

Geographic Information Systems 2023-2024

Exercise 11 - Determine a dam implantation area

Introduction

GOALS OF THE EXERCISE

- edit 3D data
- create a DEM and TIN to model terrain surface

Problems:

- Represent the dam on the map, this means to model the study area relief after the dam is built.
- To delineate the dam watershed.
- To calculate the flooded area and the volume of water in the dam reservoir when it is filled up to 595 m.

Requirements

- ArcGIS Pro:
 - Requires the module *Spatial Analyst* or *3D Analyst* to be active
- QGIS:
 - Requires the plugins *GRASS8* and *GRASS GIS Provider* to be installed and activated.

Source data

- The files for this exercise are in the course web page (FENIX). [Download](#) to your working area the file `Ex11_DAM.zip`

The data provided contains the following:

- `ApartaduraContours` - 3D shapefile of the contour lines for the study area
- `ApartaduraHydro1` - 3D shapefile of the water streams of the study area
- `ApartaduraRidges` - 3D shapefile with the lines of ridges in the study area
- `DamWall` - 3D shapefile of lines that define the dam wall

Deployment of the dam on the map

The construction of the dam wall will modify the surface of the land, altering the water lines, the contour lines and the ridges. It is necessary to know the shape of the wall surface (represented in contour lines). This information is provided in the gds `DamWall` (feature polyline 3D). The contours of the terrain and the water lines inside the polygon that delimits the horizontal projection of the dam wall will be erased and

replaced by the contours of the dam wall. The dam projection polygon can be used to erase the water lines and contour lines from its interior.

Steps to implement:

1. Create a gds of polygons (3D) corresponding to the projection of the dam wall

1. Create a polygon theme (**DamWallPolyg**) from the theme of lines representing the dam wall **DamWall**.
 - in ArcGIS, the tool is **Feature to Polygon**
 - In QGIS, the tool is **Lines to Polygon**
2. With a suitable spatial operation on vector gds, erase the water lines and contours inside the wall projection polygon:
 - create a theme (**ApartBarr_hid**) with the water lines that are not under the dam wall, based on the gds **ApartaduraHydro1**. Erase the contours from the interior of the projection polygon
 - create a theme (**ApartBarr_alt**) with contours that are not under the dam wall, based on the gds **ApartaduraContours**
3. Create a TIN named **TINApartadura**, setting **ApartBarr_hid** and **ApartaduraRidges** as **hardline**, **ApartBarr_alt** and **DamWall** as **softline**.
 - In ArcGIS, use the tool **Create TIN**
 - In QGIS, use the tool **TIN Interpolation**
 - Parameters:
 - pixel size: 20 m
 - Extent: extent of **ApartaduraContours**

2. Delimit the hydrographic basin of the dam

This operation is performed on a digital elevation model (DEM) in matrix format (raster) using spatial analysis tools that perform raster operations. The dam's watershed is delimited by a ridge line, which, starting on one side of the dam, goes around a surface of the land that contains all the water streams that will contribute to the dam, and ends at the other end of the dam wall. Within this basin there are several hydrographic sub-basins, corresponding to different effluents.

1. Create the DEM of the study area in raster format by converting **TINApartadura** to raster with the name **DEMApartadura** (TIN to Raster; in "sampling distance" choose "CELLSIZE" and value 20 to obtain a grid with a spatial resolution of 20 m).
 - In ArcGIS, use the tool **TIN to Raster**
 - In QGIS, this step was already done with the tool **TIN Interpolation**
2. Create a raster named **DEMApartFill** from the DEM **DEMApartadura**. This is required to resolve imperfections on the data (e.g. sinks, i.e., cells with undefined drainage direction):
 - in ArcGIS, use the tool **Fill**
 - in QGIS, use the tool **r.fill.dir** from Processing -> GRASS

- set as Depressionless DEM the new layer **DEMApartFill**
 - set as flow direction output a new layer called **flowdir**
- 3. Create a raster named **flowdir** with the flow directions using **DEMApartFill** as input. (see Notes)
 - in ArcGIS, use the tool **Flow Direction** in tool Spatial Analyst Tools / Hydrology / Flow Direction
 - select as Flow Direction type the option D8
 - in QGIS, the raster **flowdir** was already created in the last step, no need to perform anything else
- 4. Create a raster named **SubBasins** of the sub-basins of the study area using **flowdir** as input
 - in ArcGIS, use the tool **Basin** in tool Spatial Analyst Tools / Hydrology / Basin)
 - define a legend for this output with "Unique Values" (Value Field: VALUE). (see Notes)
 - in QGIS, use the tool **r.water.outlet** from Processing -> GRASS
 - the input raster is the **flowdir** raster
 - you need also to provide the coordinate of the outlet point: the point to which the water flow runs. This can be set to be in the center-bottom of the DAM wall, on the downstream side.
 - you can install the plugin *Coordinate Capture* in order to capture the coordinate of the outlet point. It should be similar to (264570.911,264997.294)
- 5. Create a polygon theme for the study area names **subBasinsPolyg** by converting the raster **SubBasins** to polygon shape format
 - in ArcGIS use the **Raster to Polygon** tool (Conversion Tools / From Raster / Raster to Polygon), input raster: **SubBasins**; Field: VALUE; Output polygon features : **subBasinsPolyg**; you can keep the "simplify polygons" option).
 - in QGIS, use the tool Polygonize (Raster / Conversion / Polygonize (Raster to vector))
- 6. Create a theme named **LimBasinHid** from **subBasinsPolyg** with the polygon that delimits the sub-basins with water lines that lead to the dam.
 - Select from the water streams layer **ApartBarr_hid**, the features with the value "Str2Dam" in the attribute "dam", to identify water streams that are included in the area of the basin. These features can be used to make a **Selection by location** operation on the layer **subBasinsPolyg**, in order to identify sub-basins that belong to the basin.
 - the new layer **LimBasinHid** can be created containing the selected sub-basins. Afterwards, generalize the information by grouping the resulting polygons (dissolving operation) [this step might not be necessary, depending on the sub-basins created].

