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ADDA Lab

Dzaleka Flood Risk Assessment Watershed Delineation

Overview, Objective, and Skills

Overview: A watershed is defined as the area of land that channels rainwater and snowmelt through streams and rivers to a specific outflow point (called outlet point) such as another stream or river, reservoirs, bays, or the ocean. Everything happens in a watershed. Having a clear understanding of where the watershed boundary is critical in many environmental problem-solving. Surface water naturally would not naturally cross watershed boundaries (also called as water divides). Hence, addressing water quality and flooding related problems require a focused study of the specific watershed where the study area is located. Since everything in a watershed flows downhill, an area of disturbance in the upstream direction will impact everyone downstream. So, your geographic location within a watershed can tell you more about the potential sources of water related problems.

Scenario: Due to increase in frequency of intense rain events and floods happening in the country, the United Nations Environmental Protection Agency (UN-EP) has hired you to assess and submit a report on the flood risk potential for the area covering the Dzaleka Refugee Camp. One of the first steps in performing flood modeling is to collect streams and drainage basins data. You found out that there is no such data available for the area of interest. Hence, your task for this lab is to create watershed boundaries and streams data using publicly available data to assess where in the watershed is Dzaleka Refugee Camp and to what extent its location within the watershed increases or decreases its flooding potential.

Learning Objective: In this exercise you will learn 1) the watershed concepts and procedures for delineating watershed boundaries using digital elevation model (DEM) (lecture), and 2) watershed delineation and 3D watershed visualization using Q-GIS.

Skills Introduced and Practiced: You will learn to work with DEM data (a type of raster data), learn many raster processing techniques that are required to delineate watershed, and 3D visualization of your resulting watershed. You will also practice skills involving adding various dataset and visualizing the outcomes using appropriate symbology.

Lab Completion Requirements: You will be submitting a map that contains the Watershed shape file and streams shape file. Create a proper map layout showing the Watershed boundaries and the streams. Include all map elements necessary. Include one of your 3D views as an image somewhere within the map layout. Finally, write a brief report summarizing your observations in regard to flood risk for the refugee camp.

Data Used:

- **SRTM digital elevation model data** – download and unzip data (**DEM_Dzaleka**) from Moodle. To keep consistency with what everyone is doing in the lab, I am providing the data for you, so download the lab data from Moodle.

Add DEM Data to the Project (remember, adding your data file with predefined projection sets the QGIS project coordinate system to be the same. This is important in this particular lab because some of the tools we use will be assuming your project coordinate system is same as your data coordinate system. If they don't match, it will fail to run the process and display error).

1. Open **Q-GIS** and create a new project
2. To add a raster data, click **Layer → Add Layer → Add Raster Layer** option.
3. Navigate to your lab folder where you have downloaded the DEM data and select the **DEM_Dzaleka.tif** file
4. Make note of the projection information for this data layer and the project. Make sure they are the same!
5. Save your project file

Add Base Map to the Project

1. If you don't have QuickMapServices plugin, go to menu **Plugins → Manage and Install Plugins**
2. Under **Search** box, type **QuickMapServices**
3. When the plugin is displayed, click on **Instal Plugin** button at bottom right corner of the window
4. When installation is successful, click on Menu **Web → QuickMapServices → Google → Google Satellite** (you may have to install extended package under QuickMapServices "Settings" to get this).
5. You will notice that Google Satellite Basemap is loaded to your project. Now, explore the area where the refugee camp is. It is located little north of Lilongwe area. If you are not sure, you can open a browser on your computer and go to Google Map to search for the refugee camp.

Answer the questions in red throughout the document before proceeding to the next step. These answers should be submitted with your final map.

Q1. What is the terrain like where Dzaleka Refugee Camp is located? Are there any indicators of drainages (streams or rivers) and where the watershed boundary might be?

Watershed delineation usually involves the following steps:

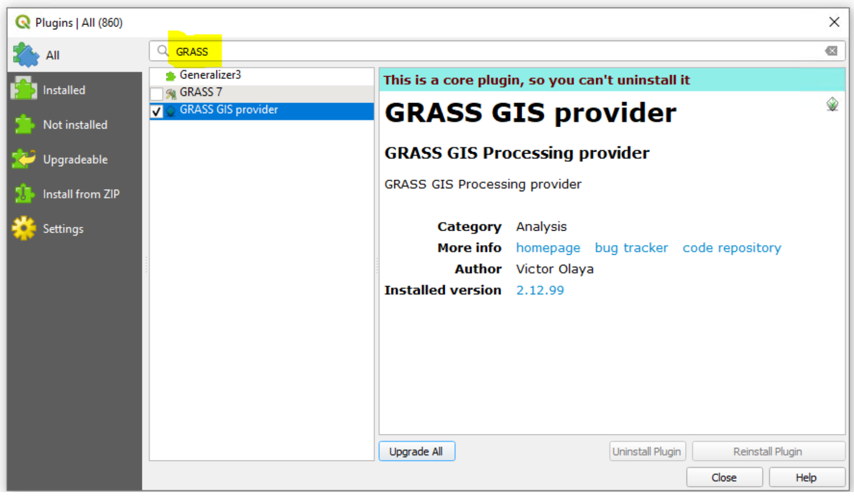
- DEM correction (getting rid of depressions in the elevation data or the landscape), also called as **DEM Fill**
- Calculating Flow Accumulation
- Calculating Flow Directions
- Defining Outlets for watershed delineation
- Watershed delineation
- Extracting streams
- Converting raster watershed and stream files to vector file format

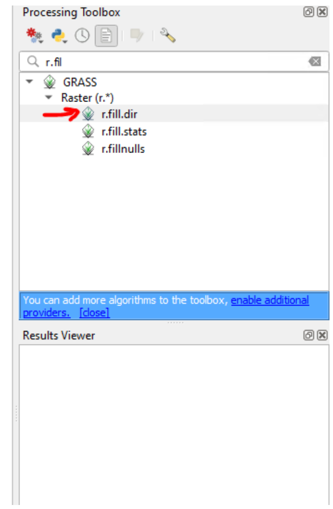
Filling the depressions in the DEM

Digital elevation data often has depressions, which are problematic for hydrologic analysis such as watershed creation and stream generation. We will first apply an algorithm to fill the sinks so that resulting DEM will be devoid of such depressions. The output from Fill operation will be a new DEM without depressions.

1. Under **Processing Toolbox**, search for **r.fill.dir**. This tool will take the DEM raster file that we provide and check if there are depressions in the data. If depressions are found it will then fill the depressions and produce a new depressionless DEM. Along with the new DEM, it will also compute the flow direction for each grid cell in the data and produce an output file.

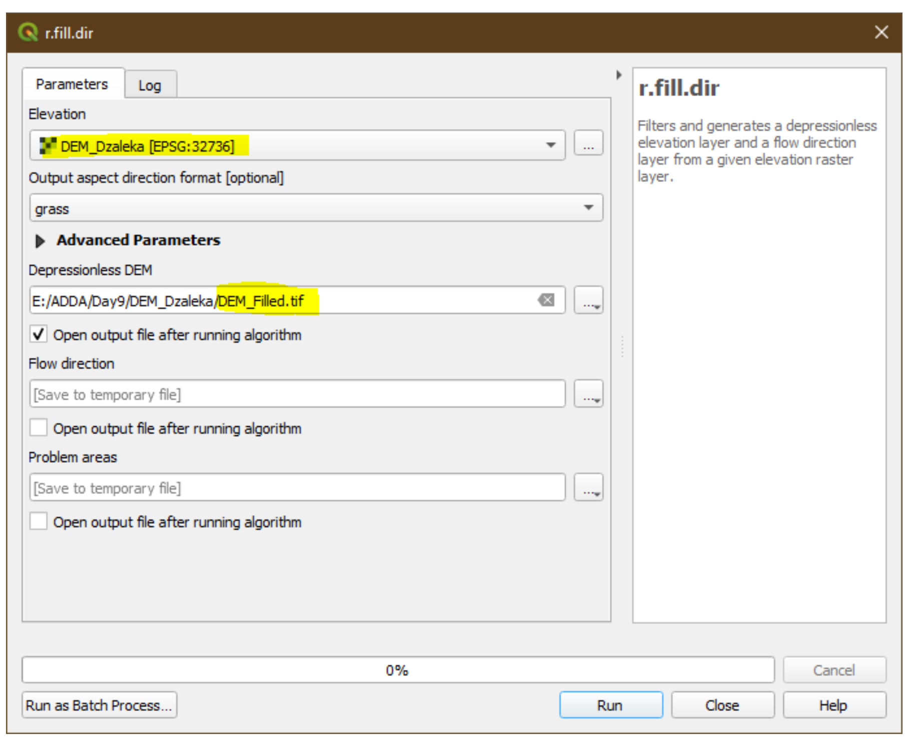
Note: If you do not see the **r.fill.dir** tool in your Processing Toolbox, you likely did not install QGIS with GRASS when you initially downloaded it. To fix this problem, go to **Plugins > Manage and Install Plugins** and type in **GRASS.** Select the option that says **GRASS GIS Provider** and install it. Then return to the **Processing Toolbox** and find **r.fill.dir**



