

## Study of monitoring the river sediments

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### Abstract

This paper presents a study conducted during 2008-2014 on determining the volume of sediments accumulated on the Danube Delta - Cernovca arm.

For this purpose has been used various methods and programs, achieving different accurate bathymetric numerical models. The first bathymetric measurements in Romania, were made in 1829 by Russia, to the mouth of the Sulina arm.

Before that date, there were measurements attempts made by the Ottoman Empire and France. The main purpose of these measurements was to establish the best routes without danger between Tulcea and the Black Sea.

Subsequently, measurements were carried out to establish the plotting of new artificial canals and fishery purposes. Today, bathymetric measurements of the Danube Delta are mainly used for navigation purposes and geomorphologic research.

It is important to monitoring the river depths in order to know the bed dynamics and sediment distribution.

### Keywords

MDT, Grid, triangulation Delaunay, Surfer, TIN, ArcMap, Global Mapper

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### 1. Introduction

The scientific model is an ideal or theoretical case but imperfect which is based on concepts.

Being based on the correlation between conceptualization and studied phenomenon or process, the modeling results may have various degrees of trust and fidelity.

In terms of geodetic the model can be defined as a set of procedures that we apply in order to evaluate some parameters that contribute directly or indirectly to describe the geometry of the figure of the Earth and its gravitational field.

Another type of model encountered often in geodesy, especially in photogrammetry is that the deterministic model applied to represent the land/terrain surface.

The Spread of Surface modeling is mainly due to the development of technology which has given us among others, the three-dimensional and generating the digital models of terrain/land.

Digital terrain model is a digital representation of the topographic surface. Can be represented in raster or vector format and can be generated by using several techniques and measurement methods, but the most used is the remote sensing.

However, traditional methods are used and surveying as well. Methods of obtaining an MDT are derived from information retrieval mode:

- kinematic GNSS measurements,
- stereofotogrammetry,
- lidar measurements,
- topographic maps relief representation by contours
- bathymetric measurements.

### 2. Problem

#### Bathymetric measurements

As measurement devices and systems are distinguished:

- sounding stick,
- hand probe
- Sonar (acoustic probe).

The sonars are presented like systems with single or multiple oscillator. Sonar measuring principle consists in the fact that

in the water are spread sound pulses produced by an oscillator until it is reflected at the area adjacent the two media of different densities, and they are received back by the same or a second oscillator.

The sonar it is used to determine the depth or transverse profiles for drawing water courses depths of hundreds of meters. Depth data determined at the sounding are usually gross values, indicating the depth of the water at the bottom of the oscillator. Gross amounts should be ordered for subsequent comparison with the initial or subsequent measurements.

By ordering we understand linking the depth values to a reference system. There are the following possibilities:

- geometric leveling (problems: near the shore, refractions);
- trigonometric leveling with zenith or vertical measurements (problems: refractions, wear down the instruments);
- water surface determining (problems: poles beaten in shore, fluviometric scale);
- Data of hydrometric stations (problems: division into intervals of hydrological scale, linear interpolation).

Determination using the and electronic positioning systems have evolved into modern equipment (multi-beam - with multiple beams) by lifting and Differential Global Positioning System (DGPS).

Horizontal position - 2D is determined by various methods. The measurement data of the depth are reported to the vessel used for lifting, either to the area of the surrounding water. The positioning data and depth data can be obtained in the same time.

**Making MDT**

Depending on how supporting points are obtain, the using of the results and the data precision we can distinguish several methods of obtaining and representation of MDT. According to [Constantin Nitu, 2009] as accurate interpolation methods we have:

- method by triangulation with linear interpolation (linear interpolation with Triangulation);
- method natural neighbor (natural neighbor).

**Triangulation with linear interpolation**

Triangulation method followed by linear interpolation uses all points with values X, Y and Z data and they are built triangle formed by neighboring points so that the entire surface is covered with triangles. A particular case is that of triangulation Delauney [Constantin Nitu, 2002].

