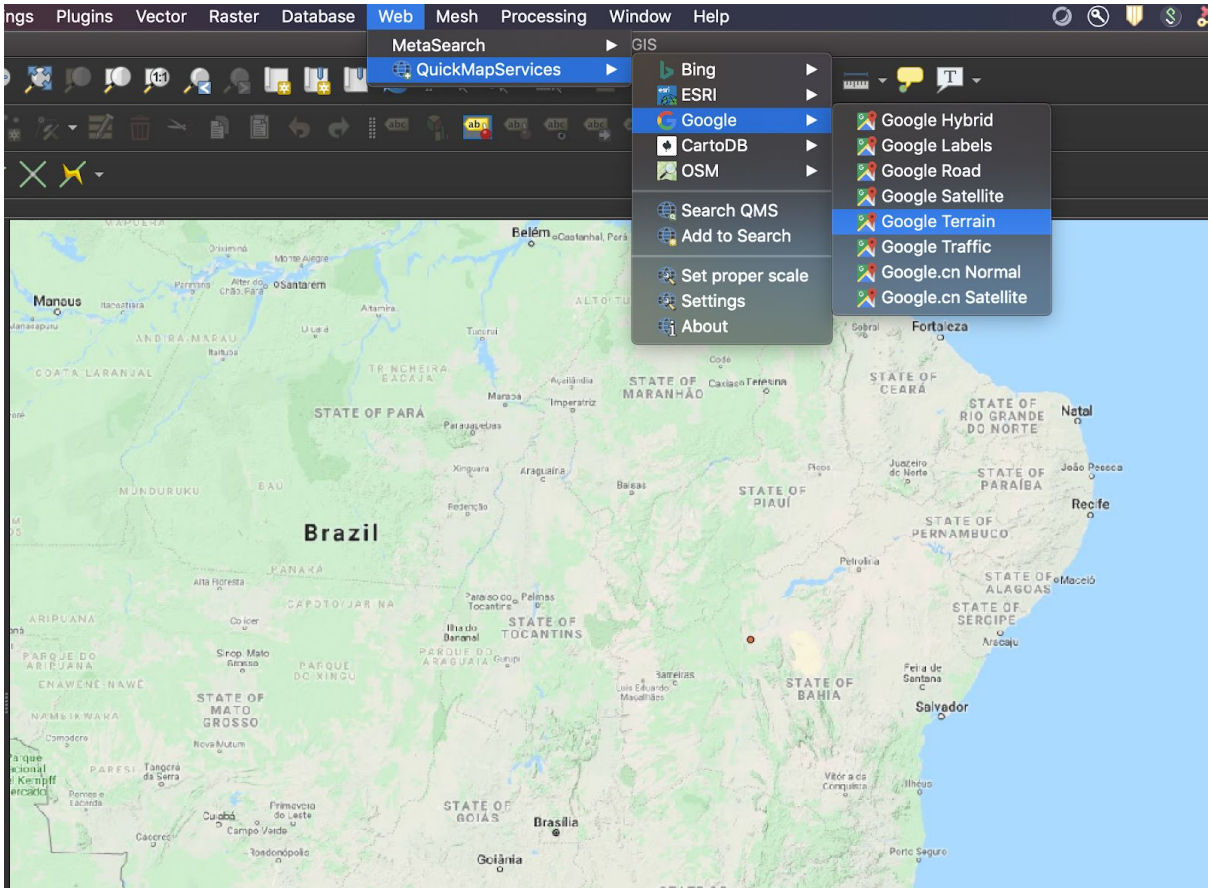
9. Click on “Delimited Text” in the left-hand column of the Data Source Manager window. Click on the ellipse on the right side of “File name” and select the CSV file you saved in ApacheOpenOffice (“BarraBrazil.csv”). Under “Geometry Definition”, specify the X field as the Long field from our CSV file and the Y field as the Lat field from the CSV file and enter the Coordinate Reference System (CRS): World Geodetic System 84 (WGS 84; EPSG:4326)
10. Click Add. You should now have a point location imported and displayed in QGIS
    a. Right-click on imported file and rename the layer “BarraBrazil”



11. Add a basemap to the project: Web —> QuickMapServices —> [Basemap]
    a. QuickMapServices Plugin is the easiest way to add basemaps in QGIS. If you don't have the plugin installed, follow the steps below:
    b. In the Menu Bar go to Plugins —> Manage and Install Plugins...
    c. In the Plugins Window, search for QuickMapServices and click the Install button
    d. After installing, you will find the QuickMapServices icon in the Web Toolbar
    e. If the Web Toolbar is not displayed, in the Menu Bar click on View → Toolbars → Web Toolbar

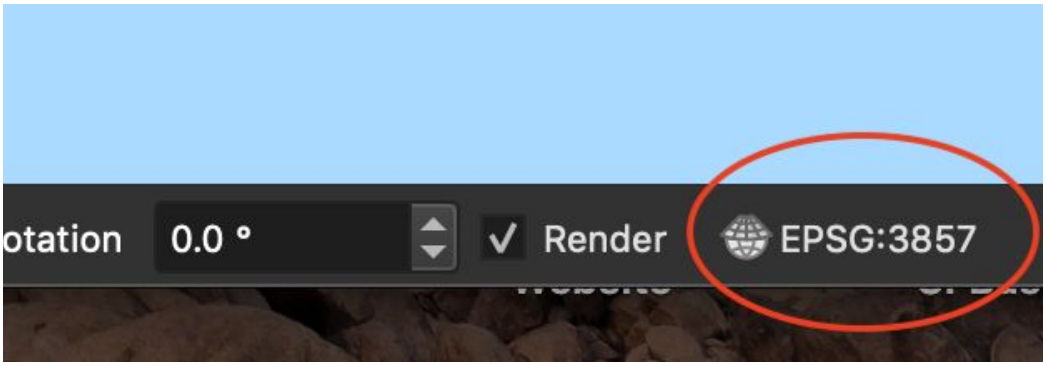


    f. Alternatively, you can access QuickMapServices under Web —> QuickMapServices —> [Basemap]

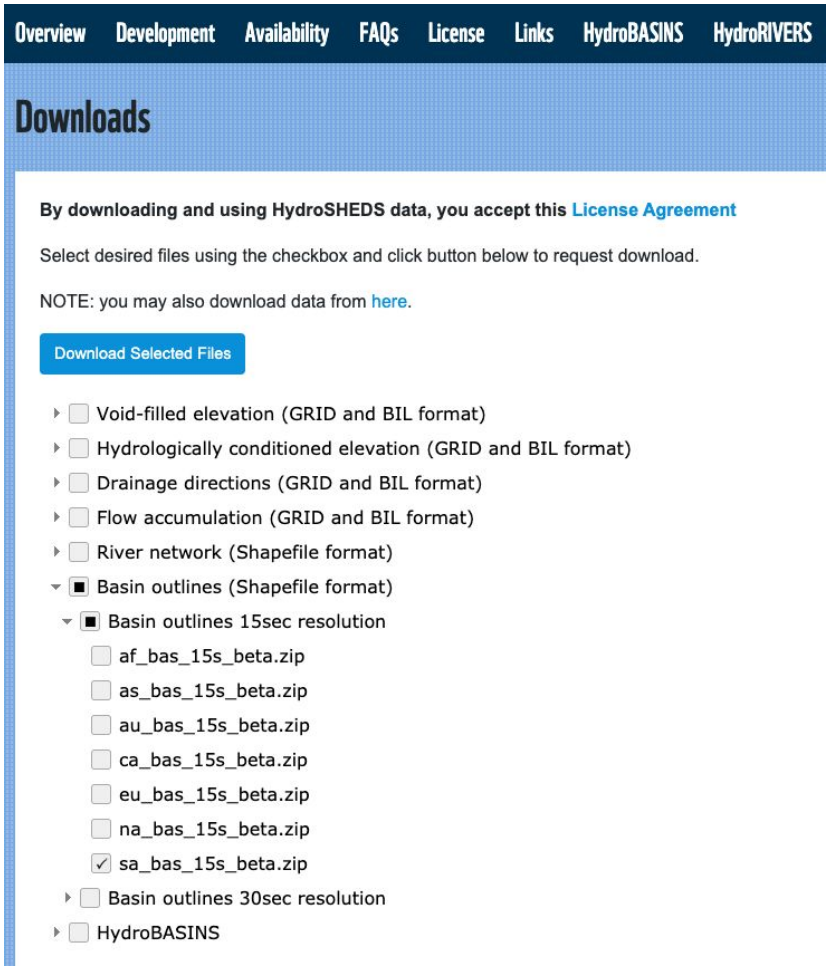


g. For a complete list of Basemap options, click on QuickMapServices —> Settings —> More Services —> Get contributed pack. Go to the Visibility tab (QuickMapServices —> Settings —> Visibility) and turn on/off the basemaps you want to display in the menu)

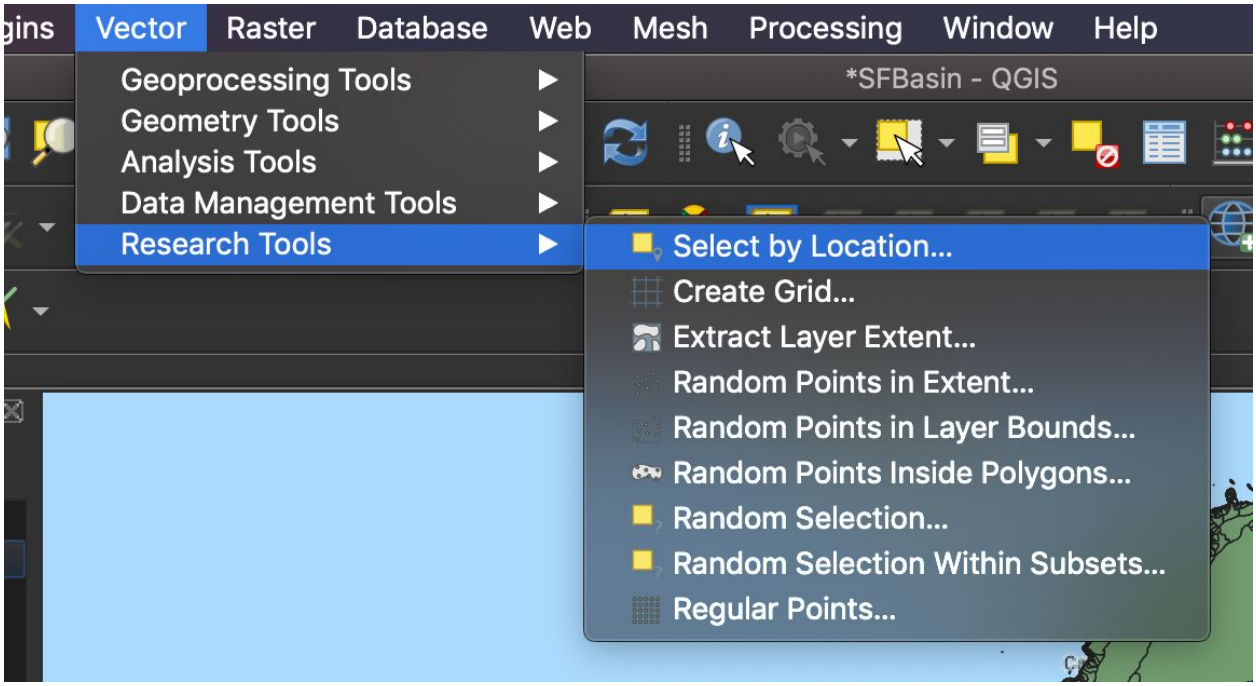
12. After adding a basemap, change the Coordinate Reference System (CRS) of the project by clicking on the CRS in the Status Bar in the bottom right of the map display

