11.205 – Intro to Spatial Analysis – Fall 2019

Week 1 – Map Composition and Design

[OCW Users: The following document refers to various online resources (Stellar and Athena) that are not available to users outside MIT.]

Week 1 Objectives

I. Gain familiarity with the QGIS interface and add data to a map
II. Symbolize your Map
    i. Explore Normalization
    ii. Symbolize a Census Variable
III. Compose and layout a map

Lab Data

Download the class files from Stellar.

Please copy the files to your external hard drive. If you don't have an external hard drive you should get one as soon as possible. In the meantime, you can download the files to your local machine.

Specifically…

On Windows…

…your C:\temp directory, on the Windows side. Remember from last week that this directory gets erased quite frequently and you should **not** leave files on c:\temp when you leave class. Please save a copy to your external hard drive or other place were you can get it again.

On Mac…

…download files to your ~/Desktop or ~/Documents folder. While these are generally understood to be 'safe' places (they're not wiped!), using them as storage media in the long term will gradually eat into your rather limited 8GB of storage space on Athena.

Unzip the materials you just downloaded from Stellar. The unzipped file consists of the following folders:

1. DOCUMENTS:
   This folder includes Word documents for this week's in-class exercise(s) and take-home Exercise.
2. PROJECTS:
   This folder contains map document(s) for the in-class exercise, if any.
3. DATA:

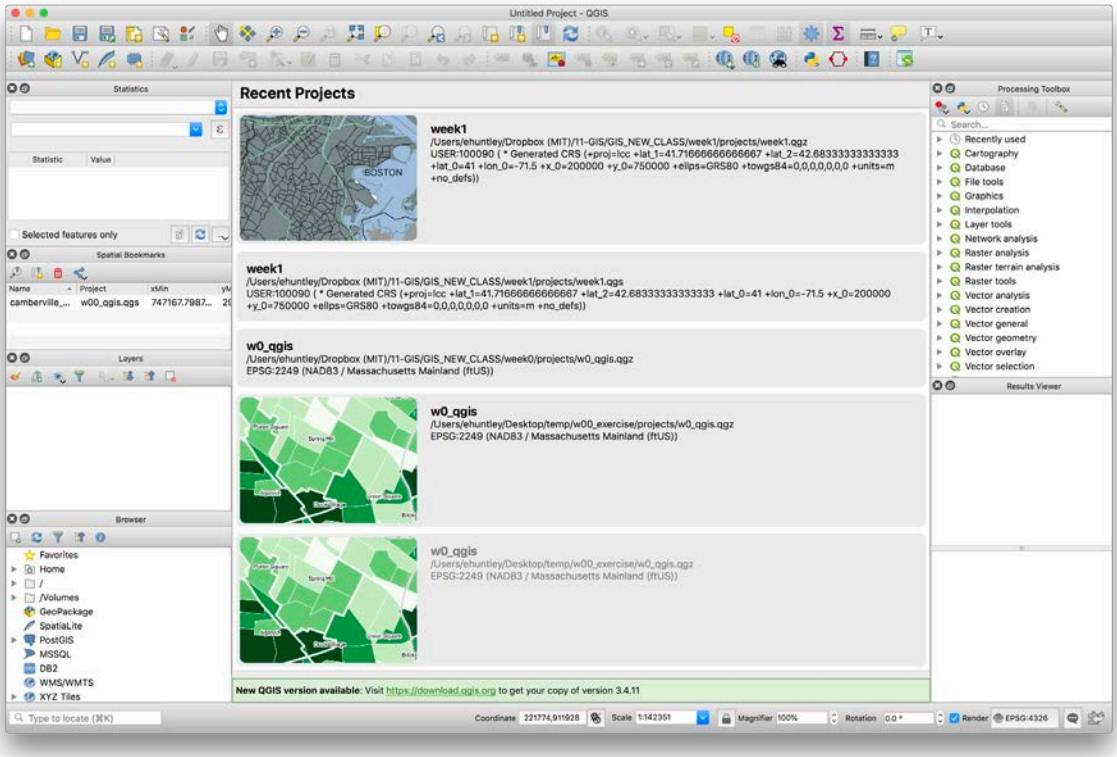
This folder contains all the shape files needed for this week's in-class exercise and the Exercise 1.

OBJECTIVE 1: GAIN FAMILIARITY WITH THE QGIS INTERFACE AND ADD DATA

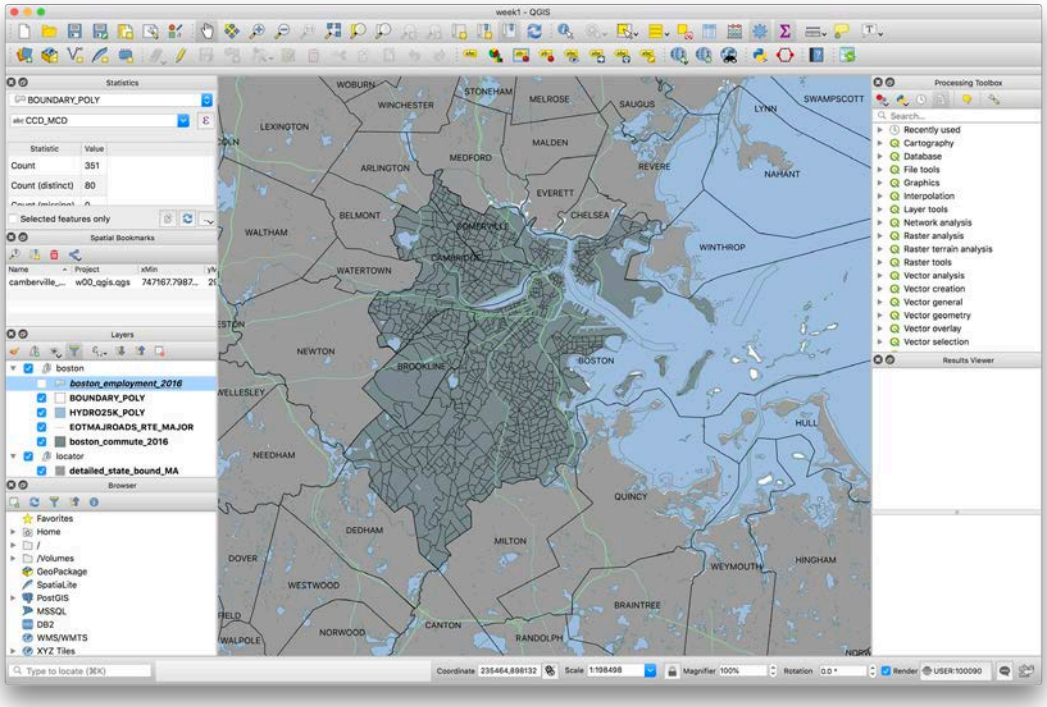
QGIS, a free and open source Desktop GIS software, is a convenient tool for spatial analysis. However, just like ArcGIS, the interface at first can be intimidating. Comfort with the interface will come over time, but one key thing to remember is as a general rule of thumb, like items and tools are grouped together. Open up QGIS Desktop, start a new project, and explore the interface. QGIS works on both Mac and Windows. Use whichever you are working on. The interfaces are very similar. However you might encounter some small differences here and there. Don't let this hinder you though, let's get going!

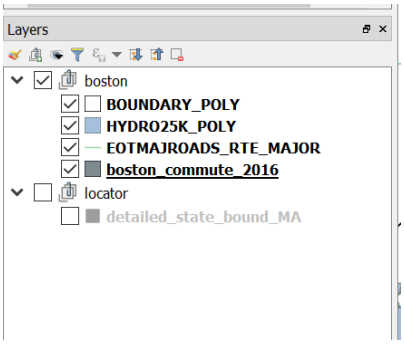
STEP 1. OPEN A MAP DOCUMENT

1. Open QGIS by navigating to Finder>Applications>QGIS Desktop (Mac Users) or open QGIS by navigating to Start>Programs>QGIS>QGIS Desktop 3.4 (Windows Users)
2. The QGIS interface will appear. Open the map that is located in our Week 1 Materials.



3. Navigate to \week1\projects\ and select the map document named week1.qgz Click open. The document will open and QGIS will draw a series of data layers from the data files the map document is referencing. Your screen should look something like the image below.

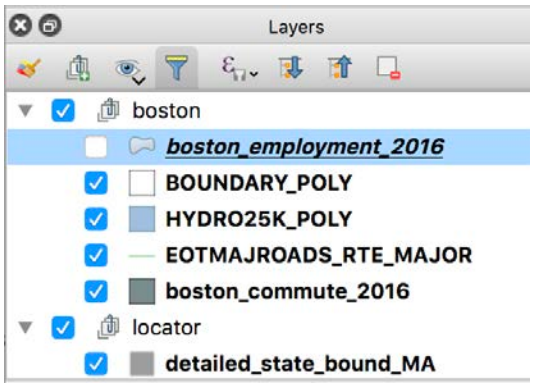




4. Map documents (.qgz) hold basic information about a map's composition. It is similar in nature to an Adobe InDesign project file, where the map is essentially a saved view of data files stored separately. The map document contains information about the various data files used in the map, manages files, allows for analysis through Processing Toolbox, and symbolizes and lays out maps. The interface may be overwhelming at first, but like items and tools are grouped together. The interface is also highly customizable - you can move around and organize your toolbars to your personal preference and to optimize your workflows.

STEP 2. LAYERS

To the left side of the QGIS Project screen, you should see the Layers Panel. The Layers Panel is where you can see what data is linked to your QGIS project, how they are symbolized, and the order the layers appear in your composition. Through the Layer Panels, you can turn layers on and off, adjust transparency, symbolize features, and modify datasets. You can also use the Layers Panel to examine the source of layers in your map and set up selectable layers. Let's turn layers on and off by selecting the check box next to the layers in your Layers Panel. Notice what happens when you toggle the layers. Notice at the top of the Layers Panel there are eight buttons. Each one of these buttons lets you view the content of your map through different information. The buttons are:



- Layer Styling
- Add Group
- Manage Map Themes
- Filter Legend by map Content
- Edit Filter Expression
- Expand all
- Collapse all
- Remove Layer/group

The **Layer Styling Button** allows you to access the symbology for a layer.

The **Add Group** button allows creating folders to group a set of layers.

The **Manage Layer Visibility** button allows you to turn on an off all the layers at the same time. It also allows you the same only to the selected layer.

The **Filter Legend by map Content** button allows you to filter the legends.

The **Edit Filter Expression** allows you to filter features on the selected layer.

The **Expand and Collapse** buttons allow you to see all the details of a layer or to hide them.

The **Remove Layer/group** button allows you to delete the selected layer or the selected group of layers.

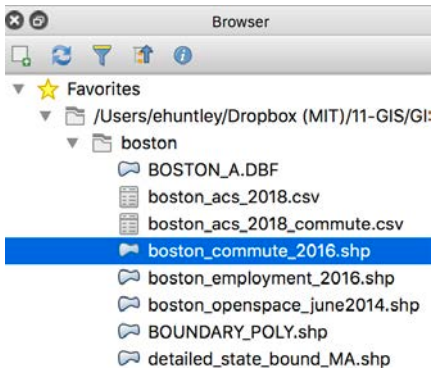
STEP 3. ADD DATA TO YOUR PROJECT

Next, we want to add data to our project. Adding data will create a new layer in our Layers Panel. This layer references a data file we specify. In our week's materials, there is another shapefile that contains data on the employment level of residents over the age of 16 by block group. This data was also taken from the American Community Survey 2012-2016.

Adding Data

QGIS give you a few options for adding data.

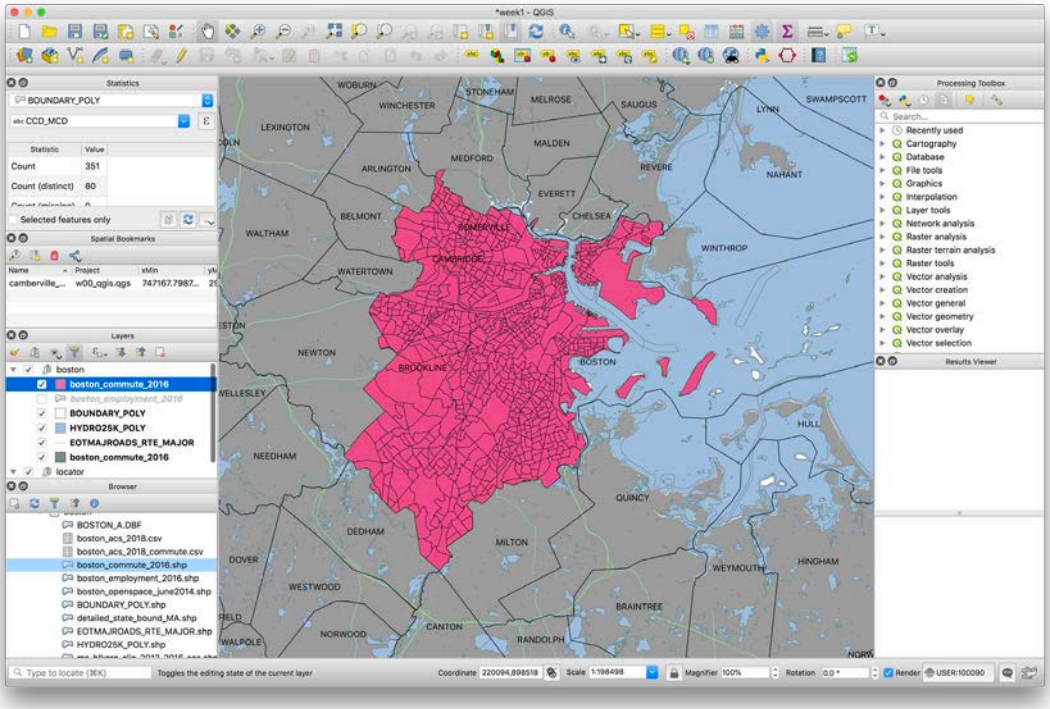
1. Open the Data Source Manager. You can do this by clicking the "Open Data Source Manager" button - - or by using the cmd-L hotkey. You can also use the Layer dropdown menu, and select **Add Layer > Add Vector Layer**.
   Either way, navigate to your Week 1 materials. Select ./data/Boston_employment_2016.shp and click Open.
2. Another method to add data is use the **QGIS Browser**. This is probably more efficient over the course of a project. You can add a favorite that you return to frequently – last week, you were instructed in how to add folders to your favorites! If you don't see the browser panel, go to View>Panels>click on Browser. Drag your data into the project.



