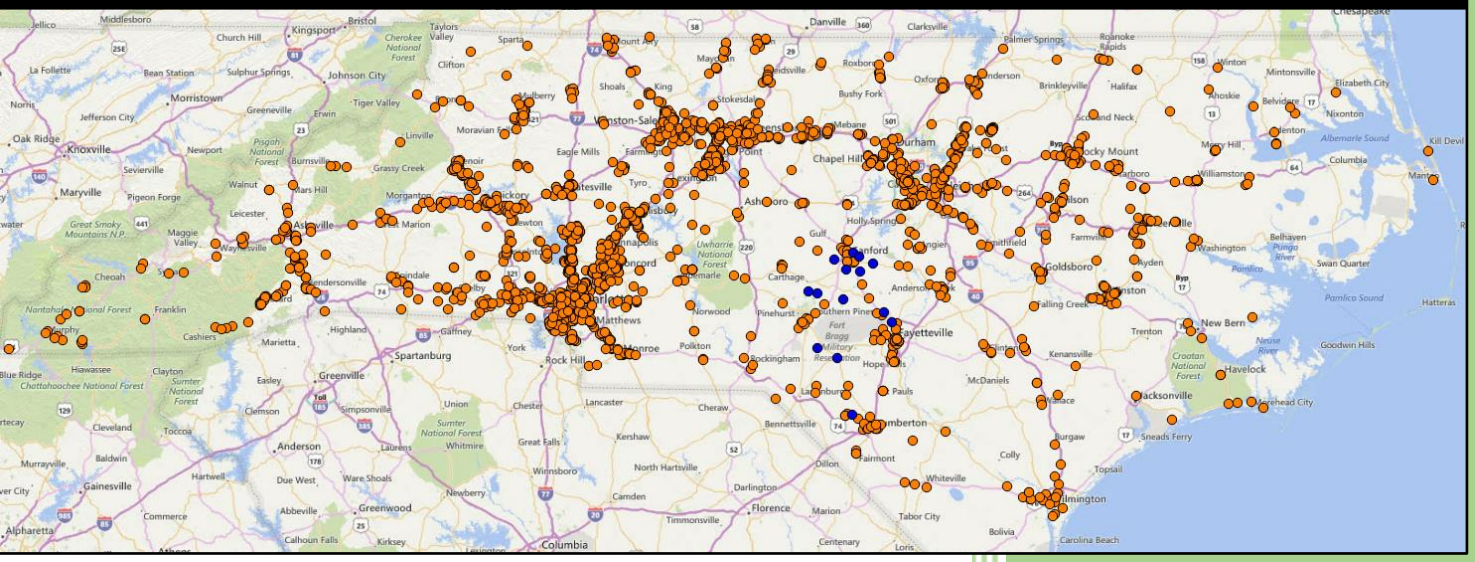
An initiative of CEFS — CENTER for ENVIRONMENTAL FARMING SYSTEMS — NCSU | NCA&T | NCDA&CS

NC GROWING TOGETHER

Connecting Local Foods to Mainstream Markets

A Crossdock Consolidation Center for Local Produce: Using QGIS to Select an Optimal Site Location



Crossdock Consolidation Centers for fresh produce are a proposed type of local food distribution infrastructure consisting of loading docks and coolers for aggregation and storage of product. The Centers are designed as part of a food distribution network to incentivize large-scale wholesalers to purchase produce that has been consolidated from rural and remote farming communities.

The following guide offers a step-by-step example (set in eastern North Carolina) to determine the optimal location of a proposed consolidation center so that the procedure can be reconstructed by others. The example uses the open-source software package QGIS, and utilizes the location of vacant warehouses as one input. The guide could be useful to advocates and researchers, as well as economic development personnel seeking to repurpose underutilized infrastructure.

A companion document provides a facility layout and expected investment and operating costs: *A Crossdock Consolidation Center for Local Produce: Investment and Operating Cost Estimates*
(See: ncgrowingtogether.org/Research)

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USDA NIFA United States Department of Agriculture National Institute of Food and Agriculture

Table of Contents

Executive Summary

The Center for Environmental Farming Systems (CEFS), a partnership between North Carolina State University, North Carolina A&T University, and the North Carolina Department of Agriculture and Consumer Services, seeks to "promote just and equitable food and farming systems that…provide economic opportunities in North Carolina and beyond."[1] To this end, the concept of a "consolidation center" has been proposed as part of a food distribution network to incentivize large-scale wholesalers to purchase produce that has been consolidated from rural and remote farming communities.

The following report serves as a procedural framework for managers or researchers who are considering the viability of this concept as part of their operations and advocacy efforts. Using Geographic Information Systems (GIS) technology and applicable datasets, this guide offers a step-by-step example (set in eastern North Carolina) to determine the optimal location of a proposed consolidation center so that the procedure can be reconstructed by others. The example utilizes the existence and location of vacant warehouses as one input, and thus could prove useful to economic development officials seeking to repurpose underutilized infrastructure.

End State

The desired end state is to identify the optimal location of a consolidation center based primarily on minimizing the proximity of the facility to a set of farms within a specific region. Distances from the optimal location to the nearest major road and nearby cooperating wholesaler facilities are also measured for consideration. Siting and operational feasibility of the consolidation center (CC) assumes that the center is used for temporary aggregation of product that has been ordered by one or more wholesalers. The CC thus has minimal personnel requirements, as it is not a location from which product is marketed to various buyers; rather, one or more wholesalers communicate directly with a group of growers which delivers cases of product to the site for pickup.

GIS Overview

Geographic Information Systems is a software package that allows the user to visualize data that is geographically referenced. It can capture, store, analyze, and manipulate these datasets to help the user better understand the data and, if applicable, develop an optimal solution to their project. Year after year, GIS software packages become simpler and more user friendly, allowing professionals who may be unfamiliar with the technology to take advantage of its benefits. In addition, county and state-level governments often employ or have access to GIS professionals that can assist with a variety of projects.

This work instruction uses an open source GIS software package called "QGIS". Open source software packages are generally free or very inexpensive. However, it should be noted that open source software can be updated frequently, so it is likely that over time readers of this work instruction will experience slight differences between what this report demonstrates and the software's current version. Should that be the case, the development group of QGIS offers a comprehensive support site at www.qgis.org where common questions are explained and answered.

[1] http://www.cefs.ncsu.edu

Throughout this work instruction, the reader will also be provided with an overview of general GIS concepts and tips, designated by an asterisk (*) in front of the explanatory paragraph. A general understanding of these concepts and tips is critical to reproduce the intended results.

Methodology

The methodology followed for this work instruction is outlined in Figure 1 below:

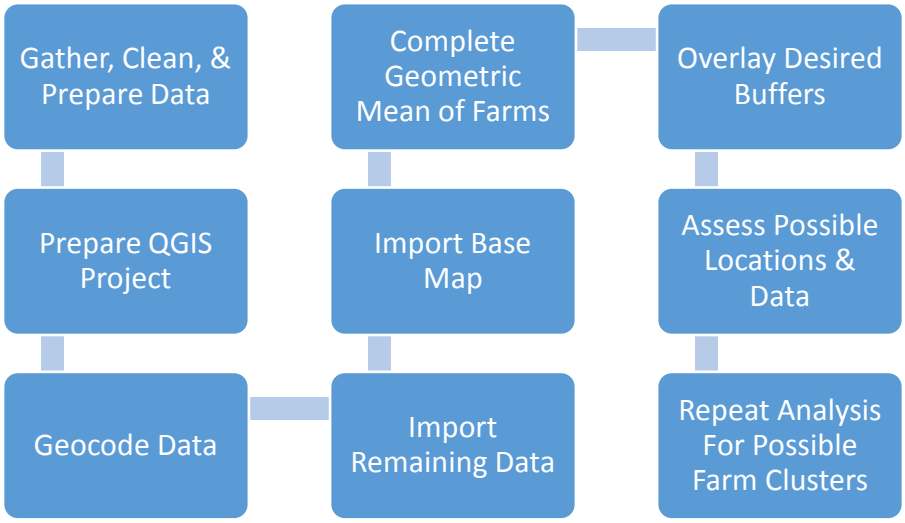


Figure 1: Overview of GIS Methodology

Before beginning, QGIS must be downloaded to your workstation. It can be downloaded, for free, at http://www.qgis.org/en/site/forusers/download.html. Download the version under "Latest release" and install the program.

Step 1 - Gather, Clean, and Prepare Data

A critical and early step in any GIS project is to research, identify, and aggregate any relevant datasets needed to reach the desired end state. For this particular project, you will need three datasets:

- A roadway dataset from local or state government encompassing the geographical area of consideration
- A dataset of all relevant farms in the geographical area of consideration
- A dataset of vacant warehouses within the geographical area of consideration that meet the project's operational constraints for the consolidation center (square footage, etc)

It is likely that once the data is collected, depending on the format, it will need to be filtered or categorized to meet the specifications of the project.

***Data Types**

GIS readable data comes in a variety of different forms. In general, files are GIS readable if they contain an attribute that allows data points to be referenced geographically, such as latitude/longitude coordinates. File types can be distinguished by the extension at the end of the file name (".doc" at the

end of a Microsoft Word file, for example). While GIS programs have a large extent of file types they can import, some of the more common file types have the following file extensions: .shp, .xml, .kml, .kmz, .txt, .map.

One important distinction between GIS readable file types is "raster" file types and "vector" file types. Raster files are simply a geographically referenced picture. A user cannot modify or interact with the file, thus, raster files oftentimes provide very little functionality. Vector files, on the other hand, contain one or more layers that can be modified and quantitatively analyzed, so the user can interface with the data to gain additional insight.

One of the most common and universally accepted forms of vector data is what is known as a "shapefile" (file extension .shp), which is actually a large grouping of individual file types. ***Because of this, as data is collected, it is important to keep the data well organized in folders and clearly labeled***. When shapefiles are downloaded they will generally include the entire group of files. To import a shapefile into a GIS program, the user selects the individual file with the .shp file extension. The projected .shp file will reference the other files in the group "behind the scenes" to maintain geographical reference and other data in the GIS program. In addition to shapefiles, it is likely that in this project the user will work with Microsoft Excel spreadsheets containing geographical references (latitude/longitude or street addresses, for example).

Data can also come in the form of a Web Mapping Service (WMS). While no WMS was used in this example, it is recommended that you search for an applicable WMS in your geographical area as these services can be very helpful and simplify the process. A WMS is a live stream of data provided by an organization or agency that can be accessed through QGIS. Once connected to a WMS, the connection provides the same data of an individual dataset but is likely more up-to-date and therefore, more accurate. This is important for data that is frequently updated; for example, the existence and location of underutilized infrastructure, such as vacant warehouses. See Appendix A for a step-by-step procedure of how to connect to a WMS in QGIS.

Roadway Dataset

In this example, a roadway dataset shapefile was obtained from an internet search[2]. This dataset contains interstates, highways, primary, and secondary roads. Download the file labeled "North Carolina Highway Shapefile" from the website listed in the reference list at the end of this report, unzip the group of files, and move them to a folder of your choosing.

Farm Dataset

The dataset used for this example, consisting of farm locations, was provided by CEFS for the purposes of this project. Similar datasets for future projects may be obtained from local advocacy groups, research groups, or the state government's Department of Agriculture or Commerce.

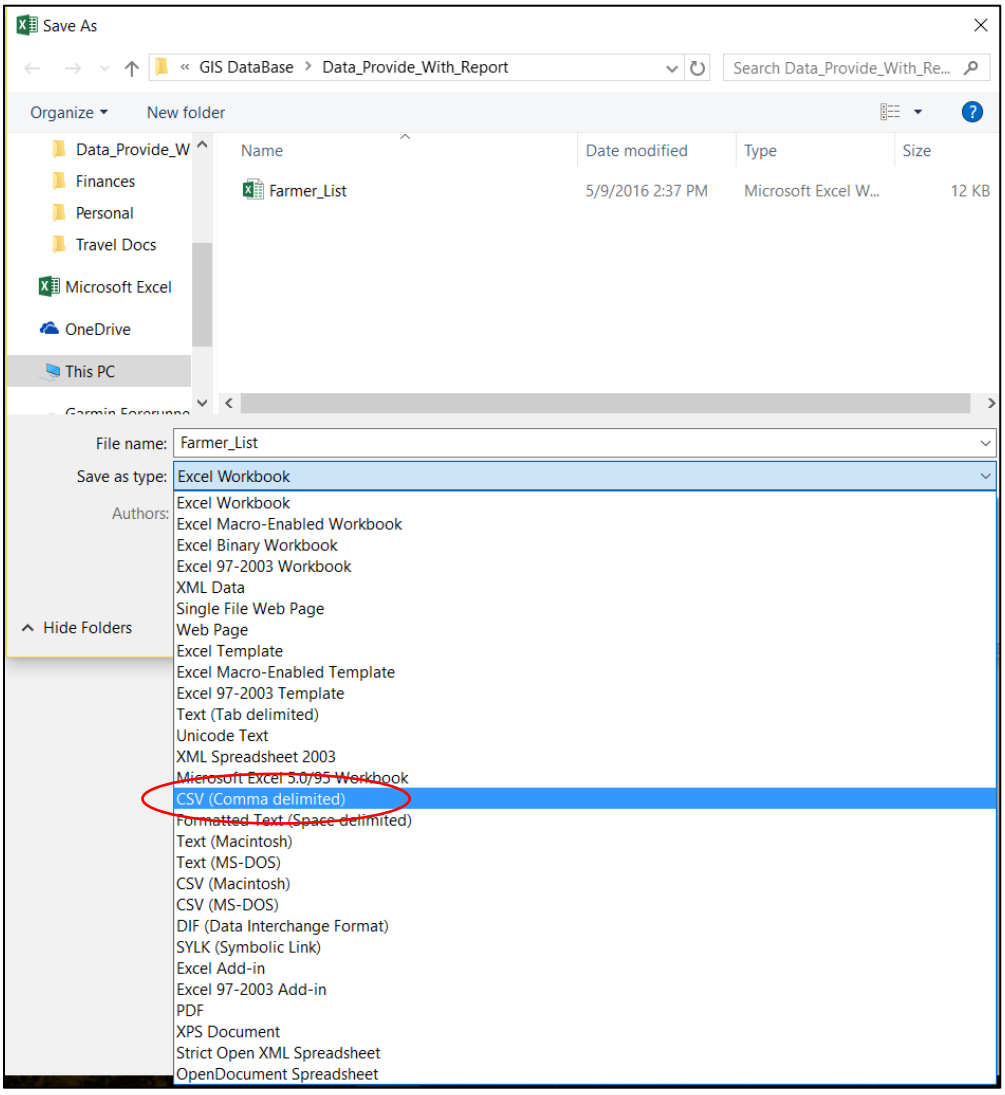
This farm dataset does not need to be filtered; however, as previously noted, datasets in this form may need to be filtered based on the parameters of your specific project. For instance, you may want to delete any farm in a certain zip code or county. If any filtering needs to take place, you have the option of doing this now in the spreadsheet or later in QGIS, but it may be

[2] http://www.mapcruzin.com/free-united-states-shapefiles/free-north-carolina-arcgis-maps-shapefiles.htm

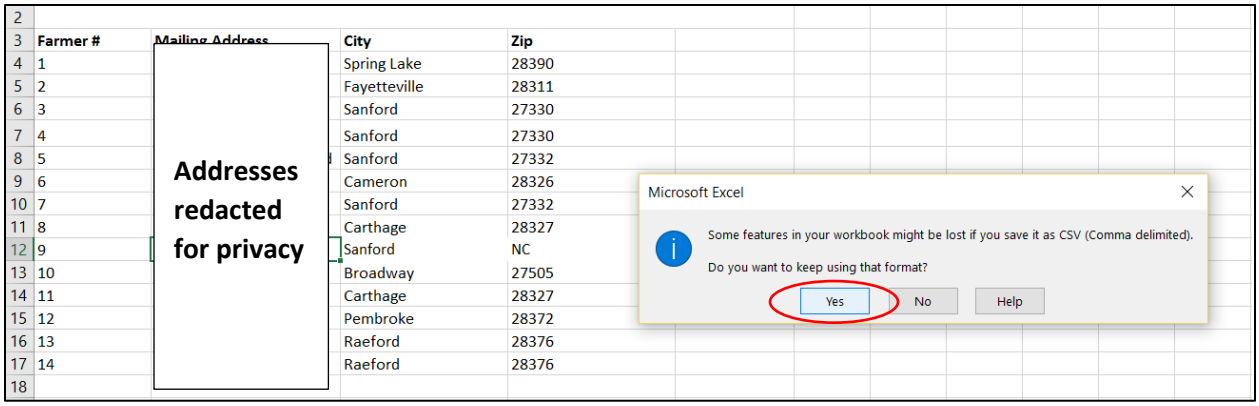
easier to do it now from the spreadsheet. ***It is important to review the data after it is filtered to ensure all geographic reference data points are accurate. Small errors in the file such as incorrect street addresses can result in an incomplete or inaccurate import into QGIS.***

Note that this dataset is in the form of a Microsoft Excel spreadsheet. ***If your project uses similar spreadsheets, it must contain either 1) an address, city, state, and country for each farm or 2) a coordinate system such as latitude/longitude for each farm.***

The dataset needs to be saved in the comma separated values format (.CSV file extension) for QGIS to read it. To do this, open the file "Farmer_List" that you downloaded from the CEFS website. Click "File" –> "Save As" –> "Browse" and in the dialogue window that opens up, click the dropdown menu "Save as type" and choose "CSV (Comma delimited)". Navigate to the folder you wish to save the file to, then click "Save". In this example, we named the new CSV file the same as the original file, "Farmer_List".

