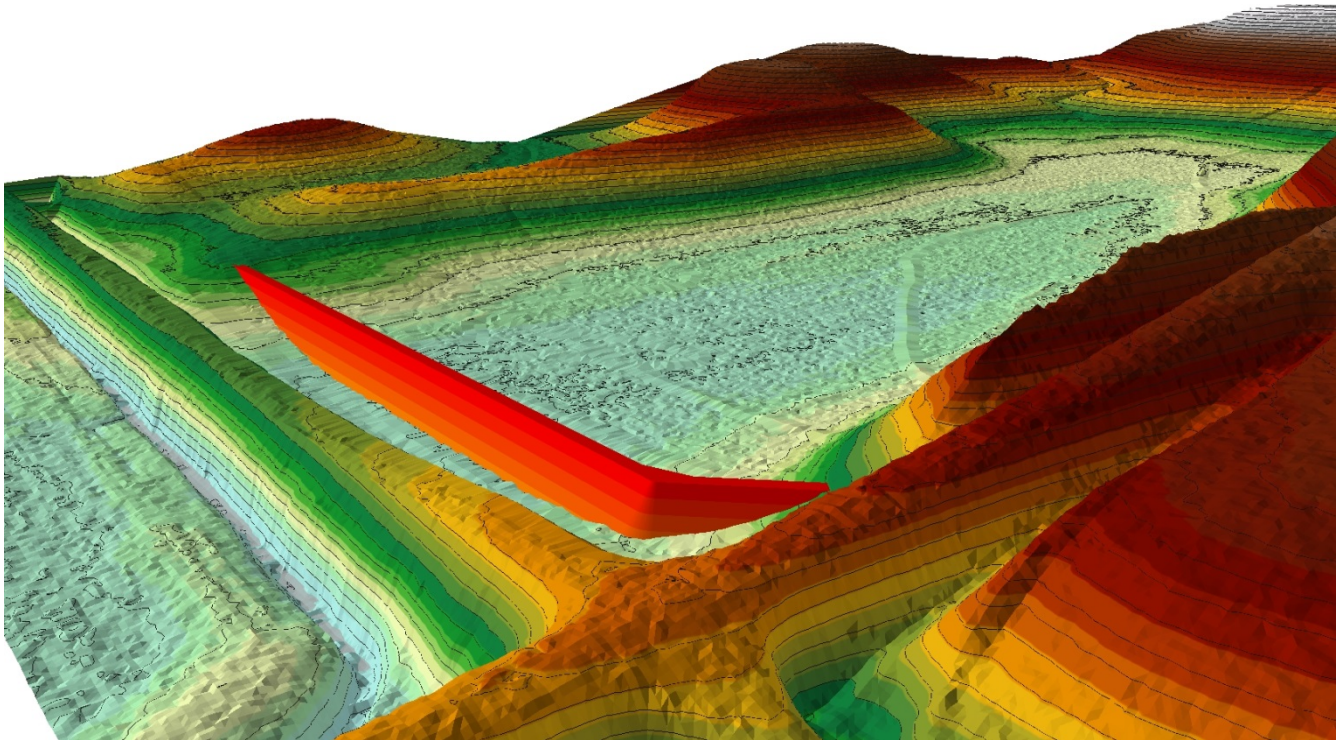


# Using LIDAR to Design Embankments in ArcGIS




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Windom Wetland Management District**

This tutorial covers the basics of how to design a dike, embankment or spillway in ArcGIS using a TIN (Triangular Irregular Network) file from LIDAR data in MN. You can do this process from any set of elevation data such as a GPS survey once it is converted into a 3D terrain surface called a TIN file. For more information on using data from a GPS see the supplemental tutorial called Trimble R8 Survey to ArcGIS Import.

*Last Updated February 2015*

1. Obtaining LIDAR data: *(Skip to Section 2 if you already have data for your county or skip to Section 7 if you have GPS Data already in a 3d TIN surface from the Trimble R8 Tutorial)*
  - a. This example is specific for users in MN. For other location you will have to consult your local resources to find if LIDAR data is available in your area or use GPS survey data you collected.
  - b. Go to <http://www.mngeo.state.mn.us/chouse/elevation/lidar.html>
  - c. Scroll down to Data Download and click on the link MNGeo's FTP Site
  - d. In the FTP Directory Click on the "County" Folder


Index of <ftp://ftp.lmic.state.mn.us/pub/data/elevation/lidar/>












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Name	Size	Last Modified
 LAS_File_Processing_Using_LASTOOLS.pdf	696 KB	12/26/2012 12:00:00 AM
 about_this_data.rtf	44 KB	3/27/2012 12:00:00 AM
 county		5/20/2014 12:00:00 AM
 county_mosaic_readme_first.rtf	643 KB	6/29/2012 12:00:00 AM
 documentation		4/28/2014 12:00:00 AM

- e. Then Click on the County you are working in
- f. Within the county folder there is a file called "elevation\_data.gdb.zip". Click on it and download it. This is a geodatabase with LIDAR for the entire county.

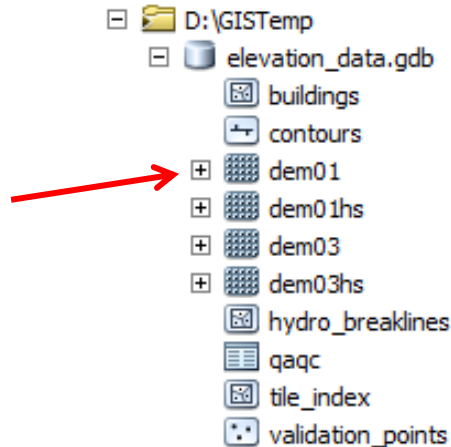
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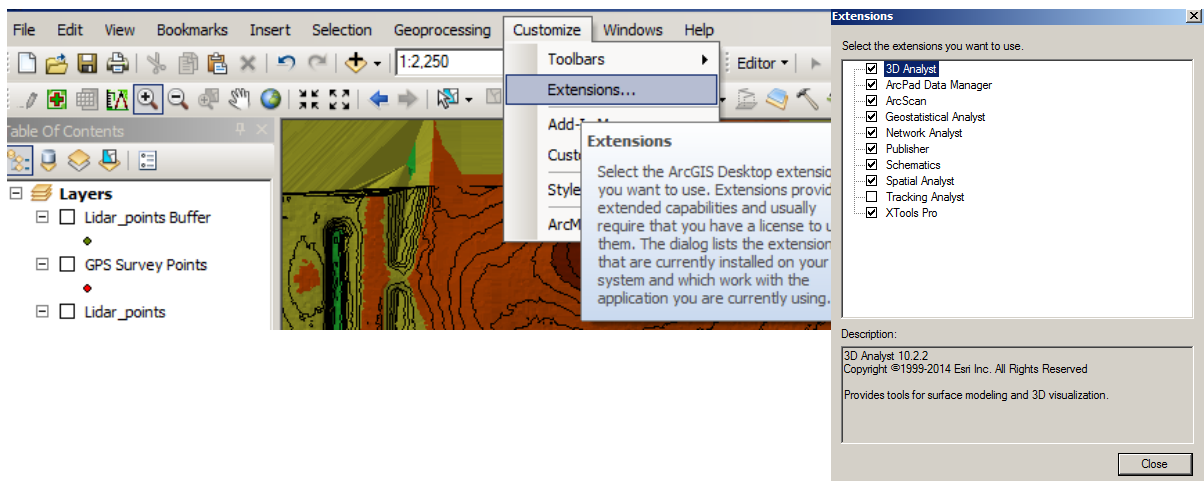
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 murray_county_validation_report.pdf	531 KB	6/8/2011 12:00:00 AM
 tile_index_map.pdf	1988 KB	8/10/2012 12:00:00 AM

- g. These are large files and will take time to download. At times the internet connection through a VPN like many USFWS offices is slower. Private home DSL networks may download significantly faster and data can then be transferred back to office servers via a large flash drive or external hard drive.
- h. Once downloaded, unzip the file and store it on your server or other location you keep GIS data.
- i. Rename the file. By default it is "elevation\_data.gdb" I would suggest renaming it to the county it belongs to such as "Countyname\_LIDAR.gdb"
- j. On the Server it will be a geodatabase file so nothing really usable in the folder. It can only be opened and viewed in ArcGIS.

