Georeferencing and Digitization

This assignment will help you learn about the following:

- Creating a geodatabase with feature datasets and feature classes
- Georeferencing (georegistration) in ArcGIS
- Digitizing features in a geodatabase

Objective

The scenario is that you have to build a geodatabase for a new section of a rapidly growing city. You have to create a geodatabase for this project and populate this geodatabase with:

- Features representing land use (e.g. parcel boundaries, parks, industrial areas, etc.)
- Features representing utilities, such as water and electrical lines.

For this purpose, your first task is to digitize the parcels of a new sub-division and estimate where water pipes will be placed. You are given a scanned paper map that represents the parcel property boundaries.

An additional task is to use a formula to estimate the property value of the new lots.

Task # 1: Geodatabase Design

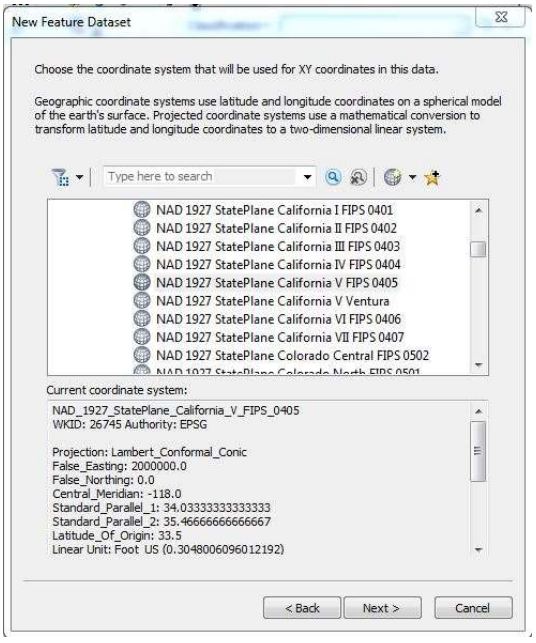
1.1 Make a new file geodatabase

- Connect to the following folder: D:\CE-210\Tutorial\Georef
- In ArcCatalog, navigate to this *Georef* folder and right-click, and then choose New → File Geodatabase.
- Name the file geodatabase ***City***. Set *City* as the default geodatabase, under File → Map Document Properties.

1.2 Define feature datasets and feature classes

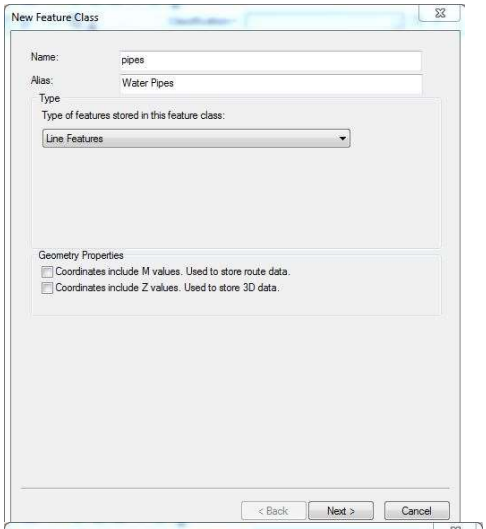
You first need to create feature datasets to hold the feature classes (layers) you will digitize.

- Right-click on the empty geodatabase and choose New → Feature Dataset (NOT Feature Class). In the dialog box that opens, specify the name as *Utilities* – this will create a feature dataset called "*Utilities*".
- Click Next to choose the coordinate system. Navigate to Projected Coordinate Systems → State Plane → NAD 1927 and select California Zone 5 (NAD 1927 StatePlane California V FIPS 0405).
- Click Next, skip the vertical coordinate system by clicking Next again. Accept the default tolerances by clicking Finish.



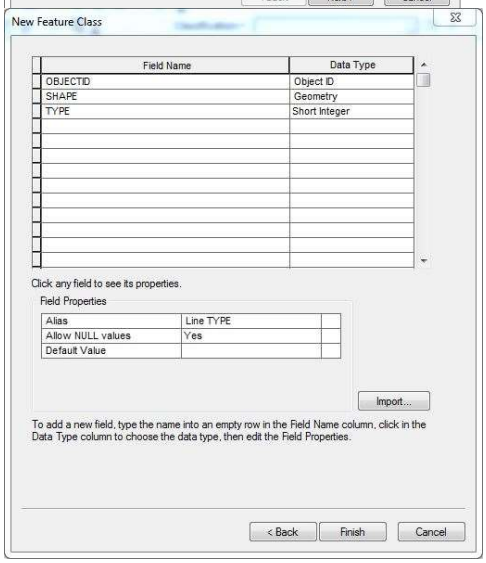
The next step is to create a feature class within the feature dataset you just created.

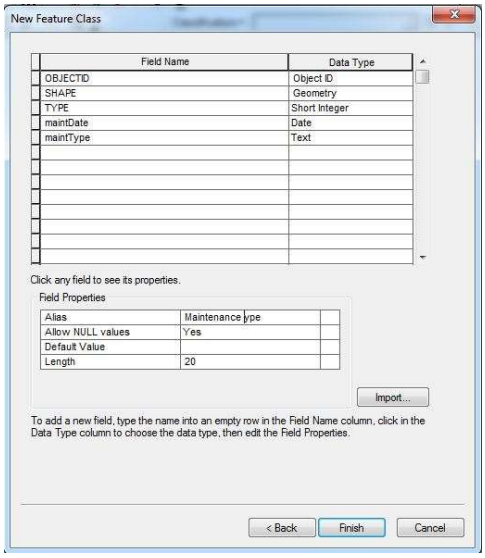
- Right-click on the Utilities feature dataset and choose New → Feature Class. Name the feature class *pipes* and give in an Alias (alternative name) *Water pipes*. This will be a vector layer with lines representing a pipe network, so chose Line Features for the type of features. Be sure that the Geometry Properties boxes are unchecked.
- Click Next.
- For the Configuration Keyword page, accept the default by clicking Next, which brings you to the attributes page.



We need to define several attributes for the pipes feature class.

