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Determination of input parameters necessary for the design of the polder in the Horná Topl'a basin, Slovakia

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Determination of input parameters necessary for the design of the polder in the Horná Topľa basin, Slovakia

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Abstract. In the last decade, there have been many destructive floods in various parts of Slovakia. Despite the extensive investment in flood control works, there are only small changes and neither flood occurrences nor damages are decreasing. A possible consequence of climate change is an increased frequency of extreme meteorological events that may cause floods. The determination of the occurrence of these extreme hydrological phenomena in a particular catchment is directly subject to the input data in dependence on climatic and geomorphological processes. This article deals with the method of comparing the retention capacity of the polder by means of geographic information systems (GIS) compared to the results from map data and design of flood wave diagram for the river of Banský Stream. This proposal is part of the flood protection of the area of Čergov Mountain in eastern Slovakia where is designed the system of polders.

1. Introduction

The basis of the models forming is data acquisition using LIDAR and orthophoto maps techniques from which the relevant data for the project can be drawn. In the design of models, map data (data obtained by the classical method of data collection or GIS data), based on the principle of contour lines creation of specific structures, fractures, height uneven terrain, and thus created spherical splines are used [1]. The entire terrain model environment should be engineered to provide optimal terrain structure while maintaining full integrity between the architectural environment of the model (BIM) and its users [2]. Several 3D modeling software such as Autodesk, AutoCAD Map 3D, AutoCAD Civil 3D, Ecotect, Vasari, INOVA AreaCAD-GIS, Unity, Edificius, Google Maps, and ESRI with ArcGIS are available on the market. Ecotect and Vasari applications are now implemented in Autodesk Revit software solutions.

Conversion of data between CAD/BIM and GIS results in a relatively large data mismatch, which requires extensive manual work due to the limitations of data exchange and acquired knowledge [3]. The reason for the individual ambiguities, their deepening and delay was that the existing CAD and GIS platforms were developed independently for various purposes, leading to significant differences in the support of data formats, the terminology they used, the concept on which they were based, the different representation of degrees and the transformation of local coordinates into a reference system for horizontal and vertical coordinates (in Slovakia used the Trigonometric Network System in GIS S-JTSK Krovak East North). Additionally, CAD models usually do not store typological information (except geodetic measurements where x and y coordinates are defined and z need to be converted) that are characteristic of geospatial models [4]. As a result, various tools are being developed to transform models using 3D data model standards to enable visualization in 3D geospatial contexts using GIS software and BIM in conjunction with Industry Foundation Classes (IFC). In addition to the above-mentioned classic method of data collection using tachymetry or GPS [5], the most commonly used data is digital terrain model (DTM) or relief [6], photogrammetry in the form of ortho-photo maps or measurement using terrestrial or aviation laser scanning [7]. Today, one of the technologies is also LIDAR [1]. The use of laser scanning in combination with LIDAR in the CAD, GIS, and BIM implementation was used and compared in the case study of Banja Luka in the urbanized area, where the results demonstrated the complexity in individual steps and the focus of the investigators on a certain part of the problem. At each step, data rating requirements increased dramatically, and most users focused only on one of the above platforms [1]. When calculating the volume of the polder, the individual errors become more pronounced, as a lot of morphological parameters enter into the calculation. The process of processing the results is described in the paper [8], where four methods of data collection (ASTER, SRTM, LIDAR and DEM) were used to estimate the capacity of the Majdany Polder. The study showed different results and the impact of quantitative and qualitative source data in determining the polder retention capacity.

This paper reviews the design of the retention capacity of the polder in the area of Čergov Mountain in the Bardejov district in eastern Slovakia using two methods of data collection and final design of a diagrammatic course of the flood wave Q_{100}. Determination of retention capacity using the classic method of collecting data from map data using calculations in combination with CAD and determination of retention capacity using a digital elevation model (DEM). DEM is used to estimate the capacity of flooded valleys and the course of the flood wave [9], flood threats [10] and risk management to assess quantitative environmental impacts [11]. The exact estimate of the bulk of the polder is particularly important and the water in it is correlated with the reduction of the flood wave and the mitigation of the threat under its dike. After the flooded area, water from the polder is taken back to the river on the principle of gravity or mechanically by means of pumps [12]. The individual results were processed in the CAD environment implemented with ArcGIS and a final diagrammatic of the flood wave was created in excel. The results will be used by the author for the design of flood protection of the territory of interest.

