

COMPARISON OF ACTUAL AND PRESUMED WATER CAPACITY OF FISH POND IN LUKÁČOVCE

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Abstract

This paper deals with the possibility of the reservoir bottom mapping for the calculation of the water depth and water volume in GIS environment with the use of the creation of 3D models of the reservoir bottom in raster and vector formats. Data collection was done in July of 2013 as the non-contact surveying with the GNSS receiver and echosounder. Surveying was executed as the RTK GNSS surveying with continuous depth measurement with echosounder during the sail with raft boat propelled with electric engine. Processing of collected data and model creation was done in ArcGIS 9.2 software. For the raster models creation we used "Spline with tension" and "Topo to raster" interpolation methods, for the vector model creation we used the TIN modelling tools with application of the Delaunay triangulation rules, these models were used for the calculation of the water volume.

Proposed method was demonstrated on fish pond in Lukáčovce, Nitra district, Slovak Republic, where the fish pond siltation is evident. Available data are from operation documentation of the fish pond from the year 2011, where is noted that the fish pond stores 81 000 m³ of water with the area of 5,8 ha. Surveying of this fish pond has found that the true water storage capacity is only 46 000 m³ of water with the area of 5,57 ha.

Key words: fish pond, bathymetric survey, water reservoir storage capacity

INTRODUCTION

Fish ponds are artificial water reservoirs determined to production of larger amount of fish with the option of total and regular emptying. Construction and technical design and operation fulfils the demands of the fish production (Čistý, 2005). The purposes of the small water reservoirs in Slovakia are various, reservoirs are usually built as multipurpose objects, which allow the fish production, flood protection, sedimentation, water accumulation for irrigation purposes and so on. Reservoirs have one primary function and the other functions are secondary (Kollár et al., 2002). Small water reservoirs, such as polders or dams are best solution of the flood protection in the landscape (Zeleňáková et al., 2013). Reservoirs siltation is a natural process, which is a result of the erosion in the hydrological watershed of the water reservoir. The presence of dam causes the solids trapping, which are transported by the river or stream system and it modifies the sediment balance. Hydrographical regime and geomorphological characteristics of the watershed affect the dimension of this effect (Molino, 2000). Knowledge of the changes of the shape of the reservoir bottom is useful information for the monitoring of the erosion and siltation processes in watershed and reservoir. Shape of the reservoir bed determines the depths in the reservoir and the volume of the accumulated water. Shape of the reservoir bottom and its changes can be mapped and monitored with the use of various techniques, such as creation and comparison of the cross sections and profiles or creation of the elevation models and bathymetric maps. Various publications are dedicated to the use of these techniques, such as Holubová (1998); Langland and Hainly (1997), Ceylan (2011), Childs et al. (2003) or Kress et al. (2005). The tasks of the volume and depth changes assessment can be executed in GIS environment.

GIS is useful and effective tool to create and use of the digital elevation models (DEM) with the goal of the research, prediction and know the spatial chronological and functional aspects of geographical sphere (Varga et al. 2013).

Digital elevation models of the bottom can be in the format of the raster models or in vector TIN models. Input data, such as point class data, can be collected with various methods and techniques of geodesy surveying (total station, GPS, laser scanning, photogrammetry/ LIDAR) in the drained reservoir or can be collected with the non-contact measurement with the use of the sonar and GPS during the standard operation as the reservoir is filled. This work deals with the possibility of the calculation of the water storage capacity of the fish pond nr. 2 in Lukáčovce, where the method of non-contact data collection was performed to obtain the input data for the creation of three DEM of reservoir bottom: two raster models and one TIN model. These models were used for the calculation of the water mass of the fish pond, which is equal to the actual accumulation capacity of this fish pond.

