Watershed and Stream Network Delineation

Requirements

提交作业图 1-作业图 3 内容

Purpose

The purpose of this exercise is to illustrate, step-by-step, how to use the major functionality available in the Arc Hydro tools for Raster Analysis. In this exercise, the user will perform drainage analysis on a terrain model for the San Marcos Basin. The Arc Hydro tools are used to derive several data sets that collectively describe the drainage patterns of the catchment. Raster analysis is performed to generate data on flow direction, flow accumulation, stream definition, stream segmentation, and watershed delineation. These data will then be used to develop a vector representation of catchments and drainage lines from selected points. The utility of the Arc Hydro tools is demonstrated by applying them to develop attributes that are useful for hydrologic modeling.

Computer and Data Requirements

Data description:

The geodatabase **NHDPlus.mdb** contains data from the National Hydrography Plus dataset. Inside NHDPlus.mdb, we are interested in the NHDFlowline and USGSGage feature classes stored in the Hydrography feature dataset and the Subbasin feature class contained in the HydrologicUnits feature dataset. The folder smdem_raw and associated files smdem_raw.aux, smdem_raw.rrd and files in the INFO folder contains the digital elevation model for this region obtained from the National Elevation dataset. (Remember that in ArcGIS single datasets are often stored in multiple files on the computer and these files should be manipulated using ArcCatalog. If you move the files using the Windows Explorer you may omit one of them and corrupt the data. Following is the ArcCatalog depiction of the data files provided

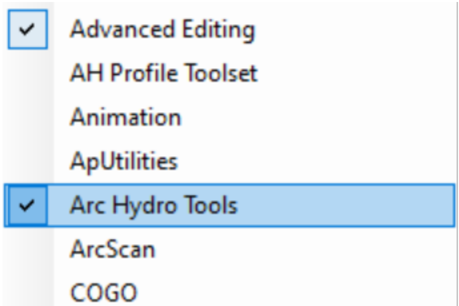
Name	Status	Date modified	Type
INFO	✓	7/21/2023 3:34 PM	File folder
smdem_raw	✓	7/21/2023 3:34 PM	File folder
NHDPlus.mdb	✓	12/14/2016 10:33 PM	Microsoft Access Dat...
smdem_raw.aux	✓	9/15/2004 7:06 PM	AUX File
smdem_raw.aux.xml	✓	11/14/2022 2:26 PM	XML File
smdem_raw.rrd	✓	9/15/2004 7:06 PM	RRD File

Getting Started

Open ArcMap and load Arc Hydro tools

Make sure the Arc Hydro tools are installed on the system.

Open ArcMap. Create a new empty map, and save it as watershed.mxd (or any other name). Right click on the menu bar to pop up the context menu showing available tools as shown below.



You should now see the Arc Hydro tools added to ArcMap as shown below. You can leave it floating or you may dock it in ArcMap.

Note
It is not necessary *to load the Spatial Analyst, Utility Network Analyst, or Editor tools* because Arc Hydro Tools will automatically use their functionality on as needed basis. These toolbars need to be loaded though if you want to use any general functionality that they provide (such as general editing functionality or network tracing).

However, the **Spatial Analyst Extension** needs to be activated, by clicking Customize>Extensions…, and checking the box next to Spatial Analyst.

Dataset Setup

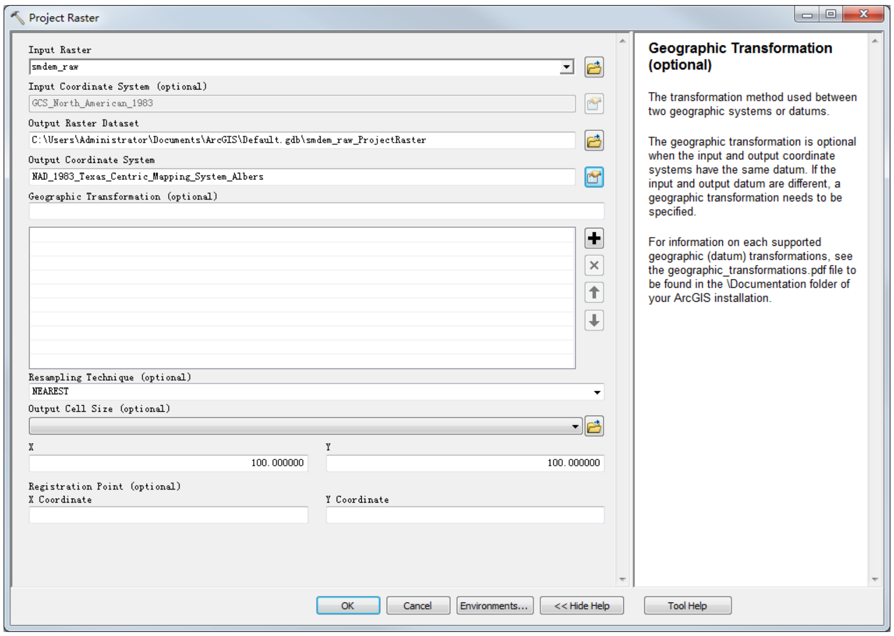
The existing NHDPlus data to be used in this exercise are stored in a geodatabase and loaded in the map. All vector data created with the Arc Hydro tools will be stored in a new geodatabase that has the same name as the stored project or ArcMap document (unless pointed to an existing geodatabase) and in the same directory where the project has been saved. By default, the new raster data are stored in a subdirectory with the same name as the dataset or Data Frame in the ArcMap document (called **Layers** by default and under the directory where the project is stored). The location of the vector, raster, and time series data can be explicitly specified using the function ApUtilities>Set Target Locations.

You can leave the default settings if they are pointing to the same directory where the ArcMap document is saved.

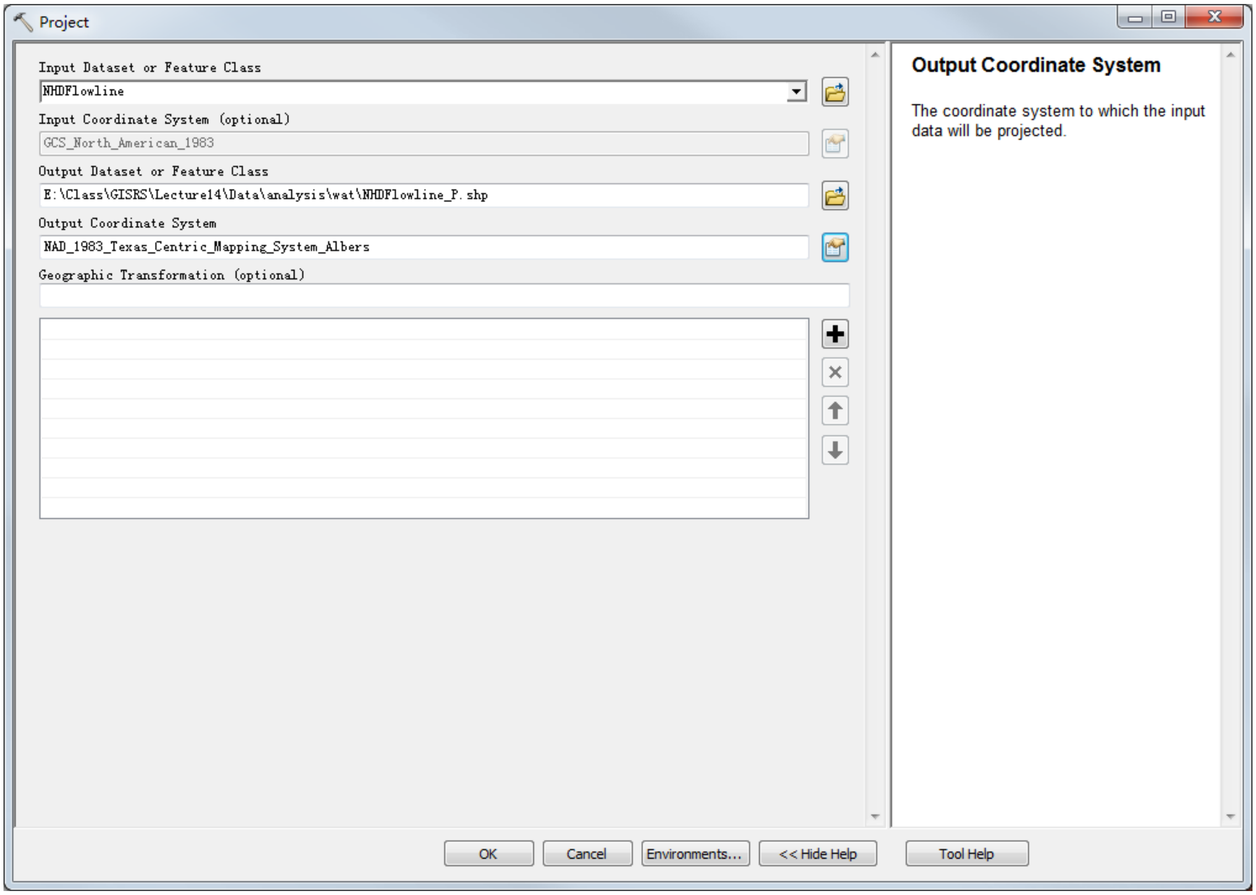
Load the data to ArcMap

Add **smdem_raw** containing the DEM for San Marcos to the map

Open **Project Raster**, The input raster is smdem_raw already added to ArcMap, name the output raster as **smdem**, choose the output coordinate system **NAD 1983 Texas Centric Mapping System Albers.** Adjust the resampling technique to **CUBIC** and the output cell size to **100 m**. (This NED data is at 1 arc second spacing which is close to 30 m, so in general 30 m would be a better choice here, but 100 m is chosen to reduce the size of the resulting grid and speed up data processing.) CUBIC refers to the cubic convolution method that determines the new cell value by fitting a smooth curve through the surrounding points. This works best for a continuous surface like topography at limiting artificial "striping" that can appear in a shaded relief map (see below) with the other methods. Click **OK** to invoke the tool. After the process is complete, the projected DEM, smdem, is added to ArcMap. You can see that the ArcMap



After defining the coordinate system for the map document, add **NHDFlowline** feature class from the Hydrography feature dataset within **NHDPlus.mdb**. The NHDFlowline feature class has geographic coordinate system. Project the NHDFlowline feature class by using the ArcToolbox. Click on **Data Management Tools→Projections and Transformations→Project**. The input feature class is NHDFlowline. Save the output feature class as **NHDFlowline_P** within the NHDPlus.mdb geodatabase, and import a coordinate system from smdem to project the flowlines to the same coordinate system as smdem (**NAD 1983 Texas Centric Mapping System Albers**).



Remove the layers Smdem_raw and NHDFlowline from the ArcMap document. From now on we will work with **projected data** and do not want to inadvertently use the raw data that does not have the correct projection. Save and close the ArcMap document. You are now ready for terrain analysis! (Closing and reopening ArcMap has the effect of making the system "forget" some of the internal information involved with projections that confounds the ArcHydro processing later.)

Set <u>coordinate system of **the Layers**</u> as **NAD 1983 Texas Centric Mapping System Albers** in TOC.

Terrain Preprocessing

Terrain Preprocessing uses the DEM to identify the surface drainage pattern. Once preprocessed, the DEM and its derivatives can be used for efficient watershed delineation and stream network generation.

All the steps in the Terrain Preprocessing menu should be performed in sequential order, from top to bottom. All of the preprocessing must be completed before Watershed Processing functions can be used. DEM reconditioning and filling sinks might not be required depending on the quality of the initial DEM. DEM reconditioning involves modifying the elevation data to be more consistent with the input vector stream network (NHDPlus). This implies an assumption that the stream network data are more reliable than the DEM data, so you need to use knowledge of the accuracy and reliability of the data sources when deciding whether to do DEM reconditioning. By doing the DEM reconditioning you can increase the degree of agreement between stream networks delineated from the DEM and the input vector stream networks.

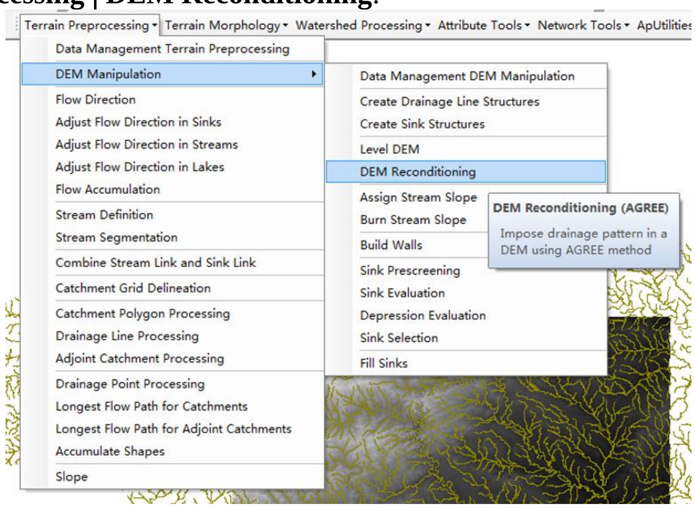
In general you should be aware that some of the terrain processes may take a long time to finish. Processes like DEM Reconditioning, Filling Sinks and Flow accumulation can take 10 to 15 minutes each for a grid with around 4000 x 4000 rows and columns. In this exercise the grid resolution has been degraded to 100 m to expedite the processing.

