

Digital Elevation Models in GIS

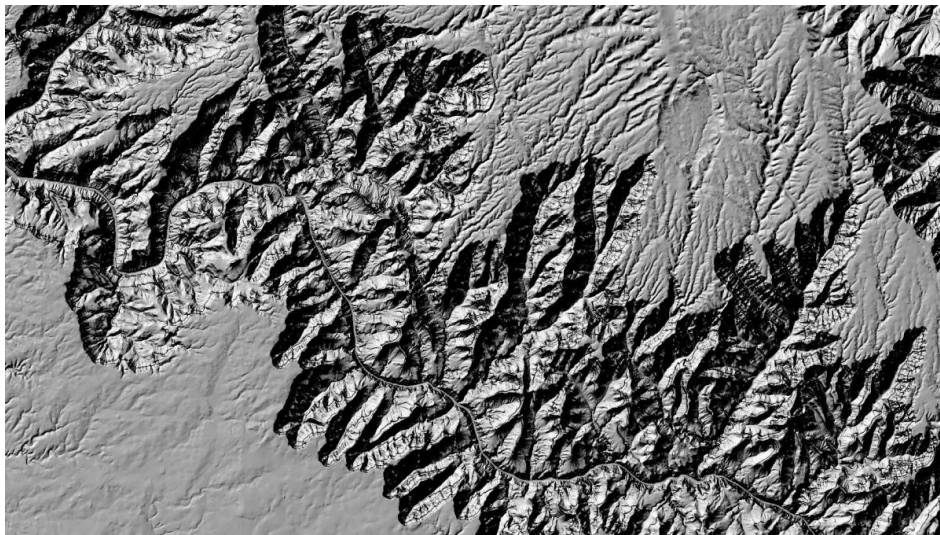
By

Dr. Charalampos (Haris) Skoulikaris

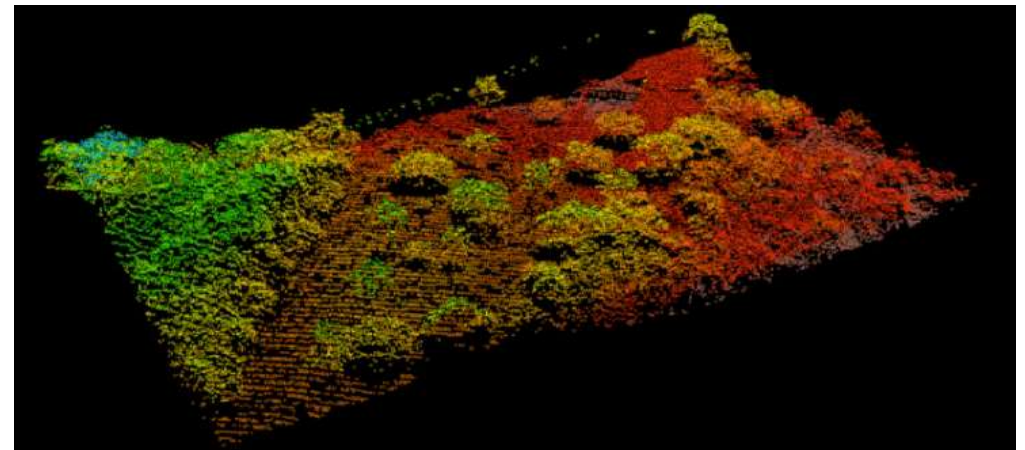
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Friday, 10/12/2021

- ❑ A Digital Elevation Model (DEM) or Digital Terrain Model (DTM) is a representation of the bare ground (bare earth) topographic surface of the Earth excluding trees, buildings, and any other surface objects.
- ❑ A Digital Surface Model (DSM) is an elevation model that captures both the environment's natural and artificial features. It includes e.g., the tops of buildings, trees, powerlines, and any other objects.

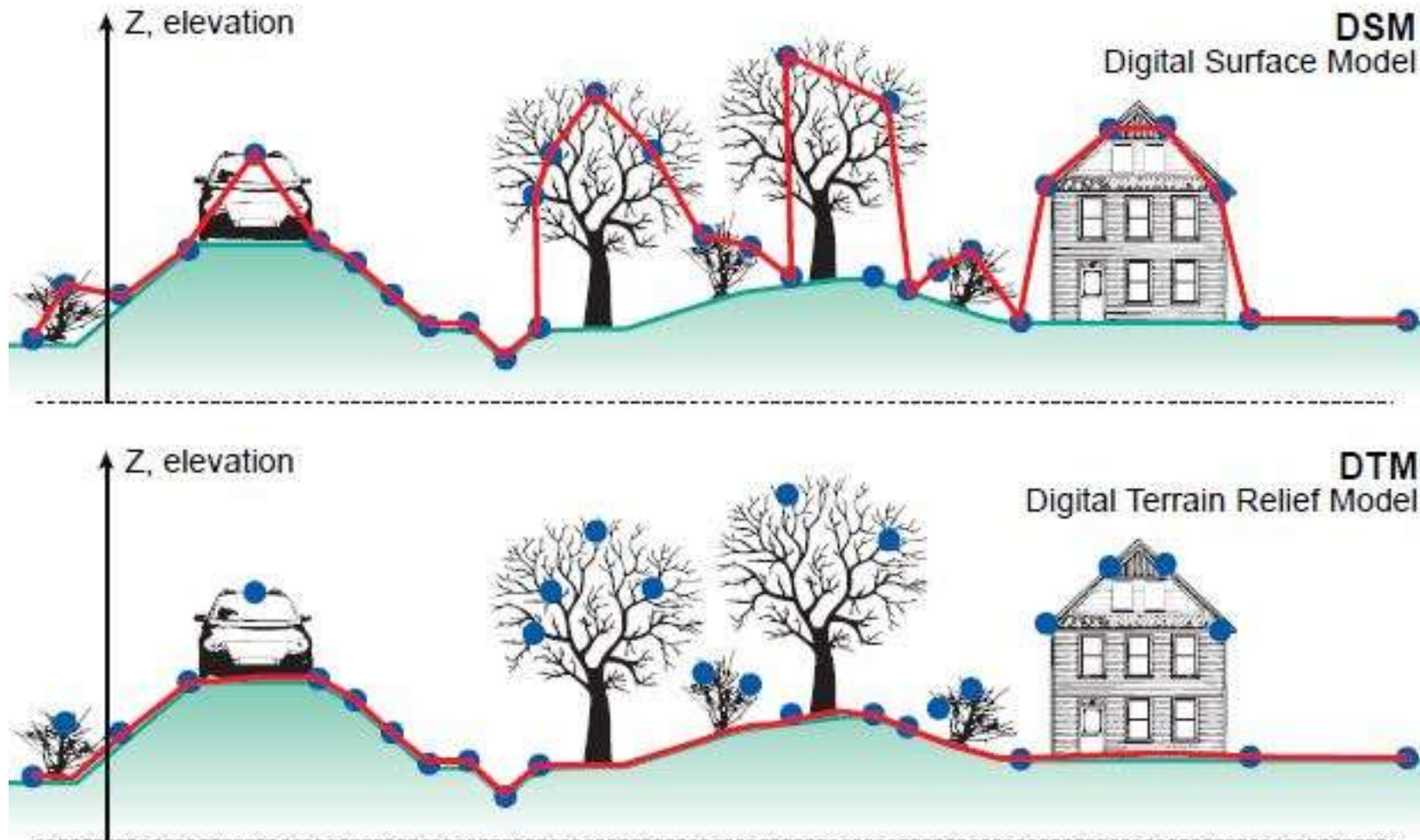


Example of DEM/DTM



Example of DSM

Digital elevation models



The difference between DSM and DTM

Image Source: <https://www.cdema.org/virtuallibrary/index.php/charim-hbook/data-management-book/3-base-data-collection/3-2-digital-elevation-models>

- DEMs can be generated by various field, remote, and laboratory techniques: conventional topographic surveys, kinematic GPS surveys, analogue, radar techniques, laser surveys, and digitizing of contours.

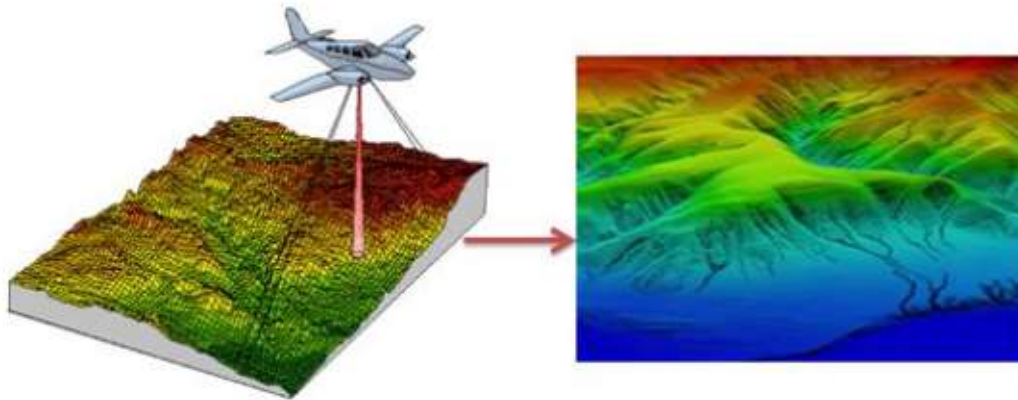
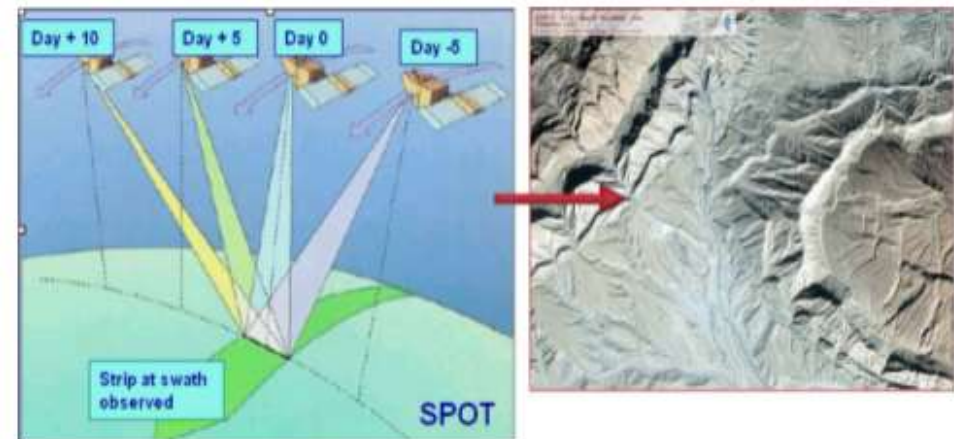