Points are thus united two by two, that one side can not override another triangle. The premise leads to an accurate

method of interpolation.

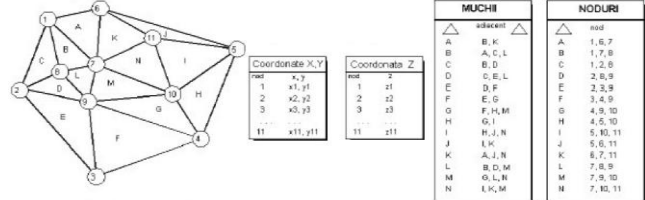


Fig.1- Rețeaua TIN și structura datelor [Constantin Nițu, Modele digitale altimetrice și geostatistică, 2009, pagina 15]

**Natural neighbor method**

Each triangle defines a plane, so that the triangle is a cuboid with the top face of the base (bottom) on the horizontal plane Z value zero. Share of each point inside the triangle resulting from linear interpolation from the values Z in the three peaks of the triangle.

This is a very simple method. Either a set of Thiessen polygons, Delaunay triangulation of a set of dual [Constantin Nitu, 2002]. If to a set of points and is added a new point, the Thiessen polygons it changes. In fact, only some polygons will shrink and none will increase. Thiessen polygon associated with the target of an existing polygon is called "borrow zone". Of natural neighbor interpolation algorithm uses a weighted average of neighboring Z data, where the weights are proportional to "borrow zone area". The Method excludes extrapolation outside the outer polygonal contour data points or polygons Thiessen Z values.

**3. Study case**

In its northern sector, the Romanian seaside is represented by the front of the Danube Delta, which as a sedimentary unit, covering an area greater than 12,600 km<sup>2</sup>. Current geomorphology of the Danube Delta is the result of continuous interaction between the river and the Black Sea.

For the case study was chosen Cernovca arm (located between Old Stambul arm and arm Babina), which was determined volume of sediment accumulated in 2008-2014.

For this purpose it been used the following tools and packages software:

- Bathymetric measurements were made with the station Garmin (GPS + sonar) model GPSMAP 298C Sounder for stage I GPSMAP 527 xs November 2008 and May 2014 for Phase II;
- For modeling various applications and analysis programs were used Surfer, Global Mapper, ArcMap and QGIS.

To check the accuracy of the results of monitoring to achieve MDT have been used the two programs and for the modeling methods were chosen natural neighbor and triangulation.

Below there are presented the steps on the follow-up study of sediment deposits. In the Danube Delta area planimetric and altimetric national network is deficient because:

- Density of points is small because large areas of water and land unstable;
- Many of these points were destroyed or there were no longer

found because they have not done network maintenance; it is necessary that data sets (measurements) to be performed in two steps in the same reference system.



Fig.2-Satellite images of the Danube Delta- NASA image source.

Georeference measurements and the creating of a database dedicated to the both format software

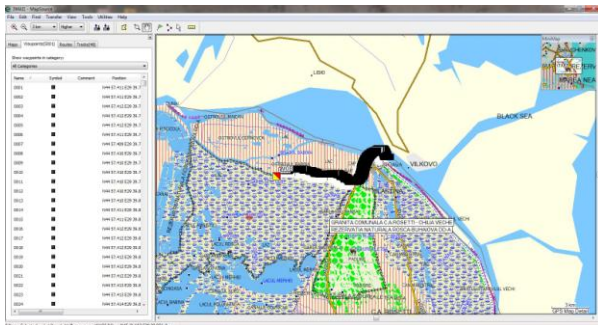


Fig. 3- Datele exportate- Map Source

The data are exported individually (waypoints and tracks) from Map Source .gpx format.