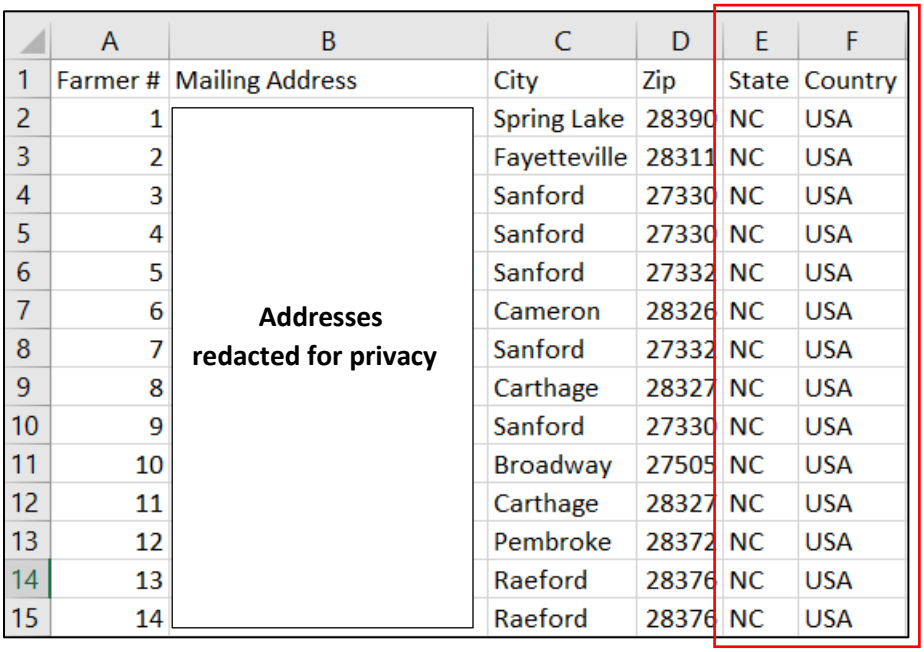


Click "Yes" in the dialogue window that opens up.



For spreadsheets that contain geographical references in the form of street addresses, it is important that each required criterion (address, city, state, and country) be in a separate column WITH A COLUMN HEADER once the file is saved as a CSV. After converting the file to a CSV format, reopen the CSV file to ensure this is the case. If all required criterion is not included, it can be manually added to the spreadsheet.

Because this spreadsheet does not include state or country columns, those columns will need to be added manually before or after the file is converted to a CSV.



Vacant Warehouse Dataset

This dataset was provided by the North Carolina Department of Commerce and contains all vacant warehouses in North Carolina. For the purposes of this example, we will not filter any of the data in this file. However, for future projects, similar datasets will likely need to be filtered based on the needs of the consolidation center such as square footage, utilities available, geographic location, etc. Filtering at this stage removes buildings that are unsuitable for conversion into a Consolidation Center. Notice that for each building in the example Excel spreadsheet, the sheet contains a street address as well as geographic latitude/longitude

coordinates. We will import this data using the geographic coordinates to show you how to import data using both street addresses and coordinate systems as a geographical reference. This file will also need to be saved in the CSV file format similar to the farm dataset in order for QGIS to import it. For details on how to save this file as a CSV, please review the instructions under "Farm Dataset" in this step.

Step 2 - Prepare QGIS Project

***Datums and Coordinate Systems**

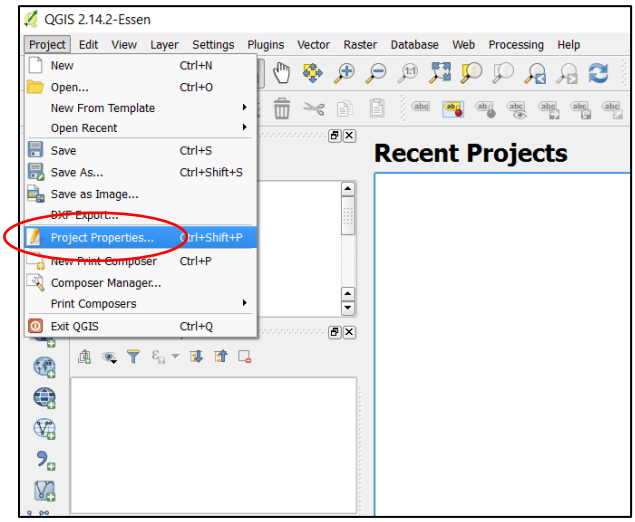
There are numerous coordinate systems that are used to geographically reference the locations of datasets around the world. Some common examples are latitude/longitude coordinates or state plane coordinates. In a GIS program, after each data layer is imported, the proper coordinate system must be selected to properly display the data. From this point forward, selecting the proper coordinate system for each data layer in QGIS will be of the utmost importance. If all data does not share the same coordinate system, data layers will be out of alignment or may not appear at all, and distance measurements may also be inaccurate. A datum is a reference point from which spatial measurements are made. Datums provide a reference for the program to properly project data in the selected coordinate system. The most common datums in North America are NAD27, NAD83, and WGS84. In the context of a GIS program, datums come preloaded into the program and are assigned to each data layer by the user. ***Regardless of what coordinate system the data uses, after it is imported it must be saved as a new shapefile and assigned the same datum as the rest of your map. This is akin to importing the same dataset again, only now with the correct datum assigned to it. Misaligning reference datums is one of the most common mistakes in GIS[3,4].*** How to properly perform this action will be discussed as each data layer is imported.

[3] http://wiki.gis.com/wiki/index.php/Datum_(geodesy)

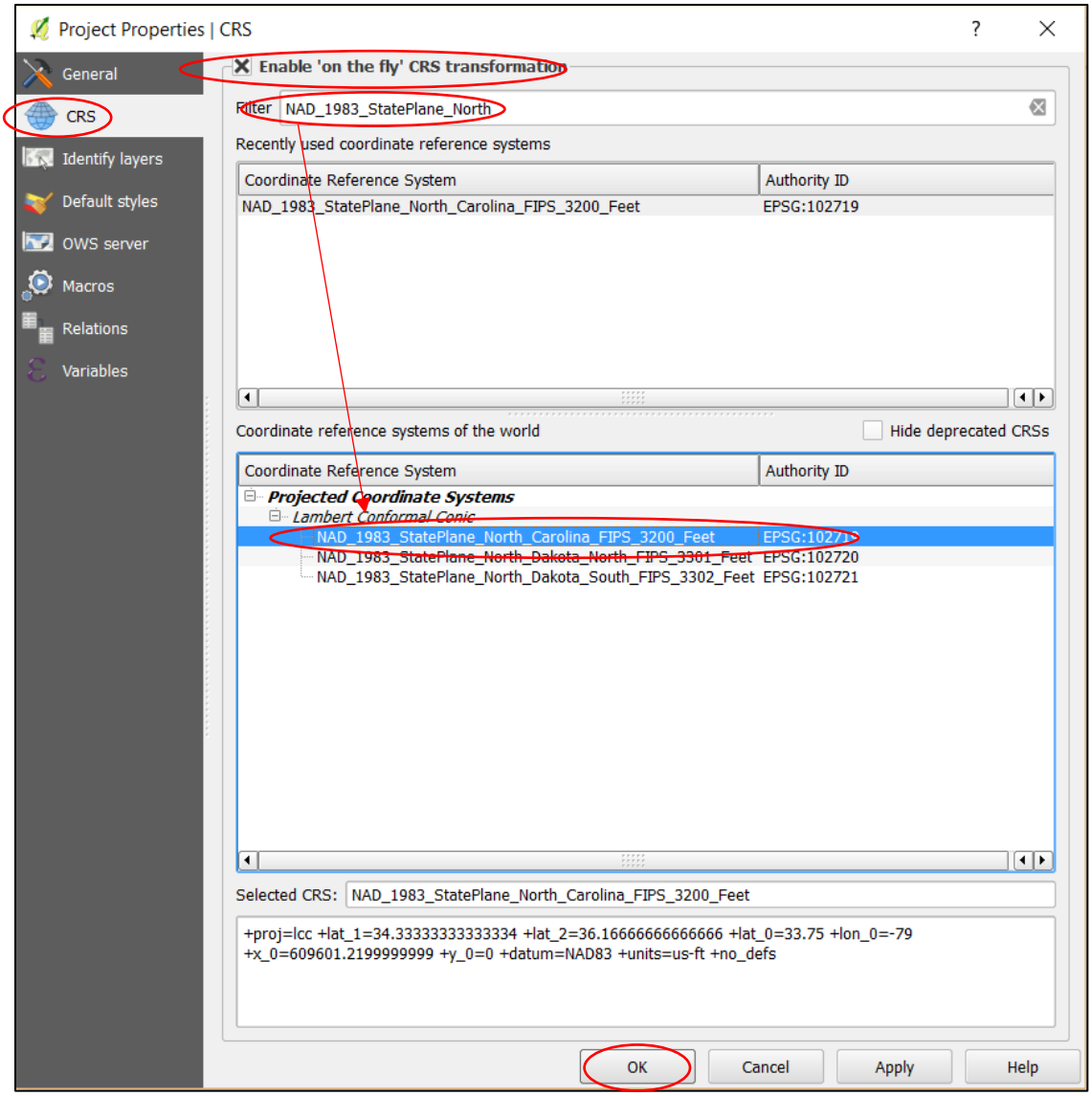
[4] http://gis.stackexchange.com/questions/664/whats-the-difference-between-a-projection-and-a-datum

Before adding any datasets, ensure the proper datum is set for your project. For this project we will be using the "NAD_1983_StatePlane_North_Carolina_FIPS_3200_Feet" datum. This datum is appropriate for this example in the state of North Carolina to get accurate distance measurements. It is recommended that you consult local government GIS analysts to identify the most appropriate datum for your area, but attempting your project with the more common datums listed above, such as WGS84, would be a good starting point.

a. From the main screen click "Project" –> "Project Properties".



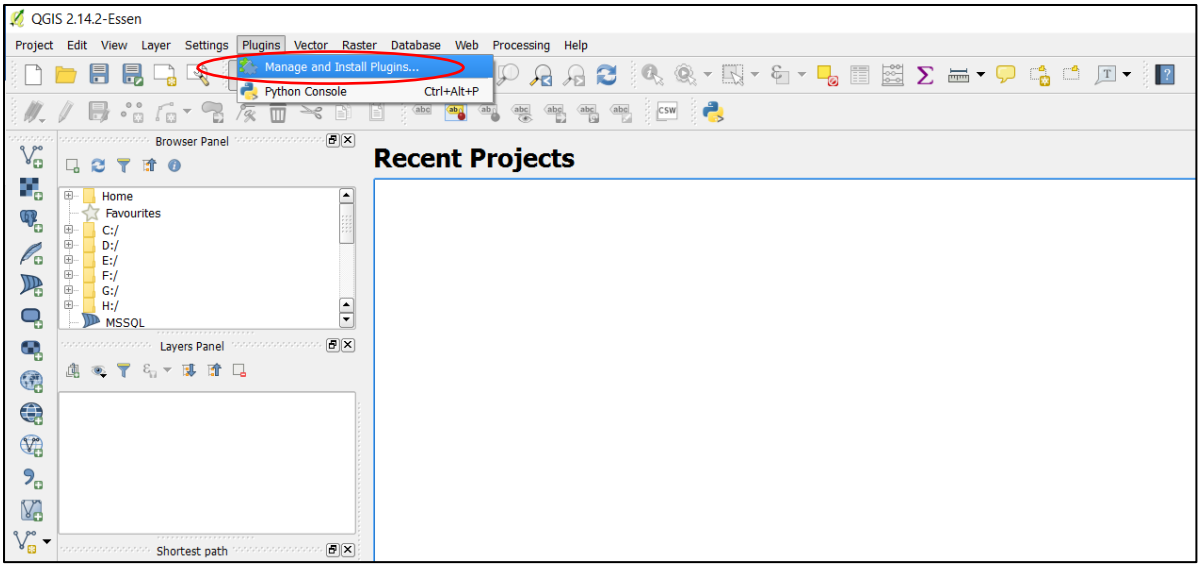
b. In the dialogue box that appears, click on the "CRS" tab. Check the box beside "Enable 'on the fly' CRS transformation". Then beside "Filter" start typing "NAD_1983_StatePlane_North_Carolina_FIPS_3200_Feet" until you see the datum appear on the results list. From this list select "NAD_1983_StatePlane_North_Carolina_FIPS_3200_Feet" (EPSG:102719). Then click "OK" to save changes.



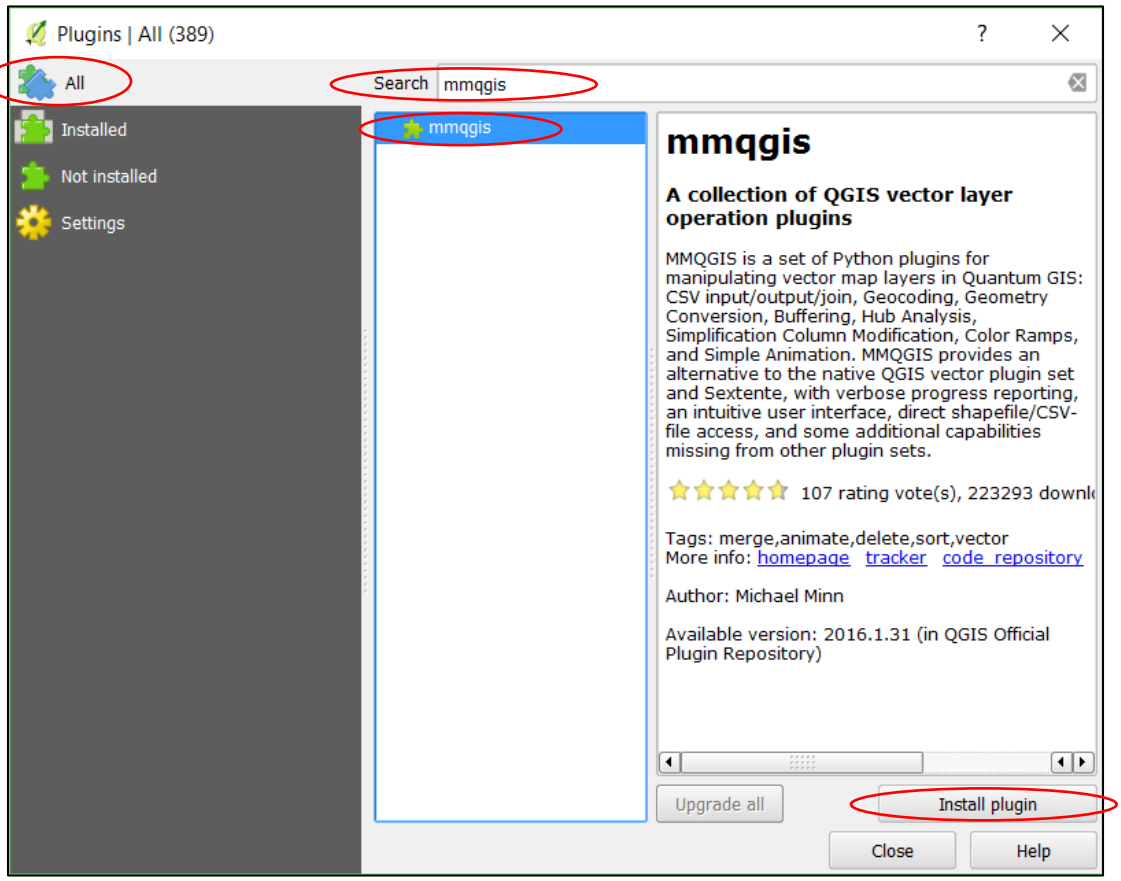
Step 3 - Geocode Data

Data layers that are geographically referenced using street addresses must be “geocoded” in order for QGIS to import the data. A plugin has been developed for QGIS that allows geocoding; that is, it allows the program to convert street addresses to a geographical reference that can be displayed in the program. For this project, we have one dataset that requires geocoding, the farm dataset. We must first install the plugin, which is called MMQGIS.

a. From the main screen, click “Plugins” –> “Manage and Install Plugins”.

