Using Geographic Information Systems (GIS)
For students in MLD-412: Greater Boston Applied Field Lab

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Learning objectives:

- Learn what GIS is, how to use it, and become familiar with the basics of QGIS software.
- Create a thematic maps of median household income for Massachusetts.
- Create subway ridership maps for Boston.
- Calculate distance from subway stations to the coast.
- Explore road expenditures for Massachusetts Towns.

QGIS mapping exercise

QGIS is an open source, free, desktop geographic information software that runs on Windows, Mac, or Linux operating systems. This goal of this exercise is to practice interacting with geographic data and map symbology using QGIS.

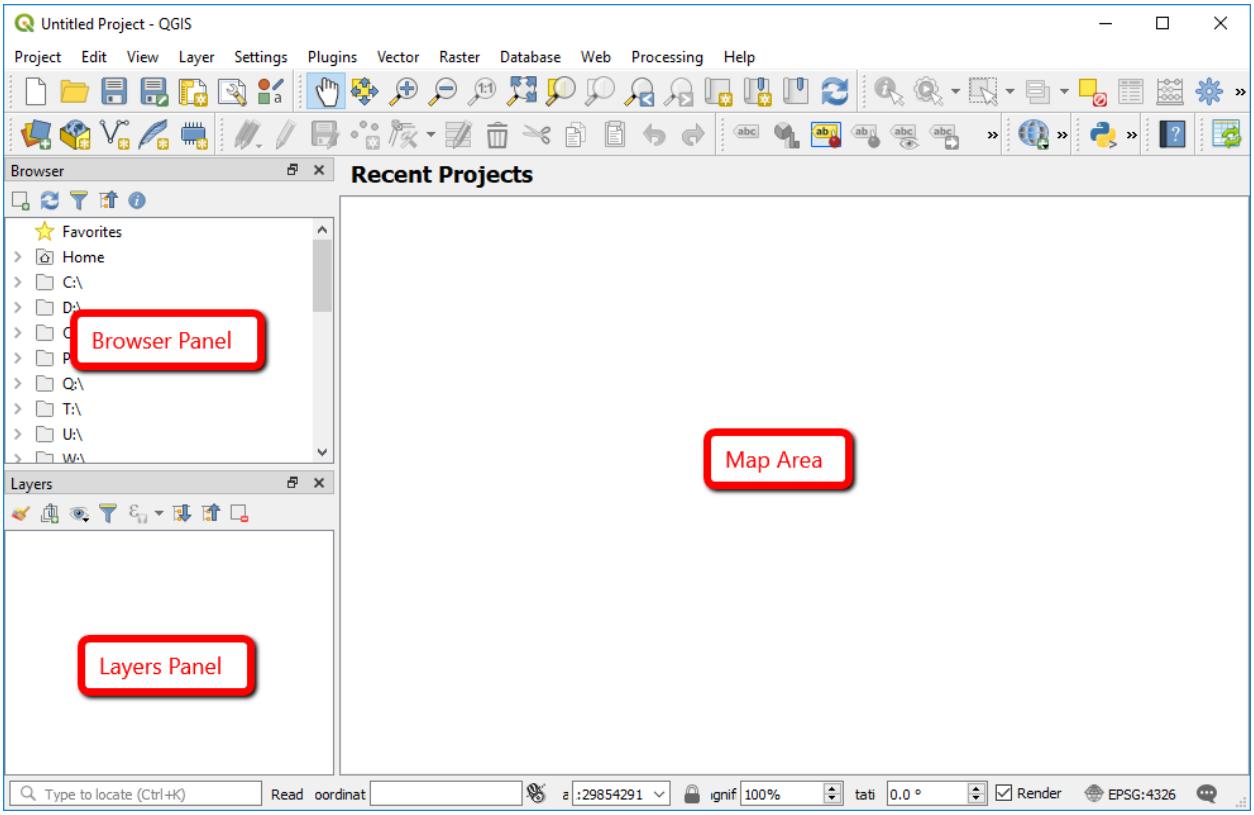
First Step: ***Download and install QGIS***. If you haven't already done this, follow instructions in the "Installing_QGIS.docx" on the class Canvas website.

PART A: DOWNLOAD THE DATA AND CONFIGURE AND EXPLORE QGIS

1) **Get the data and instructions.** Create a folder on your computer called "GIS". Download the Data.zip and Instructions.zip files from the Canvas website. Unzip these into your GIS folder. You should now have "Data" and "Instructions" subfolders in your GIS folder.

2) **Open and explore QGIS.** Start QGIS by clicking Start > All Programs > QGIS 3.4 > QGIS Desktop 3.4.4 on Windows, on a Mac go to Applications and double click the QGIS Desktop icon.