2. Materials and methods

In the article are presented two available sources of information from the interest of area in a map format at 1:10 000 and the commercially available DEM 3,5-10. The map background was processed by CAD and a result was contour lines map of an interest area. From map was created the trigonometric 3D model (TIN) processed by GIS. DEM was processed in ArcGIS 10.3.

The area of interest (figure 1) is situated in the northeast of Slovakia in the upper section of the river Topľa, in the Čergov Mountains, in the Bardejov district, in the village of Livovská Huta. Polder of the Banský Stream is located on the rkm 0.570 and is the left tributary to the Topľa river. Topľa River belongs to the Bodrog catchment and is 136.8 km long (according to GIS), which is one of Slovakia's most significant watercourses, draining the area with a total area of 1 506 km^2. In last years, the area in question has been increasingly affected by lightning floods that threaten the inhabitants of adjacent municipalities, resulting in significant morphological changes and changes in bank lines [13].

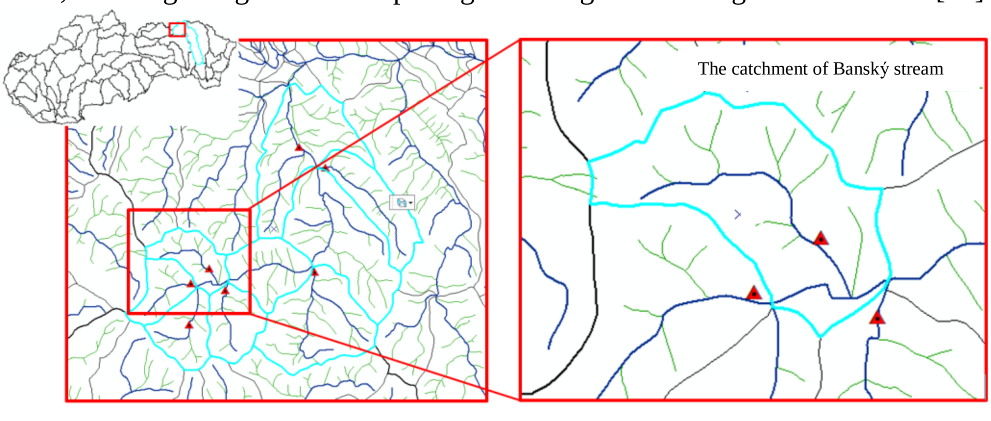


Figure 1. Area of interest Horná Topľa with the location of planned polders (left), the catchment of Banský stream with polder in rkm 0.570 (right).

2.1. Determination of the volume of the polder using a flood volume curve

The classic method of calculation of the total volume of the catchment is based on the determination of the volume of the dam (polder). In the case of reservoirs, the volume is divided into three main compartments, from the maximum level to the bottom, they are: retention, storage and permanently filled under the dead space outlet [14, 15]. The capacity of the dam in terms of the volume obtained and the flood area express the flood area curve $S=f_1$ (h) (m^2) and the flood volume line $V=f_2$ (h) (m^3). The floodplain area and the flood volume curve are basic characteristics of the reservoir and, according to [14], these curves can be determined by gradual planimetry of individual surfaces, bounded by contours in the map or graphically. The volume lines are gradually drawn from the flooded areas S_i and S_{i+1} and their height distances Δh_i by relation. The difference in the volume ΔV_i of the individual surfaces is then expressed by the equation (1).