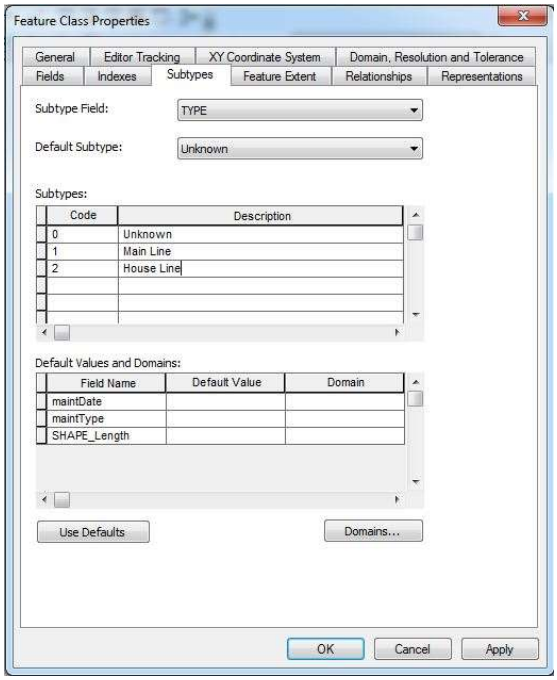
- In the Field Name column, first blank row (row 3), enter the value "Type". In the Data Type column, click the cell below Geometry (row 3) and use the pop-up menu to select "Short Integer". Left-click the cell so that window of Field Properties is visible, and change alias to "Line Type".
- Repeat the same steps to add a field called "maintDate" with a "Date" data type. In the Field Properties change the Alias to "Maintenance Date".
- Repeat the same steps to add a field called "maintType" with a "Text" data type. In the Field Properties change the Alias to "Maintenance Type". Specify the Length field as "20".
- Click Finish. Notice that the pipes feature class is added to your TOC. There is nothing drawn in the map, though, because this feature class is empty – you will have to digitize the features.
- Right-click on pipes (under the Utilities feature dataset) and open Properties. Click the Subtypes tab. We will set up "subtypes" that link integer codes in a field to text descriptions via a lookup. For Subtype Field, use the pop-up menu to select the "Type"





field. Only "Type" is available because it is the only field that we created that has integer values. Set up the subtypes for the Type field in pipes using the table below. You do this by clicking in the Code and Description boxes and then type their values. Your subtype definitions should look like the figureon the right.

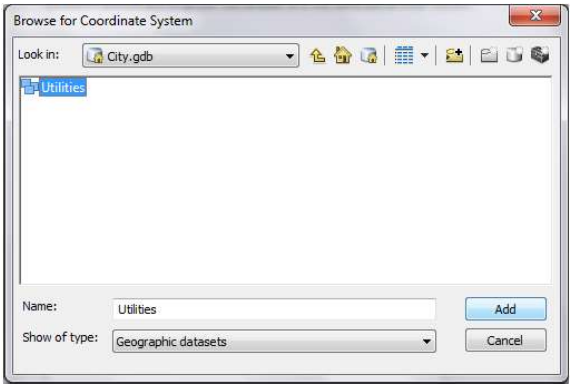
Code	Description
0	Unknown
1	Main line
2	House line



This process will allow you to choose between 3 types of pipes when you have digitized new a line segment (Unknown, Main line or House line). No other values will be permitted for the Type attribute. When you are done, click OK to close the window and finish creating your new pipes feature class.

Now create another feature dataset.

- Right-click on the City geodatabase and choose New → Feature Dataset, and name it LandUse. Click Next. The spatial reference must also be set. It needs to be the same projected coordinate system as we used for the *Utilities*feature dataset. This time you can simply import these parameters from Utilities rather than setting them manually again.
- Click on the Import button, browse through the files for your Utilities feature dataset inside the City geodatabase, and Add it. The Coordinate System is updated to match Utilities.
- Click Next, then click Next again and Finish to finish creating the LandUse feature dataset.

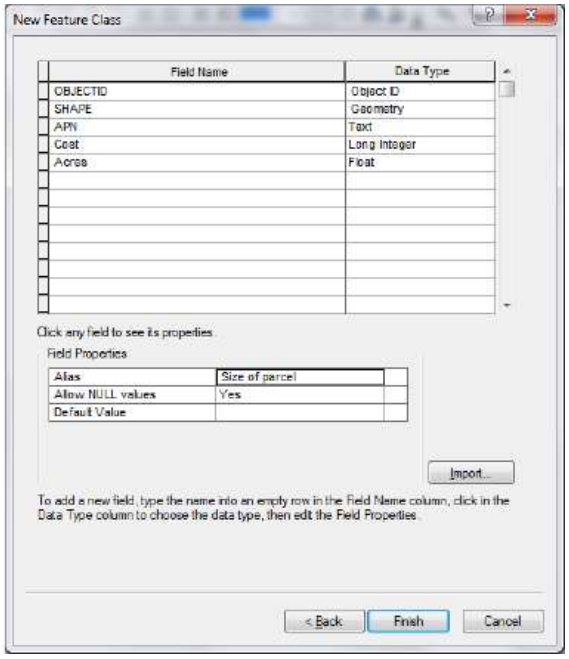


Create a new feature class called parcels in the LandUse feature dataset.

- Right-click on the LandUse feature dataset you just created, go to New → Feature class, and name it *parcels*. This will be a vector layer with polygons representing parcels, so chose Polygon Features for the type of features. Be sure that the Geometry Properties boxes are unchecked. Click Next.

Using your skills from setting up pipes, define the attribute fields as follows:

- Add a field called "APN" with a "Text" data type. In the Field Properties change the Alias to "Assessor parcel number". Specify the Length field as "15".
- Add a field called "Cost" with a "Long Integer" data type. In the Field Properties change the Alias to "Land value (in dollars)".
- Add a field called "Acres" with a "Float" data type. In the Field Properties change the Alias "Size of parcel".
- Click Finish.



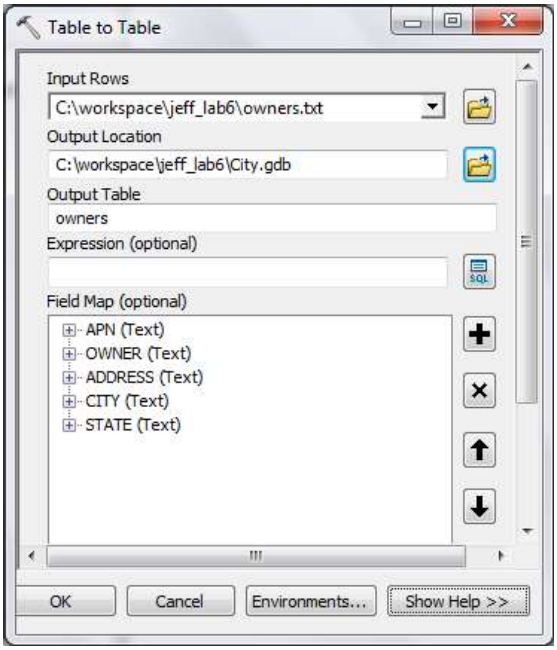
You should have the following feature datasets and feature classes in your City geodatabase, as seen in the screenshot from Catalog below.