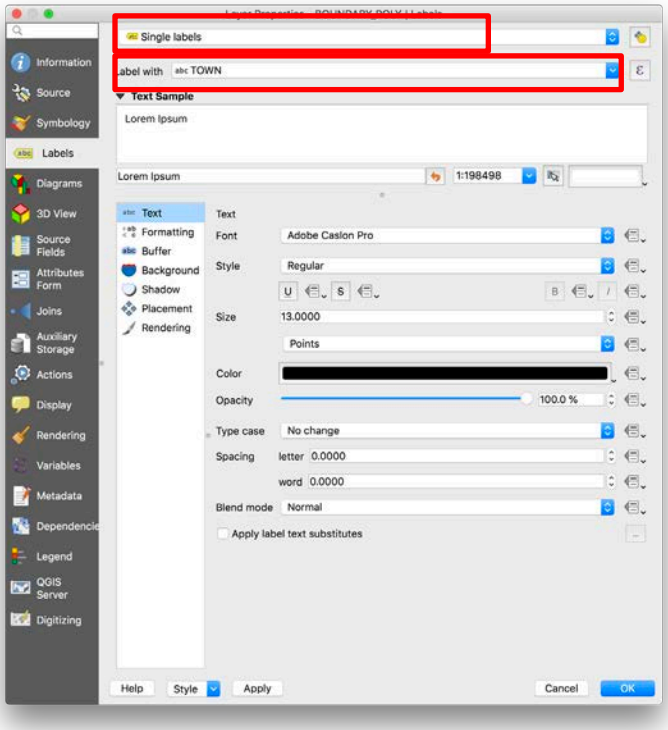
2. The data will be added to your project as a layer in the Layers Panel. It will contain no symbolization, but will include the geometry for the block groups. Each of these block groups contains various information on education levels for that geographic area.

Note: A block group is a census geography that is based on somewhat arbitrary areas of similar population size.

Notice where the layer appears in the Layer Panel. The order of these layers corresponds to their draw order – layers lower in the list will appear as though the geometry of other layers is stacked above them. Move this layer so it is below the water layer, boundary layer, and the roads layer in week1.qgz. Your document should now look something like this.



Note: You'll note that the towns are already labeled. To see how this was done, right click on the layer BOUNDARY_POLY go to properties>Label. On the upper dropdown menu go to **Single labels**. Now go to the dropdown menu called **Label with** and select the option TOWN. Click ok.

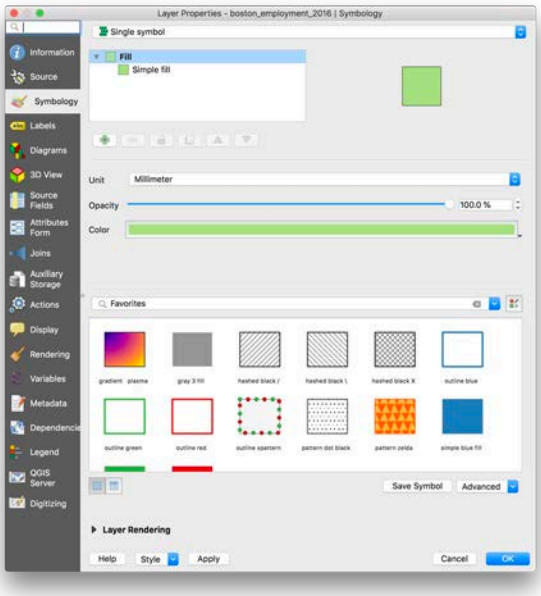


OBJECTIVE 2. SYMBOLIZE THE DATA ON THE MAP

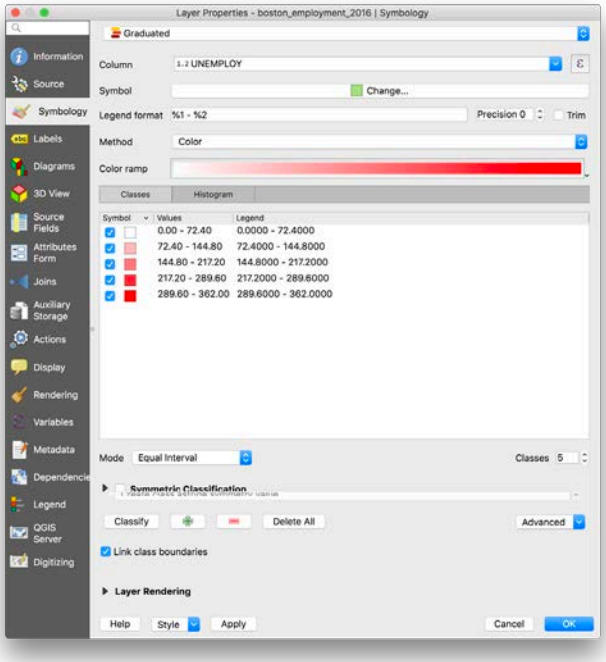
We just added a layer that contains data on employment for persons over the age of 16 at a block group level in the Boston area. However, the visualization is not yet very useful – it displays the geometries, but tells us nothing about their characteristics. We can change the layer symbology so that color gradients represent quantities.

1. To change a layer's symbology, first highlight the layer in the Layers Panel. To do this, right-click the highlighted layer and select Properties at the bottom of the dropdown. The Layer Properties dialog window will appear. You can also double click the selected layer.

2. Select the **Symbology** tab in the dialog.

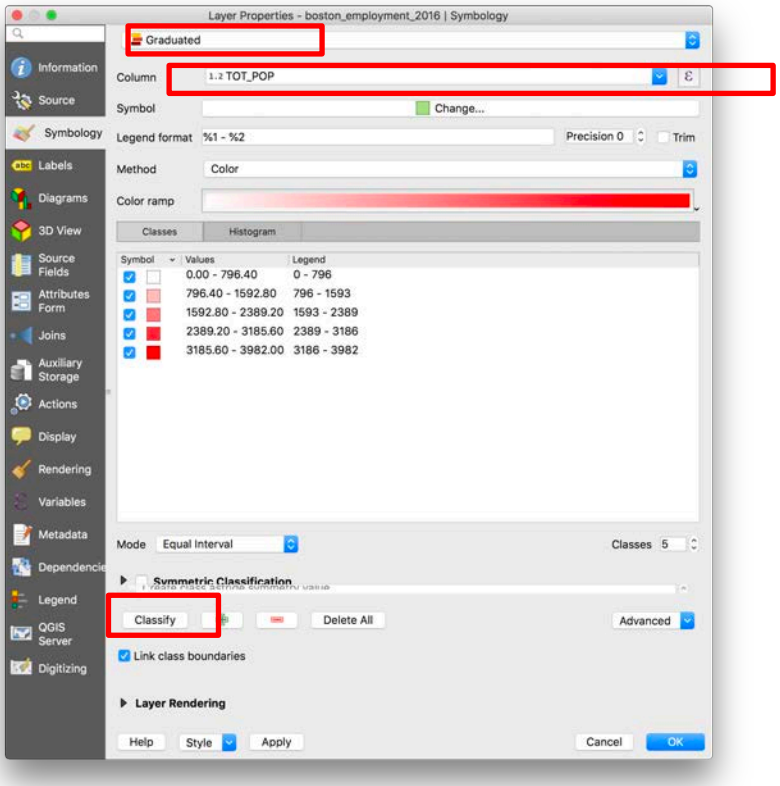


3. In this tab, you are given many options to classify and symbolize the data in your map document. At the top of the dialog select **Graduated**. Then, select a column on which to base the classification and click 'classify' – try "UNEMPLOY" at first, which represents the total number of unemployed people.

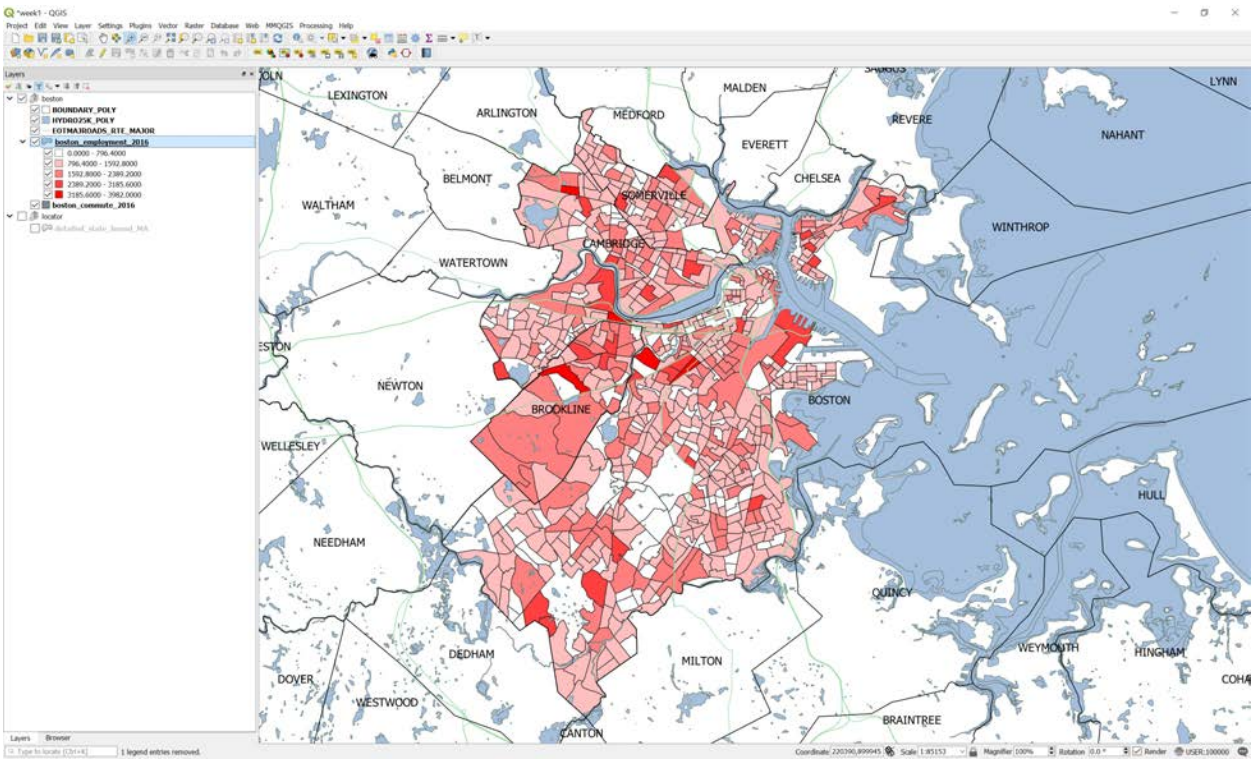


Click OK – you should now have a map in which unemployment is visualized! But this is not a super-useful map… it just represents population density, more than anything else. When making this type of map, the concept of normalization is very important. Administrative areas and other enumeration units usually vary widely in size and population. In order to minimize the effect of differences in these areas, we need to normalize our data. To normalize in QGIS, you have to write a data expression that divides the values in one field by another. To illustrate normalization, let's work with the total population numbers provided in the boston_employment_2016.shp shapefile.

1. In the Symbology tab, the estimated total population in 2012-2016 is contained in **a column called "TOT_POP".** You can find this in the metadata for the dataset, which we will discuss later in the exercise. Symbolize the layer by this dataset, setting it at the Value in the Column dropdown menu. Classify your data by clicking '**Classify**'. Your Styling dialog will look like the following:



Click OK. Your map will symbolize according to the total population number in each block group. It will look something like the following. What does it tell us? It is fairly difficult to see a true population profile of Boston.



This population data is **Unnormalized**, this means it simply shows a total number. When comparing units of vastly different size, comparisons can be misleading, if not incorrect. Larger areas logically have larger numbers, and larger populations logically have larger numbers of persons that can possess a specific characteristic.

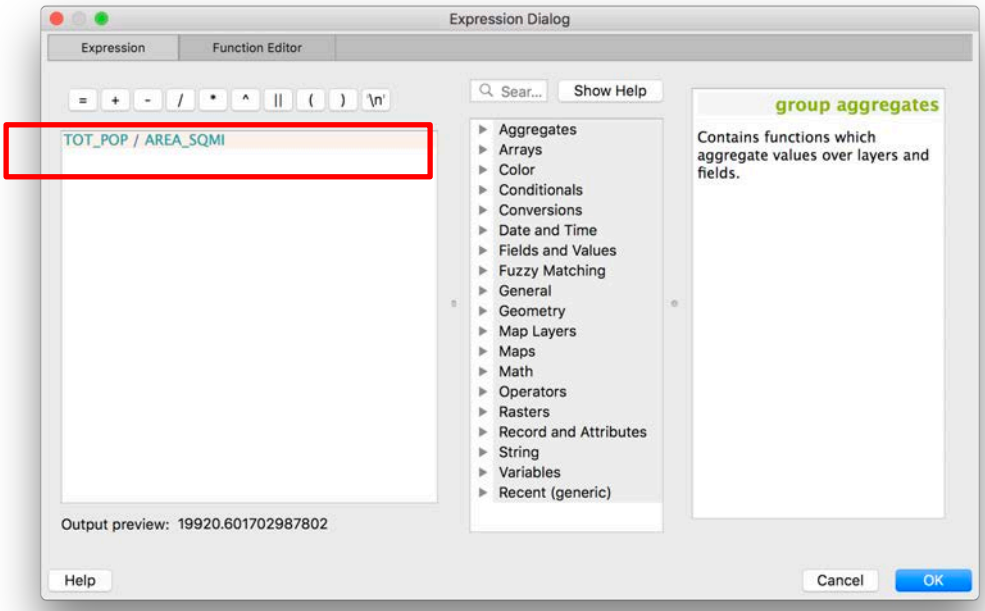
The way to address this is to **Normalize** the data. Data is normalized to account for differences that might impact a total number by looking at population as a percentage of area. A block group in suburban Boston might have more people than a block group in downtown Boston, but the block group in downtown Boston might be much smaller, and in an unnormalized map, the true comparison of the two block groups might be misleading.

When we normalize, we look at the percentage of people that live in an area per square mile, rather than the total number of people. This allows for a more even 'apples to apples' comparison. Now, let's normalize our population map to reveal the density of persons in each block group.

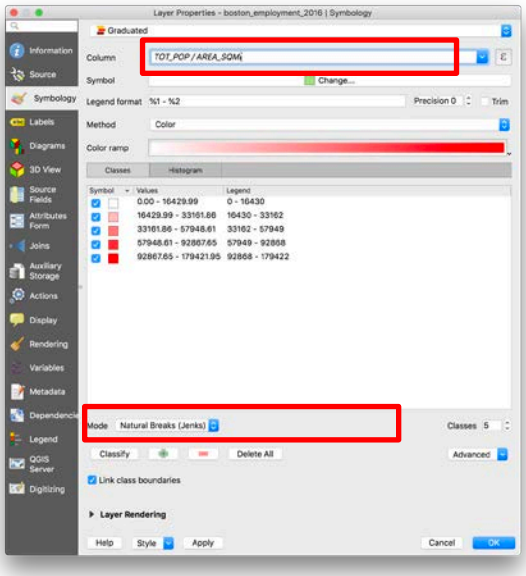
2. Navigate to Properties -> Symbology.