The QGIS interface has several parts to interact with. By default, QGIS will open with the Browser Panel, Layers Panel, Map Area, Processing Toolbox, and Search QMS dialog boxes open. The Browser Panel, Layers Panel, and Map Area are what you'll interact most with. Close the Processing Toolbox and Search QMS window by clicking on the X in the upper right of these windows. Your project should look like the screenshot on the next page:



3) **Add the MA_Towns shapefile to your map.** Use the **Browser** panel in QGIS to navigate to your GIS folder. Double click the **Data** subfolder and then **Shapefiles** subfolder. Click on the MA_Towns.shp file and drag it onto the map. You map should now show town boundaries for Massachusetts.

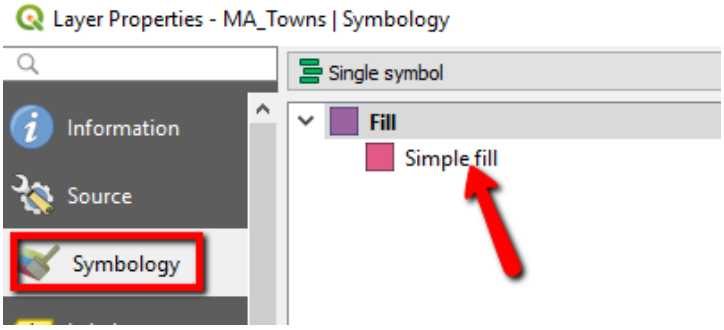
4) **Practice navigating the map**. Now that you've added a layer to your map, take a few minutes to familiarize yourself with QGIS functionality and practice using the map Navigation tools:

5) **Examine the MA_Towns attribute table.** Right click on MA_Towns in the Layer list and choose **Open Attribute Table**. This displays the total number of features in the layer, and lists the attributes in the layer. This is demographic data from the US Census Bureau. Here is a key explaining what is in each attribute:

TOWN_ID	Identification number of the town.
TOWN	Town name.
POP1980	Population in 1980.
POP1990	Population in 1990.
POP2010	Population in 2010.
POPCH80_90	Population change, 1980 - 1990.
POPCH90_00	Population change, 1990 - 2000.

POPCH00_10	Population change, 2000 - 2010.
TOTPOP_CY	Population in 2017.
POPDENS_CY	Population density in 2017.
MEDAGE_CY	Median age in 2017.
UNEMP_CY	Total over the age of 16 unemployed in 2017.
MEDHINC_CY	Median household income in 2017.
MEDVAL_CY	Median home value in 2017.
Shape_Leng	Perimeter of the Town, in meters.
Shape_Area	Area of the Town, in square meters.

6) **Change Symbology.** To change the Symbology of your MA_Towns layer, double click it in the Layers Panel. This will open the Layer Properties. Choose the **Symbology** tab on the left, and then click where it says **Simple Fill**. See screenshot below:



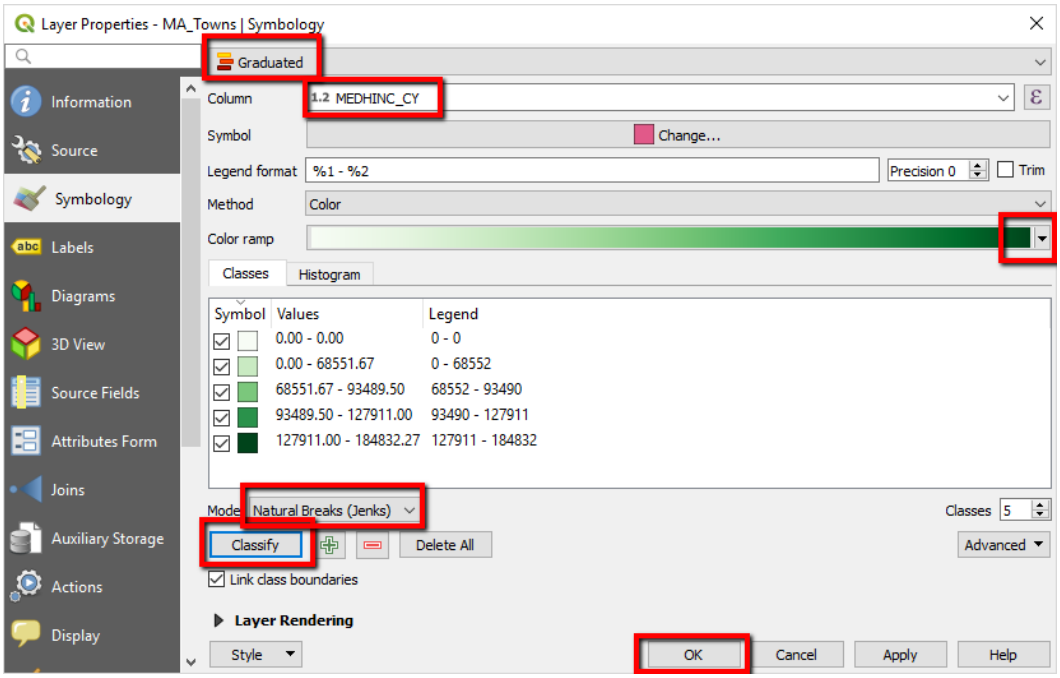
Practice changing the fill color, and the line color, border width, and border style**.** Click **Apply** at the bottom of the window to see each change on your map.