MATERIAL AND METHODS

Method of the non-contact bathymetry data collection was demonstrated at the fish pond nr. 2 in Lukáčovce. Selected fish pond belongs the system of three fish ponds, where one fish pond does not longer exist – this fish pond is buried with excavated sediment from other two fish ponds. Original project documentation of this fish pond is missing, available data are only from the operation documentation from the year 2011 (Magula, 2011). For the calculation of the water volume of the fish pond with the use of DEM was necessary to collect the input data – points in the x, y, z coordinate format. These data were collected with non-contact surveying method, where the position of the boat was surveyed with GNSS receiver Leica 1200+ as x, y, z-coordinate. Echosounder Garmin GPSMap 421s was connected to GNSS receiver via the NMEA cable connection to provide the depth measurement. Then the coordinates of the point at the bottom are x, y-coordinates of the GNSS surveying and the elevation of the point at the bottom was calculated as the subtraction of the depths (measured with the echosounder) from the z-coordinate of the GNSS surveying. Equipment was mounted to the raft boat propelled with the electric engine and the data collection was done during two sails – each sail was done along the cross sections parallel to the axis of the fish pond dam. The GNSS receiver was operating in RTK mode, which allowed us to execute the kinematic measurement with high accuracy.

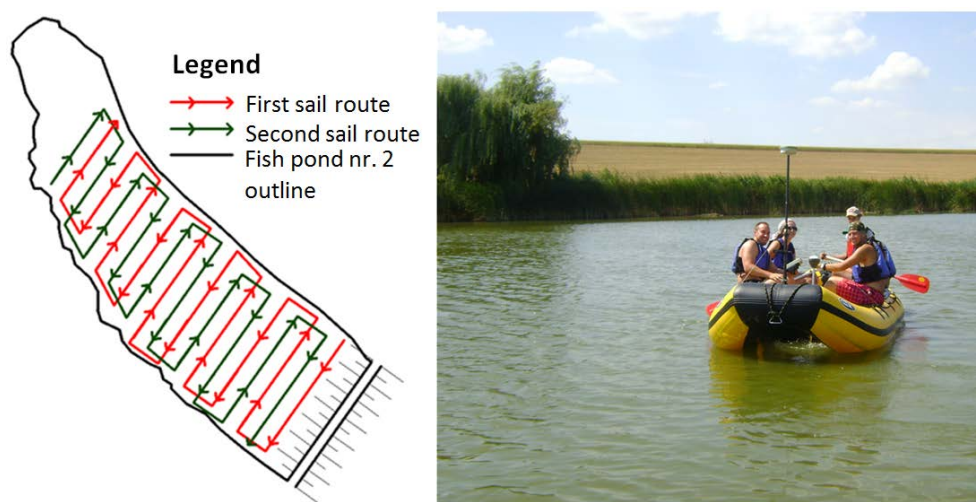


Figure 1: Non-contact surveying at Lukáčovce fish pond nr. 2 (August 17th, 2013)

Quality of the collected data was done as the verification of the GNSS elevation accuracy and verification of presence and correctness of the depth measurement of echosounder.

Collected data was processed to the format of the x, y, z-coordinates of the points laying at the fish pond bottom. These points were used for the creation of the Digital Elevation Models (DEM) in ArcGIS 9.2 with use of “Spline with tension” and “Topo to raster” interpolation methods and creation of the TIN model with use of the Delaunay triangulation rules. For the calculation of the water volume were used all three models. Raster models of the fish pond bottom were at first used for the creation of the water depth map, which was the input data for the calculation of the water volume. The calculation with the use of the TIN model was executed directly without the necessity of the creation of the water depth map.

RESULTS AND DISCUSSION

Data collection was done in August 17th, 2013 and was collected 1646 points during the first sail and 691 points during the second sail with the raft boat propelled with electric engine. The sail routes were executed in the set of profiles parallel to the dam of the pond. Distance between the profiles was approximately 10 m. Data collection was done as the automatic surveying of position with Leica 1200+ GNSS receiver connected to sonar Garmin GPSMap 421s, distance between points was set to 2 m. Depth data was sent from sonar to GNSS receiver via the NMEA cable connection, NMEA sentence was stored for each point as the Annotation. All collected data was exported from GNSS controller to the Leica GeoOffice 7 software. For the further processing was point data loaded in MS Excel 2010, where the accuracy of the GNSS elevation was executed. Points with the GNSS elevation accuracy worse than 50 mm were removed. Then the evaluation of the sonar depth

