Project:	Drainage Design Toolbox for ArcGIS 10.6 / 10.7
Location:	Cox's Bazar, Bangladesh
Document Title:	How to Use Instruction Manual
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Introduction:

- The design process of drainage systems consists of two stages:
    - **Hydrologic Analysis** that involves the quantification of the excess water to be drained from a given watershed and the rate at which it should be drained.
    - **Hydraulic design** – this refers to the calculation of geometric elements of the drainage channel to carry the design runoff and the drainage network layout.
- With the availability of Digital Terrain Model (DTM), the overall objective of this ArcGIS Toolbox is to calculate the dimensions of secondary and tertiary drainage system such as: (slope, width, depth of channel) by checking the connectivity of the drainage system.

For more information about the background of the Toolbox, please read the document 'Drainage Design Masterplan' and go to chapter 'Drainage Design Toolbox'.

Software Requirement:

To run the model, it is required to have ArcGIS 10.6 / 10.7 installed. There is specific instruction to be followed when using either of this software during data processing which will be detailed in 'Getting started' section.

Data Requirement:

- Primary input data requirement:
    - Digital Terrain Model (DTM) with National Projection in meters [m], for Bangladesh recommended to be **WGS_1984_UTM_Zone_46N**
    - Existing drainage layer (linear feature as a shape file format) of the catchment in consideration (optional). It should be noted that the projection of DTM and existing drainage later should be the same.

Getting started

- It is recommended to create your working space (folder) before you start ArcGIS (map).
- Make sure to save the raster (DTM) and drainage file (line feature) in your working folder.

- Open ArcMap. To add the raster data, click on the 'Add Data' button . Navigate to your working folder where you have saved the raster (DTM) file. Double-click the raster file to add it to the ArcMap display area.
    - If both layers saved in the same folder, use the shift key to select the raster and vector layer to add to the ArcMap display area.
    - If the raster dataset covers a larger area, then use any 'Drawing tool' to specify the Area of Interest (AOI).

- Right-click the raster dataset in the table of contents and select **Data** and then **Export Data**.
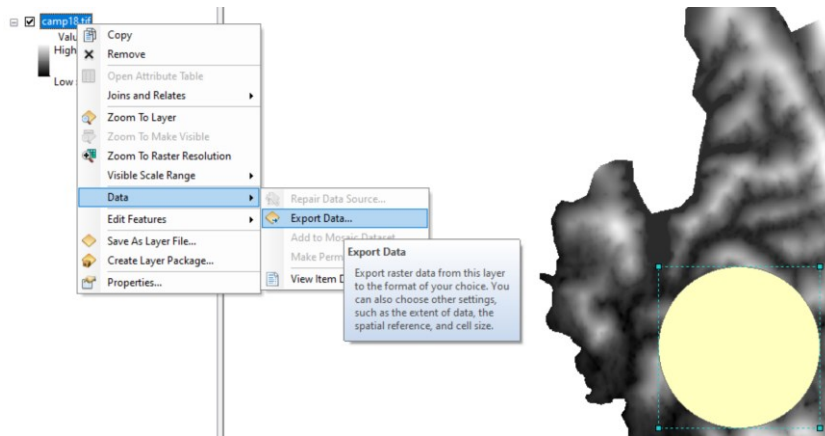
- When the 'Export Raser Data' window opens, make sure to click on the 'Selected Graphics (clipping) radio button. Navigate to your working folder and specify the location to save the raster file. Finally name the file (all required marked in blue color).
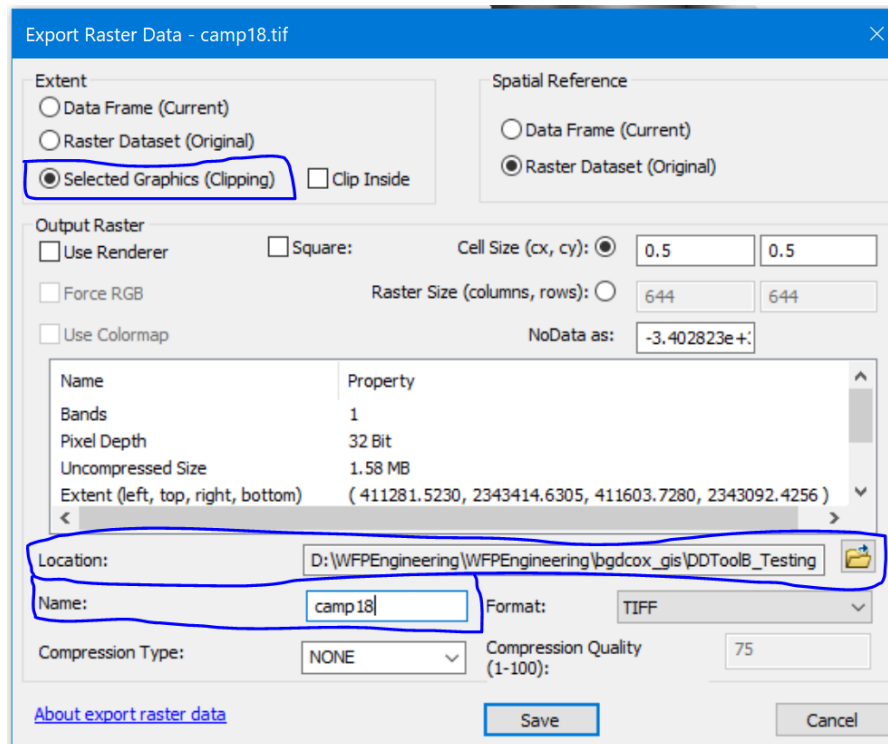
- Next open 'ArcToolbox' and right-click the 'ArcToolbox' and select 'Add Toolbox'.
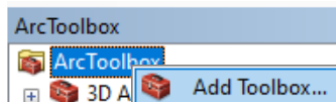
- Navigate to your working folder and add the 'Drainage Design Toolbox' to the existing ArcToolbox.

