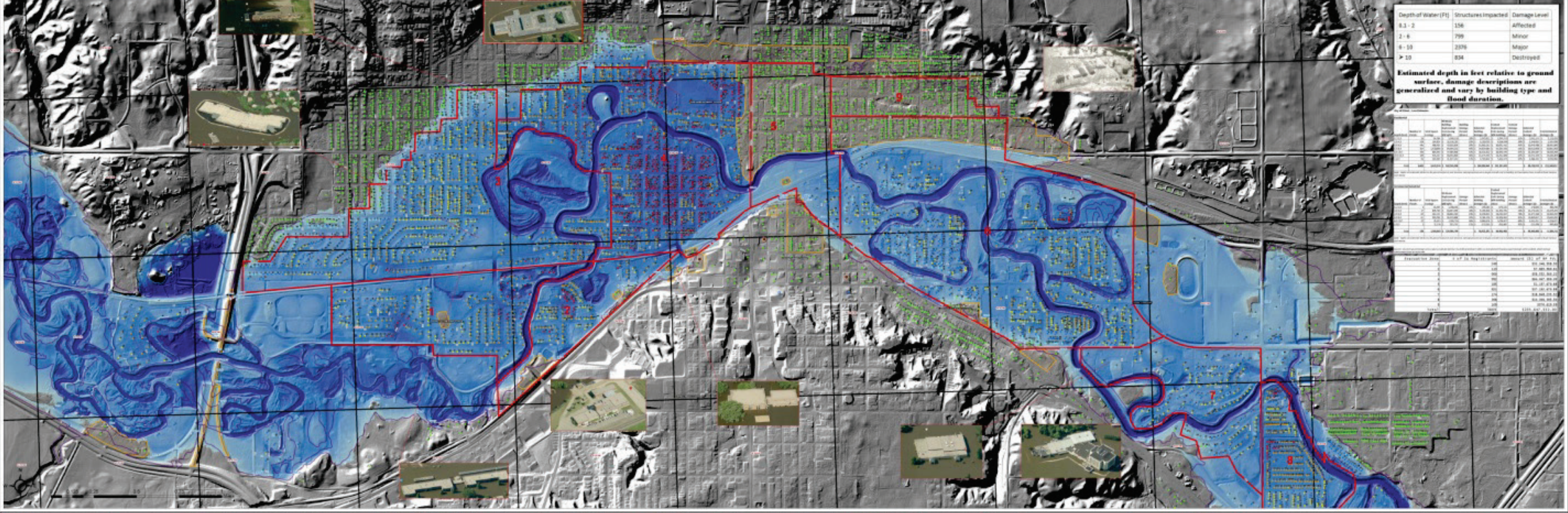

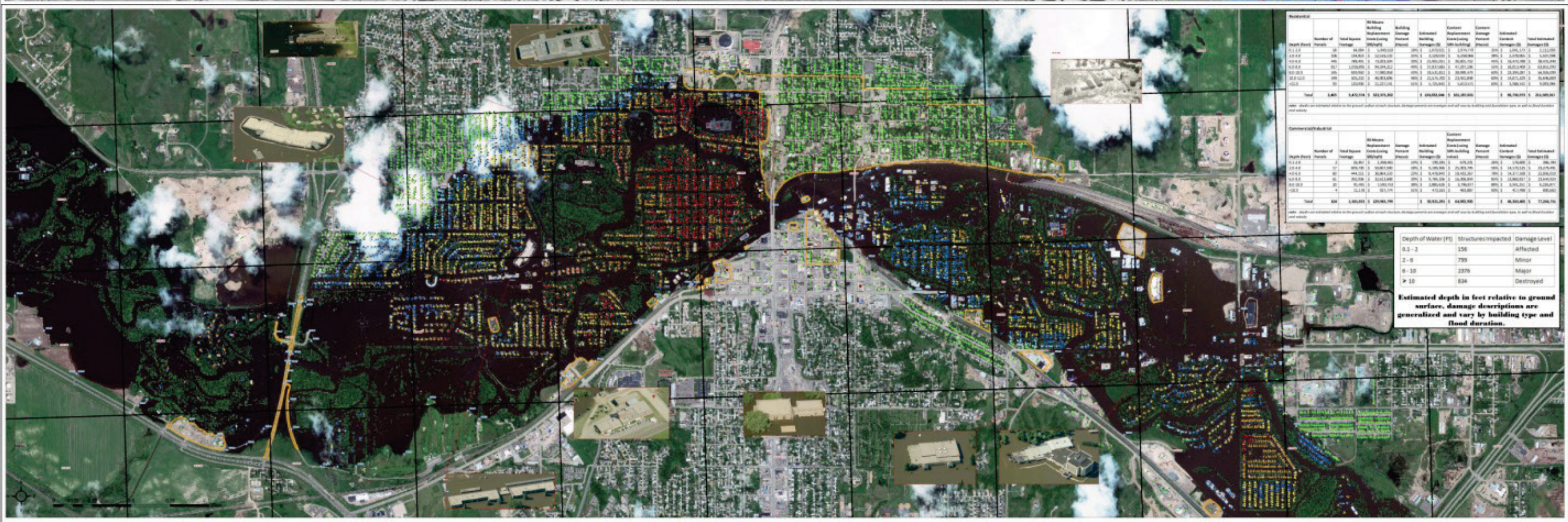

Hazus Flood Model

FEMA Standard Operating Procedure for Hazus Flood Level 2 Analysis

EARTHQUAKE • WIND • FLOOD • TSUNAMI

Credits

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Table of Contents

Overview

In order to assess flood losses, vulnerability, and risk for a community, a comprehensive understanding of the flood hazard, and the built environment needs to be developed. The purpose of this Standard Operating Procedure (SOP) is to outline the geospatial processes required to estimate flood damages from an event accurately and quickly, in order to communicate those impacts to decision makers in the response, recovery, and mitigation phases of an event in a timely manner. The flood estimation methodology will be described in this SOP in the following sections defined below:

1. **Building Inventory**: Building Inventory for a region can be developed before an event occurs so it is available for use in damage assessment. This section defines the required attributes and outlines how to create a detailed building inventory.

2. **Depth Grid Production**: This explains two methods for creating a depth grid if a depth grid for desired study region is not available to download from the Map Service Center.

3. **Analyzing Flood Losses Using FEMA's Hazus Flood Model:** This section explains the difference between an aggregated analysis and a site specific approach. This section also describes how to add data to a State Database for a study region using CDMS and how to run a "General Building Stock Damage and Loss" and "User Defined Structures" analysis.

4. **The User Defined Facilities Flood Loss Results:** This section describes how to join the Hazus UDF results to the original UDF data set.

5. **The VDatum Example Appendix:** This section shows how to use the VDatum software to transform the vertical datum of data into a useable format for Hazus.

Based on the information presented in this document, it is the Hazus Programs official recommendation that users import user-defined flood hazard information when available.

1. Building Inventory

Development of a detailed building inventory for use in a flooding event damage assessment can be done before an event takes place. This can be done ahead of time for communities with general high risk, or those who have a predicted forecast of high probability flood risk in the weeks/months to come. In order to create a detailed building inventory GIS dataset that can be used to estimate flooding damages on a structure by structure basis, following information for the built environment for the community is needed:

- Point structure location
- Foundation type
- First floor height
- Building value
- Contents value

- Occupancy type
- Number of stories

1.1. Establish Workspace and Define Data

Depth grid/flood hazard data creation - depth grid/flood hazard data can be created well before an event to be used to model scenario planning events, derived immediately before an event by H&H experts based on forecast predictions, or after an event using real world data. The following data is required to estimate flooding damages in a geospatial environment.

Flooding depth grid - consists of an Esri raster grid file, with flooding depths represented by each pixel value. Flooding extent and depth are depicted by this raster dataset.

*Import process for user-defined depth grids now support the following file formats: GRID (as before), IMAGINE (IMG), HEC-RAS (FLT), TAGGED IMAGE FILE (TIF), and fGDB. Hazus will also automatically re-project any user-defined depth grids which are not in WGS84.

Analyzing flood losses using FEMA's Hazus flood model software – the methods for incorporating the site specific building information and flood hazard data are described.

1.2. Creating the Building Inventory

In an ideal situation, the potential for flooding impacts to a community would be foreseen before the event takes place in order to give geospatial analysts time to prepare building inventory datasets ahead of time. At times, flood forecasts from the National Weather Service (NWS) allow for a few days or a few weeks' notice of the potential for high impacts in an area, but many times an event can happen with no notice. The development of the building inventory is possible to create in a timely manner, even in no notice events.

1.2.1. Create point locations for all impacted structures

When importing a building point dataset into the Hazus flood model for site specific analysis, the depth of water at a given point is applied from the depth grid to the structure based on its physical (latitude/longitude) location. Having the building point locations as accurate as possible can greatly increase the results accuracy.

A. When parcel data are available, conduct a polygon to point conversion based on the parcel centroid. To enhance accuracy, move the point on top of structure using satellite/aerial imagery. If a depth grid or post event imagery is already available, manual movement of structure point locations only need to take place in the flooded areas, which takes much less time than manual point movement for an entire community. This step can be time consuming but greatly enhances the accuracy of the analysis. In past studies, manual movement of 3,000 to 4,000 structures has been completed in just a few hours. For the greatest accuracy, place the point on structure at the lowest elevation point using LiDAR (however, the lowest elevation point method may require too much time. The building centroid method will suffice).

Figure 1-1: Points placed based on parcel centroid. If strictly using parcel centroids, many structure locations would be much too close to the flood hazard.

Figure 1-2: Points moved over structure manually. Structure locations are much more accurate.

B. When parcels are not available, manually place a point on each structure using imagery (only place points on structures in the flooded area). Damage percentages/economic loss calculations will not be possible without parcel/assessor information. This will enable increased accuracy for structure damages counts, and depth on structure totals dependent on the flood hazard data available.

Alternatively, if building footprint data is available, a polygon to point conversion using the building footprint centroid will eliminate the need to manually adjust the placement of points derived from parcel datasets as well as eliminate the need to manually place points for a whole community in the absence of parcel data.

It is important to mention that it is only necessary to create point data for primary structures. Structures such as sheds, garages, and small out-buildings do need to be included into the dataset.

1.2.2. Collect required structure attributes for Hazus Flood loss estimation

The attributes covered in this section are required to produce accurate loss estimates. In an ideal situation, these attributes from local tax assessor/parcel data would be able to obtain. Most commonly however, all of these attributes are not available. Attribute availability varies from community to community, and in place of missing values, assumptions will need to be made based on averages for an area, and RSMeans standards.

The Hazus flood model uses what are called depth damage functions to estimate the percentage of damage and thus economic impact to a structure. The depth damage function selected is a combination of occupancy type, foundation type, and number of stories. The first-floor height is then used to adjust the amount of flooding depth calculated against the structure, and the building value/contents values are used to estimate economic impacts.

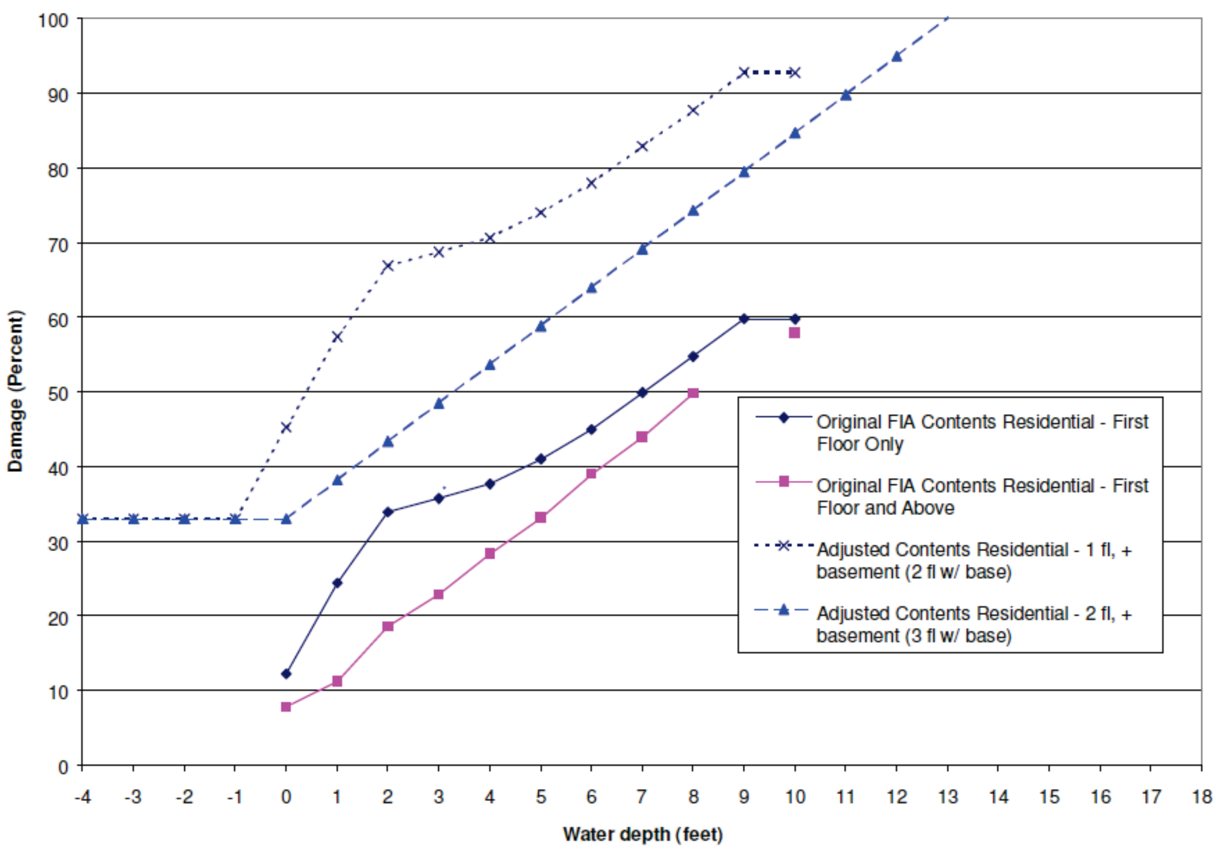


Figure 1-3: FIA-based Residential Contents Damage Curves from the Hazus Flood Technical manual (Figure 5.5).

For instance, a RES1 (single family home) occupancy type experiences different damage percentages at two feet of flooding than a light industrial facility IND1. This attribute is commonly found in local assessor's information with a name such as "use," "property type" or "zoning."

Estimation can be derived using the following methods when the required Hazus flood model attributes are not available (foundation type, first floor height, occupancy type, number of stories, building values/cost, contest cost, inventory values, latitude / longitude, building/content/inventory damage function ID (Optional), and import building data into Hazus)

1.2.2.1 Foundation type

The foundation type modifies the Hazus depth damage curve applied to the structure, thus altering the percentage damage applied and the economic losses reported for that structure. For instance, a building with a finished basement with -two feet of flooding (two feet below ground level) would experience much greater losses than a structure that did not have a basement. The Hazus foundation types are broken into the following categories:

Table 1-1: Default Floor Heights above Grade to Top of Finished Floor (Riverine)

ID	Foundation Type	Pre-FIRM	Post-FIRM
1	Pile	7 ft.	8 ft.
2	Pier (or post and beam)	5 ft.	6 ft.
3	Solid Wall	7 ft.	8 ft.
4	Basement (or Garden Level)	4 ft.	4 ft1
5	Crawlspace	3 ft.	4 ft.
6	Fill	2 ft.	2 ft.
7	Slab	1 ft.	1 ft1

Source Data: Expert Opinion Note: 1 is typically not allowed, but may exist

When classifying the foundation type for a selected structure, the ID number above should be used to identify the corresponding foundation type. This attribute is occasionally reported in local assessor's information, but when it isn't, it can be collected using the following methods:

A. Visual verification using oblique aerial imagery – oblique imagery gives the analyst a side viewing angle of the structure, and the ability to assess whether a building has a basement (windows shown in the basement below).

Figure 1-4: Visual verification using oblique aerial imagery. Photo courtesy of Pictometry.

B. Census block assumptions – census block based assumptions can be made using known common practices for an area by occupancy type, or using the Hazus default flood specific occupancy mapping schemes for a selected block/tract.

1.2.2.2 First floor height

This attribute describes the height above ground (not above sea level) of the building first floor. This can be obtained from tax assessor information (or elevation certificate where available) or approximated by using one of the following methods:

A. Subtracting the elevation certificate by ground surface elevation from high resolution LiDAR, ensuring each are in the same vertical datum.
B. Measuring in the field or from orthorectified oblique imagery from the front door threshold to the ground surface.
C. Approximation based on foundation type. The Hazus flood technical manual has approximate first floor heights based on foundation type selected shown in Table 1-1 from the Hazus Flood Technical Manuals and shown above in Figure 1-4.

1.2.2.3 Occupancy type

The Hazus flood model requires a specific occupancy identifier that corresponds to the following codes from the Hazus flood technical manual shown in Table 1-2.

Table 1-2: Hazus Building Occupancy Classes, from Hazus Technical Manual.

Label	Occupancy Class	Example Descriptions
	Residential	
RES1	• Single Family Dwelling	House
RES2	• Mobile Home	Mobile Home
RES3	Multi Family Dwelling RES3A Duplex RES3B 3-4 Units RES3C 5-9 Units RES3D 10-19 Units RES3E 20-49 Units RES3F 50+ Units	Apartment/Condominium
RES4	• Temporary Lodging	Hotel/Motel
RES5	• Institutional Dormitory	Group Housing (military, college), Jails
RES6	• Nursing Home	
	Commercial	
COM1	• Retail Trade	Store
COM2	• Wholesale Trade	Warehouse
COM3	• Personal and Repair Services	Service Station/Shop
COM4	• Professional/Technical/ Business Services	Offices
COM5	• Banks	
COM6	• Hospitals	
COM7	• Medical Office/Clinic	
COM8	• Entertainment & Recreation	Restaurants/Bars
COM9	• Theaters	Theaters
COM10	• Parking	Garages
	Industrial	
IND1	• Heavy	Factory
IND2	• Light	Factory
IND3	• Food/Drugs/Chemicals	Factory
IND4	• Metal/Minerals Processing	Factory
IND5	• High Technology	Factory
IND6	• Construction	Office
	Agriculture	
ARG1	• Agriculture	
	Religion/Non-Profit	
REL1	• Church/Non-Profit	
	Government	
GOV1	• General Services	Office
GOV2	• Emergency Response	Police/Fire Station/EOC
	Education	
EDU1	• Grade Schools	
EDU2	• Colleges/University	Does not include group housing

Occupancy type provides Hazus with a use description code that is utilized when choosing a depth damage function. Below are a few different methods for determining the Hazus occupancy code for a buildings dataset.

A. Assessor's/parcel information – attributes are commonly found in local assessor's data with either zoning information (commercial, residential, industrial, etc.) or more detailed use type information (single family home, duplex, etc.). Once acquired, these attributes will need to be converted to Hazus specific occupancy use codes from the Hazus Technical Manual shown in Table 1-2.

B. Visual verification using satellite/aerial/oblique imagery – when looking at a structure (or neighborhood) using one of these remote sensing assets, it is often easy to distinguish between a single-family home (RES1) and a retail store (COM1).

1.2.2.4 Number of stories

This attribute is commonly found in assessor's data, but when not available can be derived using the following methods:

A. Google Earth Pro, assessors/parcel data – these sources often include number of stories, depending on the location.
B. An assumption can be made based on specific occupancy using the following criteria from the Hazus Flood Technical Manual shown in Table 1-2.
C. The attribute can be derived visually using oblique aerial imagery (Image below) or Google Street View.

Note: An enhancement was made to the number of stories field for RES1 structures in UDF imports to limit the number of stories handled by Hazus. Users can enter up to 255 with 255 reserved to indicate a split-level structure, however, Hazus will treat it as no higher than five stories. Users are not advised to enter a RES1 UDF with more than five stories, as these types of structures are rare for single-family dwellings.

Figure 1-5: Number of stories for a single-family dwelling. Picture courtesy of Pictometry.

1.2.2.5 Building Values/Cost

This attribute is commonly found in local tax assessor/parcel data. Assessed value, fair market value, or replacement value can all be used as the building value in the dataset as long as clarification is made when communicating the results. When tax assessor/parcel data is not available, it can be calculated by the following methods:

A. RSMeans calculation using square footage and occupancy type eg. (Sqft x RSMeans $ per sqft) x (CPI adjustment) x (CountyModFactor). RSMeans estimates approximate value per square foot for each Hazus occupancy type and the 2006 valuations are presented in Table 14.1, 14.2, and 14.3 of the Hazus Flood Technical Manual. Standard Hazus RSMeans values are typically adjusted from 2006 values to current values using the latest Consumer Price Index calculator.
B. Hazus uses an RSMeans County Adjustment Factor for every county in the U.S., these adjustments accommodate for relative differences in the costs associated with building materials and differences in the expenses associated with contractors. A table of County modification factors is available in the Hazus State data folders (ex. syHazus.dbo.hzMeansCountyLocationFactor).
C. The RES1 (single family residential) replacement cost model utilizes socio-economic data from the census to determine an appropriate mix of construction classes (Economy, Average, Custom and Luxury) and associated replacement cost models. The 2006 valuations are presented in Table 14.3 of the Hazus Flood Technical Manual.

1.2.2.6 Contents Cost

Content values are occasionally available in local tax assessor/parcel data. When content values are not available, they can be calculated using the following method.

A. RSMeans average percent value calculated from building value/occupancy type – the table below shows average content values by occupancy type. Apply the percent to the building value of each occupancy type based on the Hazus Flood Technical Manual as shown below.

Table 1-3: Default Hazus Contents Value Percent of Structure Value. From Hazus Flood Technical Manual

NO.	Label	Occupancy Class	Contents Value (%)
		Residential	
1	RES1	Single Family Dwelling	50
2	RES2	Mobile Home	50
3	RES3	Multi Family Dwelling	50
4	RES4	Temporary Lodging	50
5	RES5	Institutional Dormitory	50
6	RES6	Nursing Home	50
		Commercial	
7	COM1	Retail Trade	100
8	COM2	Wholesale Trade	100
9	COM3	Personal and Repair Services	100
10	COM4	Processional/Technical/Business Services	100
11	COM5	Banks	100
12	COM6	Hospitals	150
13	COM7	Medical Office/Clinic	100
14	COM8	Entertainment & Recreation	100
15	COM9	Theaters	50
16	COM10	Parking	
		Industrial	
17	IND1	Heavy	150
18	IND2	Light	150
19	IND3	Food/Drugs/Chemicals	150
20	IND4	Metal/Minerals Processing	150
21	IND5	High Technology	150
22	IND6	Construction	100
		Agriculture	
23	ARG1	Agriculture	100
		Religion/Non-Profit	
24	REL1	Church/Non-Profit	100
		Government	
25	GOV1	General Services	100
26	GOV2	Emergency Response	150
		Education	
27	EDU1	Grade Schools	100
28	EDU2	Colleges/University	150

1.2.2.7 Inventory Values

For occupancies with inventory considerations (COM1, COM2, IND1 - IND6 and AGR1, inventory losses are estimated using USACE-based depth-damage functions, in conjunction with Hazus default inventory values determined as a percentage of annual sales per square foot (see Earthquake Loss Estimation Methodology Hazus Technical Manual, Section 15.2.3).

1.2.2.8 Latitude/Longitude

Latitude and longitude of the user site(s) in decimal degrees.

1.2.2.9 Building/Content/Inventory Damage Function ID (optional)

A UDF without an assigned Depth Damage Function by the user will now use Coastal DDFs for Coastal hazards using a type of depth approach similar to Hazus GBS. For structures at a depth greater than two (2) feet, a Coastal V DDF is used and for structures in two (2) feet or less of flood depth, a Coastal A DDF is used. Four (4) feet is the boundary between using Coastal A and V DDFs for Content and Inventory.

1.2.2.10 Two ways to Import Building Data Into Hazus

A. Using CDMS: Refer to section, "Importing Structural Data into the User Definer Facilities (UDF) Database using the Comprehensive Data Management System (CDMS)."

B. Import the completed buildings data into a UDF geodatabase and directly into Hazus**:** The Hazus User Defined Facilities Module requires an Esri 8.2 geodatabase format. These can't be created from newer versions of ArcGIS, but one is available in the Hazus program files at the locations listed below:
   - 32 bit operating system: C:\Program Files\Hazus-MH\Data\UDS.mdb
   - 64 bit operating system: C:\Program Files (x86)\Hazus-MH\Data\UDS.mdb
   - Copy the UDS.mdb database to a folder on the local drive (it will not import from a network drive due to MS access Jet Engine Database architecture).
   - Import the buildings database into the UDS geodatabase.
   - Open the UDF table in MS Access. Choose design view to see data types.

Table 1-4: Data types. Note: *Required, **Optional, ***required for Commercial analysis/ must not be null

Field	Type	Size
CONTACT	Text	40
NAME	Text	40
ADDRESS	Text	40
CITY	Text	40
STATE	Text	2
ZIPCODE	Text	40
PHONENUMBER	Text	47
OCCUPANCY *	Text	5
YEARBUILT	Integer	2
COST *	Currency	8
BACKUPPOWER	Yes/No	1
NUMSTORIES *	Byte	1
AREA ***	Single	4
BLDGTYPE	Text	15
LATITUDE *	Double	16
LONGITUDE *	Double	16
COMMENT	Text	40
CONTENTCOST **	Currency	8
DESIGNLEVEL	Text	1
FOUNDATIONTYPE *	Text	1
FIRSTFLOORHT **	Double	8
SHELTERCAPACITY	Integer	2
BLDGDAMAGEFNID **	Text	10
CONTDAMAGEFNID **	Text	10
INVDAMAGEFNID **	Text	10
FLOODPROTECTION **	Long Integer	4

It is important to match the above data types identically. If they are not, change them in the data type column on the right and save document. In addition, square footage is a useful attribute to maintain in order to update valuations and is used directly to estimate inventory exposure for certain industrial and commercial occupancies described in Section 14.2.7 of the Hazus Flood Technical Manual.

Once the data types are correctly identified, the UDF is ready for import into Hazus. Reference section Importing Structural Data into the User Defined Facilities (UDF) Database using the Comprehensive Data Management System (CDMS) for steps on inserting the UDF into Hazus.

2. Depth Grid Production

This section will demonstrate two methods to create a depth grid. This section will take roughly one hour total to complete.

A Depth Grid is GIS raster format data that represents the extent of riverine flooding or coastal storm surge inundation and the depth of water at a given location. Non-regulatory products, including depth grids, are available for download from FEMA's Map Service Center. If a non-regulatory depth grid for desired region is unavailable for download from the Map Service Center, there are two methods to create a depth grid. One method is using high water mark data and the other is using a DFIRM. This section will demonstrate how to create a depth grid using each method.

Depth Grids are commonly delivered in raster Esri GRID format, each pixel contains a value representing potential water depth. Factors that contribute to the resolution or level of detail displayed by a depth grid are twofold. These factors include resolution of the terrain data, and availability of flood surface elevation information.

Depth Grid accuracy is dependent on the resolution of the Digital Elevation Model (DEM) or terrain data used during the processing of a Depth Grid. The method used for collecting information on the elevation of the flood surface may vary. Common methods for generating flood surface information are: the use of High Water Mark (HWM) data, the use of BFE (Base Flood Elevation) cross sections, or local H&H (Hydrology and Hydraulics) models.

Determining the resolution requirements for a Depth Grid is reliant on the type of analyses that will be conducted with the processed Depth Grid. For example, when site specific (structure by structure) analyses are needed for loss estimation, higher resolution elevation datasets are more appropriate, whereas, if to gain a general idea of flood extent is the intent, a lower resolution elevation dataset would be adequate.

2.1. Input Data Types

High Water Mark (HWM) Data: High Water Marks are point data collected using high resolution Real Time Kinematic (RTK) GPS systems or other methods. HWM points represent the highest extent of riverine flood or coastal storm surge inundation. These points are used as the foundation for interpolating maximum flooding extent for the final processed Depth Grid.

FEMA Digital Flood Insurance Rate Map (DFIRM) Base Flood Elevations or Cross Sections: Base Flood Elevation cross sections are a product of H&H studies used in FEMA’s Digital Flood Insurance Rate Maps (DFIRM). These cross sections can be used to interpolate a flood surface which is then used as an input into the depth grid production process, ending with a representation of potential flood depth.

Terrain Data: Terrain data can be acquired from many sources. The most common venue for obtaining elevation datasets are through the USGS National Map Viewer. NED data is available nationally at resolutions of 1 arc-second (about 30 meters), 1/3 arc-second (about 10 meters), and in 1/9 arc-second (about 3 meters). NED 1/9 arc-second resolution data is limited in coverage for most areas of the U.S. In addition, high resolution LiDAR (Light Detection and Ranging) terrain data (1-3 meter resolution) may be available through local municipalities within the project area.

NOTE ON VERTICAL DATUMS: The points used for flood surface interpolation must be converted to match the vertical datum of the terrain data. It is possible for hydrologic data or terrain data to be processed in either NAVD88 or NGVD29 vertical datum. The difference in vertical elevations between NAVD88 and NGVD29 is slight, however it must be converted to ensure data accuracy and consistency. To convert the orthometric height of a dataset, determine the appropriate vertical datum to be used and navigate to the following website developed by the National Oceanic and Atmospheric Administration (NOAA). A detailed example using the Coastal Flood Loss Atlas in regards to converting the vertical datum using the VDatum software is outlined in Appendix A. Given the nature of the data, the workflow process for executing this conversion process may be different. This conversion must not be overlooked prior to beginning the depth grid processing steps outlined in the next section.

2.2. Creating a Depth Grid Using HWM Data

When creating a Depth Grid using HMW Data keep in mind that this is a rudimentary method for flood modeling; this approach does not take into consideration discharge values, flood control measures and a variety of hydrological processes. This particular example is solely based on observed high water marks during the anticipated "peak" of the flooding event. The flood depth representation generated by the following method should only be used as best available data when hydrological/hydraulic modeling data is not available and should be used for planning purposes only, not for regulatory use. This section will take approximately 20 minutes to complete.

File structure and file names in this example are guidelines. The particular GIS workflow and file structure methods utilized may be different.

2.2.1. Required Geographic Datasets

1. Terrain Data Esri GRID format (Ex. High resolution community/county specific LiDAR, NED 10m or NED 30m)

2. High Water Mark (HWM) data (DFIRM BFE's can also be used in place of HWM's to represent the flood surface elevation of 100 or 500 year flood conditions)

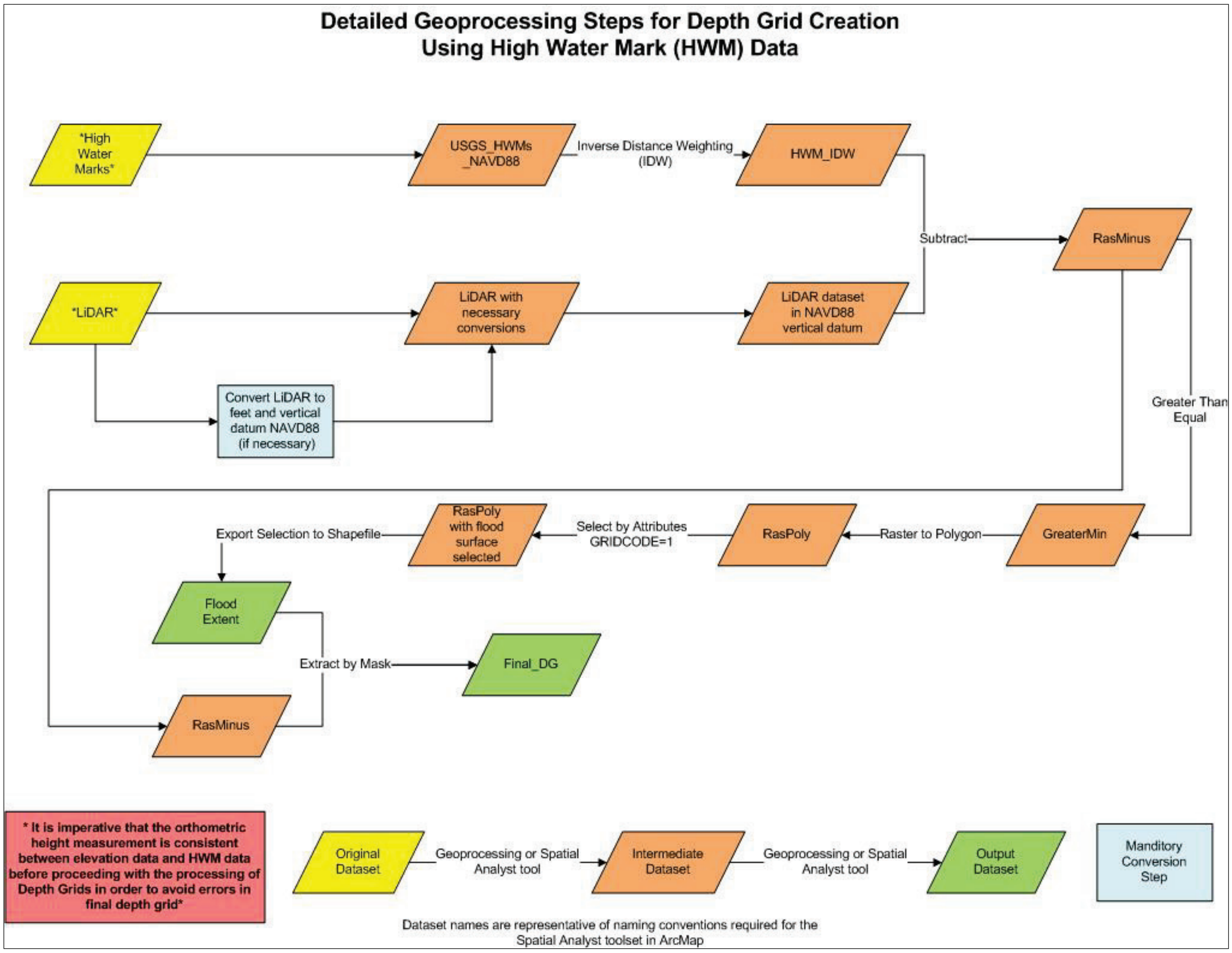


Figure 2-1: Geoprocessing steps for Depth Grid creation

2.2.2. HWM Depth Grid Example

This example below demonstrates the generation of depth grids using HWM data collected from the Souris River flooding of June 2011.

2.2.2.1 Establish Workspace and Define Data

1. Open the Catalog.

   Note: Intermediate datasets are created during the processing of a Depth Grid. It is important to ensure proper organization of these datasets during the Depth Grid creation process. The folders in this structure will also be used to delineate the geoprocessing environments in ArcMap.

2. Create a new project folder.
   2.1 Within the created project folder, create a new folder called “scratch.” This is where all intermediate geoprocessing datasets will be stored.
   2.2 Within the created project folder, create a new folder called “final_datasets”

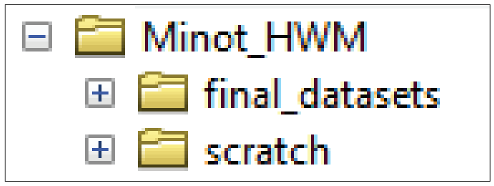


Figure 2-2: Example of creating a new folder called “final_datasets”

3. Open Arcmap.
4. Add terrain and HWM data for the project area in an ArcMap document. Make sure the orthometric height conversion has been completed.

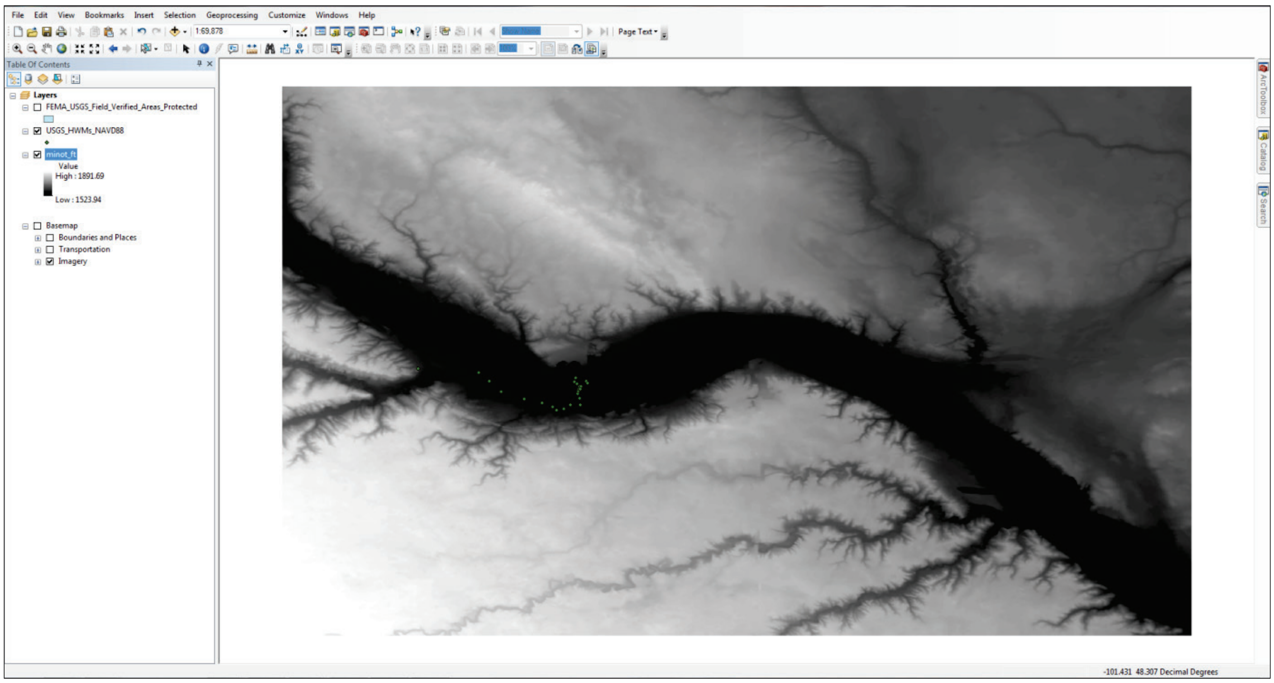


Figure 2-3: Example of adding terrain and HMW data

5. Set geoprocessing environments for ArcMap Document by clicking “Geoprocessing” in the ribbon then clicking “Environments”. It is important to indicate workspace environments inside of ArcMap; this will ensure that intermediate datasets are stored in the proper directories.

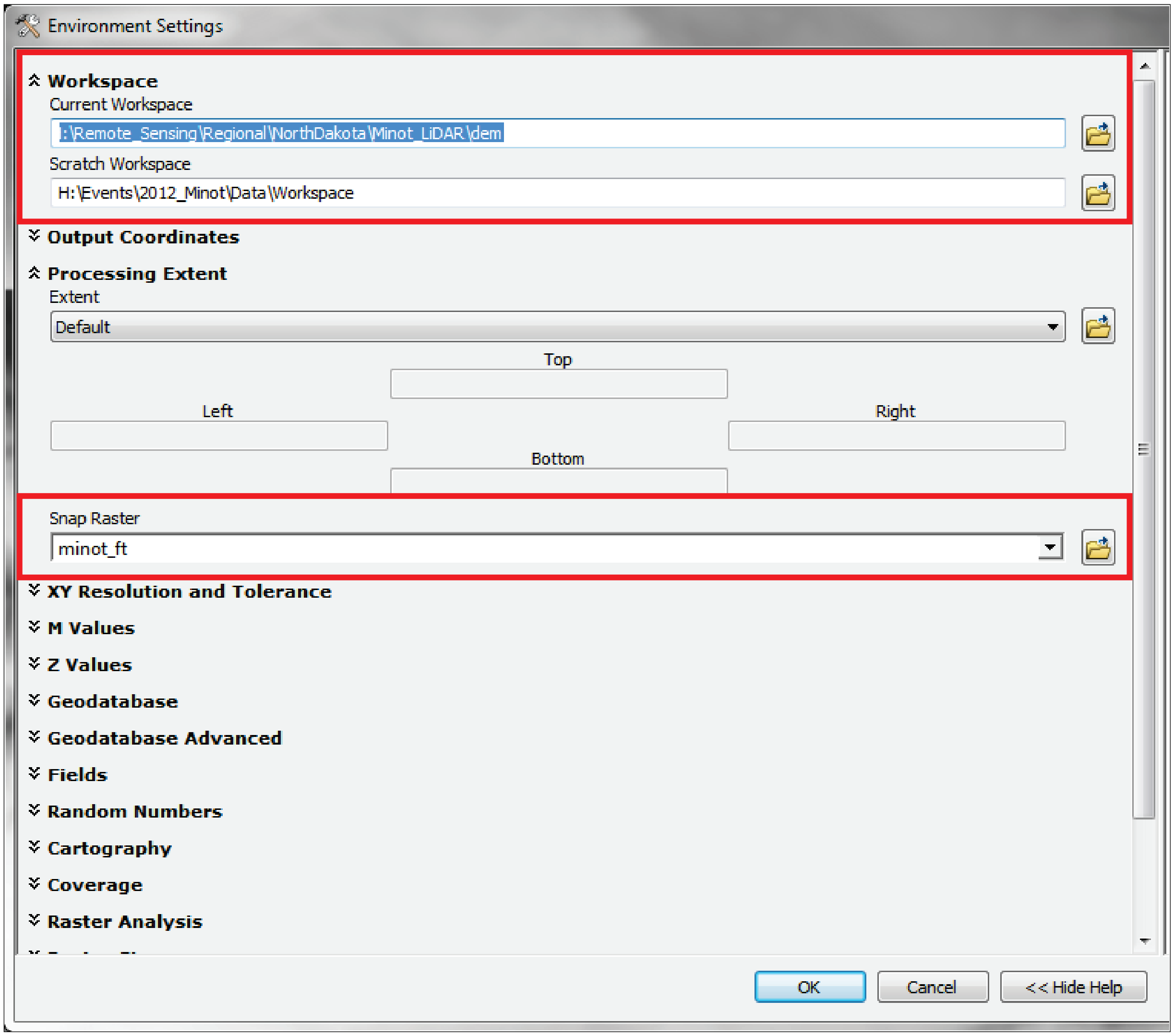


Figure 2-4: Setting geoprocessing environments for ArcMap document

5.1 Set the “Current Workspace” to mirror the location of the terrain data.

5.2 Set the “Scratch Workspace” to mirror the location of the “scratch” folder within the project folder.

5.3 It is important that the “Snap Raster” setting is pointed to the terrain data loaded into the current ArcMap document. If this step is overlooked, inconsistencies will result in the final Depth Grid.

2.2.2.2 Interpolate and Process HMW Data

1. Interpolate HWM points using Inverse Distance Weighted (IDW) Spatial Analyst Tool.
   Note: BFE (Base Flood Elevation) cross sections can also be used in place of High Water Marks to represent 100 or 500-year flood conditions (where effective DFIRMs are available). To do so, convert the BFE cross sections to points using the feature vertices to point tool, then proceed with step 1.

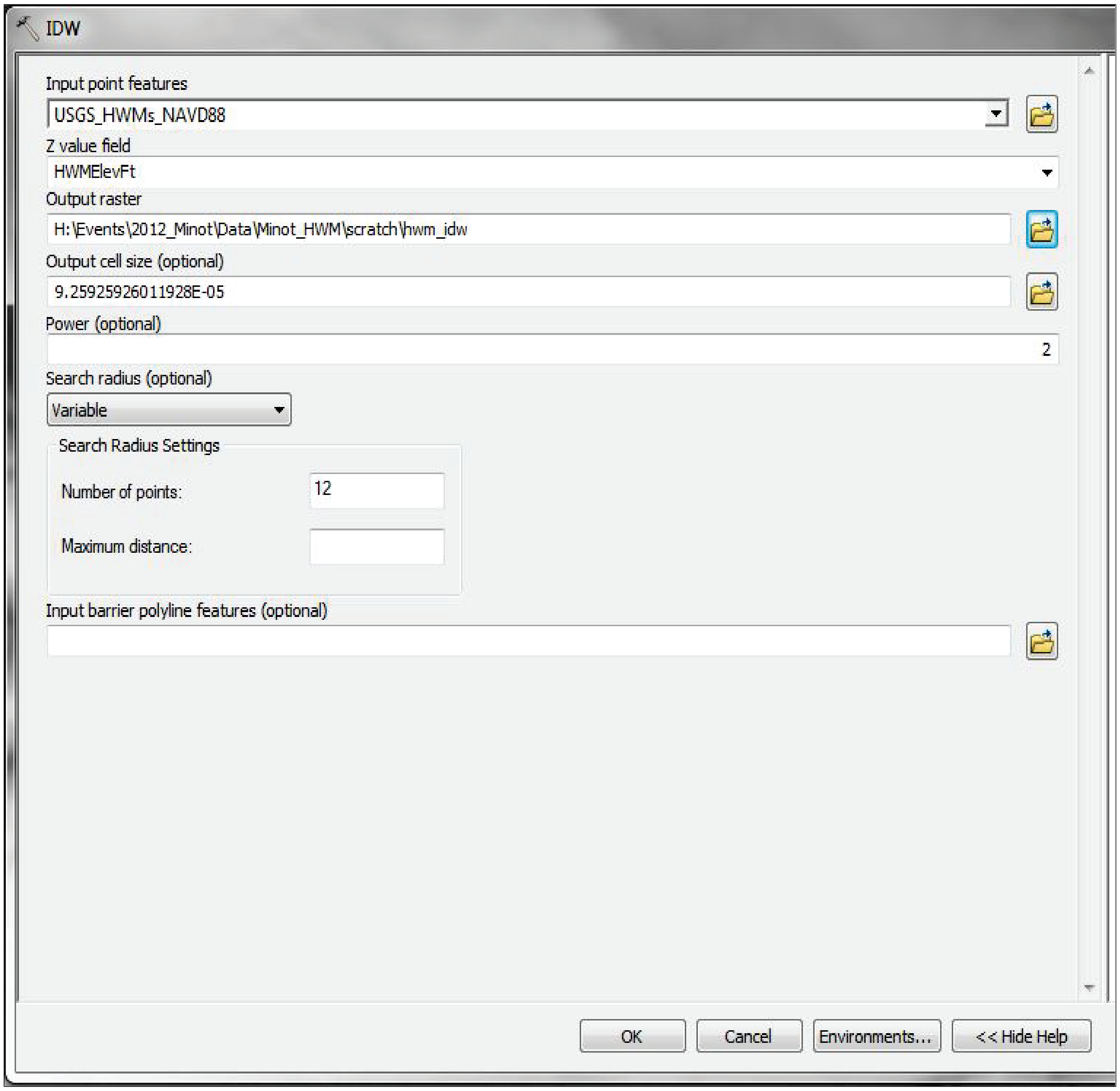


Figure 2-5: IDW

1.1 Input Point Feature: HWM dataset with converted orthometric height measurements (if necessary).
1.2 Z value field: Set this value to the Attribute field in the HWM data representing height in feet.
1.3 Output raster: Set output raster to the “scratch” folder previously created and name the output dataset “hwm_idw.”
1.4 Set the output raster cell size to that of the DEM.
1.5 Under environments set the processing extent to that of the bounding box of the project. If this is omitted, the interpolated surface will extent around the points, and could miss important areas near the edge.

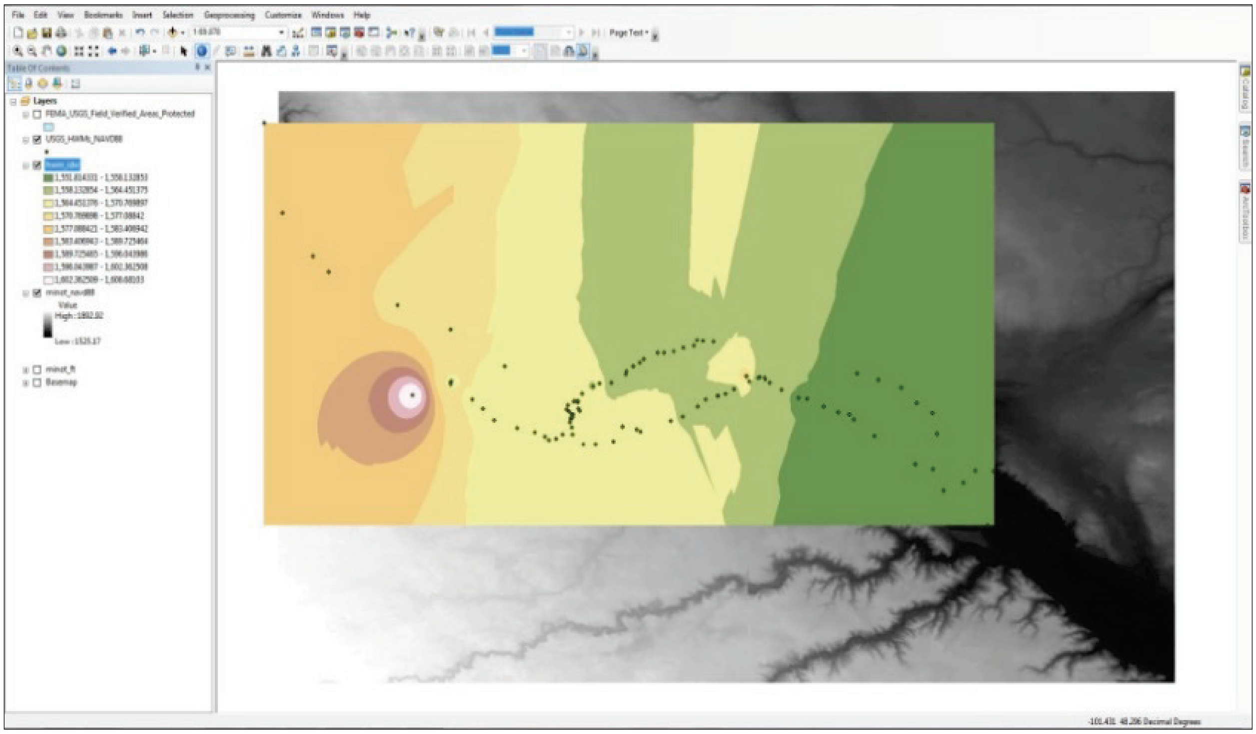


Figure 2-6: Interpolate HWM points using the IDW Spatial Analyst Tool

2. Subtract IDW surface (hwm_idw) with terrain data using the Minus Spatial Analyst Tool or Raster Calculator.

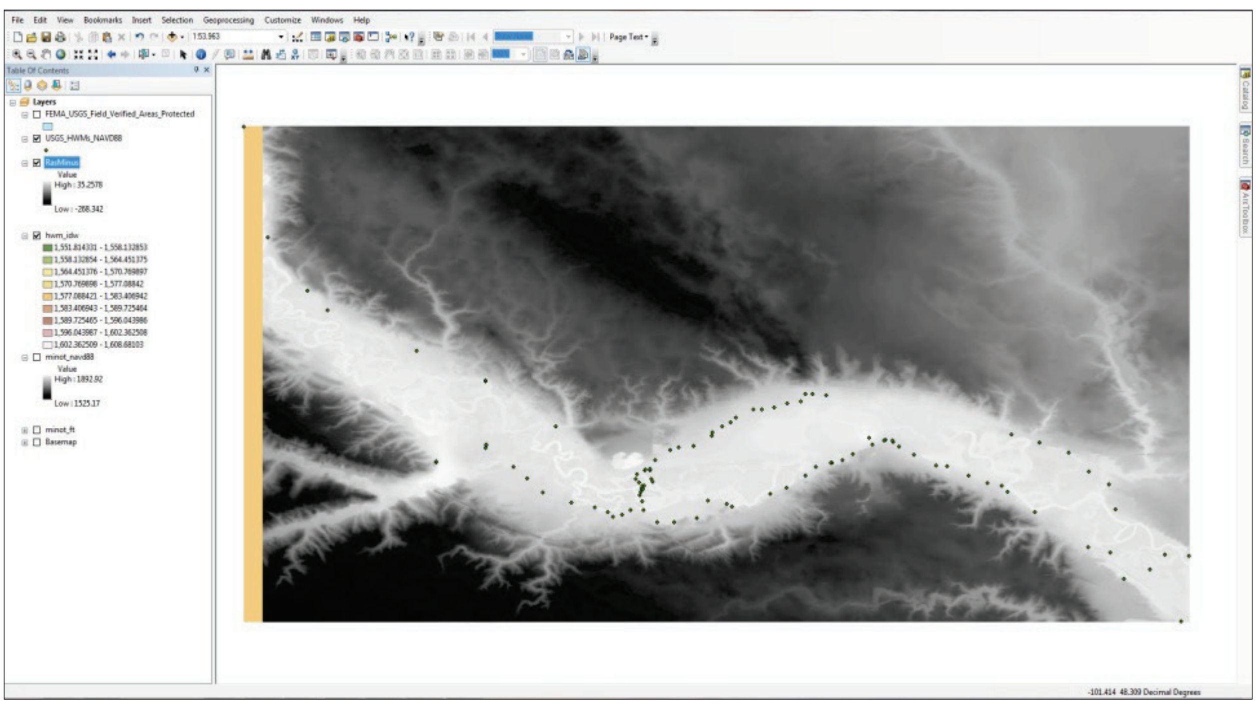


Figure 2-7: Subtract IDW surface with terrain data

2.1 Input raster or constant value 1: “hwm_idw.”

2.2 Input raster or constant value 2: "minot_navd88" (terrain data).
2.3 Output Raster: Set output raster to the "scratch" folder and name the output dataset "RasMinus."

3. In this step, the negative values that are generated in the "RasMinus" surface during the subtraction process need to be removed; this is achieved by using the *Greater Than Equal* Spatial Analyst Tool.

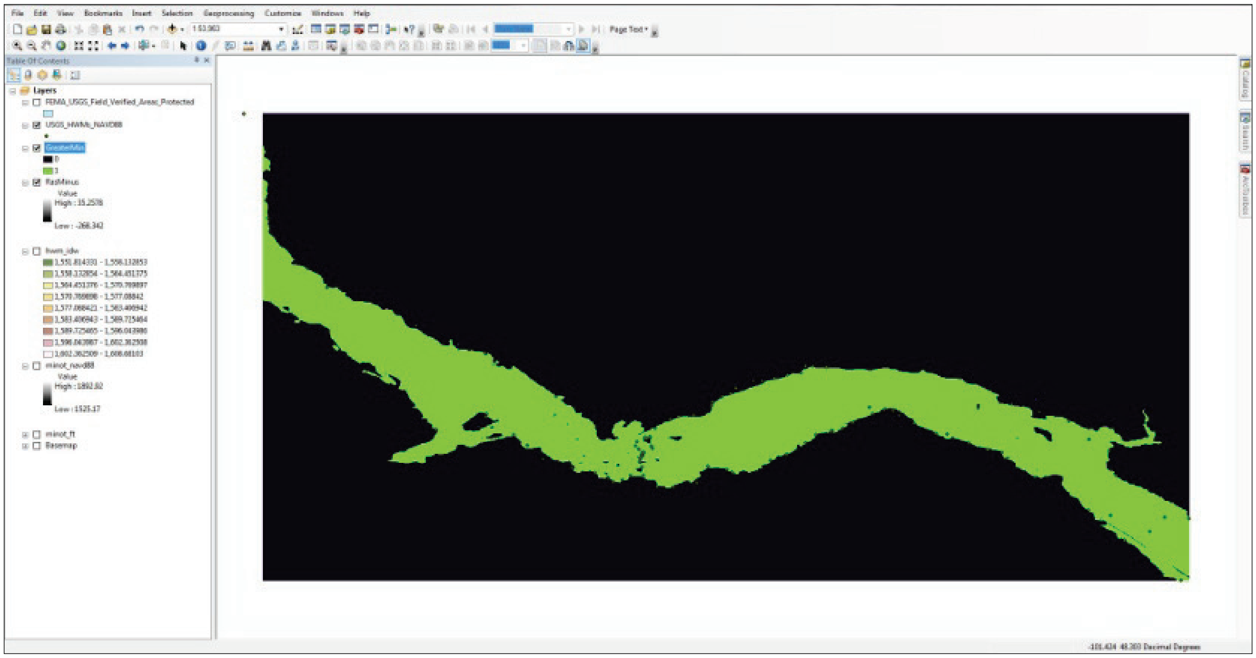


Figure 2-8: Greater Than Equal Spatial Analyst Tool

3.1 Input raster or constant value 1: "RasMinus".
3.2 Input raster or constant value 2: "0." An input value of "0" is necessary at this step since we are only interested in extracting positive values.
3.3 Output Raster: Set output raster to "scratch" folder (ArcMap should automatically default to this folder if environments are set correctly) and name the output dataset "GreaterMin."

Note: The above step will generate a raster dataset with output values of "1" and "0." Raster value "1" represents a "true" statement, in the case of this analysis, all depths greater than 0ft. Raster value "0" represents a "false" statement, meaning all other depths (in this case, all negative values).

2.2.2.3 Extract the Flood Boundary

1. In order to extract a flood extent and have a shapefile to use as a mask to create a final Depth Grid, it is necessary to convert the GreaterMin raster surface created in the previous step into a polygon shapefile. To complete this, use the *Raster to Polygon* Conversion Tool.

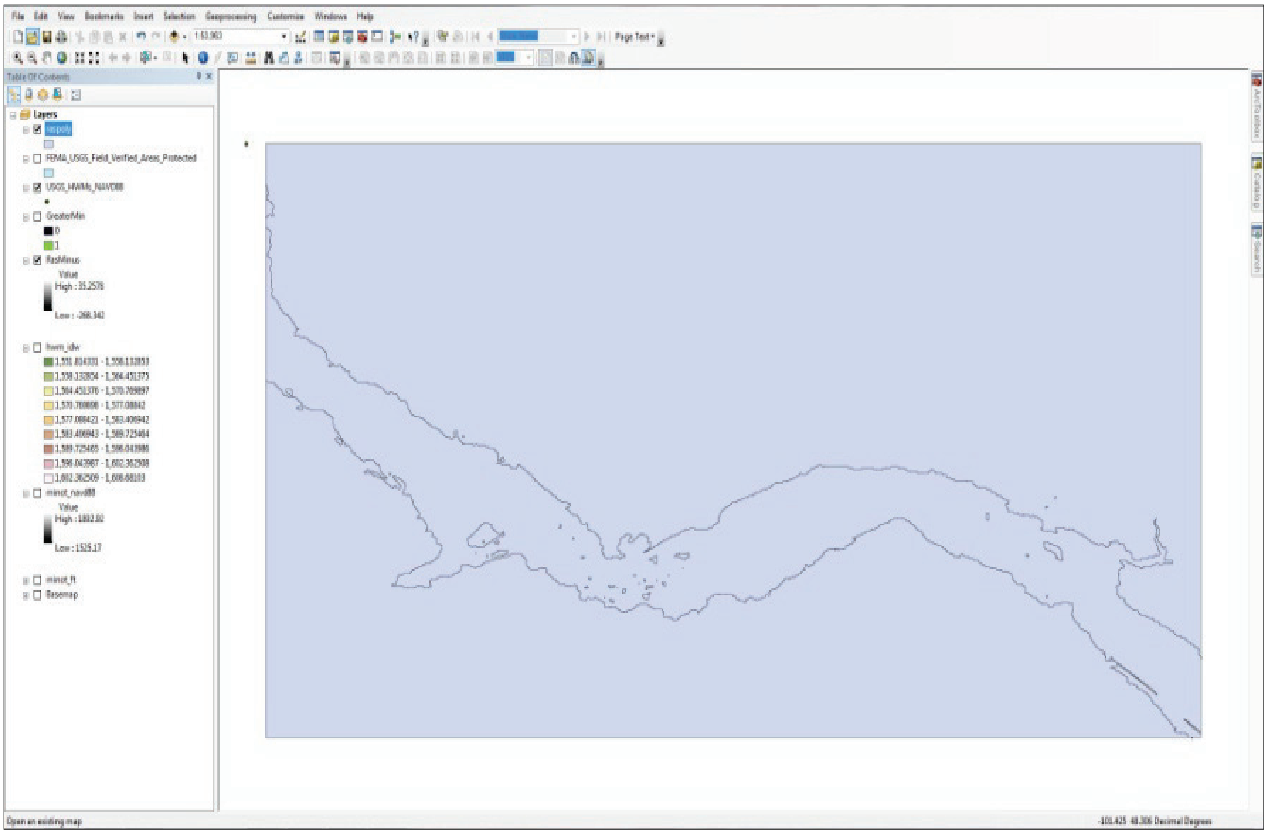


Figure 2-9: Raster to Polygon Conversion Tool

1.1 Input Raster: “GreaterMin”.
1.2 Field: “Value”.
1.3 Output polygon features: If not automatically populated, set the output polygon to “scratch” folder and name the output shapefile “RasPoly.”
1.4 Uncheck the box “Simplify Polygons” before processing.
1.5 The output polygon will contain an attribute field called “GRIDCODE.” The values of “1” and “0” are populated in this field. These values are congruent with the representations described in the previous step.

2. Right click the “RasPoly” shapefile in the ArcMap table of contents and click “Properties.”

   Note: The GRIDCODE value of “0” needs to be removed from the “RasPoly” shapefile created in the previous step. Once this step is completed, the shapefile can be exported and used as a mask to create a depth grid. Use the “Definition Query” tab under the shapefile properties to extract the “1” value.

