COMBINED MULTI-BEAM ECHO SOUNDER AND ACOUSTIC DOPPLER PROFILER MAPPING OF THE DANUBE-EPURASU BRANCH IN ORDER TO DETERMINE THE INFLUENCE OF NEWLY CONSTRUCTED HYDROTEHNICAL STRUCTURES

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***Abstract**: This article details field research conducted at the Epurasu branch of the Danube River that sought to investigate the influence of newly constructed hydrotehnical structures. The study area was surveyed with two vessels, aiming to investigate the morphology and flow field characterizing this secondary branch and to provide data in order to observe the state of the riverbed and bedforms, velocity, and possible morphologic changes. The first vessel was equipped with a multibeam echosounder and on the second one an acoustic doppler current profiler (ADCP) was used. The results of the research revealed* *changes in the riverbed morphology and highly detailed imagery of the riverbed and of the hydrotehnical works.*

Keywords: *hydrotehnical works, morphology, riverbed, Epurasu branch*

1. Introduction

The International Hydrographic Organization (IHO) defines hydrography as "the branch of applied science which deals with the measurement and description of the physical features of the navigable portion of the earth's surface (rivers) and adjoining coastal areas, with special reference to their use for the purpose of navigation."

The focus of hydrographic work is the measurement and acquisition of all parameters, which are necessary to describe the constitution and form of the riverbed and the dynamic processes of open waters. Main hydrographical tasks are: river bed measurements; discharge and current measurements; terrestrial surveying; cartography and hydrographical data management.

In this paper it is presented field research conducted at the Epurasu branch of the Danube River that investigated the influence of recent constructed hydrotehnical structures on the riverbed morphology using echo sounder technology.

The study area is represented by Epuraşu branch (fig.1) of the Danube River and presents itself as a natural branch with a length of 7 km, with relatively low depths and low water discharge, which is in an advanced process of colmatation. (INCDPM, 2005)