1. Sample Elevation

The tool samples the minimum and maximum elevation value of DTM cells along a given stream. A representative minimum elevation value for the existing or designed alignment of the 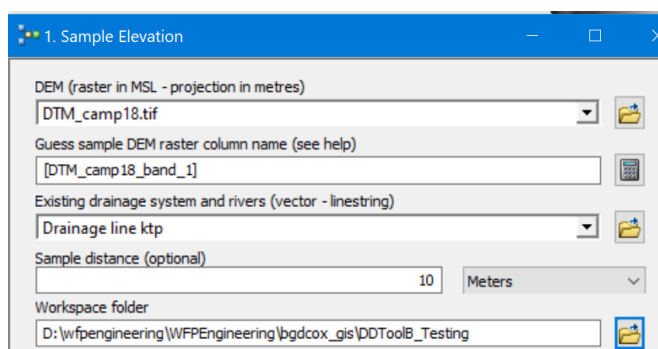drainage system. The minimum elevation value is later use for the drainage network into the elevation raster (tool 2), which helps the hydrology toolbox (tool 3) to follow the drainage network in the stream analysis.

- DTM (raster in MSL – Projection in meters[m]) Input the DTM in the first input data
    - The sample DTM raster column name – for ArcGIS 10.6 – [drainage_line_ktp_band]
    - for ArcGIS 10.7 – [drainage_line_ktp_band _1]

- Open the ArcToolbox and expand the '**Drainage Design Toolbox'**
- Double- click the '**1. Sample Elevation**' tool.
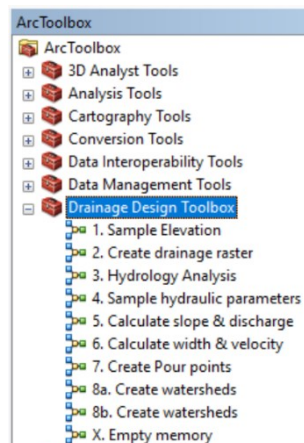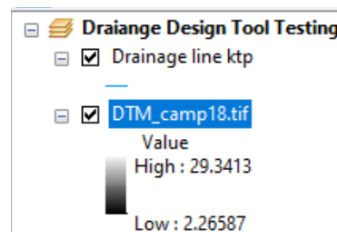
- When the 'Sample Elevation Tool' window opens, select the '**DTM_camp18.tif'** from the DEM drop-down menu. Then type **[DTM_camp18_band_1]** as the 'Guess sample DEM raster'. Please note that the raster dataset is single band therefore, we use 1 as the band. Select the 'Drainage line ktp' from the Existing drainage system and rivers (vector..). Finally navigate to your working folder to save the 'output' from the first tool; 'Sample Elevation' and then click '**OK**' to run the tool.
- Line feature named '**drainage_with_elevation**' automatically add to the table of content.

