



Environmental Engineering Field

PhD THESIS

- ABSTRACT -

Studies and research on the sustainable development of the Bistrița Ardeleană watercourse

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INTRODUCTION

After a long period in which the management and monitoring of water resources led to significant changes in riverbeds by promoting conventional hydrotechnical constructions for the purpose of economic development, in recent years a significant change in the approach paradigm has been observed. This new paradigm focuses on exploiting all opportunities where nature can become a partner in stabilizing hydraulic parameters and preventing floods.

The main objective of the doctoral thesis is to conduct the necessary studies and research to determine the hydrodynamic characteristics of the riverbed or the essential hydraulic parameters in order to identify alternative solutions or methods for the sustainable development of the Bistrița Ardeleană river. To achieve this objective, the research methodology includes performing and processing topographic measurements, developing orthophoto plans, sampling and processing alluvial material samples, followed by hydraulic modeling for different flow rates recorded in the riverbed downstream of the Colibița dam.

The doctoral thesis is structured into two parts: *The current state of knowledge (theoretical part)*, covered in chapters 1 and 2, and the *Personal contribution*, presented in chapters 3 to 8. The final chapter, chapter 9, contains the general conclusions, originality, and innovative elements of the research.

THE CURRENT STATE OF KNOWLEDGE

1. The current international and national situation regarding the impact of hydrotechnical facilities on the environment

The current state of complex hydrotechnical construction at the international and national level

The International Commission on Large Dams (ICOLD) defines a large dam as one that has a height greater than 15 meters or a dam with a height between 5 – 15 meters having a reservoir with a volume of 3 million cubic meters.

Complex hydrotechnical constructions can have a significant impact on society, both positive and negative, or in other words, dams present both opportunities and challenges. In developing countries, these engineering structures support the development of cities and manufacturing industries. Globally, only 37% of rivers longer than 1000 kilometres remain free-flowing throughout their length, and of these, 23% have a continuous flow to the ocean.

The current international situation of large dams and reservoirs

In 1950, there were approximately 5000 dams. By 2010, this number had increased to 32 473, and by 2020, it reached 58 713. These dams are found in over 167 countries, and the reservoirs formed by them cover an area of 335 000 square kilometres.

Out of the 292 major hydrographic basins worldwide, 190, which is 65%, are fragmented. In the northern hemisphere, almost 80% of rivers are fragmented due to dams.

Currently, approximately 48 000 large dams, most of which were built in the last 50 years, fragment the main watercourses globally.

Throughout the world, dams with a height exceeding 15 meters have reduced the average annual flow by up to 80% due to water retention for anthropic uses, increased evaporation, and infiltration.

The current national status of dams and reservoirs.

The Tăutu Mare reservoir in the Metaliferi Mountains is the oldest water reservoir and dates back to 1780, with a dam height of 23 meters.

The first large dam with multiple functions was built in the 1950s, namely the Izvorul Muntelui dam on the Bistrița River, with a height of 127 meters. Romania has a number of 1,232 dams in operation, with 246 of them listed in the World Register of Large Dams.

Out of the 246 dams, 128 have a height equal to or greater than 15 meters, while the remaining 118 have a height between 5 and 15 meters, with a reservoir capacity greater than or equal to 3 million cubic meters. The most significant and complex development on inland rivers in Romania is on the Lotru River (five dams and reservoirs, three hydroelectric power plants, and three pumping stations).

Among the 80 member states of ICOLD (International Commission on Large Dams), Romania ranks 20th globally and 9th in Europe.

The contribution of complex hydrotechnical constructions to global warming

Dams and reservoirs in tropical areas release more methane (CH₄) than those in other climatic zones.

The estimated contribution of permanent water reservoirs to global warming is measured in two studies:

- St. Louis and associates (2000) estimate that greenhouse gas emissions from all types of reservoirs could be 321 Tg C/year, equivalent to 7% of total carbon emissions from anthropogenic activities.
- the second somewhat more recent study by Barros and associates (2011) estimates somewhere around 51 Tg C/year emissions exclusively from hydroelectric reservoirs, which represents less than 1% of CO₂ production from anthropogenic activities.

The effects of climate change on complex hydropower constructions

At the European level, there have been numerous studies focusing on the impact of climate change on hydropower systems. The studies show a general decrease in hydropower potential across Europe, leading to a decrease in global energy production from 7% to 12%.

Functionalities of large dams at present

Analysing the purposes for which dams (36,259) were constructed, it is found that the primary purpose is for irrigation of agricultural land (38%), while the second purpose is for energy production (18%).

New trends in the construction and operation of hydrotechnical constructions producing electricity

Currently, three types of hydrotechnical constructions producing electricity are being promoted at the global level, these being:

- run of river type;
- micro hydropower plants
- large dams forming a reservoir of water;
- with reservoir by pumping.

Alternative technical solutions for the sustainable management of watercourses

In the last decade there has been a paradigm shift, and this is due to the problems encountered in flood management, exceptional floods as well as the focus of the Water Framework Directive with the objectives caught within it, have contributed to this rethinking of the basic concepts regarding water management. The new paradigm tries to maximize the possibility of making nature an ally in stabilizing the water level as well as in preventing floods.

The materials used in bioengineering technical solutions include: live fascines or branch, crib wall, live stakes, coir rolls, shrubs, root wad.

For some vulnerable sectors along watercourses, it is necessary to implement combined/green-grey solutions alongside these bioengineering measures. These may use the

following types of materials: rock revetments, vegetated rock rolls, vegetated rock gabions, mats reinforced with grass, or green concrete blocks.

Another solution to reduce water flows on watercourses during periods of hazardous hydrometeorological phenomena would be the construction of wet or retention basins in urban areas (cities, towns and villages). These basins store rainwater from slopes or road surfaces, etc., to be released later directly into the watercourse or into constructed wetlands near rivers.

2. The current state of the Bistrița Ardeleană water course

Brief history of the Ardeleană Bistrița water course

In the last 500 years, the Bistrița Ardeleană riverbed has undergone distinctive anthropogenic changes. These changes were the result of population growth and urban settlement development.

Over time, two extreme floods have been recorded. The first flood occurred in 1932, when a water level (H) of 5.2 meters was recorded at the Bistrița hydrometric station. The second flood was recorded on May 13, 1970, with a maximum water level (H) of 3.84 meters and a discharge (Q) of 618 m³/s at the Bistrița hydrometric station.