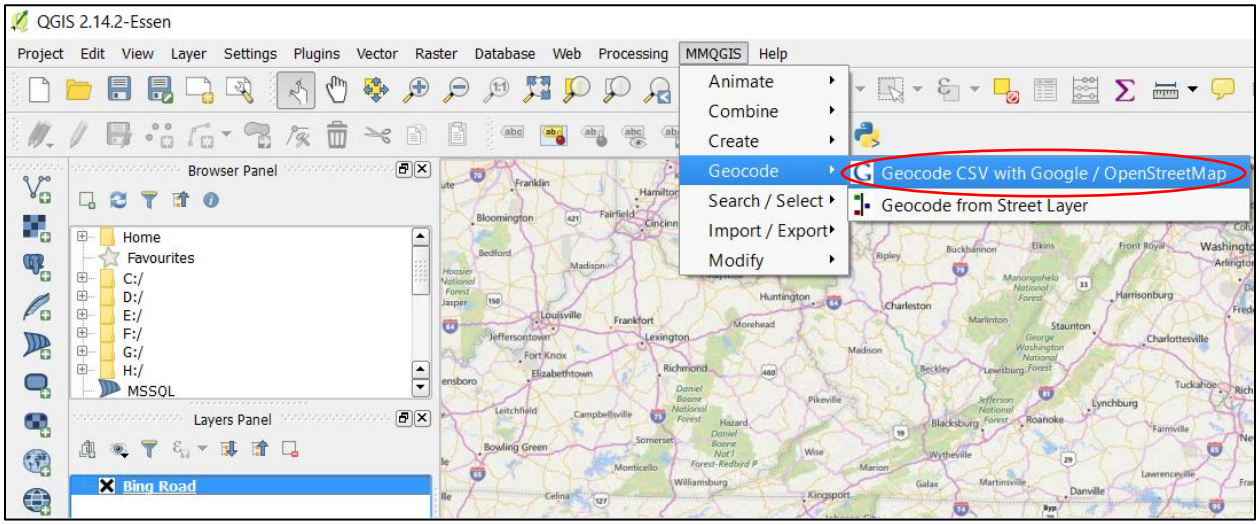


b. In the dialogue box that appears, click “All” on the left side, then start typing “MMQGIS” in the search box and it will appear in the below list. Click “mmqgis” in the list and click “Install Plugin”. Once the installation is complete, click “Close”.



c. Before geocoding the farm dataset, it is critical to review the “Farm Dataset” section in step 1 to ensure the data has been properly filtered and formatted. Otherwise the import may

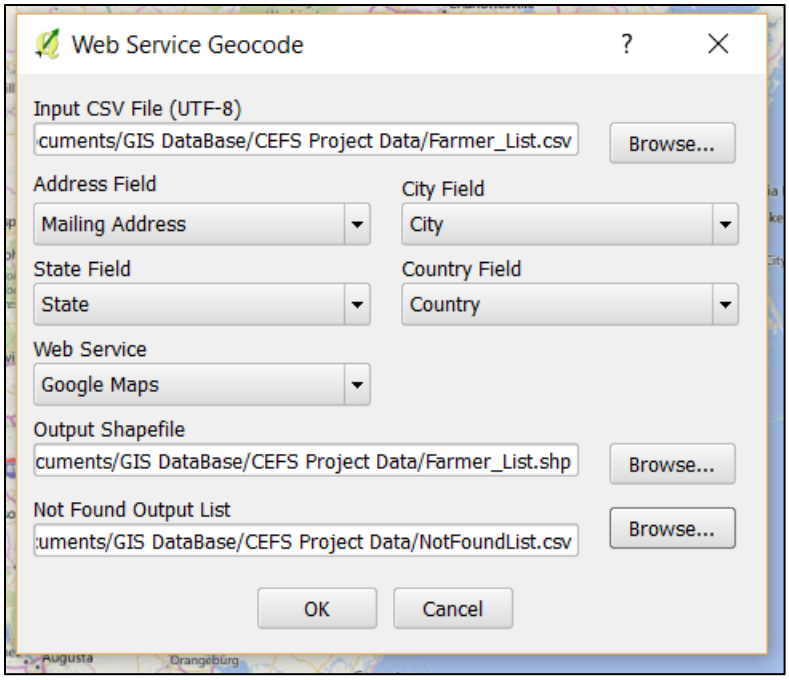
not work. On the main screen, click “MMQGIS” –> “Geocode” –> “Geocode CSV with Google / OpenStreetMap”



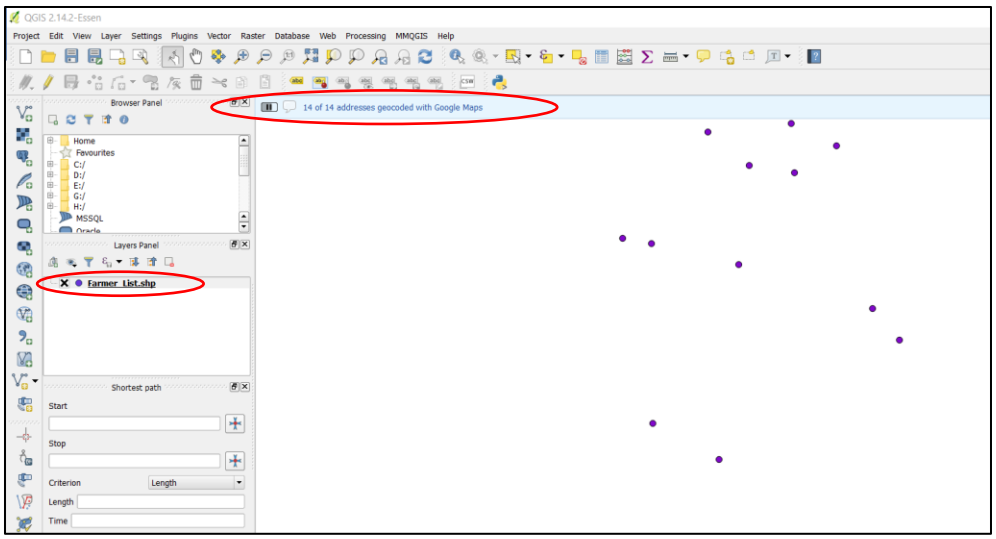
d. In the dialogue box that opens, click “Browse” and navigate to the CSV file that you created in “Farm Dataset” section of step 1 (named “Farmer_List in this example) and open it. Ensure that each column header in the CSV file is matched with the appropriate field in the dialogue box (for example, “Address Field” should match with “Mailing Address”, and so on). Your dialogue box should look the same as the below screenshot.

As a reminder, if you didn’t add state (NC) and country (USA) columns to the CSV file that you created, those will need to be added before this step can be completed. You can add these columns manually into the CSV file that you created.

Click “Browse” beside “Output Shapefile” and “Not Found Output List” and navigate to the location where you want the output data stored. Be sure to name the files and click “Save”. In this example we named the output shapefile “Farmer_List”. The output shapefile is the data that will be displayed on your map and the “not found list” is a populated list of entries that had incomplete or inaccurate data and could therefore not be geocoded. When you have decided where to save these files and what label name to give them, click “OK”.



e. Once the geocoding is complete, you should see a set of data points on your map representing the locations of the imported farms. A blue bar will temporarily be displayed at the top of the map to indicate the geocoding was successful. If geocoding failed, the bar will be red and indicate the geocoding was unsuccessful. The dataset will also show up on the left side of the main screen under the "Layers Panel". If any data points could not be mapped for any reason, they will show up in the "Not Found Output List" document in the location that you saved it.

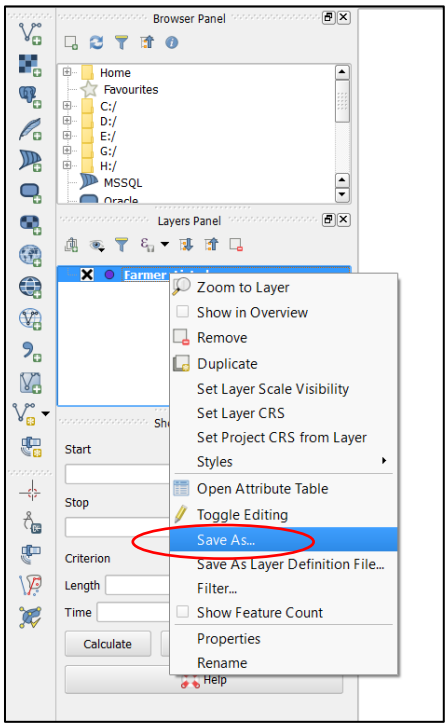


***Correcting Projection Misalignments**

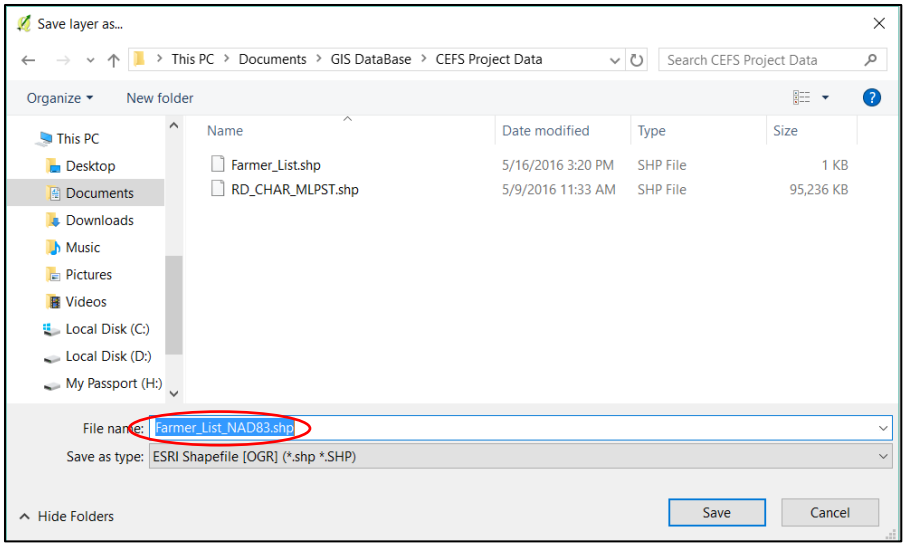
MMQGIS uses Google geocoding software, and as a result, imports geocoded data using a WGS84 projection. In order for this data to be aligned with the remainder of the project as you continue to import more datasets, this will need to be corrected. This is also the case with any datasets that are

imported using latitude/longitude coordinates, so their projections will also have to be modified from WGS84. ***It is important to have an understanding of what projection datasets are originally meant for so that an accurate re-projection can be developed. A good starting point is to know that any data imported through MMQGIS or with latitude/longitude coordinates has an original projection of WGS84.***

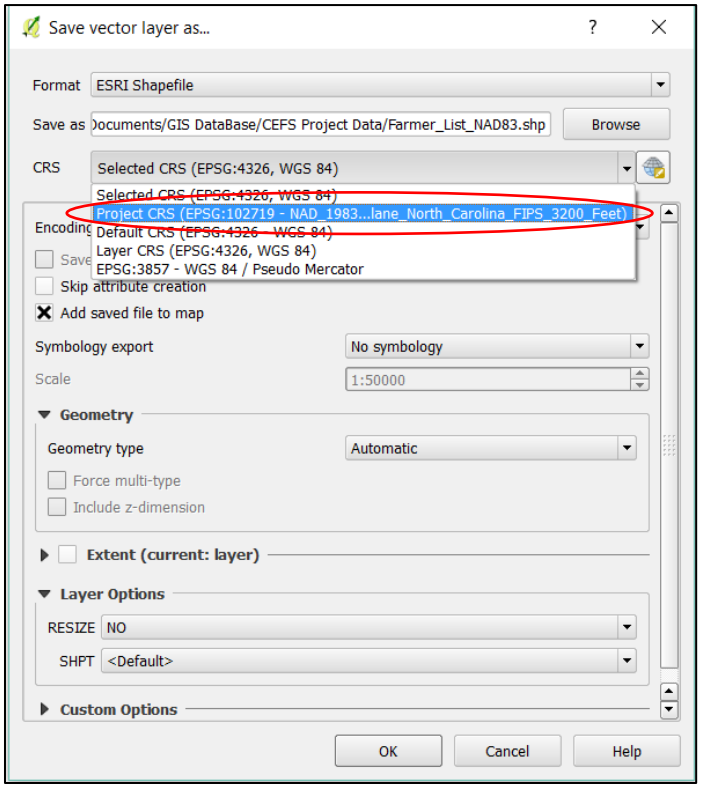
f. Because this dataset was originally imported in the WGS84 projection, a new copy of the data will have to be created under the projection of our project. To do this, right click on the layer "Farmer_List.shp" in the "Layers Panel" on the left side of the main screen and click "Save As…"



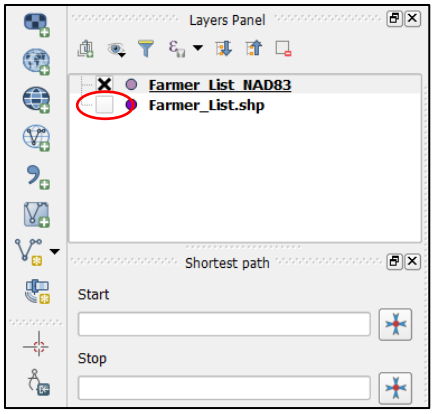
g. In the dialogue box that opens, click on "Browse" and navigate to where you want to save the new shapefile. To keep your files organized, it is recommended that you label the new file in such a way that it is easily distinguished as the shapefile with the correct projection. In this example, we included "NAD83" at the end of the new file name. Click "Save" when you've chosen where to save the file and what to name it.



h. Back at the dialogue box, click on the dropdown box by “CRS” and select the correct projection (“NAD_1983_StatePlane_North_Carolina_FIPS_3200_Feet”). If it doesn’t show up in the dropdown list, click the globe icon beside the dropdown arrow and search for the projection as you did in step 2.b. Click “OK”.



i. Back at the main screen, the new projection will appear in the “Layers Panel”. Turn off the original layer by clicking on the “X” by “Farmer_List.shp”.



Note: This section heavily references a pre-developed online tutorial[5]. For more information, visit the website listed in the footnote.