1. Sample Elevation

Executing Join Field (2)...   Cancel

6%   << Details

☑ Close this dialog when completed successfully

```
Succeeded at Mon Nov 18 17:16:22 2019
(Elapsed Time: 0.00 seconds)
Executing (Calculate Field):
CalculateField in_memory\tmp_samples
elev [dtm_ktp_band_1] VB #
Start Time: Mon Nov 18 17:16:22 2019
Succeeded at Mon Nov 18 17:16:22 2019
(Elapsed Time: 0.07 seconds)
Executing (Join Field): JoinField
in_memory\stream_points OID in_memory
\tmp_samples STREAM_POINTS elev
Start Time: Mon Nov 18 17:16:22 2019
Succeeded at Mon Nov 18 17:16:23 2019
(Elapsed Time: 0.51 seconds)
Executing (Summary Statistics):
Statistics in_memory\stream_points
in_memory\tmp_samples2 "elev MIN;elev
MAX" ORIG_FID
Start Time: Mon Nov 18 17:16:23 2019
Succeeded at Mon Nov 18 17:16:23 2019
(Elapsed Time: 0.25 seconds)
Executing (Join Field (2)): JoinField
D:\WFPEngineering\WFPEngineering
\bgdcox_gis\DDToolB_Testing
\drainage_with_elevation.shp FID
in_memory\tmp_samples2 ORIG_FID
ORIG_FID;MIN_elev;MAX_elev
Start Time: Mon Nov 18 17:16:23 2019
```
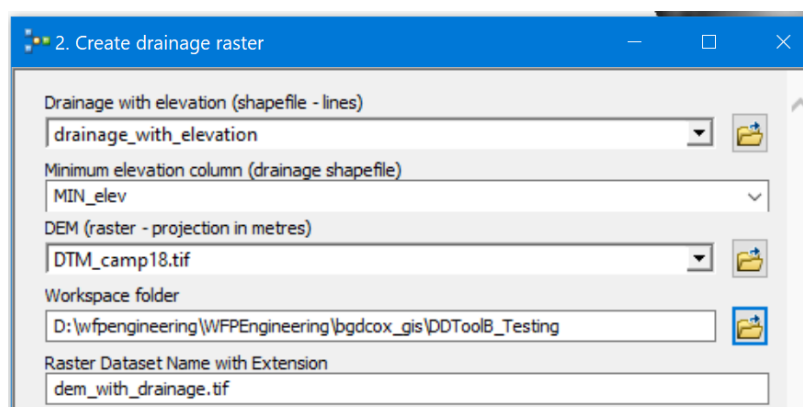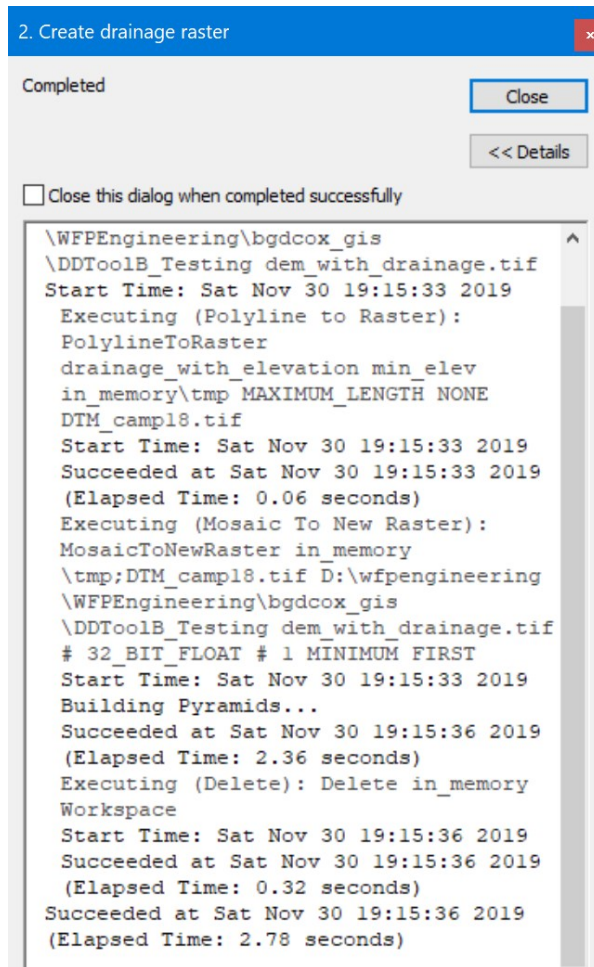