By promoting the hydrotechnical constructions with the role of defense against floods as well as the construction of the Colibița dam, they had negative effects on the aquatic and riparian ecosystems. Among the habitats lost and which are currently protected would be: woody vegetation with small buckthorn (*myricaria germanica*), beech forests (*Iuzulofagetum*), alluvial forests or meadow forests (*alno-padino*, *alnion incanae*, *salicion albae*) along rivers.

The existing state of the river

The water body in the urban area of the Bistrița municipality is included in the category of heavily anthropized water bodies.

According to Stockwell, a degraded river is defined as: "any watercourse that does not function at its hydrological and biological potential."

Awareness, information and involvement of the population in starting the redevelopment / renaturalization project of the water course

We conducted a survey of 200 respondents, of whom 91 were men and 109 were women, aged between 17 and 80.

- the importance or influence of the river in the city's culture: 93% responded affirmatively, 6.5% stated no;
- the use of the banks of the Bistrița river for recreational purposes: 57.5% responded affirmatively, 42.5% stated no;
- regarding project financing: 56% prefer funding from European sources, 26% local funding, and 17% government funding;
- the current state of the Bistrița river: 7.5% are satisfied with the current situation, 92.5% desire the restoration of the Bistrița Ardeleană river;
- necessary constructions along the river: parks along the riverbanks (40.2%), artificial beaches (17.4%), HoReCa facilities (12.3%), wetland areas (11.6%), and finally, the Bistrița river museum (9.2%).

PERSONAL CONTRIBUTION

3. Research objectives

The objectives of the doctoral thesis are to investigate and highlight the negative effects of conventional hydrotechnical constructions, which were promoted 40 years ago, and to provide alternative or green solutions for water resource management.

By addressing these objectives, the paper aims to provide new perspectives and promote sustainable and environmentally friendly practices in the management of water resources, thus contributing to the protection and conservation of aquatic ecosystems.

Starting from the purpose defined above, the work "Studies and researches regarding the sustainable development of the Bistrița Ardeleană watercourse" has as its main objectives the sustainable development of the Bistrița Ardeleană river, stopping erosions, resizing of weirs, management of water discharges from the lake accumulation Colibița in critical periods.

4. Studies on the morphological evolution of the Bistrița Ardeleană riverbed

Introduction

Flow variations cause stress among wildlife, leading to the loss of many habitats in shallow riverbeds, having a negative impact on the ecosystem, which can even lead to its complete disappearance.

The hydrographic basin of the Bistrița Ardeleană river has a total area of 650 km², its elevation varies between 350 m and 1991 m and incorporates the following sub-basins: Bistrița, Bârgău and Tănase. The Bistrița Ardeleană River is about 70 km long and originates in the Călimani Mountains, later it crosses the Bârgău Mountains which are characterized by a complex geological constitution, formed by crystalline, eruptive and sedimentary rocks and continuing to cross the Livezile-Bârgău depression and the Bistrița hills. The hills and depression are made up of clay, marl and tuff formations, trapped in a system of folds.

Objectives

The purpose of the chapter "Studies on the morphological evolution of the Bistrița Ardeleană riverbed" is to analyse the morphological evolution of the bed in the cross sections of two hydrometric stations. The shape of the riverbed is given by hydromorphological processes that have a negative impact on the thalweg and the stability of the banks, resulting in their deterioration, indirectly influencing the water quality.

Materials and Methods

For this study, annual reports from the Bistrița and Bistrița-Bârgăului hydrometric stations, carried out by the Bistrița Hydrological Station within the Bistrița Năsăud Water Management System, were consulted. Hydrological, climatic, and topographical data sets from 1972 to 2015 were extracted from these reports.

Results

The greatest degradation of the thalweg was recorded at the Bistrița Bârgăului hydrometric station between 1972 and 1979. This degradation was due to natural floods.

Following topographic surveys at the Bistrița Bârgăului hydrometric station in 1995, an elevation of the thalweg was noted compared to the profile made in 1979. After 1995, the riverbed began to degrade, and by 2015, the thalweg had lowered by 0.24 m (Figure 4.2). Analysing the profile created in 2002, six years after the Colibița complex hydrotechnical arrangement was put into operation, and comparing it to the profile recorded in 2012 (Figure 4.3), it was found that the thalweg had lowered by 0.46 m over those ten years. Figure 4.3 shows that the 2012 profile is 0.67 m lower than the 1972 profile.

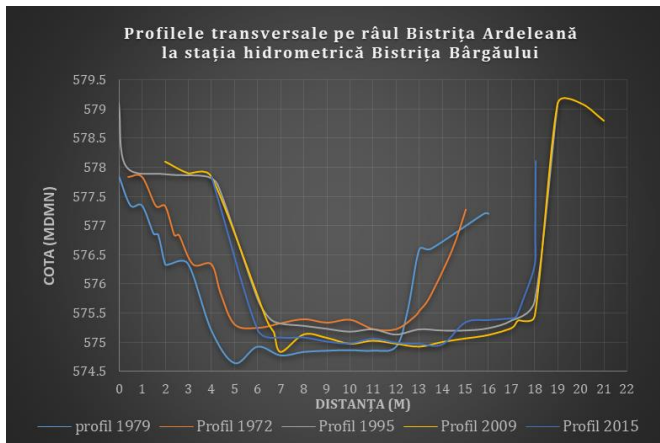


Figure 4.2 Transverse profiles of the riverbed at the Bistrița Bârgăului hydrometric station section.



Figure 4.3 Transverse profiles of the riverbed at the Bistrița hydrometric station section.

5. Research on the sustainable development of the Bistrița Ardeleana river in order to stop the erosion of the riverbanks and the thalweg

Introduction

Hydrotechnical constructions alter the natural hydromorphological regime of rivers, impacting their functionality negatively and associated with several environmental consequences, including habitat fragmentation, deterioration of water quality, nutrient depletion, loss or alteration of biodiversity, modification of trophic networks, impact on fish populations, and reduction of riparian biodiversity.

Alternative hydrotechnical constructions that have green or gray-green elements are promoted and designed to: cope with high flows recorded during extreme floods or flash floods; to create longitudinal and transversal connectivity of ecosystems in riverbeds that cross human settlements.

Objectives

The objective of this chapter "Research on the sustainable development of the Bistrița Ardeleană river in order to stop the erosion of the riverbanks and the thalweg " is to study and identify the solutions regarding the sustainable development of the Bistrița Ardeleană river in order to stop the erosion of the riverbanks and the thalweg.

