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GIS Topographic Wetness Index (TWI) Exercise Steps

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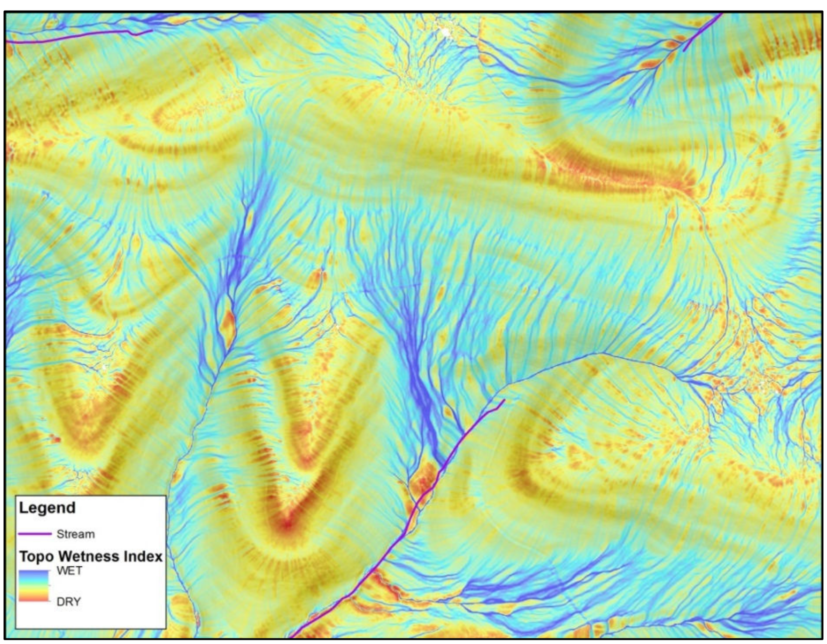

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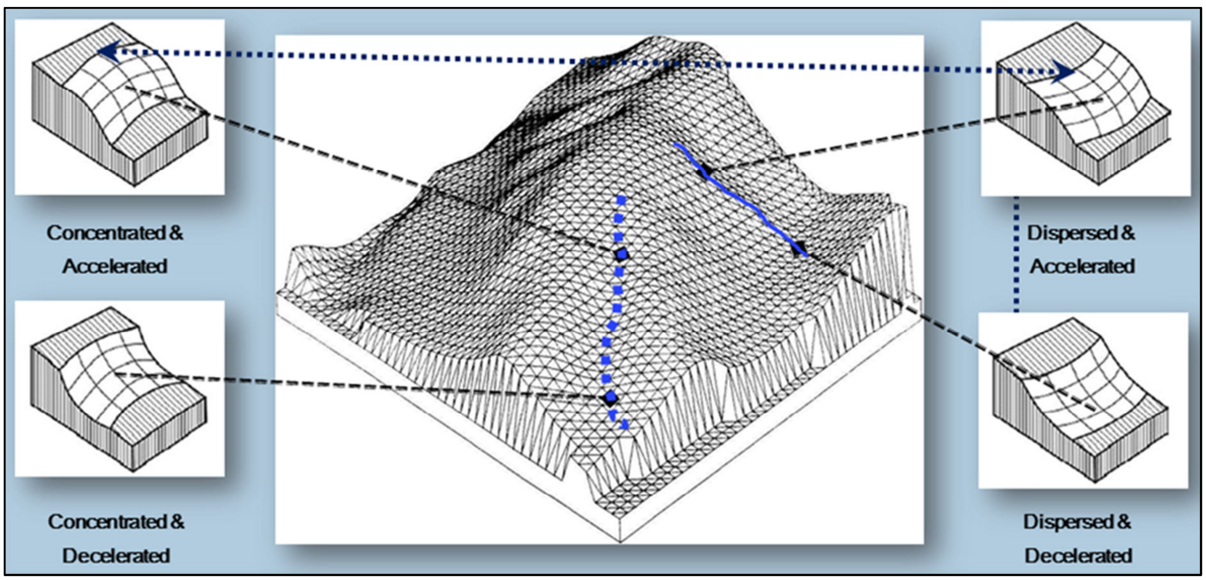
INTRODUCTION

This work flow process was partially supported through generous funding provided by the National Fish and Wildlife Foundation's (NFWF's) Chesapeake Bay Stewardship Fund (Grant No. 0603.14.045237/Marcellus Shale Sediment Control Project: 2014 – 2017).



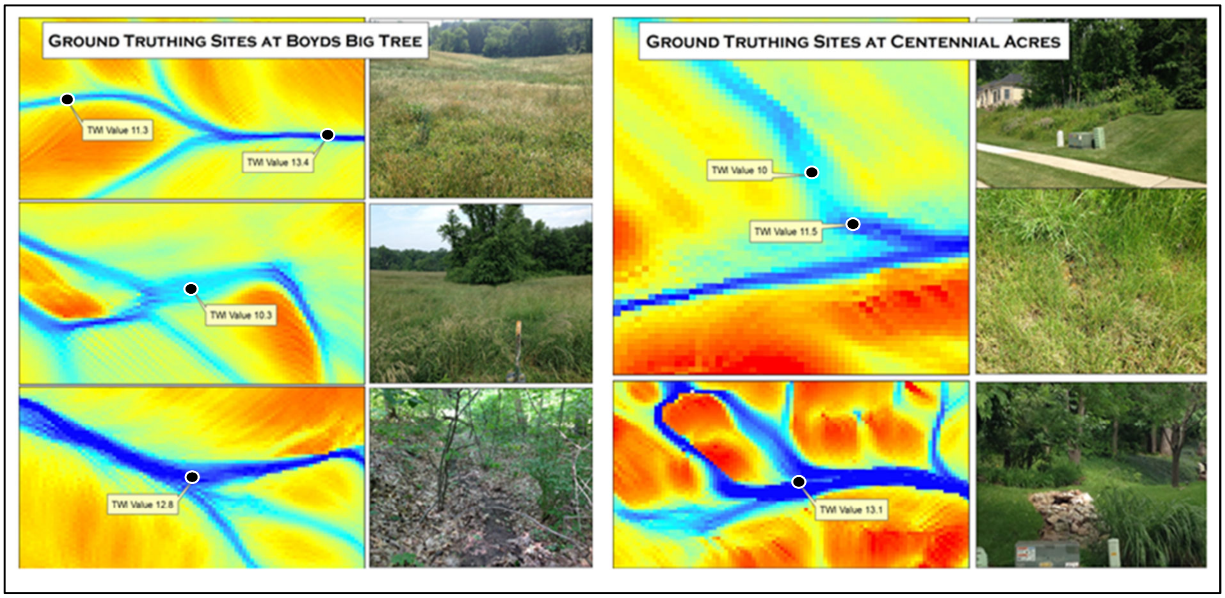
Schematic Diagram of Morphology Types Used to Compile Topographic Wetness Index