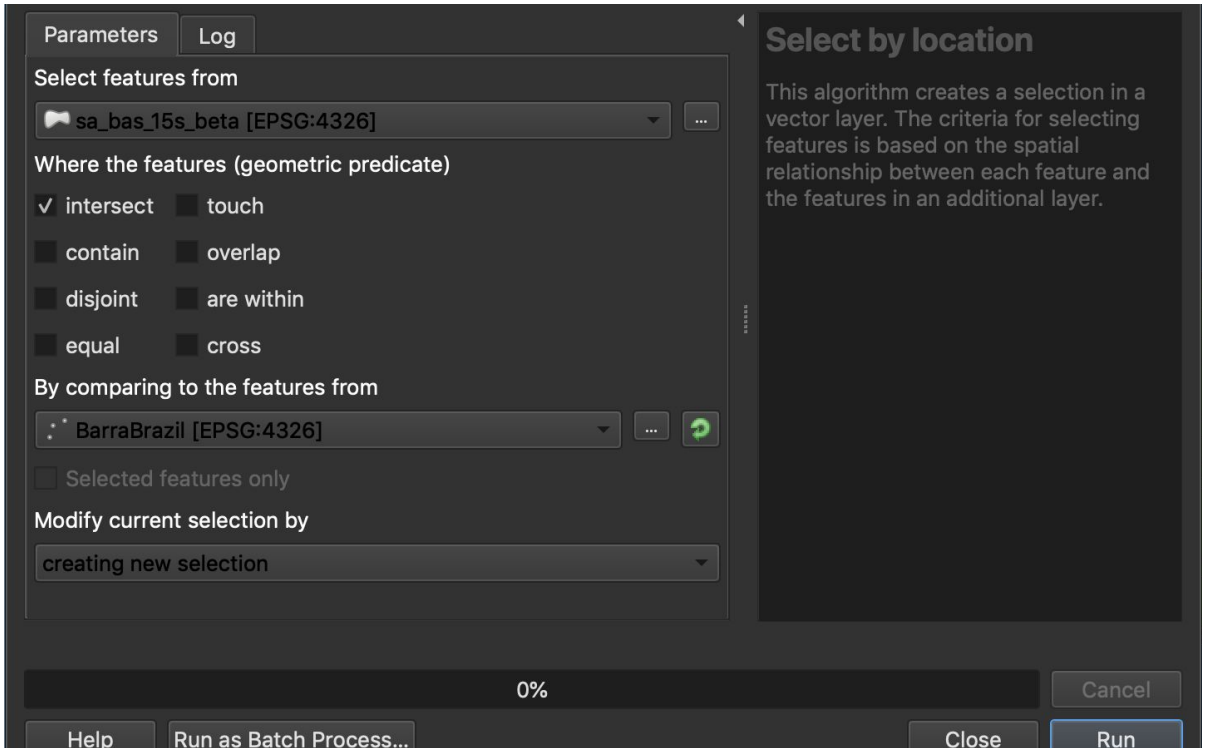


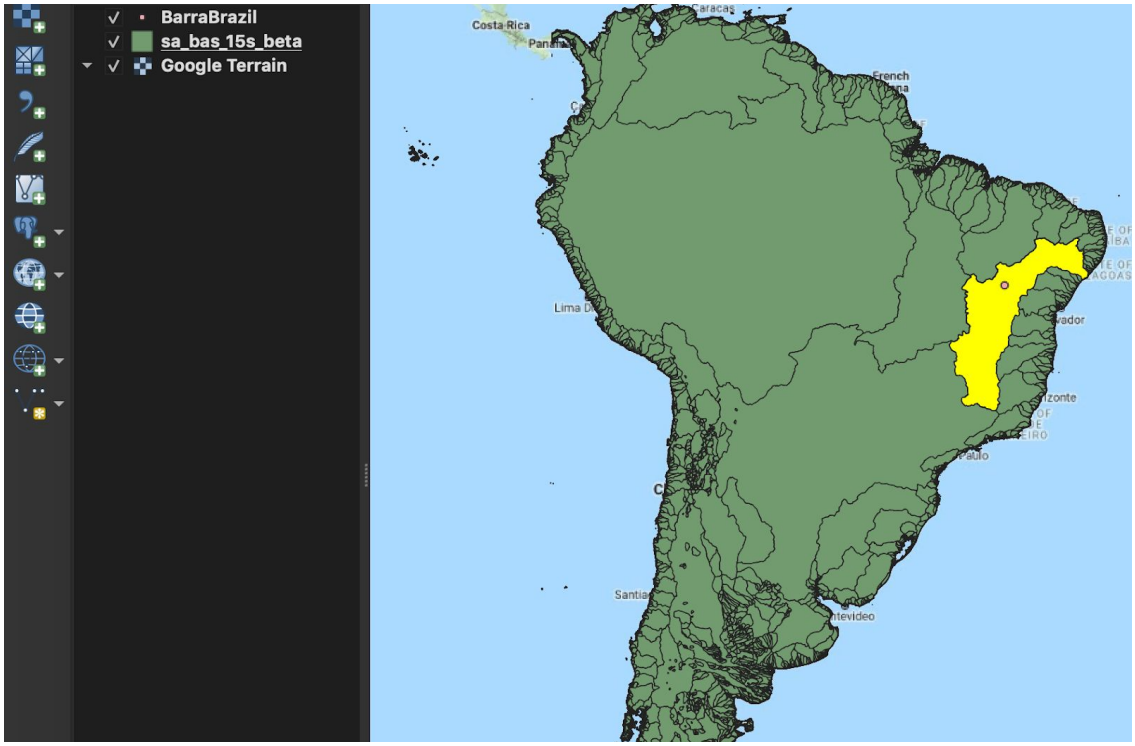
13. Change the CRS to **EPSG:4326**. You will notice after changing the CRS, the coordinates at the bottom of the map will be in Lat/Long. (e.g. -44.26,-12.37)
14. Next use a web browser and navigate to the HydroSHEDS website: https://www.hydrosheds.org/
15. Take the time to explore the website and learn how each dataset is derived
16. Click on the Download button at the top right of the webpage
17. Select Basin outlines 15sec resolution for South America: sa_bas_15s_beta.zip and click “Download Selected Files” and enter your email to submit the request



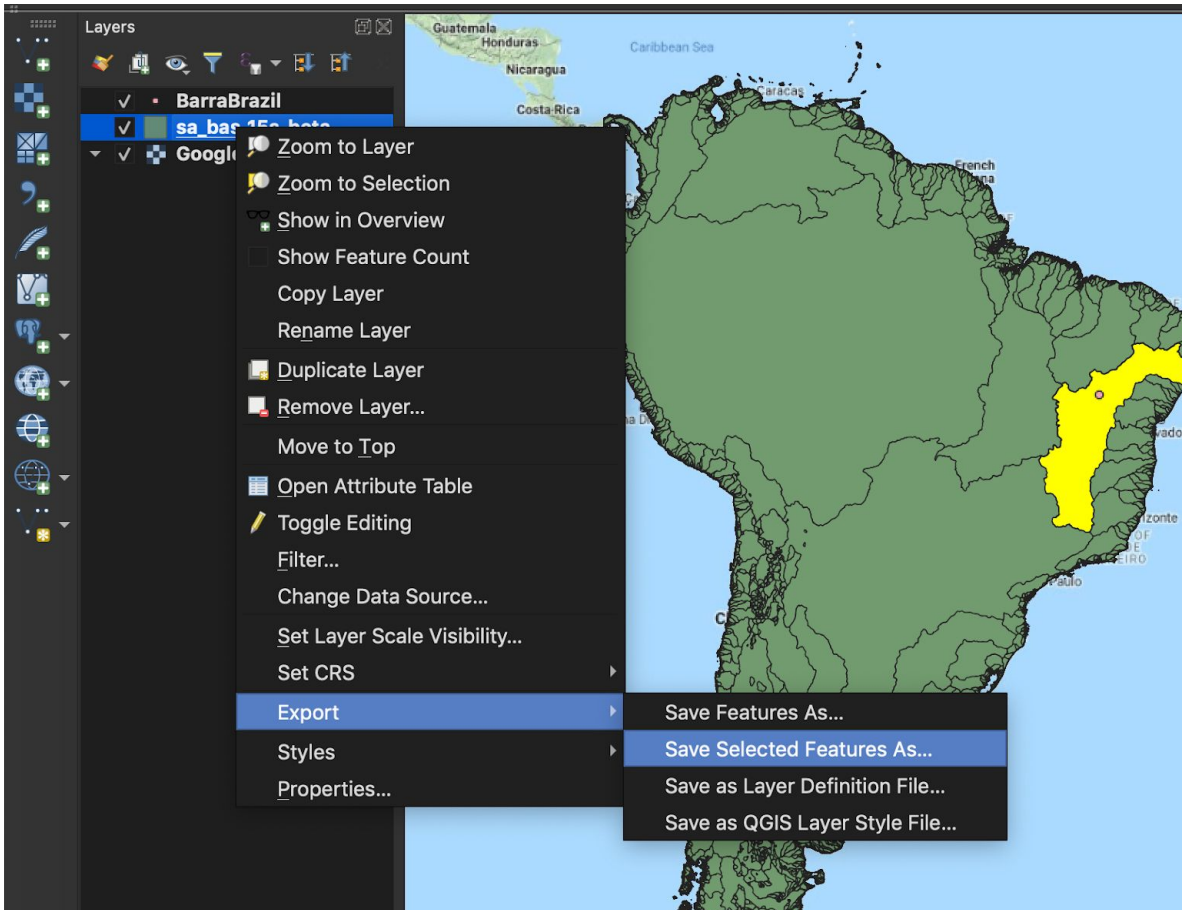
18. Once downloaded, unzip the folder and place in the “SABasins” subdirectory you created in step 2. “SABasins” stands for South America river basins
19. Add the South America basin shapefile to your project (“sa_bas_15s_beta.shp”)
20. Drag the “BarraBrazil” layer to the top of the Layers panel. We see Barra, Brazil is located within the San Francisco river basin. To delineate the basin we’ll use the “Select by Location” tool under Vector —> Research Tools.