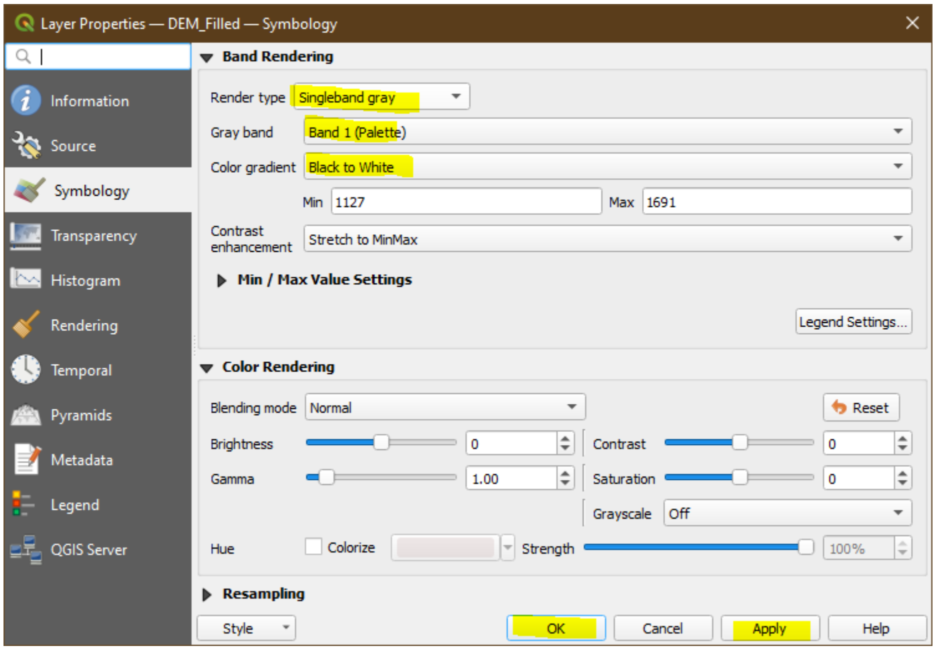


2. Provide the input DEM file from your folder under **Elevation** box.
3. For each of the <u>output files</u>, save the files into your project folder by clicking the small button with three dots on it, then navigating to your lab folder, followed by providing name for **Depressionless DEM (DEM_Filled.tif)**. We are mainly interested in the **Filled, Depressionless DEM** from this algorithm, so we don't need other output files.

Note: Flow direction raster will tell you which direction water will flow based on slope calculations for each cell. Flow direction is computed using <u>D8 algorithm</u> computations are performed for each raster cell by analyzing all 8 surrounding cells to determine the steepest downslope gradient and assign that direction to the cell. So, the output file should clearly show one of 8 possible values (equally eight directions) for any cell. We will create flow direction in a later step.



4. Click **Run**. Depending on the speed of the computer, size of the study area, and the pixel size for your data, it could take anywhere from few minutes to many hours. For this lab, it should not take more than a few minutes.
5. When complete, resulting **filled DEM** will be added to your project window
6. You may have to change the symbology to make it look similar to DEM.

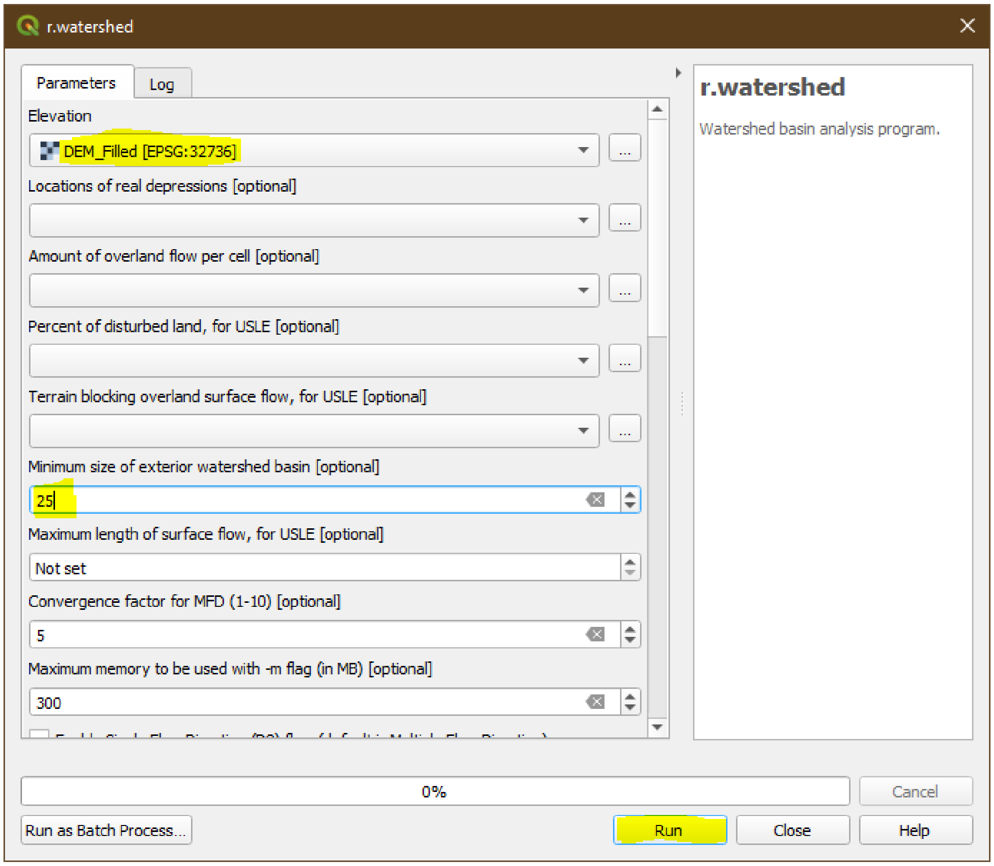


7. Explore them and understand what they display. Also, right click on the properties for the new layer and check under **information tab**, where the file is located. File location is specified under **Source** tab. If it is not where your lab folder is, you will have to make sure to save this file to your folder by right clicking and selecting **Export → Save as.**
8. We will use this filled DEM for all processing here after.

