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28. "Checking the Pulse" of Sf. Gheorghe's Arm Meanders from the Danube Delta Biosphere Reserve

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Abstract: The meanders of the Sf. Gheorghe arm of the Danube Delta Biosphere Reserve in Romania were cut through a hydrotechnical intervention in the late 80s and beginning of 90s. This river regulation was nominated in the investment plan of the National Water Council and was part of the framework scheme for the Dobrogea hydrographic area. This part of the Danube river had been rectified for 15 km altogether for the following meanders: Murighiol, Dunavat, Dranov and Ivancea which shortened the route with 32 Km. The benefit of these changes is clear: improve the water transportation by shortening the route, less time spent on transportation ergo, less fuel consumption. The downside is represented by clogging of the lateral connectivity, silting up the mouth of the river and of the adjacent water complexes. The Danube Delta would not have been a delta without water. By accelerating the discharge also, the sedimentation processes are increased. The water complexes are dependent on the direct communication with the main river through the still existing channels. If these channels would silt up and close the connection between the water complex and the main river, then the eutrophication process will increase to a point of no return but through another hydrotechnical works, then is a matter of time until the meanders turn into oxbow lakes that will dry up. And little by little the areas between the main arms of the Danube Delta would dry up since there is no water running towards them. At this moment, the mouth of the channels that link the main water course and the adjacent water complexes are almost closed, the meanders silted up and their water body considerably reduced by connected islets along their course with shallow depths. All these negative aspects could and can be avoided if the authorities would invest in upgrading these hydrotechnical works done almost 30 years ago by implementing the feasible approach for each segment of the cut. In essence, this study will provide accurate topo-bathymetrical data upon which GIS analyses will elaborate the actual state of these meanders.
Keywords: Danube Delta, wetlands, geomatics, underwater relief.

INTRODUCTION

This ongoing study represents the main author's PhD thesis. It is mainly a technical study that aims to enrich the hydrological data for the Sf. Gheorghe arm of the Danube Delta in respect to riverbed mapping of the meanders and their connection to the main river flow and the adjacent channels. Its results will help other research domains to benefit of the maps and database to estimate the environment development based on the actual state of the riverbed. The main objective of the study is to map all six meanders using

high resolution hydrological equipment and to evaluate the evolution of the riverbed correlated with the historical data, (Trifanov et al, 2018).
The Danube Delta is situated in the north-western sector of the Black Sea basin, in a mobile region of the terrestrial crust (the Predobrudjan Depression). Its limits are: 44°46'00'' N lat. (Periteasca), 45°30'00'' N lat. (South of Sasik Lake), 28°40'24'' E long. (Ceatalul Chilia), 29°40'50'' E long. (East of the Chilia secondary delta). As for its surface of 5,600 km^2, the Danube Delta, together with the floodplain sector between Ceatalul Ismail and Galaţi city, represent the most important terminal plain of any European river (except the Volga and Kuban deltas on the territory of C.I.S.). The Ukrainian part, about one-fifth of the total delta area, covers 125,000 ha of which 75,000 ha is land and 50,000 ha are water.

The Sf. Gheorghe arm is the oldest arm of the Danube Delta, which currently carries about 30% of the volume of water and sediments of the Danube. It derives from the Tulcea branch on the right-hand side of the bifurcation at kilometer 108.8, with mostly a single and meandering riverbed, which was naturally preserved until 1988. The year in which a collective effort to regulate the watercourse began so that the six meanders of the arm were subjected to a "adjustment" necessary for the protection of the shore, strongly eroded, south of the mouth of the arm and also necessary for the economic activities to the detriment of: the hydrological and sedimentological equilibrium of the adjacent aquatic complexes; the sedimentation regime at the mouths of the channels and the mouth of the arm; the reed quality; the habitats; the water surfaces; the landscape quality (Romanescu, 2010). The subject study responds to the requirements of national and international environmental and sustainable development policies and guidelines and it is of interest to the scientific environment for the following topics: behavioral studies of migratory fish, especially for sturgeon species, for the specificity of habitats and ecosystems that are dependent on certain physicochemical parameters of the water, impact studies and water flow improvement through hydrotechnical works etc. and of course for the enrichment of the poor hydrological data base on this Danube arm.

STATE OF THE ART
Regularization of Sf. Gheorghe's arm downstream from Mahmudia town was carried out on the basis of project 1274 elaborated by the Institute for Research and Development for Water Management at the command of Water Administration Office (O.G.A. Tulcea) no.1574. The work was part of the framework scheme for the Dobrogea hydrographic area and was nominated in the investment plan of the National Water Council. The regularization works consist of the rectification of the main meanders of the St. George arm in the Ivancea, Dranov, Dunavăț and Murighiol sectors. The total length of the rectification is 15 km and the shortening of the natural course of 32 km (*****, 1995). The study proposes to provide a picture as a whole of the morpho-hydrographic dynamics of the current Sfântu Gheorghe meanders using GIS and remote sensing methods, field data collected using single and multi-beam sonars and ADCP for a holistic understanding of how the water circulates now to the aquatic complexes adjacent to the Sfântu Gheorghe arm and the support capacity of its riverbed for migratory fish habitats of national and international interest.
The real issue is represented by the morphological aspect of the arm as a result of the regularization works, namely the silting of the meanders. Besides the landscape preservation importance and the value of surface water bodies, their biggest value it is the contribution of fresh and oxygenated water to adjacent aquatic complexes. Note that access (channels) to aquatic complexes lie on the edges of the meanders and the rectification directly influences the equilibrium of water distribution flows: affecting the lateral connectivity. This leads to the eutrophication of lakes in the aquatic complexes by the low intake of fresh oxygenated water, which will determine their clogging thus, extended habitat changes or even loss. Clear evidence is the two channels (from the downstream) Ivancea and Erenciuc North: completely silted. At present the Perivolovca, Uzlina, Dranov and Dunavăț canals are threatened, which already show very low depths at their river mouth.

