Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

STUDY OF THE INFLUENCE OF MANNING PARAMETER VARIATION FOR WATERFLOW SIMULATION IN DANUBE DELTA, ROMANIA

**Adrian ROȘU, Maxim ARSENI, Bogdan ROȘU, Ștefan-Mihai PETREA,
Cătălina ITICESCU, Puiu Lucian GEORGESCU**

"Dunărea de Jos" University of Galați, 47 Domneasca Street, Galați, Romania

Corresponding author email: adrian.rosu@ugal.ro

Abstract

The paper aims to present the results of the influence of variation of Manning parameter in 1D water flow simulation on one of the most important channels in the Danube Delta, located in Tulcea county, Romania. The data used for the 1D simulations include water velocity, discharge, depths and was measured using the RiverSurveyor ADCP system in the summer of 2021, on the Magistral A.P. Chilia channel located in the north of the Danube Delta. The field data were collected in two measurement stations located along the Magistral A.P. Chilia channel. The uniflow cross-section model use Cross-Section Hydraulic Analyzer which is a model developed by the United States Department of Agriculture. All the simulations were performed using the unidirectional water flow model for the measured cross-sections by varying the manning parameter. The variation of the Manning parameter used in the simulations was based on the information found at the time of the field measurements and used according to other study findings. The results of the study show the importance of the Manning parameter in the 1D water flow simulation on medium channels, also underline the importance of water flow simulation regarding the water level regime that can have an important effect on channel morphology and also on the biodiversity of the area.

Key words: *uniflow simulation, 1D water flow simulation, Manning parameter, Danube Delta, roughness.*

INTRODUCTION

Danube Delta is one of the most important ecosystems in the world with more than 3500 flora and 1800 fauna species (Gâştescu, 2009). Water flow and water level regimes in large ecosystems like Danube Delta are very important to study subjects mostly for their impact on the biota and biodiversity and have an important impact on navigation and fishing activities. Also, the study of water flow in Danube Delta channels is a subject of many studies including sediment transport and quality (V.A. Calmuc et al., 2021b; Keller et al., 1998; Tiron et al., 2009), pollutants transport (L.P.G. Calmuc, n.d.; M. Călmuc et al., 2018; M. Calmuc, Calmuc, Arseni, et al., 2020; V.A. Călmuc et al., 2018; V.A. Calmuc et al., 2021a; Cristofor et al., 1993), flood studies (Arseni, Roșu, et al., 2019; Arseni et al., 2020a; Cristofor et al., 1993; Tiron et al., 2009), trophic gradients (Arseni et al., 2018; Poncos et al., 2013), nutrients dynamics (Cristofor et al., 1993), water quality studies (L.P.G. Calmuc, n.d.; Călmuc et al., 2018; M. Calmuc, Calmuc, Georgescu et al., 2020; V.A. Calmuc et al., 2021b).

To study the water flow through a channel it is necessary to have precise data regarding the shape of the studied cross-section for depth and the underwater terrain elevation in a specific geographic location, therefore modern and precise topographic equipment are required to gather these data. Also, data regarding the interaction between the surface and the water is necessary to study the water flow regime using a variation of Manning parameters.

In channels with almost stable boundaries, it is necessary to know the total resistance to flow using data from the interaction for a bundle of elements. These parameters are particle size of riverbed material, bank irregularity, vegetation, channel alignment, bed configuration, channel obstructions, converging or diverging streamlines, sediment load, and surface waves.

The present knowledge shows that the quantitative effect of the majority of these factors is not determinable and must be estimated. This kind of data can be obtained using bathymetry measurements coupled with topography determinations but it is time-consuming if a long river or channel is the subject of the study. Similar studies were made in large rivers like the Siret river, one of the most important affluent of Danube, using a single beam echosounder coupled with flood risk maps (Arseni, 2018; Arseni et al., 2020b; Arseni, Voiculescu, et al., 2019).

In our study we aim to study the water flow through simulation in a channel in Danube Delta, using describing bathymetry and topographic measurements data in specific cross-sections by varying the Manning roughness coefficient. The variation of Manning roughness coefficient in uniflow simulations have the purpose of calibrating the simulation so that the water flow in a specific cross-section will be similar to real data and the obtained simulation parameters can be used for other channel or river cross-sections.