Materials and methods

The studied area – the riverbed sector located in the Unirea locality, which administratively belongs to the Bistrița municipality. The critical river section is positioned on the Bistrița Ardeleană watercourse approximately 17 km upstream from the confluence with the Șieu river and approximately 30 km downstream from the Colibița dam.

The methods used – topographic measurements were carried out for the area under study. The data processing was done in the AutoCAD 2023 software. Flights were made with the drone to obtain an updated orthophotoplan and a more realistic image of the water course section. The images were processed with the Agisoft Metashape program. A sample of alluvial material was taken from the thalweg of the riverbed for granulometric analysis.

Based on the data obtained from the field, a hydraulic modeling was carried out. The MIKE 11 software was used for the hydraulic modelling.

Two hydraulic modelings were carried out for two flows recorded in the hydrographic basin of the Bistrița Ardeleană river: $Q = 54.5 \text{ m}^3/\text{s}$ - flow recorded in September 2022 and $Q = 178 \text{ m}^3/\text{s}$ - flow recorded in 2019.

Results

Hydraulic modeling on the river Bistrita Ardeleana, where the flow has a value of $Q = 54.5 \text{ m}^3/\text{s}$

In Figure 5.6, the water depth in each cross-section is represented graphically, respectively the maximum value of the depth for the flow rate $Q = 54.5 \text{ m}^3/\text{s}$.

In Figure 5.7, we can see the water speed, in the longitudinal profile along the sector studied in the modelling.

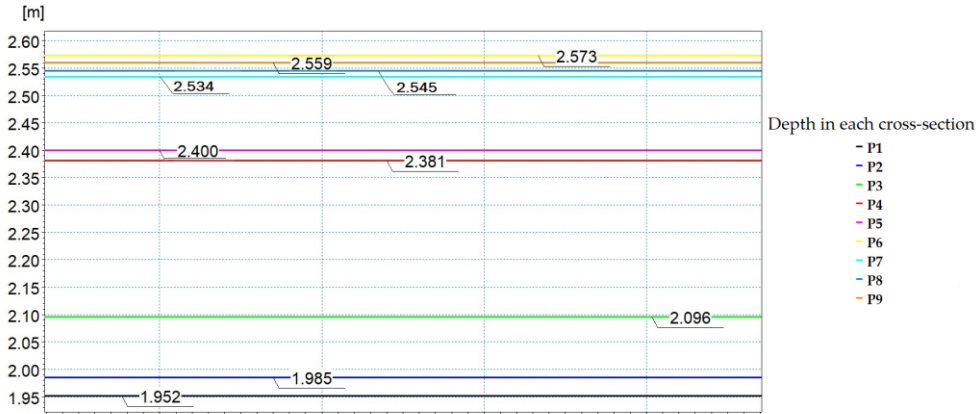


Figure 5.6. Water depth in each cross-section in graphical form for flow rate $Q = 54.5 \text{ m}^3/\text{s}$

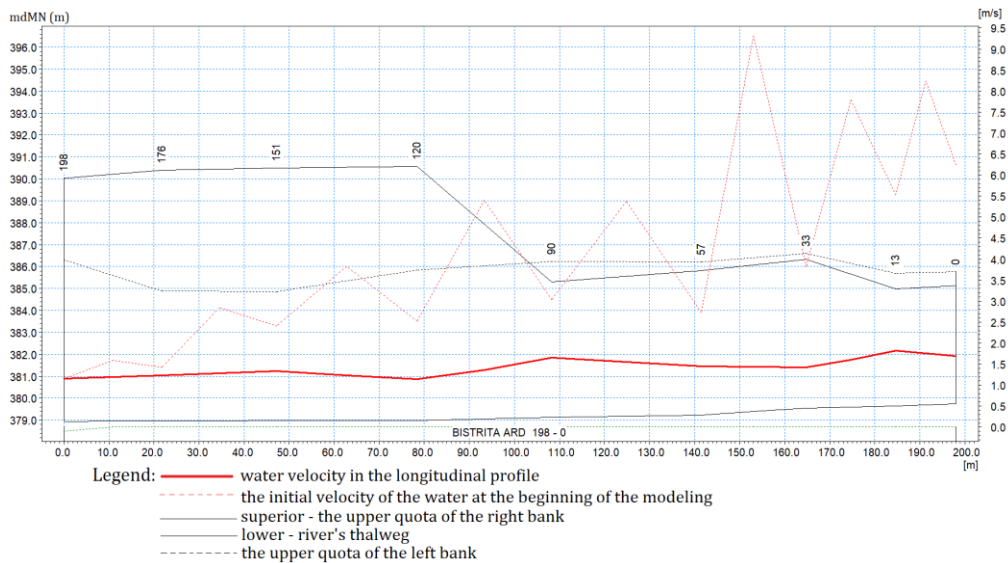


Figure 5.7. Water velocity in the longitudinal profile for $Q = 54.5 \text{ m}^3/\text{s}$.

Hydraulic modeling on the Ardelean Bistrita river, where the flow has a value of $Q = 178 \text{ m}^3/\text{s}$

In Figure 5.10 the water depth in each cross-section is represented graphically, respectively the maximum value of the depth for the flow rate $Q = 178 \text{ m}^3/\text{s}$.

In Figure 5.11 the water speed can be seen in the longitudinal profile along the sector studied in the modeling.

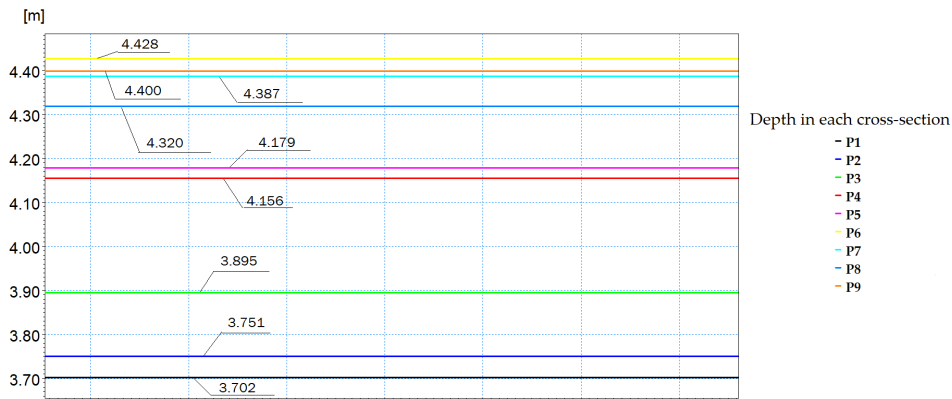


Figure 5.10 Water depth in each cross-section in graphical form for flow rate $Q = 178 \text{ m}^3/\text{s}$.