3. In the Graduated menu, you will see a drop down button called Column Expression. Here you can select the field that contains the value you want to normalize. right to that menu there is a button called Expression . Here you can select the expression that will calculate the value you want to normalize the data against. In our circumstance, we want to normalize people by square mile. This will create a density map of persons per square mile. To do this, we have to calculate the density by writing the following expression on the expression box **TOT_POP / AREA_SQMI.** You can also do it following these steps:

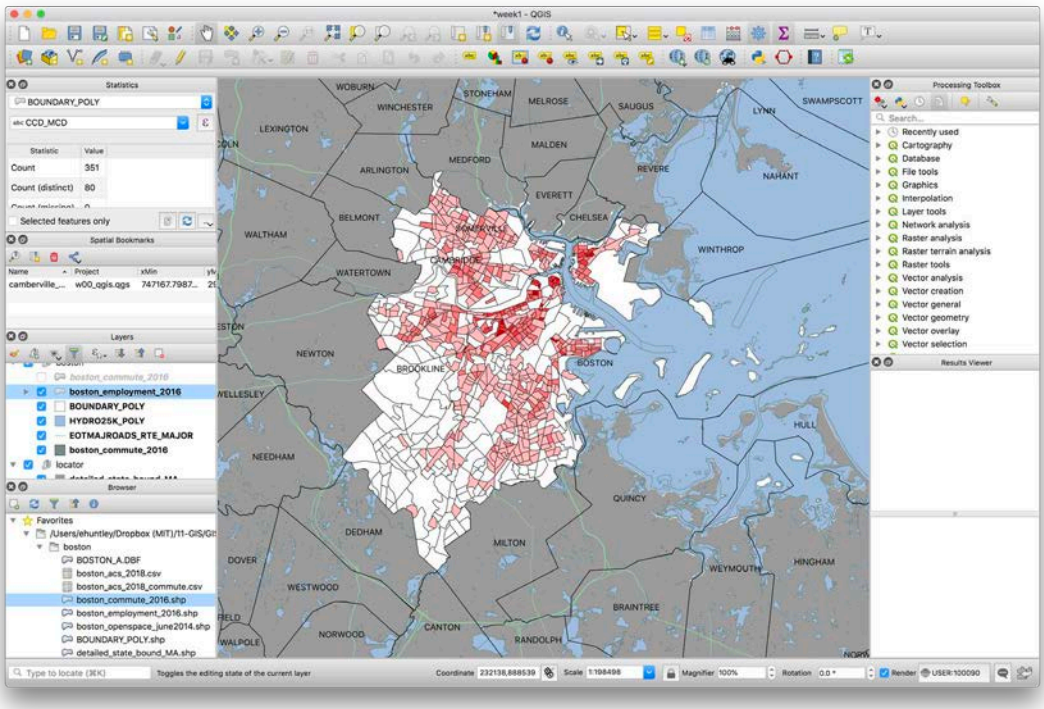
1. Click on the "(" to start the function.
2. On the Functions box go to Fields and Values drop down menu and double click on the field "TOT_POP"
3. Then click on the "/" button above the expression box
4. Go again to the Fields and Values>double click on the "AREA_SQMI"
5. Close the expression by clicking on ")" button
6. Click ok



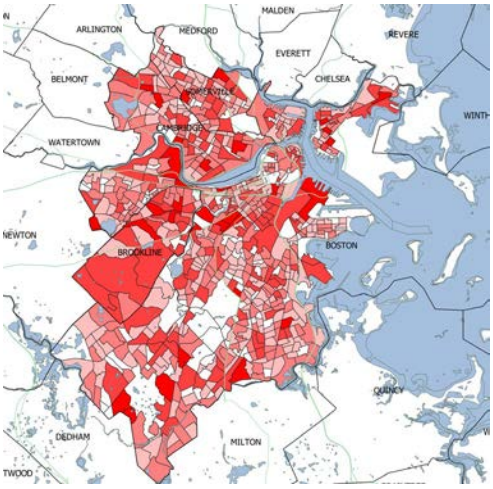
Once you are back in the Symbology tab, click on Classify to get the new classified dataset. Also, experiment with the Classification Mode. Use "Natural Breaks" instead of Equal Interval. We'll look at this more in a bit.



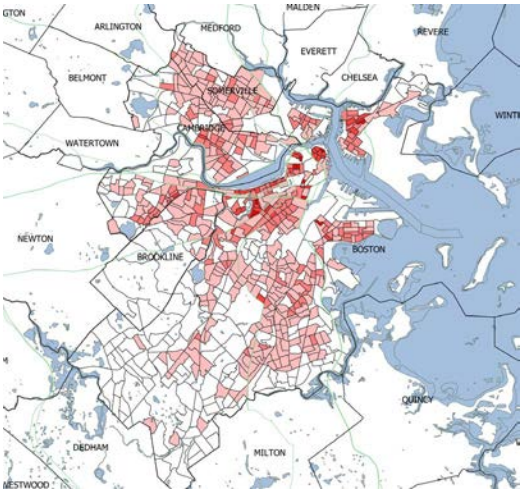
Click OK. Your normalized map showing persons per square mile will look like the following. What does this show? Are the comparisons between block groups more relevant? You will see that block groups near the Charles, in downtown, and in other densely populated areas are distinguished from the lesser dense, larger, more suburban block groups.



The images below showcase the difference that normalization makes in your dataset.



Unnormalized Data (Total Persons)



Normalized Data (Total Persons per Square Mile)

OBJECTIVE 2B: SYMBOLIZE A CENSUS VARIABLE

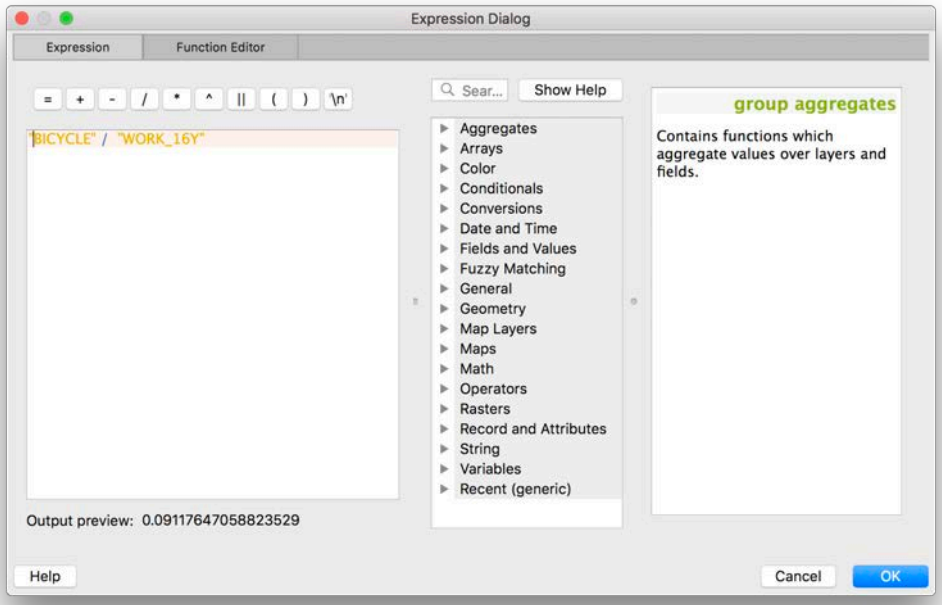
Having demonstrated the importance of normalization, the next task we want to accomplish is to make a map showing how people commute to work. The commuter data is from the U.S. Census Bureau American Community Survey. We are using the 2012-2016 Five Year Estimates.

1. Returning to **Properties -> Symbology**, set the Column value as Bicycle – this is the number of people who bicycle to work.

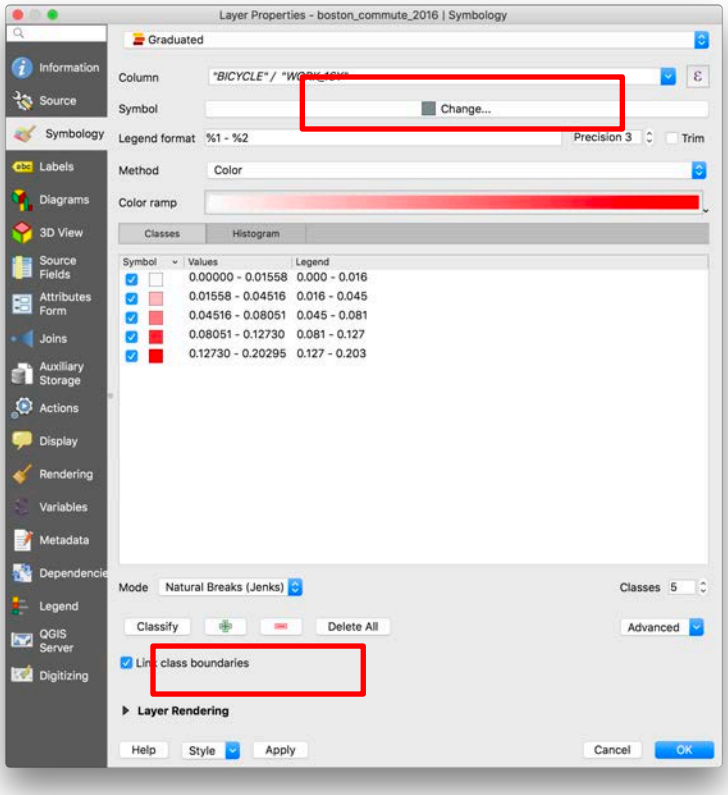
2. Just as above, we need to normalize this data. When we normalize, we look at the percentage of individuals that can commute to work, and those would be the people in the labor force. This field is called WORK_16Y.

We want to **normalize** the map by our sample population. The U.S. Census collects this commuter data for people in the Labor force 16 years and older. Set Normalization to **Work_16Y**. Put in simpler terms, we will be looking at the percentage of persons in the labor force who commute to work using their bike.

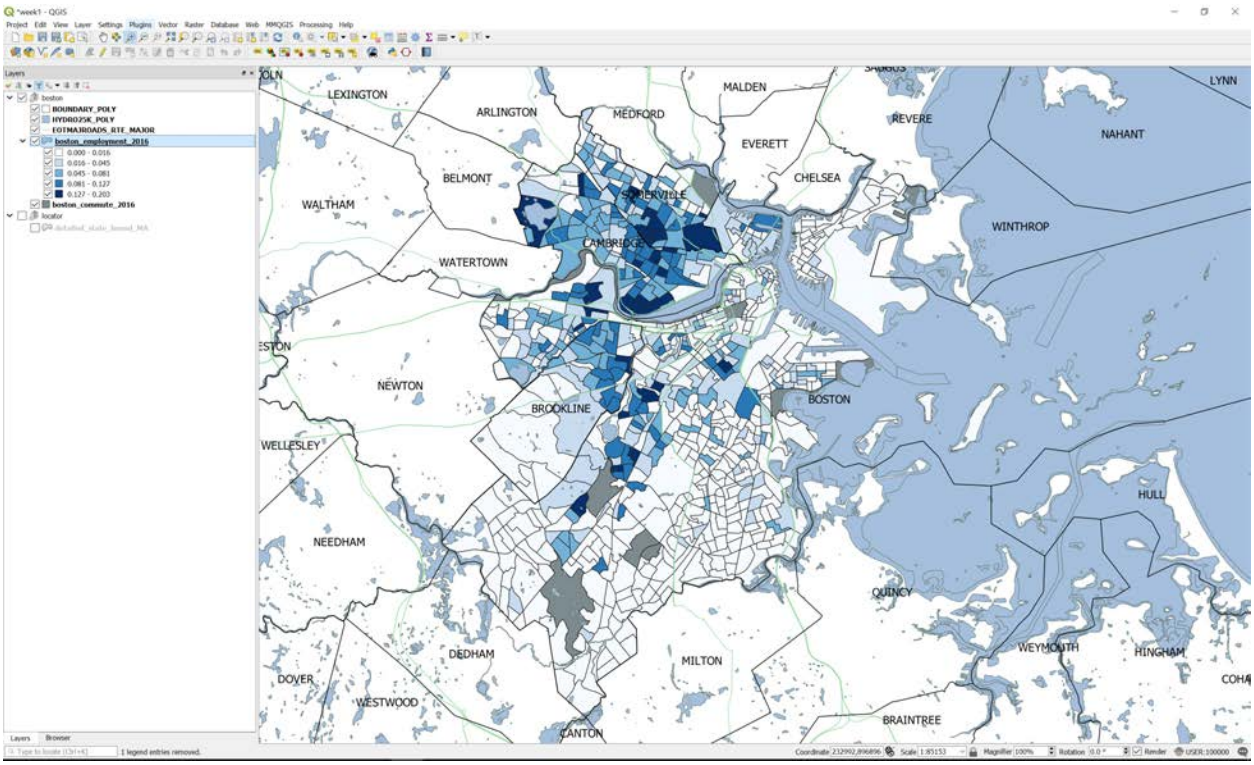
4. Go the Expression Dialog as you did previously and pick (“BICYCLE” / “WORK_16Y”) see below.



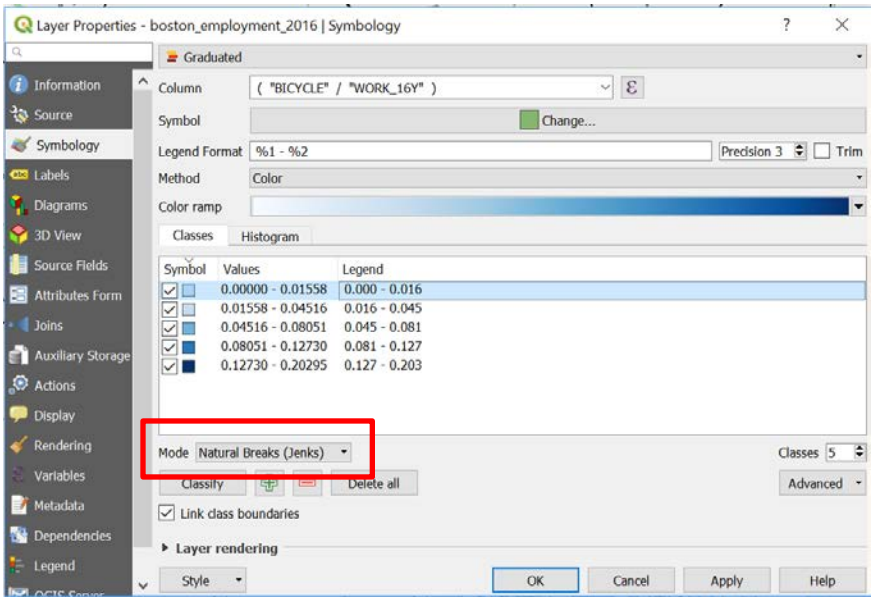
3. Select a color ramp. As we are showing sequential data, it is important to pick a sequential color scheme that goes from light (indicated less) to dark (indicating more). Pick a color ramp similar to the sequential one shown. Why do we pick a sequential color ramp over a divergent or categorical color ramp? Don't forget to hit **Classify** or your data will not apply the classification.



