Proximity Exercise: A Risk Assessment for Nuclear Power Plants in Southern New England

Written by Barbara Parmenter. Revised 10/18/2018

Introduction

In this exercise, we'll be doing a simple analysis of the population at risk around New England's four nuclear power plants and exploring potential evacuation centers and routes. You'll practice using the following tools:

- Select by location
- Statistics
- Spatial join
- Buffer and multi-ring buffer
- Near tool
- Point distance tool
- Network analysis – service area

Data Sets and Sources

The data sets have been acquired and pre-processed as described below. New England states refer to Connecticut, Rhode Island, Massachusetts, Vermont, and New Hampshire.

Directions on how to access the data are in the next section. You do NOT need to download all this data!

Northeast_states_UTM19N

Data Source: Mapcruzin.com (http://www.mapcruzin.com/nuclear-power-plant-earthquake-shapefiles/), US basemap.zip, downloaded 3/30/2011.
Processing: The five New England states plus New York were selected out and exported to the UTM WGS 1984 Zone 19N coordinate system

Nuclear_Power_Plants_UTM19N

Data Source: Mapcruzin.com (http://www.mapcruzin.com/nuclear-power-plant-earthquake-shapefiles/), downloaded 3/30/2011.
Processing: The four New England power plants were selected out and exported to the UTM WGS 1984 Zone 19N coordinate system

Airports_UTM19N

Data source: Bureau of Transportation Statistics, National Transportation Atlas Database, 2010 (http://www.bts.gov/publications/national_transportation_atlas_database/2010/), downloaded 3/30/2011
Processing: Airports in the 5 New England states were selected and exported to the UTM WGS 1984 Zone 19N coordinate system

National_Highway_Planning_Network_UTM19N

Data source: Bureau of Transportation Statistics, National Transportation Atlas Database, 2010, NHPN, Region 1 (http://www.bts.gov/publications/national_transportation_atlas_database/2010/), downloaded 3/30/2011
Processing: The roads and highways were exported to the UTM WGS 1984 Zone 19N coordinate system

EPA_region1_schools_UTM19N

Data source: EPA Region 1 public schools, accessed via Geodata.gov (http://gos2.geodata.gov/wps/portal/gos), published 2008, downloaded 3/30/2011
Processing: Schools were exported to the UTM WGS 1984 Zone 19N coordinate system

2000_blockpop_centroids_UTM19N

Data source: ESRI, Census 2000, M:\\ESRIDataMaps93\Census\Blockpop.shp
Processing: Census block points within southern New England, eastern New York and Long Island were selected graphically and exported to the UTM WGS 1984 Zone 19N coordinate system

Important attribute column names note:
Pop2000 – 2000 Census population count
HSE_Units – 2000 Census housing unit count
Household – 2000 Census household count (a household = people sharing one housing unit)

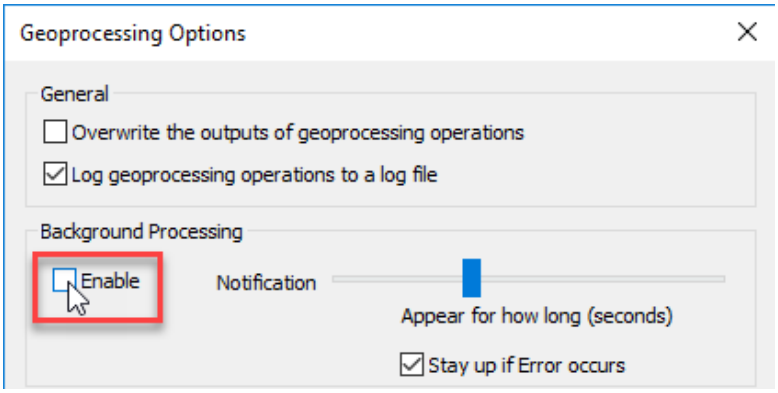
Hospitals_UTM19N

Data Source: US Department of Health and Human Services, HRSA Geospatial Data Clearinghouse – ArcIMS Server: datawarehouse.hrsa.gov, Service Name: HGDW_Mapping (ArcGIS directions can be found here: http://datawarehouse.hrsa.gov/HGDWFeatureService.aspx)
Processing: All US Hospitals were exported out of the ArcIMS server, then the hospitals in the 5 New England states were selected and exported to the UTM WGS 1984 Zone 19N coordinate system.

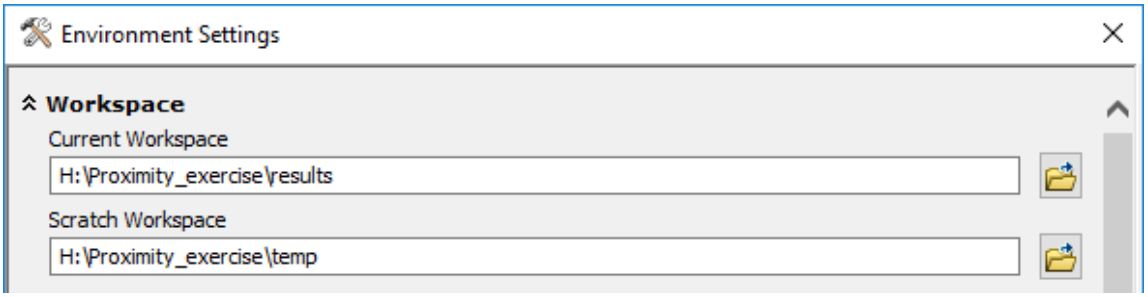
Important attribute table column names note:
HRSAgeo_5 = provider category code
HRSAgeo_6 = provider category description
HRSAgeo_7 = category sub-type code
HRSAgeo_8 = provider category sub-type description
HRSAgeo9 = Facility Name
HRSAgeo10 = Total Bed Count
HRSAgeo_11 = certified bed count

Accessing and Preparing for the Tutorial

1. From *S:\Classes\DHP_P207* copy the **Proximity_Exercise** folder to your H: drive.
    a. You can also download the data from the link on the Tufts' GIS website (here).
2. Open the **Proximity_Exercise** folder in your H drive and double-click on **start_map.mxd** – this will start ArcMap.
3. In ArcMap, go to **Customize → Extensions** – and checkmark *Spatial Analyst* and *Network Analyst.*
4. Click on **Geoprocessing → Geoprocessing Options…**
   Disable *Background Processing* by unchecking the corresponding box.



5. Click on **Geoprocessing → Environments…** In the Environment Settings box, click on *Workspace*.
6. Set the **Current Workspace** to be your *Proximity_Exercise\results* folder and your **Scratch Workspace** to *Proximity_exercise\temp*. Setting these workspaces means that when we run a tool, the output (aka resulting shapefile) will be saved in the results folder. Read about the difference between the *Scratch* and *Current* workspace by clicking on *Show Help* at the bottom right. Click **OK**.



7. Take a couple minutes to explore the different data layers – look at their attribute tables especially. Notice how the data has already been clipped to our New England states.
8. Check the **projection** of the *Data Frame* and the *layers*. What projection are we using? What are the units?

Select by Location: Calculating population estimations within 12 & 50 miles of the four nuclear plants

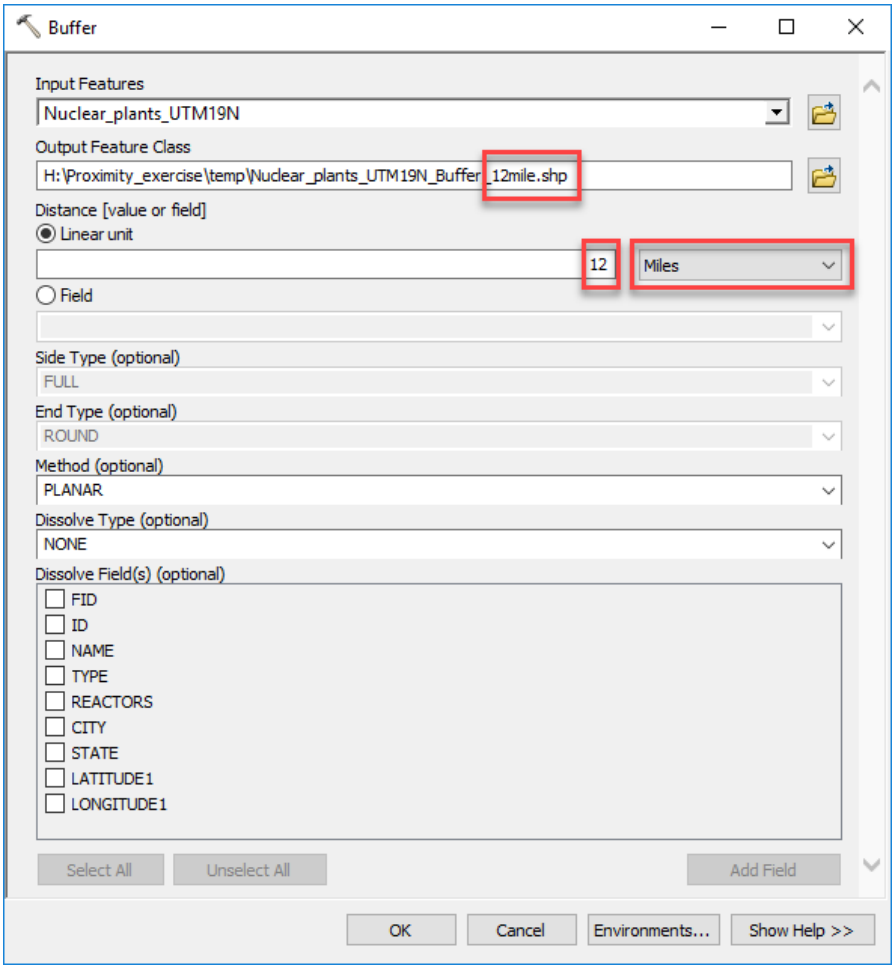
1. Using the tools you already know, how would you estimate the population within a 12 mile zone of Southern New England's four nuclear power plants? (Hint: Select by location, statistics).