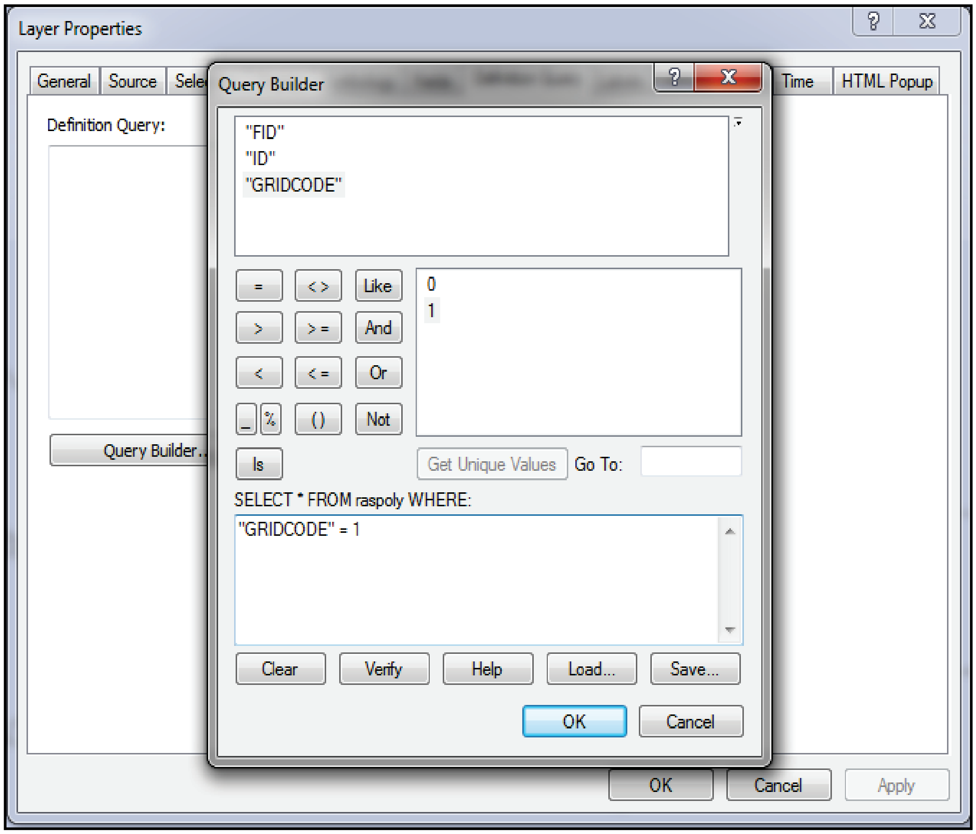


Figure 2-10: Query Builder

3. Click on the "Definition Query" tab and click "Query Builder."
   3.1 Enter: "GRIDCODE" = 1, click OK in the "Query Builder" window, click "OK" in "Layer Properties" window.

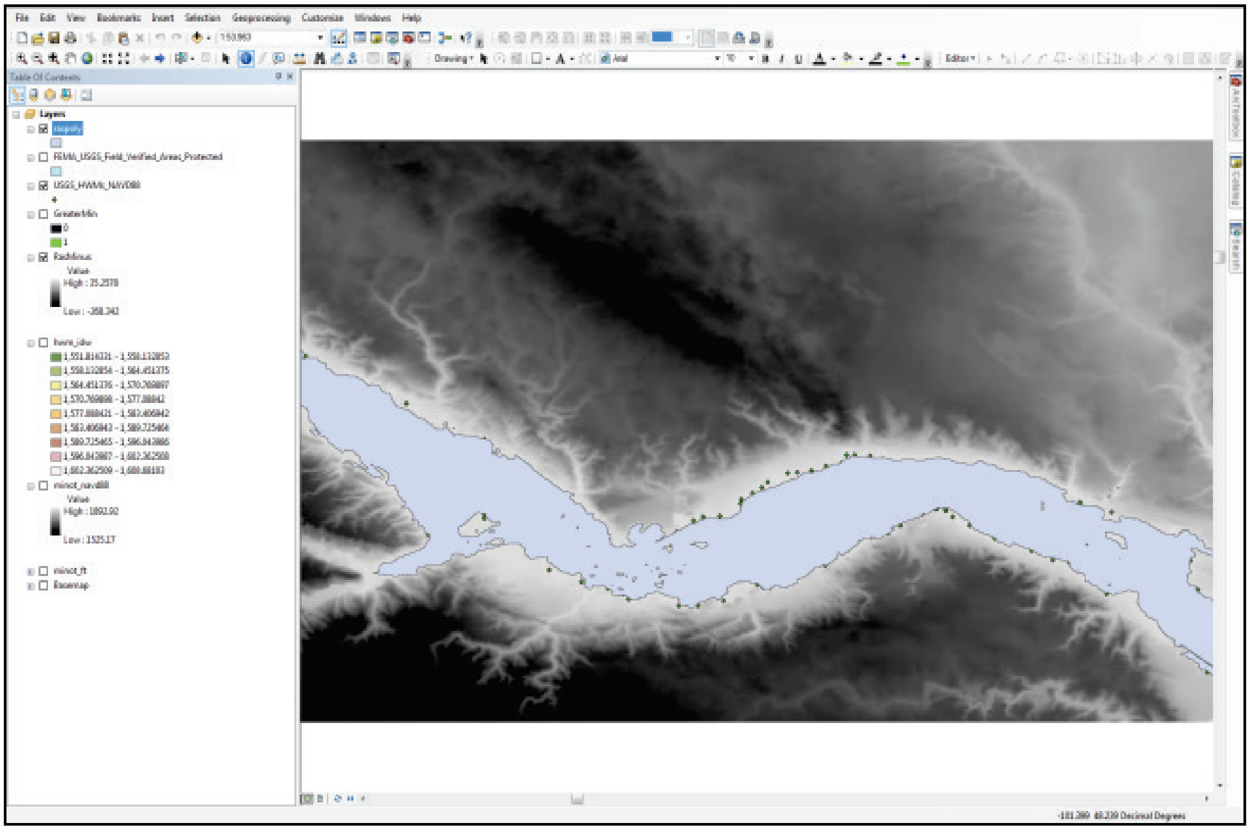


Figure 2-11: Using the "Definition Query" tab under the shapefile properties to extract the "1" values.

4. Right click the “RasPoly” shapefile in the ArcMap table of contents and click “Data” then “Export Data.” Click “OK”

   Note: Export the “RasPoly” shapefile created in the previous step (with GRIDCODE “1” extracted). This is the final flood extent polygon. This will be saved in the “final_datasets” directory.

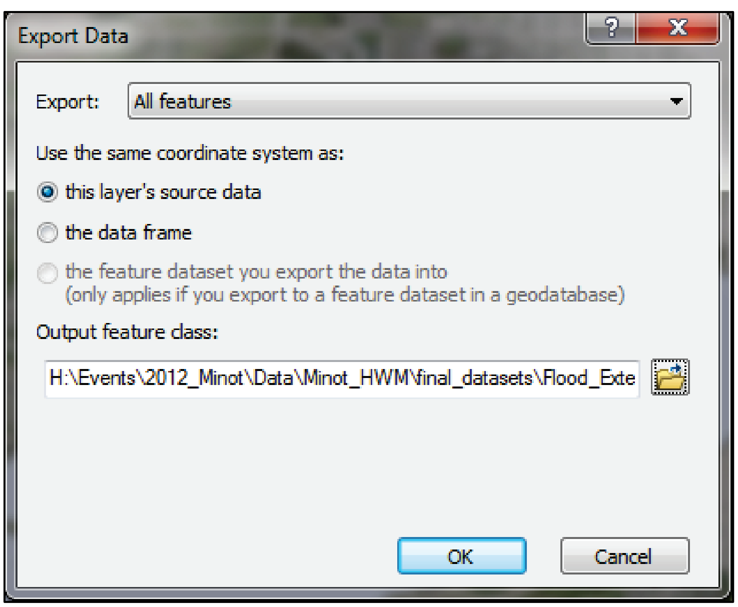


Figure 2-12: Exporting the “RasPoly” shapefile

5. Save in the “final_datasets” folder created in previous steps and name the shapefile “Flood_Extent.”

2.2.2.4 Create the Final Depth Grid

1. Create final depth grid using Extract by Mask Spatial Analyst Tool. In the previous step, a new shapefile was created showing the maximum potential flood extent derived from the High-Water Mark data. The previously created shapefile will now be used as a mask to create the final depth grid.

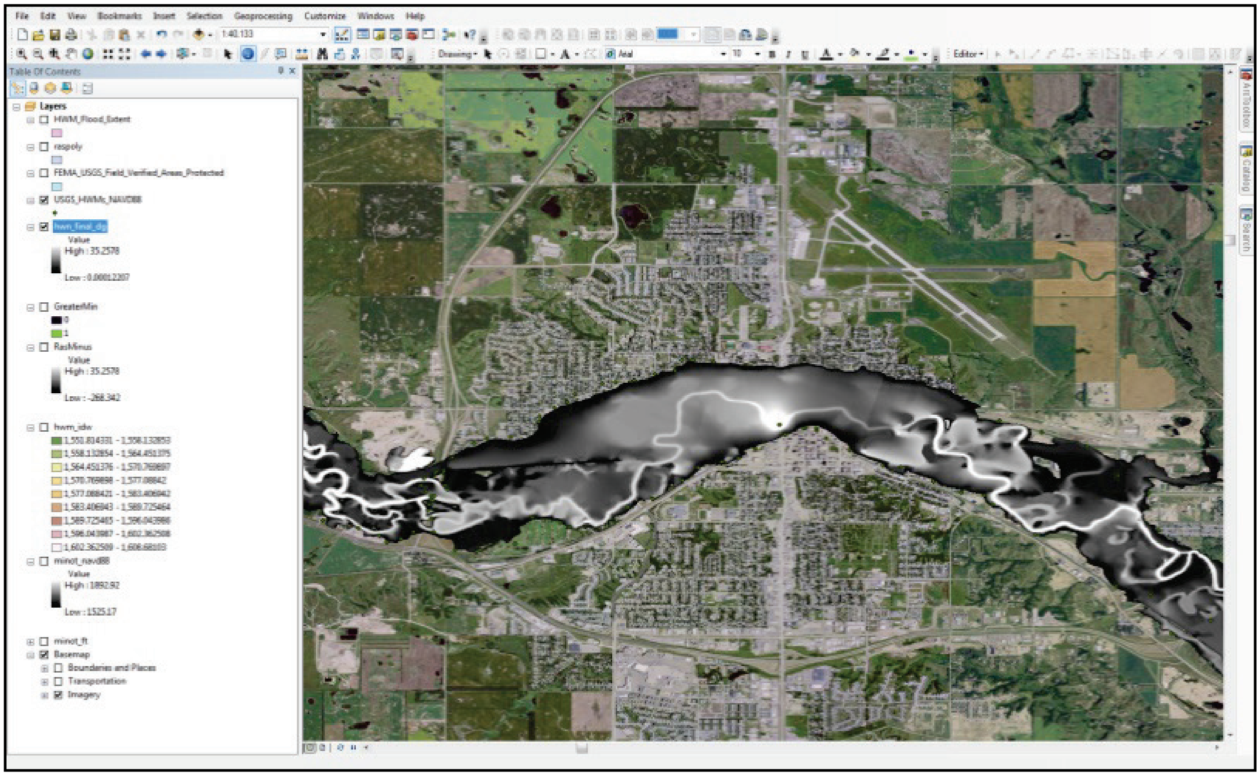


Figure 2-13: Create final depth grid using Extract by Mask Spatial Analyst Tool

   1.1 Input Raster: “RasMinus” (created in step 5).

   1.2 Input raster or feature mask data: “Flood_Extent” (created in previous step).

   1.3 Output raster: Set the output to save in the “final_datasets” folder and name the raster “final_dg.”

2. Symbolize the final depth grid to better illustrate differences in depth.

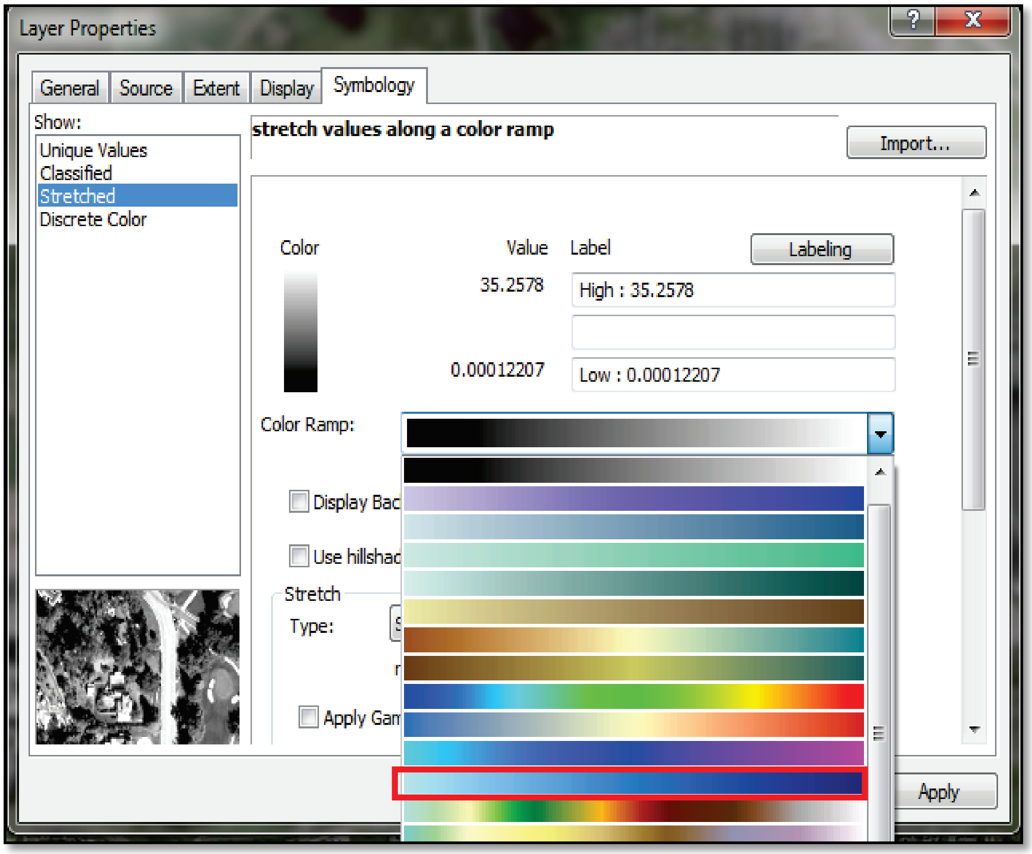


Figure 2-14 Symbolizing the final depth grid

2.1 Double click the "final_dg" raster file in the ArcMap table of contents to access the layer properties.
2.2 Click the "Symbology" tab.
2.3 Select the light-blue to dark-blue color ramp.
2.4 If desired, click the "Display" tab and set the transparency to 40 percent.
2.5 Click "OK"

2.3. Creating a Depth Grid using DFIRM Data

The example below demonstrates the geoprocessing steps to create a depth grid using the Digital Flood Insurance Rate Map (DFRIM) and Esri ArcMap spatial analyst toolset. A depth grid based off of the city and county of Denver DFIRM for an area along the South Platte River near Evans Avenue and Interstate 25 (I-25) will be created. This section will take roughly 40 minutes to complete.

2.3.1. Required Geographic Datasets

Terrain Data (DEM): Use 1 meter LiDAR collected after the 2013 Colorado floods for the exercise.

Digital Flood Insurance Rate Map (DFIRM): The data for this example is for the City and County of Denver (NFHL_080046; Last Study Effective Date: 11/20/2013; Last LOMR Effective Date: 09/29/2017) and can be located on the FEMA Maps Service Center website (https://msc.fema.gov/portal).

Area of Interest (AOI): An AOI is provided to ensure it is possible to complete this example is a reasonable timeframe.

2.3.2. DFIRM Depth Grid Example

The example below demonstrates the geoprocessing steps to create a depth grid using the Digital Flood Insurance Rate Map (DFRIM) and Esri ArcMap spatial analyst toolset. A depth grid based off of the city and county of Denver DFIRM for an area along the South Platte River near Evans Avenue and Interstate 25 (I-25) will be created.

2.3.2.1 Establish Workspace and Define Data

1. Download data for the city and county of Denver, Colorado.
    - 1.1 DFIRM Data
    - 1.2 DEM data
    - 1.3 AOI data

2. Ensure all data are projected in the Geographic Coordinate System North American Datum (GCS_NAD83) as shown in Figure 2-15.

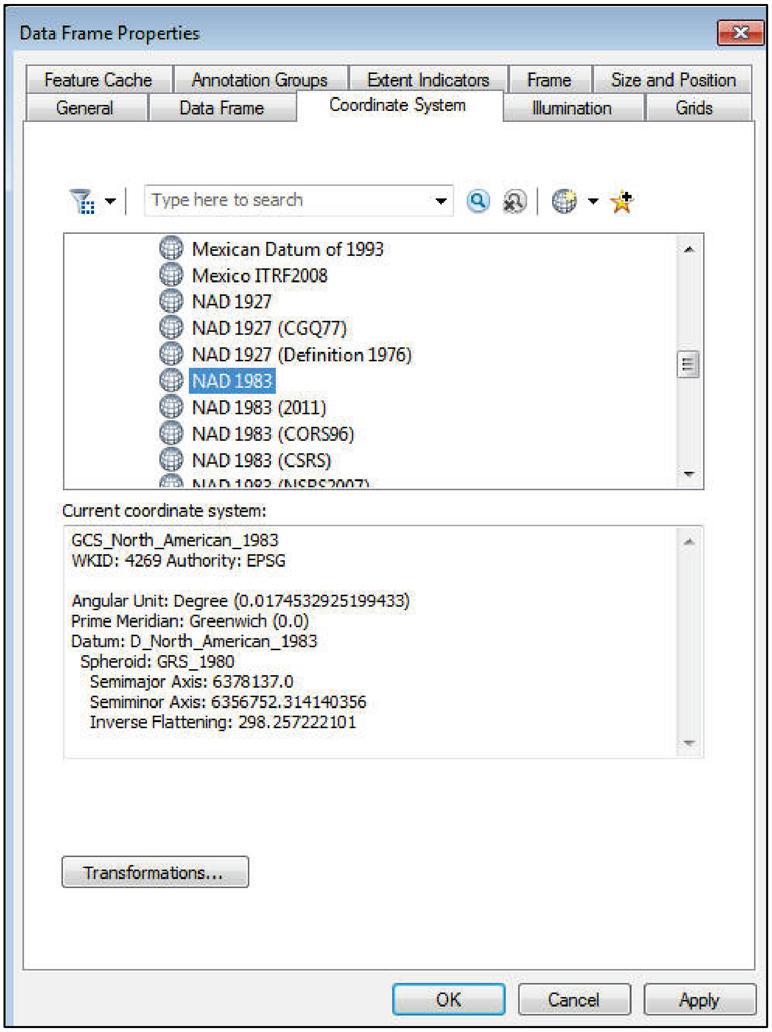


Figure 2-15: Data Frame Coordinate System

2.1 Ensure the Spatial Analyst extension is activated by navigating to "Customize," "Extensions," and check the box next to "Spatial Analyst."

3. Use the Clip tool to clip the "S_FLD_HAZ_AR" shapefile from the DFIRM data to the "Denver_DG_AOI" (see Figure 2-16).

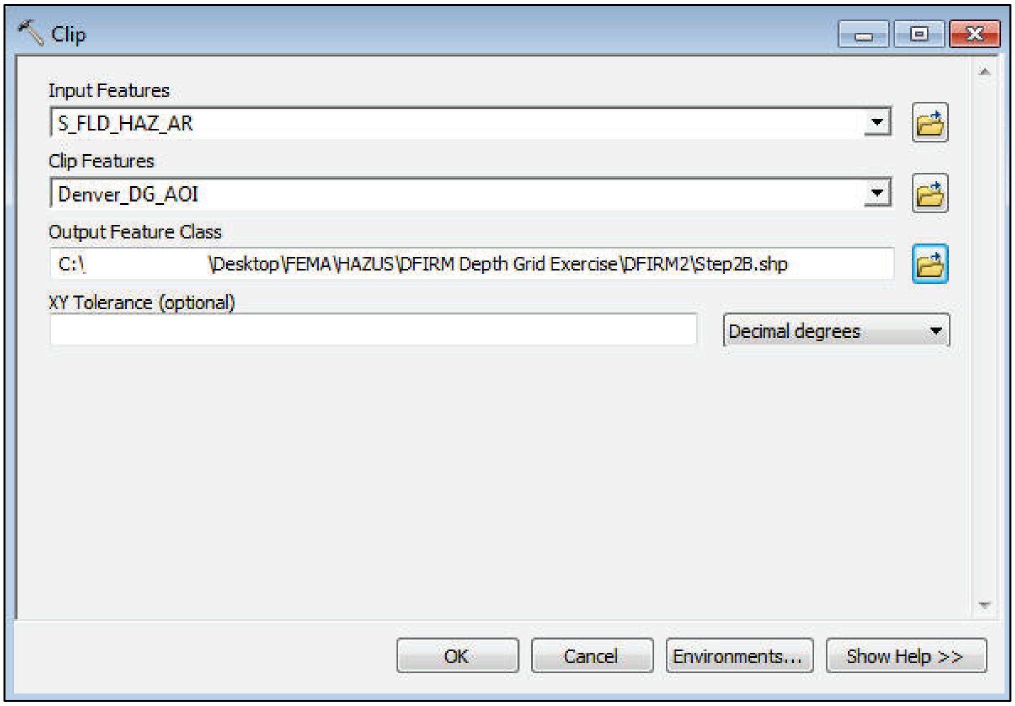


Figure 2-16: Clip Tool

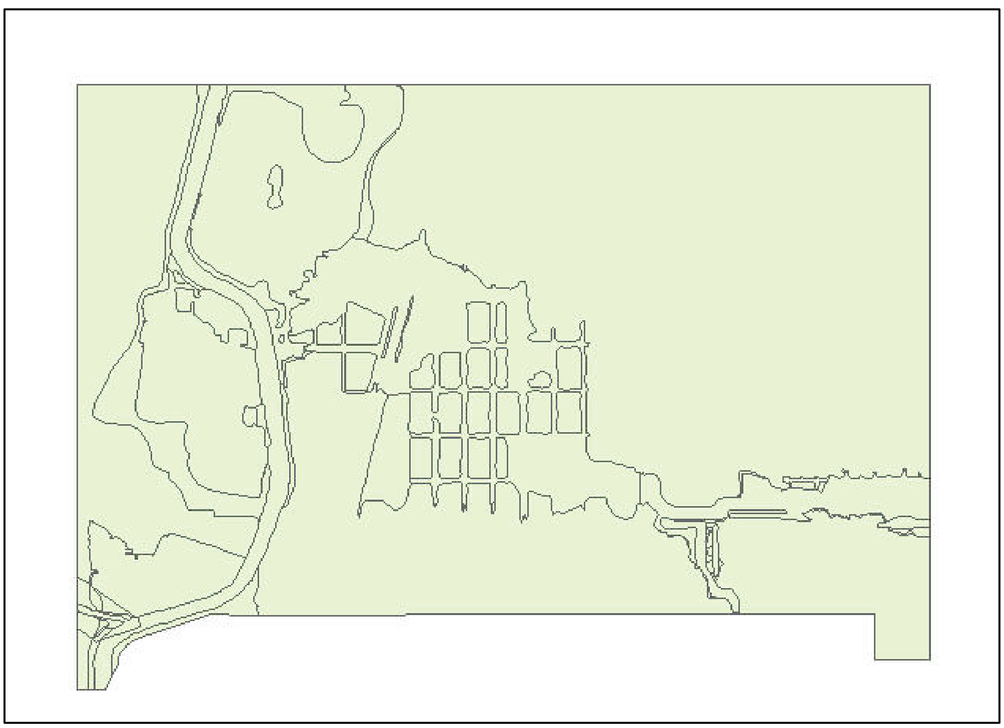


Figure 2-17: S_FLD_HAZ_AR layer clipped to Denver_DG_AOI

4. Use the “Select by Attribute” tool to select the following flood zones (FLD_ZONE) as shown in Figure 2-18.

   4.1 Select the AE flood zones and click “Apply.”

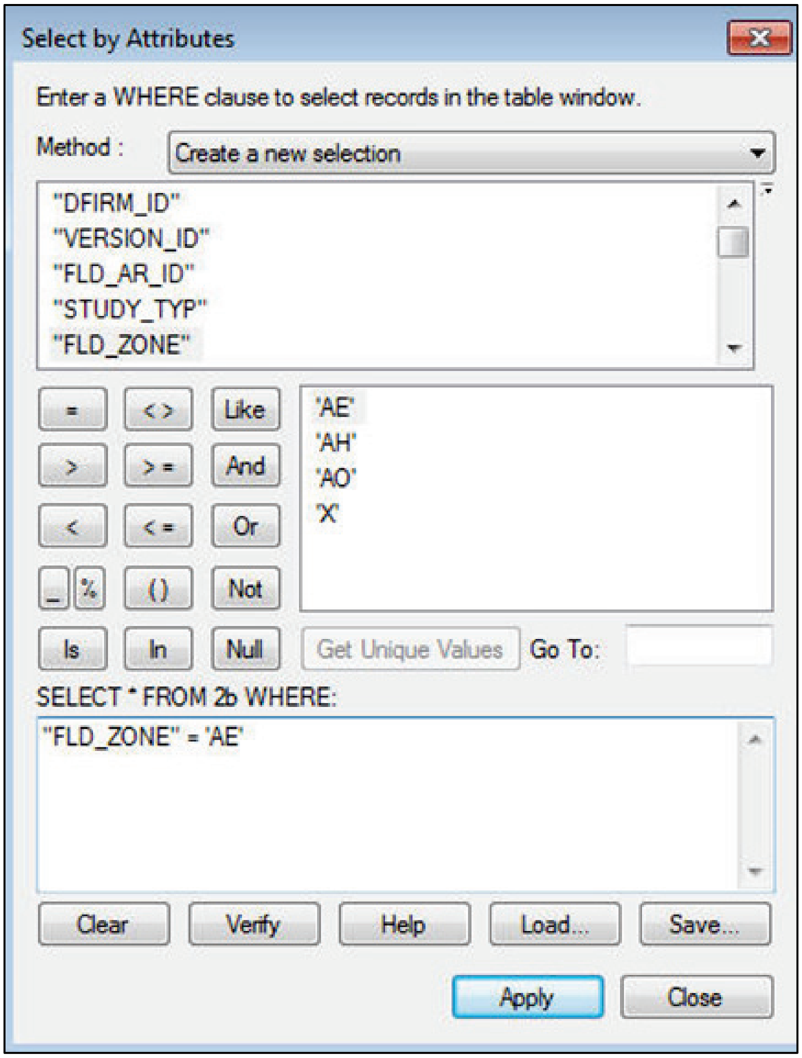


Figure 2-18: Select the "AE" Flood Zone

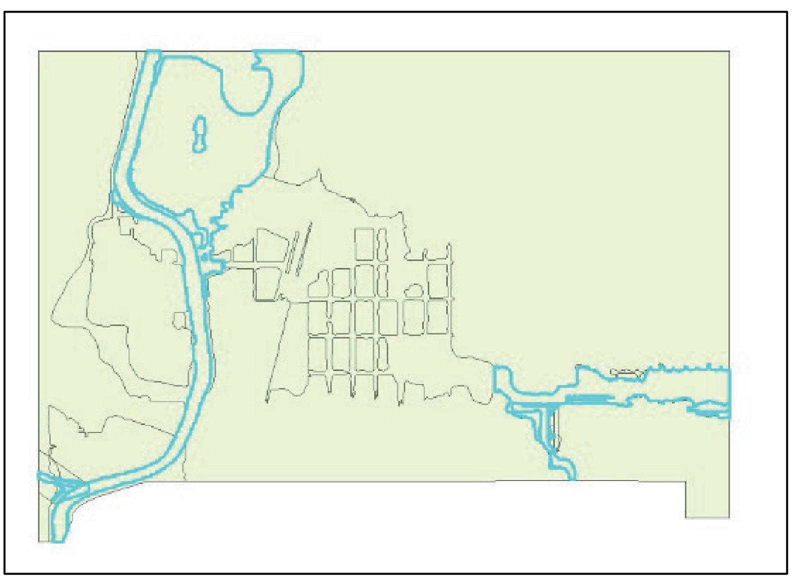


Figure 2-19: AE Flood Zone selected

4.2 Right click on the shapefile in the Table of Contents and navigate to Data and then to Export Data to export the AE flood zone selection to a new shapefile.

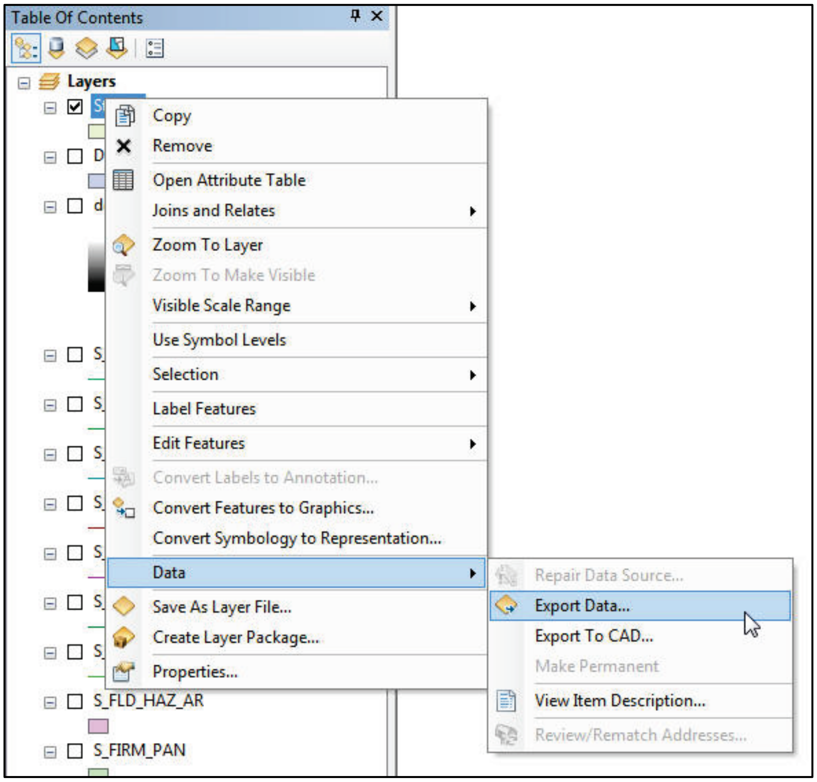


Figure 2-20: Export selection to new shapefile

4.3 Select the radio button next to "the data frame" and click "OK" to save the shapefile In the Export Data dialog box (see Figure 2-21).

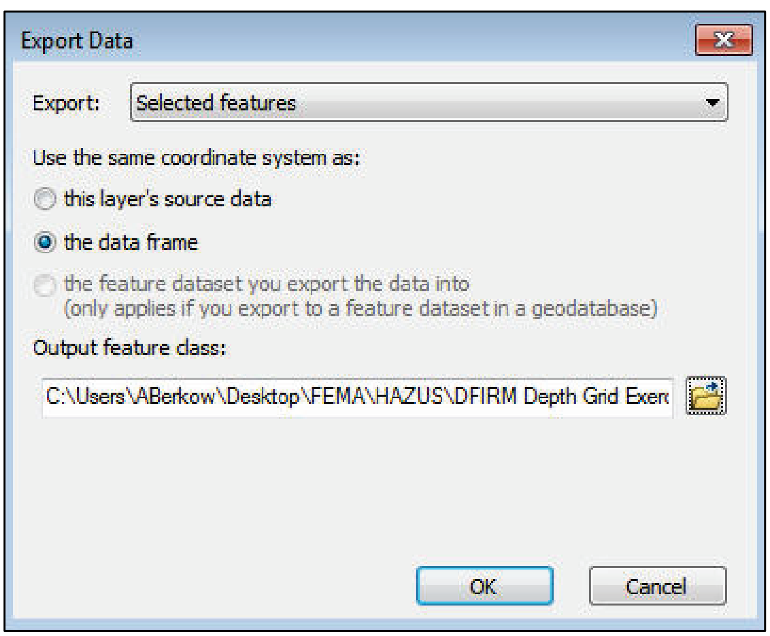


Figure 2-21: Export Data dialog box

Figure 2-22: AE Flood Zone

4.4 Select the AO flood zones and click “Apply” (see Figure 2-23).

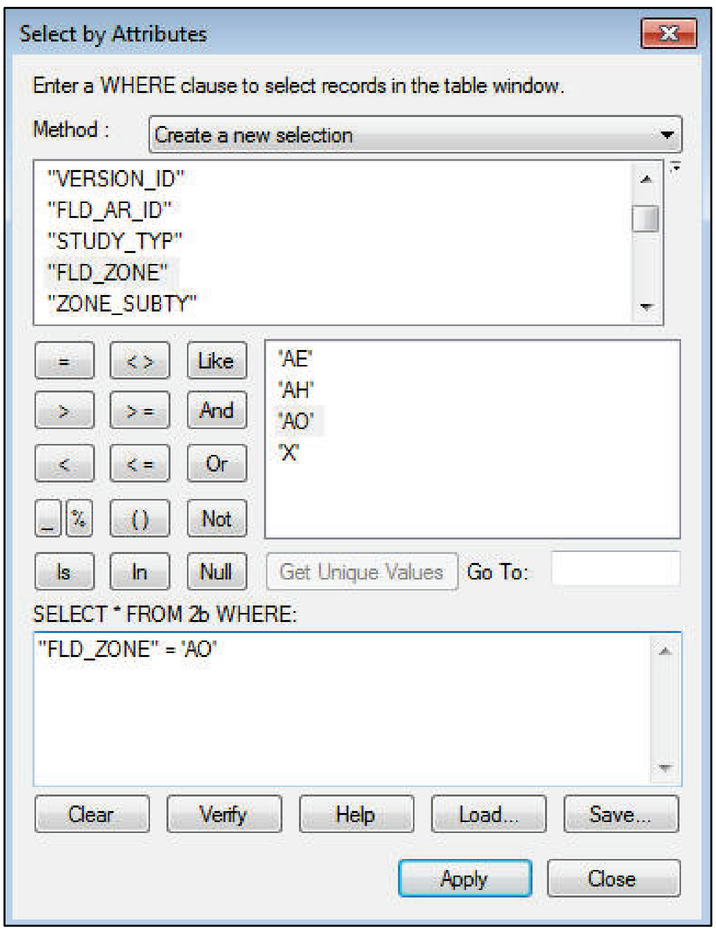


Figure 2-23: Select the "AO" Flood Zones

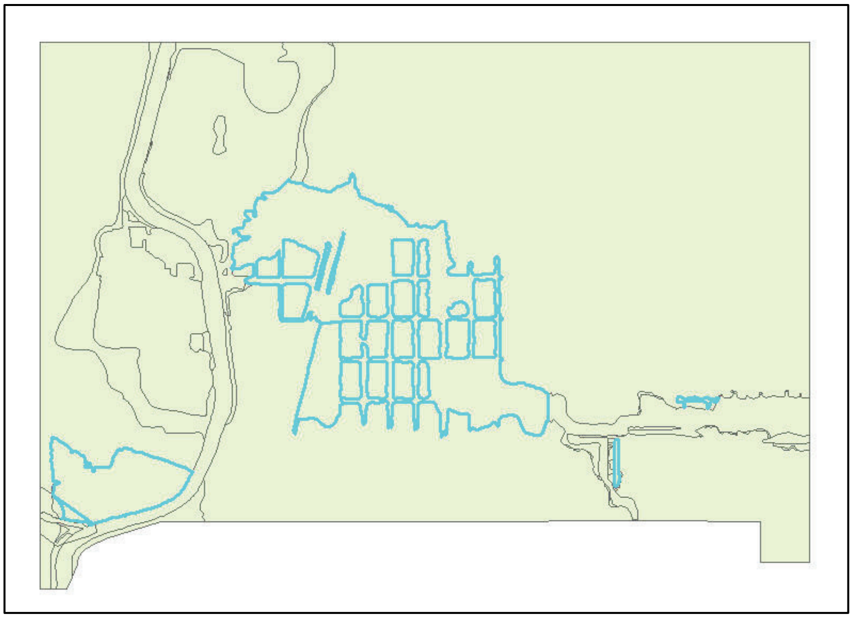


Figure 2-24: "AO" Flood Zones Selected

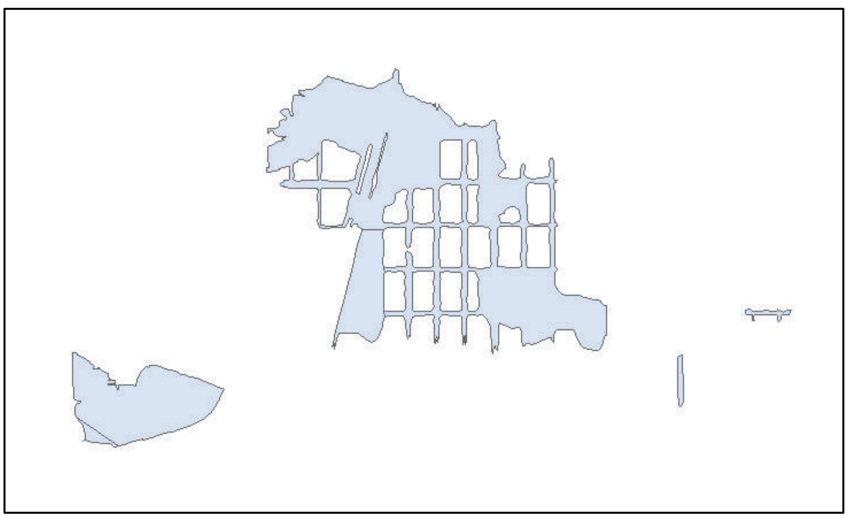


Figure 2-25: AO Flood Zone

4.5 Right click on the shapefile in the Table of Contents and navigate to Data and then to Export Data to export the AO flood zone selection to a new shapefile.
4.6 Select the radio button In the Export Data dialog box next to “the data frame” and click “OK” to save the shapefile.
4.7 Select the AH flood zones as shown in Figure 2-26.

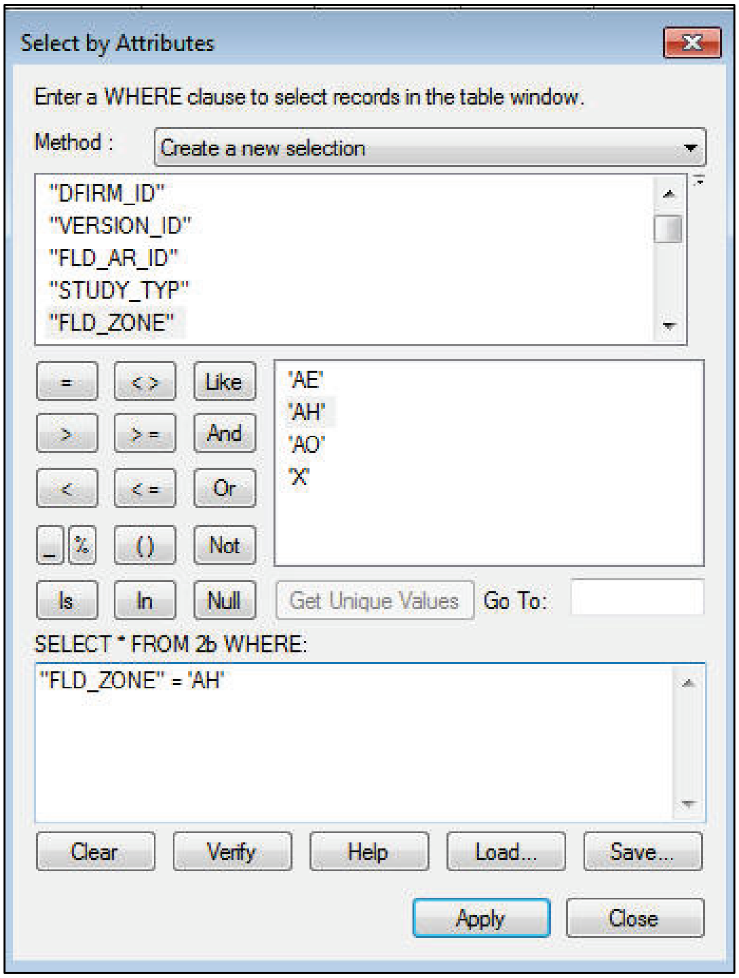


Figure 2-26: Select AH Flood Zone

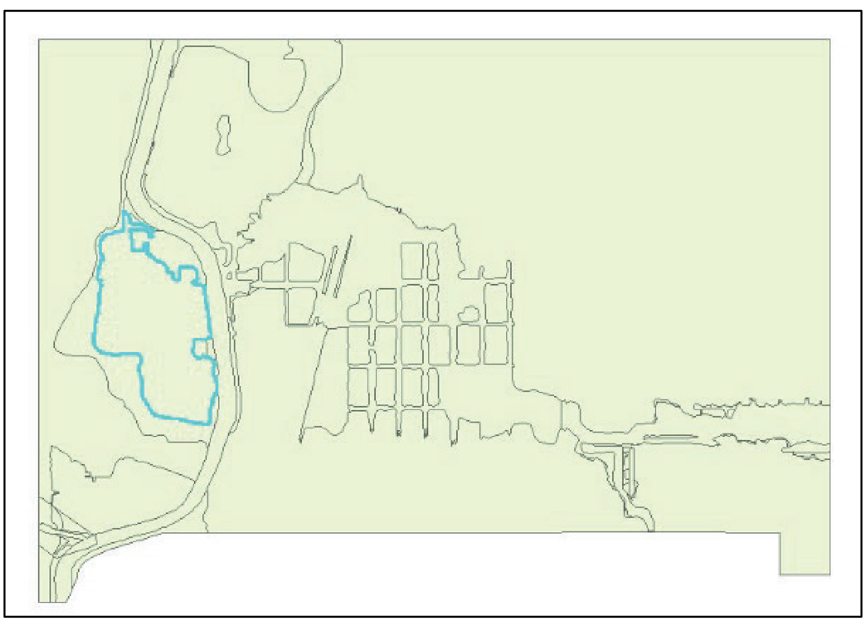


Figure 2-27: AH Flood Zone Selected

4.8 Right click on the shapefile in the Table of Contents and navigate to Data and then to Export Data to export the AH flood zone selection to a new shapefile.

4.9 Select the radio button in the Export Data dialog box next to "the data frame" and click "OK" to save the shapefile.

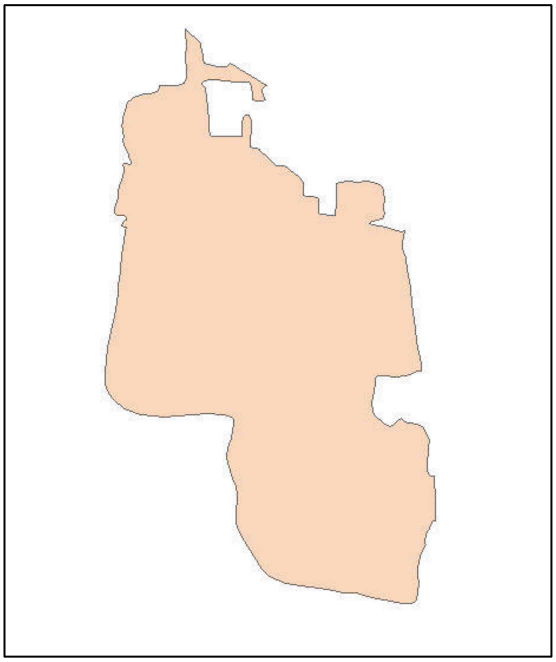


Figure 2-28: AH Flood Zone

5. Use the "Select by Attribute" tool to create a new shapefile.

   5.1 Select "SFHA_TF" = "T" and click "Apply."

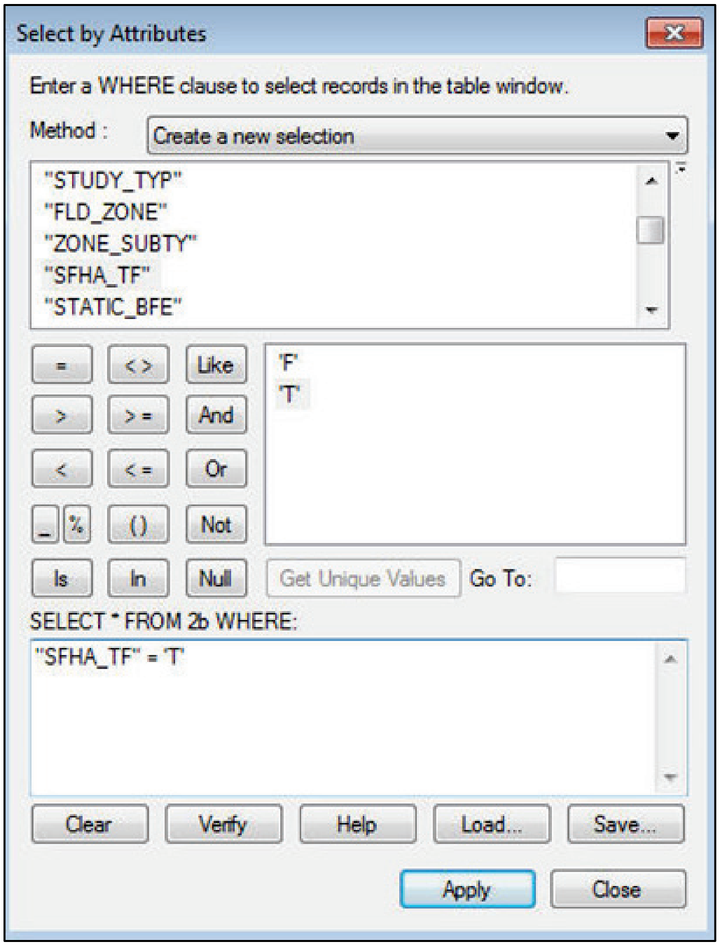


Figure 2-29: Select SFHA = T

5.2 Right click on the shapefile in the Table of Contents and navigate to Data and then to Export Data to export the "SFHA_TF" = "T" selection to a new shapefile.

5.3 Select the radio button in the Export Data dialog box next to "the data frame" and click "OK" to save the shapefile.

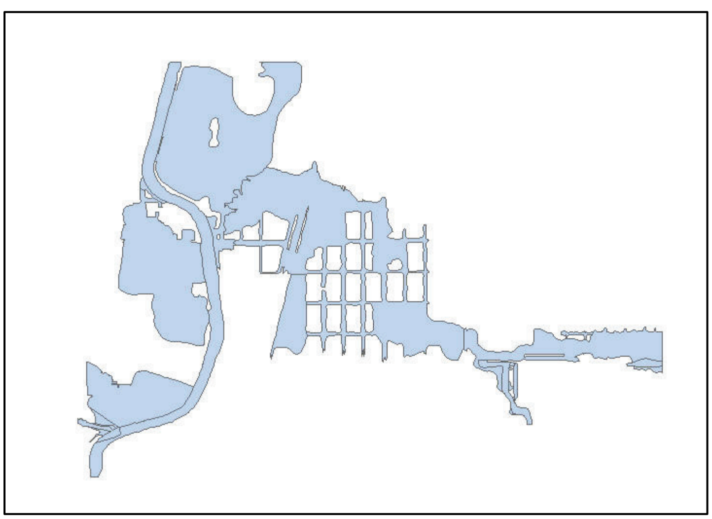


Figure 2-30: SHFA=T Selection

5.4 Use the "Dissolve" tool to create the inundation boundary.

6. The input feature class is the results from the steps above.

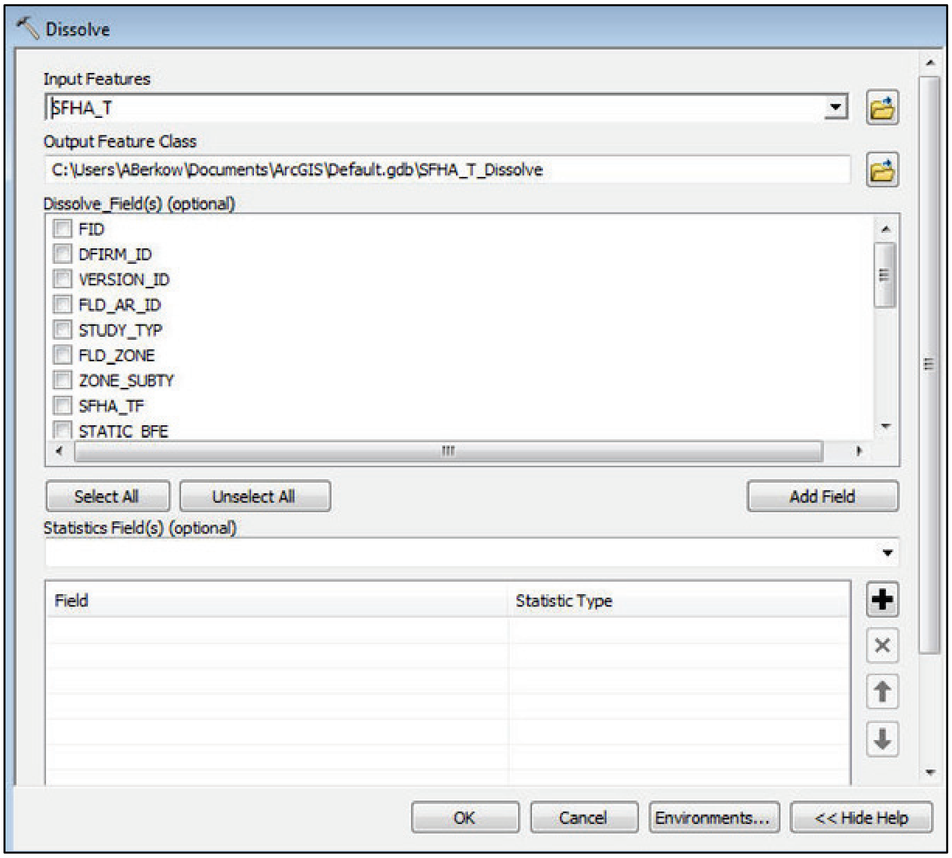


Figure 2-31: Dissolve SFHA_T polygon

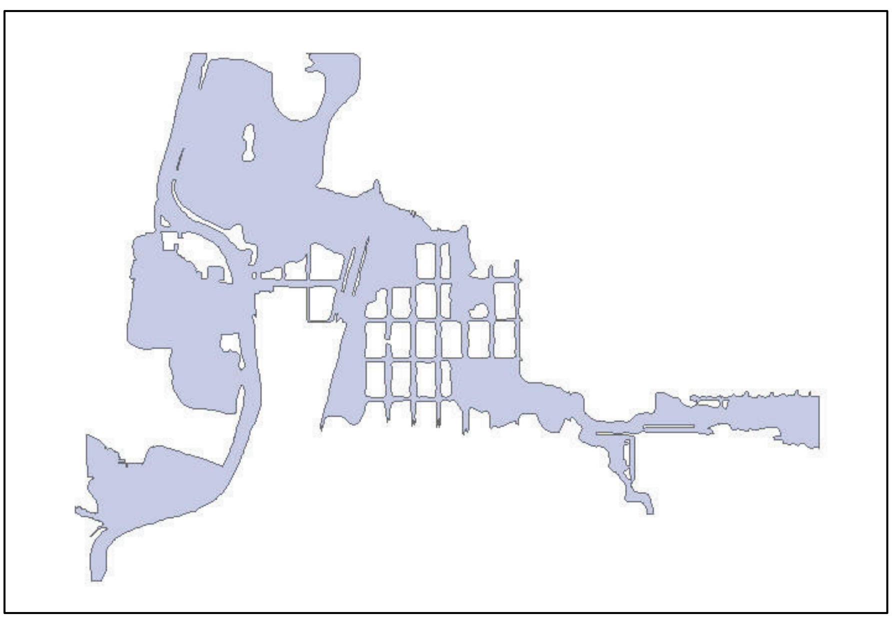


Figure 2-32: Inundation Boundary

7. Use the Clipping tool to clip "S_XS" (cross sections) by the AE_Flood_Zones (Figure 2-33).

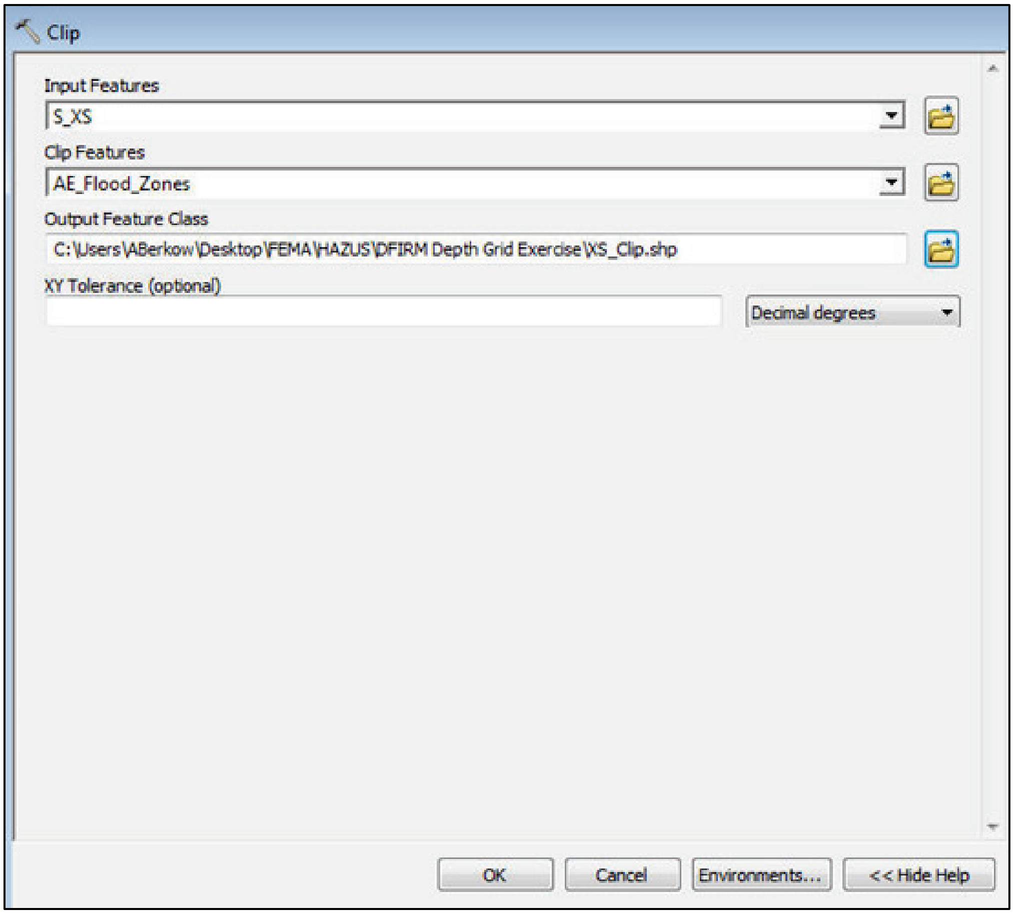


Figure 2-33: Clip the cross sections by the AE flood zones

Figure 2-34: Cross sections clipped by AE flood zones

8. Open the Feature Vertices to Points tool to convert the cross section line segments into points as shown in Figure 2-35.
   8.1 Change the input features to the "XS_Clip" file created.
   8.2 Set the Point Type to All.

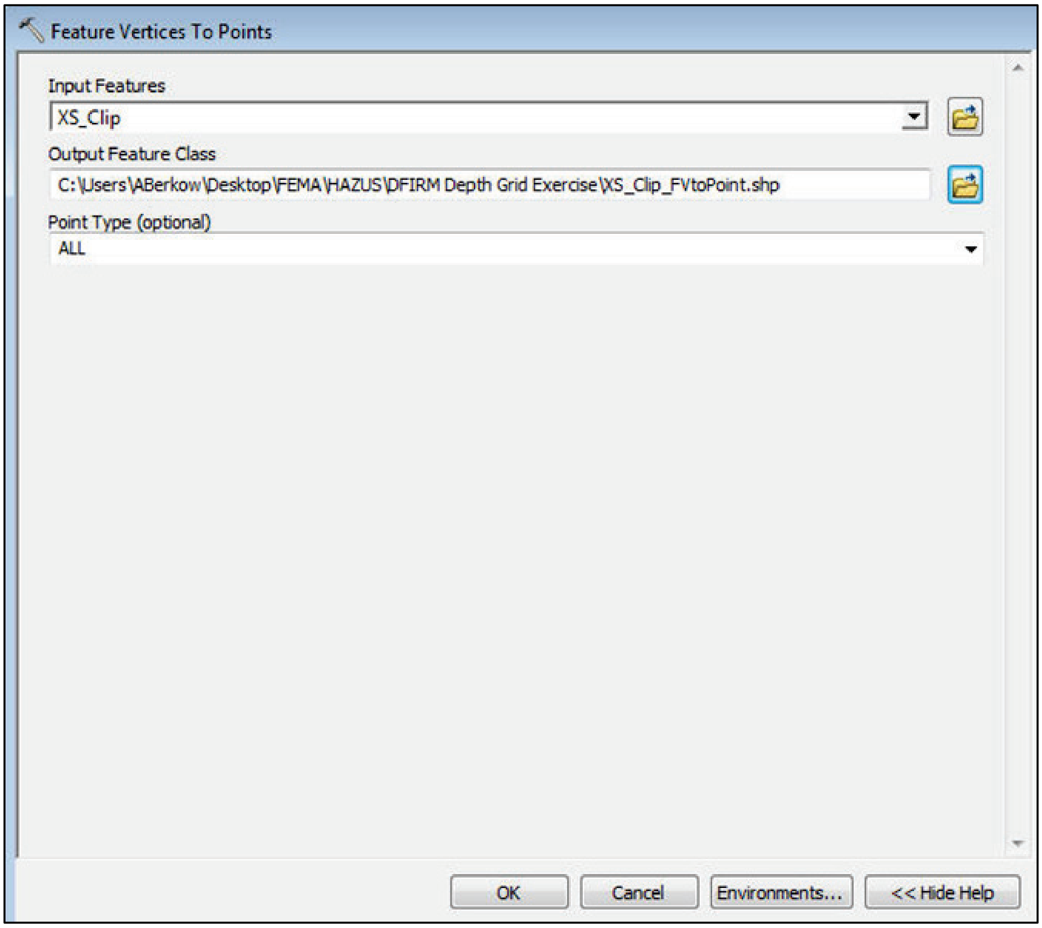


Figure 2-35: Feature Vertices to Points tool

Figure 2-36: Feature Vertices to Points conversion

9. Use the Extract Values to Points tool to extract the DEM value at each feature point as shown in Figure 2-37.
   9.1 The input features are the points from the previous step.
   9.2 The input raster is the DEM.

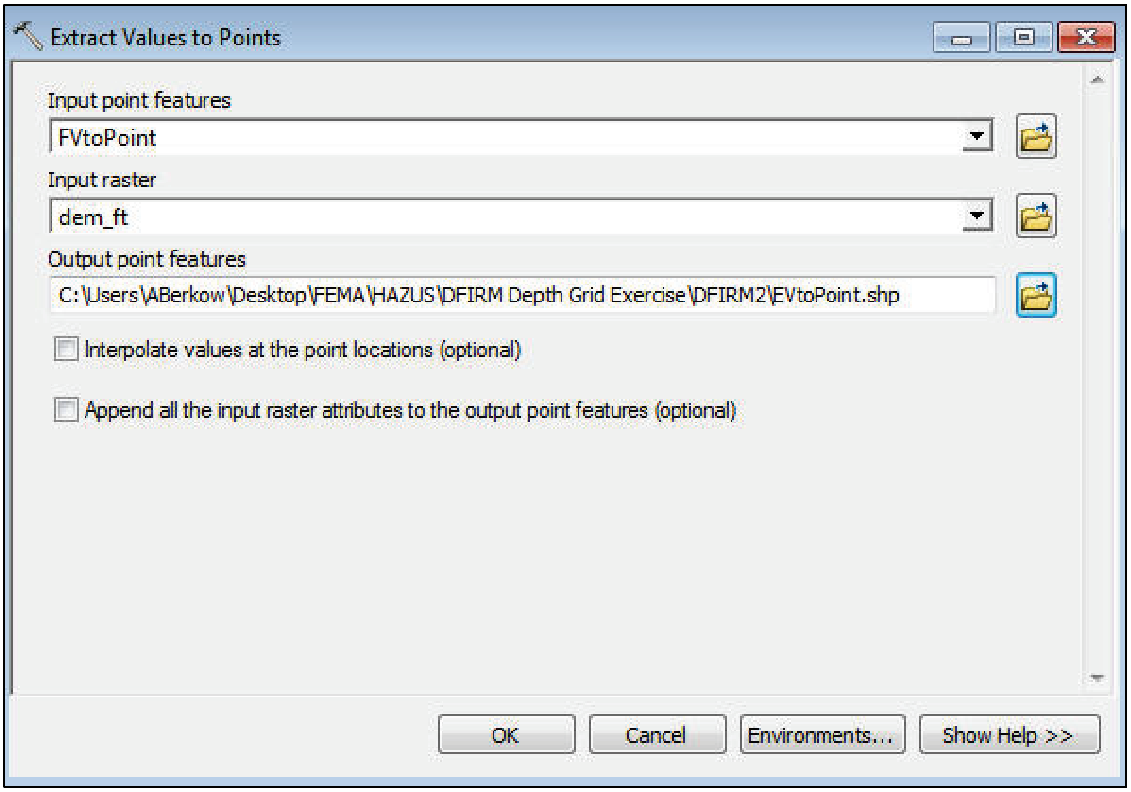


Figure 2-37: Extract Values to Points tool

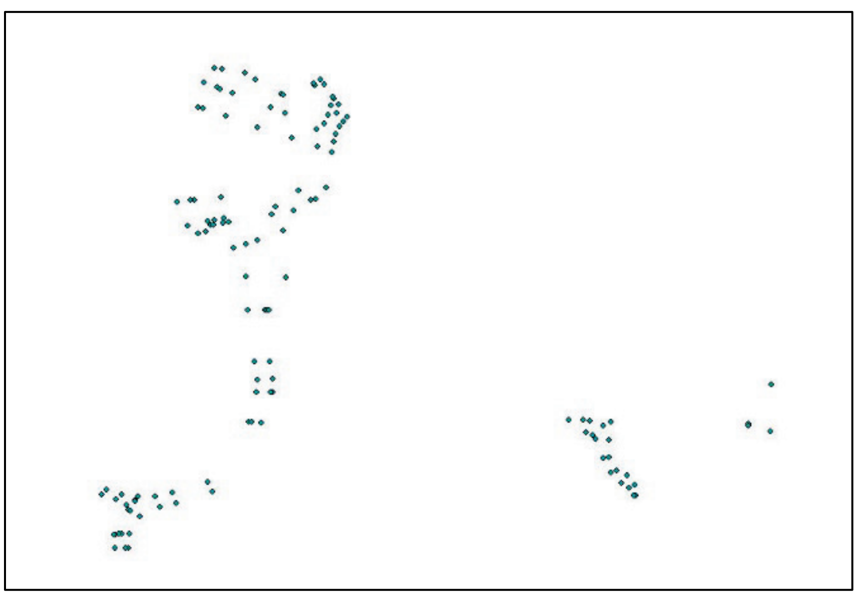


Figure 2-38: DEM Values extracted to cross section end points

2.3.2.2 *Interpolate the Water Surface*

1. Similar to the HWM example, use the Inverse Distance Weighted (IDW) tool to interpolate a water surface (steps below shown in Figure 2-39).
   1.1 The input point feature is the point shapefile created during the step above.
   1.2 Set the “Z-value field” to “RasterValu,” which stands for Raster Value.