4. Your map composition should look something like the image below (perhaps with different colors).

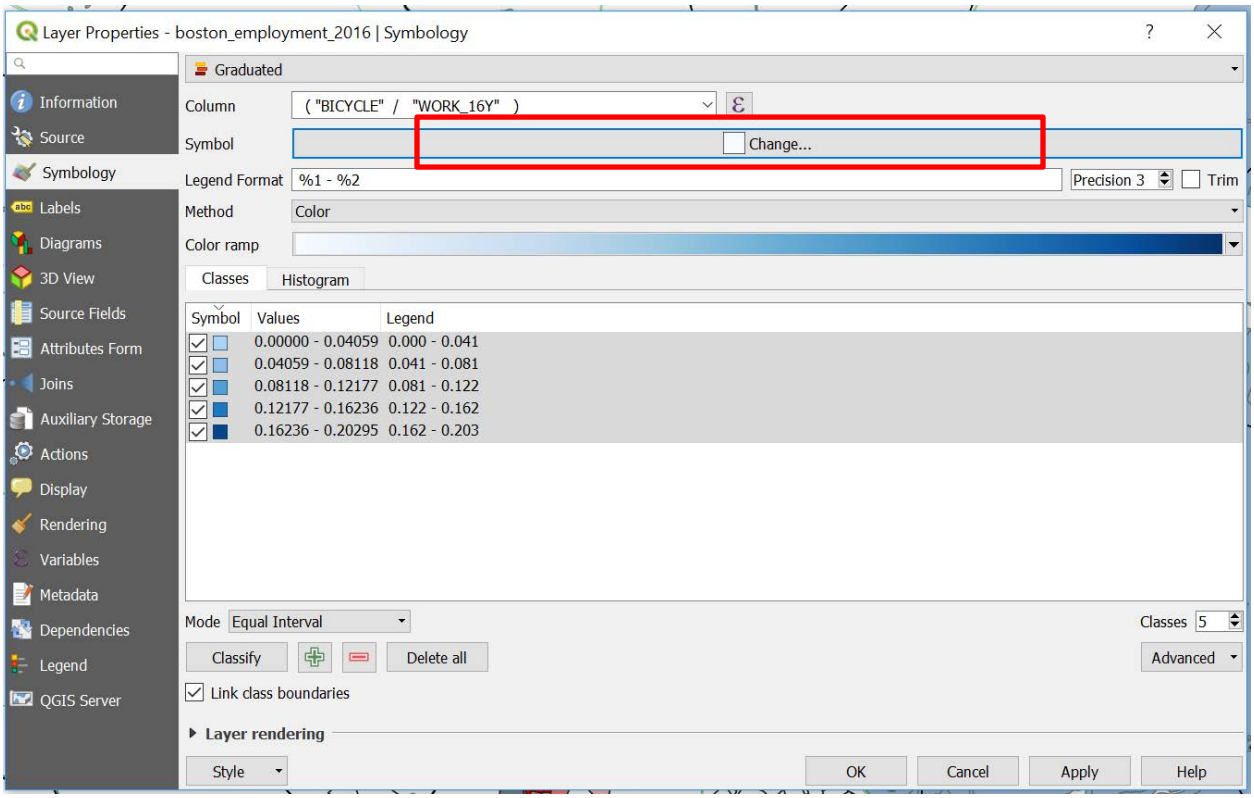


5. Next, we are going to adjust the classification scheme for our map. Return to the properties dialog by right-clicking on the boston_employment_2016 layer. In the **Properties > Symbology** tab, click the Mode drop down menu.

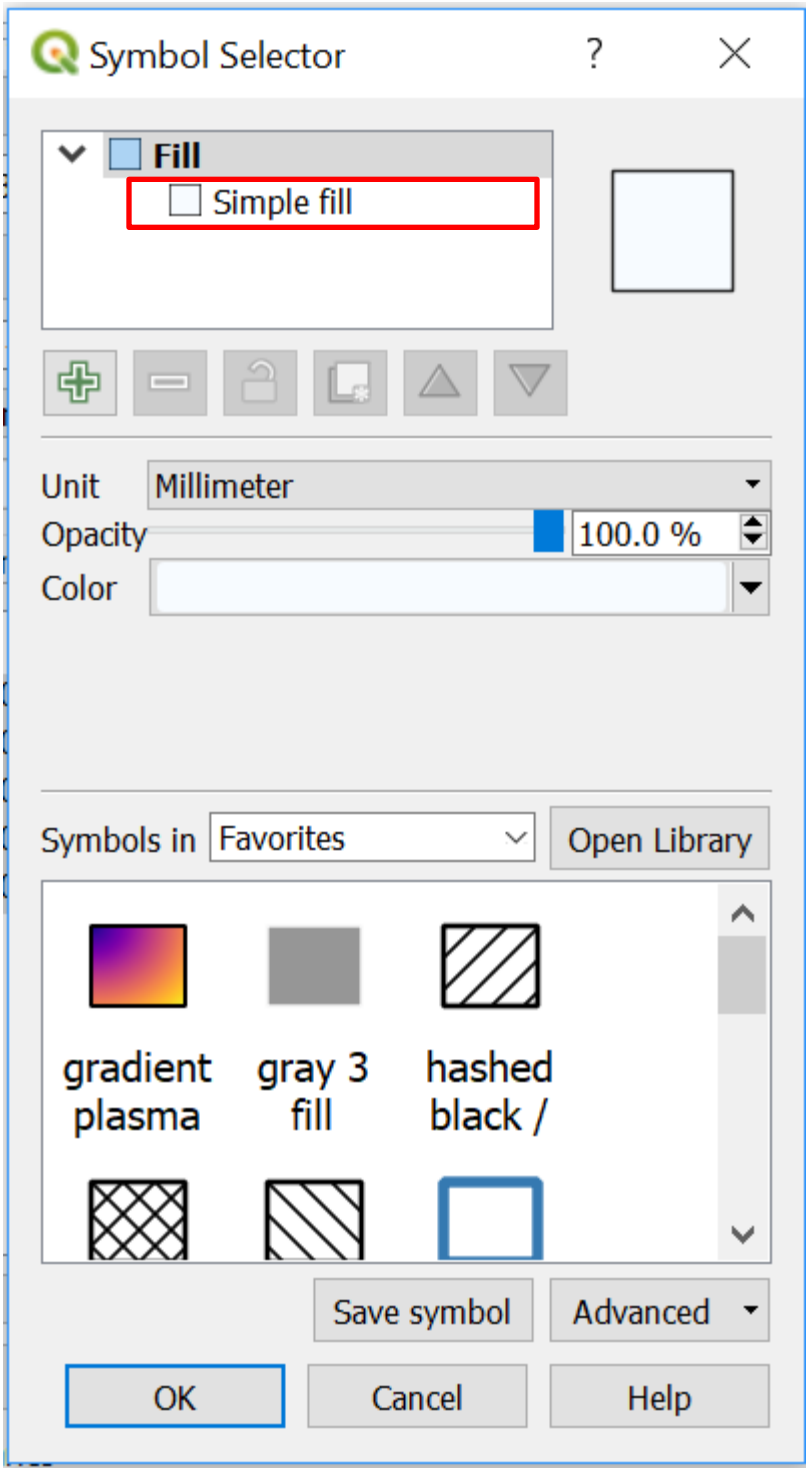


6. Notice that there are a number of different options. We read about the various classification methods in this week's assigned readings. Try a few of them and observe how the methods vary and the appearance of the map changes.

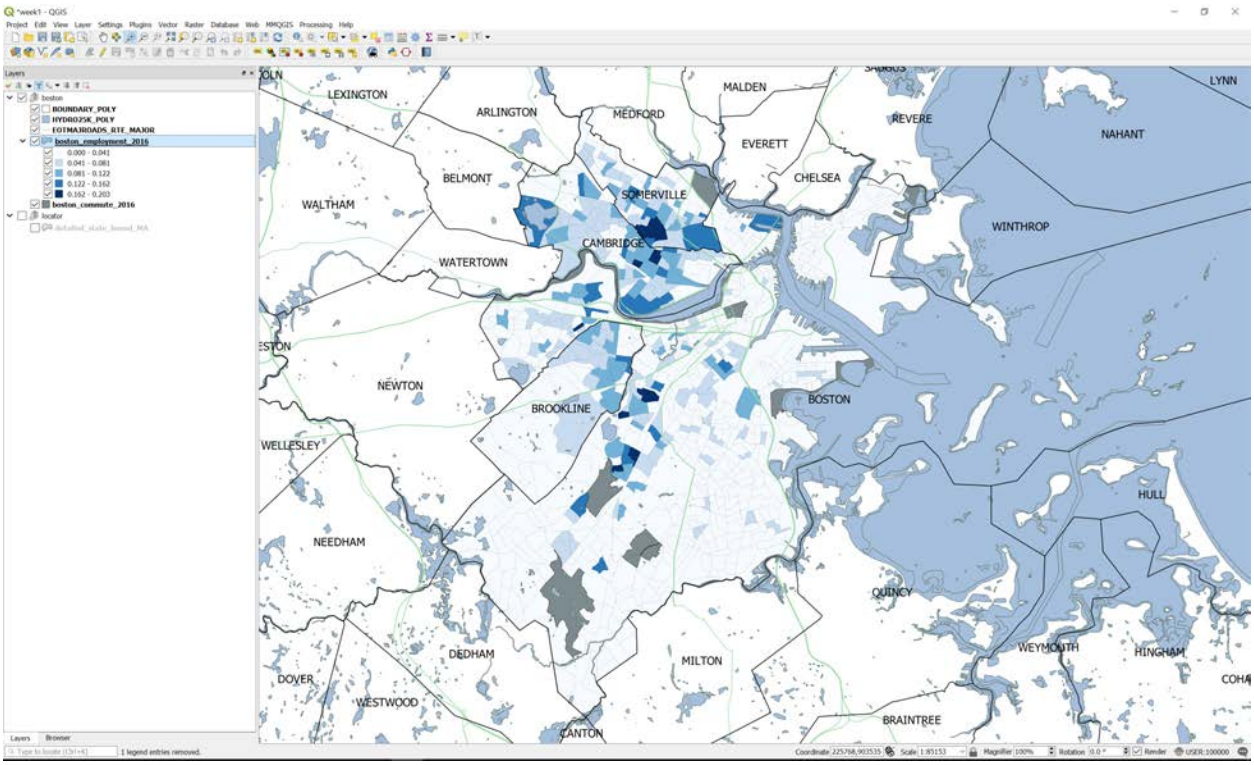
7. Each of the block groups that we have symbolized with our classification scheme has a dark outline. If we want to change the color of this outline, we can adjust it universally for all the block groups in our map. To change the properties of the symbols for all map features, click the on the “Change…” button at the Symbol Box.



The dialog pictured below will appear. Click on the simple fill button and select the outline color you want, **or no color**, and click OK. I picked Transparent stroke.



After making these changes to your map symbolization, your map should look something like the following.

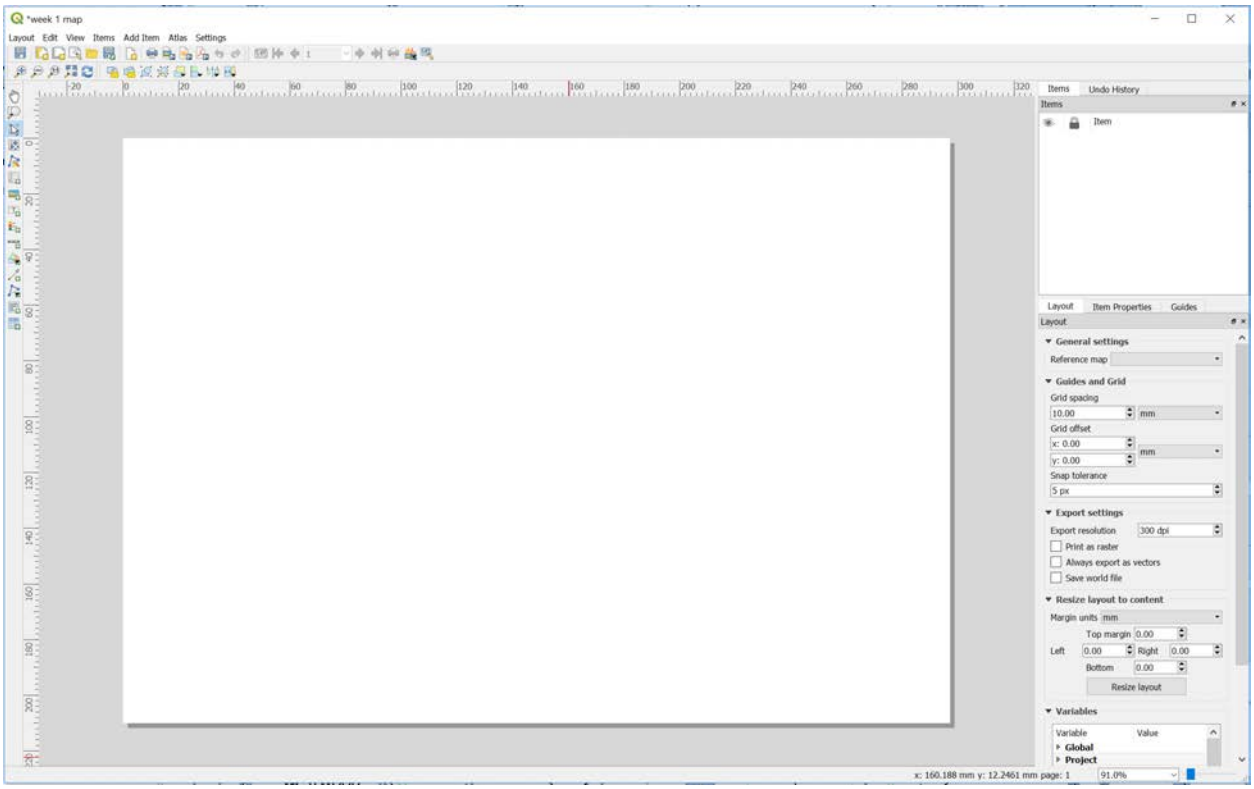


OBJECTIVE 3: COMPOSE, DESIGN, AND LAYOUT YOUR MAP

STEP 1.