2. Create drainage raster

The drainage system is normally not fully included in the elevation raster. This tool inserts the elevation of the drainage network in the elevation model. This helps the hydrology toolbox (tool 3) to follow the drainage network in the stream analysis.

- Click on ArcToolbox and double-click the '**2. Create drainage raster**' tool from the drop-down.
- Select the '**drainage_with_elevation**' for Drainage with elevation (shapefile – lines).
- DEM (raster) drop-down arrow, select the '**DTM_camp18.tif**'
- Navigate to your working folder as the '**Workspace folder**'
- Click '**OK**' to run the tool.

2. Create drainage raster

Drainage with elevation (shapefile - lines)
drainage_with_elevation

Minimum elevation column (drainage shapefile)
MIN_elev

DEM (raster - projection in metres)
DTM_camp18.tif

Workspace folder
D:\wfpengineering\WFPEngineering\bgdcox_gis\DDToolB_Testing

Raster Dataset Name with Extension
dem_with_drainage.tif

2. Create drainage raster

Completed

Close

<< Details

☐ Close this dialog when completed successfully

```
\WFPEngineering\bgdcox_gis
\DDToolB_Testing dem_with_drainage.tif
Start Time: Sat Nov 30 19:15:33 2019
 Executing (Polyline to Raster):
 PolylineToRaster
 drainage_with_elevation min_elev
 in_memory\tmp MAXIMUM_LENGTH NONE
 DTM_camp18.tif
 Start Time: Sat Nov 30 19:15:33 2019
 Succeeded at Sat Nov 30 19:15:33 2019
 (Elapsed Time: 0.06 seconds)
 Executing (Mosaic To New Raster):
 MosaicToNewRaster in_memory
 \tmp;DTM_camp18.tif D:\wfpengineering
 \WFPEngineering\bgdcox_gis
 \DDToolB_Testing dem_with_drainage.tif
 # 32_BIT_FLOAT # 1 MINIMUM FIRST
 Start Time: Sat Nov 30 19:15:33 2019
 Building Pyramids...
 Succeeded at Sat Nov 30 19:15:36 2019
 (Elapsed Time: 2.36 seconds)
 Executing (Delete): Delete in_memory
 Workspace
 Start Time: Sat Nov 30 19:15:36 2019
 Succeeded at Sat Nov 30 19:15:36 2019
 (Elapsed Time: 0.32 seconds)
Succeeded at Sat Nov 30 19:15:36 2019
(Elapsed Time: 2.78 seconds)
```

- Click the '**Close**' button to close the '2. Create drainage raster' window.
- The 'dem_with_drainage.tif' automatically adds to your ArcMap table of Content.
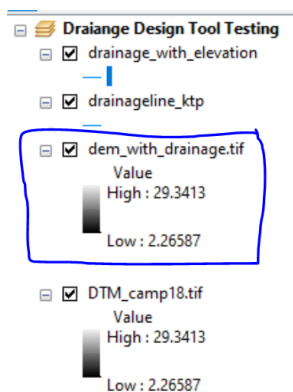
3. Hydrology analysis

