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DETERMINATION OF THE FLOOD DEFENSE EMBANKMENT ELEVATION CROWN, USING ADVANCED HYDRODYNAMIC MODELING

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Abstract

The accelerated economic and social development of some urban areas has as result the construction of different social and economic objectives in areas with a potential flood risk too, although the good practices prohibit this thing. Thus, the application of different structural and non-structural measures with the defense role against flooding those areas, is necessary. The national management strategy of the flood risk provides the application of some policies, procedures and practices in order to reduce this risk, so that all the citizen to develop in a sustainable social environment. This paper has as purpose the determination of the height of this type of hydrotechnical works (embankments) with defense role against floods of social as well economic objectives. Considering that these embankments have as purpose not only the defense against floods of an inhabited area, but also the protection of some natural water resources, the work can be included in the field of environmental problems. Very important and an additional argument to the environmental problem is the fact that Lilieci Reservoir that represents also study area, was declared wildlife reserve and is part of the special avifauna protection area Lilieci with a total surface of over 2.6 km². More than 100 species of birds, live in the over 10 hectares of reeds and rushes on the territory of the reservation and on the water surface.
Many areas of our country declared natural reserves are in danger or even destroyed year by year due to devastating floods. Thus, it is necessary to take protection measures for these areas so particularly important for the biodiversity conservation. This document presents step by step the determination of the elevation crown of these works with the defense role against floods on the natural habitat, using the advanced hydraulic modelling.

Keywords: biodiversity conservation, climatic changes, environmental protection, flood risk, quasi-2D hydraulic modelling

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1. Introduction

Recently, more and more specialists from various specialized sectors, are discussing the problem of the climatic changes and their effect on different fields. Indeed, the economic and industrial development from the last hundred years, which was based on the excessive consumption of hydrocarbons, determined considerable CO_2 emissions in the atmosphere, having the effect of global warming, resulting in climatic changes throughout the Earth (Qi et al., 2019; Stentoft et al., 2021; Toaca et al., 2012).

The climate changes have had a considerably effect also on the hydrological regime from our country. Thus, the rains have acquired a torrential character, their intensity being accentuated very much, resulting in the so-called rapid floods that have catastrophic effects on the areas where they overflow (Bartha et al., 2014; Boariu, 2016; Boariu and Bofu, 2016).

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Some of these areas represent future residential fields or even are part from the protected areas, being declared natural reserves and have as purpose the biodiversity protection and conservation. It is discussed the problem of the protection and of defending these areas against catastrophic floods that may occur during periods of the year with heavy rainfall or during the sudden melting of snow. The protection of these objectives can be made both by taking structural measures as well as non-structural measures for flood defense. It is recommended to apply both of the measures for a higher degree of protection. The non-structural measures prevent generally the catastrophes by various means, such as restricting the building permits in the areas with high flood risk, by well-developed hydrologic forecasts, by the land management, by anti-erosion measures applied at the level of the hydrographic basin and last but not least, by insuring the goods in the area exposed to risk. The structural measures are those, which include all the hydrotechnical works and constructions, with the purpose of protection against floods (Boboc et al., 2018; Cercel et al., 2015).

In this case, there will be applied structural measures for the flood defense of the area under study and namely, flood defense embankments. It is discussed how to determine more accurately and in a short time as possible, the elevation crown of these embankments so that they withstand the fierce flash floods. The answer to our problem would be the advanced hydraulic modelling, using the latest generation software. Building a hydraulic model, one can investigate in a very short time, the results obtained for different flows as well as the degree of the protection insurance, offered by the present embankments as well as the proposed ones.

2. Material and methods

The soft used to determine the elevation crown of the defense embankments is Mike 11, which is a professional engineering software for simulating flow, sediment transport and water quality in rivers, canals and other water bodies. The MIKE 11 hydrodynamic module (HD) uses an implicit, finite difference scheme for the computation of unsteady flows in rivers and estuaries (Bartha et al., 2012; Danish Hydraulic Institute, 2017a, 2017b; Waldman et al., 2017). The mathematical equations underlying modeling, are the Saint-Venant equations in one-dimensional system Eqs. (1-2) (Bartha et al., 2012).

- One-dimensional system:

Continuity equation:

$$\frac{\partial \zeta}{\partial t} + \frac{\partial (uh)}{\partial x} = 0 \tag{1}$$

Momentum equation:

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + g\frac{\partial \zeta}{\partial x} + c_f\frac{u|u|}{h} = 0 \tag{2}$$

where: y - the water local depth; A - the cross section area; B - the width of the water surface; Z - water level (compared to baseline), defined as: $\zeta = h+z_b(m)$; h - the local water depth (m); z_b – thalweg local level (m); u - flow velocity (m/s) and c_f - the coefficient of friction (dimensionless).

MIKE 11 software is designed as an interface that includes several editors (Danish Hydraulic Institute, 2017a, 2017b).

MIKE 11 allows for two different types of bed resistance descriptions: Chezy and Manning, respectively.

The description is set in the Hydrodynamic Editor under the Bed Resistance tab. For the Chezy description, the bed resistance term in the momentum equation is described as given by (Eq. 3). For the Manning description, the term is given by (Eq. 4).

$$\frac{qQ\|Q\|}{C^2AR} \tag{3}$$

where: Q is discharge; A is flow area; R is the resistance or hydraulic radius.

$$\frac{qQ\|Q\|}{M^2AR^{4/3}} \tag{4}$$

The Manning number, M, is equivalent to the Strickler coefficient. Its inverse is the more conventional Manning's n. The value of n is typically in the range 0.01 (smooth channel) to 0.10 (thickly vegetated channel). The corresponding values for M are from 100 to 10. The Chezy coefficient is related to Manning's n by means of Eq. (5): (Danish Hydraulic Institute, 2017a, 2017b).

$$C = \frac{R^{1/6}}{n} = MR^{1/6} \tag{5}$$

The hydraulic model will be made using the cross sections measured through the riverbed. We will first create the one-dimensional hydrodynamic model based on which we will analyze the results, in our case, the water level. The input data will be considered the calculation and verification flow rates according to the hydrological studies for the studied area. Table 1 shows the main editors of the MIKE 11 software.

If the water level will exceed the crown of the defense works, then we must determine also the water depth resulted from the flooded meadow. In this case, a single one-dimensional hydraulic model is not enough. We will build a quasi-2D hydraulic model that can simulate also the flood plains, in case that the crown of the embankments is exceeded by the water level. It will be possible to determine the depth of the water as well as its level behind the embankments, including the assessment of the flood risk on the environment.

Table 1. Editors includes in Mike 11

Simulation editor	Hydrodynamic editor
Rivers Network editor	Advection - dispersion editor
Cross section editor	WQ, ECO - Lab editor
Boundary editor	Sediment Transport editor
Rainfall - runoff editor	Flood Forecasting editor

Very important are also other resulted hydraulic parameters such as the water speed, which is necessary for the assessment of the flood risk or the transport capacity. Based on the hydraulic model, can be performed simulations and forecasts using simultaneously also other modules such as investigations related to the quality of the water, pollutant dispersion, sediment transport, all being included in the specific problems of the environmental protection.