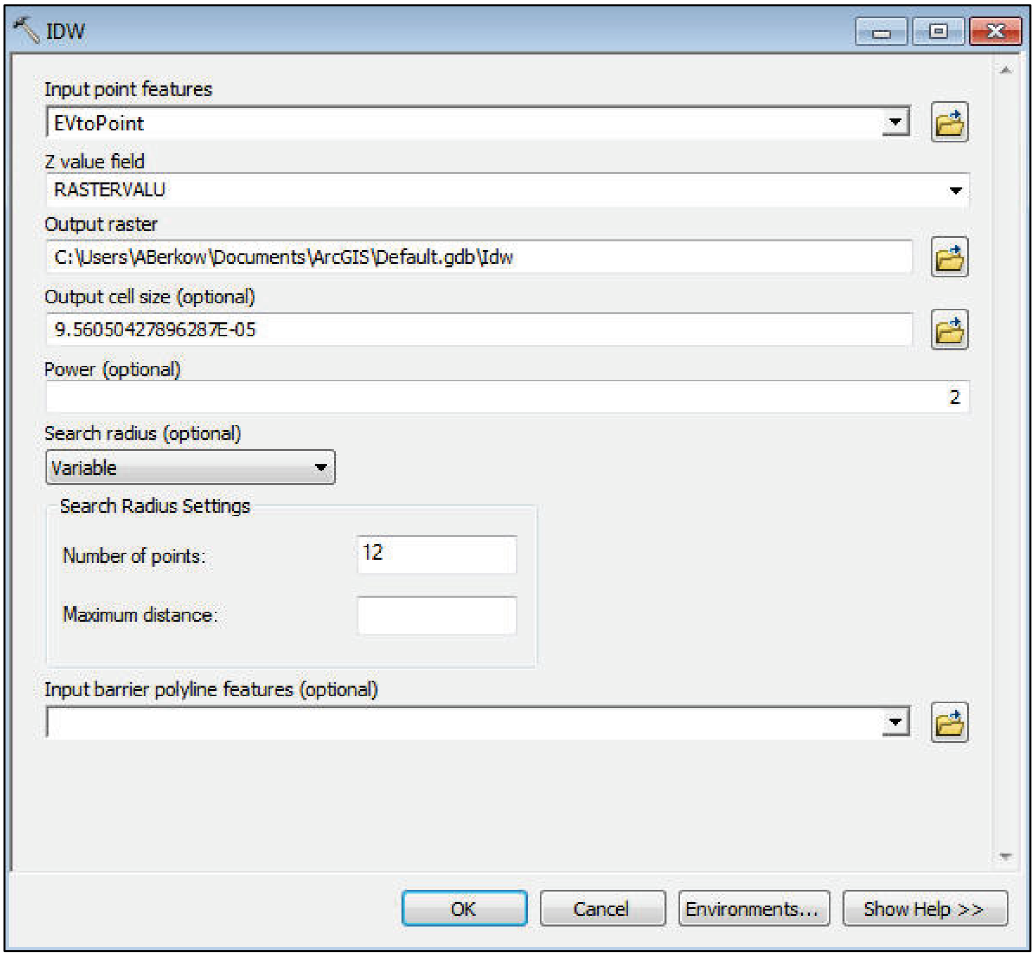


Figure 2-39: IDW tool

   1.3 Navigate to Processing Extent within Environments.
   1.4 Set the Processing Extent to the “Denver_DG_AOI.shp” and the Snap Raster to the DEM.
   1.5 Navigate to Raster Analysis within Environments.
   1.6 Set the output cell size equal to the DEM.
   1.7 Click “OK” to close the Environments window.
   1.8 Click “OK” to run the IDW tool window.

Figure 2-40: Interpolated water surface

2.3.2.3 Create the Zone Depth Grid

There are three types of Zone Depth Grids that can be developed 1) AE Flood Zone Depth Grid two (2), 2) AH Flood Zone Depth Grid and 3) AO Flood Zone Depth Grid. This section describes the steps for developing the Zone Depth Grid.

2.3.2.3.1 AE Flood Zone Depth Grid

1. Use the Raster Calculator or Minus Spatial Analyst tool to subtract the DEM from the interpolated water surface from the previous step (WSE – DEM = DG) as shown in Figure 2-41.

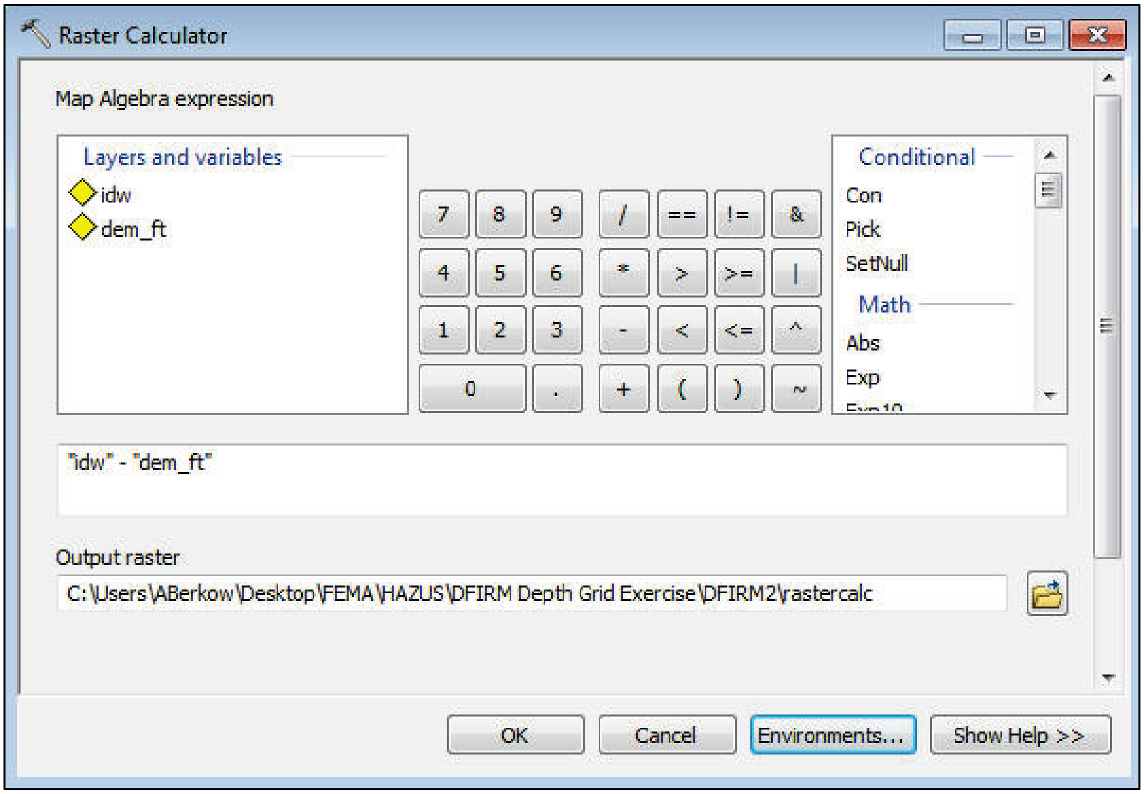


Figure 2-41: Raster Calculator

1.1 Navigate to Processing Extent within Environments.
1.2 Set the Snap Raster to the DEM.
1.3 Navigate to Raster Analysis Within Environments.
1.4 Set the output cell size equal to the DEM.
1.5 Re-read the data considerations at the beginning of the exercise if any geoprocessing errors arise.


Figure 2-42: Raster Calculator results

2. Use the Raster Calculator tool to remove the negative values from the raster output generated from the previous step as shown in Figure 2-43.

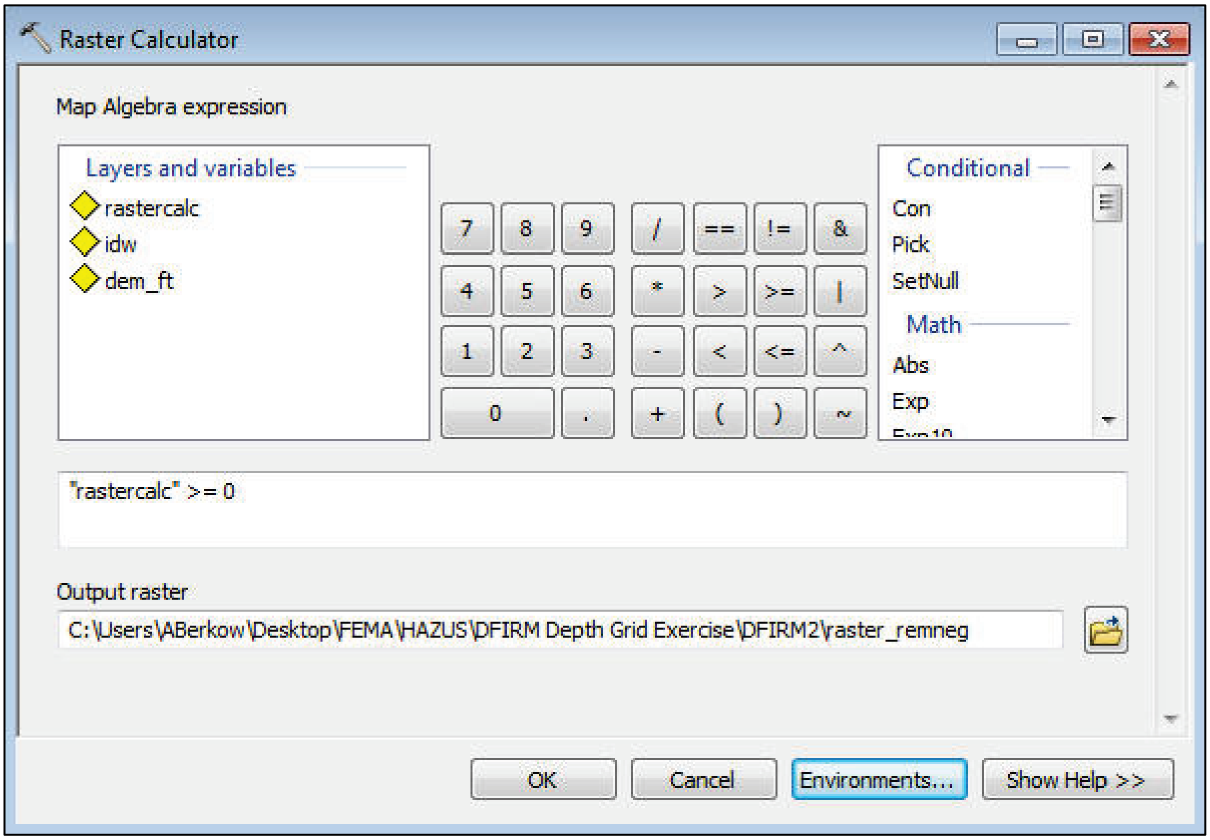


Figure 2-43: Raster Calculator tool

2.1 Navigate to Processing Extent within Environments.

2.2 Set the Snap Raster to the DEM.

2.3 Navigate to Raster Analysis within Environments.

2.4 Set the output cell size equal to the DEM.

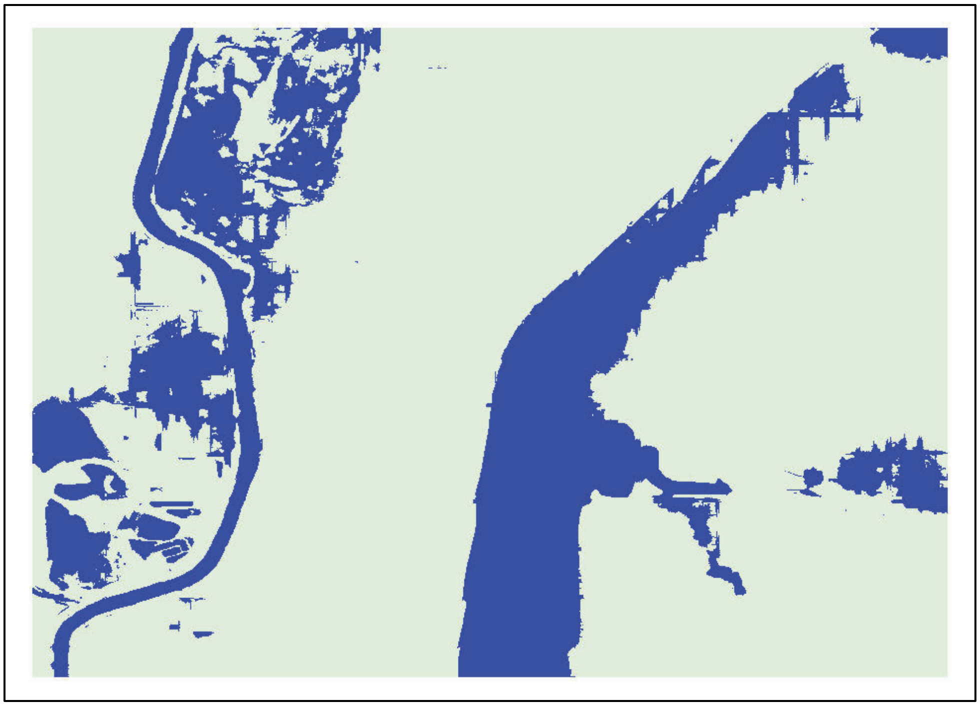


Figure 2-44: Raster Calculator results

2.5 Use the Raster to Polygon tool to convert the raster from the previous step to a vector dataset as shown in Figure 2-45.

2.6 Set the input raster as the file from the previous step.

   a. The raster output from the previous step is a “True/False” raster: “1” represents a true statement, and “0” represents a false statement.

   b. The “1” or “True” values need to be extracted to derive a flood extent.

2.7 Uncheck the box next to Simplify Polygons.

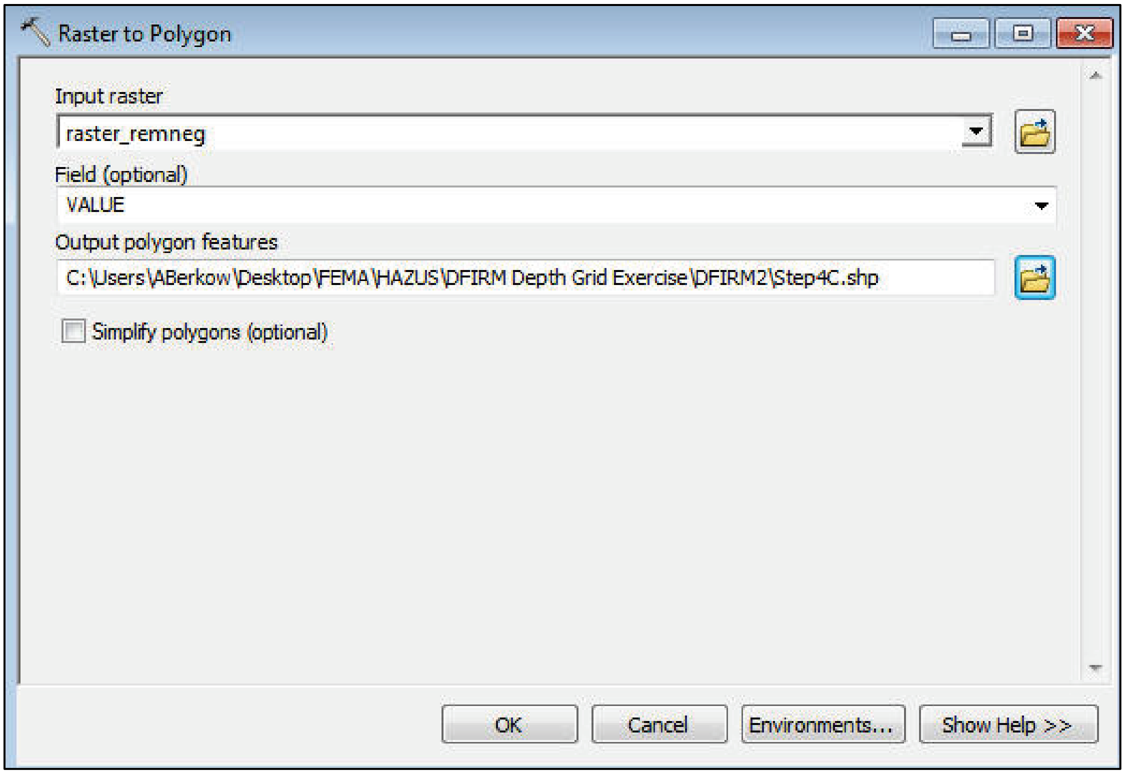


Figure 2-45: Raster to Polygon tool

2.8 Click "OK" to create the polygon conversion.

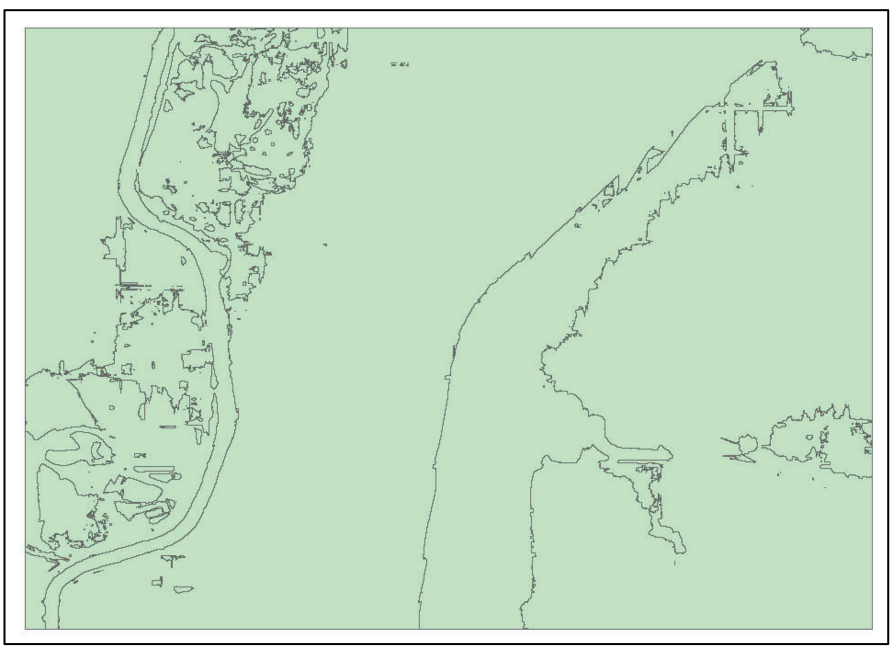


Figure 2-46: Raster to Polygon results

2.9 Use the Select by Attributes tool to select the "1" or "true" values from the output vector polygon from the previous step.

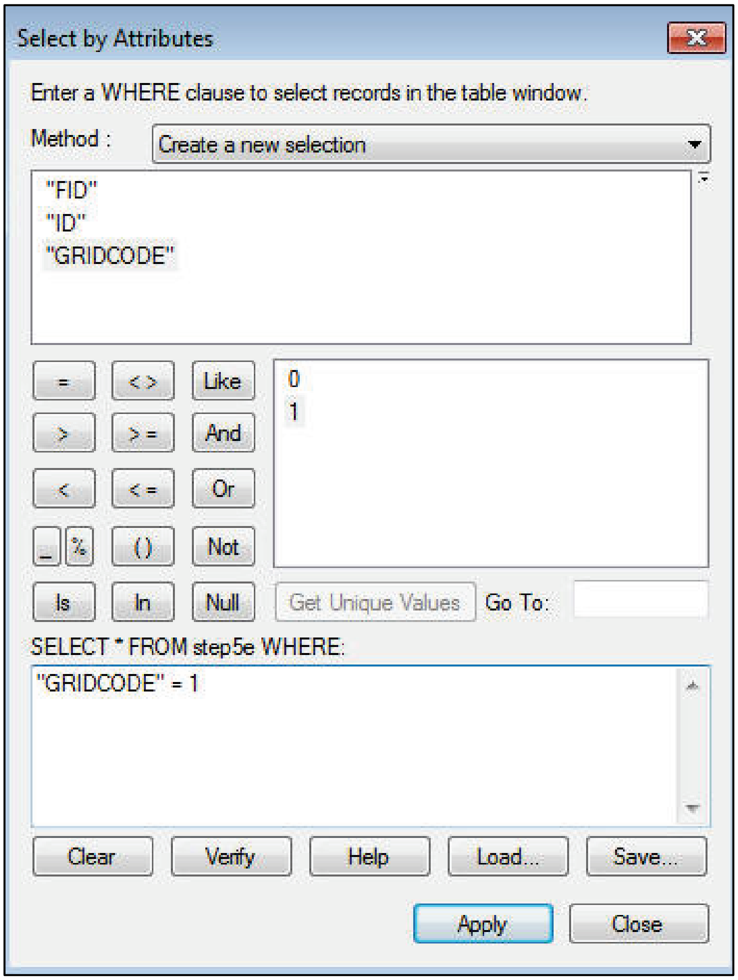


Figure 2-47: Select by Attributes tool

Figure 2-48: Gridcode = 1 Selection

2.10 Right click on the “Step4C” shapefile in the Table of Contents and navigate to Data then to Export Data to export the “1” selection to a new shapefile.

2.11 Select the radio button in the Export Data dialog box next to “the data frame” and click “OK” to save the shapefile.

Figure 2-49: Gridcode = 1 Shapefile

3. Optional: Use the Dissolve tool to dissolve the flood polygon from the previous step.
   3.1 The Dissolve Field and the Statistics Field remain unchanged.

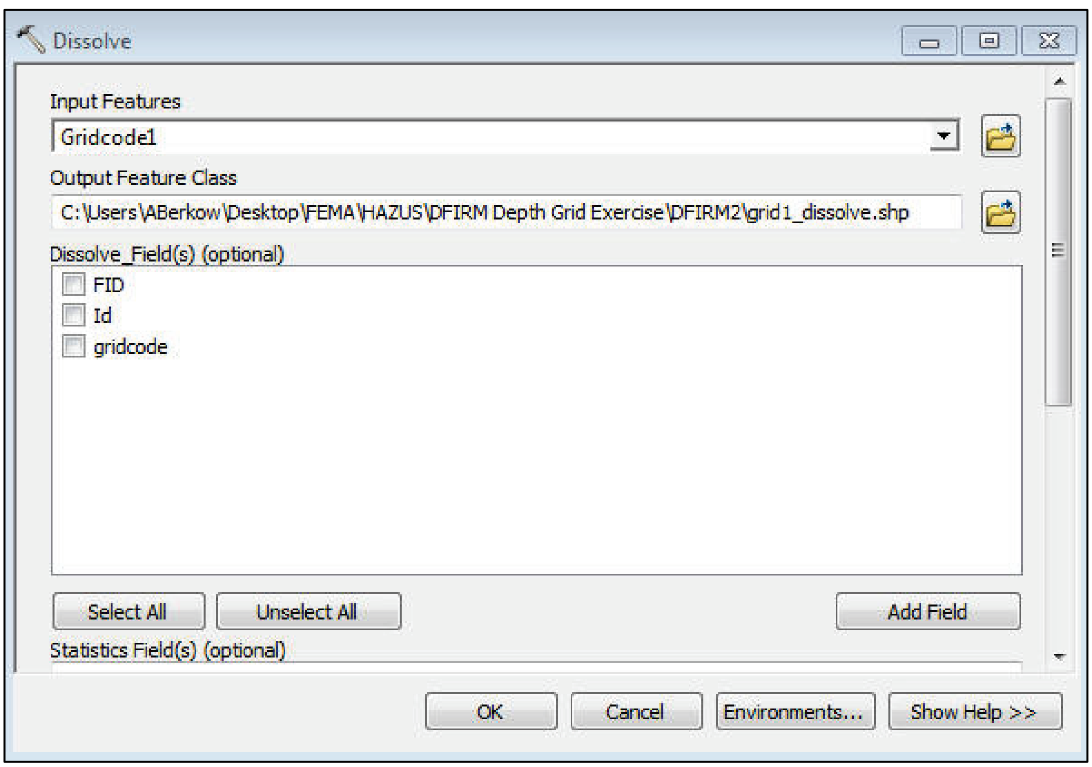


Figure 2-50: Dissolve tool

3.2 Click “OK” to dissolve the layer.

Figure 2-51: Dissolve result

4. Use the Clip tool to clip the dissolved flood polygon boundary by the AE flood zone shapefile created in the previous steps.

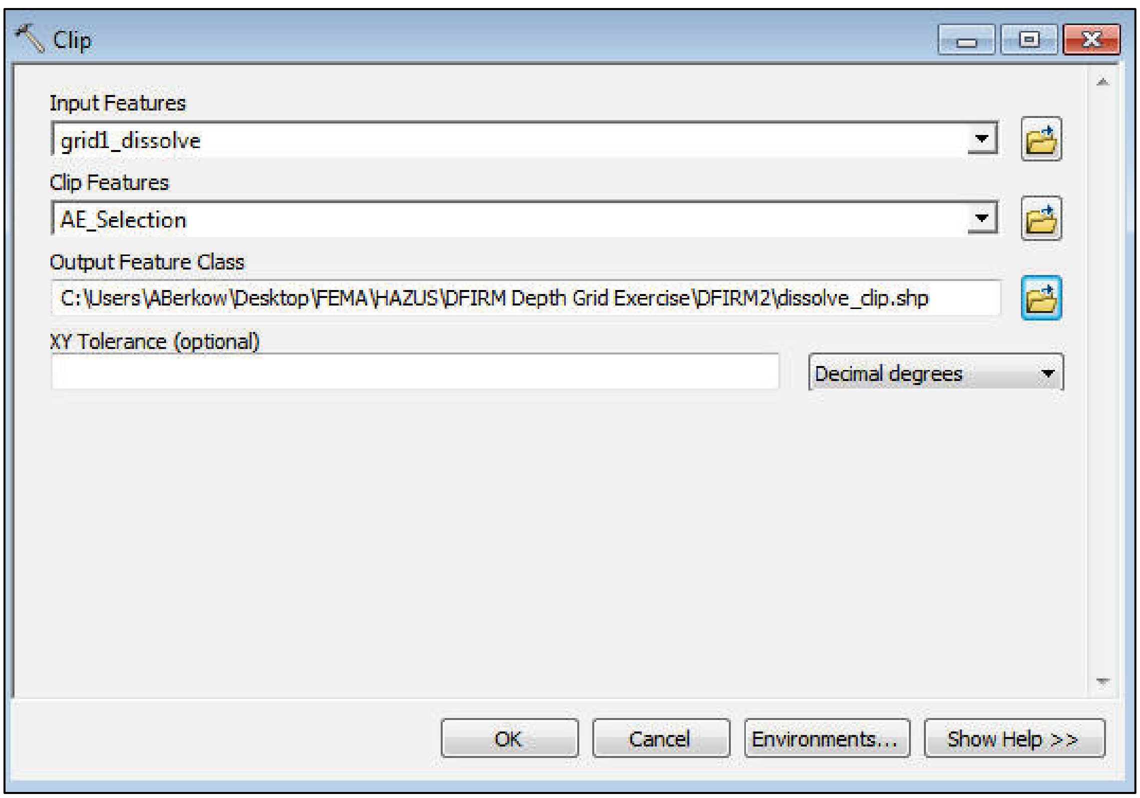


Figure 2-52: Clip tool

Figure 2-53: Clip result

5. Use the Extract by Mask spatial analyst tool to create a flood depth grid using the flood boundary polygon created in the previous step.

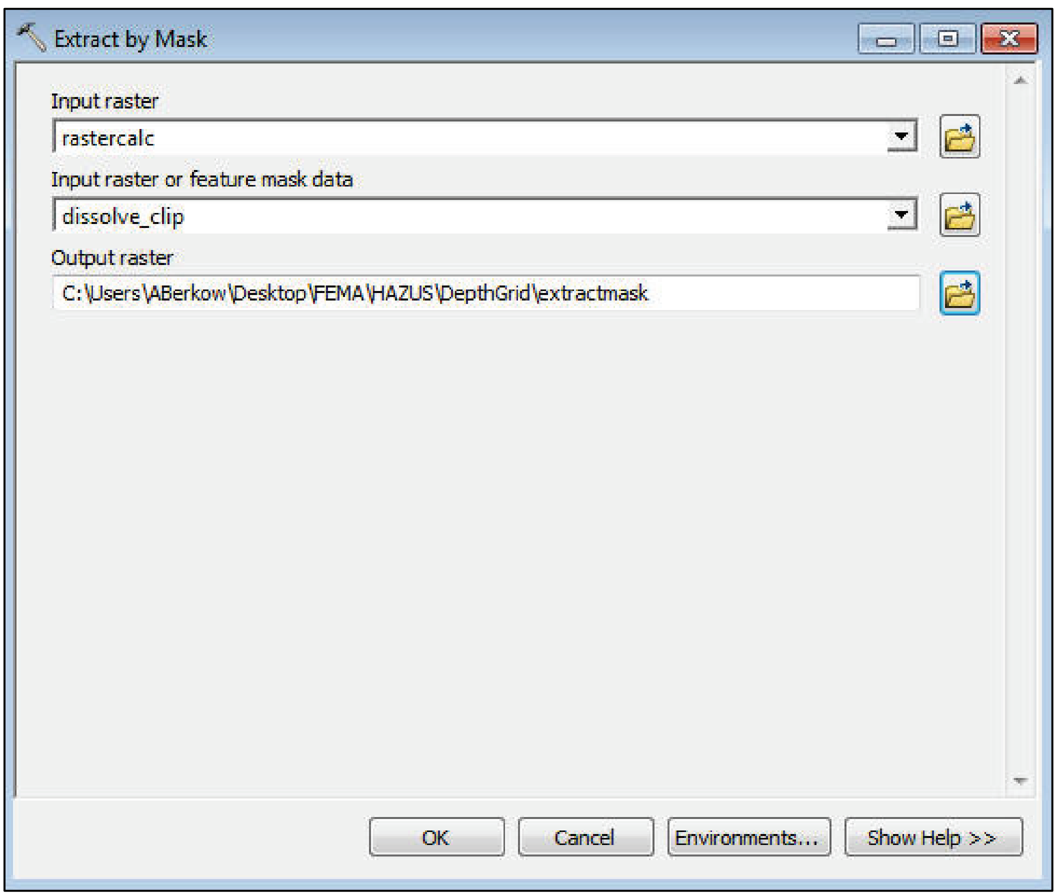


Figure 2-54: Extract by Mask

5.1 Navigate to Processing Extent within Environments.
5.2 Set the Snap Raster to the DEM.
5.3 Navigate to Raster Analysis within Environments.
5.4 Set the output cell size equal to the DEM.

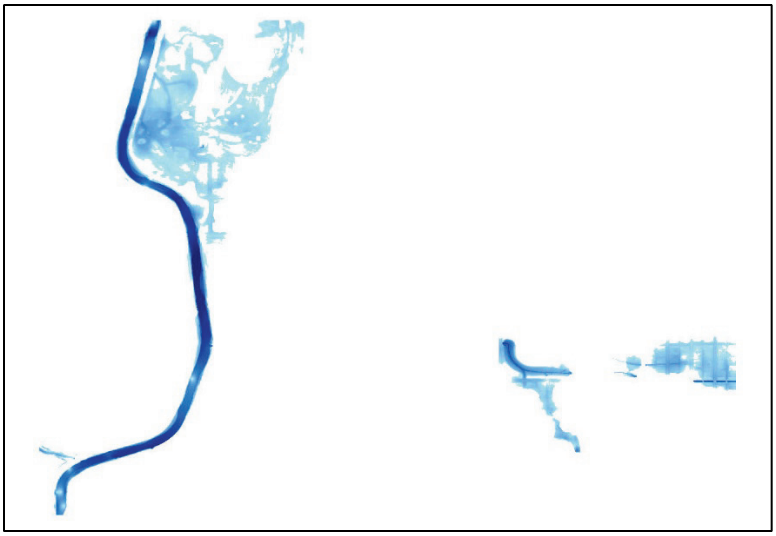


Figure 2-55: Extract by Mask result

6. Use the Erase tool and the output vector polygon from the step above to create a feature class of areas not inundated in the previous steps.

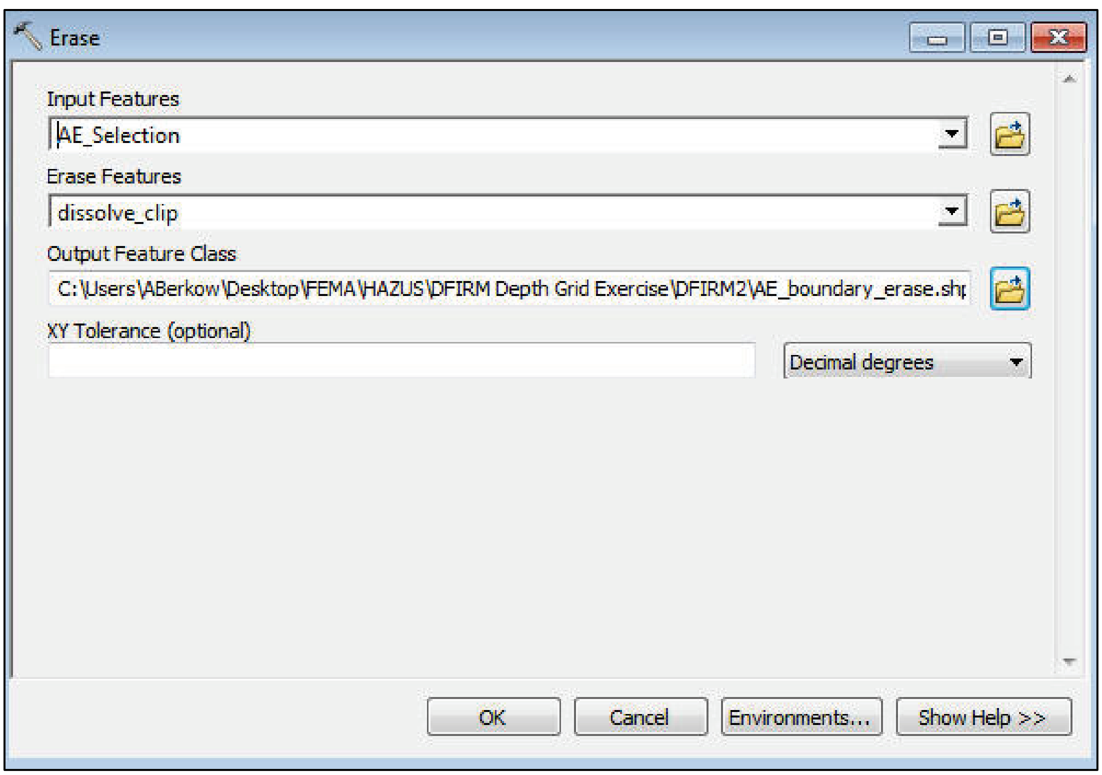


Figure 2-56: Erase tool

Figure 2-57: Erase result

7. Use the Extract by Mask spatial analyst tool and the flood boundary polygon created in the previous step to create a flood depth grid.

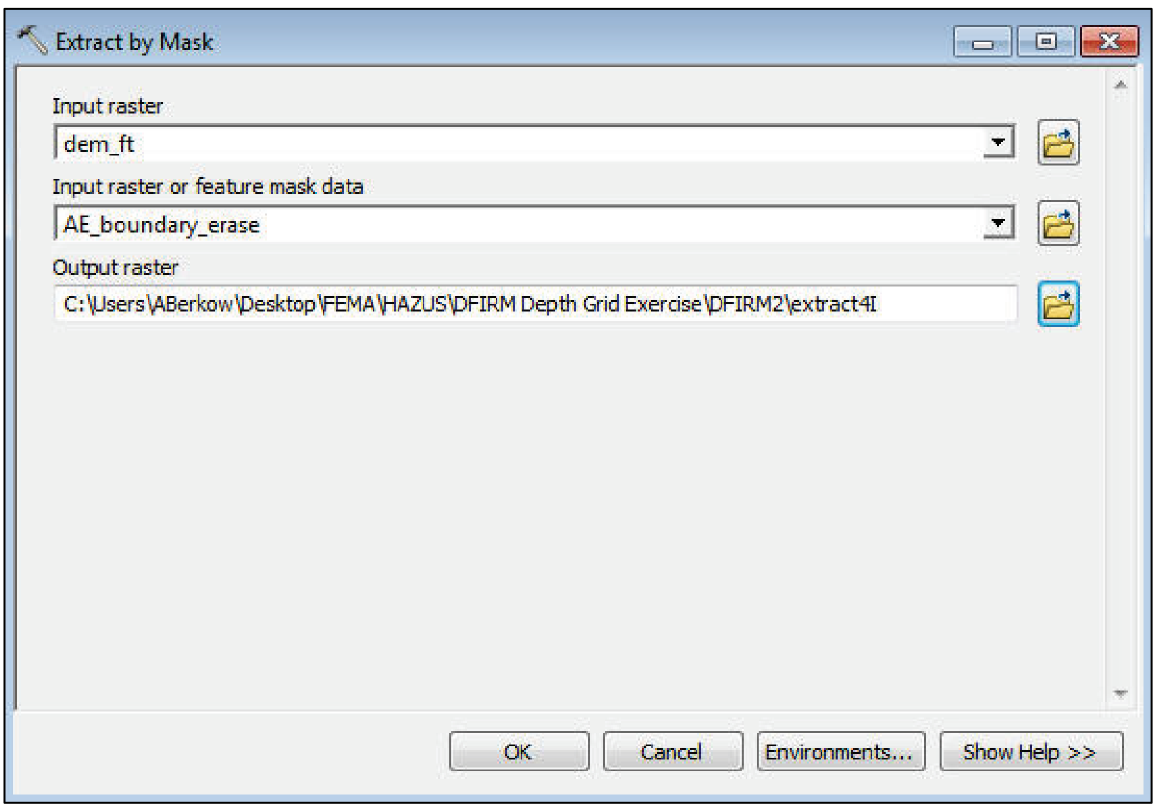


Figure 2-58: Extract by Mask tool

7.1 Navigate to Processing Extent within Environments.

7.2 Set the Snap Raster to the DEM.

7.3 Navigate to Raster Analysis within Environments.

7.4 Set the output cell size equal to the DEM.

Figure 2-59: Extract by Mask result

8. Use the Raster Calculator to set the raster equal to 0.1.

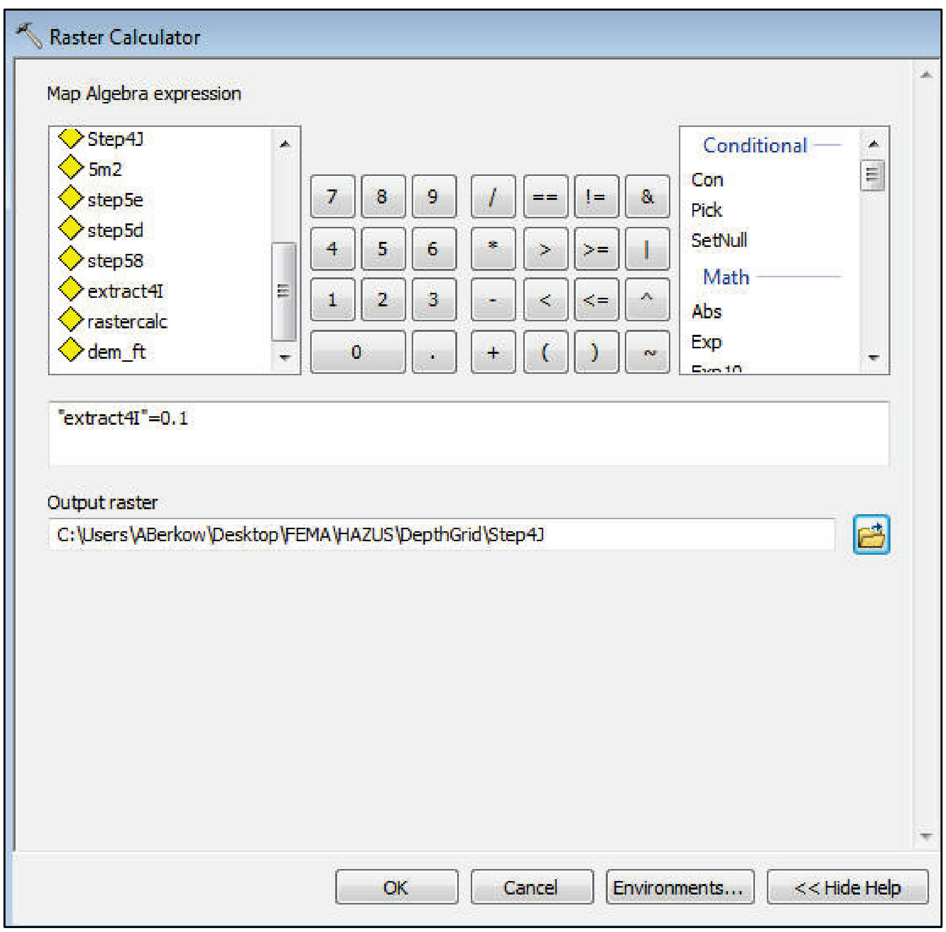


Figure 2-60: Raster Calculator tool

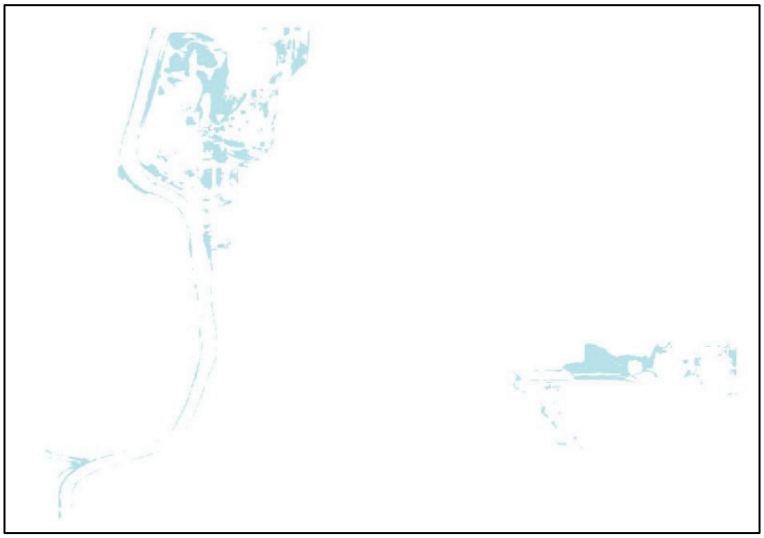


Figure 2-61: Raster equal to 0.1 feet

9. Use the Mosaic to New Raster tool to create the final AE Flood Zone Depth Grid using the two depth grids created in the previous steps.

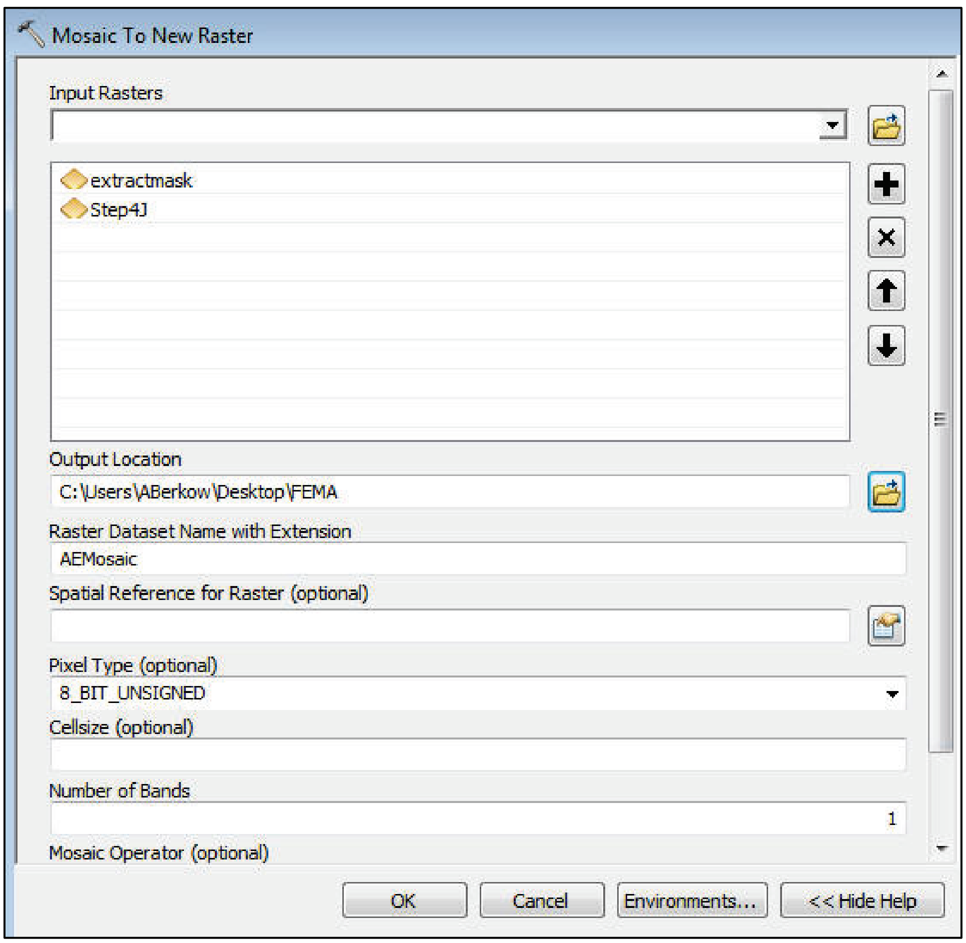


Figure 2-62: Mosaic to New Raster tool

9.1 Change the Number of Bands to 1.
9.2 Navigate to Processing Extent within Environments.
9.3 Set the Snap Raster to the DEM.
9.4 Navigate to Raster Analysis within Environments.
9.5 Set the output cell size equal to the DEM.
9.6 Click “OK” to close the Environments tab.
9.7 Click “OK” to create the mosaic.

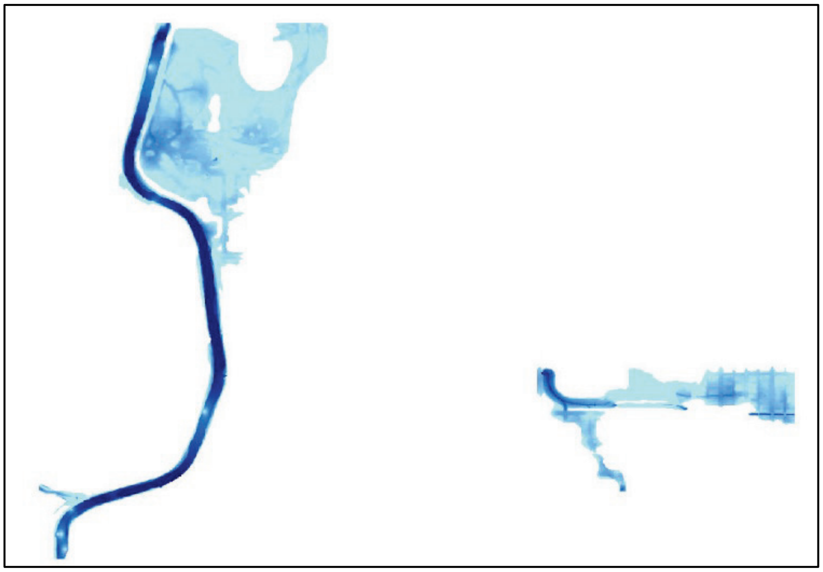


Figure 2-63: AE Mosaic Raster

2.3.2.3.2 AH Flood Zone Depth Grid

The AH Flood Zone has a constant water surface elevation, known as a static Base Flood Elevation (BFE). Recent revisions to the DFRIM database can cause errors to occur. There is no static BFE associated with the S_FLD_HAZ_AR shapefile used in steps below in this case specifically. Please refer to the FIRM (use the FIRM Panel shapefile for reference) to determine the Static BFE, which is 5,256 feet in this example, if an error occurs. It is not necessary to interpolate a water surface because the water surface elevation is predetermined at a static level for AH field zones.

1. Use the Extract by Mask tool and the AH Flood Zone boundary created to create the water surface.
   1.1 Set the input raster to the DEM.
   1.2 Navigate to Processing Extent within Environments.
   1.3 Set the Snap Raster to the DEM.
   1.4 Navigate to Raster Analysis within Environments.
   1.5 Set the output cell size equal to the DEM.
   1.6 Click “OK” to close the Environments tab.
   1.7 Click “OK” to initiate the Extract by Mask tool.

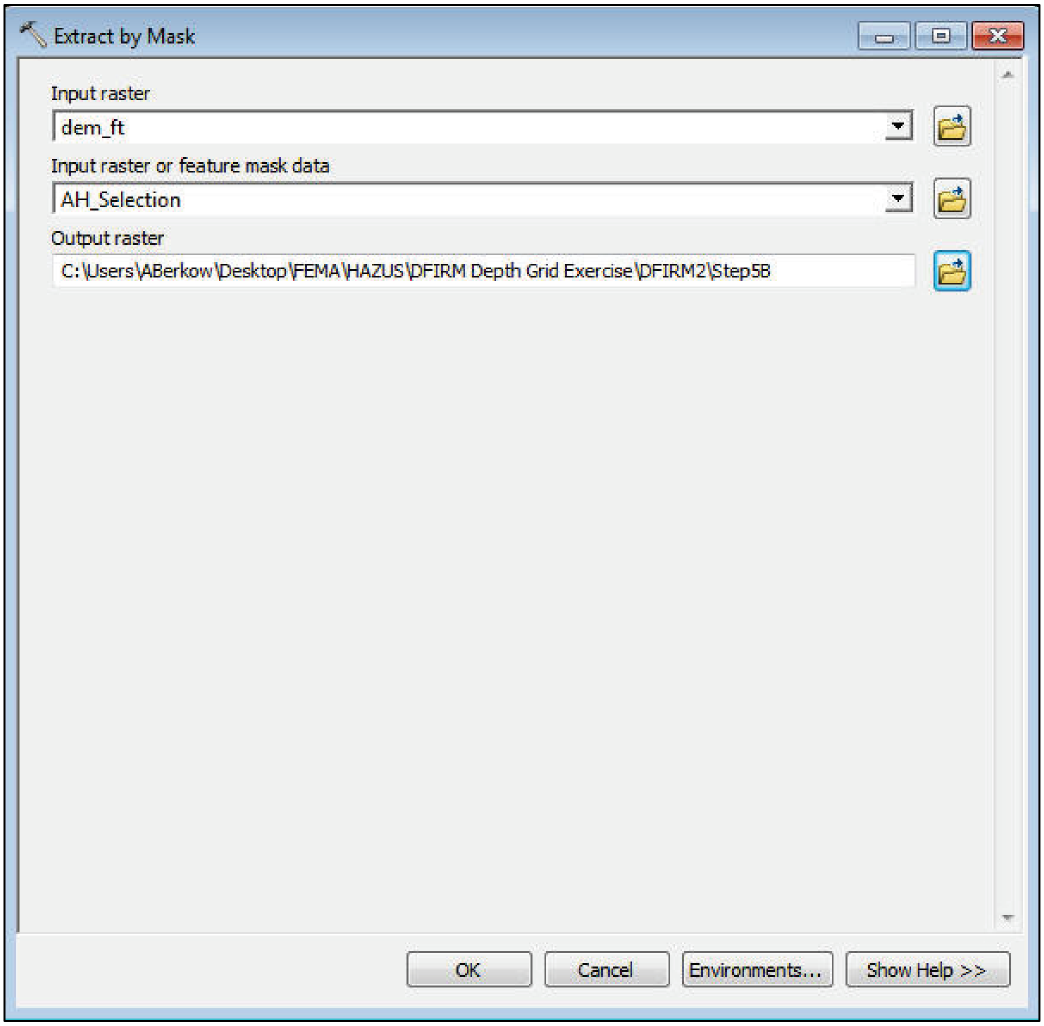


Figure 2-64: Extract by Mask tool

Figure 2-65: Extract by Mask result

2. Open the Raster Calculator tool and enter the following expression: “([Raster File from Step5-B] * 0) + [Static BFE in Feet])” to finish the creating the depth grid.
   2.1 The static BFE is 5,256 feet. This information can be found in the “S_FLD_HAZ_AR” attribute table.

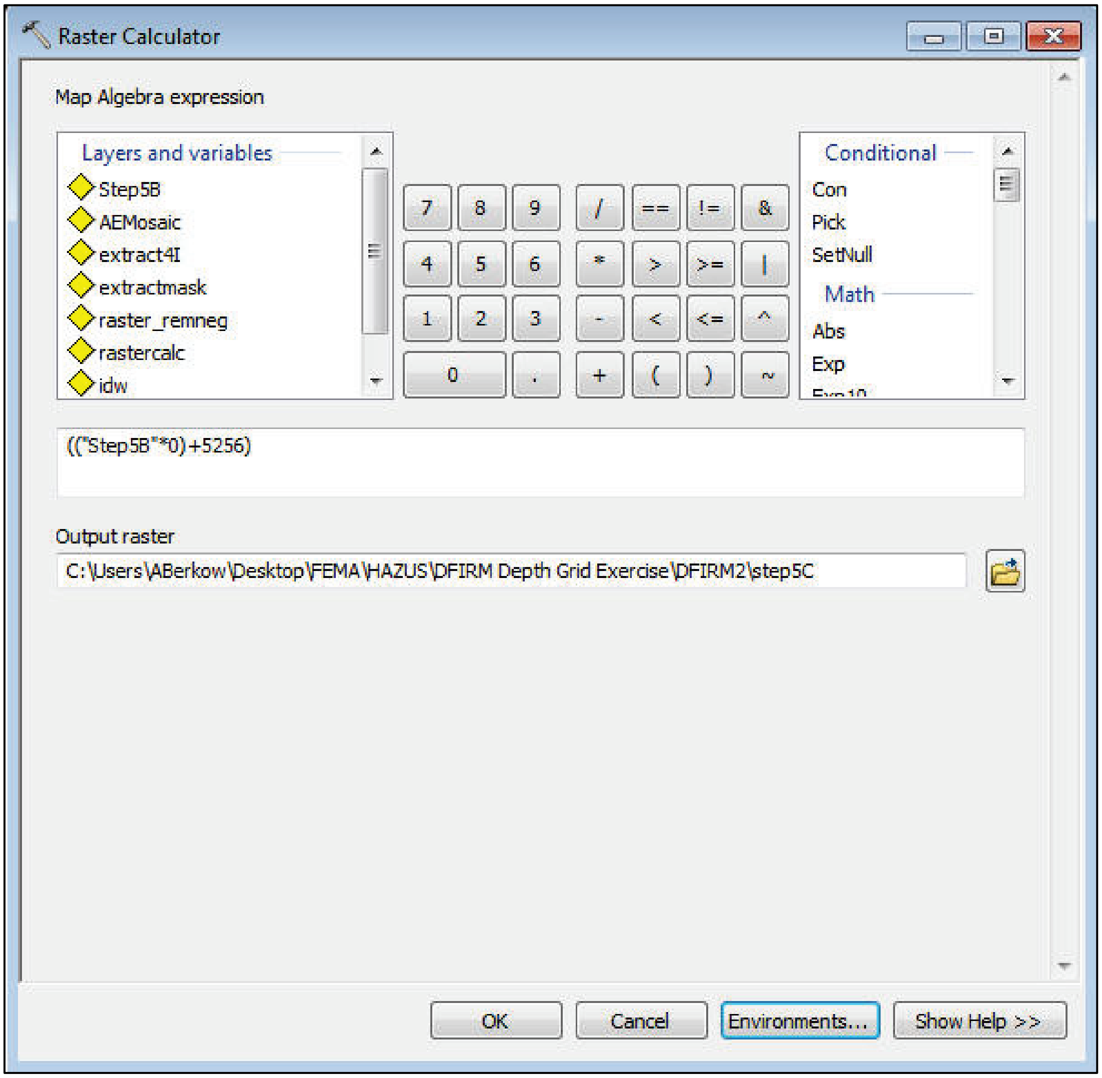


Figure 2-66: Raster Calculator tool

   2.2 Navigate to Processing Extent within Environments.
   2.3 Set the Snap Raster to the DEM.
   2.4 Navigate to Raster Analysis within Environments.
   2.5 Set the output cell size equal to the DEM.
   2.6 Click “OK” to close the Environments tab.
   2.7 Click “OK” to implement the Raster Calculator.

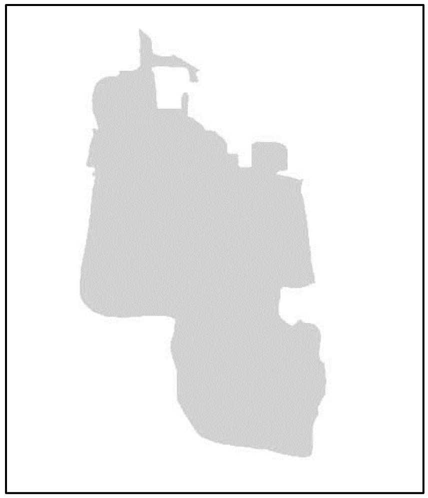


Figure 2-67: Raster Calculator Result

3. Use the Raster Calculator or Minus spatial analyst tool and the interpolated water surface from the previous step to subtract the DEM from this surface (WSE – DEM = DG).

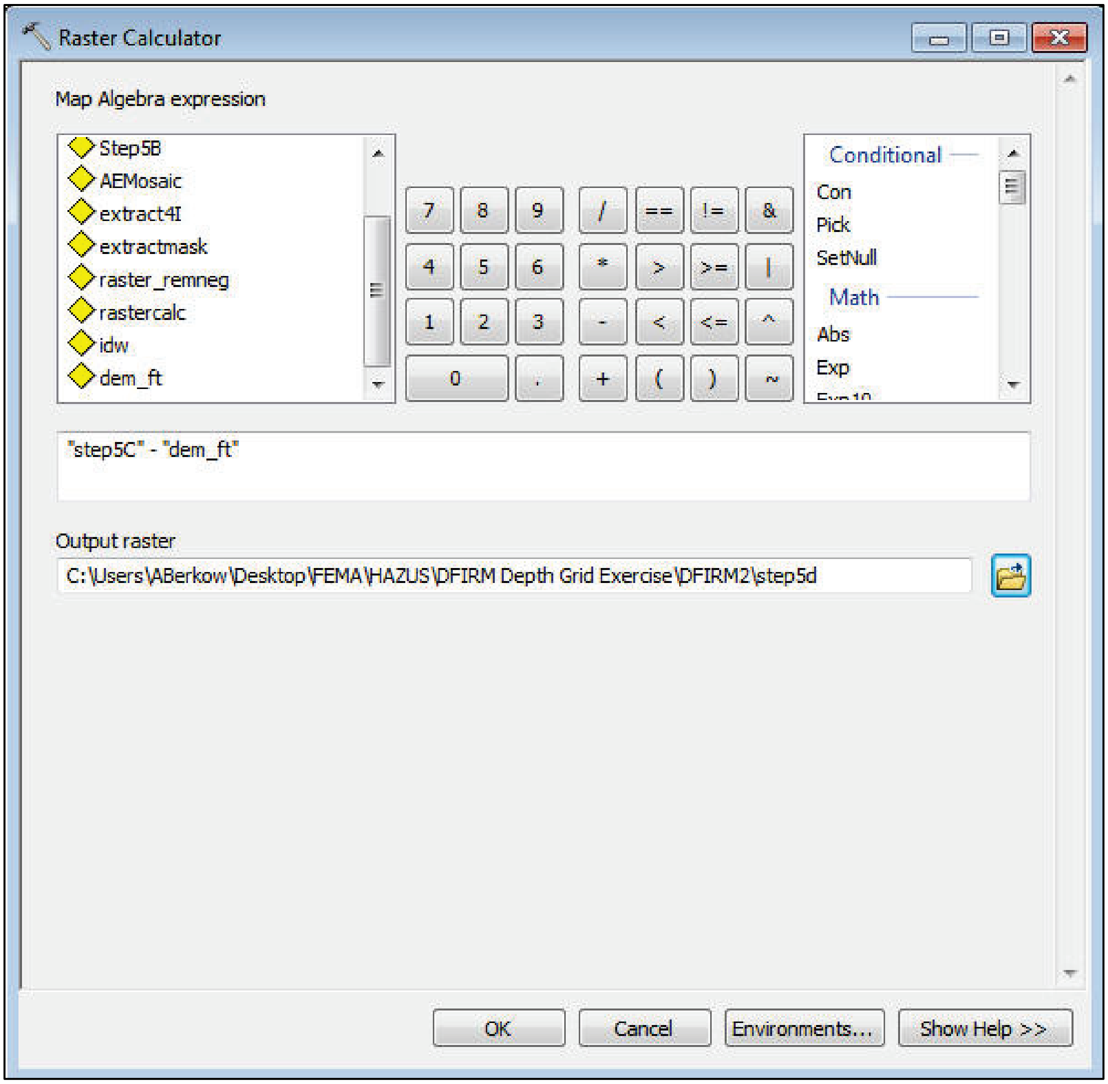


Figure 2-68: Raster Calculator tool

3.1 Navigate to Processing Extent within Environments.
3.2 Set the Snap Raster to the DEM.
3.3 Navigate to Raster Analysis within Environments.
3.4 Set the output cell size equal to the DEM.
3.5 Click OK to close the Environments tab.
3.6 Click "OK" to subtract the DEM from the interpolated water surface.
3.7 Re-read the data considerations at the beginning of the exercise and ensure the data conforms to these considerations if any geoprocessing errors arise.

