COMPARISON OF MODELS AND VOLUMETRIC DETERMINATION FOR CATUSA LAKE, GALATI

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Abstract: *Nowadays the bathymetry is one of the most important techniques to measure the depth data, especially for surveying lakes, rivers, and other bathymetric projects. Catusa Lake has a strategic importance with its location in Galati city, especially for Sidex Galati, the country's largest steel mill. In order to achieve the main purpose of this research, it was used different bathymetric models to calculate lake volumes. The study aims to present an efficient method of bathymetric measurements for creating bathymetric maps, using a singlebeam echo sounder combined with RTK GPS technique. The results of different models were compared to determine depth contours and location of maximum depth. The field measurement of water depth is unique for Catusa Lake and will be made later again (probably in next quarter of the year) to evaluate the accuracy of the various models created.*

Keywords: *bathymetric surveying, lake volume, singlebeam measurements, depth sounders*

1. Introduction

Nowadays are many studies on water relating to determine water quality, temperature, salinity, volumetric measurements of lakes, depth measurements for an accurate maintenance dredging, bathymetric mapping of supraglacial lakes, rivers, and streams, etc. The bathymetric model is the best solution to determine volume of lakes. The bathymetric model represents the bottom surface of water bodies. It can be obtained by depth measurements from the top of the water. The depth is usually measured using singlebeam or multibeam echosounder. Singlebeam sounder still is the most common instrument used in ports, lakes and rivers surveys, because it is an efficiency low cost and accessible instrument. Acoustic depth measurements systems measure the elapsed time that an acoustic pulse takes to travel from a generating transducer to the waterway bottom and back (figure 1) [1].

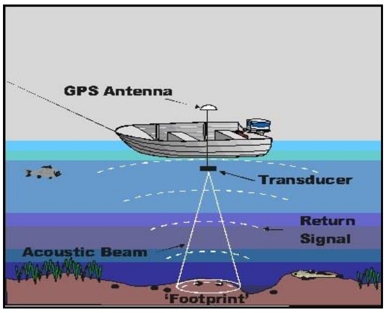

Figure 1. *Depth measurement with a singlebeam echosounder (http://www.ozcoasts.gov.au)*

In order to determine the volume of lake can be used various interpolation methods. These methods of interpolation are classified by most authors into three categories: *non-geostatistical methods, geostatistical methods, and combined methods* [2]. The general estimation formula that explains nearly all interpolation methods is described as follow [3]:

$$\hat{Z}(s_0) = \sum_{i=1}^{N} \lambda_i Z(s_i)$$

where: $Z(s_i)$ = the measured value at the *i* location;

λ_i = an unknown weight for the measured value at the *i* location;

S_0 = the prediction location;

N = the number of measured values.

ArcGIS software was used to generate bathymetric models and compare the accuracy of interpolation methods [4].

2. Study area

The primary objective of the bathymetric project was to develop the digital elevation model of the bottom and calculate the Catusa Lake water capacity (figure 2). The lake is situated in the west part of Galati city. It is a tunnel valley lake app. 2100 m length (north-south) and maximum app. 225 m width.

Figure 2. *Study area – Catusa Lake*

Catusa Lake has a strategic importance with its location in Galati city, especially for Sidex Galati, the country's largest steel mill. In the last years, this lake has a significant decrease in water volume. Also, on this lake doesn't exist any bathymetric measurements to determine the morphologic data and to compare in time. The estimated maximum lake area for water level 6.28 m above the sea is approximatively 36 ha.

3. Materials and methods

To reach the purpose of this study it was used a combination of topographic measurements and singlebeam depth technique. To determine topographic heights of the lake bottom it was used a GPS system South S82. The measurements with this equipment have very high precision and they give the possibility to measure directly the altitude above the sea (in our case altitude = 0m – Black Sea-Constanta). A 235 kHz frequency of Ohmex SonarMite /BTX Singlebeam Echo Sounder [5] was used for the depth measurements from the mounted pole to the bottom of the lake. All these instruments were mounted on a mobile platform – inflatable boat (Fig. 3).