Import an Attribute Table

Now we will import a table from the owners.txt file, which is an ASCII text file.

- Right-click on owners.txt.
- Choose Export → To Geodatabase (single). This brings up the Table to Table window. The Output Location should be your City geodatabase.
- Type in owners as the Output Table name.
- Click OK.



Task # 2: Georeference the Scanned Map

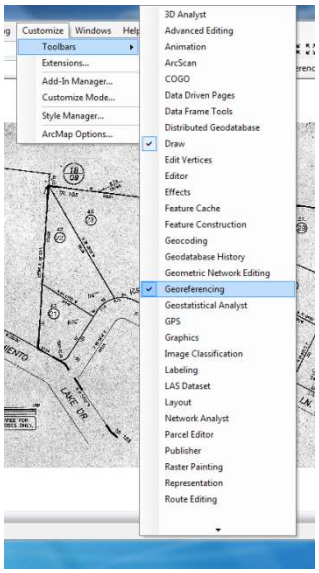
GIS users often perform "heads-up" digitizing wherein they use a pre-existing map layer or image as a guide for manually digitizing a new GIS layer. You will now prepare just such a background image that you will then use to guide you in digitizing a land parcel feature class.

2.1 Preparing for georeferencing

The scanned map that you have received is not registered to any coordinate system. In order to digitize using the scanned map as a guide, you will need to place it in its appropriate geographic location. We will do this in ArcMap.

- Open ArcMap
- Add the parcel.tifraster layer.
  Move your mouse around the scanned image and notice that the coordinates given in the lower-right corner of the ArcMap window are not what they should be for California.
- Open the Properties of parcels.tifin the TOC and go to the Source tab. Study the information in this source tab.

  In order to use the image with the *City*geodatabase, it must be registered to the same coordinate system as is set for the *Utility* and *LandUse* feature datasets in your geodatabase. This will not only place the scanned image within the boundaries of the feature datasets in the geodatabase, but will also assign correct spatial referencing information.
- Set the projection for your ArcMap session.
  - Right-click on the data frame ("Layer") and choose Properties, then click on the Coordinate System tab. Import the projected coordinate system information from either the LandUse orUtilities feature datasets. Save your map document at this point.
- ArcGIS comes with a Georeferencing toolbar to georeference feature classes. Load the toolbar by selecting Customize → Toolbars → Georeferencing



You will see a toolbar that looks like this:



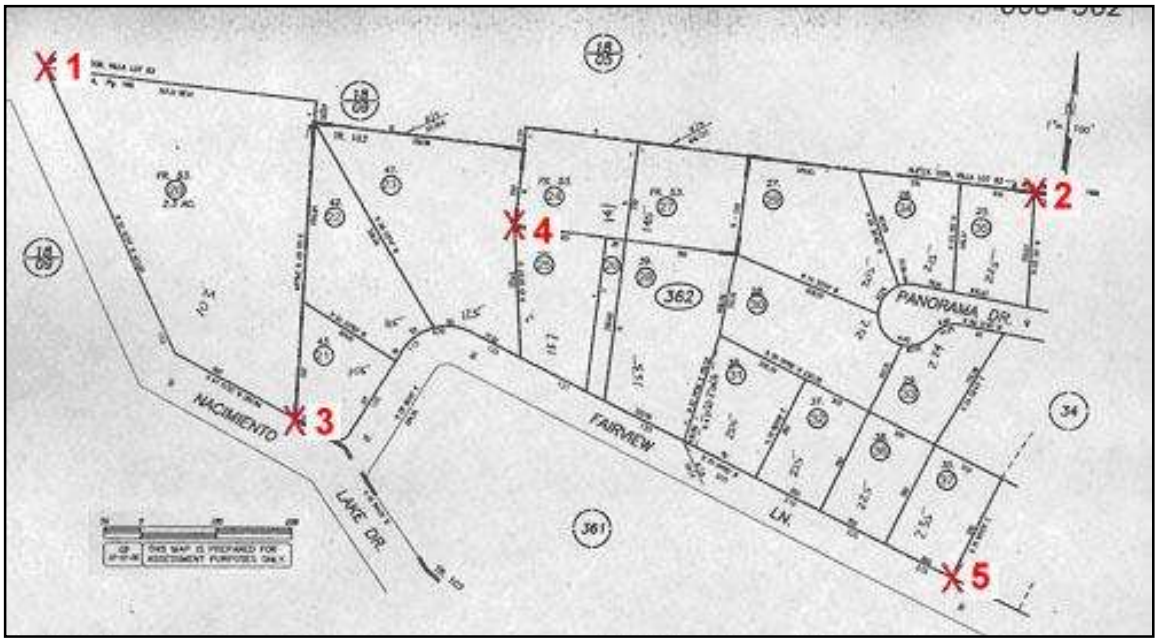
To georeference data you simply need to create a table of origin points and destination points -- matching specific points on the map (source coordinates) with their real-world coordinates (target coordinates).

2.2 Georeferencing the parcel raster

Georeferencing the parcel.tif raster scanned map involves selecting control points on the image (source) that can be referenced to the real-world geographic or projected coordinate system(target). This can be done in two main ways:

1. If you have another, coincident GIS layer (e.g. streets) that already has a coordinate system defined, you can match up selected locations (control points) on the scanned raster with the corresponding locations in that GIS layer.
2. If you do not have another GIS layer, you can use a GPS to find the coordinates of the selected locations in the field and then input those coordinates for matching points in the scanned raster.

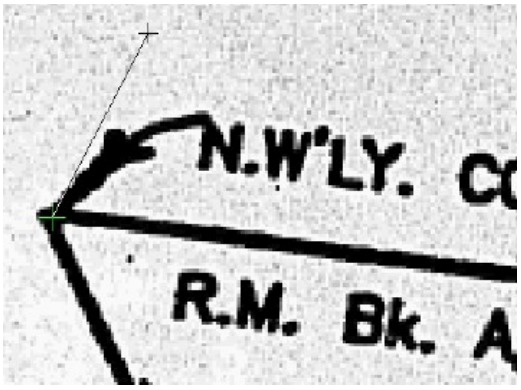
In this exercise we will use second option and the required GPS coordinates are already available. You will use five control points thathave been preselected (see image below).



