Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XIV, 2025
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

ADVANCED HYDRAULIC MODELING OF IRRIGATION CHANNEL

Mihai NEGURA, Robert Florin BEILICCI, Erika Beata Maria BEILICCI, Mirela Laura IEREMCIUC, Dorina Gabriela IONESCU

Politehnica University of Timisoara, 1A Splaiul Spiru Haret, 300022, Timișoara, Romania

Corresponding author email: robert.beilicci@upt.ro

Abstract

The Sânnicolau Mare-Saravale Canal covers an area of 20,060 ha, with land rehabilitation works accounting for 19,998 ha. Sânnicolau Mare is located in the western part of Romania, in Timiș County. The MIKE11 program was used for numerical modelling. MIKE 11 has flow calculation modules that include hydraulic structures, and ways to describe the operation of the structure. With the MIKE 11 model, they draw up flood risk maps. The keywords are productivity, reliability, quality and versatility for professional engineers who use the MIKE 11 program. The MIKE 11 model has been shown to be highly reliable for generating flood risk maps.

Key words: *advanced modelling, flood maps irrigation channel.*

INTRODUCTION

The objective of this paper is to model the movement of water in the Aranca channel in the area of Sânnicolau Mare, with the aim of determining water levels and flow rates along the channel.

This allows for the anticipation of situations that may arise under different inflow conditions in extreme precipitation or drought scenarios. The numerical modelling was carried out using the MIKE11 program.

Sânnicolau Mare drainage system - in the northern part of Timiș county there are Saravale and the Tisa - Mureș basin; subsection II Aranca being delimited as follows:

- North Mureș sewerage system and left Mureș dam km 32+000 - 43+400;
- South Basin, subsection III Aranca Galatca;
- To the west, subsection IV Aranca;
- East under the Aranca I compartment - the limit of Arad County;

Sânnicolau Mare System - The rehabilitation works of the lands belonging to Saravale occupied 19,998 ha of the total area of 20,060 ha (Figure 1).

The excess moisture in the drainage system manifests itself differently on different surfaces in local orographic, solar and hydrogeological conditions, created as a result of rainfall in the area of the drainage system and the Mureș River that produce an abundant supply of groundwater in the area.

Figure 1. Map of Timiș County, Romania

The land has a natural slope from east to west 0.02-0.05%.

The emissary is generally the Mureș River. The depression of the main collector Aranca, the regularized discharges made at Mureș being carried out through a system of dams near the Silvia Canal and SP Cenad at Aranca have reached the border restrictions, the rest is done through the periods of flow of the Aranca canal over the border with Yugoslavia through the discharge of the Tisza canal or the canal into the DTD.

The main collector system for all departments is the Aranca Canal, which conducts the inland waters generally collected across the Yugoslav Roman border to the height of 77.60 m recorded share the miraculous smiles - the confluence of the Tisza when the Yugoslav border dam closes on the Aranca.

At that time, the gates of Sections IV and II (Aranca km 40+250) and Compartments II and

I (Aranca km 77+940) are closed, and the appropriate distribution of the collected domestic wastewater and drainage subunits is carried out.

Existing natural conditions - partitioning perimeter imposed by Sânnicolau Mare - Saravale drainage system, four independent functional units as follows:

1. UD Sânnicolau Mare - Tomnatic an area of 6,390 ha located on the left bank of the Aranca between 40+250 - 53+300 km forming the northern limit, Dc27 Simpetru-Lovrin the eastern limit of the drainage system compartment III Aranca and Section IV the southern limit of the southern limit.
2. Simpetru Lovrin UD, area of 3,885 ha located on the left bank of the canal, also Aranca, between 53+300 - 59+700 km, northern limit, bordered to the northeast and south, Periam UD, compartment III (Galatca), to the west, is limited to the DU. Sânnicolau Mare-Tomnatic.
3. Saravale UD - the Igris area of 3,690 ha on the right bank of the Aranca canal (km 40+250 - 59+ 700) and Silvia (km 0+000 - 0+300) limited to the northern Mureșan and left Mureș dam system (km 31+000 - 35+000) and to the east by the Periam UD dam system.
4. The Periam UD area, 6,033 ha, is located in the upstream compartment II, Aranca (km 59+ 700 - 77+940) to the left with the dam north of the Mures river (35+000 - 43+500 km) to the east the Aranca subdivision dam with section. I, the southern limit of the Checea - Jimbolia Aranca drainage system compartment III and UD Lovrin Simpetru - and west - Lovrin Simpetru UD and UD Saravale - Igriș.