1. DEM Reconditioning

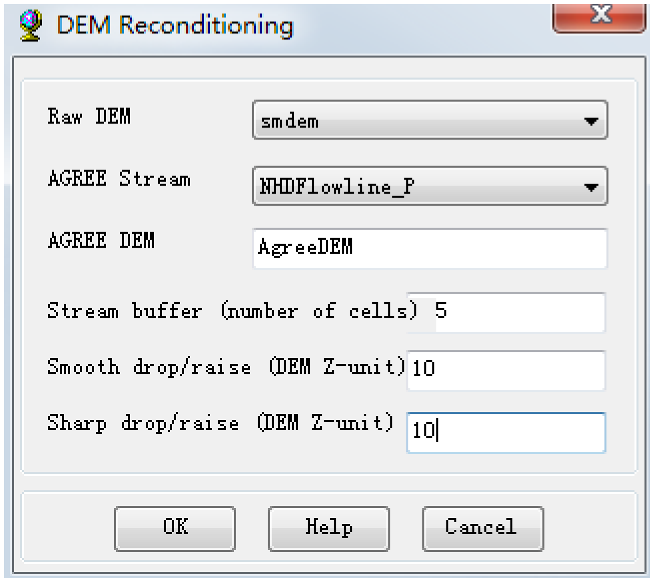
This function modifies a DEM by imposing linear features onto it (burning/fencing). It is an implementation of the AGREE method developed Center for Research in Water Resources at the University of Texas at Austin.

The function needs as input a raw dem and a linear feature class (like the river network) that both have to be present in the map document.

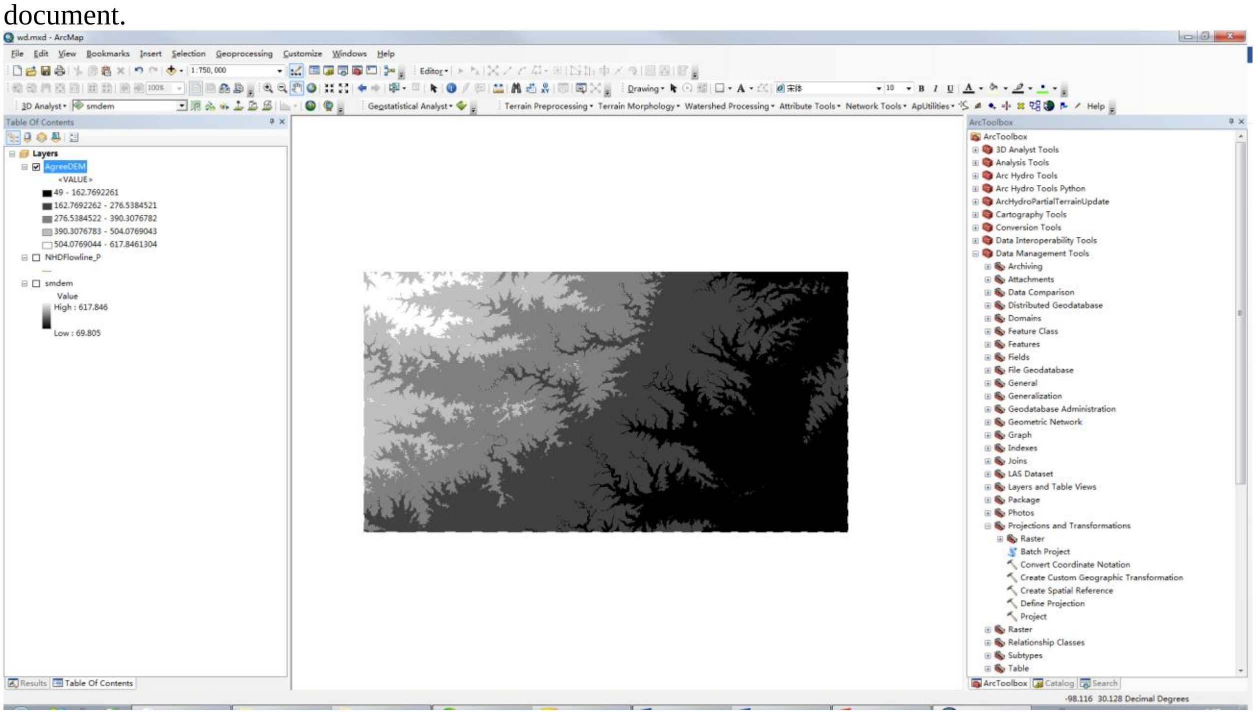
Select **Terrain Preprocessing | DEM Reconditioning**.



Select the appropriate Raw DEM (**smdem**) and AGREE stream feature (**NHDFlowline_P**). Set the Agree parameters as shown. You should reduce the Sharp drop parameter to **10** from its default 1000. The output is a reconditioned Agree DEM (default name AgreeDEM).



If you are curious you can examine what AGREE has done to the DEM. First examine **AgreeDEM properties→Source**. Check that the cellsize and number of rows and columns are the same as the original DEM. If these are changed then Agree has performed some sort of interpolation, which seems to occur if projections have been changed and can be avoided by closing and re-opening the ArcMap document.



Next use 3D analyst to examine profiles across streams. Check that **3D Analyst** is checked under **Customize→Extensions**. Then Activate 3D Analyst on **View→Toolbars**

Use the Interpolate Line and Create Profile Graph tools to examine a profile cross section across a stream.

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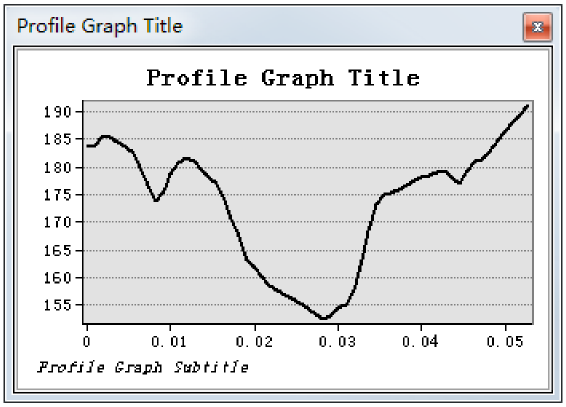
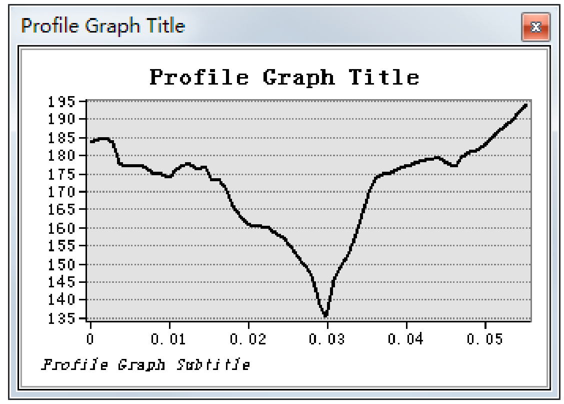




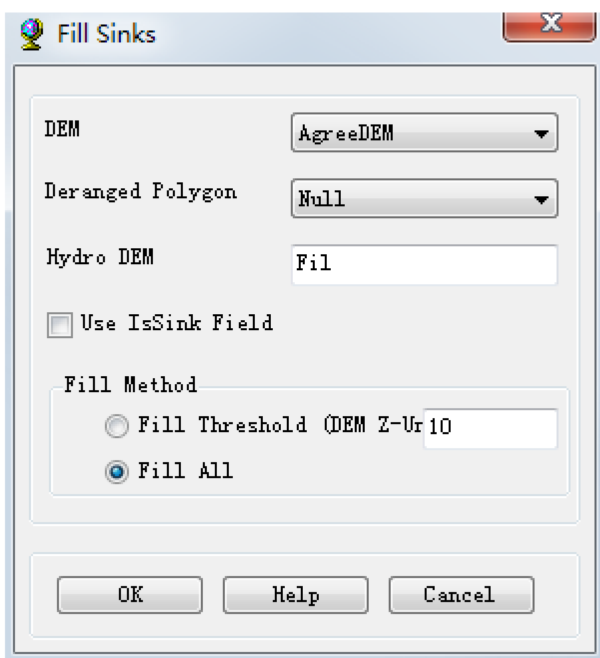
作业图1: Screen captures that illustrate the effect of AGREE DEM Reconditioning. Show the location where you made a cross section as well as the DEM cross sections with and without reconditioning.

2. Fill Sinks

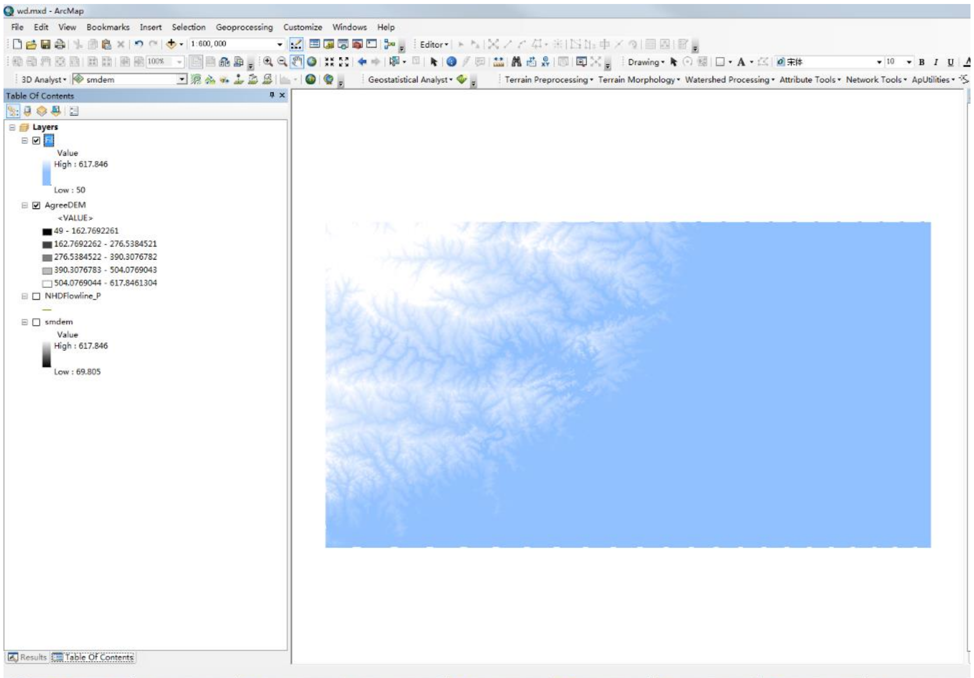
This function fills the sinks in a grid. If cells with higher elevation surround a cell, the water is trapped in that cell and cannot flow. The Fill Sinks function modifies the elevation value to eliminate these problems.

Select **Terrain Preprocessing | DEM Manipulation | Fill Sinks**.

Confirm that the input for DEM is "AgreeDEM" (or your original DEM if Reconditioning was not implemented). The output is the Hydro DEM layer, named by default "Fil". This default name can be overwritten.



Press OK. Upon successful completion of the process, the "Fil" layer is added to the map. This process takes a few minutes.