Figure 3. *Used instruments and mounting method on an inflatable boat*

To achieve high accuracy of bathymetric measurements and to record bottom height of lake, the measurements were performed in different ways, in a jag and longitudinal alignments (figure 4) [6].There were registered 5864 values overall. The topographic and bathymetric measurement was performed in the local projection system – stereographic 1970.

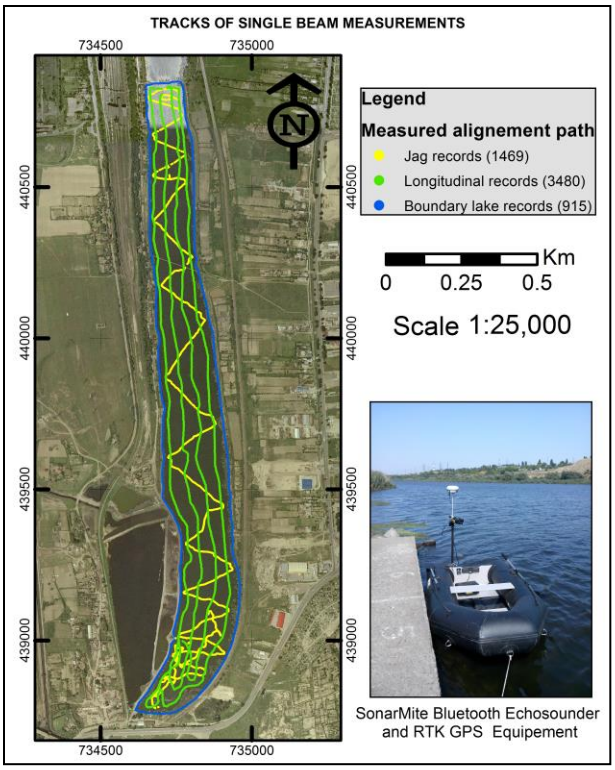

Figure 4. *Jag and longitudinal method of depth measurements*

4. Analysis and Results

To generate a continuous area of bottom of Catusa Lake it is necessary to approximate the cell values in areas where data doesn't exist. To analyze the quality of each interpolation method was used all 5864 points from measurements using the ArcGIS extension from Geostatistical Analyst tool. To calculate the existent volume of Lake Catusa was used the following 4 interpolations method: Inverse Distance Weighting (*IDW*), Radial Basic Function with Completely Regularized Spline (*RBF-CRS*), Simple Kriging (*SKRG*) and Universal Kriging (*UKRG*).

Table 1. Cross validation results

	IDW	RBF-CRS	SKRG	UKRG
Samples	5864	5808	5864	5864
MinMV	2.750	2.750	2.750	2.750
MinPV	3.474	3.576	3.553	3.691
MaxMV	6.281	6.281	6.281	6.281
MaxPV	6.281	6.281	6.259	6.000
MeanError	-0.032	-0.050	0.005	-0.039
RMSE	0.251	0.299	0.232	0.532

The statistical terms usually used to evaluate the performance of the methods are: mean, maximum, minimum, mean absolute, root mean square errors and other statistical values (table 1).

The basic statistical value which defines the dispersion of the frequency distribution of deviations between the measured and unmeasured interpolated values is the Root Mean Square Error (*RMSE*) [7]. Figure 5 represent a bar chart that indicates how closely the created model predicts the measured values. A good model can be obtained when this error is smaller and is closer to zero.

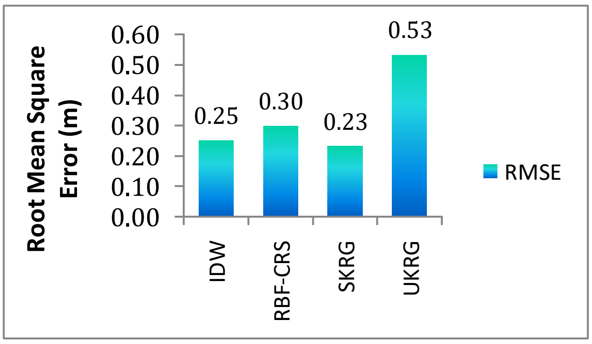

Figure 5. *The standard deviation of the residuals*

The best result of RMSE is observed at SKRG interpolation method. A good representation is confirmed by the scatterplots, where the SKRG distribution between measured and predicted values is better constrained.