   You'll know it's worked if you've found that there is a *sum* of **438,673** people living within 12 miles of the nuclear power plants.
2. How many households are there? How many housing units? Why might we want to know population, households, and housing units, rather than just one of these numbers?
3. Estimate the population within a 50 mile zone of the 4 nuclear power plants. What do you find?

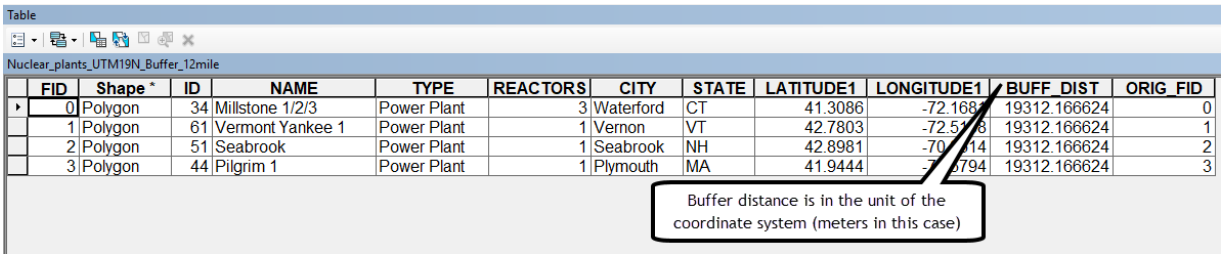
Buffer Tools - Visualizing a 12 mile & 50 mile evacuation zone

While **select by location** is useful, **buffers** can help us visualize zones and perform further analysis. We are going to create **buffers** of 12 miles and 50 miles around these nuclear plants.

1. Make sure to start by clearing your selection. When running tools, make sure nothing is selected (unless you want it selected). If you run a tool while things are selected, the tool will **ONLY** run on selected features!
2. Click on the **ArcToolbox** icon to open it. It might take a minute, which is totally normal!
3. Click on **Analysis Tools → Proximity** – you'll see **Buffer** and **Multiple Ring Buffer.**
4. Double-click on **Buffer.** Click **Show Help.** As you saw above, the help is context sensitive, so when you click on a box, it will tell you about that specific part of the tool.
5. Fill out the dialog box as you see below (using your personal folder path and saving in the *results* folder), making sure to include "12mile" in the new file name.



6. Press OK.
7. When the processing is complete, click Close and if prompted, view the results on your map. The buffer you just created will appear automatically in your table of contents.
8. Click on **File→ Save As** and save your map file in the Proximity Exercise folder in your H drive as *Proximity1.mxd*
9. You can set the 12-mile buffer zones to be semi-transparent by right-clicking on the buffer data layer and going to *Properties → Display*. Set the Transparent: field to 50% and click **OK.**
10. Open the attribute table of the new buffer data layer. What do you see?



FID	Shape *	ID	NAME	TYPE	REACTORS	CITY	STATE	LATITUDE1	LONGITUDE1	BUFF_DIST	ORIG_FID
0	Polygon	34	Millstone 1/2/3	Power Plant	3	Waterford	CT	41.3086	-72.1681	19312.166624	0
1	Polygon	61	Vermont Yankee 1	Power Plant	1	Vernon	VT	42.7803	-72.5178	19312.166624	1
2	Polygon	51	Seabrook	Power Plant	1	Seabrook	NH	42.8981	-70.8514	19312.166624	2
3	Polygon	44	Pilgrim 1	Power Plant	1	Plymouth	MA	41.9444	-70.5794	19312.166624	3

Notice how this buffer layer attribute's table looks just like the attribute table for *Nuclear_plants*, except that it also has a field for **Buff_Dist**. This shows how large the buffer is, but it uses the units from our **projection,** which in this case is meters!

The difference between a dissolved buffer and a non-dissolved buffer

When you created that 12 mile buffer, you chose **NONE** for the ***Dissolve Type***. This results in **separate** buffers around each nuclear power plant point, each represented by their own row in the attribute table.

If you choose **DISSOLVE ALL**, all your buffers would be one feature, shown in one row, and the attribute information of the nuclear power plants would be lost. By keeping the ***Dissolve Type*** option set to **NONE**, you have the four separate buffer features, with the associated nuclear power plant information.

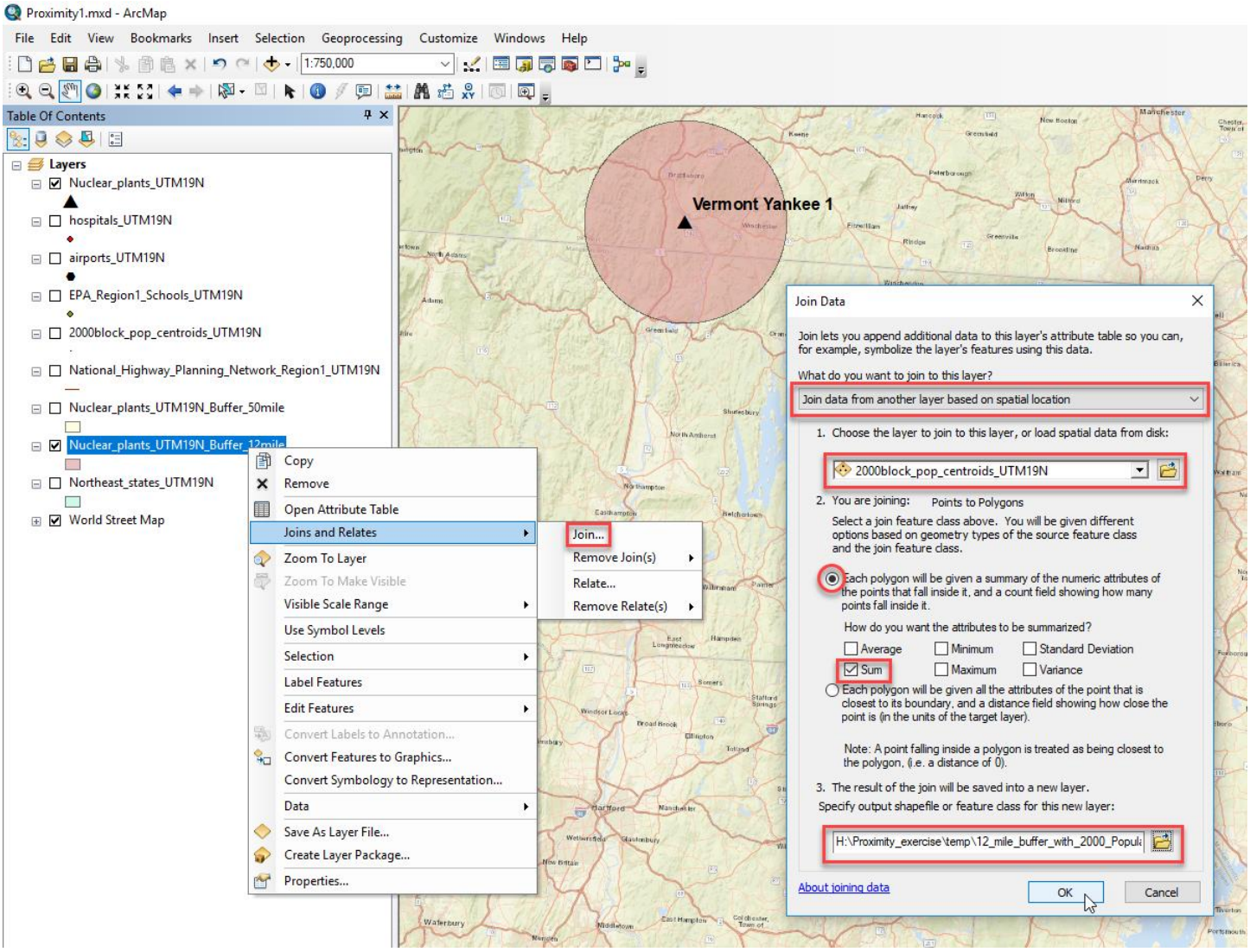
1. Repeat the process but this time create **50 mile buffers** around the nuclear power plants. Set your dissolve type to **ALL** so you can see the difference in the resulting attribute tables!
2. One the tool runs, open the attribute table to see the difference between the two buffers. Also, notice how the buffers are connected where they overlap rather than 4 separate buffers. Why might this be important if we were trying to calculate the total population of people within 50 miles of a nuclear power plant?
3. We will base the rest of our analyses on the **12 mile zones**, so make sure your 12 mile buffer is turned on. Turn off the 50 mile buffer.

Performing a spatial join to estimate the population with 12 miles of each nuclear power plant

If we want to know the population within 12 miles of each nuclear power plant, we could select each plant one at a time, and then use **select by location** to select all the *2000block_pop_centroids* within 12 miles of the selected plant, then look at the attribute table. We would have to do this four separate times for each power plant, which is not very efficient.

Or we can use a function called a ***Spatial Join***, which makes it much easier and joins the population data INTO each of the buffers.