3. Case study

The case study is located in the northeastern part of Bacau City, Romania, along Bistrita riverbed, downstream of Lilieci accumulation, as shown in Fig. 1. This is a protected area of national interest that corresponds to the class IV (natural reserve of avifauna type). The present work has as purpose the determination of the elevation crown of the defense embankments against floods based on the levels in Bistrita River downstream of Lilieci accumulation, for flows with certain calculation probabilities.

The levels in the riverbed have been determined, according to the flow with the probability of 1% having the value of 1900 cbm/s, the flow with the probability of 0.5% having the value of 2215 cbm/s, the flow corresponding to the value of the maximum capacity of discharge from Lilieci lake having the value of 1960 cbm/s as well as the flow with the probability of 0.1% having the value of 3585.3 cbm/s.

For the study area, topographic measurements were made for the determination of the cross sections, necessary for building the hydraulic model. On the right bank of Bistrita River, there is already a defense embankment against floods. In the future, it is proposed to build a new defense embankment against floods on the left bank of Bistrita River, downstream of Lilieci accumulation, which will protect against floods a future area of community interest, as shown in Fig. 2.

The problem is to determine the elevation crown of the new proposed embankment on the left bank of Bistrita River, so that this to not be exceeded by the extreme floods. It will be also determined the protection degree of the present embankment on the right bank, namely at which flows resists without exceeding the crown.

The modelling will be made in permanent motion, namely constant flows, introduced in the model at the upstream end. The cross sections will be divided in the minor riverbed, respectively the major left riverbed and major right riverbed. The roughness coefficient „n" in the minor riverbed, after Manning, was considered n = 0.05, in the idea of taking a safety margin, regarding the existence in the riverbed of some big river boulders, trees, rich vegetation that increases the roughness coefficient. Regarding the roughness coefficient from the major riverbed, this was considered according to the use of the land on the two banks, consulting the orthophoto plans corresponding to the studied sector

Fig. 1. Case study location

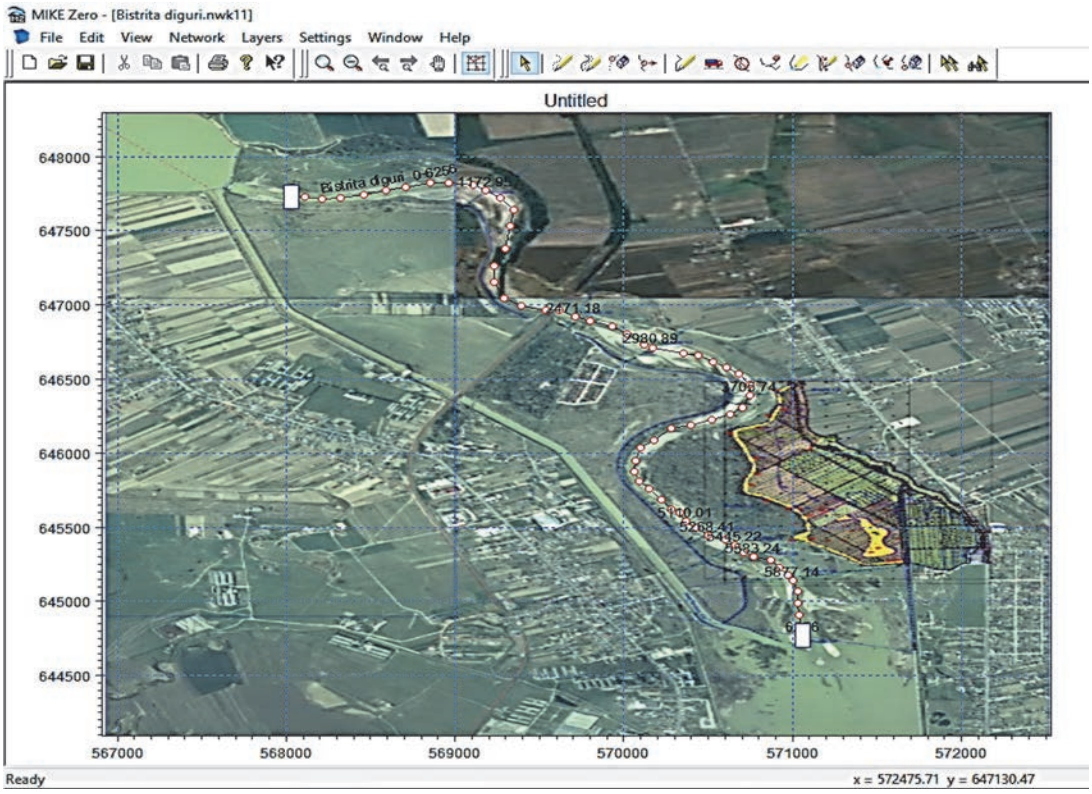

Fig. 2. Area of study

Thus, for the forest was considered the roughness coefficient n= 0.15, for orchards, n=0.10, for unproductive land n=0.07, for grasslands n=0.05 and for arable land n=0.05 (Hraniciuc et al., 2016, 2017a, 2017b). It will be create first a unique one-dimensional 1D hydraulic model, based on the cross sections measured through the riverbed. If the crown of the proposed embankment is not exceeded by the water level correspondingly to the probabilities taken in account, then the study is considered completed. But if for one of the flows, the water level exceeds the elevation crown of the proposed embankment, the building of quasi-2D model is needed in order to be able to analyze the effects of the flood wave on the protected area.

Once we have chosen the type of the model (hydrodynamic in our case), we practically go the basic stages to start a simulation. (Hraniciuc et al., 2016, 2017a, 2017b). The first stage involves editing the river networks. The river networks editor has two main functions:

- introduction and editing of the network;
- overview of all model information from the current simulation.

The network editing includes:

- digitization of the river networks and their connection;
- defining the hydraulic structures on each river;
- defining the entry points within a river basin.

The digitization of the network was made based on the *georeferenced orthophoto* plans from the respective area, as shown in Fig. 3. The built hydrographic network is indicated by the dotted line and the black numbers present on it represent the chainage where the cross sections are located.

The second stage represents the editing of the cross sections. The editor of the cross sections manages all the cross sections stored, but allows also to be viewed (Hraniciuc et al., 2016, 2017a, 2017b). Each cross section is unique and is identified by the following three keys:

- the name of the river;
- topographic identification;
- chainage;

There are two types of data on the cross sections:

- gross and unprocessed measured data;
- processed derived data.

Fig. 4 represents the positioning in the plan of the cross sections and in Fig. 5 is presented the visualization of a section and the characteristic gross data. Fig. 5 shows both the raw data of a cross section, such as the coordinates of each point, the roughness coefficient in both the minor and major riverbed, chainage, present on the left side of the figure and the allure of the cross section on the right side drawn with black line. The red vertical lines divide the section into minor riverbed and major riverbed using some markers and the blue lines indicate the variation of the roughness coefficient over the entire section.

The next stage is the editing the boundary conditions. This editor is used to specify the boundary conditions for a certain model from MIKE 11. It is used not only to specify the usual boundary conditions like the water level, the inlet flow rates or the inlet hydrographs but also to specify the lateral flows, outflows along a river, concentration of solutions in a hydrograph, different meteorological data and certainly, boundary conditions used in the connection with the structures applied to the model.