- k. If you open ArcMap and hit Add data button and navigate to your new LIDAR file you will see several files within the geodatabase. The only file you really need is the DEM01 file. If you need to save server space you can delete the other files.

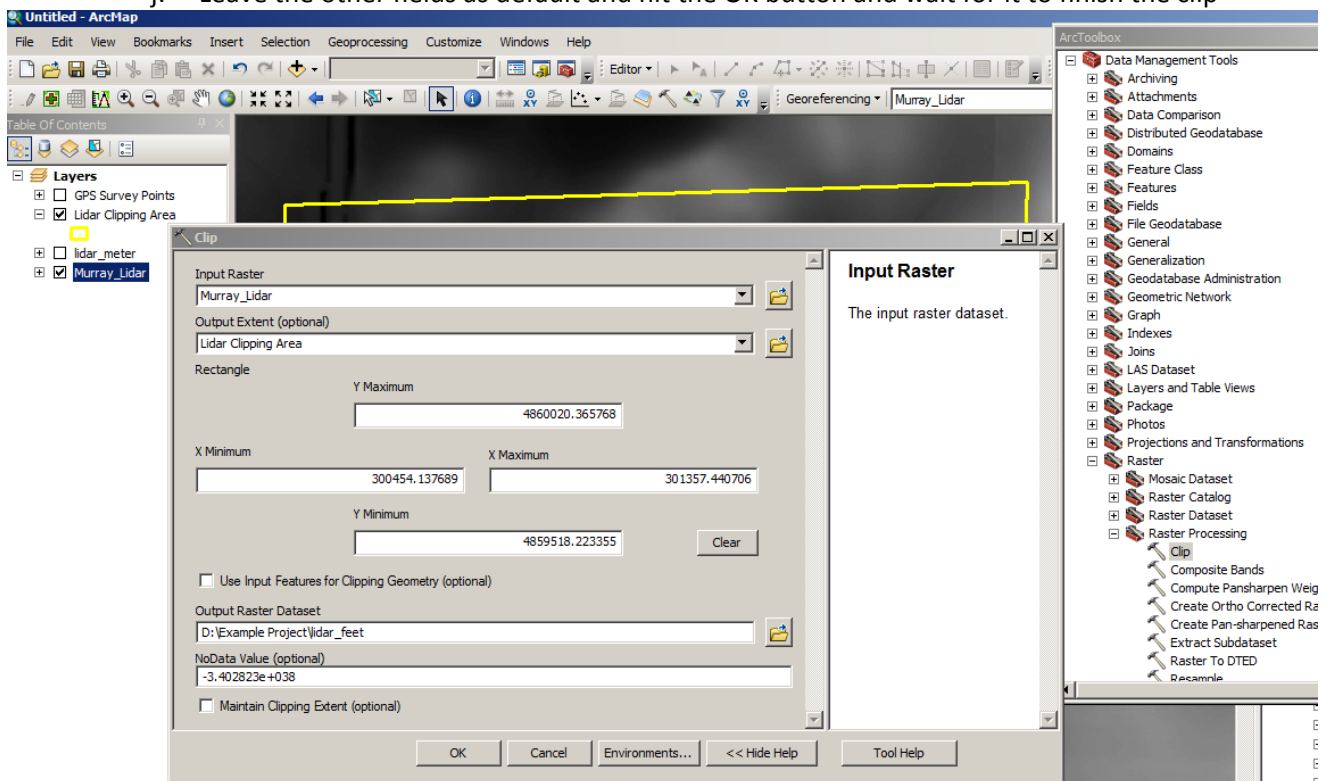


- l. DEM01 is a “Digital Elevation Model” with 1meter resolution which means that if you zoom in close enough to see individual square pixels that make up the image, each square represents 1 square meter on the ground and the value for that pixel is the mean sea level elevation measures in meters.
- m. On hard clear surfaces like crop or short grassland LIDAR is usually within about 6 inches of survey GPS elevation. Less confidence in heavy vegetation like trees & wetlands. It will generally error on the side of over estimating elevation due to a return from hitting an obstruction like vegetation. LIDAR does not penetrate water so will return the water surface only.
- n. Make sure you have the spatial analyst and 3d analyst extensions in ArcMap enabled. On the top menu bar go to Customize, Extensions then check the boxes on all extensions you need.



2. Clip LIDAR to your work area:
  - a. County LIDAR files are large. It will be cumbersome and slow to try to work on the entire county dataset and may result in computer crashes or freeze. Clip out only the area you need such as the watershed area for your wetland basin.
  - b. Open ArcMap