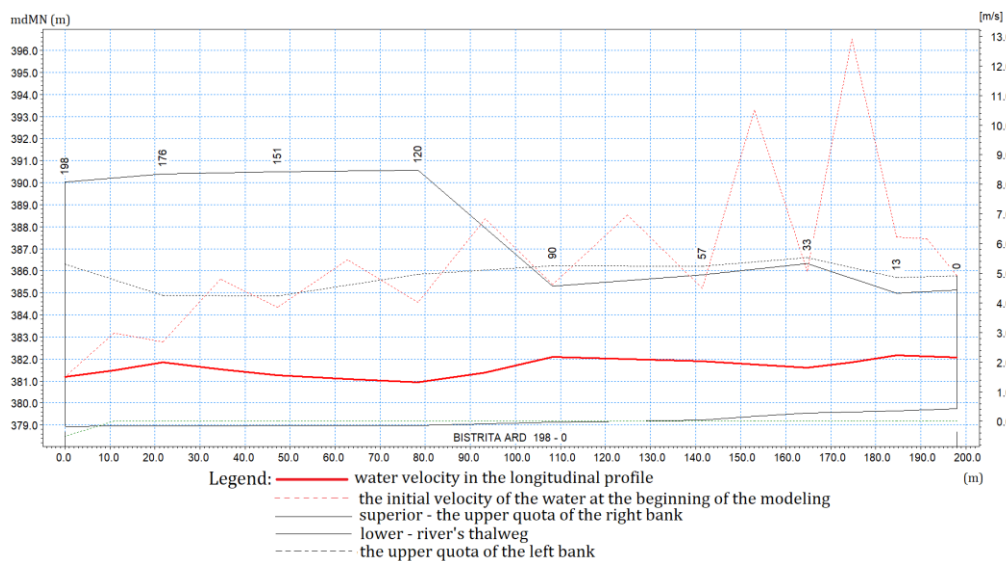


Figure 5.11 Graphical representation of water velocity in the longitudinal profile for $Q = 178 \text{ m}^3/\text{s}$

Determination of the average diameter of the particles in the thalweg of the riverbed

Following the granulometric analysis, the granulometric composition and the granulometric curve of the alluvial material were obtained. Later, the average diameter of the particle in the thalweg of the riverbed was determined, corresponding to the sieve through which 50% of the sample passed, is $D_{50} = 25.18 \text{ mm}$.

According to PD 95-2002- Normative regarding the hydraulic design of bridges and decks, the sample taken from the thalweg of the riverbed has a $D_{50} = 25.18 \text{ mm}$, representing medium river gravel which at a water depth of 2 m the average particle entrainment speed is 2 m/s.

Proposed solution to stop the erosion of the riverbanks and reduce thalweg degradation

The proposed solution for the right bank and the left bank of the Bistrita Ardeleană river has the role of stopping the erosion of the bank and reducing the degradation of the thalweg.

The bioengineering methods used in hydrotechnical constructions with the role of defence or protection of the riverbanks and stopping the degradation of the thalweg are: live fascines or branch, boulder revetment, vegetated rock gabions, crib wall, live stakes, vegetated rock rolls, coir rolls, shrubs, root wad, mats reinforced with grass.

The green hydro-technical constructions with the role of protecting the banks and stop-ping the degradation of the thalweg have lengths of: right bank – 217.5 m, left bank – 149.5 m.

6. Research on the sustainable development of the Bistrita Ardeleana river through the resizing of weirs

Introduction

The transversal constructions obstruct the longitudinal movements of these aquatic organisms in the feeding and reproduction process, which leads to a decrease in their population, in the present case the endangered fish species are: Moiağa (Barbus meridionalis) and Petroc (Gobio uranoscopus) other protected animals of the law are: northern crested newt (Triturus cristatus), the yellow-bellied toad (Bombina variegata).

Objectives

The aim of the chapter "Research on the sustainable development of the Bistrita Ardeleană river through the resizing of weirs " is to offer viable technical solutions in order to restore the longitudinal connectivity of the segmented aquatic ecosystems.

Materials and methods

The studied area - the analysed riverbed sector is part of a heavily anthropized body of water that crosses the urban area of Bistrița municipality. The transversal hydrotechnical construction (weir) is positioned on the Bistrița Ardeleană water course, 10.866 km from the confluence with the Șieu river and approximately 37 km downstream from the Colibița dam

Methods used - to obtain an orthophoto plan of the weir topographic measurements were made with the Leica FlexLine TS 07 total station and flights with the Phantom 4 Pro v 2.0 drone. ProfLT v 10.3 software was used to make the transverse and longitudinal profiles.

Regarding the hydraulic modeling, the MIKE 11 software was used. The modeling was carried out for three flows that have the values $Q = 3.56 \text{ m}^3/\text{s}$ (summer flow recorded in 2022), $Q = 8.37 \text{ m}^3/\text{s}$ (average flow in 2021), $Q = 128 \text{ m}^3/\text{s}$ (flood flow recorded in 2020).

Results

Hydraulic modeling for the case of a single weir (existing)

In Figure 6.6 is the water level in the longitudinal profile for the flow $Q=3.56 \text{ m}^3/\text{s}$.

In Figure 6.8 is the water level in the longitudinal profile for the flow $Q=8.37 \text{ m}^3/\text{s}$.

Figure 6.10 there is the water level in the longitudinal profile for the flow $Q= 128 \text{ m}^3/\text{s}$.