MATERIALS AND METHODS

In the summer of 2017, the first data collection campaign started. For 7 days topographical and bathymetrical surveys were conducted on Ivancea meander (Fig.1). The details about this first campaign of data collection are described in "Alteration of the Morpho-Hydrological Conditions of the Aquatic Complexes Adjacent to the Sf. Gheorghe Branch (Danube Delta) as a Result of the Hydrotechnical Works", published in the International Scientific Conference GEOBALCANICA 2018, p. 421-431, DOI: http://dx.doi.org/10.18509/GBP.2018.46. In this second field data collection campaign, which took place between 13th and 23rd of August 2018, the same topographical and bathymetrical surveys were applied but for the upstream meanders: Dranov and Dunavat. The procedure in acquiring the data was the same as in the previous campaign only the areas were different.

Figure 1 - Boat routes for covering the Ivancea meander in the 2017 survey campaign

Throughout the period of PhD studies, field data will be collected at well-established time intervals in normal and special hydrological conditions to identify the evolution and trends of the riverbed on the main course of the arm and meanders. Historical and current bathymetric data will be used that will help to correlate the erosion and silting indicators in critical areas with hydrological events. At the same time, remote sensing techniques will be used on satellite and aerial images to extract historical information on the aspect of islands and bank configuration and their correlation with hydrological events. To start with, there is a need to know how much water the Sf. Gheorghe arm takes from the Tulcea arm. Various measurements were done before by different scientists and the variation between the measurements are dependent of the water level regime and this measurement was done at the average water level quota. The flow distribution situation is very interesting now: Sulina 40% and Sf. Gheorghe 60%. The bifurcation is presented in the Figure 2 and represents the starting point of the studied riverbed: Sf. Gheorghe.

Figure 2. The "Sfântu Gheorghe" bifurcation

In 2017, when the data collection campaign started, the first question regarding this arm of the Danube was: how much water does it take from the Sf. Gheorghe bifurcation in normal hydrological conditions? By using the flow and velocity measurement equipment on each arm of this the bifurcation, namely: Tulcea, Sulina and Sf. Gheorghe, it was possible to answer to that question and the values were described above and also in the Table 1. The positions of these profiles and the overall distribution of the currents are represented in Figures 3, 4 and 5.

Table 1. The flow distribution at the “Sfântu Gheorghe” bifurcation

Arm Name	**Measured Flow (mc/s)**	**Flow with correction**	**Distribution %**
Tulcea	3674	3674	
Sulina	1425	1457,5	39,67
Sf. Gheorghe	2184	2216,5	60,33

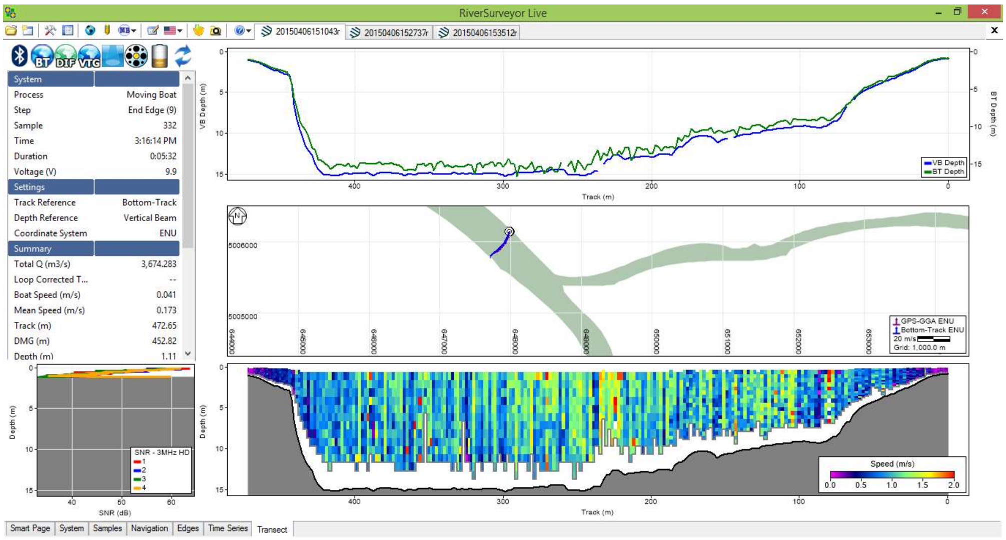

Figure 3. Hydrometrical profiles at the Sf. Gheorghe bifurcation – Tulcea arm.