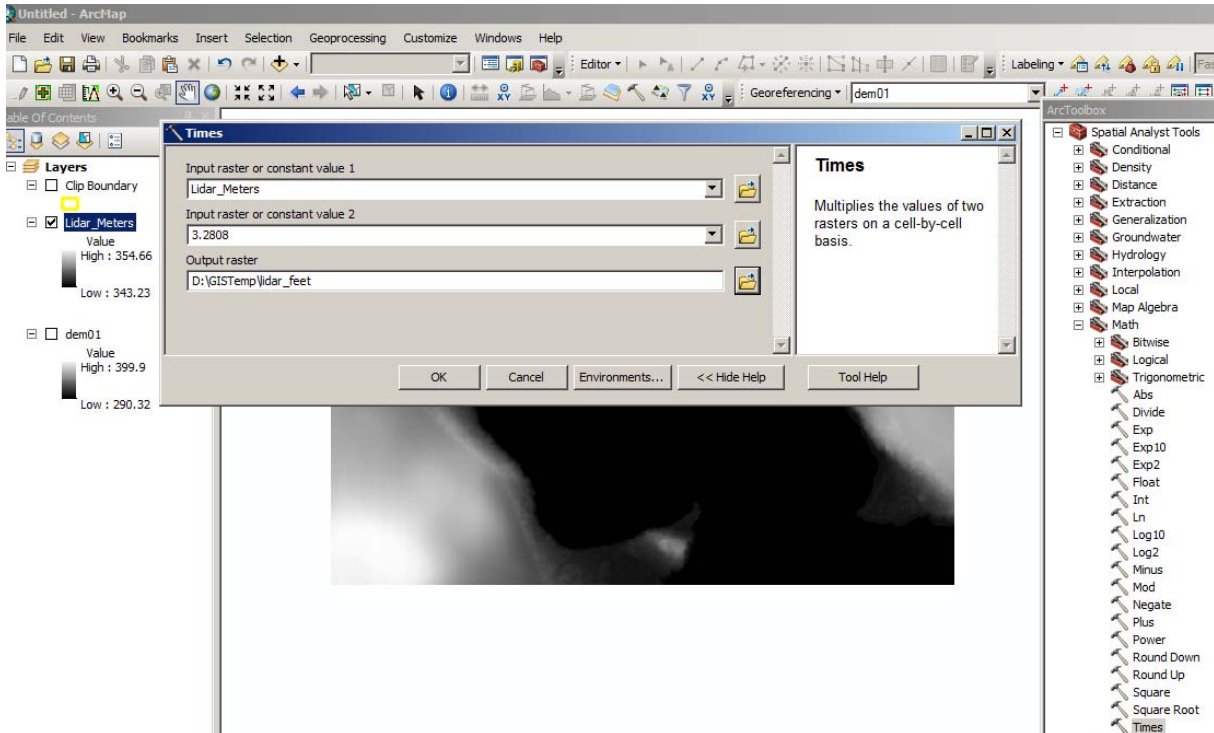
- c. Add whatever data is relevant to you project including the dem01 Lidar file from the county.
- d. You will need a layer that defines your work area such as a project boundary shapefile. If you don't already have one then create a new shapefile, start editing it and draw your work boundary. In this step we will clip the Lidar based on your shapefile so if you have multiple polygons in the shapefile be aware it will clip to the maximum extent covered by all polygons in that shapefile. It is best to use a dedicated shapefile with only one polygon that defines the area you want to clip.
- e. Open ArcToolbox (Red Toolbox icon on your top taskbar)
- f. In ArcToolbox go to Data Management Tools > Raster > Raster Processing > Clip
- g. The input Raster is the Lidar layer for the county you are in. You can drag and drop into the blank or use the drop down list and scroll down to the right layer. Otherwise you can also brows to the county LIDAR layer using the folder button
- h. The Output Extent is the analysis work boundary layer you created earlier (your cookie cutter). You can again drag and drop the layer or use the dropdown list or browse to it.
- i. The Output Raster Dataset is wherever you want to save the data and whatever name you want to give it. I would suggest something simple and descriptive such as LIDAR\_meters.
- j. Leave the other fields as default and hit the OK button and wait for it to finish the clip



3. Convert Units: Raw LIDAR data may be in meters. We will use the data in meters at a later point but for much of the design work it may be more useful in feet. *(Skip this section if you don't need unit conversion)*
  - a. Open ArcToolbox from the red toolbox icon on the top toolbar.
  - b. Go to Spatial Analyst Tools > Math > Times
  - c. Input Raster is the LIDAR file you just clipped
  - d. Constant value is 3.2808 (Conversion factor for meters to feet)

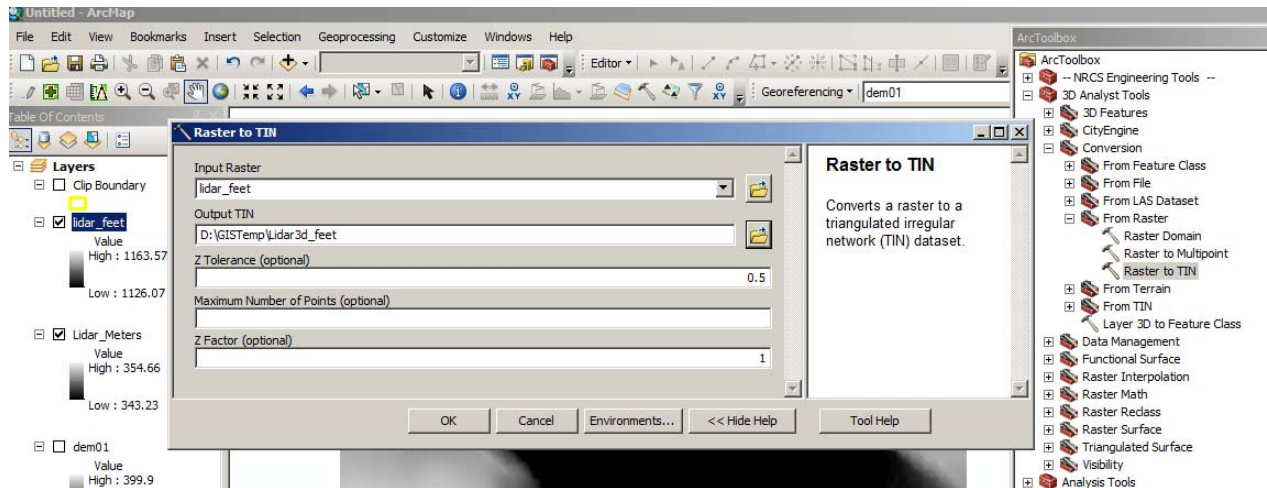


- e. Output raster is wherever you want to save it and what you want to name it. I would suggest simple naming such as LIDAR\_feet
- f. Press OK