$$\Delta \boldsymbol{V_i} = \frac{\mathbf{1}}{\mathbf{3}}\left(\boldsymbol{S_i} + \sqrt{\boldsymbol{S_i} \times \boldsymbol{S_{i+1}}} + \boldsymbol{S_{i+1}}\right) \times \Delta \boldsymbol{h_i} \tag{1}$$

2.2. Determination of volume of the polder from DEM

ArcGIS 10.3 has been developed by ESRI to work with maps and geographic information and works as a comprehensive GIS platform that allows users to collect, organize, manage, analyze, communicate and distribute geographic information. ArcGIS is capable of reading CAD formats and integrating them into GIS as a layer. With the interoperability extension, convergence can be done for CAD and BIM formats [16].

The method for determining the basin volume (polder) in ArcGIS is typically done using the "3D Analyst" extension with the selected interval of peers (e.g. 5 m). Is necessary to create a separate layer contours.shp. After creating this layer, it is possible to specify the graphical properties and the marking of individual peers in the attribute table. Consequently, you need to create a TIN, and the quality of each model depends on the accuracy of the DEM input data. Enter the command "Open ArcToolbox> 3D Analyst Tools> TIN Management> Create TIN" or leave the GRID file. To determine the volume of the basin and the flood area, we derive from the maximum permissible height of the dike and the maximum water level read from it, assuming that the dam is divided into the above-mentioned main compartments. It is necessary to create a polygon in the form of the .shp flood area at the assumed elevation, when using the "Polygon Volume" tool to calculate the total volume of the polder. Then enter the necessary input parameters and run the calculation. As a result of the calculation, two new fields are generated in the attribute table: "Volume" and "Area_2D (3D)". If we work in an international SI system, the result is flood volumes in cubic meters and total flooded area in square meters.

3. Results

As mentioned above a map base for contouring the base in CAD, a map of the Banský Stream (tributary to Topľa) was used in M = 1: 10 000, with the hydrological number of catchment 4-30-09-003. The height difference of the individual planimetric surfaces spline a contour line was determined by Δh = 5 m from the map and supplemented by Δh = 1 m by interpolation. Since the data of maps are interpolated using spline the precision of the final results depends primarily on the quality of the map background. Figure 2 shows the processing of the map base and the final line of Banský Stream volumes.

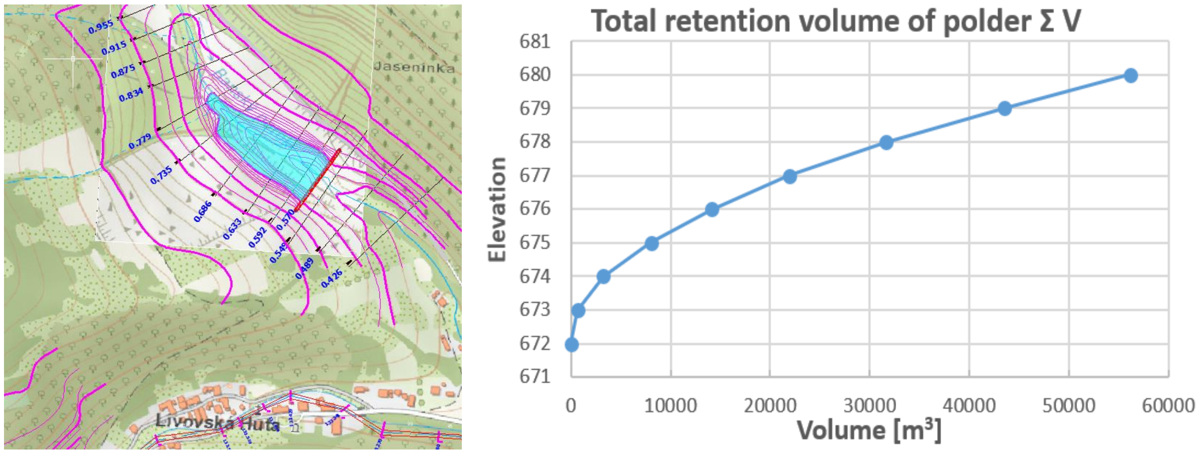


Figure 2. The resulting flooded area (left) and the total retention capacity of polder at a maximum dam height of 8 m (right).