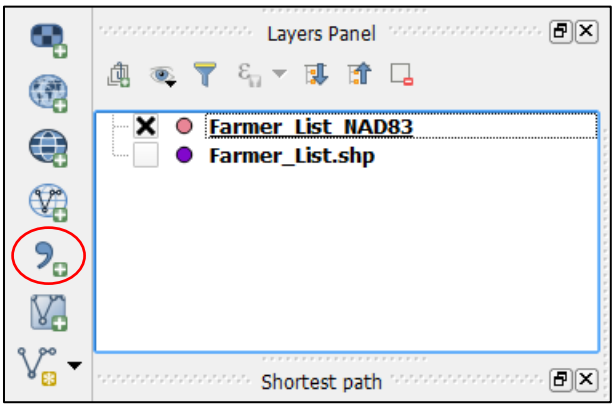
Step 4 - Import Remaining Data

Now the remaining two datasets must be imported (roadways and vacant warehouses).

Vacant Warehouse Dataset

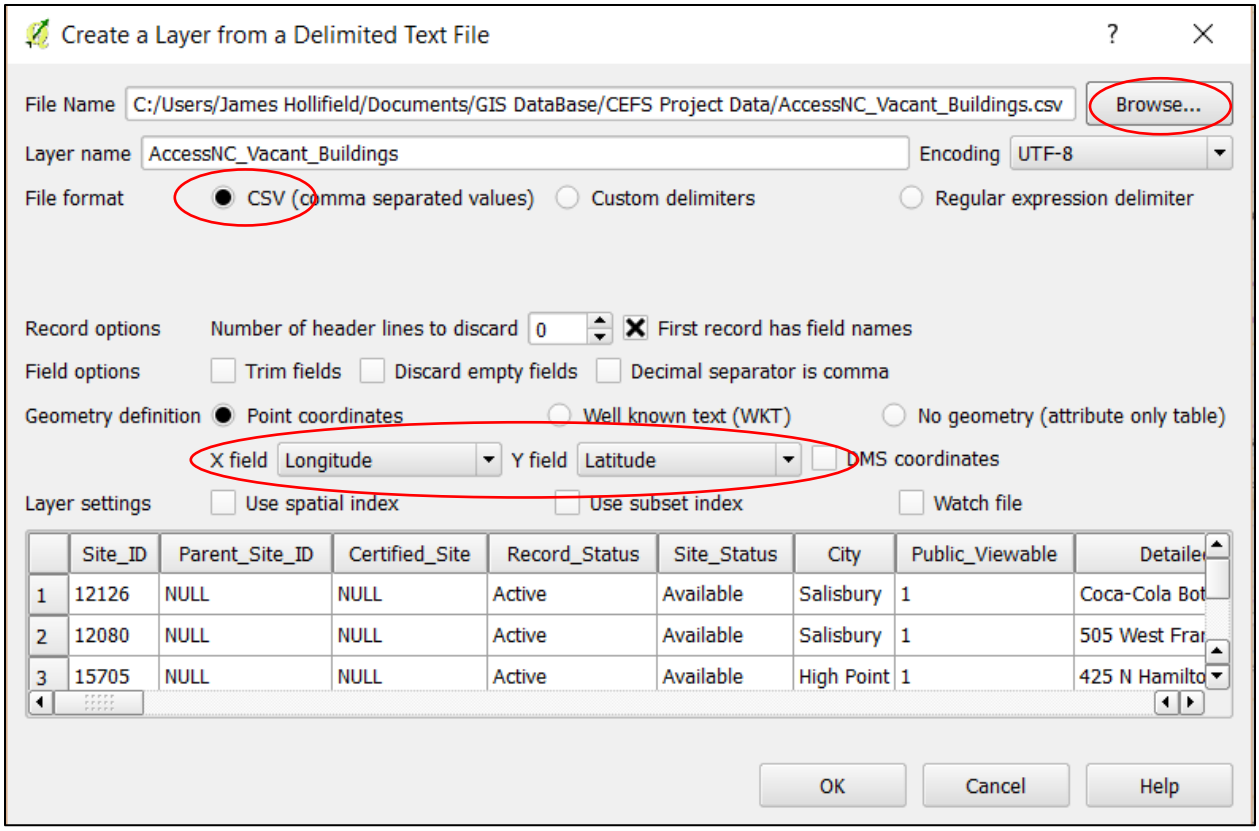
Recall that we converted this file to a CSV in step 1. As a reminder, any datasets in the form of Microsoft Excel files should be converted to a CSV format in order to be imported into QGIS.

a. To begin importing this file, select the "Add Delimited Text Layer" icon on the left side of the main screen (shaped like a comma).

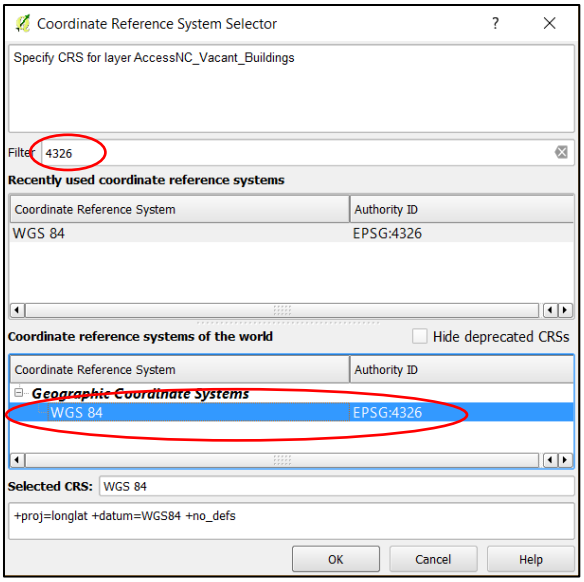


b. In the dialogue box that opens, click "Browse", navigate to and select the CSV file you created from the "AccessNC_Vacant_Buildings" Excel file (the CSV file and the Excel file have the same name in this example). Then click "Open". The fields in the CSV file should populate in the dialogue box's preview screen automatically. Check that the CSV "File format" is selected. Ensure that the "X field" and "Y field" dropdown menus match up with the latitude and longitude columns in the spreadsheet. Change the desired name of the layer if needed and click "OK".

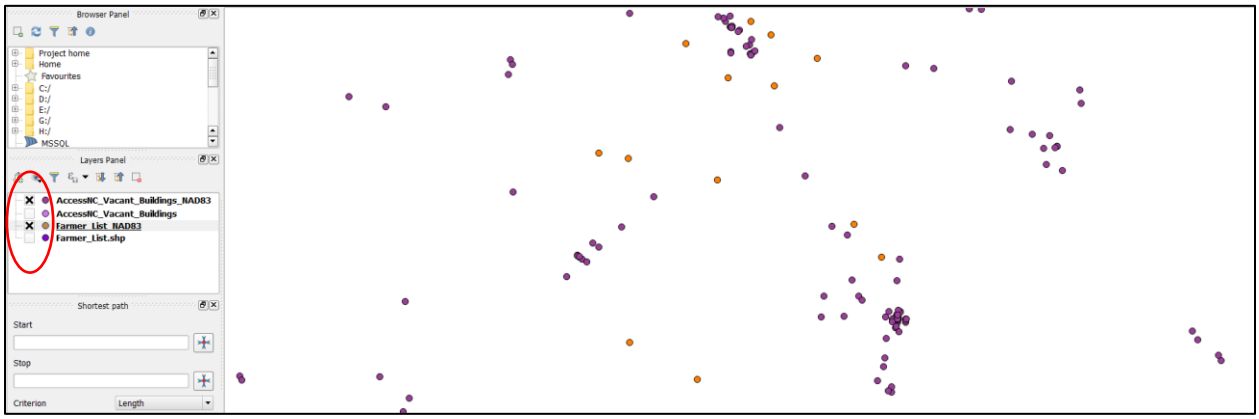
[5] http://blog.mangomap.com/post/74368997570/how-to-make-a-web-map-from-a-list-of-addresses-in



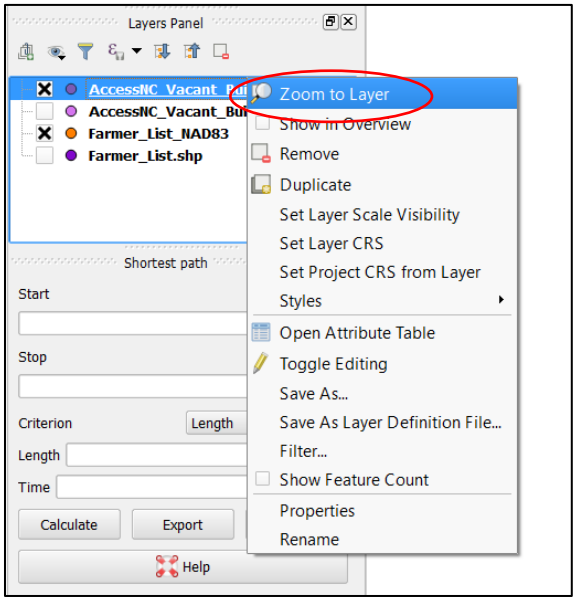
c. At this point another dialogue box will open to select the correct projection of the data. As mentioned earlier, the original projection of this dataset is WGS84. In QGIS this projection is labeled “WGS 84” (EPSG: 4326). You must select this projection (even though it is not the projection we have been working with in our project) so QGIS can accurately import the data. Once it is successfully imported we can re-project the data layer in the appropriate projection. Start typing the EPSG number (4326) in the “Filter” text box until the projection is displayed in the results. Select the correct projection and click “OK”.



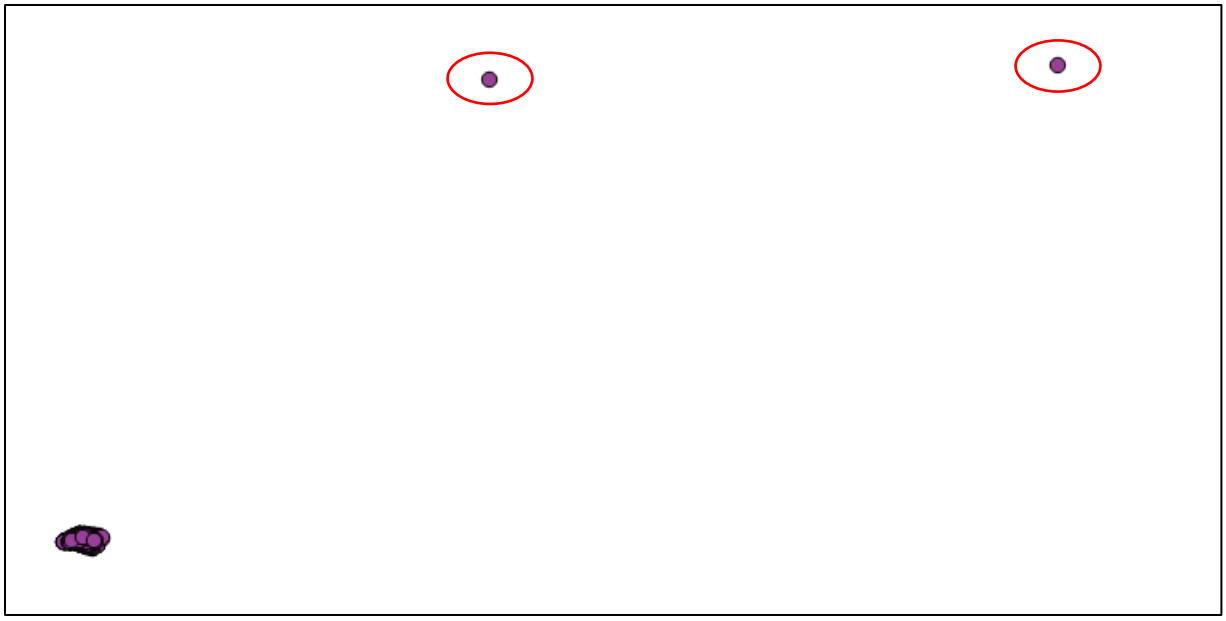
d. Now that the data layer has been successfully imported, the projection needs to be modified to align with our project's projection. Follow the instructions starting at step 3.f again to save another copy of this data layer in the "NAD_1983_StatePlane_North_Carolina_FIPS_3200_Feet" projection. In our example we named the new data layer "AccessNC_Vacant_Buildings_NAD83". Your screen should now look similar to the below screenshot with both original data layers unselected and the new data layers in the correct projections selected.



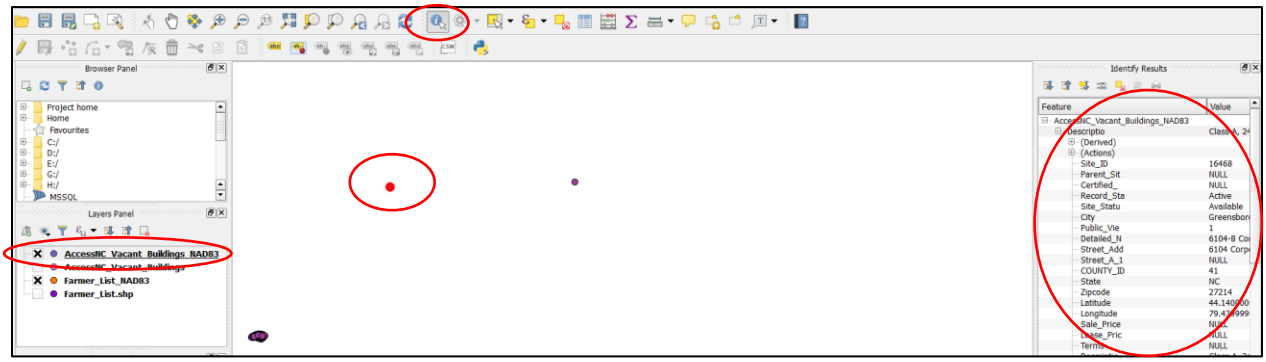
***"Zoom to Layer":** A useful tool you can use to see the full extent of a dataset is called "Zoom to Layer". If the full extent of the dataset is not displayed but it was successfully imported, you can right click on the dataset in the "Layers Panel" and click "Zoom to Layer". This will zoom the display out until all the points in the dataset are visible.



"Zoom to Layer" can also be a valuable tool in discovering errors in the dataset. As it can be seen in the below screenshot, there are a few errors in the data. For the purposes of this example these errors can be ignored but for future projects it may be necessary to go back and make corrections. GIS programs can help you easily identify these errors to avoid hours of manual review.



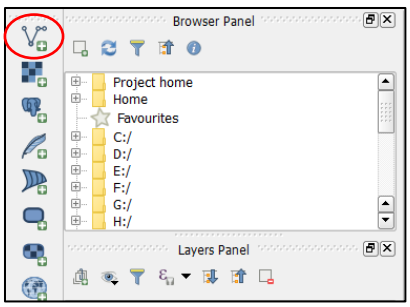
***"Identify Features":** In order to quickly identify which data points have errors, you can use the identify features tool. Select the layer you wish to search on the "Layers Panel", then select the identify features tool from the main screen (highlighted in the below screenshot). Click on the data point of interest and a panel will appear on the right side of the screen with all the information on that data point.