The tool first estimates the location of the main and small streams inside the study area and secondly, if available, estimate where the streams follow the drainage system.
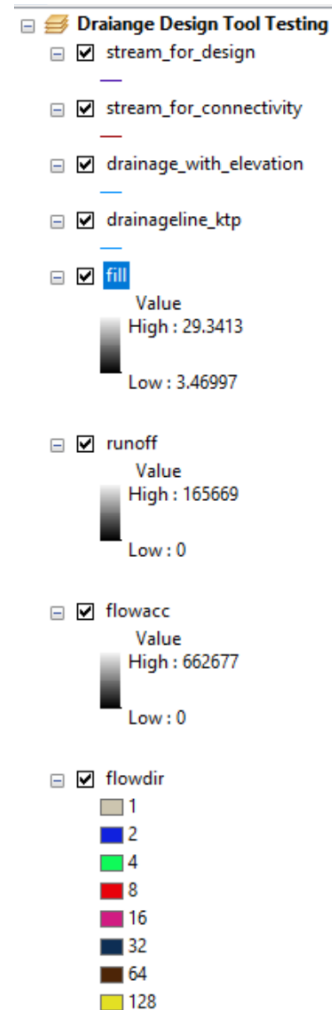
- If not, expand the Drainage Design Toolbox and double-click the '**3. Hydrology Analysis**' tool.
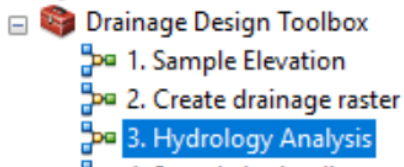
- For the DEM, use the drop-down arrow to select the '**DTM_camp18.tif**'
- The default value for 'DEM Raster cell size' is **0.5**.
- Navigate to your working folder for the 'Workspace folder' and click '**OK**' to run the tool.
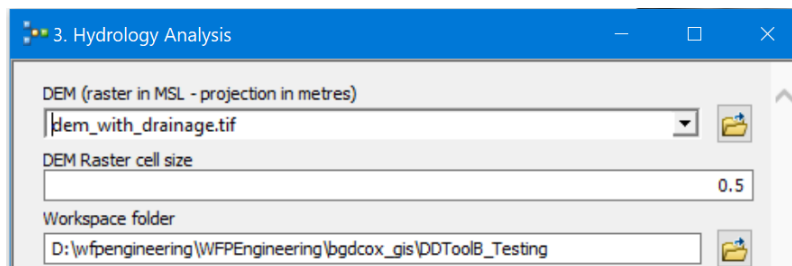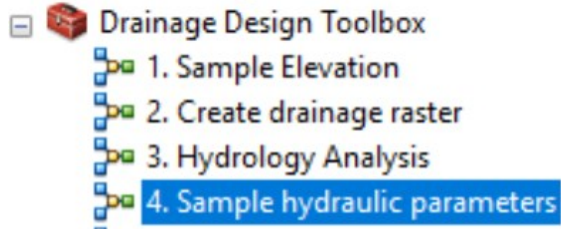

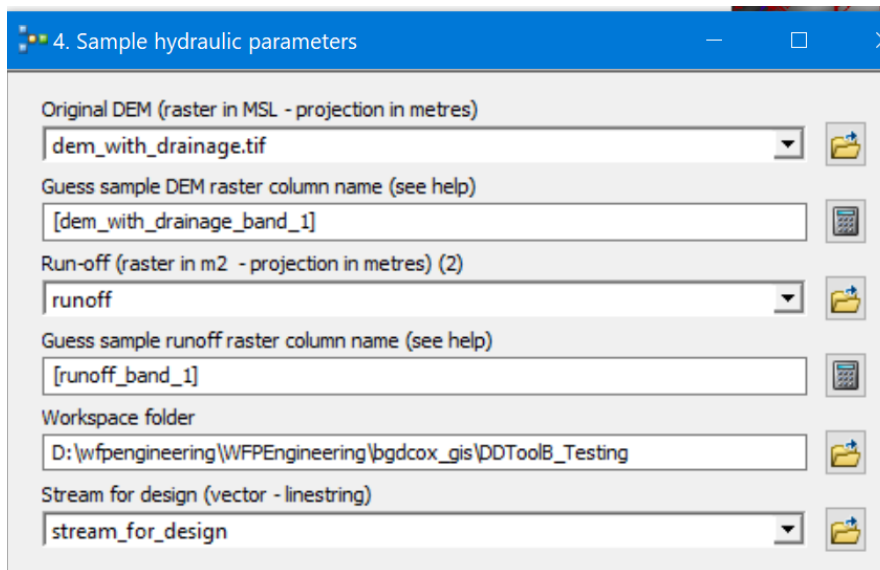- All layers will automatically add to the ArcMap Table of Content.

4. Sample hydraulic parameters

The tool estimate elevation and runoff of the area for slope and discharge calculation.