Zoom into the first point (X1 in the image above). To georeference the image, click on the "Addcontrol points" button on the georeferencing toolbar. Your mouse pointer will turn intocrosshairs.

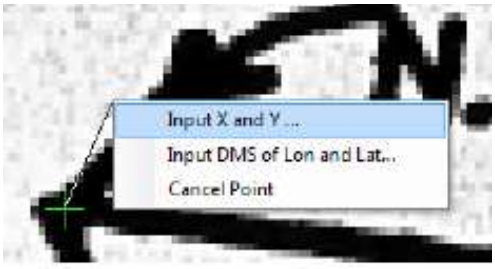


Place the crosshairs on the intersection of the two lines. When you left-click the mouse button, you will set the X and Y coordinates for your source data. When you move the mouse off of that point, it will have a line connected to the point on the source, scanned map.



If you had a reference GIS layer (such as the streets data mentioned above) you would simply zoom to the reference layer and click on the corresponding location. The coordinate information for both of these points would then be added to the "link table", which lists all of the control points and their correct referenced location.

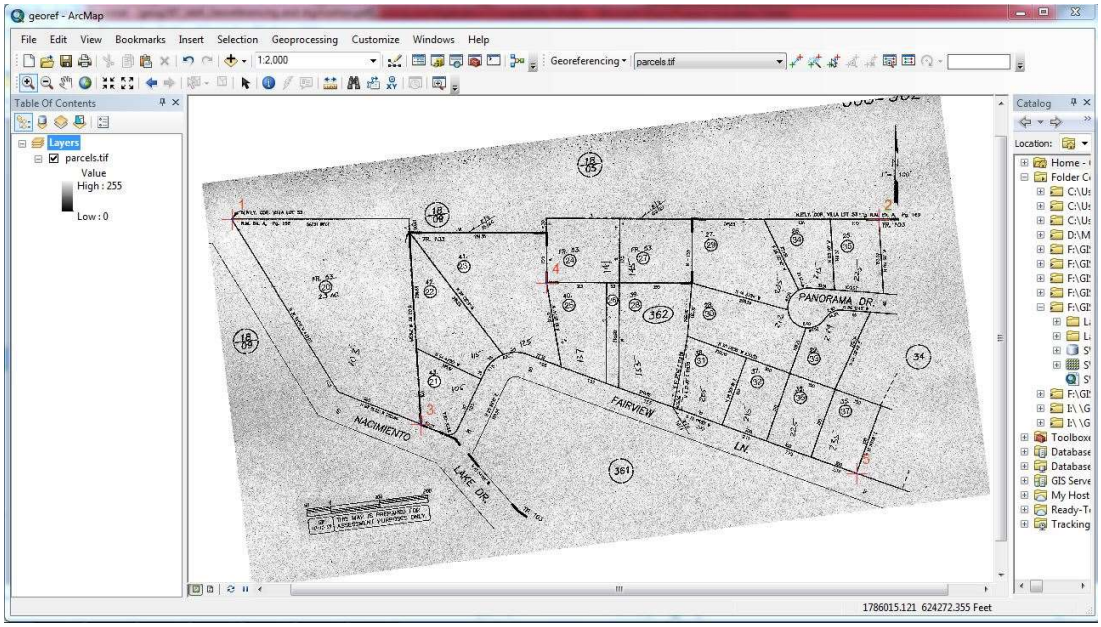
Since you do not have a reference GIS layer, you must manually input GPS data that has been gathered for you. After clicking on the first control point, right-click and select "Input X and Y."



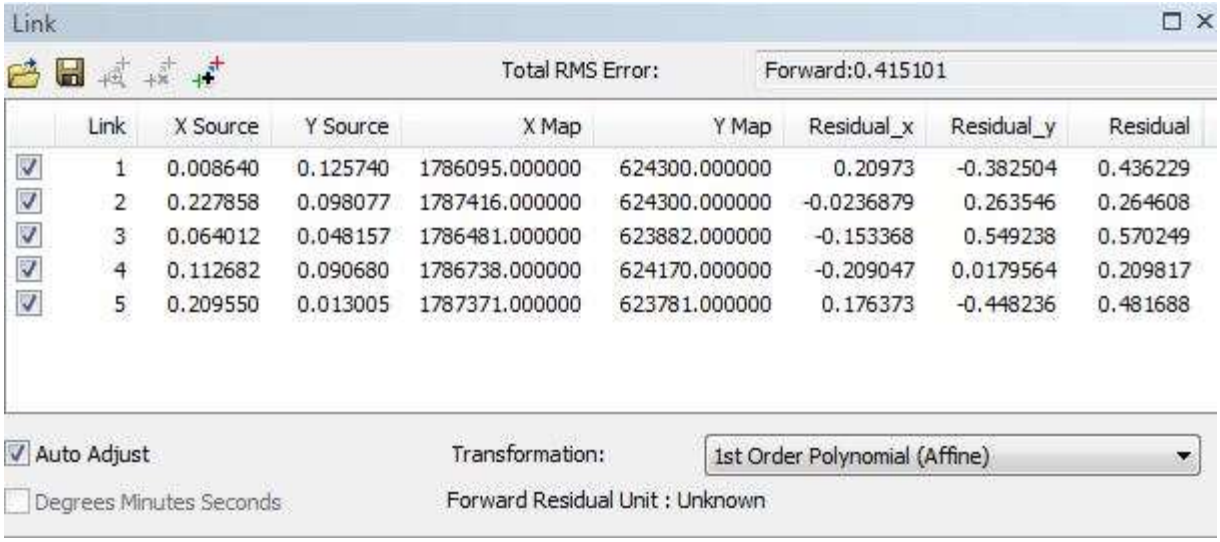
This will open a window for you to enter the GPS x,y coordinates for that control point. For each of the control points, you will enter California State Plane coordinate data using the following table:

Control point	GPS X coordinate	GPS Y coordinate
X1	1786095	624300
X2	1787416	624300
X3	1786481	623882
X4	1786738	624170
X5	1787371	623781

As you enter the data, the raster will automatically move to fit the new coordinates. If the raster moves offscreen, click on the Full Extent tool  on the main toolbar to shift the display to the raster's new location. Continue to digitize and enter GPS coordinates for all five control points.