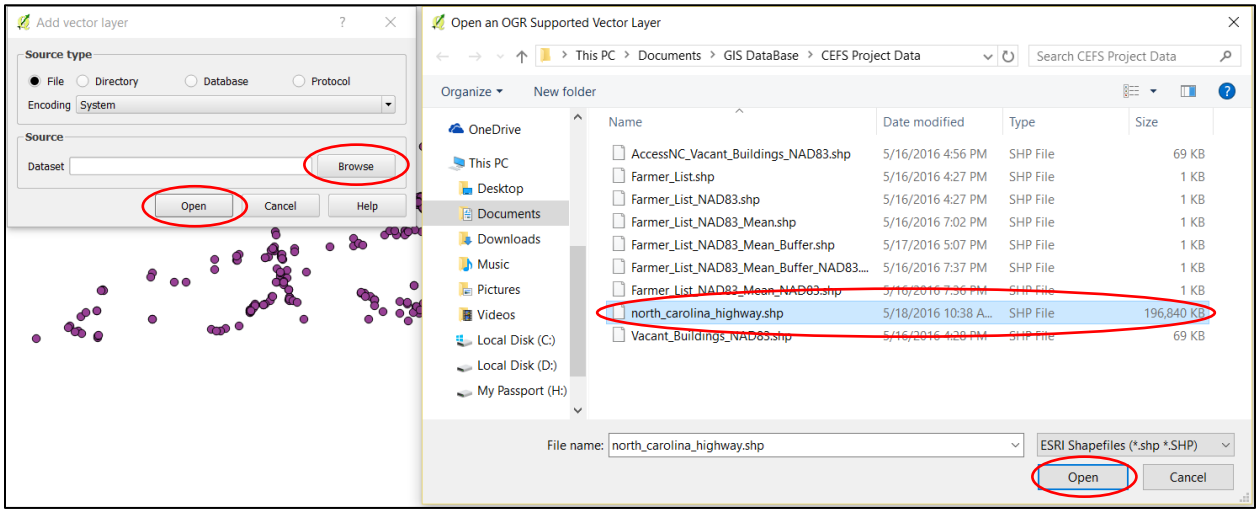
Roadway Dataset

Since this dataset is in the form of a shapefile, it will be imported differently.

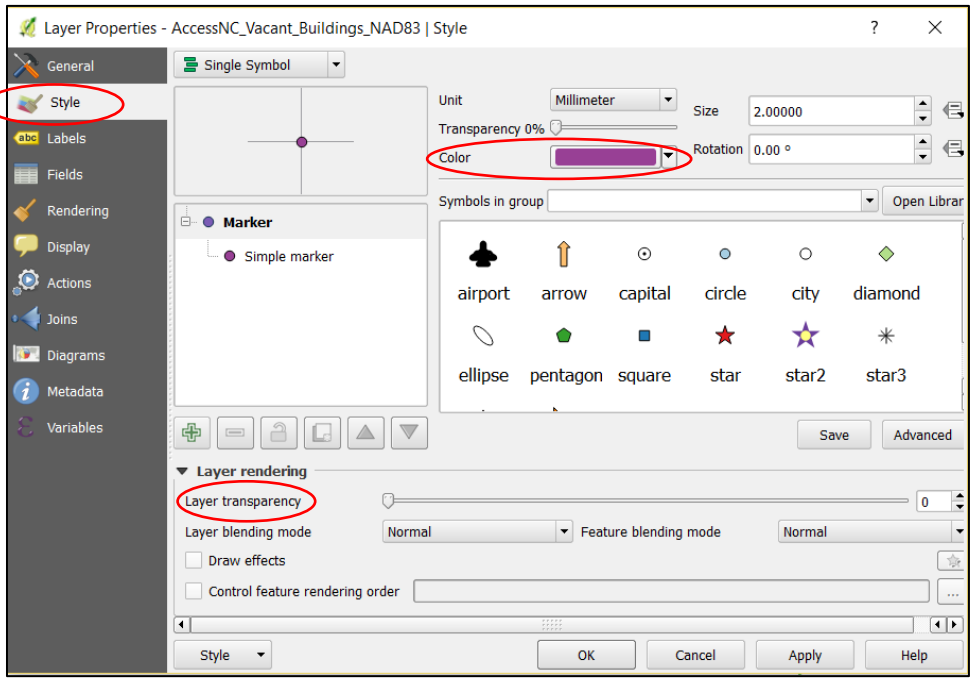
a. To import shapefiles, click on the "Add Vector Layer" icon on the left side of the main screen.



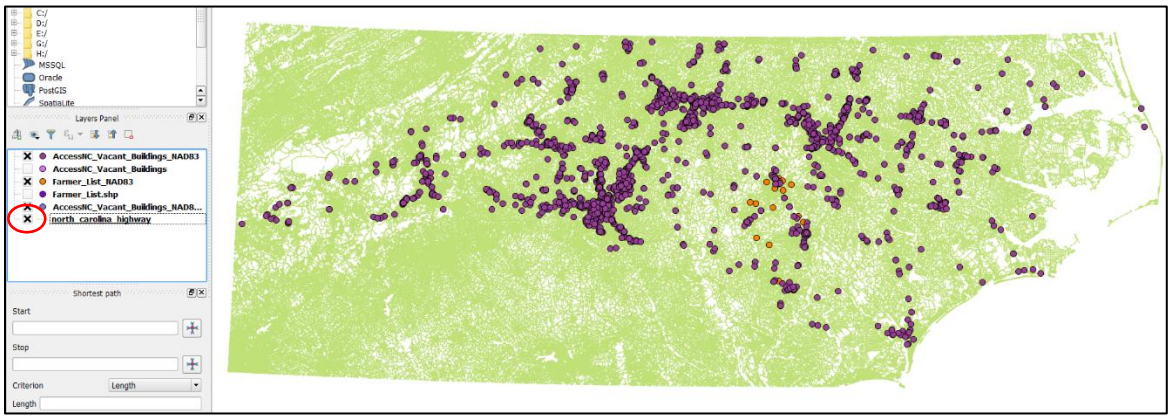
b. In the dialogue box that appears, click “Browse”, then navigate to the folder where you unzipped the downloaded shapefile in step 1. Select the larger file with the .shp file extension and click “Open” on both dialogue boxes.



***Layer Order, Color, and Transparency**: In the “Layers Panel” on the left side of the main screen, all your data layers will populate as they are imported. This panel dictates the order in which your data layers appear from top to bottom. In other words, a data layer may be obscured by another data layer that is on top of it. To avoid this, you can choose the order in which your data appear by clicking a layer in the panel and dragging it to the top or bottom. You can also set the transparency of any given layer by right clicking on the layer in the “Layers Panel” and clicking “Properties” –> “Style” and then sliding the transparency ruler to the desired level of visibility. In this dialogue box you can also change to color of a dataset for better contrast and easier viewing.



c. It is recommended that the roadway dataset be moved towards the bottom of the "Layers Panel" with the farm and warehouse dataset on top. The roadway dataset is very large so you may prefer to turn the layer off while moving your map to avoid lags. As a reminder, you can do this by unchecking the check box beside the data layer in the "Layers Panel" (highlighted by the red circle in the below screenshot).

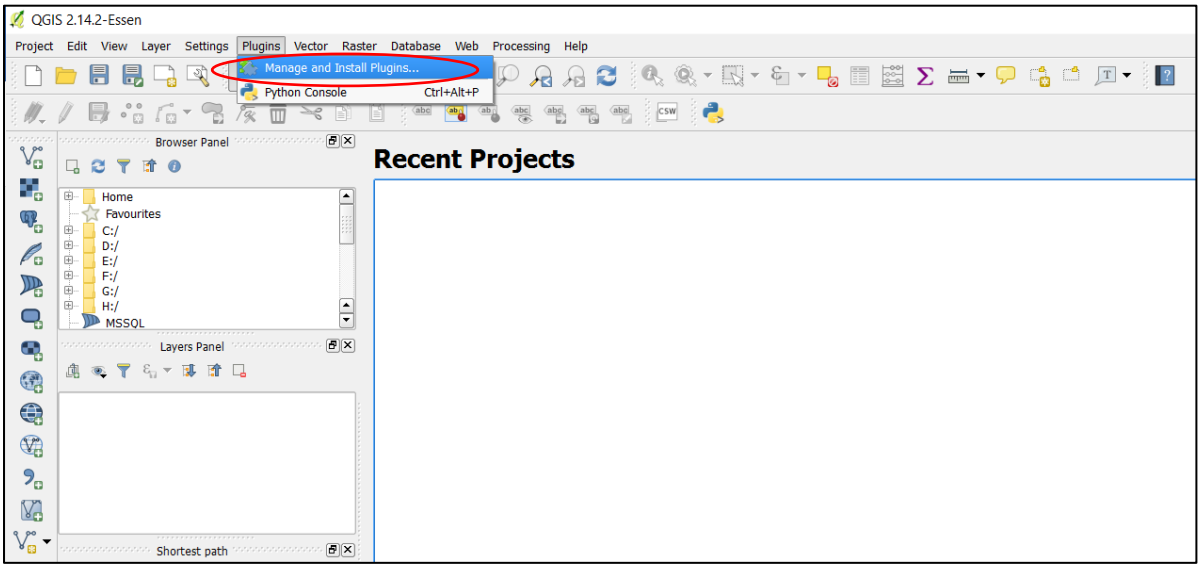


Step 5 - Import Basemap

***Basemaps**: Basemaps serve as a background in GIS software packages. They provide the user with a geographically referenced map onto which all relevant information is placed. A basemap can provide as much or as little information as the user wishes.

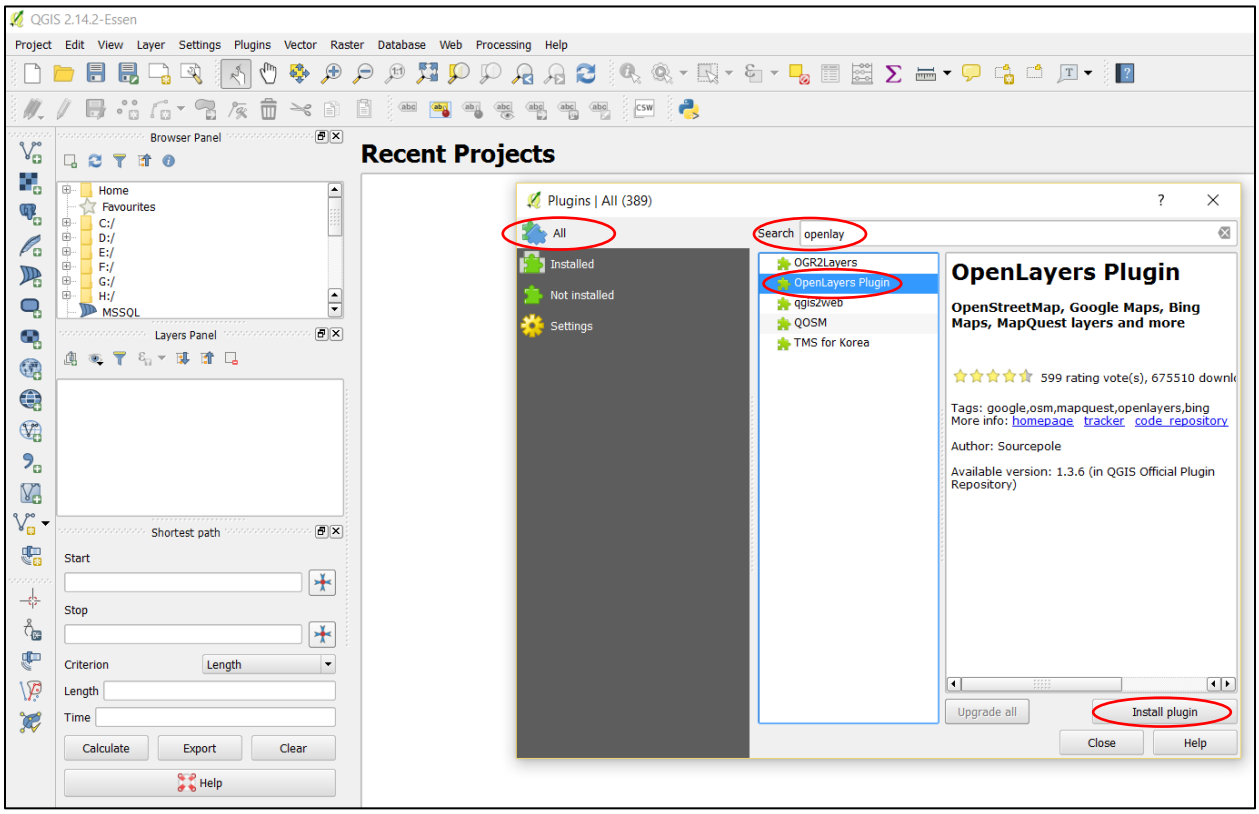
While there are several ways to import a basemap into QGIS, we will be using a popular plugin called "OpenLayers" which acts similar to a WMS in that it allows the user to add a number of outside services to their map:

a. From the main screen, click "Plugins" –> "Manage and Install Plugins".

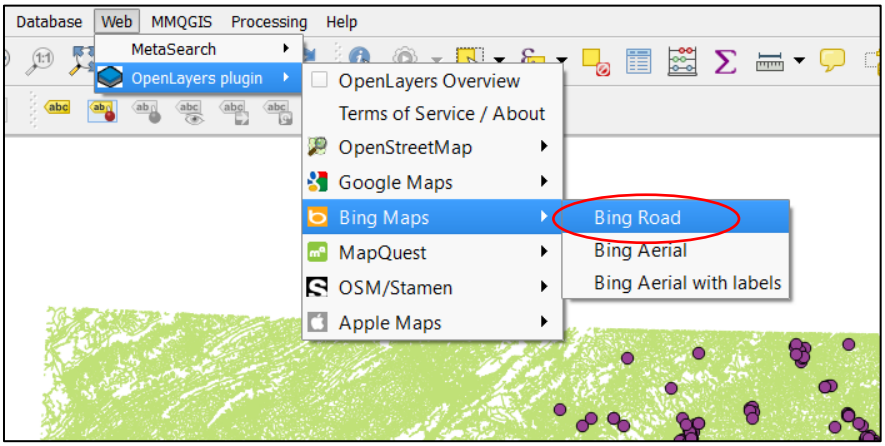


b. In the dialogue box that appears, click “All” on the left hand side then start typing “OpenLayers” in the search box and it will appear in the below list. Click “OpenLayers Plugin” in the list and click “Install Plugin”. Once the installation is complete, click “Close”.

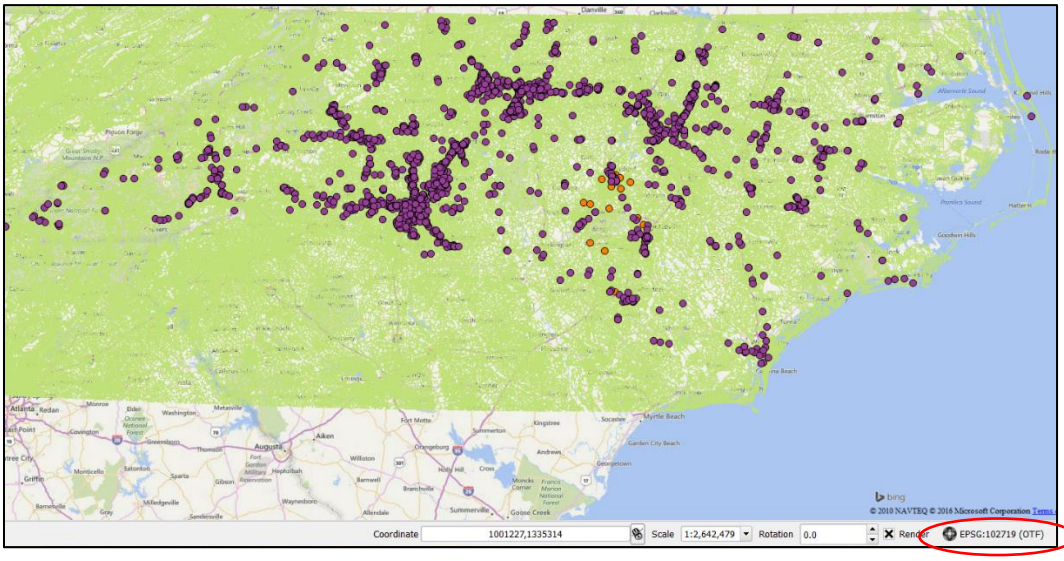
Note: OpenLayers may already be installed. If this is the case, it will be indicated by a blue square beside the plugin name (versus the green puzzle piece seen below) and a check box beside the blue square. If the plugin is already installed but you get an error when using the plugin, follow these same steps to uninstall the plugin and reinstall a fresh version.