Figure: LiDAR and the DEM

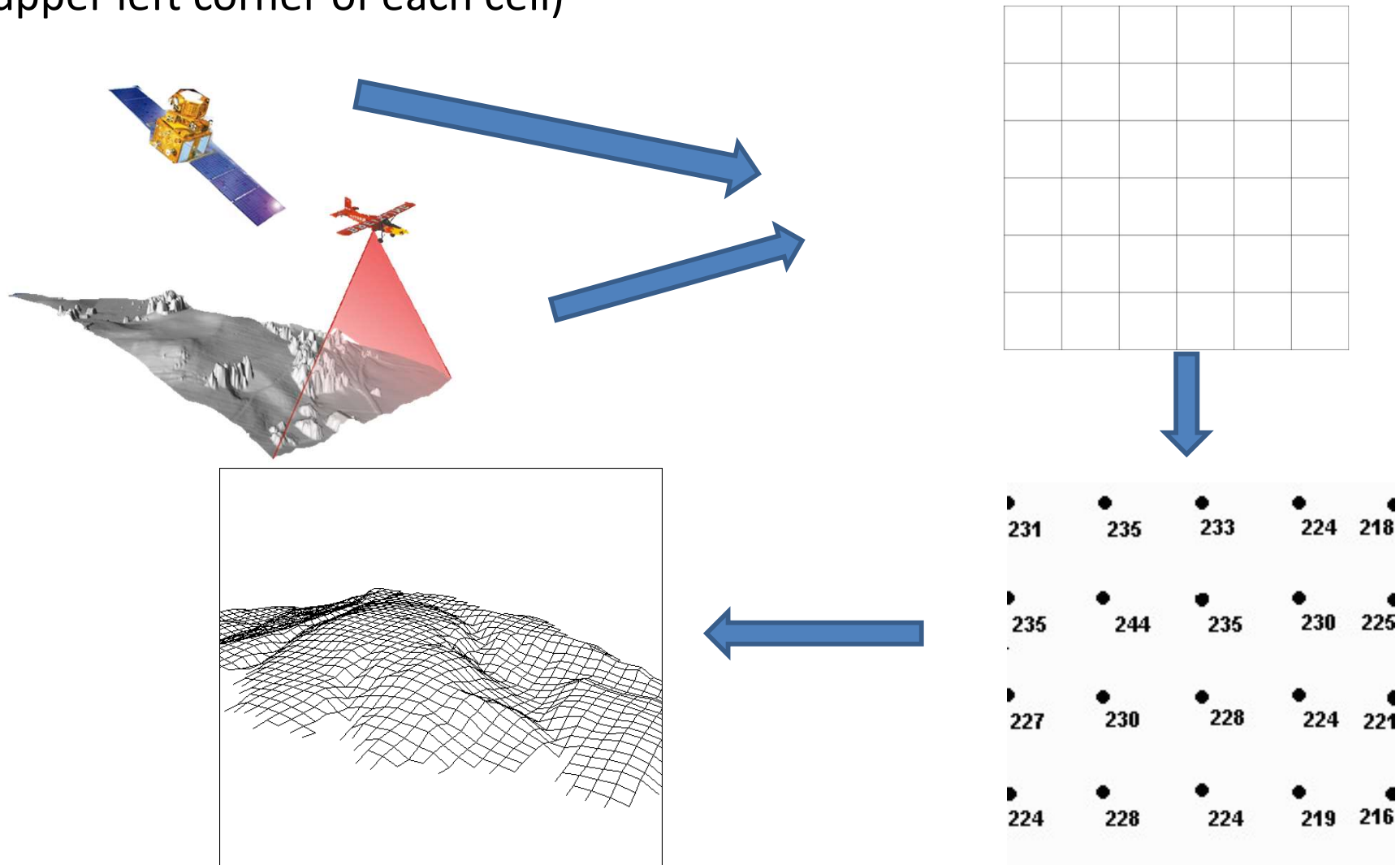
Figure: SPOT 5 Stereo capability and the DEM



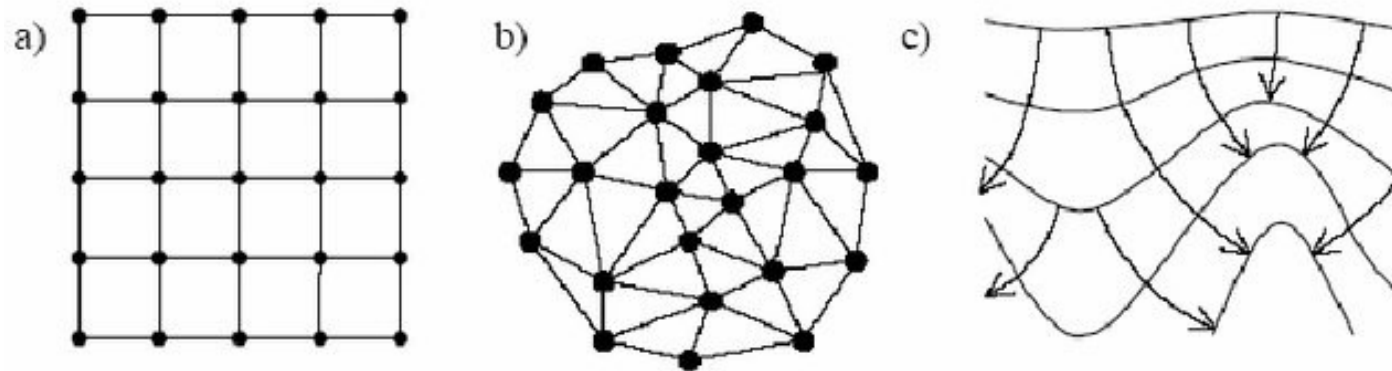
Digital elevation models



DEM: represents to grid formats of the altitude points at specific x,y coordinates and at various resolutions (5m, 30m, 50m, etc.). Each point of the grid (usually the upper left corner of each cell)



The most common type of DEMs:



Typical DEM data structures: a) DEM grid; b) TIN; c) Contours (by Moore et al., 1991).

DEM sources:

- [Earth Science Data Systems \(ESDS\) Program](#)
- [EU Copernicus programme](#)

Digital Terrain Models - DTMs

Data availability

http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available/Elevation_Products

- [Shuttle Radar Topography Mission \(SRTM\) Research Grade](#)

3 arc second (90 meter)

- [Global 30 Arc-Second Elevation Dataset \(GTOPO30\)](#)

Global 1-km

Geospatial Hydrologic Modeling System GeoHMS

**U.S. Army Corps of Engineers (USACE) Hydrologic
Engineering Center (HEC)**

- HEC-HMS: Hydrologic Modeling System

<http://www.hec.usace.army.mil/software/hec-hms/>

- HEC-GeoHMS: Geospatial HMS

<http://www.hec.usace.army.mil/software/hec-geohms/index.html>

GeoHMS: A cascade of GIS based tools



1. Arc Hydro Tools (ESRI)
2. HEC-GeoHMS Main View (USAGE)
3. HEC-GeoHMS Project View (USAGE)

DEMs in ArcGIS



File Edit View Bookmarks Insert Selection Tools Window Help

Editor Task: Create New Feature Target: Georeferencing Layer: Z_41_4.ASC

HMS Project Setup Help Terrain Preprocessing Terrain Morphology Watershed Processing Attribute Tools Network Tools ApUtilities Basin Processing Basin Characteristics Hydrologic Parameters HMS Utility Help

Layers

- Fil
- Z_41_4.ASC
 - Value
 - High : 2147483647
 - Low : -2147483648

The main map area displays a dark gray Digital Elevation Model (DEM) with a white, irregularly shaped area at the bottom right corner, likely representing a water body or a specific terrain feature. The map is surrounded by a standard GIS interface with various toolbars and a status bar at the bottom.

Display Source Selection

22.875 39.803 Decimal Degrees

DEM: Fill Sinks

The screenshot displays the ArcMap interface with the following components:

- Menu Bar:** File, Edit, View, Bookmarks, Insert, Selection, Tools, Window, Help.
- Toolbars:** Standard toolbar, Editor toolbar, and a secondary toolbar with various processing tools.
- Taskbar:** Shows the current task as 'Create New Feature' and the target layer as 'Z_41_4.ASC'.
- Layers Panel:** Lists the following layers:
 - Fill (Value: High: 2915, Low: -22)
 - Z_41_4.ASC (Value: High: 2147483647, Low: -2147483648)
- Tool Menu:** The 'DEM Manipulation' menu is open, showing the 'Fill Sinks' tool selected. Other options include:
 - Data Management DEM Manipulation
 - Level DEM
 - DEM Reconditioning
 - Assign Stream Slope
 - Burn Stream Slope
 - Build Walls
 - Sink Prescreening
 - Sink Evaluation
 - Depression Evaluation
 - Sink Selection
- Map Area:** A grayscale DEM is displayed with a white-filled sink at the bottom right.
- Status Bar:** Shows coordinates: 18.232 42.306 Decimal Degrees.