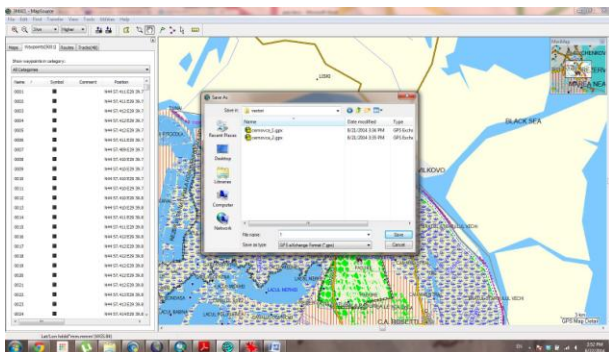


Fig.4- Saving and exporting individual data

Importing data into Global Mapper .gpx and cut to mask Cernovca arm.

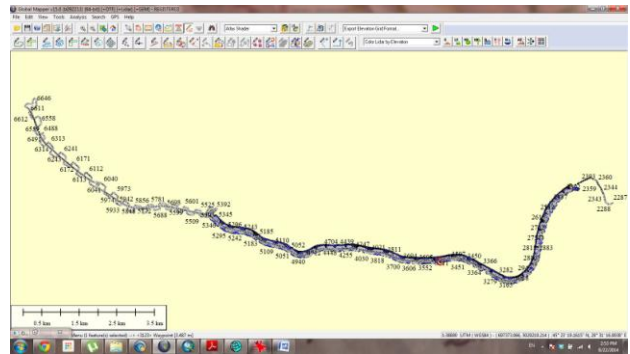


Fig.5- Vizualizarea datelor în Global Mapper

The data is exported in .shp format that point in Global Mapper.

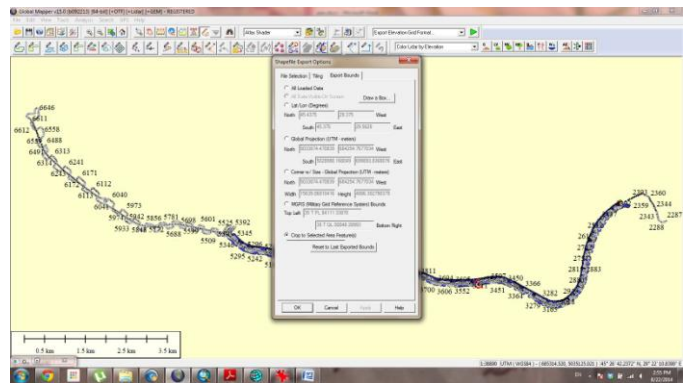


Fig.6-Exporting data in .shp format

Data are imported into Global Mapper and they are added in the table of attributes x and y coordinates.

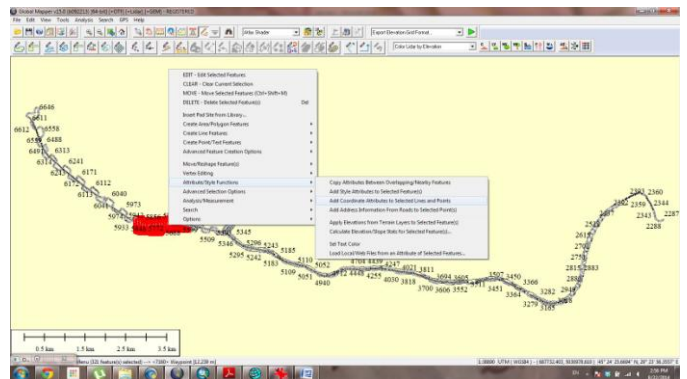


Fig.7- The addition of x and y in the table of attributes

The data format type shp point, bring it into QGIS and attribute table is modified so that it remains only x, y and z.