The process described herein uses a type of digital terrain analysis (DTA) resulting in a Topographic Wetness Index (TWI) that quantifies topographic controls of basic hydrological processes (Schillaci et al., 2015). TWI is derived through interactions of fine-scale landform coupled to the up-gradient contributing land surface area according to the following relationship (Beven et al., 1979):

TWI = ln [CA/Slope]

where; CA is the local upslope catchment area that drains through a grid cell and Slope is the steepest outward slope for each grid cell measured as drop/distance, i.e., tan of the slope angle (Tarboton, 1997).

Upon completion, TWI raw output is displayed as a dimensionless linear color gradient, with starting and ending point colors based on the minimum and maximum flowpath intensities unique to each catchment. Part of the NFWF study included evaluation of TWI qualitative as well as quantitative field trial verification. Repeated field trial visual assessments of hydrologic indicators, in-situ soil moisture measurements, and laboratory soil moisture quantification results (Khalequzzaman, unpublished) all converged to identify the color gradient equivalent numeric value of "11" as the reliable threshold for TWI that is consistent with preferential storm flowpaths. The color-equivalent value "11" also equated to the 99th percentile (P99) flowpath intensity of TWI output.



Examples of Paired TWI Model Output and Field Trial Site Photographs

TWI was applied in the Marcellus Shale Sediment Control Project as a probability-based surrogate for preferential flowpaths during storm events, although TWI offers the utility to serve a broad array of purposes.

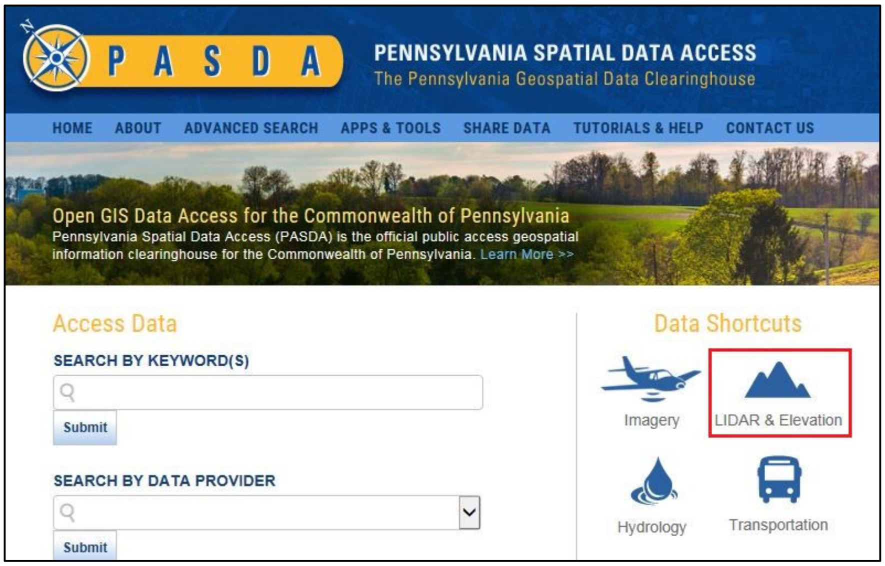
ACKNOWLEDGEMENT

This procedure was adapted from the methodology(s) described by Cody M. Fink in Chapter 4 of his thesis entitled *Dynamic Soil Property Change in Response to Natural Gas Development in Pennsylvania*.

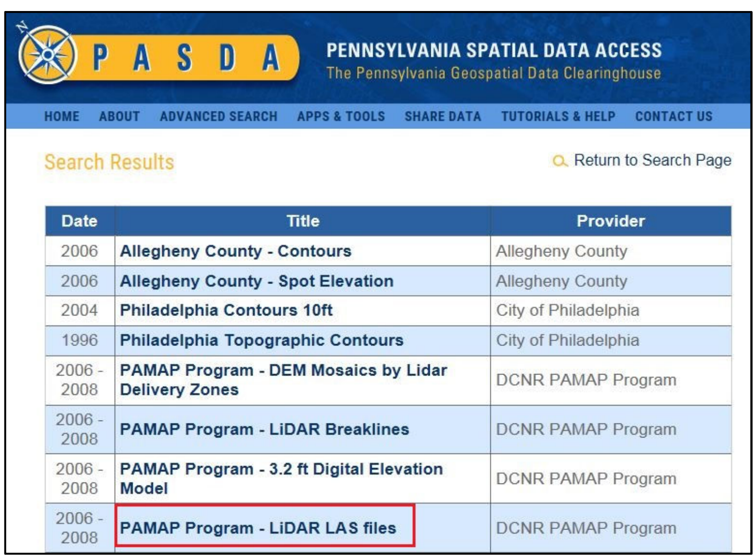
Fink, Cody M. 2013. Dynamic Soil Property Change in Response to Natural Gas Development in Pennsylvania. Pennsylvania State University, College of Agricultural Sciences. University Park, Pennsylvania.