1. Right click on the *Nuclear_plants_UTM19N_Buffer_12mile* and select **Joins and Relates → Joins**…
2. Make sure to change the top dropdown to **Join data from another layer based on a spatial location**.
3. Select the ***2000block_pop_centroids*** as the layer that you want into the buffers. Choose the statistic you care about calculating. In this case, we want to know the sum of the population living within these zones, so check **Sum.**
4. Name the output file ***12_mile_buffer_with_2000_Population_Estimates.shp*** and make sure you are saving it in the ***Proximity_Exercise*** folder in your *H drive*. Double check the graphic below to make sure everything is the same before running the tool.

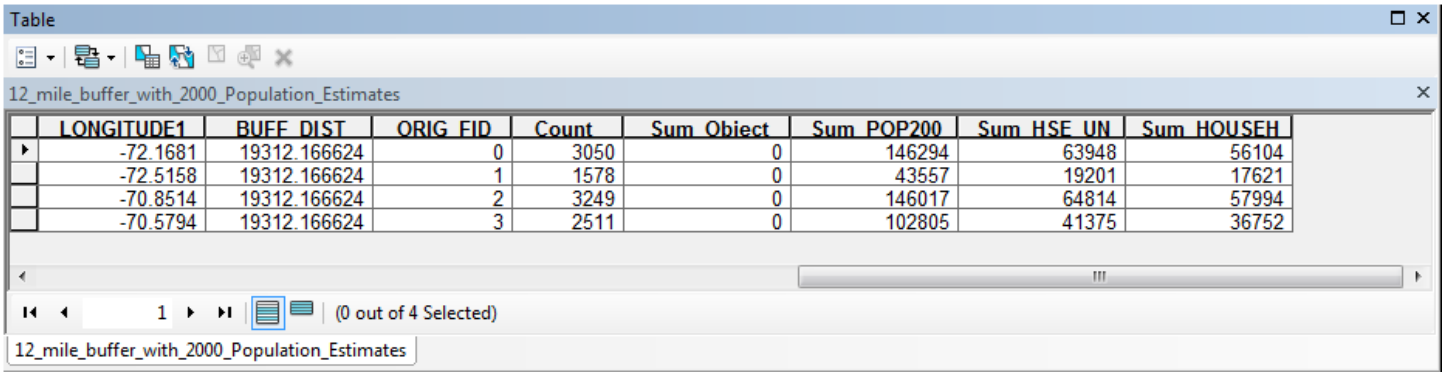


This may take a few minutes. A new layer is created, which *looks* the same as the buffers but when you explore the attribute table, you see that the population data from the underlying blocks are summed for each 12 mile buffer zone!

5. Why did we select *sum* instead of *average* in the spatial join?

   We did this because we wanted the sum of all the block groups within a buffer so we could know the total population, not the average number of people for just 1 block group within the 12 mile buffer.

6. Explore the resulting attribute table of the ***12_mile_buffer_with_2000_Population_Estimates.shp***. The **sum** of population and households is at the far right of the table. The **count** is the number of blocks within each buffer.

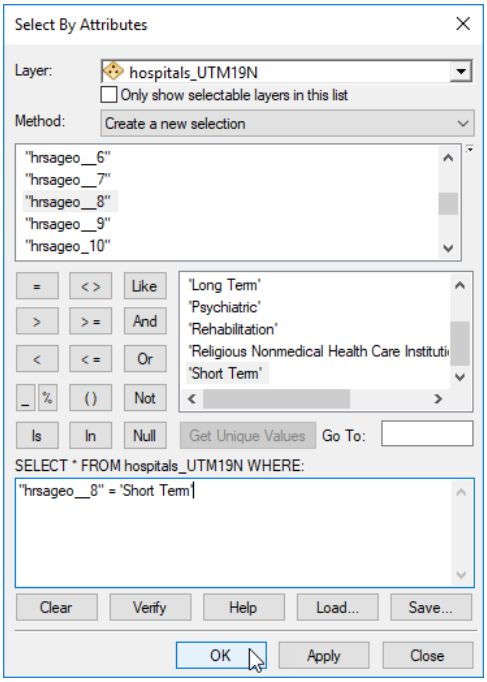


LONGITUDE1	BUFF_DIST	ORIG_FID	Count	Sum_Object	Sum_POP200	Sum_HSE_UN	Sum_HOUSEH
-72.1681	19312.166624	0	3050	0	146294	63948	56104
-72.5158	19312.166624	1	1578	0	43557	19201	17621
-70.8514	19312.166624	2	3249	0	146017	64814	57994
-70.5794	19312.166624	3	2511	0	102805	41375	36752

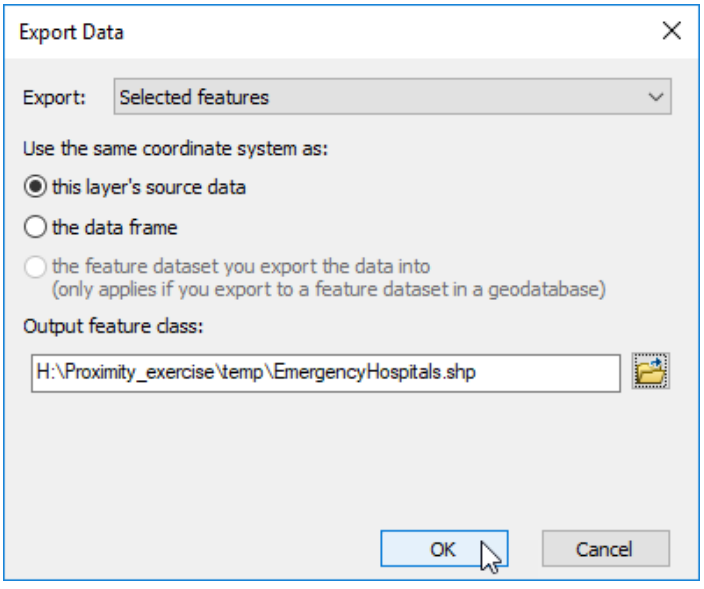
NEAR Tool: What is the nearest hospital to each nuclear plant and how many beds does it have?

For better emergency planning, we now want to know the nearest hospital to each nuclear plant and how many beds it has for emergency training and planning purposes. The near tool examines the closest feature in another field to each point in the original field. However, rather than following a road network, it measures distance "as the crow flies" – aka a straight line from point to point, not taking roads into account.

1. Turn off the ***2000block_pop_centroids*** and turn on ***hospitals*** and look at its attribute table. Which type of hospital would be good to serve as a medical provider in the event of an emergency at a nuclear plant? (*HRSAgeo_8* has the hospital sub-type description)
2. Use **Select by Attribute** to select the *short term hospitals.*

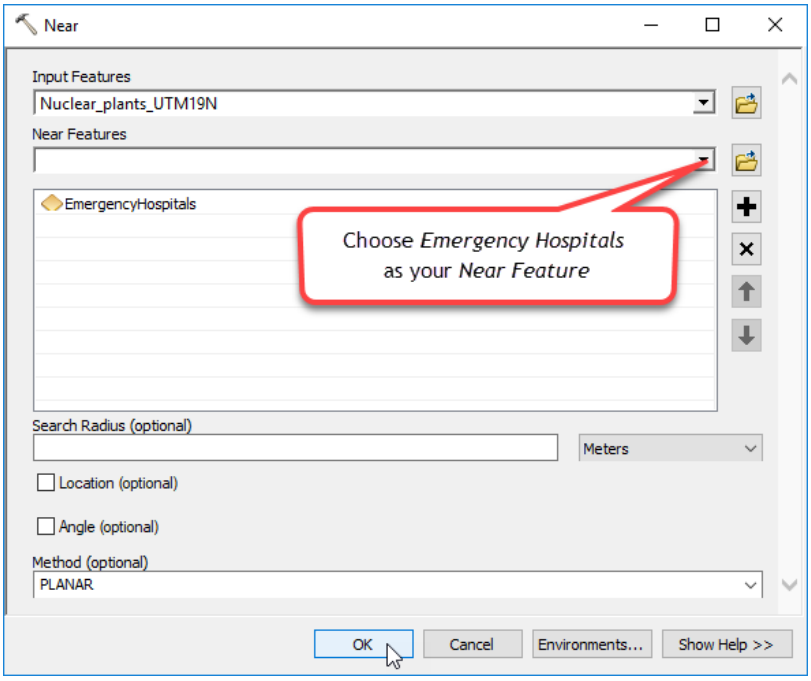


3. Right click on the **Hospitals** layer and **Data → Export Data.** Save the new shapefile in your *H drive* → *Proximity_Exercise\results* folder and call it ***EmergencyHospitals.shp.*** Then clear your selection.



4. Go to **ArcToolbox → Analysis Tools → Proximity** and double-click on **NEAR** – make sure to *Show Help* and read about what the tool does.

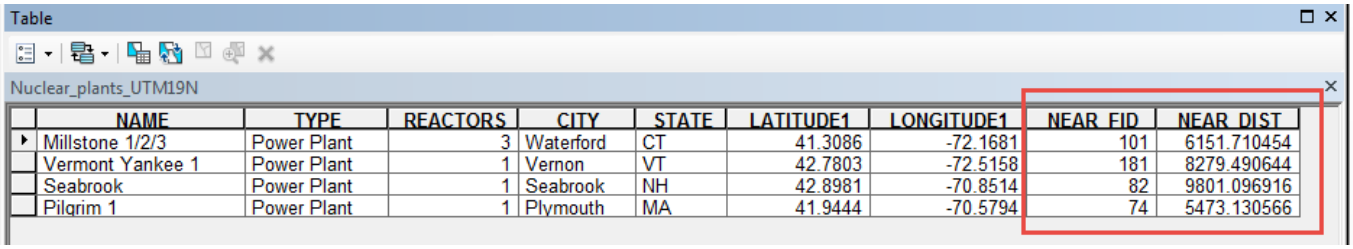
5. Fill out the dialog box as follows:



6. Click **OK**.

7. This tool does NOT create a new shapefile, but instead adds two new fields to your existing ***Nuclear_plants_UTM19N*** *attribute table.* Open the attribute table to see.