MATERIALS AND METHODS

Study area

The subject of this study is the Magistral A.P. Chilia channel located in the Matiţa - Merhei depression located in the wing northern part of the Danube Delta (between the arms of Chilia and Sulina). The channel location in the Matiţa - Merhei aquatic complex can be observed in Figure 1.

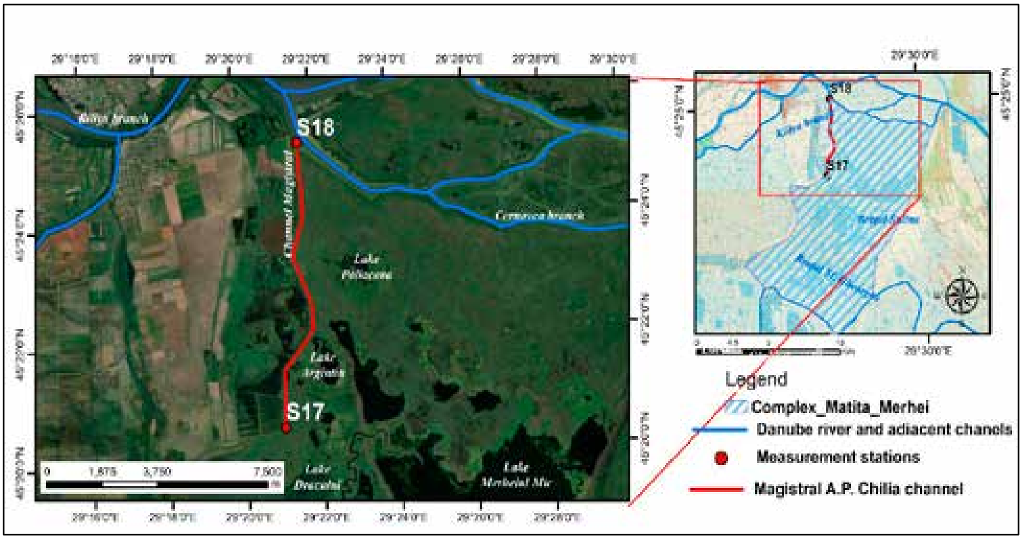


Figure 1. Detail map of Matiţa - Merhei aquatic complex (upper right map). Monitoring points on Magistral A.P. Channel Cell between the Cernovca arm and the Radacinoase canal: S17, S18 (left map)

Figure 1 is presented the map of the Matiţa – Merhei aquatic complex, also the spatial locations of the two measurements field stations are presented with the used codes S17 and S18.

Data gathering

The data that describes the spatial location and shape of the Magistral A.P. Chilia channel in the measurement field stations were collected using topographic equipment along with bathymetric equipment, which was used in station data measurements in the wetland, including water level, depth, discharge, and velocity. Topographic measurements on banks were done using Topcon HiPer HR GNSS receiver and Topcon DL-501 electronic digital level (Figure 2).

The bathymetry measurements of the wetland in the measurements stations were done using the Riversurveyor M9 ADCP (Acoustic Doppler Current Profiler) system presented in the next figure during the field measurements alongside the boat Parker 900 which were used for the measurements and travel to measurement stations. The Riversurveyor M9 ADCP system measurement can be used in obtaining data regarding the water depth, velocity, and discharge.

All the equipment used is high-end topographic and bathymetric equipment so that the data collected present the best accuracy that range between 0.1-5 cm on all tridimensional axis. The bathymetric system was used to measure the wetland and the topography equipment was used to obtain data on the dry land in the field station located along the Magistral A.P. Chilia channel.