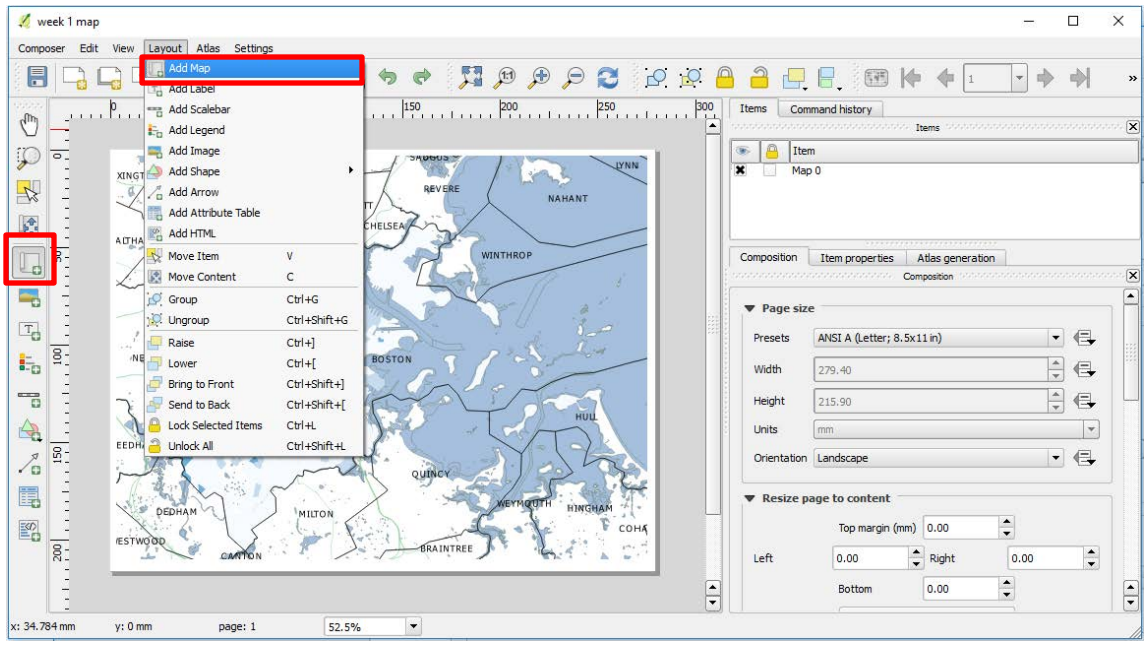
When working in QGIS, there are two main methods in which you view your data, edit it, and create a map. We have been working in **data mode**. In our following steps, we are going to layout our map. To do this, we use **Layout Mode**. This mode will allow us to arrange our map items in relation to one another with respect to the appearance of our final layout.

1. Go to **Project>New Print Layout** on the QGIS menu bar. Create a name for your Layout, such as **'week 1 map'** and click OK. A new window will appear.



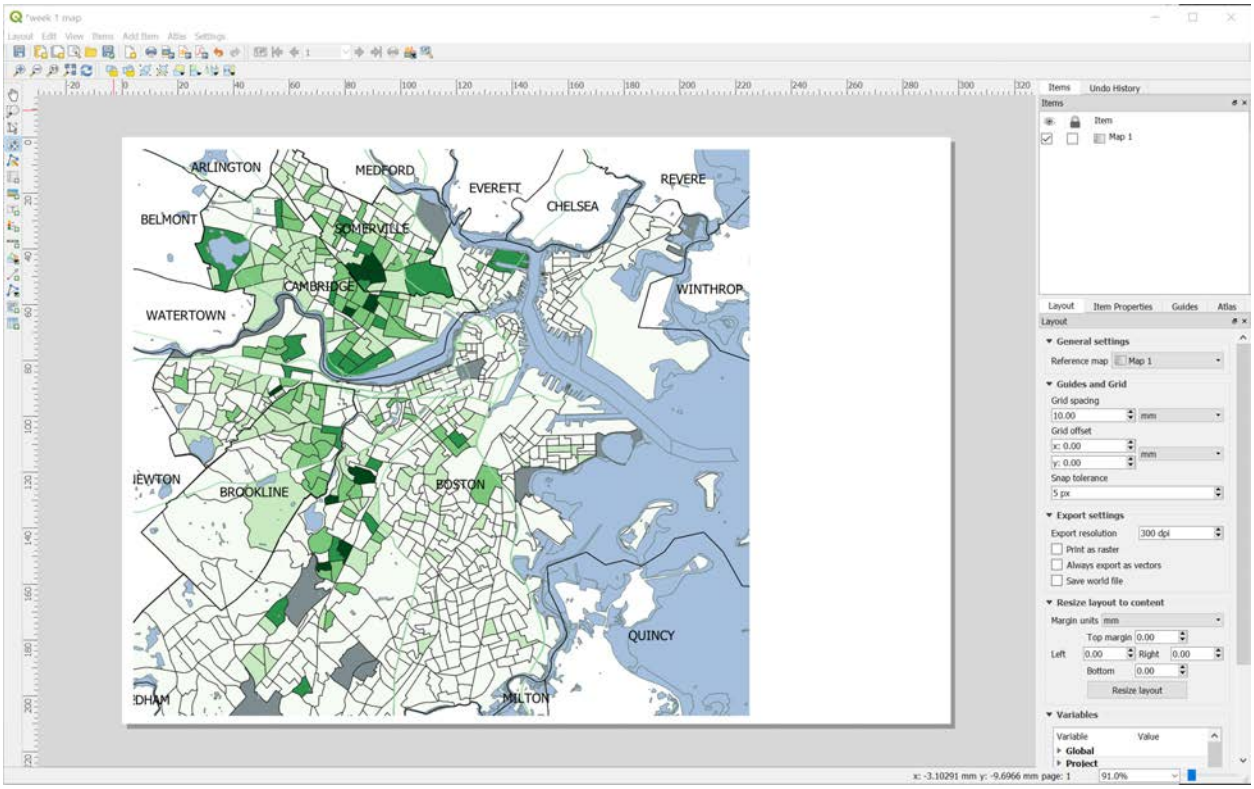
2. We now can see our map as it is laid out on the page. Right now, we are using a standard 8.5 x 11 page layout set in landscape orientation. If you want to change the format go to the left option panel and click on **Layout>Page Setup** dropdown menu and set the page layout.

3. The Add Item menu allows you to add our map elements, including the viewports and the legend that will inform our reader what the colors and classifications mean on our map. To create a viewport, go to **Add Item** and click on the **Add Map** button.



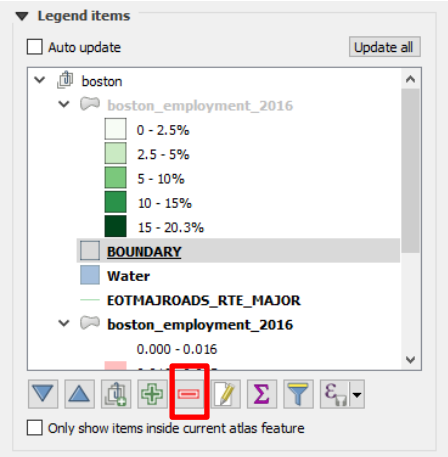
Once the Add Map button is active, hold the left mouse button and drag a rectangle where you want to insert the map. You will see that the rectangle window will be rendered with the map from the main QGIS canvas. The rendered map may not be covering the full extent of our interest area. **Click Edit>Move Content** or the button below. To move content around on the map.

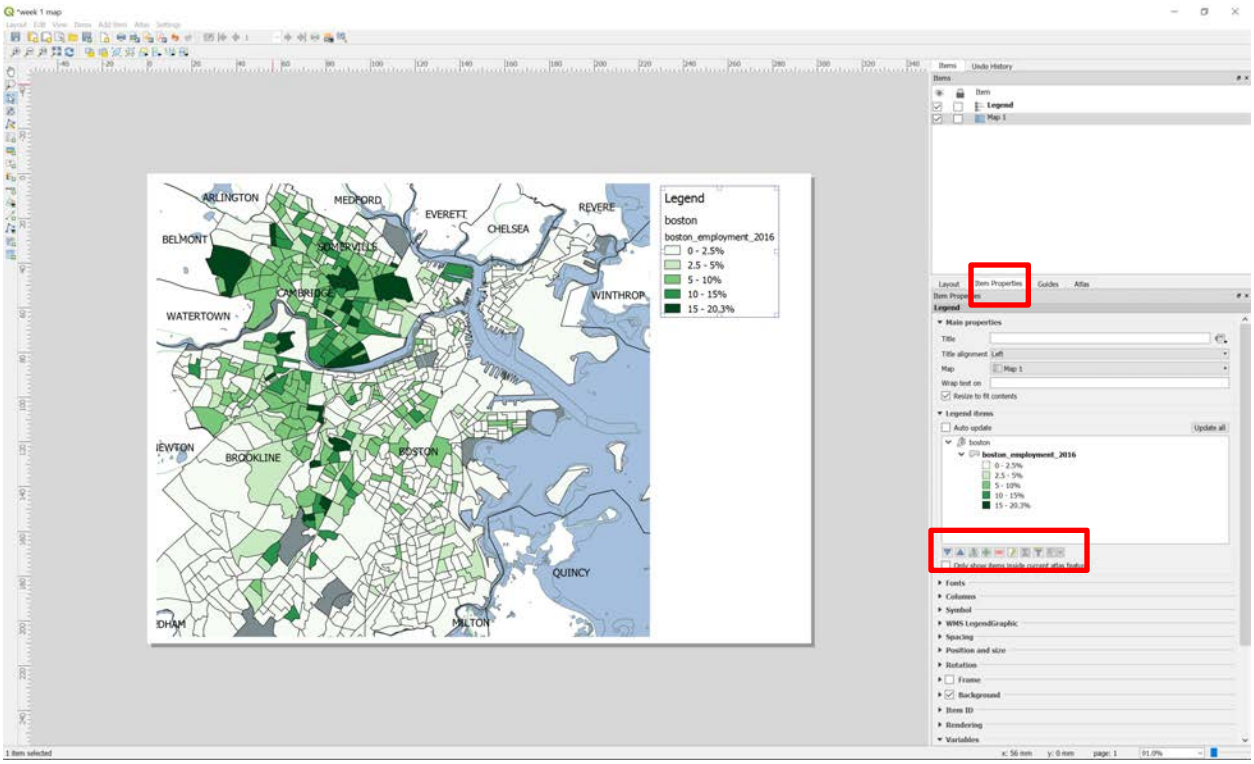
Your map should look something like the following.



To create a legend, go to **Add Item** and click on the Add legend button. Just like when you added the map you will need to click on the left mouse button and drag to make the size of the legend.

If you want to change the text and content of the legend first select the legend, right-click and say **Item properties** and the items will appear on the right. Make sure **AUTO UPDATE is NOT CHECKED**. You can remove legend items by selecting them and then clicking on the red 'minus' button.



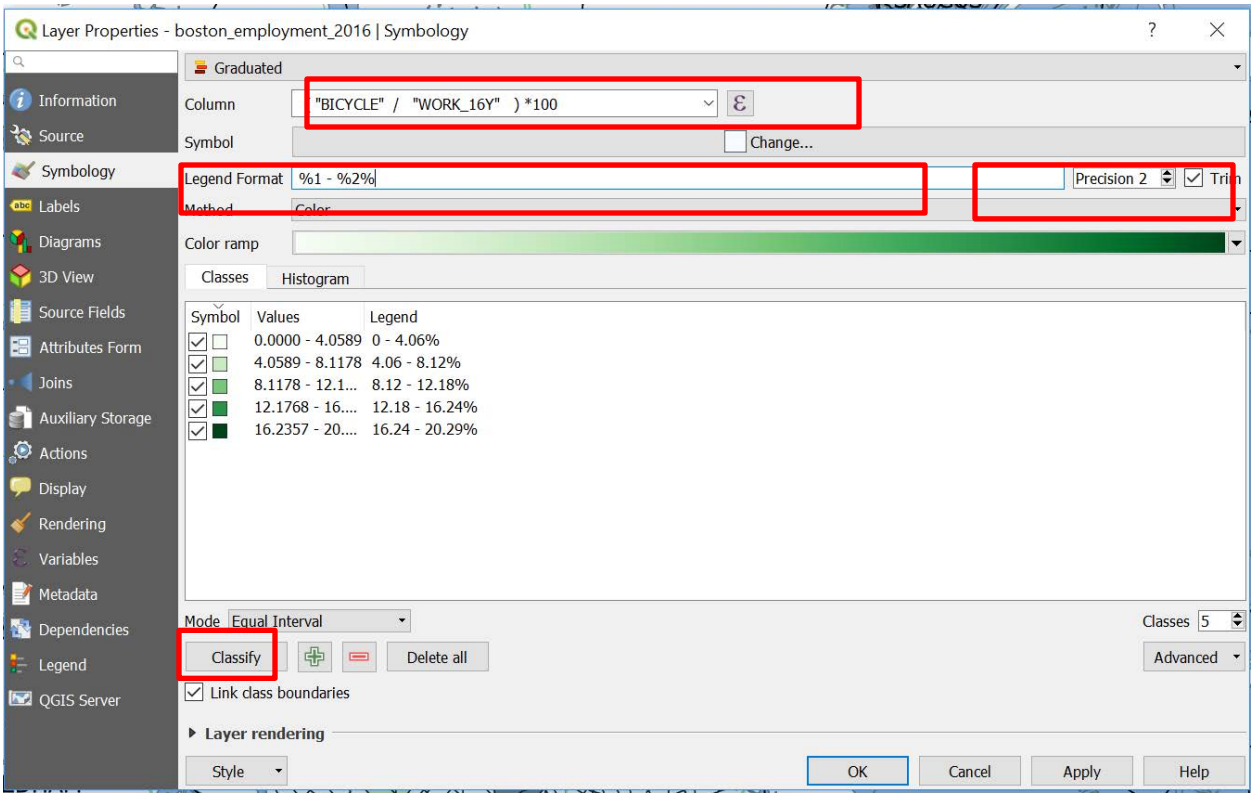


Next, notice that our legend actually represents percentages, but the values shown are currently decimals that might not make much intuitive sense to the map reader. Let's reformat the legend text to show our results as percentages.