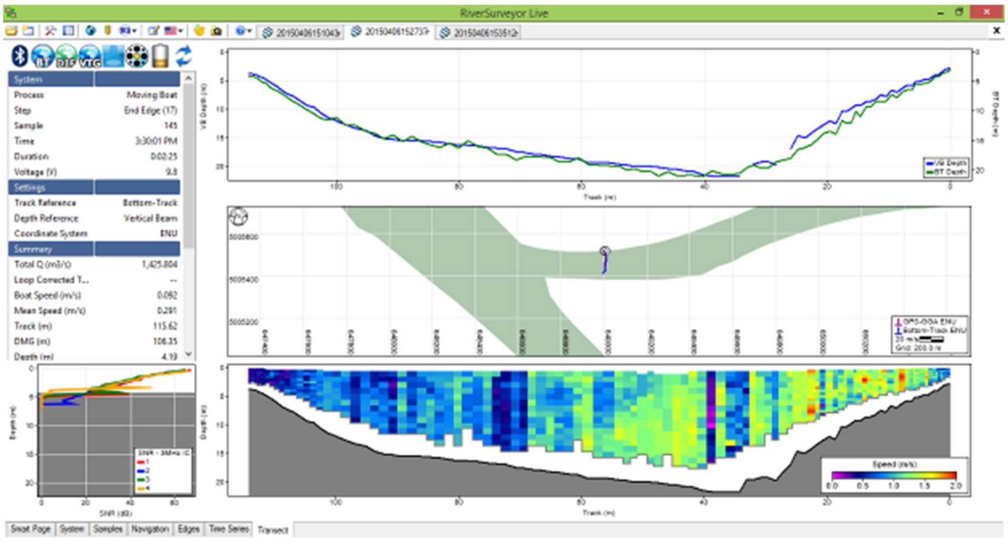

Figure 4 - Hydrometrical profiles at the Sf. Gheorghe bifurcation –Sulina arm

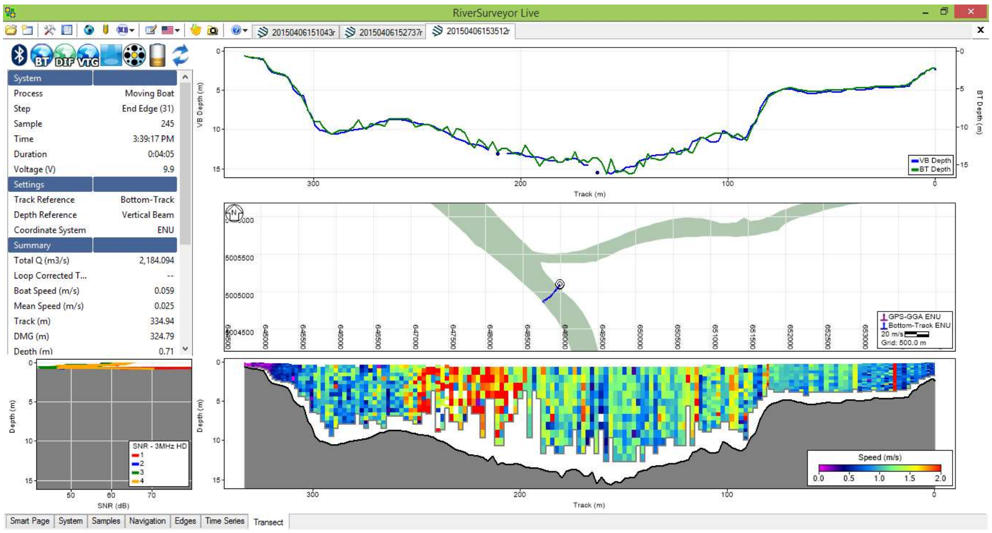

Figure 5 - Hydrometrical profiles at the Sf. Gheorghe bifurcation – Sf. Gheorghe Arm

Comparing these values to the historical values from 1992, after the hydrotechnical interventions one can notice a major change in the proportions of flow distribution on the two arms, from 63% on the Sulina arm and 37% on the Sf. Gheorghe arm to 40% on the arm Sulina and 60% on the Sf. Gheorghe branch. However, it can be noticed that the current distribution of the flows due to the hydro-morphological dynamics reached the same values as in the period 1928-1929 (41% on the Sulina arm and 59% on the Sf. Gheorghe branch).[4]

This second expedition was possible using the “Danube Delta” National Institute for Research infrastructure, namely ANTIPA as headquarters boat and the data collection using NAUTILUS 500, a small survey boat. The data collection process is an aggregate of different equipment for specific tasks. In order to properly map any riverbed, information such as water level quota, water velocity and discharge is critical for the final output. Beside the collection of the already mentioned data, an impetuous task (for the Danube delta) is to develop the topographic support network. Since the GSM/DGPS signal is scarce throughout the whole area, determining fixed topographical points in key locations along the measured area is critical when using RTK positioning corrections of the multibeam interferometer.

The multibeam interferometer is a complex aggregate of different sensors (Fig. 6) such as: the transducer, as the emitter and the receiver of the sounding data; SVS (Sound Velocity Sensor) that applies corrections of the water sound speed, MRU (Motion Reference Unit) that applies corrections regarding the boat movement on all the three axes, Heading that applies corrections concerning the survey direction of the boat, Double frequency GPS (Global Positioning System) in RTK mode (Real Time Kinematic) for accurate positioning of the soundings and also time synchronization. All these sensors are integrated into an RTA console (Real Time Appliance) that transmits the data through UTP (Unshielded Twisted Pair) connection to a computer that runs ES3 together with Hypack software (Fig. 7), where all this data is integrated and carefully calibrated.[1]