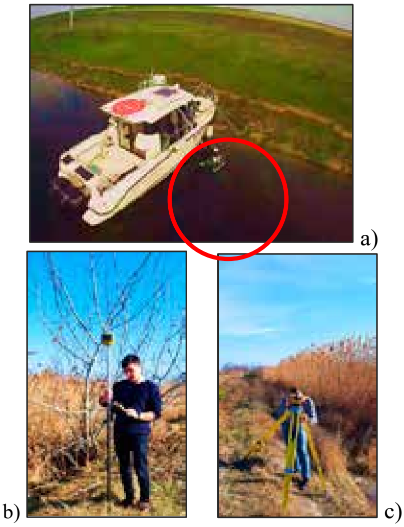


Figure 2. Equipment used for data collecting in the two field stations on Magistral A.P. Chilia channel: a) Mobile platform (boat Parker 800) for RiverSurveyour M9 ADCP bathymetric system (red circle); b) Topcon HiPer HR GNSS; c) Topcon DL-501 electronic digital level

Method used

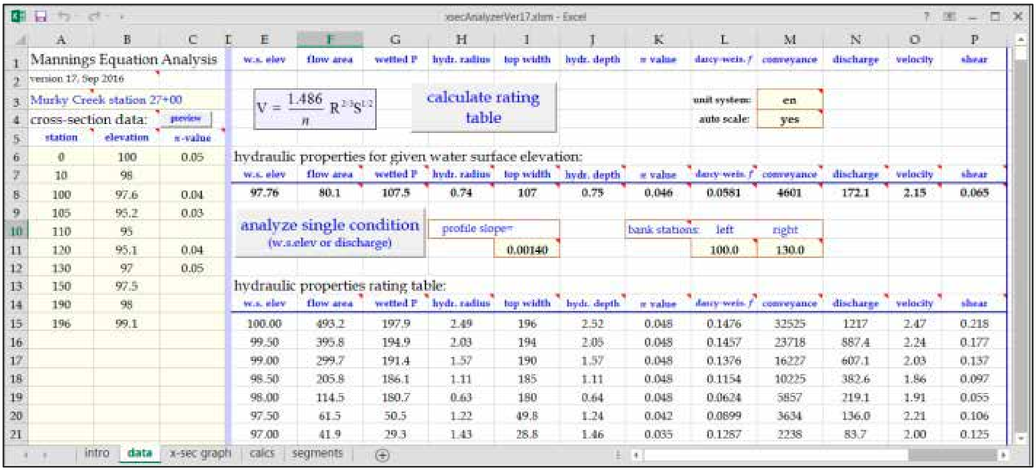
The water flow simulations were performed using the uniflow model Cross-Section Hydraulic Analyzer “xsecAnalyzerVer18.xlsm” developed by the Natural Resources Conservation Service (NRCS) Water Quality and Quantity Technology Development Team from the United States Department of Agriculture (*Cross-Section Hydraulic Analyzer*, n.d.).

The uniflow simulation model tool enables you to examine stream or river cross-sections and determine hydraulic parameters, such as flow area, discharge, and average velocity.

The below image shows the data entry sheet. The user may input data into any cell with a light-yellow background.

Cross-section station-elevation coordinates, data gathered with bathymetric and topographic equipment, are entered in columns A and B, along with Manning parameters as “n-values” in column C. In cells L11 and M11, the user is required to enter bank stations.

The reason these data are required is that, for many natural cross-section shapes, the results are affected by how overbank flow is accounted for. See details below in the section "overbank flow".



Mannings Equation Analysis
version 17, Sep 2016
Murky Creek station 27+00
cross-section data:

station	elevation	n-value
0	100	0.05
10	98	
100	97.6	0.04
105	95.2	0.03
110	95	
120	95.1	0.04
130	97	0.05
150	97.5	
190	98	
196	99.1	

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

unit system: en
auto scale: yes

hydraulic properties for given water surface elevation:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis. f	conveyance	discharge	velocity	shear
97.76	80.1	107.5	0.74	107	0.75	0.046	0.0581	4601	172.1	2.15	0.065

profile slope= 0.00140
bank stations: left 100.0 right 130.0

hydraulic properties rating table:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis. f	conveyance	discharge	velocity	shear
100.00	493.2	197.9	2.49	196	2.52	0.048	0.1476	32525	1217	2.47	0.218
99.50	395.8	194.9	2.03	194	2.05	0.048	0.1457	23718	887.4	2.24	0.177
99.00	299.7	191.4	1.57	190	1.57	0.048	0.1376	16227	607.1	2.03	0.137
98.50	205.8	186.1	1.11	185	1.11	0.048	0.1154	10225	382.6	1.86	0.097
98.00	114.5	180.7	0.63	180	0.64	0.048	0.0624	5857	219.1	1.91	0.055
97.50	61.5	50.5	1.22	49.8	1.24	0.042	0.0899	3634	136.0	2.21	0.106
97.00	41.9	29.3	1.43	28.8	1.46	0.035	0.1287	2238	83.7	2.00	0.125