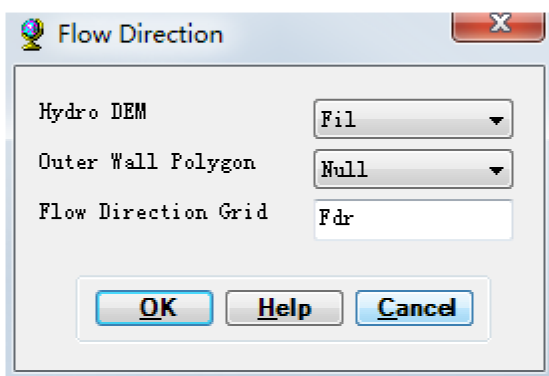


3. Flow Direction

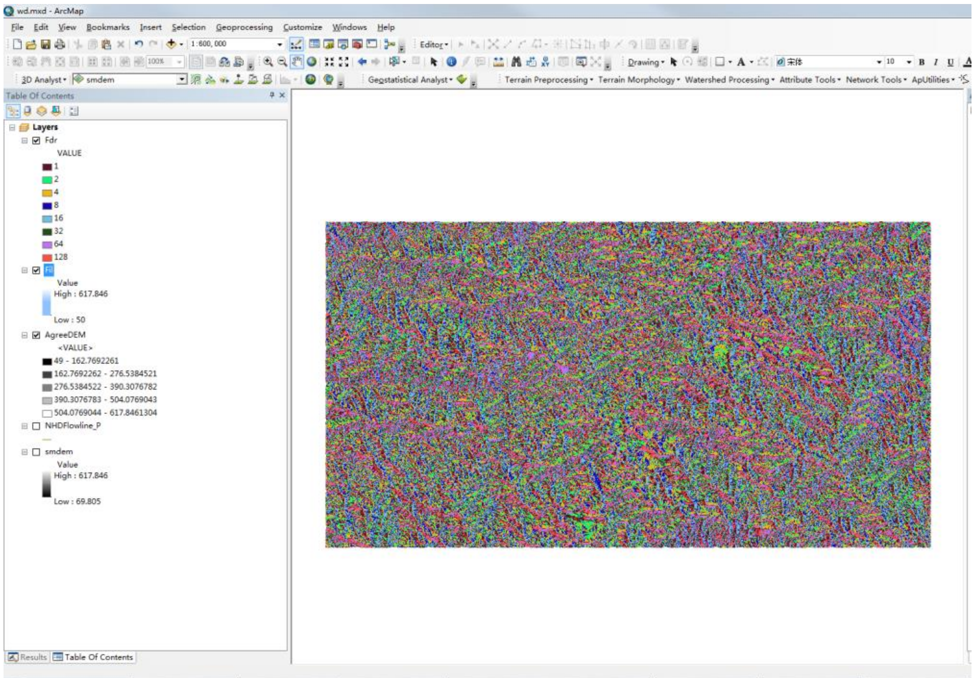
This function computes the flow direction for a given grid. The values in the cells of the flow direction grid indicate the direction of the steepest descent from that cell.

Select **Terrain Preprocessing | Flow Direction**.

Confirm that the input for Hydro DEM is “Fil”. The output is the Flow Direction Grid, named by default “Fdr”. This default name can be overwritten.



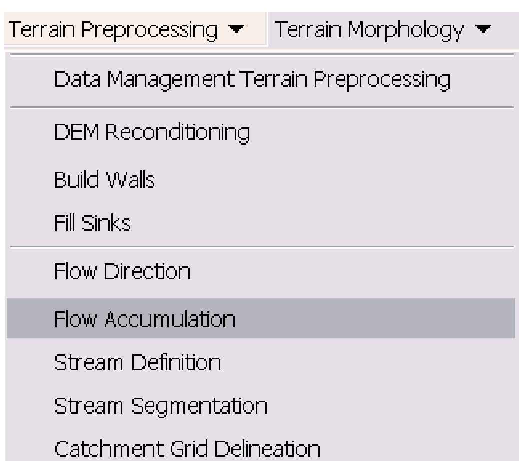
Press OK. Upon successful completion of the process, the flow direction grid “Fdr” is added to the map.



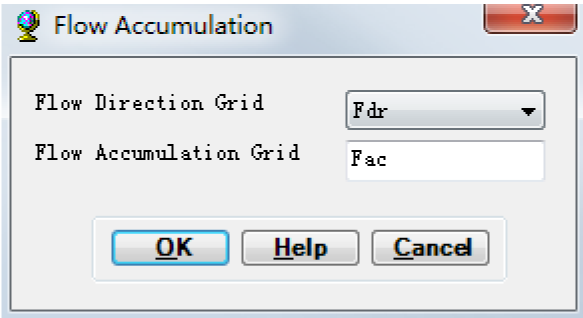
4. Flow Accumulation

This function computes the flow accumulation grid that contains the accumulated number of cells upstream of a cell, for each cell in the input grid.

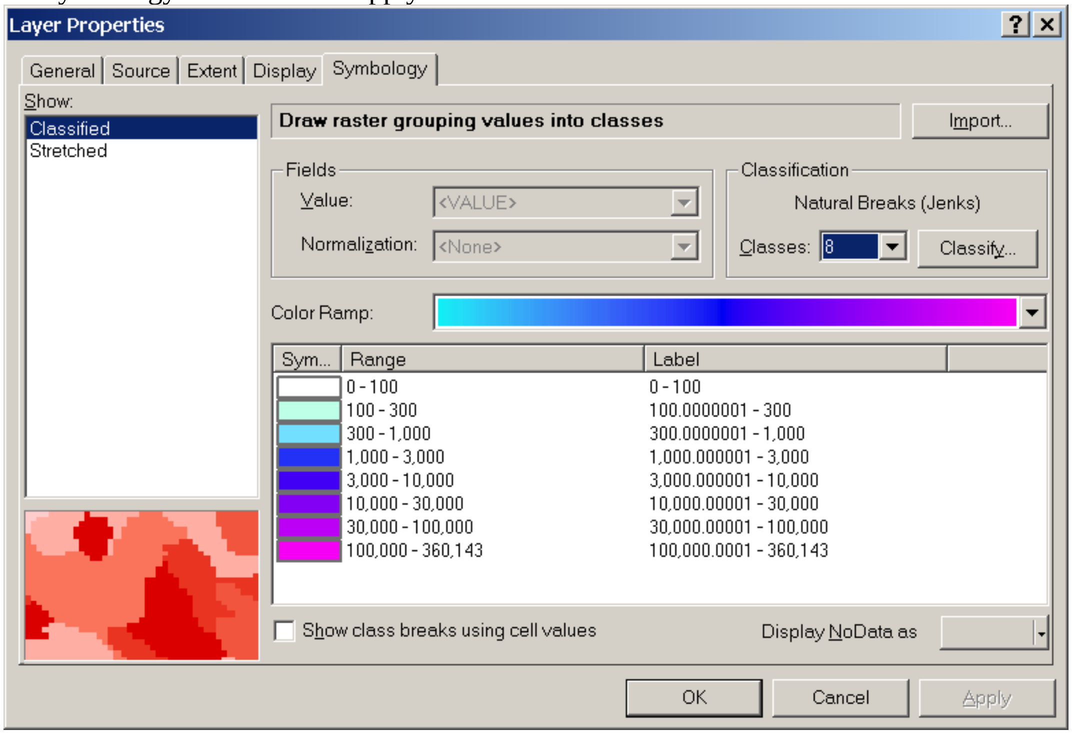
Select **Terrain Preprocessing | Flow Accumulation**.



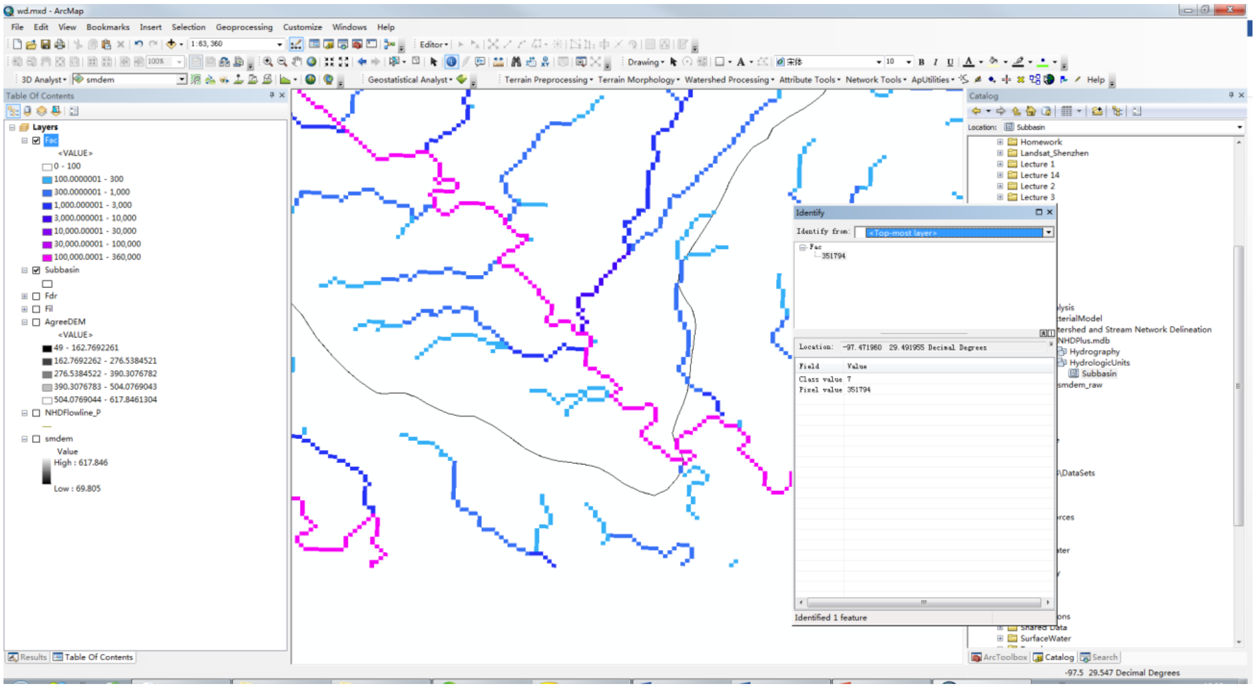
Confirm that the input of the Flow Direction Grid is “Fdr”. The output is the Flow Accumulation Grid having a default name of “Fac” that can be overwritten.



Press OK. Upon successful completion of the process, the flow accumulation grid "Fac" is added to the map. This process may take several minutes for a large grid! Adjust the symbology of the Flow Accumulation layer "Fac" to a multiplicatively increasing scale to illustrate the increase of flow accumulation as one descends into the grid flow network. After applying this layer symbology you may right click on the "Fac" layer and Save As Layer File. The saved Layer File may be imported to retrieve the symbology definition and apply it to other data.

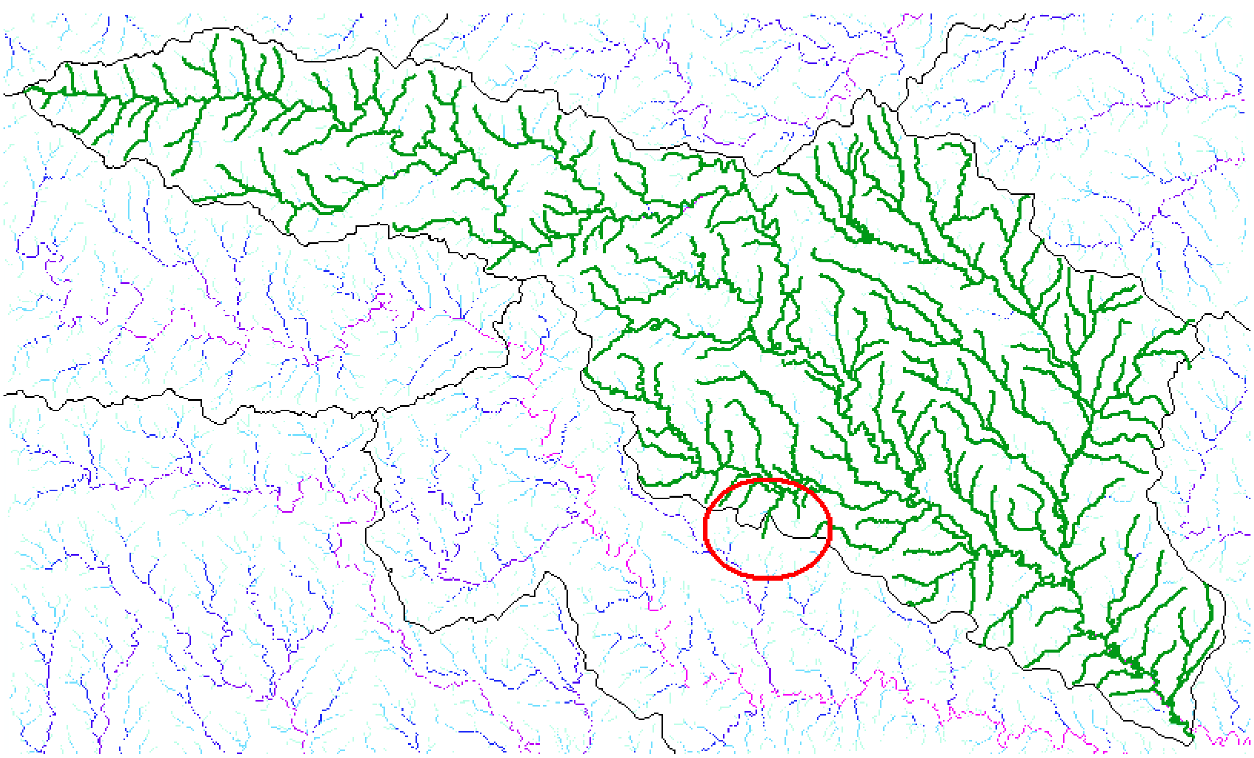


Add the NHDPlus Subbasin feature class from the HydrologicUnits feature dataset in the NHDPlus geodatabase. This shows the outline of the HUC's surrounding the San Marcos basin. Change the symbology so that these are displayed as hollow and zoom in on the outlet in the South West corner. Use the identify tool to determine the value of "Fac" at the point where the main stream exits the area defined by the San Marcos Subbasin polygon. This location is indicated in the following figure.