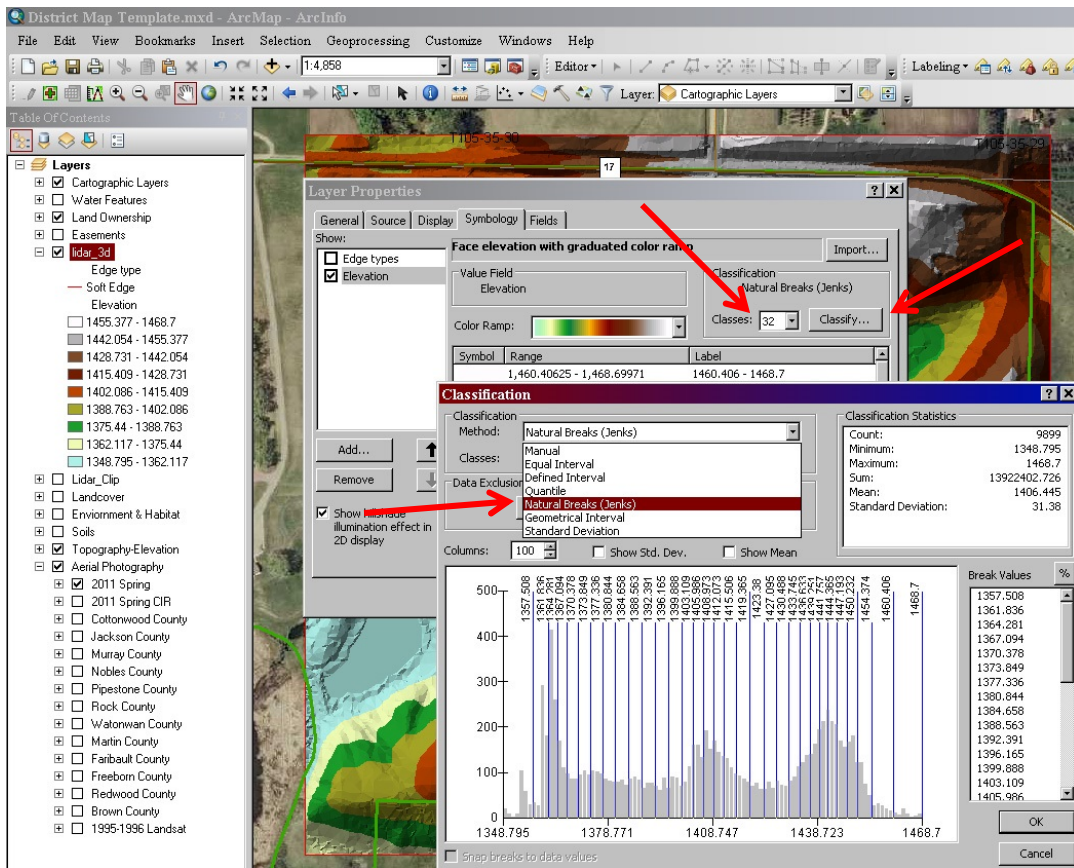
#### 4. Create a TIN/ 3D Terrain model

- a. The raw LIDAR is usable but not visually appealing so a 3D Terrain image called a TIN (Triangular Irregular Network) is much easier to look at.
- b. Again open ArcToolbox (Red toolbox icon)
- c. In ArcToolbox go to 3D Analysis Tools > Conversion > From Raster > Raster to TIN
- d. Input Raster is the Lidar layer you just clipped and converted units such as LIDAR\_Feet (Drag and drop, use the drop down list or browse to it)
- e. Output TIN is the location and filename you want to give the new layer such as LIDAR3d\_feet
- f. Z Tolerance is the accuracy vs. the smoothing & generalization, generally we want the 3d terrain to follow very accurate to the original LIDAR data so use a value of 0.5 but if you have issue of too large of file sizes or don't need exact detail use the default or pick a different higher number.
- g. Maximum points leave blank.
- h. Z Factor is 1 unless for some reason you want to amplify your terrain in which case elevations will be multiplied by whatever factor you put in. This field could also be used for doing unit conversions.
- i. Hit the OK button to Create your TIN
- j. Repeat this process but use the LIDAR\_meters input instead and name the output Lidar3d\_meters. You will use the Meters version at a later point for calculating dike volume.



## 5. Displaying your TIN

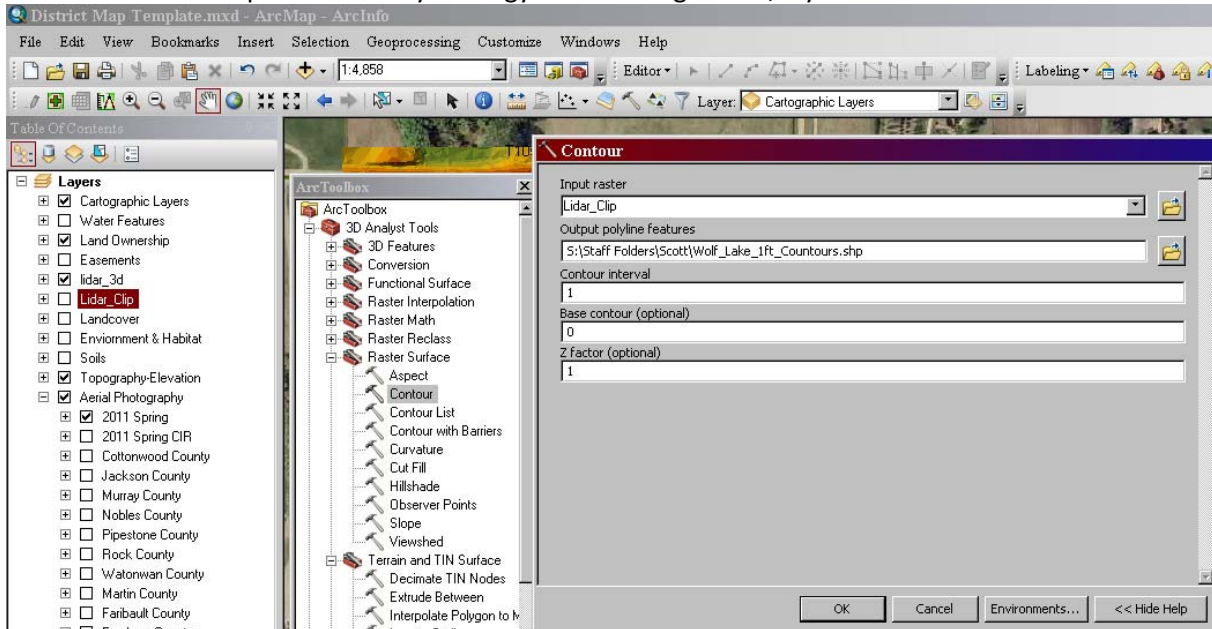
- a. Generally the greater the color gradation the better the visual display of elevation data.
- b. Double click on your new TIN/3D Layer or right click and choose properties
- c. Look under the Symbology tab and highlight Elevation under the Show Box.
  - i. Choose your color Ramp, which the default generally works the best (White, brown, red, yellow, green blue)
  - ii. Under classes choose 32 which is the maximum unless you don't want as much color gradation
  - iii. Hit the Classify button and choose Natural Breaks which will put more gradations in areas that have closer elevations to help differentiate change.
  - iv. Sometimes the color ramp gets flipped so make sure under the default color scheme that white is your highest elevation and blue is the lowest. If it is backward, right click over top of the colors in the symbol column and choose "Flip Symbols".
- d. Under the display tab there is an option for transparency if you want to see an air photo through the Tin as well.
- e. Hit the OK button when you finish setting up your display.



## 6. Create Contour Lines

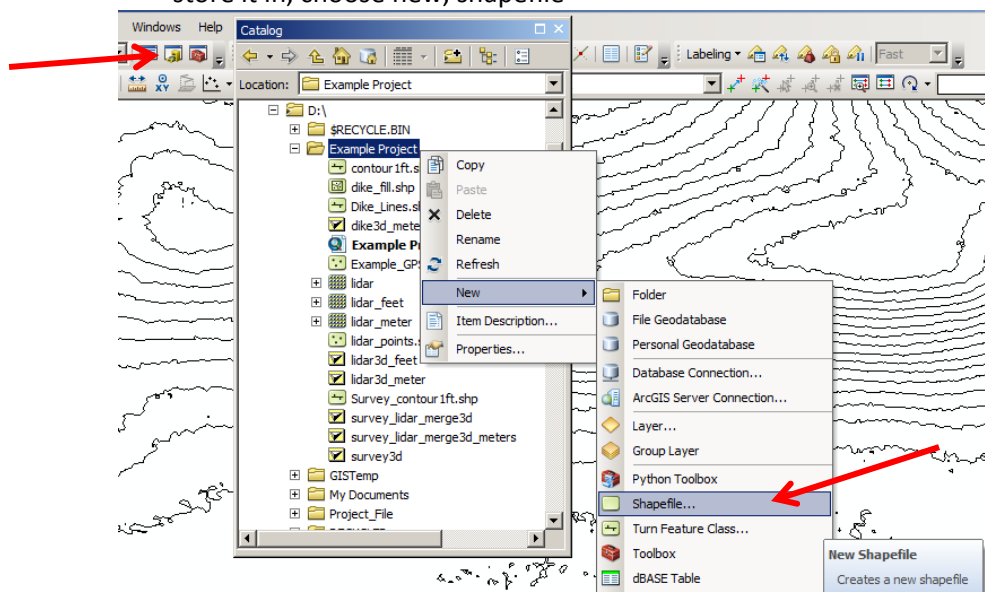
- Contour lines can be created either from the raw LIDAR layer you clipped or from the 3d-TIN layer you created. The Lidar will be more accurate but the TIN layer will be a little smoother and less cluttered.
- Again open ArcToolbox (Red toolbox icon)
- In ArcToolbox go to
  - 3D Analysis Tools > Raster Surface > Contour for creating Contours from your raw LIDAR
  - 3D Analysis Tools > Terrain and TIN Surface > Surface Contour for creating Contours from your 3D TIN
- Your Input layer is either the Clipped LIDAR or the 3d-TIN depending which method you chose
- Output is wherever you want to save it and your filename such as Contour1ft.shp
- Contour interval is whatever detail you want. Generally 1 ft but if contour lines are too tightly packed and it is hard to read on your map you may want 2ft or even 5ft intervals. Lidar is fairly accurate within about 6 inches so don't go less than 0.5ft (6inches) contours or you will be trying to display accuracy that isn't really there in your raw data.
- Base contour leave at 0 unless you have a specific elevation you want to start your contour intervals from
- Z factor is 1 unless you have a need to exaggerate your elevations or do unit conversions here.
- Creating contours from a TIN has a few extra options but leave them default or read the help menu for details on those items.
- Hit the OK button to process your contours