Figure 3. Example of a filled uniflow simulation model using Cross-Section Hydraulic Analyzer spreadsheet

The Manning or roughness parameter can be estimated using data from previous studies or estimated using data from literature tables in which variation of Manning parameter is displayed according to the wetted surface composition and in dependence with it. Such

Manning tables that were used in our study are presented in the below Table 1 (Arseni, 2018; Limerinos, 1970a).

Table 1. Values of Manning parameters used in previous water flow, hydrodynamic studies, based on in-field measurements (Arseni, 2018; De Doncker et al., 2009; García Díaz, 2005; Limerinos, 1970b; Tiron et al., 2009)

Natural flow channels (rivers)- **Minor bed**			
Surface/Area characteristics	Manning lowest value	Manning highest value	Manning averaged value
Clean, small slope, without rocks	0.025	0.030	0.033
Clean, small slope, with rare rocks, little vegetation	0.030	0.035	0.040
Clean, meandering, rare stones, a few sandbanks	0.033	0.040	0.045
Clean, meandering, rare stones with vegetation and large stones	0.035	0.045	0.50
Clean, meandering, rare stones and steep slopes	0.040	0.048	0.055
Clean, meandering, sandbanks, many stones	0.045	0.050	0.060
Slow, vegetated and very deep courses	0.050	0.070	0.080
Courses with abundant vegetation, deep depths or courses with many stones, and dense woody vegetation	0.070	0.100	0.150

To use this uniflow simulation model it is necessary that the bank stations must be specified because, for many natural cross-sections, the total section output is significantly affected by how overbank flow is treated. The issue relates to how wetted perimeter varies with depth. If the cross-section has a relatively wide flat overbank, then the wetted perimeter can increase significantly with a minor increase in flow depth (between in-channel flow and out-of-bank flow). As a result, the hydraulic radius will decrease with an increase in-depth, along with a reduction in computed total discharge.

If the overbank hydraulic parameters are computed separately from the channel, then this computational artifact is avoided. However, the onus remains upon the user to select appropriate bank stations (*Cross-Section Hydraulic Analyzer*, n.d.). The uniflow model is based on the next equation:

$$n = \frac{0.0926R^{1/6}}{1.16 + 2.0\log\left(\frac{R}{d_{84}}\right)} \tag{1}$$

where n is the surface roughness parameter, R is the hydraulic radius, d_{84} is the gravel size.

The method used for this article was first to identify the n parameters and try to estimate them using field data (site observation) and other studies' findings of the value of the rugosity parameter. The second step was to have a precise measurement of the channel cross-sections in the field stations using advanced topographic and bathymetric equipment.

The data about water depth, velocity, and discharge was collected using the ADCP system. The measurement method used is presented in Figure 4.

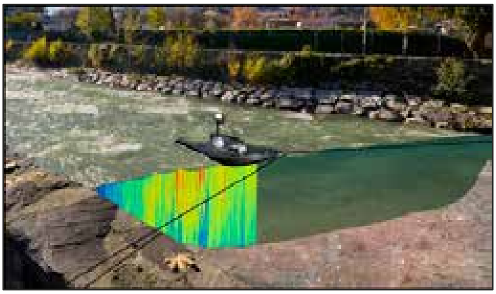
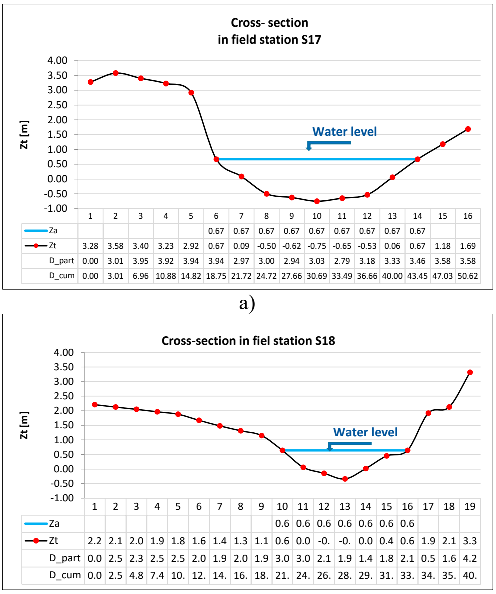