The value obtained represents the drainage area in number of 100 x 100 m grid cells. Calculate the drainage area in km^2. Notice that the coarseness of the DEM has resulted in some meanders being cut off. The outlet should be identified upstream of this location so as not to "capture" extraneous terrain from outside.

Also examine the southern rim of the basin where there is a NHDPlus stream crossing the NHDPlus subbasin boundary.



Zoom in on this location and use identify to determine the value of "fac" at the point where this small stream "enters" the delineated HUC. Determine the corresponding area in km^2. If we assume that the DEM (from NED) and NHDPlus flowline data is higher quality than the NHDPlus subbasin boundary this indicates an omission of area due to inaccurate delineation of the subbasin boundary.

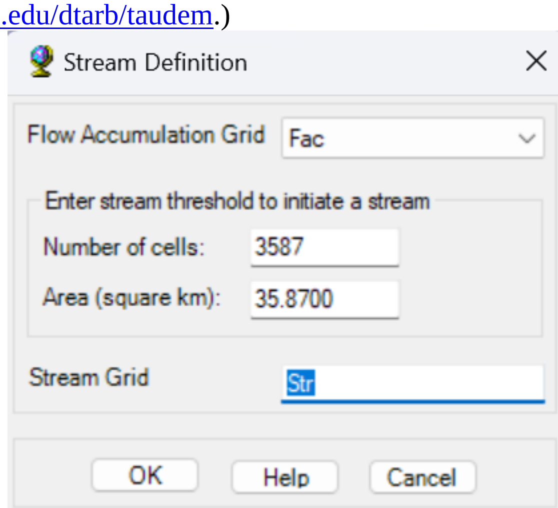
5. Stream Definition

This function computes a stream grid which contains a value of "1" for all the cells in the input flow accumulation grid that have a value greater than the given threshold. All other cells in the Stream Grid contain no data.

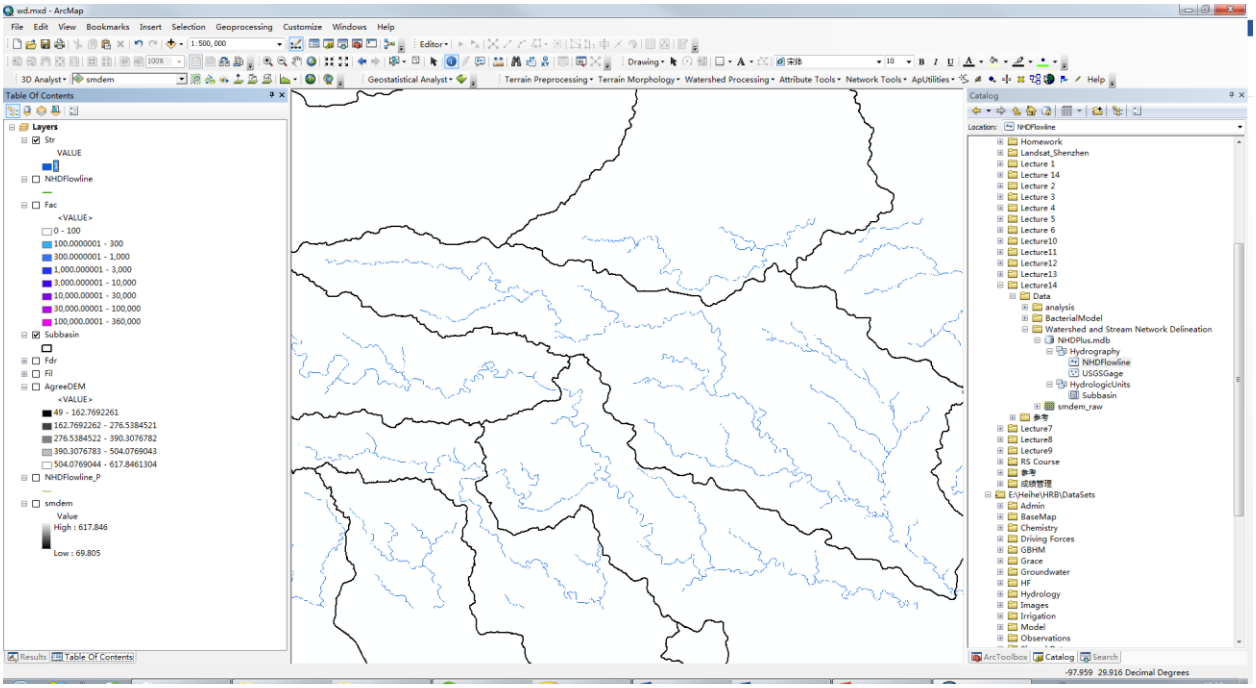
Select **Terrain Preprocessing | Stream Definition.**

Confirm that the input for the Flow Accumulation Grid is “Fac”. The output is the Stream Grid. “Str” is its default name that can be overwritten.

A default value is displayed for the river threshold. This value represents **1%** of the maximum flow accumulation: a simple rule of thumb for stream determination threshold. The threshold drainage area to generate a stream is then 3587 x 100 x 100 / 1000000 = 35.9 km^2. However, any other value of threshold can be selected. A smaller threshold will result in a denser stream network and usually in a greater number of delineated catchments. Objective methods for the selection of the stream delineation threshold to derive the highest resolution network consistent with geomorphological river network properties have been developed and implemented in the TauDEM software (http://www.engineering.usu.edu/dtarb/taudem.)



Press OK. Upon successful completion of the process, the stream grid “Str” is added to the map.

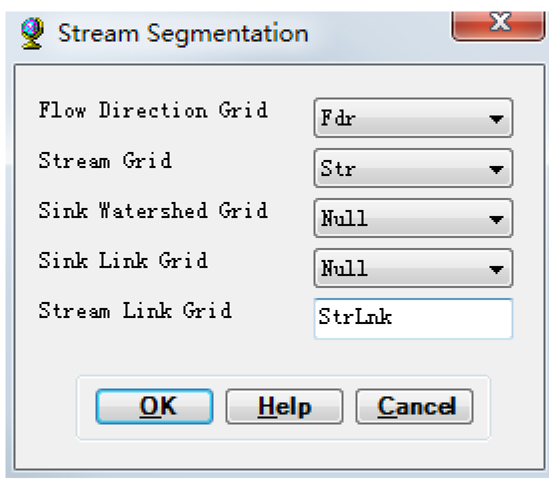


6. Stream Segmentation

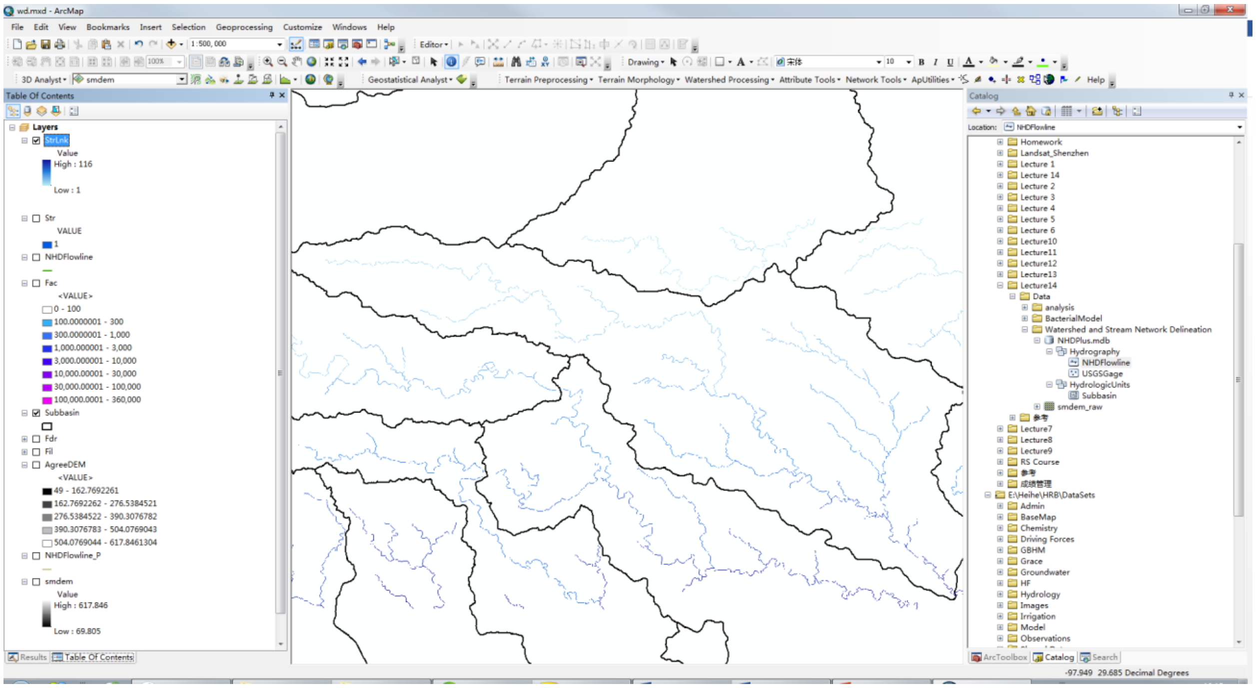
This function creates a grid of stream segments that have a unique identification. Either a segment may be a head segment, or it may be defined as a segment between two segment junctions. All the cells in a particular segment have the same grid code that is specific to that segment.

Select **Terrain Preprocessing | Stream Segmentation.**

Confirm that “Fdr” and “Str” are the inputs for the Flow Direction Grid and the Stream Grid respectively. The output is the Link Grid, with the default name “StrLnk” that can be overwritten.



Press OK. Upon successful completion of the process, the link grid “StrLnk” is added to the map.



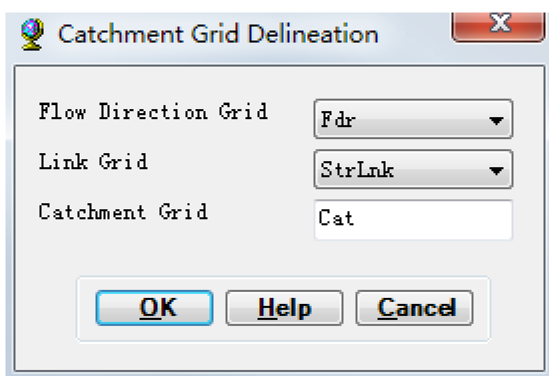
At this point, notice how each link has a separate value.

