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15. Water circulation system data analysis in fluvio- maritime Danube Delta

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Abstract: The present study aims to collect and analyse the data related to the water circulation system and the hydrological risk, for the channels in the Danube Delta, near the Letea and Caraorman units. The data collected supports the researches to understand the water circulation system in the context of an accelerated dynamics of the hydro-morphology of the Danube Delta complexes. Also, the context of climate change by modifying the rhythm of high water – low water cycle as well as by intensifying the extreme hydrological phenomena, imposes the population of the databases and the updating of the hydrological model to know and understand the current state of the deltaic ecosystem. For the data acquisition, there were 3 expeditions of field measurements to allow quantification of changes during a period (respectively low water period), to set up a data series. The channels where the hydrological data were collected during the three expeditions are Crișan - Caraorman, Eracle, Căzănele, Bogdaproste, Dovnica, Busurca, Cordon Litoral, Tataru, Cernovca, Sulimanca, Ceatal Izmail. Updating this information in the hydraulic modeling process is mandatory. The use of new techniques for collecting data on the water circulation system (discharge and water level) adds to the accuracy of the hydraulic model. If now the discharge calculation is done with the help of the rating curve, updating these data series in real-time at low, medium and high water, increases the accuracy of the results after running the model. Considering the high sedimentation rate, as well as the increase of investments for the unclogging works, in the context of the dynamics of the deltaic system, the updated hydraulic model of the Danube Delta is one of the key tools.
Keywords: Danube Delta, water flow, water circulation

INTRODUCTION

Danube Delta is a low alluvial plain, predominantly represented by a unique and complex landscape of wetlands, marshes, canals, rivers, and lakes. As for the geomorphological processes, it acts as a very dynamic system, stimulated by a strong dependence and an important accumulation of sediments, being the youngest form of relief of Europe, created by depositing sediments (sand, dust) brought by the Danube (Catianis, et al., 2014)

The morpho-hydrographic changes in the Danube Delta are determined by complex sedimentation or erosion processes, which have the effect of creating or clogging the secondary arms, streams, etc., changes of the submersion relief, sedimentation of the inner lakes and the depression areas. The Fluvial Delta is the oldest part of the Danube Delta area. As a result of a longer period of evolution, the fluvial waters reached 3 m altitude. Depression zones, where the sedimentation process takes place at a high intensity, are reduced in size and they have many small lakes. After 1970, as a result of the construction of the Iron Gates Dam, the sediment flow of the Danube reduced to 30-40% of the previous values. Under these conditions, in recent decades, the Danube Delta has become largely inactive, partly because of human interventions (Cioaca, 2001)).

The hydrologic subsystem, by water circulation, is the determinant cause of the delta's space evolution, by means of the following Danube River inputs (average values of 1840-1990 period)

- water discharge of 6,284 m3/sec;
- water volume: 198.20 km3/ an
- discharge of alluvia: 1,737.40 kg/s;

- quantity of alluvia: 54.80 million tones/year (Bondar, 1991)

The present study aims to collect and analyse the data related to the water circulation system and the hydrological risk, for the channels in the Danube Delta, near the Letea and Caraorman hydro-morphological units. The data collected supports the researches for understanding the water circulation system in the context of an accelerated dynamics of the hydro-morphology of the Danube Delta complexes. The dredging and embankment works done to Danube branches and delta channels led to accelerated hydro-morphological processes which affect the water flow conditions. Updating the databases regarding the hydrology and bathymetry information, enhances the knowledge of these dynamics particularly for the Fluvio-Maritime Delta, detailing a piece of the puzzle for the entire Danube Delta.

METHODS

The measurements were made in September – October 2019, under conditions of low water levels of the Danube river, recorded at the hydrometric station in Tulcea-port, (recorded levels: 0.52 - 0.67 m). Data collected during the hydrological measurements were selected from profiles taken on the channels Crișan - Caraorman, Eracle, Căzănele, Bogdaproste, Dovnica, Busurca, Cordon Litoral, Tataru, Cernovca, Sulimanca and on Tulcea Arm near Ceatal Izmail area (Figure 1).