This window shows you the control point number (e.g., Link 1, etc.), the source coordinates, the GPS State Plane map coordinates (target), and the residual error of the georeferencing equation. Notice that the equation is using a 1st Order Polynomial, also called an Affine transformation. This is the least-complicated transformation and can perform **translation**, **scaling** and **rotation** of our raster image. The parameters for the transformation equation are estimated from your digitized points and the associated GPS coordinates. If there are errors in your point selection on the screen (source coordinates) or in the GPS measurements (e.g., from range errors), then the transformation will be less accurate. The residual gives you an idea of how much error each point contributes to the overall transformation equation.



Link	X Source	Y Source	X Map	Y Map	Residual_x	Residual_y	Residual
1	0.008640	0.125740	1786095.000000	624300.000000	0.20973	-0.382504	0.436229
2	0.227858	0.098077	1787416.000000	624300.000000	-0.0236879	0.263546	0.264608
3	0.064012	0.048157	1786481.000000	623882.000000	-0.153368	0.549238	0.570249
4	0.112682	0.090680	1786738.000000	624170.000000	-0.209047	0.0179564	0.209817
5	0.209550	0.013005	1787371.000000	623781.000000	0.176373	-0.448236	0.481688

Save your table to an ASCII text file with the Save button in the Link Table window. Pick an appropriate file name, with your last name first (e.g., links.txt). Click OK.

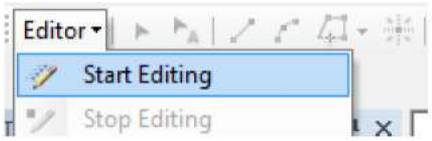
On the Georeferencing toolbar, click on Georeferencing → Update Georeferencing to save the parcels.tif raster's new, georeferenced coordinate system. Open the parcels.tif properties from the TOC to answer the following questions:

Task # 3: Digitization

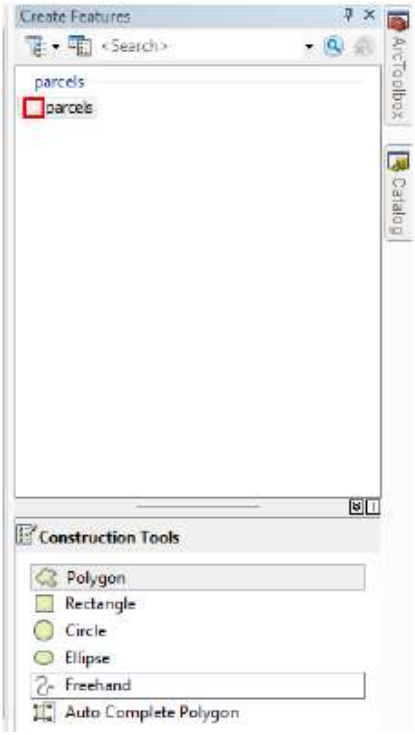
Now that you have a base image that has been georeferenced, you can digitize your parcel polygons from it and they will be in the correct coordinate system.This lab will only touch the basics of digitzation with these tools, and you are strongly encouraged to experiment on your own and read the ArcGIS help to learn more about its digitization capabilities.

Add the parcels feature class from your geodatabase. Turn it on in the TOC and be sure it is **on top of the raster**.

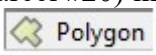
For digitization, you will need the **Editor Toolbar**. You can get this toolbar by clicking the button on the Editor Toolbar select **Editor → Start editing**.



You should see a new **Create Features window** appear on the right of ArcMap with your parcels polygon layer displayed. *For the digitization process, it is useful to make the polygon hollow with a bright and thick border.* In this screenshot, the parcels layer has been symbolized with a red outline width of 2. **The parcels seen in the Create Feature windows has been imported as a "feature template", which provides automatic symbolization for any features that you decide to digitize.** If you have many feature classes in the TOC, you would have multiple feature templates, with their corresponding symbology, from which you could digitize new features. In our case, we only have one layer in the TOC, and so there is just one type of feature template.



Notice that there is a bottom window called **Construction Tools**. If needed, use the middle handle between the windows to make the Construction Tools window tall enough to show all six available tools, as shown in the screenshot above.

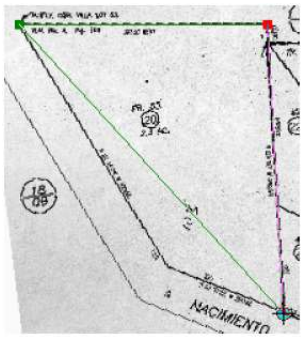
To digitize a polygon for one parcel, first zoom in to the first parcel (parcel #20) in the upper left corner of the scanned raster. Click on the **"Polygon"** construction tool 

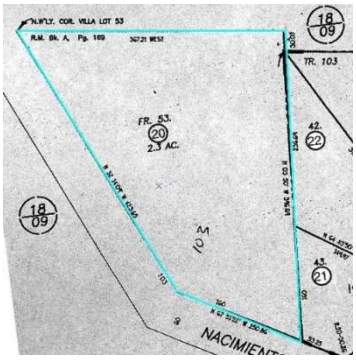
Notice that in the Editor Toolbar, a series of buttons are now available for **"segment construction"**.



The default segment construction method is "Straight Segment". **Note that all of these segment construction buttons were unavailable (gray colored) before you select a feature construction tool** – in this case, you selected Polygon.

With the Straight Segment tool selected, digitize a polygon by clicking in succession on the upper-left corner, the upper-right corner, and the lower-right corner of the parcel. Notice that a triangular polygon has been created based on these 3 points.