7. Catchment Grid Delineation

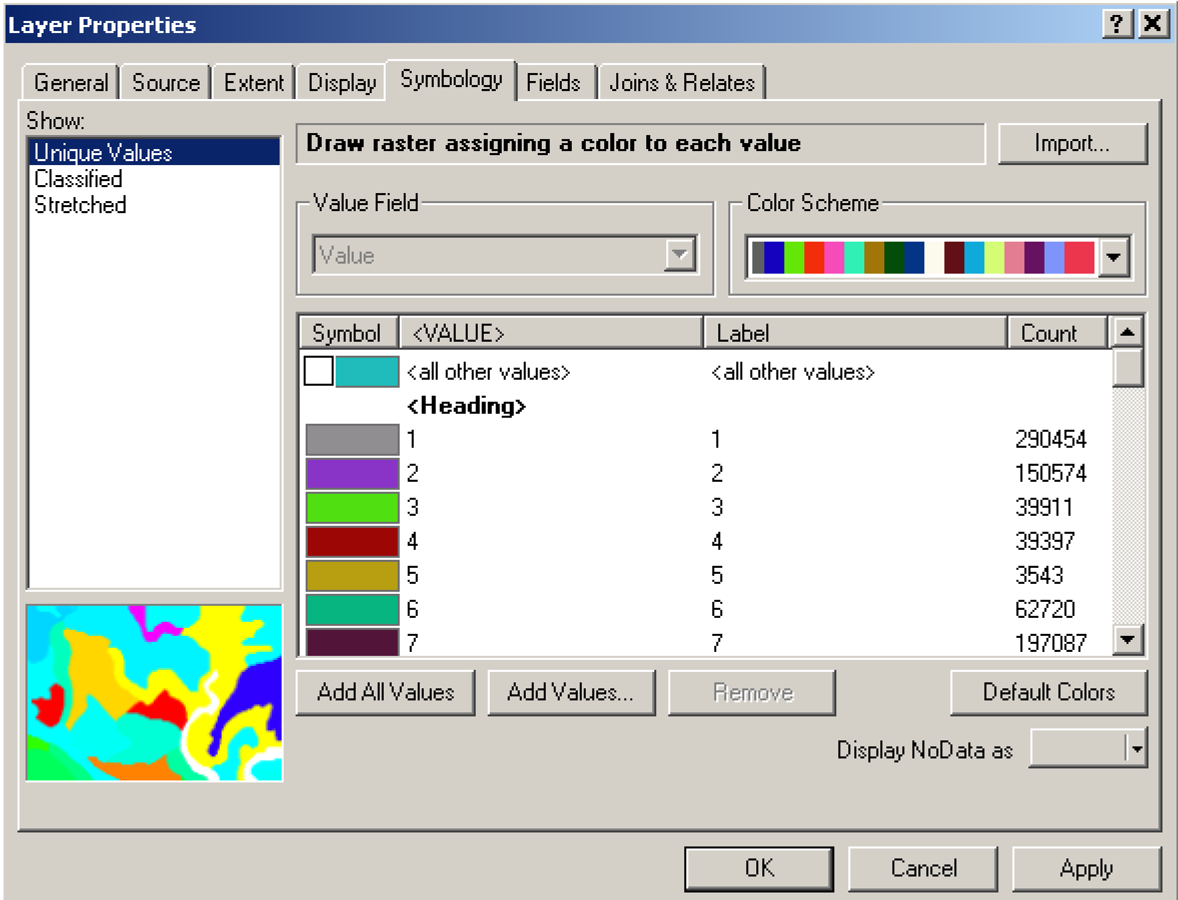
This function creates a grid in which each cell carries a value (grid code) indicating to which catchment the cell belongs. The value corresponds to the value carried by the stream segment that drains that area, defined in the stream segment link grid

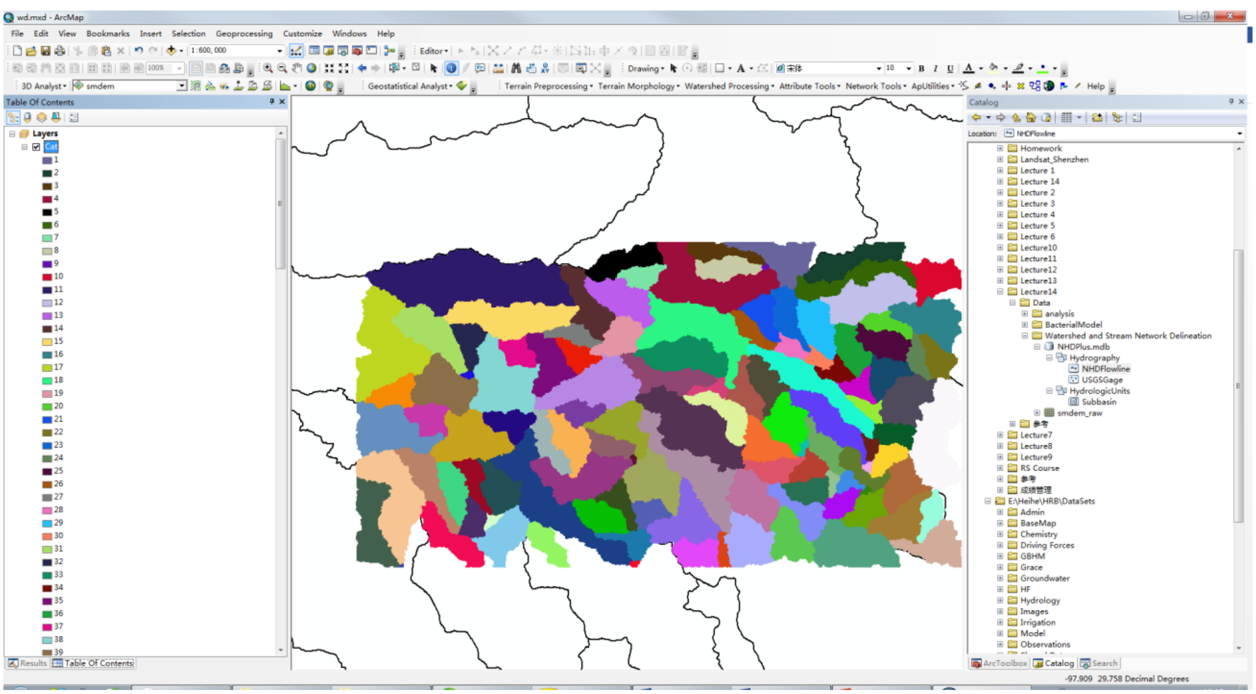
Select **Terrain Preprocessing | Catchment Grid Delineation**.

Confirm that the input to the Flow Direction Grid and Link Grid are “Fdr” and “StrLnk” respectively. The output is the Catchment Grid layer. “Cat” is its default name that can be overwritten by the user.



Press OK. Upon successful completion of the process, the Catchment grid “Cat” is added to the map. You can recolor the grid with unique values to get a nice display.


Layer Properties
General
Source
Extent
Display
Symbology
Fields
Joins & Relates
Show:
Unique Values
Classified
Stretched
Draw raster assigning a color to each value
Import...
Value Field
Value
Color Scheme
Symbol
<VALUE>
Label
Count
<all other values>
<all other values>
<Heading>
1 1 290454
2 2 150574
3 3 39911
4 4 39397
5 5 3543
6 6 62720
7 7 197087
Add All Values
Add Values...
Remove
Default Colors
Display NoData as
OK
Cancel
Apply

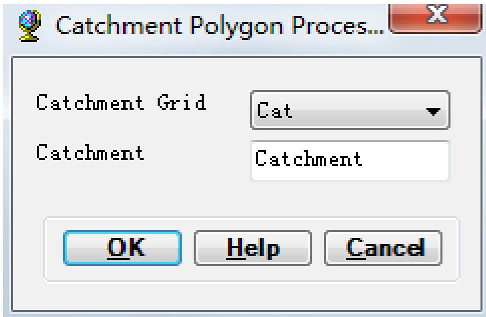


8. Catchment Polygon Processing

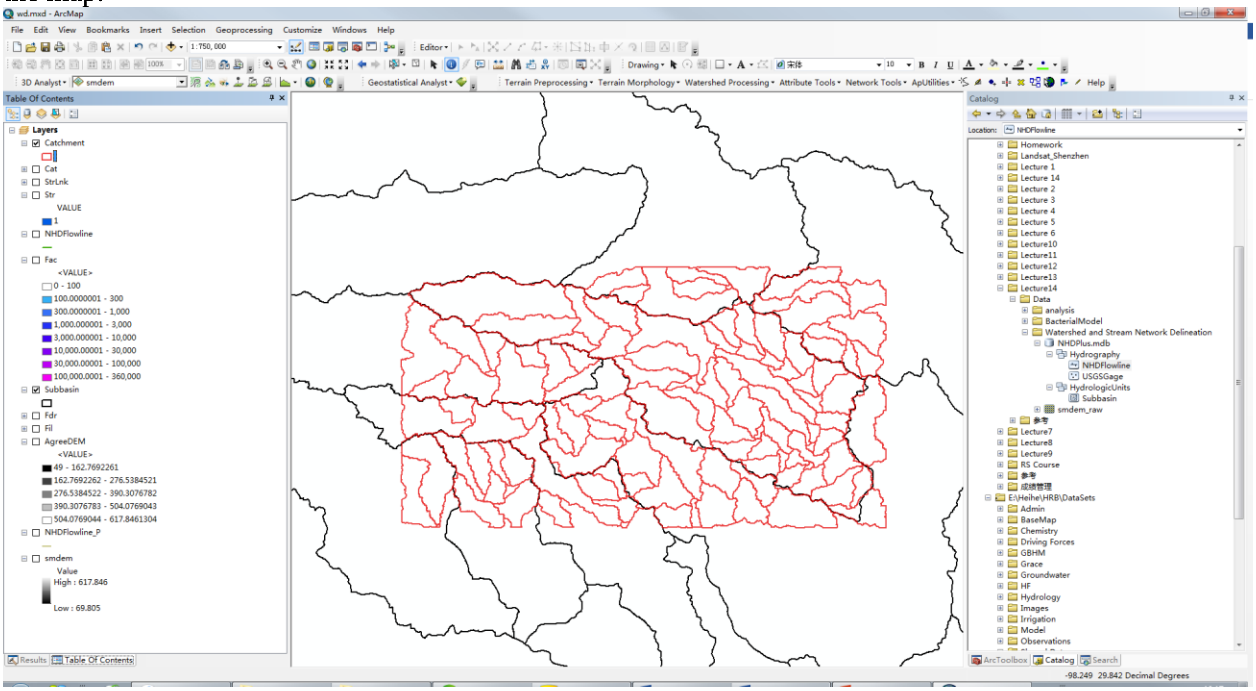
The three functions Catchment Polygon Processing, Drainage Line Processing and Adjoint Catchment Processing convert the raster data developed so far to vector format. The rasters created up to now have all been stored in a folder named "Layers". The vector data will be stored in a feature dataset also named "Layers" within the geodatabase associated with the map document. Unless otherwise specified under APUtilities→Set Target Locations the geodatabase inherits the name of the map document (Ex4.mdb in this case) and the folder and feature dataset inherit their names from the active data frame which by default is named "Layers".

Select **Terrain Preprocessing | Catchment Polygon Processing**.
This function converts a catchment grid into a catchment polygon feature.

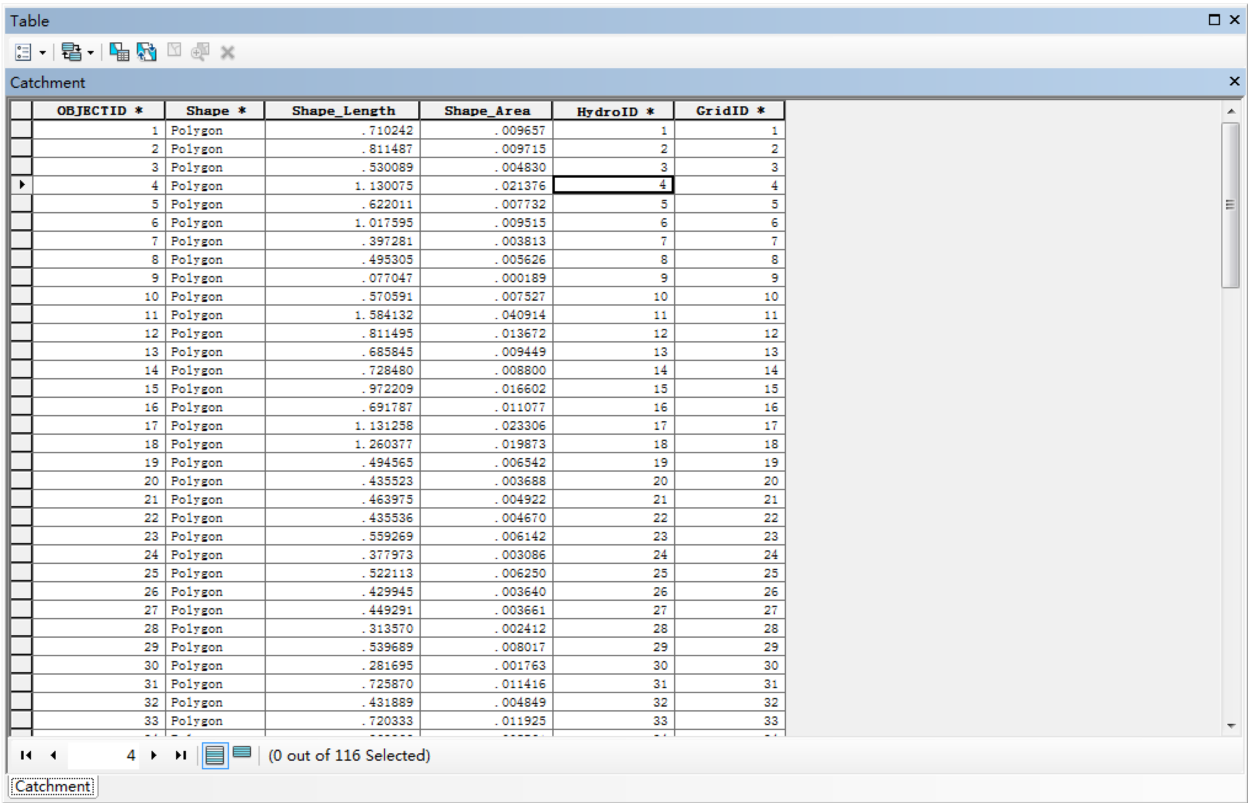
Confirm that the input to the CatchmentGrid is "Cat". The output is the Catchment polygon feature class, having the default name "Catchment" that can be overwritten.