Observe the boundary of the **LimBasinHid** polygon over the terrain representation given by **tinApartadura**. Please note that the inclusion of additional breaklines could lead to an improvement in the delineation of the dam's watershed boundary.

3. Calculate the flooded area and the volume of water in the reservoir (only for ArcGIS)

In full storage, the reservoir reaches the project quota of 595 m, called **full storage level (NPA)**. This surface is bounded by a closed contour. The volume of water between this surface and the land surface is

the storage volume.

1. Create a new TIN named `tinApart_basin` (use `ApartBarr_hid` as "hardline", `ApartBarr_alt` and `DamWall` as "softline" and `LimBasinHid` with value in "height_field" of and "SF_type" of hardclip). The basin boundary will cut the TIN, preventing triangulation between the vertices of the boundary.
2. Calculate the volume of water in the reservoir at an elevation of 595 m with the tool **Surface Volume** (3D Analyst / Area and Volume / Surface Volume – Input surface: `tinApartadura`; Output text file: `volume.txt`; Plane height: 595; Reference plane: below the plane). Open the volume.txt file that was created and observe the values of the reservoir area at an elevation of 595 m and the volume of water it stores.
3. Create a TIN that includes the dam with the flooded surface (you will have to find out how!). Observe the result in ArcScene.

Notes:

Fill depressions: Some local sinks, meaning cells that have undefined drainage direction (no cell in surroundings is lower) can create problems in determining the flow direction, in the delineation of basins and streams. A solution is to fill them. [See more here](#).

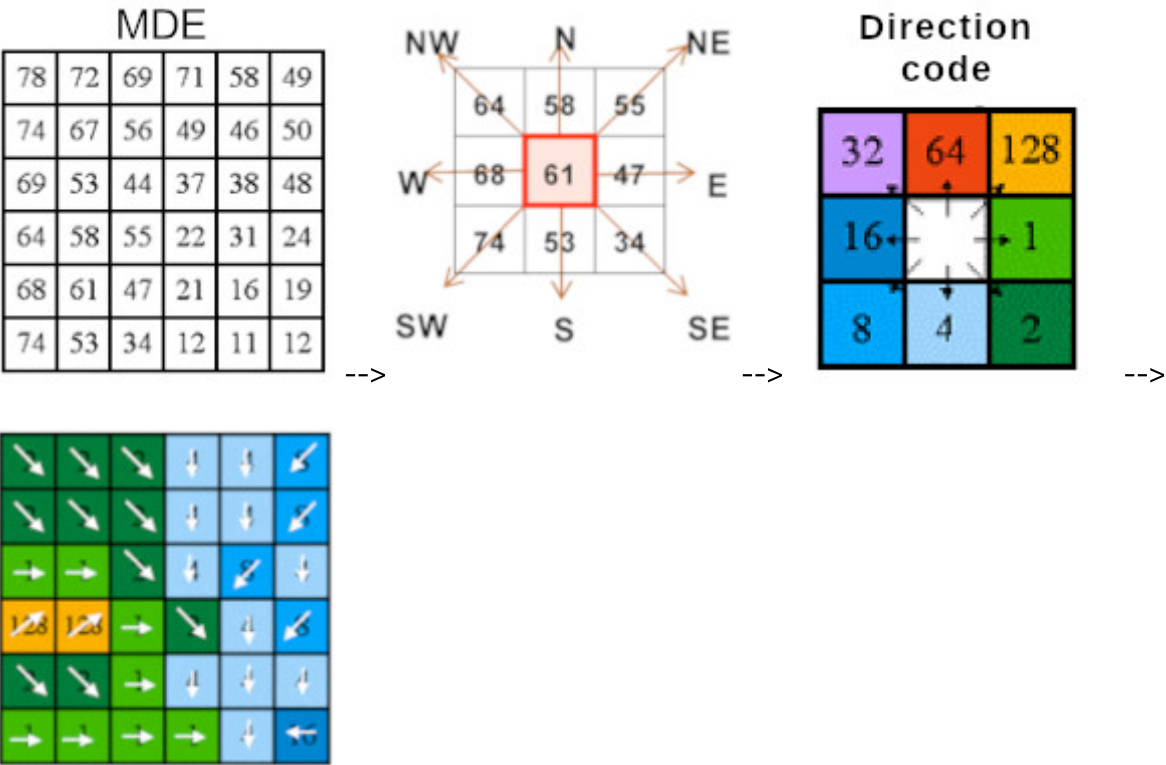
Flow direction: It provides the direction of the water flow in each pixel.

The flow direction is determined on a raster digital elevation model (DEM) by finding the direction of the greatest downward slope at each pixel. The slope is calculated in the DEM, for 8 directions (8 neighboring pixels), by:

$$\text{slope} = \text{rate of change of } z / \text{distance}$$

For each flow direction a different code is attributed. If the maximum slope is the same for several cells, the neighborhood is extended until a higher value is found. If all neighbors have an altitude higher than the cell then it is a well (sink).

Building a raster with flow directions:



Basin: analyzes the flow direction raster to find the entire set of pixels that belong to the same drainage basin. Cells that do not receive flow from any other cells belong to the ridge line. The set of these cells constitutes a ridge line, which closes in a cell that concentrates all the flow, a concentration point (pour point), coming from the cells inside the ridge line.