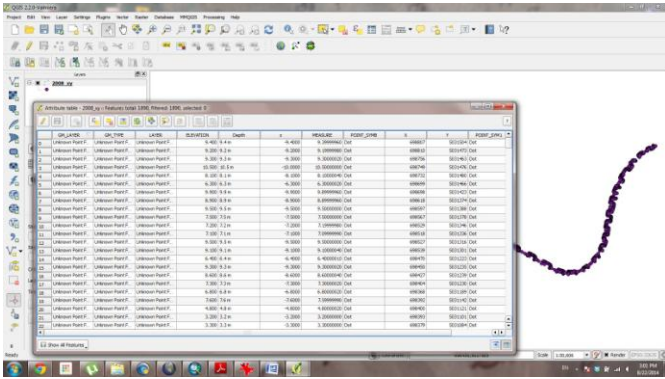


Fig.8- Creating depth of field

**Making MDT**

To achieve MDT for the years 2008 and 2014 using the same settings as follows:

- Step grid is 10 m;
- Due to the irregular shape of the scanned area bathymetric numerical models will be cut mask commonly used previously;
- Calculating the difference between the two grids - grid Oldest always subtracted from the newest;
- Erosion will have negative values, and the sediments will have positive values (Constantinescu, 2012);

**Modeling software like Surfer**

**1. Natural Neighbor method**

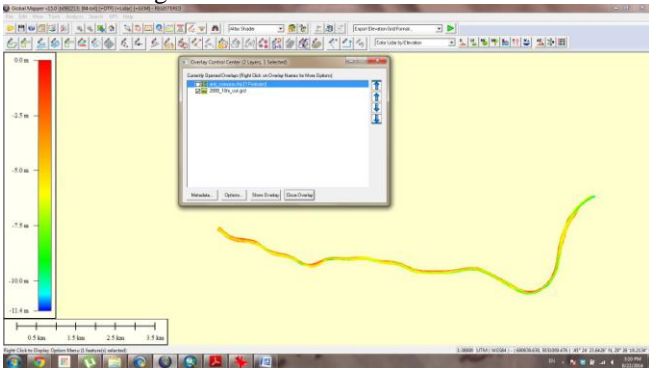


Fig.9- MNB result after cutting

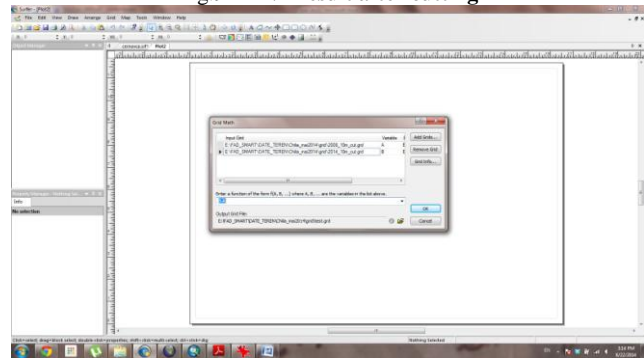


Fig.10- Differences Calculation between the two grids

The new result is divided by the number of years apart and erosion rates are obtained / accumulated sediments / year,

then multiply by 100 to represent values in cm / year.

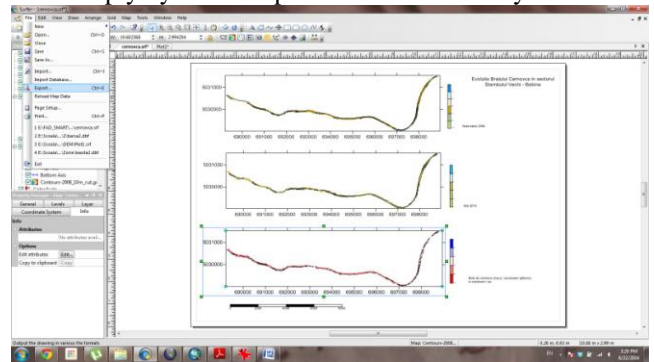


Fig.11- Models for measurements made in 2008, 2014 and rates in cm / year

All data are brought into ArcMap to make surfboards position in the Danube Delta, Cernovca arm and measurements results. All data (gpx the station, gpx exported from MapSource, shp exported from Global Mapper and degrees after interpolation) are projection UTM (Universal Transverse Mercator), Z35 N (Zone 35 North - specifies the eastern part of Romania), WGS 85 Datum (World Geodetic System 1984).