The Aranca originates from the Felnac Mureș Valley - where dam construction began in 1816 - and flows into the Tisza River. It passes through the center of Sânnicolau Mare, having been channelized in 1888 following severe spring floods. The Aranca hydraulic system was developed between 1887 and 1894 (Figure 2). The crossing of the Aranca Sânnicolau Mare canal was aimed at draining the flooded lands, being widened and deepened in 1959 and 1960. The canal has a total length of 10.532 km, a depth ranging from 1 to 3 meters, and a width between 6 and 16 meters. It has a slope of 0.1 to 0.15 per km, with a difference in elevation between the entry points and the exit points outside the city. The maximum flow occurs in spring, reaching 2.5 m³/s, while the minimum flow is observed in summer (Biali et al., 2022).

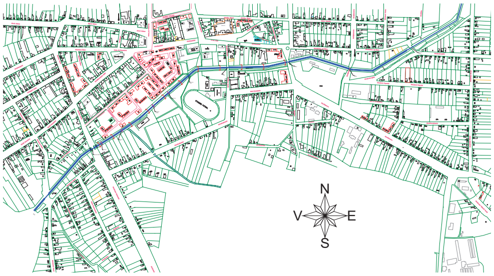

Figure 2. Map of the Aranca Canal, Timiș county

MATERIALS AND METHODS

The movement of water is free on watercourses, rivers, canals and pipes.

"Level-free, straight, and prismatic channels exhibit uniform flow. In straight, artificial, and prismatic channels, uniform flow occurs under free surface conditions (gutters, canals, galleries, ditches, etc.). Hydraulic calculation formulas are the Chezy-type analytical solutions that are obtained by the Manning relation.

$$Q = \frac{1}{n}\frac{S^{\frac{5}{3}}}{P^{\frac{2}{3}}}\sqrt{i} \qquad (1)$$

For the trapezoidal section we have:

$$Q = \frac{1}{n}\frac{(\beta+m)^{1.5+y}}{(\beta+m')^{1.5+y}}h^{2.5+y}\sqrt{i} \qquad (2)$$

where:

- $m' = 2\sqrt{1+m^2}$ (David, 1984).

Given the complexity of water movements in surface courses, it is an analytical calculation that considers the natural conditions of the land. Modeling the water flow and displacement in the Aranca Canal requires numerical simulation using the MIKE 11 program.

Description of MIKE 11 modules (input data, results)

Input data HD:
- Longitudinal profile;
- cross-sections;
- boundary conditions: hydrograph of flows, levels and boundary key.

Input data ST:
- data on sediments.

Input data RR:
- precipitation, temperature, evapotranspiration;

- data on the hydrographic basin (area, average slope and uses).

Input data ECO-LAB:
- water quality measurements.

Output Data HD:
- hydrograph of flows and levels in each cross-section (flow and level);
- the variation of the water level in longitudinal profile.

Output Data ST:
- Dragged suspended solid flow;
- modification of the levels of the bottom of the riverbed (small erosions, deposits).

Output Data RR:
- hydrograph of flows in the outlet section of the hydrographic basin.

Output Data ECO-LAB:
- the variation of the water quality parameters in the longitudinal profile (Paudel et al., 2022).

MIKE 11 is a widely used tool for simulating flow, water quality, and sediment transport in irrigation canals, rivers, estuaries, and other surface water bodies.

It provides a wide range of solutions, from basic flow routing to complex dynamic modeling, while remaining efficient and user-friendly. The efficient, fast, and robust hydrodynamic simulation engine is the computing core of this program-MIKE 11.

Every aspect of watercourse modeling is a combination of modules and extensions.

The calculation of unsteady flows in rivers and estuaries is performed using a default finite difference scheme of the MIKE 11 hydrodynamic module.

Depending on the local flow conditions, (in space and time) the module can describe both subcritical and supercritical flow conditions through a numerical relationship.

Calculation modules are included for the operation of the hydraulic structure and flow description. On floodplains of flow (Lagos et al., 2024) quasi-two-dimensional formulations and simulations of loop networks can be applied.

From river flows to tidally influenced estuaries, calculation schemes for homogeneous vertical flow conditions are applied (Nannawo et al., 2022). This System is used worldwide for engineering studies

For river management, hydraulic models are applied. For flood warning or planning the operation of reservoirs in forecasting systems, certain flood mitigation potential analysis applications are used (Kumar et al., 2021).

The models provide descriptions of the variations in flow and water level at certain points along, which are then interpreted by the user of the model regarding the consequences it may have on the population and properties in the vicinity of the river (Pareta et al., 2023).

The calibration of the model was performed for fixed inflow discharges measured upstream, which corresponded to water levels measured downstream by National Agency for Land Reclamation (ANIF). After calibration, by adjusting the roughness coefficients, validation was carried out for other measured values, resulting in an accuracy of approximately 96%.