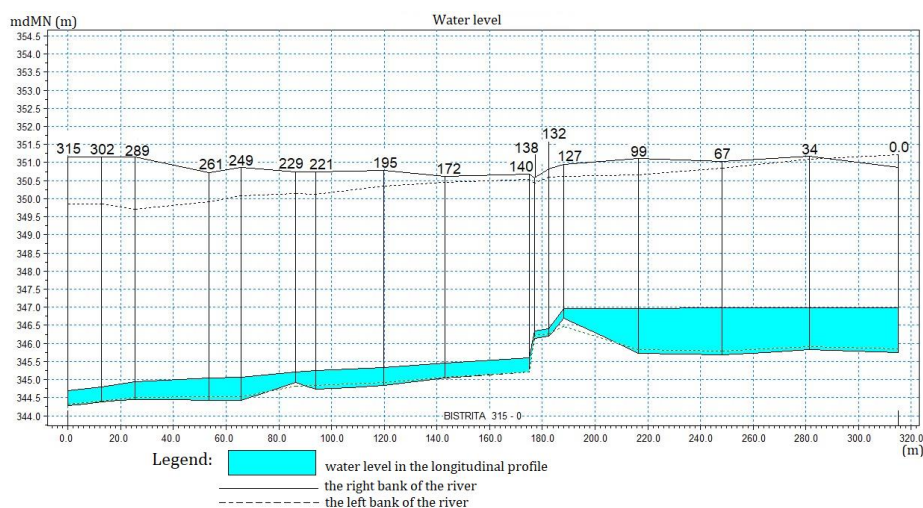


Figure 6.6 Water level for flow $Q = 3.56 \text{ m}^3/\text{s}$, summer flow recorded in June 2022.

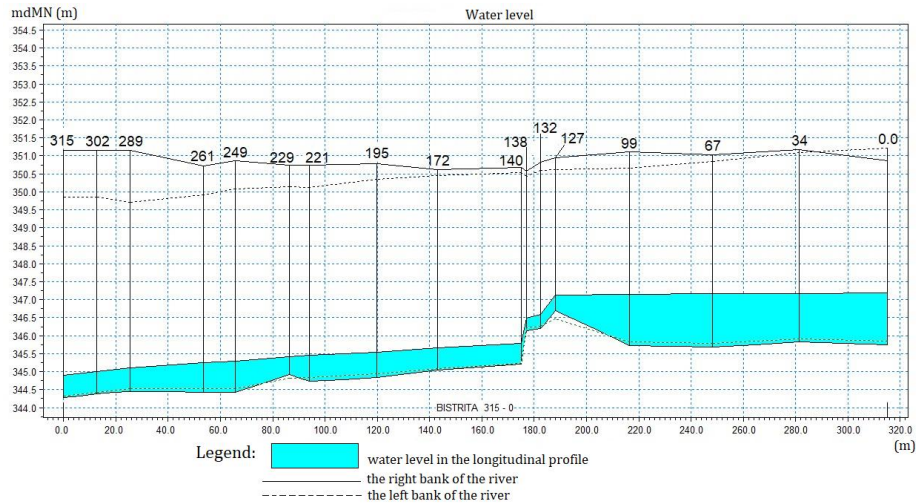


Figure 6.8 Water level for flow $Q = 8.37 \text{ m}^3/\text{s}$, the average annual flow calculated for the year 2021.

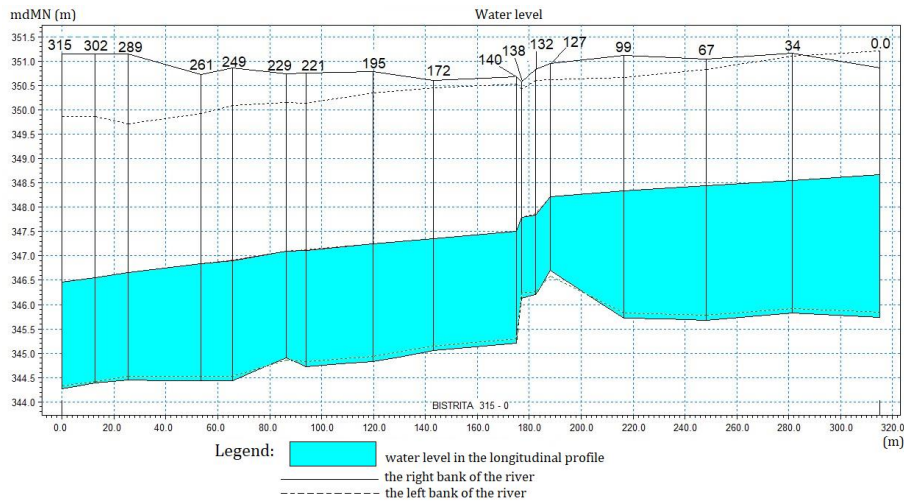


Figure 6.10 Water level for flow $Q = 128 \text{ m}^3/\text{s}$, representing an extreme flood flow recorded in 2020.

Hydraulic modeling for the proposed case with the lowering of the crest of the existing weir and the construction of three weirs with a low height downstream

In Figure 6.12 is the water level in the longitudinal profile for the flow $Q=3.56 \text{ m}^3/\text{s}$.

In Figure 6.14 is the water level in the longitudinal profile for the flow $Q=8.37 \text{ m}^3/\text{s}$.

Figure 6.16 there is the water level in the longitudinal profile for the flow $Q= 128 \text{ m}^3/\text{s}$.

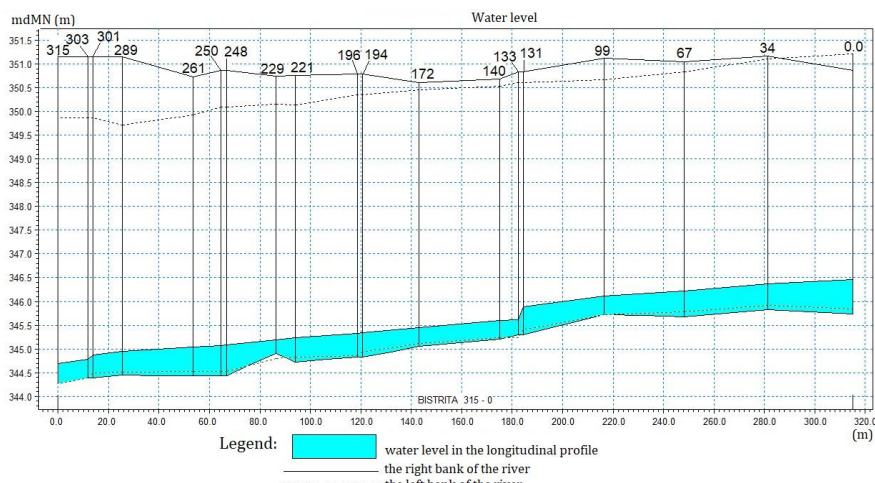


Figure 6.12 Water level for flow $Q = 3.56 \text{ m}^3/\text{s}$, summer flow recorded in June 2022.