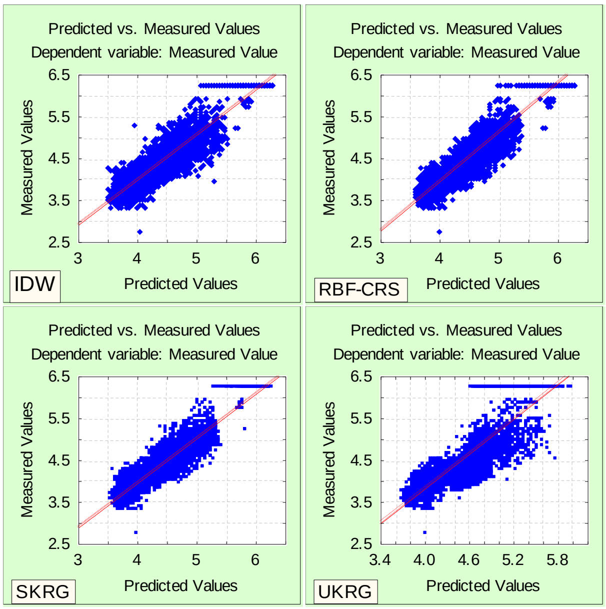

Figure 6. *The relationship between measured and predicted values*

The SKRG method with a linear semivariogram model was used to be consistent and this is considered the standard method. The other 3 methods are compared with this one to analyze the differences. Each interpolation method created a bathymetric model for the bottom of Lake Catusa. To analyze the models, one-meter contour lines for each bathymetric model were created (figure 7).

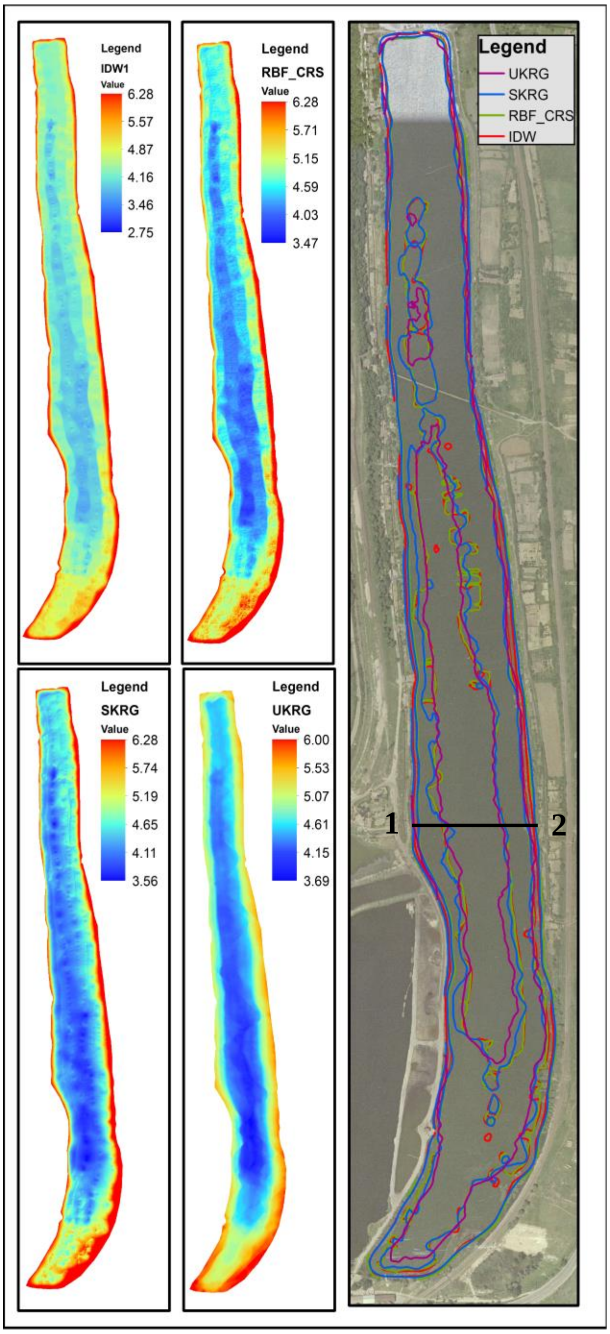

Figure 7. *The obtained bathymetric models and 1 meter depth contours*

To achieve the main purpose of this study and understand how the model influences the calculation of lake volume, we also calculated and graphically compared a transversal cross section for each of the models (figure 8).