8. Scroll to the end of the table. You see **NEAR_FID** and a **NEAR_DIST**. The NEAR_FID is the Feature ID (FID) of the nearest hospital. The NEAR_DIST is the distance (straight line) to the nearest hospital. Note the NEAR_DIST is measured in the same units used by the coordinate system, so in this case they are in **meters**.



Table

Nuclear_plants_UTM19N

NAME	TYPE	REACTORS	CITY	STATE	LATITUDE1	LONGITUDE1	NEAR_FID	NEAR_DIST
Millstone 1/2/3	Power Plant	3	Waterford	CT	41.3086	-72.1681	101	6151.710454
Vermont Yankee 1	Power Plant	1	Vernon	VT	42.7803	-72.5158	181	8279.490644
Seabrook	Power Plant	1	Seabrook	NH	42.8981	-70.8514	82	9801.096916
Pilgrim 1	Power Plant	1	Plymouth	MA	41.9444	-70.5794	74	5473.130566

9. If we open up the **EmergencyHospitals** table, you'll see the FID at the very beginning of the table. If you look at the **Nuclear Plant** attribute table, we find the nearest hospital to the Millstone Power Plant in Waterford, CT, is the Lawrence and Memorial Hospital located approximately 6151 meters away.

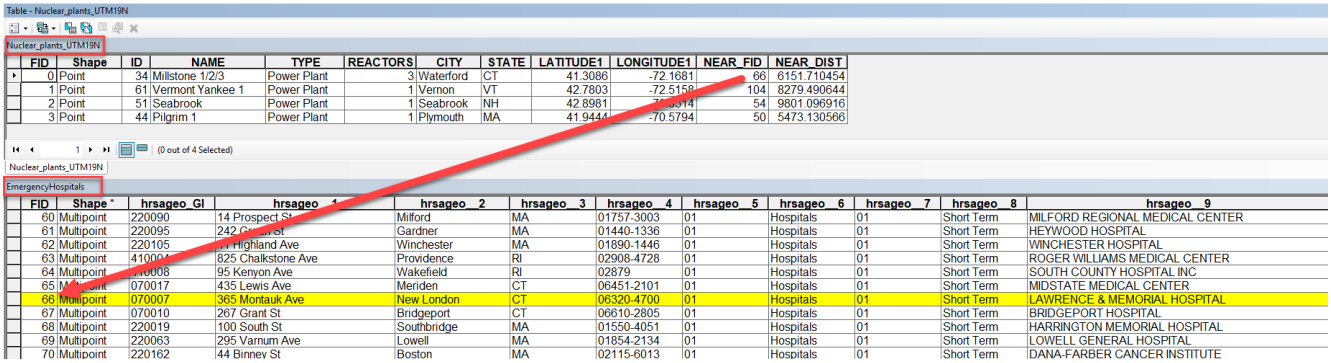


Table - Nuclear_plants_UTM19N

Nuclear_plants_UTM19N

FID	Shape	ID	NAME	TYPE	REACTORS	CITY	STATE	LATITUDE1	LONGITUDE1	NEAR_FID	NEAR_DIST
0	Point	34	Millstone 1/2/3	Power Plant	3	Waterford	CT	41.3086	-72.1681	66	6151.710454
1	Point	61	Vermont Yankee 1	Power Plant	1	Vernon	VT	42.7803	-72.5158	104	8279.490644
2	Point	51	Seabrook	Power Plant	1	Seabrook	NH	42.8981	-70.8514	54	9801.096916
3	Point	44	Pilgrim 1	Power Plant	1	Plymouth	MA	41.9444	-70.5794	50	5473.130566

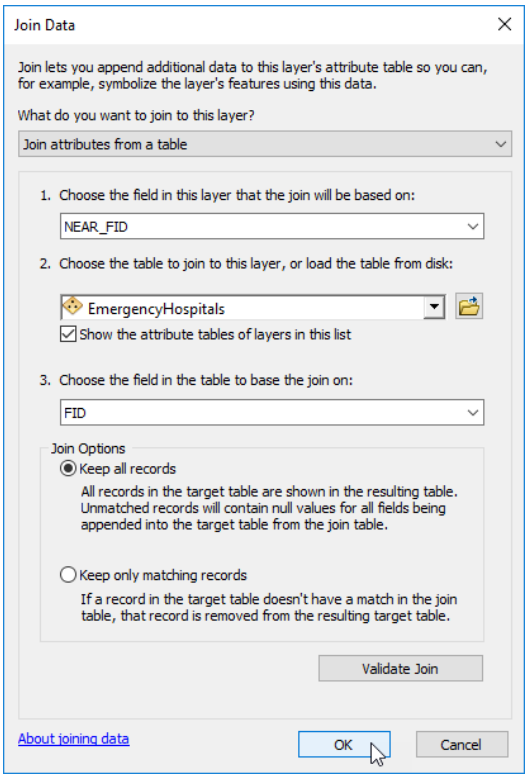
(0 out of 4 Selected)

Nuclear_plants_UTM19N

EmergencyHospitals

FID	Shape *	hrsageo_GI	hrsageo_1	hrsageo_2	hrsageo_3	hrsageo_4	hrsageo_5	hrsageo_6	hrsageo_7	hrsageo_8	hrsageo_9
60	Multipoint	220090	14 Prospect St	Milford	MA	01757-3003	01	Hospitals	01	Short Term	MILFORD REGIONAL MEDICAL CENTER
61	Multipoint	220095	242 Gr... St	Gardner	MA	01440-1336	01	Hospitals	01	Short Term	HEYWOOD HOSPITAL
62	Multipoint	220105	... Highland Ave	Winchester	MA	01890-1446	01	Hospitals	01	Short Term	WINCHESTER HOSPITAL
63	Multipoint	410004	825 Chalkstone Ave	Providence	RI	02908-4728	01	Hospitals	01	Short Term	ROGER WILLIAMS MEDICAL CENTER
64	Multipoint	410008	95 Kenyon Ave	Wakefield	RI	02879	01	Hospitals	01	Short Term	SOUTH COUNTY HOSPITAL INC
65	M...	070017	435 Lewis Ave	Meriden	CT	06451-2101	01	Hospitals	01	Short Term	MIDSTATE MEDICAL CENTER
66	Multipoint	070007	365 Montauk Ave	New London	CT	06320-4700	01	Hospitals	01	Short Term	LAWRENCE & MEMORIAL HOSPITAL
67	Multipoint	070010	267 Grant St	Bridgeport	CT	06610-2805	01	Hospitals	01	Short Term	BRIDGEPORT HOSPITAL
68	Multipoint	220019	100 South St	Southbridge	MA	01550-4051	01	Hospitals	01	Short Term	HARRINGTON MEMORIAL HOSPITAL
69	Multipoint	220063	295 Varnum Ave	Lowell	MA	01854-2134	01	Hospitals	01	Short Term	LOWELL GENERAL HOSPITAL
70	Multipoint	220162	44 Binney St	Boston	MA	02115-6013	01	Hospitals	01	Short Term	DANA-FARBER CANCER INSTITUTE

10. If you scroll to the right, you can see the hospital's name, along with its bed count (HRSAgeo_10). After running this tool, you know that the closest hospital to the Millstone plant is hospital FID 66, The Lawrence & Memorial Hospital in New London, and it has 280 beds.
11. Since we now have a common **attribute field** between the two data layers (FID in *hospitals* and NEAR_FID in our *Nuclear_plants*), we can perform a table join to view all the information within the *Nuclear_plants* layer.
12. Right-click on the ***Nuclear_plantsUTM19N*** layer and choose **Joins and Relates → Join** and fill in the box as follows:



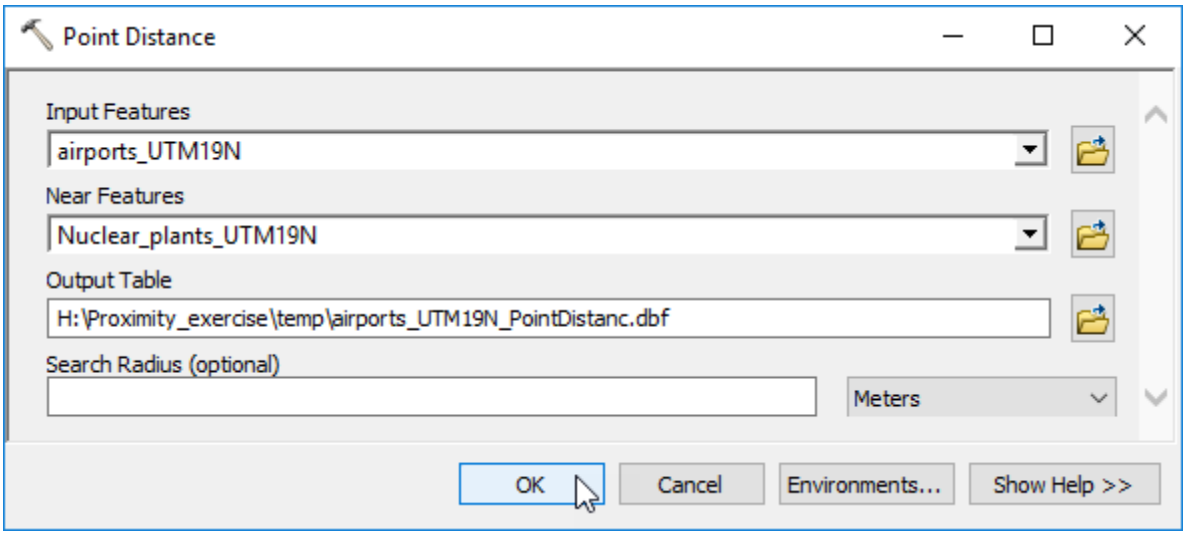
13. Open the **attribute table** for the nuclear plants. Now, all the hospital information for the closest short term hospital to the nuclear plants has been added to the table!
14. Save your map!