measurement was executed - points with missing (55 points) or incorrect (9 points) depth measuring were removed. Incorrect depth measurement occurred in the parts, where the depth was smaller than minimum depth that is measurable with the used sonar (about 0,35 m). In these parts the sonar has shown the incorrect depth about 0,7 – 1,0 m (even the real depth was about 0,35 m). Verified point class data of non-contact data collection was processed to the format of x, y, z coordinates in MS Excel 2010, where the elevation of GNSS surveying was decreased by sonar depth for obtaining of the z-coordinate of the point at the fish pond bottom and processing of x, y coordinates to S-JTSK coordinate system. Directly collected data was processed to format of x, y coordinates in S-JTSK coordinate system, z-coordinate was used from the GNSS surveying. All data was exported to text file and loaded in ArcGIS 9.2 as XY data (with added point elevation attribute as z-coordinate).

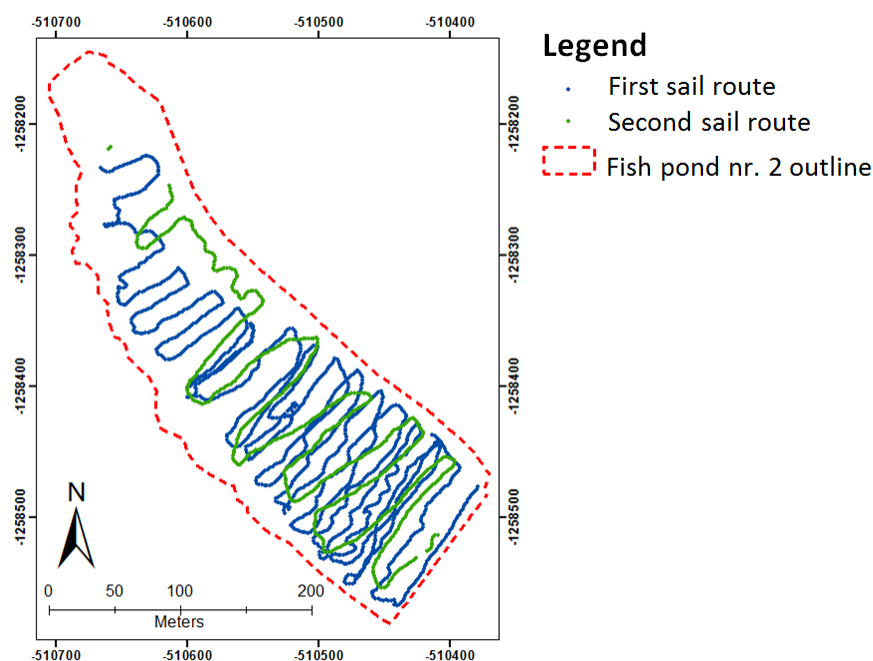


Figure 2.: Collected data of the non-contact surveying at Lukáčovce fish pond nr. 2

Complete set of all points collected with non-contact method of the data collection was used for the creation of the separate shapefile that is built of the points with the distance approx. 10 m between the points. Bank of the fish pond was outlined as polygon from the orthophotomap in ArcGIS 9.2 as the direct surveying of the pond bank was unable to execute (presence of the strong reed and cat tail brushwood). Elevation of the water level was surveyed with the GNSS receiver at level 163,295 m AMSL. The depth of water at the bank was surveyed only at few accessible parts in values 0,30 m - 0,40 m, so the steady water depth was set as 0,35 m at pond bank. Vertices of outlining polygon were exported as point class data. The elevation of these points was set to 192,945 m (elevation of the water level decreased by water depth at the fish pond). Points at the bottom and points at the fish pond bank were used for the production of three models of fish pond (Figure 2) with various interpolation techniques:

- I. Topo to raster – raster model, cell size 2×2 m, outline polygon set as boundary, points of non-contact data collection and points of pond bank as the input data, enforced drainage with Sinks
- II. Spline with tension – raster model, cell size 2×2 m, points of non-contact data collection and points of pond bank as the input data, weight of tension 0,1. This model was clipped in extent of the circumference polygon
- III. TIN model – vector model with the use of the Delaunay triangulation, outline polygon set as hardclip, points of non-contact data collection and points of pond bank set as the masspoints

Both raster DEMs were processed in “Raster calculator” to obtain the water depth maps created as the subtraction of the bottom elevation from the water level elevation. These rasters of the depth were used for the calculation of the accumulated water volume with the use of the “Zonal statistics as Table” tool. This tool calculated the sum of the depths at each cell of raster DEM. This sum of depths was multiplied by the area of one

cell (4 m²) to obtain the volume of the accumulated water in accordance to DEMs created with the “Topo to Raster” and “Spline with Tension” interpolation method. Calculation of the water volume based on the TIN model of the fish pond bottom was done with the “Polygon Volume”, which used the TIN model as the input surface and polygon of the fish pond bank as the reference plane.

Table 1.: Calculated volume of accumulated water in Lukáčovce fish pond nr. 2

Model interpolation method	Topo to Raster	Spline with tension	TIN	Average
Water volume [m ³]	47479	46803	46376	46886
% of average volume	101.26	99.82	98.91	100