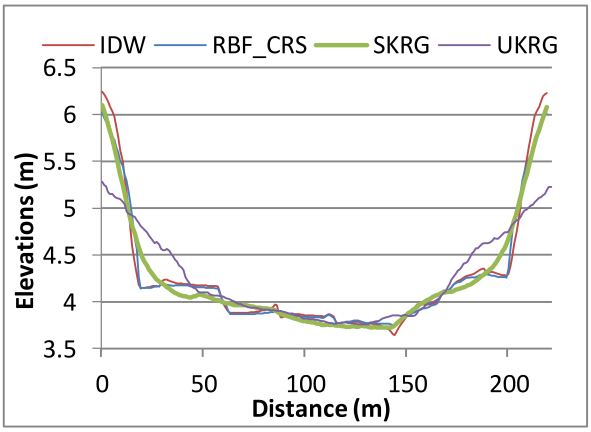

Figure 8. *Cross section profile 1-2, represented in figure 8, from different interpolation method*

Lake Catusa volume was calculated and compared for all 4 models (figure 9). The volume was calculated with 3D surface analysis package from ArcGIS [8,9].

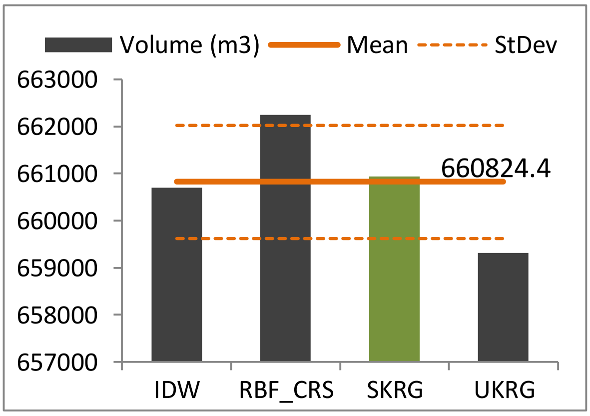

Figure 9. *Volume calculated using different models*

The mean value between volumes computed from all models was 660824.4 m^3 with a standard deviation of 1200 m^3. A good result of the volume values was obtained for simple kriging interpolation method. The second best result and which resemble with the result of SKRG method is model obtained by IDW interpolation.

5. Conclusion

To perform the bathymetric survey on Catusa Lake was used a singlebeam echo sounder combined with an RTK GPS system. To calculate lake volume was used 4 different bathymetric models. The bathymetric maps created by singlebeam measurement depend on the accuracy of used interpolation methods. If we analyze the data of cross-validation results, the simple kriging interpolation has a 0.23 root min square error. The coefficient of the determination R^2 between the predicted and measured values also confirm that the SKRG is better, so that: R_{IDW}^2=0.913, R_{RBF}^2=0.895, **R_{SKRG}^2=0.925**, R_{UKRG}^2=0.639.

The differences are observed for the cross section profile represented in figure 8. The SKRG interpolation method describes an attenuated and smoothed profile. We can remark that the volume calculated by IDW model is nearby the volume obtained by SKRG model. The two other values of volume obtained by RBF and UKRG are out of calculated standard deviation.

In conclusion, it can be said that the creation of digital elevation model of an area depends on the measurements number (in this case points number), the GPS signal effectiveness, and on the chosen interpolation method. The last one can help to calculate more precisely the plan and volumetric areas of the lake, and also its morphometric analysis in time. The analysis points out that the measurements combination in a more uniform grid (combination between transversal and longitudinal bathymetric surveys) can provide a more high precision to the data processing [10].

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