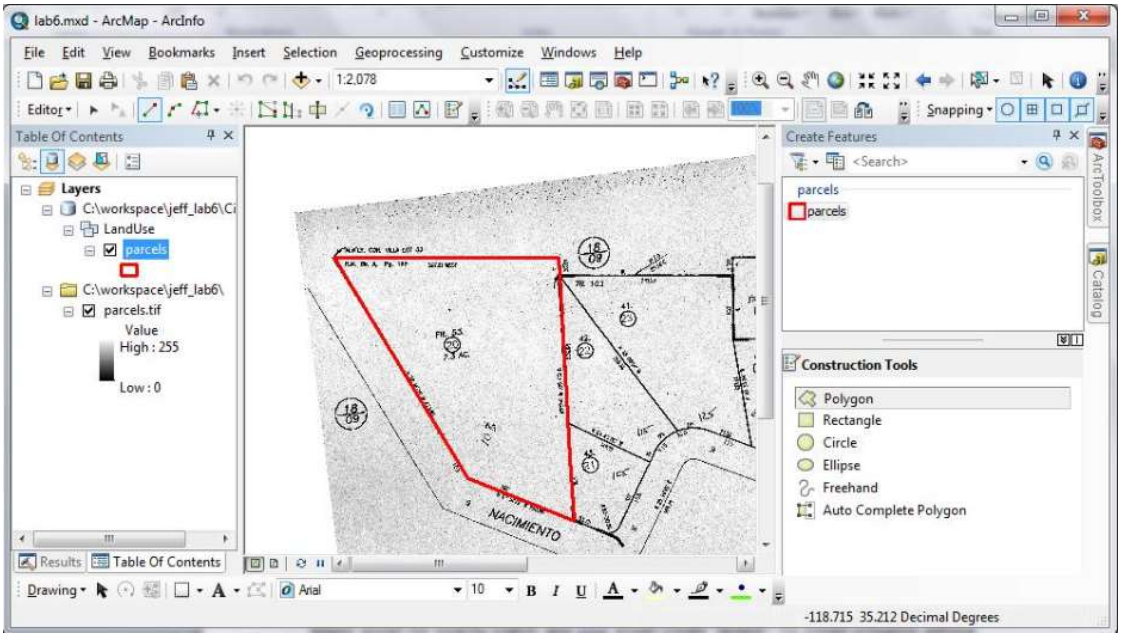




Finally double-click on the lower-left corner of the parcel (below the diagonal of the triangle) to finish the polygon. Doing this will automatically snap the nodes. You should see a completed polygon with a cyan (light-blue) highlight color and possibly a fill color if you chose not to make the polygon have a hollow fill.

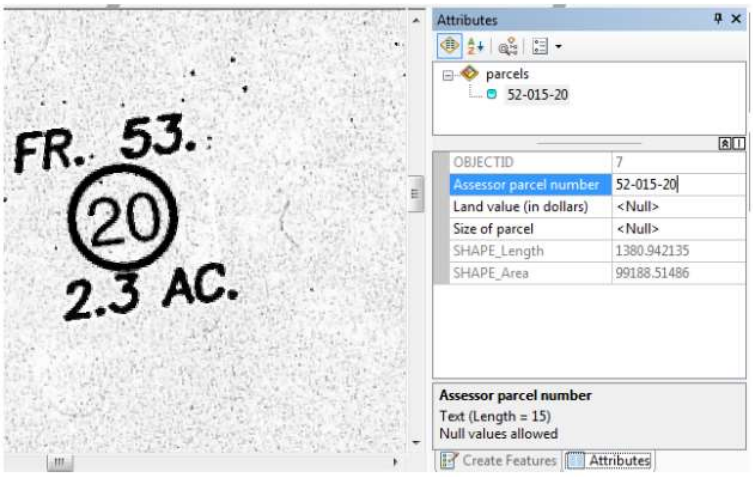
While you are digitizing, it is a good idea to periodically save your edits (Editor →Save edits).

The feature has a cyan outline because it is selected. You can deselect the feature by selecting the Edit Tool  and clicking anywhere on the display. You can also use this tool to select any polygon that has already been digitized. Once selected, the polygon can be deleted by pressing the Delete button on your keyboard. An existing polygon feature can also be edited (e.g., move, delete and add vertices) by double-clicking the desired polygon.



Select your polygon, if it isn't already selected, and enter its attribute information by clicking on the Attributes button  on the Editor Toolbar. The Assessor Parcel Number (APN) for each polygon will take the form: 52-015-parcel#, where parcel# is the number in the circle inside each polygon.

For example, the APN is 52-015-20 for the first digitized polygon. **We will leave the Cost and Acres attributes Null for now**. Notice that the attributes have full descriptions. For example, APN is described as "Assessor parcel number". Also notice that the character length allowed for APN is 15, as noted in the bottom of the Attributes window while entering a value for APN. The full descriptions and length were set by you when you created the parcels feature class. See screenshot on the right.

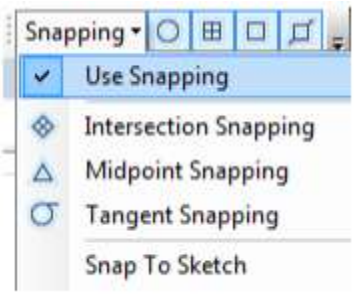


You now need to digitize the other parcel polygons. At this point it is helpful to unpin the Attributes window, by clicking the pin symbol in the upper-right of the window. You should now **click on** the hidden **Create Features window**.
You could digitize the adjacent polygons with the Polygon construction tool, the same way you did the first polygon. However, no matter how careful you are, the edges would not exactly match and you would create **"slivers".**
To create polygons without slivers and have planar topology, change the construction tool to "Auto Complete Polygon" . The **Auto Complete Polygon construction tool** will allow you to join new polygons to existing polygons so that they share borders without you having to digitize them multiple times. To make the process of joining polygons you should **turn on the "snapping" of features**.

Go to the **Editor → Snapping → Snapping Toolbar**. From the Snapping Toolbar, select the End, Vertex, and Edge boxes (Point is already selected by default). This will automatically "snap" the digitizing cursor to existing features.

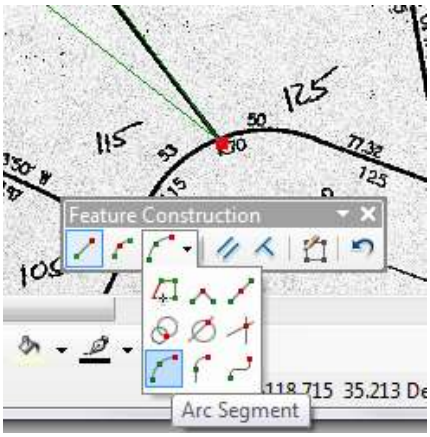


Click the Snapping menu on this toolbar and make sure that there is a **check next to "Use Snapping"** – we want to use snapping properties.