What if we want to know the closest hospitals outside the 12 mile zone? Can you think of a solution for this problem using tools you know? (*Hint:* One approach would be to select by location for all emergency hospitals within 12 miles, then switch selection to all other hospitals, then use NEAR on the selected emergency hospitals. You can find *Switch Selection* if you right click on the selected Emergency Hospitals, and go to *Selection → Switch Selection*.)

Point Distance Tool – Find the distance from all airports to all four nuclear plants

Since we may have to use multiple airports to respond to a crisis, we'd like to know how far EVERY airport in New England is to each of the nuclear plants. The **POINT DISTANCE** tool will calculate the distance from all points in one layer to all points in another layer.

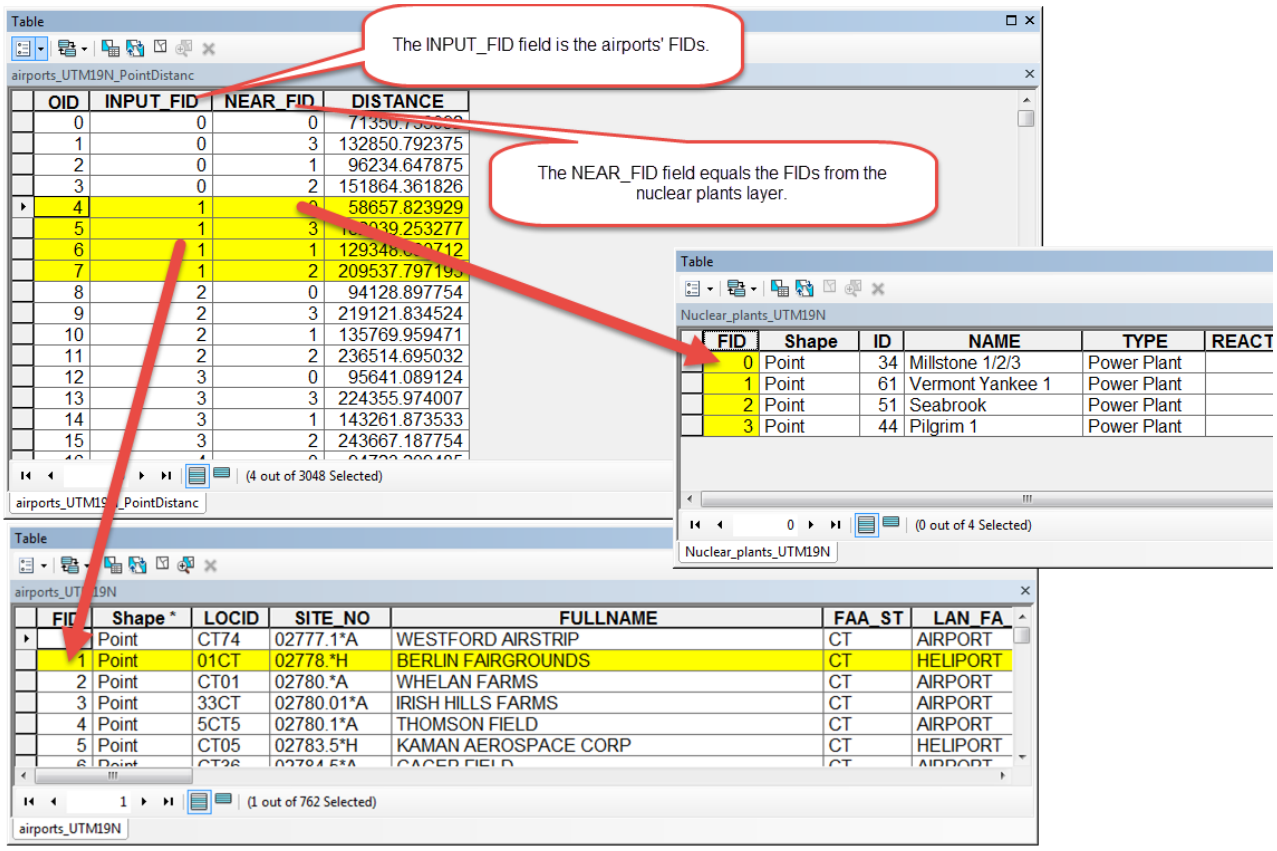
1. Clear any selections you have.
2. Go to **ArcToolbox → Analysis → Proximity** and double click on the **POINT DISTANCE** tool.
3. Fill in the dialog box as follows – note that the result will be a .dbf database table – remember the name and location!



4. Click OK and once is completed click **close** on the new window. Note that the new table has been added in the *List by Source* frame of the Table of Contents, not the *List by Drawing Order* we most commonly use.

5. Open the new table which has been added to the bottom of the table of contents. You'll see the **INPUT_FID** which is the FID of the Airports and the **NEAR_FID** which is the FID of the Nuclear Plants (you can open those tables to see) – again the distance is in meters. See the graphic for guidance.

   Each *INPUT_FID* (airports) repeats 4 times because it is measuring the distance to each of the 4 nuclear plants (*NEAR_FID*).



From this new point distance table you could run a query in an emergency to find all the airports within a certain distance of a specific nuclear power plant.

What would you need to do to find the distances of all airports to the Pilgrim 1 Nuclear Plant in Plymouth? Because each airport record is repeated four times, once for each of the four power plants, you'd first have to select out all the airport records for *NEAR_FID* = 3 (Pilgrim).

Then you would export this to its own table (e.g., *Pilgrim_airport_distances)*. In that table the airport records are not repeated – that is there is a unique airport record on each row since we're only looking at the distance to Pilgrim 1.

Now, the exported table can be joined back to the Airports table using the FID in Airports and the *INPUT_FID* from *Pilgrim_airport_distances* table.

Save your map again!

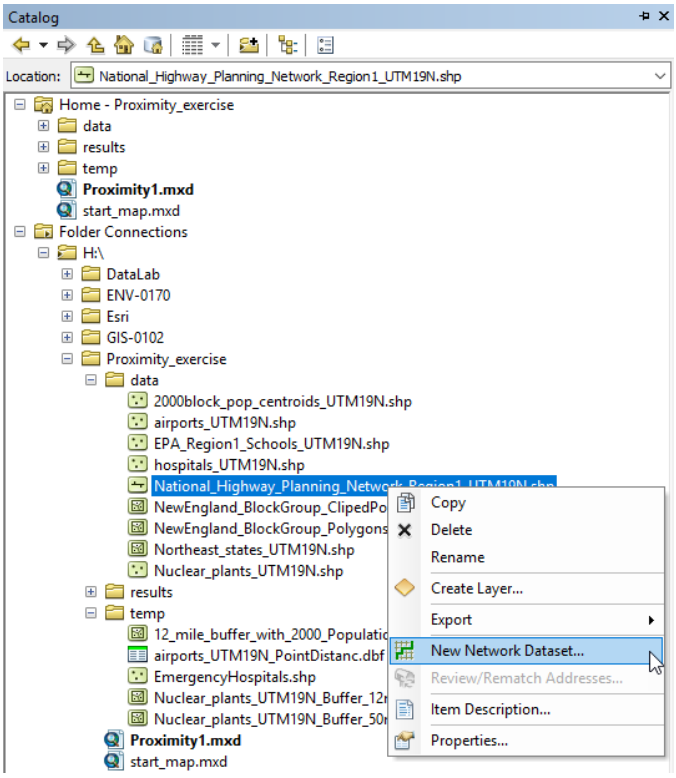
Network Analyst – Service Area Analysis: Visualize a 50 mile drive from each Nuclear Power Plant using a Road Network

We want to be able to visualize what response and relief resources are **within a 50 mile drive** of our nuclear power plants using a road network. The "as the crow flies" buffer (or Euclidean distance) will not do this for us. But the **Network Analyst** *extension* has the functions we need.