Five field trips were organized, on 25, 26, 30 September and on 23,24 October.

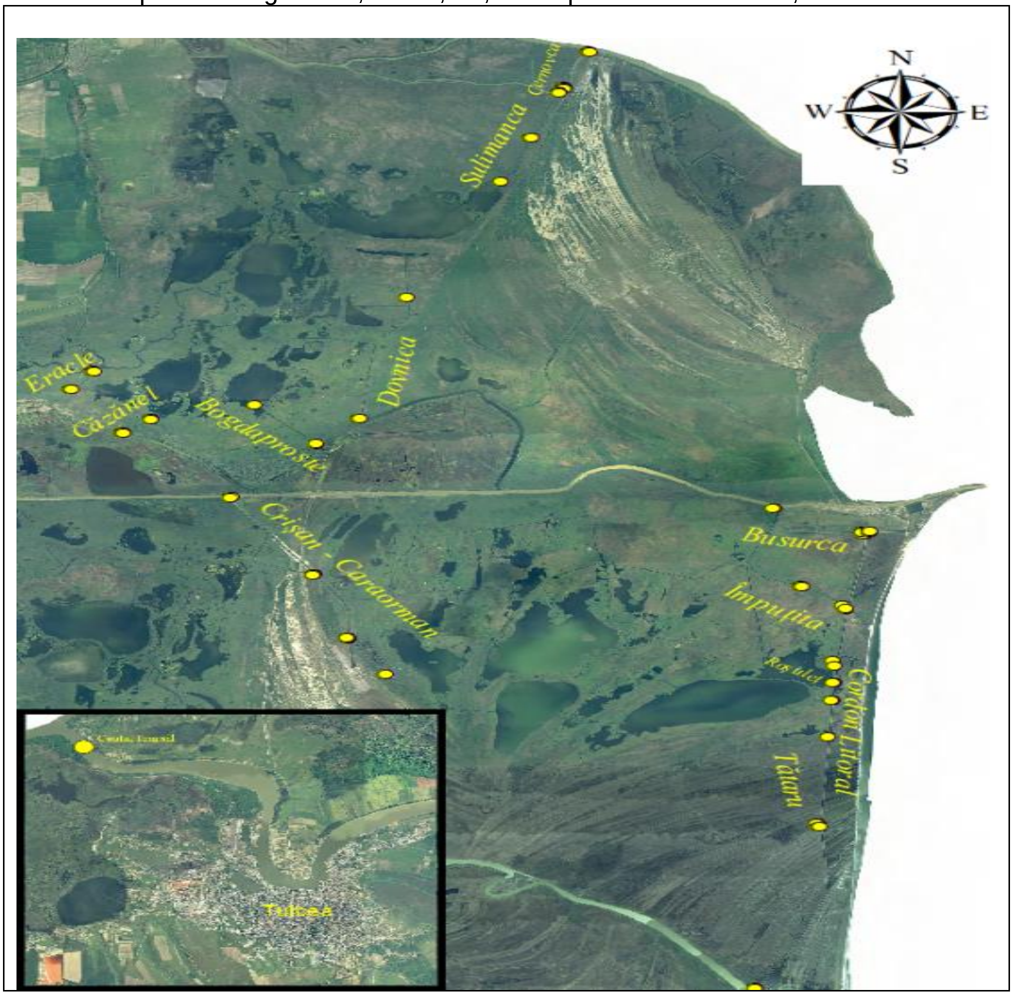

Figure 1. Cross-sections location

Fluvial geo-morphological research had an important evolution lately due to the development of new data acquisition and processing techniques. Single and multi-phase bathymetric mapping, acoustic current meter (Doppler) and sediment sampling are the new methods used to analyze the morphology of the riverbed.