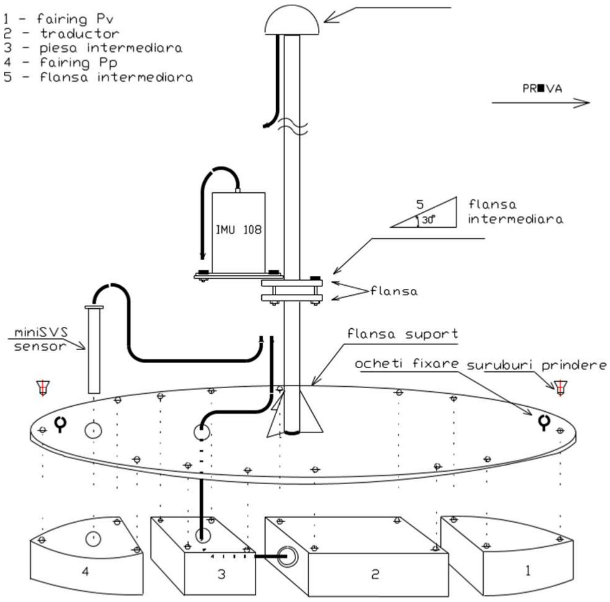

Figure 6 – The mount for the multibeam equipment

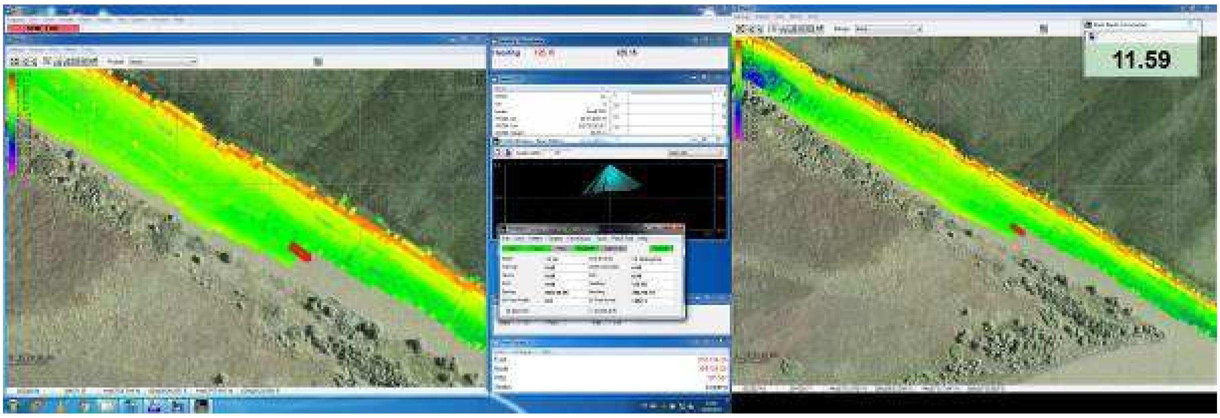

Figure 7 – A print screen describing the actual multibeam data acquisition within the Hypack software.

The left panel represents the map area and the information about the sensors and measured parameters for the surveyor, the right area represents the map of the survey area along with the perpendicular depth used by the boat driver.

These water discharge and velocity values were acquired by using an ADCP (Acoustic Doppler Current Profiler) called "River Surveyor M9". This easy to use plug-n-play equipment delivers in situ high accuracy data. This rather small sensor is mounted on a hydro board, runs on batteries and is wirelessly connected to a windows-based terminal. The board is anchored at the starboard of the boat and it acts like a surface towfish. The measurements are in fact profiles from one bank to another. In the measurement and control software is easy to set the bank where measurement starts and from there a steady 3-4 knots speed towards the opposite bank will do the job (Fig. 8).

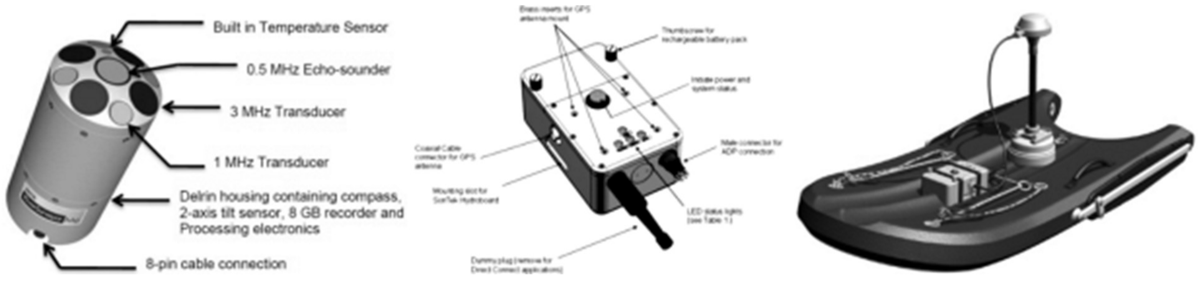

Figure 8 - The RiverSurveyor M9 ADCP and the Hydro Board

RESULTS AND DISCUSSION

The Dranov area meanders is composed of two consecutive meanders: The Erenciuc meander (downstream) and the Dranov meander (upstream). Their water course was regulated from 6.1 Km to 2.5 Km for the Dranov meander (Fig. 9) and 8.7 Km to 1.3 Km for the Erenciuc meander (Fig. 10). These two meanders are only reachable by boat. Their banks are covered mostly by willows and poplar, inside the isle there are grazing and forestry activities (Fig. 9).