RESULTS AND DISCUSSIONS

The results of the topographic studies for the Aranca Canal are: width at the bottom b = 3.0 m, slope inclination m = 2, slope i = 0.0002, roughness n = 0.02.

For the existing channel curve Q = Q (h) is presented in Figure 4.

The MIKE11 program was used for numerical modeling. Initially, the existing conditions of the Aranca Canal were modeled. Figure 3 shows the location of the canal, and in Table 1 nods coordinates for the model.

The cross-sections through the canal in the form of topographic studies in Figure 6 and raw data in Figure 7 respectively de processed data in Figure 8.

The input of the data according to the formulated boundary conditions, of the upstream flow to the 35+600 chainage are the flood evacuation hydrograph and downstream to the 34+600 chainage the graph of the key curve of the downstream section presented in Figure 5 (Damian et al., 2022).

The flow hydrograph is shown in Figure 9 and the discharges in all periods are presented in Table 2.

Figure 3. Plan view with grid pattern

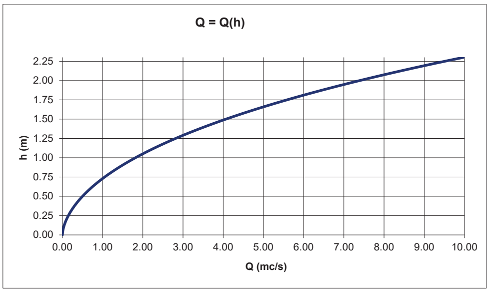

Figure 4. Curve Q = Q (h) for the upstream Aranca Canal

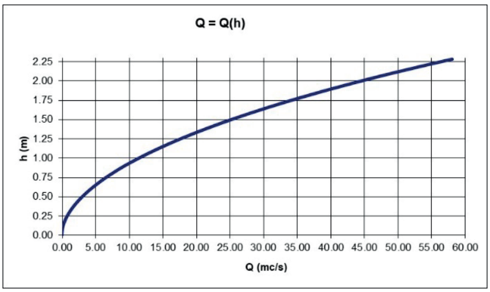

Figure 5. Key curve of the downstream section

Table 1. Nods coordinate for the model

X	Y	River	Chainage
490	2910	Aranca	34600
630	3090	Aranca	34657.1
890	3430	Aranca	34764.3
1210	3780	Aranca	34883
1420	4200	Aranca	35000.6
1660	4560	Aranca	35109
1940	4840	Aranca	35208.1
2320	4880	Aranca	35303.8
2590	4860	Aranca	35371.6
2970	4940	Aranca	35468.8
3370	5090	Aranca	35575.8
3590	4940	Aranca	35642.5
3880	4780	Aranca	35725.4
4340	4740	Aranca	35841
4720	5030	Aranca	35960.7
4960	5370	Aranca	36065
5250	5710	Aranca	36176.9
5510	6030	Aranca	36280.1
5590	6460	Aranca	36389.6
5550	6860	Aranca	36490.3
5430	7380	Aranca	36623.9
5310	7670	Aranca	36702.5
5070	7970	Aranca	36798.7
4800	8190	Aranca	36885.9
4560	8510	Aranca	36986.1
4760	8730	Aranca	37060.5
4920	8630	Aranca	37107.8
5170	8490	Aranca	37179.5
5470	8430	Aranca	37256.2
5850	8270	Aranca	37359.4
5970	8670	Aranca	37464
6130	8960	Aranca	37546.9
6320	9120	Aranca	37609.1
6560	9320	Aranca	37687.3
6820	9500	Aranca	37766.5
7060	9440	Aranca	37828.5
7220	9160	Aranca	37909.2
7220	8840	Aranca	37989.4
7120	8670	Aranca	38038.7
7060	8390	Aranca	38110.4
7060	8070	Aranca	38190.6
7040	7770	Aranca	38265.9
7040	7460	Aranca	38343.5
6980	7200	Aranca	38410.3
6980	6900	Aranca	38485.4
6980	6560	Aranca	38570.6
7020	6260	Aranca	38646.4
7060	5890	Aranca	38739.6
7060	5530	Aranca	38829.7
7060	5210	Aranca	38909.8
7120	5030	Aranca	38957.3
7400	4980	Aranca	39028.6
7460	5330	Aranca	39117.5
7610	5770	Aranca	39233.9
7890	6010	Aranca	39326.2
7970	6400	Aranca	39425.9
7970	6900	Aranca	39551.1
8210	7300	Aranca	39667.9
8190	7690	Aranca	39765.7
8190	8090	Aranca	39865.9
8370	8410	Aranca	39957.8
8530	8650	Aranca	40030.1
8880	8900	Aranca	40137.8
9320	9060	Aranca	40255