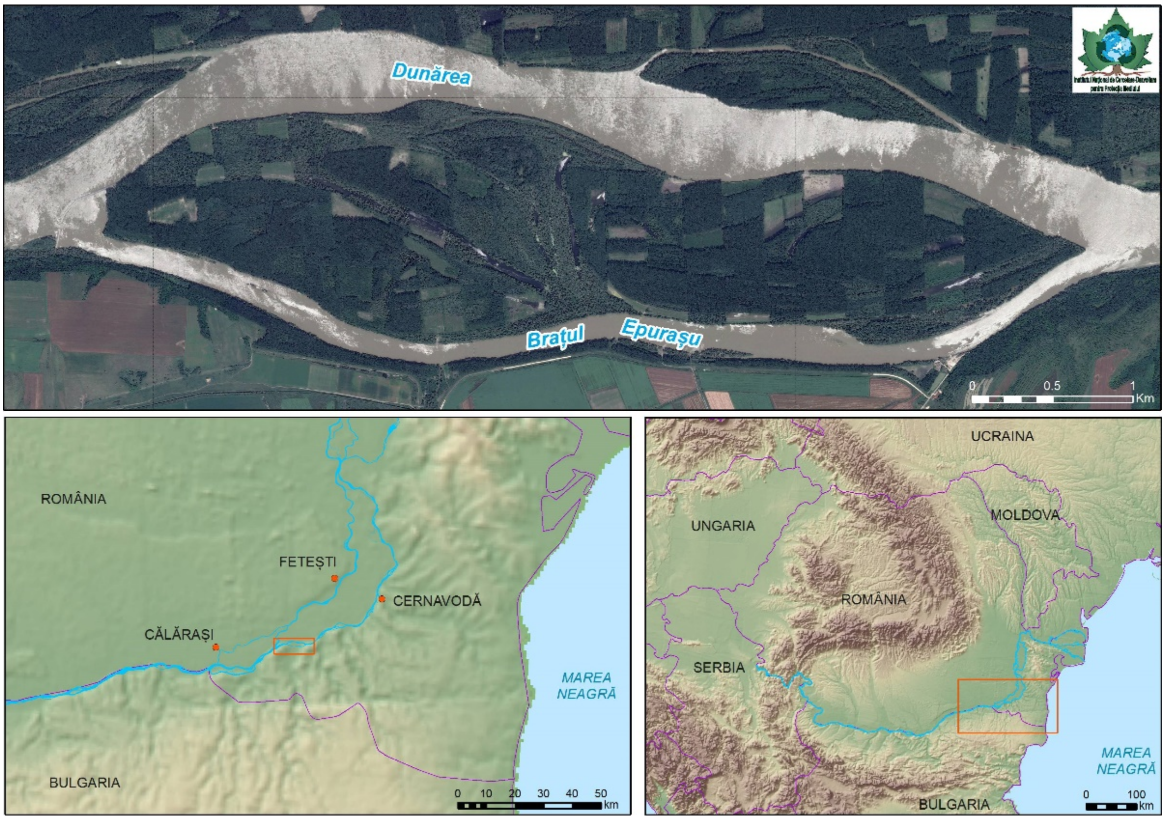

Fig.1. Location of Epurașu branch

To improve the navigation conditions by modifying the distribution of flows during the small and medium water levels, in the area of the Epurasu branch was proposed the construction of a submerged dam and bank defences (AFDJ, 2014). As a result of the implementation of these hydrotechnical works, the water flow on the Epurasu branch was significantly reduced, which may favour an increase in the eutrophication potential in certain periods, by the excessive development of filamentous algae and macrophytes (INCDPM, 2015). As a solution to this issue, a groove was built into the closure dam body. Over the years, under the influence of this anthropogenic intervention, the water discharge has shaped the riverbed, leading to significant morphological changes. Changes that are currently monitored with the latest echo sounder technologies.

2. Methods and materials

In order to observe the riverbed morphology evolution, the following equipment was used: 2 x ADCP produced by Teledyne and Sontek and a multibeam produced by Kongsberg.

Basically, we distinguish two different surveying systems, the single-beam and multibeam echo sounding system. In the following some principle advantages and disadvantages of single beam versus multi beam are given:

a) Single-beam echo sounder

- Measurements are linearly in the form of profiles;
- Single-beam measurements are faster and cheaper as multi-beam measurements, at least along shallow water stretches;
- Easier handling of data due to smaller amount;
- Unfavourable distribution of soundings for generating 3D-Models and bathymetric plans, because of high density along profiles, lack of data between profiles.

Assignment: Measurements for the preservation of evidence, Measurements for controlling dredging projects.

b) Multi-beam echo sounder

- Produce a „swath" of sounding (i.e. depths) to ensure full coverage of an area;
- Higher expenditure in comparison to single-beam measurements;
- Data handling is more sensitive.

Assignment: for special measurements, for example detecting wrecks or measurements for river engineering projects, Bridge pier erosion sounding, etc.

The Advance Doppler Current Profiler (ADCP) system measures real-time water velocity profiles and determines the discharge rates on the profiles. This system was used attached to the craft.

The ADCP RDI RiverRay 600kHz (fig. 2), consisting of: Bottom Track circuit, high-resolution profiling, cables, batteries, memory card and dedicated software, required a shock-proof and moisture-proof computer for data collection, and was served by the built-in GPS. The ADCP used are four/eight sensors with different orientation for generating a water-tight narrow beam without reflections due to water particles (e.g. sediment and suspension, organic matter, organisms or gas bubbles) to determine the discharge rate of the water.

Fig. 2. ADCP RiverRay

For data processing, a Teledyne RDI-WinRiver II software was used to record, process, and analyze the velocity and discharge data.

The second single-beam ADCP system is River Surveyour (Sontek, 2010), being a portable echosond with a ± 0.5% water depth accuracy. The ceramic transducer has a power of 300W at a frequency of 10KHz. The central ecosystem unit is connected to a 10-30VDC power supply with transducer, GPS and laptop to allow recording, integration and storage of information for each profile. This system was installed on the craft and was immersed at a depth of 30-40 cm, measurements being made on transverse profiles, starting at a distance from the shore that provides a minimum depth of 2 m and crossing the opposite bank of the Danube the same conditions. It has been attempted to maintain a more straightforward track and a steady velocity.

The bathymetric profiles were executed on pre-set sections having at least one mark on which the topographic profile with the perpendicular orientation on the Danube course from one shore to another. At the beginning and at the end of the series of measurements the Danube's level was recorded at the nearest hydrometric station. The velocity of the craft was about 2 knots (about 3.5 km/h), depending on the state of the hydro meteorological regime, the wind, the nature of the riverbed, etc.

The Kongsberg GeoSwath Plus Compact Sonar (fig. 3) is a sonar that allows simultaneous bathymetric measurements and lateral scans of the riverbed with precision that meets OHI (International Hydrographic Organization) standards (Kongsberg, 2010).