A. Download LiDAR LAS Data from PASDA Website

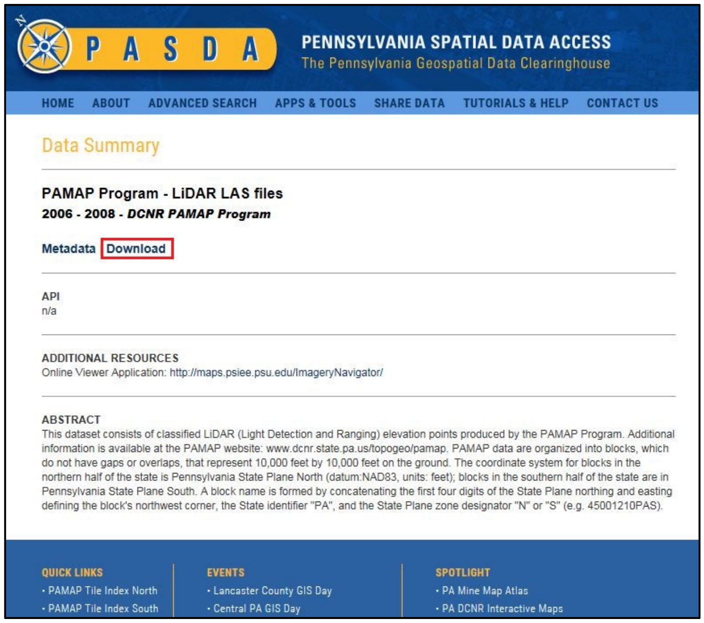
1. Download the "PAMAP Program – Tile Index North/South" shapefiles here: http://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=266 or http://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=267
2. Unzip the Tile Index shapefile
3. In ArcMap, overlay the Tile Index shapefile on a study area to determine necessary LiDAR LAS datasets
4. Navigate to the PASDA homepage at http://www.pasda.psu.edu/
5. Click the LiDAR & Elevation Data Shortcut



6. Click the "PAMAP Program – LiDAR LAS files" link



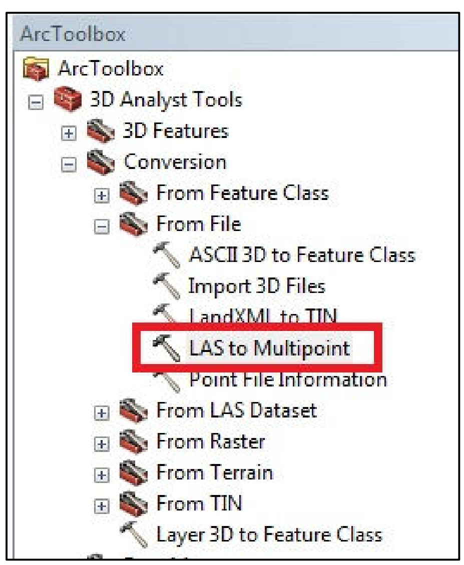
7. On the PASDA PAMAP Program - LiDAR LAS files Data Summary web page, click on the "Download" link



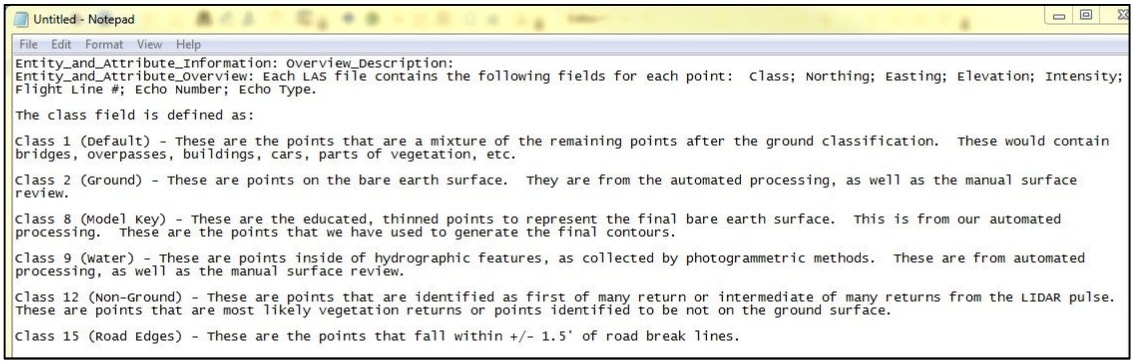
8. On the FTP directory web page, click the “LAS” directory link
9. On the next FTP directory web page, click either the “North” or “South” directory link
10. Navigate to the appropriate FTP directories to download the necessary LAS datasets
11. Unzip the LAS datasets

B. <u>Convert the LAS Data to a Digital Elevation Model (DEM)</u>

12. In ArcMap, click the Customize dropdown menu and select ‘Extensions…’
13. Activate the 3D Analyst extension
14. Open the ArcToolbox window
15. Expand the 3D Analyst Tools toolbox
16. Expand the Conversion toolset
17. Expand the From File toolset
18. Open the LAS to Multipoint geoprocessing tool



19. Add all of the LAS dataset files as inputs
20. Specify the output feature class
21. Set the Average Point Spacing to 4.6 feet (1.4 meters)
22. Add the following Input Class Codes: 2, 8, 9, 15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File Edit Format View Help

Entity_and_Attribute_Information: Overview_Description:
Entity_and_Attribute_Overview: Each LAS file contains the following fields for each point: Class; Northing; Easting; Elevation; Intensity; Flight Line #; Echo Number; Echo Type.

The class field is defined as:

Class 1 (Default) - These are the points that are a mixture of the remaining points after the ground classification. These would contain bridges, overpasses, buildings, cars, parts of vegetation, etc.

Class 2 (Ground) - These are points on the bare earth surface. They are from the automated processing, as well as the manual surface review.