The introduction of boundary conditions is very important. We cannot practically run the modelling without having introduced these conditions. In Fig. 6 can be seen the file of the boundary conditions for the case study.

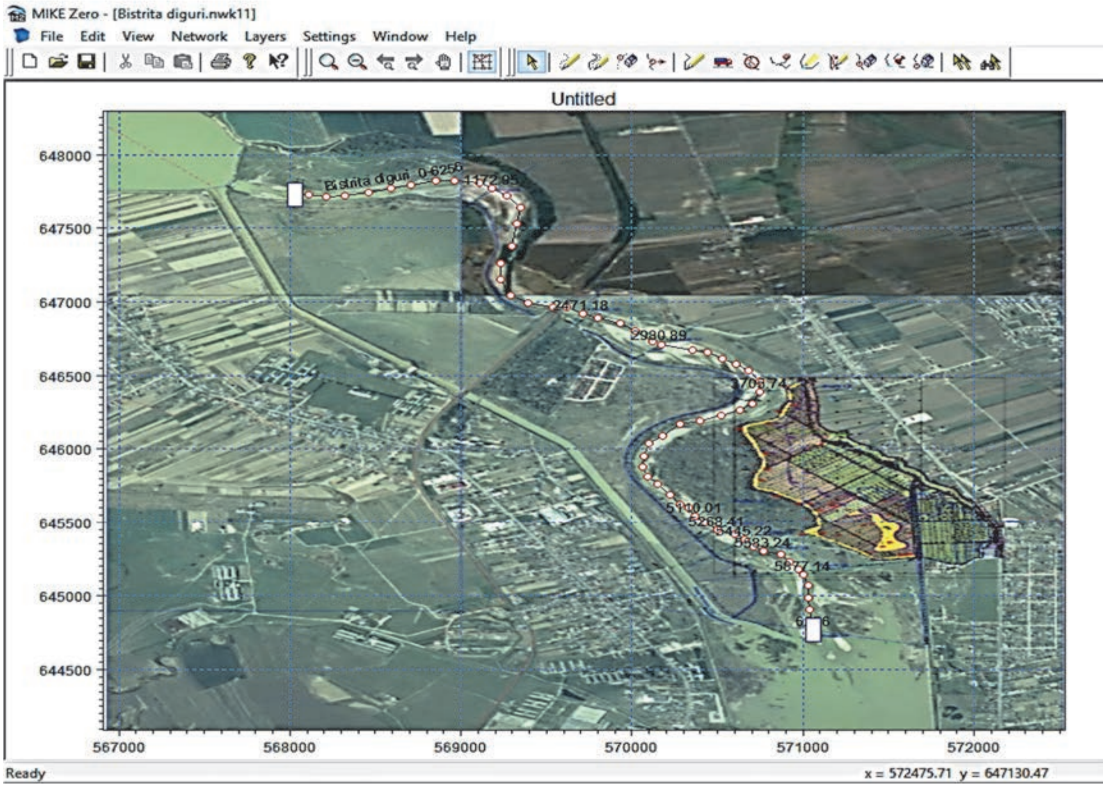

Fig. 3. The hydrographic network (downstream sector of Lilieci accumulation)

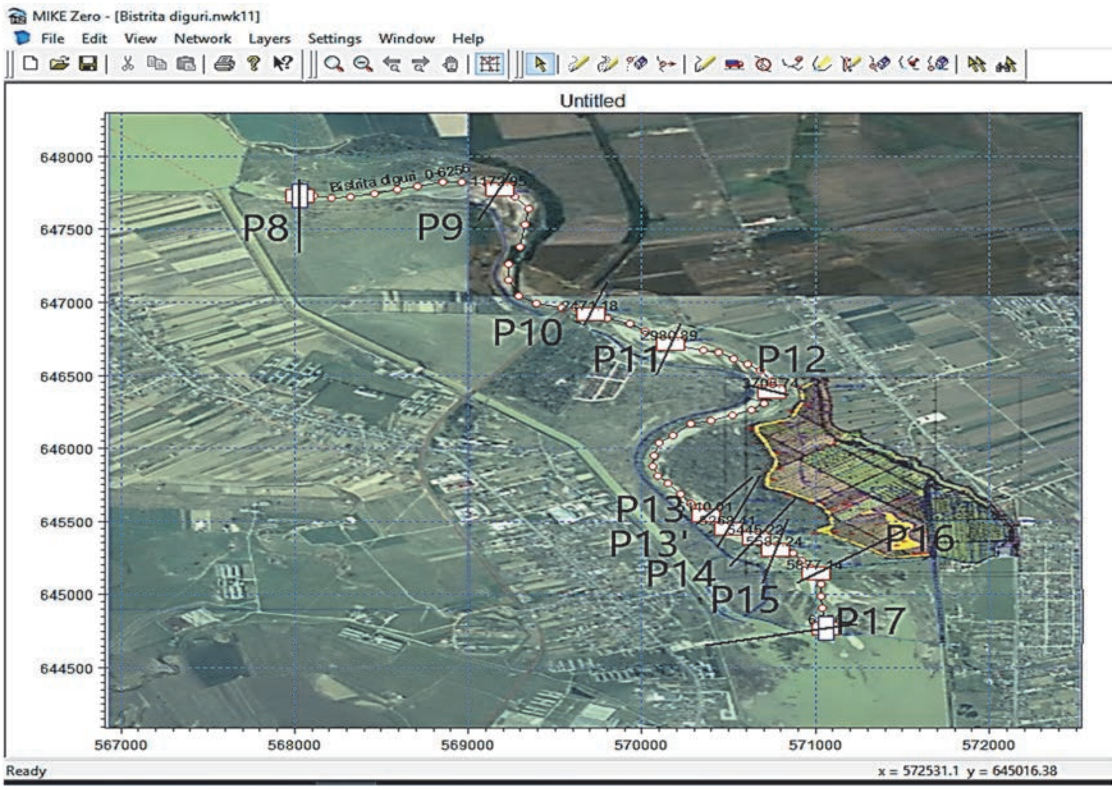

Fig. 4. Positioning of the cross sections (P8-P17)