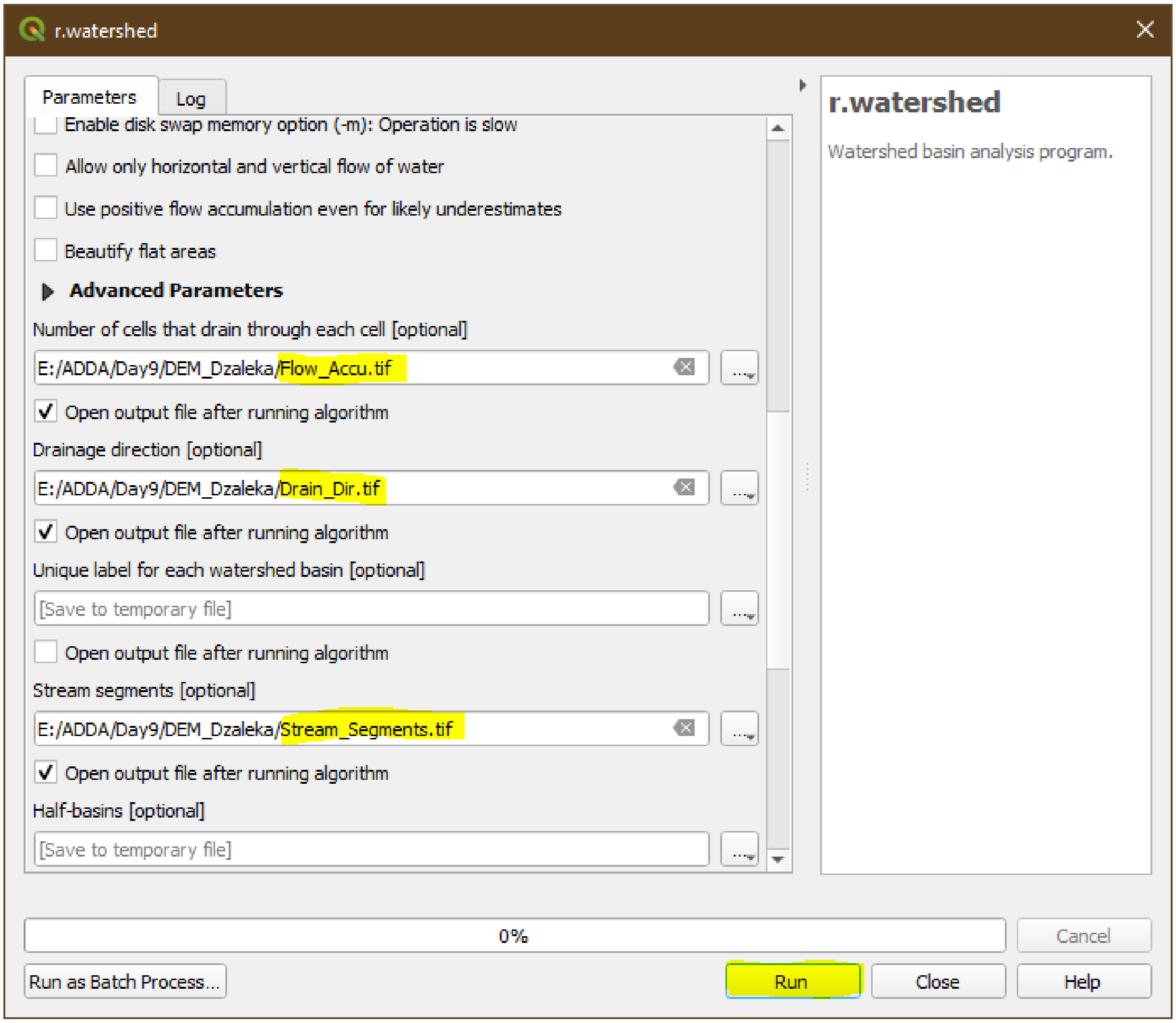
You may have to go to the properties for Flow Direction layer and make changes in symbology to bring the actual values in discrete/unique format to see them.

Flow Direction and Flow Accumulation Calculations:

1. Using the filled DEM (hydrologically corrected DEM), we can now calculate the flow accumulation and flow direction using **r.watershed** tool in Q-GIS
2. Search for **r.watershed** under **Processing Toolbox** panel.
3. This tool was designed to calculate many parameters for several different modeling exercises. We are not interested in all of them for this exercise. So, we will only use what we need.
4. When the tool opens, select your Depressionless DEM (DEM_Filled.tif) file under **Elevation**
5. We will skip several of the optional input parameters and go to **Minimum size of exterior watershed basin**. This is required for us to be able to run the watershed delineation. This number defines the minimum size of the catchment area for stream definition and watershed delineation. There is no standard value for this – we must use our own judgement and trial and error method to derive this. We know our DEM pixels are 30 m x 30 m in size, which is 900 m^2 for each pixel. So, if we roughly say we cannot accept any pixel draining less than 2 hectares (20,0000 square meter area) to be categorized a stream pixel, this gives us a **value of 25** (calculation: 25 * (30x30) = 22,500 m^2 which is about 2 hectares). If this does not produce us good results, we can re-run this with either a smaller or a larger value for this. Increasing this number will produce fewer streams and decreasing this will produce more streams in the resulting output.



6. Leaving other boxes with default values, scroll down the window to enter <u>output file names</u> (which will be generated by this tool) for **Number of cells that drain through each cell** (which is Flow Accumulation), **Drainage Directions** (Flow Direction), and **Stream Segments.**

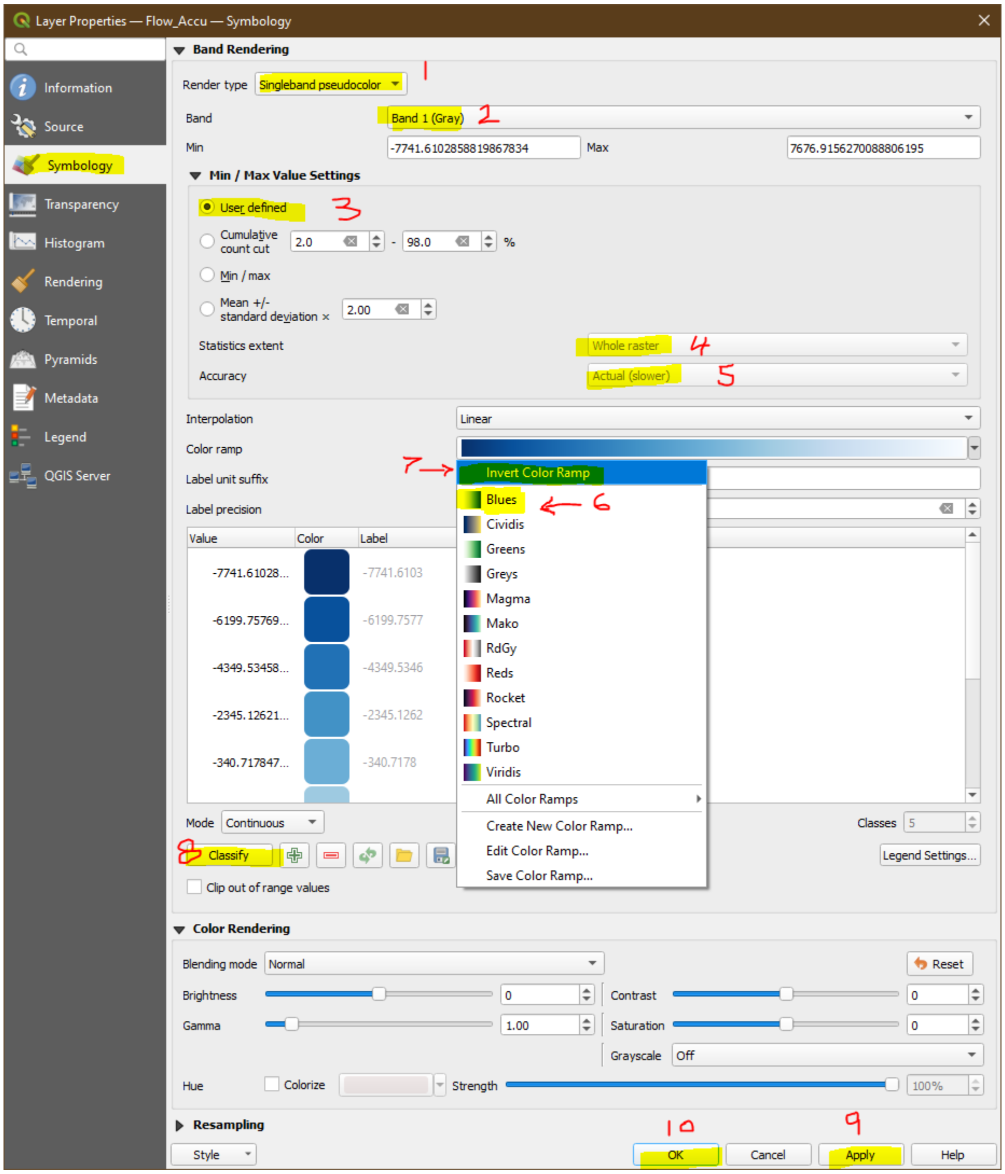


7. When completed entering file names at appropriate location, click **Run**

You will notice that three new output files have been added to the project. You should explore them to understand what they show. Turn **Off** the **Stream Segments** layer and look closely at the **Flow Accumulation** raster (in older versions of QGIS, this output file is probably named **Number of cells that drain through each cell)**. It may look gray all over, except upon closer examination, you will notice faint lines that look like stream segments.