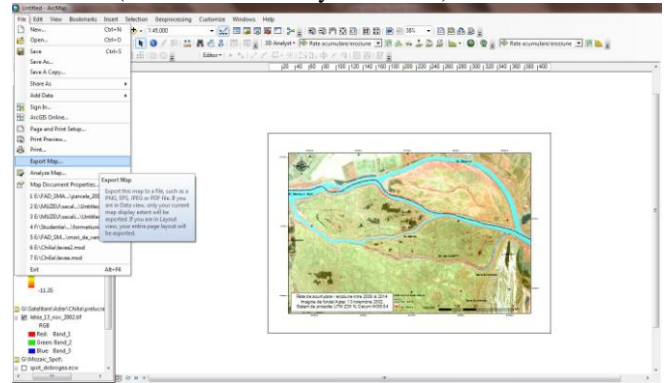


Fig.12-ArcMap

**2.Triangulation method**

The same steps were followed above for achieving those models and also to determination of erosions and accumulation of sediments on the arm.

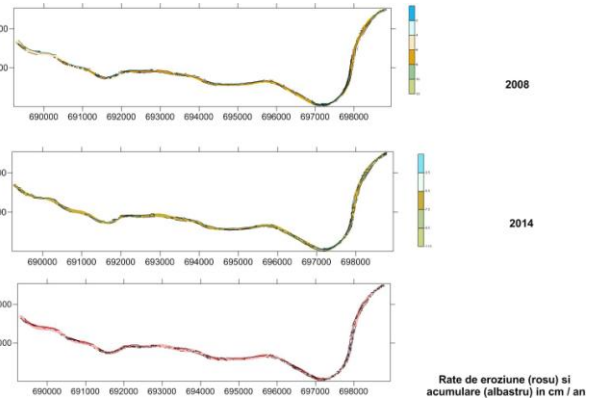


Fig.13- Models for measurements made in 2008, 2014 and rates in cm / year

### Modeling software using Global Mapper

#### Triangulation method

In Global Mapper software, interpolation can be done only by a single method, that of triangulation.

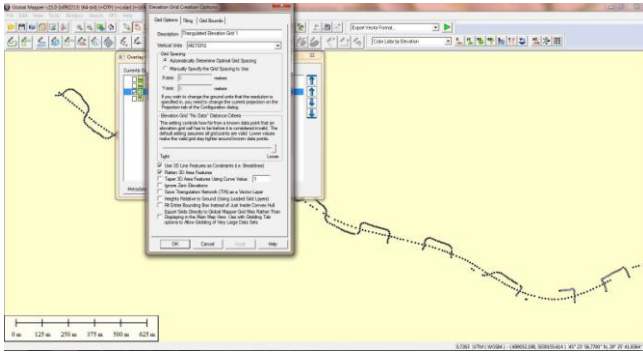


Fig.14- Making MDT triangulation method

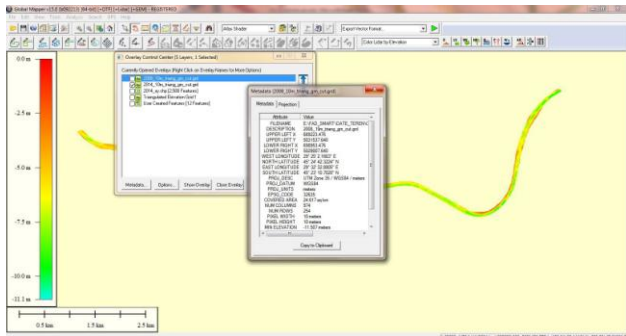


Fig.15-Raport informații statistice cu privire la realizarea MDT MDT algorithm achieving the same as for 2008 data and 2014 data.