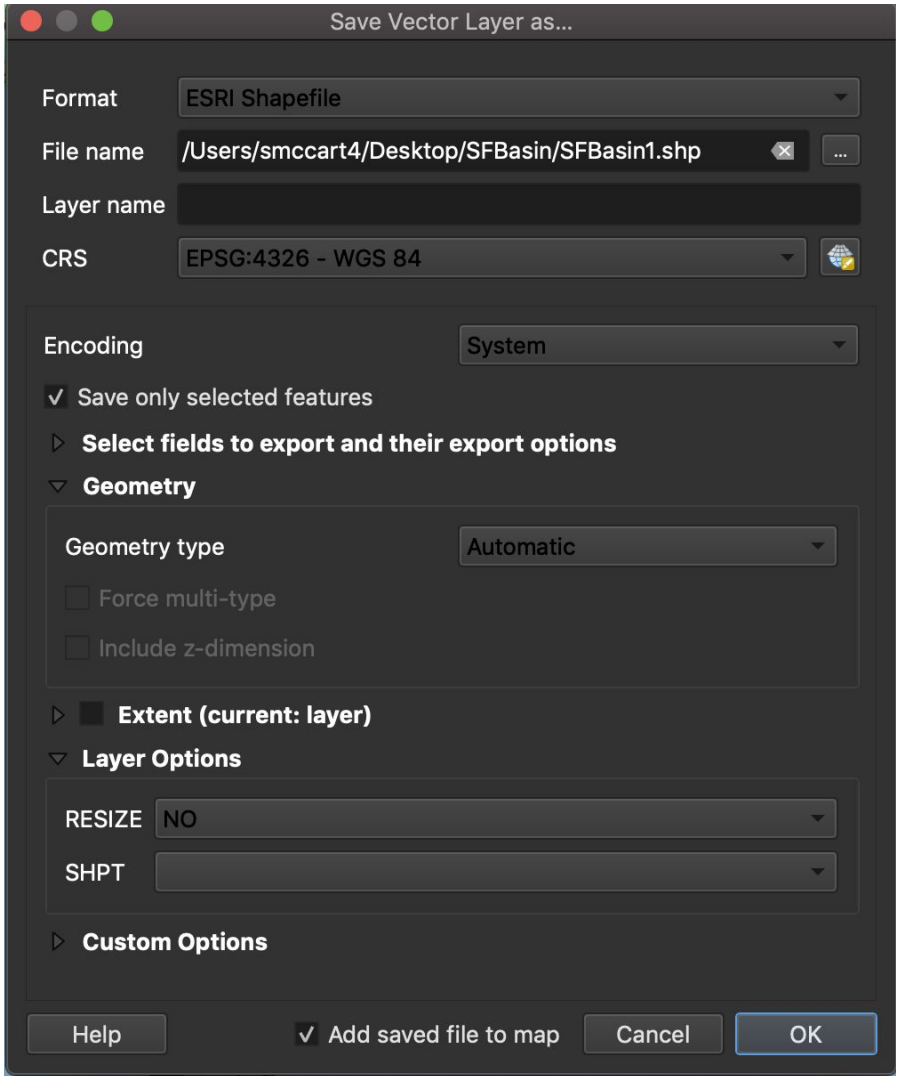

gins
Vector
Raster
Database
Web
Mesh
Processing
Window
Help
*SFBasin - QGIS
Geoprocessing Tools
Geometry Tools
Analysis Tools
Data Management Tools
Research Tools
Select by Location...
Create Grid...
Extract Layer Extent...
Random Points in Extent...
Random Points in Layer Bounds...
Random Points Inside Polygons...
Random Selection...
Random Selection Within Subsets...
Regular Points...


Parameters
Log
Select features from
sa_bas_15s_beta [EPSG:4326]
Where the features (geometric predicate)
intersect
touch
contain
overlap
disjoint
are within
equal
cross
By comparing to the features from
BarraBrazil [EPSG:4326]
Selected features only
Modify current selection by
creating new selection
Select by location
This algorithm creates a selection in a vector layer. The criteria for selecting features is based on the spatial relationship between each feature and the features in an additional layer.
0%
Cancel
Help
Run as Batch Process...
Close
Run

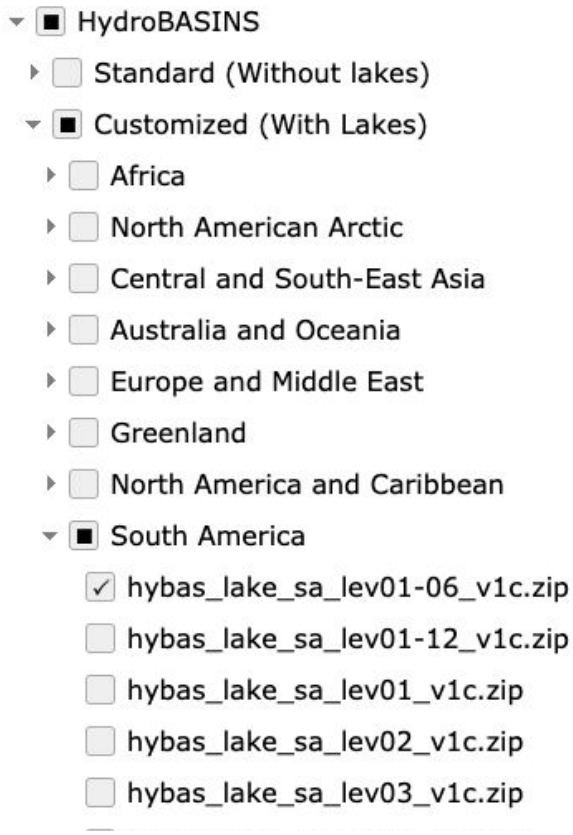


21. Export the selected river basin as a shapefile: right-click on the layer sa_bas_15s_beta —> Export —> Save Selected Feature As… —> (Save the file as “SFBasin1” in your working folder) and add it to your map

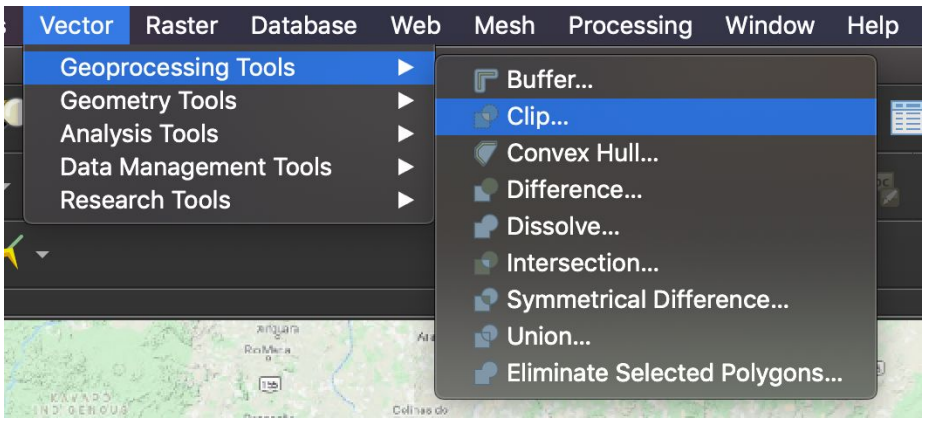

Layers
BarraBrazil
Zoom to Layer
Zoom to Selection
Show in Overview
Show Feature Count
Copy Layer
Rename Layer
Duplicate Layer
Remove Layer...
Move to Top
Open Attribute Table
Toggle Editing
Filter...
Change Data Source...
Set Layer Scale Visibility...
Set CRS
Export
Styles
Properties...
Save Features As...
Save Selected Features As...
Save as Layer Definition File...
Save as QGIS Layer Style File...
Guatemala
Honduras
Nicaragua
Costa Rica
Caribbean Sea