Fig.3. Kongsberg Geoswat Plus Compact System

Kongsberg GeoAcoustics GeoSwath Plus Compact 250kHz system is designed for topographic digital maps (DTMs) for depths of up to 200 meters. The multi beam system consists of:

- 250 kHz multifascic transducer, equipped with SVS mini (for measuring the sound velocity in water) and MRU (to obtain altitude correction);
- a compact unit providing energy supply and sensor communications;
- a dedicated software that allows for data acquisition and post-processing;
- a RTK reference station transmitting corrections to the pole mounted rover;
- connection cables between system elements;
- a craft which assures the installation of all the equipment and the energy required for its use.

Kongsberg GeoAcoustics GeoSwath Plus system specifications:

Highest depth	200 m
Measuring band	390 m
Ray	12 * water depth
Bottom resolution	3 mm
Ray width	0,75° Azimuth
Impulses	64 µs up to 448 µs
Update rate	At 30 seconds

In order to achieve high quality imagery of the riverbed morphology, the ArcGis software was used to process raw data acquired *in situ* with the echo sounder systems.

3. Results

During the construction period on the Epurasu branch several campaigns of multi-beam bathymetric measurements (fig.4) were carried out, but the low water level during these measurements did not allow measurements to be performed all over the Epuraşu bay and branch.

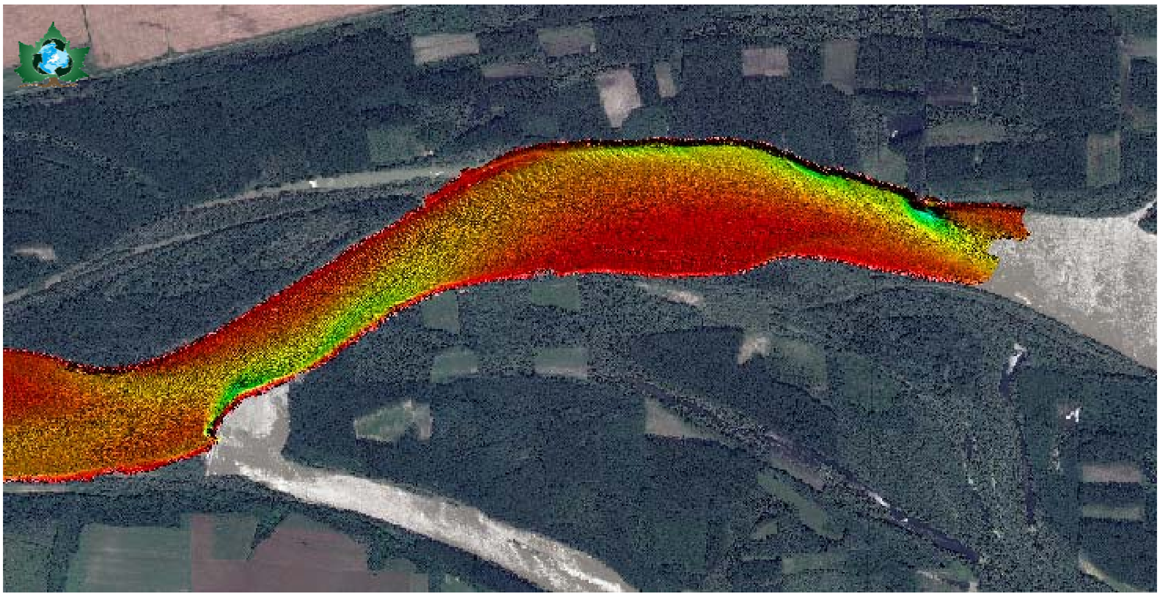

Fig.4. Multi beam measurements (raw data) on the Old Danube

The results obtained from the processing of these measurements, combined with the single-beam measurements (fig.5), allowed us to continuously update the bathymetric model in the Epurasu branch.

Fig.5. Single beam measurements locations on the Old Danube and Epurasu branches

The multibeam measurements achieved in May 2015 in the bay area behind the Epuraşu led to a high detail 3D model of the riverbed morphology (fig.4 and fig.5).

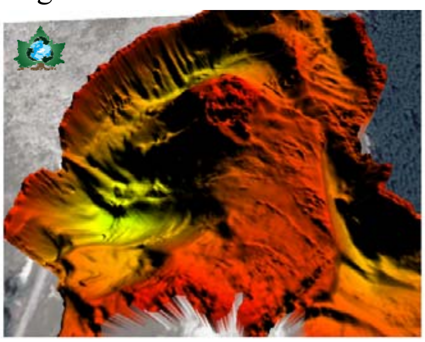

Fig.6. 3D detail of the area in Epurasu Bay May 2015

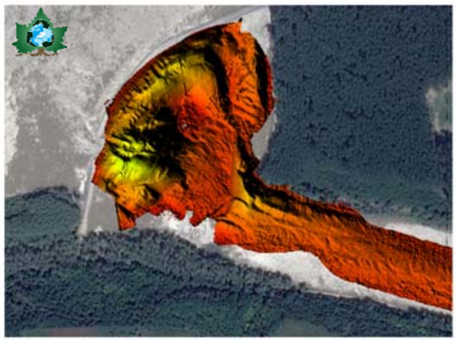

Fig.7. Bathymetric measured area May 2015

Also using GIS software the digital elevation model (DEM) of the branch riverbed and of the hydrotehnical structure was made for March 2016 (fig.8).