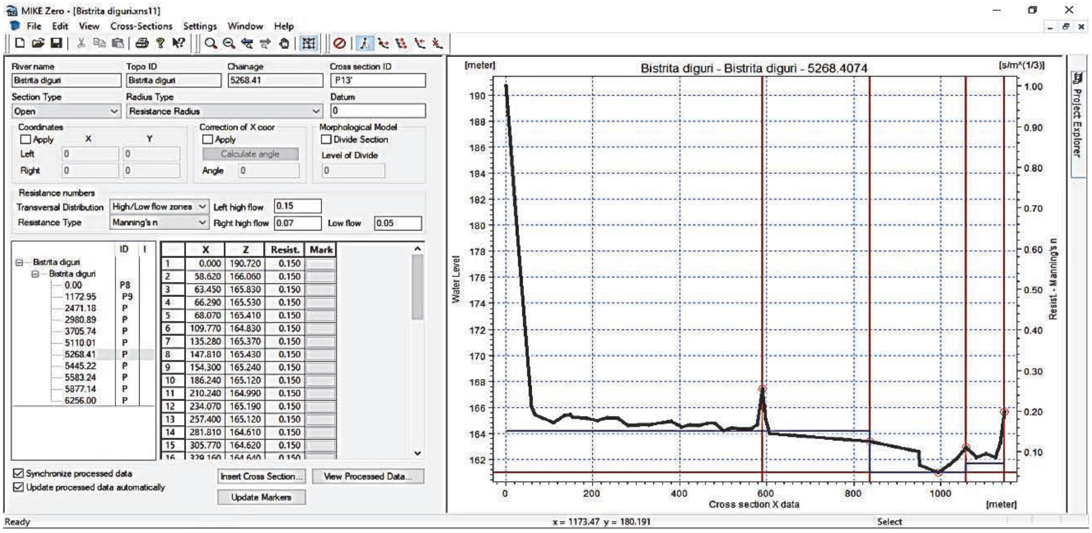

Fig. 5. View on the gross data of a cross section

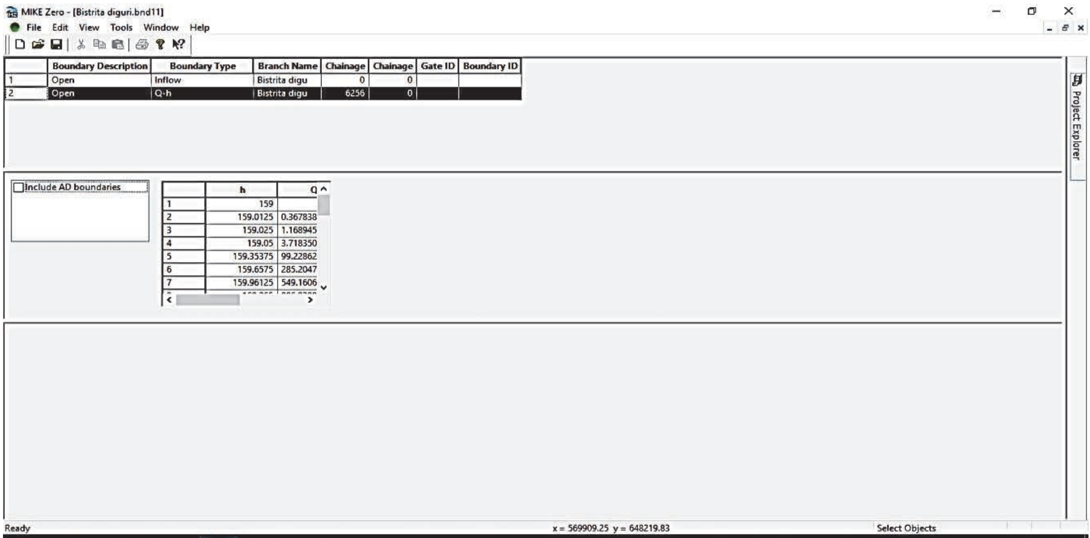

Fig. 6. Boundary condition in the relation flow-level

The last stage involves editing the hydrodynamic model. This editor is used for setting the additional data used in simulation. Most of the parameters in this editor have unspecified values and, in most cases, it is enough to get satisfactory simulation results. Among the additional parameters, we can list: initial conditions such as the level, the flow, the depth, conditions regarding the influence of the wind, of the waves, resistances in calculations, different coefficients, maps, etc. In Fig. 7 can be observed the window for editing the initial conditions, which in the present case are null. Was not introduced any initial flow rate through the riverbed, and no initial water depth (Hraniciuc et al., 2016, 2017a, 2017b).

After introducing these last conditions, practically one can start the simulation, if we don't have any errors introduced in the other editors.

4. Results and discussion

The simulation was made in permanent motion, namely, constant flows were introduced as boundary conditions, for the probabilities reminded in the paragraphs. First, we interpret the results for the one-dimensional 1D hydraulic model, considering the proposed embankment for the left bank of the river (Hraniciuc et al., 2016, 2017a, 2017b). Have been introduced in the model 11 cross sections designated P8, P9, P10, P11, P12, P13, P13', P14, P15, P16 and P17. Thus, will be analyzed the water level resulted for each flow, in longitudinal profile an in each cross section. Will compare these levels with the elevation crown of the proposed embankment on the left bank, but also with that on the right bank, following if they are exceeded by the resulted levels. Thus, for the flow with the flow rate with the probability of 1%, Q=1900 cbm/s, in longitudinal profile, the water level is shown in Fig. 8.

Above the blue contour that represents the water level, the line of the right bank can be observed (immediately above the water level, figured with continuous line, and the line of the left bank much higher with discontinued line). One can observe that none of the banks is exceeded by the water level.