They provide information about the river sedimentation processes. The measurements were made to identify the water flow regime during low waters of the Danube river (September-October 2019).
The technical means used were a motorboat and an ADCP (Acoustic Doppler Current Profiler), fitted with sensors for measuring the parameters characteristic of water flow. SonTek ADCP RiverSurveyor has 3 sets of sensors, each with a different orientation. Each of these sensors generates a narrow sound beam that is projected through water and allows determinations at different depth regimes. The physical parameters collected by the ADCP are water depth, cross-section width, mean velocity, and water discharge. The data is transmitted in real-time through the radio system, to a laptop where the specialized software of the ADCP (River Surveyor) is installed. A good ADCP's position is vital for accurate data acquisition. For this, the tool was attached to the starboard of the boat so the sensors are positioned upstream of the boat's engine. In this situation, the data measured by the sensors is not influenced by the turbulent currents generated by the boat's engine. At the top of the sensor unit is mounted a GPS antenna. It collects the geographical positioning data so the data recorded by the ADCP are georeferenced.

For Post-Processing of the geospatial data the following software were used:

1. RiverSurveyor Live to process and visualize the bathymetric and flow regime data (Figure 2). The ADCP is generating .rivr files that contain information regarding water depth, mean velocity, and discharge value for each transect of the cross-section.
2. Digital (numerical) maps are processed in ArcGIS /ArcMap software, in Geographic Coordinate System (either GCS_WGS_1984 or GCS_Dealul_Piscului_1970), Projected Coordinate System (either WGS_1984_UTM_Zone_35N or Stereo_70, respectively). They show the spatial distribution/location of hydrographic network zones where measurements were performed (Cioacă, et al., 2009)

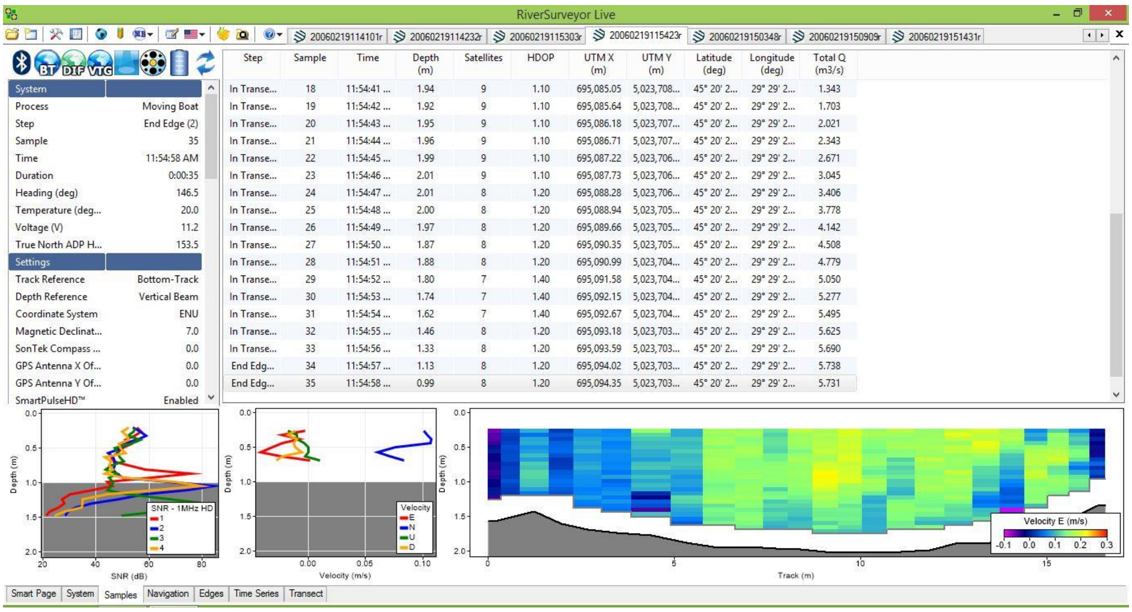

Figure 2. Data visualization using RiverSurveyor Live.