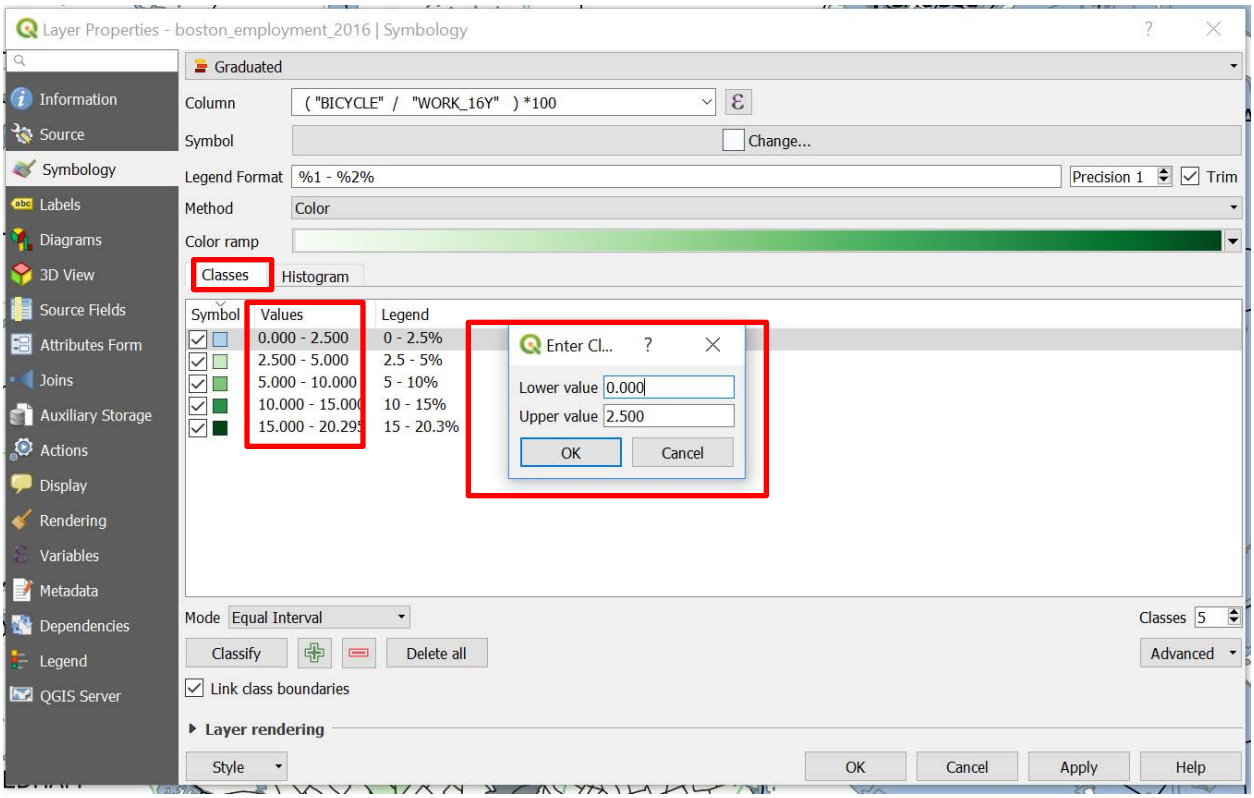
Reopen your layer properties in the **main map document**, not the layout document and go to Symbology.

Click on Expression button multiply the expression that you wrote before by 100.

Now your formula should look like this:
("BICYCLE" / "WORK_16Y") * 100. Below the expression box is the Legend Format box add the symbol **%**. Click on the button Classify to add the changes. Finally go to precision box and set the number of decimal places shown to 2. This will get rid of extra decimal places on our map that may confuse readers. Also, don't forget to hit classify to make sure your changes are made.

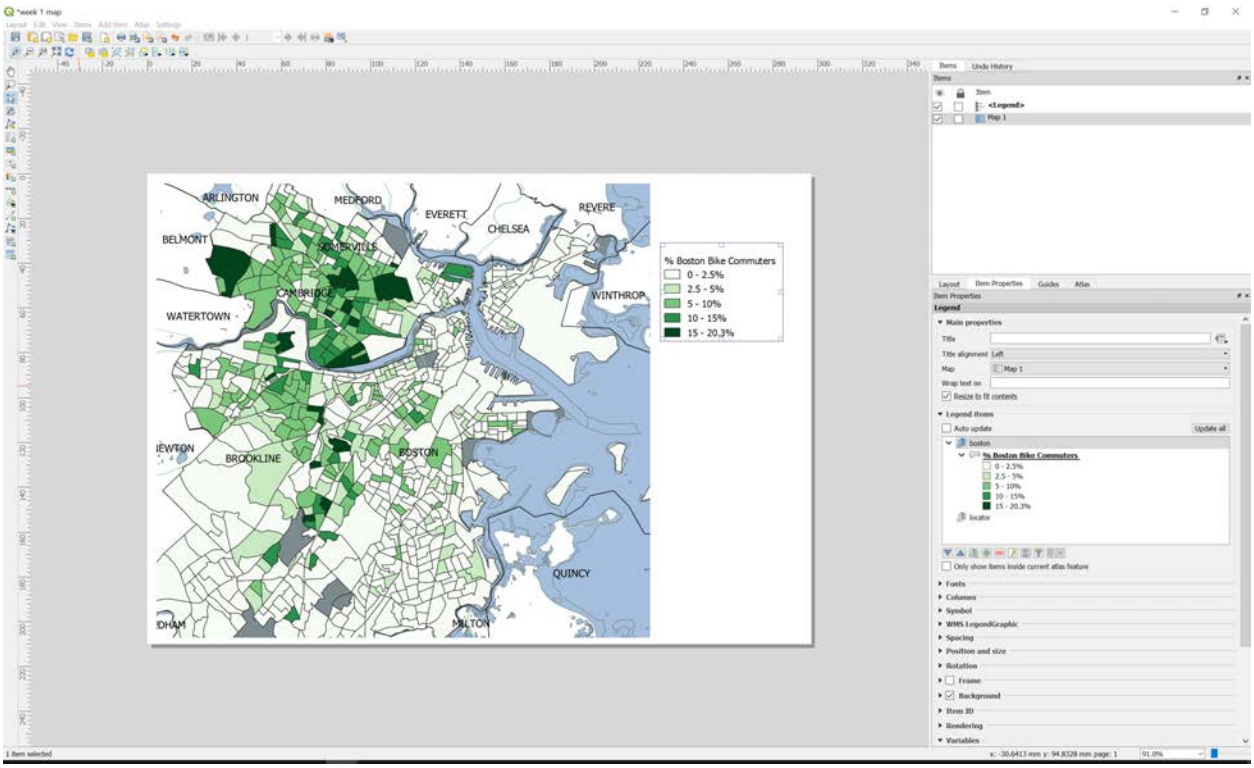


10. Let's make our map easier to understand for our readers. Currently, our symbolization categories, or classes, have breaks at unusual numbers. Modify the breaks in the classification scheme to show more logical, 'common sense' numbers. Double-click on each of the row entries under **Values**, and in the **Break values** window, change the numbers.



For this classification, use 2.5, 5, 10, and 15. Leave the highest value as is, this represents the maximum value in the data. You now have a manual classification scheme, based off of the Jenks classification scheme. (The image below is an example of what your window should look like.) Click OK.

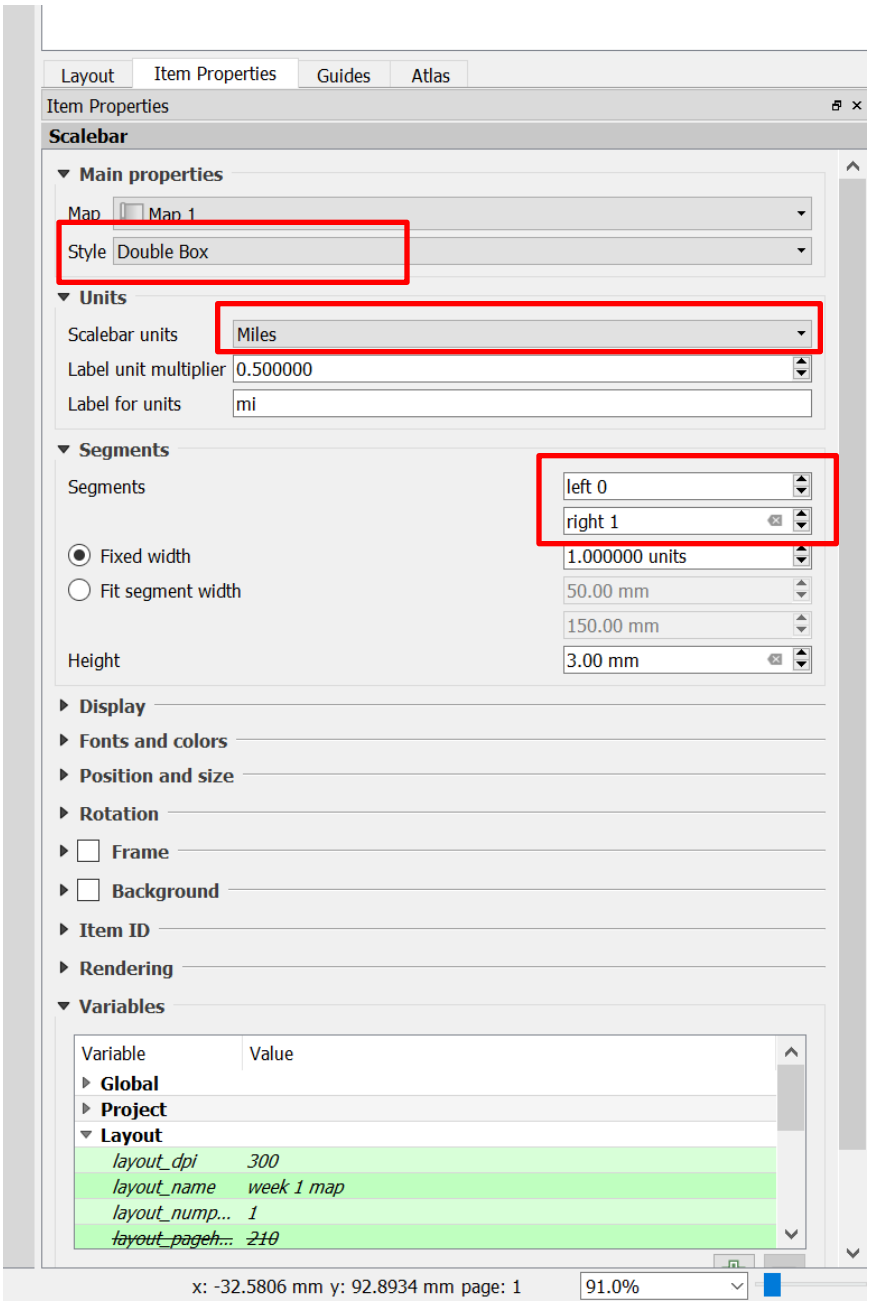
11. Your map is now laid out with a legend. It should look like the following:

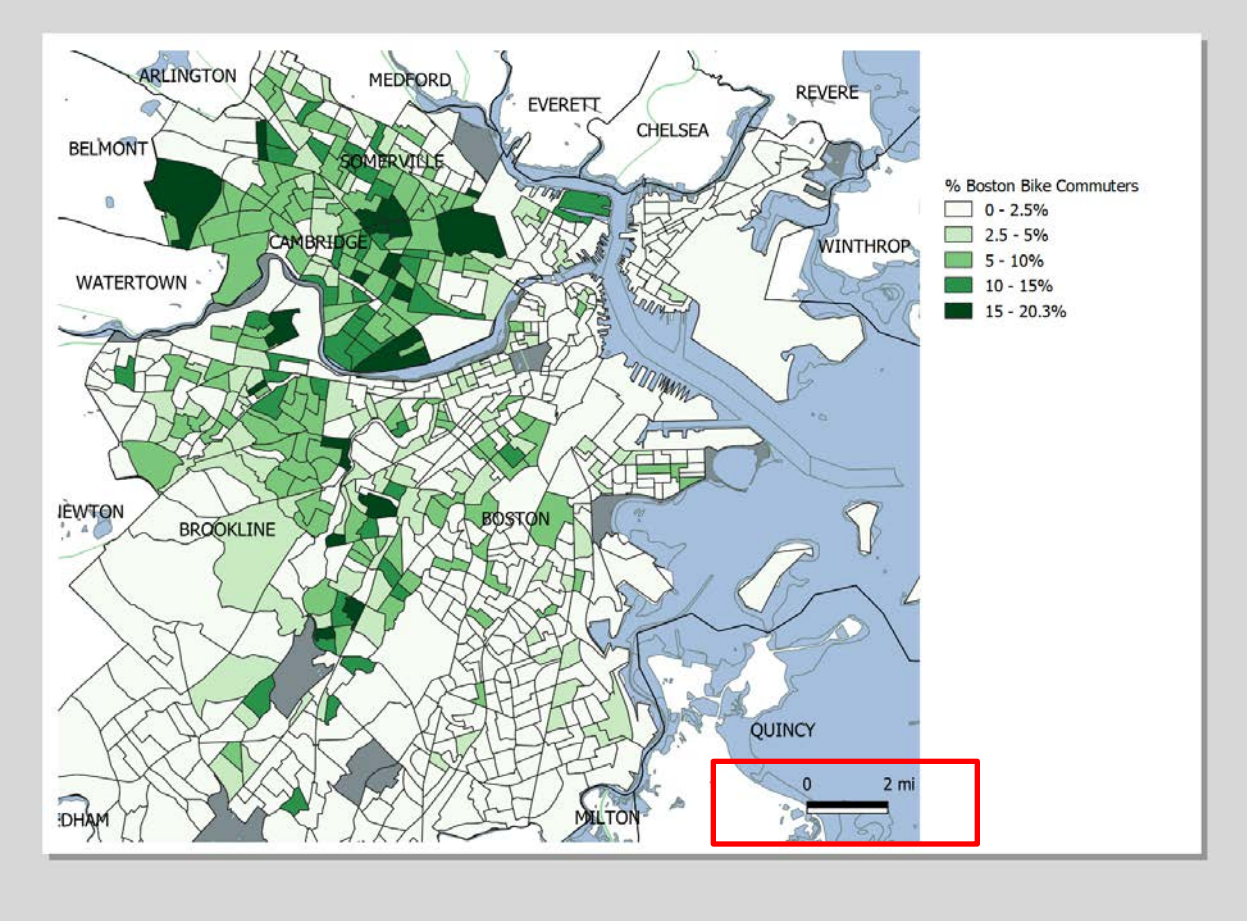


STEP 2. ADD A NORTH ARROW AND SCALE BAR

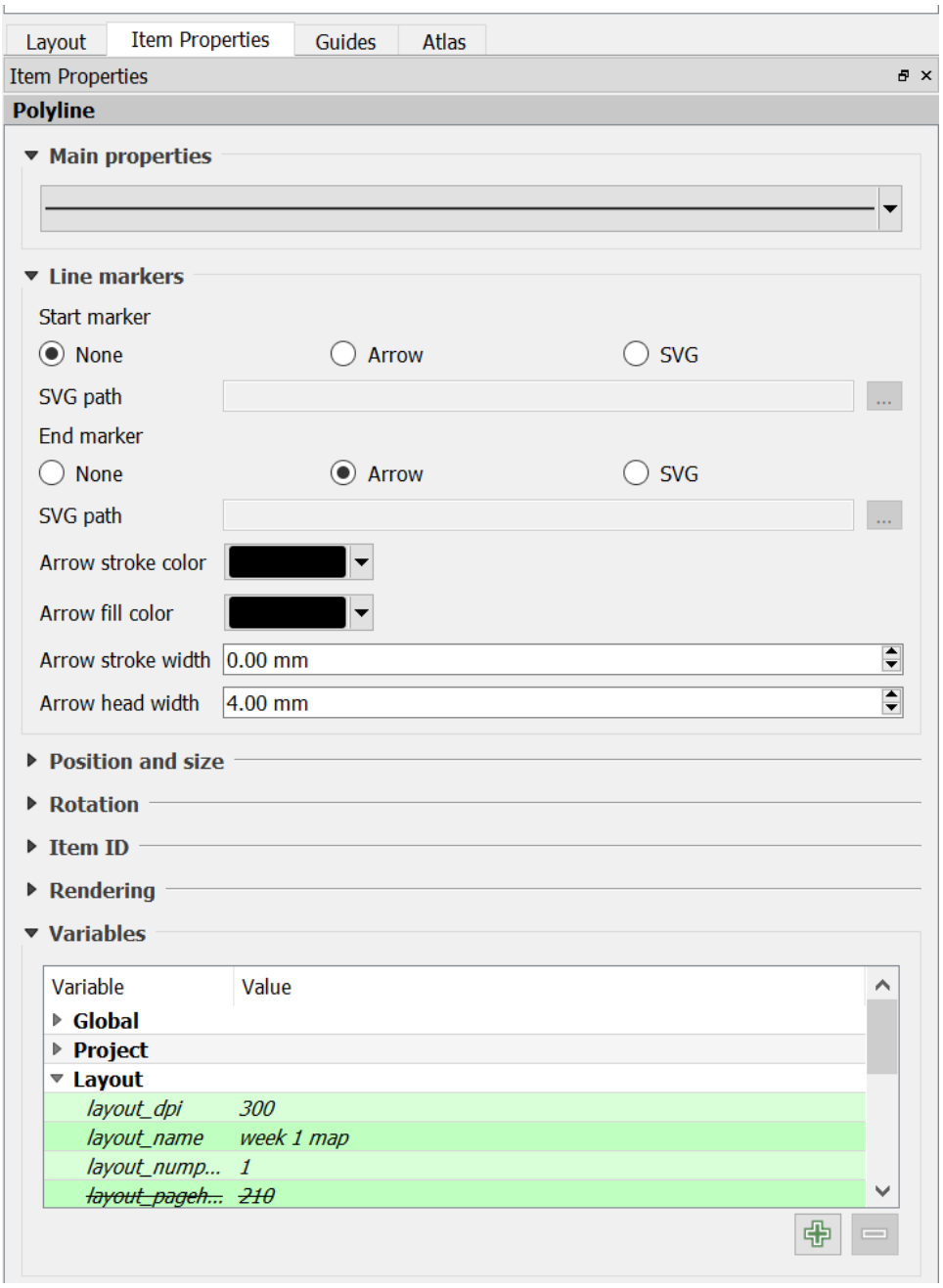
There are a certain number of elements that are standard to include on a map. These items are standard because they provide the map reader with information that they need to properly interpret the map. The two most important items are a scale bar that tells the map reader the translation between the map and ground distance, and a north arrow to orient the map reader on how to properly know which direction is which on the map. Let's add these two items to our map.

1. To add a scale bar, make sure you are in the **Layout Manager** window. Go to **Add Item> Add Scale bar** and click to place it on the map. Select the scale bar and go to the right-hand side menu and click on **Item Properties**. Play with the options to modify the features of the scale bar such as units, style, font, etc. Go to Main Properties dropdown **and pick Double box**. Now go to **Units>Scalebar units> Mile**. Change the rest of the properties to match what is below.


Layout
Item Properties
Guides
Atlas
Item Properties
Scalebar
Main properties
Map
Map 1
Style
Double Box
Units
Scalebar units
Miles
Label unit multiplier
0.500000
Label for units
mi
Segments
Segments
left 0
right 1
Fixed width
1.000000 units
Fit segment width
50.00 mm
150.00 mm
Height
3.00 mm
Display
Fonts and colors
Position and size
Rotation
Frame
Background
Item ID
Rendering
Variables
Variable
Value
Global
Project
Layout
layout_dpi
300
layout_name
week 1 map
layout_nump...
1
layout_pageh...
210
x: -32.5806 mm y: 92.8934 mm page: 1
91.0%

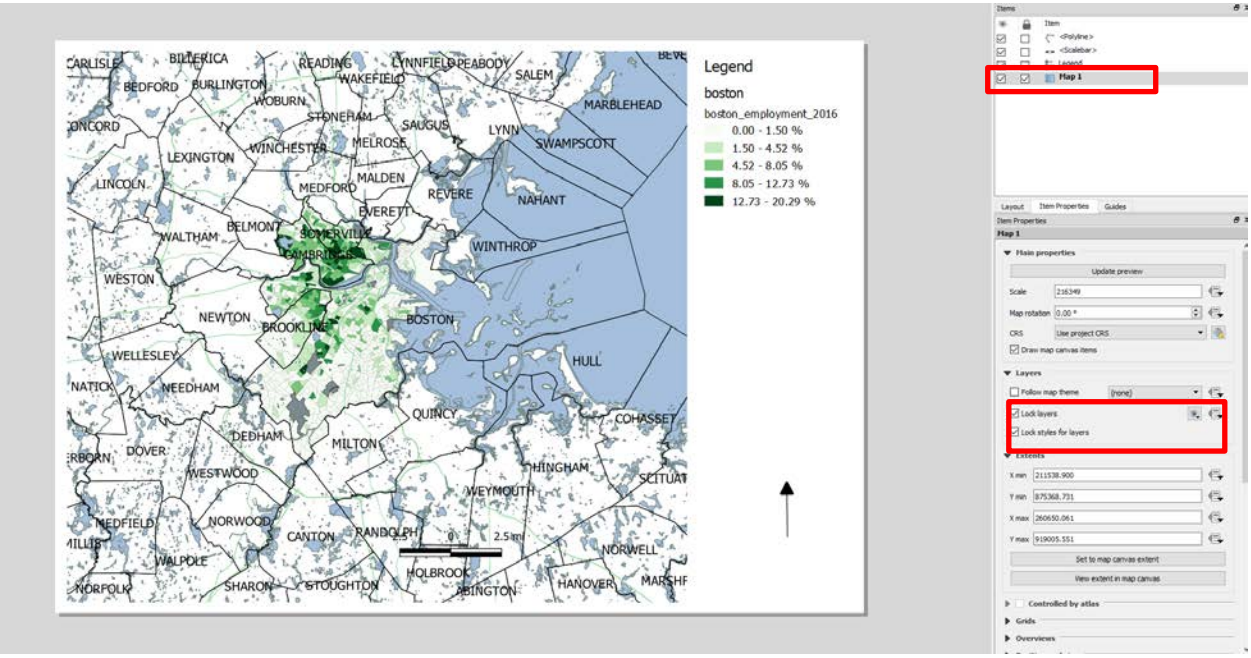


2. To add a north arrow, go to **Add Item > Add Arrow**. Draw the north arrow by clicking a straight line from bottom to top (since the arrow should be north-facing). Right-click to release the drawing. Select the Arrow and go to the right-hand menu and click on **Item Properties**. Play with the options to modify the features of the Arrow.

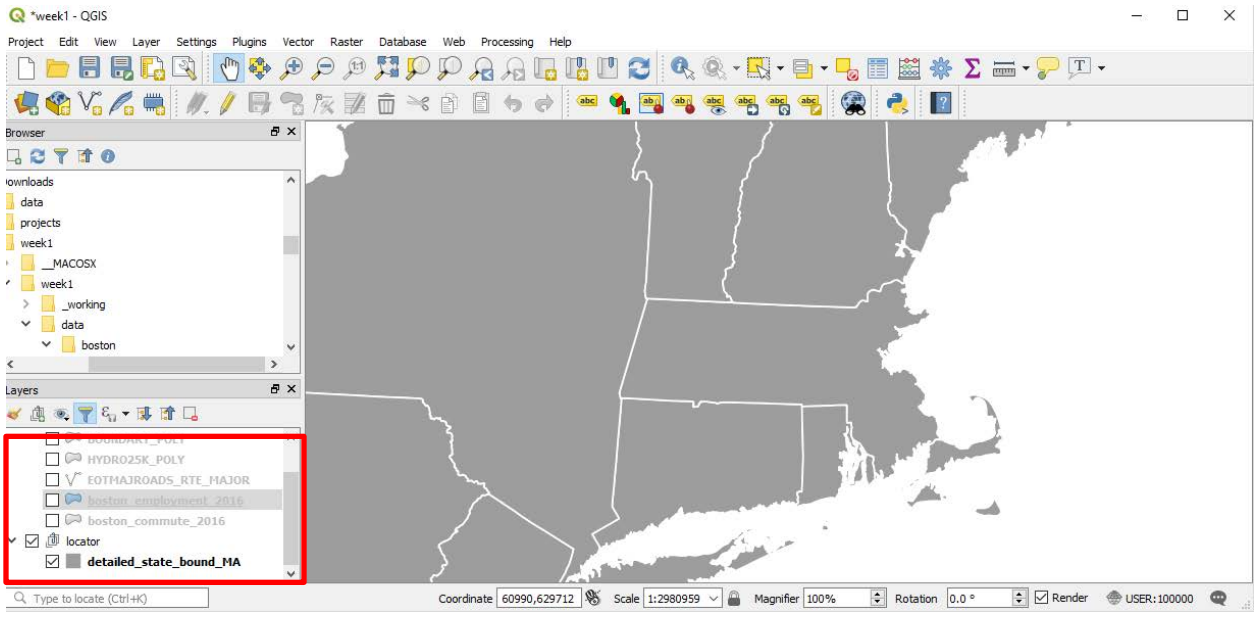


STEP 3. ADD AN INSET (LOCATOR) MAP USING A SECOND MAP FRAME

Now we will add a map inset that shows a zoomed out view for the Boston area. **Before we make any changes to the layers in the main QGIS window, check the Lock layers for Map 1 item and Lock layer styles for map item boxes.** This will ensure that if we turn off some layers or change their styles, this view will not change.



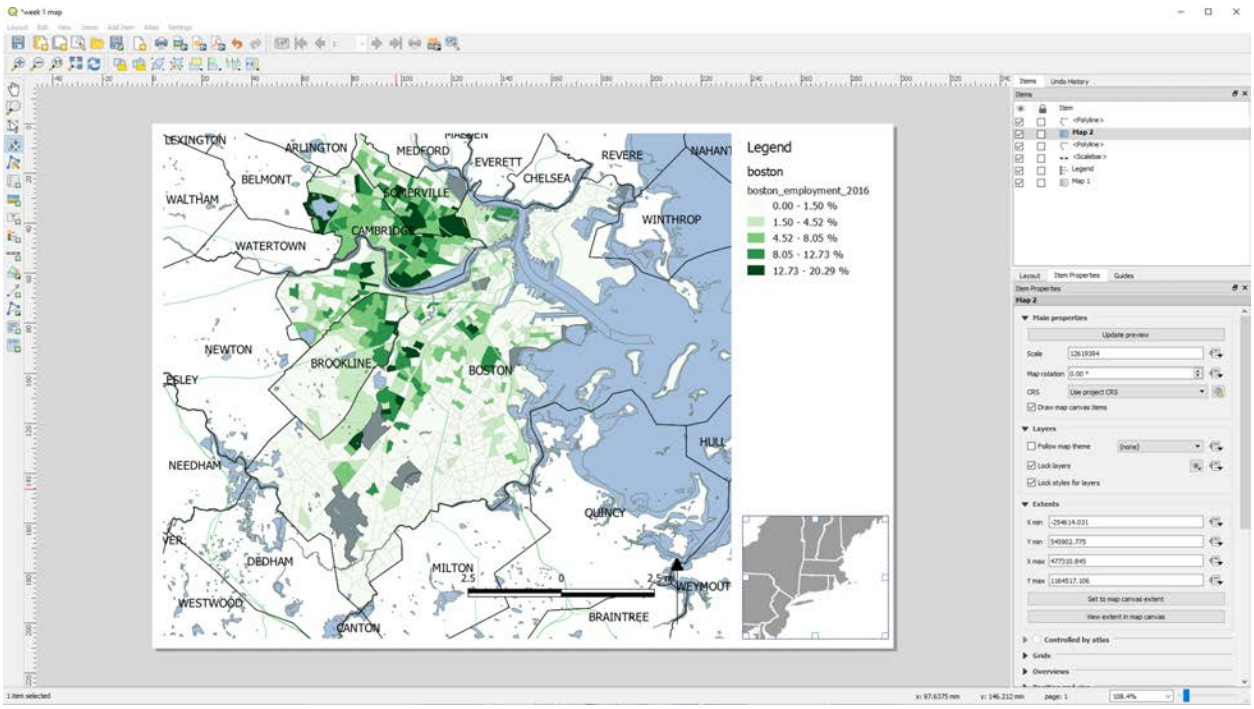
Switch to the main QGIS window. Use the Zoom out button to zoom to the level of the state of Massachusetts. Turn off all the layers from the previous map and turn on the layer **detailed_state_bound_MA**.



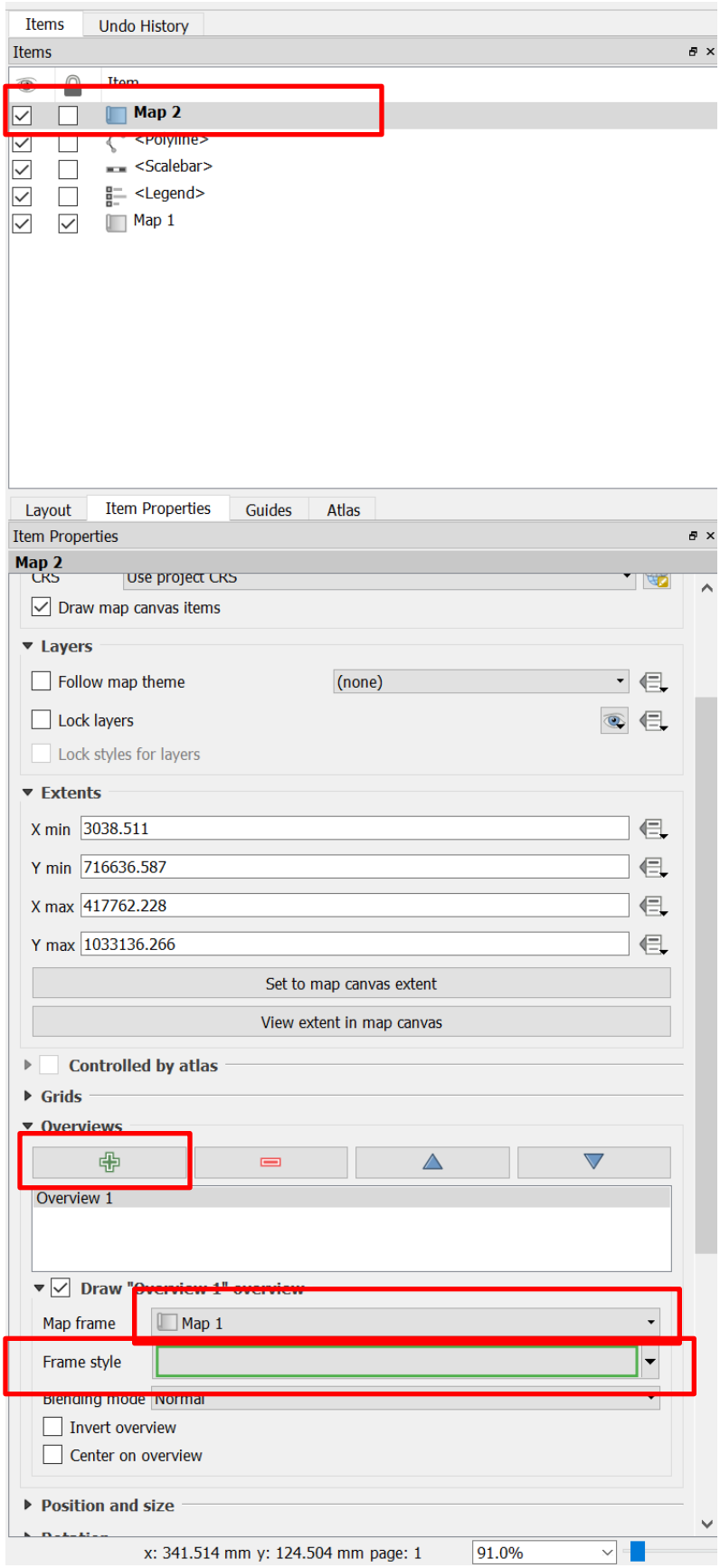
We are now ready to add the map inset. Switch the Map Layout window. Go to **Add Item ‣ Add Map**

Drag a rectangle at the place where you want to add the map inset. You will now notice that we have 2 map objects in the Layout Manager. **When making changes, make sure you have the correct map**

selected. Select the Map 2 object that we just added from the Items panel. Select the Item properties tab. Scroll down to the Frame panel and check the box next to it. You can change the color and thickness of the frame border so it is easy to distinguish against the map background.