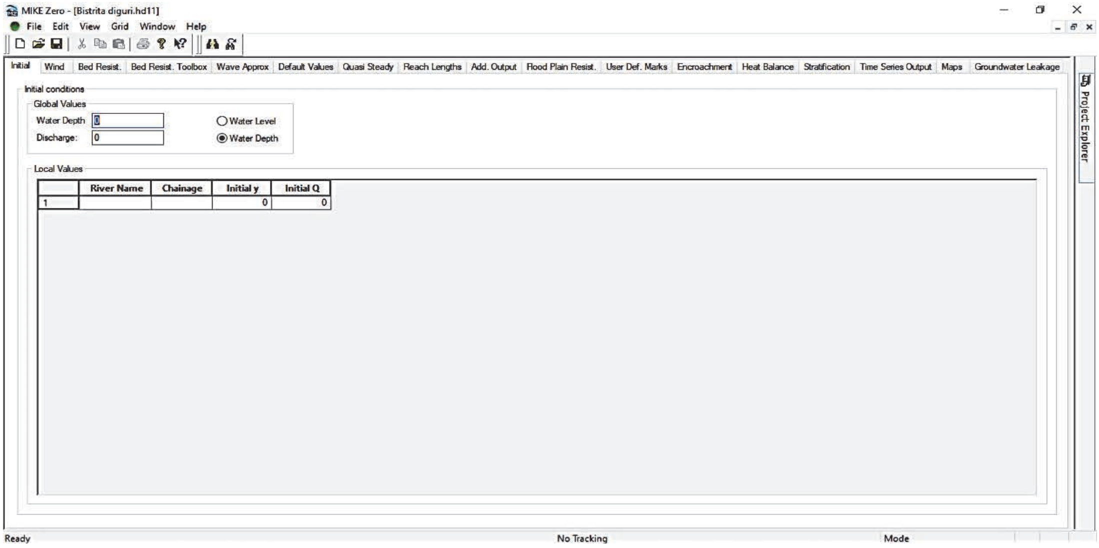

Fig. 7. Initial conditions

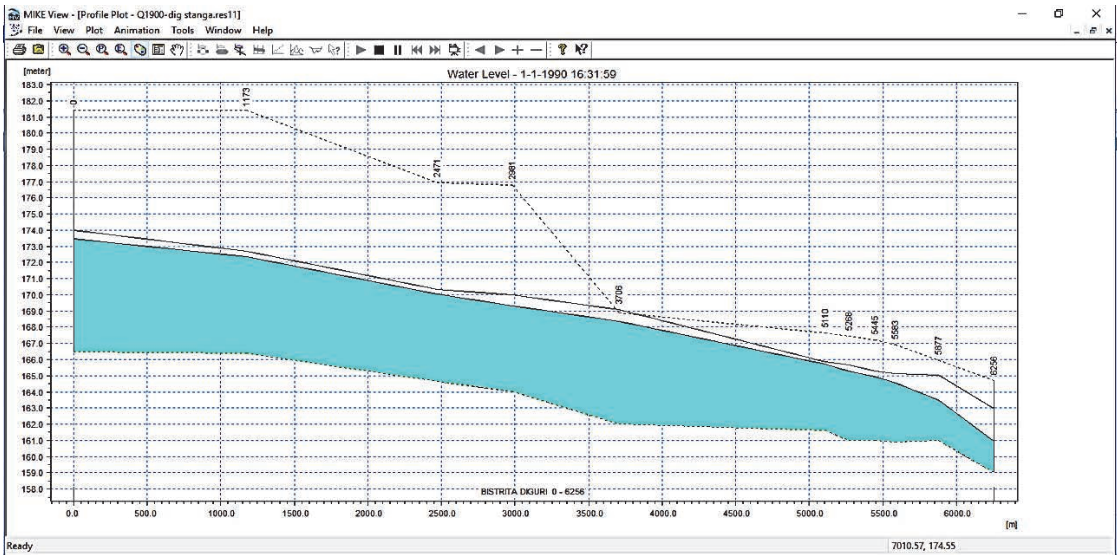

Fig. 8. The free water level in longitudinal profile (Q=1900 cbm/s)

In Fig. 9, we will show as example, the water level from the section P14, where the two embankments on the left bank, respectively the right bank can be observed. In Fig. 10 can be observed the maximum water levels in all the sections of the model.

The legend shows the water level in each cross section indicated by the chainage of the section, from 0 for section P8 to kilometer 6256 for section P17, in chronological order. You can also see the color associated with each cross section corresponding to the lines with the water level resulting from the graph. As it can be seen in the situation with the proposed embankment on the left bank, for the flow with the probability of 1% with Q=1900 cbm/s, the free water level doesn't exceed the crown of the existent embankment on the right bank and doesn't exceed the crown of the proposed embankment on the left bank of the river. The proposed embankment on the left bank of the river is included in the model in the cross sections from P12 up to P15 inclusive.

For the flow rate Q=1960 cbm/s resulted from the modelling that neither the crown of the embankment existent on the right bank, nor the crown of the proposed embankment on the left bank, are exceeded by the water level.

For the flow with the probability of 0.5%, with Q = 2215 cbm /s, Fig. 11 shows the water level resulted in the longitudinal profile.

For the flow with the probability of 0.5% having Q = 2215 cbm/s, from the analysis of the results, it was observed that the maximum water level doesn't exceed in any section the crown of the proposed embankment on the left bank of the river. Thus, the water level is very close to the elevation crown of the proposed embankment in section P12, as it can be seen in Fig. 12, so there is no danger level. (Hraniciuc et al., 2016, 2017a, 2017b).

Regarding the crown of the existent embankment on the right bank, this is exceeded by the maximum water level in the sections P9, P10, P13.

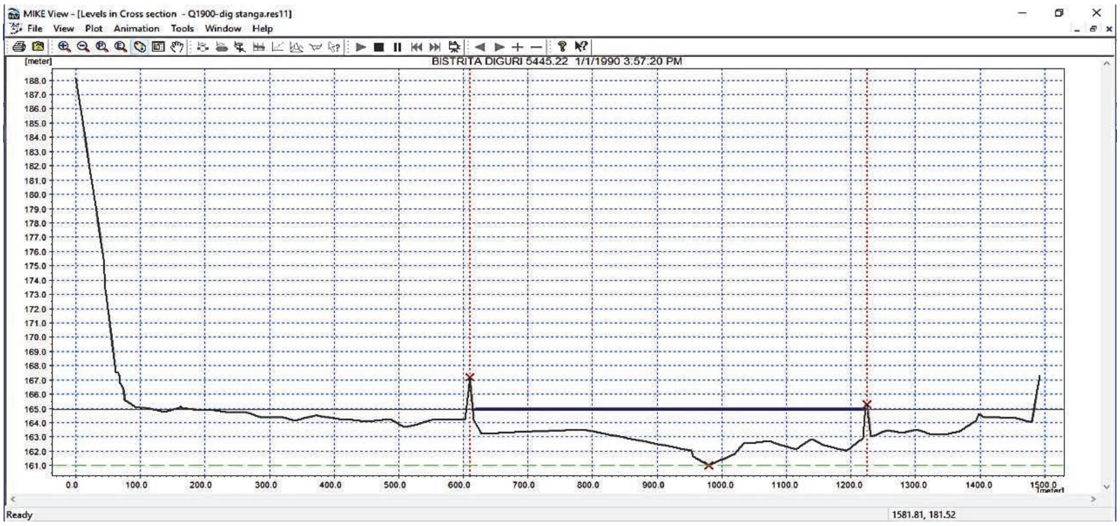

Fig. 9. The free water level in the section P14 (Q=1900 cbm, /s) - doesn't exceed the crown of the embankments

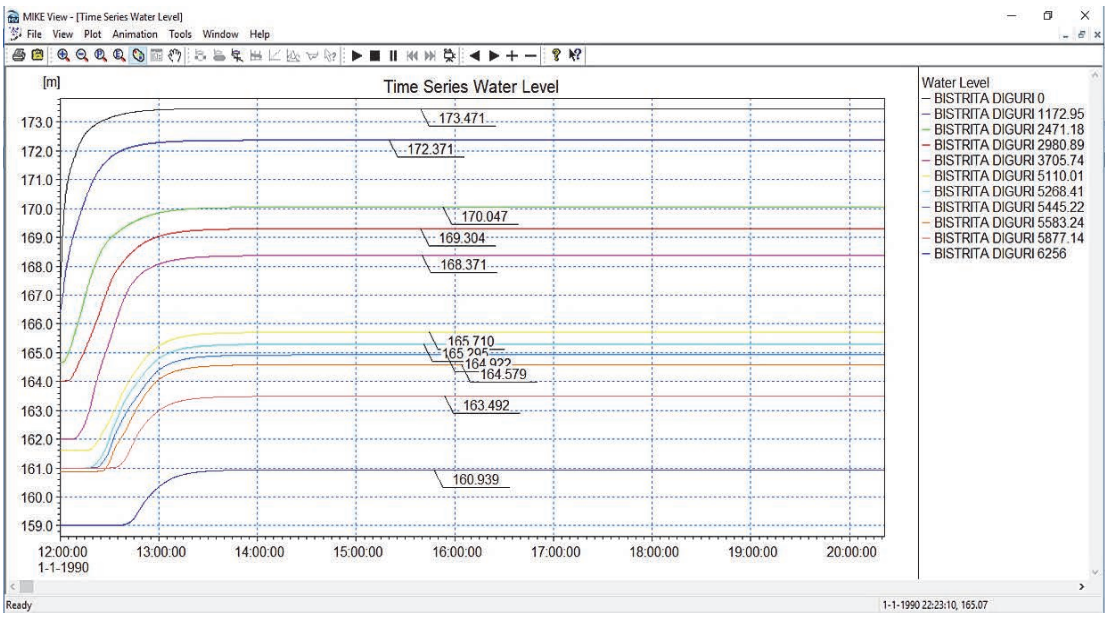

Fig. 10. The maximum water levels in all sections from P8 up to P17 (Q=1900 cbm/s) - regime arranged with the proposed embankment on the left bank