Figure 2-69: Raster Calculator result

4. Use the Raster Calculator tool to remove the negative values from the raster output from the previous step.

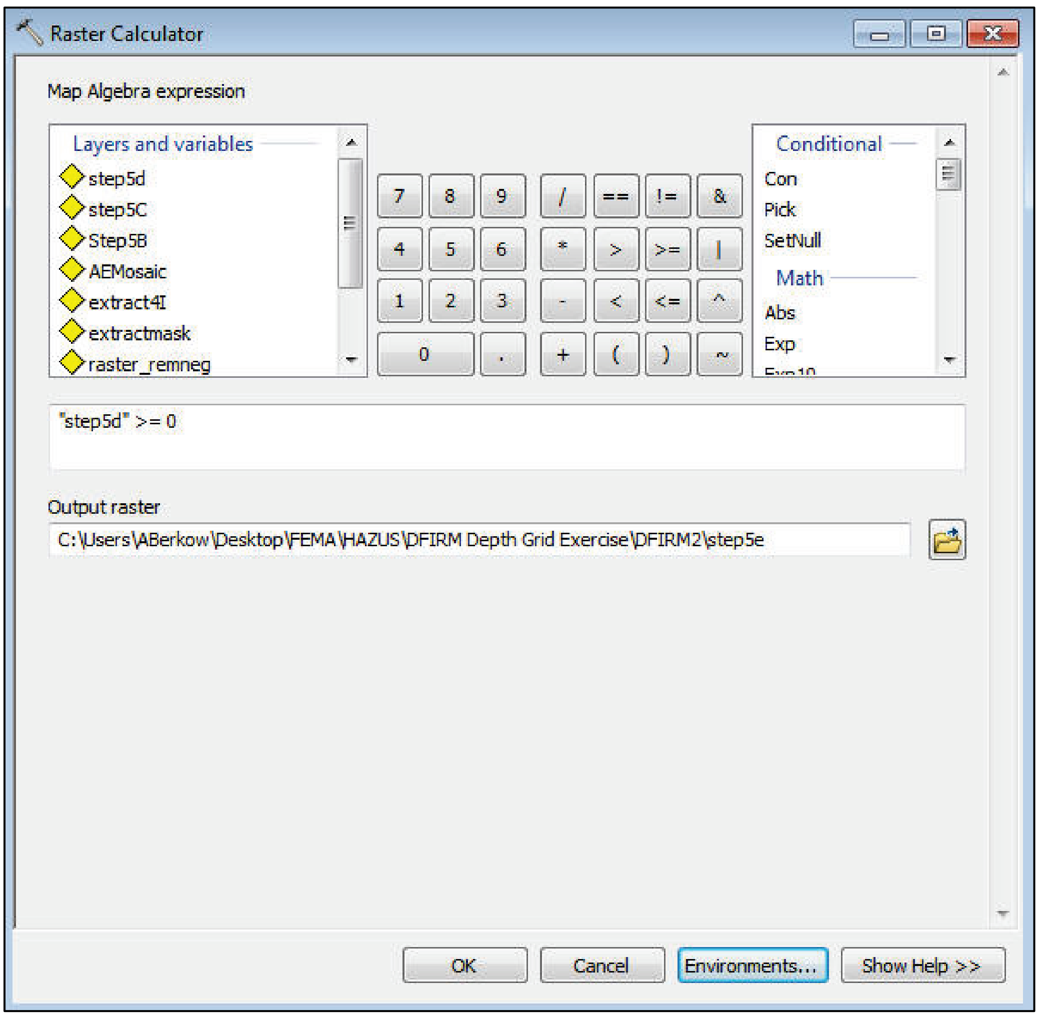


Figure 2-70: Raster Calculator tool

4.1 Navigate to Processing Extent within Environments.
4.2 Set the Snap Raster to the DEM.
4.3 Navigate to Raster Analysis within Environments.
4.4 Set the output cell size equal to the DEM.
4.5 Click “OK” to close the Environments tab.
4.6 Click “OK” to remove the negative values.

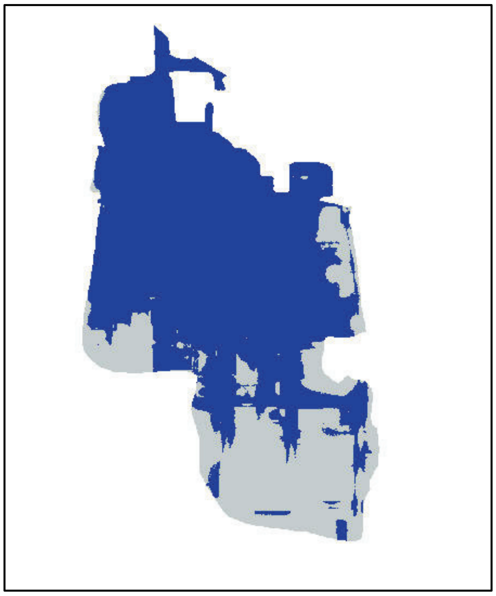


Figure 2-71: Raster Calculator result

5. Use the Raster to Polygon conversion tool to convert this raster into a vector dataset.
   5.1 Set the file from the previous step as the Input raster.
   5.2 The raster output from the previous step is a “True/False” raster where “1” represents a true statement, and “0” represents a false statement.
   5.3 Uncheck the box next to “Simplify Polygons.”
   5.4 Click “OK” to initiate the conversion.

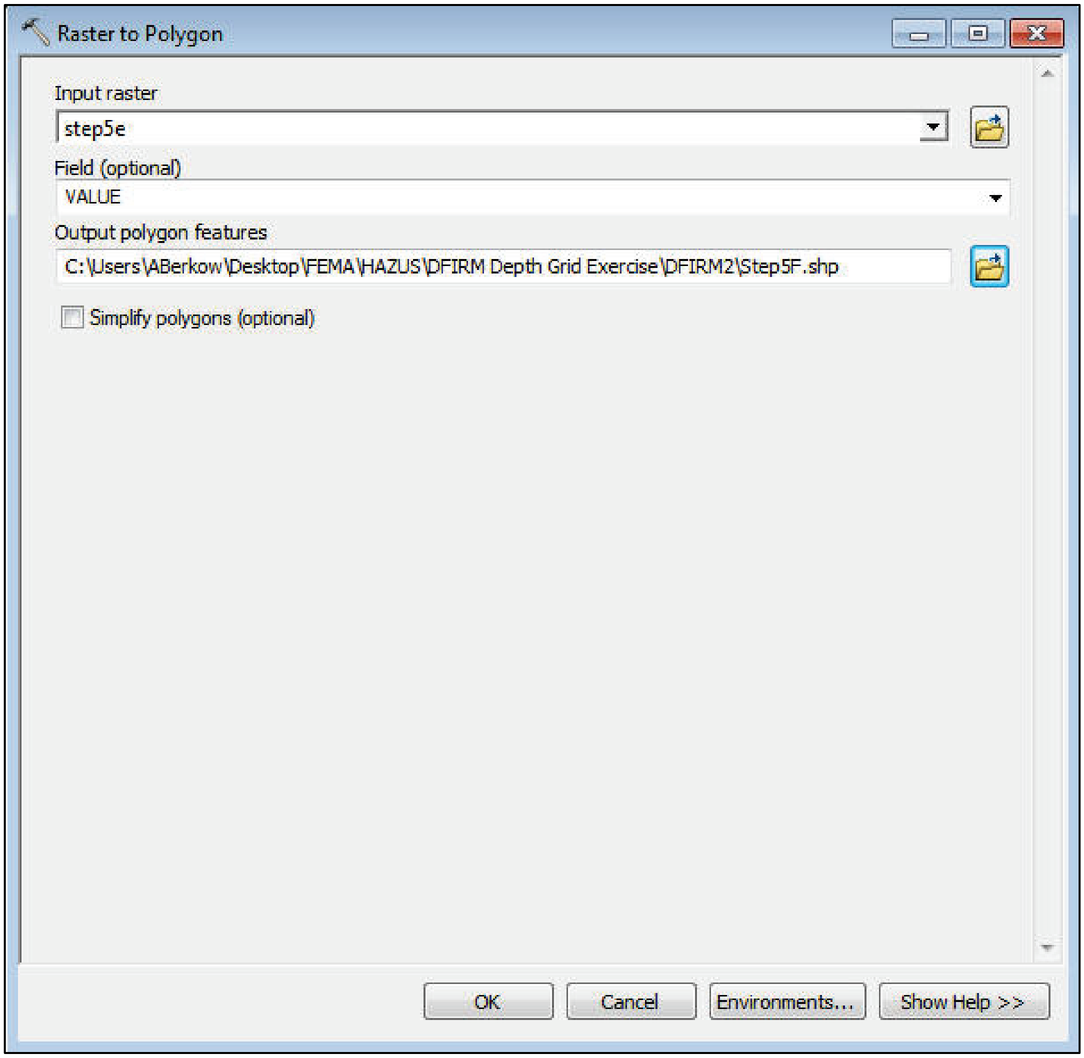


Figure 2-72: Raster to Polygon tool

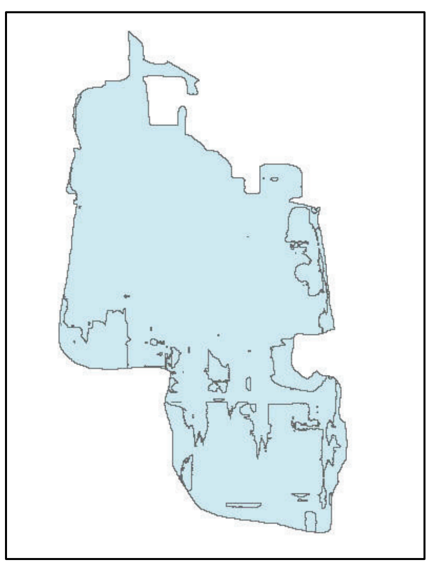


Figure 2-73: Raster to Polygon result

6. The “1” or “True” values from the previous step needs to be extracted to derive a flood extent.
7. Use the Select by Attributes tool to export the “1” values from the “Gridcode” field in the attribute table.
   7.1 Click “Apply” to select.

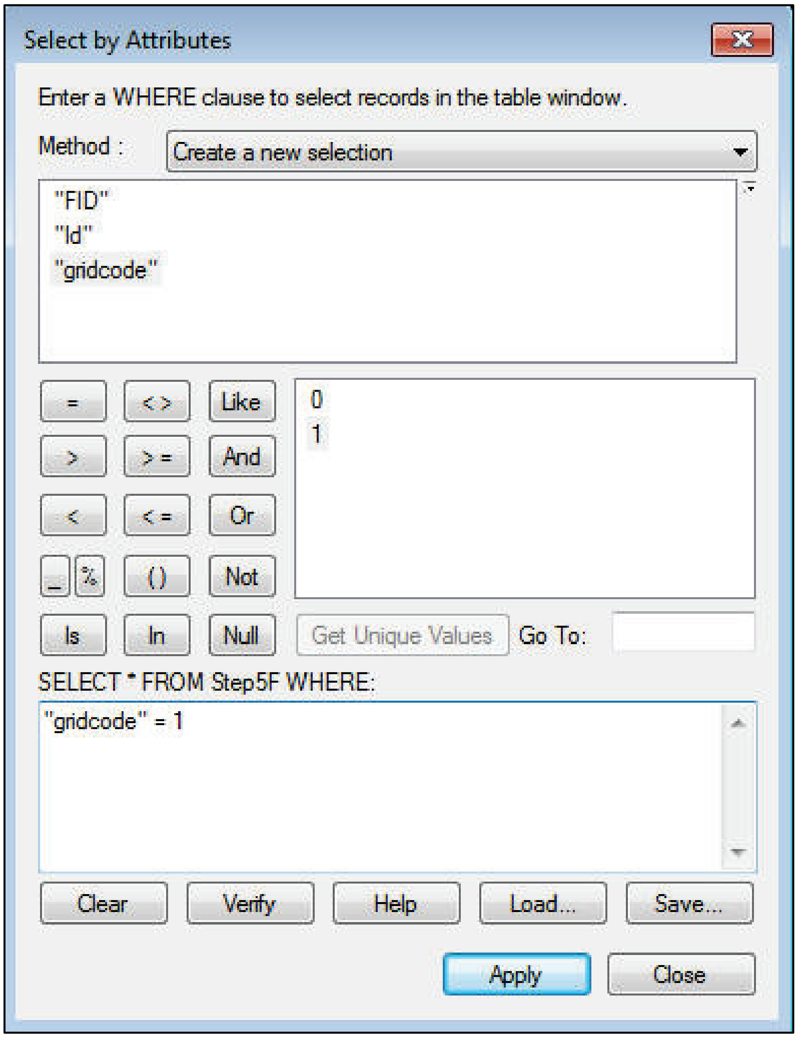


Figure 2-74: Select by Attribute tool

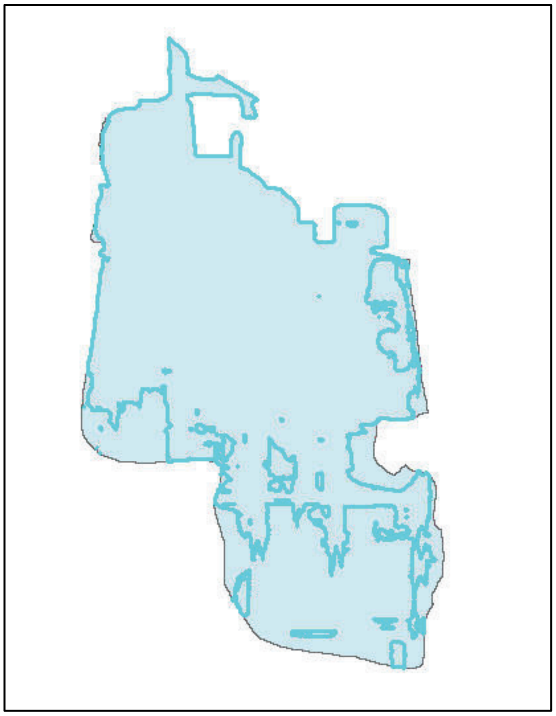


Figure 2-75: Gridcode = 1 selection

7.2 Right click on the Step5F shapefile in the Table of Contents and navigate to Data then to Export Data to export the "1" selection to a new shapefile.

7.3 Select the radio button in the Export Data dialog box next to "the data frame" and click "OK" to save the shapefile.

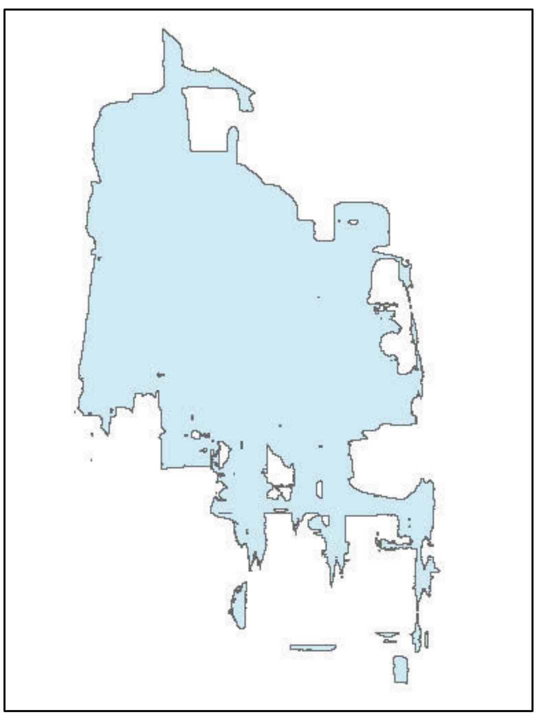


Figure 2-76: Gridcode = 1 shapefile

8. Optional: Use the Dissolve tool to dissolve the flood polygon.
   8.1 The Dissolve Field and Statistics Field remains unchanged.

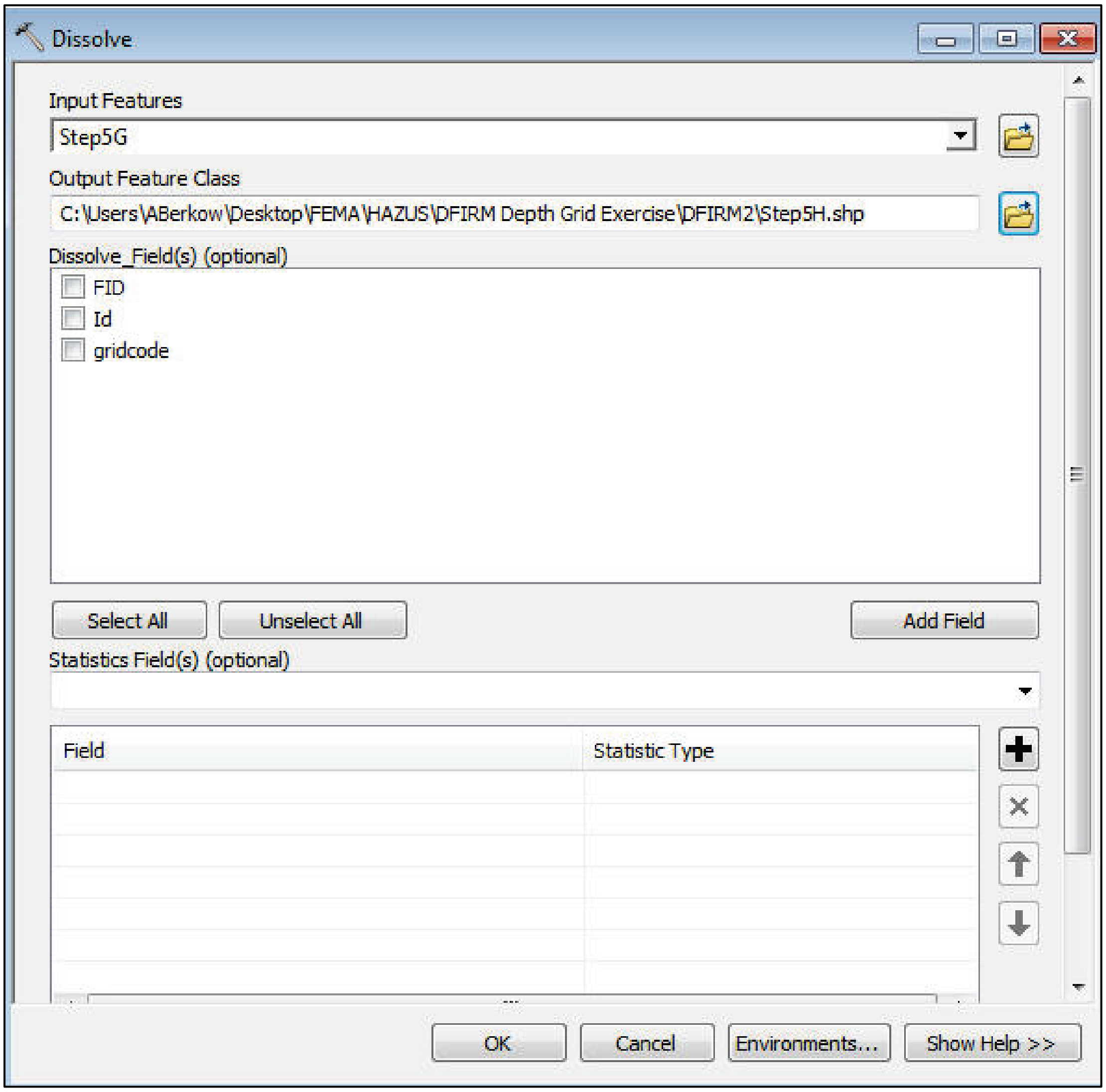


Figure 2-77: Dissolve tool

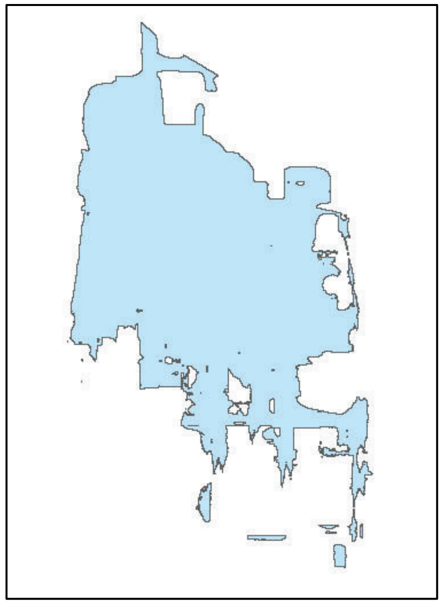


Figure 2-78: Dissolve result

9. Use the Clip tool to clip the dissolved flood polygon boundary by the AH flood zone shapefile created in the previous steps.

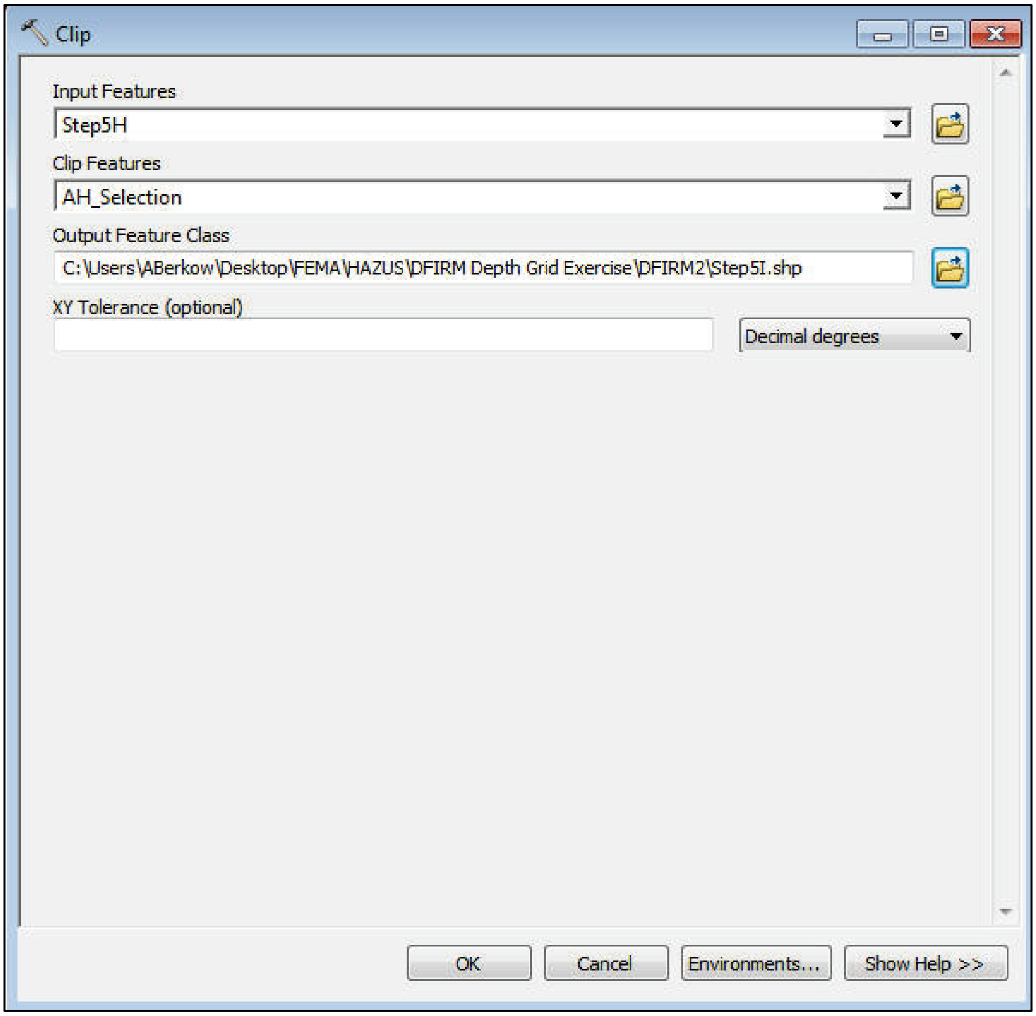


Figure 2-79: Clip tool

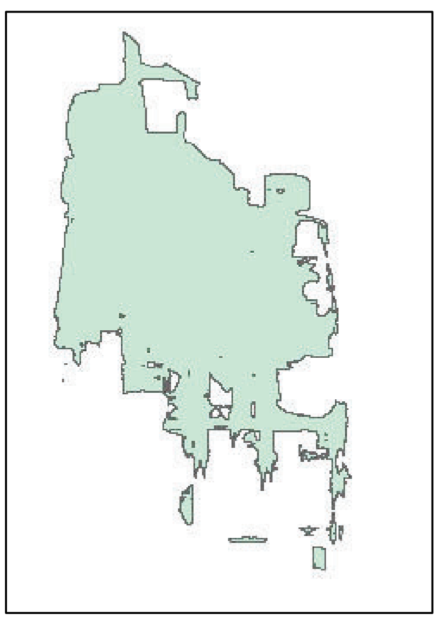


Figure 2-80: Clip result

10. Use the Extract by Mask spatial analyst tool to create a flood depth grid using the flood boundary polygon created in the previous step.
    10.1 Navigate to Processing Extent within Environments.
    10.2 Set the Snap Raster to the DEM.
    10.3 Navigate to Raster Analysis within Environments.
    10.4 Set the output cell size equal to the DEM.

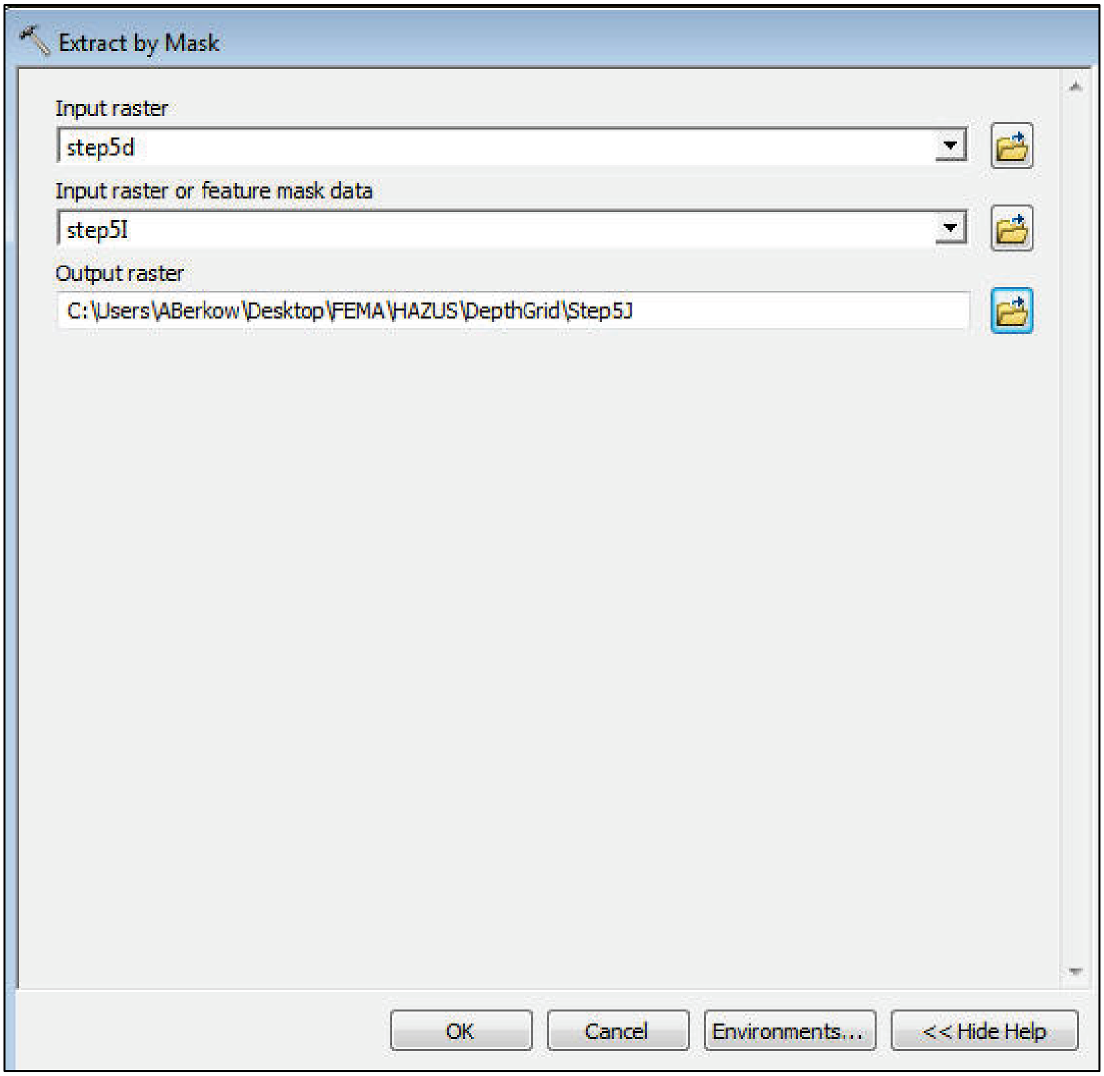


Figure 2-81: Extract by Mask tool

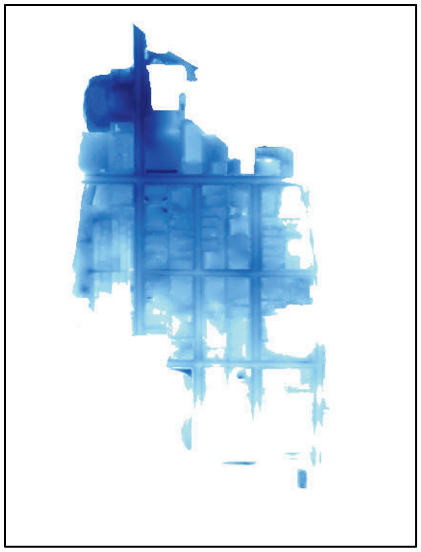


Figure 2-82: Extract by Mask result

11. Use the Erase tool and the output vector polygon from the step above to create a feature of the areas not inundated in the previous steps.

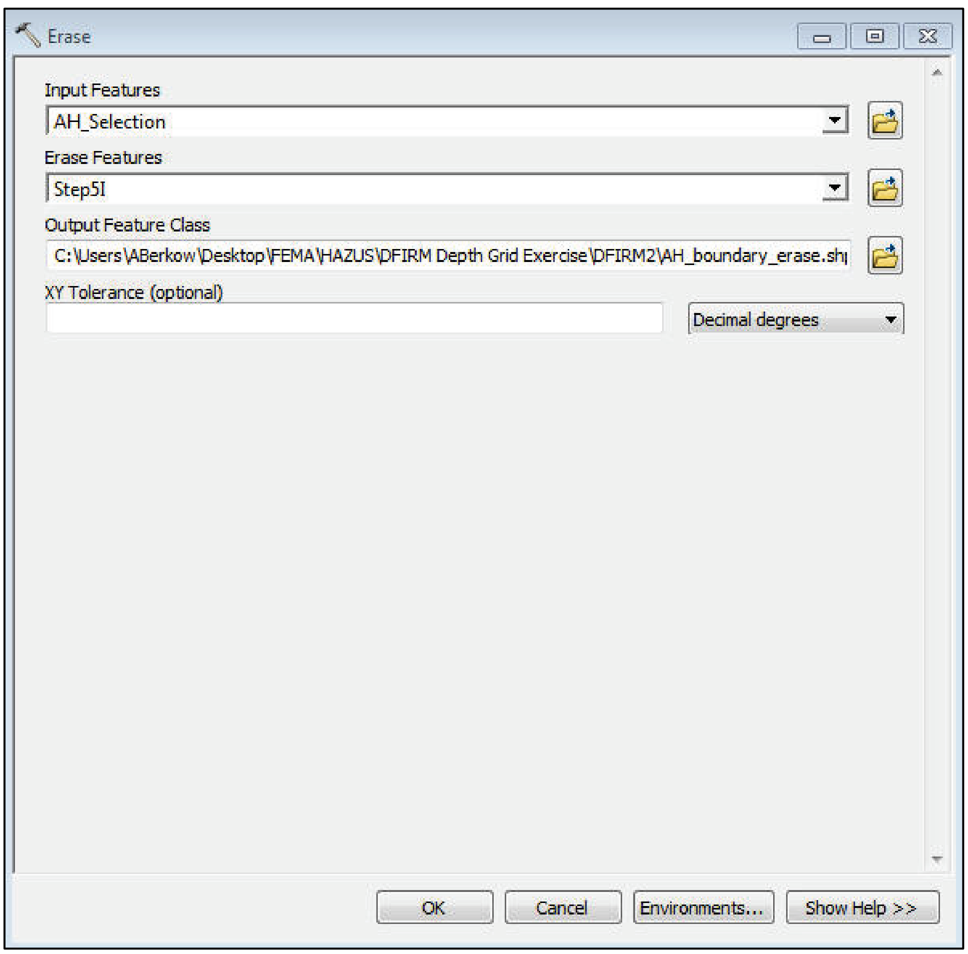


Figure 2-83: Erase tool

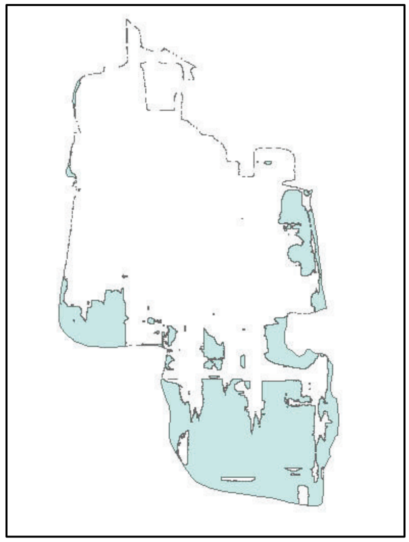


Figure 2-84: Erase results

12. Use the Extract by Mask spatial analyst tool and the flood boundary polygon created in the previous step to create the 0.1 ft flood depth grid.

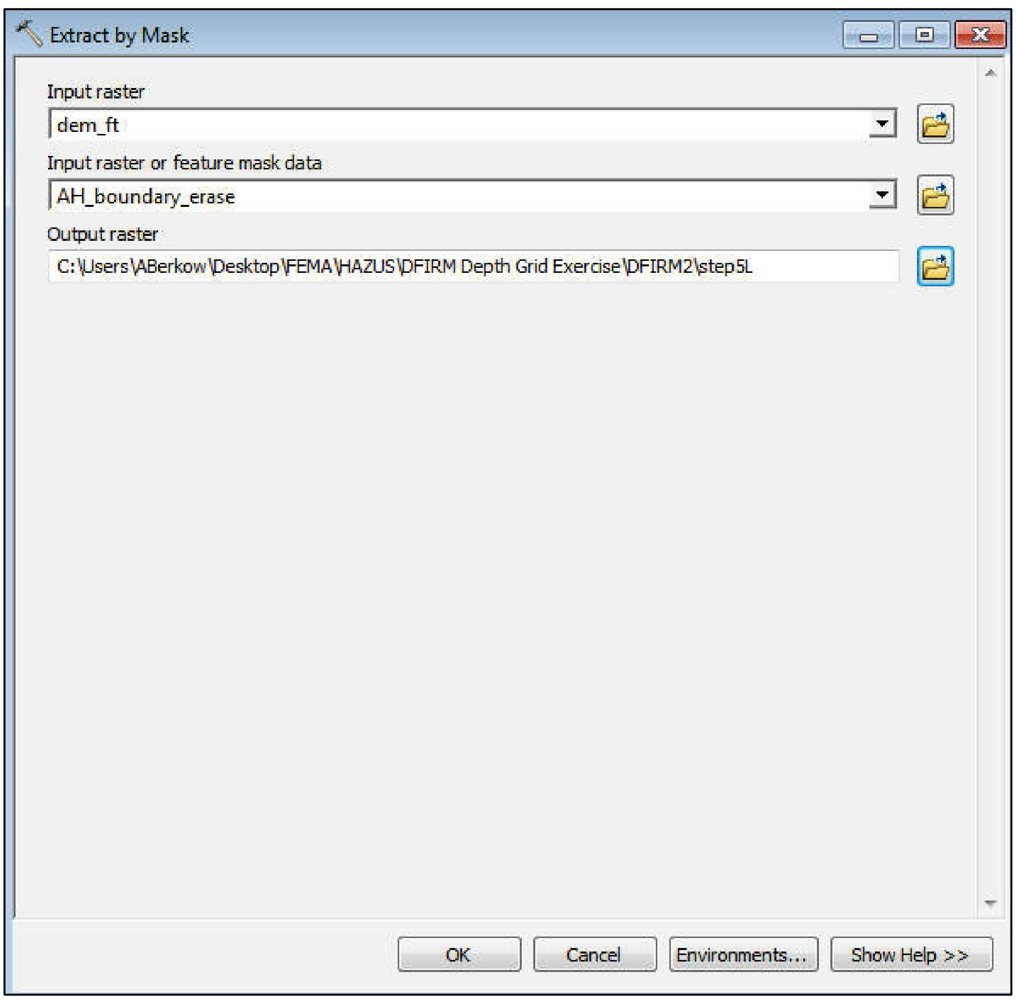


Figure 2-85: Extract by Mask tool

12.1 Navigate to the Processing Extent within Environments.
12.2 Set the Snap Raster to the DEM.
12.3 Navigate to Raster Analysis within Environments.
12.4 Set the output cell size equal to the DEM.
12.5 Click “OK” to close the environments tab.
12.6 Click “OK” to extract the new flood depth grid.

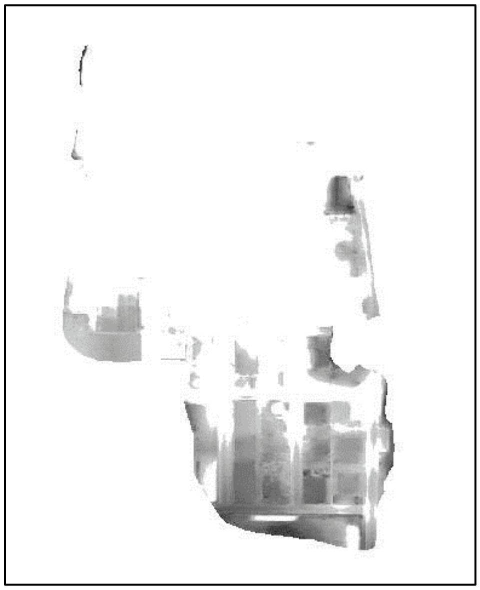


Figure 2-86: Extract by Mask results

13. Use the Raster Calculator to set the raster equal to 0.1 feet.

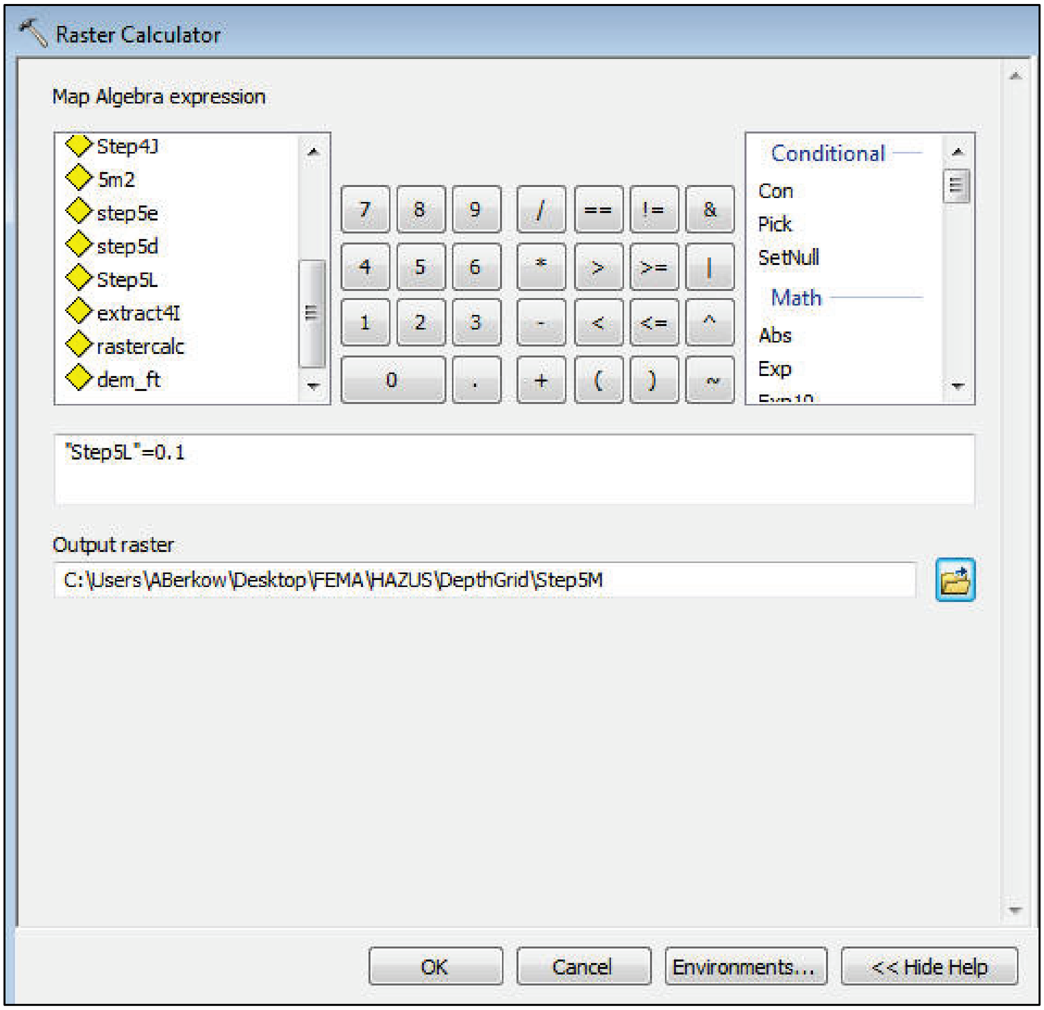


Figure 2-87: Raster Calculator tool

Figure 2-88: Raster equal to 0.1 feet

14. Use the Mosaic to New Raster tool to create the final AH Flood Zone Depth Grid using the two (2) depth grids created in the previous steps.

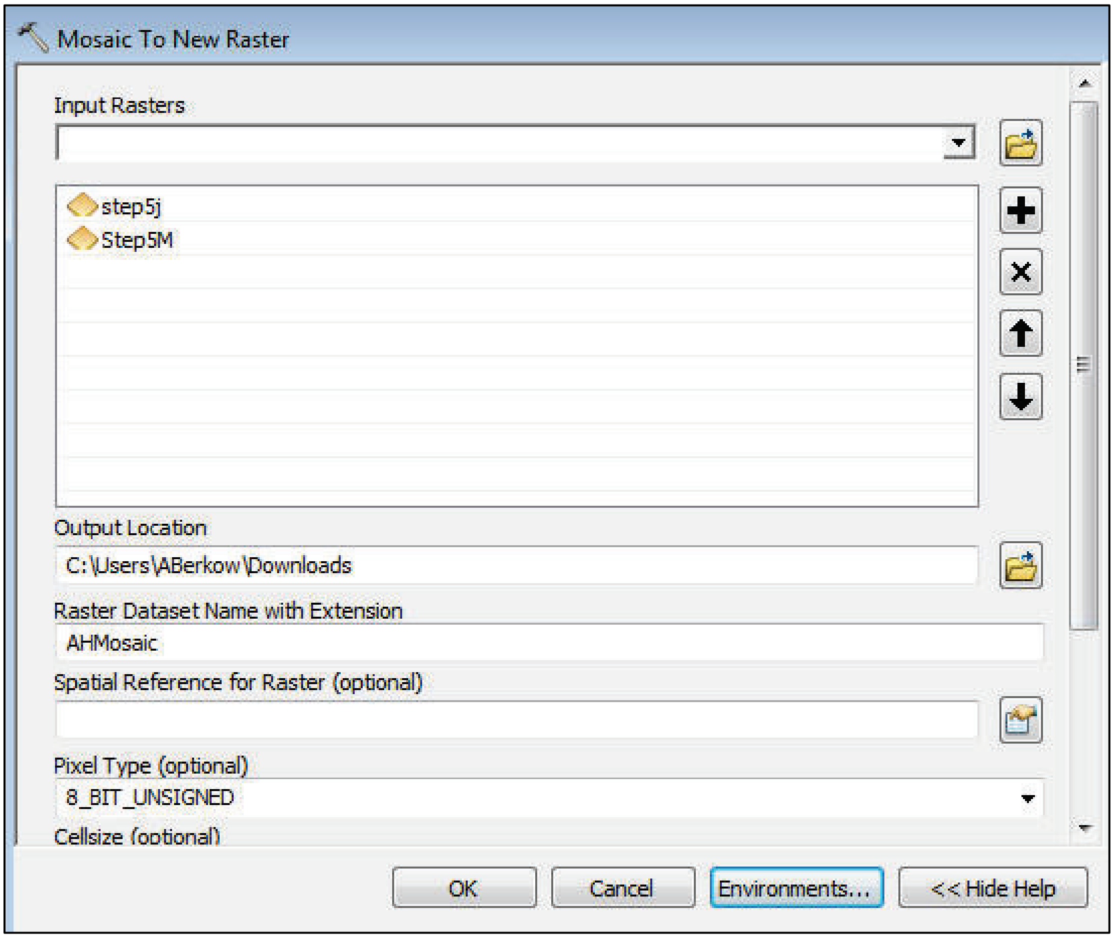


Figure 2-89: Mosaic to New Raster tool

14.1 Change the Number of Bands to 1.
14.2 Navigate to Processing Extent within Environments.
14.3 Set the Snap Raster to the DEM.
14.4 Navigate to Raster Analysis within Environments.
14.5 Set the output cell size equal to the DEM.
14.6 Click “OK” to close the Environments tab.
14.7 Click “OK” to create the mosaic.

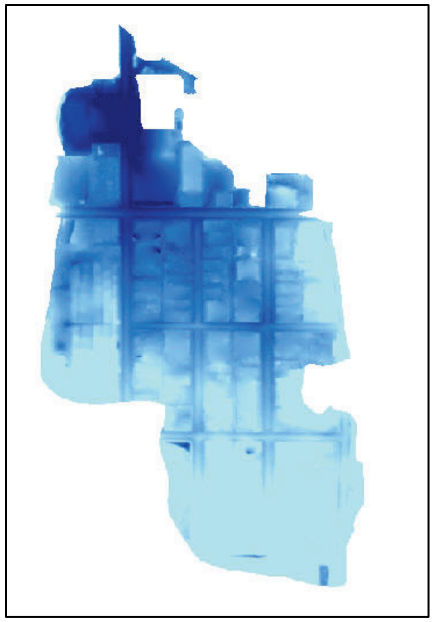


Figure 2-90: AH Mosaic Raster

15. There is only one AH Flood Zone in this exercise. There are multiple AH zones with different depths in many cases. A depth grid should be created for each separately when there are many cases.

2.3.2.3.3 AO Flood Zone Depth Grid

The AO Flood Zone has a constant water depth, generally below 3 feet in foot increments. Each AO can be unique, and the process is much simpler to create a depth grid for this zone of the same water depth. The water surface elevation is not necessary with AO Zones; therefore, it is not necessary to interpolate a water surface. The water depth in the AO zone can be found in the S_FLD_HAZ_AR attribute table.

1. Use the “Extract by Mask” tool and the AO Flood Zone boundary created to create the water surface.

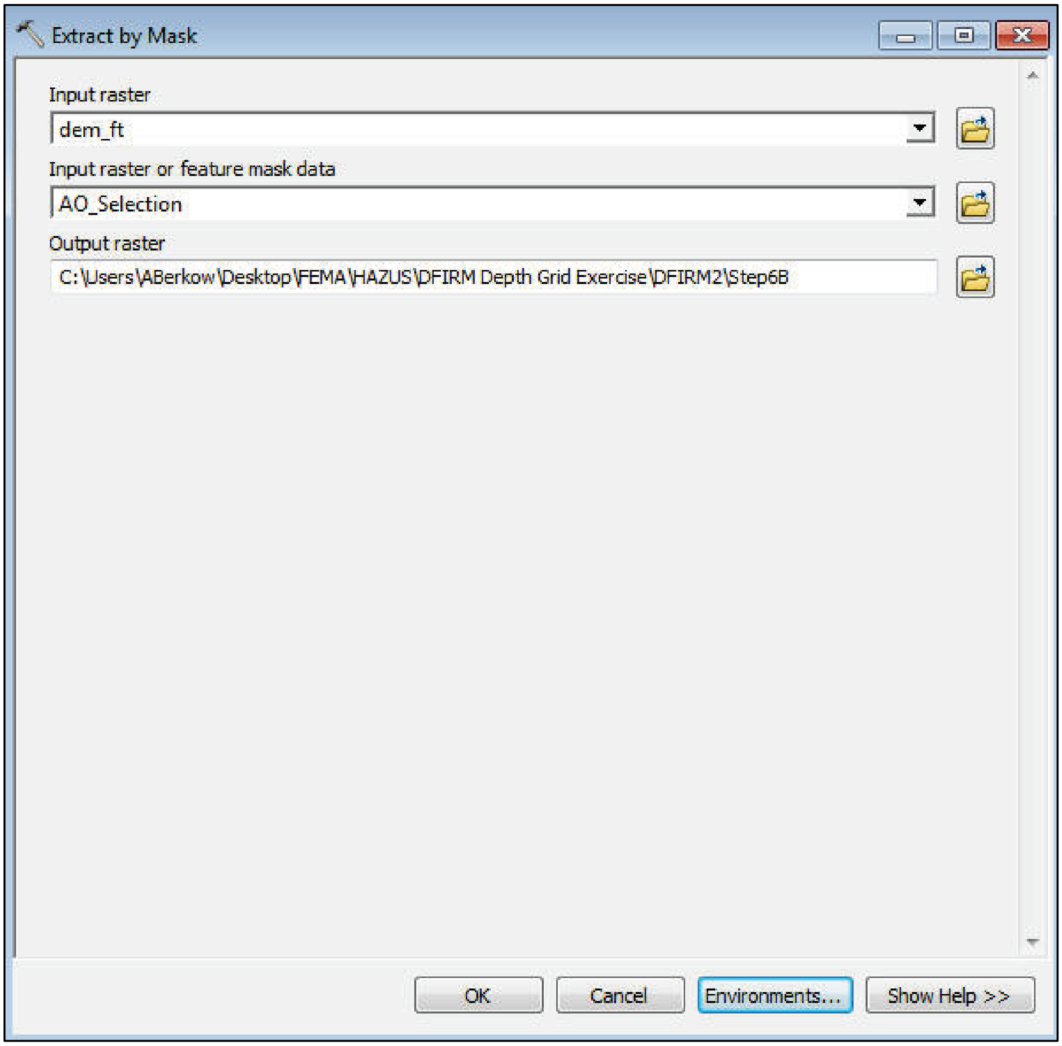


Figure 2-91: Extract by Mask tool

1.1 Navigate to Processing Extent within Environments.
1.2 Set the Snap Raster to the DEM.
1.3 Navigate to Raster Analysis within Environments.
1.4 Set the output cell size equal to the DEM.
1.5 Click "OK" to close the Environments tab.
1.6 Click "OK" to extract the water surface.

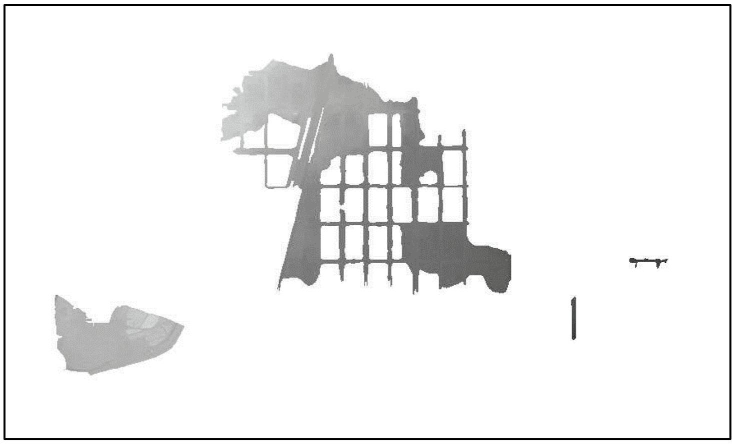


Figure 2-92: Results from Extract by Mask tool

2. Open the Raster Calculator tool and enter the following expression: ([Raster from Step 6-B * 0) + [Constant Water Depth]) to finish creating the depth grid. "Constant Water Depth" is two (2), but this value could also be one (1) in this example.

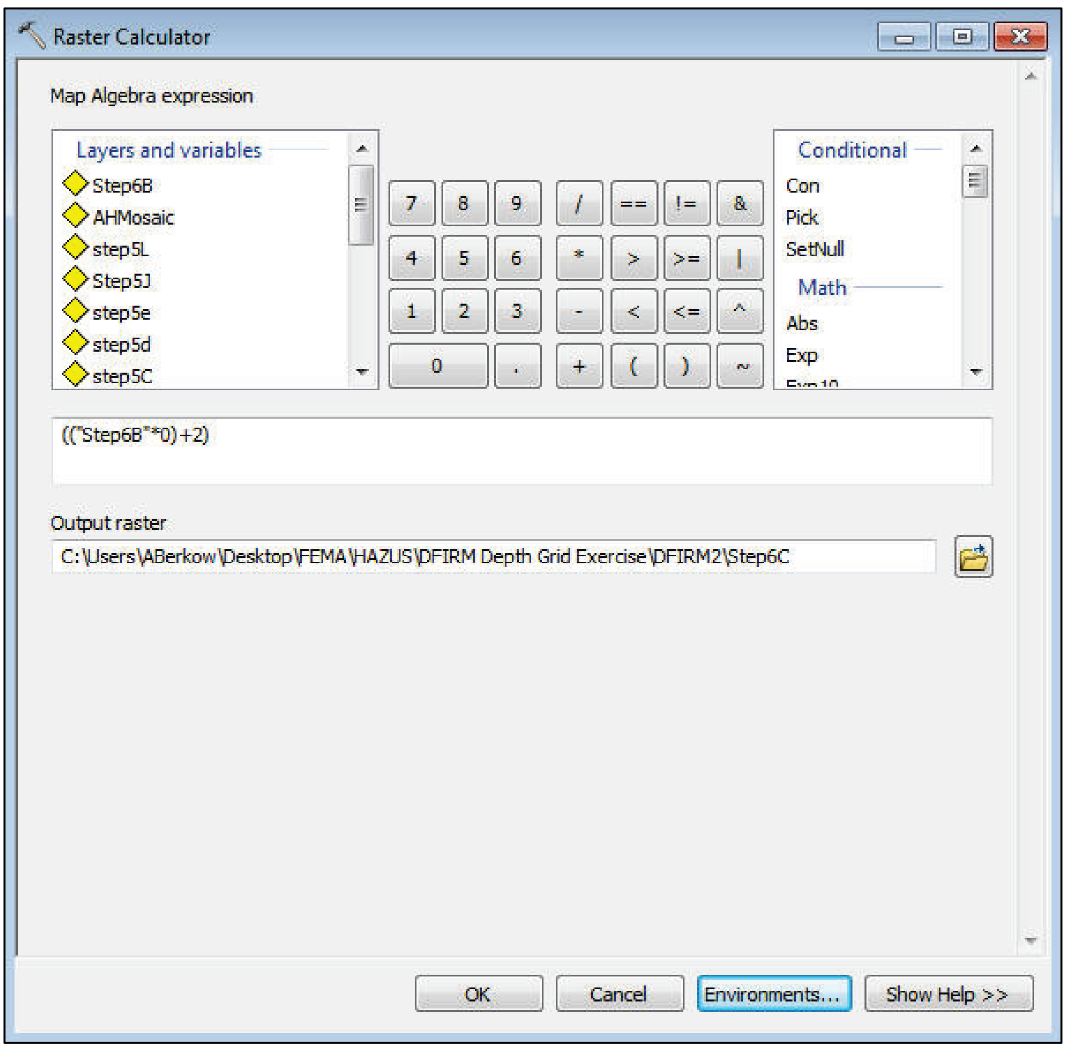


Figure 2-93: Raster Calculator

2.1 Navigate to Processing Extent within Environments.
2.2 Set the Snap Raster to the DEM.
2.3 Navigate to Raster Analysis within Environments.
2.4 Set the output cell size equal to the DEM.
2.5 Click "OK" to close the Environments tab.
2.6 Click "OK" to extract the water surface.

Figure 2-94: Raster water depth

3. There is only one AO Flood Zone in this exercise. There are multiple AO zones with different depths in many cases. A depth grid should be created for each separately.

2.3.2.4 Create the Final Depth Grid

1. Use the "Mosaic to New Raster" tool to create the final DFIRM Depth Grid.
   1.1 Add the raster surfaces created in steps above.

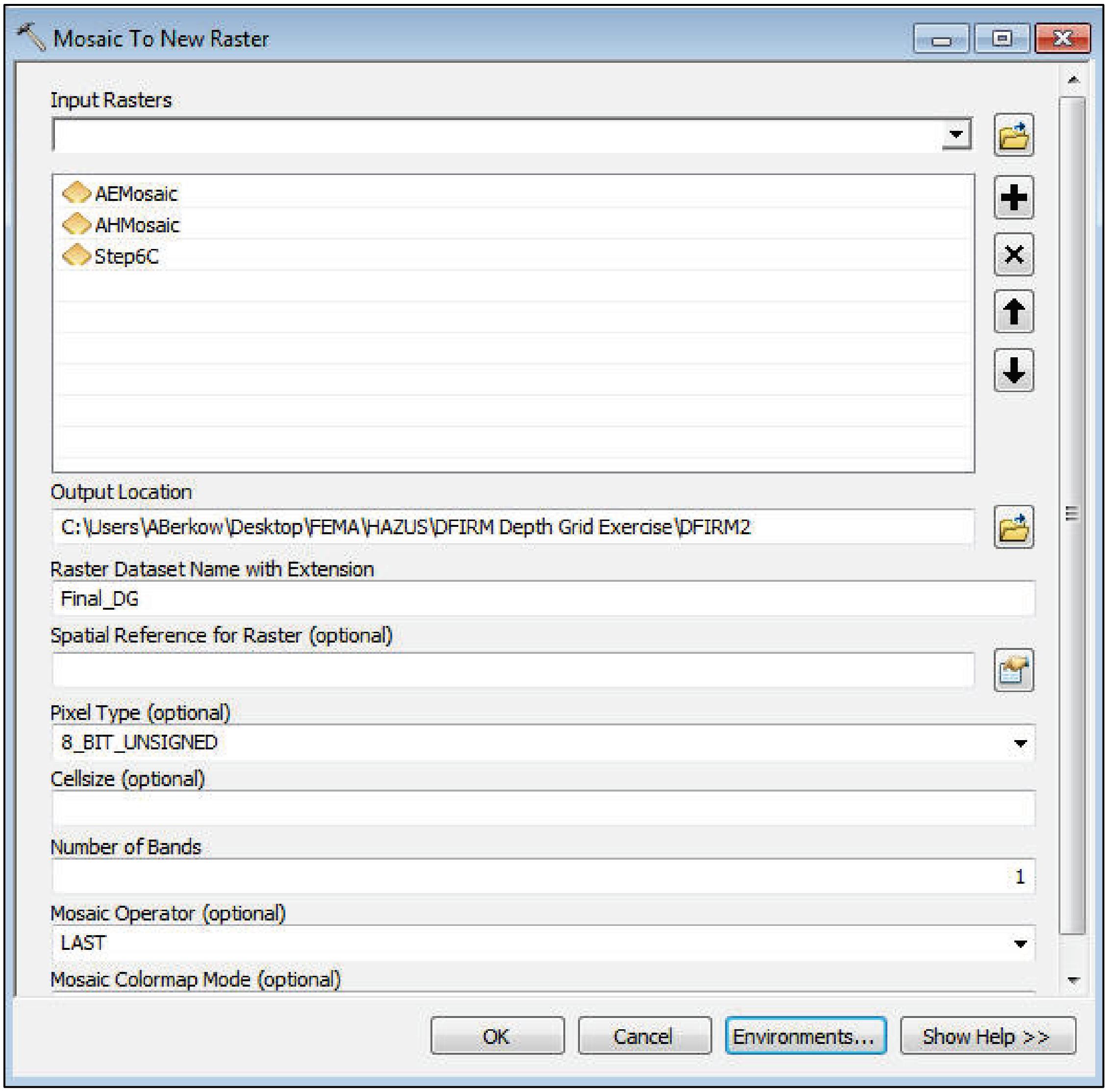


Figure 2-95: Mosaic to New Raster tool

1.2 Change the Number of Bands to 1.
1.3 Navigate to Processing Extent within Environments.
1.4 Set the Snap Raster to the DEM.
1.5 Navigate to Raster Analysis within Environments.
1.6 Set the output cell size equal to the DEM.
1.7 Click “OK” to close the Environments tab.
1.8 Click “OK” to create the mosaic.

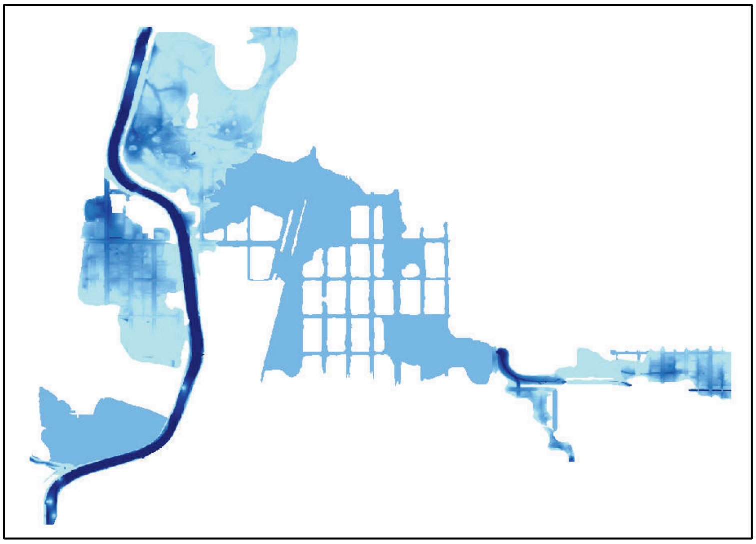


Figure 2-96: Final Depth Grid

3. Analyzing Flood Losses Using FEMA's Hazus Flood Model

Once the building inventory and flood depth grid are created, a site specific (structure by structure) flood analysis can be run through the Hazus flood model. Hazus can be used at an aggregated (census block) level or a site specific level. An aggregated approach uses an area weighting scheme to estimate losses on the built environment, assuming a uniform distribution of structures across the census block. Aggregated flood analyses can be appropriate for understanding regional flood risk as the nature of the analysis will over estimate losses in some areas, while underestimating in others. However, when smaller geographic areas need to be assessed or more accurate results are needed, the site specific approach, in all cases, should be favored over the aggregated loss estimation analyses. The site specific flood loss approach is much more accurate, estimating damages structure by structure instead of across an entire census block.

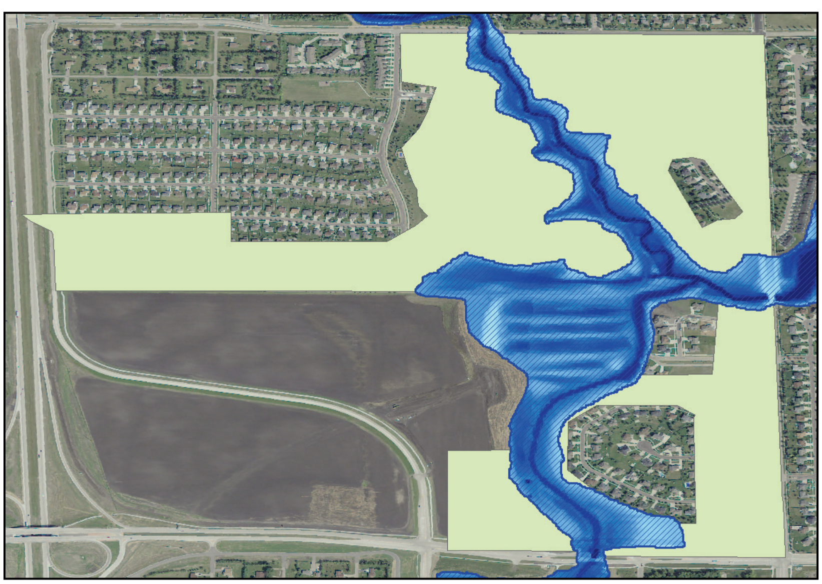


Figure 3-1: Displays one census block in Fargo, ND.