One neat feature of the Map Layout is that it can automatically highlight the area from the main map, which is represented in our inset. Select the Map 2 object from the Items panel. In the Item properties tab, scroll down to the Overviews section. Click the Add a new overview button . What this is telling the Layout is that it must highlight our current object Map 1 within the Map 2 object, which is the zoomed-out map of Massachusetts. Make the properties look like the dialog below.


Items
Undo History
Items
Item
Map 2
<Polyline>
<Scalebar>
<Legend>
Map 1
Layout
Item Properties
Guides
Atlas
Item Properties
Map 2
CRS
Use project CRS
Draw map canvas items
Layers
Follow map theme
(none)
Lock layers
Lock styles for layers
Extents
X min
3038.511
Y min
716636.587
X max
417762.228
Y max
1033136.266
Set to map canvas extent
View extent in map canvas
Controlled by atlas
Grids
Overviews
Overview 1
Draw "Overview 1" overview
Map frame
Map 1
Frame style
Blending mode
Normal
Invert overview
Center on overview
Position and size
x: 341.514 mm y: 124.504 mm page: 1
91.0%

Your locator will now look similar to the following.

STEP 4. ADD TEXT AND LABELS TO YOUR MAP

There are two main ways to add text to your map, automatically, using the labeling tools, and manually, using the Drawing toolbar.

1. You earlier labelled the cities on your map (pg. 6). These labels, including Boston, Cambridge, Somerville, etc., are added using the QGIS labeling features. These labels are based off attributes for that layer. Settings can be changed in the Labels tab of the Layer Properties. As these are already set, we don't need to change them right now, but if we wanted to base our labels off of a different field in our attributes, we would change on the label tab. You can easily toggle these on and off, and change the properties of the labels. We will expand on this as the semester goes on.

3. To manually add text go to **Add Item >Add Label> click on the area which you want to add the text**. Select the text you added and go the right feature box on the screen. Go to Item properties>Main properties. On the Box that appears write MASSACHUSETTS. Now go to Appearance to modify the fonts, color, etc. of the text.

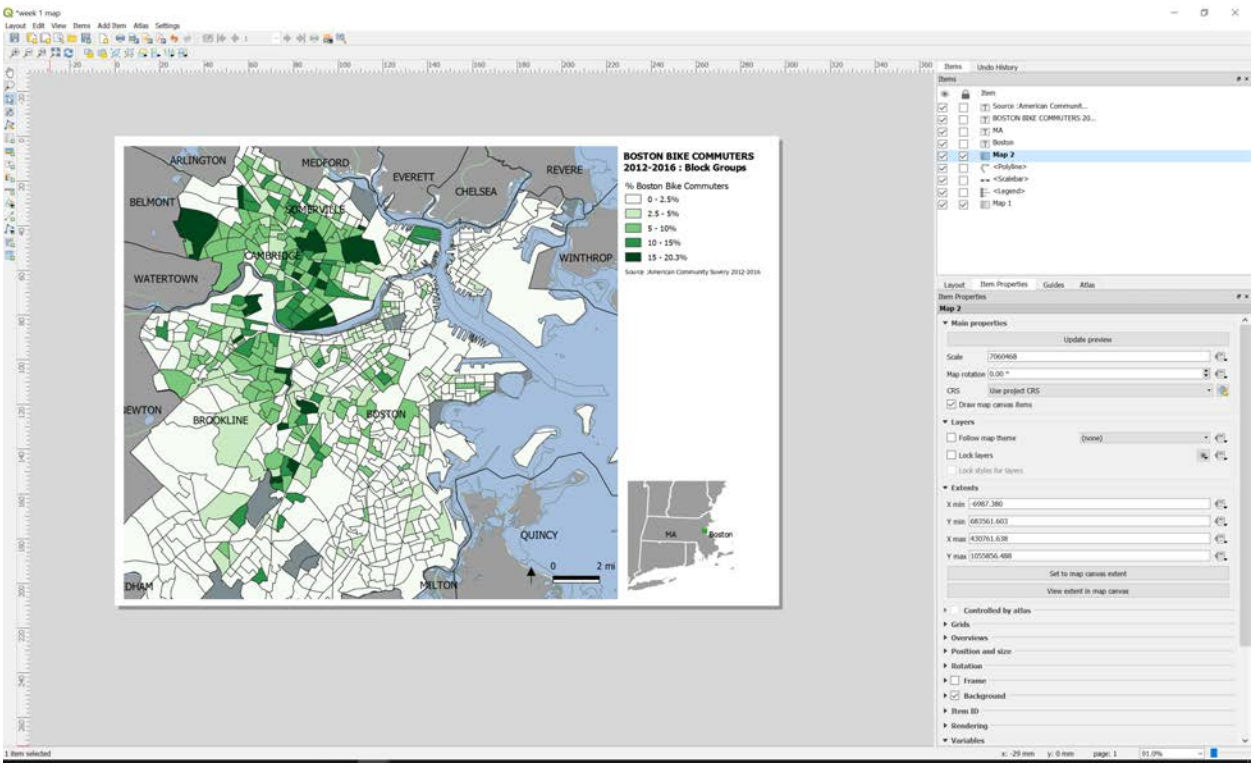
STEP 5. CHANGE THE TITLE, ADD SOURCE, AUTHOR, AND DATE CREATED TO LAYOUT

1. Our map now needs an informative title. We need a title that states the map is showing Boston Bicycle Commuters. Go to layout>Add Label. Type "Boston Bicycle Commuters"

2. One of the most important components of a map is the source information. Our data is from the American Community Survey, 2012-2016. We need to include this on the map. Add another text box below the title using the Draw toolbar and write the text "American Community Survey Estimates 2012-2016"

2. The final component is to add author and date information. Put this information in the lower-right-hand corner of the map, underneath the locator map. Here add a text box that includes your name and the date you created the map.

After these steps, your map should now look like the following.



STEP 6: EXPORT YOUR MAP TO PDF FORMAT

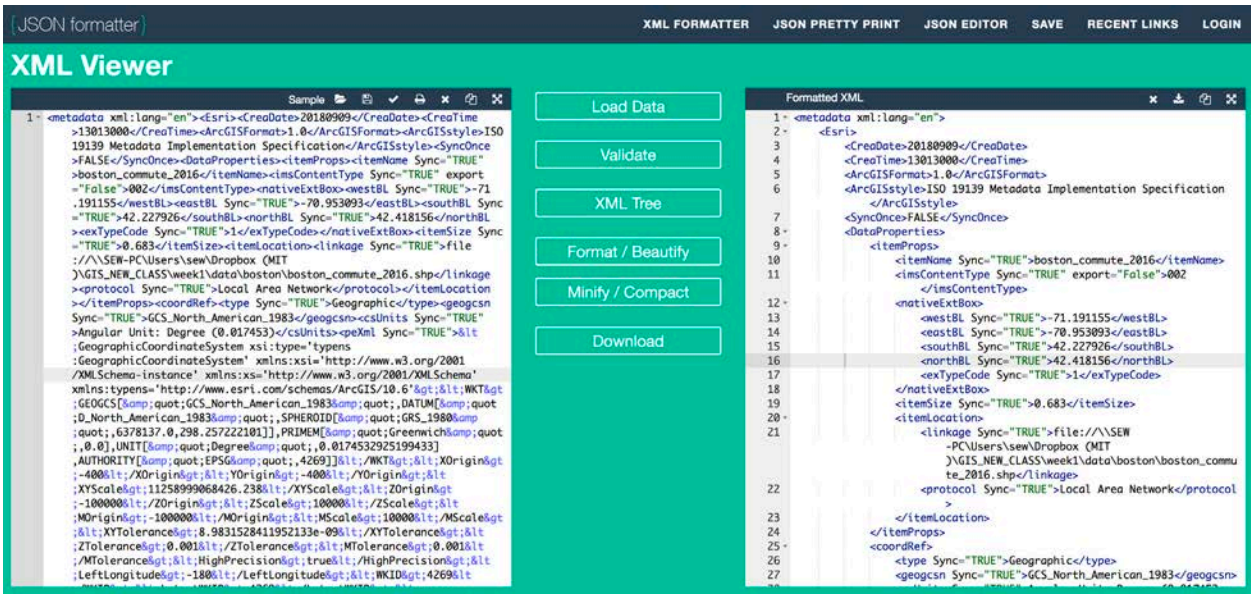
Now that our map layout is complete, we are ready to export the file to a PDF format so it can be printed or viewed online. To do this, go to Layout > Export as PDF. Save the file to your workspace. It is best practice to keep your files well organized and create a folder called 'Exports' or 'Graphics' for all your exports and final exported maps. Open the file in Adobe Acrobat to make sure that your export worked.

OBJECTIVE 4. VIEW METADATA IN JSON FORMATTER

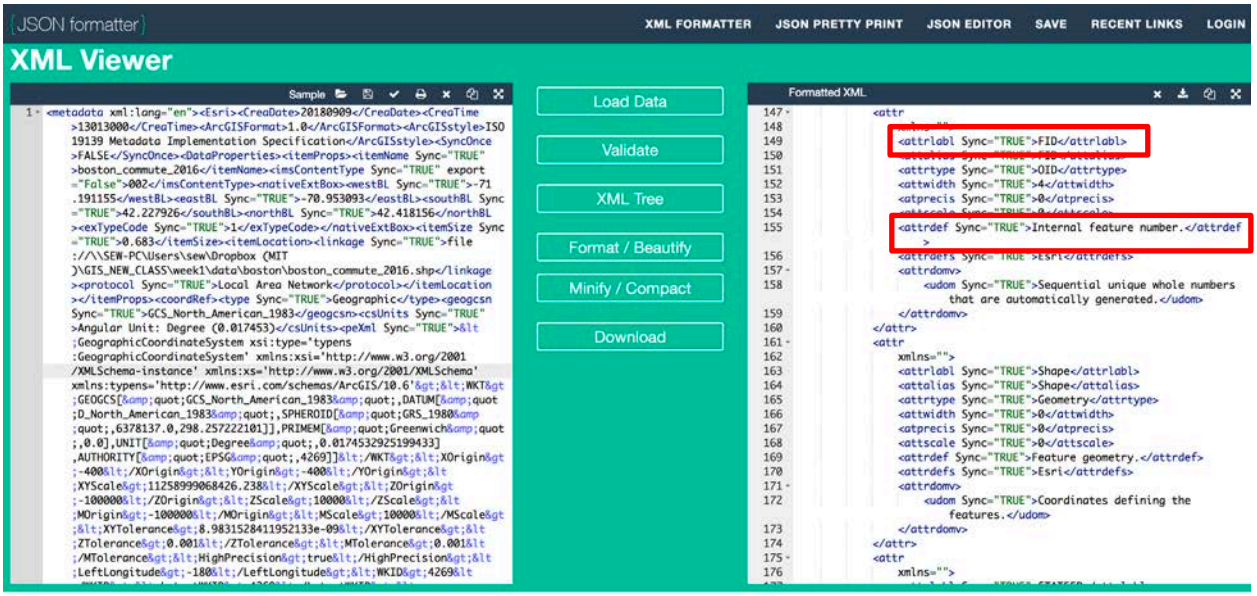
Each GIS file you use contains Metadata. Metadata is where you find information about the data you are using, such as what each field represents and other attributes. While metadata is important and valuable in understanding a dataset, you will often find it is incomplete. The datasets for this week have completed metadata that we can view in ArcCatalog.

Metadata is often stored in a file format called extensible Markup language (XML). These are long files that store structured information, in this case about our data. To make these readable, it's common to use a *parser,* or *viewer*.

Navigate to jsonformatter.org/xml-viewer. Select 'load data' and add data/boston_commute_2016.shp.xml, and select 'Format / Beautify'. Your screen should look like the screen below:



Whoa, what a mess… but actually, we can parse this fairly easily! Search for 'eainfo' (command-f) within the XML. Within the <eainfo> tag, you should see a series of attributes (<attr>). Each of these corresponds to a field, and each contains a <attrdef> field. This is the metadata description of the field! For example, the FID field (highlighted below) is the 'Internal Feature Number'…



You can make modifications to the file in the Formatted/Beautified interface and re-download it as an XML. You will need to examine metadata to complete Take-home Exercise 1.

THE 11.205/520 MAP DESIGN CHECKLIST

We encourage you to explore various cartographic methods and be creative with your deliverables during the course of this class. That said, each map you submit must contain the following qualities and features. We will check each map to make sure it includes the following. Run through this checklist as you complete maps in this course.

All maps should contain:

1. Informative Title – The titles to your maps should allow the reader to quickly understand the map.

2. Legend – A legend that clearly describes the thematic layers on the maps.

3. Data Source – The source of your data is also important in validating your map results, interpreting the map, and allowing the reader to explore your data further.

4. Scale Bar – The scale bar is the translation between the map and the real life features.

5. Date – The date you create your map is important, especially if multiple versions are being made.

6. North Arrow – A north arrow is necessary to properly orient the reader to the map.

7. Author – Your name is important to include on all maps you author. You should also include organization information (i.e. MITDUSP) to help the reader.

Other items, such as locator maps and data analysis methods, are often helpful to readers, but not required in this course.

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11.205 Introduction to Spatial Analysis

Fall 2019

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