- Double-click the '**4. Sample hydraulic parameters**' tool.

- For the DEM, use the drop-down arrow to select the '**DTM_camp18.tif**'
- Type **[dem_with_drainage_band_1] (ArcGIS 10.7) or [dem_with_drainage] (ArcGIS 10.6)** for the 'Guess sample DEM raster column name (see help)'. Please note, that *raster dataset is 1 band*.
- From the dropdown arrow, select **'runoff'**
- Type **'[runoff_band_1] (ArcGIS 10.7) or [runoff] (ArcGIS 10.6)'** for the 'Guess sample runoff raster column name (see help)'.
- Navigate to your working folder for the 'Workspace folder'.
- Leave default for **Stream for design (vector – linestring)' – "stream_for_design"**
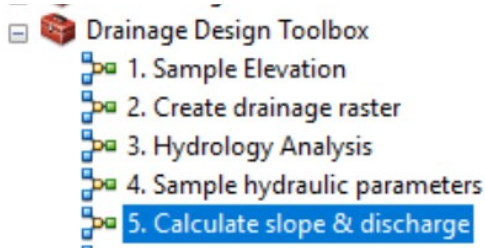- Click '**OK**' to run the tool.

- Layer will automatically add to the ArcMap Table of Content.
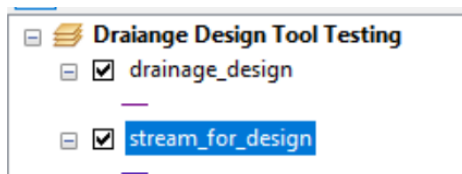
5. Calculate slope & discharge

Preparing '**width and velocity**' to calculate slopes and discharge.

- Double-click the '**5. Calculate slope & discharge**' tool.

- Drainage Design Toolbox
  - 1. Sample Elevation
  - 2. Create drainage raster
  - 3. Hydrology Analysis
  - 4. Sample hydraulic parameters
  - 5. Calculate slope & discharge

- From the 'Drainage network with attributes (vector - ….)' drop-down list, select '**drainage_design**'.
- *Default value of rainfall intensity 50 (mm/hr) is assigned. However, this is optional, and it can be changed based on the target design rainfall intensity. Generally, it is estimated that the 5 years return period rainfall intensity for Cox's Bazar to be about 50 (mm/hr) by taking into account some infiltration as well.*
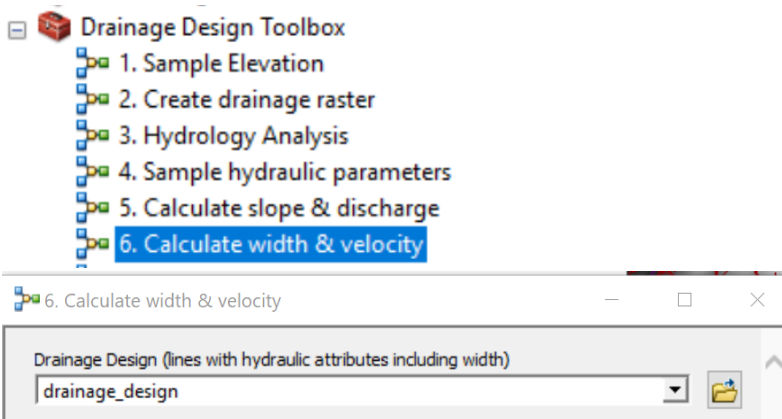- Click '**OK**' to run the tool.

5. Calculate slope & discharge   —   □   ✕

Drainage network with attributes (vector - linestring)
drainage_design

Design Rainfall Event [mm/hr] (default: 50)
50
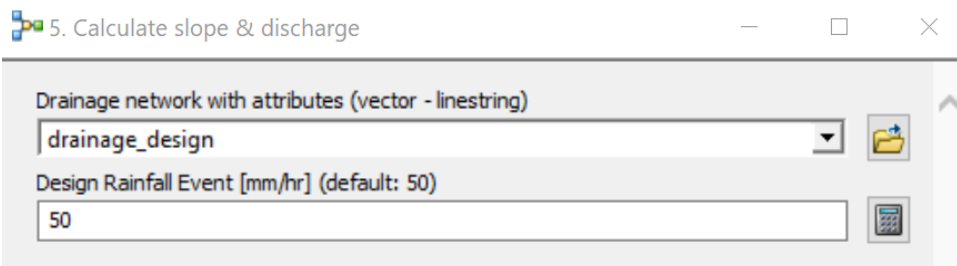
- No layers adding to the ArcMap table of content from this tool.