#### Estimation accuracy for the models results

To calculate the precision of numerical models bathymetric measurements results for 2008 and 2014, has been used a set of control points, represented 10% of each set of data. Thus, the 2008 data set were 188 randomly selected control points (Fig. 16), while the 2014 data set, 254 control points (Fig. 17).

Tab.1 - Depths values measured and calculated for 2008 data

Nr. pct	Mesured values[m]		Surfer[m]			G.M[m]
	X	Y	Z	Z <sup>nn</sup>	Z <sup>triangulație</sup>	Z <sup>triangulație</sup>
1	692304	5029931	-5,3	5,427	-5,566	-5,576
2	698014	5030458	-6,6	6,478	-6,384	-6,424
3	696453	5029393	-5	4,151	-3,880	-3,480
4	698444	5031233	-9	8,884	-8,857	-8,851
5	692566	5029925	-6,3	5,037	-5,059	-5,016
6	698541	5031357	-6,6	6,232	-6,495	-6,524
7	690282	5030328	-4,9	4,562	-4,503	-4,546

8	691238	5029847	-6,5	5,497	-5,510	-5,359
9	691994	5029840	-5,8	8,160	-7,933	-7,774
10	697867	5029704	-8,5	7,719	-7,684	-7,689
...	...	...	...	...	...	...
188	691869	5029831	-2,1	3,465	-3,415	-3,430

Tab.2- Estimate of the accuracy of the data set MDT 2008

2008	Surfer		G.M
	NN	Triangulație	Triangulație
[vv]	78,349	79,565	87,371
S <sub>0</sub> [m]	0,646	0,651	0,682

Tab.3 - Depths measured and calculated values for the data from 2014

Nr. Pct.	Mesured values [m]		Surfer[m]		G.M[m]	
	X	Y	Z	Z <sup>nn</sup>	Z <sup>triangulație</sup>	
1	693528,8	5029776	-4,8	5,676	-5,548	-0,504
2	692706,7	5029935	-6,1	6,808	-7,233	0,180
3	698385,3	5031214	-7	5,852	-5,932	-0,151
4	691843	5029799	-6,1	5,346	-5,188	0,253
5	692391,4	5029929	-5	6,764	-6,763	-0,092
6	697970	5030338	-6,9	3,896	-3,853	0,121
7	691897,7	5029845	-3,7	5,349	-5,271	0,346
8	692382,3	5029930	-5	7,413	-7,380	-0,022
9	697727,3	5029426	-4,6	5,567	-5,555	-0,030
10	692564,6	5029912	-7,5	7,128	-6,727	-0,404
...	...	...	...	...	...	...
254	694108,8	5029699	-6,2	5,607	-5,046	-5,579

Tab.4 - Estimate of the accuracy of the data set MDT 2014

2014	Surfer		G.M
	NN	Triangulație	Triangulație
[vv]	137,362	151,293	197,200
S <sub>0</sub> [m]	0,735	0,772	0,881

#### Calculation of volumes of sediments

Calculation of the volume of sediments was done by two methods namely trapezoidal method (Surfer) and Simpson method (Global Mapper).

Tab.5 – Calculation of volumes of result sediments

Interpolation method	Volume[m <sup>3</sup> ]		Sediment volume (V2014-V2008)[m <sup>3</sup> ]		
	2008	2014	Surfer	Global Mapper	
Surfer	NN	6150397	4921375	1229022	959879,3
	Triangulație	6740392	5030022	1710370	993155,9



Fig.16 - Representation of control points for data in 2008



Fig.17 - Representation of control points for data in 2014

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## Conclusions

It can be realise a monitoring of sediment deposition and erosion of the riverbed both for fishery, navigatingl purposes and geomorphological research with low cost devices and programs.

Where monitoring is carried out in an area where geodetic reference network is missing, the bathymetric measurements has to be brought to a common reference in order to eliminate errors due to difference in water level between the various stages of measurements.

The study conducted on Cernovca arm shows that despite expectations, the absolute value of the erosion is greater than sediment accumulation, leading to greater water level in the area.