- k. Change the display of the finished contour lines if you wish by double clicking on the layer and use options in the symbology tab to change color, style etc.



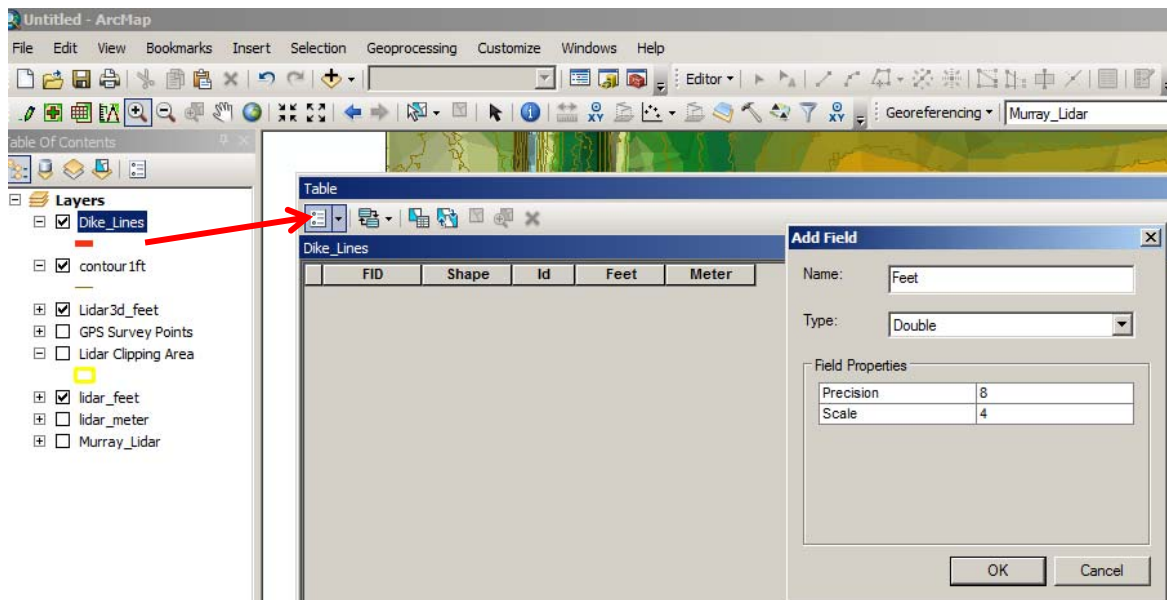
## 7. Creating a virtual dike

- a. Display your 3d Lidar Tin you created as well as your contour lines, zoom in to your dike area. Based on your site survey and/or the contour lines and basic engineering determine the elevations of your dike and if needed in the design your spillway.
- b. This example will be just a basic dike between to valley walls to separate a wetland from a road right of way. It can be as simple or complicated as you need just take more time to draw your dike and or spillway.
- c. Create a shapefile layer called "Dike\_Lines". It needs to be a "polyline" type of file. This is for drawing lines not points or polygons. Make sure to define a coordinate system, most likely using the same the other data such as UTM NAD83 Zone##.
  - a. To create a new shapefile open ArcCatalog, right click on the folder you want to store it in, choose new, shapefile





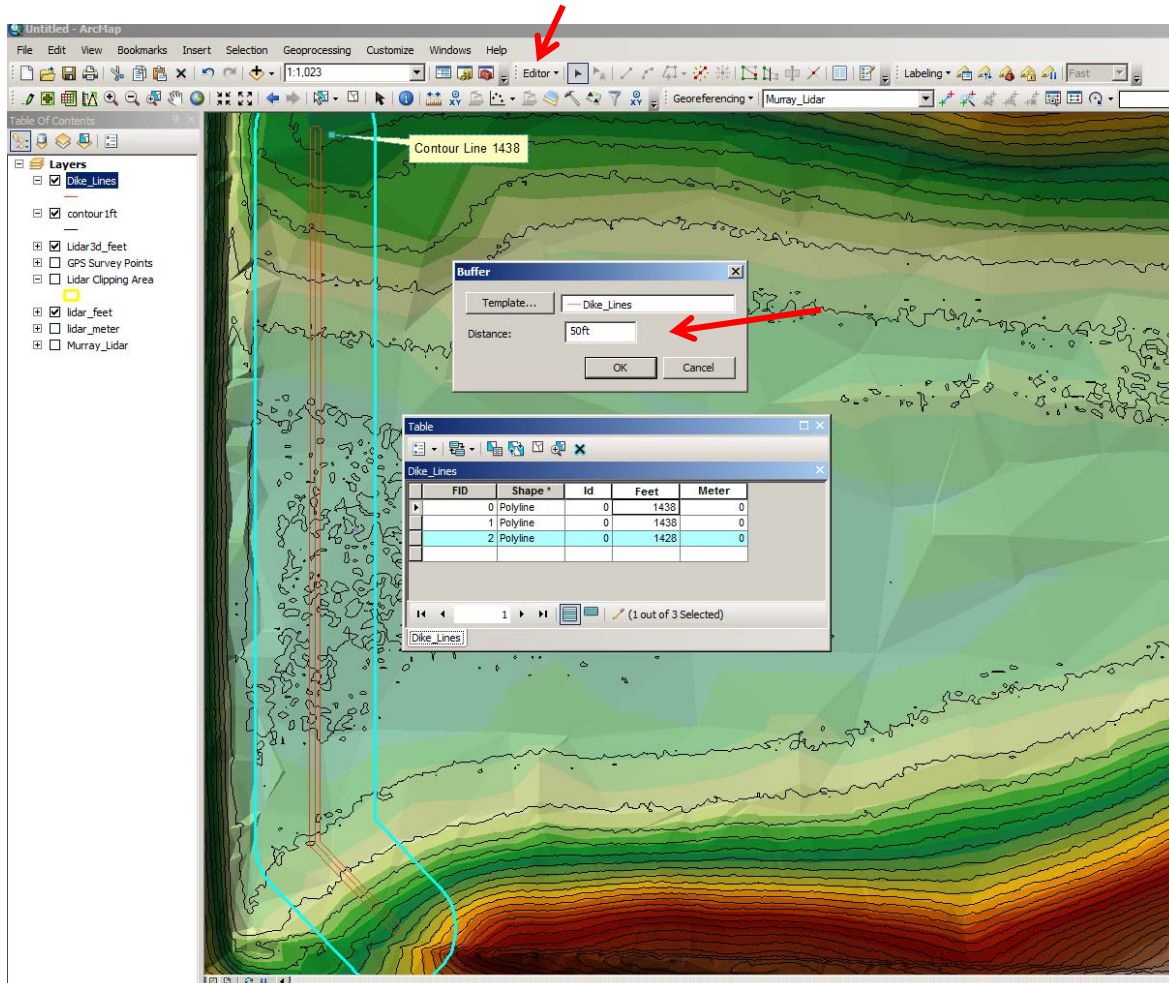
- d. Create a field in the attribute table to record elevation.
  - i. Open the attribute table for your dike layer
  - ii. On the table menu bar at the top left click the drop down arrow next to the white box
  - iii. Click add field
  - iv. Name it "Feet"
  - v. Type, Choose Double
  - vi. Precision choose 8 (this is the total number of digits allowed)
  - vii. Scale choose 4 (this is the number of decimal places to use)
  - viii. Hit OK
  - ix. In the attribute table you should now have a column called feet
  - x. Repeat these same steps but create a field called "meters"