6. Calculate width & velocity

Provides a preliminary design of the drainage system, by calculating the width based on an assumed depth without freeboard. In this tool, the velocity will be calculated to check for expected high velocities.

- Double-click the '**6. Calculate width & velocity**' tool.

- Drainage Design Toolbox
  - 1. Sample Elevation
  - 2. Create drainage raster
  - 3. Hydrology Analysis
  - 4. Sample hydraulic parameters
  - 5. Calculate slope & discharge
  - 6. Calculate width & velocity

6. Calculate width & velocity   —   □   ✕

Drainage Design (lines with hydraulic attributes including width)
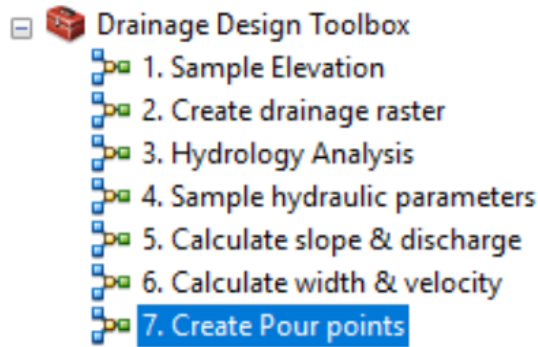drainage_design

- "**drainage_design**" already set as the default. Therefore, click '**OK**' to run the tool.
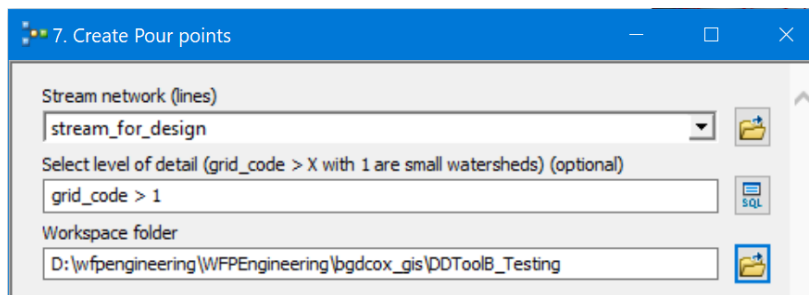- no change to your ArcMap table of content or Map Area.

7. Create Pour points

Automatically generate pour points at some confluence points of two or more streams.
- Double-click the '**7. Create Pour points**' tool.

Drainage Design Toolbox
- 1. Sample Elevation
- 2. Create drainage raster
- 3. Hydrology Analysis
- 4. Sample hydraulic parameters
- 5. Calculate slope & discharge
- 6. Calculate width & velocity
- 7. Create Pour points

- Select '**stream_for_design**' from the stream network (lines) drop-down arrow.
- Don't change the default value for 'Select level of detail ……..'. Set it as '**grid_code > 1**'.
- Navigate and select your **workspace folder**.
- Click '**OK**' to run the tool.

7. Create Pour points

Stream network (lines)
stream_for_design

Select level of detail (grid_code > X with 1 are small watersheds) (optional)
grid_code > 1

Workspace folder
D:\wfpengineering\WFPEngineering\bgdcox_gis\DDToolB_Testing

- Process time depending on you AOI and when the tool executed, layer name '**pourpoints**' will automatically add to your ArcMap table of content.
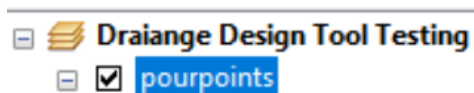
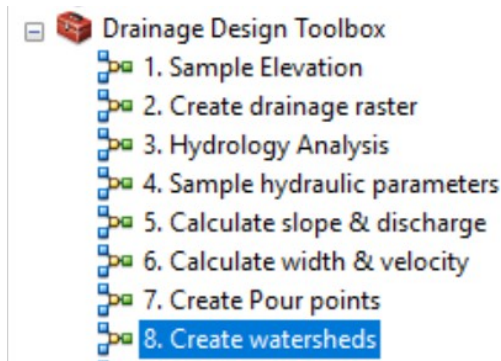Draiange Design Tool Testing
- ☑ pourpoints