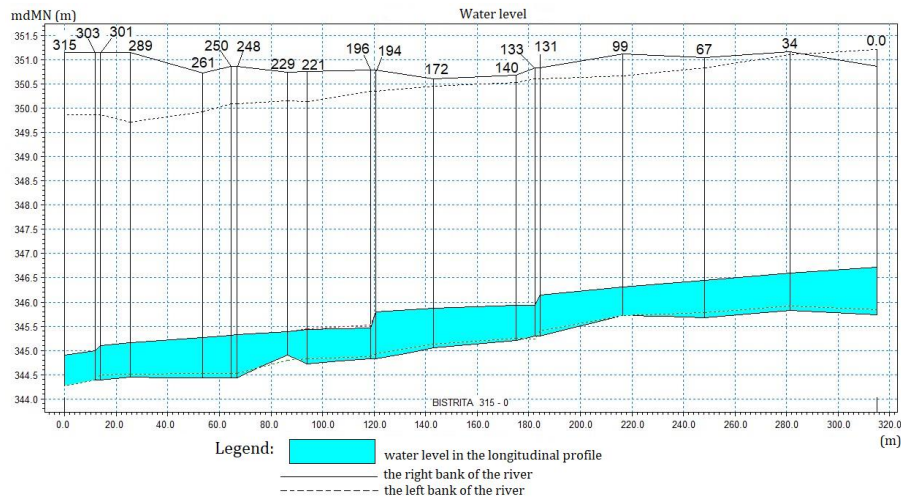


Figure 6.14 Water level for flow $Q = 8.37 \text{ m}^3/\text{s}$, the average annual flow calculated for the year 2021.

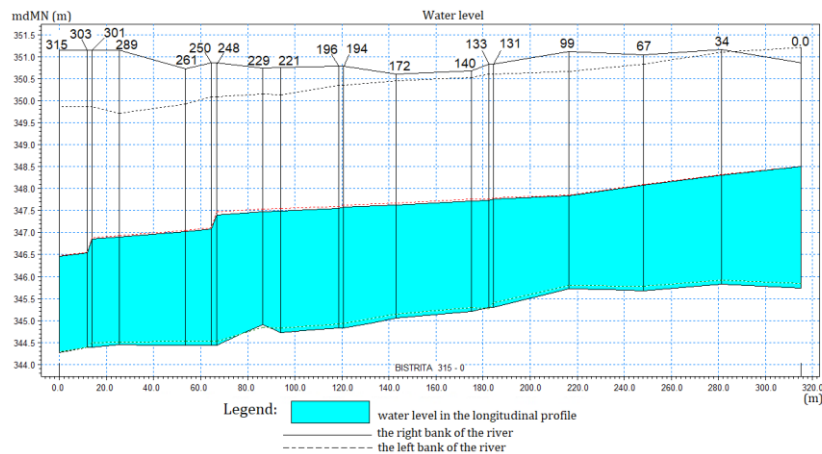


Figure 6.16 Water level for flow $Q = 128 \text{ m}^3/\text{s}$, representing an extreme flood flow recorded in 2020

7. Flood hazard assessment of bottom outlets at the Colibița large dam, using 1D hydraulic modeling

Introduction

Building a large dam can bring significant economic and social benefits, but it can also represent a danger to the population located downstream due to incidents, accidents, etc. In conclusion, great attention must be paid to dams to eliminate the possibility of incidents or accidents occurring.

Objectives

The purpose of this chapter, "Flood hazard assessment of bottom outlets at the Colibița large dam, using 1D hydraulic modeling," is to provide comprehensive information on managing the hazard resulting from the release of water volumes from the Colibița reservoir through the dam's bottom outlets.

Materials and methods

The studied area - the studies and research in this chapter are carried out along the entire length of the Bistrita Ardeleană watercourse, which has a hydrographic basin with an area of 650 km^2 . The elevation of the basin varies between 350 mdMN and 1991 mdMN.

Methods used - the data processing was carried out using AutoCAD 2023 software. The resulting cross-sectional profiles were 138 (riverbed), 1 (dam crest), and 4 (reservoir). The modeling is performed using MIKE 11 software and a 1D (one-dimensional) hydraulic model.

The flow rates that might be found in the riverbed at the time of water release from the reservoir are: low flow rates of $Q=1.25 \text{ m}^3/\text{s}$ (Bistrița Bârgăului hydrometric station) and $Q=2.59 \text{ m}^3/\text{s}$ (Bistrița hydrometric station), and high flow rates of $Q=9.1 \text{ m}^3/\text{s}$ (Bistrița Bârgăului hydrometric station) and $Q=55.2 \text{ m}^3/\text{s}$ (Bistrița hydrometric station).

Results

The results of the hydraulic modeling for the first considered hypothesis, when water evacuation is carried out through the main bottom outlet with the valve opening at 50% and 100% of capacity.

Results for main bottom outlet in the period with low flow rates

When the bottom outlet valve is 50% open, the water level at s. h. Bistrița Bârgăului exceeds the attention quota by 8 cm. With the valve open 100% the water level exceeds the attention quota by 47 cm (Figure 7.7). At s. h. Bistrita, in the case of opening the valve by 50%, respectively 100% from bottom outlet, the water level does not exceed the attention quota (Figure 7.8).

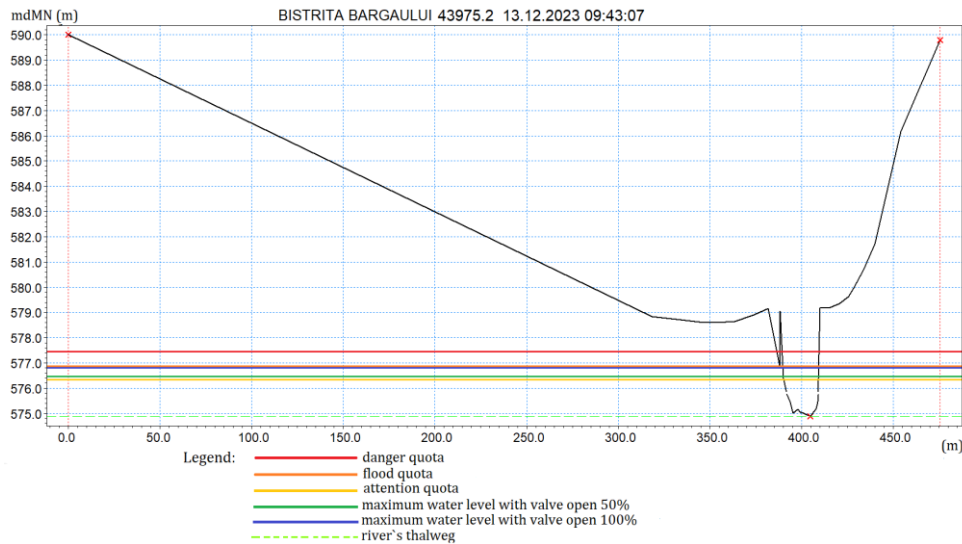


Figure 7.7 Graphical representation of the water level in the Bistrita Ardeleană riverbed, result for the bottom outlet during the period of low flows in the transverse profile of the Bistrita Bârgăului h. s., with valve openings at 50% and 100%.