What this file shows is how many upslope pixels are contributing flow into each pixel. As we can imagine, the lower in the landscape a pixel is representing, the greater number of pixels flowing into that pixel. With that logic, it is easy to understand that pixels at the valley bottoms where streams are flowing, are going to have some of the highest flow accumulation values. So, the bright line that is visible in the image, is likely a stream at the bottom of the valley in the landscape. Negative values indicate flow accumulation for those cells have origins outside of our data extent.

8. Right-click on Flow Accumulation layer and click on **Properties.** Go to **Symbology** option and experiment with different ways to make the layer show the higher flow accumulation values more effectively.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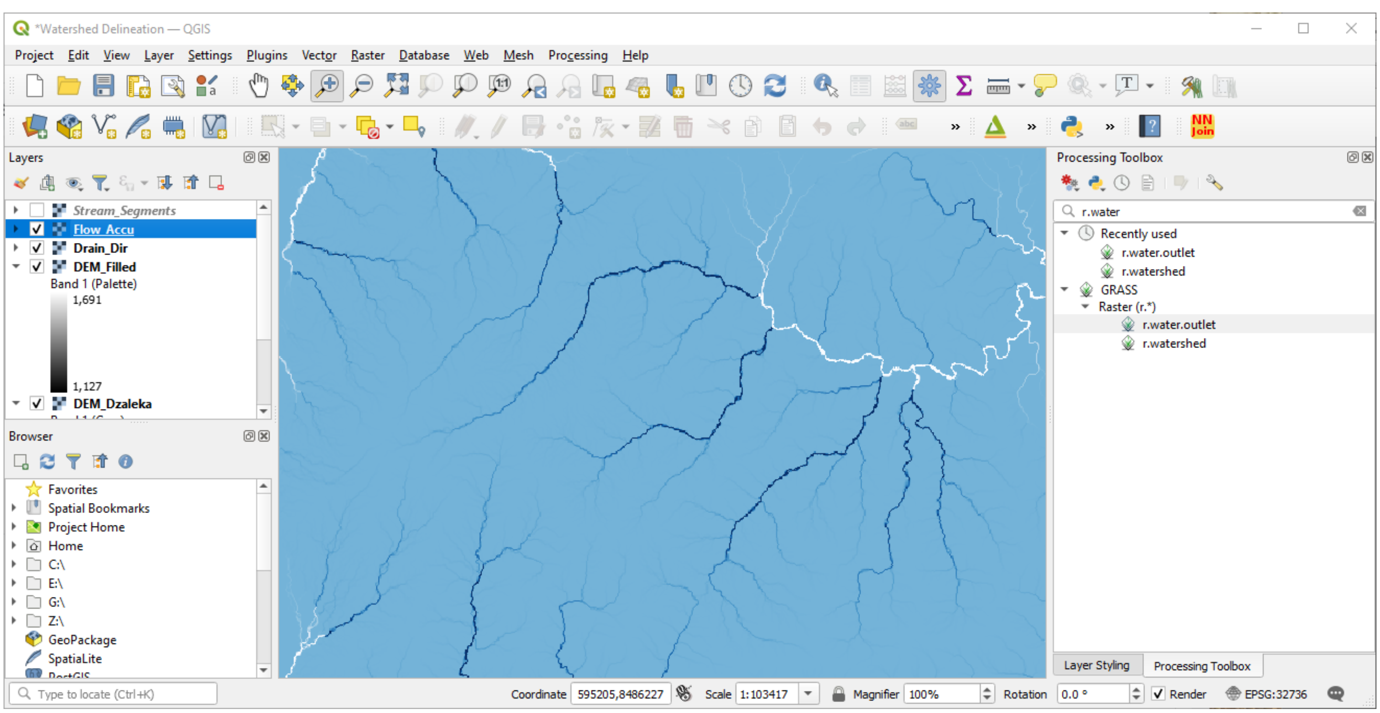
*Watershed Delineation — QGIS
Project Edit View Layer Settings Plugins Vector Raster Database Web Mesh Processing Help
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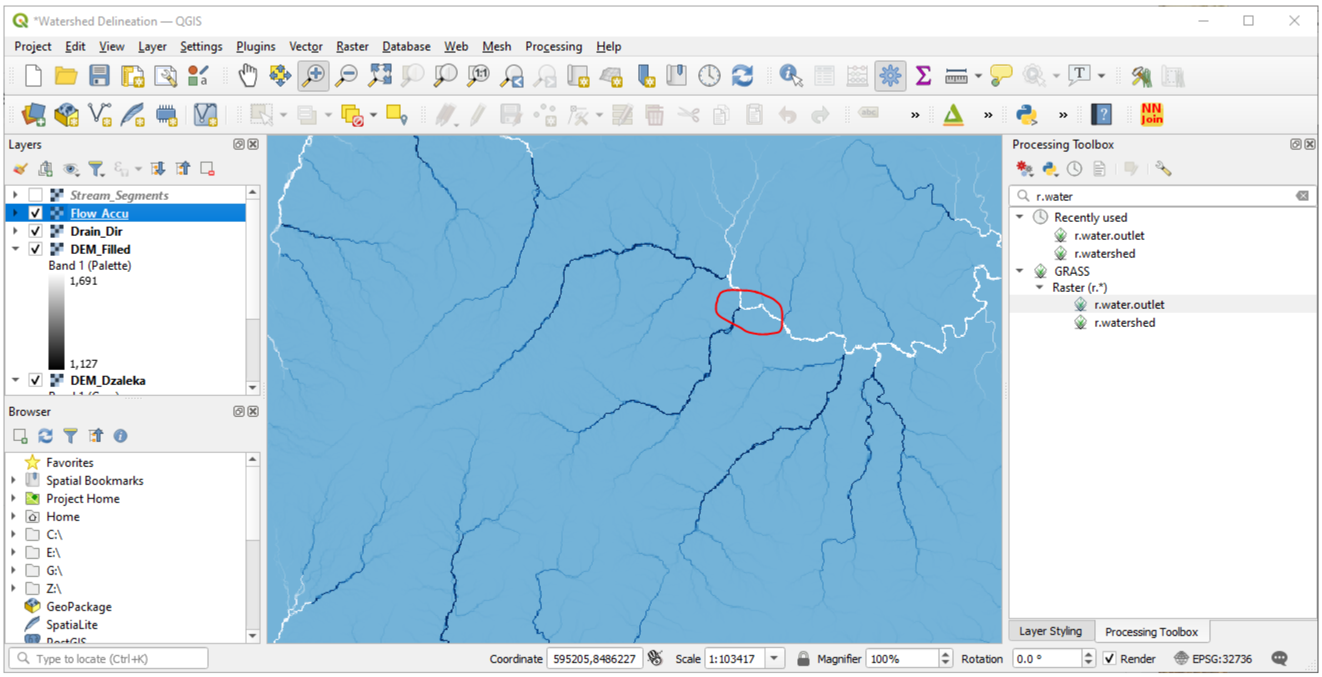
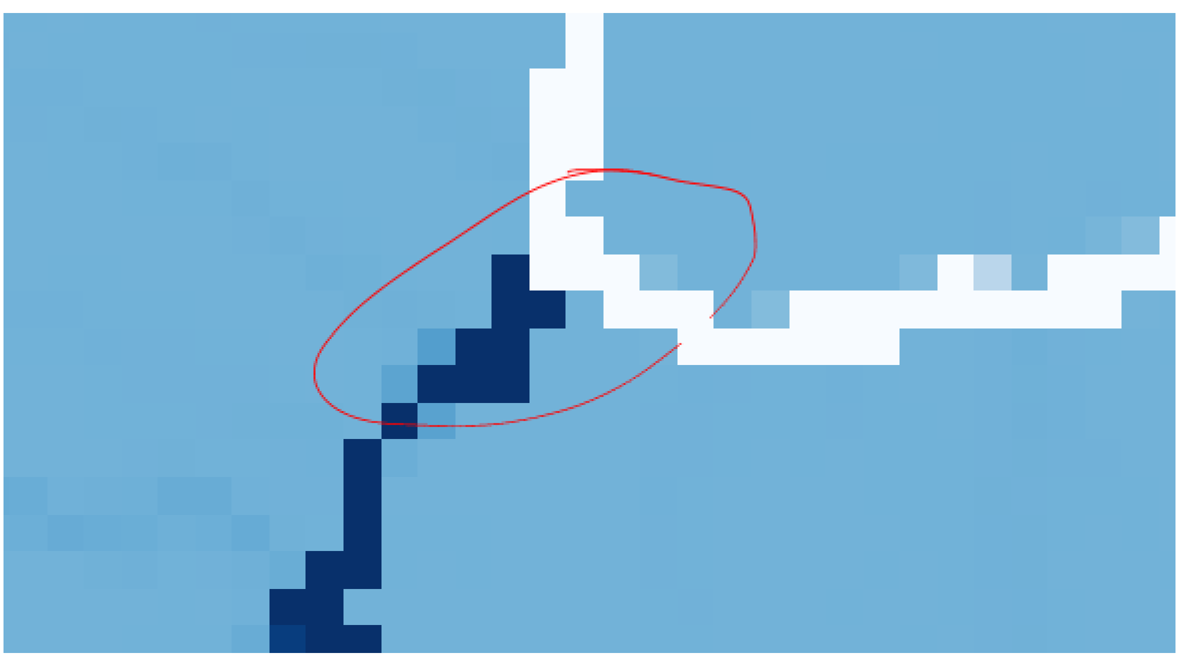
Outlet Creation