There might be some issues in this tool regarding the extent. If this is happening, please make sure that the environment settings are set towards the whole area.
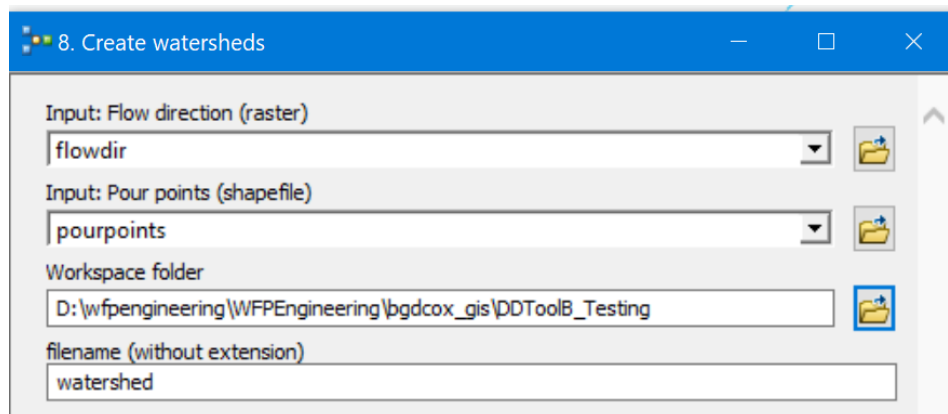
8. Create watersheds

Determine the watersheds to get a feeling of which area is contributing to the streams or drainage system in your project area. These extents could help in the design process.

- Double-click the '**8. Create watersheds**' tool.

Drainage Design Toolbox
- 1. Sample Elevation
- 2. Create drainage raster
- 3. Hydrology Analysis
- 4. Sample hydraulic parameters
- 5. Calculate slope & discharge
- 6. Calculate width & velocity
- 7. Create Pour points
- 8. Create watersheds

- When the tool window opens, select the '**flowdir**' from the Input: Flow…
- From "Input: Pour points" drop-down arrow, select '**pourpoints**'.
- Click on the navigate folder and browse to your '**Workspace folder'**
- Let the default '**watershed**' as the filename.
- Click '**OK**' to run the tool.

8. Create watersheds

Input: Flow direction (raster)
flowdir

Input: Pour points (shapefile)
pourpoints

Workspace folder
D:\wfpengineering\WFPEngineering\bgdcox_gis\DDToolB_Testing

filename (without extension)
watershed

- When the tool complete, the layer '**watershed**' automatically added to your ArcMap, table of content.
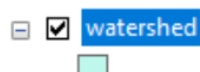
☑ watershed

There might be some issues in this tool regarding the extent. If this is happening, please make sure that the environment settings are set towards the whole area.

To run the next tool, you need to have the 'landslide susceptibility classes' rasterfile saved in your working folder. If you do not have the datafile, then you will not be able to run the 'Drainage Connectivity Check' tool.

9. Drainage Connectivity Check

Creating a map that shows the most vulnerable locations to landslide risk due to missing drainage.
These locations are a priority for drainage improvement after ground-truthing.

- Double-click the '**9. Drainage Connectivity Check**' tool.
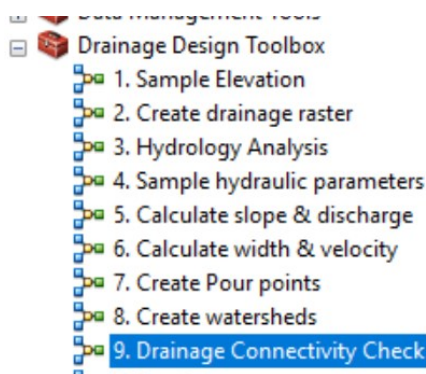
10. Empty memory

If one of your tools is interrupted during the process, it might be happening that your memory is not emptied. This could cause an error if you try to rerun the same tool.

All temporary files created during these steps, will automatically deleted from your working folder after executing the "**Empty memory**" tool.

- Double-click the '**X. Empty memory**' tool.
- Click '**OK**' to run the tool.