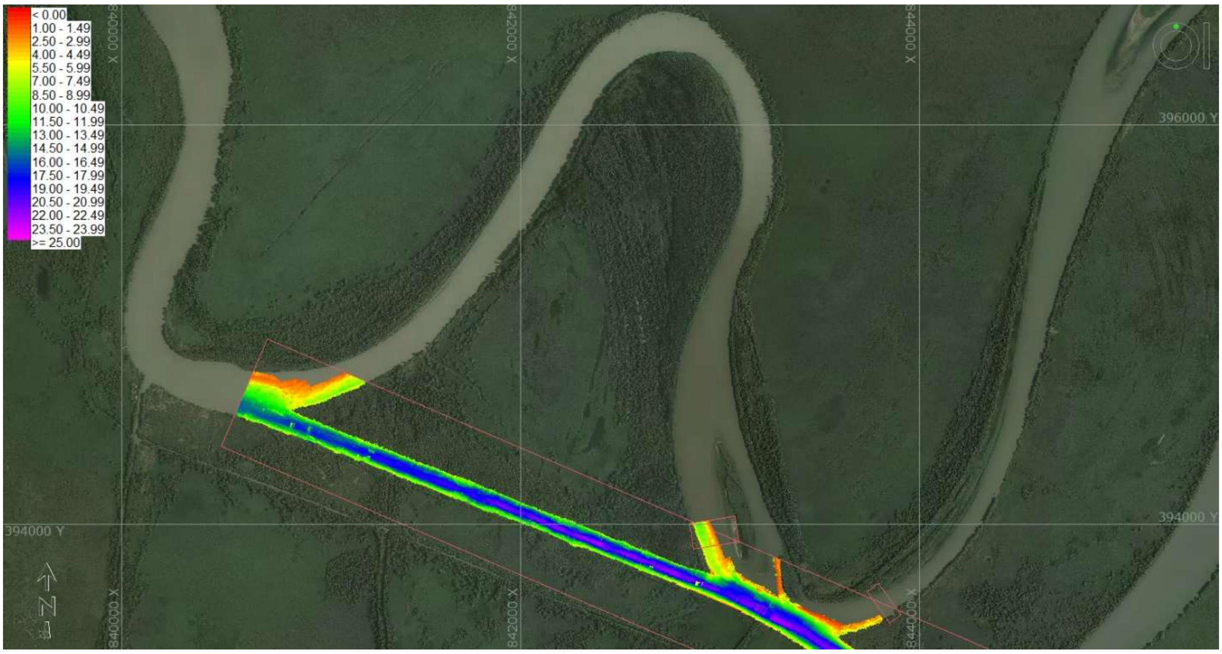

Figure 9 – The Dranov meander

Figure 10 – The Erenciuc meander

Figure 11 describes the area that have been surveyed with the multibeam sonar. By comparing the Ivancea survey and this second campaign, is clearly visible that the boat was unable to reach the inside meander due to shallow waters. Whereas the Ivancea meander held safe depths to survey, these upstream meanders are a totally different situation. The risk was too high to advance with the multibeam in shallower waters than 2 m and this restricted in proceeding with the multibeam sonar survey that was submerged at 0.5 meters.

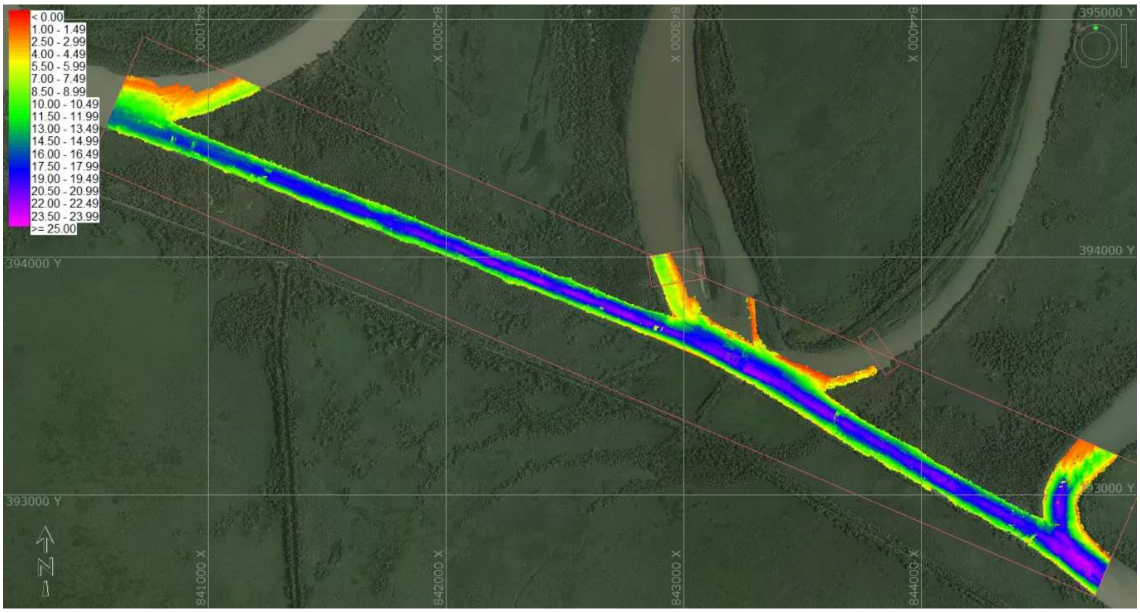

Figure 11 – The bathymetric matrix for Dranov meander area

The Dunavat meander area (Fig. 12), just as the Dranov meander area, is composed of two consecutive meanders: Dunavat meander in the upstream and Perivolovca, the second, in the downstream. The Dunavat meander (Fig. 13) got its name from the Dunavat channel, positioned just in between these two meanders towards the south and the Perivolovca meander (Fig. 14) from the channel with the same name, positioned in the NE of the meander bent. These two meanders were cut just as the other ones and their water course was reduced from 3.4 Km to 1.8 Km for the Dunavat meander and from 4.7 Km to 1.9 Km for the Perivolovca meander. Again, these meanders are only reachable by boat, only a suitable car cand reach the right-side bank of the Danube river – across the Dunavat meander, by driving on a dirt road. Their banks are shaded by willows and poplar and the islets accommodate grazing and forestry activities.