We are normally interested in delineating the watershed at a particular point on the landscape - it might be the point where a road crosses the river (where water sampling is conducted usually) or it could be a point where stream gauge measurements are done. We call this point as the **Outlet** point. We need to know the location of this point in order to create the watershed. We will use the tool **r.water.outlet** to perform watershed delineation at a point of our interest.

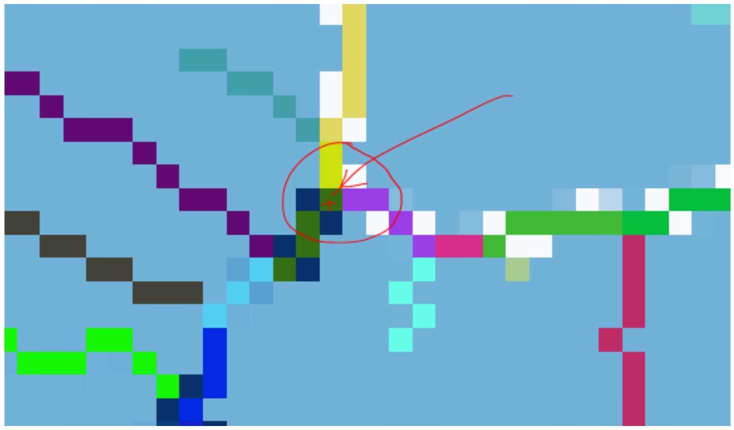
1. Search for **r.water.outlet** tool under **Processing Toolbox** panel. Double click the tool to open the tool. This tool requires **Drainage Directions** raster file that we generated in the previous step and coordinates for the **outlet** point. The coordinates should be in the same units as the map. In our case, it will be UTM coordinates.
2. Under **Name of input raster map**, select the **Drainage Directions** file.
3. Now, on the flow accumulation grid (usually named as **Number of cells that drain through each cell**), zoom into the east most (right most) part of the map where bright pixels that look like streams are located.



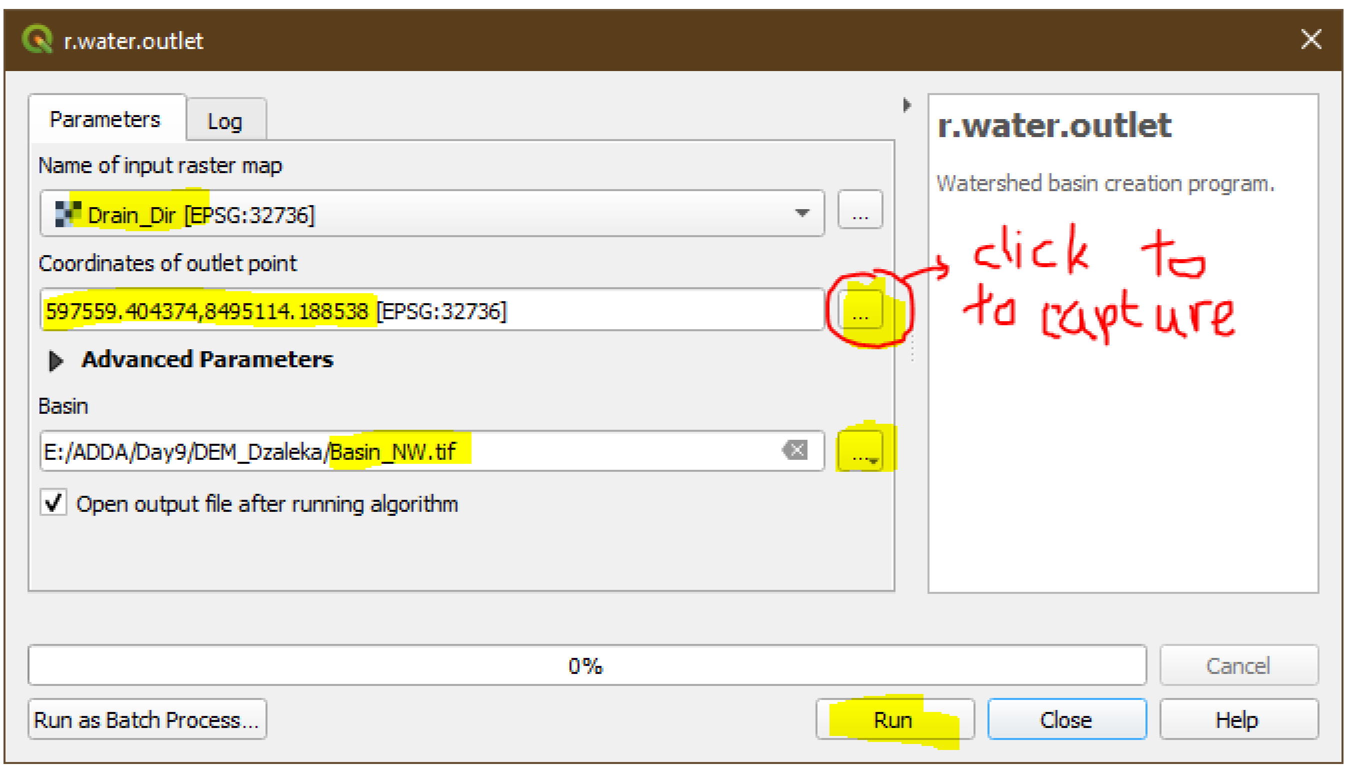
4. Zoom until you start seeing individual pixels