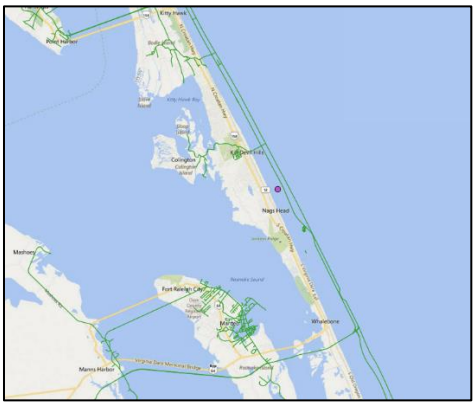
c. Back at the main menu, click “Web” –> “OpenLayers plugin” –> “Bing Maps” –> “Bing Road”.



d. You should see a basemap appear on the main screen and the layer added to the “Layers Panel” on the left side of the screen. At this point a few adjustments may need to be made. It is recommended that the basemap be moved to the bottom of the “Layers Panel” so that all data layers are visible. Also, sometimes the OpenLayers plugin can change your project’s projection. If this is the case, you will need to repeat step 2 to reset the projection, otherwise future analysis may be inaccurate. You can check to see if the plugin altered the projection by looking at the bottom right hand corner of the main screen (highlighted in the below screenshot). If the project’s projection was not altered, it should read “EPSG: 102719”.



e. It is important to note that the OpenLayers plugin has been known to misalign data layers depending on the project’s projection, as can be seen in the below screen shot (as well as the above screenshot if you look closely enough). If this happens, you may be able to correct the error by right clicking on the basemap data layer in the “Layers Panel” and click “Remove”. Then repeat step 5.c to reload the basemap. If the basemap never perfectly aligns with your data when in the correct projection, you can either accept the error or you can find another source for a basemap such as a WMS. In this example, since the basemap is only used as a visual reference and not for quantitative analysis, and the error is minor, we will accept it and move on.

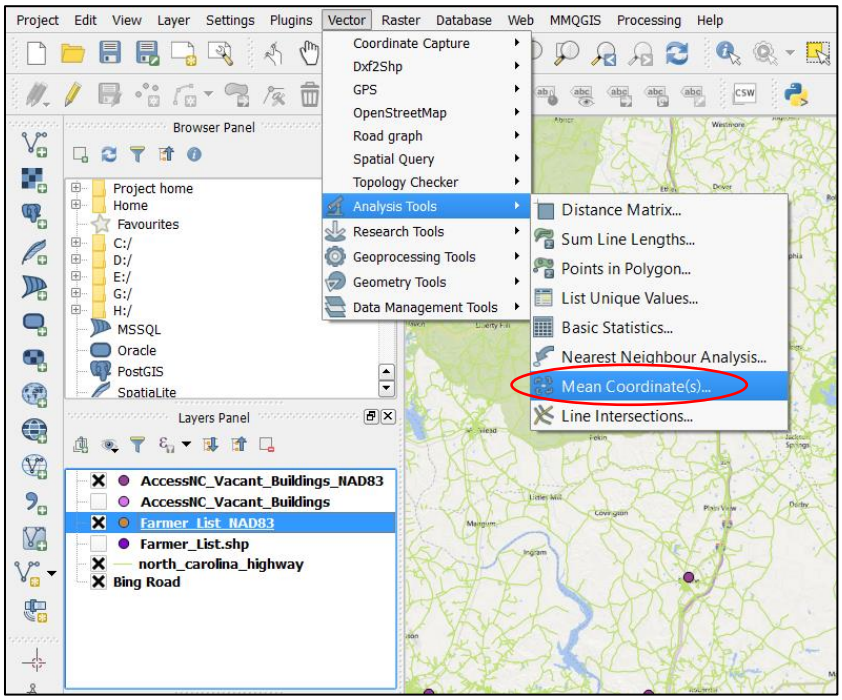


Note: This section heavily references a pre-developed online tutorial[6]. For more information, visit the website listed in the footnote.

Step 6 - Complete Geometric Mean of Farms

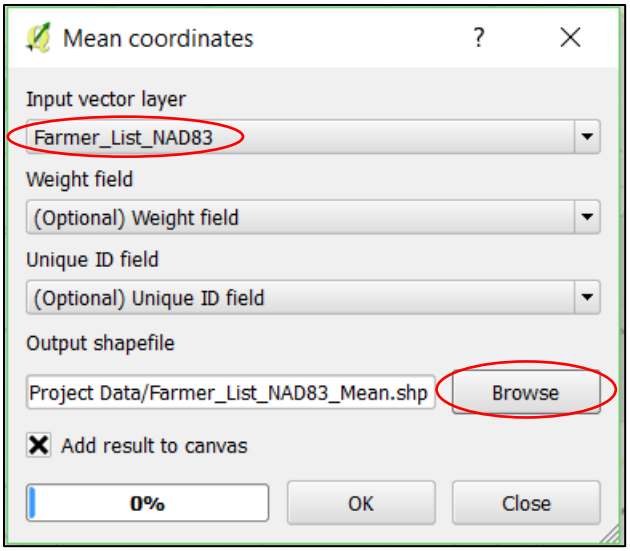
QGIS can determine the central point of a data layer with a tool called "Mean Coordinate(s)". This tool finds the location that minimizes the total straight line distance between all the points in a data layer. Note that this tool may be less accurate for areas with terrain that causes straight line distances to significantly underestimate actual transportation distances (areas with large mountains or bodies of water, for example). However, in our area of consideration, this is not the case. QGIS can be configured to follow roads rather than straight-line distances (using the pgrouting tool), but this requires advanced SQL coding skills of the user.

a. In the "Layers Panel", right click the shapefile you created from the farm dataset (called "Farmer_List_NAD83" in this example) and click "Zoom to Layer". Then click "Vector" –> "Analysis Tools" –> "Mean Coordinate(s)".

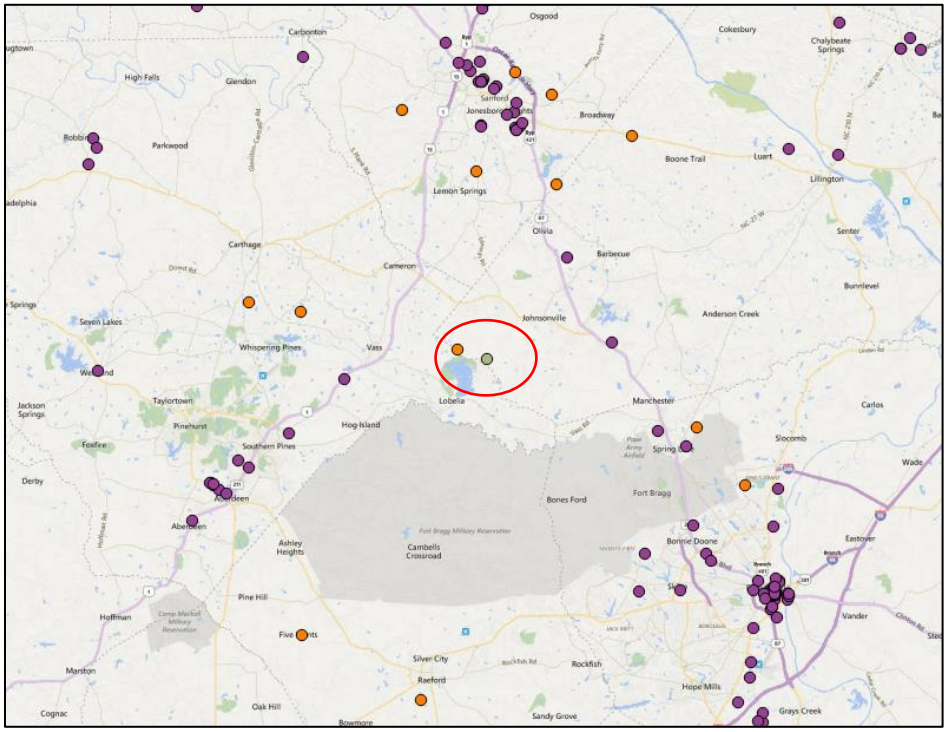


b. In the dialogue box that opens, use the dropdown list to select the same file as the "Input vector layer" ("Farmer_List_NAD83"). Click "Browse", navigate to where you want to save the output shapefile, name the shapefile, and click "Save". In this example we named the shapefile "Farmer_List_NAD83_Mean". When finished click "OK".

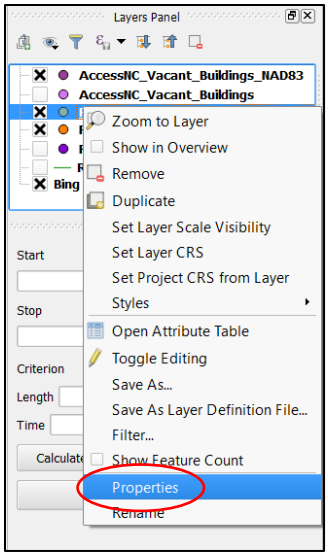
[6] http://maps.cga.harvard.edu/qgis/wkshop/basemap.php

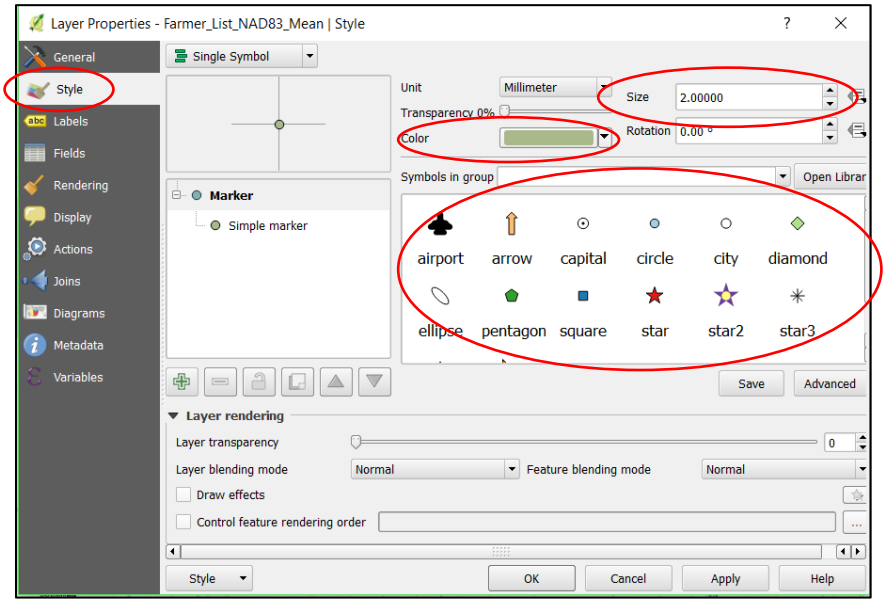


c. When complete, you should see the geometric mean appear as a dot in a different color close to the center of the farm data points.



d. To make this dot appear more visible, you can right click on the data layer in the “Layers Panel”, and click “Properties”. In the dialogue box that opens, click the “Style” tab on the left side and change the color, size, or shape of the data point to your liking.



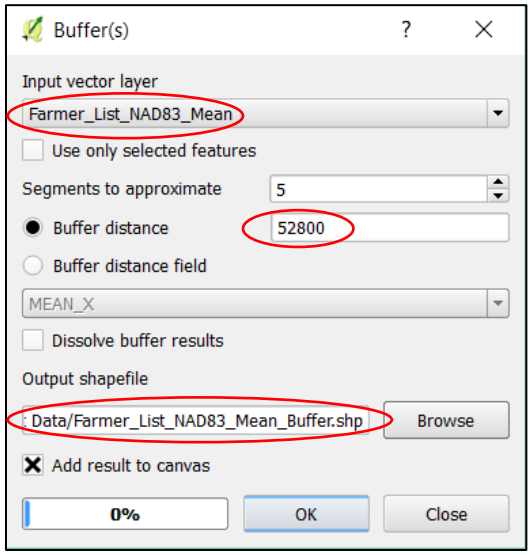


Step 7 - Overlay Desired Buffers

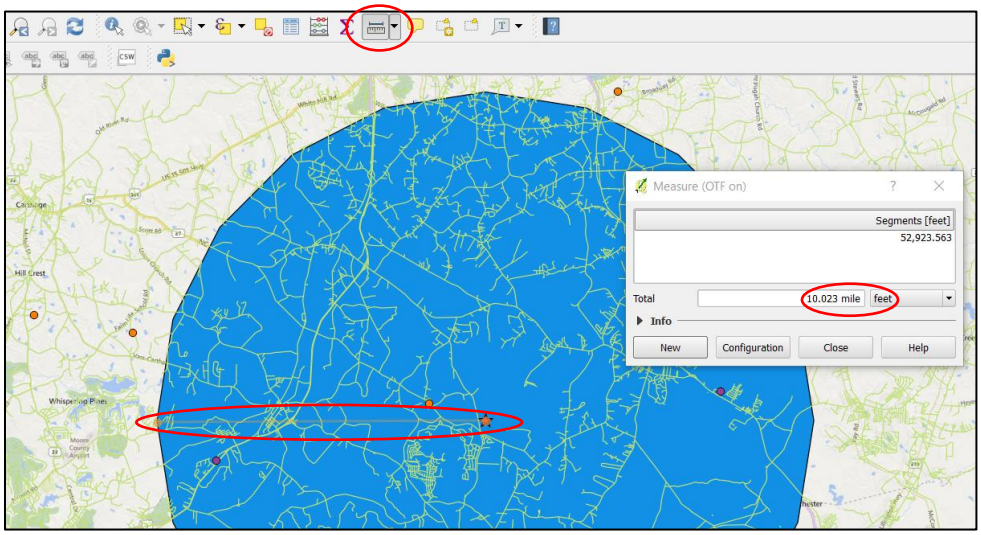
Buffers are used in GIS programs to create a subset of data points that are located in a certain area. In this example, we are using a buffer to show us which warehouses are close enough to the optimal consolidation center location and can therefore be considered a viable solution without having to build a new facility. Buffers are not only good visualizations of radial distances from a central point, but they are also shapefiles, and can therefore integrate with other data layers for additional analysis (as we will see later).

On the main screen click on “Vector” –> “Geoprocessing Tools” –> “Buffer(s)”. In the dialogue box that opens, select the mean coordinate shapefile that you created in the previous step as the “Input vector layer”. In this example we named it “Farmer_List_NAD83_Mean”. Enter the “Buffer distance” that you desire. This number will be based on the projection that you use in your project. In our projection we are using feet as our benchmark measurement so for the buffer we will enter in 52,800 feet (which

equates to 10 miles). A 10-mile radius is what we have determined as our constraint, your criteria may be different. Lastly, click, "Browse", navigate to the location you wish to save the shapefile to and name the file. In this example we named the file "Farmer_List_NAD83_Mean_Buffer". Click "Save" then "OK" and the buffer should appear. Practically speaking, this buffer provides a visualization of what warehouses are within an acceptable distance from the optimal location of the consolidation center (the geometric center calculated in step 6).



***Measure Tool**: With all the changes to data layer projections, it is a good idea to double check the distances that you specify in the buffer. Another useful tool in QGIS is the Measure Line, which allows you to take linear measurements (you can also use the tool to measure areas and angles). To use this tool, click on the Measure Tool icon on the main screen, specify the units you wish to measure in the dialogue box, left click on a location to start your measurement, and right click on the ending location to take the measurement. You can see that our buffer is measuring a 10-mile radius as we intended.