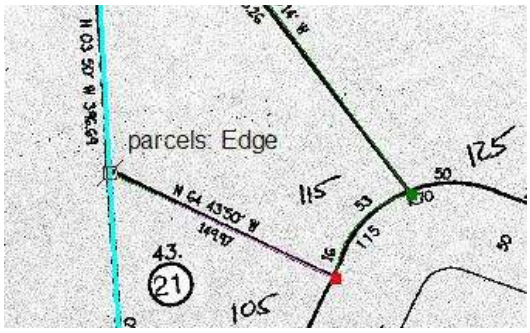
With the Autocomplete Polygon feature construction tool selected, you digitize the remaining polygons (the ones that are closed and that have small numbers within circles). **Since you are using Auto Complete Polygon you must start and end on the vertex, edge, or end of an existing polygon (this is where snapping is particularly helpful)**. As you digitize each polygon, you can enter the APN attribute as you did for the first polygon. If you prefer, you can enter the APN information for all of the polygons after you have finished digitizing. In this case, you would selected each polygon with the Edit Tool , then use the Attribute button .

On parts of the map where there are **curves in the polygon** that you are **digitizing**, you can use the **Arc Segment Tool**. You do this the first time by clicking the pop-up button in the floating Feature Construction Toolbar that appears when you digitize. Then select the Arc Segment tool See screenshot at right. From a starting vertex, click a mid-point for the arc, and then click a terminating vertex.



When you have digitized your arc segment, go back to the Straight Segment tool to finish your polygon.

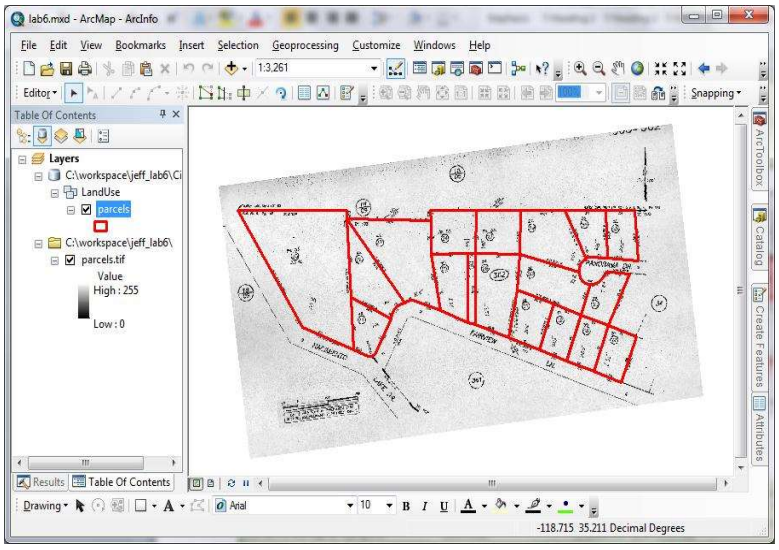
You can switch between tools as you digitize a polygon. When digitizing a linear section, use the Straight Segment tool, and then when you get to the curve, select the Arc Segment Tool and then digitize the curved part of the feature.



Note that Construction Tool window follows you when you digitize. You can click it and drag it out of the way, which is sometimes necessary. Also, all of the segment construction tools found in this floating window are also available in the Editor toolbar.



These tools are only available when you select a feature construction tool in the Create Features window (e.g., Autocomplete Polygon, Polygon, etc). So at times you may have to pop up the Create Features windows to reselect the feature construction tool. It takes time to get used to all the options available to you as you digitize features. Experiment and settle on a method that works best for you. At right, see a screenshot of what your digitized parcels should look like. If you did not already assign APNs to the polygons, do so now. **Be sure to save your edits!!**



Be sure to open your attribute table for parcels and verify that every polygon feature has an APN value. See screenshot below. Your object IDs and order will not match, as they are dependent on the order in which you digitize polygons; however, you should have the same range of APN codes as shown in the screenshot. If you do not, then resolve the problem before going forward in the lab.

Table

parcels

OBJECTID *	SHAPE *	Assessor parcel number	Land value (in
7	Polygon	52-015-20	<Null>
8	Polygon	52-015-22	<Null>
9	Polygon	52-015-23	<Null>
10	Polygon	52-015-25	<Null>
11	Polygon	52-015-21	<Null>
12	Polygon	52-015-26	<Null>
13	Polygon	52-015-28	<Null>
14	Polygon	52-015-31	<Null>
15	Polygon	52-015-32	<Null>
16	Polygon	52-015-36	<Null>
17	Polygon	52-015-37	<Null>
19	Polygon	52-015-33	<Null>
20	Polygon	52-015-30	<Null>
23	Polygon	52-015-29	<Null>
24	Polygon	52-015-34	<Null>
25	Polygon	52-015-35	<Null>
26	Polygon	52-015-24	<Null>
27	Polygon	52-015-27	<Null>

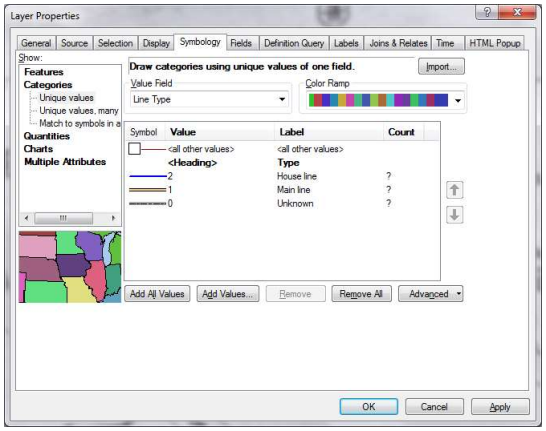
Task # 4: Calculation of Attributes

There are still two fields that do not have attributes -- Cost and Acres. The georeferenced data are in feet (State Plane projection), so the Shape_Area calculation that is automatically computed for the polygons will be in square feet. There are 43560 square feet in an acre. You can use this information to calculate the acreage for each of the polygons. Make sure that no records are selected in the parcels feature class (on the main ArcMap menu click on Selection → Clear Selected Features).

- Calculate the Acres (alias "Size of parcel") based on the Shape_Area attribute. This entails using the Field Calculator. Alternatively, you could use the Calculate Geometry tool.
- Property value is based on size of parcel and is $300,000 per acre. Use the Field Calculator to perform this calculation in the Land Value field. Save your edits to the table: Editor Toolbar → Stop Editing.

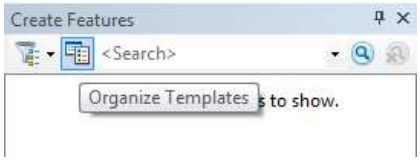
Task # 5: Digitize a Basic Pipe Network

Now you have to digitize the pipes that will connect to each parcel and form a water network. Turn off the parcels feature class in the TOC. Add the pipes feature class from the Utilities feature dataset. Turn on pipes in the TOC.