Figure 4. Bathymetric measurements using ADCP system in a river /channel cross-section. The colour ramp represents the variation of the water velocity in the measured cross-section by using an ADCP system.

RESULTS AND DISCUSSIONS

The measured profiles in the two Magistral A.P. Chilia channel stations (S17 and S18) using bathymetry and topographic measurements are presented in Figure 5. The field data were post-process to eliminate gaps or errors caused by the flow debriefs or other aquatic noises to obtain clean and abundant data sets that would describe the real cross-section in the field station.



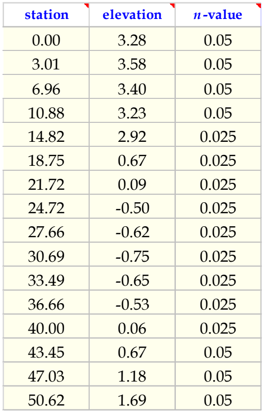
a)

b)

Figure 5. Magistral A.P. Chilia channel cross-sections for the S17 (a) and S18 (b) field stations.

In the above figure are presented the post-processed data from the two cross-sections from the field station S17 and S18 on the Magistral A.P. Chilia channel chosen for our uniflow modelling study. The data was processed from bathymetry and topography data from the locations of the study. As we can see in the above figure the resulting cross-section is simple and includes a maximum of 16 points of elevation for S17 and 19 for S18. The resulted cross-sections are obtained from the interpolation of hundreds of elevation points in each cross-section, data gathered with advanced bathymetric and topographic equipment. The abridgment of each cross-section through interpolation was done to simplify the cross-sections so the uniflow simulation can be performed fast without the need for large computational resources. Also, this method using interpolation of large datasets can result in the accurate shape of the cross-sections without losing the contribution of each elevation point measured with advanced bathymetry and topographic equipment. In Figure 5 it is presented the water level in the cross-section measured and referenced to the national reference "0 m" elevation point known as Marea Neagra Sulina (MNS). All data regarding the depth and elevation was referenced to MNS.

All the elevation points of the S17 cross-section were used in the uniflow model Cross-Section Hydraulic Analyzer "xsecAnalyzerVer18.xlsm" as elevation and the length from one point to another along the cross-section were defined as point stations. Several simulations were performed to obtain similar water discharge and velocity as it was measured by our ADCP system. The input data for the uniflow model is presented in Figure 6.



station	elevation	*n*-value
0.00	3.28	0.05
3.01	3.58	0.05
6.96	3.40	0.05
10.88	3.23	0.05
14.82	2.92	0.025
18.75	0.67	0.025
21.72	0.09	0.025
24.72	-0.50	0.025
27.66	-0.62	0.025
30.69	-0.75	0.025
33.49	-0.65	0.025
36.66	-0.53	0.025
40.00	0.06	0.025
43.45	0.67	0.05
47.03	1.18	0.05
50.62	1.69	0.05

Figure 6. Printscreen of the input data for the uniflow simulation in the S17 cross-section on the Magistral A.P. Chilia channel using Cross-Section Hydraulic Analyzer "xsecAnalyzerVer18.xlsm"

As we can observe in the above figure (and Figure 5 a) the n-value was set to 0.05 for the dry area of the cross-section and 0.025 for the wetted area, according to in-field findings of the area in the cross-section. Also, the n-value was approximated using the findings of previous studies as is presented in Table 1. A bundle of uniflow of water simulation were performed for this cross-section using different inputs of n-value, according to infield approximation in the S17 located on the Magistral A.P. Chilia channel. The most representative result of the uniflow simulations is presented in Figure 6 where the best fit with the field data of the n-value is presented.