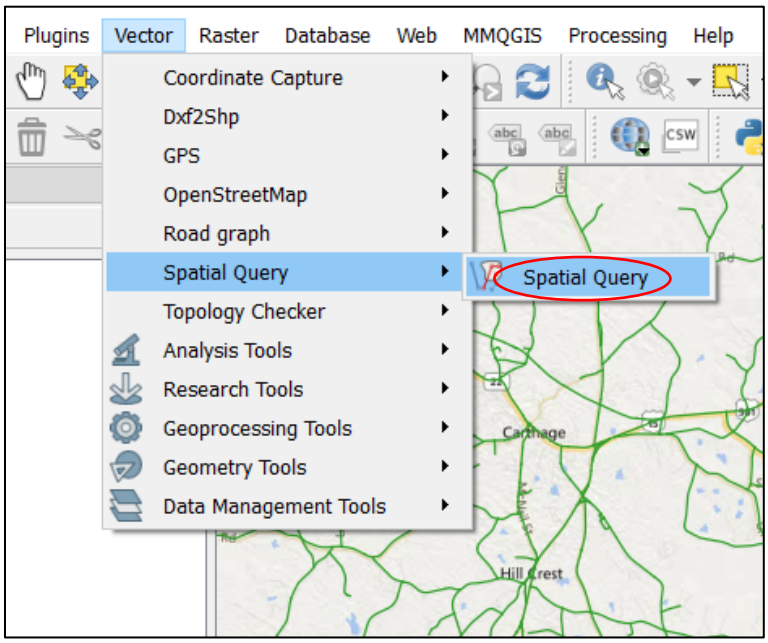
Step 8 - Assess Possible Locations and Data

Let's recap. At this point you've loaded all the data so you can visualize where all the farms and vacant warehouses are. With the basemap you loaded, it is easy to see roughly where each data point is actually located. Using the geometric mean of the farms, you've also calculated the optimal location for a consolidation center that minimizes the total linear distance from all farms. Finally, you've created a buffer with a 10-mile radius around the optimal location to better visualize potential vacant warehouses that meet the criteria of the consolidation center.

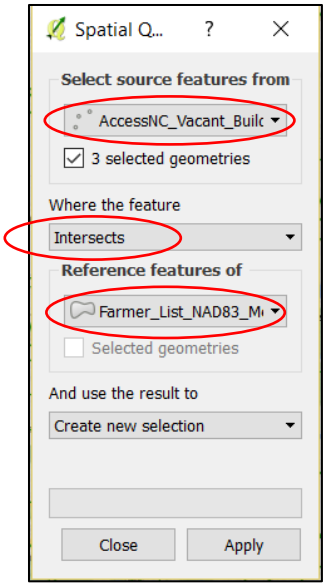
Create Subset of Warehouses

In this example, we have decided to consider not only the proximity of a vacant warehouse to the optimal consolidation center location, but also the distance of each potential site to a major road and to a nearby wholesaler. To do this, we first want to create a separate data layer containing only the vacant warehouses within the buffer we specified. We will use another QGIS tool called "Spatial Query" to accomplish this.

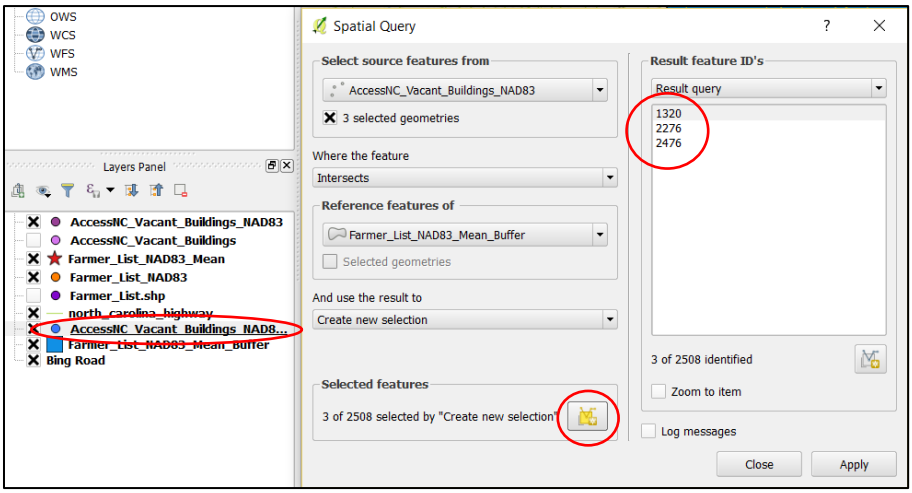
a. Right click on the buffer you just created and click "Zoom to Layer". In the main screen, click "Vector" –> "Spatial Query" –> "Spatial Query".



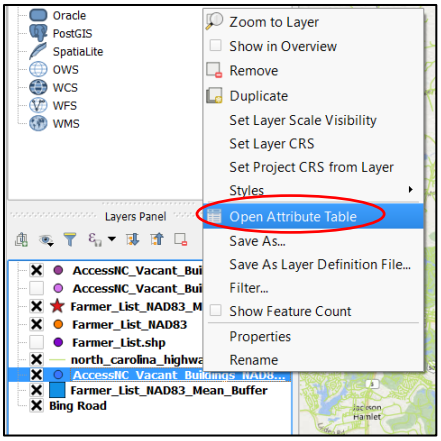
b. In the dialogue box that opens, select the vacant warehouse dataset ***in the proper projection*** under "Select source features from". In this example we named the dataset "AccessNC_Vacant_Buildings_NAD83". Select "Intersects" under "Where the feature" and select the buffer layer under "Reference features of". Then click "Apply".

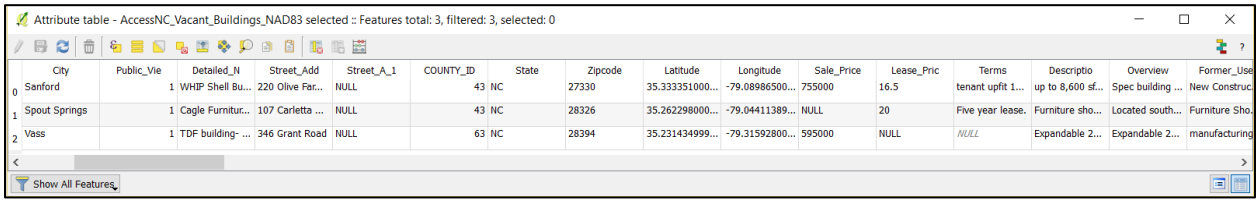


c. The dialogue box that appears will list all the vacant warehouses that are inside the buffer. Click on the icon in the "Selected features" section in the lower left corner and a new data layer will appear in the "Layers Panel" that only includes the warehouses in this subset. Then click "Close".



d. Right click on the new data layer in the "Layers Panel" and click "Open Attribute Table". You can use the table to review all the attributes of the warehouse subset within your buffer. All of the attributes that were included in the original spreadsheet are also included in this subset.





In this example, this step may seem unnecessary because there are only 3 vacant warehouses in the 10-mile buffer, but this tool can be quite useful and save you a lot of time if you find that you have several data points within the chosen buffer and need to assess each one.

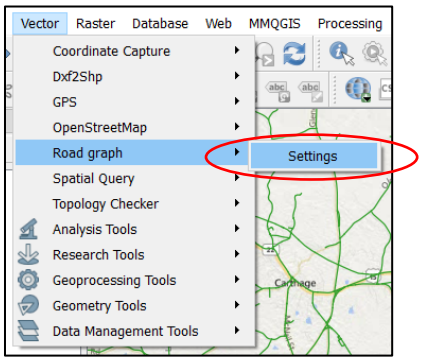
e. In the "Layers Panel" turn on this new data layer and deselect the original vacant warehouse dataset. We are now only concerned with the warehouses that are captured in our buffer.

Now that we've created the separate data layer, we can assess the proximity of each warehouse to a major road and a nearby wholesaler.

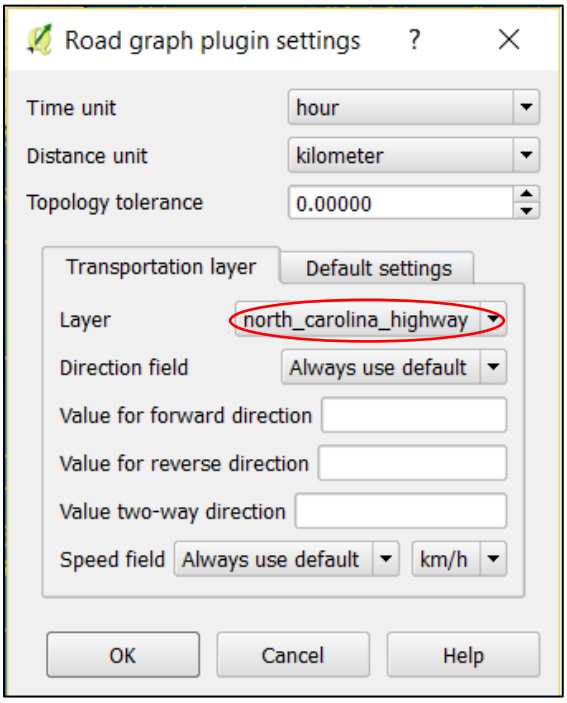
Proximity to Major Road

To determine the proximity of each warehouse to a major road we can use another QGIS tool called "Shortest path", which uses the roadway shapefile to determine the shortest driving distance from one point to another.

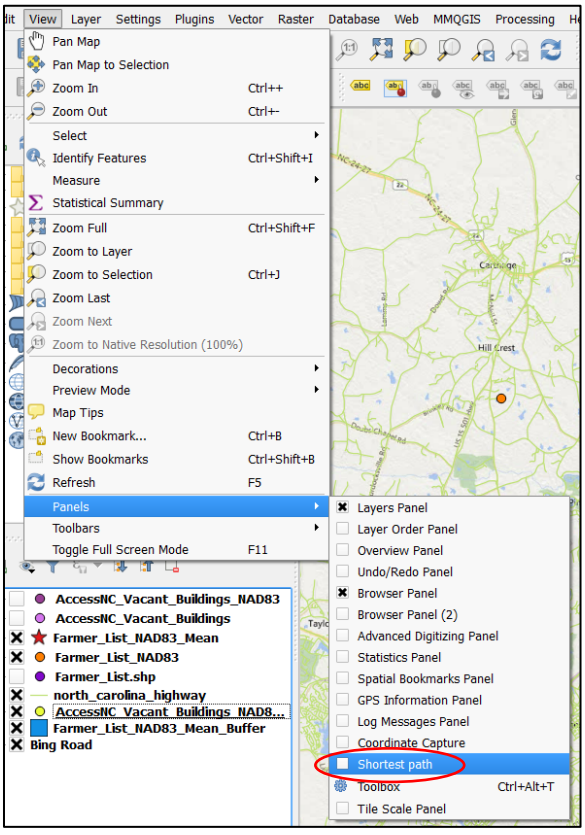
a. First, you must choose the settings for the tool. On the main screen, click "Vector" –> "Road graph" –> "Settings".



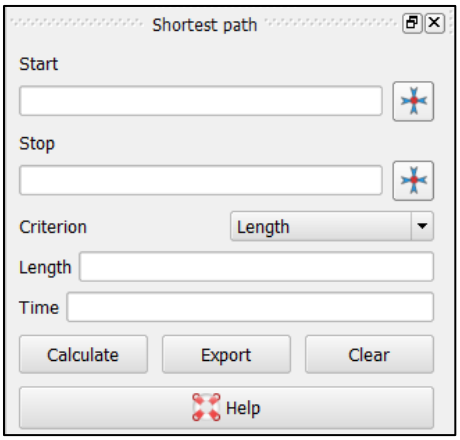
b. In the dialogue box that opens, make sure your settings match the screenshot below, and ensure the roadway data later is selected in the “Layer” dropdown box. Click “OK”.



c. On the main screen, click “View” –> “Panels” –> “Shortest path”



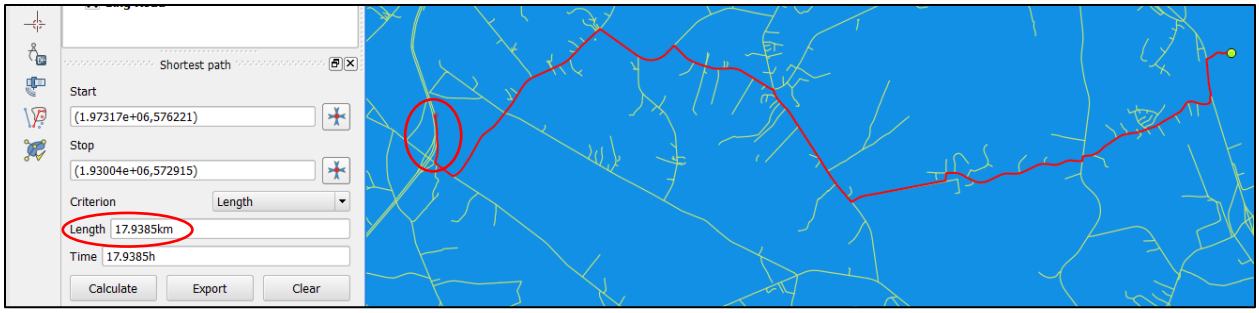
d. This will pull up a new panel on the left side of the main screen.



e. Zoom in to the area you want to analyze (here we focus on the upper half of the buffer), click on the cross beside the text box under "Start" and then click on the starting location on the map (in this example the starting location will be one of our vacant warehouses within our buffer). Next, click on the cross beside the text box under "Stop" and then click on the closest major road. Then click "Calculate" in the panel. The calculation may take a couple of minutes.

Note: In this example we've selected what roads we consider "major". However, individual projects may have different criteria for a road to be considered "major".

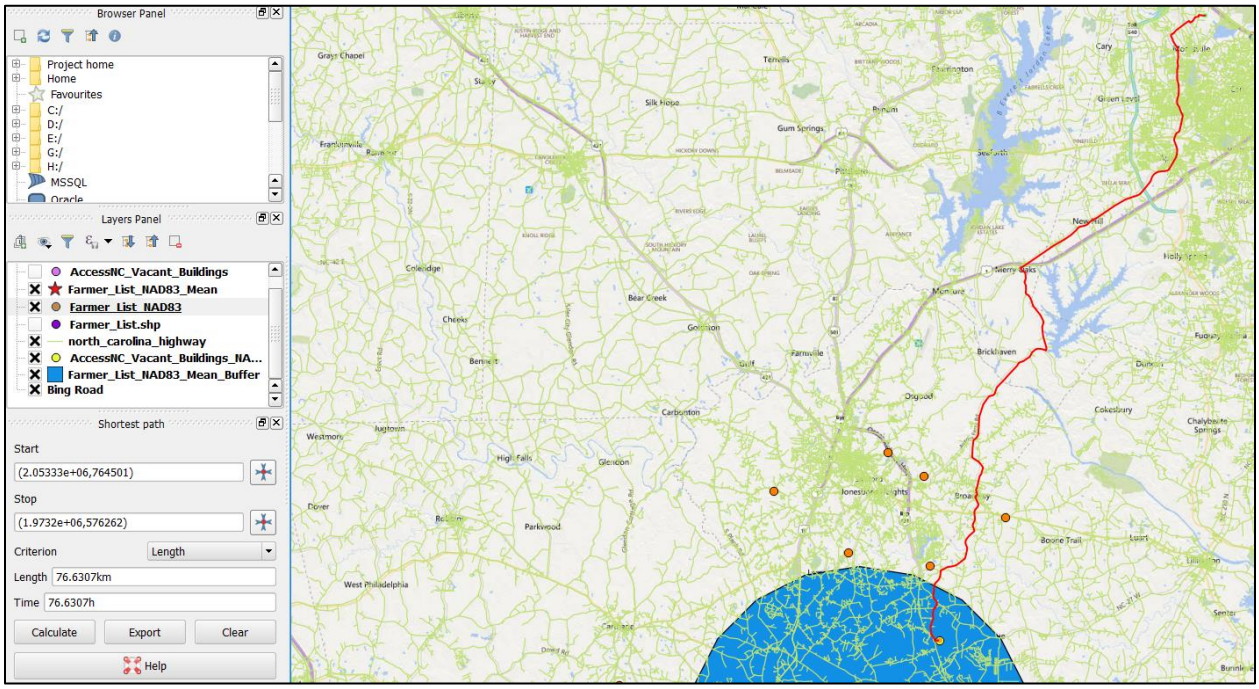
f. When the calculation is complete, a red line will be highlighted from your start and stop locations and the total distance will be displayed in the "Shortest path" panel. You can redo the calculation with a new stop location based on the closest exit from a major road to get a more accurate distance if you wish. This additional distance is circled in the below screenshot.