Hazus uses an area weighted approach to calculate the percentage of flooded area at each one-foot depth interval. The total losses sustained for this census block using the area weighted approach is $3,325,000.

Figure 3-2: Illustrates the site specific analysis approach.

The buildings in yellow are inundated by the depth grid; the buildings in orange are not. Only eight structures would have actually been inundated due to the real 2009 event which is apparent in the site specific analysis, with losses totaling $442,437 as opposed to over $3.3M using the area weighted approach. The initial building valuations for this block based on local assessor's data are $82,636,800 and $41,980,000 based on Hazus building valuations; therefore, the overestimation based on the area weighted approach is more than an order of magnitude.

3.1. Importing Structural Data into the User Defined Facilities (UDF) Database using the Comprehensive Data Management System (CDMS)

This section will cover how to use CDMS to import UDF for a study region. This section will take roughly 45 minutes to complete. Users can use an old Access geodatabase (.mdb), a shapefile (.shp), or an old excel file (.xls).

To improve the fidelity of analysis, Hazus state geodatabase default data can be updated and enhanced with the Comprehensive Data Management System (CDMS) when known changes have occurred, such as accessor data for particular buildings after floods or when essential facilities like fire stations or Emergency Operation Centers (EOCs) have closed or opened. The example below shows how to add a User Defined Facilities (UDF) geodatabase with CDMS in Arapahoe County, Colorado. Once a database has been updated in CDMS, every newly created study region will have these UDFs; the old study regions will not show the newly updated data.

In recent versions of Hazus, users can import UDF points with a minimum of occupancy type, and CMDS will apply Hazus default attributes for the remaining fields.

3.1.1. File Preparation

Place the Excel file with updated data (in this example, ArapahoeTest.xls) in the Hazus Data folder on the hard drive of the computer where the analysis is being conducted (in this example, the C:\HazusData\Regions\ folder).

Download the Colorado State data from the [FEMA Maps Service Center (MSC) Resources webpage](https://msc.fema.gov/portal/resources/hazus) (https://msc.fema.gov/portal/resources/hazus), move the file to the C:\HazusData\Inventory\ folder and then unzip (double click the CO file and it will extract itself to the correct location) the folder onto the hard drive of the computer on which the analysis is being conducted (in this example, C:\HazusData\Inventory).

3.1.2. Specify State in CDMS

Specify the state where UDF information is being added.

1. Open "CDMS."

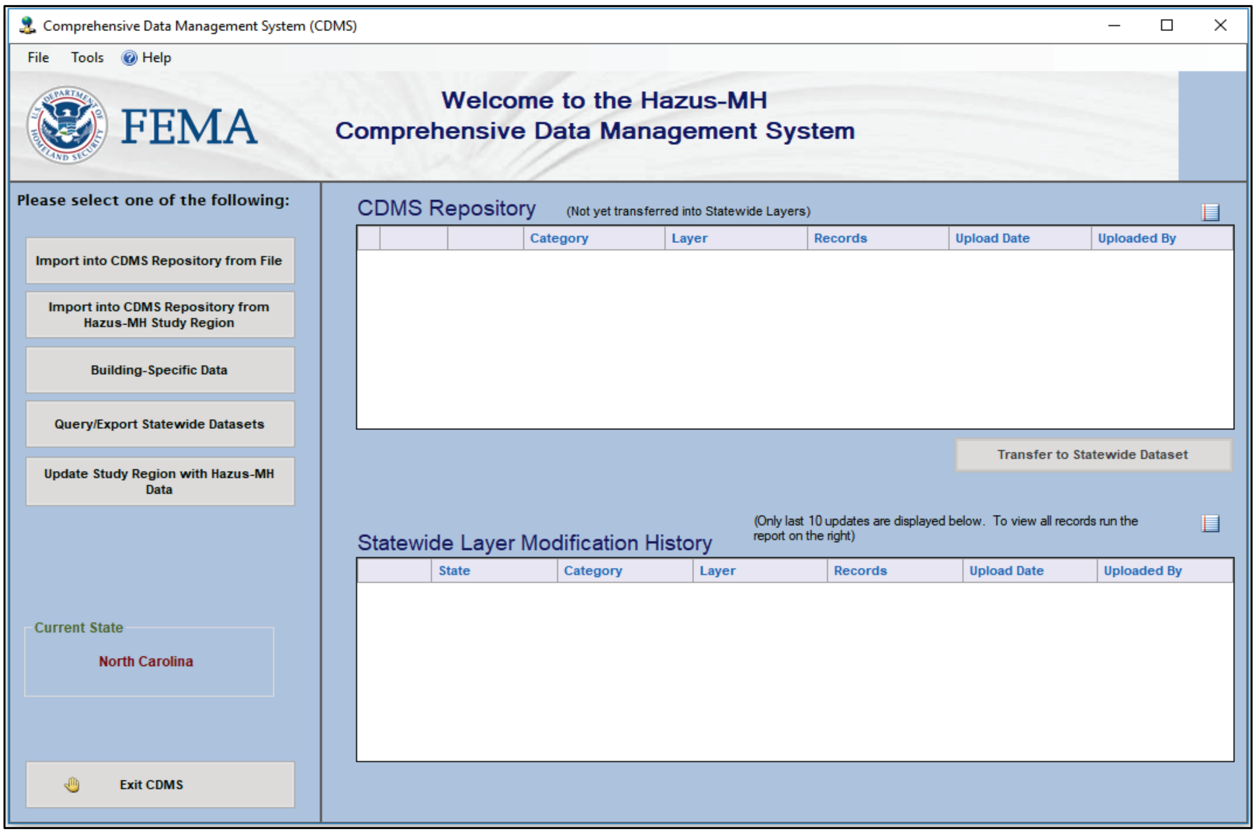


Figure 3-3: CDMS main page.

2. Click "Tools" in the menu options in the upper left-hand corner of the CDMS window and then click "Specify Hazus-MH Data Location" from the dropdown menu as shown in Figure 3-4.

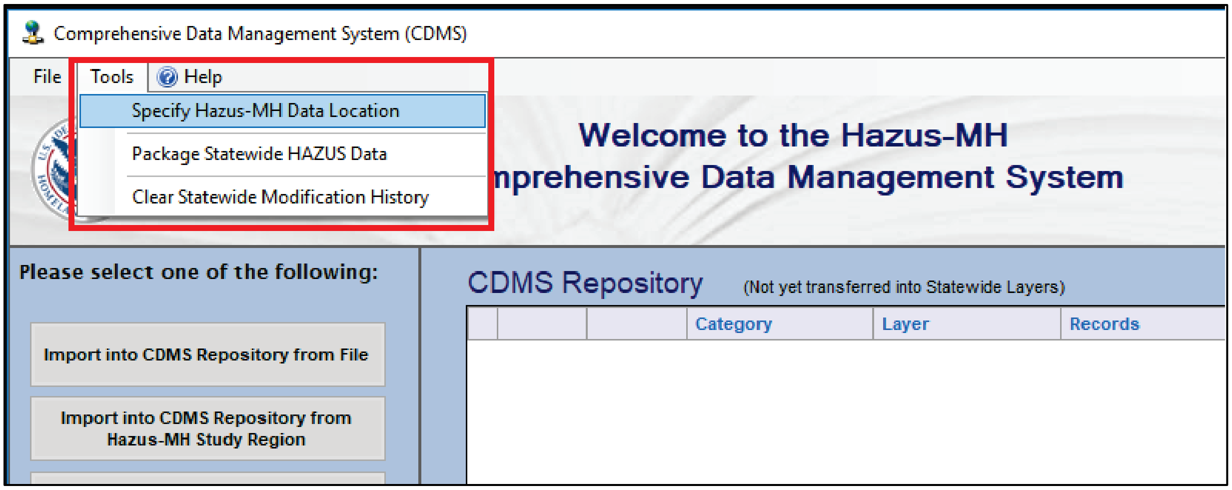


Figure 3-4: Selecting "Specify Hazus-MH Data Location" from dropdown menu

3. The CDMS Statewide DB Configuration window will open.

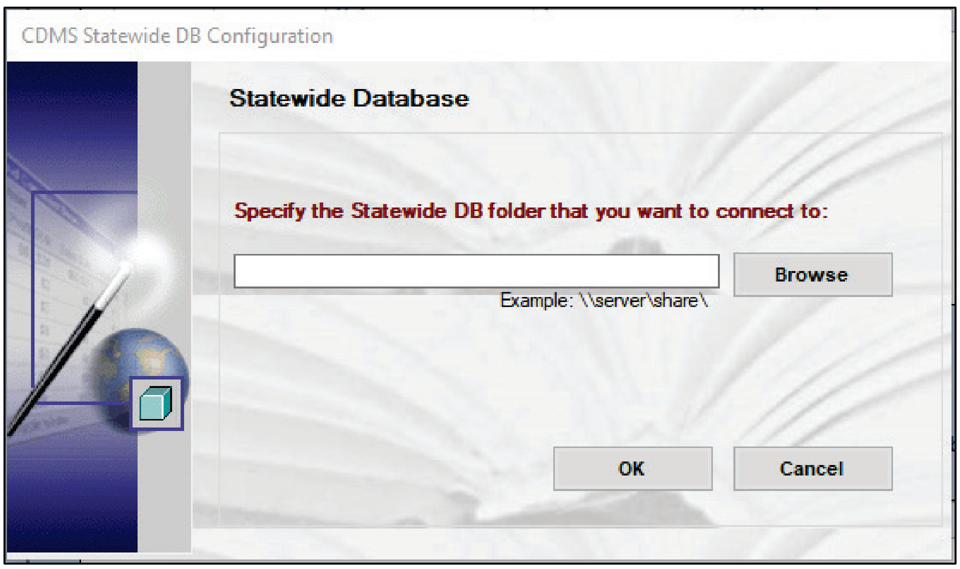


Figure 3-5: CDMS Statewide DB Configuration window.

4. Click "Browse" and then select the respective state from the HazusData folder in the browse window that opens (in this example, the State data for Colorado is selected).

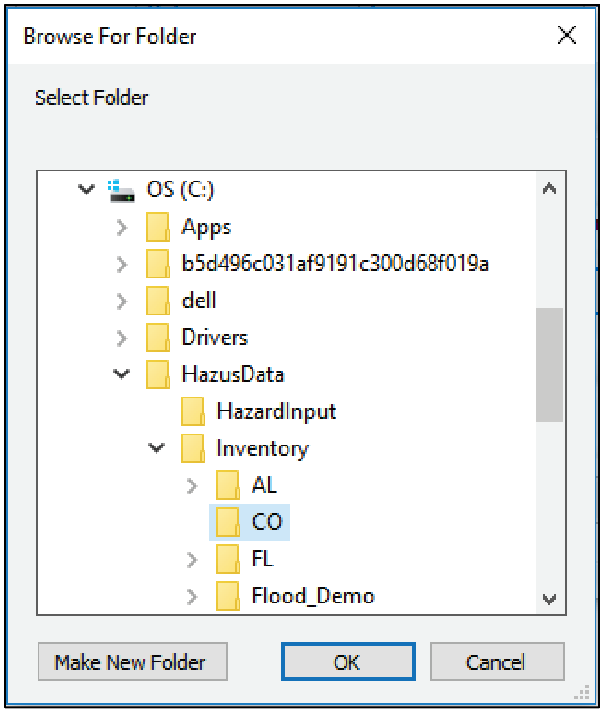


Figure 3-6: Selecting the State from the Browse window.

5. Click "OK." This will change the Current State in the CDMS to Colorado, as shown below in the red box in Figure 3-7.

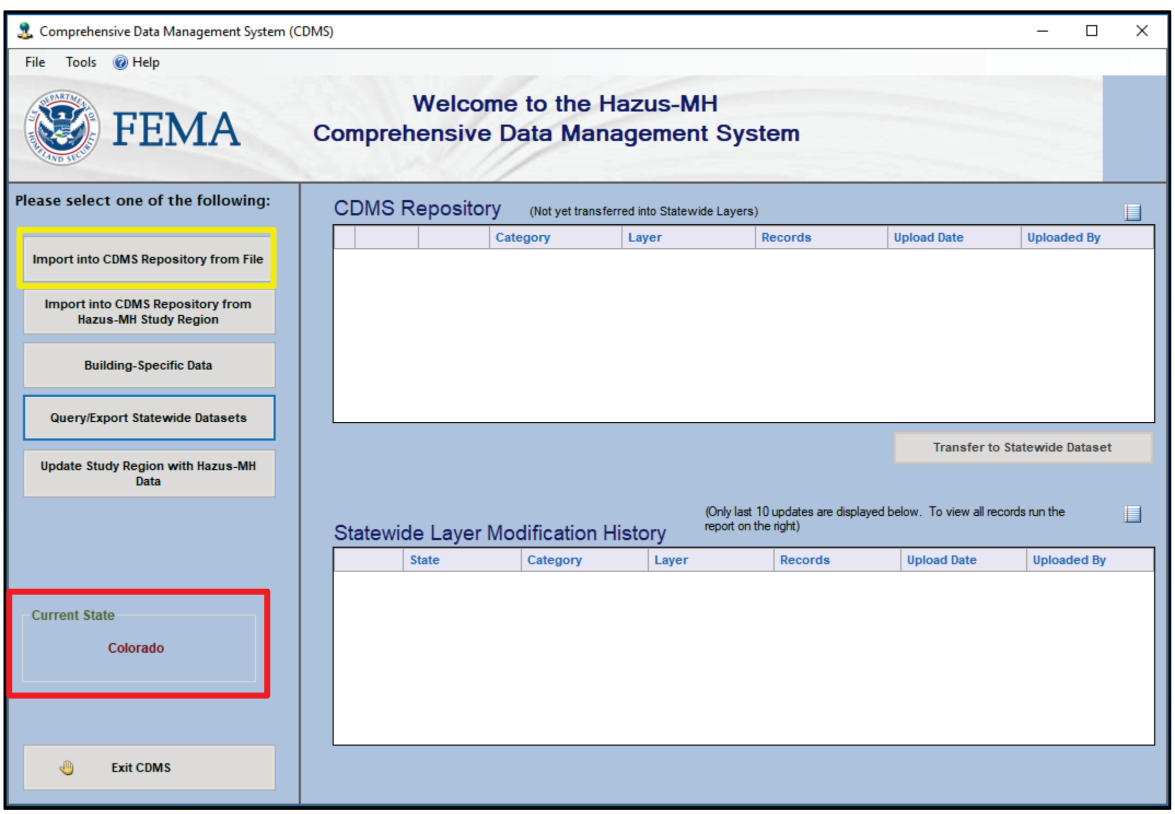


Figure 3-7: Current State in CDMS has changed.

3.1.3. Select Data for Import

Select the data to import into CDMS and tell CDMS what kind of data it is.

1. Click the “Import into CDMS Repository from File” button highlighted in the yellow box in Figure 3-7.
2. Then click “Browse” under “Select a file for Import”.
3. Select the Excel file from the location on the computer’s hard drive. In this example, the file “ArapahoeTest.xls” is located in the C:\HazusData\Regions\ folder (see Figure 3-8). In the drop-down menu in the bottom right, the user must select “Microsoft Excel file (*.xls) to see the file.

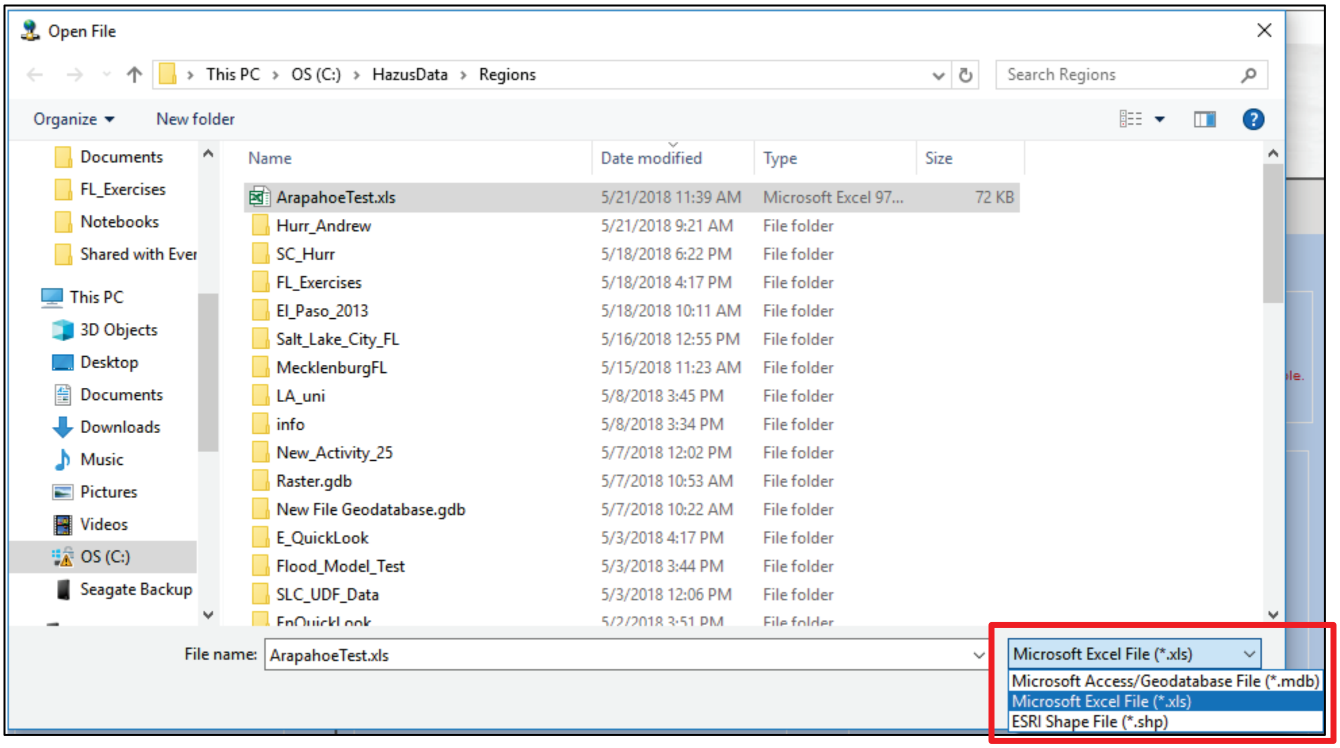


Figure 3-8: Selecting updated Excel file to import.

4. Uncheck the Earthquake box and select “User Defined Facilities” from the Select Hazus-MH Inventory Category and Select Hazus-MH Inventory Dataset (Layer) dropdown menus.

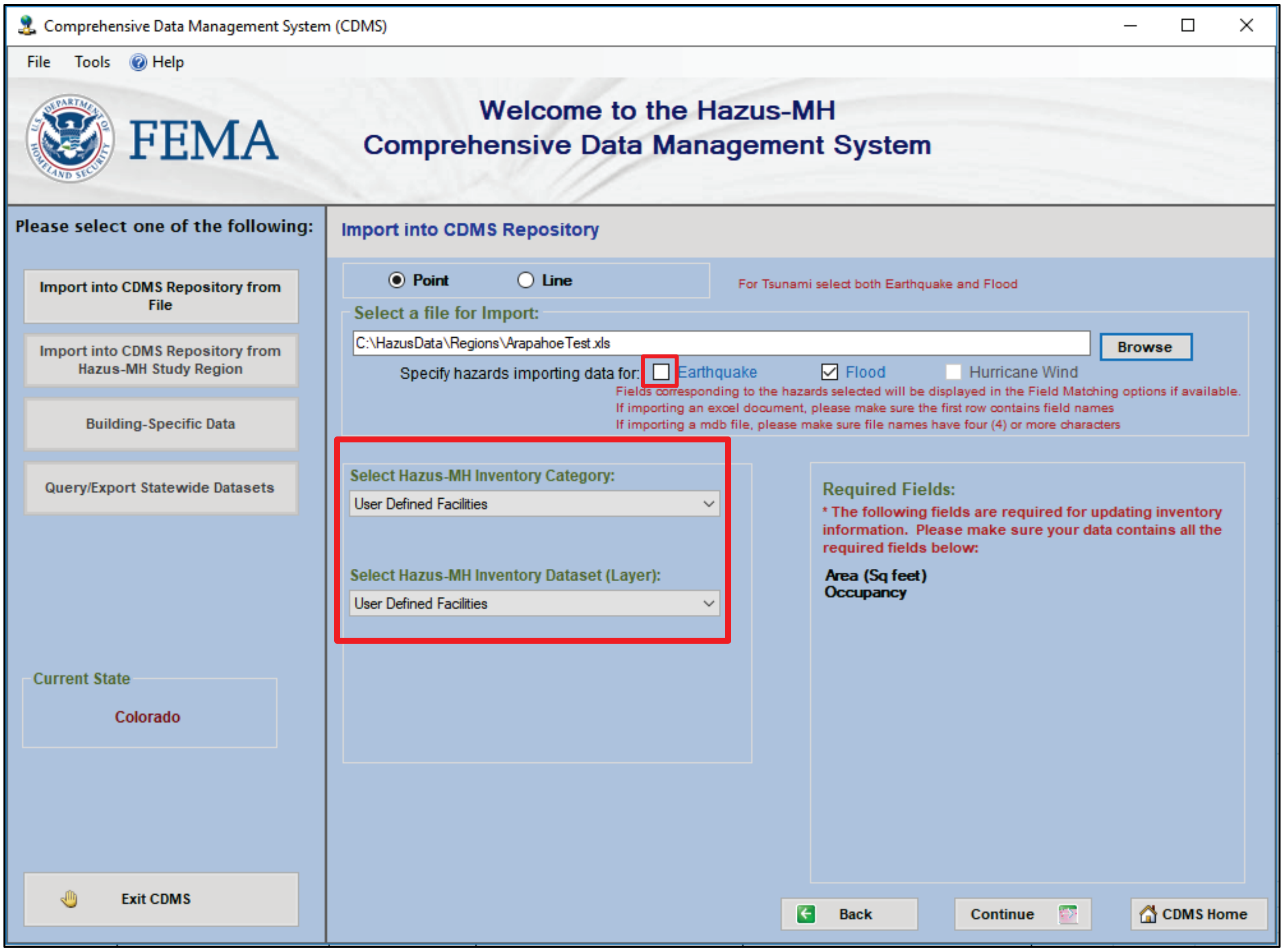


Figure 3-9: Options to select before the file is imported into CDMS.

5. Click "Continue," and the CDMS window should refresh.

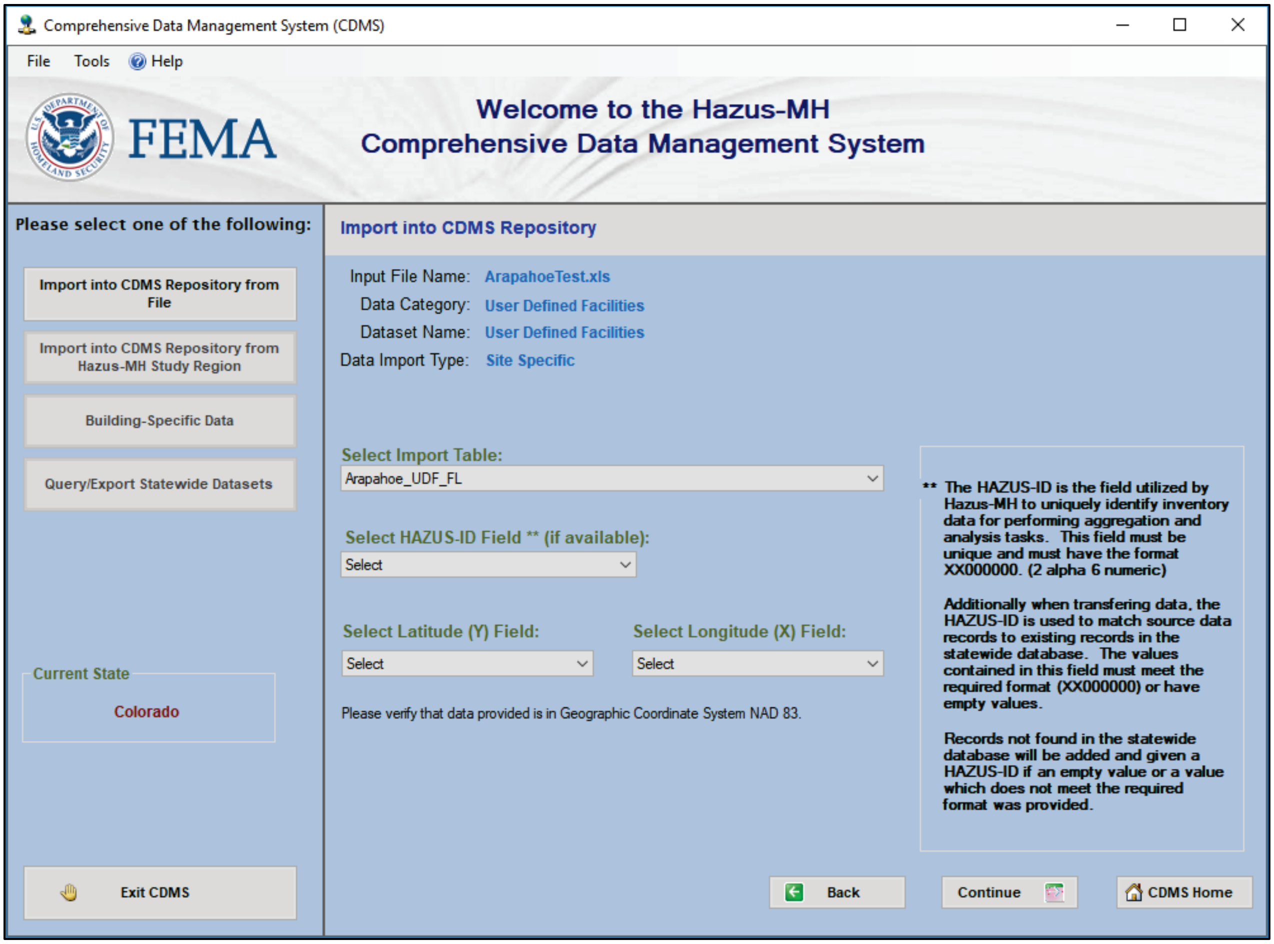


Figure 3-10: Options after the Excel file has been imported into CDMS.

6. Select the user defined facilities table of data for the import table. This data must be in WGS-84. From the "Select Import Table" drop-down menu, the only option is "Arapahoe _UDF_FL" because that is the only worksheet in the Excel file (see Figure 3-10). There would be more than one option in the drop-down menu if there were more sheets.

7. Select "No HAZUS ID" from the "Select HAZUS_ID Field" drop-down menu (see Figure 3-11). The user will most frequently use the "No HAZUS ID option" unless the user has exported a Hazus dataset using the "Query/Export Statewide datasets" and only edited the information. When exporting from CDMS, all the Hazus fields are maintained and the data can be edited. The field names should not be changed. The Hazus ID field is what connects all the tables together, for example, the fire stations table is connected to a unique flood hazard table and a separate earthquake hazard table, which are all connected to the study region tables. Select "Latitude" from the "Select Latitude (Y) field" drop down menu and select "Longitude" from the "Select Longitude (X) field" drop down menu.

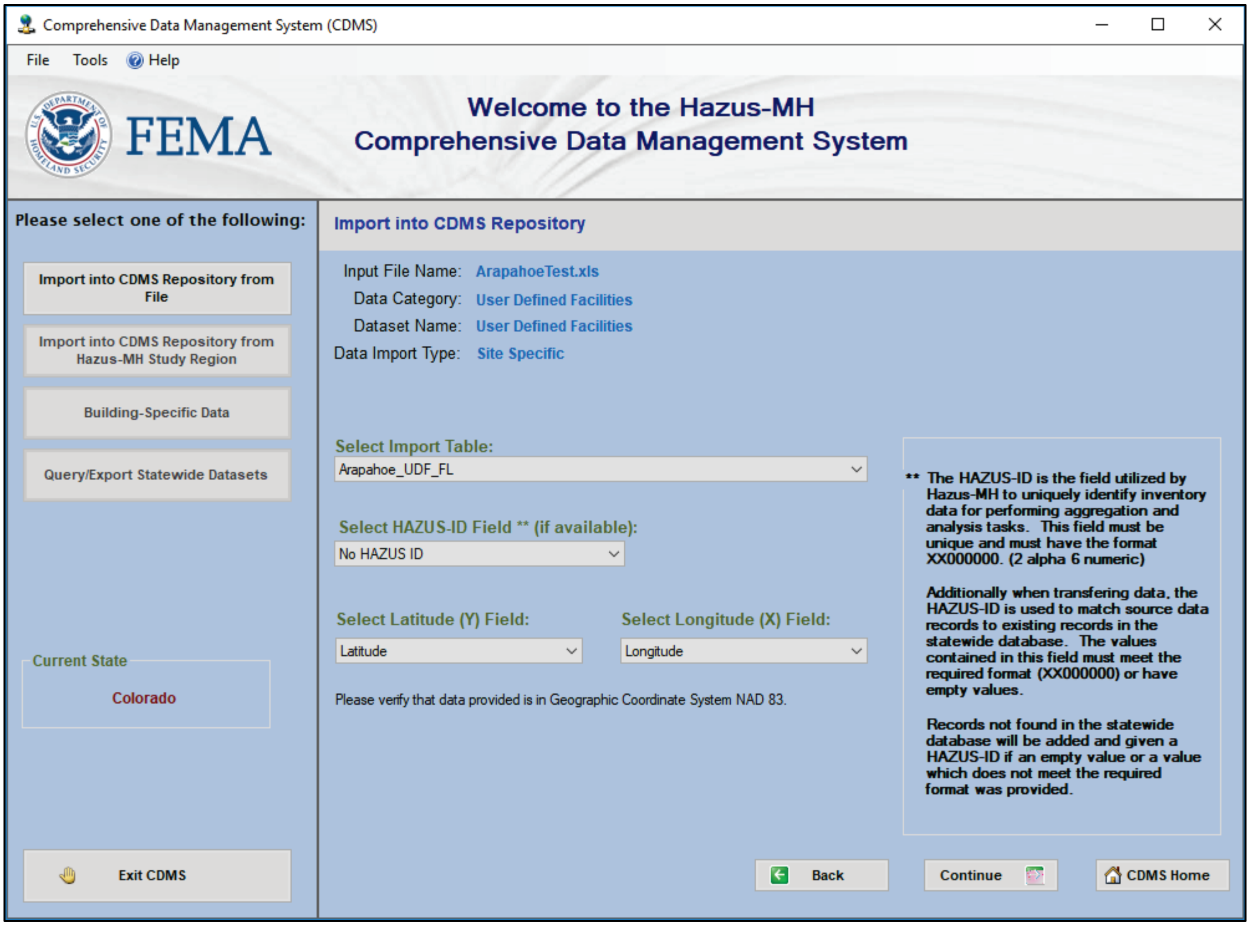


Figure 3-11: Selecting options in dropdown menus.

Note: Earlier versions of Hazus used the Geographical Coordinate System 1984 (GCS-1983) as its projection, Hazus 4.2 uses World Geodetic System 1984 (WGS-1984) as its new projection. In this example, the user is importing an Excel file, so the data does not have a projection associated with it. The user must know this information before importing it. Hazus will assume the Latitude and Longitude coordinates are already in WGS-1984. If the user chooses to import an incorrectly projected Access geodatabase (mdb) as the imported table and clicks “Continue,” CDMS will inform the user that the table is not in the correct projection. To correct this, the user can project the geodatabase using ArcMap and place the projected data into the same MDB file by using the Feature Class to Feature Class tool. Many Access MDB files have multiple different tables, the user can open the table on the computer to explore the data and figure out which table would be best to import into Hazus through CDMS.

8. Click “Continue,” and the CDMS window should refresh to display the Data Field Matching window.

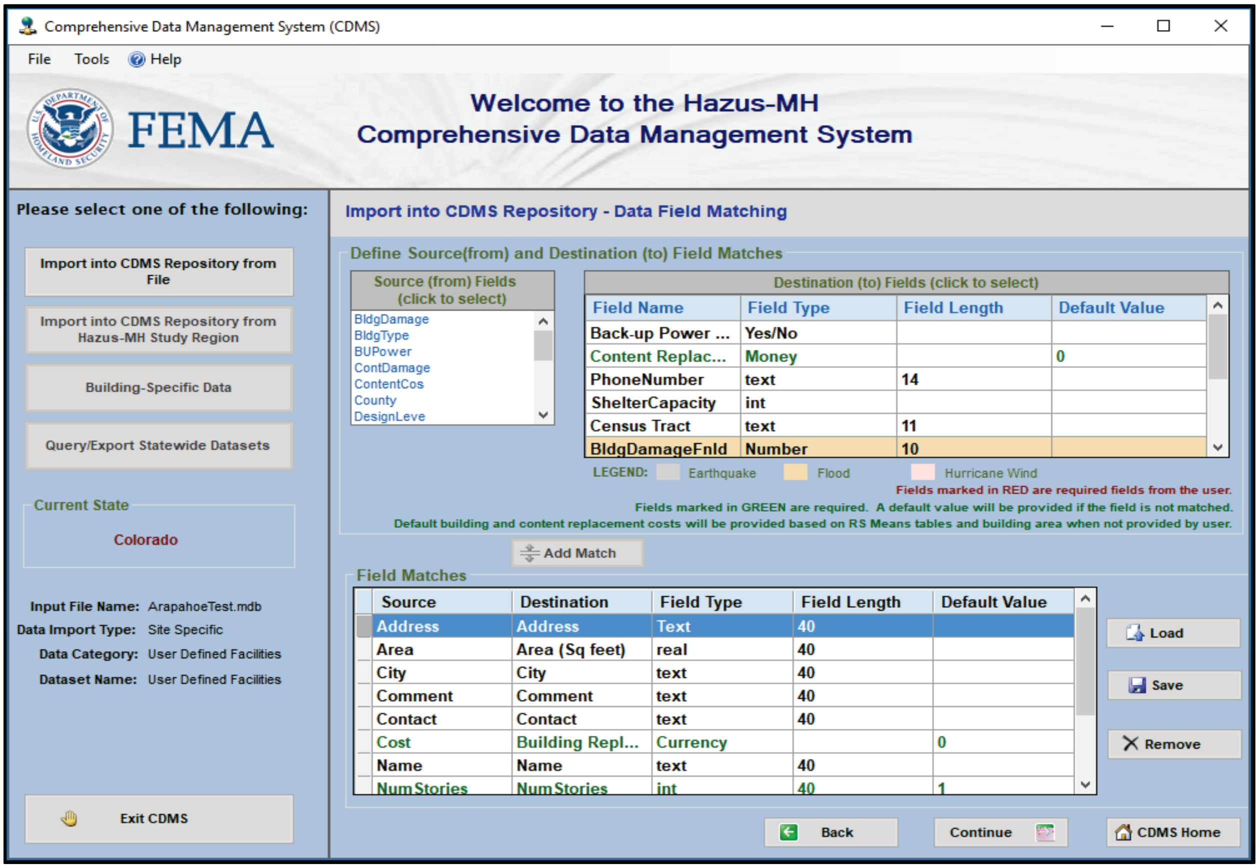


Figure 3-12: Data Field Matching window.

3.1.4. Matching Fields in the Datasets

Hazus does not automatically match all columns; the user must map the database columns to the respective Hazus fields.

1. In the “Source (from) Fields (click to select)” menu, select “BUPower.”
2. In the “Destination (to) Fields (click to select)” menu, select “Back-up Power.
3. Click the “Add Match” button to confirm the column mapping.

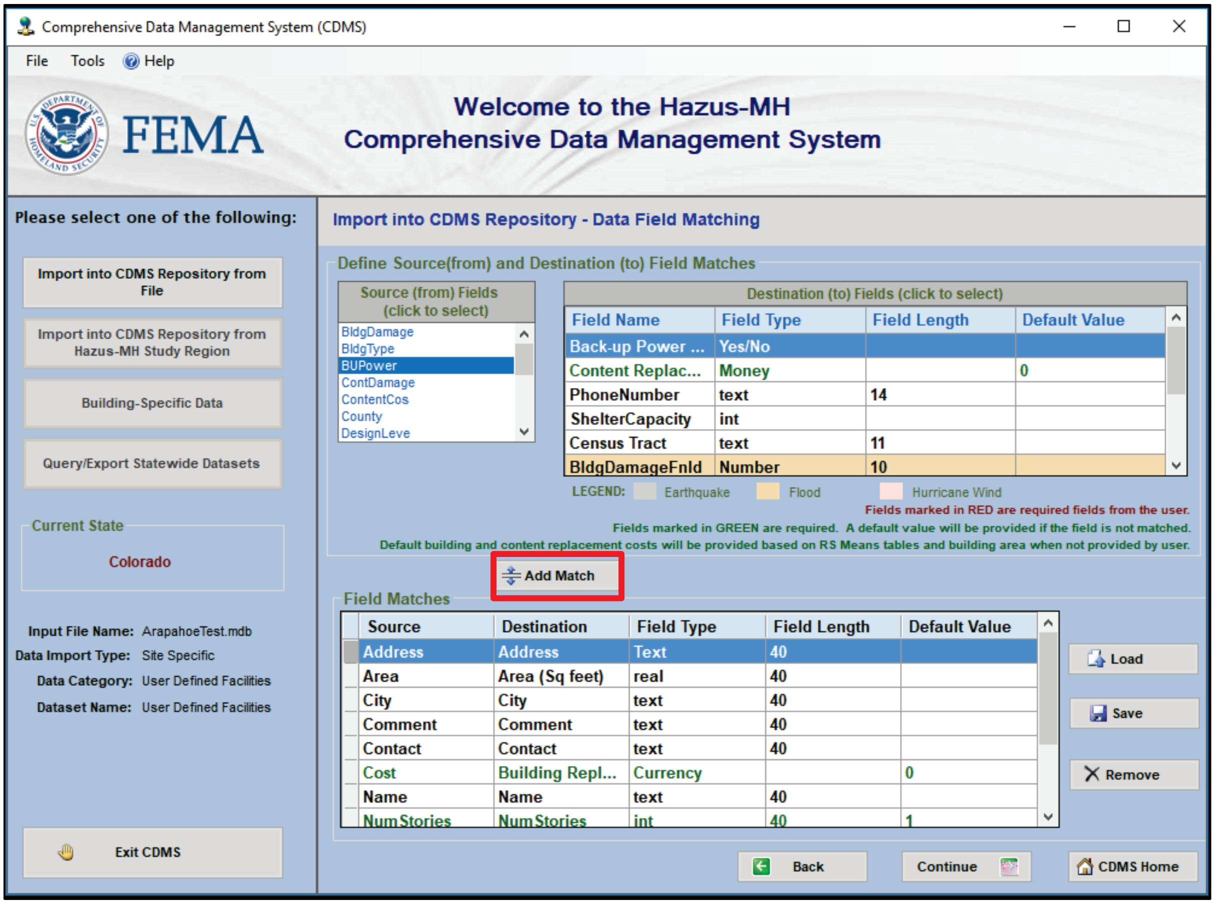


Figure 3-13: Matching fields in the datasets.

4. After adding the match, it will be listed with the other Field Matches at the bottom of the window.

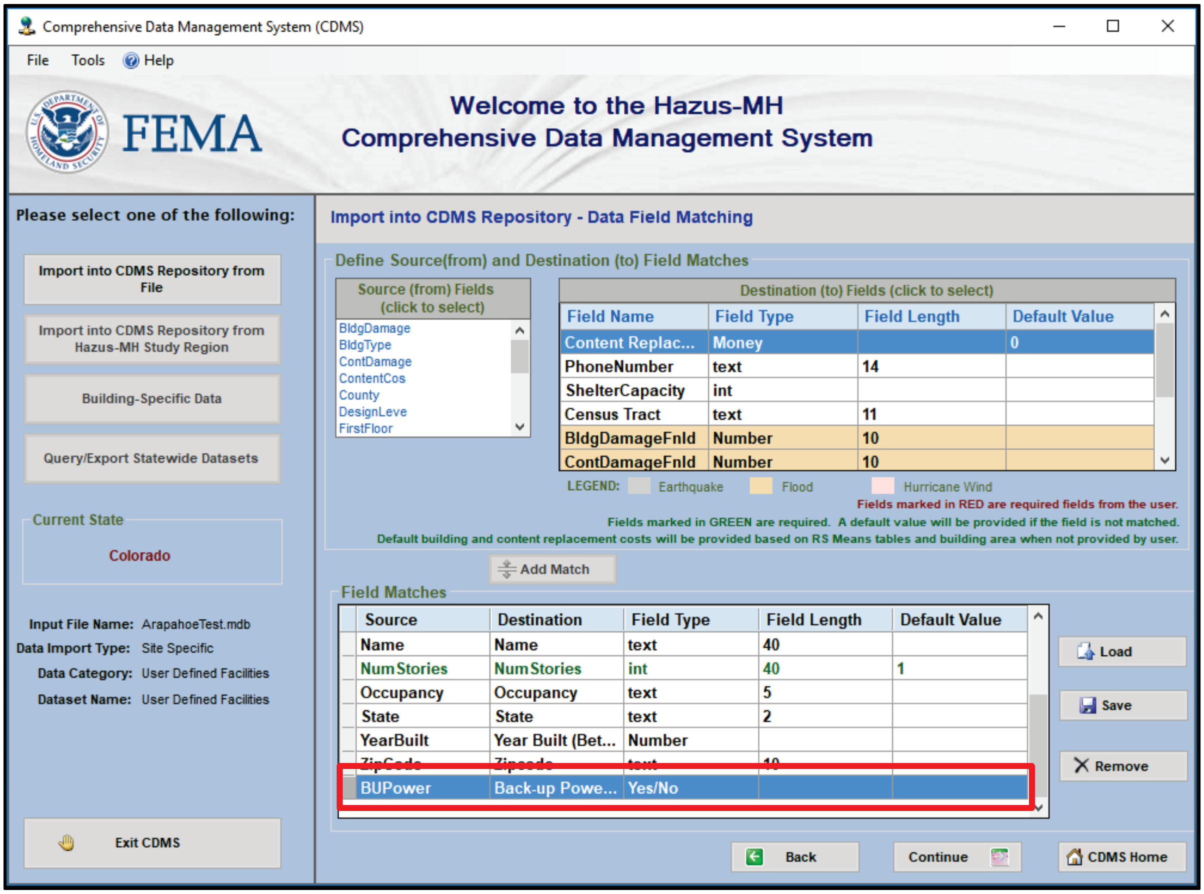


Figure 3-14: New match shown in Field Matches window.

5. Use the same process to add the following column mappings:

Table 3-1: Source and Destination column mappings.

SOURCE (FROM) FIELDS	DESTINATION (TO) FIELDS
BLDGDAMAGE	BldgDamageFnld
CONTDAMAGE	ContDamageFnld
CONTENTCOS	Content Replacement Value
FIRSTFLOOR	First Floor Height
FLOODPROTE	FloodProtection
FOUNDATION	Flood Foundation Type
INVDAMAGEF	InvDamageFnld
PHONE	PhoneNumber
SHELTERCAP	ShelterCapacity

Note: In general, the user will have to map some of the fields. CDMS automatically matches fields with similar names but will not recognize all of them. After field mapping is complete, if the user has multiple files that they wish to import with the same field names, the user can create an FMP file, which can be uploaded and used to match fields more quickly. To do this, after manually matching fields, the user would click the “Save” button. CDMS will bring up a file explorer window to save the FMP file. The user can name and place the file on their computer. When importing a new file through CDMS with the same field names, the user can click the “Load” button and browse and select the FMP file. When loaded, the FMP file will match the source and destination fields automatically.

6. After the source and destination columns are mapped, click “Continue.”

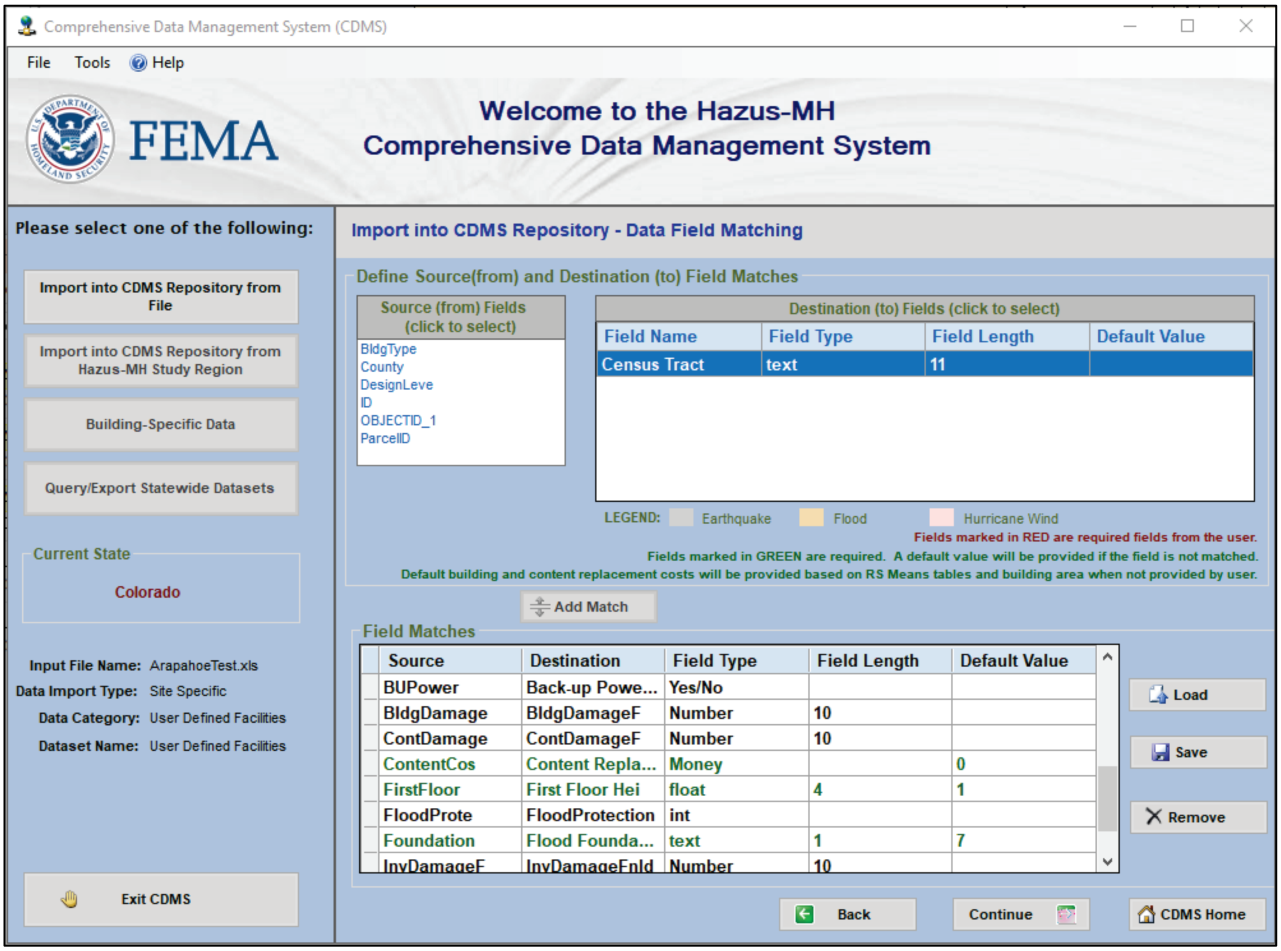


Figure 3-15: Data Field Matching window after source and destination columns have been mapped.

Note: In this example, the UDF data only has values for the Flood field categories. The UDF database will populate the Earthquake values too, but they will be set to default values. There are available defaults for many Hazus fields. If the imported UDF dataset does not have values, they will be set to Hazus’ predefined defaults, if they exist, which can be seen in the default value columns. The only required fields for a UDF import are Area (sq ft) and Occupancy.

7. CDMS will bring up a “Categorize Fields” window. Because CDMS doesn’t always recognize the values or codes in the imported database, some values that are not numeric in nature, like “Area” or “Cost,” may need to be specified. Click ”OK.”

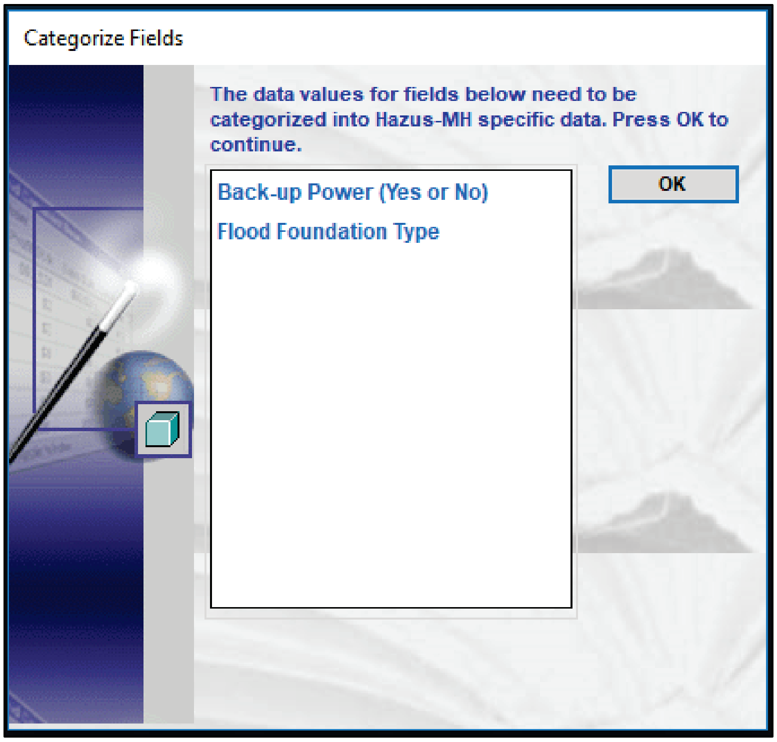


Figure 3-16: Example of fields that are not numeric values and will need to be specified.

8. Verify that the value and description align, and then click "Continue" to confirm that "0" means "No" in the database.

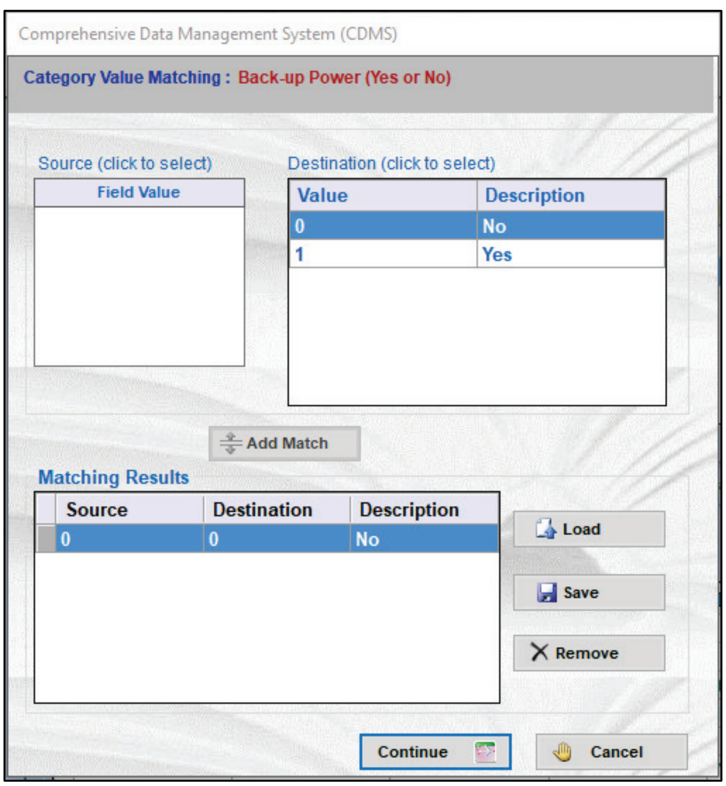


Figure 3-17: Example of specifying value for Back-up Power.

9. Click "Continue" to confirm that "4" means "Basement/Yard" and "7" means "Slab on Grade." If the automatic matching is incorrect, the user can select the incorrect match and click the "Remove" button. This will remove the match from the "Matching Results" table and place the numbers back in the source and destination tables above. The user can then select the source field value and destination and click the "Add Match" button. This is similar to mapping table fields, but instead, the user is matching column values to their Hazus attributes.

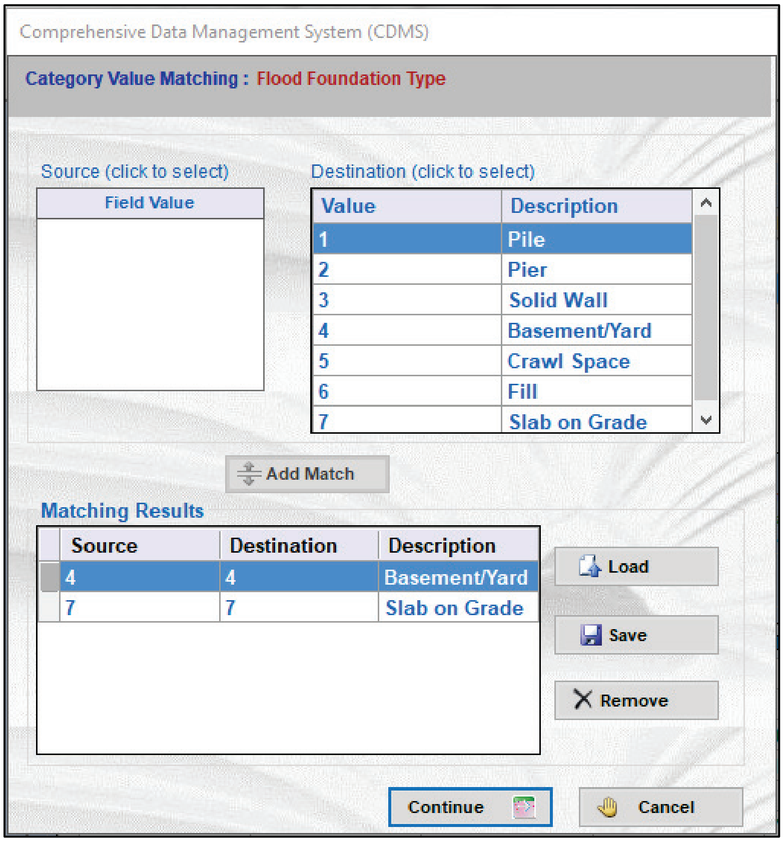


Figure 3-18: Example of specifying value for Flood Foundation Type.

10. CDMS will then take a moment to process the selections for matching the imported columns and codes to the Hazus-expected format.

11. Click "OK."

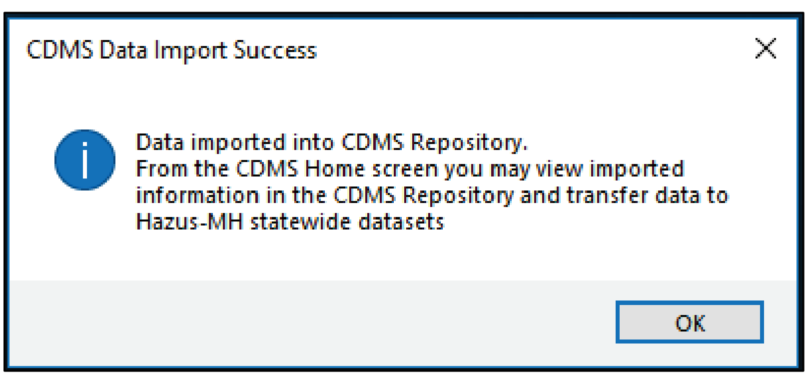


Figure 3-19: CDMS import success message.

3.1.5. Merging New Data with State Database

1. View and edit the incoming information in the "CDMS Repository." This is a "holding tank" for data before importing it into a State Inventory folder. When satisfied that the data is correct, click "Transfer to Statewide Dataset."

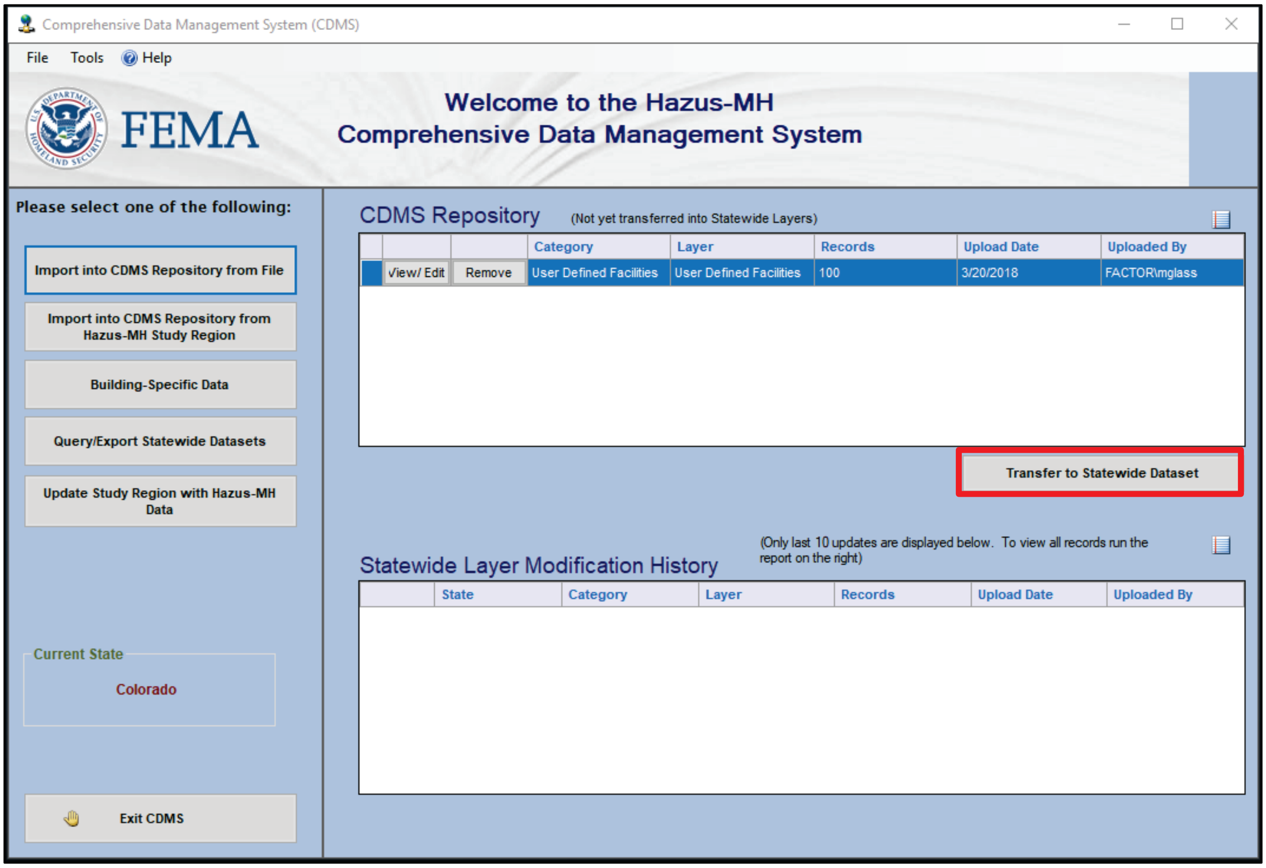


Figure 3-20: Example of CDMS Repository window.

2. A window with two transfer options will open: "Append/Update Data" or "Replace Data." Select "Append/Update Data" and Click "Submit." Append/Update means all the new data is going to be added and then any existing duplicated information is going to be updated based on the Hazus-ID value. The replace data option tells CDMS that wherever it finds a new record in a census tract, it is going to delete anything that is currently in the state database in that tract and replace it solely with the imported data (for that type of inventory). In this case, all previous UDFs would be left and new UDFs would be added or appended if the Hazus-ID was the same.

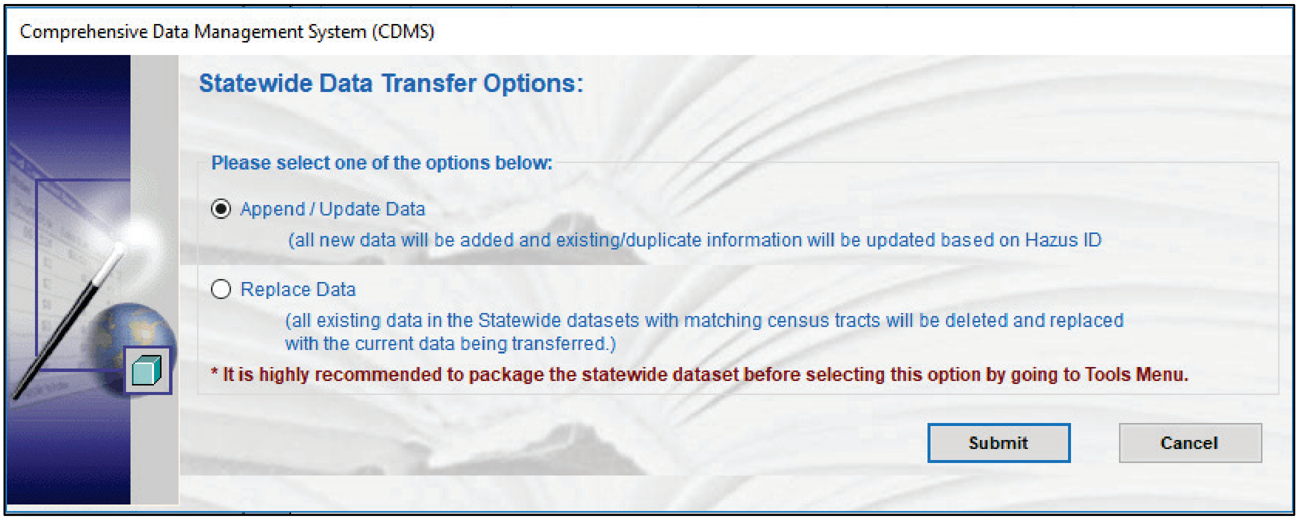


Figure 3-21: Statewide Data Transfer Options window.