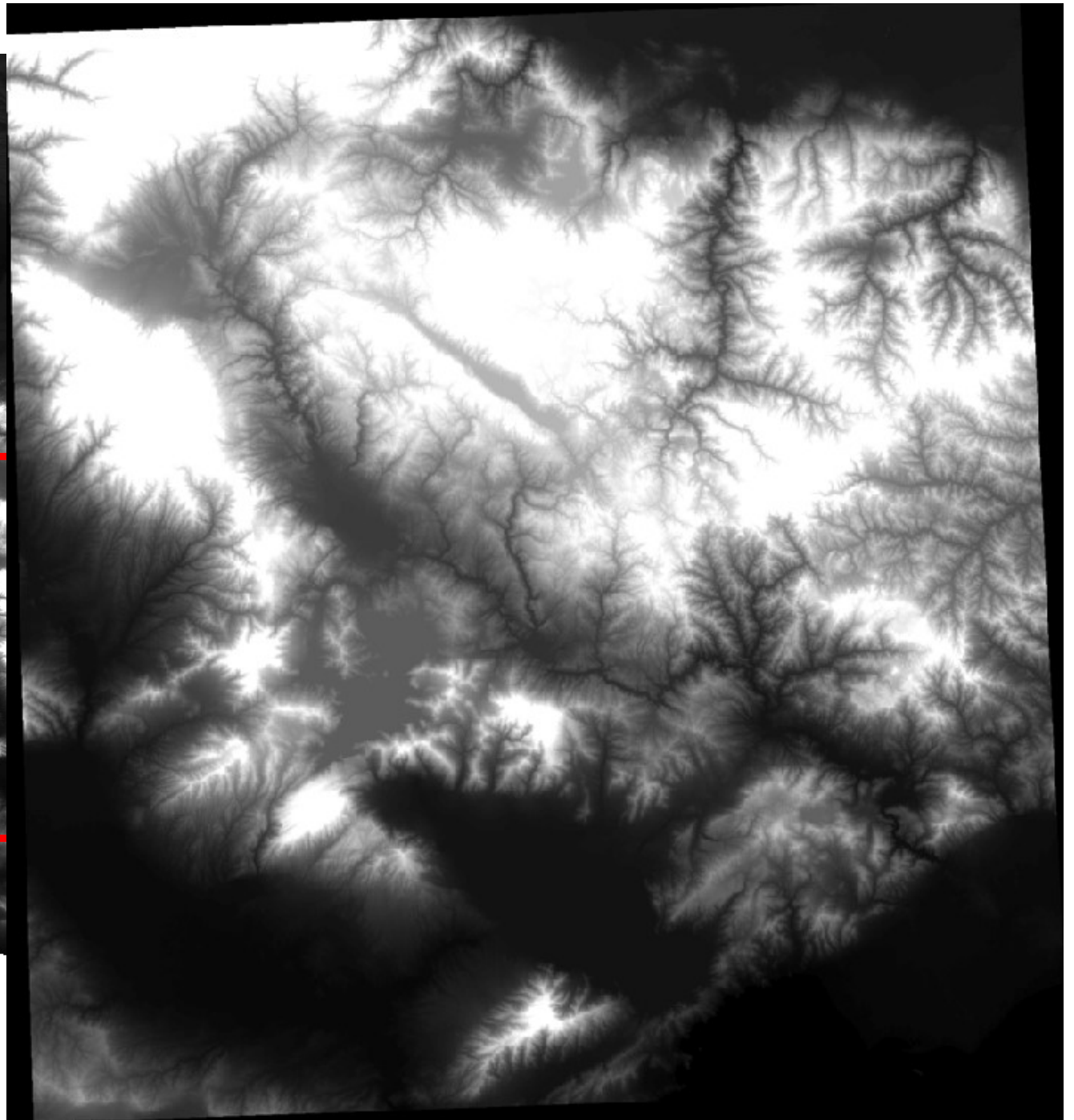
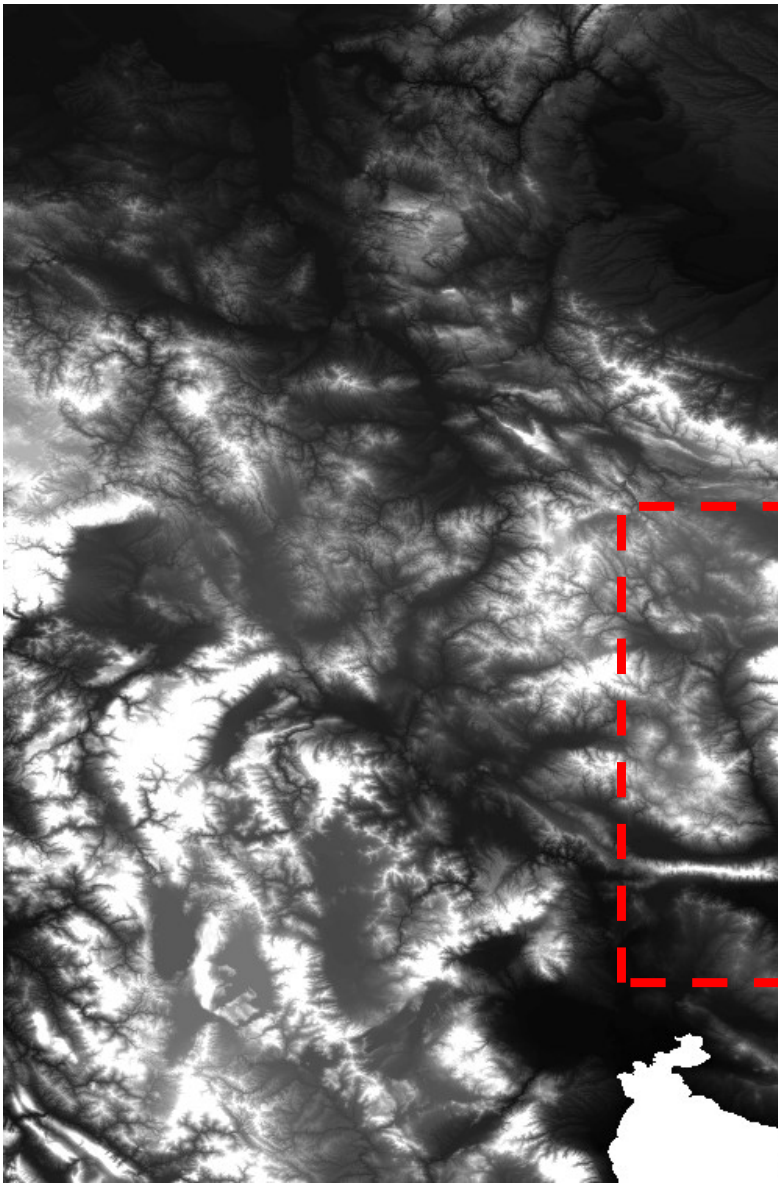
Fill sinks in a DEM

18.232 42.306 Decimal Degrees

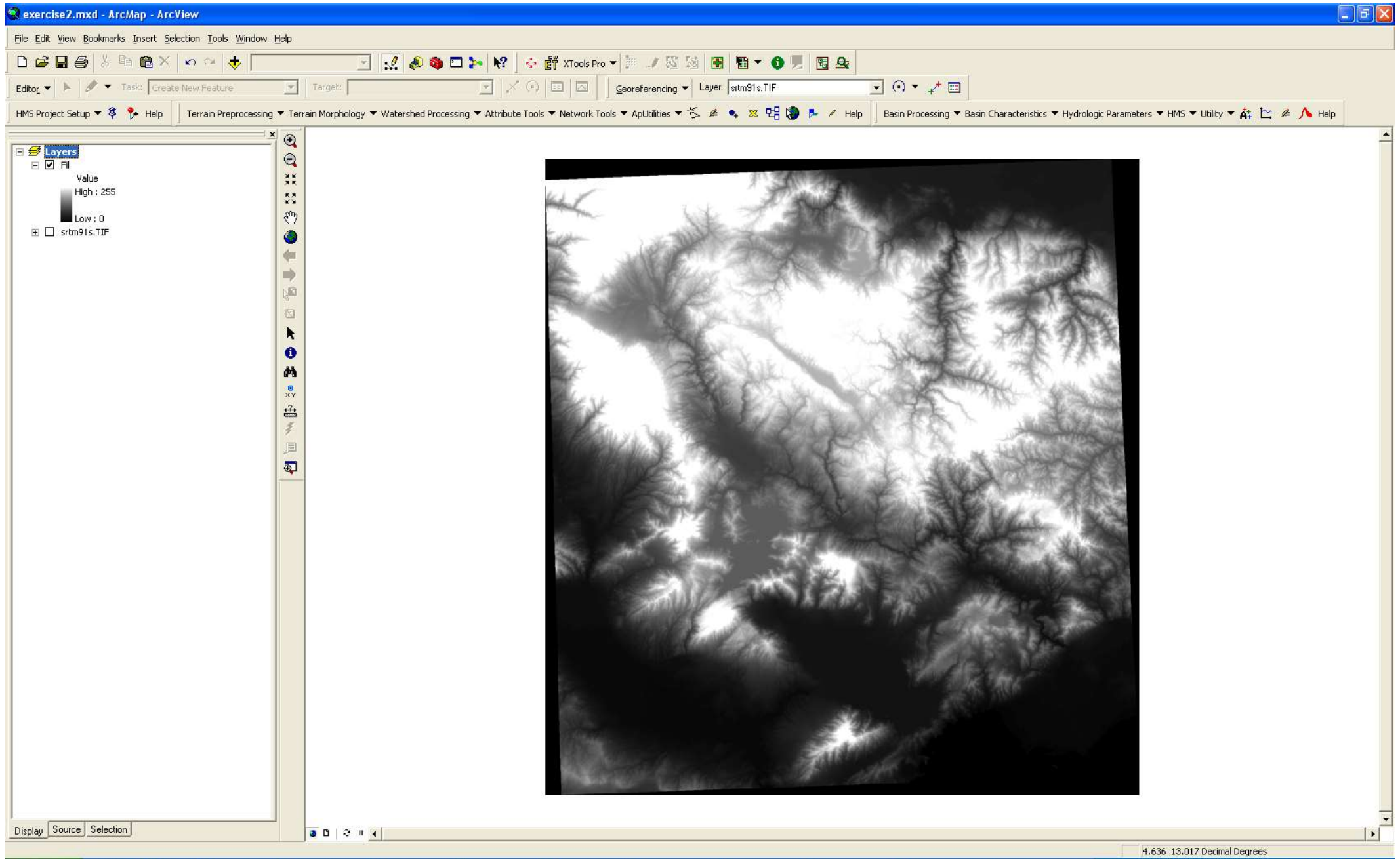
DEM: Fill Sinks

The screenshot displays the ArcMap interface for a project named "exercise1.mxd". The main map area shows a grayscale Digital Elevation Model (DEM) with a network of channels. The "Layers" panel on the left lists two layers: "Fill" and "Z_41_4.ASC". The "Fill" layer is selected, and its properties are shown: Value, High: 2915, Low: -22. The "Z_41_4.ASC" layer is also listed with its properties: Value, High: 2147483647, Low: -2147483648. The map area shows a complex network of channels, with some areas appearing white, indicating filled sinks. The status bar at the bottom shows coordinates: 18.232 42.615 Decimal Degrees.