Note: This tool only calculates distances in kilometers so you will have to make any conversions manually.

Proximity to Nearby Wholesaler

Now we must select a nearby wholesaler of interest and use the same tool to determine the driving distance to that wholesaler. The easiest way to do this is to look up the address online and use an online reference like Google Maps to identify the location of the address. Then simply make that location your start or stop point in the "Shortest path" panel. In our example, we use the produce wholesale/distributor FreshPoint, located southwest of the Raleigh-Durham International Airport. Calculating the shortest path between two locations that are farther away may take additional computing time.



Repeat this analysis for every warehouse inside the 10-mile buffer (finding the proximity to the nearest major road and a nearby wholesaler). Using this information, we can now make a quantitatively-backed analysis to identify the optimal warehouse to choose as our consolidation center.

It is important to reiterate that in this project we have chosen three criteria to select our optimal consolidation center location:

- Minimizing the proximity to the largest number of farms
- Minimizing the proximity to a major road
- Minimizing the proximity to a nearby wholesaler of interest

However, for your project there may be a variety of other constraints and criteria that must be met or weighted differently in order for your location to be considered "optimal". These include criteria such as the farthest distance between farmers or the proximity of an individual, larger farm to the optimal location. The goal of this instruction is to provide you with an understanding of the QGIS program and some of the program's tools so that you can leverage this technology to meet your individual project needs.

Step 9 – Repeat Analysis For Possible Farm Clusters

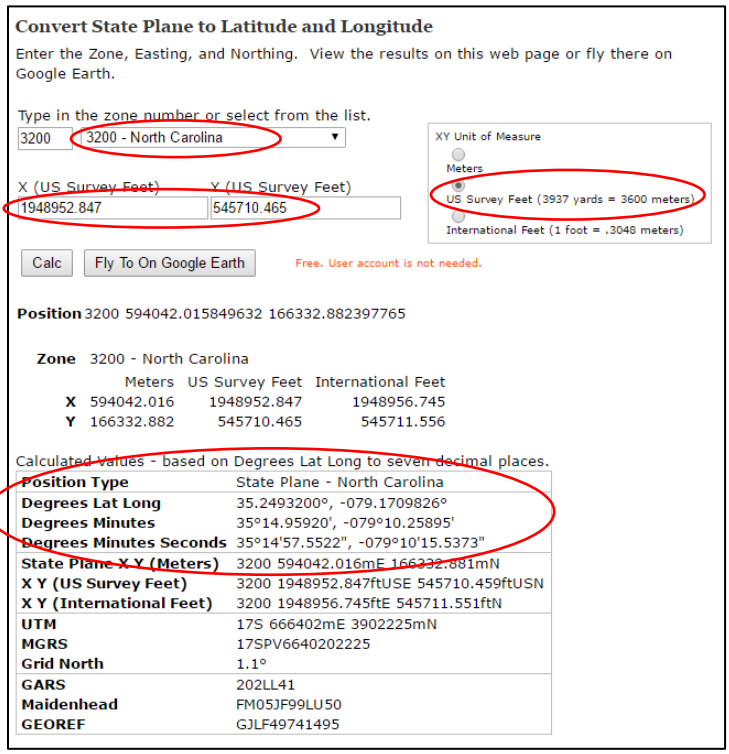
It is possible that your data will have obvious clusters of farms, say for instance in an eastern and western region. If this is the case, it is recommended that you separate the data into two or more regions while the data is still in an Excel format (before it is imported into QGIS). To do this, you can separate and filter the data by any geographical attribute such as latitude/longitude coordinates or counties. Then repeat this analysis for each region.

Conclusion and Results

In this example we assessed 1 of the 3 warehouses within the 10-mile buffer that potentially satisfies our criteria for a consolidation center. Using the identify features tool described in step 4, you can see this warehouse is located at 220 Olive Farm Drive, Sanford, NC. We compiled the below statistics using some of the previously described tools to further analyze the optimal site (the geometric mean of the farms calculated in step 6) as well as the location of this warehouse. Short descriptions on how to obtain some of these statistics are described below the table:

Optimal Site Location (Geometric Mean of Farms)	35.249° N, 079.171° W
% of Farms Within 10 Miles of the Optimal Site	21%
% of Farms Within 20 Miles of the Optimal Site	85%
% of Farms Within 40 Miles of the Optimal Site	100%
Three Farms Closest to Optimal Site	108 CVP Lane, Cameron, NC 5948 Lemon Springs Road, Sanford, NC 1606 Pickett Road, Sanford, NC
Location of Vacant Warehouse Within 10 Miles of Optimal Site	220 Olive Farm Drive, Sanford, NC
Distance from Vacant Warehouse to Nearest Major Road	10.7 miles
Distance from Vacant Warehouse to Interested Wholesaler	47.7 miles

- To convert the state plane coordinates to latitude and longitude coordinates, you can use a website such as http://www.earthpoint.us/StatePlane.aspx. In this website, select the zone you are using in your project (in our case it is "3200 – North Carolina"), be sure to select feet as your units of measure, enter in the state plane coordinates, then click "Calc". You can find the state plane coordinates by using the identify features tool from step 4 to select the geometric mean point. The results will appear below after you click "Calc".



Convert State Plane to Latitude and Longitude

Enter the Zone, Easting, and Northing. View the results on this web page or fly there on Google Earth.

Type in the zone number or select from the list.

3200 | 3200 - North Carolina

X (US Survey Feet): 1948952.847 | Y (US Survey Feet): 545710.465

XY Unit of Measure
- Meters
- US Survey Feet (3937 yards = 3600 meters)
- International Feet (1 foot = .3048 meters)

Calc | Fly To On Google Earth | Free. User account is not needed.

Position 3200 594042.015849632 166332.882397765

Zone 3200 - North Carolina

	Meters	US Survey Feet	International Feet
X	594042.016	1948952.847	1948956.745
Y	166332.882	545710.465	545711.556

Calculated values - based on Degrees Lat Long to seven decimal places.

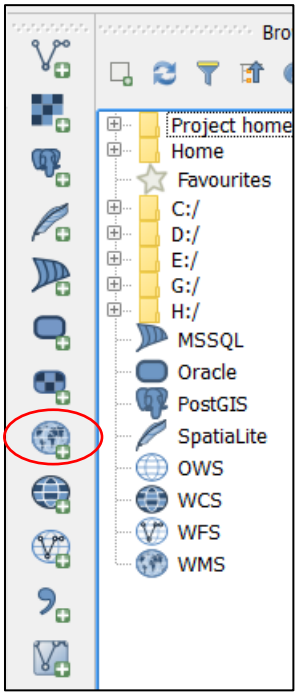
Position Type	State Plane - North Carolina
Degrees Lat Long	35.2493200°, -079.1709826°
Degrees Minutes	35°14.95920', -079°10.25895'
Degrees Minutes Seconds	35°14'57.5522", -079°10'15.5373"
State Plane X Y (Meters)	3200 594042.016mE 166332.881mN
X Y (US Survey Feet)	3200 1948952.847ftUSE 545710.459ftUSN
X Y (International Feet)	3200 1948956.745ftE 545711.551ftN
UTM	17S 666402mE 3902225mN
MGRS	17SPV6640202225
Grid North	1.1°
GARS	202LL41
Maidenhead	FM05JF99LU50
GEOREF	GJLF49741495

- To find the percent of farms within a 20 and 40-mile distance from the optimal site, repeat steps 7 and 8 using a buffer input of 105,600 feet (20 miles) and 211,200 feet (40 miles).
- Use the identify features tool (described step 4) and the measure tool (described in step 7) to find the three closest farms to the optimal site.

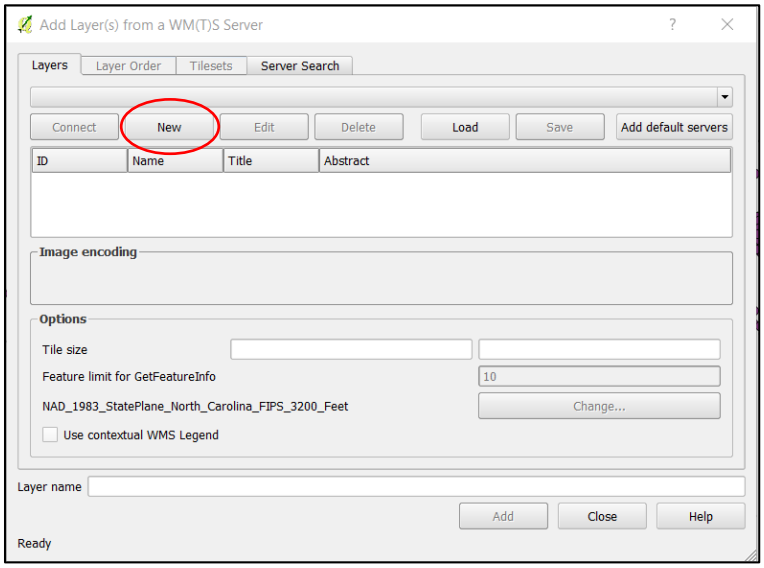
In conclusion, we were able to narrow our potential consolidation center site down to 3 vacant warehouses that were located less than 10 miles from the optimal location, and therefore minimized the total distance that all farmers would have to drive to deliver their produce. From this narrowed list we reviewed the driving distance from the warehouse to a major road as well as an interested wholesaler to ascertain how cumbersome that location would be to the wholesaler for pickup. As mentioned earlier, we chose these three criteria as a basis for the desirability of our consolidation center site, but there are numerous variables that can be considered based on your individual circumstances.

Appendix 1: Connecting to a WMS

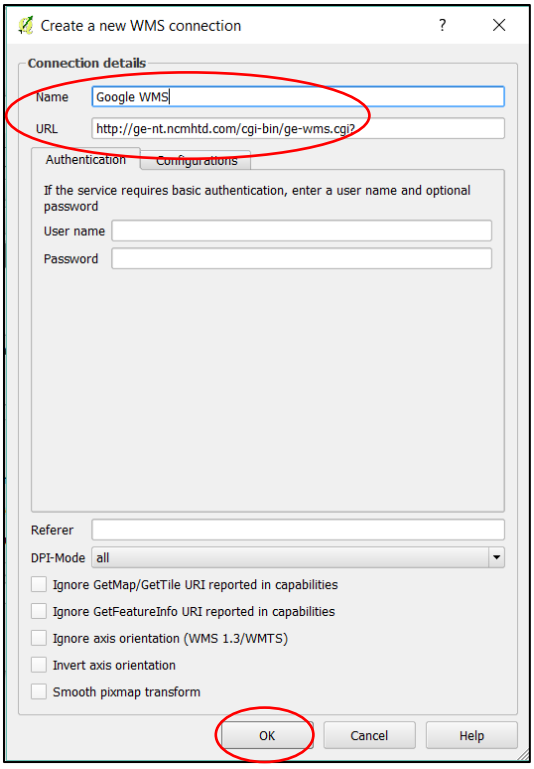
a. Click on the WMS icon on the left side of the main screen.



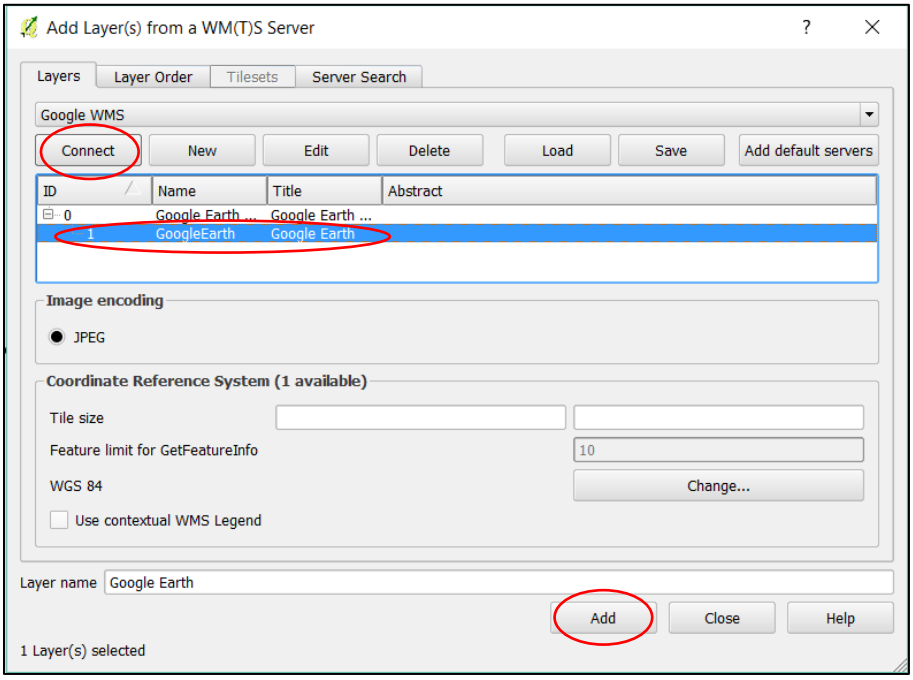
b. In the dialogue box that opens, click “New”.



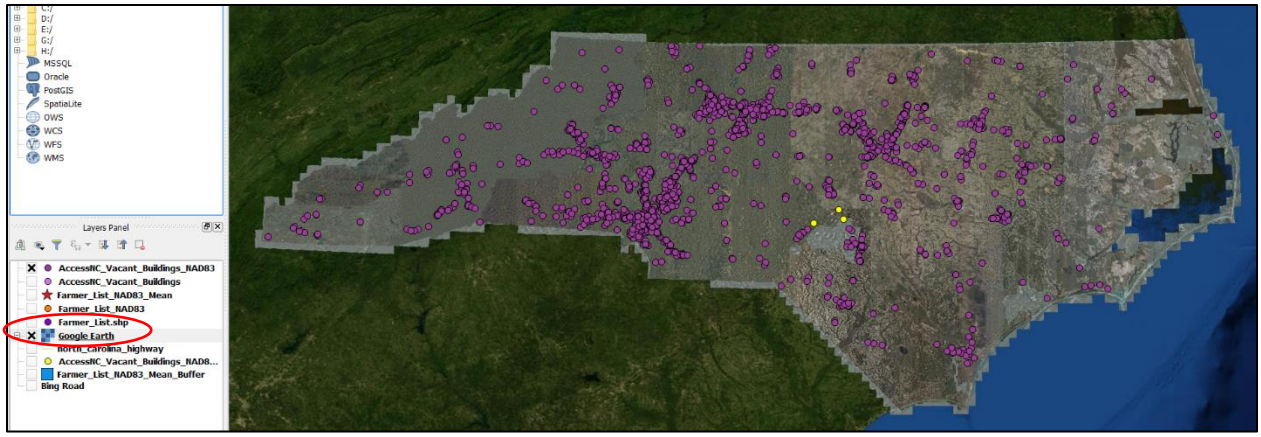
c. In the next dialogue box, beside “Name” enter the name you wish to call the WMS connection. Beside “URL” enter the URL of the WMS that you have found. WMS URLs all look different, but in general they are similar to a typical website URL. A WMS URL can typically be found through simple internet searches. In this example we will use a WMS URL that provides aerial imagery by Google: **http://ge-nt.ncmhtd.com/cgi-bin/ge-wms.cgi?** When finished, click “OK”.



d. Back in the first dialogue box, click “Connect” and you will see the WMS appear. Select one of the WMS layers and click “Add”.



e. The new imagery will appear on your map and the WMS layers will appear in your “Layers Panel”.


C:/
D:/
E:/
G:/
H:/
MSSQL
Oracle
PostGIS
SpatiaLite
OWS
WCS
WFS
WMS
Layers Panel
AccessNC_Vacant_Buildings_NAD83
AccessNC_Vacant_Buildings
Farmer_List_NAD83_Mean
Farmer_List_NAD83
Farmer_List.shp
Google Earth
North_Carolina_highway
AccessNC_Vacant_Buildings_NAD8...
Farmer_List_NAD83_Mean_Buffer
Bing Road