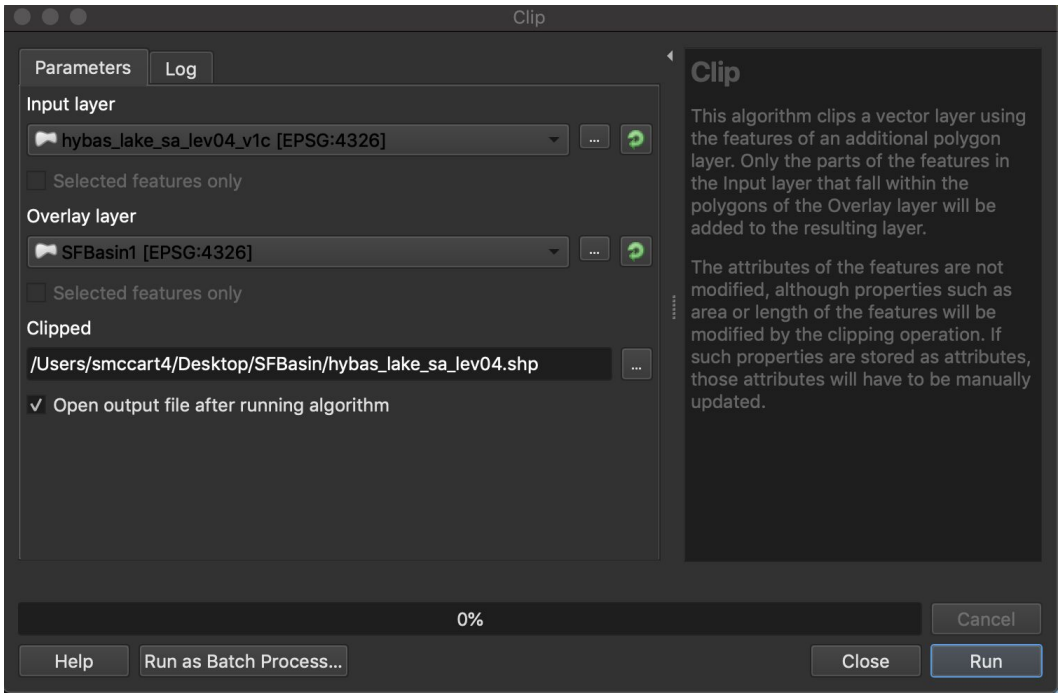
22. Remove “sa_bas_15s_beta” from the Layers panel
23. You should now have a base map, a shapefile for the San Francisco river basin, and a point layer showing Barra, Brazil in CRS: World Geodetic System 1984 (WGS84, EPSG:4326)
24. Go back to the HydroSHEDS Download webpage: https://www.hydrosheds.org/downloads
25. Select HydroBASINS → Customized (With Lakes) → South America → hybas_lake_sa_lev01-06_v1c.zip



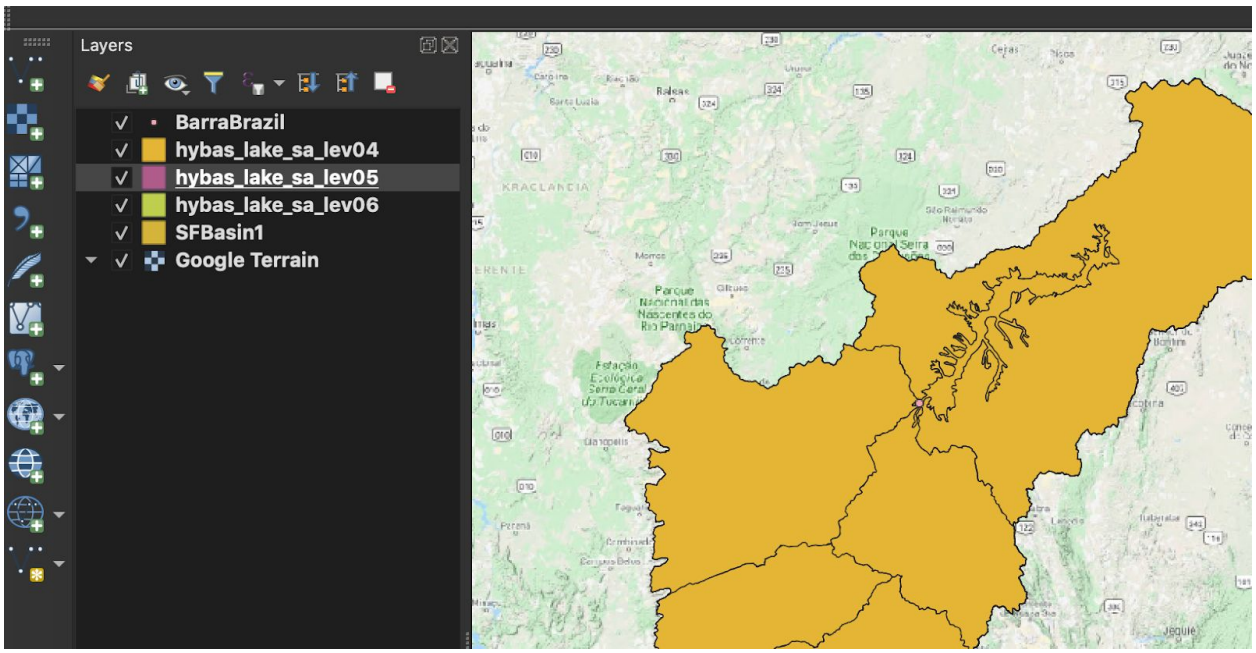
26. Click “Download Selected Files” and enter your email to submit the request
27. Unzip the downloaded file and move to the “HydroBASINS” subdirectory we created in step 2
28. Add the following river sub basins to your map
    a. Add Vector Layer…
    b. hybas_lake_sa_lev04_v1c
    c. hybas_lake_sa_lev05_v1c
    d. hybas_lake_sa_lev06_v1c
29. Clip each river basin file by the “SFBasin1” file



30. For Input layer add “hybas_lake_sa_lev04_v1c [EPSG:4326]”
31. For Overlay layer add “SFBasin1 [EPSG:4326]”
32. Under Clipped click on the ellipse on the right side and choose “Save to File”
    a. Desktop → SFBasin → hybas_lake_sa_lev04.shp → click “Run”

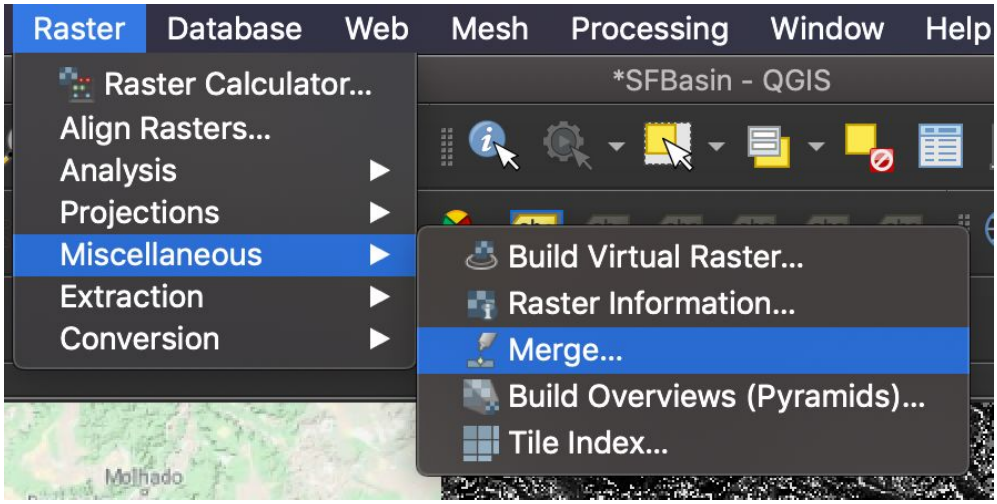


33. Rename the new file in the Layers panel
    a. Right-click on the newly clipped file → Rename Layer → hybas_lake_sa_lev04
34. Remove the layer “hybas_lake_sa_lev04_v1c” from the Layers panel
35. Repeat steps 31 - 35 with the files
    a. “hybas_lake_sa_lev05_v1c [EPSG:4326]”
    b. “hybas_lake_sa_lev06_v1c [EPSG:4326]”
36. Save your QGIS project
37. You should now have a project with layers as shown below

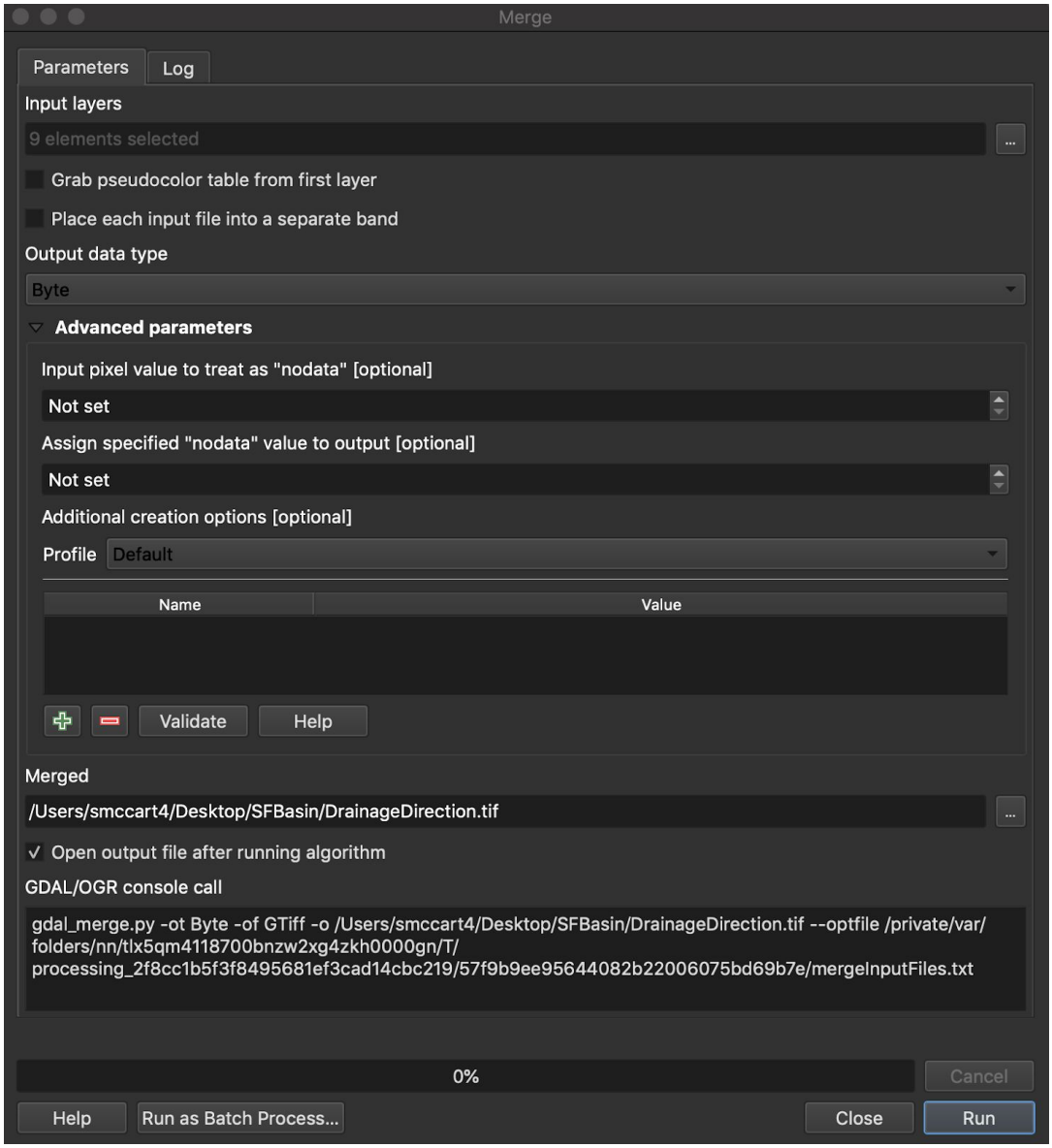


38. For information on how HydroSHEDS delineates sub basins refer to the webpage: https://www.hydrosheds.org/page/hydrobasins
39. Before we download more data from HydroSHEDS, we need to know the extent of the San Francisco river basin. Right-click on the SFBasin1 layer and select “Properties...”
    a. Click on “Information” on the left side of the window
    b. You will see metadata for the file including Name, Path, Source, CRS, Unit, etc. We are interested in the **Extent**: -47.6...,-20.9… | -36.3…, -7.2...
    c. The first set of coordinates correspond to the bottom left (southwest) extent