Press OK. Upon successful completion of the process, the polygon feature class "Catchment" is added to the map.



Open the attribute table of "Catchment". Notice that each catchment has a HydroID assigned that is the unique identifier of each catchment within ArcHydro. Each catchment also has Shape Length and Area attributes. These quantities are automatically computed when a feature class becomes part of a geodatabase.



Table

Catchment

OBJECTID *	Shape *	Shape_Length	Shape_Area	HydroID *	GridID *
1	Polygon	.710242	.009657	1	1
2	Polygon	.811487	.009715	2	2
3	Polygon	.530089	.004830	3	3
4	Polygon	1.130075	.021376	4	4
5	Polygon	.622011	.007732	5	5
6	Polygon	1.017595	.009515	6	6
7	Polygon	.397281	.003813	7	7
8	Polygon	.495305	.005626	8	8
9	Polygon	.077047	.000189	9	9
10	Polygon	.570591	.007527	10	10
11	Polygon	1.584132	.040914	11	11
12	Polygon	.811495	.013672	12	12
13	Polygon	.685845	.009449	13	13
14	Polygon	.728480	.008800	14	14
15	Polygon	.972209	.016602	15	15
16	Polygon	.691787	.011077	16	16
17	Polygon	1.131258	.023306	17	17
18	Polygon	1.260377	.019873	18	18
19	Polygon	.494565	.006542	19	19
20	Polygon	.435523	.003688	20	20
21	Polygon	.463975	.004922	21	21
22	Polygon	.435536	.004670	22	22
23	Polygon	.559269	.006142	23	23
24	Polygon	.377973	.003086	24	24
25	Polygon	.522113	.006250	25	25
26	Polygon	.429945	.003640	26	26
27	Polygon	.449291	.003661	27	27
28	Polygon	.313570	.002412	28	28
29	Polygon	.539689	.008017	29	29
30	Polygon	.281695	.001763	30	30
31	Polygon	.725870	.011416	31	31
32	Polygon	.431889	.004849	32	32
33	Polygon	.720333	.011925	33	33

4 (0 out of 116 Selected)

Catchment

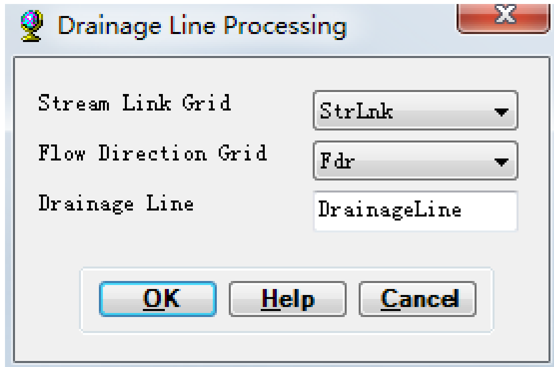
If any catchments are missing Length or Area this would be symptomatic of a problem with the X/Y domain of the feature dataset that ArcHydro created that occurred with earlier versions of Arc Hydro. If this problem occurs for you refer to the appendix for how to correct it.

9. Drainage Line Processing

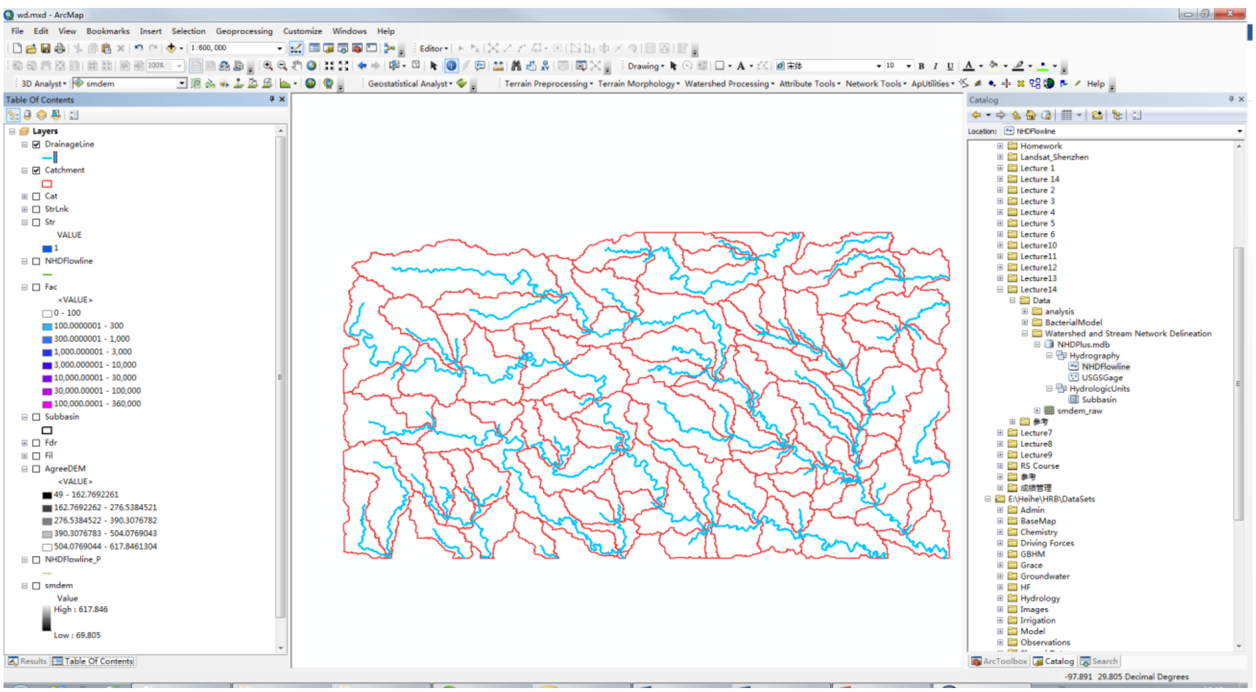
This function converts the input Stream Link grid into a Drainage Line feature class. Each line in the feature class carries the identifier of the catchment in which it resides.

Select **Terrain Preprocessing | Drainage Line Processing**.

Confirm that the input to Link Grid is “Lnk” and to Flow Direction Grid “Fdr”. The output Drainage Line has the default name “DrainageLine”, that can be overwritten.



Press OK. Upon successful completion of the process, the linear feature class “DrainageLine” is added to the map.



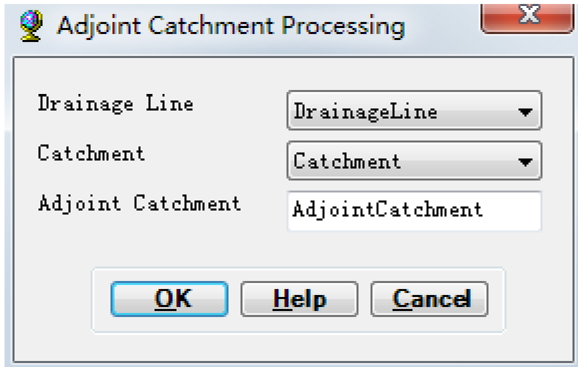
Compare the drainage lines delineated from the DEM procedure with the NHDPlus flowlines.

10. Adjoint Catchment Processing

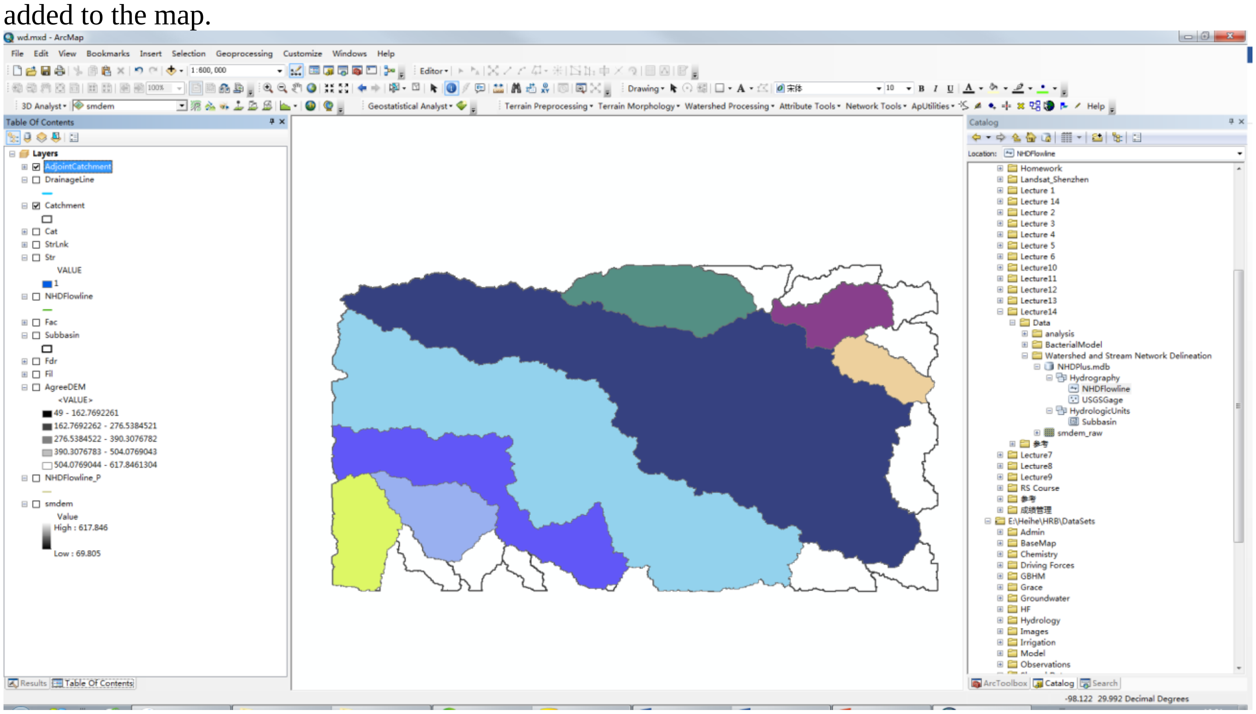
This function generates the aggregated upstream catchments from the "Catchment" feature class. For each catchment that is not a head catchment, a polygon representing the whole upstream area draining to its inlet point is constructed and stored in a feature class that has an "Adjoint Catchment" tag. This feature class is used to speed up the point delineation process.

Select **Terrain Preprocessing | Adjoint Catchment Processing**.

Confirm that the inputs to Drainage Line and Catchment are respectively "DrainageLine" and "Catchment". The output is Adjoint Catchment, with a default name "AdjointCatchment" that can be overwritten.



Press OK. Upon successful completion of the process, the polygon feature class "AdjointCatchment" is added to the map.