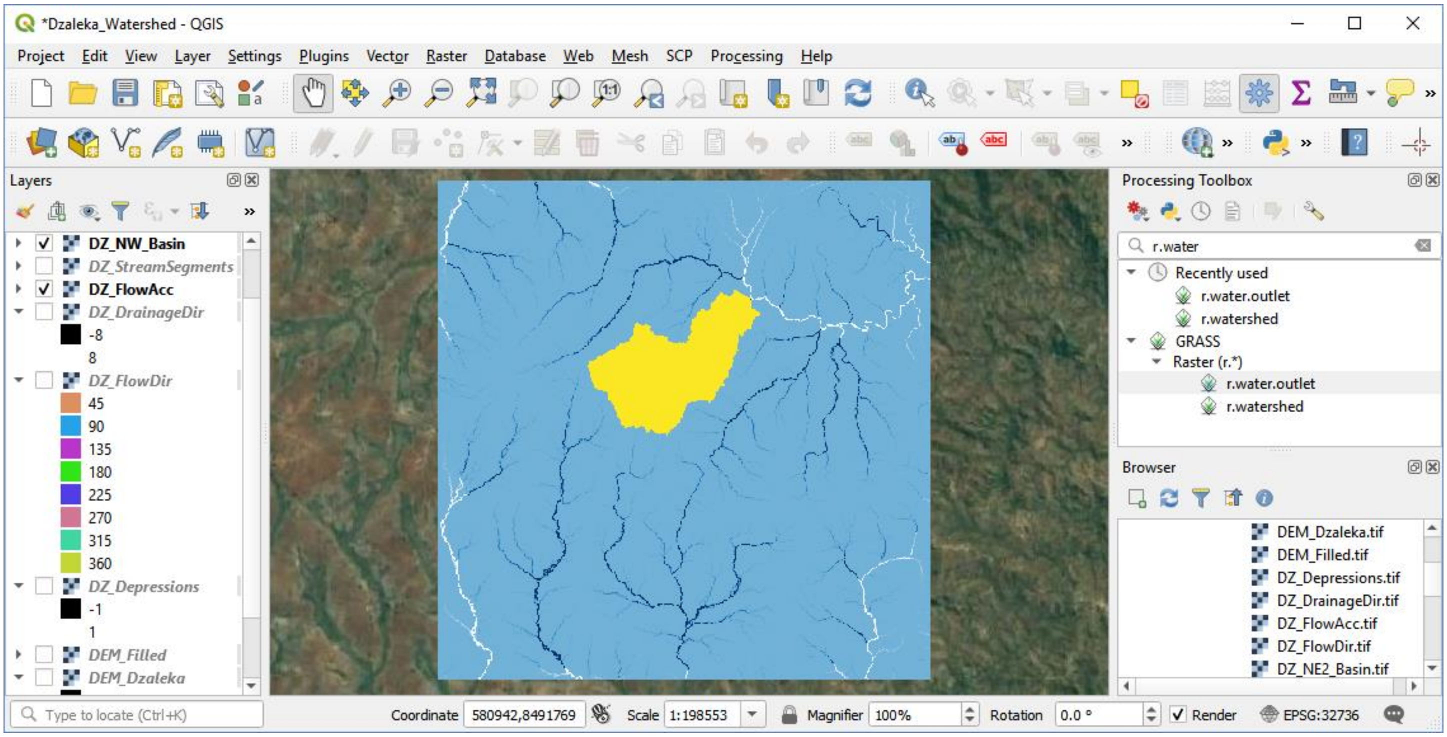
5. We will get the coordinates for one of the pixels with highest flow accumulation from the area highlighted. You should turn the Stream Segments layer on to see which one of these has been identified by the program as a stream pixel, so you can match your selection with it. Once you have identified the pixel where we want the watershed to be delineated, we are ready to start watershed delineation for that point.



6. Under **Coordinates of outlet point** option, click on the button with three dots next to the field. It will activate **coordinate capture tool**, which will allow you to click any pixel to get the UTM coordinate (or latitude and longitude, whichever might be the case for your project) of that pixel, and paste the values into your box automatically. If you messed up while clicking, just go back and redo this until you are satisfied.
7. Under **Basin**, enter a file name for the resulting drainage basin file, to be saved in your lab folder.
8. Click **Run.**

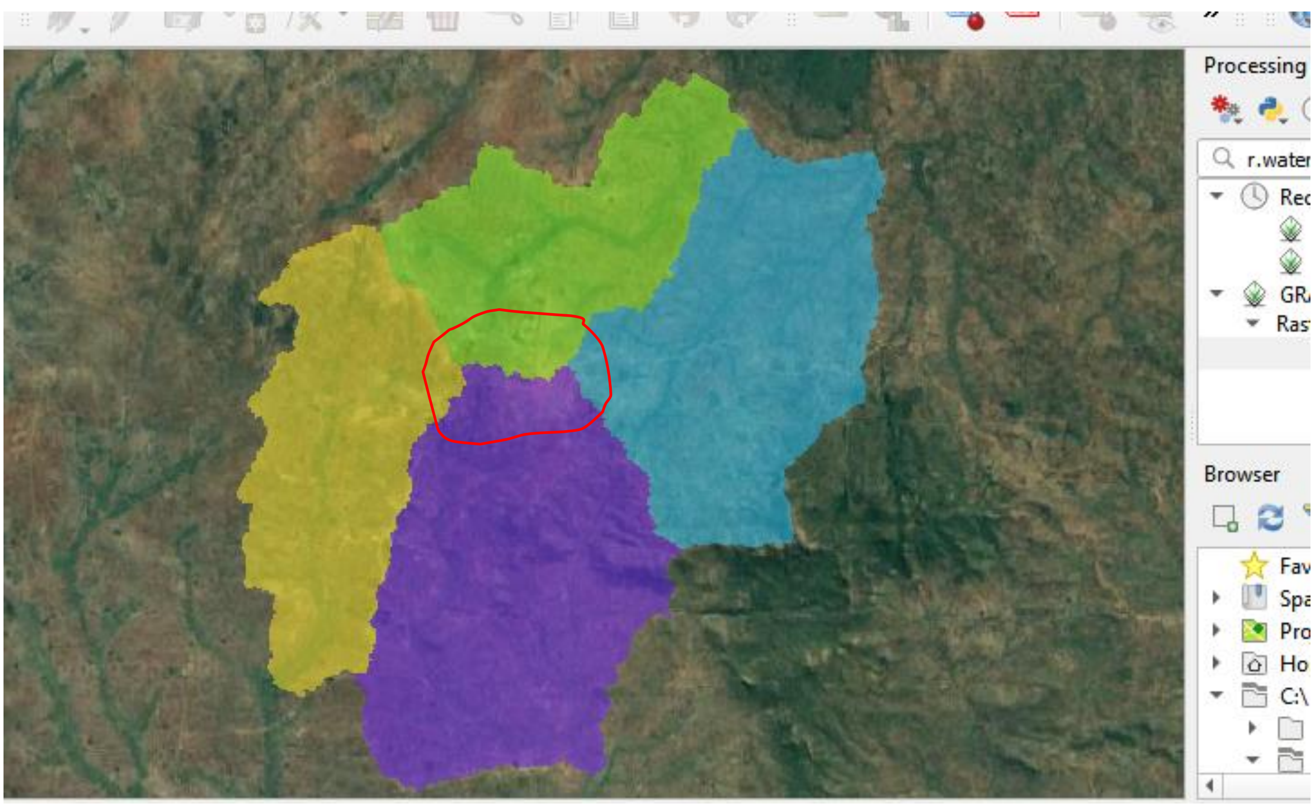


9. When the process finishes, it displays the drainage basin boundary! Congratulations! If it didn't show the watershed as expected, that means you have to zoom in and make sure to pick a pour point pixel that is one of the high flow accumulation pixels.



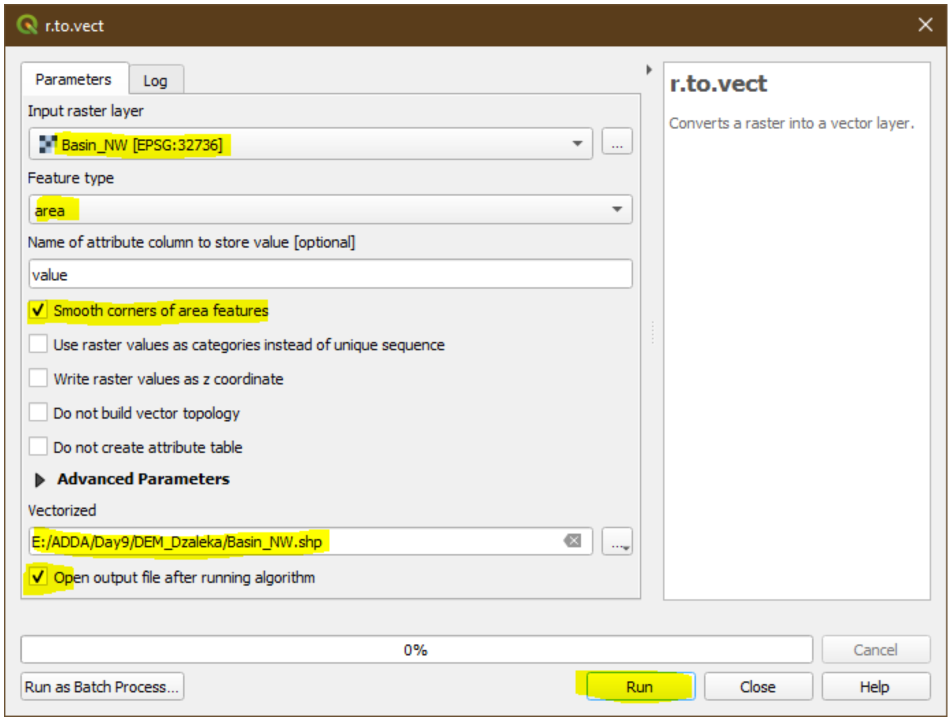
10. The output file shows the area that drains water up to the point you selected as the outlet point for watershed delineation. The output file named **Stream Segments** displays the streams layer for the study area.