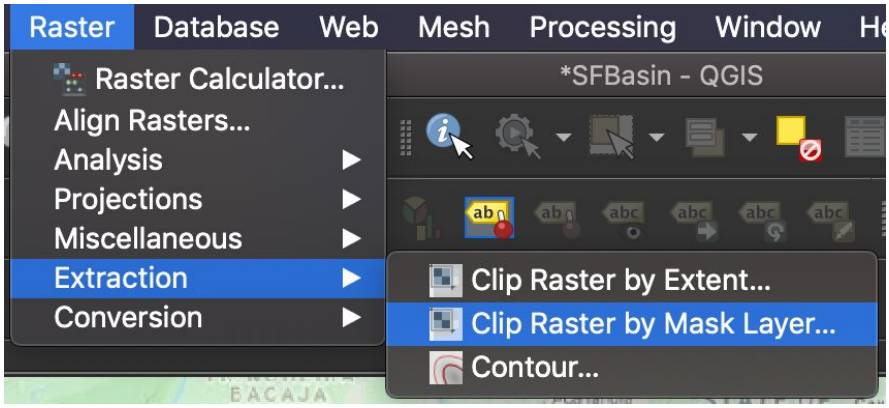
   d. The second set of coordinates correspond to the top right (northeast) extent
   e. The extent informs what data to download from HydroSHEDS
40. Go back to the HydroSHEDS Download webpage: https://www.hydrosheds.org/downloads
41. Select Drainage directions (GRID and BIL format) → Flow direction 3 sec resolution GRID → South America (5x5 tiles) → select the 9 files below
   a. s10w040_dir_grid.zip
   b. s10w045_dir_grid.zip
   c. s15w040_dir_grid.zip
   d. s15w045_dir_grid.zip
   e. s15w050_dir_grid.zip
   f. s20w045_dir_grid.zip
   g. s20w050_dir_grid.zip
   h. s25w045_dir_grid.zip
   i. s25w050_dir_grid.zip
42. Click “Download Selected Files” and enter your email to submit the request
43. Unzip the downloaded files and place in the “DrainageDirection” subfolder we created in step 2
44. Add the drainage direction raster files from each downloaded folder:
   a. Add Raster Layer… → Desktop → SFBasin → DrainageDirection → s10w040_dir → prj.adf → click “Open” → click “Add”
   b. Repeat these steps for subsequent drainage direction raster files
45. Merge the drainage direction files into one file:
   a. Raster → Miscellaneous → Merge



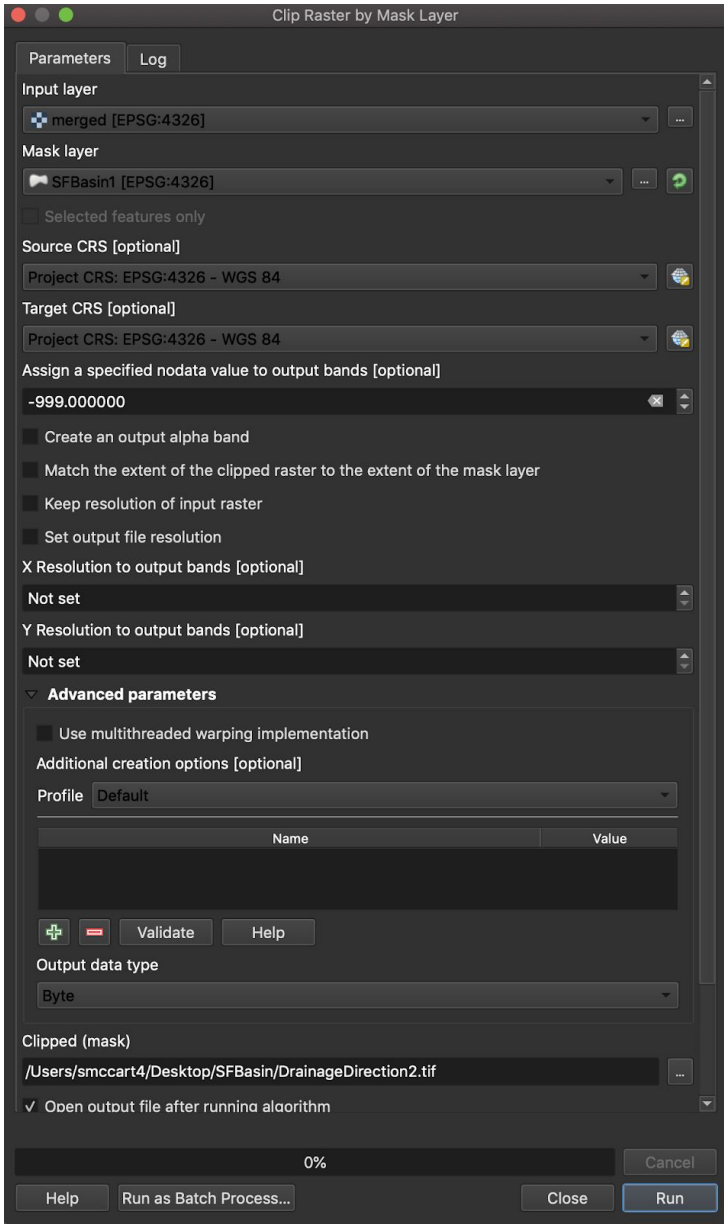
b. For Input layers, select all 9 drainage direction raster files → click OK
c. For Output data type select “Byte” from the dropdown list
d. Under Merged click on the ellipse on the right → Save to File… → navigate to the working folder (“SFBasin”) and save the file as “merged.tif”
e. Click the dropdown and select TIF files (*.tif) and click Save
f. Click Run



46. Clip the merged drainage direction file by the SFBasin1 vector file

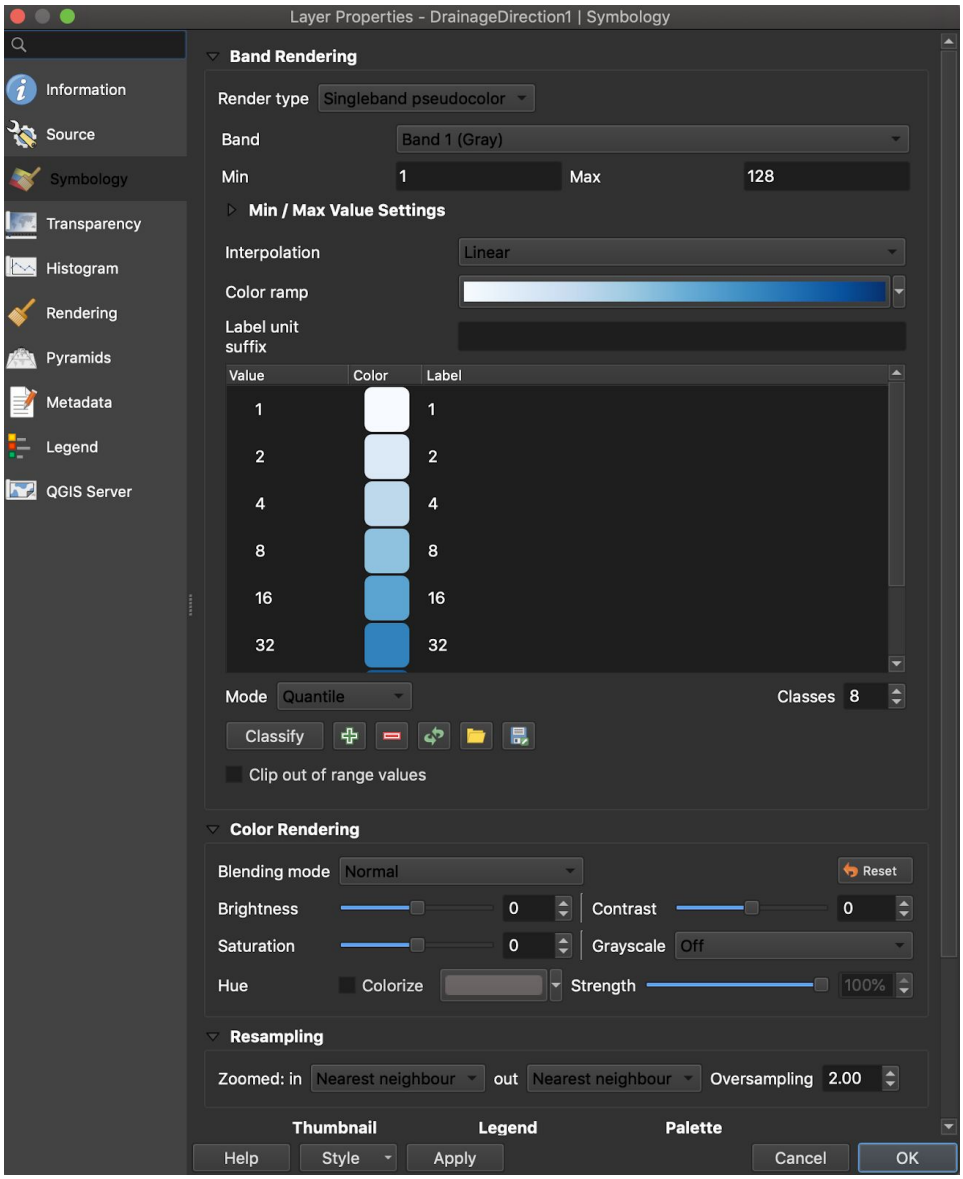


47. Clip Raster by Mask Layer
    a. Input layer → merged [EPSG: 4326]
    b. Mask layer → SFBasin1 [EPSG:4326]
    c. Source CRS → Project CRS: EPSG 4326 - WGS 84
    d. Target CRS → Project CRS: EPSG 4326 - WGS 84
    e. Assign a specified no data value… → -999
    f. Uncheck “Match the extent of the clipped raster to the extent of the mask layer”
    g. Output data type → Byte
    h. Clipped (mask) → Save to File… → Desktop → SFBasin → “DrainageDirection1.tif”
    i. Click Run