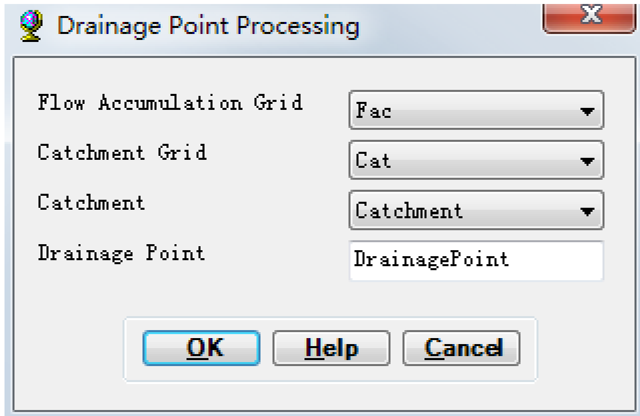


11. Drainage Point Processing

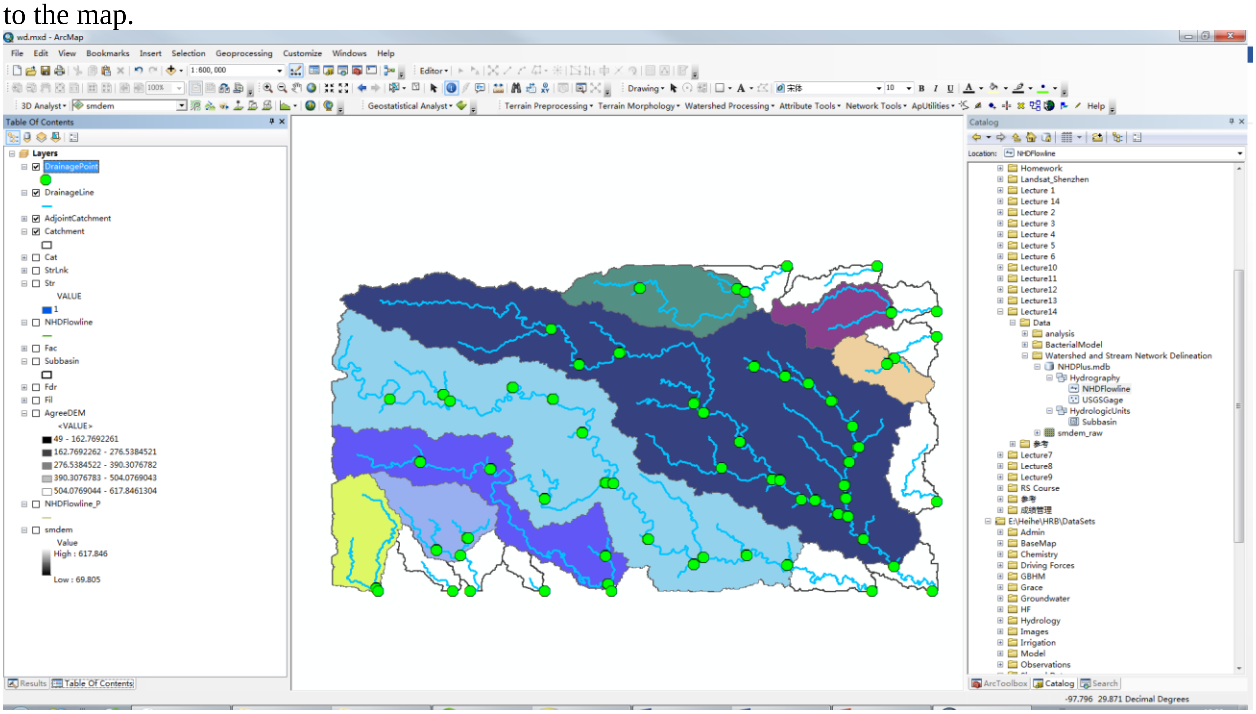
This function allows generating the drainage points associated to the catchments.

Select **Terrain Preprocessing | Drainage Point Processing**.

Confirm that the inputs are as below. The output is Drainage Point, having the default name "DrainagePoint" that can be overwritten.



Press OK. Upon successful completion of the process, the point feature class "DrainagePoint" is added to the map.

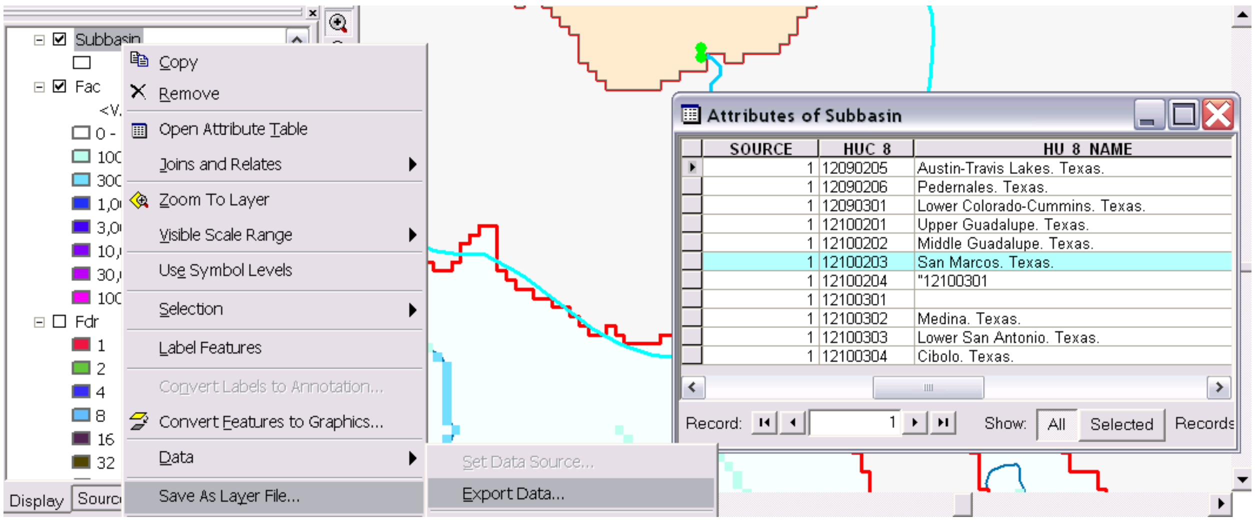


作业图2： *How many DrainagePoints, DrainageLines and Catchments are there? What is the ID field in each feature class that associates the appropriate DrainagePoint with its DrainageLine and Catchment? Make a graphic showing how one associated DrainagePoint, DrainageLine and Catchment are related.*

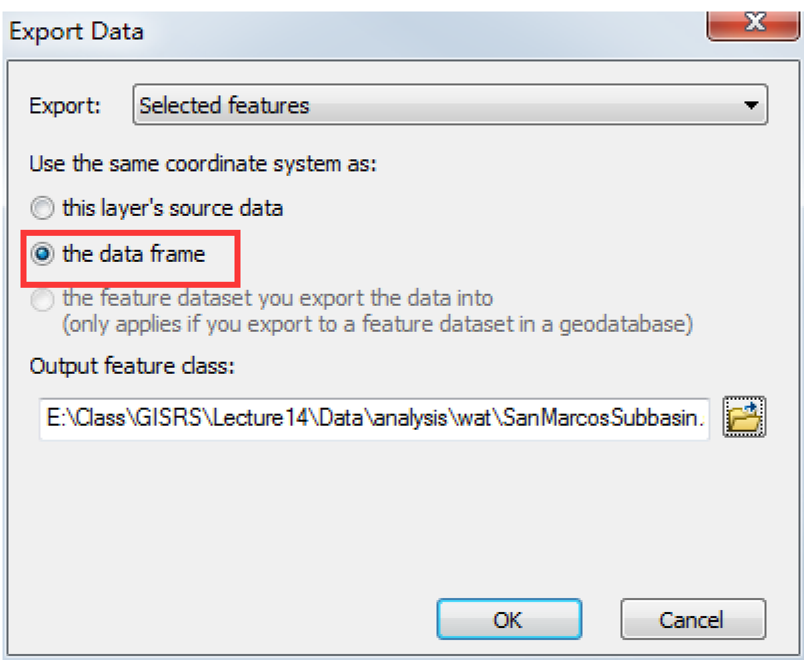
12. Drainage Density Evaluation

Now we will do some analysis to evaluate the drainage density of the San Marcos stream network. Drainage density is a fundamental property in Geomorphology because it specifies the scale where there is a transition from hillslope to channel processes. First we need to determine the drainage area of the San Marcos basin. We have one estimate from the flow accumulation grid above. How does this compare to area of the San Marcos subbasin HUC polygon?

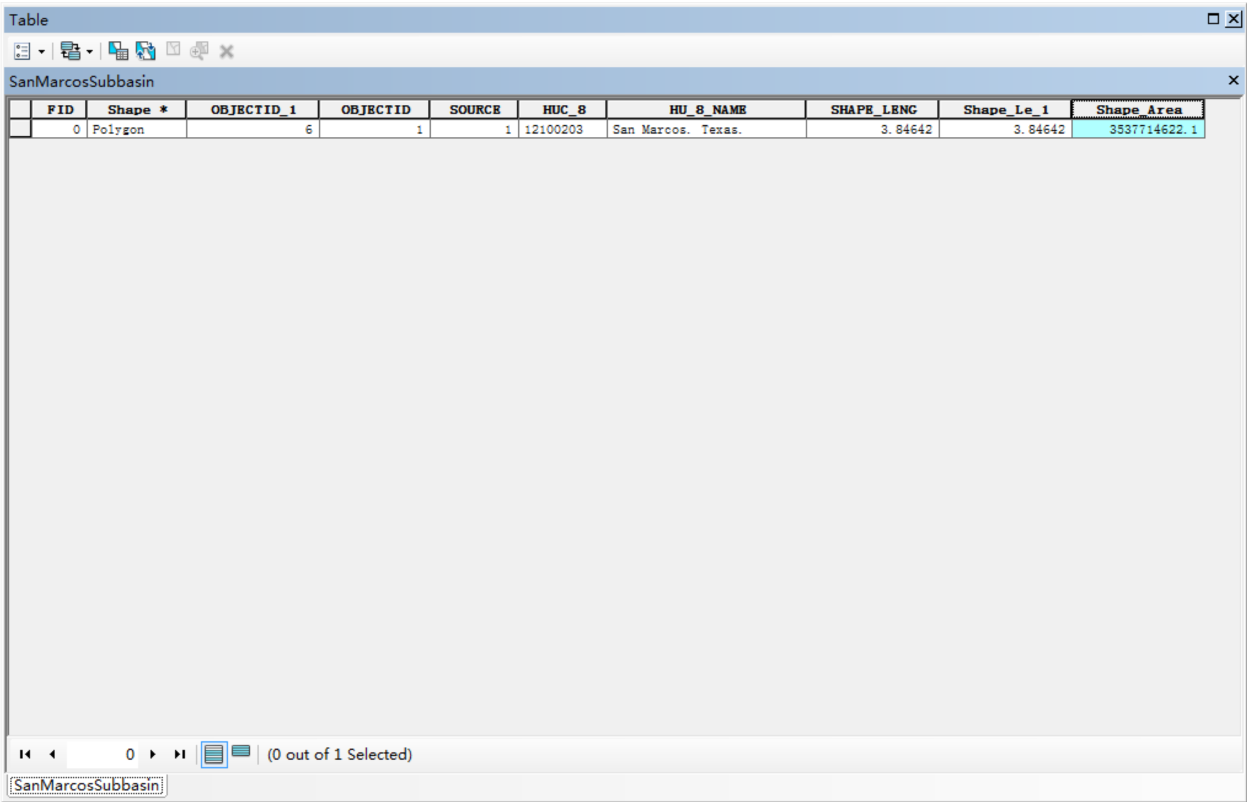
The attribute table of the Subbasin feature class within the HydrologicUnits feature dataset in the NHDPlus geodatabase gives a shape area but the units of this are decimal degrees because the spatial reference of this feature class is geographic coordinates. To evaluate the area of the San Marcos Subbasin select it within the Subbasin feature class then right click on Subbasin in the table of contents and select Data→Export data:



Designate the output feature class as one named **SanMarcosSubbasin**"



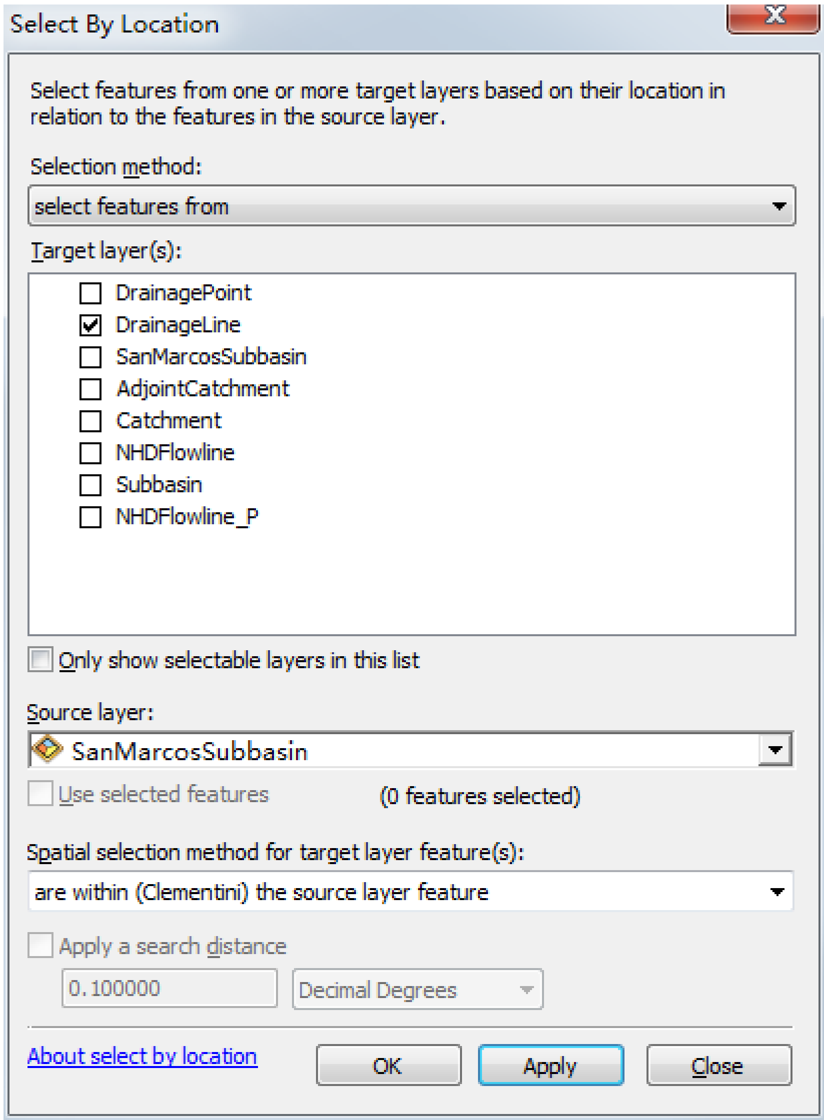
Click OK to add the exported data to the map. Open the attribute table of the feature class "SanMarcosSubbasin". Calculate area for the Shape_Area field. This area is therefore in m^2 and may be compared to the drainage area obtained from flow accumulation. Note this drainage area.