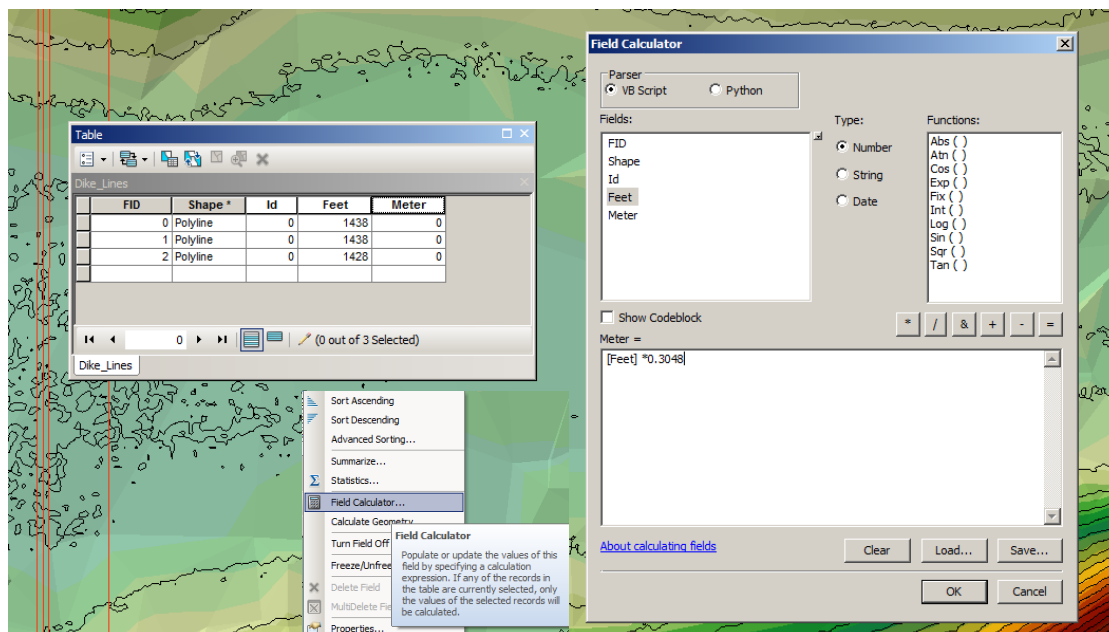
- e. Start editing your dike shapefile
- f. Draw the centerline of your dike
  - i. In simple scenarios basically draw a line from a contour line on one side of a valley to the contour line on the opposite side of the valley.
  - ii. Open the attribute table for the dike and in the Feet Field, type in the elevation of the top of the dike such as 1438.0000
- g. Create the dike top width.
  - i. You can either manually draw the dike top like you did with the centerline or use a buffer from the centerline to make it quicker.
  - ii. Make sure the centerline is selected/highlighted
  - iii. From the editor toolbar drop down menu at the top choose buffer
  - iv. In distance enter half of the desired dike top width. i.e. if I want a 10ft dike top I need to buffer 5ft each side of my centerline. (make sure to type the units in the blank or it will default calculate to meters)
  - v. Hit OK and a buffer should now appear showing the dike top
  - vi. Open the attribute table and fill in the elevation in the feet column which if the dike top is flat will be the same as the centerline elevation

h. Create the dike slopes

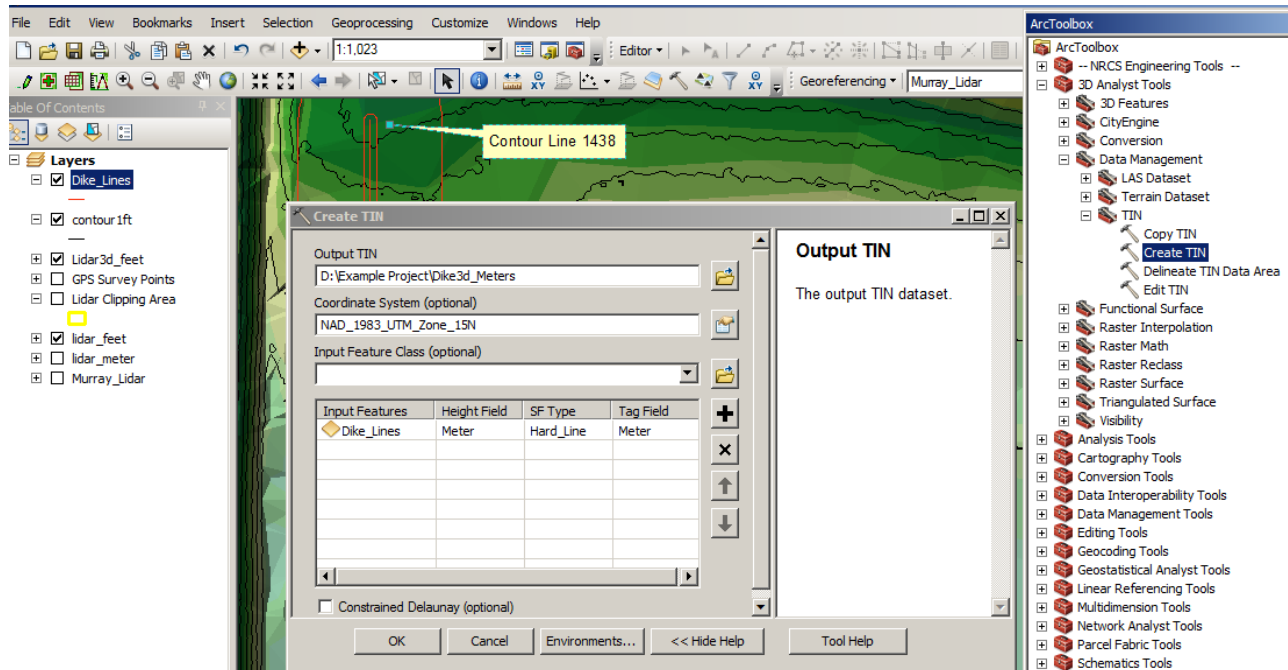
- i. Again you can draw manually or it will be easier and more accurate to use the buffer tool to create the base of the dike.
- ii. You need to decide on your dike slope grade. Minimum recommendation for wetland restorations is 5:1 slope.
- iii. You need to determine the maximum height of your dike from base to top. This may be easiest by counting contour lines. It is more important to overestimate when creating the dike base to make sure you encompass the entire footprint which will be important in later volume calculations. If it is estimated at a 6ft high dike then for easy calculations just use 10ft tall. Math, 5:1 slope on 10ft tall is  $5 \times 10 = 50\text{ft}$  buffer needed from the dike top edge to the dike base.
- iv. Select the dike top buffer ring so it is highlighted
- v. From the editor toolbar drop down menu at the top choose buffer
- vi. For distance enter the dike base distance you just estimated so in this example 50ft (make sure to type the units in the blank or it will default calculate to meters)
- vii. You will now have a 50ft dike base ring around your dike top ring.
- viii. Open the attribute table and enter the elevation of that dike base ring. Remember if you over exaggerated use the elevation of the exaggeration. Example if the max dike height was estimated at 6ft but we used 10ft in our slope/base calculation then the elevation we enter is 10ft lower than the dike top.