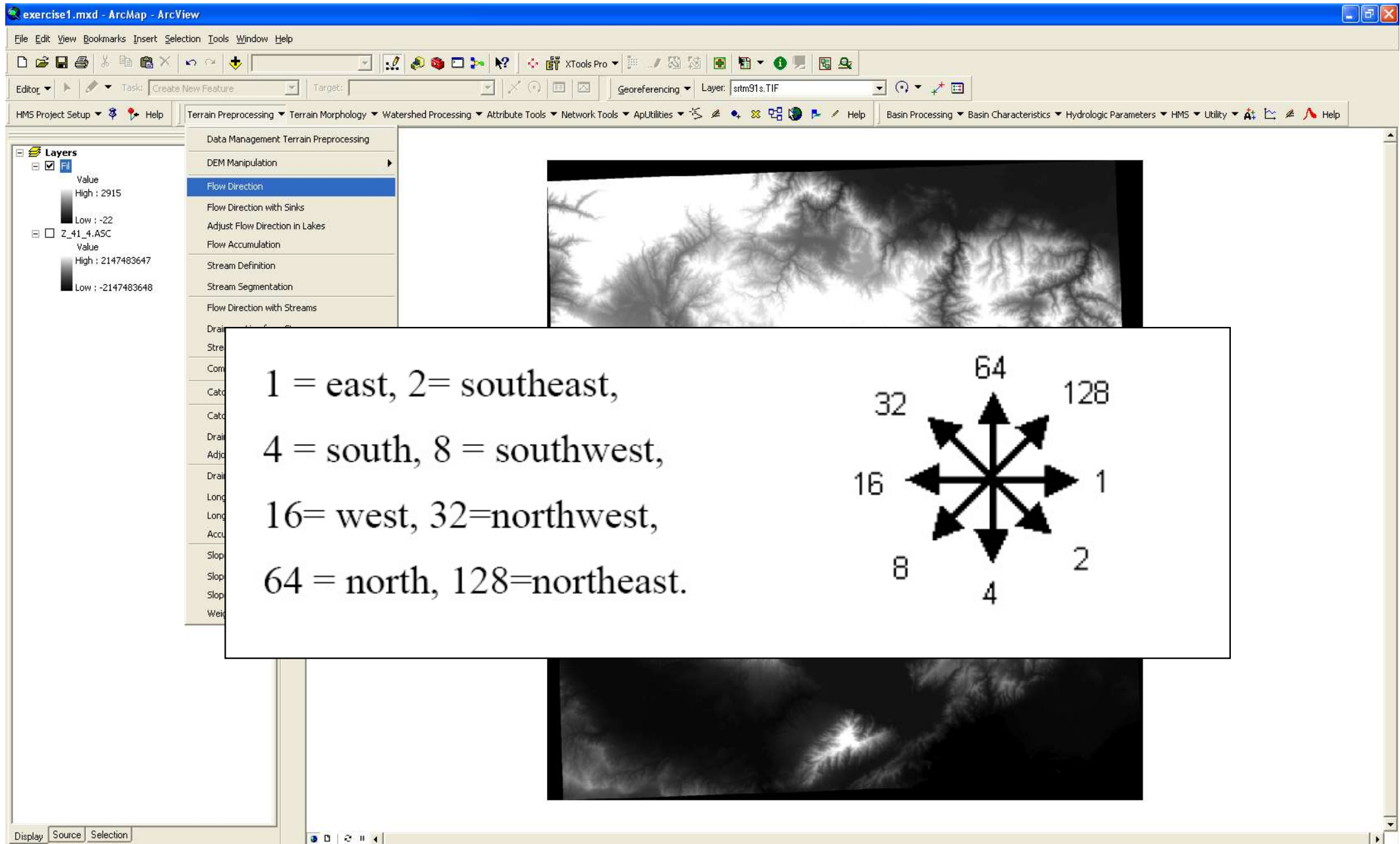
DEM: Focus on a specific area



DEM: Focus on a specific area

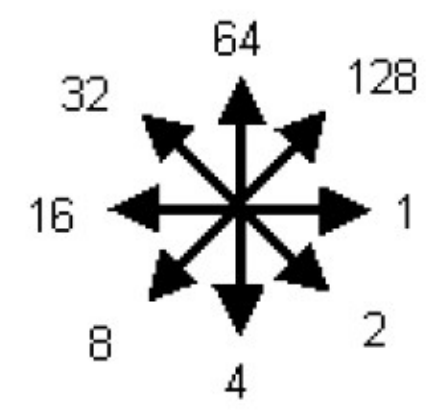


DEM: Flow Direction



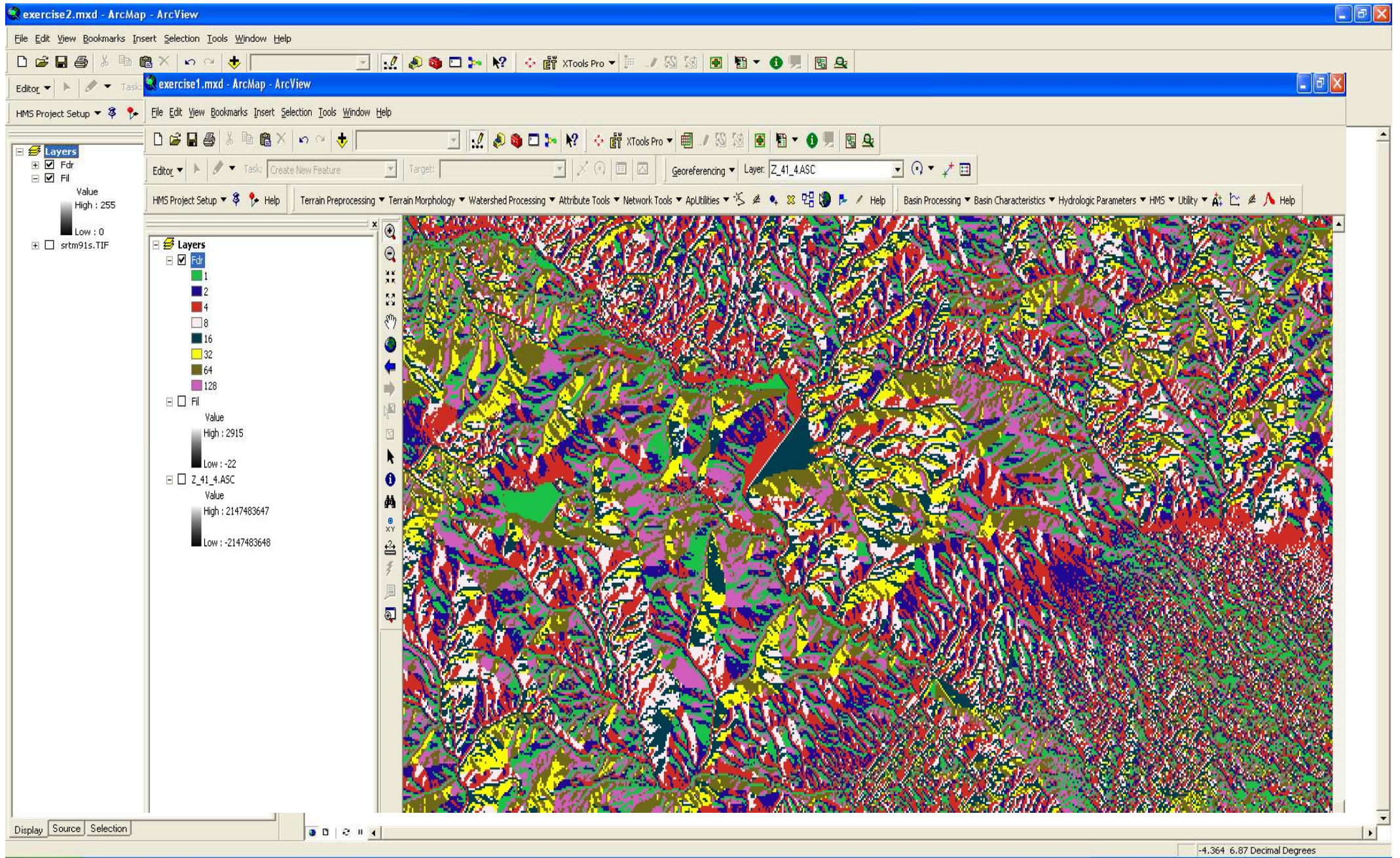
The screenshot shows the ArcMap interface with the 'Flow Direction' tool selected in the 'Terrain Morphology' menu. The map displays a watershed with flow direction arrows. A legend in the bottom-left corner shows the flow direction values: 1 (east), 2 (southeast), 4 (south), 8 (southwest), 16 (west), 32 (northwest), 64 (north), and 128 (northeast).

1 = east, 2 = southeast,
4 = south, 8 = southwest,
16 = west, 32 = northwest,
64 = north, 128 = northeast.



The diagram shows a central point with eight arrows pointing outwards, each labeled with a number representing a flow direction: 1 (east), 2 (southeast), 4 (south), 8 (southwest), 16 (west), 32 (northwest), 64 (north), and 128 (northeast).

DEM: Flow Direction



DEM: Flow Accumulation

The screenshot shows the ArcMap interface with the following components:

- Layers Panel:** Shows a layer named 'srtm91s.TIF' with a value range from 0 (Low) to 255 (High).
- Tools Panel:** Lists various terrain processing tools, with 'Flow Accumulation' selected.
- Main View:** Displays a flow accumulation map where colors represent the amount of flow accumulation at each cell. Blue indicates low accumulation, while red and purple indicate high accumulation.
- Taskbar:** Shows the Windows taskbar with the Start button and several open applications, including ArcMap and other software.
- Status Bar:** Displays the current coordinates as -4.627 9.345 Decimal Degrees.