Table 2. Discharges in all periods in the upstream section

No	Time	Q	No	Time	Q
1	21 Jul 2008 06:00:00	0.92	66	25 Jul 2008 23:45:00	5.17
2	21 Jul 2008 18:00:00	0.92	67	25 Jul 2008 23:55:00	5.24
3	22 Jul 2008 06:00:00	0.92	68	26 Jul 2008 00:40:00	5.35
4	22 Jul 2008 18:00:00	1.11	69	26 Jul 2008 01:00:00	5.36
5	22 Jul 2008 23:00:00	1.37	70	26 Jul 2008 01:30:00	5.39
6	23 Jul 2008 01:00:00	1.74	71	26 Jul 2008 02:00:00	5.35
7	23 Jul 2008 02:00:00	1.02	72	26 Jul 2008 03:00:00	5.10
8	23 Jul 2008 04:00:00	1.26	73	26 Jul 2008 04:00:00	4.83
9	23 Jul 2008 06:00:00	1.24	74	26 Jul 2008 04:15:00	4.72
10	23 Jul 2008 07:00:00	1.20	75	26 Jul 2008 05:00:00	4.43
11	23 Jul 2008 09:00:00	1.38	76	26 Jul 2008 05:30:00	4.28
12	23 Jul 2008 10:00:00	1.70	77	26 Jul 2008 06:00:00	4.07
13	23 Jul 2008 11:00:00	2.24	78	26 Jul 2008 07:00:00	3.88
14	23 Jul 2008 11:30:00	2.61	79	26 Jul 2008 08:00:00	3.73
15	23 Jul 2008 11:50:00	2.76	80	26 Jul 2008 09:00:00	3.73
16	23 Jul 2008 12:00:00	2.85	81	26 Jul 2008 10:00:00	3.73
17	23 Jul 2008 12:45:00	3.46	82	26 Jul 2008 11:00:00	3.68
18	23 Jul 2008 14:00:00	4.32	83	26 Jul 2008 12:00:00	3.63
19	23 Jul 2008 14:15:00	4.51	84	26 Jul 2008 13:00:00	3.54
20	23 Jul 2008 14:45:00	4.78	85	26 Jul 2008 14:00:00	3.43
21	23 Jul 2008 15:15:00	4.97	86	26 Jul 2008 15:00:00	3.34
22	23 Jul 2008 16:00:00	5.32	87	26 Jul 2008 16:00:00	3.24
23	23 Jul 2008 16:45:00	5.78	88	26 Jul 2008 17:00:00	3.17
24	23 Jul 2008 17:15:00	5.84	89	26 Jul 2008 18:00:00	3.12
25	23 Jul 2008 18:00:00	5.97	90	26 Jul 2008 19:00:00	3.06
26	23 Jul 2008 18:30:00	6.00	91	26 Jul 2008 20:00:00	3.02
27	23 Jul 2008 19:00:00	6.00	92	26 Jul 2008 21:00:00	3.00
28	23 Jul 2008 20:00:00	5.97	93	26 Jul 2008 23:55:00	3.03
29	23 Jul 2008 21:00:00	5.90	94	27 Jul 2008 01:00:00	3.10
30	23 Jul 2008 22:00:00	5.77	95	27 Jul 2008 02:00:00	3.13
31	23 Jul 2008 23:00:00	5.57	96	27 Jul 2008 03:00:00	3.18
32	23 Jul 2008 23:55:00	5.29	97	27 Jul 2008 04:00:00	3.22
33	24 Jul 2008 01:00:00	4.94	98	27 Jul 2008 05:00:00	3.28
34	24 Jul 2008 02:00:00	4.68	99	27 Jul 2008 06:00:00	3.24
35	24 Jul 2008 03:00:00	4.34	100	27 Jul 2008 07:00:00	3.19
36	24 Jul 2008 04:00:00	4.07	101	27 Jul 2008 09:00:00	2.82
37	24 Jul 2008 05:00:00	3.83	102	27 Jul 2008 18:00:00	2.27
38	24 Jul 2008 06:00:00	3.63	103	28 Jul 2008 06:00:00	2.24
39	24 Jul 2008 07:00:00	3.49	104	28 Jul 2008 18:00:00	1.57
40	24 Jul 2008 07:20:00	3.43	105	29 Jul 2008 06:00:00	1.80
41	24 Jul 2008 09:30:00	3.31	106	29 Jul 2008 10:40:00	1.64
42	24 Jul 2008 10:00:00	3.29	107	29 Jul 2008 11:10:00	1.61
43	24 Jul 2008 11:00:00	3.22	108	29 Jul 2008 18:00:00	1.44
44	24 Jul 2008 13:00:00	2.97	109	30 Jul 2008 06:00:00	1.18
45	24 Jul 2008 14:00:00	2.95	110	30 Jul 2008 18:00:00	1.14
46	24 Jul 2008 15:00:00	2.82	111	31 Jul 2008 06:00:00	1.09
47	24 Jul 2008 18:00:00	2.67	112	31 Jul 2008 18:00:00	1.07
48	24 Jul 2008 20:00:00	2.48	113	1 Aug 2008 06:00:00	1.06
49	25 Jul 2008 06:00:00	2.19	114	1 Aug 2008 18:00:00	0.96
50	25 Jul 2008 13:00:00	1.87	115	2 Aug 2008 06:00:00	0.94
51	25 Jul 2008 17:00:00	2.00	116	2 Aug 2008 18:00:00	0.93
52	25 Jul 2008 17:45:00	2.48	117	3 Aug 2008 06:00:00	0.92
53	25 Jul 2008 18:00:00	2.55	118	3 Aug 2008 18:00:00	0.92
54	25 Jul 2008 18:45:00	2.63	119	4 Aug 2008 06:00:00	0.91
55	25 Jul 2008 19:30:00	2.95	120	4 Aug 2008 18:00:00	0.91
56	25 Jul 2008 20:10:00	3.28	121	5 Aug 2008 06:00:00	0.91
57	25 Jul 2008 20:20:00	3.46	122	5 Aug 2008 18:00:00	0.91
58	25 Jul 2008 21:00:00	3.89	123	6 Aug 2008 06:00:00	0.91
59	25 Jul 2008 21:30:00	4.14	124	6 Aug 2008 18:00:00	0.90
60	25 Jul 2008 22:00:00	4.34	125	7 Aug 2008 06:00:00	0.90
61	25 Jul 2008 22:10:00	4.55	126	7 Aug 2008 18:00:00	0.90
62	25 Jul 2008 22:25:00	4.70	127	8 Aug 2008 06:00:00	0.90
63	25 Jul 2008 22:35:00	4.75	128	8 Aug 2008 09:30:00	0.89
64	25 Jul 2008 23:00:00	4.78	129	8 Aug 2008 10:00:00	0.89
65	25 Jul 2008 23:20:00	5.05	130	8 Aug 2008 18:00:00	0.89