The processing in ArcGIS software was less labor-intensive in terms of time and effort. The location of the polder was chosen at the same river of rkm 0.570 and as a verification tool served the CAD file. After processing the DEM and creating the TIN a polygon was defined and a .shp was created at the upper elevation of 680 m above sea level, which was used to define the flooded area and started the calculation. At this level, the maximum retention capacity of the polder is assumed. Figure 3 shows the flooded area of the polder in the TIN and the final depth map of the DEM after the calculation. At the bottom of the figure is a table of result of inundation and volume of polder.

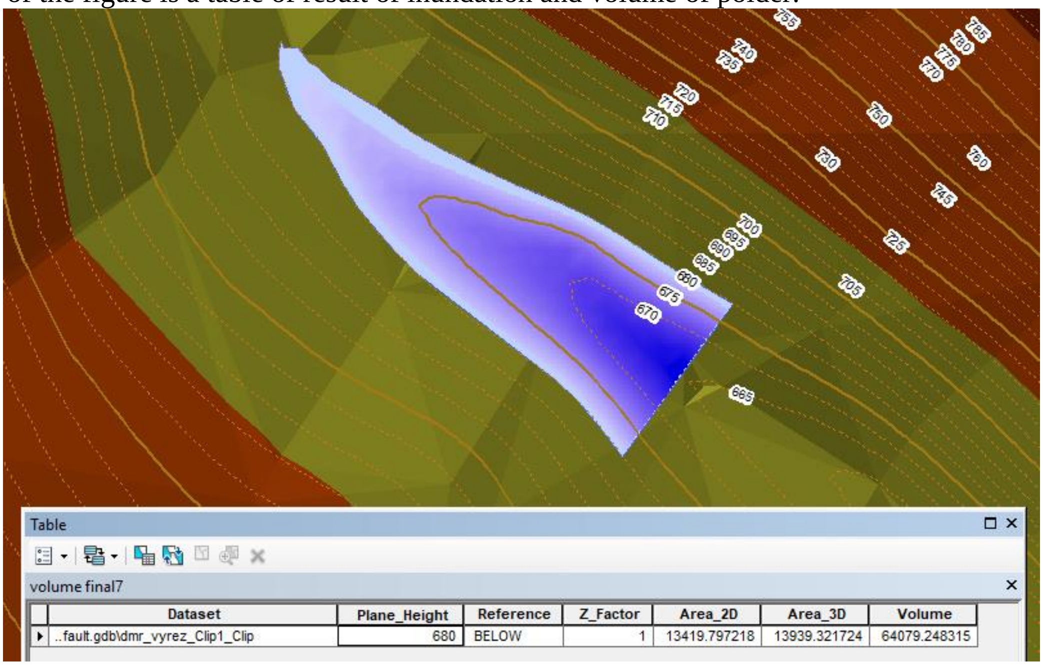


Figure 3. Total retention capacity of polder from GIS.

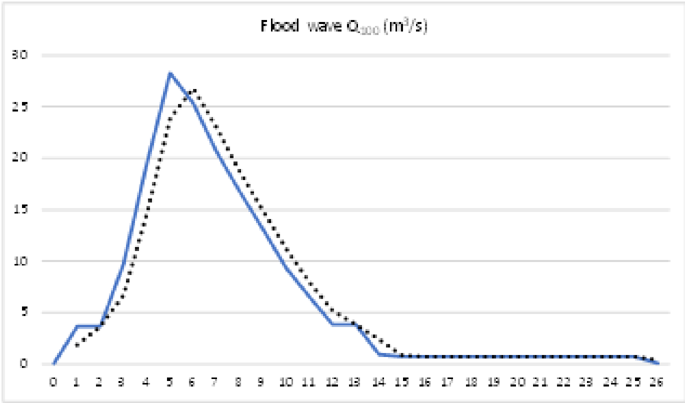
According to [8], it is assumed that there is a high correlation between the map profiles generated and the data provided with DEM or LIDAR-DEM. However, if the map and DEM are compared, the difference is more pronounced. The contour lines that were created and processed into CAD from freely available sources of maps are partly different from the models of DEM. This error was also confirmed in this case. This is mainly about defining CAD and GIS contour line and the initial location of the polder in the river in question. The elevation level of the bottom of the polder is assumed at the dimension of the CAD at the 672 asl. and in the case of the DEM at the elevation of 667 asl. This difference was also reflected in the final volume of the polder.