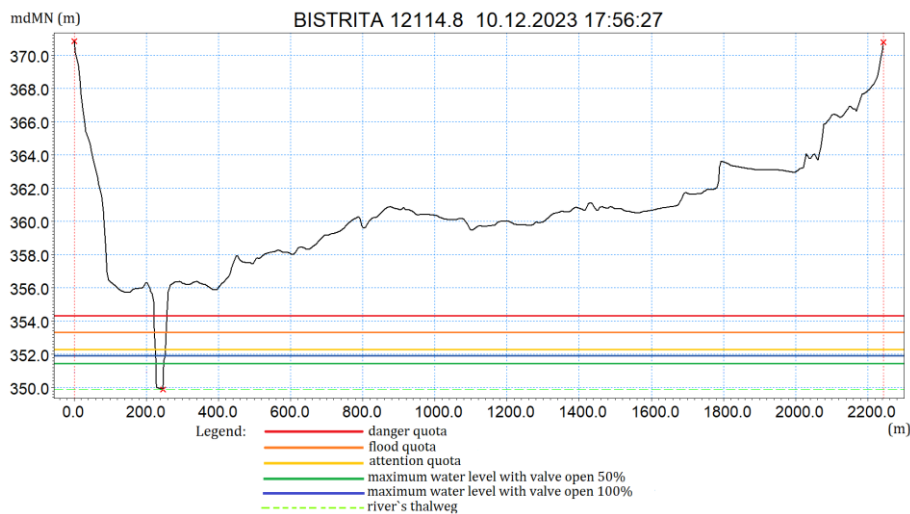


Figure 7.8 Graphical representation of the water level in the Bistrita Ardeleana riverbed, result for the bottom outlet during the period of low flows in the transverse profile of the Bistrita h. s., with valve openings at 50% and 100%.

The results for bottom outlet during the period with increased flows resulting from heavy precipitation and yielding water from the snow layer.

At the Bistrița Bârgăului hydrometric station, the flood quota is exceeded by 2 cm with the valve open 50%, for a 100% opening, the flood quota is exceeded by 41 cm (Figure 7.9). At the Bistrița hydrometric station, for opening the valve 50% the water level exceeds the attention quota by 2 cm, for opening the valve 100% the water level is 46 cm above the attention quota (Figure 7.10).

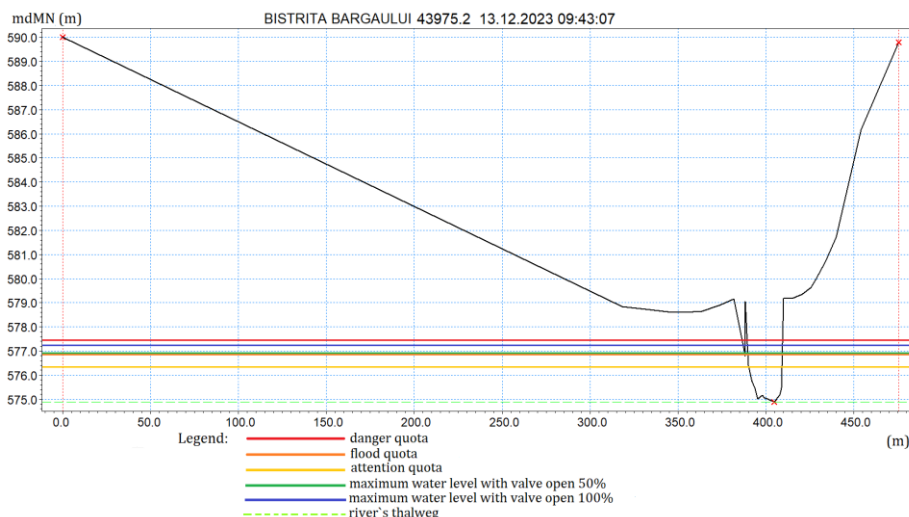


Figure 7.9 Graphical representation of the water level in the riverbed of the Bistrița Ardeleană river, result for bottom outlet during the period with increased flows in the transverse profile of the Bistrița Bârgăului h. s., with valve opening 50% and 100%.

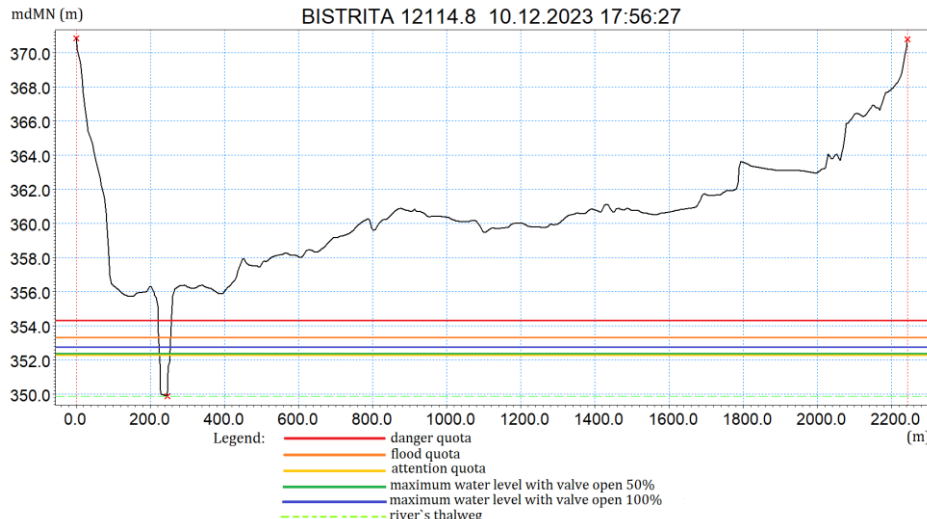


Figure 7.10 Graphical representation of the water level in the riverbed of the Bistrița Ardeleană river, result for bottom outlet during the period with increased flows in the transverse profile of the Bistrița h. s., with valve opening 50% and 100%.