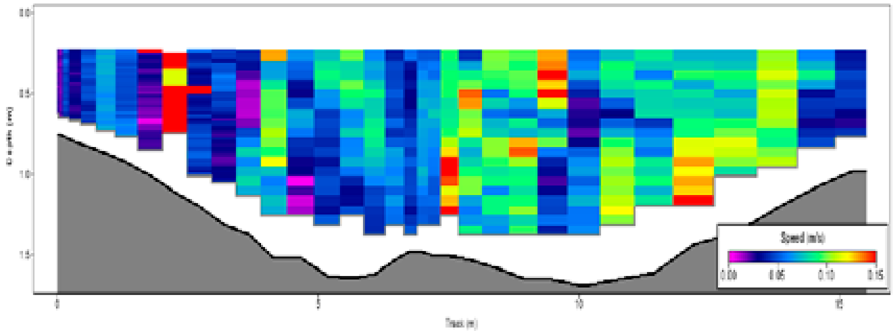


Figure 7. Results of water velocity during the in-field measurements in the S17 field station on the Magistral A.P. Chilia channel using RiverSurveyour M9 ADCP bathymetric system

In Figure 7 we can see the measured water velocity profile for the S17 field station on the Magistral A.P. Chilia channel show water velocity ranged between 1.4 m/s and 1.6 m/s, and an average value of 1.37 m/s.

Results of the ADCP measurements and uniflow simulations using Cross-Section Hydraulic Analyzer "xsecAnalyzerVer18.xlsm" for S17 field station on the Magistral A.P. Chilia channel are presented in Table 2.

As we can observe in Table 2, the errors using the uniflow simulation are very low and ranged between 10% and 12% of the measured values in all cases.

This was found when using proper input parameters for the simulations. These results show that if we had just the elevation of the cross-section measured with just a single beam acoustic doppler, which is low-cost equipment, and using an approximated n-value (Manning parameters) with respect to other research findings we can obtain by using Cross-Section Hydraulic Analyzer "xsecAnalyzerVer18.xlsm" values similar to the infield measurements.

Table 2. Comparison and errors between measured and simulated water discharge and velocity for S17

Instrument/Simulation Model	w.s. elev (m)	*n* value	Discharge (m^3/s)	Velocity (m/s)
"xsecAnalyzer Ver18.xlsm"	0.670000	0.029000	1.440000	0.065000
RiverSurveyour M9 ADCP batimetic system	0.670000	N/A	1.370000	0.067000
Erorr Model vs ADCP system	0.000000	N/A	0.070000	-0.002000
MSE	0.000000	N/A	0.004900	0.000004

Same input values as for S17 were used in the uniflow simulation of the S18 field station using Cross-Section Hydraulic Analyzer "xsecAnalyzerVer18.xlsm". the results are presented in Table 3 along with the in-field verification of the results using the same ADCP system as it was used for S17 measurements.

As expected, the results showed (Table 3) very small errors when we apply the same settings of the uniflow simulations on the same channel. Therefore, this method can be used to obtain precise data regarding the discharge and water velocity in known channels cross-sections with respect to infield approximations of the Manning parameter distribution along the cross-section. Also, for this method to work, it is necessary to have some data regarding the water depth in certain cross-sections (using a simple ADCP) and the elevation value of the waterline.