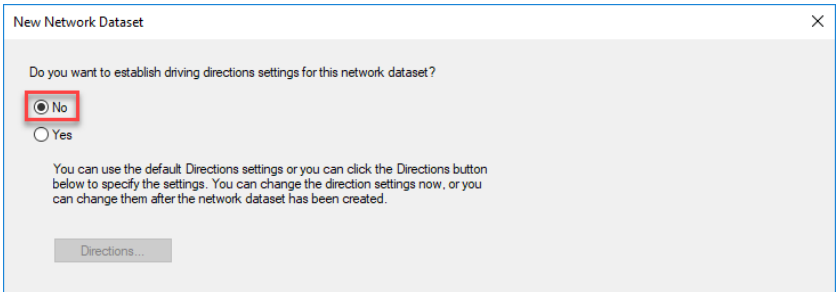
This analysis is unfriendly in terms of the user interface but not difficult to do – here are the basic steps:

Create the network data set in ArcCatalog

1. Enable the **Network Analyst** extension if not already enabled (**Customize → Extensions**).
2. In the **Catalog**, navigate to your proximity practice folder in your H drive and find the ***National_Highway_Planning_Network_UTM19N*** shapefile in the **Data folder.**
3. Right click on that data set and choose the option for **New Network Dataset.**



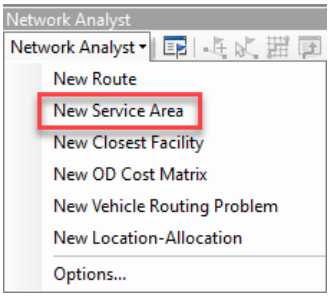
4. Accept all the defaults by clicking **Next**, except click **NO** for driving directions (the page before the **Finish** screen). Hit the **Finish** button, and finally say **Yes** to building the network dataset. Also say **Yes** to adding it to your map and the other prompts.



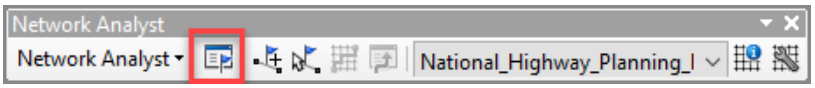
5. Turn off the junction points layer (*National_Highway_Planning_Network_Region1_UTM19N_Junctions*) in your *Table of Contents*. Leave the Edges on – this is your network data set.

Performing the Service Area Analysis in ArcMap

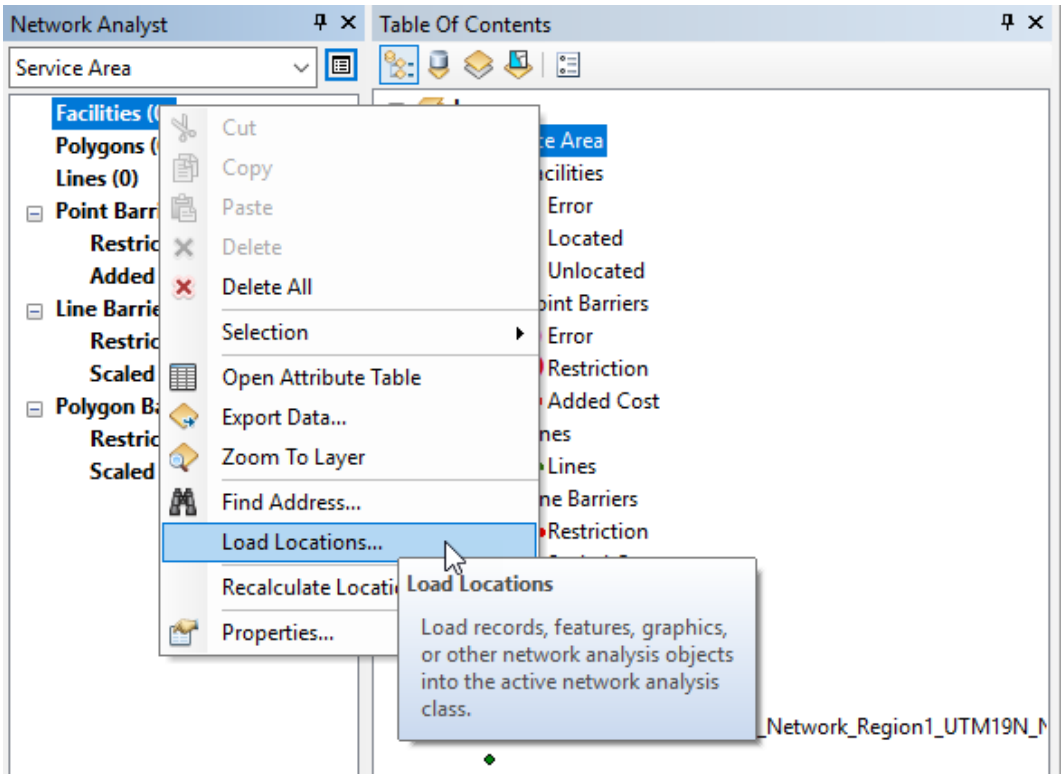
1. Go to **Customize → Toolbars** and check mark the **Network Analyst**. Then using the drop down, select **New Service Area.**



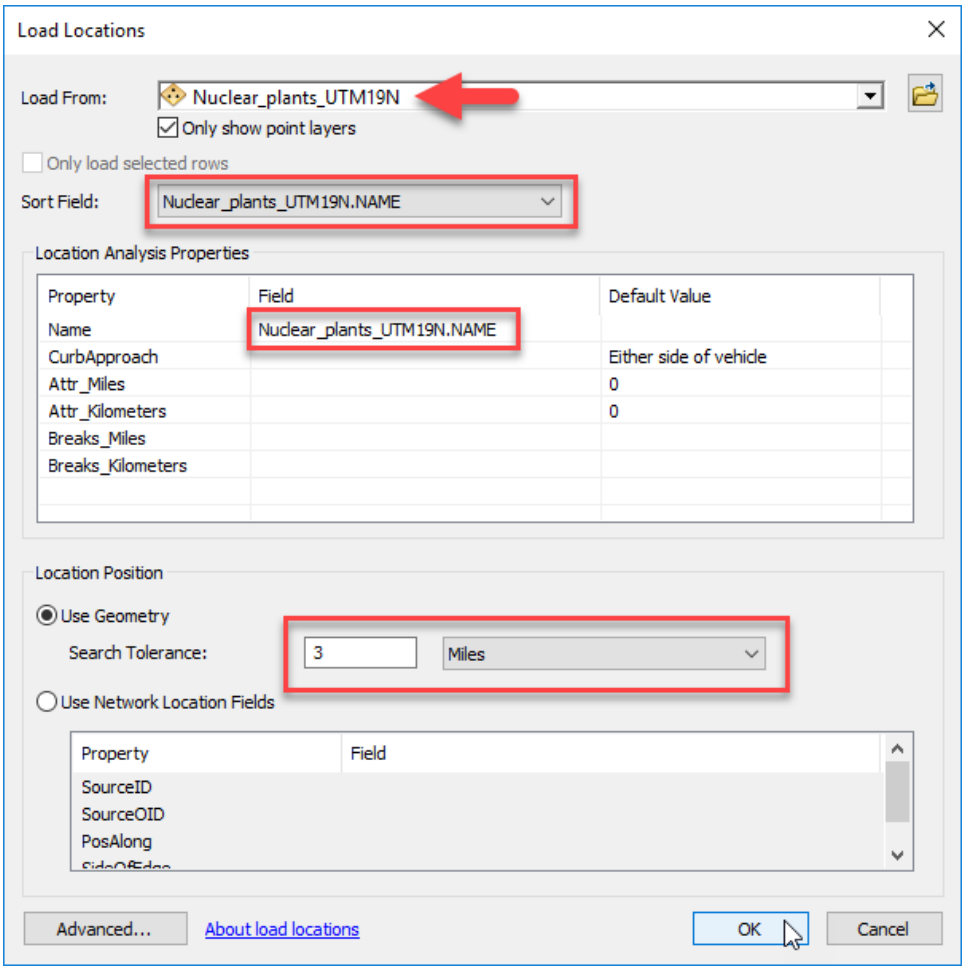
2. From the **Network Analyst** toolbar, click *on Network Analyst Window* (see screenshot). A new window to the left of the Table of Contents will appear.



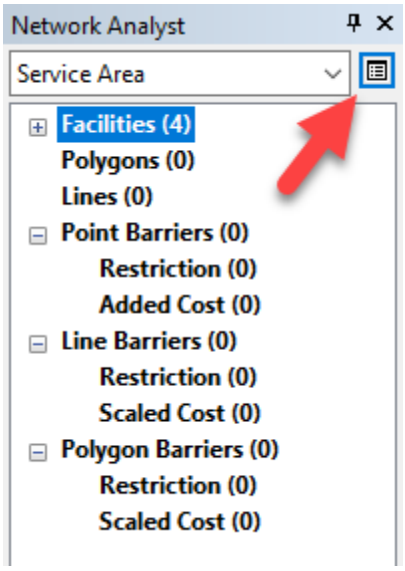
3. In the new **Network Analyst Window**, right-click on *Facilities* and choose *Load Locations* – these will be our Nuclear Power Plants:



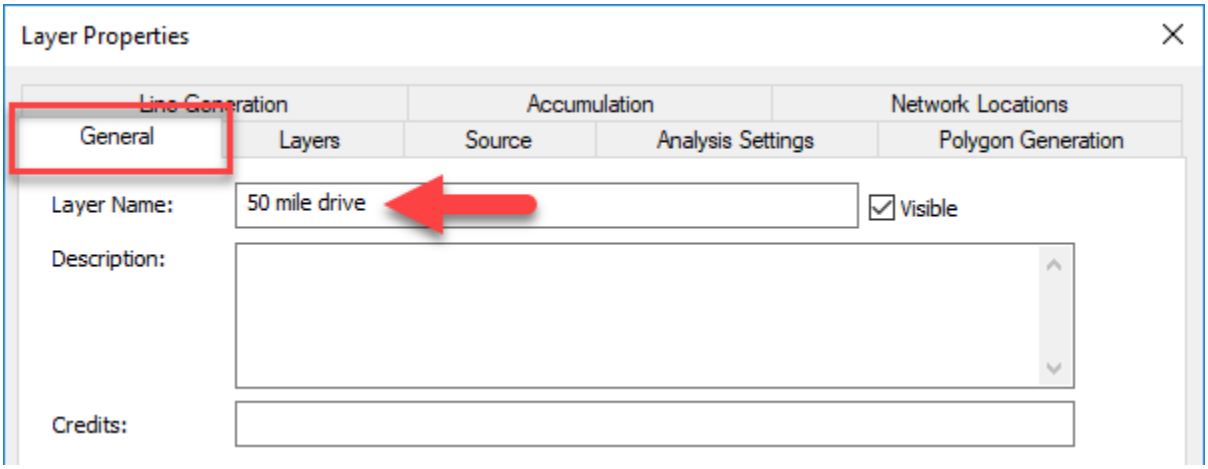
4. Fill out the **Load Locations** dialog box as follows then press **OK**.