Click **OK** to close the Layer Properties window.

7) **Save your work.** To save your work thus far, click **Project** > **Save**. Name the map "Median Household Income", and save into your GIS folder. This will create a ".qgz" file. Save every few minutes so you don't lose any work!

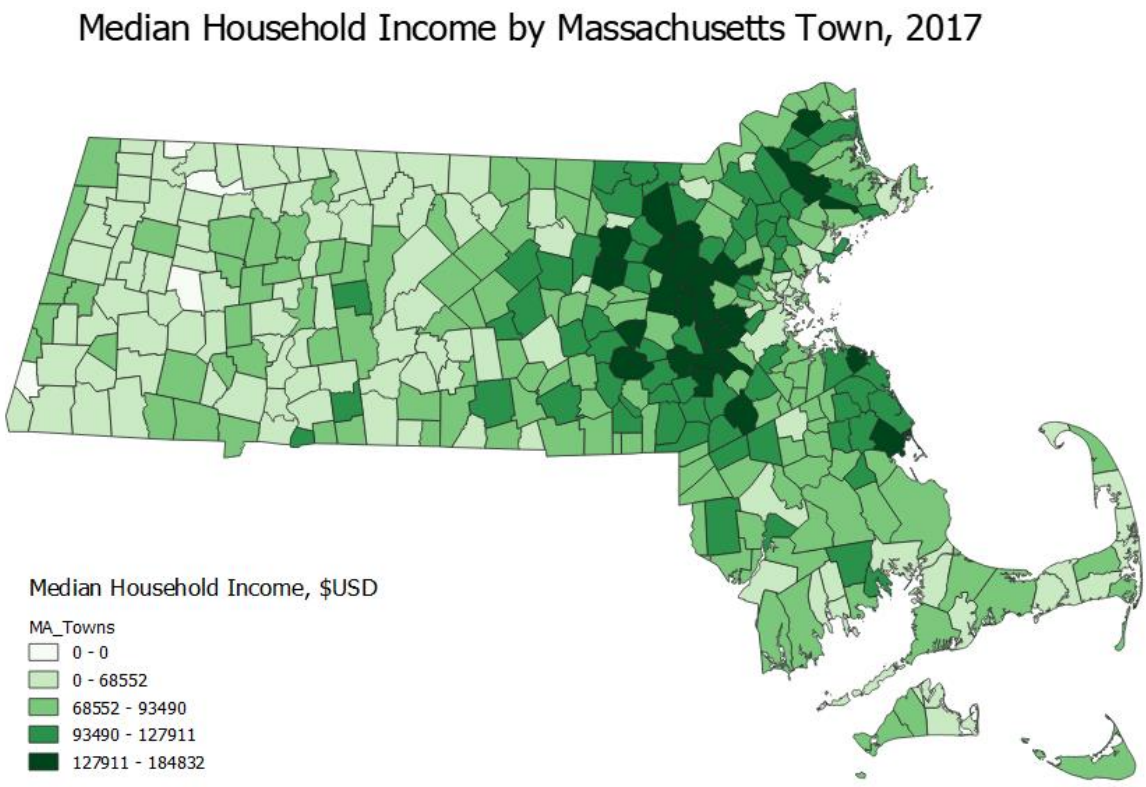
PART B: MAKE A THEMATIC MAP OF MEDIAN HOUSEHOLD INCOME

1) Zoom the map to show all towns. Right click your MA_Towns layer and choose Zoom to Layer to reset the map to all of Massachusetts.**Symbolize MA Towns by median household income.** Double click the MA_Towns layer to open Layer Properties, and click the **Symbology** tab. On the top of the window, click where it says **Single symbol** and choose **Graduated**. For the Column, choose **MEDHINC_CY**. Change the Color ramp from "Blues" to "Greens". Change the **Mode** to **Natural Breaks (Jenks),** and click **Classify**. Your window should look like the screenshot below:



Click **Apply** and **OK**, and your map will now display towns in MA by median household income in different shades of green.