Table 3 Comparison and errors between measured and simulated water discharge and velocity for S18

Instrument/Simulation Model	w.s. elev (m)	*n* value	Discharge (m^3/s)	Velocity (m/s)
"xsecAnalyzer Ver18.xlsm"	0.670000	0.029000	0.160000	0.02000
RiverSurveyour M9 ADCP batimetic system	0.670000	N/A	0.160000	0.021000
Erorr Model vs ADCP system	0.000000	N/A	0.000000	-0.001000
MSE	0.000000	N/A	0.00000	0.000001

CONCLUSIONS

The results of the study show that by using the uniflow model Cross-Section Hydraulic

Analyzer "xsecAnalyzerVer18.xlsm", by using approximated Manning parameter with respect to literature and infield approximations, also using simple bathymetry (single beam equipment) we can obtain precise data regarding the water flow (water velocity and discharge data). The use of uniflow simulated results calibrated on several profiles can contribute to obtaining fast results for the entire section of the channel without the need to travel in the field and thus reduce costs and make predictions that can be subsequently be verified in selected profiles. Random checks of the model can be performed by carrying out bathymetric measurements in random cross-sections of the channel taken into study.

Also, this technique using the profile method requires a long time to measure in the field, using this method considerably reduces the time of working in the field and the processing of the data collected from the field measurements. By running such water flow simulations, we can obtain data that can be used in conducting sediment and pollutants transport studies in the channels and assess the environmental impact of their spatial distribution.

ACKNOWLEDGEMENTS

The present research/article/study was supported by the project An Integrated System for the Complex Environmental Research and Monitoring in the Danube River Area, REXDAN, SMIS code 127065, co-financed by the European Regional Development Fund through the Competitiveness Operational Programme 2014-2020, contract no. 309/10.07.2021.

REFERENCES

Arseni, M. (2018). Tehnici moderne GIS pentru determinarea riscurilor teritoriale [PhD Thesis]. Universitatea" Dunărea de Jos" din Galați.

Arseni, M., Rosu, A., Calmuc, M., Calmuc, V. A., Iticescu, C., & Georgescu, L. P. (2020a). Development of flood risk and hazard maps for the lower course of the Siret River, Romania. *Sustainability*, 12(16), 6588.

Arseni, M., Rosu, A., Calmuc, M., Calmuc, V. A., Iticescu, C., & Georgescu, L. P. (2020b). Development of flood risk and hazard maps for the lower course of the Siret River, Romania. *Sustainability*, 12(16), 6588.

Arseni, M., Roșu, A., Iticescu, C., Georgescu, L. P., Timofti, M., Pintilie, V., Călmuc, M., & Roman, O. (2018). A review of bathymetric measurements from August 2018 campaign on the lower course of the Danube. Analele Universității" Dunărea de Jos" Din Galați. Fascicula II, Matematică, Fizică, Mecanică Teoretică/*Annals of the" Dunarea de Jos" University of Galati. Fascicle II, Mathematics, Physics, Theoretical Mechanics*, 41(2), 212–219.

Arseni, M., Roșu, A., Murariu, G., Georgescu, L. P., Iticescu, C., Calmuc, M., & Calmuc, V. (2019). The role of river channel roughness for water level modeling during the 2005 year flood on Siret river using HEC-RAS model. Analele Universității" Dunărea de Jos" Din Galați. Fascicula II, Matematică, Fizică, Mecanică Teoretică/*Annals of the" Dunarea de Jos" University of Galati. Fascicle II, Mathematics, Physics, Theoretical Mechanics*, 42(1), 68–76.

Arseni, M., Voiculescu, M., Georgescu, L. P., Iticescu, C., & Rosu, A. (2019). Testing different interpolation methods based on single beam echosounder river surveying. Case study: Siret River. *ISPRS International Journal of Geo-Information*, 8(11), 507.

Calmuc, L. P. G. (n.d.). Preliminary Analysis on the River Danube Water Quality by Using Different Kinds of Methods.

Călmuc, M., Călmuc, V. A., Dragu, M. D., Rosu, A., Munteanu, D., Rosu, B., & Murariu, G. (2018). Comparative study of descriptive statistics on physico-chemical parameters describing water quality. Case study-the Danube River in the Galati area. *Annals of the University Dunarea de Jos of Galati: Fascicle II, Mathematics, Physics, Theoretical Mechanics*, 41.

Calmuc, M., Calmuc, V. A., Georgescu, L. P., Iticescu, C., & Arseni, M. (2020). Assessment of nutrients and oxygen regime in the Lower Danube water. Analele Universității" Dunărea de Jos" Din Galați. Fascicula II, Matematică, Fizică, Mecanică Teoretică/*Annals of the" Dunarea de Jos" University of Galati. Fascicle II, Mathematics, Physics, Theoretical Mechanics*, 43(1), 68–74.