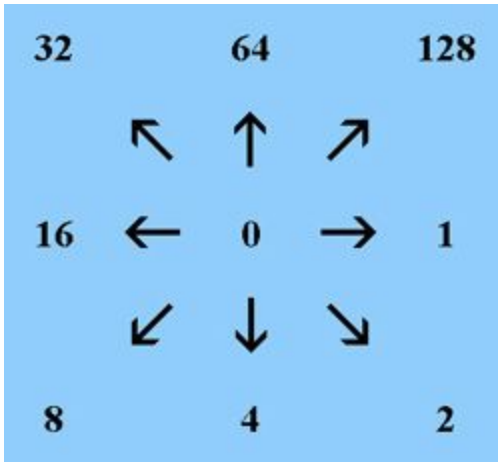


48. Rename the clipped layer in the Layers panel “DrainageDirection1”
49. Symbolize the drainage flow layer using the steps below:
    a. Right-click on the “DrainageDirection1” layer
    b. Click on “Properties”
    c. Click on “Symbology” in the left-hand column of the Layer Properties window
    d. Render type → Singleband pseudocolor

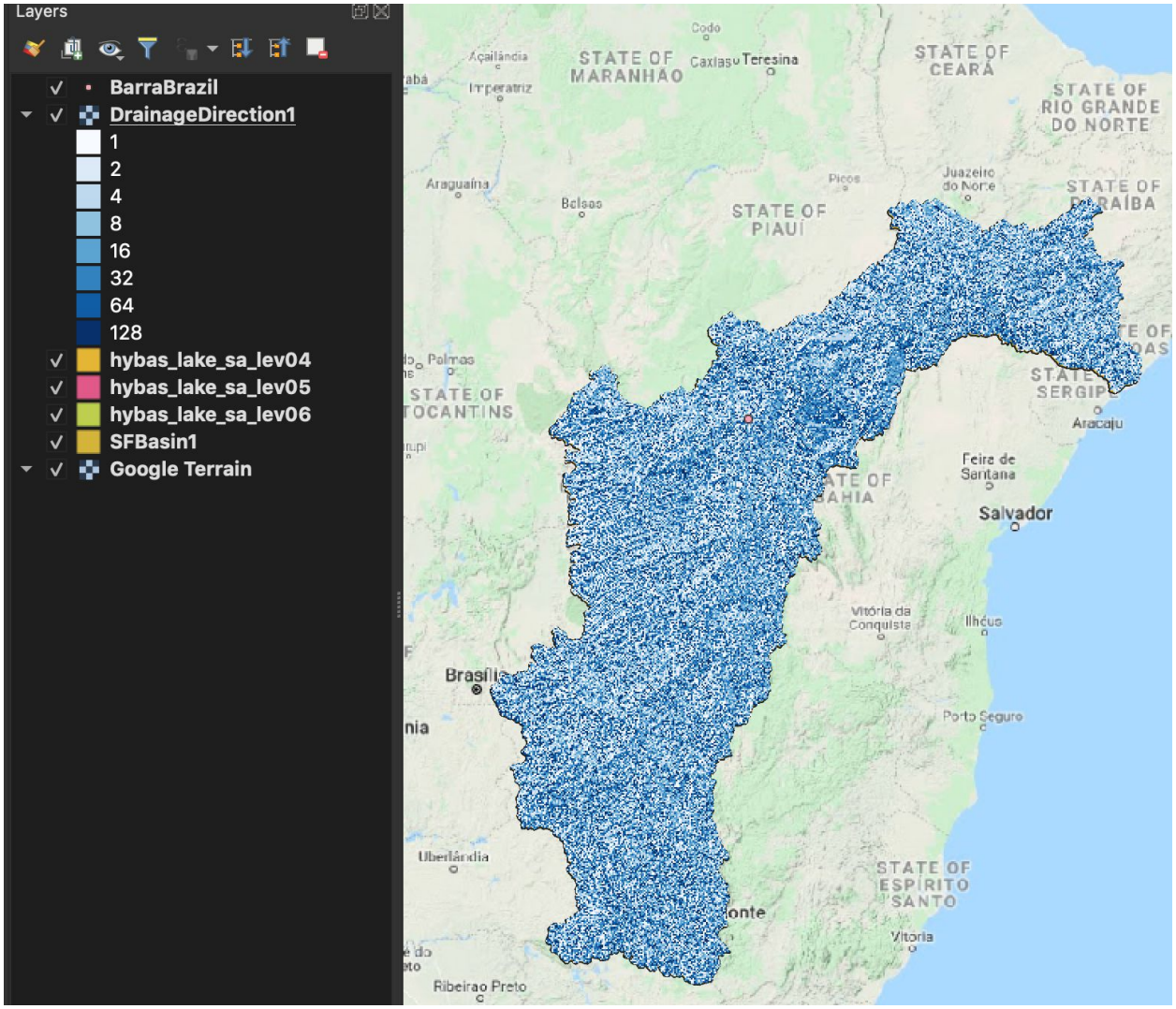
e. Color ramp → Blues
f. Mode → Quantile
g. Classes → 8
h. Leave the rest of the parameters as default and click OK



50. The drainage direction maps distributed with HydroSHEDS define the direction of flow from each cell to its steepest down-slope neighbor. Values of flow direction vary from 1 to 128. All final outlet cells to the ocean are flagged with a value of 0. All cells that mark the lowest point of an endorheic basin (inland sink) are flagged with a value of -1. The flow direction values follow the convention adopted by ESRI's flow direction implementation:



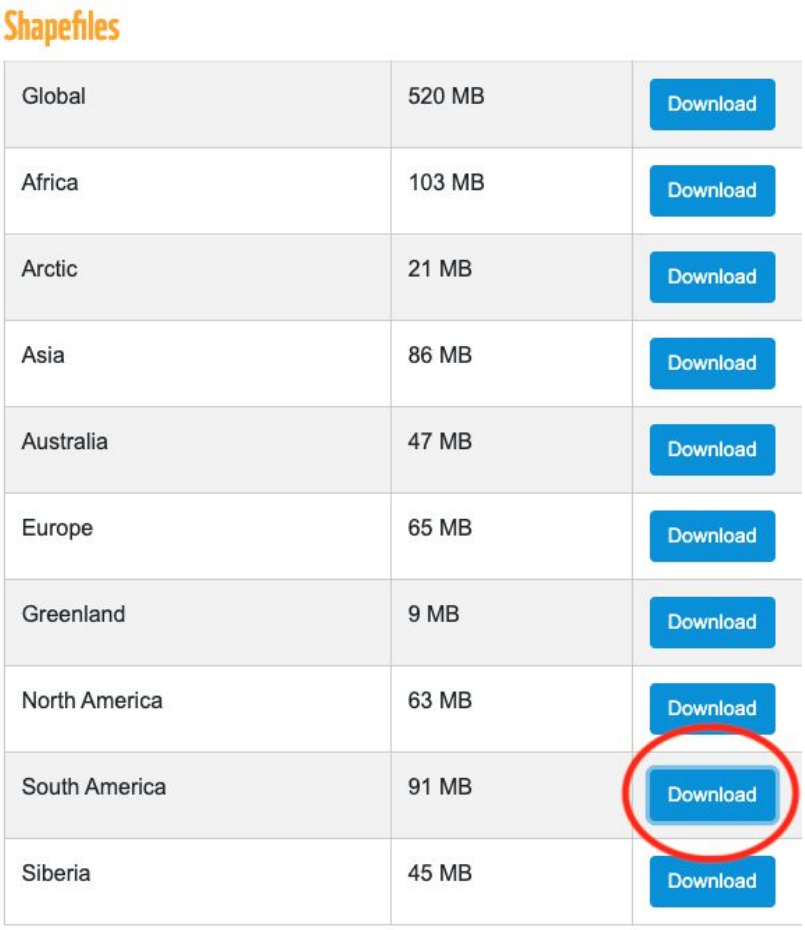
51. Remove the 9 drainage direction layers from the Layers panel
52. Remove the merged layer from the Layers panel
53. Save your QGIS project
54. You should now have a project with a delineated layer for the San Francisco river basin, 3 sub basin layers, a symbolized flow direction layer, a layer for Barra, Brazil, and a basemap



55. At this step you have downloaded and processed HydroSHEDS data based on a geographic location. You have delineated a river basin and sub basins including the direction of flow from each cell to its steepest down-slope neighbor. **These steps can be followed for any other geographic location**

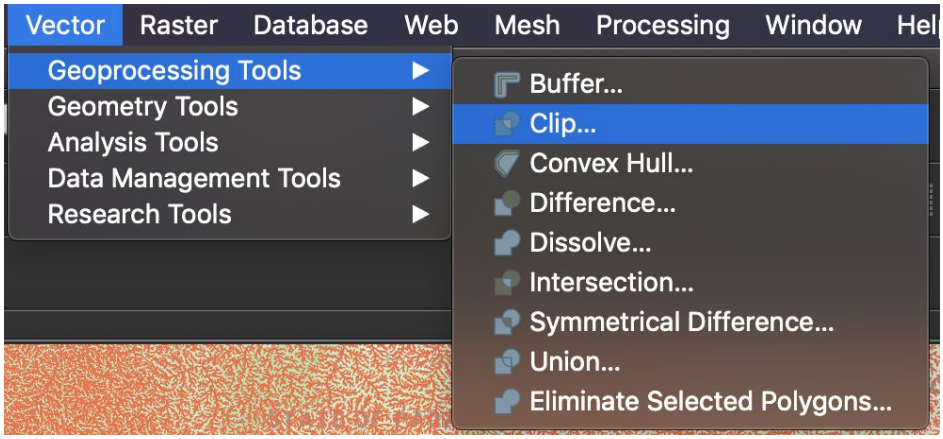
The remaining steps are optional for this webinar but highly encouraged