One of the hydro-morphological risk factors with a significant impact on the water circulation system is the flow velocity in the channels. The flow velocity is a parameter with a systematic influence on both the sedimentation rate and the risk factors presented in the previous chapter. The collection of water velocity values with ADCP (Acoustic Doppler Current Profiler) is an important step for updating, recalibrating and revalidating the hydraulic model.
For Hydraulic models we are using Sobek Rural software, developed by Deltares, Delft Hydraulics the Netherlands, which allows 1D modeling which can be connected with 2D models, using "Overland" Module. The software calculates the flow in simple or complex channel networks, consisting of thousands of reaches, cross-sections, and structures. To create a stable hydraulic model the hydraulic

network shall be defined with the corresponding boundary conditions. The main components for the hydraulic network are the nodes, reaches, and cross-sections.
Because the morphology of the canal is affected in time by composition, erosion, and human interaction, the hydraulic model needs to be constantly updated.
The data collected from field trips are used to update the information regarding the cross-sections shapes, discharge, and velocity trough reaches.

RESULTS

Field measurements were made on the channels: Eracle, Căzănele, Bogdaproste, Dovnica, Crișan - Caraorman, Cordon Litoral, Busurca, Tătaru, Cernovca, Sulimanca and Tulcea Arm near Ceatal Izmail area. The water flow data for each cross-section is presented in **Error! Reference source not found.**

Table 1. Measured data: water discharge and velocities

Canal	Cross Section No	September 2019	October 2019		October 2006 (data from Hydraulic Model)	
		Q [m³/s]	Q [m³/s]	V [m/s]	Q [m³/s]	V [m/s]
Crișan - Caraorman	1	10.49	6.56	0.2	2.95	0.07
Căzănel	5	3.53	2.36	0.04	0.45	0.05
	6	3.16	2.41	0.06	0.45	0.05
Eracle	7	15.8	11.81	0.06	5.5	0.026
	8	12.34	8.7	0.06	1.09	0.035
Dovnica	10	2.57	0.63	0.04	3.6	0.016
Bogdaproste	11	11.85	2.45	0.036	1.8	0.035
	12	9.96	1.76	0.037	1.5	0.035
Busurca	13	12.75	4.94	0.039	3.8	0.042
	14	11.02	4.34	0.038	3	0.063
Cordon Litoral	15	11.68	7.48	0.025	3	0.023
	23	1.02	2.16	0.053	0.4	0.024
Împuțita	16	0.74	0.29	0.015	0.77	0.023
Intrare lac Roșuleț	17	12.72	10.09	0.05	~ 0	~ 0
Canal Tătaru	22	0.84	0.31	0.039	0.01	-
Cernovca	24	159	129.7	0.16	149	0.16
Sulimanca	26	6.51	2.98	0.045	2.38	0.18
	28	5.53	3.32	0.043	2.37	0.11
Dunărea Veche	30	-	4.67	0.035	-	-

To analyze the evolution of sedimentation processes and determine their influence on the water circulation system, a comparative analysis of the flow velocities is required: the values collected in 2019 during low water levels of the Danube (September-October 2019) are compared with the average values of the velocities, from a similar period, extracted from the hydraulic model (values for 2006). It can be observed that there are major differences between the flow rates of the two data series, for the channels with high sedimentation potential which is caused by the action of the hydro-morphological risk factors (Figure 3 and Figure 4).

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A remarkable case is the Cordon Litoral channel, where the speeds have increased significantly since 2006. Also, it is observed the flow velocity on the inlets of Matița-Merhei complex has increased significantly, which led to the acceleration of sedimentation processes in the lakes, especially in the context of low velocities on the lakes drainage channels.