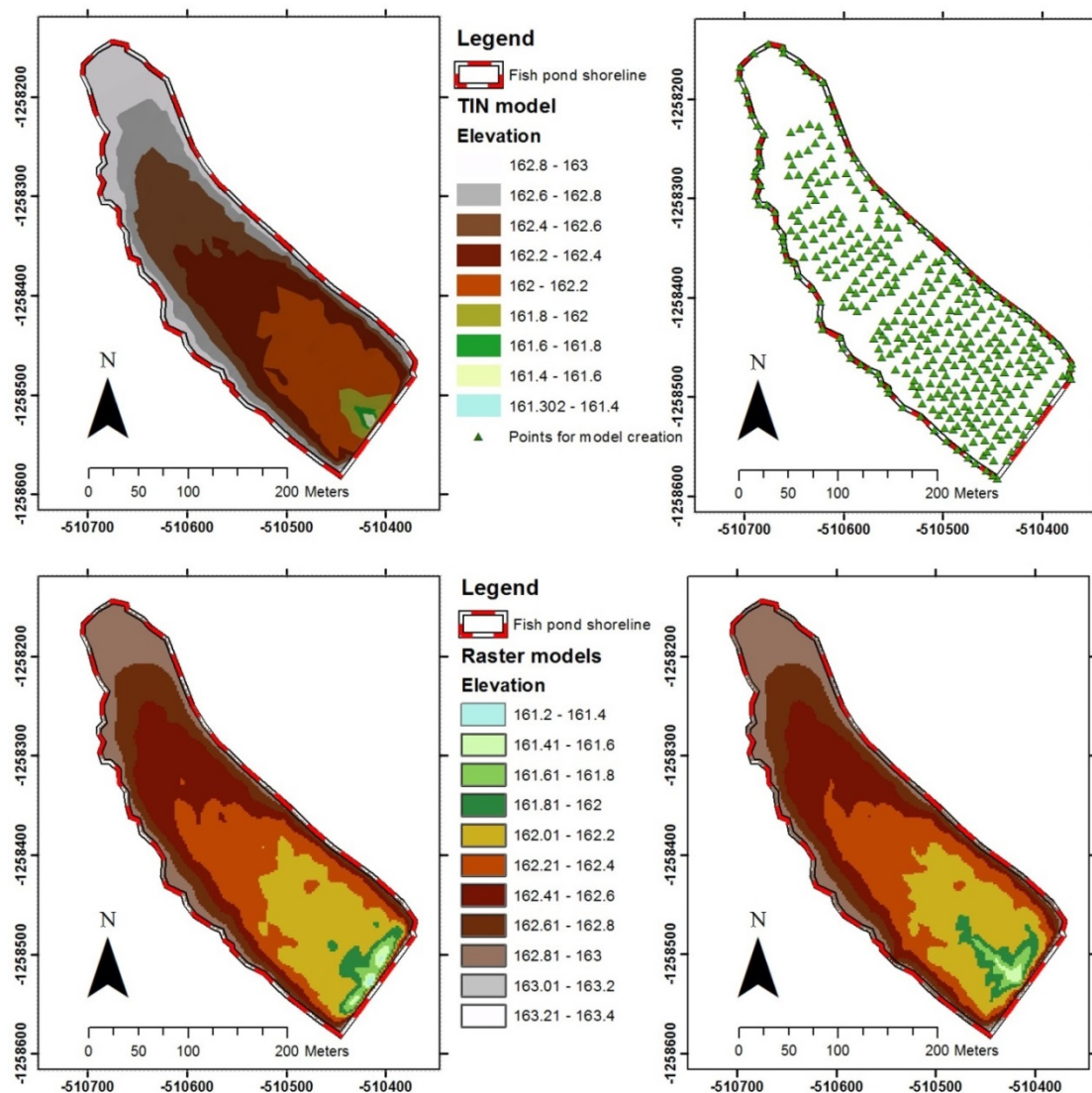


Figure 3.: DEMs of the Lukáčovce fish pond nr. 2: TIN model (top left); Input points (top right); Spline with Tension model (bottom left); Topo to Raster model (bottom right)

Calculated water volume of the fish pond, in accordance to average of the calculations from each model of the bottom, is 46886 m³. Water volume, calculated as the average of volumes gathered from all methods of model creation, is 46886 m³. All three results are differing from the average volume for less than 2%. It is important to note, that the available operation documentation of this fish pond states and presumes the volume of the

accumulated water in amount of $81\,200\text{ m}^3$. That means the actual and real volume is only 57% of the presumed volume. Another interesting point of view is the data of the mentioned depths: minimal depths near the banks are stated as 0,6 m and maximum depth is stated as 1,4 m. Surveying has shown, that the depth near the fish pond bank is ranging from 0,30 m to 0,40 m and the largest depth – in the fish collecting pool in front of the withdrawal object is 2,0 m. The depth in fish collecting pool is probably smaller as the result of the maintenance actions and cleaning of this part during the fish harvest. The depth decrement at the pond bank confirms the decrement of the volume of accumulated water. We presume that the silted sediment was steadily spread at the surface of the bottom during the maintenance actions in the past, when the part of the excavated material was also removed from the fish ponds and used to bury the third fish pond, which does not exist anymore.

There is no data about this works as the documentation of the fish ponds, only the verbal statement from the current fish pond user. The information about buried third fish pond is neither in maps nor the operation documentation. The actual water surface area is smaller than the original area (Fig. 6). We outlined the original shoreline of the fish ponds nr. 1 and 2 and presumed shoreline of the fish pond nr. 3. The size of the original water surface area of fish pond nr. 2 is in value 6,57 ha. We calculated the actual water level area in value 5,57 ha. In the operation documentation is stated the original area of the water surface in value of 5,8 ha. The original area of the water surface is not certain as the available data from the operation documentation and from the basic state map are not equal.

CONCLUSIONS

Natural processes of water erosion in the watersheds lead to the siltation of water reservoirs and ponds and processes. These processes result in the changes of the elevation of the bottom, accumulation of the sediment and decrement of the depth and volume of the water. These processes take action in any size of the watershed and can cause serious problems in the operation of the water reservoirs by direct or indirect impact to their functions and purposes.