2) **Add a map Legend and Title using Print Layout.** Click **Project** > **New Print Layout**. Type in the name "MA median household income" as the layout name and click **OK**. This will open the print layout interface, defaulting to a page size of 8.5" x 11". **2a)** Add your map to the print layout by clicking **Add Item** > **Add Map**, and then clicking on the page and dragging a box to fill the entire page. **2b)** Add a legend by clicking **Add Item > Add Legend** and dragging a smaller box on your page. After adding a legend, on the right had side under "Legend, Main Properties", enter "Median Household Income, $USD" and hit Enter. **2c)** Add a title to your map by clicking **Add Item > Add Label** and click and drag a box on the top of the map. On the right under Label, Main Properties, delete the default text "Lorem ipsum" and enter "Median Household Income by Massachusetts Town, 2017" click **Font** and change the font size to 24. You may have increase the size of the title box on the layout to display the title on one line. Your map should now look similar to the one below:



3) **Export the map to PDF.** Click **Layout** > **Export As PDF**. Specify a name for the PDF and a location on disk, and click Save. You're done!

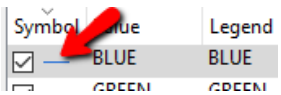
Optional: Map a different variable. *The same procedure can be used to make a thematic map of a different variable, like poverty, population, or median age by town. To do this, simply choose a different Column in Step 1 above.*
Optional: Make a block group map. *Also included in the Data/Shapefiles folder is a MA_block_groups shapefile. This contains median household income and other demographic data for the year 2017 at the block level. This could be used to make a median household income (or other) map that shows variation* ***within*** *a specific town.*

PART C: MAP BOSTON SUBWAY RIDERSHIP

1) Open a new QGIS Project by clicking **Project** > **New.**

2) **Add subway lines and stops.** Add the MBTA_NODE and MBTA_ARC shapefiles to your map by dragging them from your GIS/Data/Shapefiles folder onto the map. These were downloaded from MassGIS, and include the subway stops (NODE) and lines (ARC) for the Boston area. Open the Attribute Table (right click and choose Open Attribute Table) to inspect attributes for these layers.

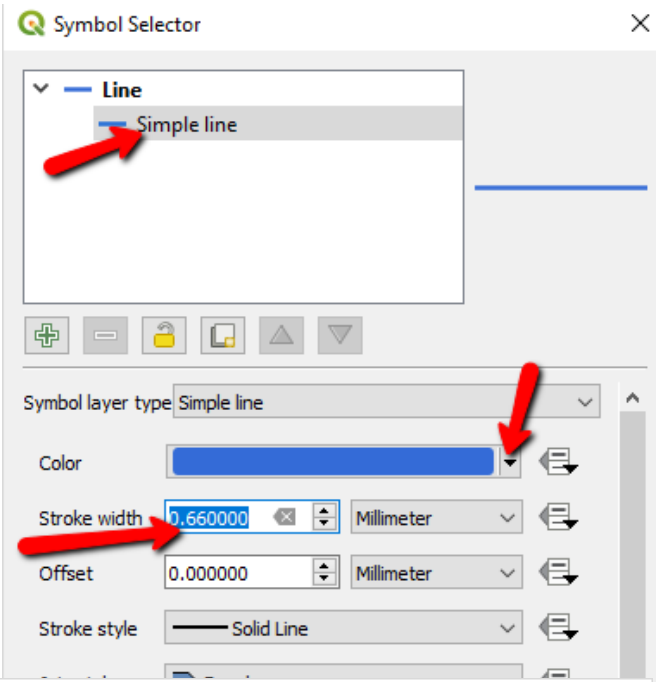
3) **Symbolize the MBTA_ARC layer categorically**. Double click the MBTA_ARC layer and choose the **Symbology** tab. At the top click **Single Symbol** and change this to **Categorized**. For the column choose **LINE**. Change the color of each line to match its name, and make each line thicker. To do this, double click on the small line symbol to the left of the line name, see screenshot at right:

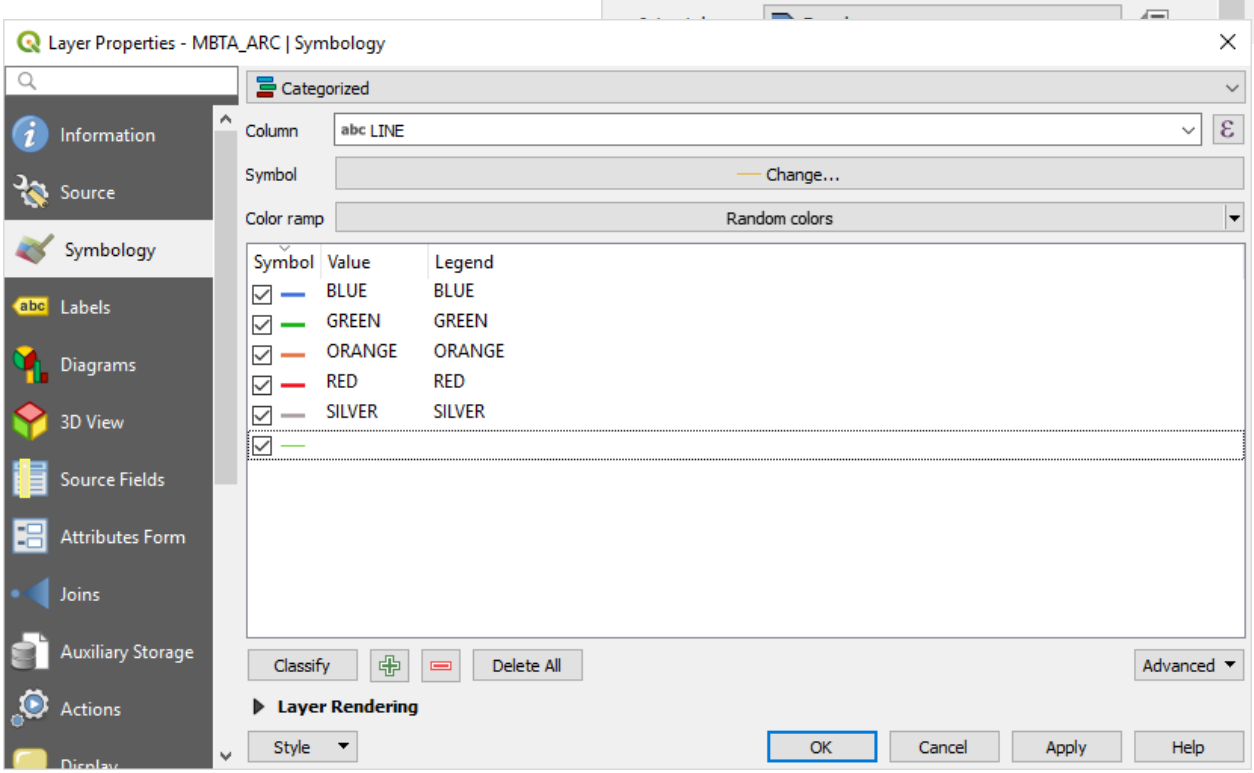


In the Symbol Selector window that opens, click where it says **Simple Line**, and change the color to match the line name, and change the Stroke Width to 0.66 mm and click OK. (see screenshot at right).

Repeat this for each of the line colors.

Your Layer Properties window should look like the one below:

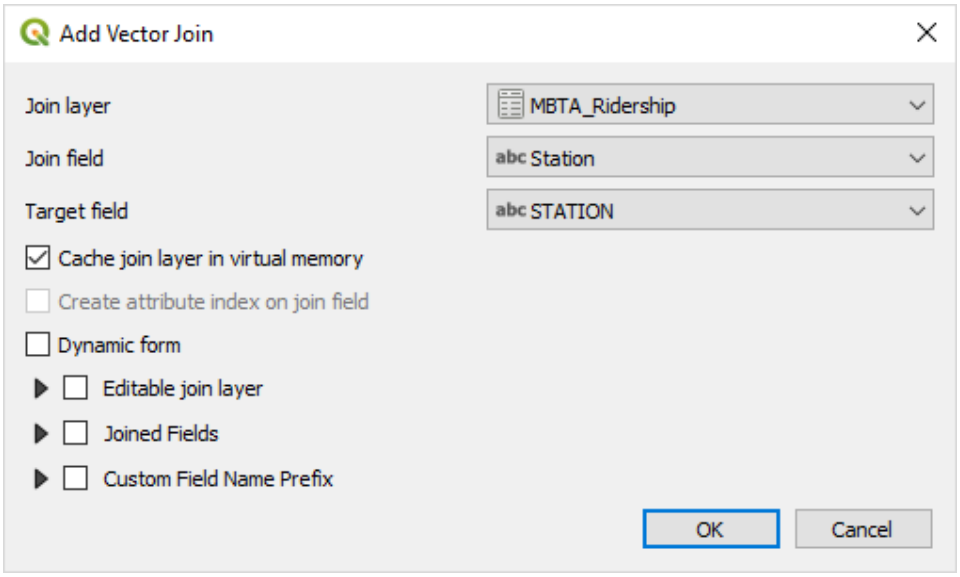




Click Apply and OK and your lines should now be colored on the map.