DEM: Flow Accumulation

The screenshot displays the ArcMap interface with the following components:

- Title Bar:** exercise2.mxd - ArcMap - ArcView
- Menu Bar:** File, Edit, View, Bookmarks, Insert, Selection, Tools, Window, Help
- Toolbars:** Standard toolbar, Editor toolbar, and a specialized toolbar with tools like XTools Pro, Georeferencing, and various navigation tools.
- Taskbar:** HMS Project: Setup, Terrain Preprocessing, Terrain Morphology, Watershed Processing, Attribute Tools, Network Tools, ApUtilities, Basin Processing, Basin Characteristics, Hydrologic Parameters, HMS, Utility, Help
- Layers Panel:**
 - Fac: Value, High: 191786, Low: 0
 - Fdr: Value, High: 255, Low: 0
 - Fl: Value, High: 255, Low: 0
 - srtm91s.TIF
- Main Viewport:** A map showing a flow accumulation result. The background is black, and the flow accumulation is represented by white lines forming a network of channels and catchment areas.
- Status Bar:** 1.62 12.788 Decimal Degrees
- Taskbar (Windows):** start, Anoteleá..., H:\POSTD..., HEC-GeoH..., Έγγραφο..., F:\Hydrod..., 4.PNG - P..., untitled - ..., flow_dir..., trokiko - ..., exercise2..., EN, 2:24 PM

DEM: Stream definition

The screenshot displays the ArcMap interface with the 'Stream Definition' tool selected in the 'Terrain Preprocessing' menu. The 'Layers' panel on the left shows the following layers:

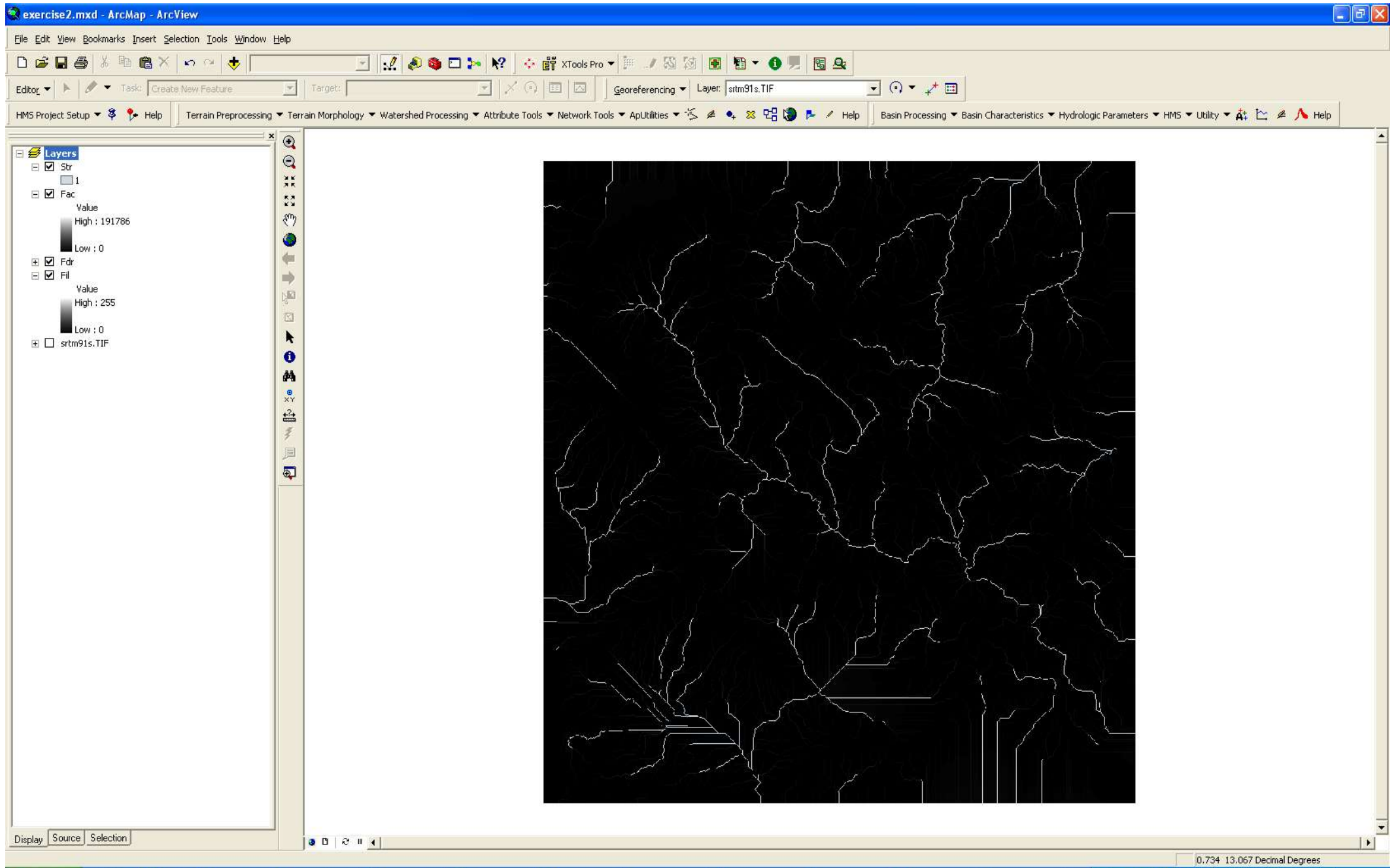
- Fac: Value High: 191786, Low: 0
- Fdr: Value High: 255, Low: 0
- Fill: Value High: 255, Low: 0
- srtm91s.TIF

The 'Stream Definition' tool menu is open, listing various options:

- Data Management Terrain Preprocessing
- DEM Manipulation
- Flow Direction
- Flow Direction with Sinks
- Adjust Flow Direction in Lakes
- Flow Accumulation
- Stream Definition**
- Stream Segmentation
- Flow Direction with Streams
- Drainage Line from Stream
- Stream Segmentation from Drainage Line
- Combine Stream Link and Sink Link
- Catchment Grid Delineation
- Catchment Polygon Processing
- Drainage Line Processing
- Adjoint Catchment Processing
- Drainage Point Processing
- Longest Flow Path for Catchments
- Longest Flow Path for Adjoint Catchments
- Accumulate Shapes
- Slope
- Slope greater than 30
- Slope greater than 30 and facing North
- Weighted Flow Accumulation

The main map area shows a stream network overlaid on a dark background, representing the result of the stream definition process. The status bar at the bottom indicates the coordinates: -4.676 10.739 Decimal Degrees.

DEM: Stream definition



Επεξεργασία ΨΜΕ: Stream segmentation

The screenshot displays the ArcMap interface with the 'Stream Segmentation' tool selected in the 'Terrain Preprocessing' menu. The main map area shows a network of white stream segments on a black background. The 'Layers' panel on the left lists several layers: 'Str', '1', 'Fac', 'Fdr', 'Fil', and 'srtm91s.TIF'. The 'Fac' layer has a value range from 0 to 191786, and the 'Fil' layer has a value range from 0 to 255. The 'Stream Segmentation' tool menu includes options such as 'Flow Direction', 'Stream Definition', 'Stream Segmentation', and 'Combine Stream Link and Sink Link'. The status bar at the bottom indicates the coordinates -4.741 12.395 Decimal Degrees.

exercise2.mxd - ArcMap - ArcView

File Edit View Bookmarks Insert Selection Tools Window Help

Editor Task: Create New Feature Target: Georeferencing Layer: srtm91s.TIF

HMS Project Setup Help Terrain Preprocessing Terrain Morphology Watershed Processing Attribute Tools Network Tools ApUtilities Basin Processing Basin Characteristics Hydrologic Parameters HMS Utility Help

Layers

- Str
- 1
- Fac
 - Value
 - High : 191786
 - Low : 0
- Fdr
- Fil
 - Value
 - High : 255
 - Low : 0
- srtm91s.TIF

Data Management Terrain Preprocessing

- DEM Manipulation
- Flow Direction
- Flow Direction with Sinks
- Adjust Flow Direction in Lakes
- Flow Accumulation
- Stream Definition
- Stream Segmentation**
- Flow Direction with Streams
- Drainage Line from Stream
- Stream Segmentation from Drainage Line
- Combine Stream Link and Sink Link
- Catchment Grid Delineation
- Catchment Polygon Processing
- Drainage Line Processing
- Adjoint Catchment Processing
- Drainage Point Processing
- Longest Flow Path for Catchments
- Longest Flow Path for Adjoint Catchments
- Accumulate Shapes
- Slope
- Slope greater than 30
- Slope greater than 30 and facing North
- Weighted Flow Accumulation

Display Source Selection

Determine stream segment grid

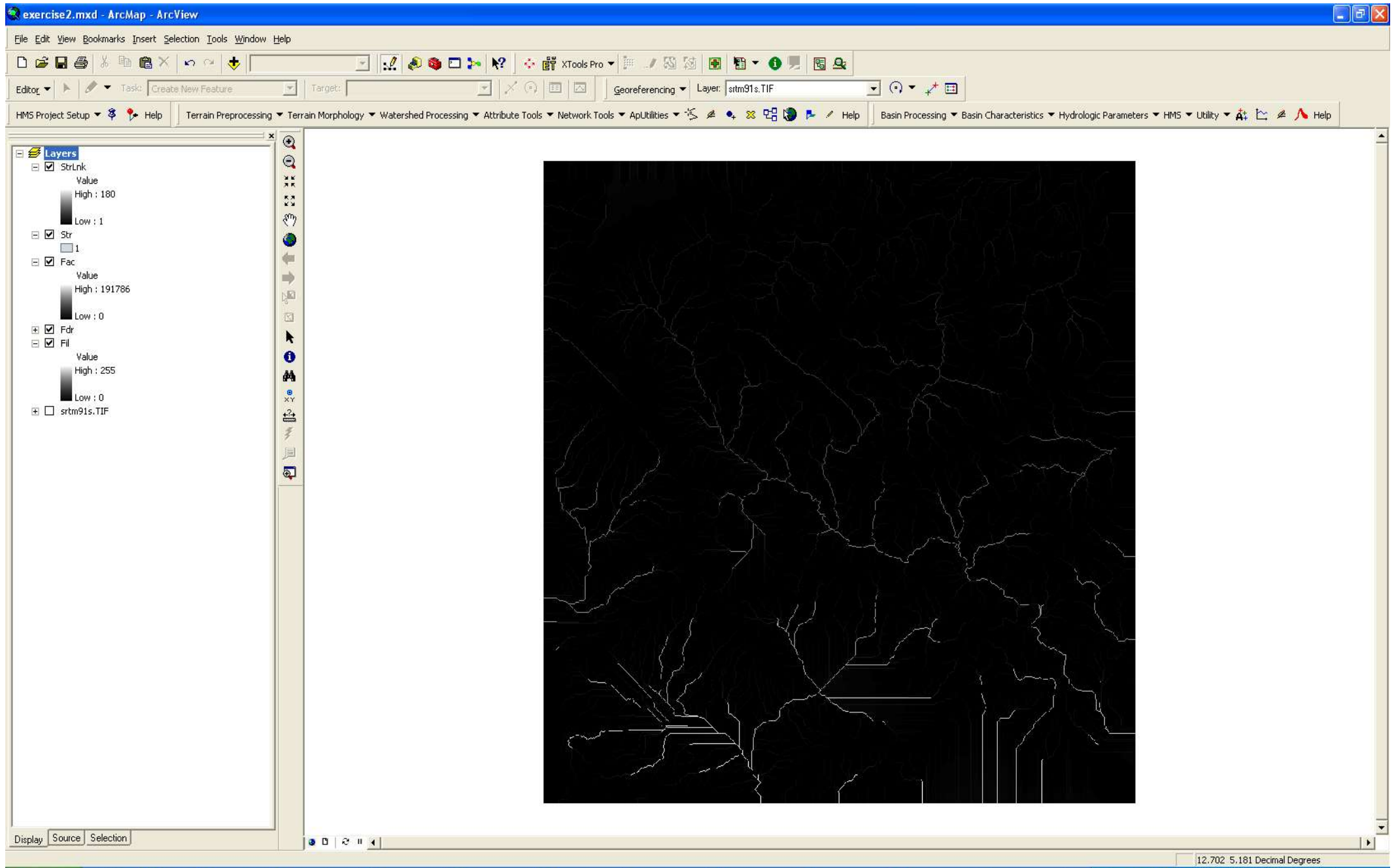
-4.741 12.395 Decimal Degrees

start

Αποτελέσ... H:\POSTD... HEC-GeoH... Έγγραφο... F:\Hydrod... 7.PNG - P... untitled - ... flow_dir... trokiko - ... exercise2... EN