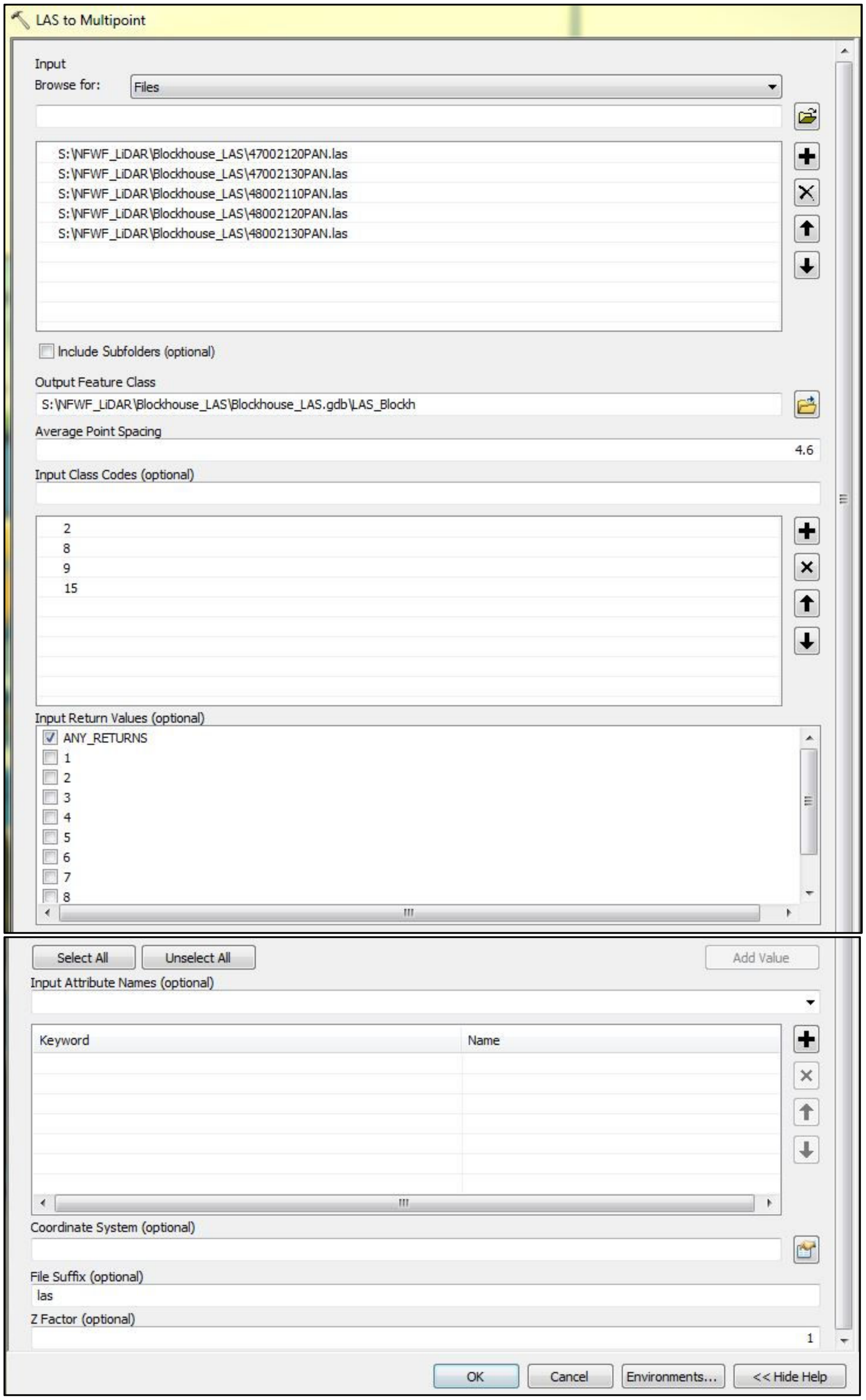
Class 8 (Model Key) - These are the educated, thinned points to represent the final bare earth surface. This is from our automated processing. These are the points that we have used to generate the final contours.

Class 9 (Water) - These are points inside of hydrographic features, as collected by photogrammetric methods. These are from automated processing, as well as the manual surface review.

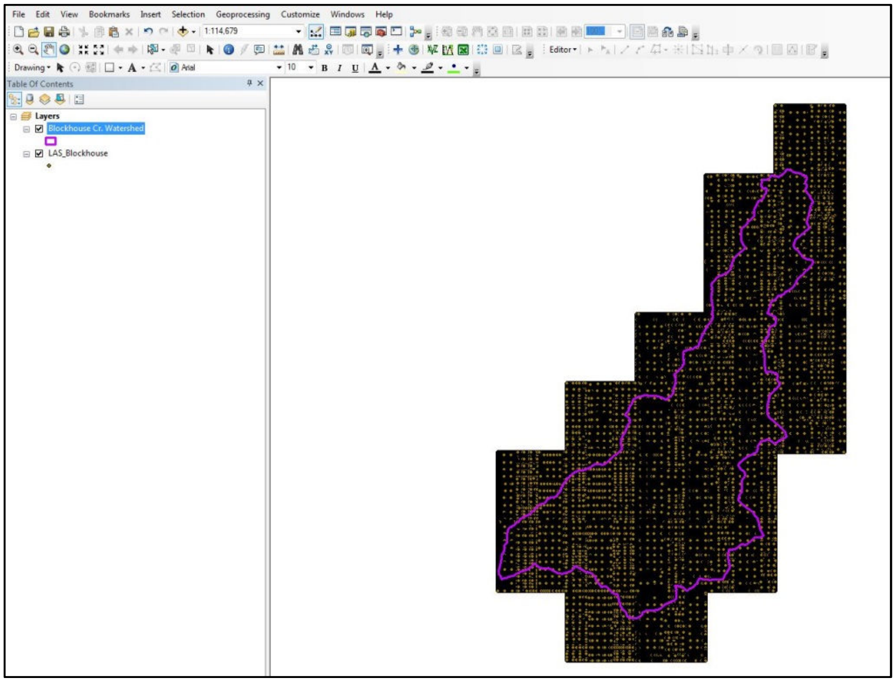
Class 12 (Non-Ground) - These are points that are identified as first of many return or intermediate of many returns from the LIDAR pulse. These are points that are most likely vegetation returns or points identified to be not on the ground surface.

Class 15 (Road Edges) - These are the points that fall within +/- 1.5' of road break lines.