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XIV, 2025
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

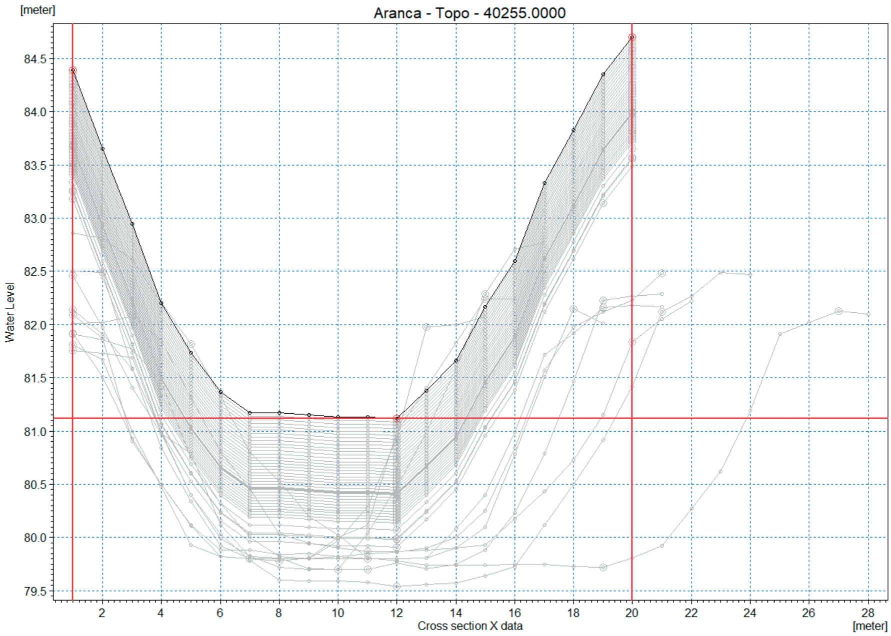

Figure 6. Cross-section for the Aranca Canal

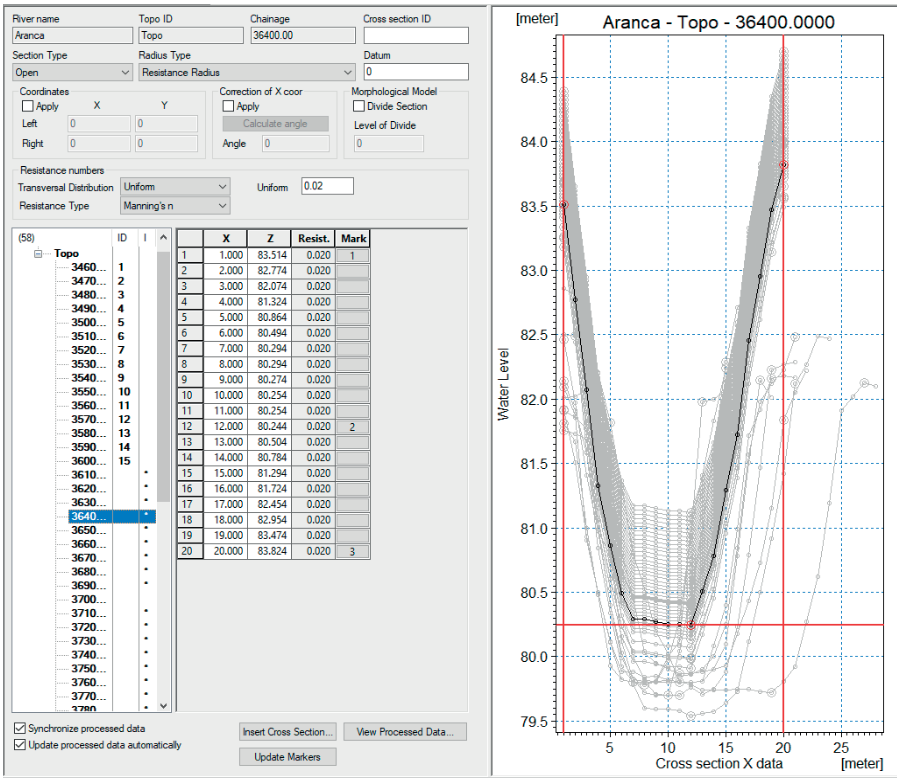

Figure 7. Raw data in Cross-sections

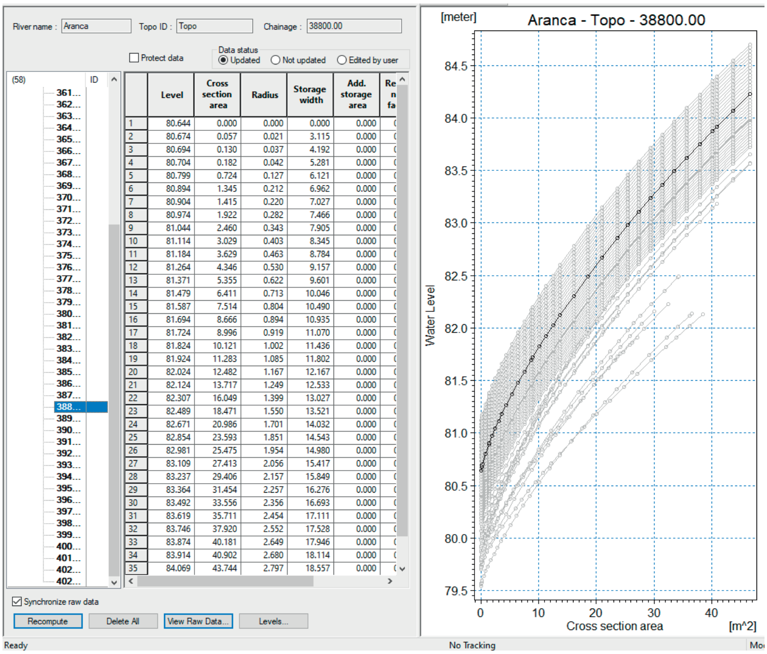

Figure 8. Processed data in Cross-sections