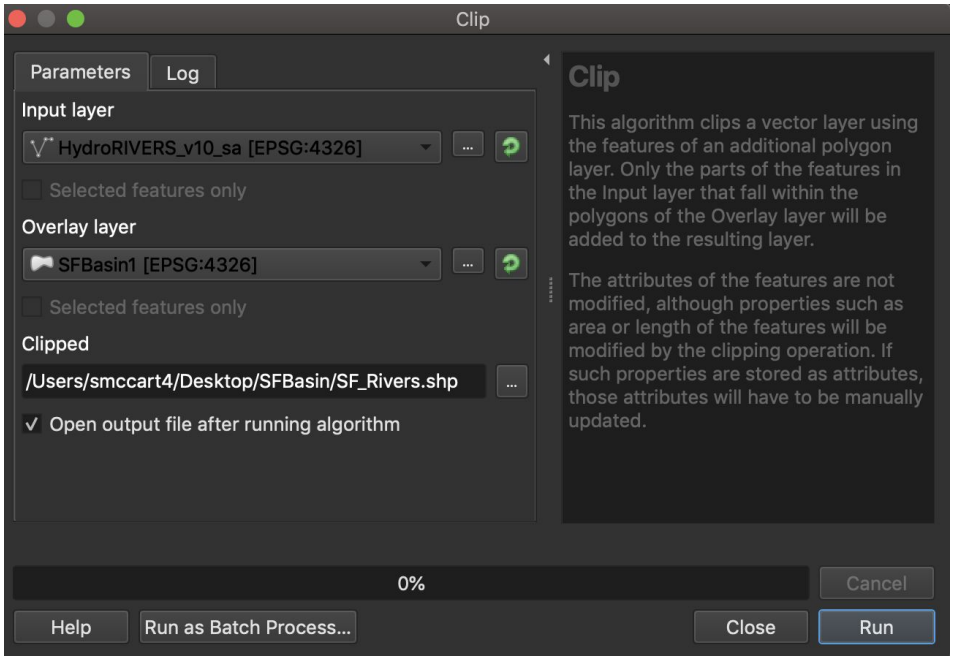
56. Download and process HydroRIVERS data layers. HydroRIVERS provide a global coverage of consistently sized river reaches: https://www.hydrosheds.org/images/inpages/HydroRIVERS_TechDoc_v10.pdf
57. Go to the HydroRIVERS webpage: https://www.hydrosheds.org/page/hydrorivers
58. Scroll down to Shapefiles and click “Download” next to South America



59. Download and unzip the contents of the folder into the “RiverNetwork” directory you created in step 2
60. Add the “HydroRIVERS_v10_sa.shp” file to your project

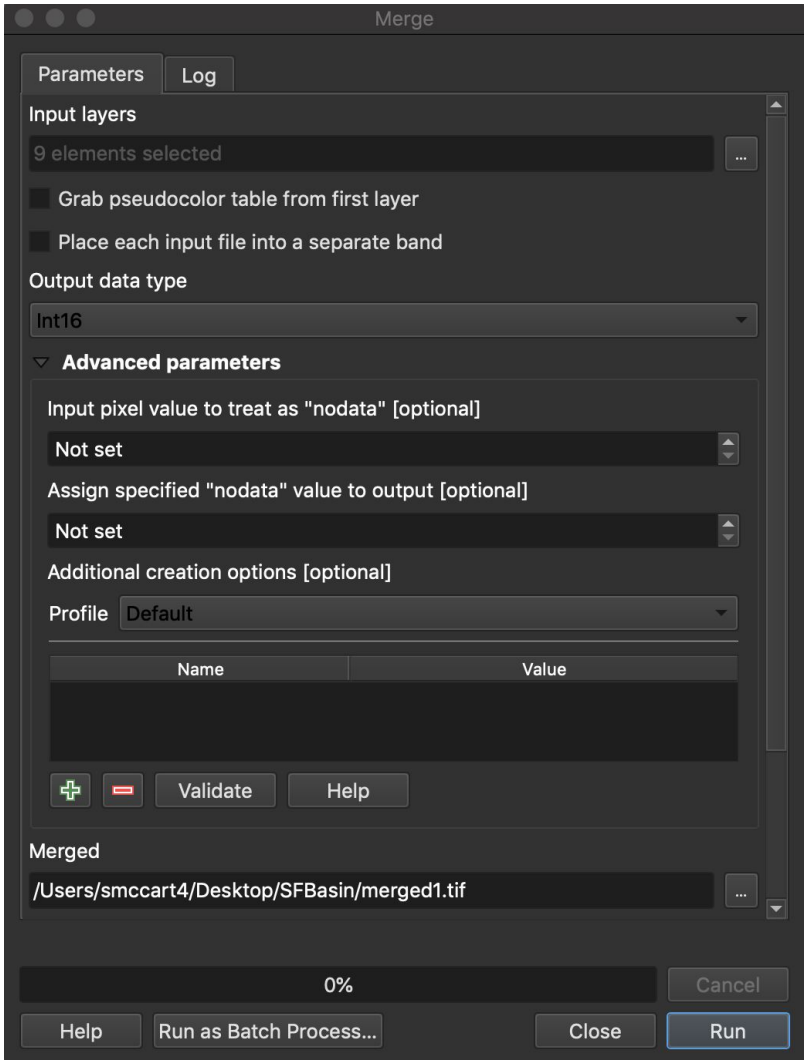
61. Clip the HydroRIVERS file by the SFBasin1 layer and save the new file in your working folder as “SF_Rivers”. Click Run





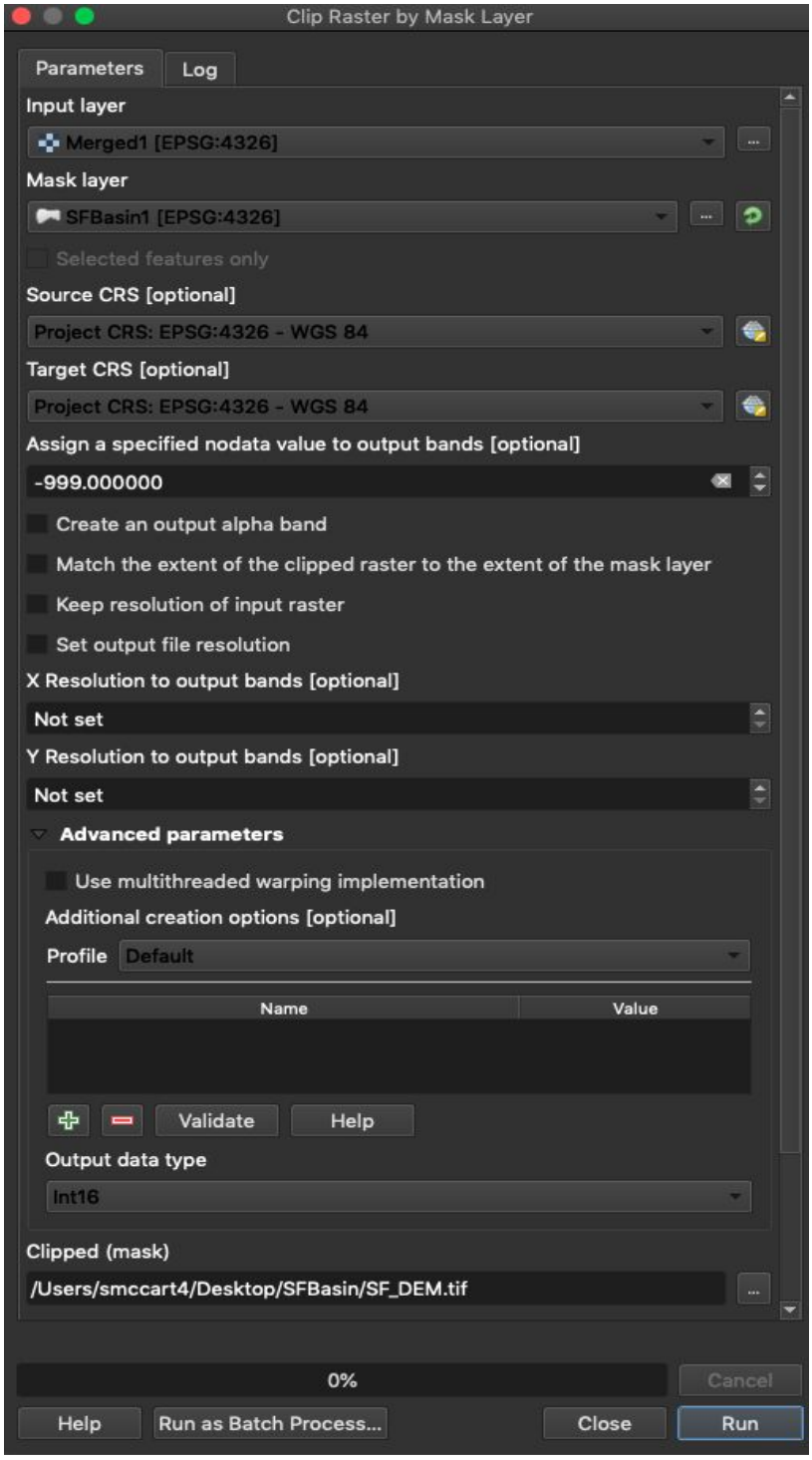
62. Rename the clipped layer “SF_Rivers” in the Layers panel
63. Symbolize the SF_Rivers layer with a blue hue
64. Remove HydroRIVERS_v10_sa from the Layers panel

65. Save your QGIS project
66. Go back to the HydroSHEDS Download webpage: https://www.hydrosheds.org/downloads
67. Select Void-filled elevation (GRID and BIL format) → Elevation 3sec resolution GRID → South America (5x5 tiles) → select the 9 files below
    a. s10w040_dir_grid.zip
    b. s10w045_dir_grid.zip
    c. s15w040_dir_grid.zip
    d. s15w045_dir_grid.zip
    e. s15w050_dir_grid.zip
    f. s20w045_dir_grid.zip
    g. s20w050_dir_grid.zip
    h. S25w045_dir_grid.zip
    i. s25w050_dir_grid.zip
68. Click "Download Selected Files" and enter your email to submit the request
69. Unzip the downloaded files and place in the "DEM" subdirectory we created in step 2
70. Add the elevation raster files from each downloaded folder:
    a. Add Raster Layer… → Desktop → SFBasin → DEM → s10w040_dem → prj.adf → click "Open" → click "Add"
    b. Repeat these steps for subsequent elevation raster files
71. Merge the 9 elevation files into one file:
    a. Raster → Miscellaneous → Merge
    b. For Input layers, select all 9 elevation raster files → click OK
    c. For Output data type select "Int16" from the dropdown list
    d. Under Merged click on the ellipse on the right → Save to File… → navigate to the working folder ("SFBasin") and save the file as "merged1.tif"
    e. Click the dropdown and select TIF files (*.tif) and click Save
    f. Click Run