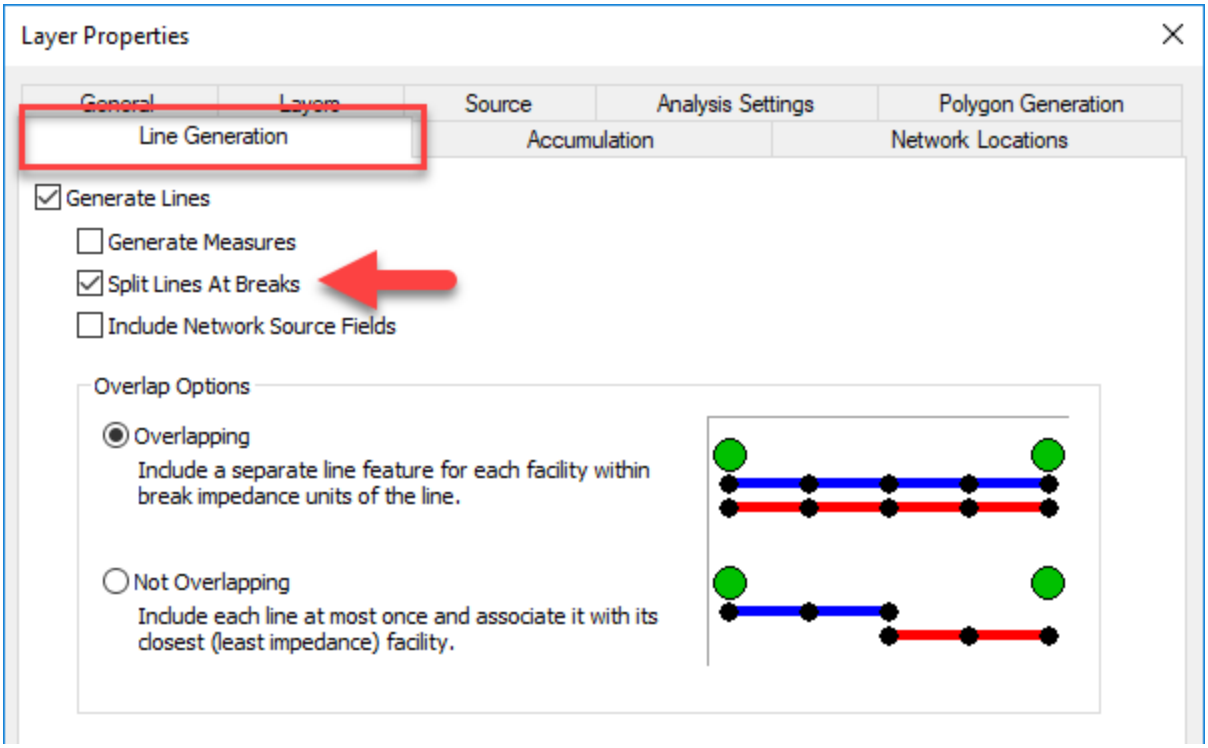


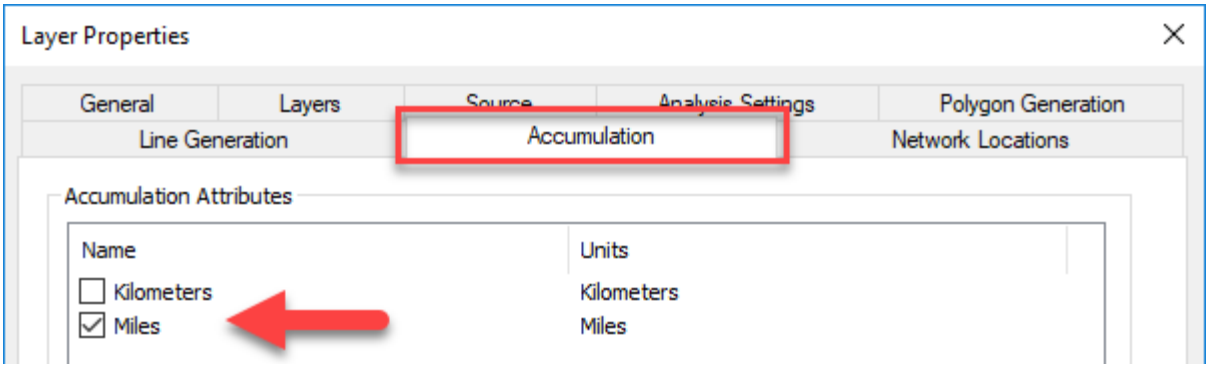
5. You should have 4 facilities located (the four nuclear plants). Click on the **Service Areas Properties** box:

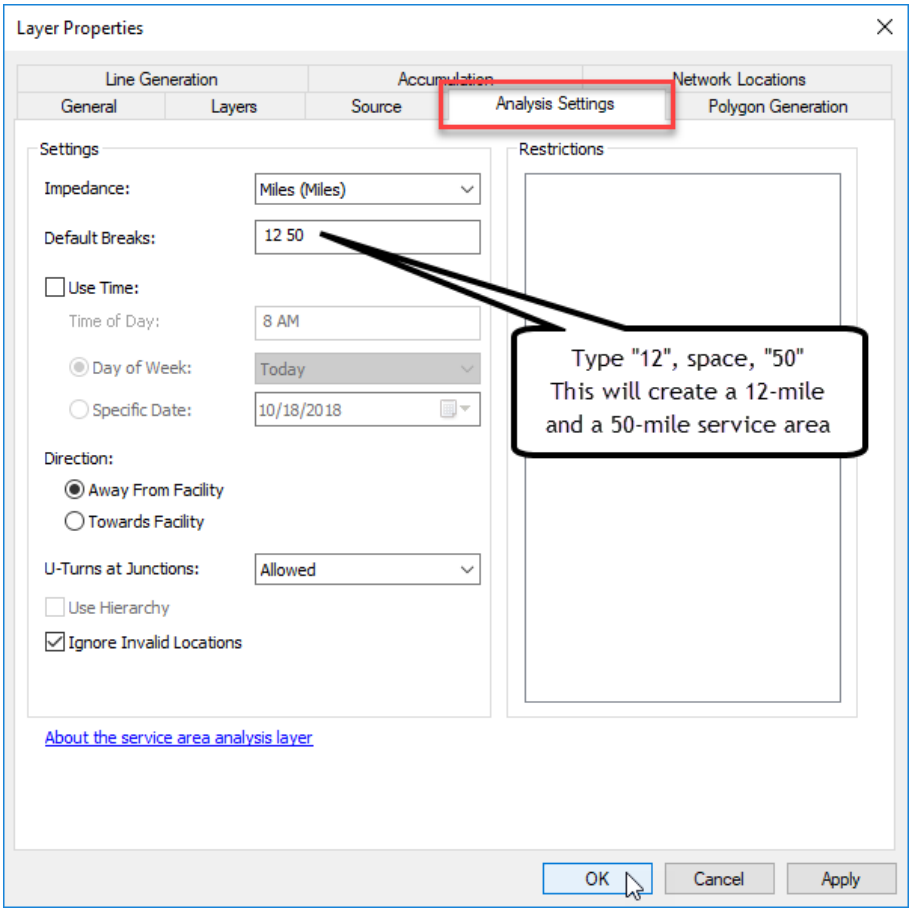


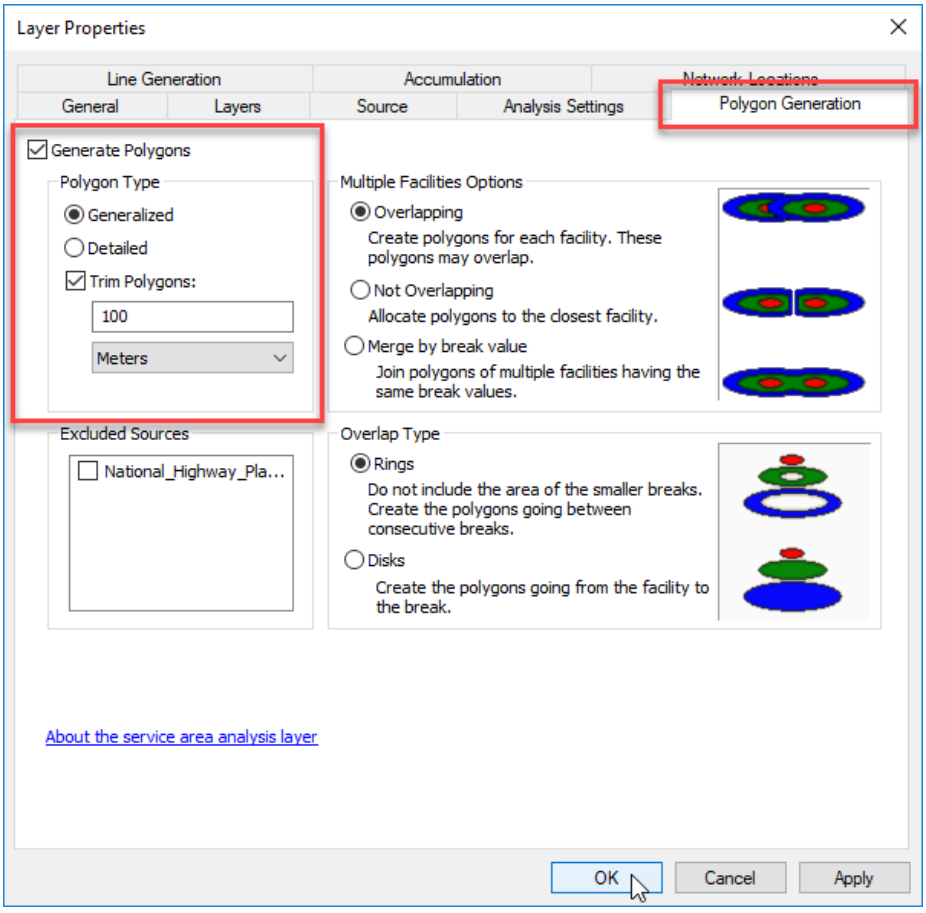
6. Fill out the dialog box as follows:



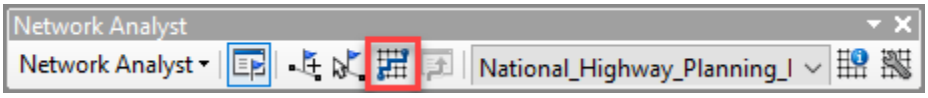





Layer Properties
Line Generation
Accumulation
Network Locations
General
Layers
Source
Analysis Settings
Polygon Generation
Settings
Impedance:
Miles (Miles)
Default Breaks:
12 50
Use Time:
Time of Day:
8 AM
Day of Week:
Today
Specific Date:
10/18/2018
Direction:
Away From Facility
Towards Facility
U-Turns at Junctions:
Allowed
Use Hierarchy
Ignore Invalid Locations
Restrictions
Type "12", space, "50"
This will create a 12-mile
and a 50-mile service area
About the service area analysis layer
OK
Cancel
Apply

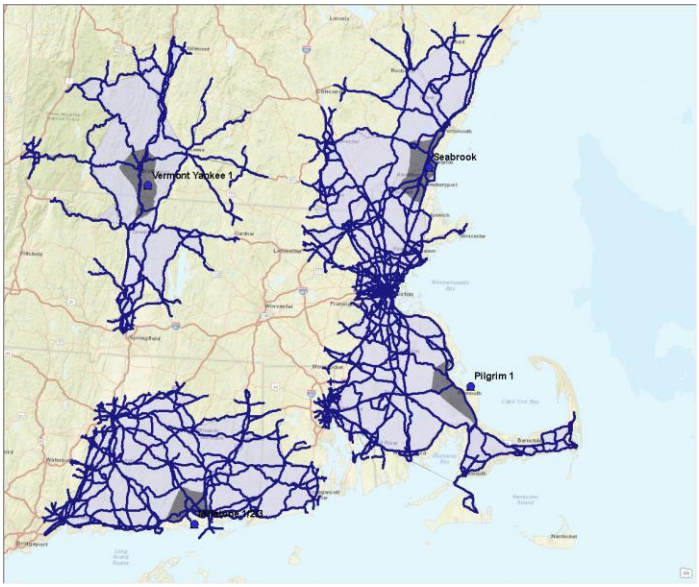

Layer Properties
Line Generation
Accumulation
Network Locations
General
Layers
Source
Analysis Settings
Polygon Generation
Generate Polygons
Polygon Type
Generalized
Detailed
Trim Polygons:
100
Meters
Multiple Facilities Options
Overlapping
Create polygons for each facility. These polygons may overlap.
Not Overlapping
Allocate polygons to the closest facility.
Merge by break value
Join polygons of multiple facilities having the same break values.
Excluded Sources
National_Highway_Pla...
Overlap Type
Rings
Do not include the area of the smaller breaks. Create the polygons going between consecutive breaks.
Disks
Create the polygons going from the facility to the break.
About the service area analysis layer
OK
Cancel
Apply

7. Click **OK**. Nothing happens yet!
8. Now click on the **SOLVE** icon

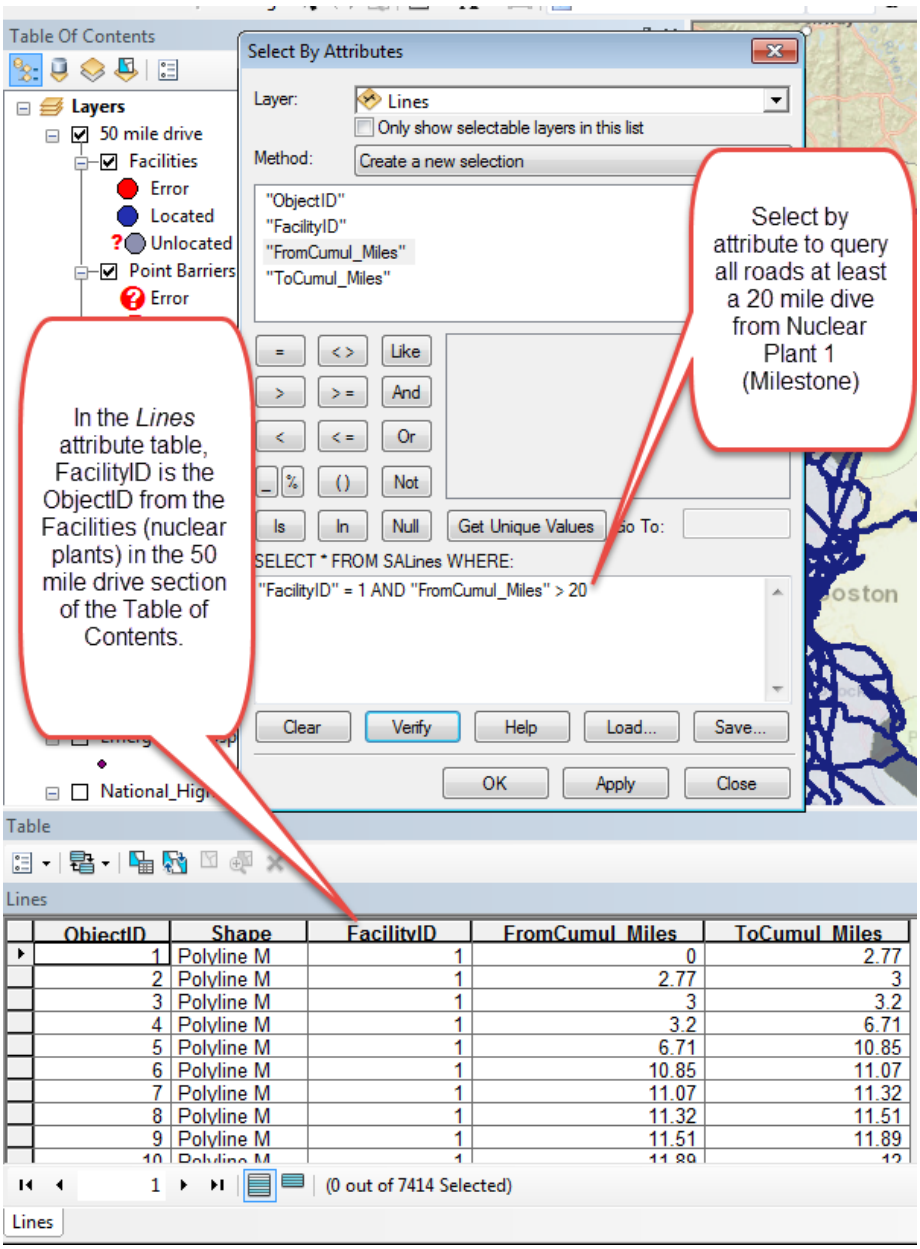


9. Your map should now look something like this. The purple roads are a 50-mile drive from nuclear power plants. Also, if you turn off the lines, you can more clearly see the 12-mile (grey) and 50-mile (purple) drive polygons known as **service areas**. If you turn on your 12 and 50 mile buffers, notice how being 50 miles away by road is not the same as being 50 miles away in straight line distance!

   The **service area analysis** is more typically used to find things like who lives within 5 miles (driving distance) of places like stores or hospitals.



10. You can turn on hospitals, schools or airports to visualize where potential resources are within these zones.
11. Explore the attribute tables for **Lines** in the **50 mile drive** area of the *Table of Contents* – note you can do things like select for all roads that are at least a 20 mile drive from a particular facility:



ObjectID	Shape	FacilityID	FromCumul_Miles	ToCumul_Miles
1	Polyline M	1	0	2.77
2	Polyline M	1	2.77	3
3	Polyline M	1	3	3.2
4	Polyline M	1	3.2	6.71
5	Polyline M	1	6.71	10.85
6	Polyline M	1	10.85	11.07
7	Polyline M	1	11.07	11.32
8	Polyline M	1	11.32	11.51
9	Polyline M	1	11.51	11.89

You could continue this analysis with tools you know. For example, what if we wanted to find all the high schools that are within a half mile of our selected highway lines from the Millstone plant above so that they could serve as relief centers in the case of a problem.

That's enough for now. But think about how these tools can help quickly respond in an emergency and to plan for the unexpected.