After the data collection, comparative analysis, and margins proposed, the map of sections on the with the highest sedimentation rate was generated

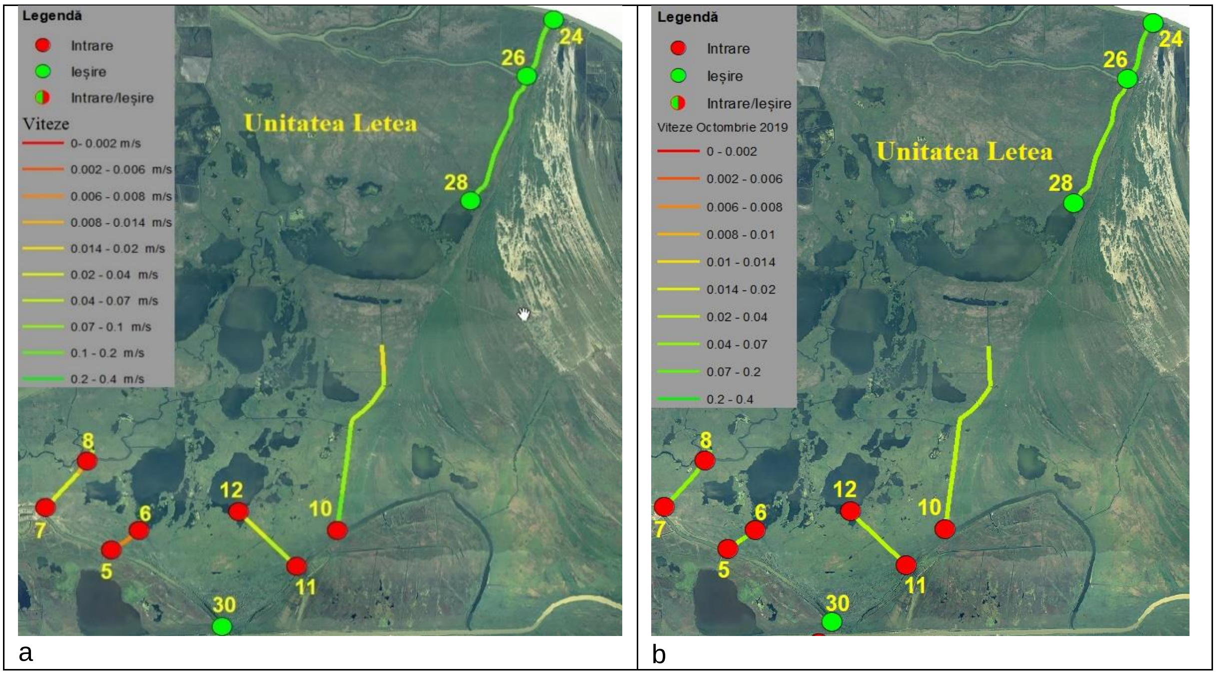

Figure 3. Average velocity values for Letea Unit: a. Measured values b. Values from the hydraulic model