23. Set the X,Y Coordinate System to Pennsylvania State Plane North (US Feet), NAD83
24. Accept the default values for the remaining parameters
    - Input Return Values – Any Returns
    - Input Attribute Names – None
    - File Suffix – las
    - Z Factor – 1



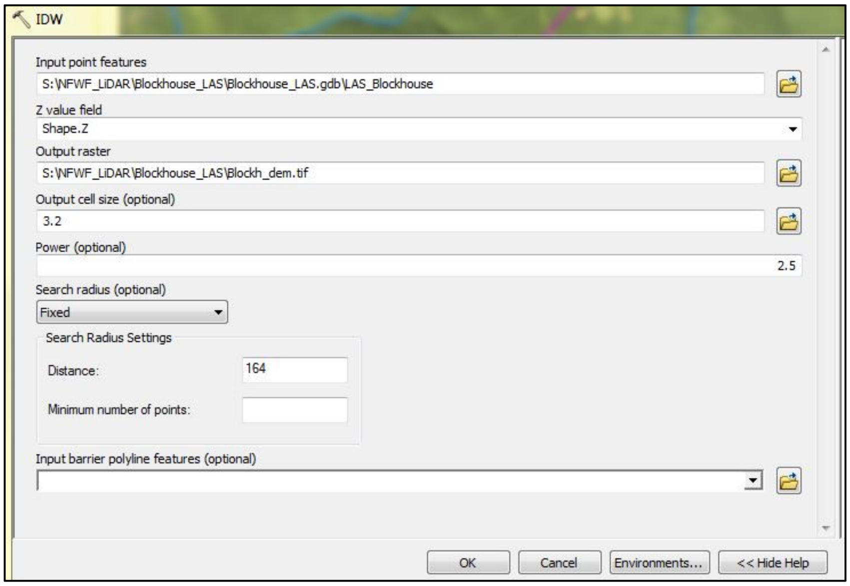
25. Click OK to execute the LAS to Multipoint geoprocessing tool



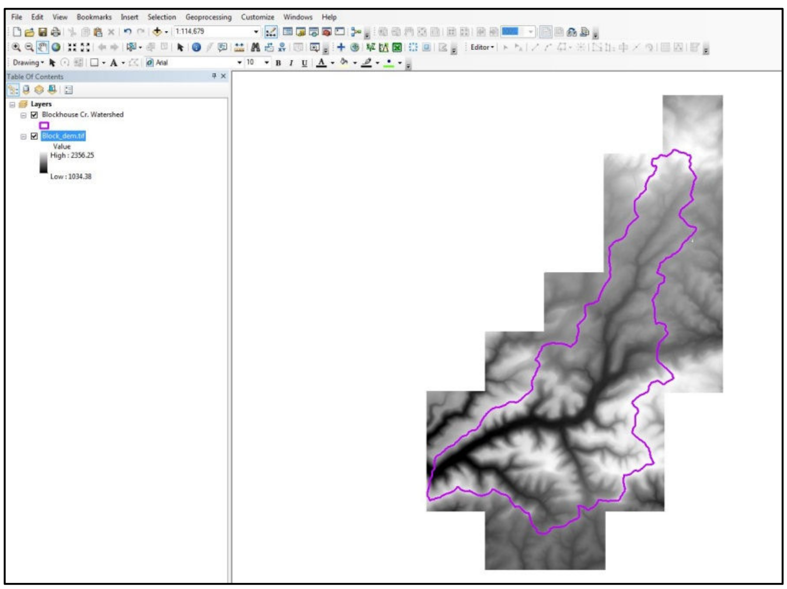
26. In ArcMap, click the Customize dropdown menu and select ‘Extensions…’
27. Activate the Spatial Analyst extension
28. Open the ArcToolbox window
29. Expand the Spatial Analyst Tools toolbox
30. Expand the Interpolation toolset
31. Open the IDW geoprocessing tool

32. Add the LAS multipoint feature class as the Input point features by clicking the folder icon
33. Specify an Output raster with a file extension of .tif
34. Select ‘Shape.Z” as the Z value field
35. Set the Output cell size to 3.2
36. Set the Power to 2.5

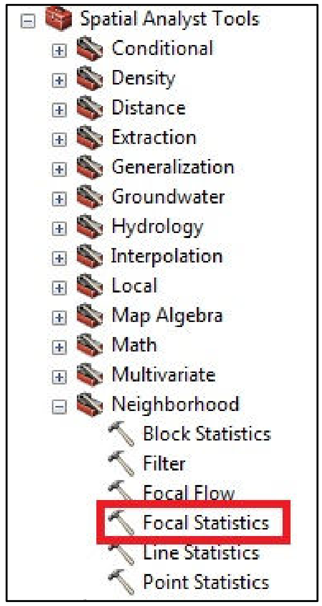
37. Use a Fixed Search radius with a distance of 164 feet (50 meters) and no minimum points



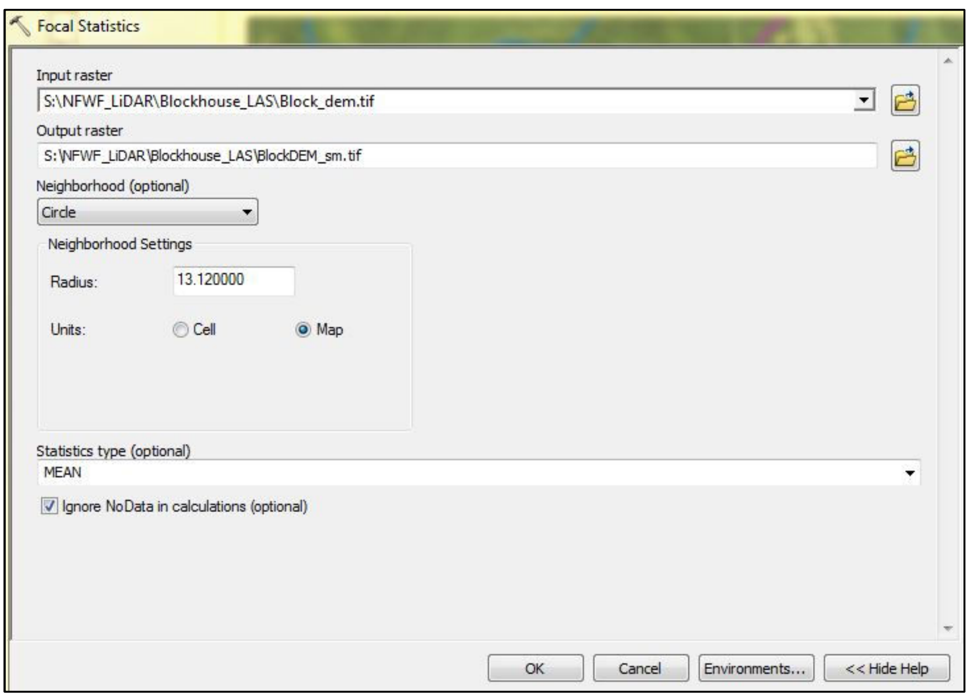
38. Click OK to execute the IDW geoprocessing tool (NOTE – this may take a long time to complete depending on the size of the study area)