Given that our Dzaleka Refugee Camp (marked by the red circle) occupies area that contributes runoff into four different stream segments that are draining in different directions, I went ahead and delineated all four watersheds. If you are interested in doing the same, just repeat the steps in capturing coordinates and running the watershed delineation process.

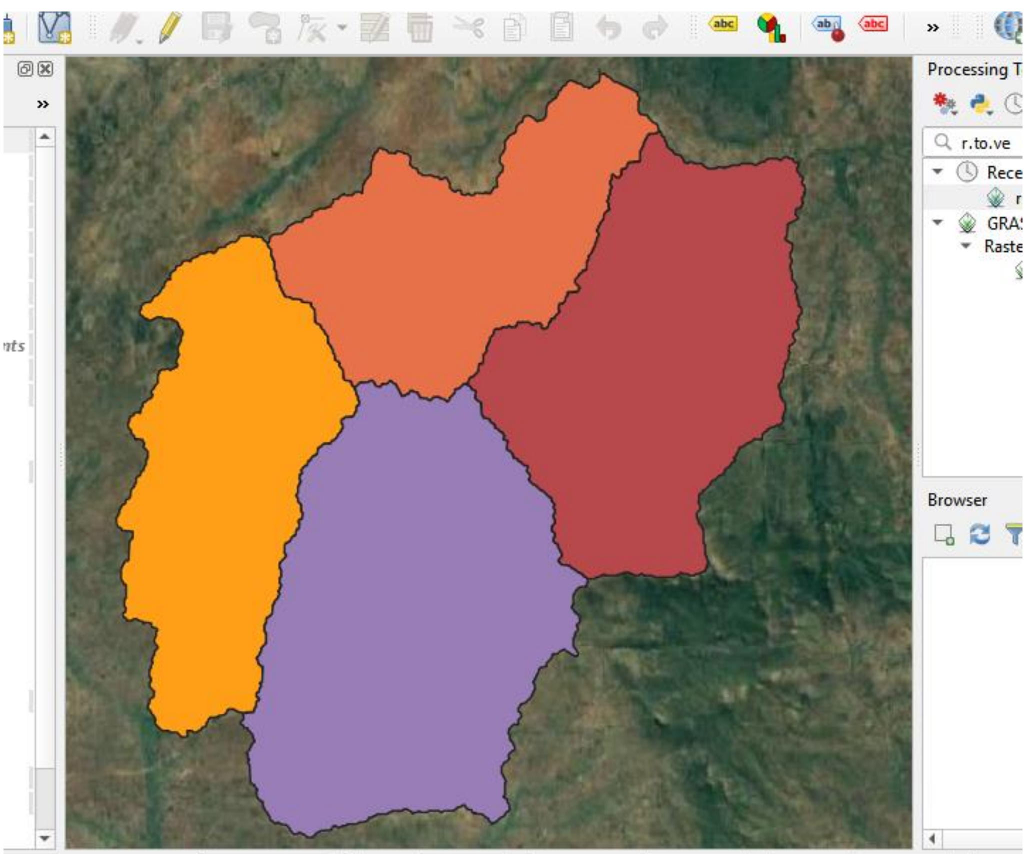


Raster to Vector Conversion:

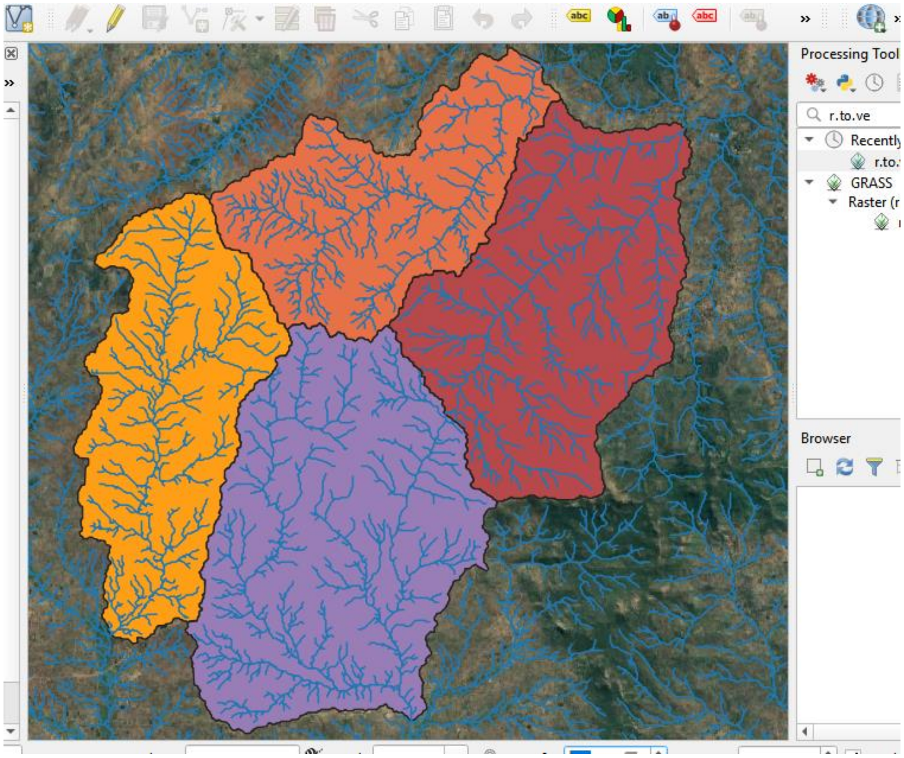
The final watershed boundary and streams layers from previous steps are in raster file format. It is better to convert the raster files to vector format before we use it in maps. To carry out this conversion, we will use **r.to.vector** tool.



1. Open **r.to.vect** tool from the **Processing Toolbox** Panel
2. Enter the **Basin** file under **Input raster layer**
3. Select **Feature Type** to be **Area** (if you are converting streams layer, select **line** here)
4. Select **value** as the **Name of the attribute column to store values**
5. Check to **enable Smooth corners of area features.**
6. Under **Vectorized** output file box, use **Save to File** option to **Save as type SHP files.** Click **Run**
7. When successful, a vector layer representing the watershed is added to the project. Using the same tool, you can also generate the streams layer from our earlier output **Stream Segments.** Try this on your own to see if you can generate it. Remember to select **Line** as the **Feature Type**.



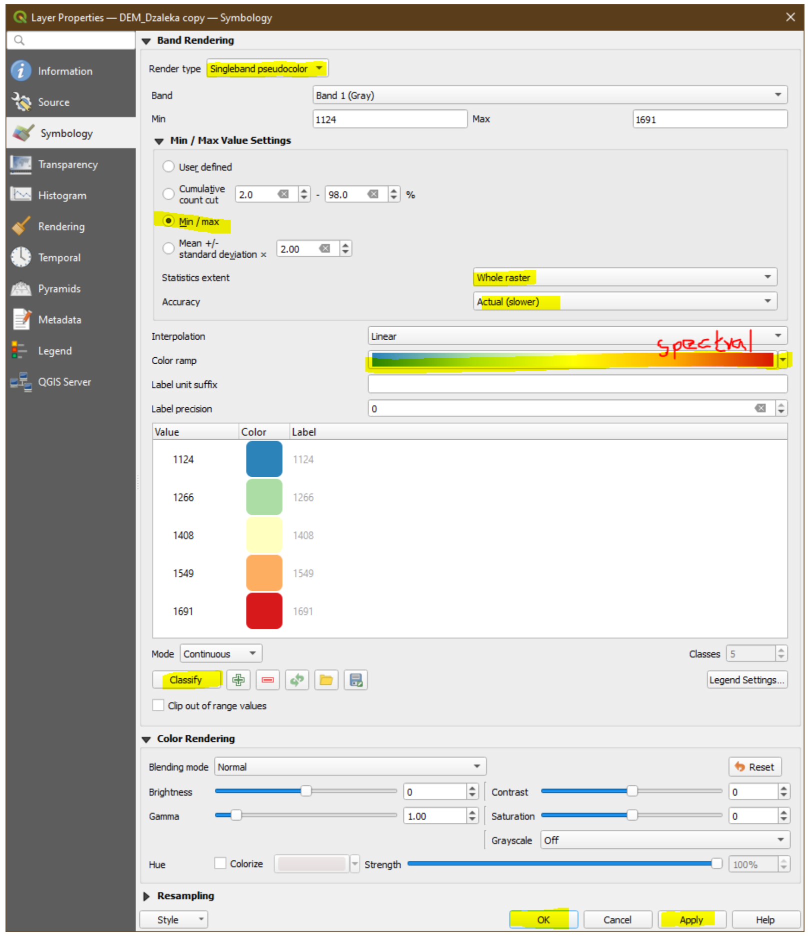
8. You can view newly created watershed and streams shape file layers and see how they are different from the raster version of the same file.