Figure 12 – The Dunavat meander area

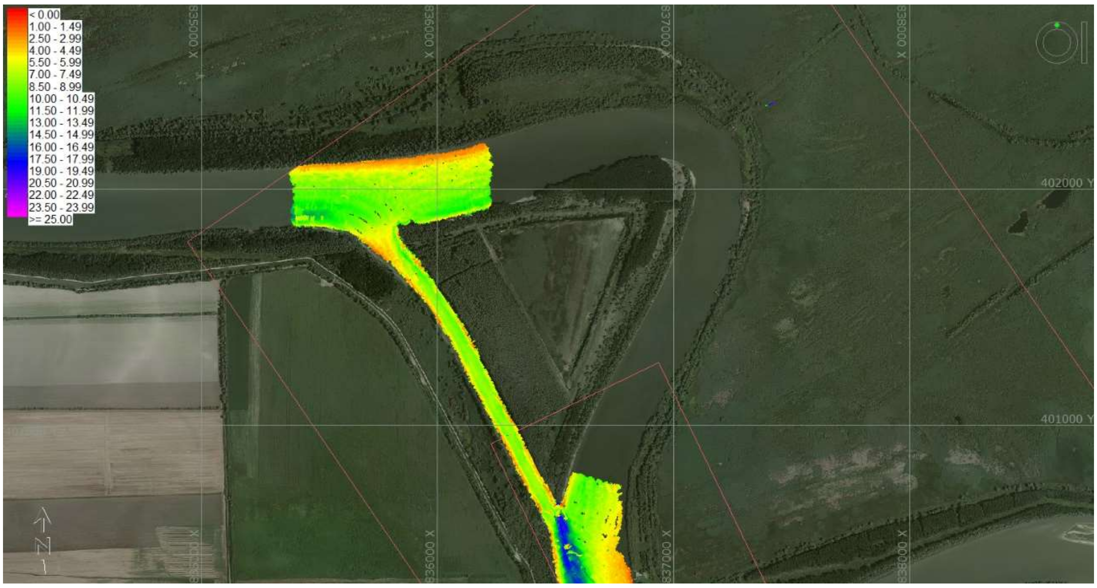

Figure 13 – Dunavat meander

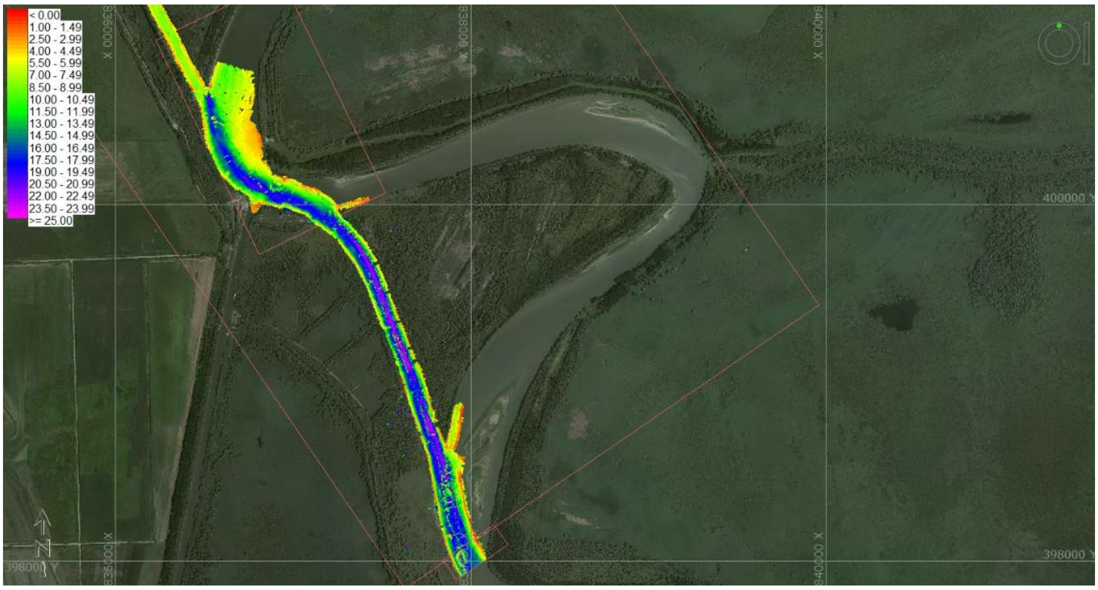

Figure 14 – Perivolovca meander

The survey area could only be possible, just as in Dranov meander area, on the regulated water course and just at the meander confluence with the main flow. The same risks as in the Dranov meander area influenced this survey campaign. The shallow waters prevented the team to advance inside the meander.
In both cases, Dranov and Dunavat meander area, multibeam survey coverage inside the meanders was impossible. As an alternative, the ADCP equipment was used to record bathymetric profiles along these meanders. The profile frequency was 500m and for each channel that flows into these meanders and each profile, the ADCP recorded the bathymetric profile, the discharge and the velocity in the water column. The bathymetric data may be not a point cloud as in the multibeam sonar but valuable historical data base is available considering the profiles in this area with a frequency of 250m that will serve as a comparison between hydrological years and not only.