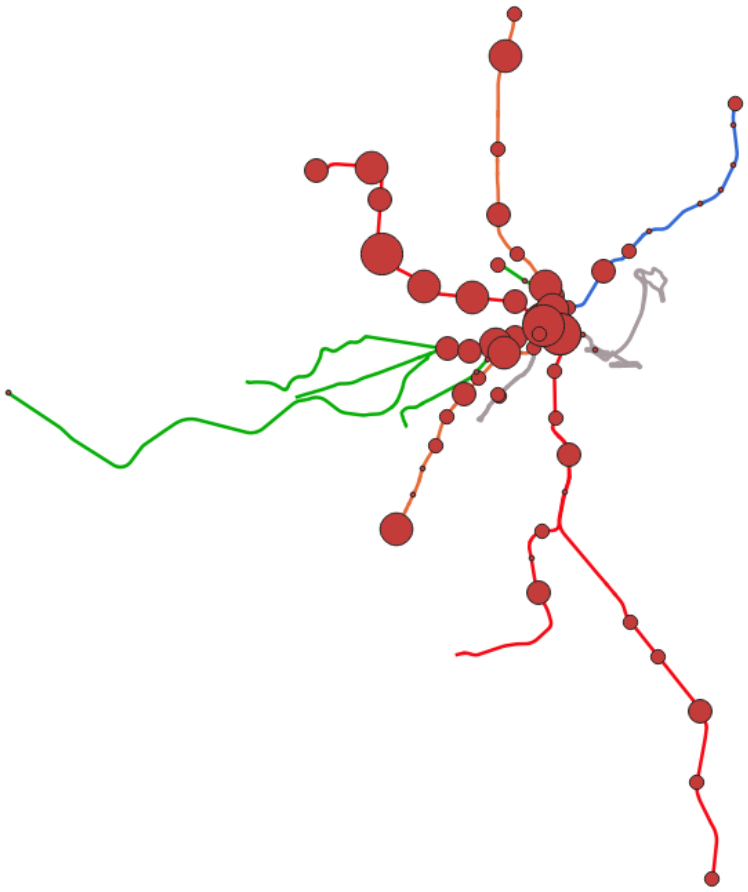
4) **Add and inspect ridership information.** The table on page 16 of [this PDF document] lists transfers for a typical weekday from 2013 for each station in downtown Boston. This data was copied from the PDF, and formatted into a spreadsheet (MBTA_Ridership.xlsx, in your Data folder). Add the MBTA_Ridership.xlsx spreadsheet to the map by dragging it over from the Browser. Open it's attribute table for a quick inspection.

5) **Join the ridership data to the subway station layer based on station name.** Double click the MBTA_NODE layer and choose the **Joins** tab. Click the **green plus button** to add a Join. In the Add Vector Join window, specify **MBTA_Ridership** as the Join layer, **Station** as the Join field, and **STATION** as the Target field. Your Add Vector Join window should look like this:



Click **OK** to initiate the join, and **OK** to close Layer Properties. Open the MBTA_NODE attribute table, and now you'll see the ridership fields appended to the table. Where the station names matched from the two files, ridership data was brought in. Now the ridership data can be mapped. This is a common technique in GIS – bringing in tabular data to a GIS layer based on a common field name.

6) **Map the ridership data.** Double click your MBTA_NODE layer and choose the **Symbology** tab. At the top change Single symbol to **Graduated**. For the **Column** choose **MBTA_Ridership_Riders**. For **Method**, choose **Size**. For **Mode** choose **Natural Breaks** and click **Classify**. Click **Apply**, and your map will now size each station location according to the amount of ridership. Your map should look similar to the one on the right. Click **OK** to close layer properties, and inspect your ridership map.



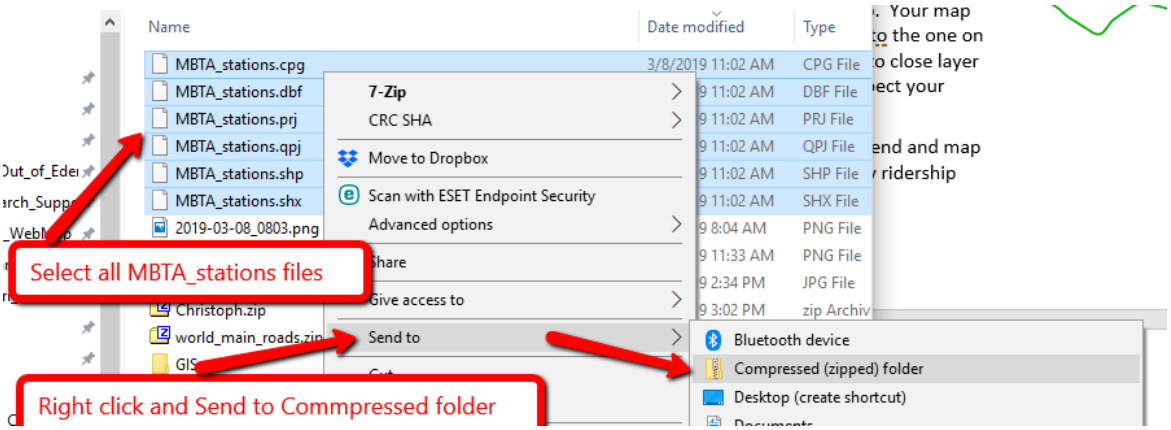
7) **Optional:** Add a legend and map title to your Subway ridership