39. Open the ArcToolbox window
40. Expand the Spatial Analyst Tools toolbox
41. Expand the Neighborhood toolset
42. Open the Focal Statistics geoprocessing tool to smooth the DEM



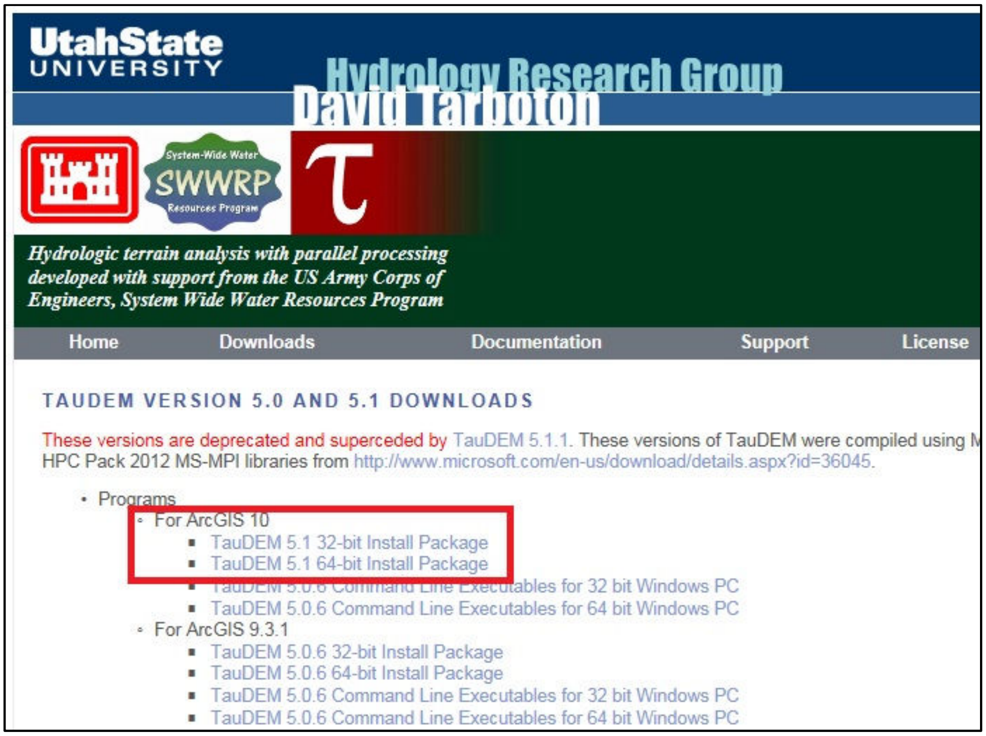
43. Add the DEM as the Input Raster
44. Specify an Output raster with a file extension of .tif
45. Choose a Circle for the Neighborhood with a radius of 13.12 feet (4 meters) in map units
46. Select MEAN for the Statistics type



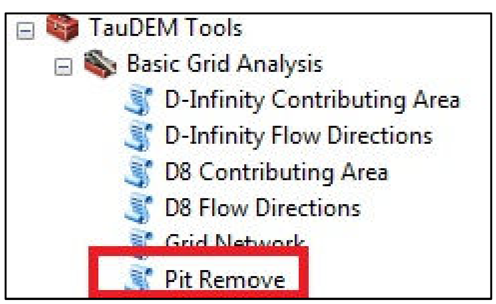
47. Click OK to execute the Focal Statistics geoprocessing tool
48. Save and close ArcMap

C. Use TauDEM Extension to Generate D-Infinity Slope and Contributing Area

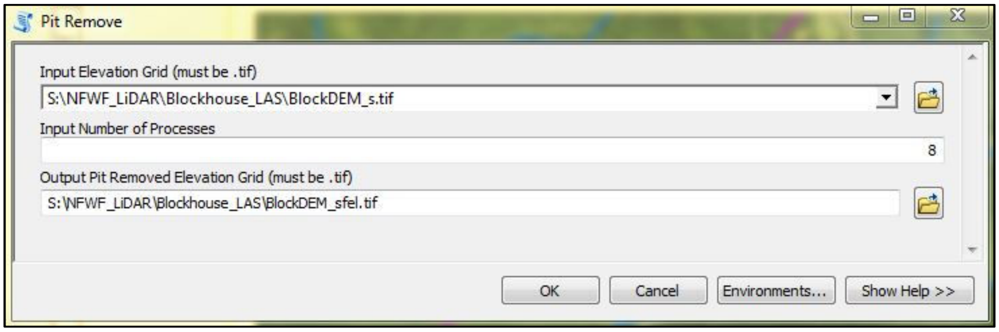
49. Open a web browser and navigate to the Utah State University TauDEM Version 5 download web page at http://hydrology.usu.edu/taudem/taudem5/downloads5.0.html
50. Download the appropriate TauDEM Install Package



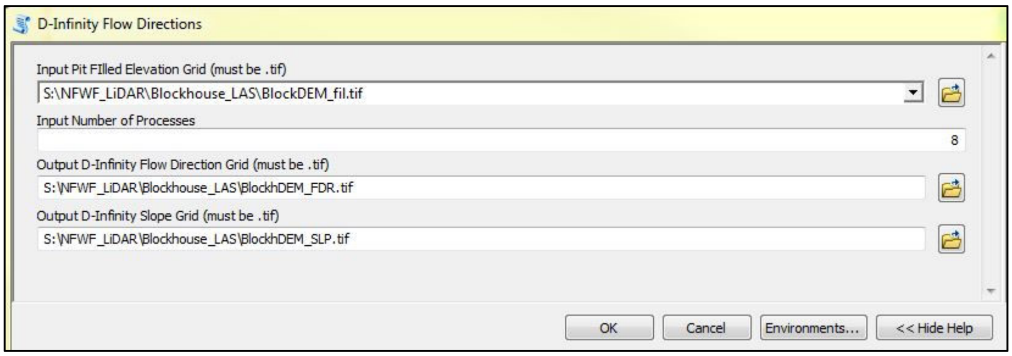
51. Install the TauDEM extension and any necessary prerequisite software
52. In ArcMap, open ArcToolbox
53. Right-click the ArcToolbox folder at the top of the window and select 'Add Toolbox'
54. Navigate to C:\Program Files\TauDEM\TauDEM5Arc and select 'TauDEM Tools.tbx
55. Expand the TauDEM Tools toolbox
56. Expand the Basic Grid Analysis toolset
57. Open the Pit Remove script to remove sinks in the smoothed DEM