Călmuc, M., Călmuc, V. A., Țopa, M. C., Timofti, M., Ilticescu, C., & Georgescu, L. P. (2018). Review on water quality assessment in the Danube River basin. Analele Universității" Dunărea de Jos" Din Galați. Fascicula II, Matematică, Fizică, Mecanică Teoretică/*Annals of the" Dunarea de Jos" University of Galati. Fascicle II, Mathematics, Physics, Theoretical Mechanics*, 41(2), 189–195.

Calmuc, M., Calmuc, V., Arseni, M., Topa, C., Timofti, M., Georgescu, L. P., & Iticescu, C. (2020). A Comparative Approach to a Series of Physico-Chemical Quality Indices Used in Assessing Water Quality in the Lower Danube. *Water*, 12(11), 3239. https://doi.org/10.3390/w12113239

Calmuc, V. A., Calmuc, M., Arseni, M., Topa, C. M., Timofti, M., Burada, A., Iticescu, C., & Georgescu, L. P. (2021a). Assessment of heavy metal pollution levels in sediments and of ecological risk by quality indices, applying a case study: The Lower Danube River, Romania. Water, 13(13), 1801.

Calmuc, V. A., Calmuc, M., Arseni, M., Topa, C. M., Timofti, M., Burada, A., Iticescu, C., & Georgescu, L. P. (2021b). Assessment of Heavy Metal Pollution Levels in Sediments and of Ecological Risk by Quality

Indices, Applying a Case Study: The Lower Danube River, Romania. *Water*, 13(13), 1801. https://doi.org/10.3390/w13131801

Călmuc, V. A., Călmuc, M., Țopa, M. C., Timofti, M., Iticescu, C., & Georgescu, L. P. (2018). Various methods for calculating the water quality index. Analele Universității" Dunărea de Jos" Din Galați. Fascicula II, Matematică, Fizică, Mecanică Teoretică/*Annals of the" Dunarea de Jos" University of Galati. Fascicle II, Mathematics, Physics, Theoretical Mechanics*, 41(2), 171–178.

Cristofor, S., Vadineanu, A., & Ignat, G. (1993). Importance of flood zones for nitrogen and phosphorus dynamics in the Danube Delta. *Hydrobiologia*, 251(1), 143–148.

Cross-Section Hydraulic Analyzer. (n.d.). Retrieved March 8, 2022, from https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/?cid=stelprdb1042510

De Doncker, L., Troch, P., Verhoeven, R., Bal, K., Meire, P., & Quintelier, J. (2009). Determination of the Manning roughness coefficient influenced by vegetation in the river Aa and Biebrza river. *Environmental Fluid Mechanics*, 9(5), 549–567.

García Díaz, R. (2005). Analysis of Manning coefficient for small-depth flows on vegetated beds. Hydrological Processes: An International Journal, 19(16), 3221–3233.

Gâștescu, P. (2009). The Danube Delta biosphere reserve. Geography, biodiversity, protection, management. *Rev Roum Géogr*, 53(2), 139–152.

Keller, B. E., Lajtha, K., & Cristofor, S. (1998). Trace metal concentrations in the sediments and plants of the Danube Delta, Romania. *Wetlands*, 18(1), 42–50.

Limerinos, J. T. (1970a). Determination of the Manning coefficient from measured bed roughness in natural channels.

Limerinos, J. T. (1970b). Determination of the Manning coefficient from measured bed roughness in natural channels.

Poncos, V., Teleaga, D., Bondar, C., & Oaie, G. (2013). A new insight on the water level dynamics of the Danube Delta using a high spatial density of SAR measurements. Journal of Hydrology, 482, 79–91.

Tiron, L. J., Le Coz, J., Provansal, M., Panin, N., Raccasi, G., Dramais, G., & Dussouillez, P. (2009). Flow and sediment processes in a cutoff meander of the Danube Delta during episodic flooding. *Geomorphology*, 106(3–4), 186–197.