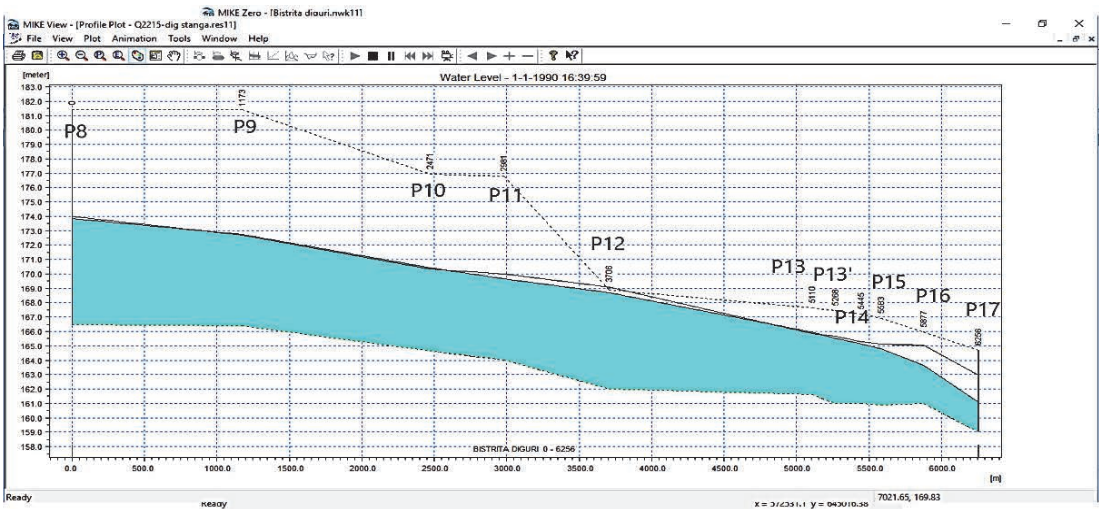

Fig. 11. The free water level in longitudinal profile (Q=2215 cbm/s)

Next, we will analyze the results, in case of building a new quasi-2D model too. This model is necessary to be built in case that we have floodplains, like the land behind a flood defense embankment, as in Fig. 13. The 1D image shows how to represent a simple one-dimensional hydraulic model, based only on simple cross sections. This model cannot simulate the flow in floodplains. The quasi-2D image shows how the quasi-2D hydraulic model is represented, and is a model that can simulate flow in a floodplain as represented in the middle image. The 2D image shows how to represent a two-dimensional hydraulic model, which is based on a numerical terrain model for simulation and not on cross sections as in 1D and Quasi-2D. The 1D-2D image shows a combined hydraulic model 1D with 2D, applied on a sector where both the data from the cross sections and the data from the numerical terrain model are used. The combined models are used if in a region we do not have exact data from the minor riverbed and then we use the cross sections, and in the major riverbed we use the data from the numerical model of the terrain.

In case of the quasi-2D model, two separate connections will be built. One will represent the main river, the other will represent the floodplain behind the proposed embankment. They will be connected at the level of the crown of the embankment of a channel that will allow the water to pass over the embankment only in case that the crown will be exceeded by the water level. The resulted network can be observed in Fig. 14. Practically a second connection was built containing the floodplain behind the embankment on the left bank.

Thus, the section behind the embankment will be filled with water only in the case that the embankment is exceeded by the water level from the main river. One simple 1D model cannot model this passage over the crown of the embankment and to show how deep the water would be in each section, so the construction of the quasi-2D model was necessary.

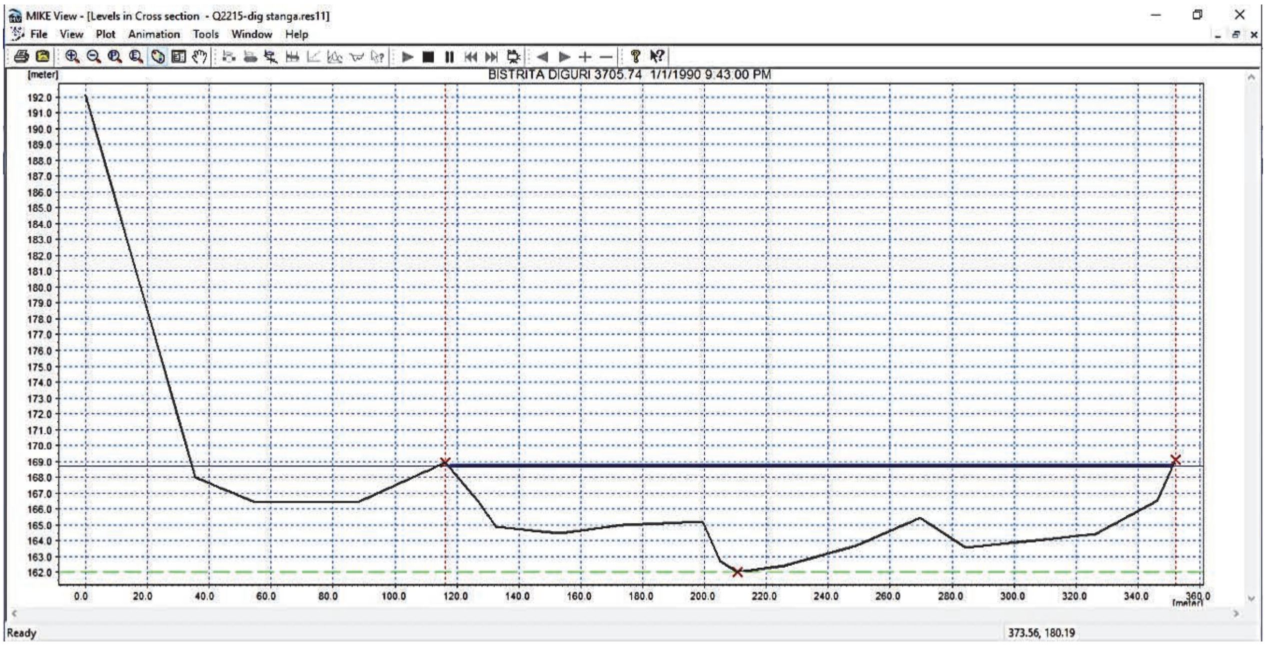

Fig. 12. The free water level in the section P12 (Q=2215 cbm/s)

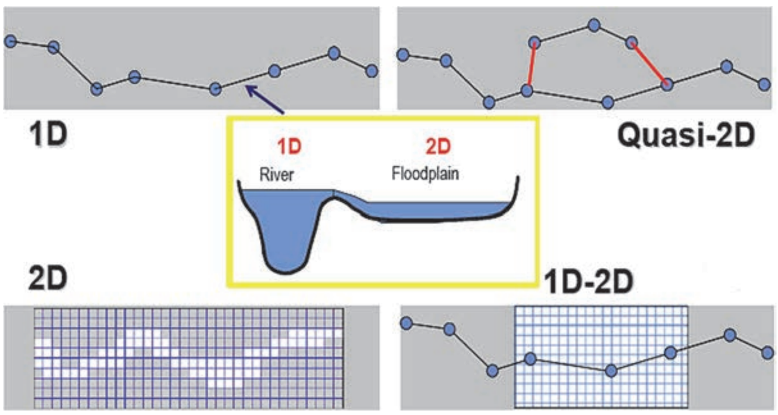

Fig. 13. Types of numeric models used for flood modelling

Following the simulation for the quasi-2D network, it was noted that for the flow with the probability of 1% as well for the flow with the probability of 0.5%, the crown of the embankment on the left bank is not exceeded. For the flow with the probability of 0.1% having the value Q (0.1%)=3585.3 cbm/s, the results of the modelling were centralized in the Table 2. For the flow with the probability of 0.1% it can be seen that the only one section where the crown of the embankment is exceeded, is in section P12. The result is a difference of 77 cm between the maximum water level resulted in Bistrita River and the crown of the embankment, the water overflowing the embankment.