CONCLUSIONS

At first glance, a typical characteristic of meandering morphology is observed on the color palette. The river bed scours occur at a range of scales and settings and are most pronounced at river bends and channel confluences.[4] Both surveyed areas contain a set of two consecutive meanders and both illustrate that the intake upstream meander is less clogged than the downstream one. For Dunavat area, the river flows directly into the meander (Fig. 15) which maintain a self-dredging status, at least for the first half of its length. The Dranov upstream meander intake shows have a different configuration than the previous but the water coming from the main water curse, a considerable amount, is being redirected towards the meander due to the actual hydro morphological layout of the river. The N to S flow of the river and the acute bent towards the left (Fig. 16), determines the trajectory of the water from the right bank (heavily eroded) towards the left bank, thus flowing into the meander. The matrix, though, displays shallower depths (4.5 m) than in Dunavat situation (8 m). The threat of sedimentation processes is there and in time this intake will silt up.

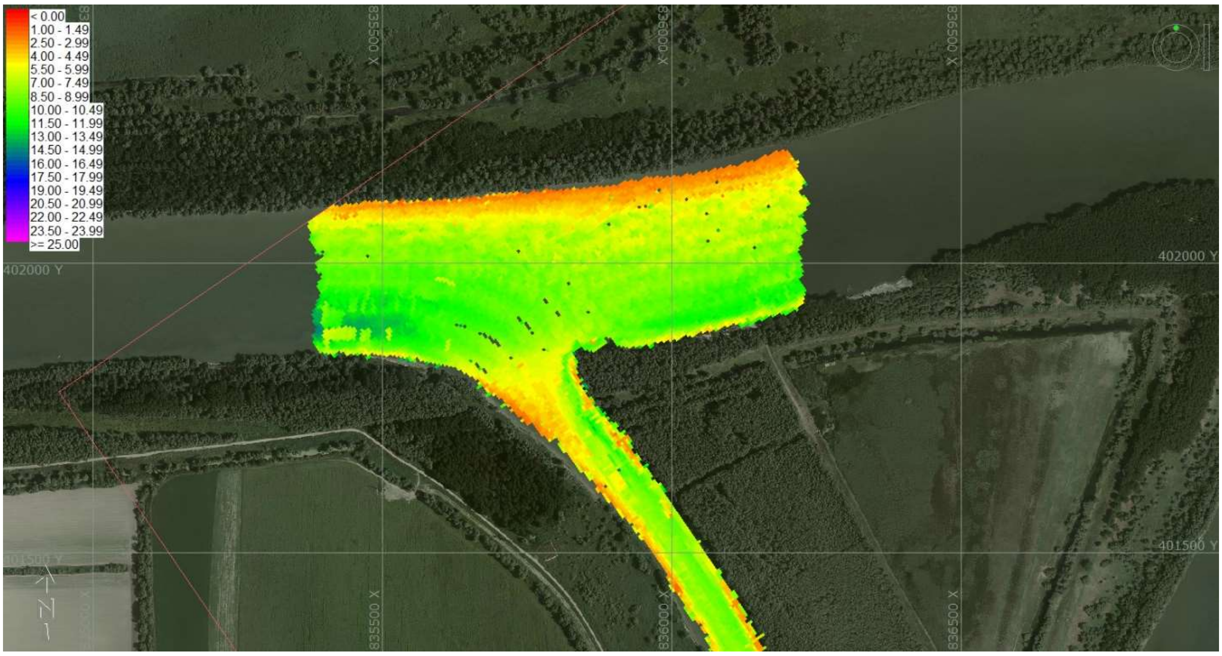

Figure 15 – The intake of the Dunavat meander

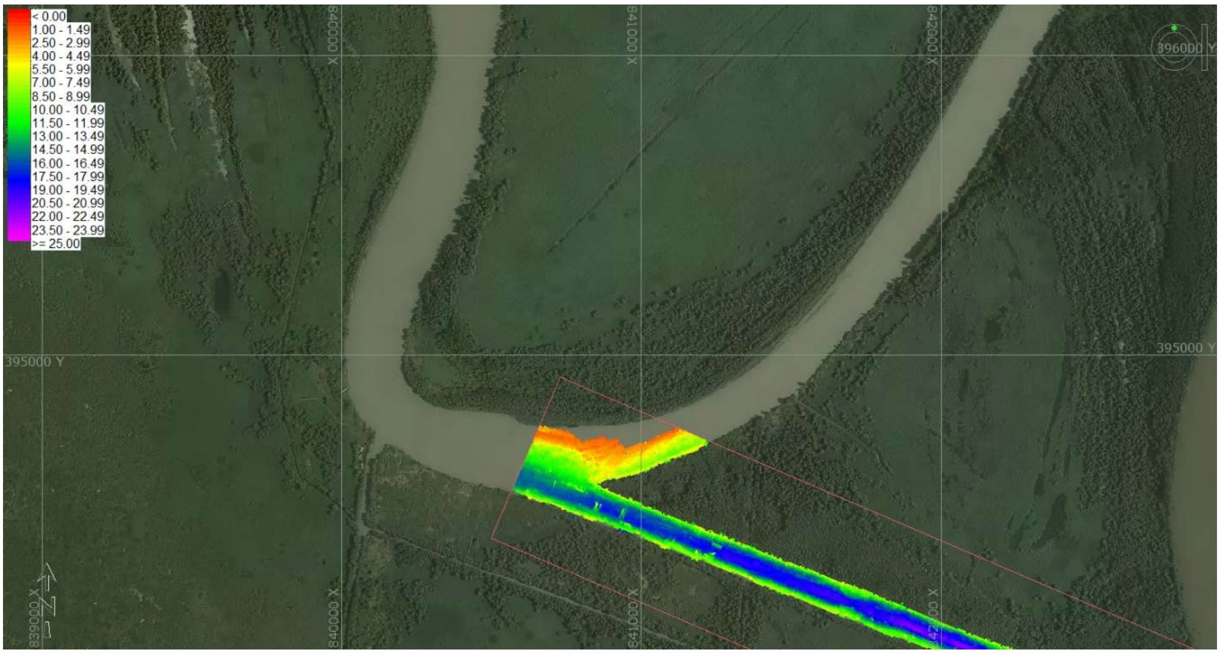

Figure 16 – The intake of the Dranov meander

The outtakes of both upstream meanders from these two areas have a totally different status. Their mouths are almost clogged (Fig. 17) due to heavy but normal (in their case) sedimentation process where the regulation channels are flowing with great velocities in comparison with the velocities of the meanders. The velocities on the regulated channels act as a barrier for the sediments (along with other fluid mechanics principles) which determine to settle down and create islets. The confluence of the outtake of the meanders with the regulation channels is taking place in a wide hydro morphological layout (25 Ha for Dunavat area and 3 Ha of Dranov area) of open water in which a fairway built up along the axes of the regularization channels and beyond this, only shallow waters.