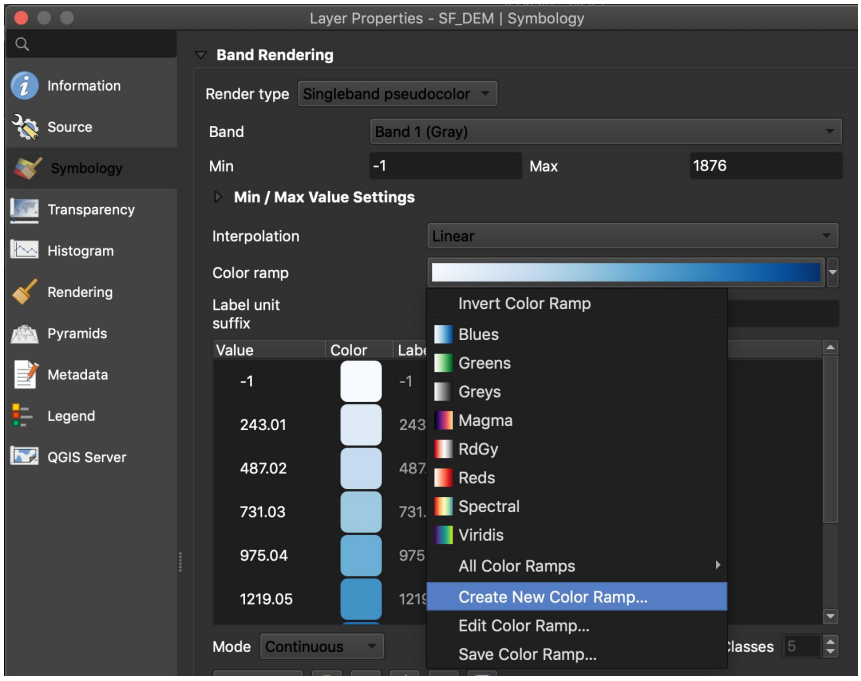


72. Clip the merged1 layer by the SFBasin1 layer
    a. Raster → Extraction → Clip Raster by Mask Layer…
    b. Input layer → Merged1
    c. Mask layer → SFBasin1
    d. Source CRS → Project CRS: EPSG: 4326 - WGS84
    e. Target CRS → Project CRS: EPSG: 4326 - WGS84
    f. Assign a specified no data value… → -999
    g. Uncheck “Match the extent of the clipped raster to the extent of the mask layer”

h. Output data type → Int16
i. Clipped (mask) → Save to File… → Desktop → SFBasin → “SF_DEM.tif”
j. Click Run

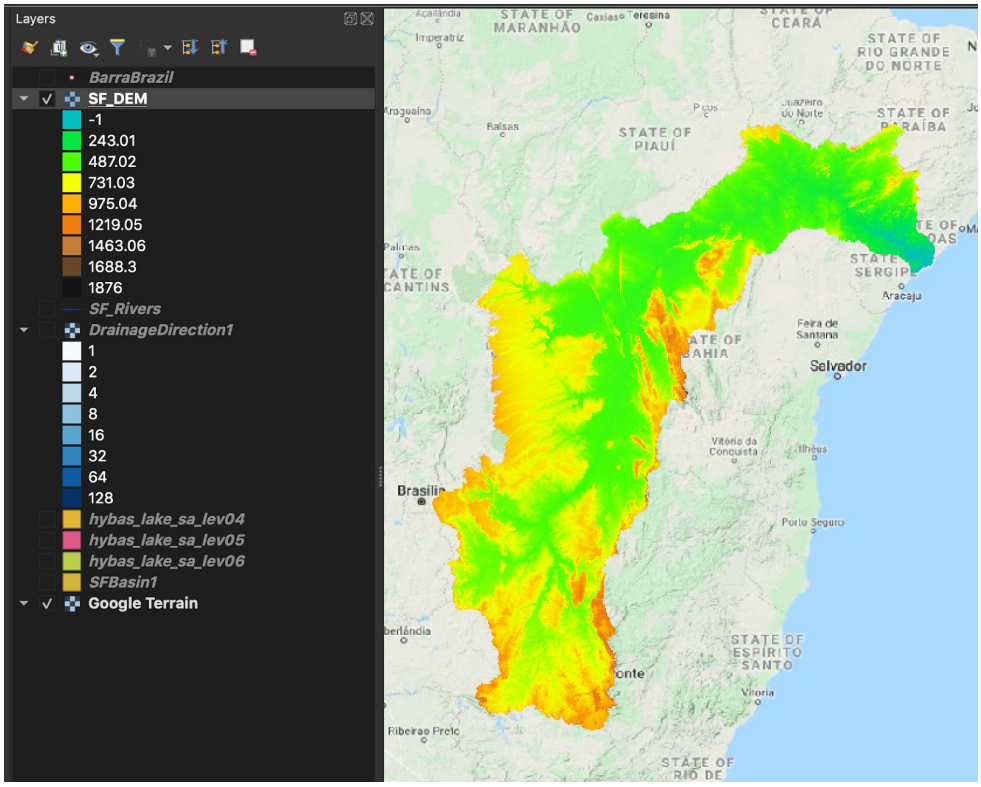

Clip Raster by Mask Layer
Parameters
Log
Input layer
Merged1 [EPSG:4326]
Mask layer
SFBasin1 [EPSG:4326]
Selected features only
Source CRS [optional]
Project CRS: EPSG:4326 - WGS 84
Target CRS [optional]
Project CRS: EPSG:4326 - WGS 84
Assign a specified nodata value to output bands [optional]
-999.000000
Create an output alpha band
Match the extent of the clipped raster to the extent of the mask layer
Keep resolution of input raster
Set output file resolution
X Resolution to output bands [optional]
Not set
Y Resolution to output bands [optional]
Not set
Advanced parameters
Use multithreaded warping implementation
Additional creation options [optional]
Profile
Default
Name
Value
Validate
Help
Output data type
Int16
Clipped (mask)
/Users/smccart4/Desktop/SFBasin/SF_DEM.tif
0%
Cancel
Help
Run as Batch Process...
Close
Run

73. Rename the clipped elevation file “SF_DEM”
74. Remove the 9 elevation layers and merged layer
75. Change the symbology of the SF_DEM layer
    a. Right-click on the SF_DEM layer
    b. Click on Symbology in the left column
    c. Render type → Singleband pseudocolor
    d. Click on the down arrow at the right side of Color ramp

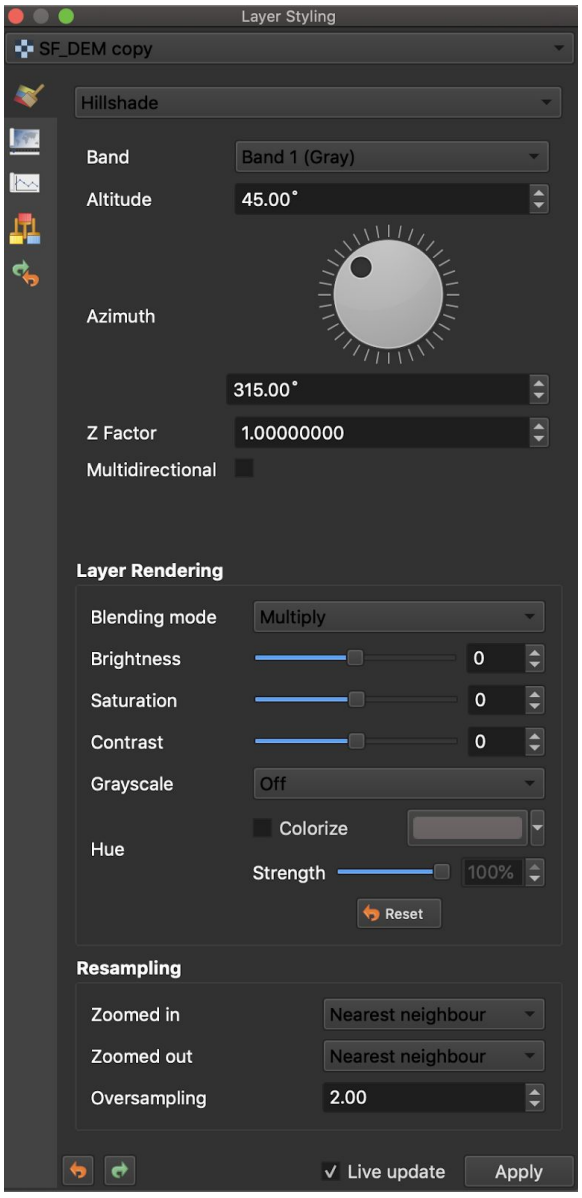


    e. Click on Create New Color Ramp…
    f. Select Catalog: cpt-city from the dropdown list. Click OK
    g. From the Name panel → Topography → elevation (palette)
    h. Click OK

76. You should have a map that looks like the one below



77. To improve the rendering of the elevation data, we will blend the DEM with a hillshade layer following the steps below
    a. Right-click on the SF_DEM layer → Duplicate Layer
        i. This creates a layer named “SF_DEM copy” in the Layers panel
    b. Drag “SF_DEM copy” above “SF_DEM” in the Layers panel
    c. Menu Bar → View → Panels → Layer Styling (for a shortcut you can use F7)
    d. Select the Symbology icon on the left side of the Layer Styling window
    e. Select “SF_DEM copy” from the dropdown list of layers
    f. Select Hillshade from the second dropdown
    g. Layer Rendering → Blending mode → select “Multiply” from the dropdown
    h. Click Apply
78. Save your QGIS project



79. For the San Francisco river basin, you now have delineated sub basins, delineated drainage direction, a river network, and an enhanced DEM. This

same methodology applies to any river basin on the planet and can be used for further scientific analysis and visualization of data.