map and export to PDF. Time permitting, follow the steps in Step 2 of Part B above to add a legend, and title to your map, and export to PDF.

PART D: (Optional) MAKE A WEB MAP OF BOSTON SUBWAY RIDERSHIP

1) **Export your ridership data to a new shapefile.** After completing Part C, your subway ridership data will be joined to your MBTA_Node shapefile layer. You can export this joined data to make a permanent copy of this data to display on a web map. To do this, right click on the MBTA_NODE layer and choose **Export** > **Save Feature As**. For the format, choose ESRI Shapefile. Enter a File name of "MBTA_stations" and specify the GIS/Data/Shapefiles folder to save it into. Click OK to export the data.

2) **Create a ZIP file of the MBTA_stations shapefile.** In order to load this data to an online GIS, the .shp and associated files must be compressed into a .zip file. To do this (on Windows), open File Explorer, and browse to your GIS/Data/Shapefiles folder. Select all of the files starting with "MBTA_stations". Then right click and choose **Send to** > **Compressed (zipped) folder**. Doing this on a Mac you'll use Finder. See screenshot below for how this looks in Windows:



Name the resulting file MBTA_stations.zip, saving it into your Shapefiles folder.

3) **Open a web browser and login to ArcGIS Online**. Open a web browser (Chrome, Firefox, Edge, Safari, etc.) and go to http://www.arcgis.com and click the blue **Sign In** button.

   3.3.1 Click on the ENTERPRISE LOGIN button on the lower right.

   3.3.2 Enter "harvard-cga" under where it says "Enter your ArcGIS organization's URL below." And click Continue.

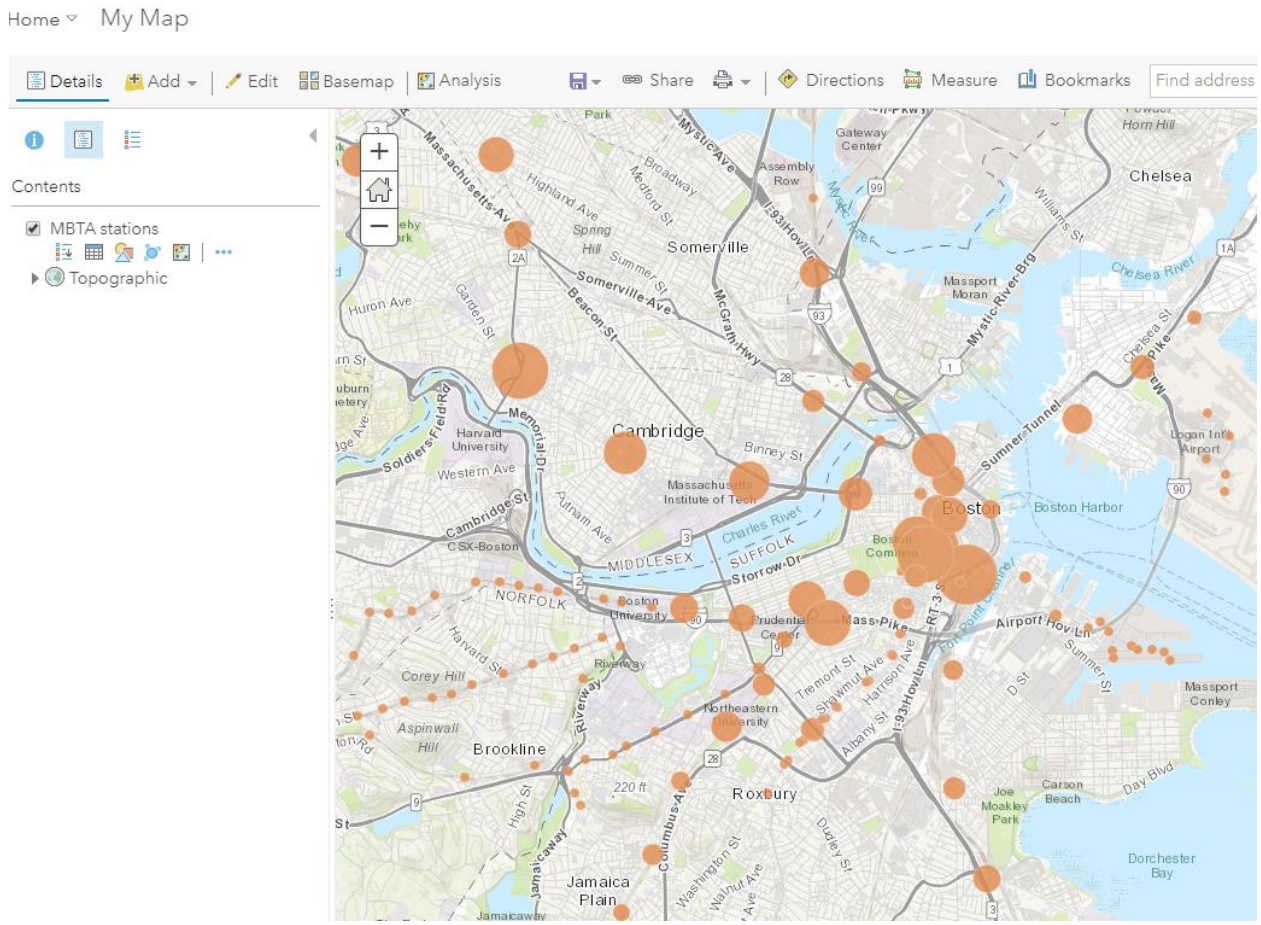
   3.3.3 Click the HARVARD UNIVERSITY button. Enter your Harvard Key information and you'll be logged into the Center for Geographic Analysis Harvard account under your login.