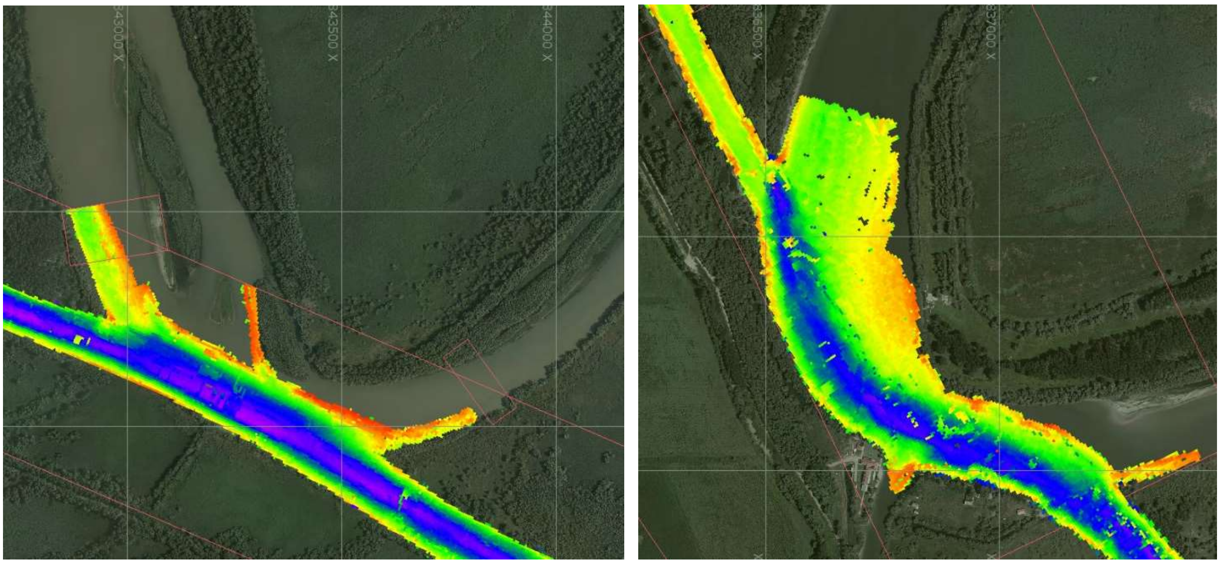

Figure 17 – The Dranov (left) and Dunavat (right) meander area, the outtakes of the first meanders, their confluence with the main river flow and the intakes of the second meanders.

The intake of the regularization channel in Dunavat upstream meander is shallower than the rest of the canals of its type. In this area, the river flows from SW to NE and the direction of the regularization channel is from NW to SE (Fig. 15). This, almost, perpendicular direction of the channel on the river flow determines a lower intake of water and because of its orientation is threatened to silt up and cannot maintain a self-dredging status. Most probably, at some point in time, the authorities will fell the need to take measures in dredging this 1.8 Km of channel.

For the downstream meanders from both surveyed areas, the situation is critical. Both meanders have silted up, there are heavy sedimentations processes from the intake area all the way to the outtake. Extended islets have formed at both ends of the meanders that in some cases have merged with the banks and there is only one stream of water flowing inside the meander. Along their trajectory, other small submerged islets or emerged and narrow but elongated islets are present along both banks. These are rapidly building up, rising the riverbed and will join at some point but by then, the intake of the meander will long be naturally cut away from the main river flow.

Both campaigns show similarities in the dynamics of the riverbed. This study is attempting to be as accurate as possible with the actual state of these ineffable landscapes of which functions have been neglected. Also, the built-up database for this area will serve as a precursor for future research projects as a tool to focus lens on the future, to investigate and challenge scientific theories, to inspire and encourage speculation about the nature of the river and our place beside it.

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