3. Click "Yes" to confirm the transfer of UDF data to the State Database.

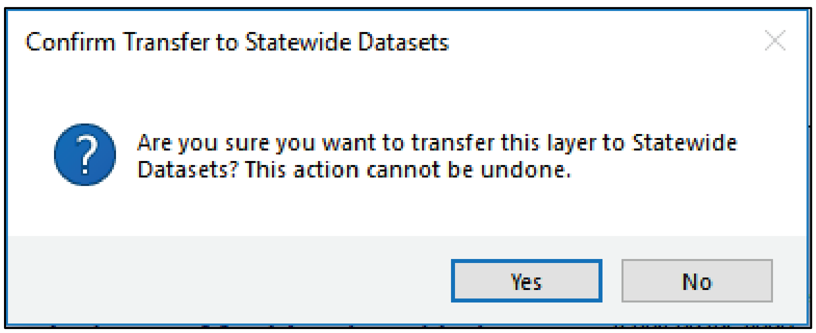


Figure 3-22: Pop-up window to confirm transfer to Statewide Datasets.

4. The UDF data transfer will appear in the "Statewide Layer Modification History."

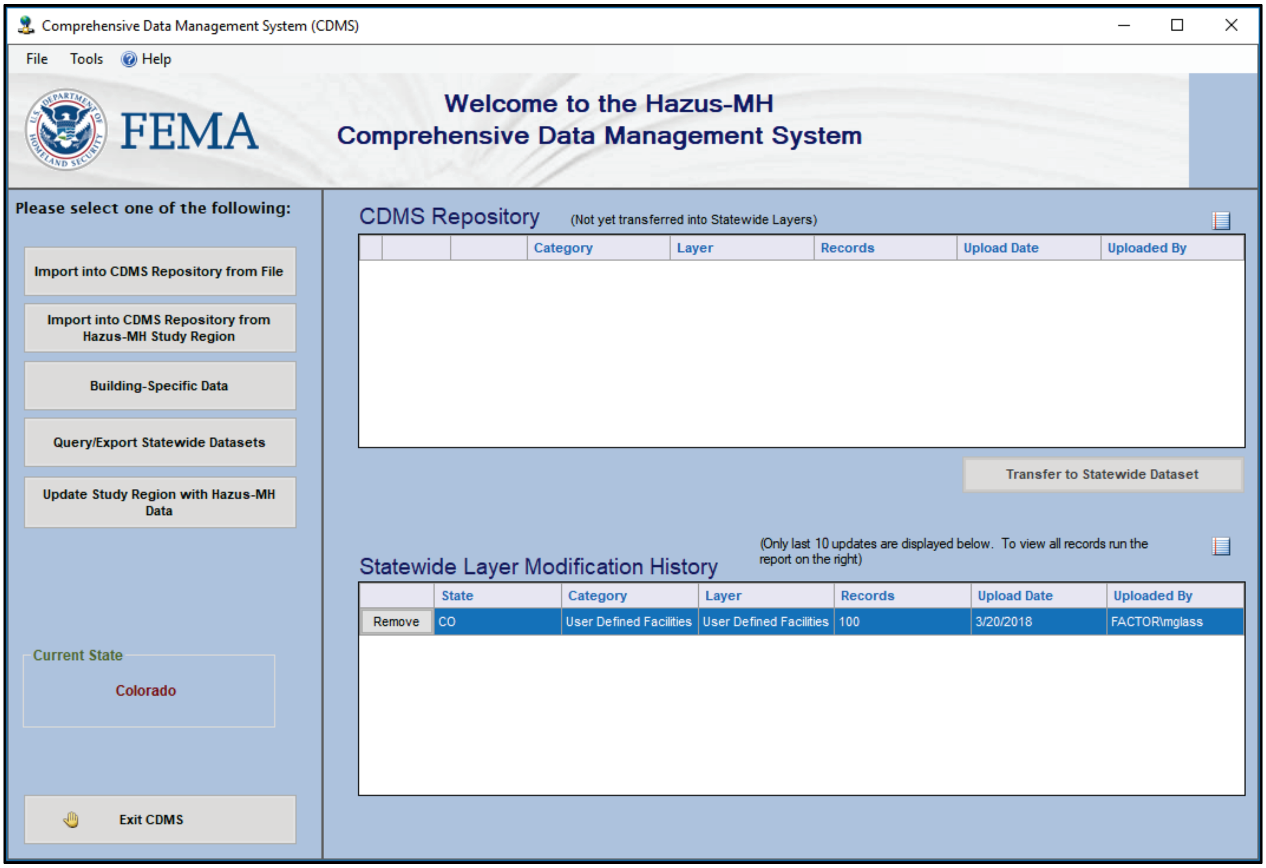


Figure 3-23: Example of UDF data transfer updating the modification history.

5. Clicking “Remove” in the “Statewide Layer Modification History” window will not remove the data from the State database but will only clear the user’s “Modification History.” Before the user can go to any new State database in CDMS in tools, the user must clear their “Modification History.”

6. To delete added data or any data in a State database, click “Query/Export Statewide Datasets,” find the data and delete or export it.

3.2. Build a Study Region

1. Build a Hazus flood study region for the tracts that intersect the user’s depth grid.

   1.1 Aggregate at the census tract level.

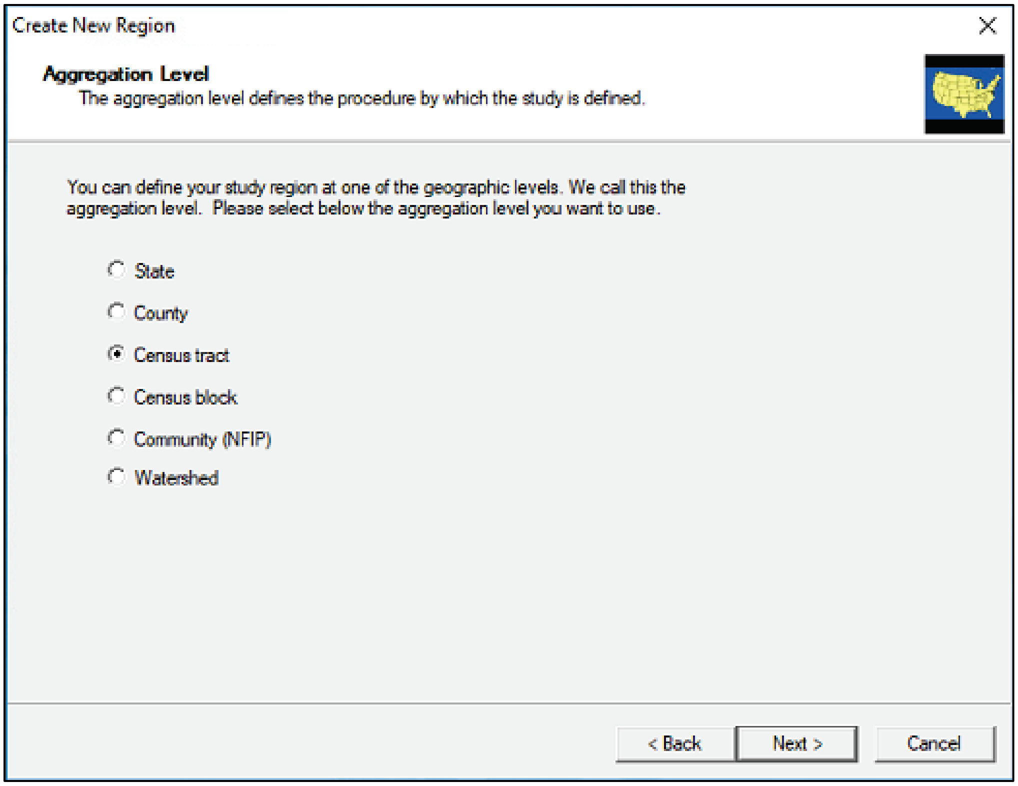


Figure 3-24: Create new region and aggregate at the census tract level.

1.2 When the census tract ID screen appears, choose "show map."

2. Bring in the "flood_extent" shapefile by clicking the "Add Data" (Top Left) button.

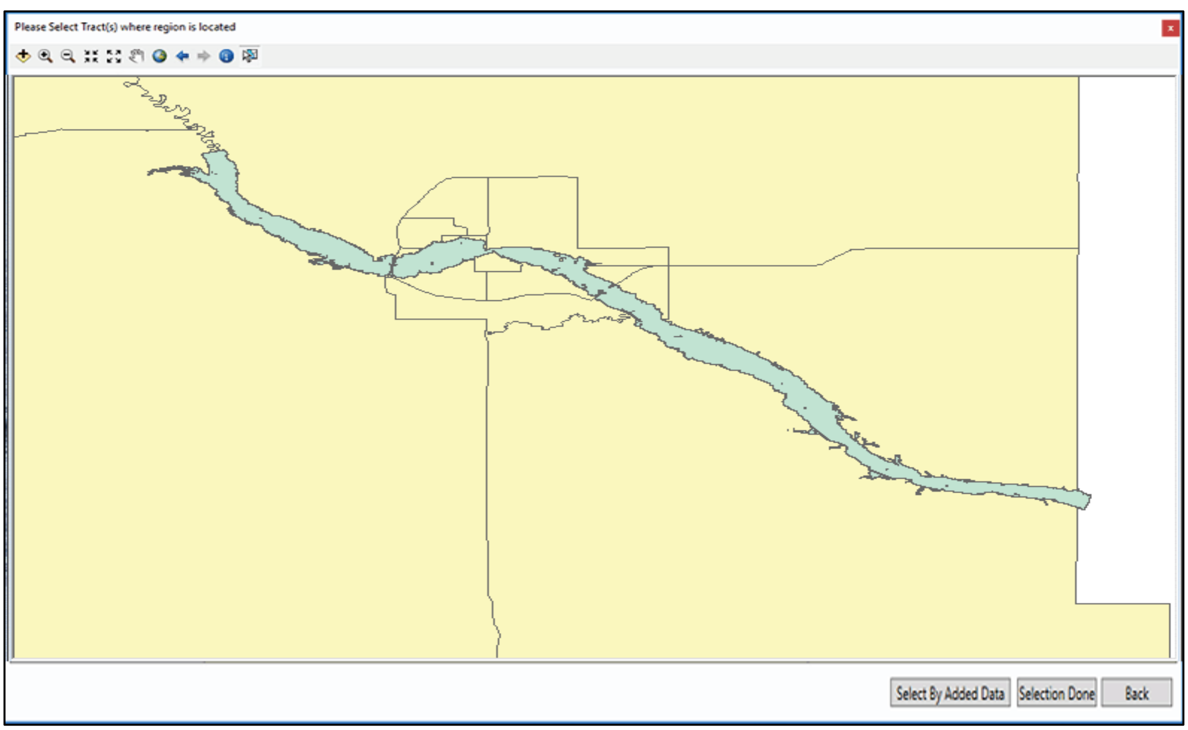


Figure 3-25: Add flood_extent shapefile to map.

3. Use the "Select by Added Data" located on the bottom right of the window to select all the tracts that intersect the flood extent.
4. Choose “next” on the remaining screens and aggregate the study region.

3.3. Create a New Study Region

The updated UDF data will be inside a Hazus study region. To use the updated State data, a new study region must be created as old study regions will not be updated.

1. Open Hazus and select “Create a new region” from the start up window. Click “OK.”

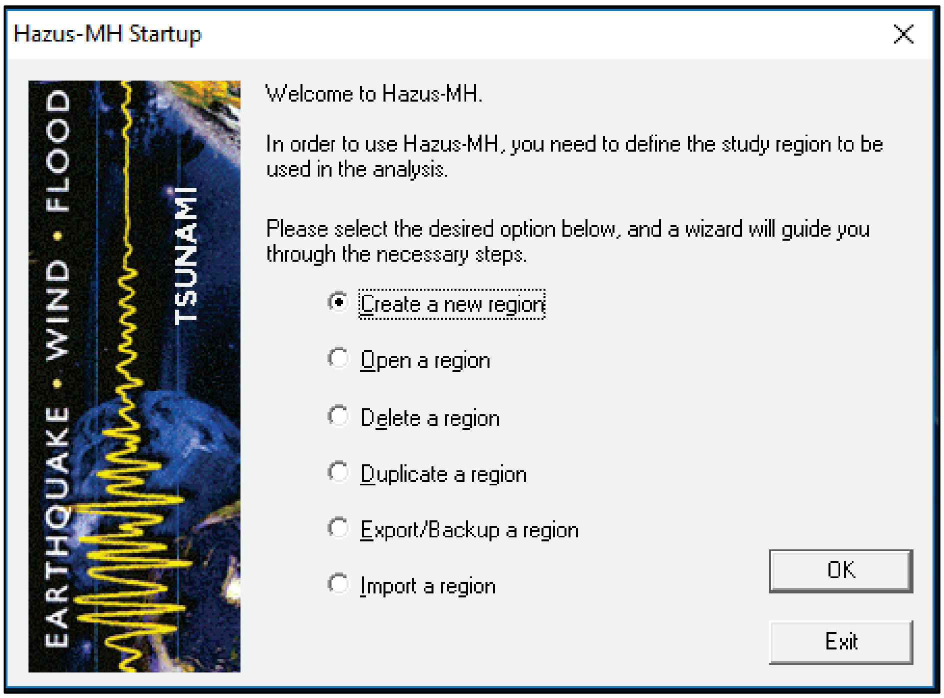


Figure 3-26: Creating a new region in Hazus.

2. Click “Next” on the “Create New Region” start page.
3. Insert a name and an optional description and click “Next.

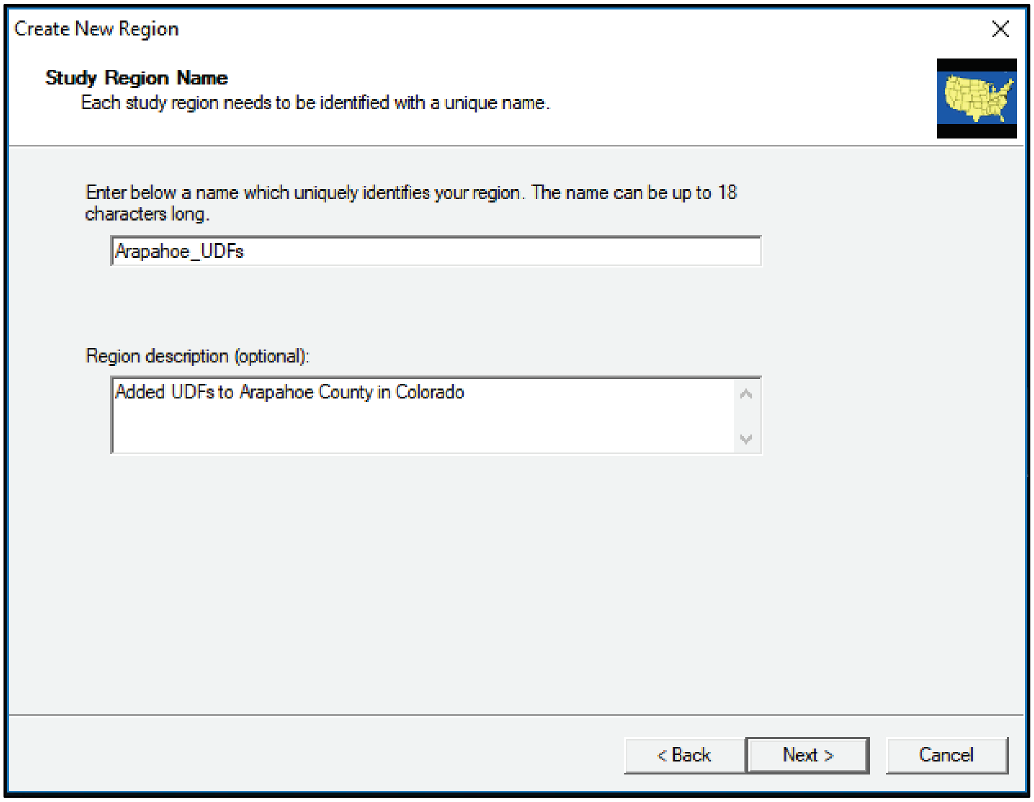


Figure 3-27: Insert name and description for new region study.

4. Check the appropriate hazard types for the new study region and click "Next." In this example, check the "Flood" box.

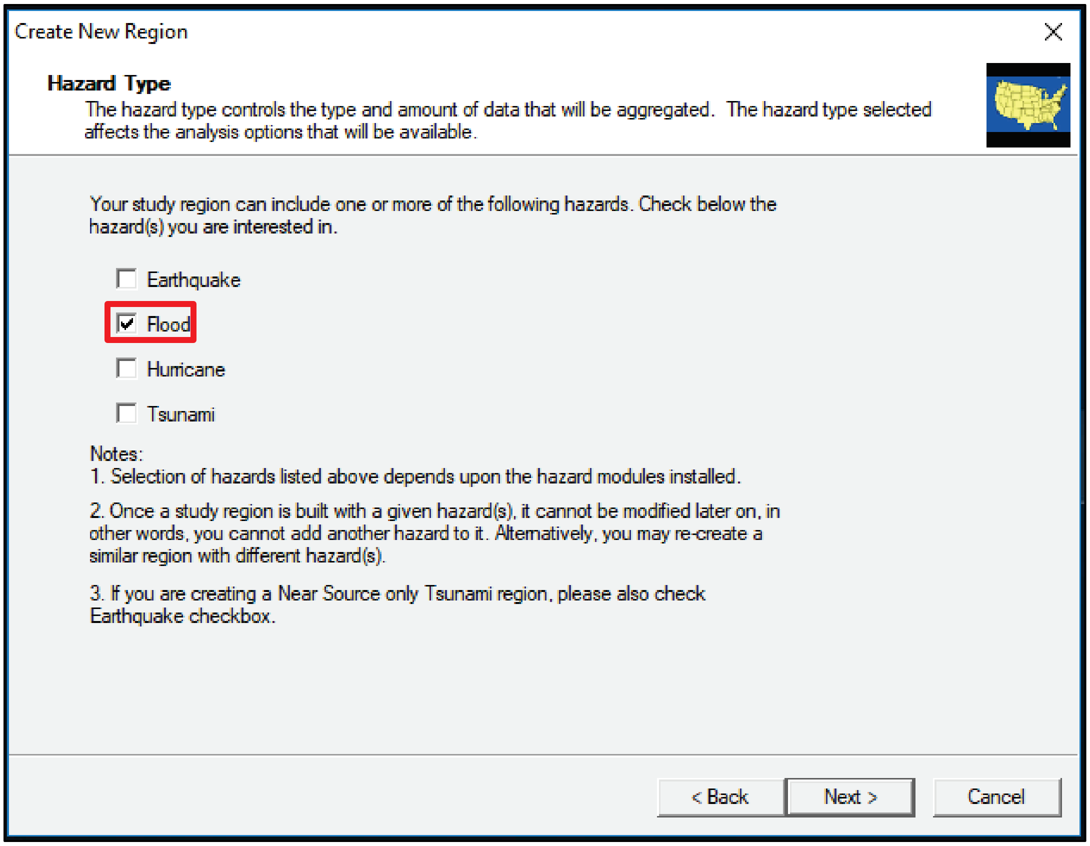


Figure 3-28: Selecting hazard for new study region.

5. Select the appropriate aggregation level for the new study region and click “Next.” In this example, select “County.”

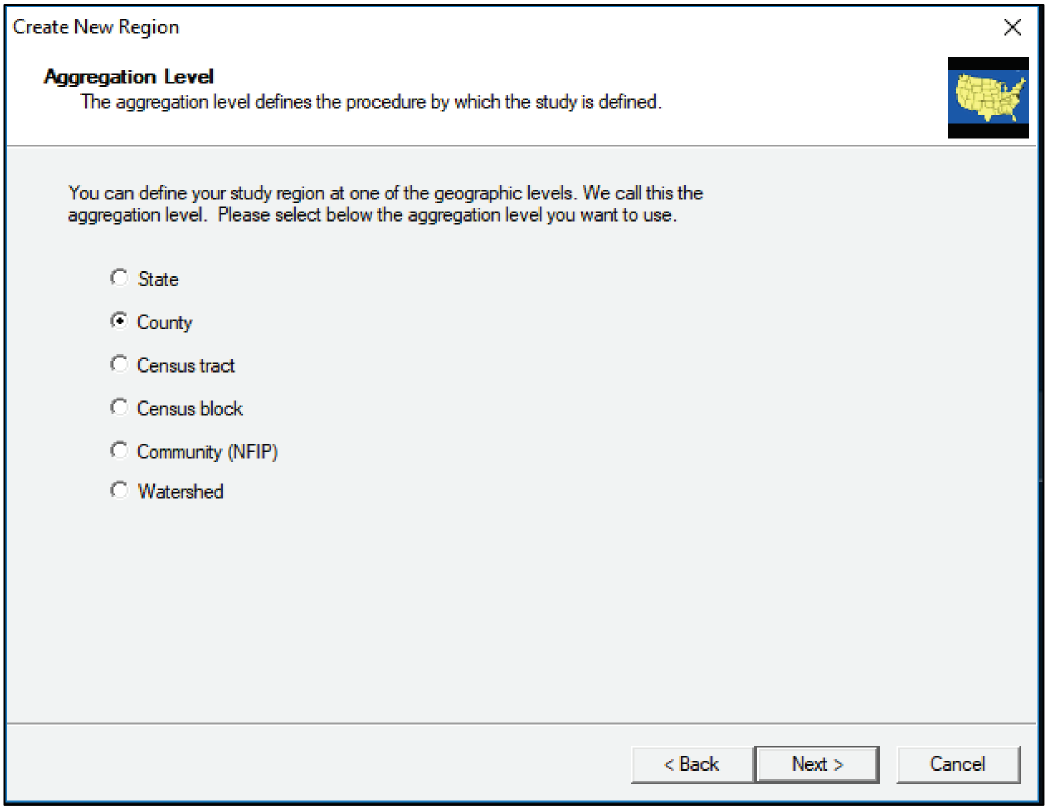


Figure 3-29: Selecting aggregation level for new study region.

6. Select the state or states for the new study region and click "Next." In this example, select "Colorado."

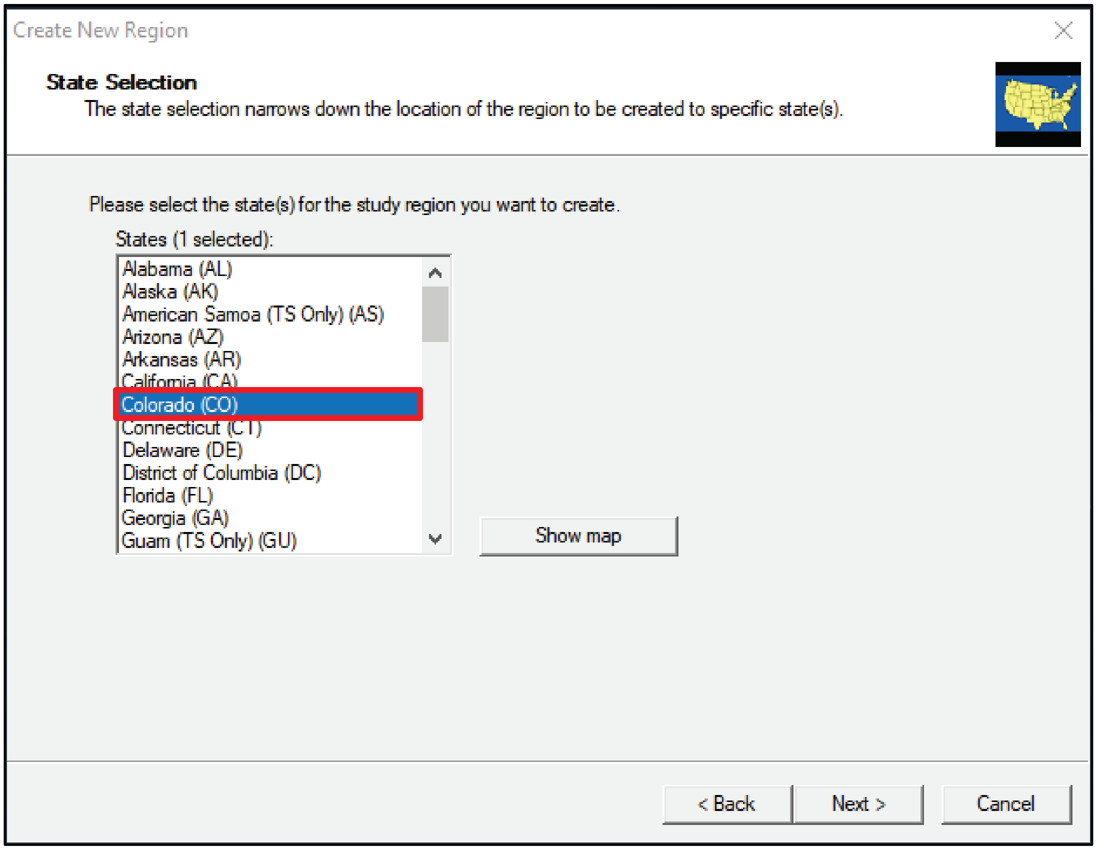


Figure 3-30: Selecting states for new study region.

7. Since county was selected in the aggregation level, select the appropriate county or counties and select "Next." In this example, select "Arapahoe."

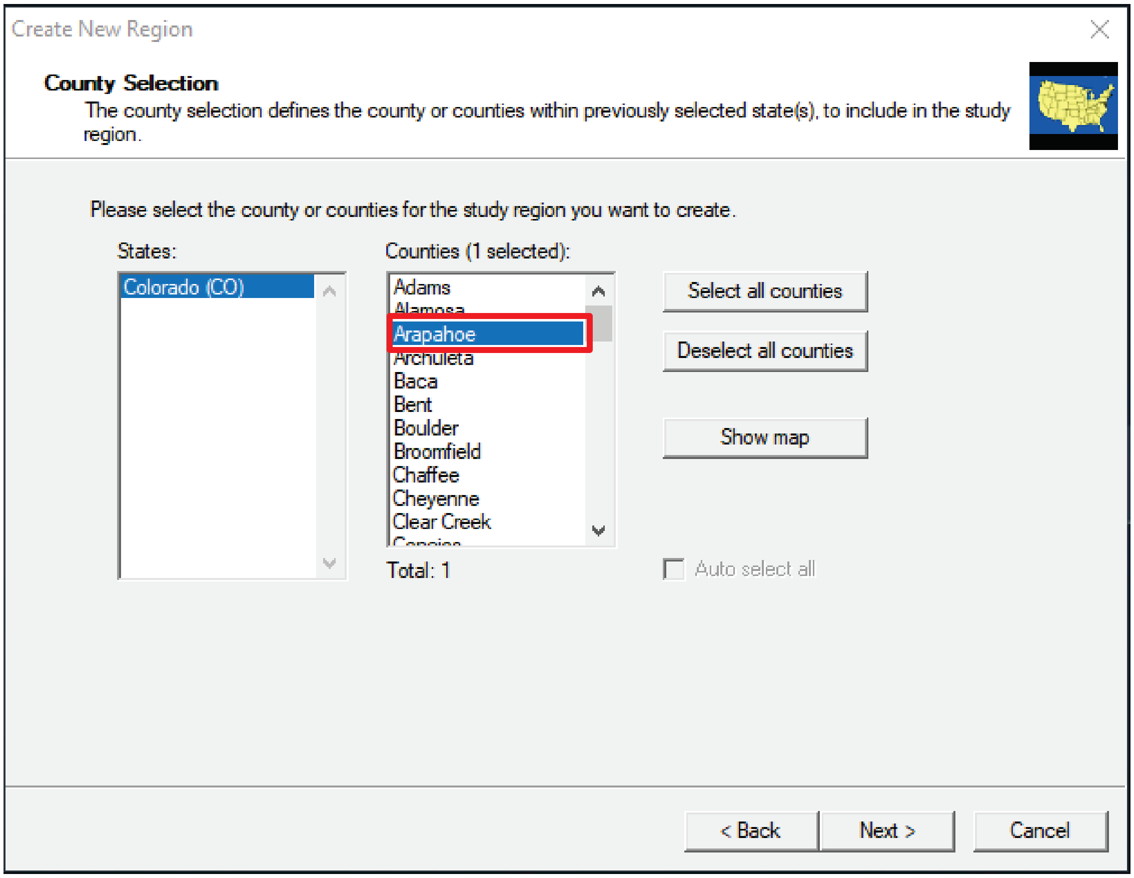


Figure 3-31: Selecting counties for the new study region.

8. Click "Finish."

3.4. Opening a Study Region

1. Select "Open a region" and click "OK."

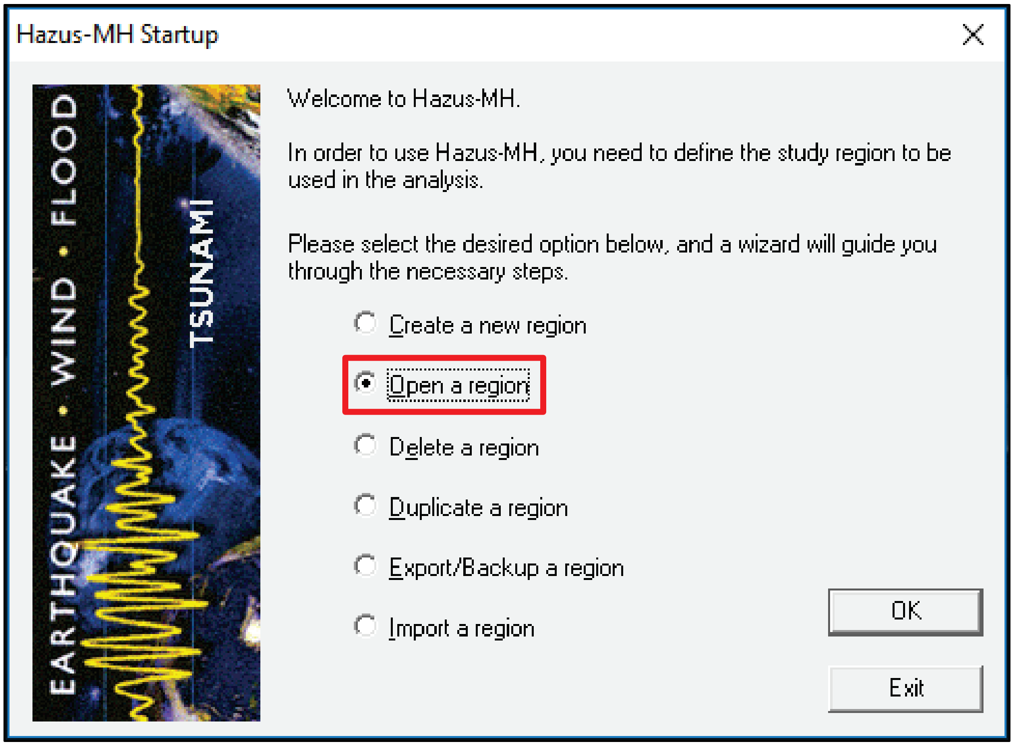


Figure 3-32: Opening a region in Hazus.

2. Select the UDF study region created in Section 1.6 and click "Next." In this example, the new study region is "Arapahoe_UDFs."

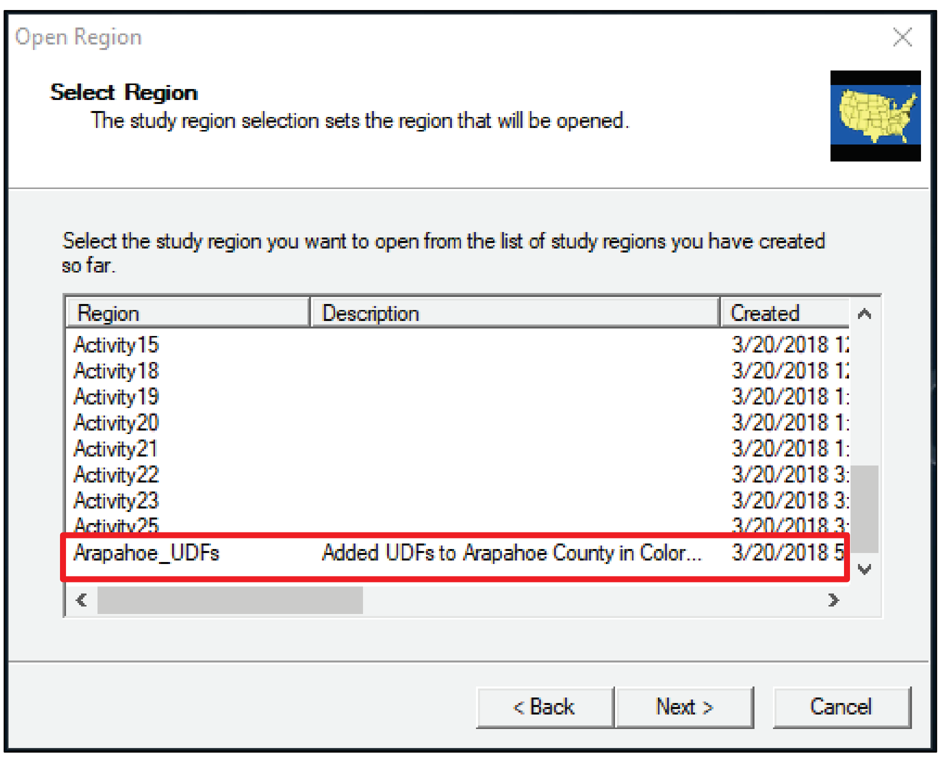


Figure 3-33: Selecting a new study region.

3. Click “Finish.” This will open an ArcMap document of the region.
4. Select “Inventory” in the top ribbon.
5. Click “User Defined Facilities” from the “Inventory” dropdown menu.

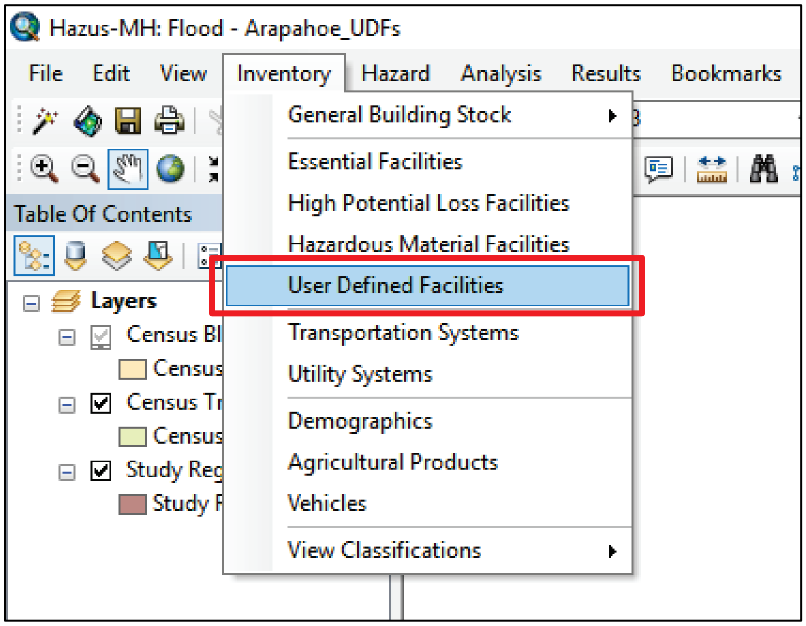


Figure 3-34: Inventory dropdown menu.

6. The UDFs added in CDMS will open and can now be used in Hazus analyses.
7. Click on the “Cost” column and click the “Map” button to display the UDF data in the study region.

3.5. Importing Depth Grid

The procedure outlined below will guide the user on how to import a user defined Depth Grid into the Hazus flood model.

1. Inside the study region, click “Hazard -> User Data.” The “User Data” menu will now be visible. Click the “Depth Grid” tab.

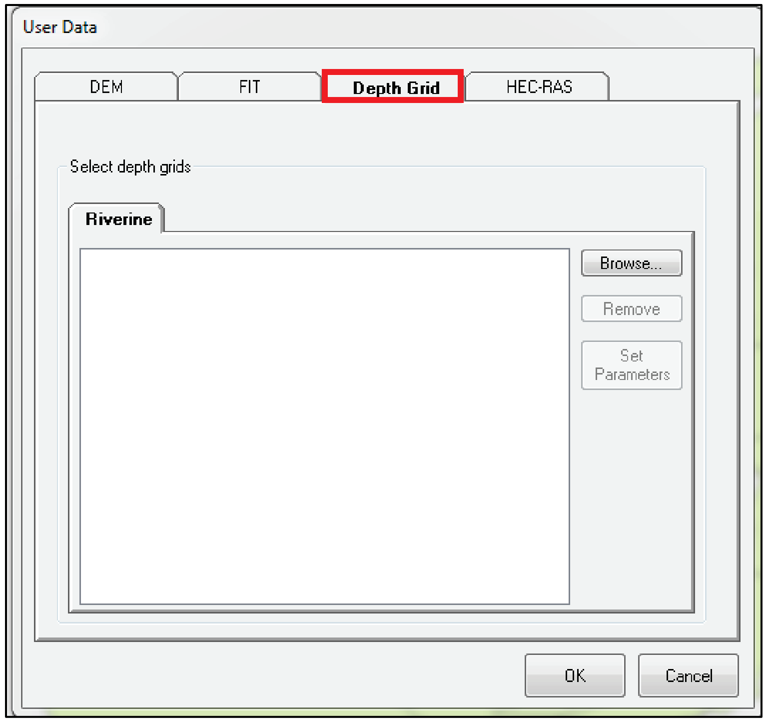


Figure 3-35: User Data dialog box.

2. Inside the "Depth Grid" tab, click "Browse" and navigate to the depth grid representing the desired flood hazard. It is important that the depth grid is in "Esri Grid" format. Once the depth grid is imported, it will be visible in the "Select depth grids" menu. Click "Set Parameters."

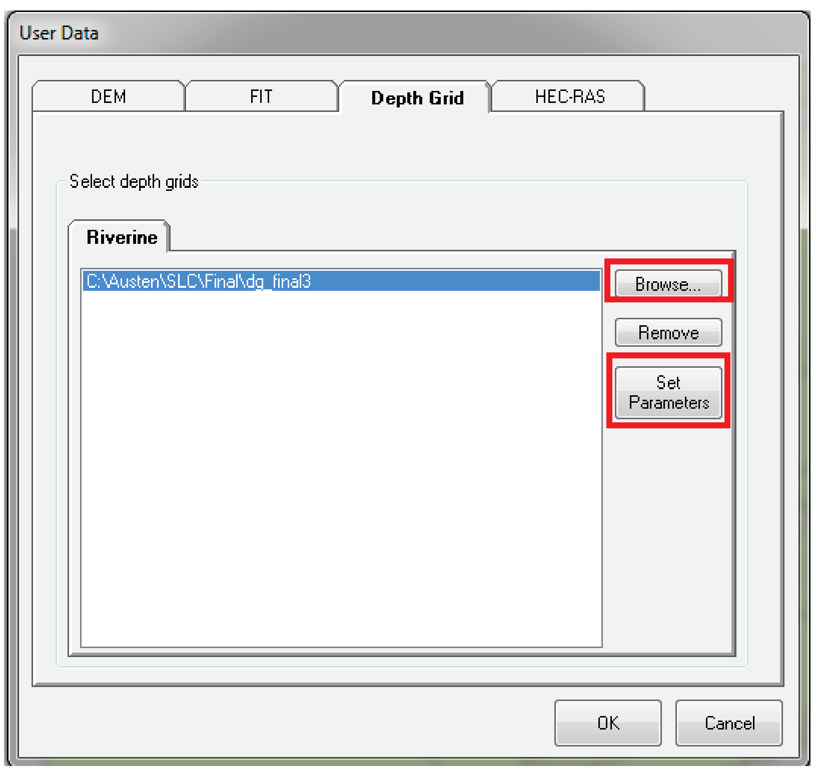


Figure 3-36: Browse to add depth grid.

3. Inside the “Set Parameters” menu, indicate the vertical units of the depth grid under the “Units” dropdown. The “Return Period” textbox is optional, however, adding a return period here will help identify results when multiple scenarios have been created in the Hazus study region. Click “OK” in the “Set Parameters” menu. Click “OK” in the “User Data” menu. Hazus will now start processing the user defined depth grid.

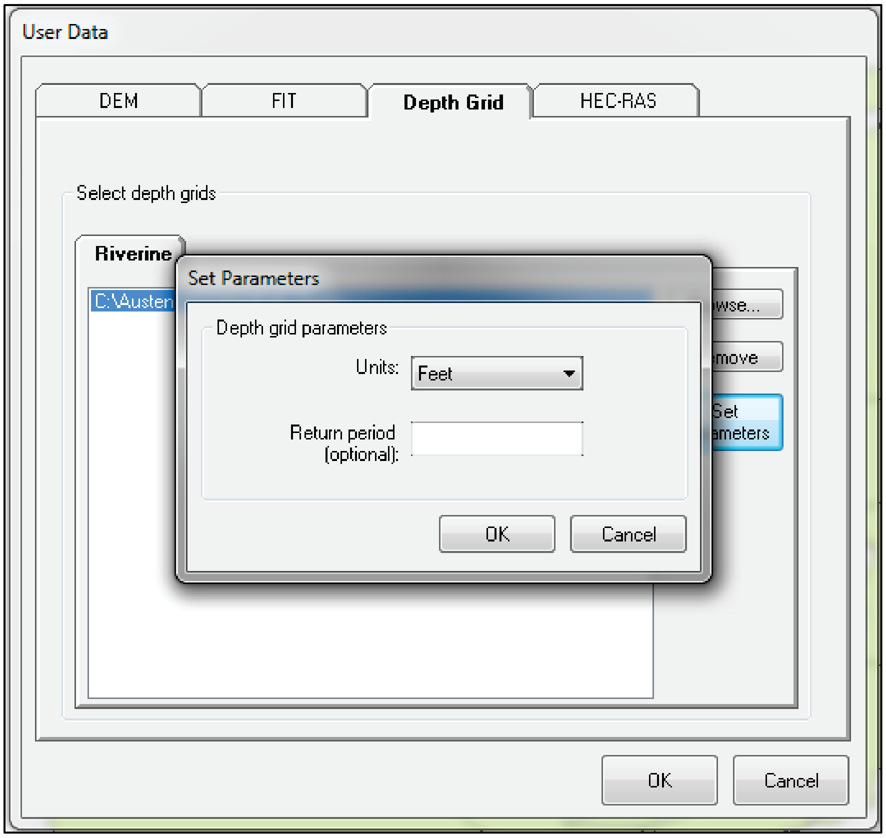


Figure 3-37: Set Parameters for the depth grid.

Now that User Defined Facilities and depth grid have been imported, proceed with defining a new scenario, Delineating Floodplain, and running the User Defined Structures analysis within the Hazus study region.

3.6. Dasymetric General Building Stock Processing

This section will take roughly five (5) minutes per 1,000 records for importing and ten (10) minutes per 1,000 records for analysis. The above estimates are based on the minimum required Hazus setup. Results are subject to changes depending on user CPU, memory allocation, etc.

1. Create a new study region.
   Note: The selected region will use the "Dasymetric" data by default as shown in Figure 3-38.

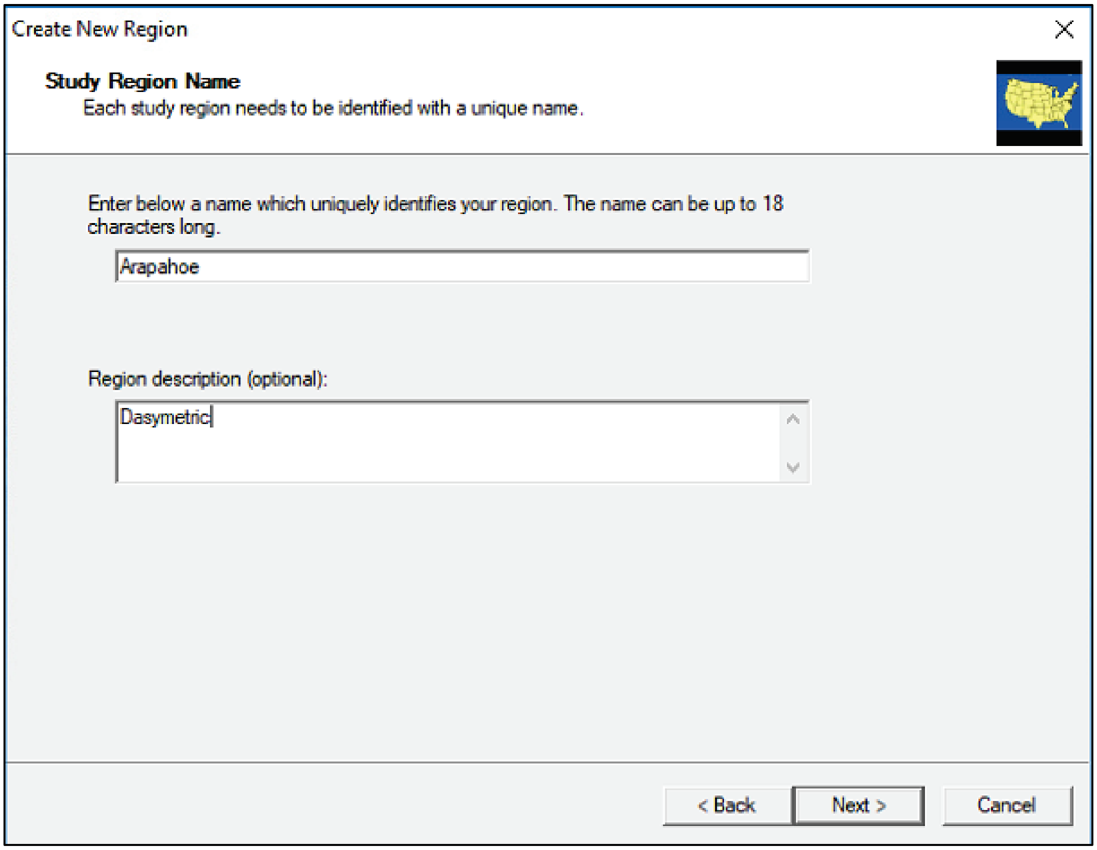


Figure 3-38: Create new study region.

2. Select "Flood" then select "Next."

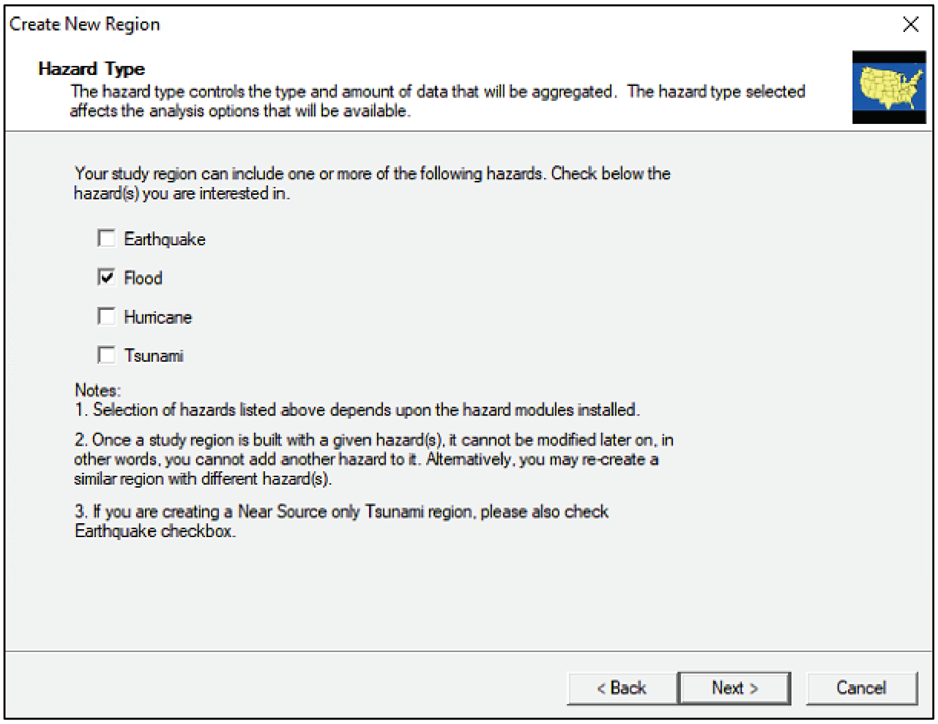


Figure 3-39: Select Flood as the hazard type.

3. Select preferred County.

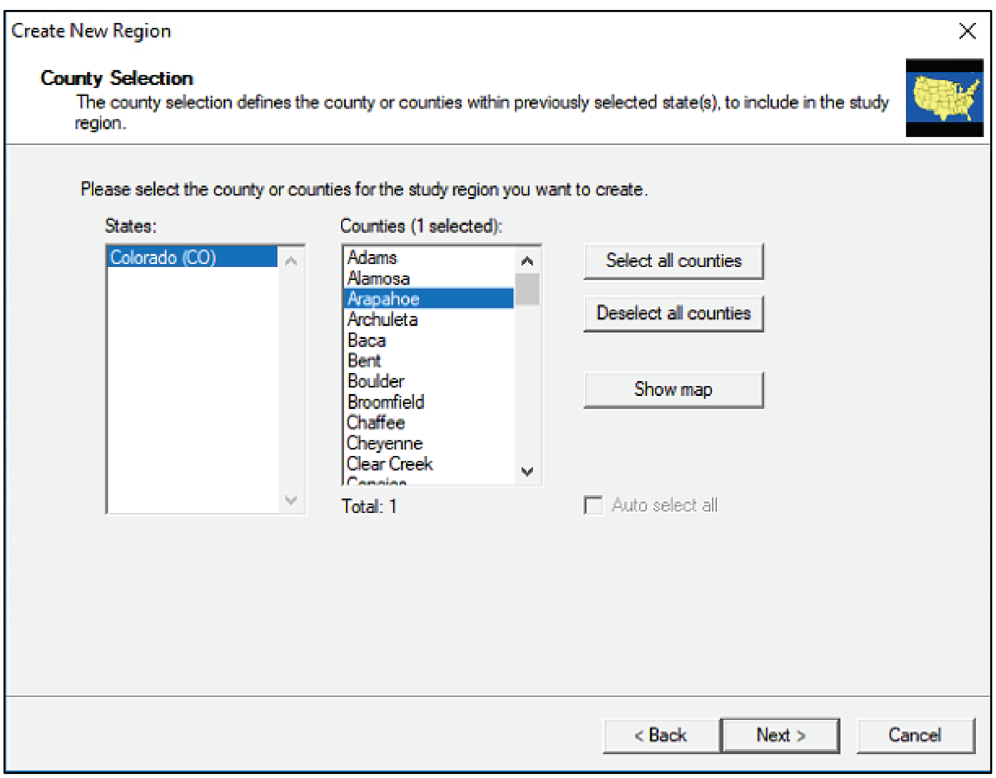
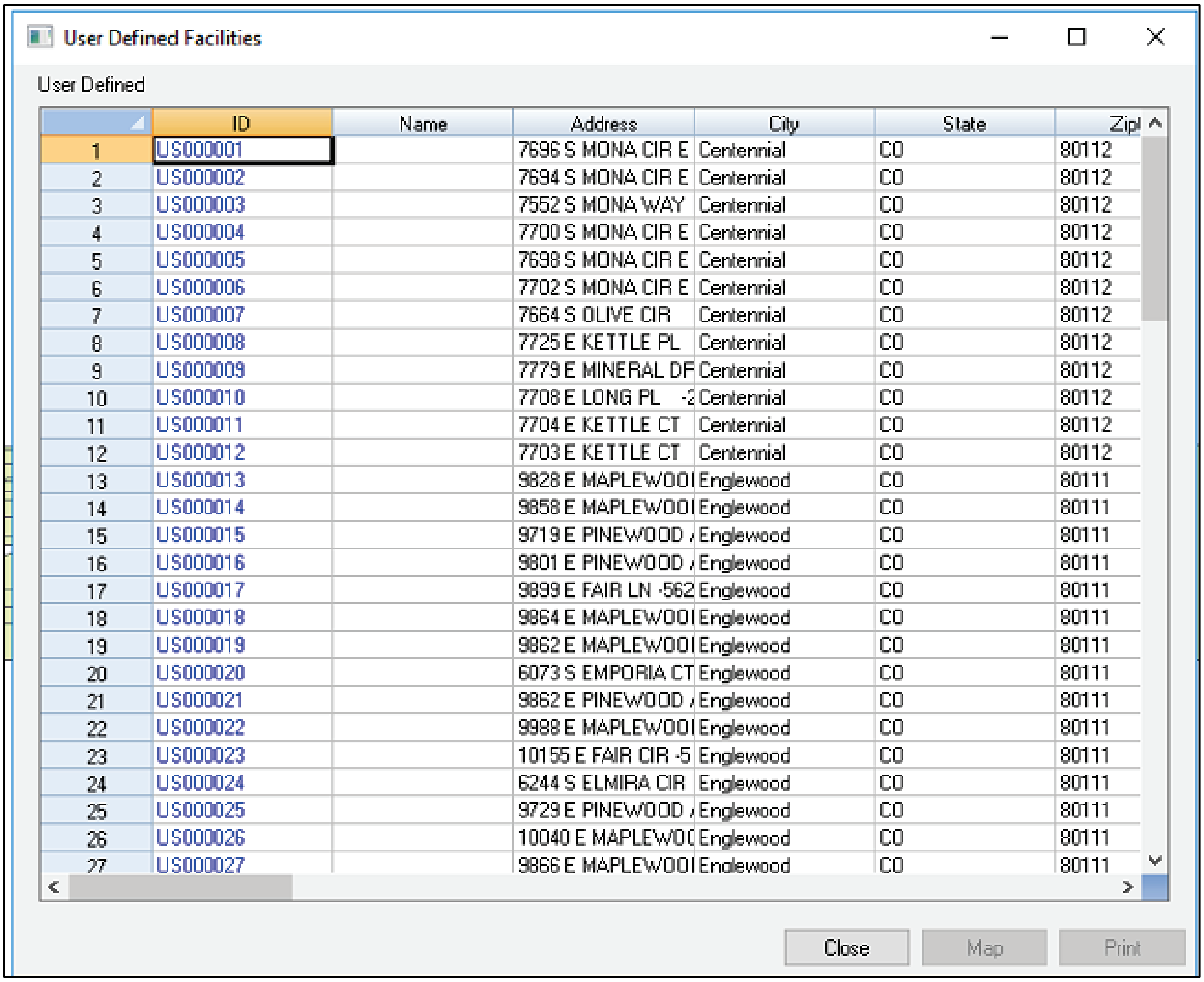


Figure 3-40: Select the county of interest.

4. Open “Study Region,” Go to “Inventory->User Defined Facilities” and Import the point data.



	ID	Name	Address	City	State	Zipl
1	US000001		7696 S MONA CIR E	Centennial	CO	80112
2	US000002		7694 S MONA CIR E	Centennial	CO	80112
3	US000003		7552 S MONA WAY	Centennial	CO	80112
4	US000004		7700 S MONA CIR E	Centennial	CO	80112
5	US000005		7698 S MONA CIR E	Centennial	CO	80112
6	US000006		7702 S MONA CIR E	Centennial	CO	80112
7	US000007		7664 S OLIVE CIR	Centennial	CO	80112
8	US000008		7725 E KETTLE PL	Centennial	CO	80112
9	US000009		7779 E MINERAL DF	Centennial	CO	80112
10	US000010		7708 E LONG PL -2	Centennial	CO	80112
11	US000011		7704 E KETTLE CT	Centennial	CO	80112
12	US000012		7703 E KETTLE CT	Centennial	CO	80112
13	US000013		9828 E MAPLEWOOI	Englewood	CO	80111
14	US000014		9858 E MAPLEWOOI	Englewood	CO	80111
15	US000015		9719 E PINEWOOD /	Englewood	CO	80111
16	US000016		9801 E PINEWOOD /	Englewood	CO	80111
17	US000017		9899 E FAIR LN -562	Englewood	CO	80111
18	US000018		9864 E MAPLEWOOI	Englewood	CO	80111
19	US000019		9862 E MAPLEWOOI	Englewood	CO	80111
20	US000020		6073 S EMPORIA CT	Englewood	CO	80111
21	US000021		9862 E PINEWOOD /	Englewood	CO	80111
22	US000022		9988 E MAPLEWOOI	Englewood	CO	80111
23	US000023		10155 E FAIR CIR -5	Englewood	CO	80111
24	US000024		6244 S ELMIRA CIR	Englewood	CO	80111
25	US000025		9729 E PINEWOOD /	Englewood	CO	80111
26	US000026		10040 E MAPLEWOC	Englewood	CO	80111
27	US000027		9866 E MAPLEWOOI	Englewood	CO	80111

Figure 3-41: Import user defined facilities.

5. Go to “Hazard->User Data” in the ribbon, then in the “Choose a Riverine depth grid…” window, select “quickdepth.”
6. Set the depth grid parameters in the “Set Parameters” window and click “OK,” then “OK” again to process.
7. Go to “Hazard->Scenario->New” in the ribbon. Under the “Create New Scenario” window, name the scenario.
8. Select “Depth Grid” on the map, click “Save selection,” and click “OK.”

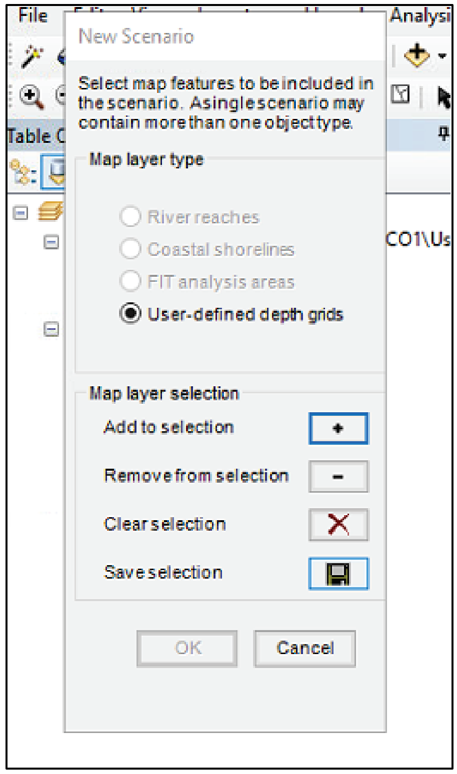


Figure 3-42: Select the depth grid.

9. Go to "Hazard->Riverine" and Click "Delineate Floodplain."

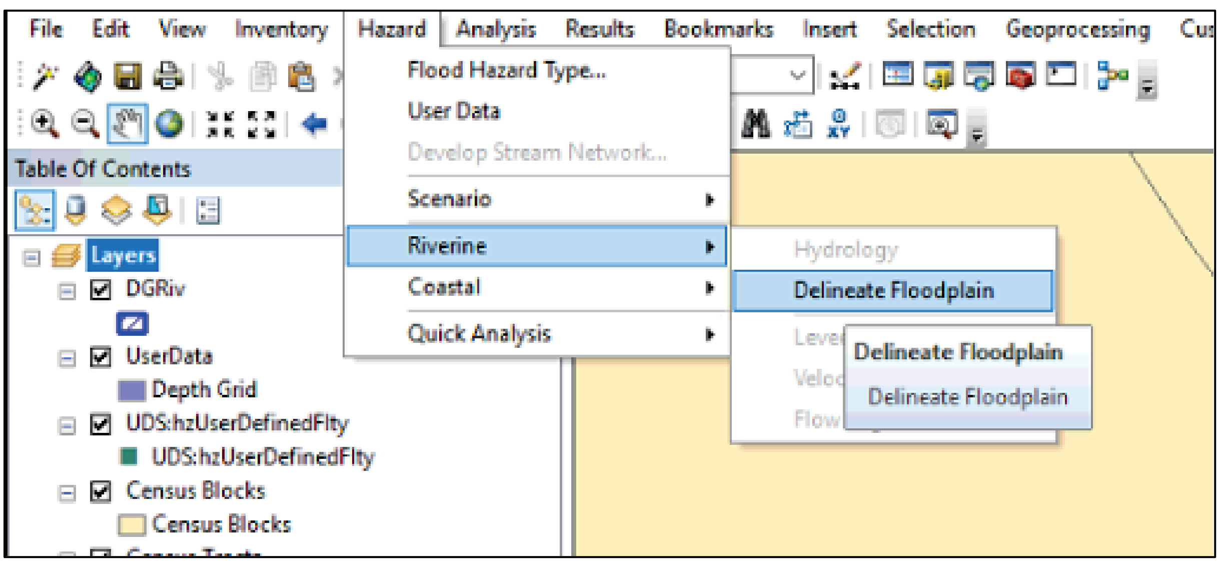


Figure 3-43: Delineate Floodplain.

10. Click "OK" to "Hydraulic Analysis."

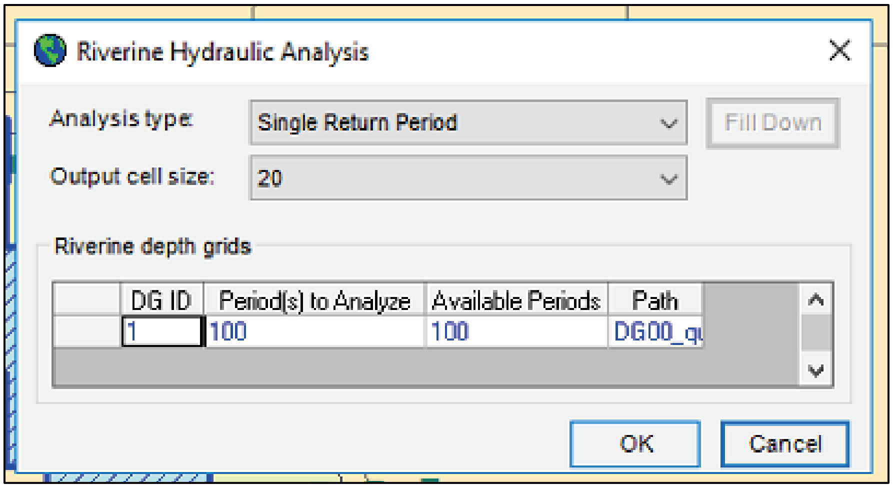


Figure 3-44: Run Hydraulic Analysis.

11. Click “Yes” to process.
12. Go to “Analysis,” click “Run.”

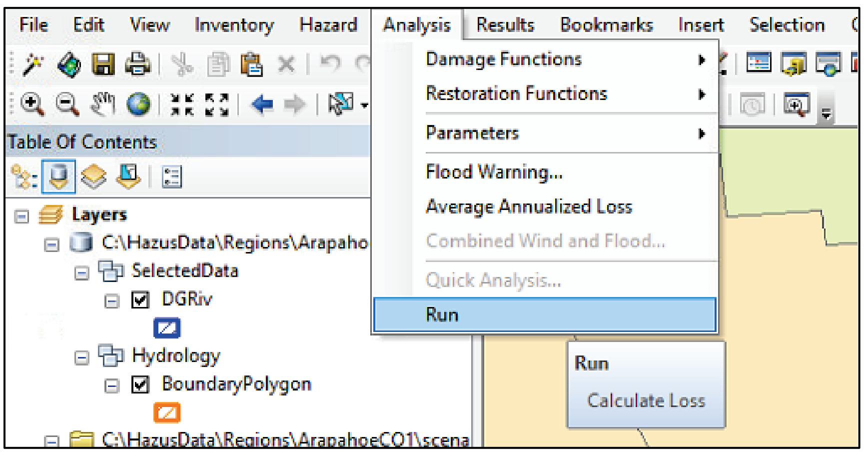


Figure 3-45: Run the analysis.