The resulting flood wave shown in figure 4 is generated from the map results. The retention capacity is derived from formula (1) and Δh = 1m. The total retention capacity is thus set at 56147.03 m^3 and total surface inundation is 13452.4 m^2.

Diagrammatic course of the flood wave Q_{100}

Banský stream

Time [hod]	Time [min]	Time [sek]	*Q_{100} [m^3/s]	Q_{median} [m^3/s]	W -volume [m^3]
0	0	0	0.0600	1.8622	216.00
1	60	3600	3.6644	3.6644	13191.77
2	120	7200	3.6644	6.7168	13191.77
3	180	10800	9.7693	14.6184	35169.52
4	240	14400	19.4674	23.8787	70082.67
5	300	18000	28.2900	26.8194	101844.00
6	360	21600	25.3489	23.0038	91255.89
7	420	25200	20.6587	18.7062	74371.34
8	480	28800	16.7536	14.9248	60313.13
9	540	32400	13.0960	11.2175	47145.77
10	600	36000	9.3389	7.9384	33620.19
11	660	39600	6.5379	5.1826	23536.44
12	720	43200	3.8272	3.8272	13778.07
13	780	46800	3.8272	2.3842	13778.07
14	840	50400	0.9411	0.8294	3387.98
15	900	54000	0.7176	0.7176	2583.39
16	960	57600	0.7176	0.7176	2583.39
17	1020	61200	0.7176	0.7176	2583.39
18	1080	64800	0.7176	0.7176	2583.39
19	1140	68400	0.7176	0.7176	2583.39
20	1200	72000	0.7176	0.7176	2583.39
21	1260	75600	0.7176	0.7176	2583.39
22	1320	79200	0.7176	0.7176	2583.39
23	1380	82800	0.7176	0.7176	2583.39
24	1440	86400	0.7176	0.7176	2583.39
25	1500	90000	0.7176	0.4084	2583.39
26	1560	93600	0.0992	0.0496	357.07



Retention capacity of polder

KH(asl.)	h	∑S	∑V
672	0	0	23.392
673	1	405.1	664.7389
674	2	1264	3247.463
675	3	5459.4	8014.411
676	4	5794.3	14128.19
677	5	7245.7	21884.6
678	6	9087.3	31596.09
679	7	11158.1	43489.18
680	8	13452.4	56147.03

Figure 4. The diagrammatic course of the flood wave from CAD.

From a geological point of view, the area covered by the Čergov Mountains is located in flysch zone. Even after mild rains is involved regular maintenance of the channel flow. This represents a considerable financial burden on the affected municipalities along the stream and forces local governments to find available solutions to this situation. The catchment area of the Banský Stream, with its area of 3.9 km^2, represents from the total catchment area of Topľa (1506 km^2), only 0.259 %, but from the regional point of view of the territory of the Horná Topľa with an area of 63.41 km^2 represents 6.15 % relatively large territory.