This thickness of the overflowing blade of 77 cm, could cause a big breach in the body of the embankment on a significant length, considering that between the section P12 and P13 which is quite large distance, we don’t have any information about the level of the crown of the embankment (no other section). In the other sections, the crown of the embankment is not exceeded by the water level, the minimum difference being 90 cm. In Table 3 are shown the maximum water levels, the lowest elevations of the land and the depths resulted in the corresponding sections behind the embankment (flooded plain).

It can be seen that a water depth between 3 m and 4.5 m results, which means a very high risk of floods for the land behind the embankment. The results can be also seen in longitudinal profile as in Figs 15 and 16.

Fig. 14. Quasi - 2D network

Table 2. The results in Bistrita River for Q (0.1%)=3585,3 cbm/s

Cross section	*Chainage*	*Heights of the embankment crown*	*Water level in Bistrita River*
P12	3705.74	168.90	169.671
P13	5110.01	167.62	166.708
P13’	5268.41	167.44	166.274
P14	5445.22	167.21	165.913
P15	5583.24	166.94	165.484

Table 3. The results with the water level behind the embankment for Q (0.1%) = 3585.3 cbm/s

Cross section	*Chainage*	*The lowest level of the land (m)*	*Maximum water level (m)*	*Maximum water depth (m)*
P12	12	166.42	169.779	3.359
P13	1296.95	164.72	167.767	3.047
P13’	1440	164.20	167.760	3.560
P14	1640	163.68	167.755	4.075
P15	1750	163.25	167.754	4.504

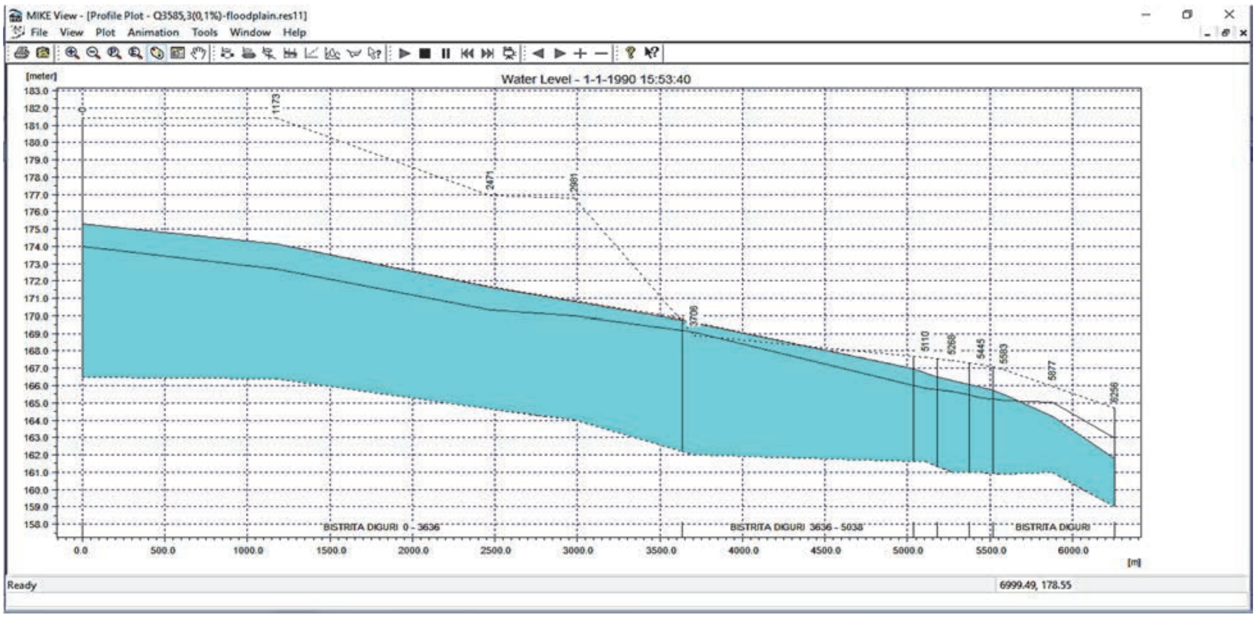

Fig. 15. The maximum water level in Bistrita River for Q 0.1% in longitudinal profile

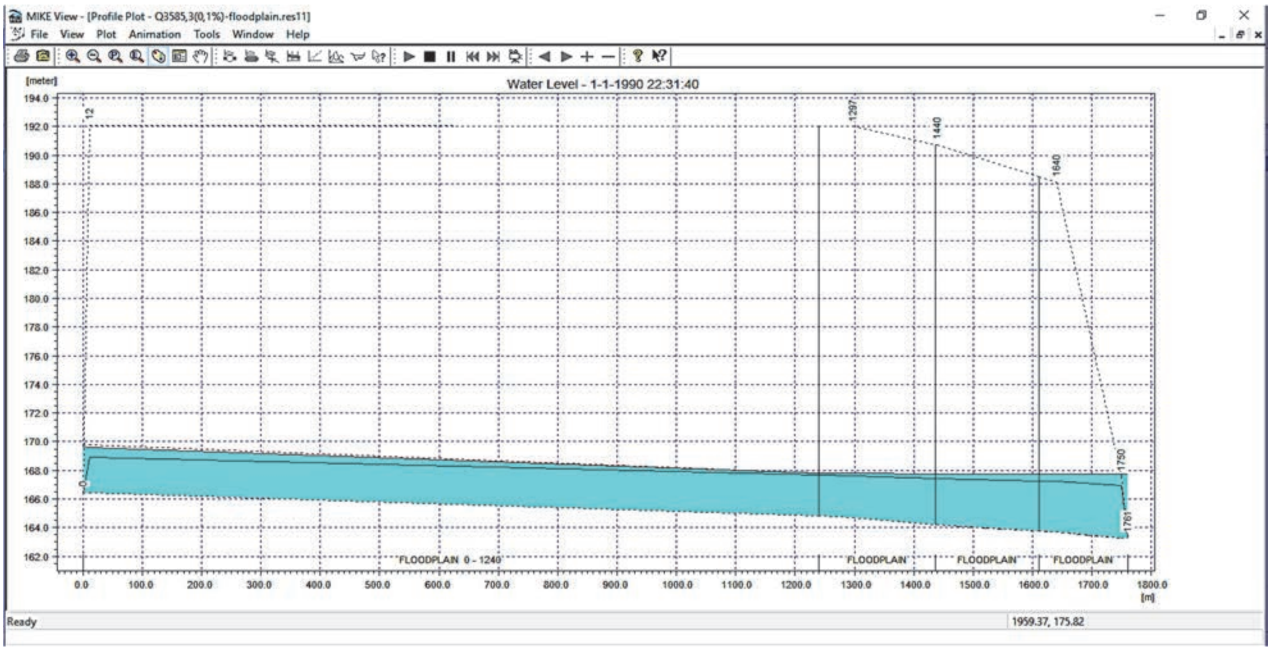

Fig. 16. The maximum water level behind the embankment (the floodplain between the sections P12-P15) for Q 0.1% in longitudinal profile