13. In the “Analysis Options” window, check “General Building Stock Damage and Loss,” “User Defined Structures” and Click “OK.”
14. Go to “Results->View Current Scenario Results.”

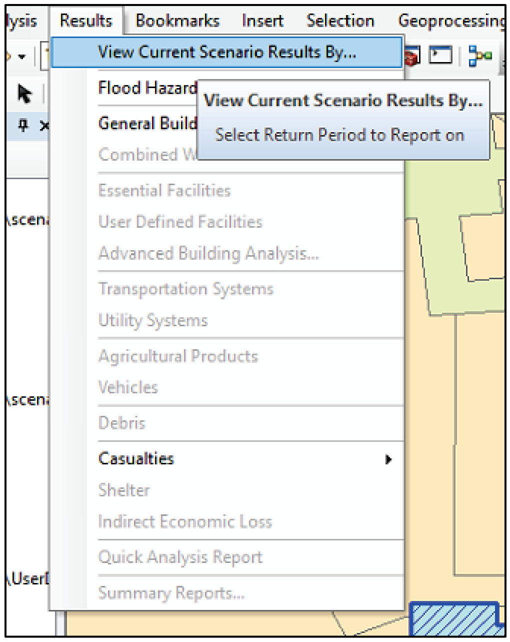


Figure 3-46: View Current Scenario Results.

15. In the “View Results by” window, select the “Available Results” and Click “OK.”
16. Go to “General Building Stock->Economic Loss,” Select “By Full Replacement.”

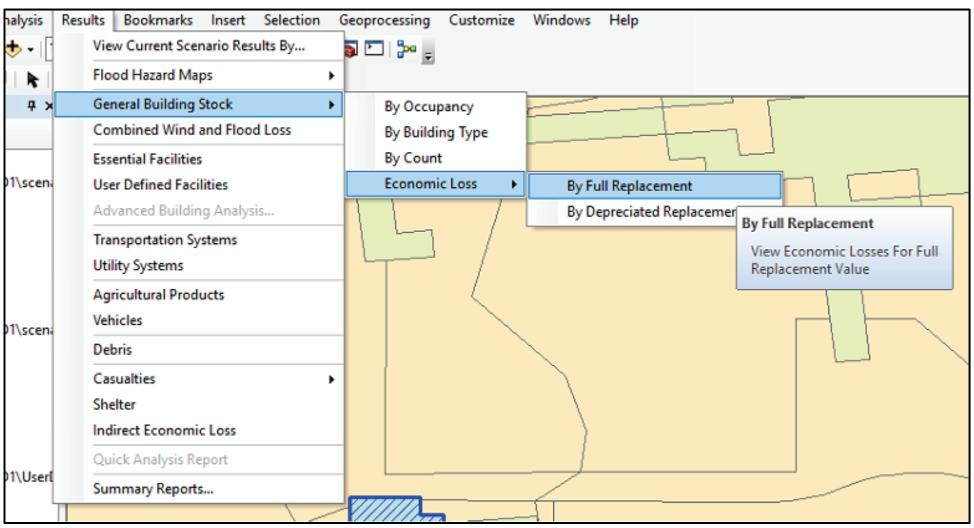


Figure 3-47: View General Building Stock results.

17. View “Results by Census block.”

18. Go to “General Building Stock,” select “User Defined Facilities.”

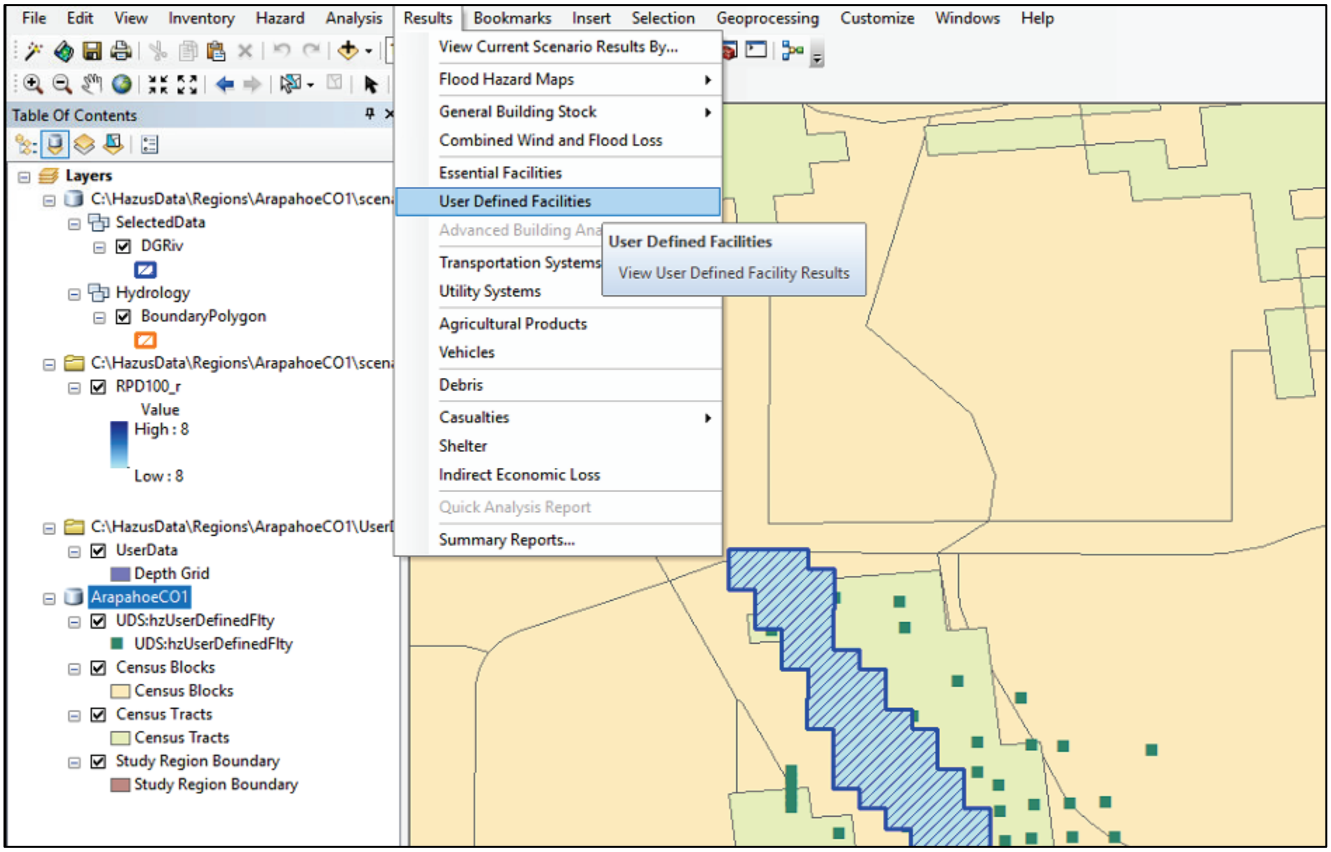


Figure 3-48: View User Defined Facilities results.

19. View “User Defined Facilities Loss” results for respective scenario.

4. User Defined Facilities Flood Loss Results

Once Hazus has completed the User Defined Facilities analysis, the results generated by the analysis will be placed in separate database tables within the unique Hazus database structure. Consequently, UDF results generated by Hazus will not contain attributes native to the original UDF dataset imported into Hazus. Changing the Hazus results back to the original imported UDF dataset is often necessary for visualization purposes but not always needed. The process of joining the Hazus UDF results to the original UDF data set is summarized below.

4.1. Viewing and Mapping Results

1. Inside the Hazus study region, Click “Results” --> View “Current Scenario Results By…” Under “Available Results” select either the default (only one scenario within the study region has been defined) or another set of results. The names given to the “Available Results” reflects the optional input return period text box described in the previous section.

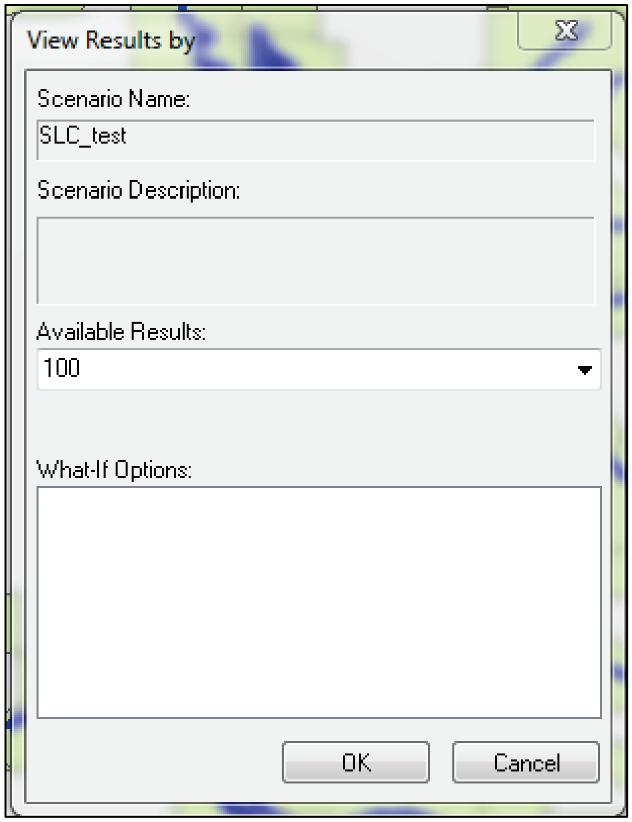
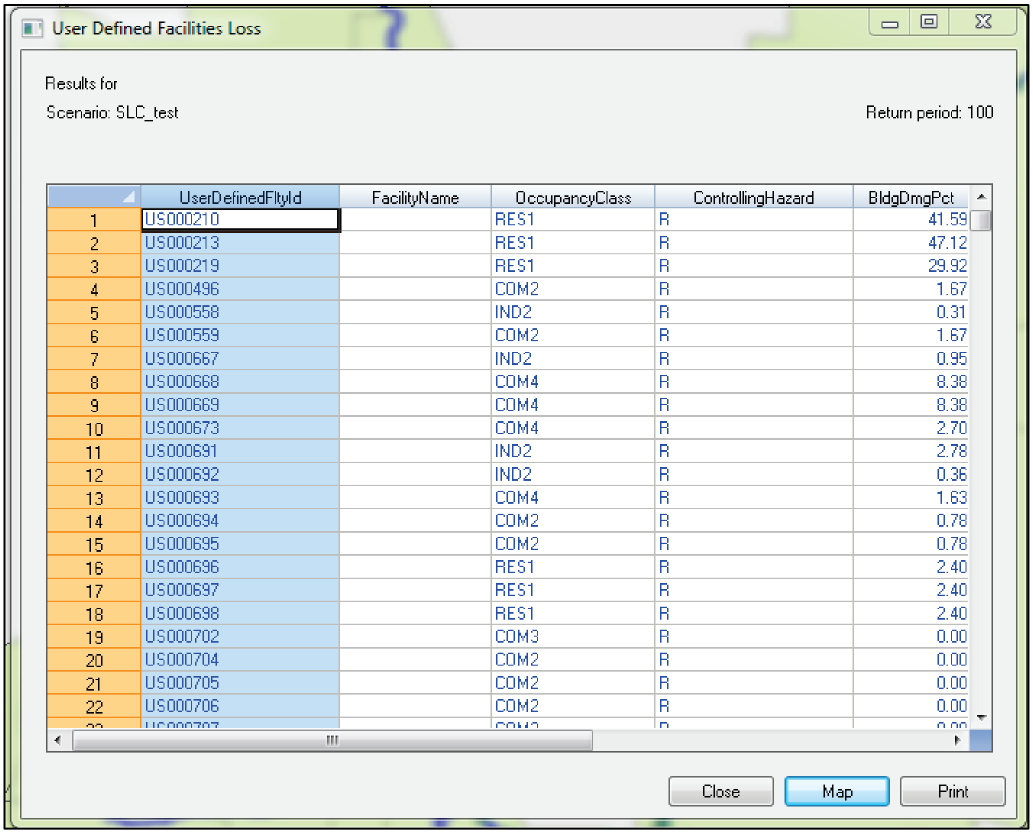


Figure 4-1: View results by window

2. Inside the Hazus study region, Click “Results” --> “User Defined Facilities.” Click the “UserDefinedFltyID” field to highlight the column and then click “Map.” Hazus will now map the User Defined Facilities results.



	UserDefinedFltyId	FacilityName	OccupancyClass	ControllingHazard	BldgDmgPct
1	US000210		RES1	R	41.59
2	US000213		RES1	R	47.12
3	US000219		RES1	R	29.92
4	US000496		COM2	R	1.67
5	US000558		IND2	R	0.31
6	US000559		COM2	R	1.67
7	US000667		IND2	R	0.95
8	US000668		COM4	R	8.38
9	US000669		COM4	R	8.38
10	US000673		COM4	R	2.70
11	US000691		IND2	R	2.78
12	US000692		IND2	R	0.36
13	US000693		COM4	R	1.63
14	US000694		COM2	R	0.78
15	US000695		COM2	R	0.78
16	US000696		RES1	R	2.40
17	US000697		RES1	R	2.40
18	US000698		RES1	R	2.40
19	US000702		COM3	R	0.00
20	US000704		COM2	R	0.00
21	US000705		COM2	R	0.00
22	US000706		COM2	R	0.00

Figure 4-2: User defined facilities loss window

3. Open the attribute table of the UDF results layer by right-clicking the “UserDefinedFlty” layer in the Hazus/ArcMap table of contents and clicking “Open Attribute Table.” Scroll to the right, to the end of the table, to find individual building flood loss values.

Note: Listed below are the five main Hazus result output attributes in the “UserDefinedFlty” table.

- **BldgDmgPct -** Percent building damage to individual structure.
- **BldgLossUSD** – Building loss in US Dollars.
- **ContDmgPct** – Percent content damage to individual structure.
- **ContentLossUSD** – Building Content loss in US Dollars.
- **InventoryLossUSD** – Total loss (Building + Content losses).

Table 4-1: Five main Hazus Result Output Attributes

BldgDmgPct	BldgLossUSD	ContDmgPct	ContentLossUSD	InventoryLossUSD
41.59082	78068.048681	60	56311.5	0
47.122069	41137.566237	41.944335	18308.702228	0
29.915525	36437.408605	23.09863	14067.181163	0
1.66992	4326.635186	7.341792	18621.941483	22852.625557
0.310547	29125.047895	0	0	0
1.66992	4326.635186	7.341792	18621.941483	22852.625557
0.953125	14768.185781	0	0	0
8.376464	50491.565935	13.335936	80386.221661	0
8.376464	50491.565935	13.335936	80386.221661	0
2.703125	16122.329531	3.25	19384.0725	0
2.781248	27322.034728	2.003904	29528.507353	3062.155773
0.356445	2662.975644	0	0	0
1.63086	2675.637842	1.63086	2675.63842	0
0.78369	622.837628	5.037594	4003.627832	5047.512883
0.78369	622.837628	5.037594	4003.627832	5047.512883
2.400882	27921.225281	1.746096	10153.172829	0
2.400882	27921.225281	1.746096	10153.172829	0
2.400882	27921.225281	1.746096	10153.172829	0
0	0	0.4	1325.672	0
0	0	0.3	1661.206	2213.608
0	0	0.3	1661.206	2213.608
0	0	0.3	1661.206	2213.608
0	0	0.3	1661.206	2213.608
0	0	0.3	1661.206	2213.608
0	0	0.3	1661.206	2213.608
0	0	0.3	1661.206	2213.608
0	0	0.3	1661.206	2213.608
0.753418	3300.7996	0	0	0

Notice that many attributes native to the original User Defined Facilities building inventory dataset do not exist in the resulting output table. Depending on the users desired end result, often times attributes contained in the original dataset are needed for visualization purposes. The following section will demonstrate the process involved with joining the Hazus UDF results back to the original input UDF dataset.

4.2. Joining Hazus UDF Results to Source Data

1. Using the “ArcCatalog” tab inside Hazus/ArcMap, Double click “Add Database Connection” located under the “Database Connections” folder. In the “Database Connection” dialog, select “SQL Server” for database platform, “Localhost\HAZUSPLUSSRVR” for instance, and “Database Authentication” for authentication type. To get the user name and password, open the “settings.xml” file in the “<<LocalInstall>>\Program Files (x86)\Hazus-MH” directory with a text editor and search for UserID and Password tags. Select the Hazus study region from the drop-down menu and click “OK.”

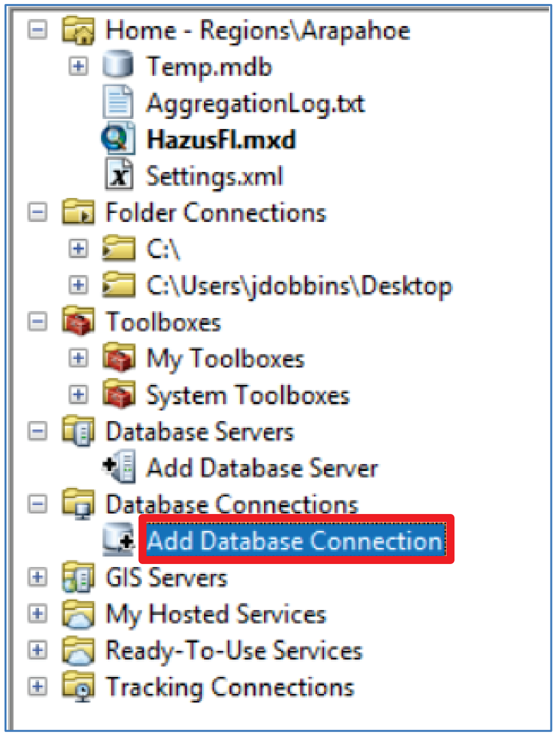


Figure 4-3: Catalog and database link properties

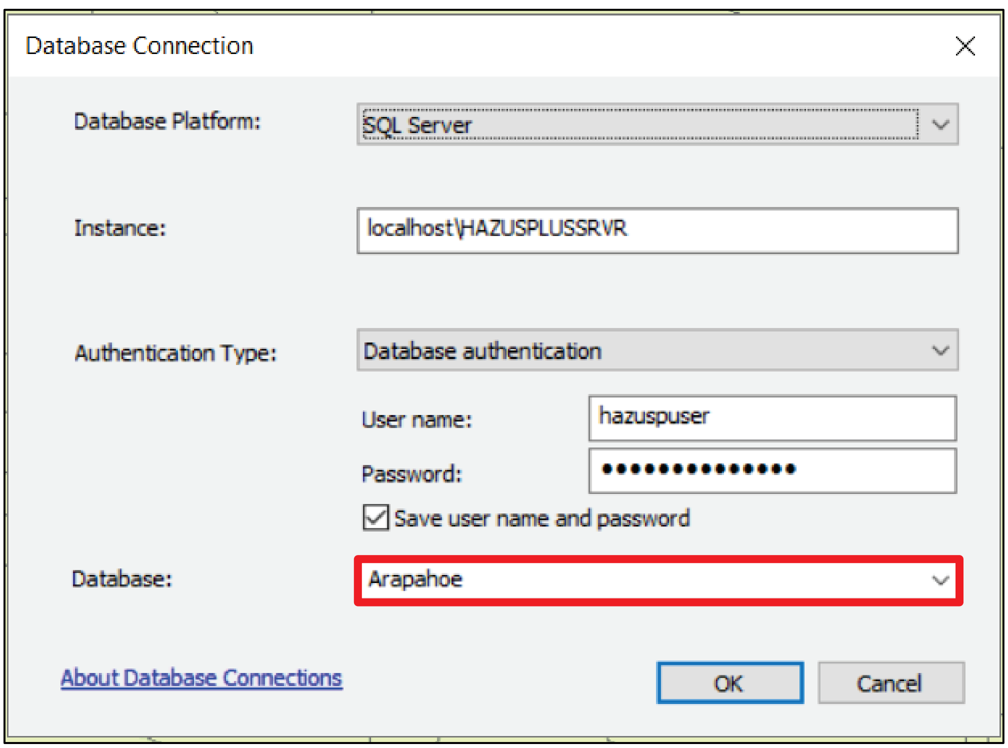


Figure 4-4: Database connection properties

2. Under the “ArcCatalog” tab in Hazus/ArcMap, expand the newly created database connection in order to display the Hazus data tables. Find “dbo.absv_FRUserDefinedFlty” and “dbo.hzUserDefinedFlty” from the list of tables and add the tables to Hazus/ArcMap.

3. Notice that both tables added to the Hazus/ArcMap instance have a field titled "UserDefinedFltyId." Perform a tabular join in ArcMap to join the tables using the "UserDefinedFltyId" field. Also notice, contained in the "dbo.hzUserDefinedFlty" table is the "Comment" field, created in the development of the original UDF feature class.

4. Once the combination in the previous step has been performed, export the newly joined table.

5. After the export in the previous step has been completed, join the exported table to the original UDF feature class using the "UserDefinedFltyId" Field. The Hazus UDF analysis results are now contained in the original UDF feature class.

4.3. Installing and Using the Hazus Export Tool

This section will guide the user in the installation and use of the Hazus Export tool to export Hazus results. The steps outlined assume the user has completed a scenario and has the scenario open in a Hazus session and is ready to install the tool and export the results.

The Hazus Export tool is composed of a Python script and an ArcToolbox (.tbx) file that, once installed, will be located in the Hazus program files directory (\Hazus-MH\BIN\Tools) on the computer's hard drive (in this example, the toolbox file and Python script are located in C:\Program Files (x86)\Hazus-MH\BIN\Tools).

1. Install the Hazus Export Tool. In the Hazus interface, open ArcCatalog by clicking the ArcToolbox icon or selecting "Geoprocessing" from the toolbar options and then "ArcToolbox" from the drop-down menu.

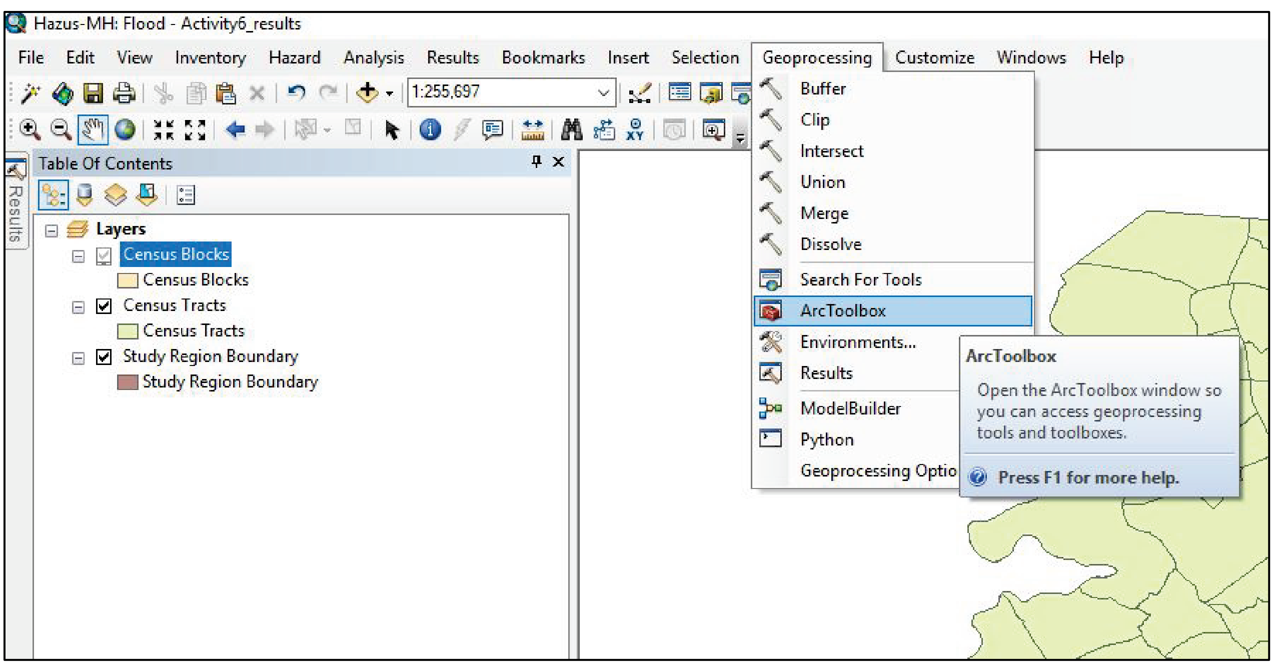


Figure 4-5: Open the ArcToolbox from within ArcMap.

2. In the ArcCatalog window, right click on "ArcToolbox" and select "Add Toolbox."

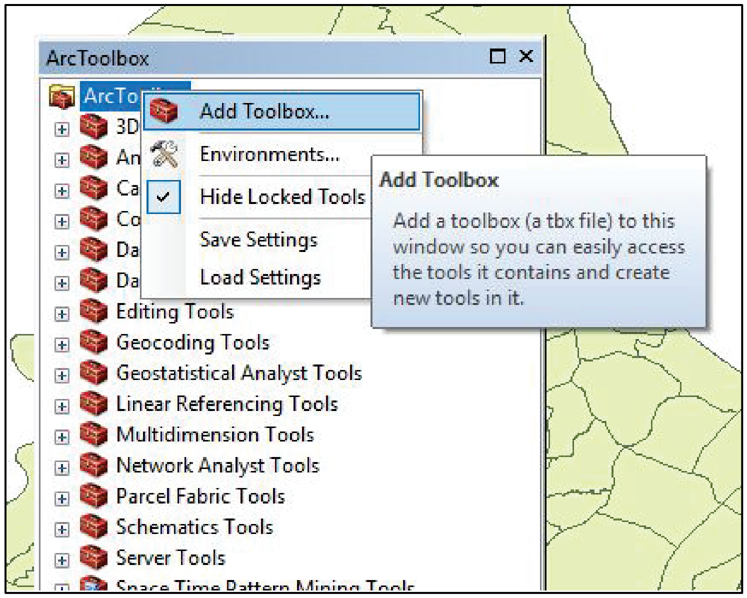


Figure 4-6: In the ArcCatalog window, right click on "ArcToolbox" and select "Add Toolbox."

3. Navigate to the Hazus-MH folder where the tool is located (in this example, C:\Program Files (x86)\Hazus-MH\BIN\Tools), select "Hazus_Export.tbx," and click "Open." The tool is now installed and ready to use.

4. To use the Hazus Export tool, a folder named "ExportResults" will be needed in the the HazusData directory (in this example, the HazusData directory is located on the C:\ drive, under C:\HazusData). Create this folder using Windows File Explorer if it does not already exist.

5. In ArcCatalog, expand the "Hazus_Export" toolbox and double-click the "Hazus_Export" script to start the tool.

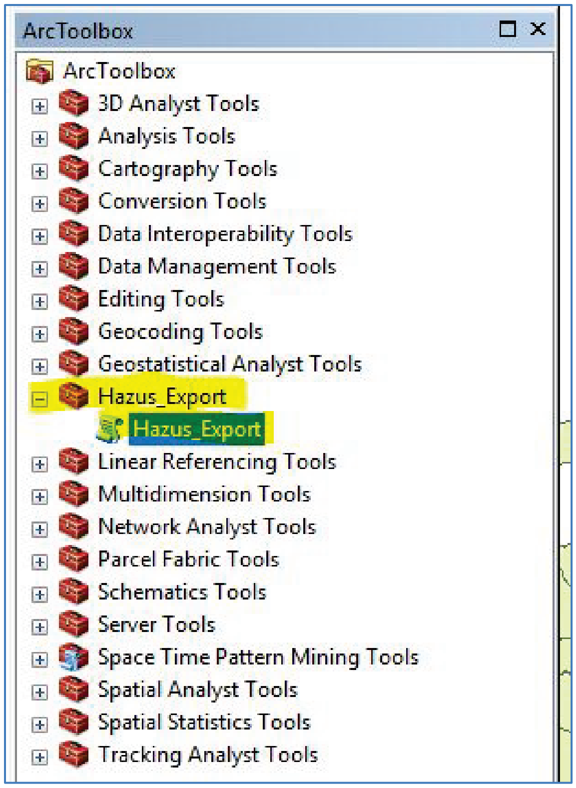


Figure 4-7: Start the Hazus Export tool.

6. In the Hazus_Export dialog, click the folder button next to the "Export Folder" textbox to open the file browsing window. Select the "ExportResults" file created in step 1 above (in this example, C:\HazusData\ExportResults folder). In the Hazus Study Region Name textbox, type the Hazus activity name exactly as it appears in the title bar of the Hazus application. In this example, our activity name is "Activity6_results." Click "OK" to continue.

7. This will create a geodatabase file with the activity name inside the "ExportResults" folder (in this example, C:\HazusData\ExportResults\Activity6_results).

8. Browse the layers of the created geodatabase (in this example, Activity6_results.gdb) in ArcMap. The feature layers are stored in seven feature datasets:
    - AEBM_UDF (Advanced Engineering Building Module – User-Defined Facilities)
    - Essential_Facilities
    - General_Building_Stock
    - High_Potential_Loss_Facilities
    - Study_Region_Base_Data
    - Transportation
    - Utilties

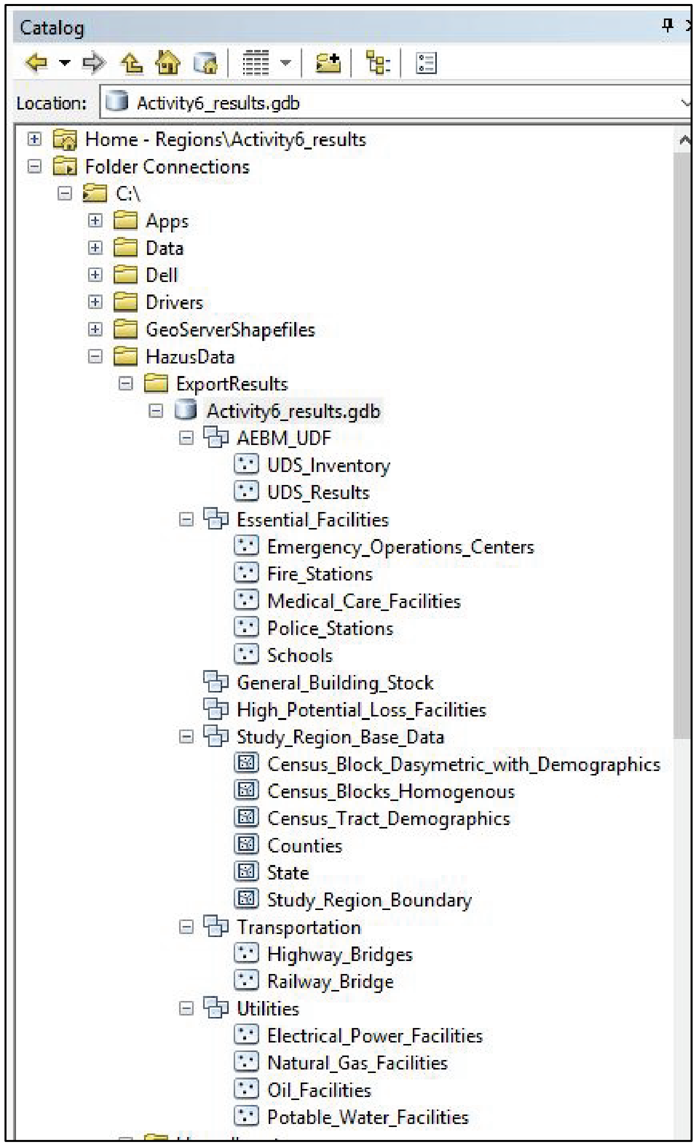


Figure 4-8: Browse the exported results in the geodatabase using ArcCatalog.

4.4. Export Results to a Geodatabase

1. Please refer to the section "Installing and Using the Hazus Export Tool" to export the analysis results to a geodatabase. The remainder of this section assumes all results are residing in a subfolder in C:\HazusData\ExportResults.

2. Open the Hazus application and the region for the desired results to view. Browse to the geodatabase in ArcCatalog where the results are exported. In this example, this is C:\HazusData\ExportResults.

4.5. Export Geodatabase Layer to Shapefile

1. Add the "GBSFullRepDirectEconLoss" layer to the map window.

Note: This layer includes all Census Blocks left-joined to the analysis results. The Census blocks with modeled damage is all that is needed. Select "Selection >> Select by Attributes" to do this. Scroll through the fields and add the one ending "_TotalLoss" so the text box below the WHERE clause looks as follows (greater than 0):

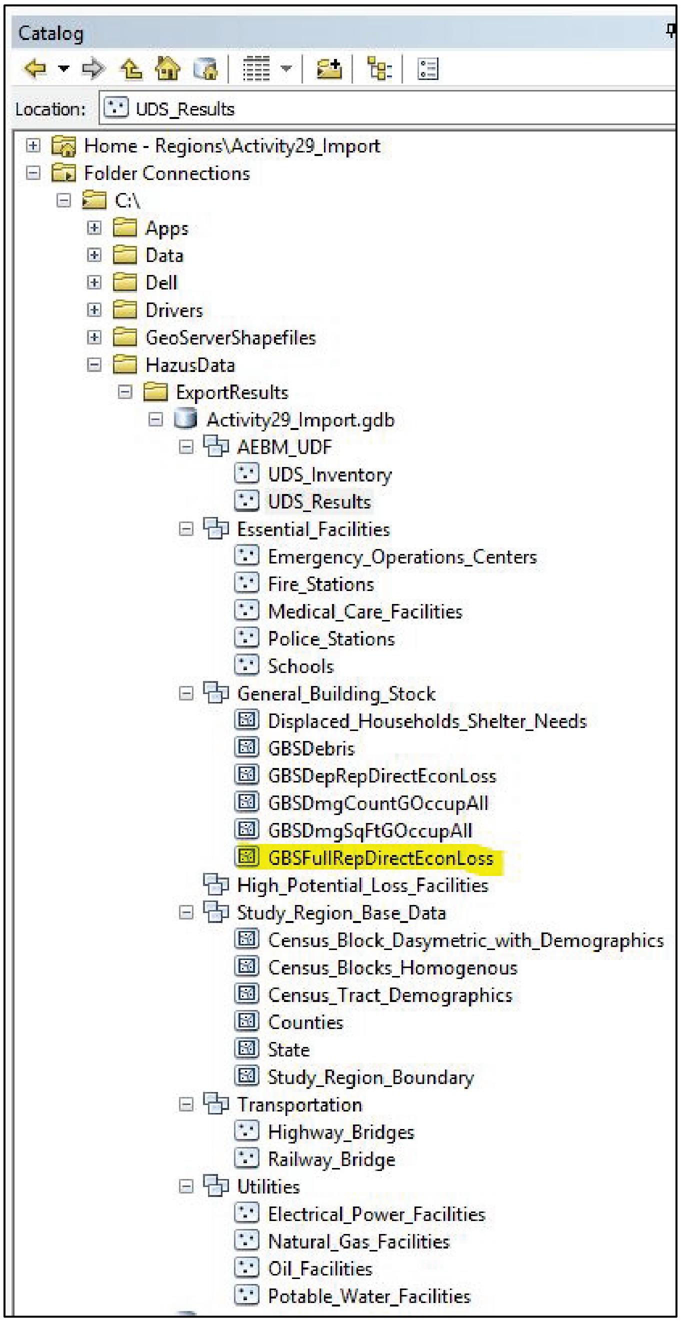


Figure 4-9: Add GBSFullRepDirectEconLoss layer to map window.

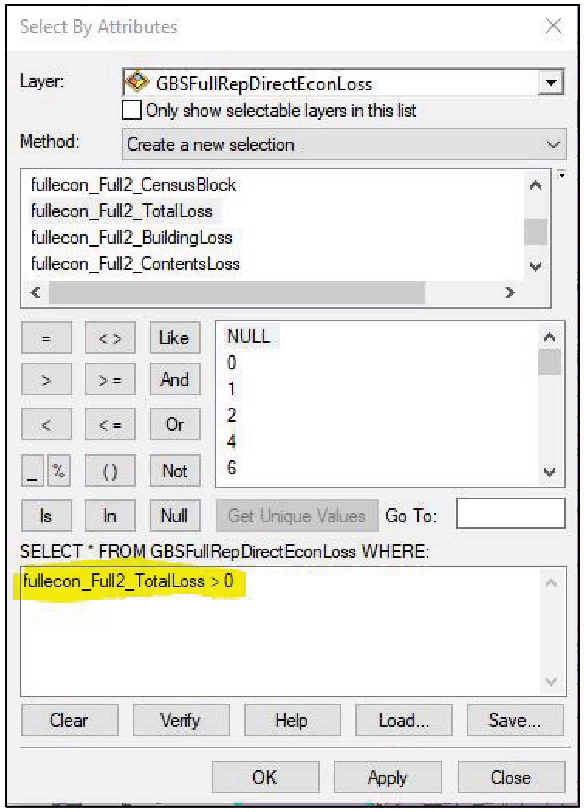


Figure 4-10: Add "_Total Loss" below "WHERE" clause.

1.1 Click "OK" and only records with losses will be selected.

1.2 Right-click on the layer and select "Data >> Export Data."

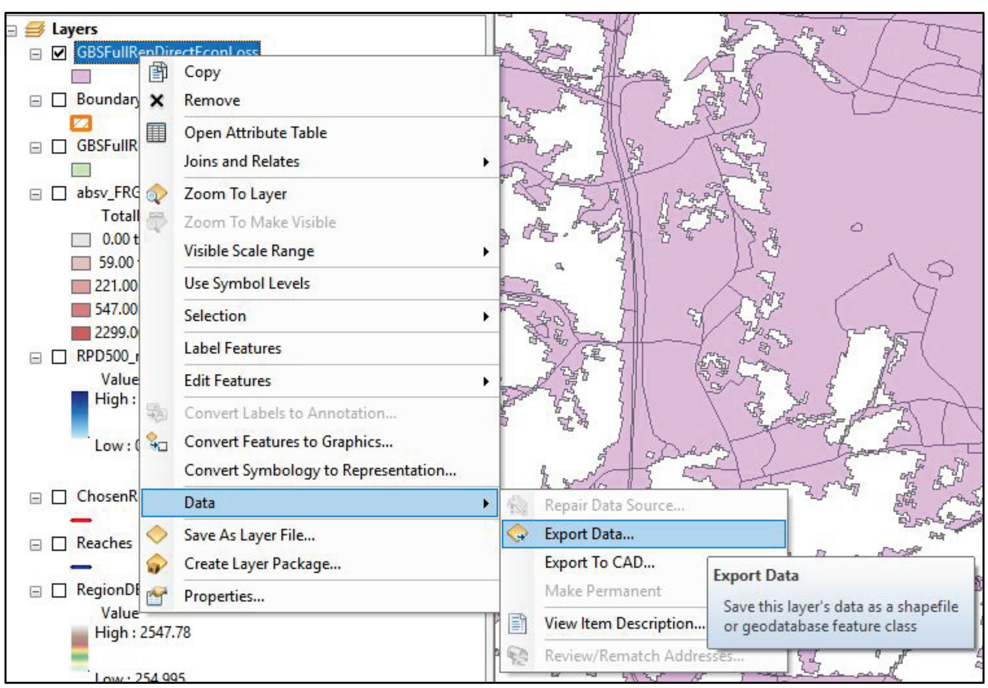


Figure 4-11: Export Data.

2. Ensure “Selected features” is selected in the drop-down in the next dialog and browse to the C:\HazusData\ExportResults folder, choosing Shapefile as “Save as type:” and specifying “TotalLosses.shp” as the name of the file.

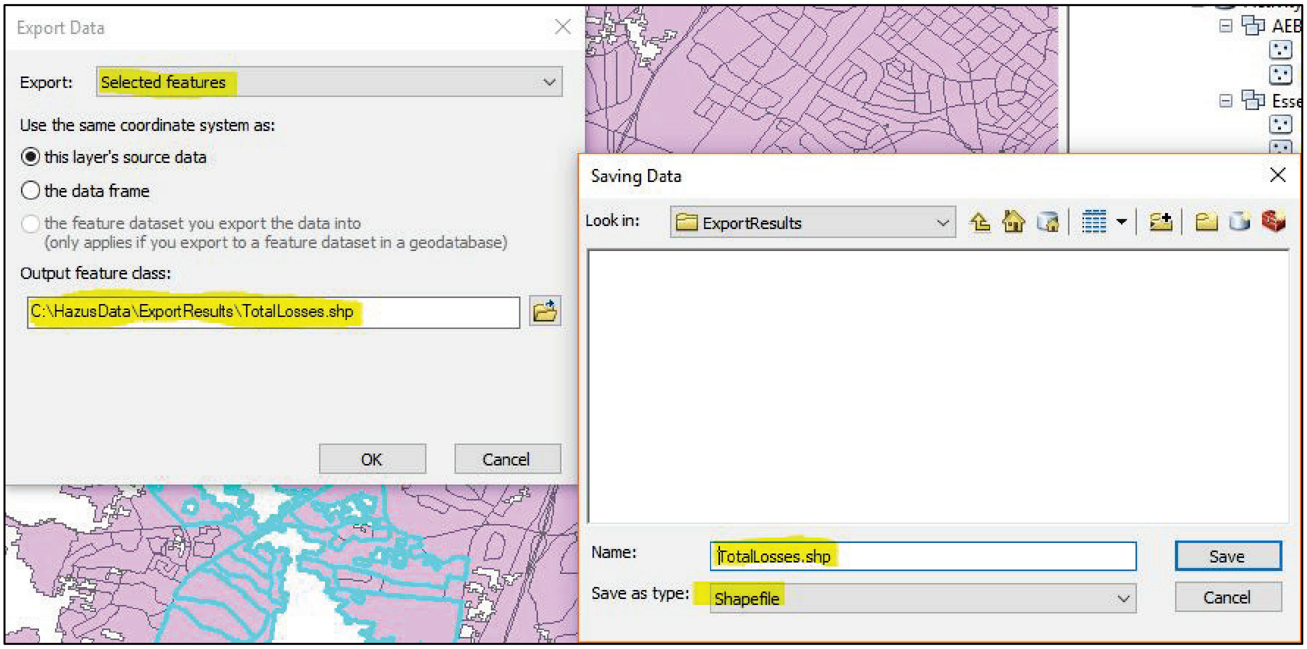


Figure 4-12: Saving file as "TotalLosses.shp."

2.1 Click “OK” and the shapefile will be created.

Note: any number of shapefiles may be exported to a chosen folder using the “Feature Class to Shapefile (Conversion)” tool in ArcCatalog.

Note: It is possible to bring in the exported data to verify it contains only the Census blocks with total losses > 0.

4.6. Displaying in Online GIS Viewer

This section will guide the user in displaying the Hazus analysis results in an online GIS Web Viewer, ArcGIS Online. The steps generally include setting up an ArcGIS Public account (if not already done), selecting layers for inclusion in the map, uploading the layers, styling the map and sharing it with others. Additionally, this section includes steps for sharing a map package file containing the map document and layers directly from ArcGIS to ArcGIS Online.

1. Create an ArcGIS Public account on the ArcGIS website.
2. Use femadata.com to request a user account for the FEMA GeoPlatform.

This will help create a basic map with the content of the analysis results as well as a base layer (e.g., satellite imagery, streets, terrain).

4.6.1 Compress the Shapefile

1. Navigate to the location of the exported shapefile in Windows Explorer.

2. Select all of the “TotalLosses” files making up the shapefile (The file extension will likely be cpg, dbf, prj, sbn, sbx, shp, shp.xml and shx). Right-click and select “Send to >> Compressed (zipped) folder.” Accept the file name, “TotalLosses.zip.”

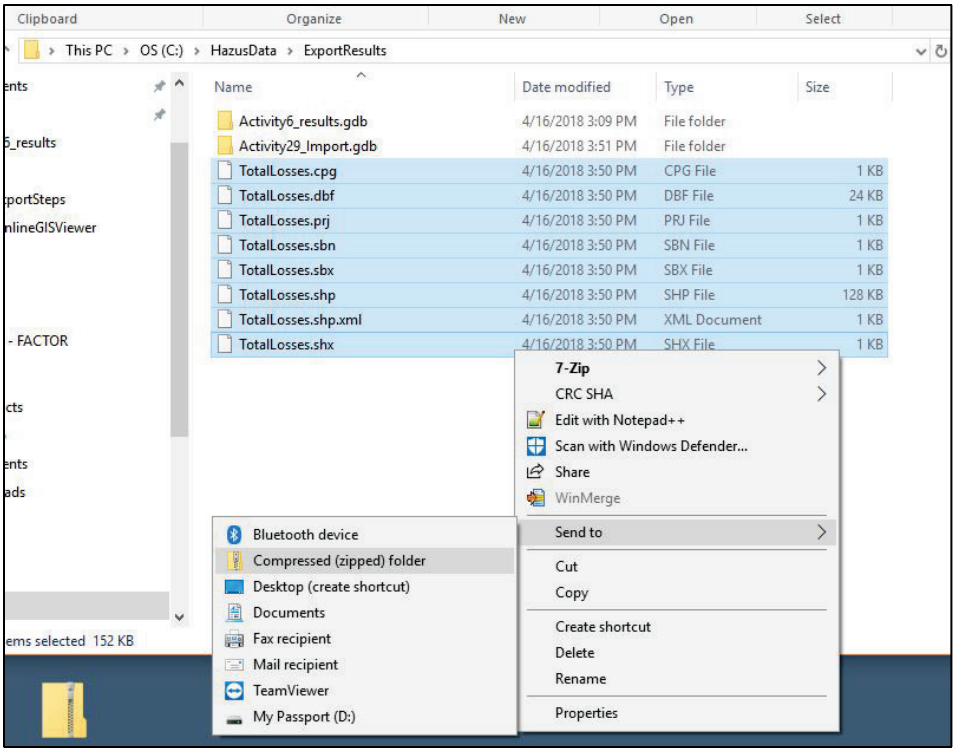


Figure 4-13: Send all "TotalLosses" to compressed folder.

4.6.2 Navigate to ArcGIS Online

1. Open a browser and navigate to ArcGIS Online.
2. Sign in with user credentials by clicking “Sign In” in the upper right-hand corner of the page.
3. Click the header “Content” and then click the newly created map package (“Arapahoe” in this example).
4. There are four options on the right-hand side of the page:

   4.1 “Open in ArcGIS Desktop” and “Download” – both of these options will download the .mpk file (i.e., to the Downloads folder). Double-clicking on this file will open the package in ArcGIS and display all of the layers.

   4.2 “Update” – this option enables a user to manually update a map package by uploading another .mpk file.

   4.3 “Share” – change the sharing settings (visible to everyone or made available to select ArcGIS Online groups).

5. Click “Open in ArcGIS Desktop” and double-click the downloaded file to open and view the map package in ArcMap. Verify that the map and data are what was exported from the region.

Note: without an ArcGIS Online for Organizations subscription, it is not possible to publish directly to ArcGIS Online and have the layers/data viewable through a browser. Explore an ArcGIS Online for Organizations subscription or purchasing ArcGIS Server if this functionality is required.

4.6.3 Upload the Shapefile to ArcGIS.com and Create a Map

1. Select “Add” and choose “Add Layer from File” on the map page.

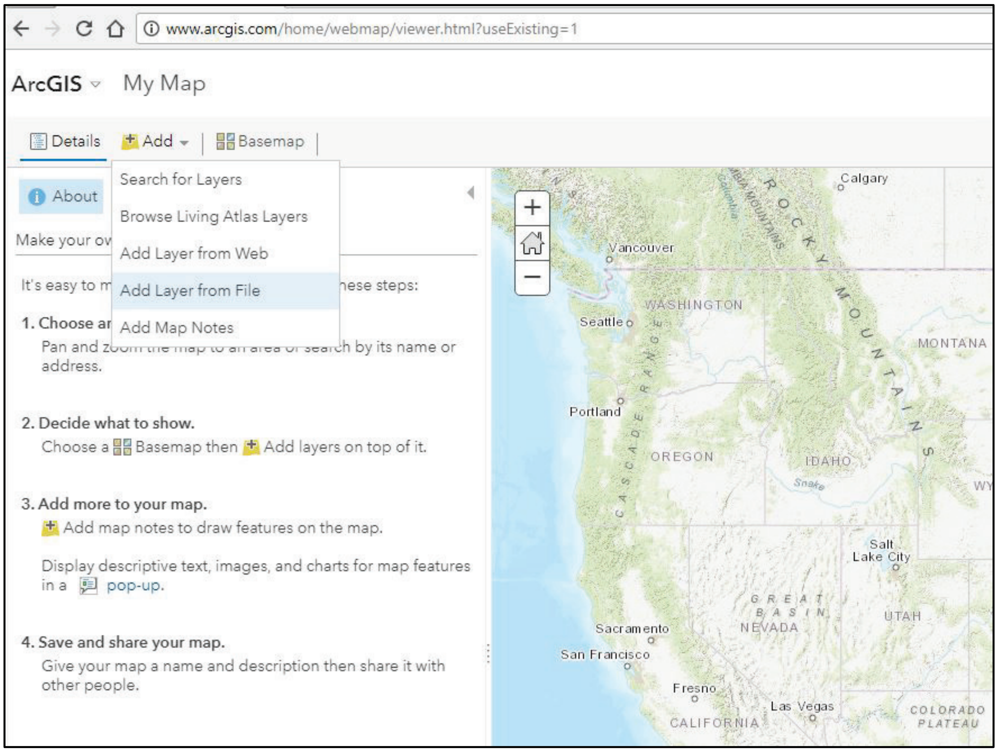


Figure 4-14: Uploading the Shapefile to ArcGIS.com and creating map.

2. Click the “Choose File” button in the next window and navigate to the “TotalLosses.zip” file created earlier (C:\HazusData\ExportResults\TotalLosses.zip). Specify “Keep original features” to keep the features with all of the shapepoints (this will not generalize the features’ geometry).

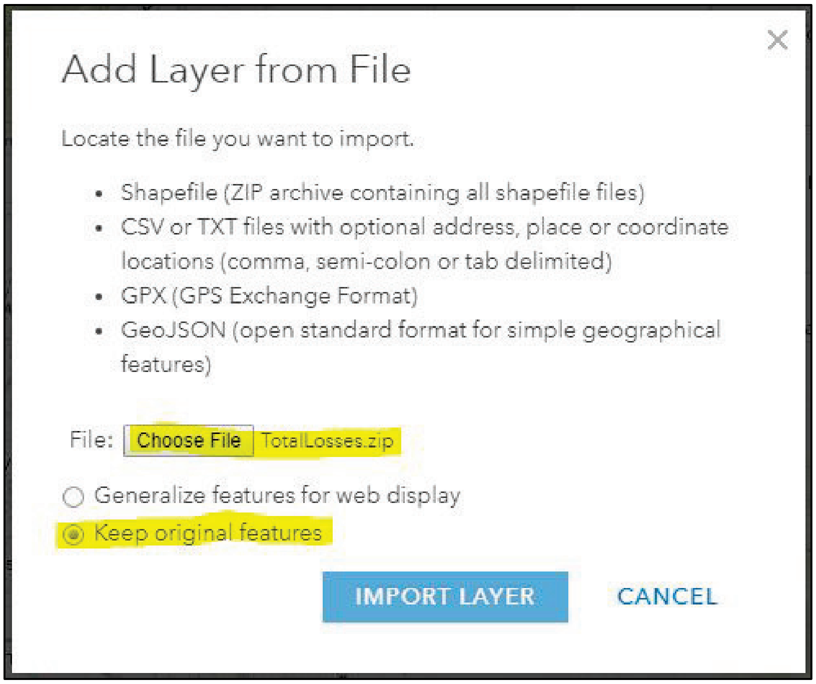


Figure 4-15: Keeping original features.

3. Click the "Import Layer" button.

Note: A limitation of ArcMap needs to be discussed here; ArcMap is not able to display long field names (more than 10 characters). As a result, the exported field names are renamed fullecon_1, fullecon_2, etc. In this example, we know that the TotalLoss field corresponds to fullecon_4, but in specific cases, renaming the fields before exporting the shapefile could be done. Go to the ArcGIS renaming shapefile website for more information.

Note: It is possible to specify the style of map to display at this point. There are numerous ways to display single layer, but use "Counts and Amounts (Color)" for the purposes of this exercise.

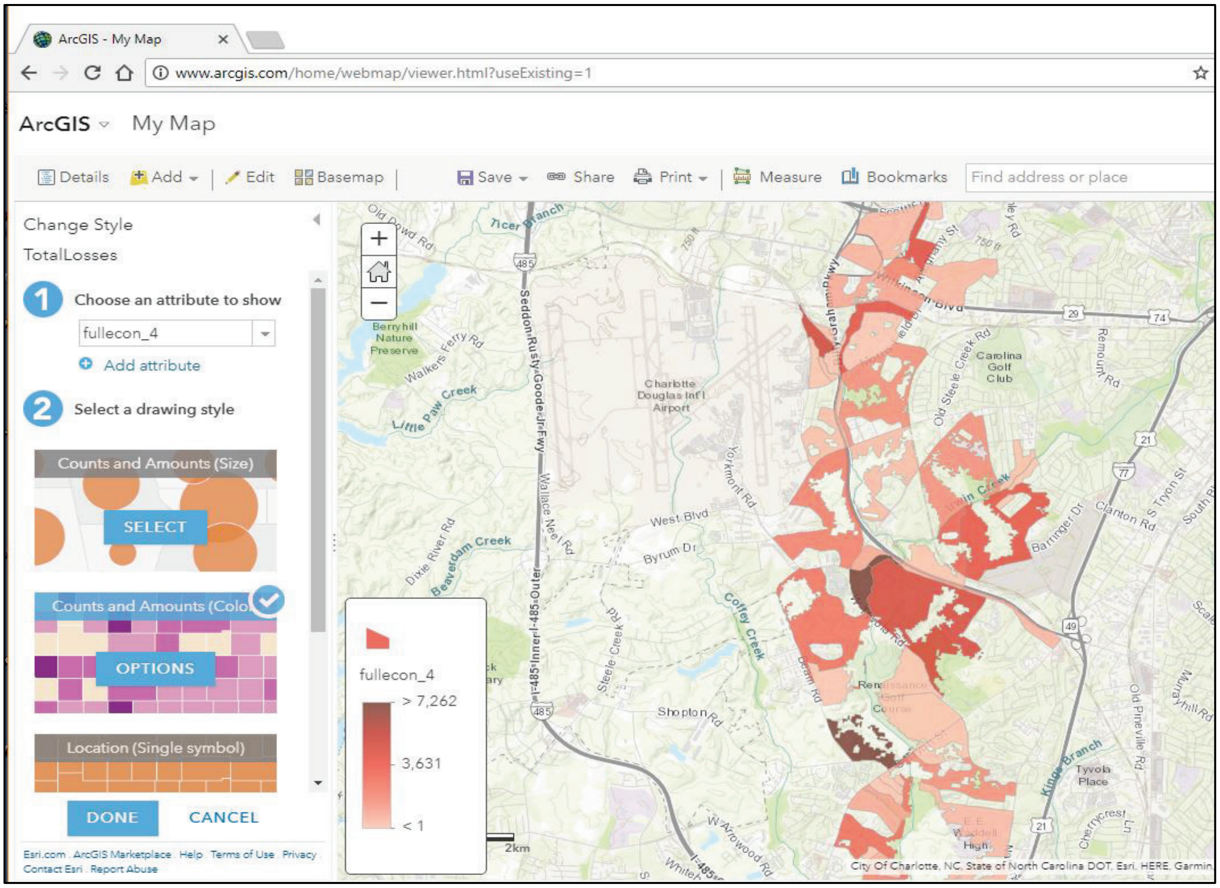


Figure 4-16: Creating map.

4. Click "Done" and the map is created.

   4.1 There are several options to experiment with, including addition of other layers, changing the basemap, adding bookmarks, etc. These are beyond the scope of this document. Please reference ArcGIS.com help for information on how to customize this map further.

   4.2 The map must be saved before sharing it with others.

5. Click "Save" on the toolbar, then give the map an appropriate title, tags and summary and click "Save Map."

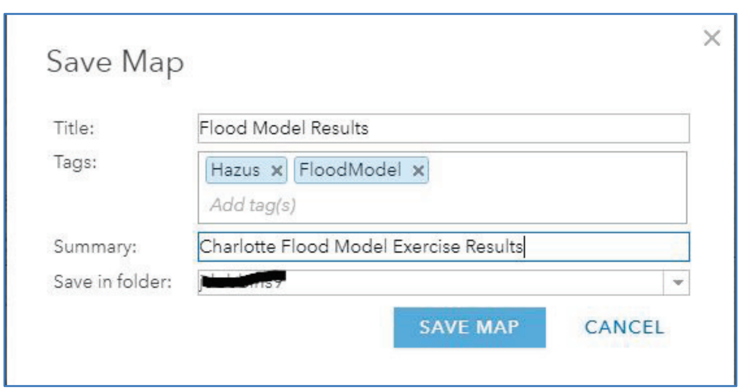


Figure 4-17: Saving map.

4.6.4 Sharing the Map

The map has now been saved and can be shared with others via URL or as a Map Package.

4.6.4.1 Sharing the Map via URL

1. Click “Share” on the map toolbar and check the box next to “Everyone (public)” to allow anyone with the link to view the map.

2. Copy the url and paste in an email to allow recipients to view the content.

   Note: The recipient must have a public ArcGIS.com account to view the content. There is an additional method for sharing GIS data created by Hazus with others via ArcGIS Online. This involves the creation of a portable map package (.mpk) file that includes the map document and data referenced by the layers it contains. This map package file is uploaded directly to ArcGIS Online, where it can be downloaded by others and referenced in ArcMap.

4.6.4.2 Sharing as a Map Package

1. Select “File,” then “Share As” then “Map Package” to bring up the Map Package dialog.

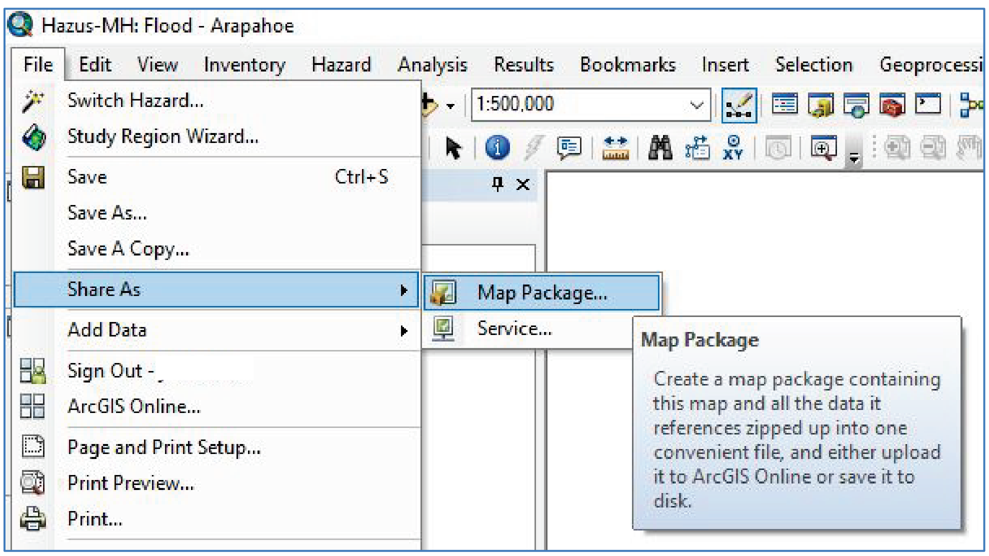


Figure 4-18: Share as Map Package.

2. Select the “Map Package” tab, make sure the “Upload package to my ArcGIS Online Account” option is selected and name it appropriately. In this example, we will name the map package, “Arapahoe.” Make sure that the option “Include Enterprise Geodatabase data instead of referencing the data” is unchecked. This option would attempt to reference the data published by the user’s organization rather than the locally referenced data.

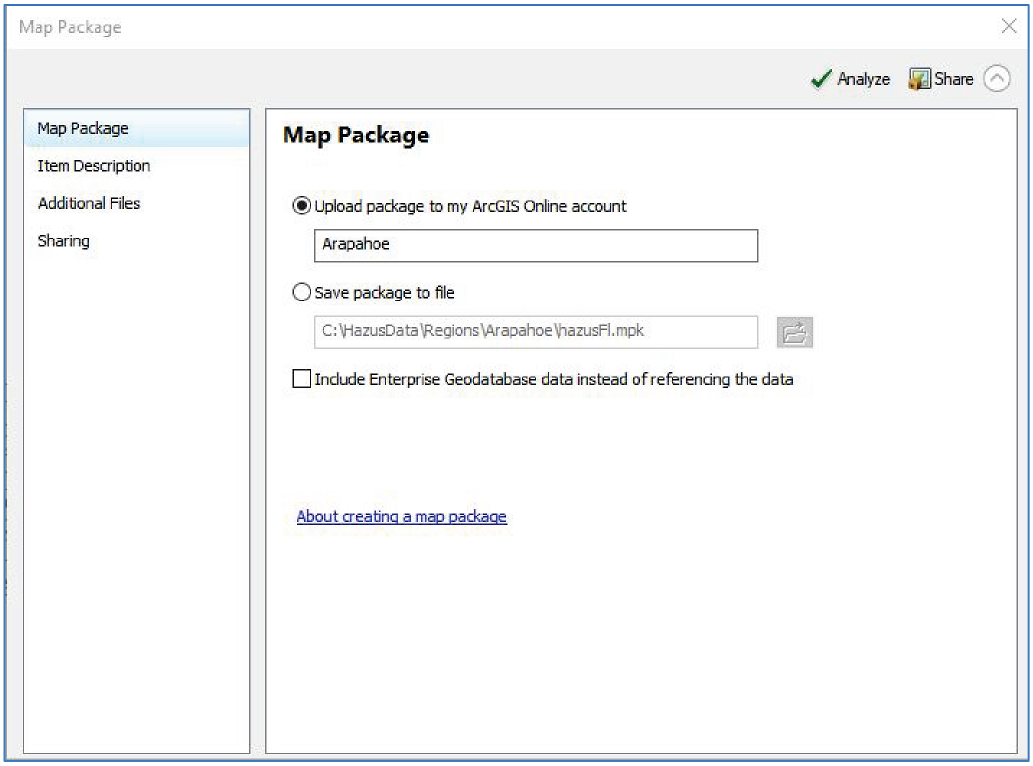


Figure 4-19: Screenshot of Map Package Dialog (Specify Details).