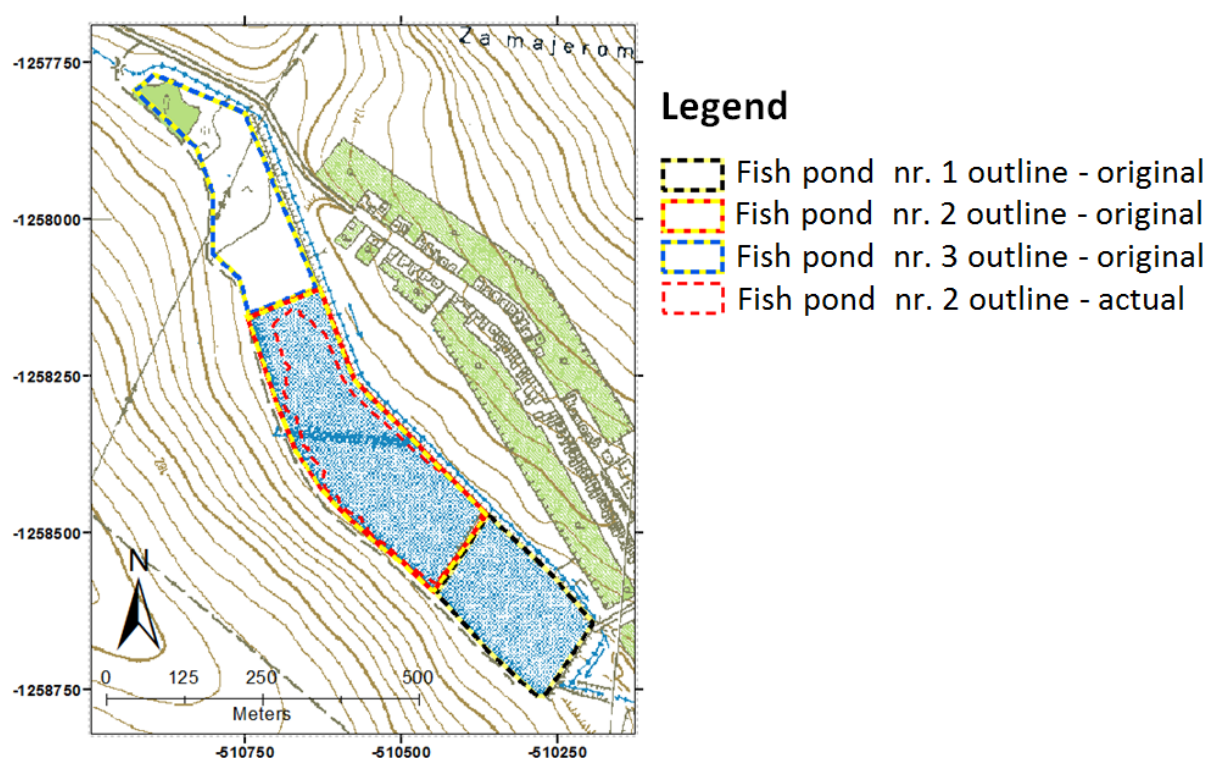


Figure 4.: Lukáčovce fish ponds (SAŽP)

Mapping of the actual storage capacity of the fish ponds and other small water reservoirs can be done with the usage of the non-contact surveying based on the GNSS and sonar surveying and processing of the digital elevation model of the reservoir bottom. This method was demonstrated at the Lukáčovce fish pond nr. 2, where

the calculation of the actual storage capacity was executed with the use of two raster models created with “Topo to Raster” and “Spline with Tension” interpolation methods and one vector model TIN based on the Delaunay triangulation method. Results of the mapping, data processing and calculations have shown, that the actual storage capacity is about 46 900 m³. This surveying has shown that the storage capacity is only 57% of the original fish pond volume (81 200 m³). Actual area of the water surface is 5,57 ha, original area is uncertain as the operation documentation and the available data from the basic state map are not coherent (5,8 ha in operation documentation; 6,57 ha in basic state map).

ACKNOWLEDGMENTS

This work was supported with the following grants VEGA 1/0456/14 “Management of the Soil Moisture Regime as a Tool for Climate Change Adaptation”, VEGA nr. 1/0027/12 „Development and validation of indirect assessment of anthropogenic immission load” APVV nr. 0274-10 "Quantification of input data influence on correctness of outputs of dispersion simulation models for surface water".

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