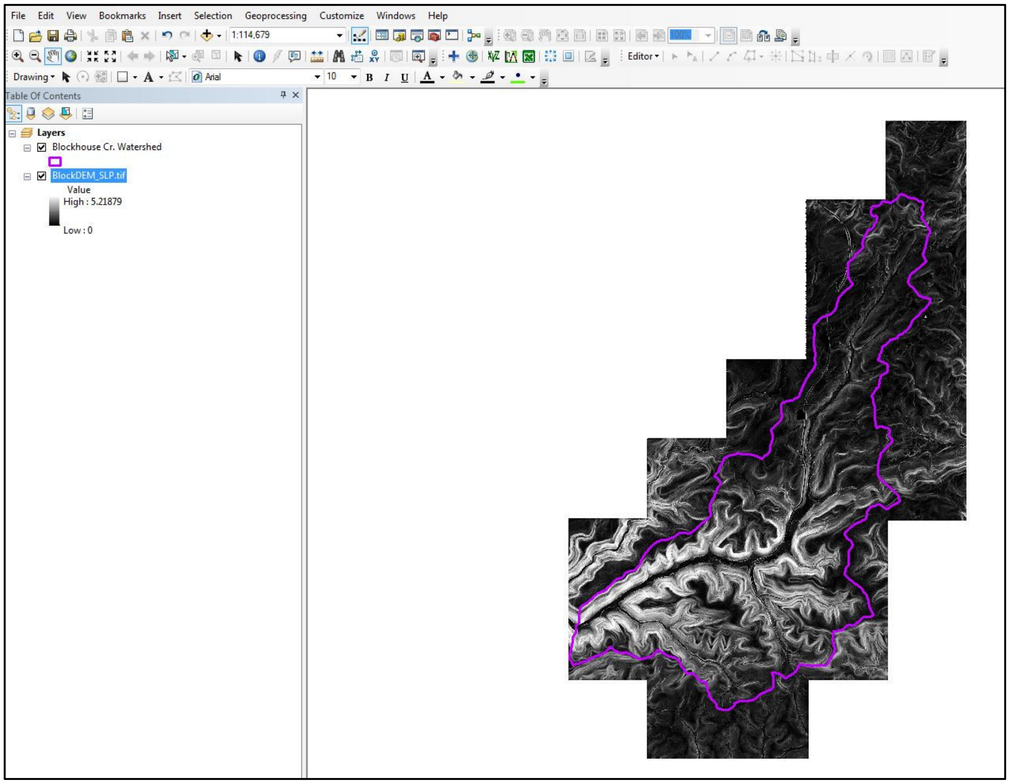
58. Add the smoothed DEM as the Input Elevation Grid
59. Use the default (8) Input Number of Processes
60. Specify an Output Pit Removed Elevation Grid with a file extension of .tif



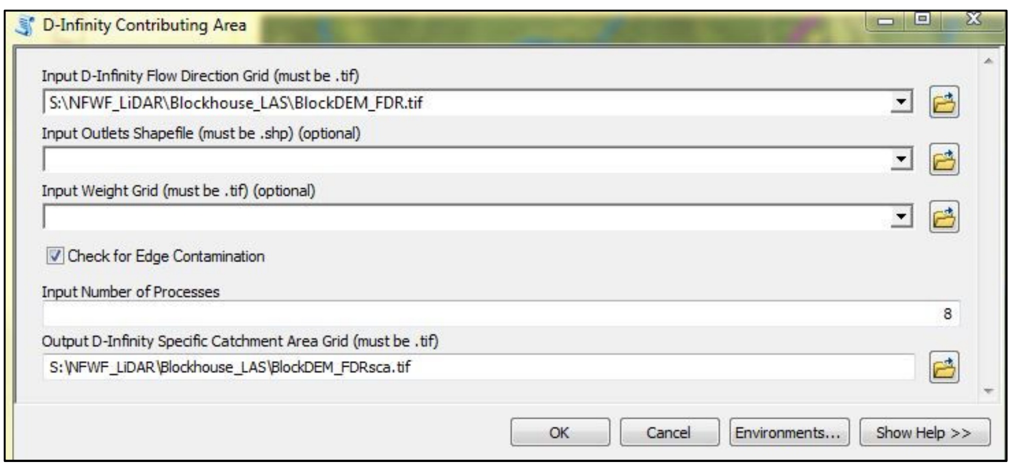
61. Click OK to execute the Pit Remove script
62. In ArcToolbox, TauDEM Tools toolbox, Basic Grid Analysis toolset, open the D-Infinity Flow Directions script
63. Add the Pit Removed Elevation Grid as the Input
64. Use the default (8) Input Number of Processes
65. Specify an Output D-Infinity Flow Direction Grid with a file extension of .tif
66. Specify an Output D-Infinity Slope Grid with a file extension of .tif