3D Visualization of your Watershed:

Let's have some fun making these watersheds pop-out in 3D. Since we have DEM data that represents elevation values, we can use that to make 3D views. In order to do this, we have to download another plugin.

1. Go to menu **Plugins → Manage and Install Plugins**
2. Under **Search** box, type **Qgis2threejs**
3. When the plugin is displayed, click on **Instal Plugin** button at bottom right corner of the window

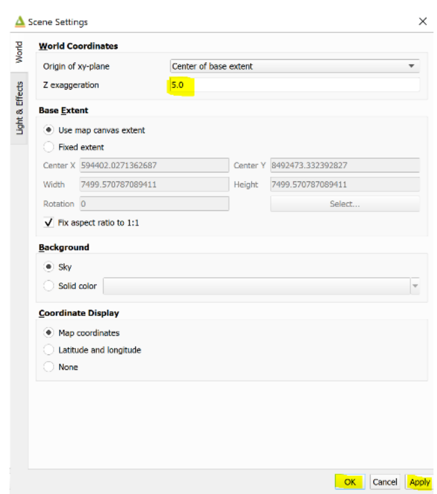


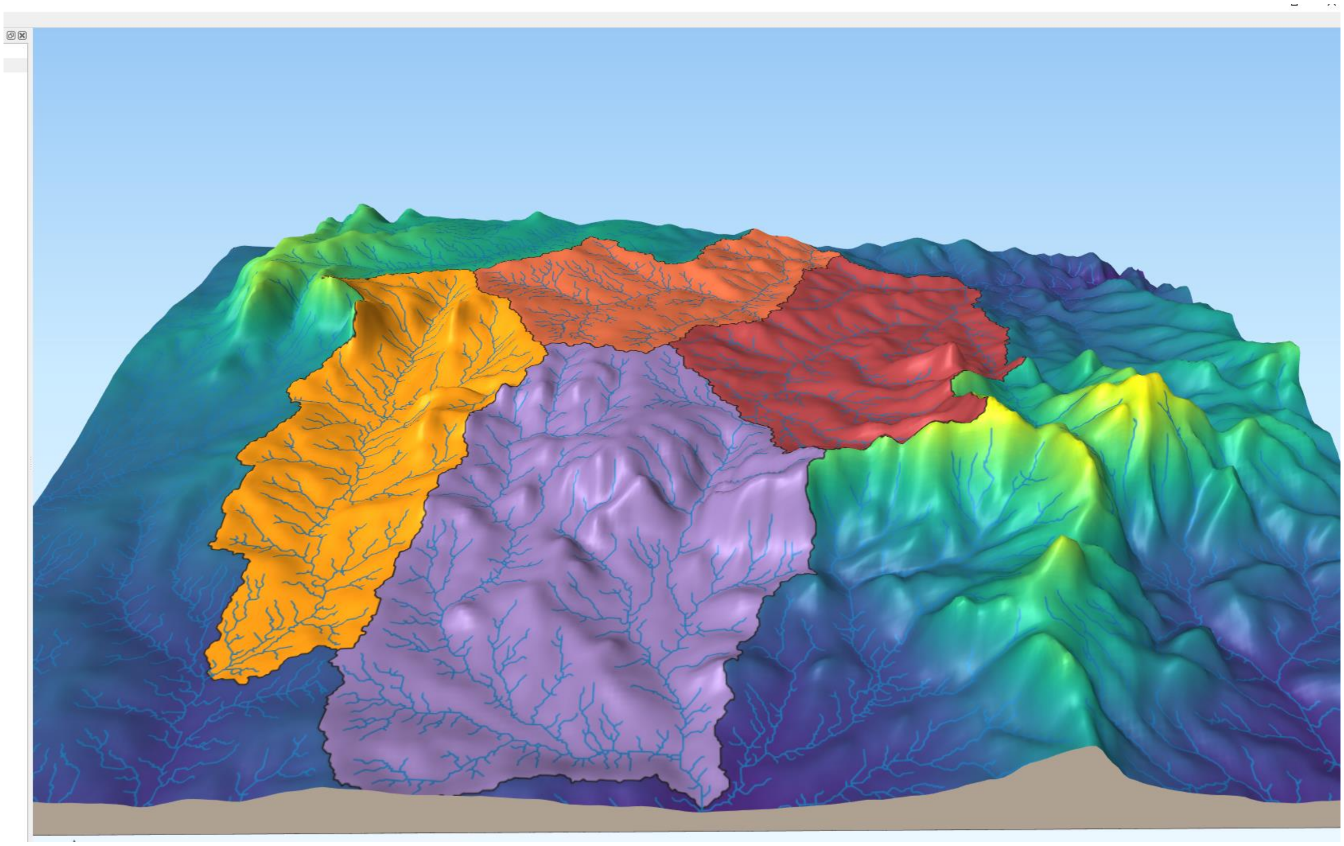
Let's prepare the data for 3D visualization.

4. Turn off all layers except your watersheds and stream **shapefiles**, and the original DEM data.
5. Now, right click on DEM_Dzaleka layer and click **duplicate** (make sure the duplicate DEM is sitting above the original DEM in your table of contents). We are making a copy just so that we still have the original layer available if you need to have gray scale background. You can turn off the original DEM and keep the duplicate one ON.
6. Right click on **DEM_Dzaleka copy** and click **Properties →** then **Symbology**
7. Follow the recommendations provided in the window to the right------------------→
8. Now, make your watershed layers slightly transparent so the elevation colors can come through them (under properties window, go to **Transparency** tab)

Now, click on Menu **Web → Qgis2threejs → Qgis2threejs Exporter**

9. A new 3D visualization window will open with all layers from QGIS window pre-loaded.
10. To make the elevation data stand out, we need to exaggerate (enhance) the vertical elevation representation. To do this, click on **Scene → Scene Settings.** You can try out different numbers for the Z Exaggeration and hit apply to see how that affects your view. Settle down on the numbers that you like.
11. The 3D view can be saved as an image by clicking **File → Save Scene As** menu. Save the file to your folder as a jpg file. This can be included in your final map that you are going to produce next.





12. If you want to show the interactive 3D without using the QGIS software, you can export this as a webpage and open the page using most standard web browsers. Try that on your own!
13. Now, close the 3D visual window and get back to your QGIS window.

Final Submission:

For this lab, you will be submitting a cartographic map that contains the Watershed boundaries and streams. Create a proper map layout showing the Watershed boundaries and the streams. Include all map elements necessary. Include one of your 3D views as an image (screen capture is fine) somewhere within the map layout.

Write a page (single spaced, 12 font) report that address the following questions: In QGIS project window, carefully observe and evaluate the location of Dzaleka Refugee Camp and its areal extent. Which watersheds does it fall under? Is the refugee camp sitting at the bottom of a watershed or near the headwater region of the watersheds? What difference does it make? What impact its location has on the potential to be flooded during heavy rain? What about the impact on water quality? Who gets impacted by polluted water that might flow downstream from the refugee camp? Based on this, do you have any recommendations for dealing with water quantity or quality?

Reflect on your experience going through this lab. What part was most challenging in this exercise? What part was most rewarding and exciting about this lab? Can you provide an example project or scenario where you can use this skillset you just learned?

CONGRATULATIONS on Completing Advanced Watershed Delineation Modeling!