2:25 PM

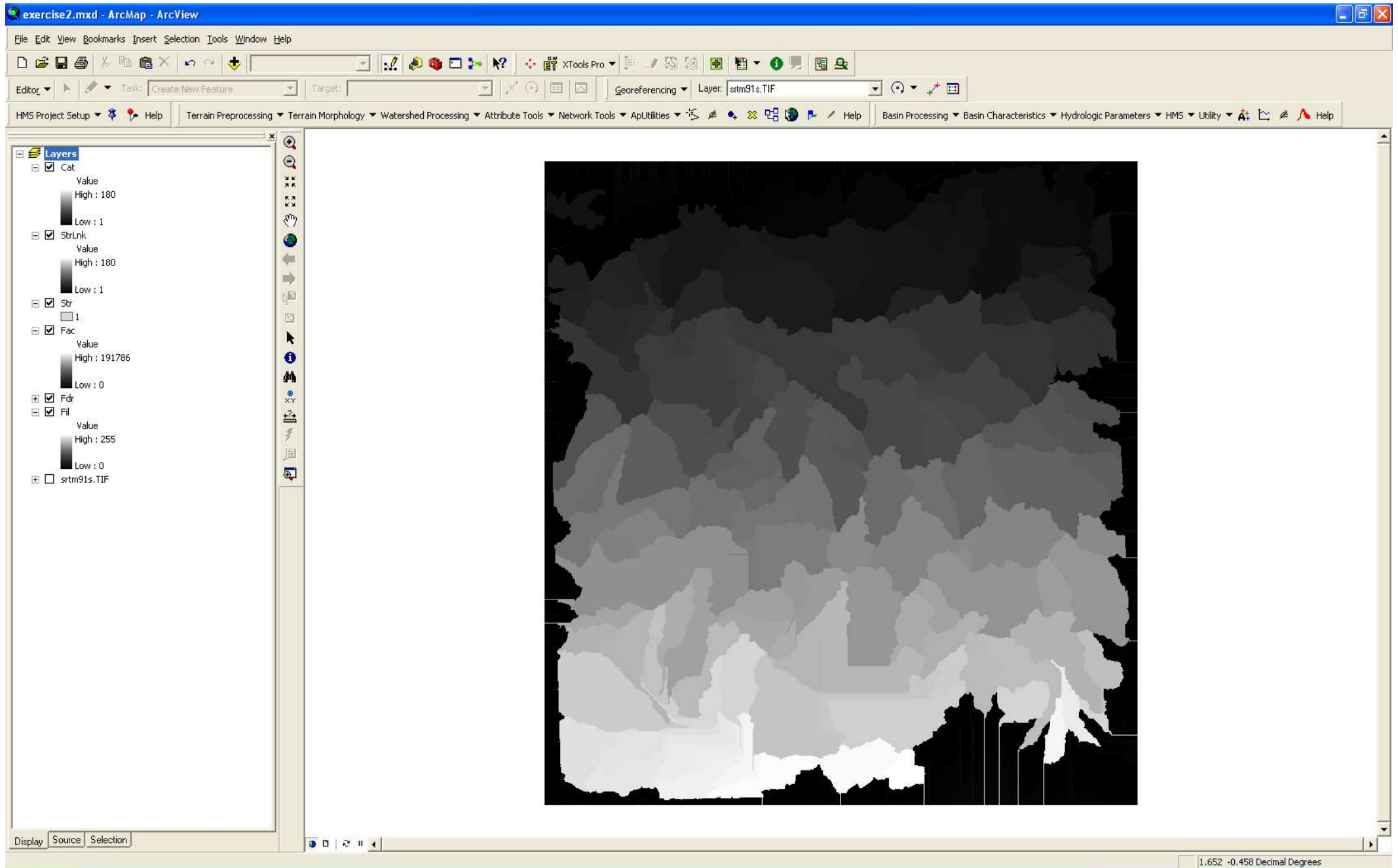
DEM: Stream segmentation



DEM: Catchment Grid Delineation

The screenshot displays the ArcMap interface for a project named 'exercise2.mxd'. The 'Terrain Preprocessing' menu is open, with 'Catchment Grid Delineation' highlighted. The main map area shows a catchment grid overlaid on a dark background. The Layers panel on the left lists several layers: StrLnk (Value: High: 180, Low: 1), Str (Value: 1), Fac (Value: High: 191786, Low: 0), Fdr (Value: High: 255, Low: 0), and srtm91s.TIF. The Windows taskbar at the bottom shows various open applications, including 'start', 'Αποτελέσ...', 'H:\POSTD...', 'HEC-GeoH...', 'Έγγραφο...', 'F:\Hydrod...', '9.PNG - P...', 'untitled - ...', 'flow_dir...', 'trobtiko - ...', 'exercise2...', and 'EN'. The system clock shows 2:26 PM on 10/31/2010.

DEM: Catchment Grid Delineation



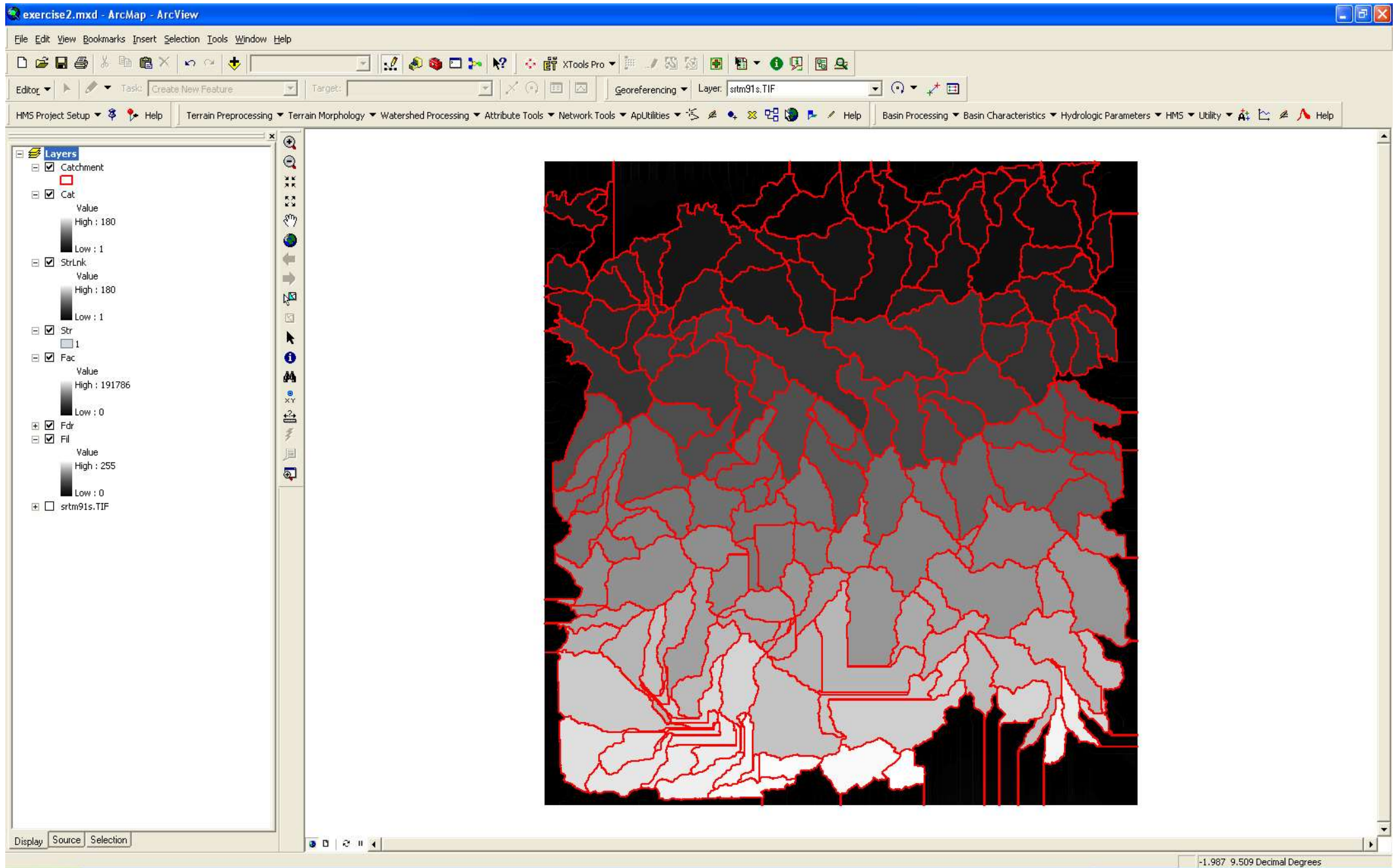
DEM: Catchment polygon processing

The screenshot displays the ArcMap interface with the 'Catchment Polygon Processing' menu open. The menu items include:

- Data Management Terrain Preprocessing
- DEM Manipulation
- Flow Direction
- Flow Direction with Sinks
- Adjust Flow Direction in Lakes
- Flow Accumulation
- Stream Definition
- Stream Segmentation
- Flow Direction with Streams
- Drainage Line from Stream
- Stream Segmentation from Drainage Line
- Combine Stream Link and Sink Link
- Catchment Grid Delineation
- Catchment Polygon Processing**
- Drainage Line Processing
- Adjoint Catchment Processing
- Drainage Point Processing
- Longest Flow Path for Catchments
- Longest Flow Path for Adjoint Catchments
- Accumulate Shapes
- Slope
- Slope greater than 30
- Slope greater than 30 and facing North
- Weighted Flow Accumulation

The main map area shows a grayscale Digital Elevation Model (DEM) with a catchment polygon overlaid. The polygon is a light gray area, and the background is a darker gray. The interface includes a 'Layers' panel on the left, a 'Task' bar at the top, and a 'Georeferencing' toolbar. The status bar at the bottom indicates the coordinates: -4.692 9.198 Decimal Degrees.