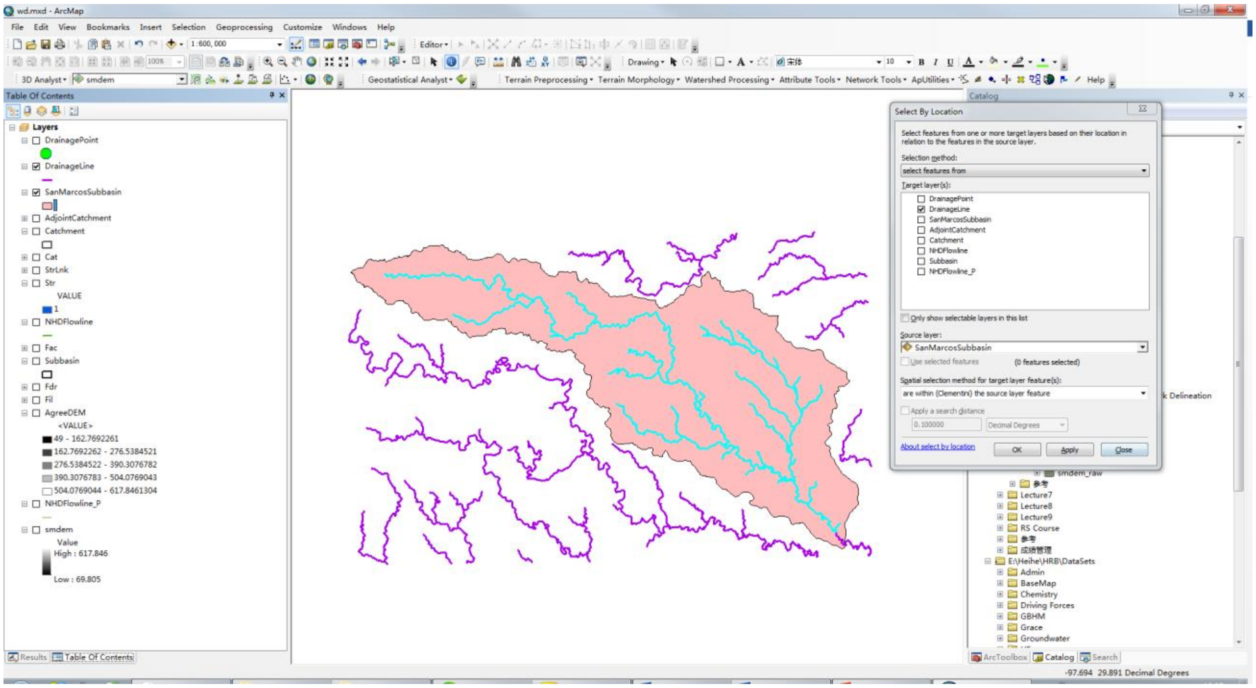
FID	Shape *	OBJECTID_1	OBJECTID	SOURCE	HUC_8	HU_8_NAME	SHAPE_LENG	Shape_Le_1	Shape_Area
0	Polygon	6	1	1	12100203	San Marcos. Texas.	3.84642	3.84642	3537714622.1

Next we'll calculate the length associated with the DrainageLine feature class delineated from the DEM. This feature class includes streams outside the San Marcos basin. To obtain only those features within the San Marcos basin select: **Selection→Select by Location**

Select features from "DrainageLine" that intersect 'SanMarcosSubbasin" in the dialog below:



Click Apply and Close. The DrainageLine features that intersect with the San Marcos subbasin should be selected.



Open the attribute table associated with DrainageLine and Click Show "Selected"

Table

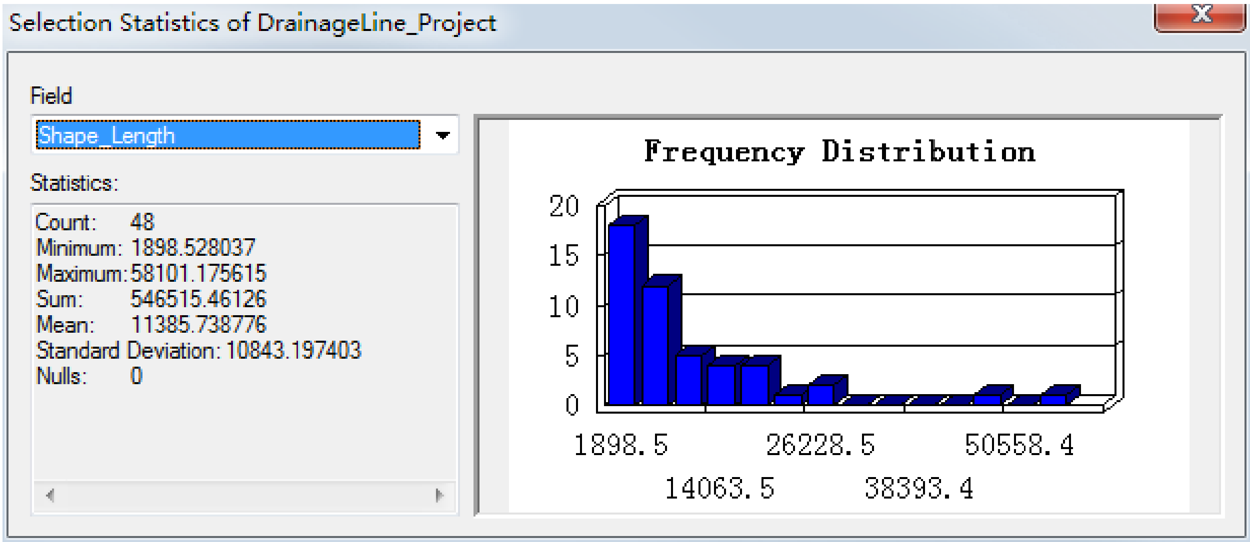
DrainageLine

Shape *	arcid	from_node *	to_node *	HydroID *	GridID *	NextDownID *	DrainID	Shape_Length
Polyline	12	11	17	128	11	135	11	58101.175615
Polyline	13	15	22	129	13	156	13	14386.753361
Polyline	15	20	17	131	15	135	15	26678.53208
Polyline	18	25	28	134	21	142	21	4495.584583
Polyline	19	17	30	135	14	140	14	16609.54526
Polyline	20	32	28	136	26	142	26	2219.238674
Polyline	21	31	30	137	27	140	27	2481.371062
Polyline	24	30	22	140	19	156	19	12532.589839
Polyline	25	21	35	141	23	144	23	8431.118572
Polyline	26	28	35	142	28	144	28	9232.589798
Polyline	27	27	37	143	29	148	29	8461.879515
Polyline	28	35	37	144	30	148	30	7059.798187
Polyline	32	37	44	148	34	161	34	7742.64087
Polyline	33	39	44	149	36	161	36	2967.766882
Polyline	36	38	47	152	33	158	33	18183.809482
Polyline	39	50	47	155	43	158	43	19129.394036
Polyline	40	22	52	156	18	165	18	47277.164164
Polyline	42	47	52	158	49	165	49	3879.899087
Polyline	45	44	56	161	42	167	42	8774.011478
Polyline	46	51	56	162	46	167	46	5202.691052
Polyline	49	52	63	165	48	176	48	16326.703001
Polyline	50	55	63	166	51	176	51	6792.640658
Polyline	51	56	64	167	52	170	52	5911.269684
Polyline	52	53	64	168	50	170	50	10444.72212
Polyline	53	46	67	169	45	180	45	23954.267575
Polyline	54	64	67	170	59	180	59	4869.848835
Polyline	56	60	70	172	55	178	55	10851.828755
Polyline	59	59	70	175	54	178	54	26864.928301
Polyline	60	63	75	176	58	177	58	20479.393977
Polyline	61	75	76	177	69	189	69	2114.213392
Polyline	62	70	75	178	68	177	68	14778.174971
Polyline	64	67	79	180	62	186	62	7418.376253

(48 out of 116 Selected)

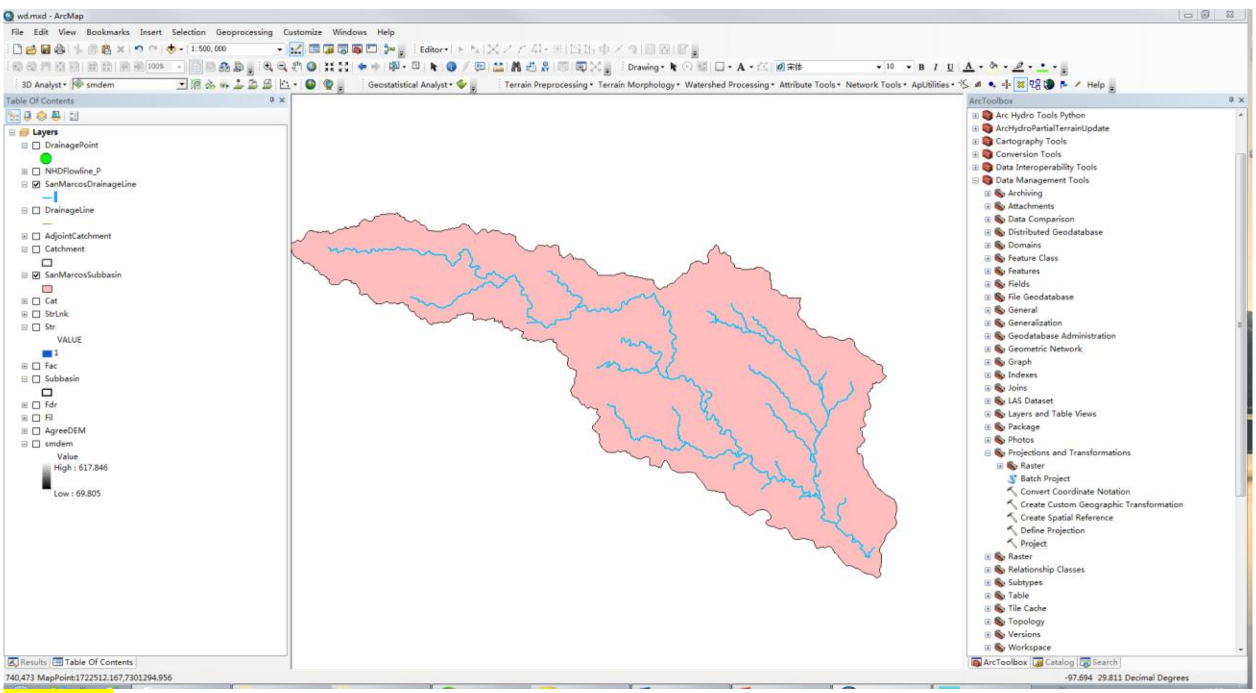
DrainageLine

Right Click on Shape Length and select Statistics. Note the Sum in the statistics that are displayed. This represents the length of DrainageLine features that intersects with the San Marcos subbasin in meters. Note this result.



Export the selected DrainageLine features to a new feature class **SanMarcosDrainageLine** in the Layers feature dataset. Use this for preparing a map of the generated drainage lines for the San Marcos.

Use a similar procedure to select the features from the projected NHDFlowline feature class that intersect with Subbasin and use Statistics on Shape Length to obtain the total length of streams from NHDPlus. Export the selected NHDFlowline features to a new feature class **SanMarcosNHDflowline**. Use this for preparing a **map of the NHD flow lines for the San Marcos Basin**.



作业图 3 **提交 SanMarcos 流域的水系提取图，计算每个 catchment 内的河网密度**