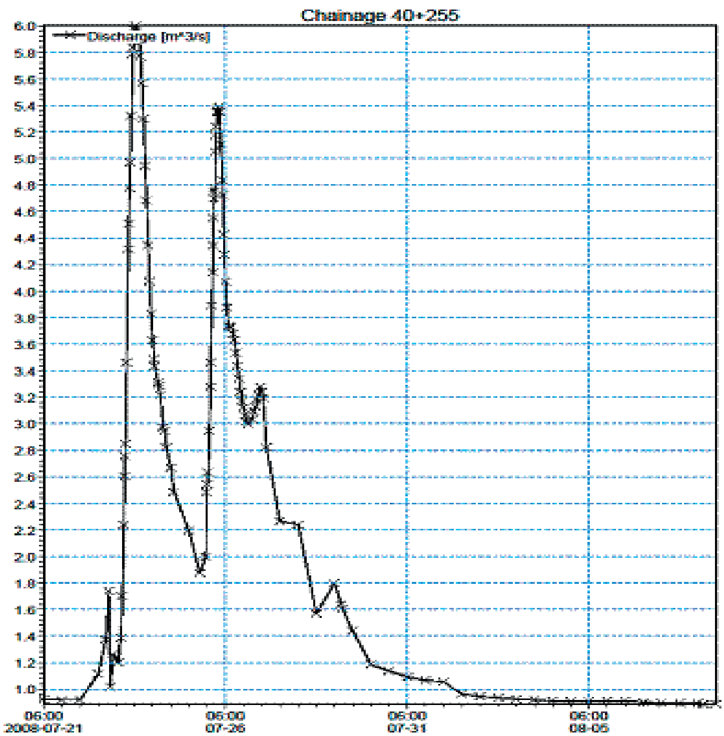

Figure 9. Flood evacuation hydrograph

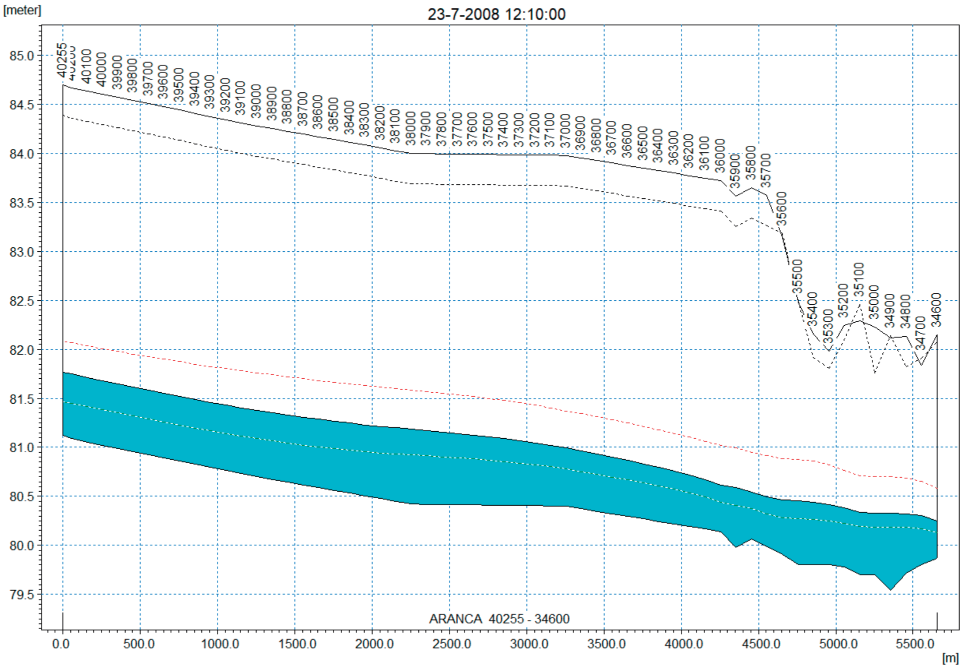

Figure 10. Longitudinal profile whit water level

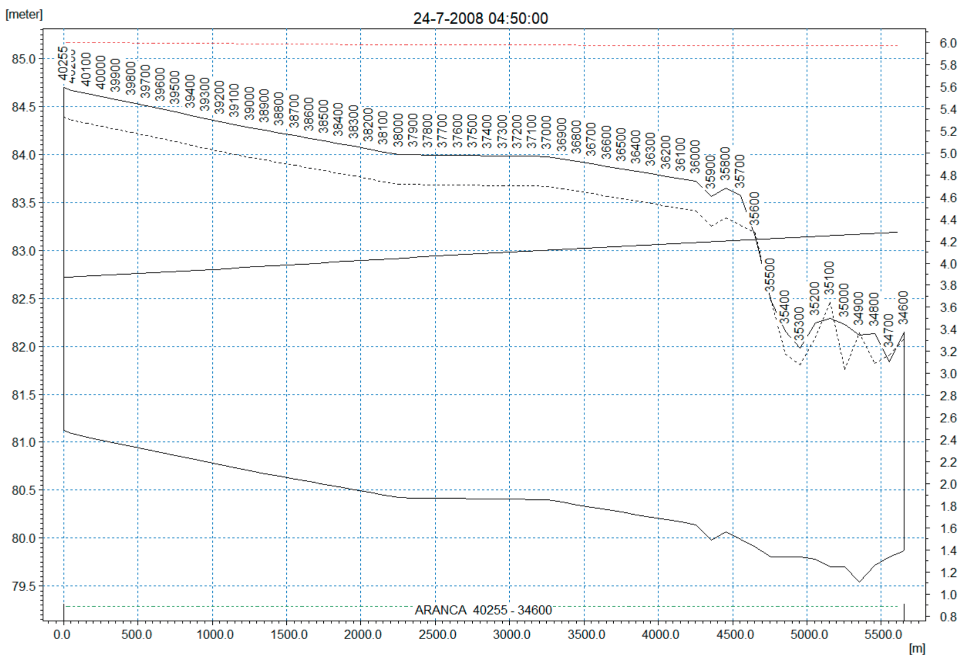

Figure 11. Longitudinal profile with discharge

By carrying out the MIKE11 program, a longitudinal profile of the canal was obtained with the water level for the entire period. (Figure 10) respectively with the discharge for the entire period (Figure 11). From Figures 10 and 11, it follows that for the hydrograph of the inflows introduced in 2008 on the Aranca Canal, the maximum water transport capacity of the canal was not exceeded, with the flood risk occurring for flows greater than those considered.