- i. Convert from feet to meters
  - ii. ArcGIS uses the units of measurement for the coordinate system to calculate volume of fill which for UTM coordinates it is in meters so you need to convert all other measurement units to meters also.
  - iii. Open the dike attribute table
  - iii. Field calculations only are done on those selected or on all records if none are selected so select all or none of the dike lines your drew. For a simple dike you should have 3 sets of lines including centerline, dike top width and dike base all with elevations entered in the feet column.
  - iv. Right click on the top of the meters column and choose field calculator
  - v. In the Fields box double click Feet and it will appear in the formula box below.
  - vi. Click the \* button and it will also be added to the formula below
  - vii. The manually type in the formula 0.3048 which is the conversion factor from feet to meters.
  - viii. Press OK and you should see the meters column is now calculated

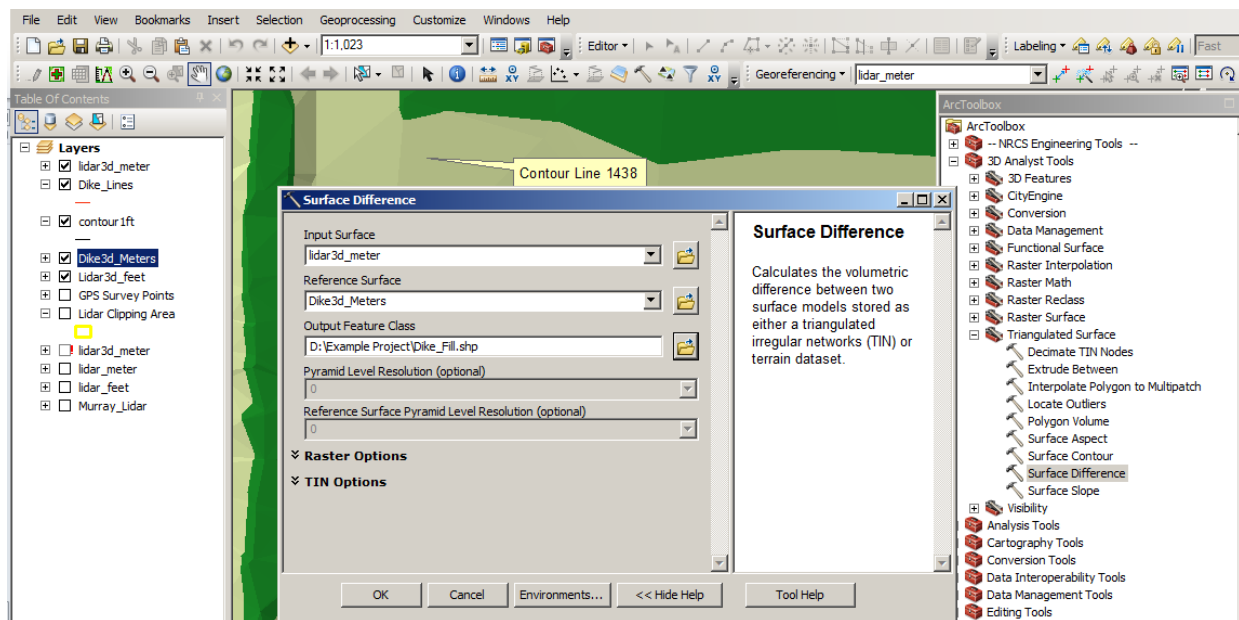


8. Create a 3d TIN file from your dike
  - a. Open ArcToolbox (red toolbox icon at the top toolbar)
  - b. Go to 3D Analyst Tools > Data Management > TIN > Create TIN
  - c. Output Tin is where you want to save it and what you want to name it such as DIKE3d\_Meters
  - d. Coordinate system define the same as the other files such as UTM NAD83 Zone ##
  - e. Input feature class is your Dike layer you just drew
  - f. Use the dropdown for Height Field and Tag Field to both be "meters"
  - g. Hit OK and your new 3d dike layer will be made.



9. Create a LIDAR TIN layer in meters. (If you didn't already do this in step 4j above)
  - a. For design purposes you may have used a LIDAR TIN surface in feet units however for volume calculations all units need to be in meters.
  - b. Repeat step 4 above for creating a Tin from the LIDAR clip but use the original LIDAR\_meters layer you clipped in step 2 above which would have normally been in meters for the units from raw county data. If you didn't have a LIDAR layer in Meters to start with then use the directions in step 3 to convert a feet units layer to meters using the conversion factor of 0.3048.
  - c. If you are using GPS data to create your terrain surface instead of LIDAR data then do your unit conversions for elevation (step 7i above) in the attribute table of the GPS point file to go from feet to meters and create a TIN using directions from step 8 above to create the 3d TIN from the GPS point shapefile in the same way you made the Dike TIN.
  - d. End result is you will have a 3d TIN terrain surface in meters elevation units.
10. Calculate dike volume
  - a. In ArcToolbox go to 3D Analyst Tools > Triangulated Surface > Surface Difference
  - b. Input Surface is the LIDAR terrain in meters
  - c. Reference Surface is the Dike 3d TIN you created in meters
  - d. Output feature class is the location and name you want to give to the dike cut/fill layer such as dike\_fill
  - e. Hit OK