DEM: Catchment polygon processing



DEM: Drainage line processing

The screenshot displays the ArcMap interface for a DEM processing task. The 'Layers' panel on the left shows the following layers and their properties:

- Catchment (checked)
- Cat (checked)
 - Value: High: 180, Low: 1
- StrLnk (checked)
 - Value: High: 180, Low: 1
- Str (checked)
- Fac (checked)
 - Value: High: 191786, Low: 0
- Fdr (checked)
- Fil (checked)
 - Value: High: 255, Low: 0
- srtm91s.TIF (unchecked)

The 'Toolbox' on the right is open to the 'Drainage Line Processing' menu, which includes the following tools:

- Data Management Terrain Preprocessing
- DEM Manipulation
- Flow Direction
- Flow Direction with Sinks
- Adjust Flow Direction in Lakes
- Flow Accumulation
- Stream Definition
- Stream Segmentation
- Flow Direction with Streams
- Drainage Line from Stream
- Stream Segmentation from Drainage Line
- Combine Stream Link and Sink Link
- Catchment Grid Delineation
- Catchment Polygon Processing
- Drainage Line Processing** (highlighted)
- Adjoint Catchment Processing
- Drainage Point Processing
- Longest Flow Path for Catchments
- Longest Flow Path for Adjoint Catchments
- Accumulate Shapes
- Slope
- Slope greater than 30
- Slope greater than 30 and facing North
- Weighted Flow Accumulation

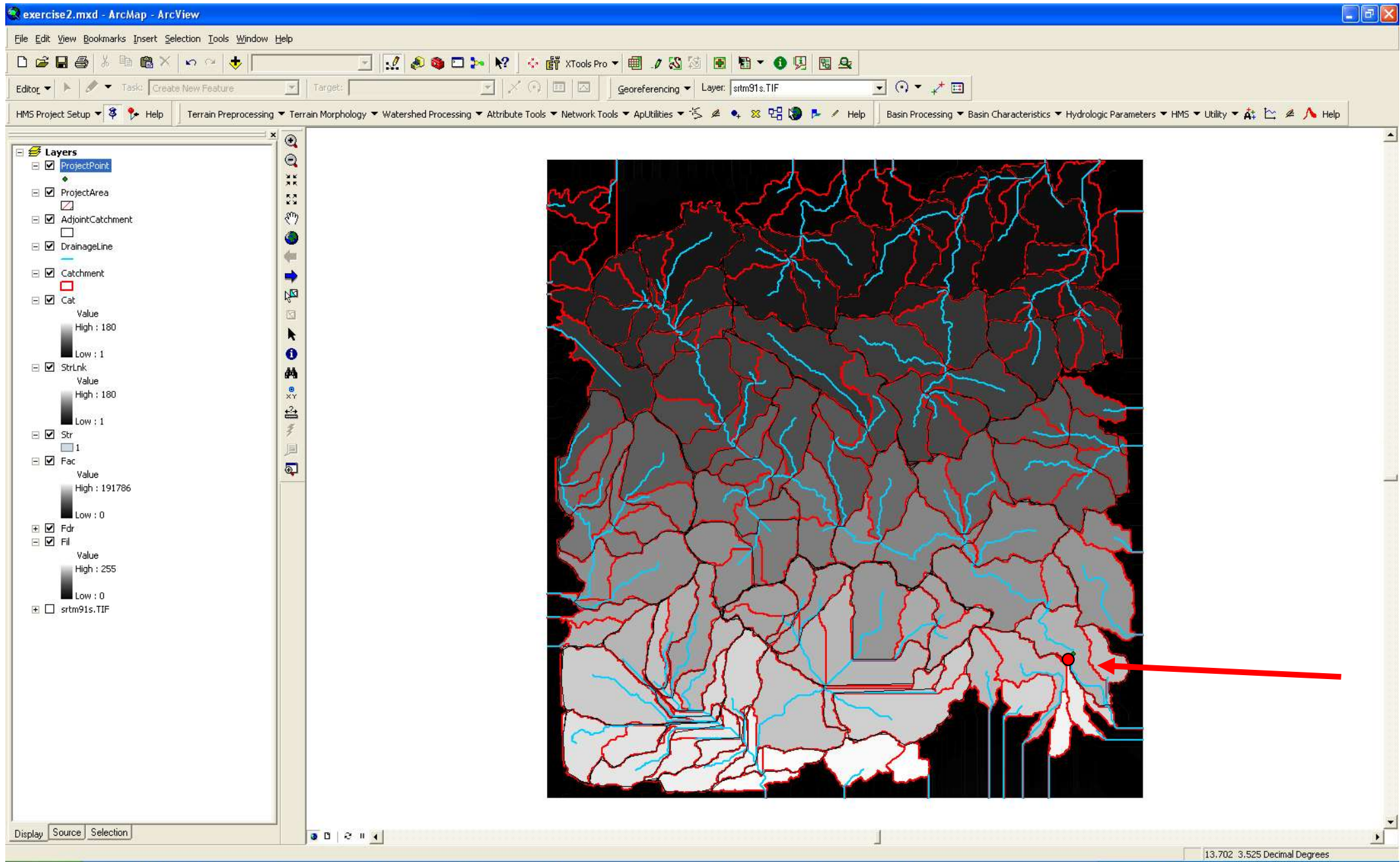
The main map area shows a grayscale DEM with red stream lines overlaid, representing the drainage network. The status bar at the bottom indicates the coordinates: -4.741 8.362 Decimal Degrees.

DEM: Drainage line processing

The screenshot displays the ArcMap interface with the following components:

- Title Bar:** exercise2.mxd - ArcMap - ArcView
- Menu Bar:** File Edit View Bookmarks Insert Selection Tools Window Help
- Toolbars:** Standard toolbar, XTools Pro toolbar, and a toolbar with Georeferencing, Layer, and other map navigation tools.
- Taskbar:** HMS Project Setup, Help, Terrain Preprocessing, Terrain Morphology, Watershed Processing, Attribute Tools, Network Tools, ApUtilities, Basin Processing, Basin Characteristics, Hydrologic Parameters, HMS, Utility, Help.
- Layers Panel (Left):**
 - DrainageLine (checked)
 - Catchment (checked)
 - Cat (checked)
 - Value: High: 180, Low: 1
 - StrLnk (checked)
 - Value: High: 180, Low: 1
 - Str (checked)
 - Fac (checked)
 - Value: High: 191786, Low: 0
 - Fdr (checked)
 - Fil (checked)
 - Value: High: 255, Low: 0
 - srtm91s.TIF (unchecked)
- Main View:** A map showing a complex drainage network. The catchment boundaries are outlined in red, and the drainage lines are shown in cyan. The background is a grayscale DEM.
- Status Bar (Bottom):** -0.758 7.476 Decimal Degrees