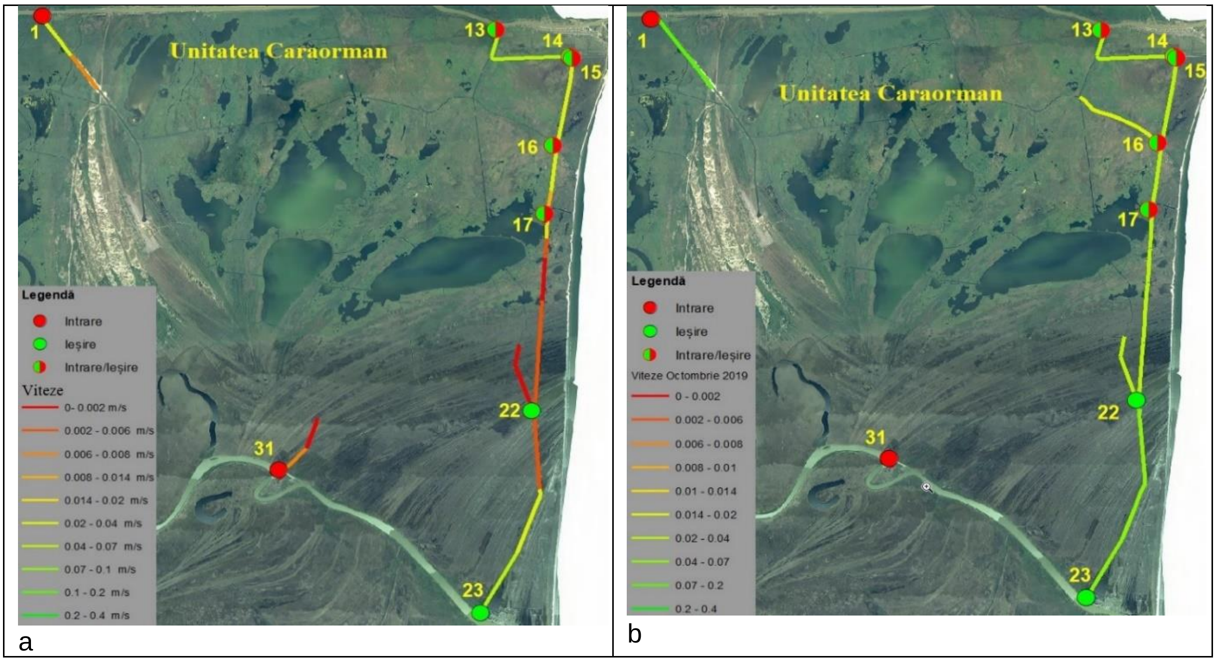

Figure 4. Average velocity values for Caraorman Unit: a. Measured data b. Data from the hydraulic model

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CONCLUSIONS

The measurements made in this project were performed to characterize the water flow regime, under conditions of low levels of the Danube river (September - October 2019). The field measurements were made on the channels: Eracle, Căzănele, Bogdaproste, Dovnica, Crișan - Caraorman, Coastal Cord, Busurca, Tataru, Cernovca, Sulimanca but also on Tulcea Arm in Ceatal Izmail area.

The proposed methodology refers to the coherent integration of hydro-geomorphological knowledge and ecosystem dynamics, by updating data sets with new values, considering the changes in the deltaic system. The process is based on updating the hydraulic model, starting from the Fluvio- Maritime, taking into account the large surface of the Danube Delta, which slows the processing of data. From this point of view, the project aims to update the information from the hydraulic model for the specific area in the Fluvio-Maritime Delta area. The information related to the hydro-morphological risk factors is the starting point also for defining the working methodology in assessing the cumulative impact on ecosystem functions.

The hydraulic model of the Danube Delta is the core instrument for identifying, analyzing and evaluating the hydrological risk factors in the study area. Considering the significant dynamics of the dredging works, as well as the impact of climate change, updating the model with new data, improves the level of knowledge and accuracy of the studies regarding the adaptive management of the deltaic system.

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REFERENCES

Bondar, C., 1991. Hydrological study of the Șontea-Fortuna hydrographic complexe.

Catianis, I., Rădan, S. & Grosu, D., 2014. Loss of ignition as a proxy indicator for assessing the lithological composition of the recent sediments accumulated in some freshwater lakes from the Danube Delta, Romania. *International Journal of Innovation and Applied Studies,* 9(1), pp. 260-278.

Cioaca, E., 2001. Morphohydrographic evolution of the Danube Delta Biosphere Reserve zones subject to the ecological reconstruction process. Tulcea: *Scientific Annals of the Danube Delta Institute for Research and Development.*

Cioacă, E., Bondar , C., Borcia, C., 2009. Danube Delta Biosphere Reserve hydrographic. 15 ed. Tulcea: *Scientific Annals of the Danube Delta Institute for Research and Development.*

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