CONCLUSIONS

The model simulation using the MIKE 11 program showed that the Aranca Canal can manage a maximum flow of 58 m³/s, at which the town of Sânnicolau Mare does not experience flooding. This indicates that under current hydrological conditions, the canal is adequately designed to handle major flood events. However, changes in climate patterns or land use may alter these conditions, requiring periodic reassessment.

The model can provide real-time data or predict water levels and flow rates along the canal for any measured or hypothetical inflows from future flood events. Authorities can manage defense or prediction methods for any high-water events real-time flood forecasting, and optimization of irrigation water distribution. By leveraging MIKE 11's predictive capabilities, stakeholders can enhance proactive flood mitigation strategies and ensure efficient water resource management in the region.There are usually constraints in the modeling process due to the availability of data regarding the roughness of the canal bed along the entire studied section.

Future studies should compare MIKE 11 results with real flood events observed in the past to validate the model's accuracy. The Danish Institute of Hydraulics (DHI) simulates the flow in rivers with the MIKE 11 program and creates models.

ACKNOWLEDGEMENTS

Thanks to the project: Development of knowledge centers for lifelong learning through the involvement of specialists and decision-makers in flood risk management, this activity can be possible using advanced hydroinformatics tools, AGREEMENT NO. LLP-LdV-ToI-2011-RO-002/2011- 1-RO1-LEO05-5329, was funded with the help of the European Commission.

REFERENCES

Biali, G., & Cojocaru, P. (2022). GIS hydrological modeling in an agricultural river basin with high potential for water erosion. *Scientific Papers – Series E: Land Reclamation, Earth Observation & Surveying, Environmental Engineering, 11*, 418–425.

Damian, G., Pricop, C., & Stătescu, F. (2022). The study of hydrological regime modeling using HECRAS model: Case study river basin Bahlueț. *Scientific Papers – Series E: Land Reclamation, Earth Observation & Surveying, Environmental Engineering, 11*, 338–343.

David, I. (1984). *Hidraulics* [In Romanian] (Vol. 2, pp. 42–73). Institutul Politehnic Traian Vuia, Timișoara.

Kumar, PKumar, PrashantDebele, SEDebele, Sisay E.Sahani, JSahani, JeetendraRawat, NRawat, NidhiMarti-Cardona, BMarti-Cardona, BelenAlfieri, SMAlfieri, Silvia MariaBasu, BBasu, BidrohaBasu, ASBasu, Arunima SarkarBowyer, PBowyer, PaulCharizopoulos, NCharizopoulos, NikosGallotti, GGallotti, (2021). Nature-based solutions efficiency evaluation against natural hazards: Modelling methods, advantages and limitations. *Science of the total environment, 784,* DOI10.1016/j.scitotenv.2021.147058.

Lagos, MS; Muñoz, JF; Suárez, FI; Fuenzalida, MJ; Yáñez-Morroni, G; Sanzana, P (2024). Investigating the effects of channelization in the Silala River: A review of the implementation of a coupled MIKE-11 and MIKE-SHE modeling system. *Wiley interdisciplinary reviews-water, 11*(1), Special Issue SI, DOI10.1002/wat2.1673.

Nannawo, ASNannawo, Abera ShiguteLohani, TKLohani, Tarun KumarEshete, AAEshete, Abunu AtlabachewAyana, MTAyana, Melkamu Teshome (2022). Evaluating the dynamics of hydroclimate and streamflow for data-scarce areas using MIKE11-NAM model in Bilate river basin, Ethiopia. *Modeling earth systems and environment, 8*(4), 4563-4578, DOI10.1007/s40808-022-01455-x.

Pareta, KPareta, Kuldeep (2023). Hydrological modelling of largest braided river of India using MIKE Hydro River software with rainfall runoff, hydrodynamic and snowmelt modules. *Journal of water and climate change, 14*(4), Page1314-1338, DOI10.2166/wcc.2023.484.

Paudel, SPaudel, SabinBenjankar, RBenjankar, Rohan (2022). Integrated Hydrological Modeling to Analyze the Effects of Precipitation on Surface Water and Groundwater Hydrologic Processes in a SmallWatershed. *Hydrology, 9(*2), DOI10.3390/hydrology9020037.