DEM: Selecting of basin outlet

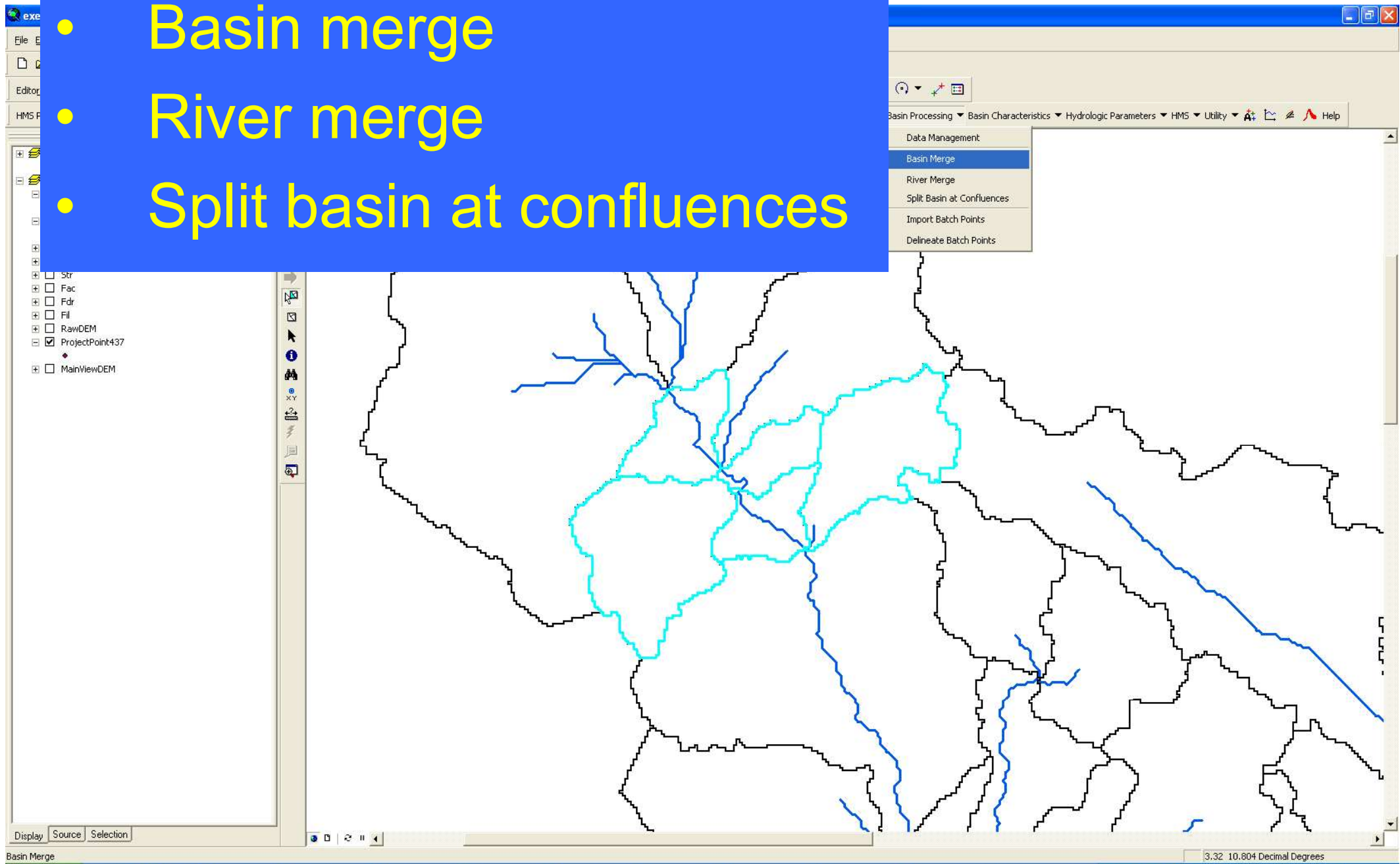


Basin and subbasins creation

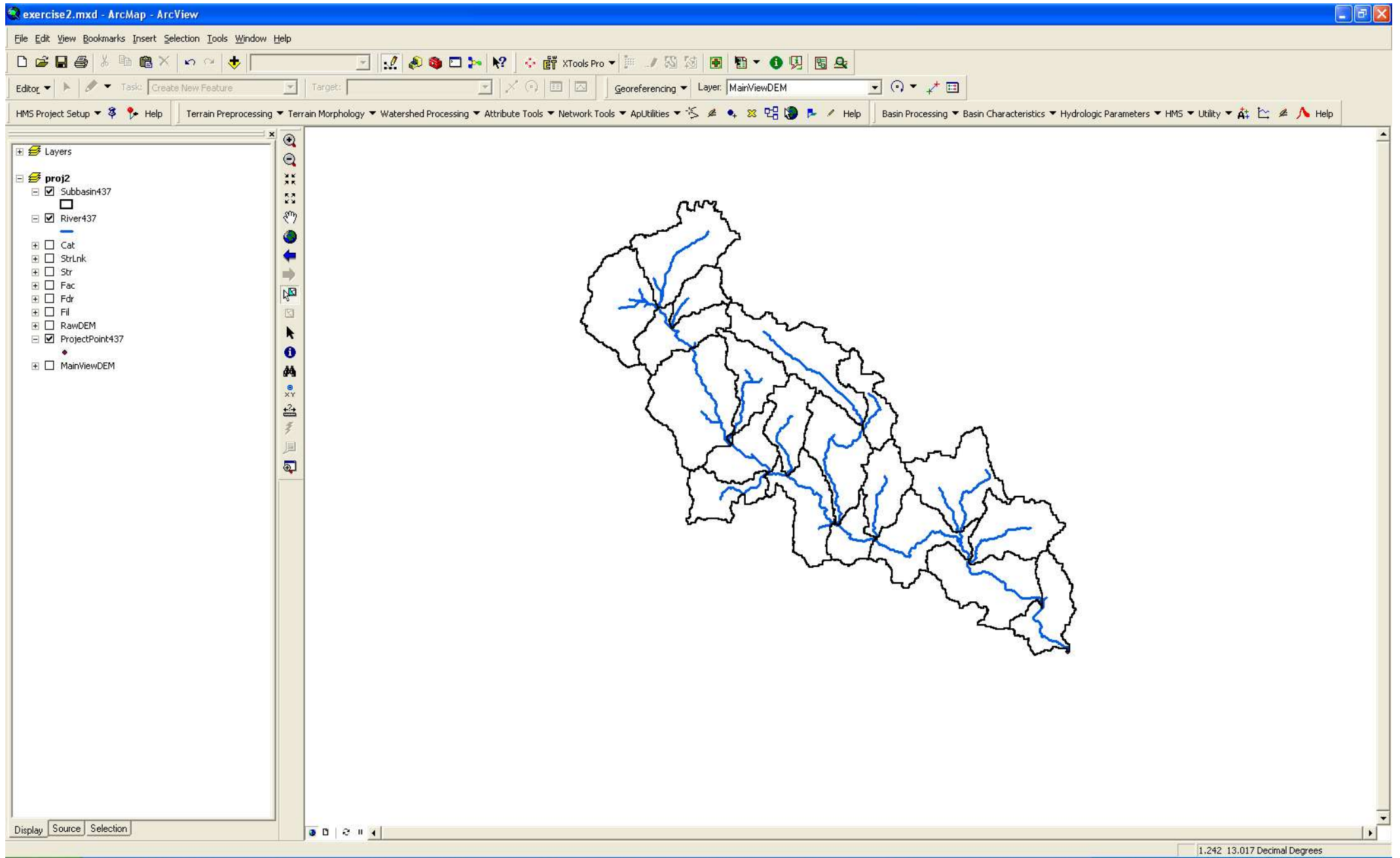
The screenshot displays the ArcMap interface for a project named 'exercise2.mxd'. The main map area shows a watershed delineation with subbasins outlined in black and a network of rivers shown in blue. The 'Layers' panel on the left lists the following layers: proj2 (expanded), Subbasin437 (checked), River437 (checked), Cat (unchecked), StrLnk (unchecked), Str (unchecked), Fac (unchecked), Fdr (unchecked), Fil (unchecked), RawDEM (unchecked), ProjectPoint437 (checked), and MainViewDEM (unchecked). The 'MainViewDEM' layer is currently selected in the 'Layer' dropdown menu. The interface includes a menu bar (File, Edit, View, Bookmarks, Insert, Selection, Tools, Window, Help), a toolbar with various GIS tools, and a task bar at the bottom showing the current task as 'Create New Feature'. The status bar at the bottom right indicates the coordinates '9,399 11,793 Decimal Degrees'.

Utilities for basin editing

- Basin merge
- River merge
- Split basin at confluences



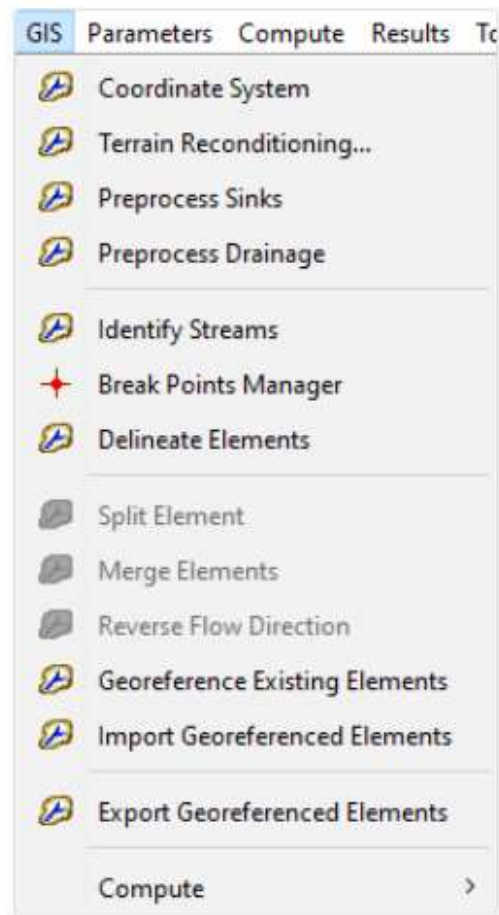
Final basin model

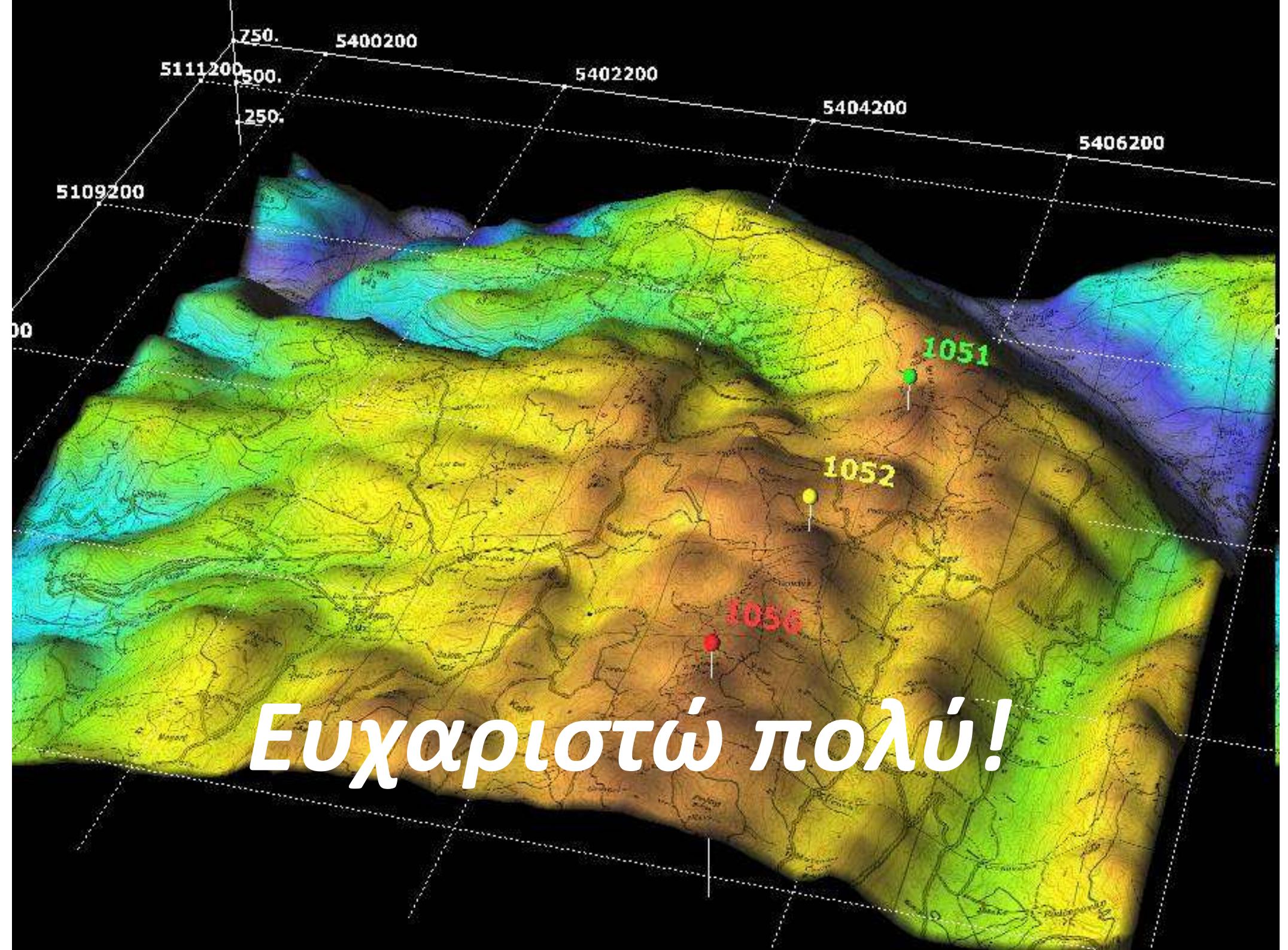


HEC GeoHMS

As of the release of HEC-HMS version 4.8 in April 2021, there is no longer a requirement that modelers use HEC-GeoHMS to delineate elements for an HEC-HMS project.

HEC-HMS 4.9 includes GIS tools that allow modelers to delineate elements, define a discretization, compute subbasin and reach characteristics, and estimate model parameters.





Ευχαριστώ πολύ!