67. Click OK to execute the D-Infinity Flow Directions script



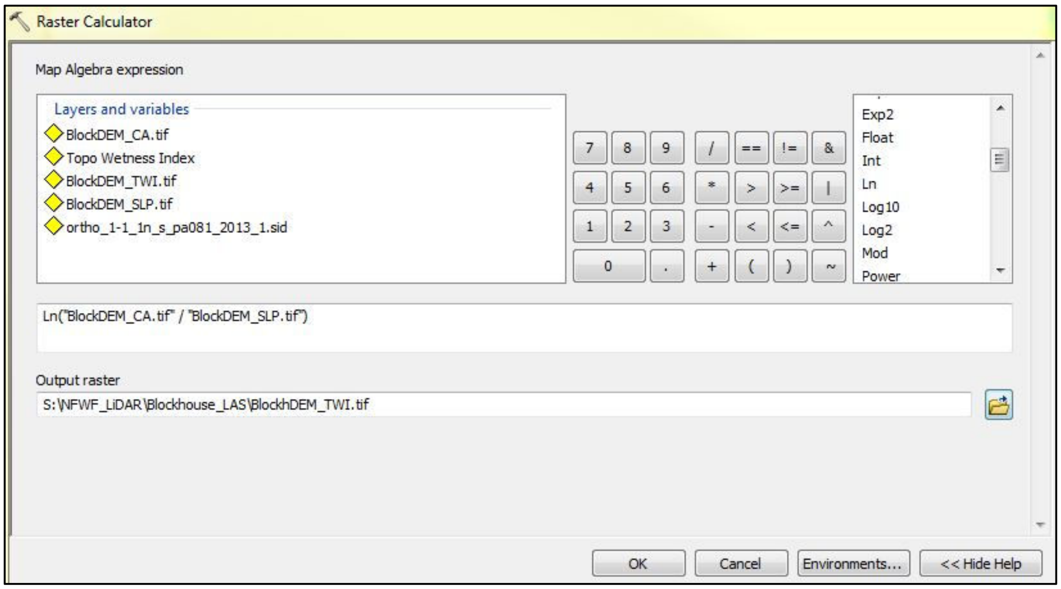
68. In ArcToolbox, TauDEM Tools toolbox, Basic Grid Analysis toolset, open the D-Infinity Contributing Area script
69. Add the D-Infinity Flow Direction Grid as an Input
70. Use the default (8) Input Number of Processes
71. Specify an Output D-Infinity Specific Catchment Area Grid with a file extension of .tif



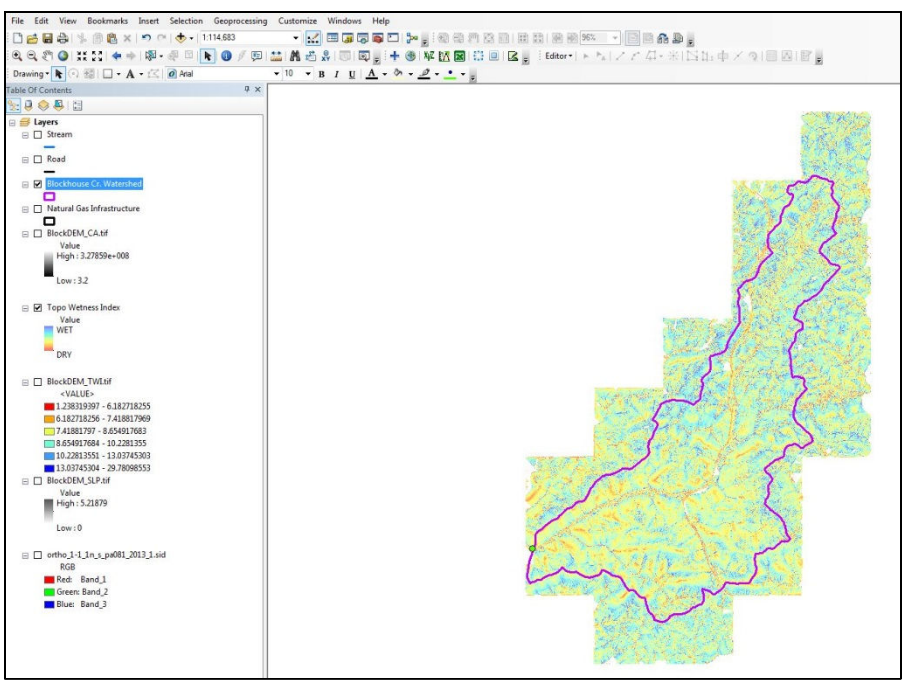
72. Click OK to execute the D-Infinity Contributing Area script

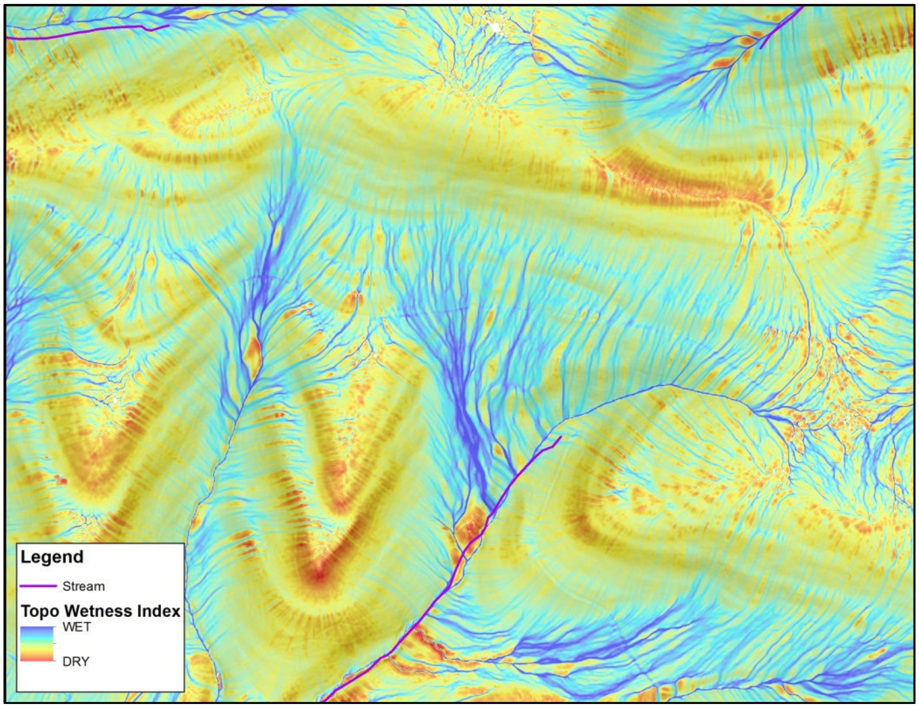
D. Calculate the Topographic Wetness Index (TWI)

73. In ArcToolbox, Spatial Analyst Tools toolbox, Map Algebra toolset, open the Raster Calculator geoprocessing tool
74. Add the following natural logarithm (Ln) equation in the expression window: Ln(Contributing Area/Slope)
75. Specify an Output TWI raster



76. Click OK to execute the Raster Calculator geoprocessing tool





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Tarboton, D.G. 1997. A New Method for the Determination of Flow Directions and Contributing Areas in Grid Digital Elevation Models. Water Resources Research, 33(2): 309-319.