5. Conclusions

Due to the intensive increase of the volume of waste, of air and water pollution, the environmental problems should be treated with more interest in the future by specialists in all fields. The climatic changes cause also more and more imbalances at the level of the planet. One of the effects is the change of the hydrologic regime. Thus, in some regions, the rains became more aggressive in terms of intensity, resulting in massive hydrologic runoff. These runoffs lead inevitably to floods that can cause major flooding of the areas with high risk for this type of hazard. We can avoid in such way a social, economic and environmental risk.

This document has as purpose the determination of elevation crown for the defense works against floods in a region that was declared wildlife reserve. Thus, on the sector of Bistrita River, downstream of Lilieci accumulation, from Bacau County, on the left bank of the river was proposed the building of a flood defense embankment in order to protect a land surface from the risk of floods. This defense work should resist and must not be exceeded by the water levels for flows with probabilities up to 0.1%, namely the flow that can occur once every thousand years.

In order to determine the level corresponding to this flow and more than this, the volume and the depth of the water resulted behind the embankment in case that this could be exceeded, the hydraulic model was used. The hydraulic model became in the last time an indispensable tool for all specialists in this field, because the manual classical calculations have no satisfactory results in certain situations, respectively, the results based on the model are more accurate and explicit. The working time is also much shorter than the classical calculations used in the past, and so, in crisis situations, the modelling becomes even more a priority.

It can be seen from the results of the modelling, that it was possible to determine with accuracy in all sections, the water level for all the flows taken in account, as well as the protection degree of the proposed embankment. Very important, it can be seen that the water depth behind the embankment could be determined, in case that its crown was exceeded by the water level corresponding to the flow with the probability of 0.1%. The classical calculations would find these values with greater difficulty. For this, a quasi-2D model was necessary, the simple 1D models not being able to predict the water passage over the crown of the embankment.

It was found after running the program that the crown of the embankment is not exceeded by the water level corresponding to the flows with probability of 1% and 0.5%. Instead, for the probability of 0.1% occurs an exceeding of the crown of the embankment near section P12 close to section P13. Thus, in order to ensure the maximum protection degree, the crown of the embankment between the sections P12 and P13 should be raised with at least 0.5 m above the maximum water level, corresponding to the flow with the probability of 0.1% of Bistrita River.

In conclusion, the use of the modern software for hydraulic modelling, for solving such environmental problems is recommended, due to the strong tools it has, the speed of finding the results and last but not the least its explicit visualization.

References

Bartha I., Vlad L.M., Toma D., Toaca D., Cotiusca-Zauca D., (2014), Rehabilitation and extension of wetlands within floodplains of embanked rivers, *Environmental Engineering and Management Journal,* **13**, 3143-3152.

Bartha I., Marcoie N., Toma D., Toaca D., Gabor V., Molnar A.G., Lupusoru A., (2012), *The Free Level Post-Darcy Filtration Through Homogenous Media*, Conf. on Modelling Fluid Flow (CMFF'12), The 15th Int. Conf. on Fluid Flow Technologies, Budapest, Hungary, September 4-7, Conf. Proc., vol. II, 622-627.

Boariu C., (2016), Safety assurance on existing dams. Case study - Sarca Dam, *Bulletin of the Polytechnic Institute of Iasi, Hydrotechnics Section*, **62**, 59-66.

Boariu C., Bofu C., (2016), Works with a minimum environmental impact in riverbeds, *Environmental Engineering and Management Journal*, **15**, 1205-1211.

Boboc V., Sarbu G.C., Marcoie N., Toma D., (2018), *Aspects Regarding Modeling of the Flood Caused by Earth Dams Failure*, Proc. 18th Int. Multid. Sci. Geoconference SGEM 2018, vol. 18, 79-86.

Cercel P., Boariu C., Vorovei C., (2015), The rehabilitation and assurance the abandoned hydro accumulations, Case study, *Bulletin of the Polytechnic Institute of Iasi, Hydrotechnics Section*, **LXI**, 1-2.

Danish Hydraulic Institute, (2017a), MIKE 11, A Modelling System for Rivers and Channels, Reference Manual, On line at: https://manuals.mikepoweredbydhi.help/2017/Water_Resources/Mike_11_ref.pdf.

Danish Hydraulic Institute, (2017b), MIKE 11, A Modelling System for Rivers and Channels, User Guide, On line at: https://manuals.mikepoweredbydhi.help/2017/Water_Resources/MIKE11_UserManual

Hraniciuc T.A., Boariu C., Bofu C., (2016), *Calibration of Minor Bed Rivers Hydraulic Parameters Using Modern Software,* Proc. 16th Int. Multid. Sci. GeoConference SGEM 2016, Albena, vol. 1, 105-112.

Hraniciuc T.A., Cercel P., Boariu C., Bofu C., (2017a), *Creating Flood Hazard Maps Using 2D Hydraulic Models,* Proc. 17th Int. Multid. Sci. Geoconference SGEM 2017, Albena, vol. 17, 173-182.

Hraniciuc T.A., Cercel, P., Trofin F., Boariu C., Bofu C., (2017b), *Considerations on Water Storage Lakes Safety in Case of Extreme Meteorological Phenomena. Case Study - Mileanca Water Storage Lake,* Proc. 17th Int. Multid. Sci. Geoconference SGEM 2017, Albena, vol. 17, 165-172.

Qi W., Liu J., Leung F., (2019), A framework to quantify impacts of elevated CO_2 concentration, global warming and leaf area changes on seasonal variations of water resources on a river basin scale, *Journal of Hydrology,* **570**, 508-522.

Stentoft P.A., T. Munk-Nielsen T., Møller J.K., Madsen H., Valverde-Pérez B., Mikkelsen P.S., Vezzaro L., (2021), Prioritize effluent quality, operational costs or global warming? – using predictive control of wastewater aeration for flexible management of objectives in WRRFs, *Water Research*, 116960, https://doi.org/10.1016/j.watres.2021.116960

Toaca D., Bartha I., Marcoie N., Gabor V., Toma D., Lupusoru A., (2012), Effect of groundwater abstraction from wells on aquifers, *Journal of Environmental Protection and Ecology*, **13**, 764-774.

Waldman S., Bastón S., Nemalidinne R., Chatzirodou A., Venugopal V., Side J., (2017), Implementation of tidal turbines in MIKE 3 and Delft3D models of Pentland Firth & Orkney Waters, *Ocean & Coastal Management,* **147**, 21-36.