4) **Map your subway station data.** Click Map at the top – this will create a new blank map for you.

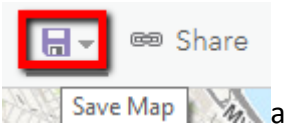
   3.4.1 Click Add > Add Layer from file, and click the Choose File button.

3.4.2 Browse to your MBTA_stations.zip file and choose it. Click the IMPORT LAYER button.

3.4.3 Now your web map will show subway stations. Next #1 "Choose an attribute to show" click the dropdown arrow and choose "MBTA_Rid_1" and click the DONE button at the bottom. Your map should look like the one below:



This is an interactive web map that you can zoom in and out on, or click on a subway station to identify it. Experiment with changing the base map by clicking the Base Map button.

Save the map by clicking Save Map: 

and give the map a name. Click the Share button to get a URL link that you can send to anyone so they can see the map. You're done! Congrats on making your first web map.

PART E: (Optional) CALCULATE DISTANCE FROM EACH SUBWAY STATION TO BOSTON HARBOR in QGIS

1) Create a new map in QGIS, and add the MBTA_NODE.shp (subway stops) and COAST25K_ARC.shp (the Massachusetts coastline) Shapefiles to the map.
2) Convert the coastlines to points by clicking: **Vector** > **Geometry Tools** > **Extract Vertices**. Specify COAST25K_ARC as the input layer, and click Run. Click Close.

3) Click **Processing** > **Toolbox** and in this window search for "distance". Double click the "Distance to nearest Hub (points)" tool. Specify MBTA_NODE for the Source points layer, Vertices for the Destination hubs layer and click Run, and Close.

The resulting layer on your map named "Hub_distance" contains an attribute listing the distance in meters from it to the nearest coastline vertex. A good way to visualize these is to use graduate symbols by color using the "distance" column and adding an OpenStreetMap basemap, see below.

4) **Adding an interactive OpenStreetMap base**. To add some context to your map, add a pre-made street map. These are fed into QGIS from various sources on the web. Click **Plugins** > **Manage and Install Plugins**, and search for "QuickMap". Check the box next to **QuickMapServices**, and click **Install Plugin**. Close the window, and back in QGIS click **Web > QuickMapServices > OSM > OSM Standard**. This layer displays the standard web map put together by the Open Street Map project.

PART F: (Advanced only) **Use QGIS or ArcGIS to help answer the question "What sort of expenditures on roads should localities in MA expect".** Answering this will involve:

- Spatial overlay with towns and roads.
- Distance calculation of road mileage per town.
- Area calculation of road width to estimate total paved surface.
- Applying a cost per square area to estimate cost.
- Normalizing by Town population to produce a cost per capita.

Optional - Present results to class.

Appendix A: Helpful QGIS links, and to explore further:

- The QGIS publication "A Gentle Introduction to GIS": http://docs.qgis.org/testing/en/docs/gentle_gis_introduction/index.html
- The **QGIS** users guide: http://docs.qgis.org/testing/en/docs/user_manual/index.html

Data for this lab was downloaded from MassGIS:

https://www.mass.gov/service-details/massgis-data-layers