In general, water retention in the land is one the best for the community and one of the ways is also a polder whose construction will reduce the height of the flood wave on the river. One of the main responsibilities already in the preparatory phase of the project is the determination of the total volume of the basin, which was also the subject of this article. Two methods for determining the volume were used in the article. Determination of volume by planimetry from individual flood areas by CAD and determination by GIS calculations. From the volume curve (figure 2), which was determined by the calculation according to (1) in the CAD, it is evident that the volume of water in the created area of Banský Stream is 56147.03 m^3 and the flooded area is 13452.4 m^2. The total height of the dam is 8 meters in this case. Using GIS, the volume of the polder was set at 64079 m^3, which at the maximum capacity of the polder represents an area of 13419.79 m^2. In this case, it should be pointed out that in the same rkm profile a difference of 5 m was intended and the height of the dam, in this case, was set at 13 m. This difference can be verified by locating the GPS directly on site or repeating the process on a more detailed DEM. The difference in volume between CAD and DEM 3.5-10 is 7932 m^3, corresponding to a difference of 12.37% and for an area of flooded is the difference of 0.25%. This has confirmed the assumption that map and DMR have a similar flooded area, but for the volume, we need measurement of the cross-section profile where the dam of the polder is located.

4. References

[1] Mijic N, Sestic M and Koljancic M 2017 CAD - GIS BIM integration - case study of Banja Luka city center *Advanced Technologies, Systems, and Applications* vol 3 (Cham: Springer) pp 267-281
[2] ACCA software S.p.A 2017 *Terrain modelling using contour lines and BIM software* citate: http://biblus.accasoftware.com/en/terrain-modelling-using-contour-lines-and-a-bim-software/
[3] El Meouche R, Rezoug M and Hijazi I 2013 Integrating and managing BIM in GIS, software review *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* **2** W2
[4] Lapierre A and Cote P 2007 Using Open Web Services for urban data management: A testbed resulting from an OGC initiative for offering standard CAD/GIS/BIM services *Urban and Regional Data Management. Annual Symposium of the Urban Data Management Society (Electronic Materials)* pp 381-393
[5] Torge W and Müller J 2012 *Geodesy* (Walter de Gruyter)
[6] Daňová S 2010 Digitálne modely reliéfu na území Slovenskej republiky *Geodetická a kartografická podpora protipovodňovej ochrany* (Bratislava: STU v Bratislave SvF) pp 26-31
[7] Dolanský T 2004 *Lidary a letecké laserové skenování* (Ústí nad Labem: Univerzita JE Purkyně)
[8] Walczak Z, Sojka M, Wrózyński R and Laks I 2016 Estimation of Polder Retention Capacity Based on ASTER, SRTM and LIDAR DEMs: The Case of Majdany Polder (West Poland) *Water* **8** p 230
[9] Teng, J, Vaze J, Dutta D and Marvanek S 2015 Rapid inundation modelling in large floodplains using LIDAR DEM *Water Resources Management* **29** pp 2619-2636
[10] Fijko R, Zeleňáková M and Alkhalaf I 2016 Flood risk modeling of Stulianský stream in Lopúchov village, Slovakia *International Journal of Safety and Security Engineering* **6** pp 529–537
[11] Zeleňáková M and Zvijáková L 2017 Risk analysis within environmental impact assessment of proposed construction activity *Environ. Impact Assess. Rev.* **62** pp 76–89
[12] Gichamo TZ, Popescu I, Jonoski A and Solomatine D 2012 River cross-section extraction from the ASTER global DEM for flood modeling *Environ. Model. Softw.* **31** pp 37–46
[13] Frandofer M and Lehotský M 2013 Stupňovitá štruktúra dna koryta vodného toku s výrazným pozdĺžnym sklonom (na príklade horného toku rieky Topľa) *Geographical Journal* **65** pp 141-159
[14] Švecová A and Zeleňáková M 2005 *Vodné stavby* (Košice: Stavebná fakulta TU v Košiciach) p 190
[15] Ondrejka Harbulakova V and Lechamn M 2018 Flood control measures - dry basins - case study, *Public recreation and landscape protection - with nature hand in hand!*, 2.- 4.5.2018, Křtiny-Brno: Mendel University, pp 168-173
[16] El Meouche R, Rezoug M and Hijazi I 2013 *Integrating and managing BIM in GIS, software review* (Istanbul: Turkey) pp 31-33

Acknowledgments

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