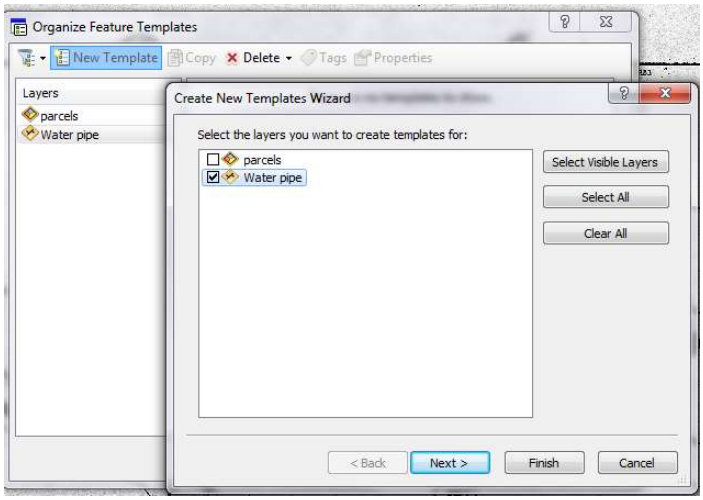


Change the symbology for the different kinds of pipes (Line Type field). When you select a symbol for editing, in the Symbol Selector there is an option for Style References. From this you can select from a wide variety of themed symbol sets -- including Water/Wastewater. Also, you can turn off the "All other values" class by unchecking its box in the Symbology tab. An example of symbology for the pipe types is shown here.

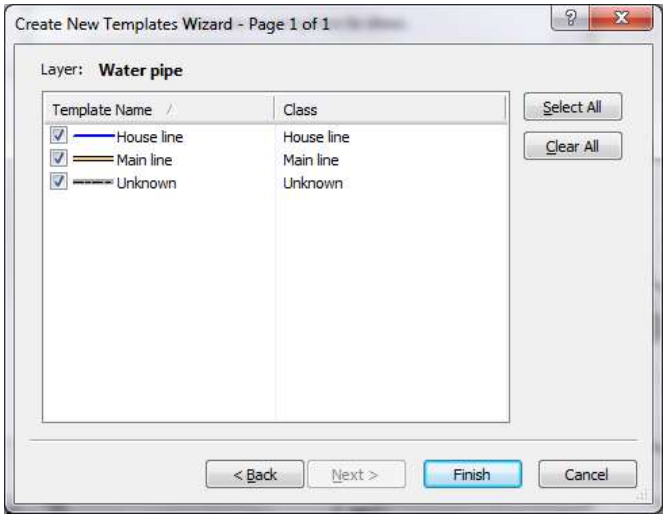
Start by selecting Editor → Start Editing. The **Create Features** window should appear on the right. In this case, there are multiple symbols in pipes to choose from, and before you can see these pipe types as templates for digitization, you have to create a **"template"** for the layer. You do this by clicking the **Organize Templates** button in the Create Features window.



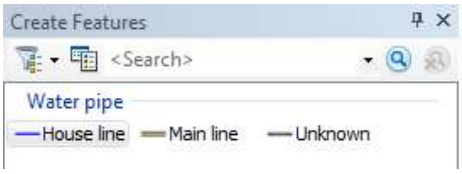
Select New Template, which then opens a Create New **Template Wizard window**. Check Water pipe. Be sure parcels is unchecked (we already have a template for parcels from earlier in the lab). Click Next.



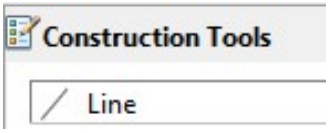
Be sure all of the Water pipe classes are checked, as shown in the screenshot below.



Now click Finish. Close the Organize Feature Templates window. There should now be three types of water pipes to choose from in the Create Features window, and they have acquired the symbology that you set in the TOC.

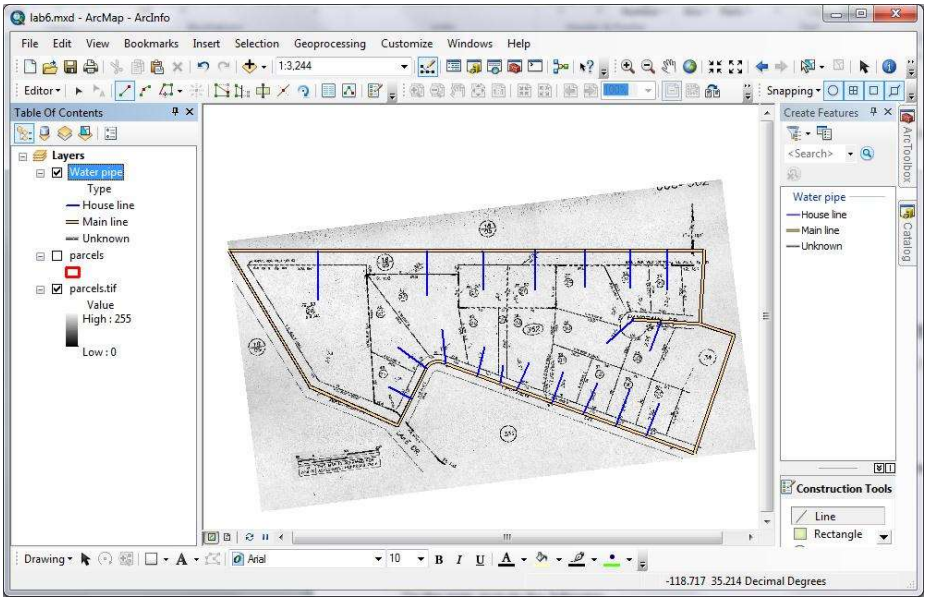


Click on your desired water pipe template, and then use the Line construction tool to digitize your pipes. Be sure to save your digitized pipes as you go along. The only rules guiding your design are:



- Main pipes can only run down the middle of streets. (You can consider the blank area at the top of the scanned map to be a street.)
- Each parcel must have at least one house water line
- There should be no "unknown" pipe types when you are done digitizing

An example of a digitized network is shown in the screenshot below. Your network does not need to look like this example.



When you are satisfied with your pipe network, stop editing with Editor → Stop Editing.