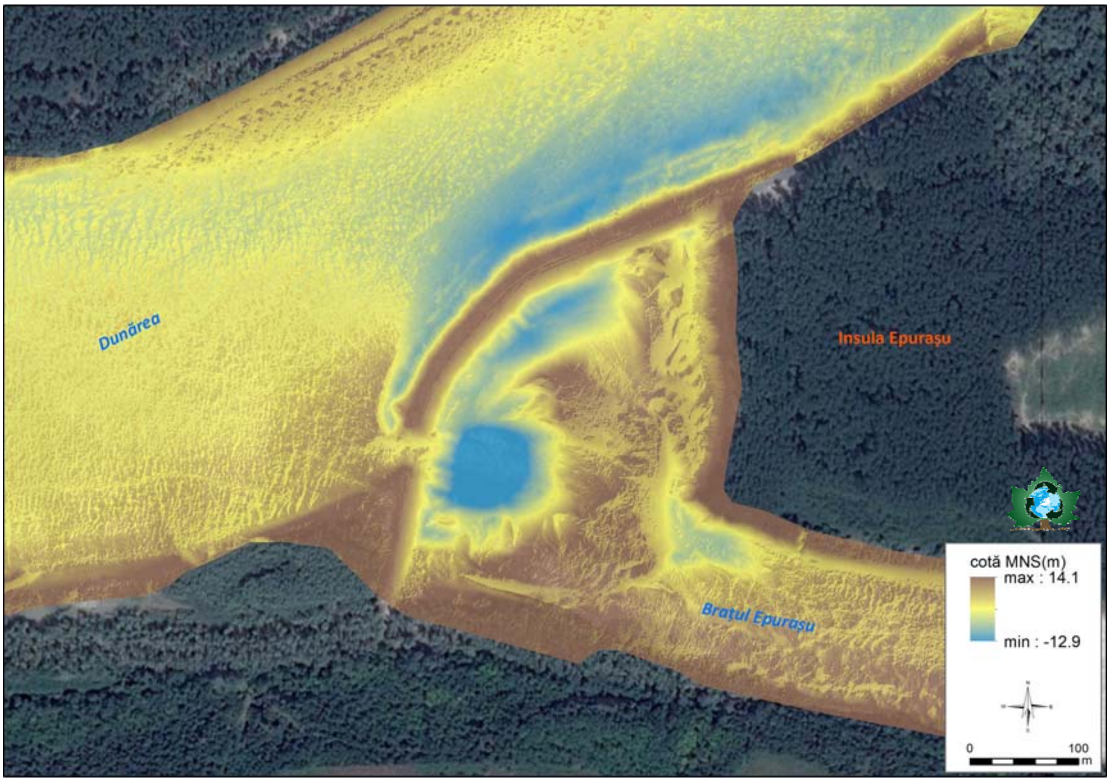

Fig. 8. Epurasu area DEM in March 2016

In the 3D detail imagery is the represented the riverbed situated downstream of the submersible dam on Epuraşu branch. Immediately downstream of the dam, near the groove, the water stream favoured the formation of an erosion scour with a maximum elevation of approx. -13 m MNS downstream of a sandbank. Also, after processing the data from the multi beam measurements, the presence of an erosion channel at the upstream contour of the submersible dam was revealed.

4. Conclusions

Detailed measurements of bed morphology and three-dimensional processed imagery have enabled to observe the influence of the hydrotehnical structure on the riverbed morphology. Dune morphology at the field site is complex with considerable variations in dune height, wavelength, scour depth and crest line curvature.

This combination of techniques is fit for application in field conditions. The rules of thumb described in the generation of the acoustic maps and the considerations on the spatial-temporal features of the data acquisition process, as related to the actual dynamics of the bedforms, are valid for *in-situ* conditions. The technique is especially well suited and desirable for field data acquired with the increasingly popular acoustic technique for riverine environments, i.e., Acoustic Doppler Current Profilers and Multi-beam Echo-sounders. Targeting field implementation with this technique is of special importance as it provides a surrogate measurement that revolutionizes the way the riverbed measurements are currently made.

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