3. Click the “Item Description” tab and populate the required text boxes: “Summary,” “Tags” and “Description.” Populate the other text boxes on this tab as desired (i.e., Access and Use Constraints and credits).

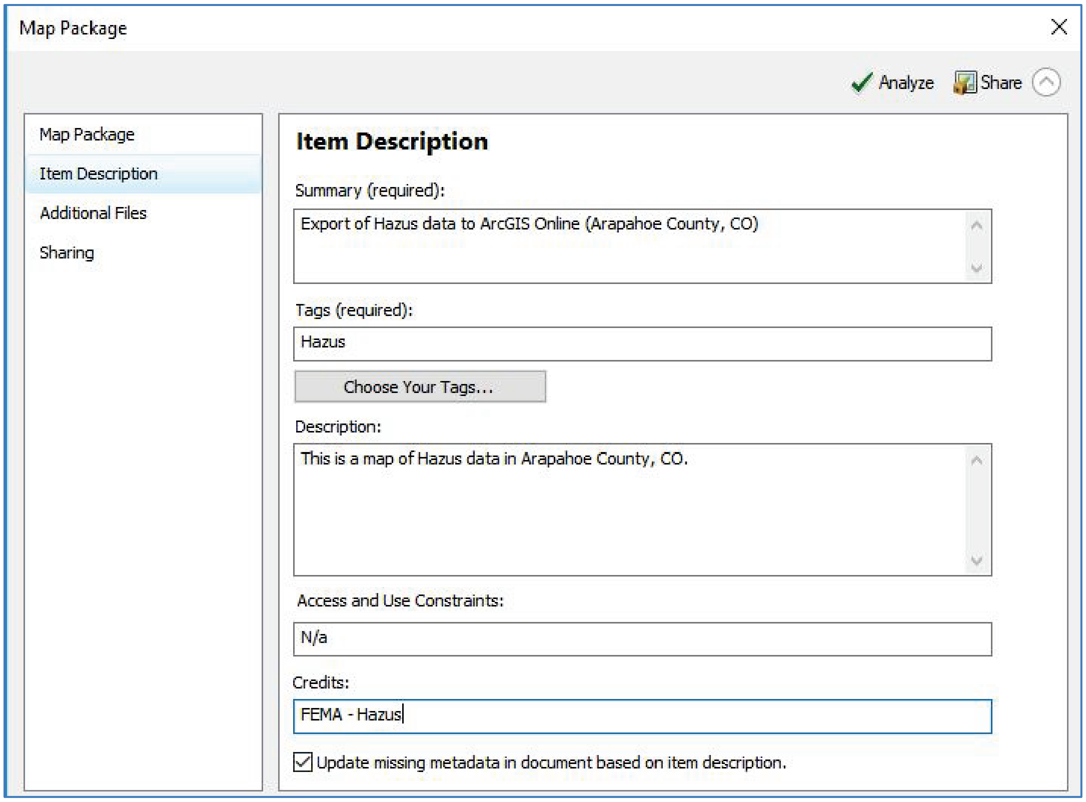


Figure 4-20: Screen Capture of Map Package Item Description.

4. Click the "Sharing" tab. There is the option to choose to make this map package visible to everyone (Public) or share this with certain groups. Check the box next to "Everyone (public)."

   Note: Explore ArcGIS Online support on groups to learn more about how to restrict the visibility of shared map packages.

5. Click the "Analyze" option (with the green check) in the upper right corner of the Map Package dialog to check for any issues that might prevent a successful package publish. If there are no issues discovered, click the "Share" button. This may prompt the user to save the map document before creating the map package; click "Yes" to confirm.

6. Click "OK" to confirm the successful map package creation.

4.6.5 Open a Region

1. Open a region in Hazus. In this example, we are going to use the base flood scenario with user defined facilities in Arapahoe County, CO.

2. Sign in to ArcGIS Online by selecting the "File" menu and "Sign In."

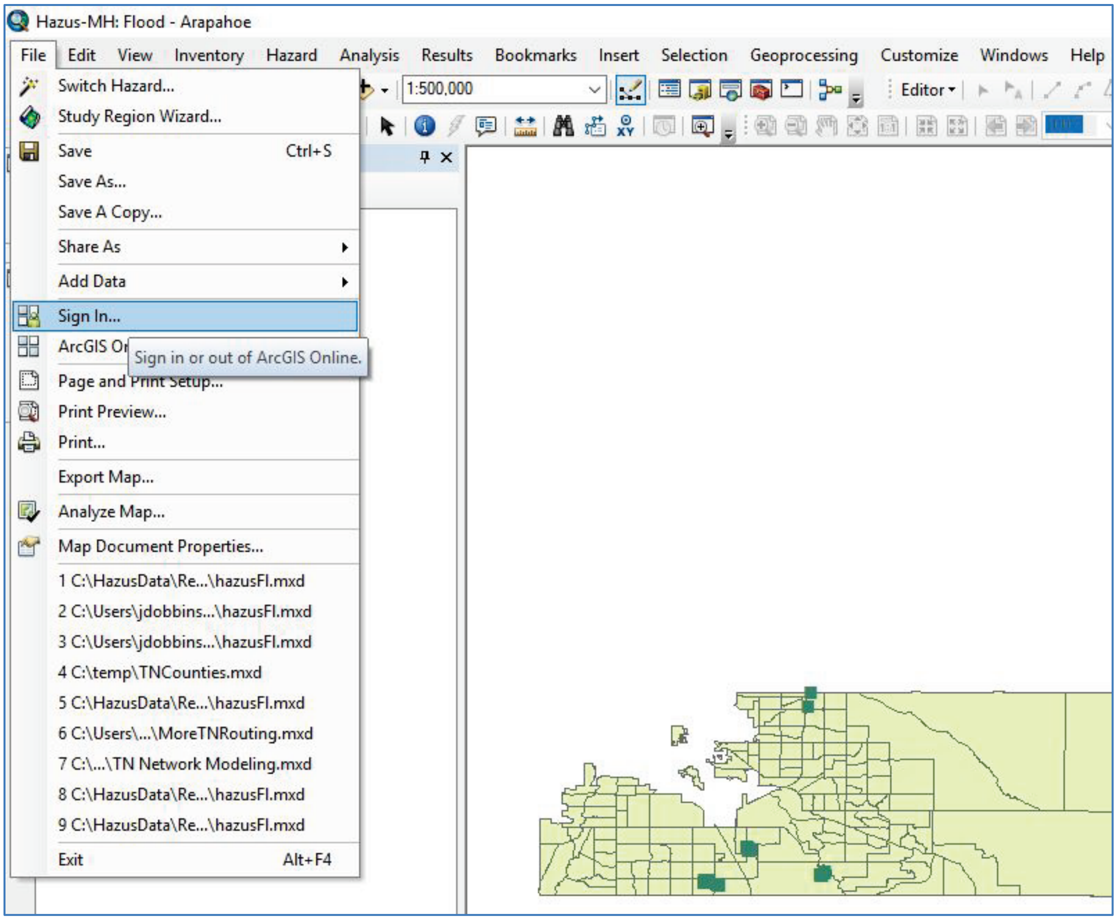


Figure 4-21: Sign in to ArcGIS Online from ArcMap.

3. Enter the user specific ArcGIS Online credentials (username and password) and click "Sign In."

5. Appendix A: VDatum Example

Hazus requires data to be in NAVD 1988 vertical datum, thus NGVD 1929 data must be converted. The section below details how this can be done. It will take roughly two (2) hours (one (1) hour of data processing).

In this example, the user will be converting a shapefile of elevations in Corvallis, Oregon, from NGVD 1929 to NAVD 1988 in VDatum and confirming the change in ArcMap. For a short explanation of the difference between vertical datums and why conversions are necessary, watch these videos from the National Oceanic and Atmospheric Administration (NOAA):

- NOAA's VDatum: Transforming Heights between Vertical Datums
- What are Geodetic Datums?

VDatum is able to transform many different types of horizontal and vertical datums with a choice of units (meters, international feet, or U.S. feet), as well as a selection of particular geoid models, including Light Detection and Ranging (LiDAR) data, American Standard Code for Information Interchange (ASCII) files, rasters, GeoTIFF files, and points with Latitude and Longitude or Easting and Northing units. Not all the features of VDatum will be explored in this example. For more information, go to NOAA's VDATUM website.

This example assumes the user is familiar with the ArcGIS software.

5.1 Update Java software

VDatum can be run directly through a command prompt window, but for users who are unfamiliar with programming and the VDatum software, the VDatum Graphic User Interface (GUI) is utilized in this example, which necessitates a current version of Java on the computer used for the analysis.

1. Go to the Java download website.
2. Click the "Free Java Download" button on the webpage.
3. Read the disclaimer and click the "Agree and Start Free Download" button to start the download.
4. When the execute file (.exe) is downloaded, click "Run" to start the installation process.
5. Click "Yes" to allow the app to make changes to the device.
6. Click "Install" on the Java window to start the installation process.

5.2 Download the Elevation Dataset

This example will use Elevation points from Corvallis, Oregon, because it has clearly documented metadata. Any dataset in which the source's horizontal and vertical projections, as well as the units of those projections, are known can be converted.

1. Go to the Corvallis, Oregon, data download webpage.
2. Scroll down to the "Elevation" dataset.

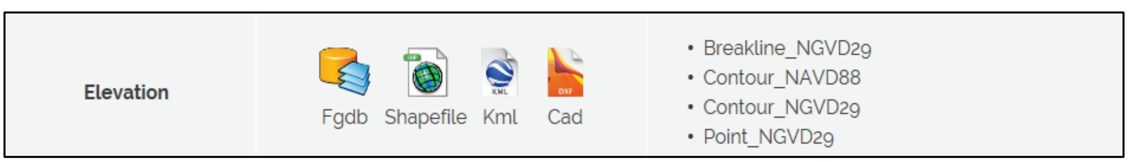
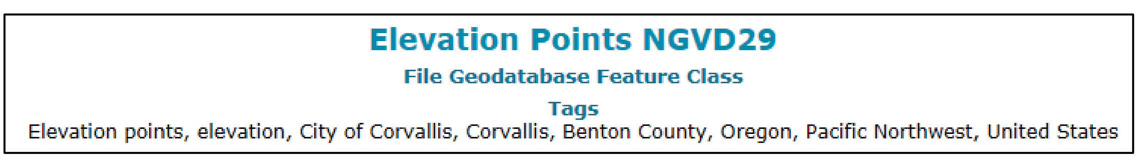


Figure 5-1: Screenshot of Elevation dataset on the Corvallis, Oregon, website.

3. Click "Point_NGVD29" to read the metadata, the horizontal and vertical projections are of most interest.


Elevation Points NGVD29

File Geodatabase Feature Class

Tags

Elevation points, elevation, City of Corvallis, Corvallis, Benton County, Oregon, Pacific Northwest, United States

Figure 5-2: Screenshot of the metadata for the Point_NGVD29 file.

4. Click the "Shapefile" icon to start downloading the dataset.
5. When the computer prompt appears, click "Save" (see Figure 5-3).

Figure 5-3: Example of computer prompt to save the Point_NGVD29 file to the computer

6. Open "File Explorer" and go to the "Downloads" folder.
7. Unzip the compressed "Elevation" file by right-clicking the file and then selecting "Extract All…" Keep the default information for the file extraction destination. In this example, the folder will remain in the "Downloads" folder as C:\Downloads\Elevation. The user can place the folder anywhere on their computer as long as they note the location for future reference.

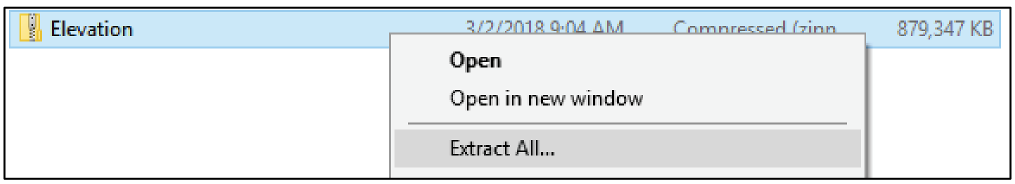


Figure 5-4: Drop down menu after right-clicking the file. Select "Extract All..."

5.3 Download VDatum

VDatum is a free software distributed by NOAA, previously called VERTCON. VDatum only works for the United States and U.S. territories.

1. Go to the VDATUM user agreement webpage.

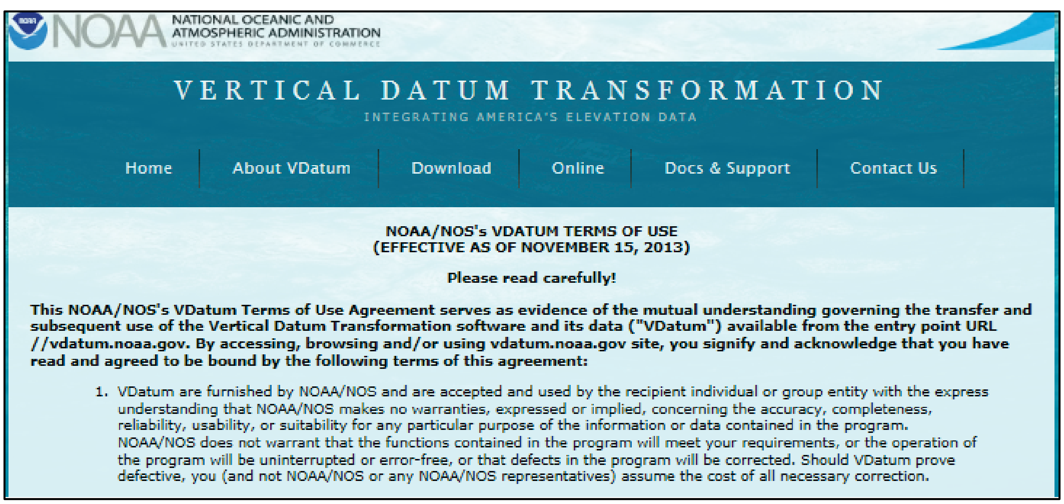


Figure 5-5: Screenshot of VDatum webpage

2. Read the VDatum Terms of Use.
3. Click the "Agree and Start Free Download" button near the bottom of the webpage.
4. If need be, install prerequisites "GEOTIFF(GDAL)," if the user wishes to convert a GeoTIFF. In this example the GeoTIFF download is not required because the user will be converting an Esri shapefile.

5. Click the “vdatum_all_20180306.zip” file (or the most current version of the data) to begin the download.
6. Unzip the file using “Extract All…”

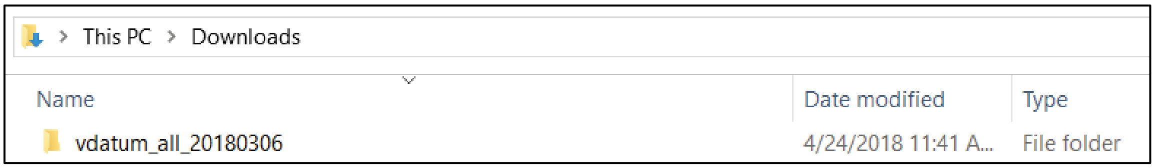


Figure 5-6: Unzip the VDatum file in File Explorer.

7. Move the newly unzipped folder “vdatum_all_20180306” to “Program Files” on the computer’s hard drive (in this example, C:\Program Files).

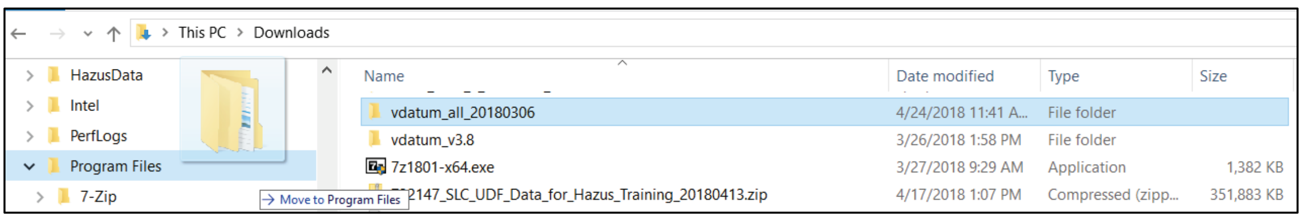


Figure 5-7: Moving the VDatum file to the Program Files folder

8. Open the “vdatum_all_20180306” folder in C:\Program Files.
9. Open “vdatum” folder.
10. Double-click the “vdatum” batch file. This will open a command prompt window and a NOAA GUI.

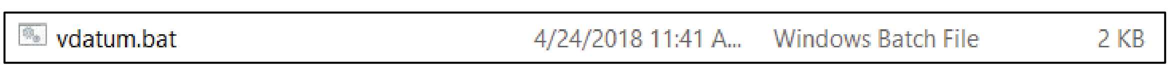


Figure 5-8: VDatum batch file

11. Leave the command prompt window open to execute the GUI (see Figure 5-9).

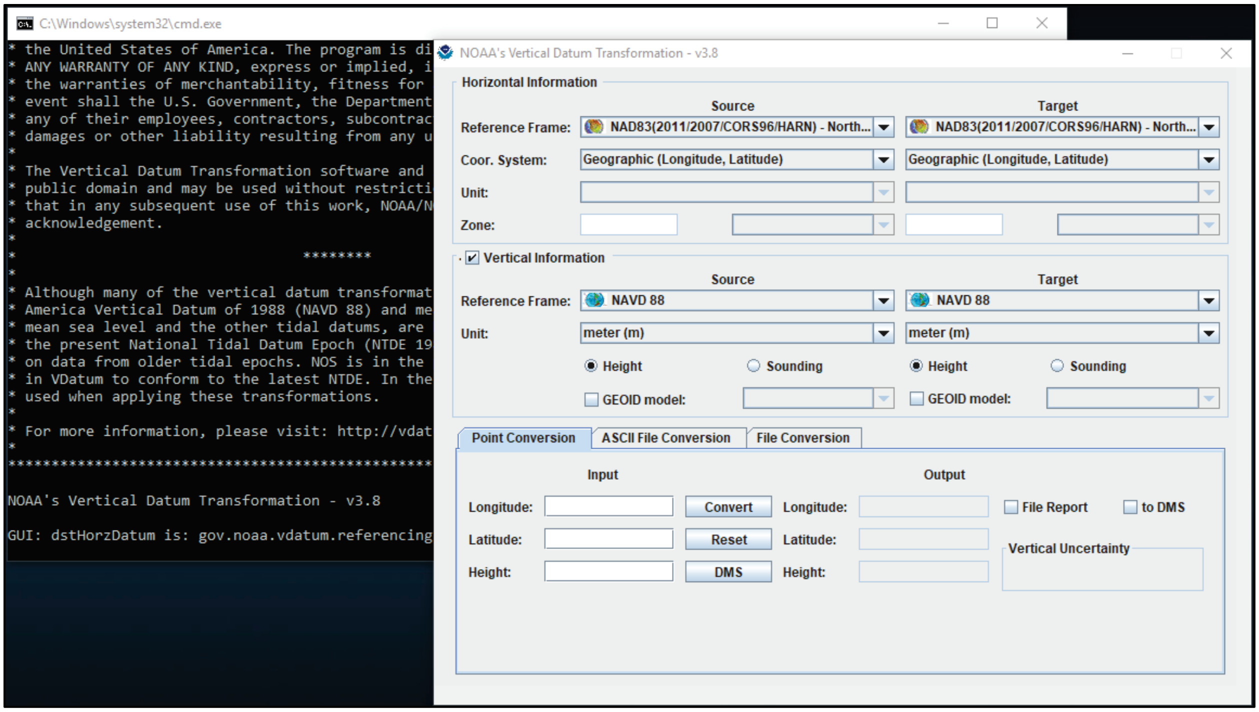


Figure 5-9: Example of command prompt window and VDatum GUI

Note: If Java is up to date and the GUI does not execute, all the files may not have transferred to the new folder location. In the "Downloads" folder, open the unzipped folder "vdatum_all_20180306," click on the "vdatum" folder, and then click on the "vdatum" batch file. If the GUI executes, continue the instructions from this folder location.

5.4 Input Dataset into VDatum and Convert the Vertical Datum

Using the VDatum software downloaded for Corvallis, Oregon, convert the Elevation file downloaded in the previous step from NGVD 1929 to NAVD 1988.

1. In the VDatum GUI, click the "File Conversion" tab.

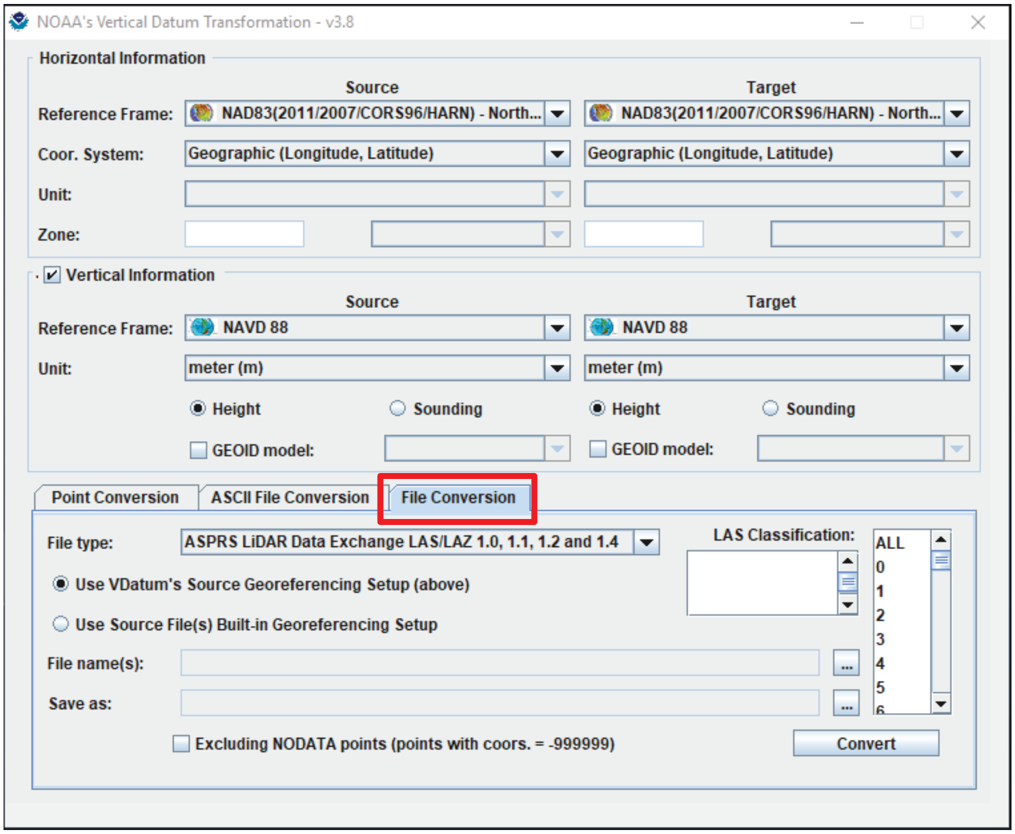


Figure 5-10: File Conversion tab in VDatum

2. Click the “File type” drop-down menu and select the appropriate file type indicated by the user’s source data file (in this example, select “Esri Shapefile Vector Format”).

3. Select the “Use Source File(s) Built-in Georeferencing Setup” radio button.

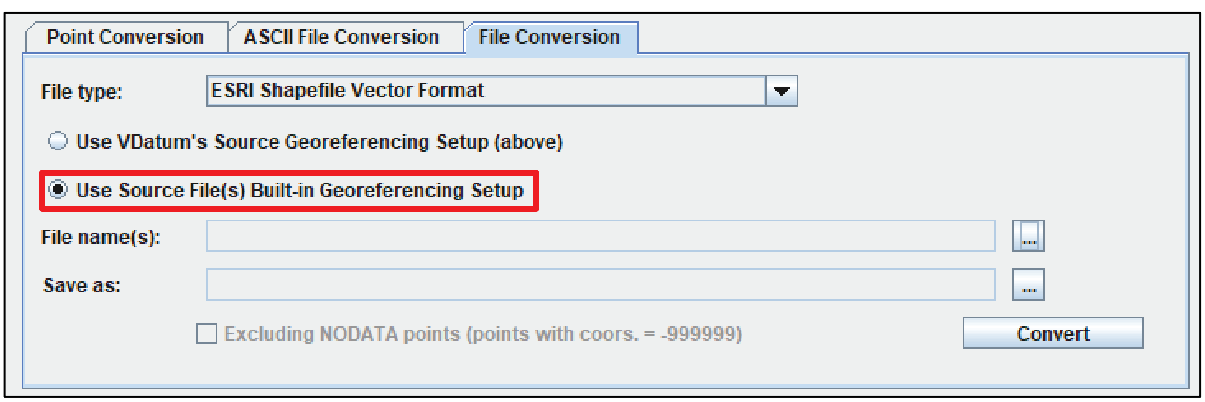


Figure 5-11: Selecting the georeferencing setup

Note**:** The “Coor. System” of the Source and the Zone is already defined by the source file inside the metadata. This information can only be changed by selecting the “Use VDatum’s Source Georeferencing Setup (above)” radio button if the user knows that the information is incorrectly referenced.

4. Click the "…" (Browse) button next to "File name(s):" to select the file to import.
5. Locate the Corvallis, Oregon, Elevation dataset in the "Downloads" folder on the computer (or the folder where the Elevation dataset is located) and select the file the user wishes to convert to a different datum, (in this example, "Elevation_Point_NGVD29.shp").

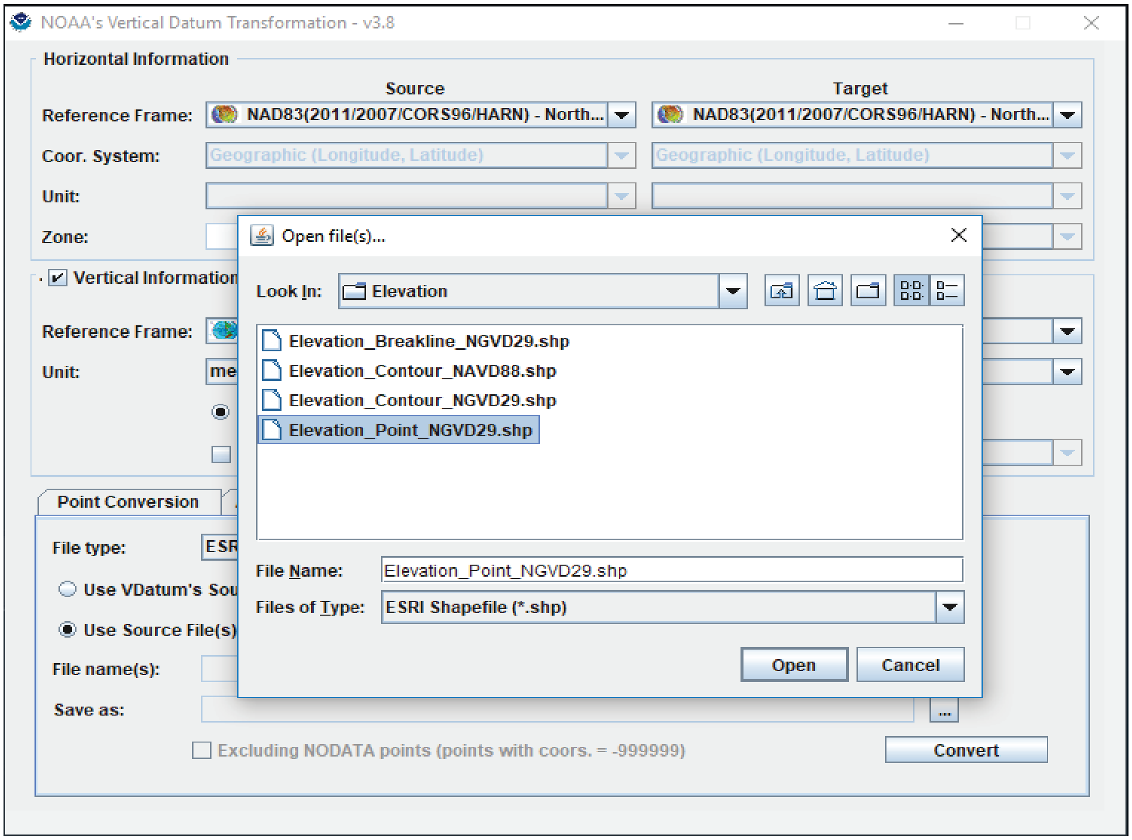


Figure 5-12: Selecting the Elevation file to import into VDatum

6. Click "Open" to select the file to import.

   Note: After selecting the file to import, the "Save as" field will automatically populate with a new "result" folder in which the converted shapefile will be placed (in this example, C:\Downloads\Elevation\result).

   Note: The Horizontal Information for the Reference Frame of the Source column will also automatically populate; however, the Vertical and Target Information does not change automatically.

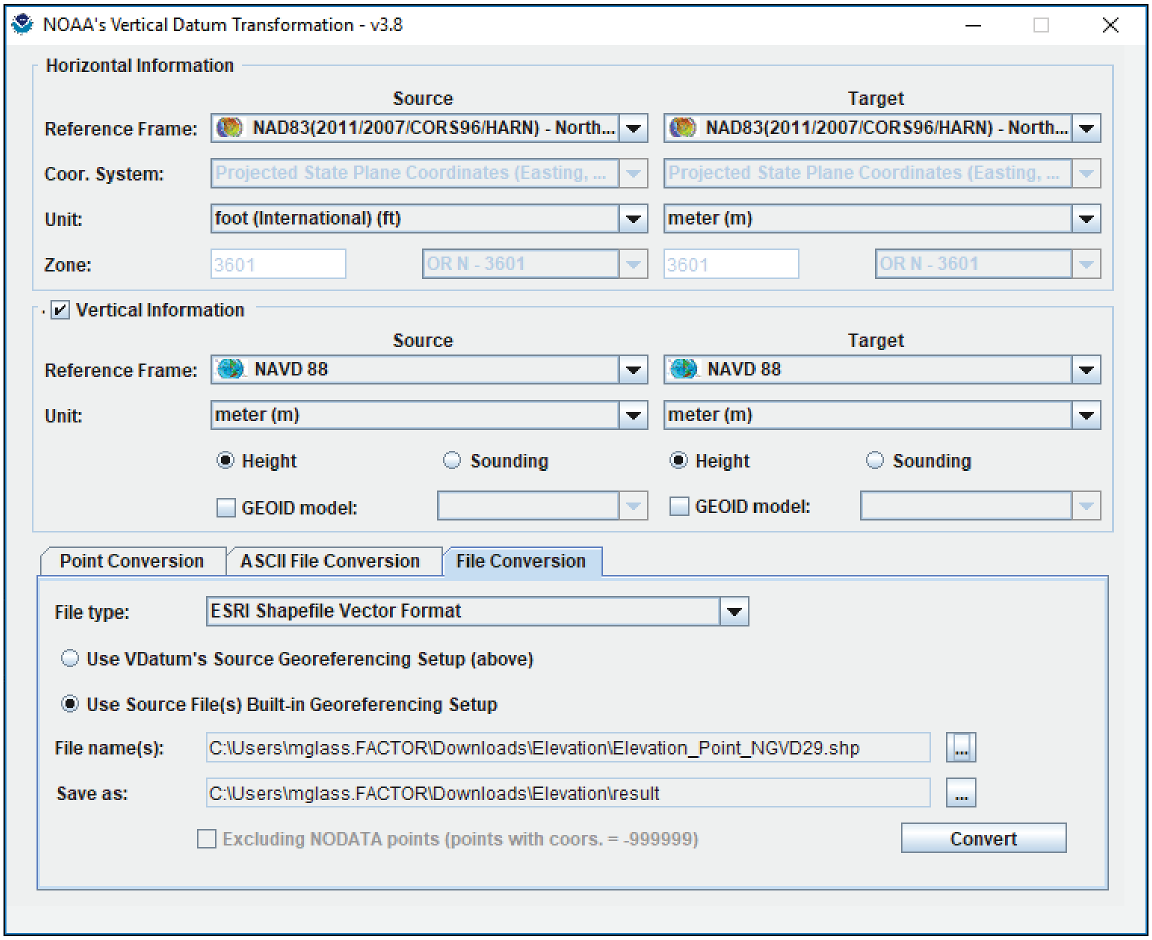


Figure 5-13: Fields automatically populate after selection of file to import.

7. In the Horizontal Information, change target units to the desired units of measurement (in this example, from "meter (m)" to "foot (International) (ft)") in the drop-down menu (see Figure 5-14).

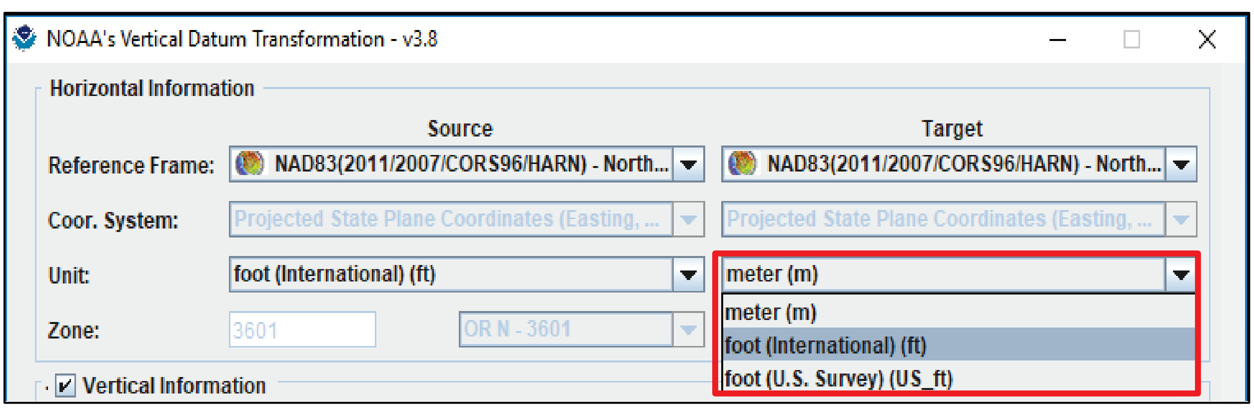


Figure 5-14: Changing Horizontal Information unit measurements for Target

8. In the Vertical Information, change the Source Reference frame to the source's file type and units of measurement (in this example, "NGVD 1929" and "foot (International) (ft)," respectively) using the correlating drop-down menus. Change the target units to the desired unit of measurement, (in this example, "foot (International) (ft)").

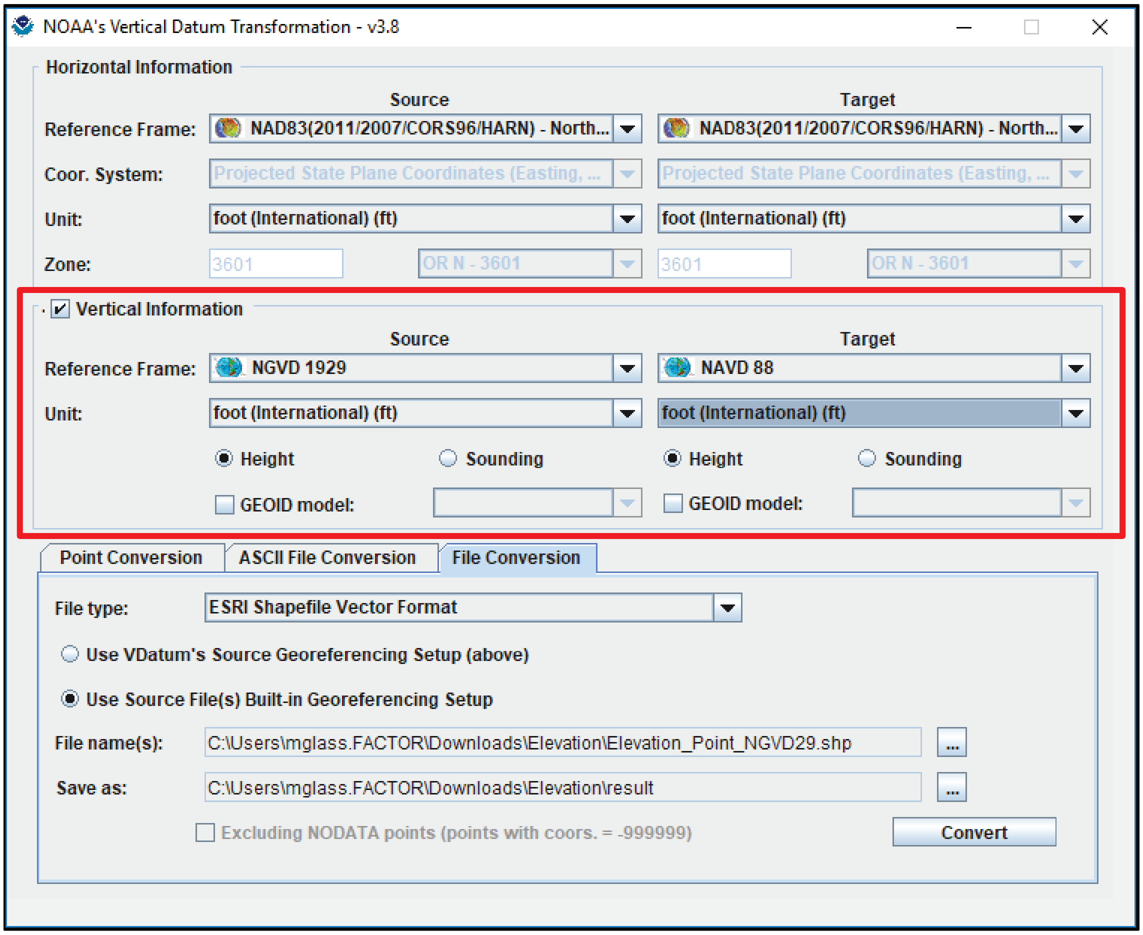


Figure 5-15: Vertical Information changed.

9. If the GEOID model boxes are NOT checked, then the VDatum program will use the most up-to-date GEOID model. Leave these boxes unchecked.

10. Click the "Convert" button at the bottom of the window. A new window showing the progress of the transformation should appear.

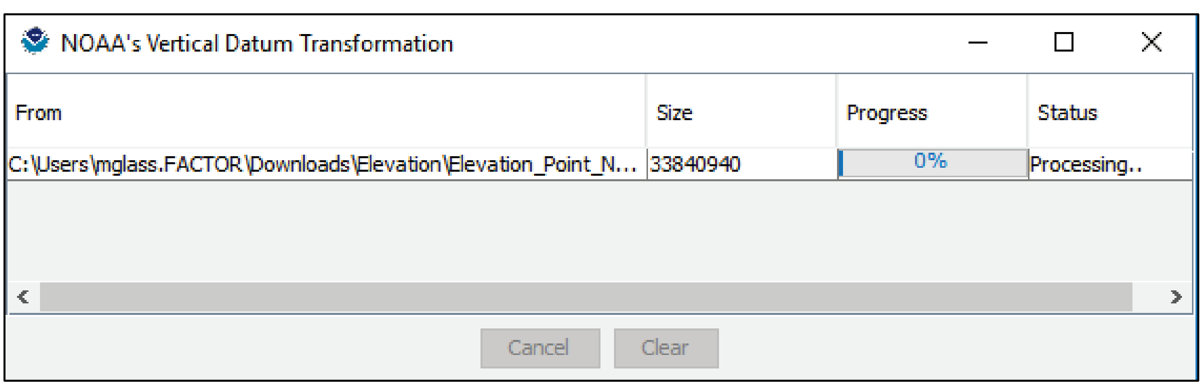


Figure 5-16: Example of progress window that appears when converting the file

Note: Depending on the size of the file, it may take up to several hours to convert, this example will take approximately one (1) hour.

11. Once the conversion is complete, the new shapefile can be found in the folder from the previous step (in this example, “C:\Downloads\Elevation\result”) inside the original data folder.

Name	Date modified	Type	Size
result	4/25/2018 12:21 PM	File folder	
Elevation_Breakline_NGVD29.dbf	4/24/2018 1:04 PM	DBF File	80,210 KB
Elevation_Breakline_NGVD29.prj	4/24/2018 1:04 PM	PRJ File	1 KB
Elevation_Breakline_NGVD29.sbn	4/24/2018 1:04 PM	SBN File	2,654 KB
Elevation_Breakline_NGVD29.sbx	4/24/2018 1:04 PM	SBX File	85 KB

Figure 5-17: New "result" folder located in the original data folder

12. Because the names of the original file and the converted file will be identical, rename the new shapefiles with “NAVD88” instead of “NGVD29” (in this example, “Elevation_Point_NAVD88”)

Elevation › result

Name	Date modified	Type	Size
Elevation_Point_NAVD88.dbf	4/24/2018 1:04 PM	DBF File	217,815 KB
Elevation_Point_NAVD88.prj	4/25/2018 11:16 AM	PRJ File	1 KB
Elevation_Point_NAVD88.shp	4/25/2018 12:21 PM	SHP File	33,048 KB
Elevation_Point_NAVD88.shp.log	4/25/2018 12:21 PM	Text Document	2 KB
Elevation_Point_NAVD88.shx	4/24/2018 1:04 PM	SHX File	6,009 KB

Figure 5-18: Renaming the new shapefiles

5.5 Confirm Change in Height Points

When the vertical datum was converted, the height of each point in the shapefile will have changed. This step will show how the Z-value of points changed, while their elevations stayed the same. Confirming this change does not have to be executed every time VDatum is used.

1. Open “ArcMap.”
2. Add both the source and the new converted shapefiles (in this example, “Elevation_Point_NGVD29.shp” and “Elevation_Point_NAVD88.shp”) to a new Map document.

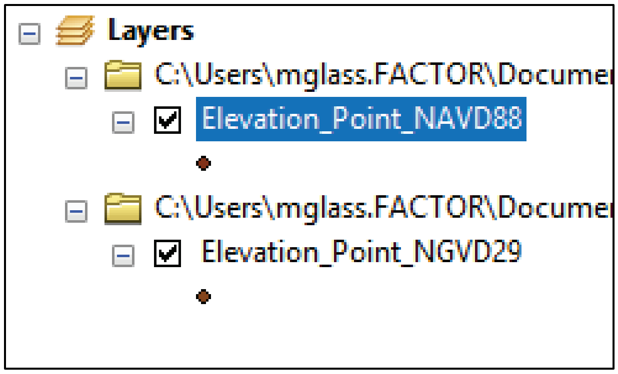


Figure 5-19: Adding both shapefiles as layers in new Map document

3. Open the "Add XY Coordinates" tool found under System Toolboxes, Data Management Tools, and then Features (see Figure 5-20).

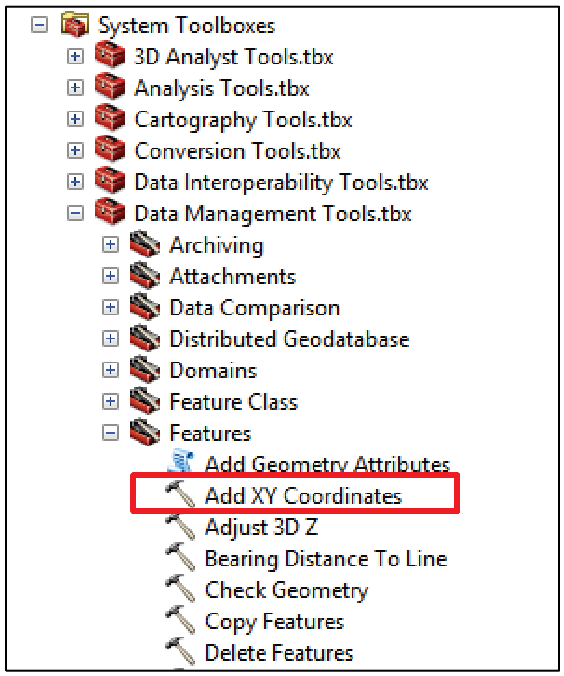


Figure 5-20: Where to find the "Add XY Coordinates" tool.

4. Insert each one of those two files separately as the Input Features and click "OK" each time. This will add four columns to each one of the shapefiles (Point_X, Point_Y, Point_Z, and Point_M).

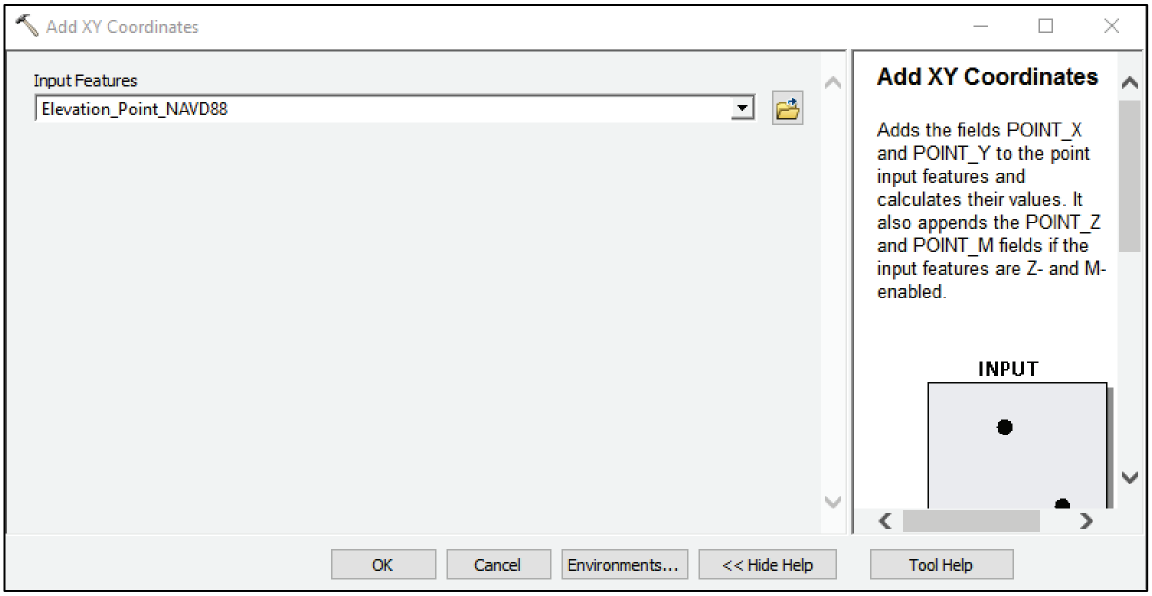


Figure 5-21: Example of the Add XY Coordinates tool.

5. Open both attribute tables by right-clicking the "Elevation point" files and selecting "Open Attribute Table." to compare the Z-values.

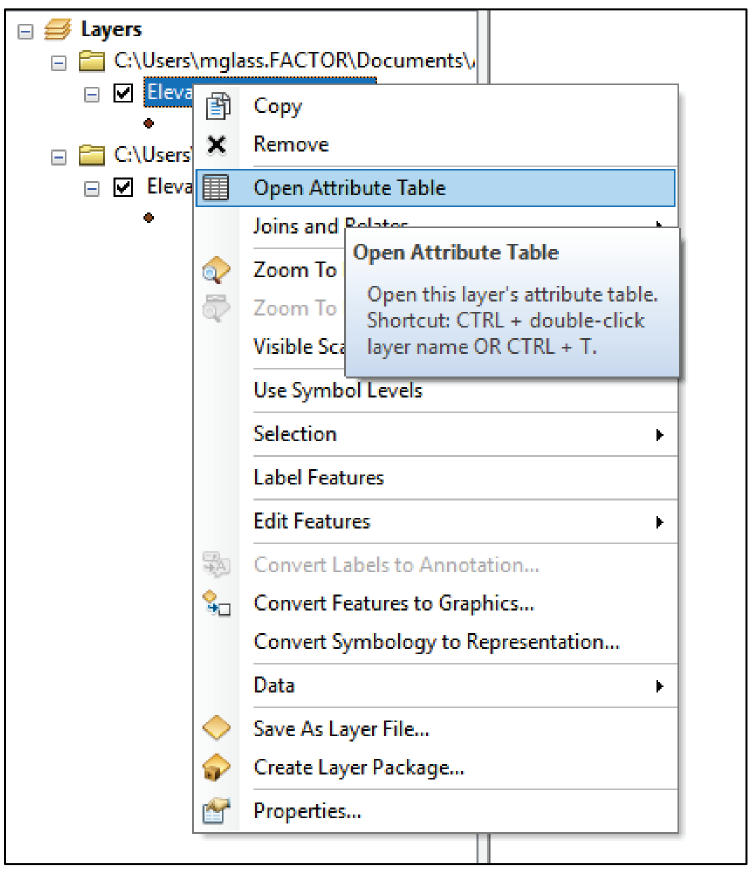
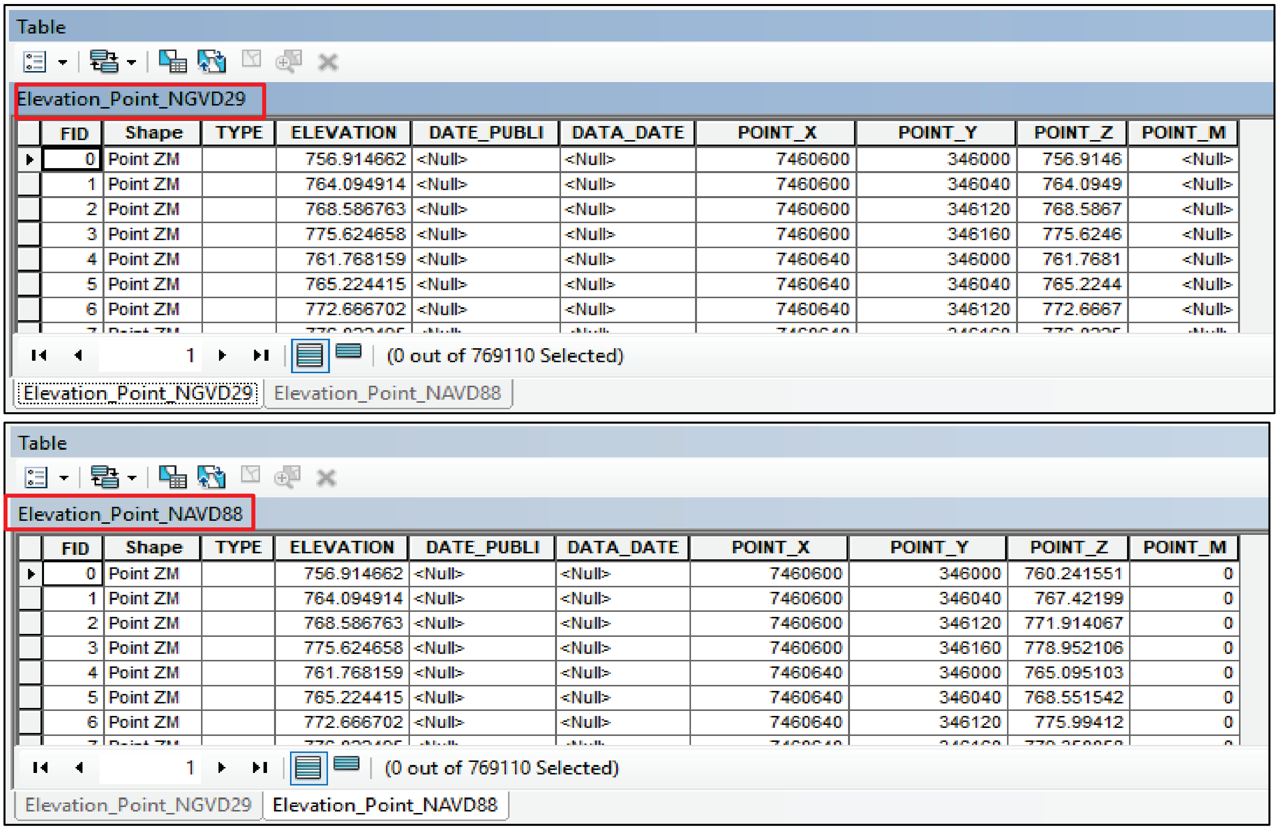


Figure 5-22: Opening the attribute tables.

Note: The X and Y coordinates are given in terms of Easting and Northing.



FID	Shape	TYPE	ELEVATION	DATE_PUBLI	DATA_DATE	POINT_X	POINT_Y	POINT_Z	POINT_M
0	Point ZM		756.914662	<Null>	<Null>	7460600	346000	756.9146	<Null>
1	Point ZM		764.094914	<Null>	<Null>	7460600	346040	764.0949	<Null>
2	Point ZM		768.586763	<Null>	<Null>	7460600	346120	768.5867	<Null>
3	Point ZM		775.624658	<Null>	<Null>	7460600	346160	775.6246	<Null>
4	Point ZM		761.768159	<Null>	<Null>	7460640	346000	761.7681	<Null>
5	Point ZM		765.224415	<Null>	<Null>	7460640	346040	765.2244	<Null>
6	Point ZM		772.666702	<Null>	<Null>	7460640	346120	772.6667	<Null>

FID	Shape	TYPE	ELEVATION	DATE_PUBLI	DATA_DATE	POINT_X	POINT_Y	POINT_Z	POINT_M
0	Point ZM		756.914662	<Null>	<Null>	7460600	346000	760.241551	0
1	Point ZM		764.094914	<Null>	<Null>	7460600	346040	767.42199	0
2	Point ZM		768.586763	<Null>	<Null>	7460600	346120	771.914067	0
3	Point ZM		775.624658	<Null>	<Null>	7460600	346160	778.952106	0
4	Point ZM		761.768159	<Null>	<Null>	7460640	346000	765.095103	0
5	Point ZM		765.224415	<Null>	<Null>	7460640	346040	768.551542	0
6	Point ZM		772.666702	<Null>	<Null>	7460640	346120	775.99412	0

Figure 5-23: Comparing the Z-Point values in the NGVD29 and NAVD88 files.

5.6 Confirm conversion is Accurate Using VDatum

In the previous step, all the points of a shapefile were converted. Using the information from the attribute tables in ArcMap, the user can confirm that the points were converted properly using the VDatum point conversion method. This step does not have to be executed every time VDatum is used.

1. Move back to the VDatum GUI window.
2. Select the "Point Conversion" tab.

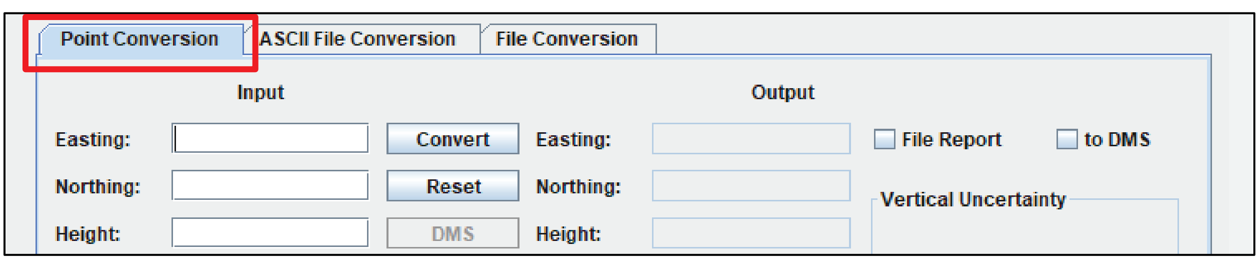


Figure 5-24: Selecting the Point Conversion tab in VDatum

3. From the first row of the NGVD 1929 attribute table in ArcMap, as shown in Figure 5-25, enter the value of "Point_X" into the Easting box, the value for "Point_Y" into the Northing box, and the value for "Point_Z" into the Height box.

Elevation_Point_NGVD29

FID	Shape	TYPE	ELEVATION	DATE_PUBLI	DATA_DATE	POINT_X	POINT_Y	POINT_Z	POINT_M
0	Point ZM		756.914662	<Null>	<Null>	7460600	346000	756.9146	<Null>

Figure 5-25: First row of the NGVD29 attribute table

4. Ensure that the Horizontal Reference frame is in "NAD83(2011/2007/CORS96/HARN)-North…," the "Coor. System" is the "Projected State Plane Coordinates (Easting,…," the Unit is in "foot (International) (ft)," and the zone is "OR N – 3601;" this is from the source file metadata.

5. Under Vertical Information, the Source Reference Frame should be the source's file type and the Units should be the units used in the source file (in this example, "NGVD 1929" and "foot (International) (ft)," respectively). The target Reference Frame should be the converted file type and the desired units of measurement (in this example ("NAVD 88" and "foot (International) (ft)," respectively).

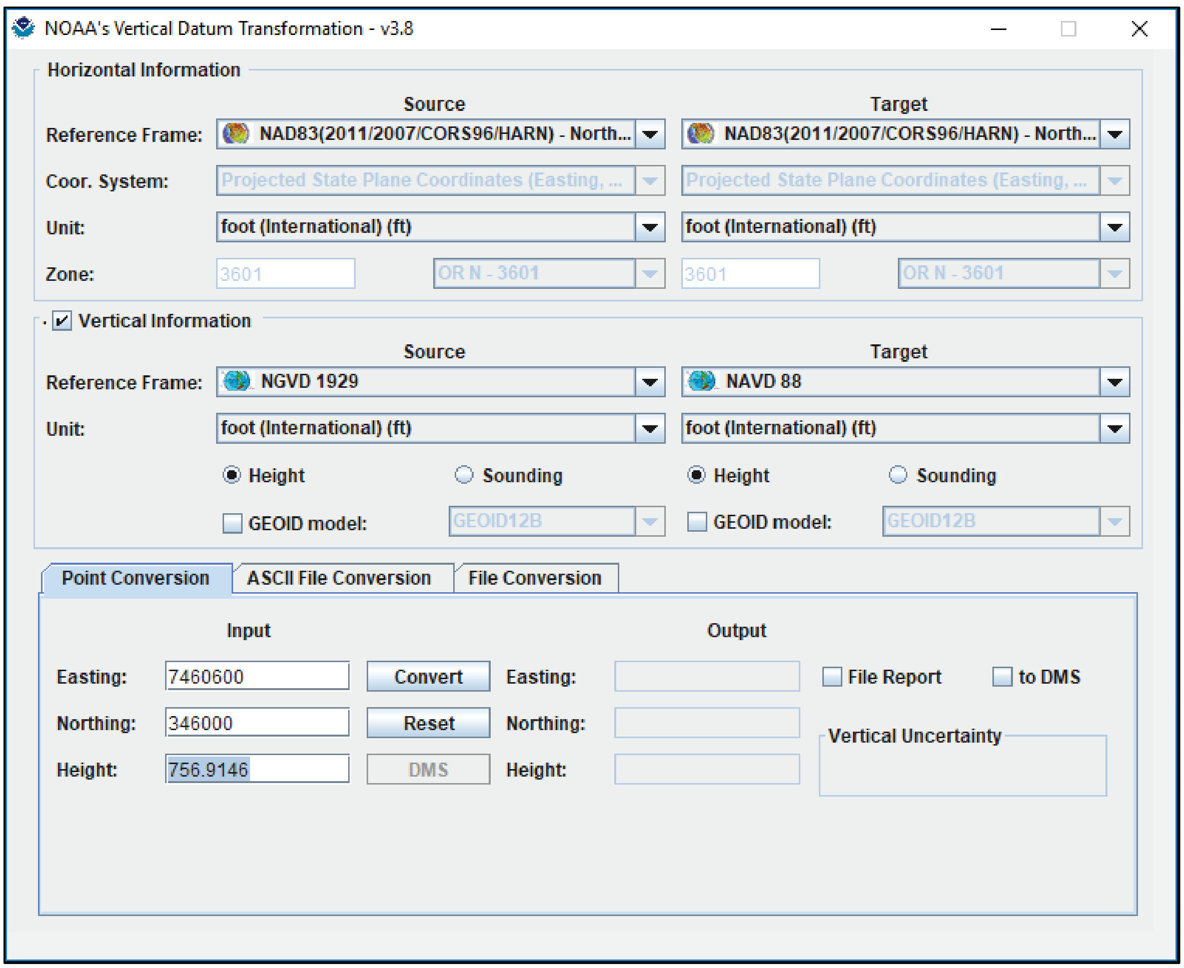


Figure 5-26: Final data points for point conversion

6. Leave the GEOID model boxes unchecked so that the most up-to-date GEOID model in VDatum is used.

7. Click "Convert" and the gray Output boxes will be populated.

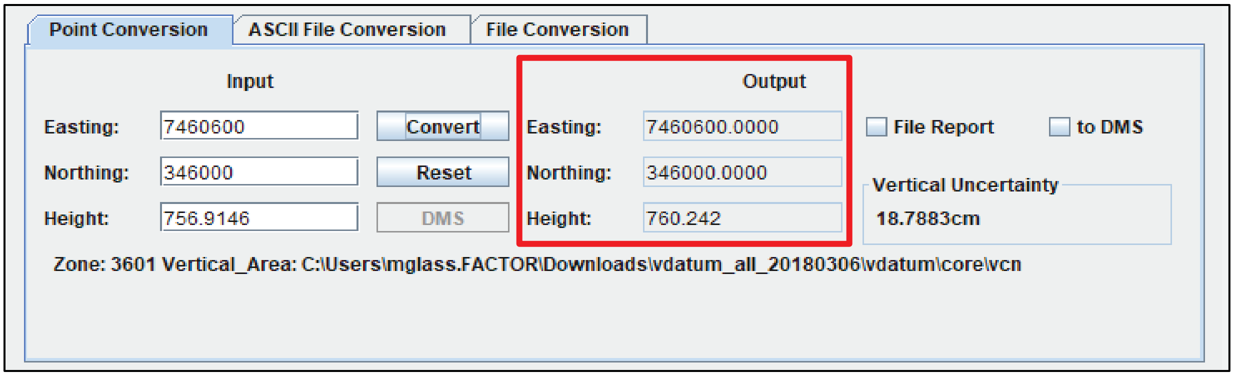


Figure 5-27: Point conversion in Output boxes.

The Northing and Easting Input and Output values should stay the same, while the Output Height value should have been converted. The Output Height in VDatum should match the “Point_Z” value of the identical point in the “Elevation_Point_NAVD88” ArcMap attribute table. In this example, the Output Height in VDatum is 760.242, and the Point_Z value from the ArcMap attribute table is 760.241551. The accuracy of the conversion has been confirmed.

Elevation_Point_NAVD88

	FID	Shape	TYPE	ELEVATION	DATE_PUBLI	DATA_DATE	POINT_X	POINT_Y	POINT_Z	POINT_M
▸	0	Point ZM		756.914662	<Null>	<Null>	7460600	346000	760.241551	0

Figure 5-28: Point_Z from the NAVD88 ArcMap attribute table