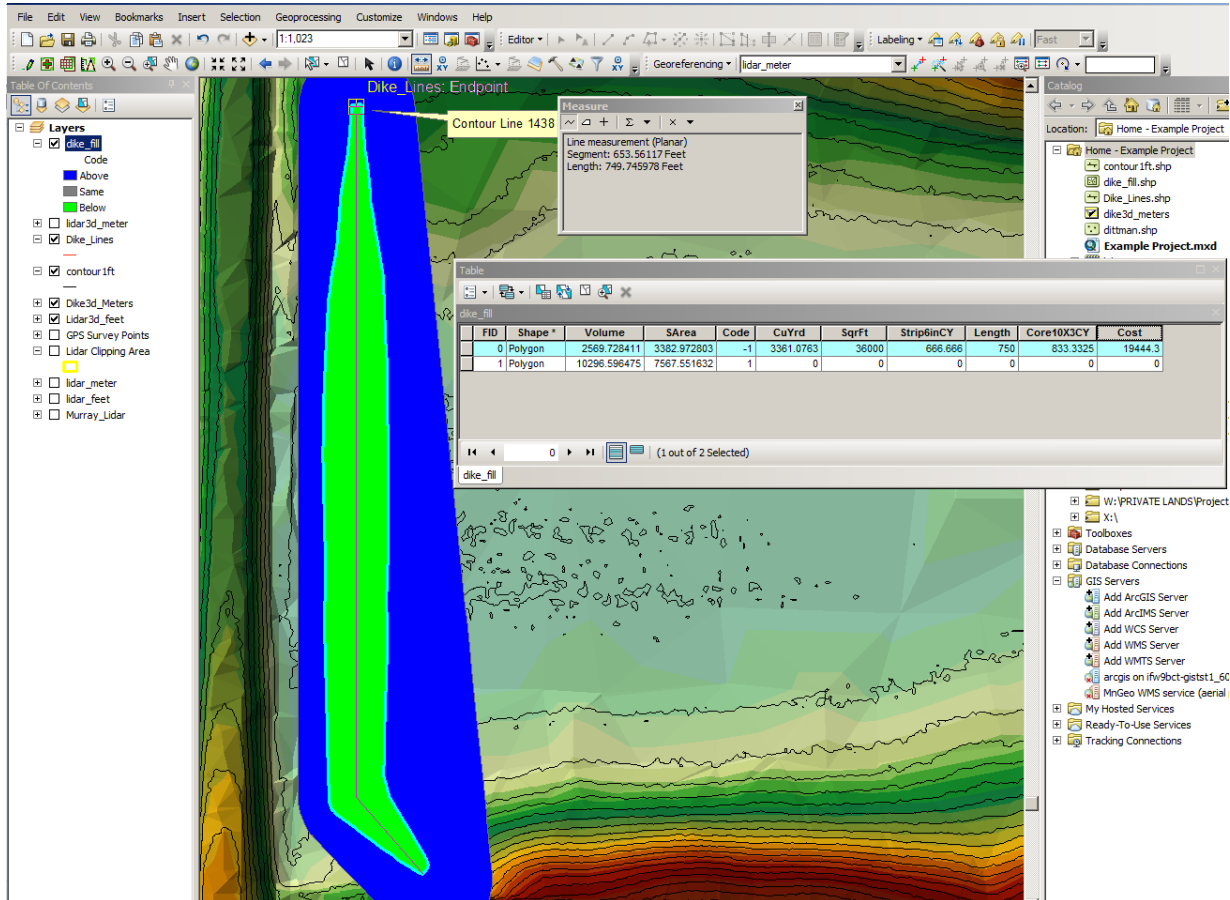




## 11. Interpreting results

- a. You just created a cut/fill layer. Default colors are often green for areas that need to be filled (which would be the dike you are building) and blue if you were making spillway cut.
- b. The cut area can be ignored or even deleted if you were using this method for creating a dike only. It would be opposite if you were using this method for creating a spillway where you need to know the cut volume and ignore the fill. Just start editing the layer and select and delete the parts you don't need.
- c. You can open the attribute table for this new cut/fill layer and select the polygon representing your dike.
- d. Any of the following calculations you can do and record outside of GIS or record and calculate in new columns in the attribute table using steps outlined above in section 7d to create new field and use the field calculator to do the math.
- e. The Volume is fill needed in cubic meters. Multiply that number by 1.30795 to convert to cubic yards used by most contractors. Note to contractors that this is compacted volume not loose volume. Compacted fill is generally about 1.3Xloose fill to haul.
- f. The SArea column is square meters footprint area. Do appropriate conversion units to get into the format that suite you. For example multiply by 10.7639 to get into square feet
- g. If you are stripping the dike footprint before building, use the area calculation. Example you convert from square meters to square feet. Then want to strip 6 inches so take the square feet multiply by 0.5 which gives you cubic feet. Multiply by 0.037037 to get cubic yards for contractor estimates.
  - i. Often the strip material is pushed to the side during construction then spread back over the top at the end for better revegetation so this volume of material could be noted it will be moved twice in estimates.
- h. If you require a core trench
  - i. Use your measurement/ruler tool in ArcMap to measure the length of the centerline shown by the dike fill layer
  - ii. Determine the depth and width you want the core trench to be (10ft wide is common if you want to run a sheepsfoot down in the trench, 3ft deep is common for many standard conditions).

- iii. Length X width X depth gives you volume of the core trench in cubic feet.
- iv. Multiply by 0.037037 for cubic yards.
- v. Note if this is decent material (clay) it can be used in the downstream toe of the dike as it is excavated thus deducting this fill volume from the total needed for the dike. i.e. don't pay for that volume of material twice.



## 12. Load Dike footprint into GPS for dike toe staking.

- a. For dike footprint delete other polygons (cut areas) so only the dike footprint polygon remains.
- b. Make sure the coordinate system is the same as what you will use in your GPS unit.
- c. Copy the shapefile made up of at least 3 files (.dbf, .shp, .shx) to your GPS.
- d. For Trimble Access on a TSC3 controller copy to the same location the .job files are located.
- e. In your job setup – Properties of job, under Active Map add the dike shapefile.
- f. View and zoom to your location on the map screen and you will see the shapefile boundaries.
- g. Navigate along the edges of the dike footprint on-screen and place your dike toe stakes for the contractor.
- h. Same can be done for a centerline if you load a centerline file in your GPS.

**Other great Lidar Tools for ArcGIS** – The NRCS has a customized toolbox for ArcGIS. Download it from their website: [ftp://ftp.lmic.state.mn.us/pub/data/elevation/lidar/tools/NRCS\\_engineering/](ftp://ftp.lmic.state.mn.us/pub/data/elevation/lidar/tools/NRCS_engineering/)

These tools have a tutorial of their own so details will not be covered here.

Index of [ftp://ftp.lmic.state.mn.us/pub/data/elevation/lidar/tools/NRCS\\_engineering/](ftp://ftp.lmic.state.mn.us/pub/data/elevation/lidar/tools/NRCS_engineering/)

 [Up to higher level directory](#)

Name	Size	Last Modified
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 <a href="#">ENGINEERING_TOOLS_WORKFLOW.pdf</a>	1014 KB	2/6/2013 12:00:00 AM
 <a href="#">ExampleData_Readme.txt</a>	1 KB	2/1/2013 12:00:00 AM
 <a href="#">NRCS_GIS_ENGINEERING_TOOLS_ver 1.1.7.zip</a>	1953 KB	4/26/2013 12:00:00 AM
 <a href="#">version 1.1.7_ReadMe.txt</a>	7 KB	4/26/2013 12:00:00 AM

1. Download the toolbox, unzip it and store it wherever you want to store programs.
2. Open ArcMap and open ArcToolbox (red toolbox icon at the top of the toolbar)
3. Right click on a blank space in ArcToolbox and hit Add Toolbox from the context menu
4. Navigate to where you saved the downloaded file
5. You should now have the NRCS Engineering Tools in your Toolbox
6. IMPORTANT – a few factors to consider to reduce errors in their toolbox.
  - a. Sometime you have errors if data layers have different coordinate systems so keep all data in the same coordinate system
  - b. This tool does not like file name paths with spaces such as D:\Example Project\ so instead use underscores such as D:\Example\_Project\
  - c. Unit conversions don't always work within the program so try to make sure all data has the same units of measurement. Since UTM coordinate systems measure lat & long in Meters then it is best to keep all measurements in meters and convert to other units after.
7. Combine some of their tools with steps outline above to simplify the steps such as their tool for Clipping the LIDAR works great as well as their create contours is also very good. Their hydrology tools such as defining watersheds and flow paths/stream network are useful.