The results of the hydraulic modeling for the second considered hypothesis, when water evacuation is carried out through the secondary bottom outlet with the valve opening at 50% and 100% of capacity.

Results for the second bottom outlet during periods of low flow rates

For the valve 50% open at the Bistrița Bârgăului h. s., the water level is 1 cm below the attention quota. When the valve 100% open, the water level exceeds the attention quota by 34 cm (Figure 7.11). The resulting water level at the Bistrița hydrometric station, for both 50% and 100% opening of the secondary bottom outlet valve, is below the attention quota (Figure 7.12).

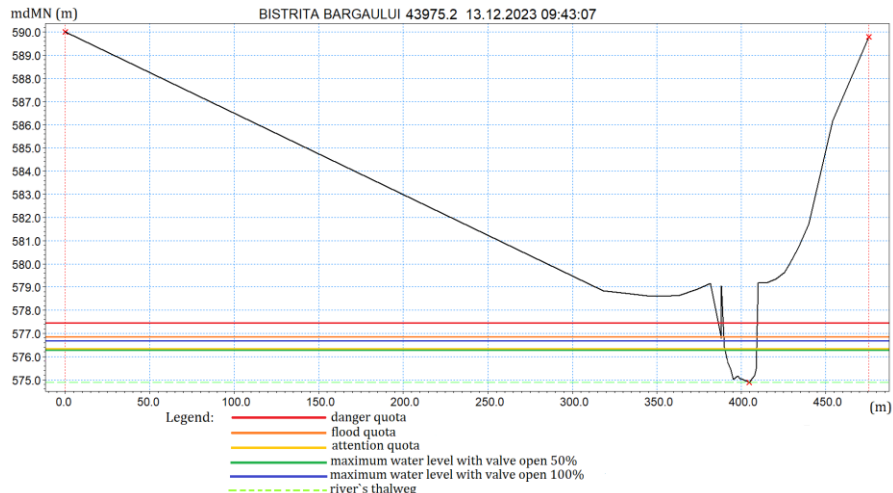


Figure 7.11 Graphical representation of the water level in the Bistrita Ardeleană riverbed, result for the secondary bottom outlet during the period of low flows in the transverse profile of the Bistrita Bârgăului h. s., with valve openings at 50% and 100%.

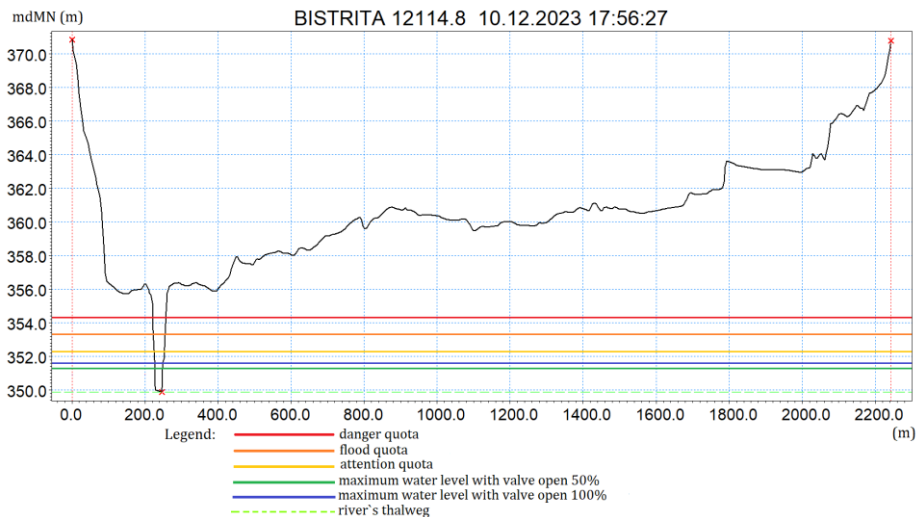


Figure 7.12 Graphical representation of the water level in the Bistrita Ardeleană riverbed, result for the secondary bottom outlet during the period of low flows in the transverse profile of the Bistrita h. s., with valve openings at 50% and 100%.

The results for second bottom outlet during the period with increased flows resulting from heavy precipitation and yielding water from the snow layer.

With the valve 50% open, the water level at the Bistrița Bârgăului h. s. exceeds the attention quota by 43 cm. For the valve fully open (100%), the water level exceeds the flood quota by 28 cm (Figure 7.13). At the Bistrița h. s., with the valve 50% open, the water level is below the attention quota, but with the valve fully open (100%), the water level exceeds the attention quota by 20 cm (Figure 7.14).

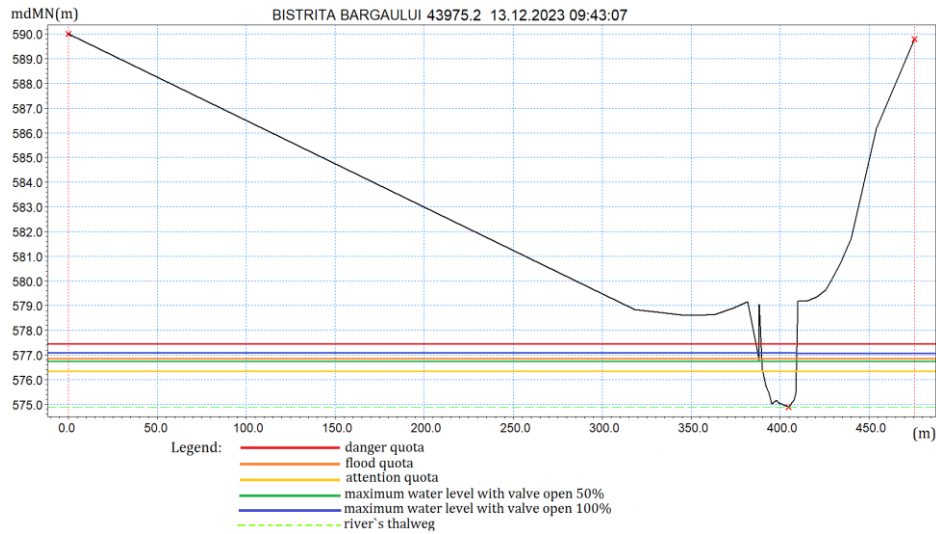


Figure 7.13 Graphical representation of the water level in the riverbed of the Bistrița Ardeleană river, result for the secondary bottom outlet during the period with increased flows in the transverse profile of the Bistrița Bârgăului h. s., with valve opening 50% and 100%.

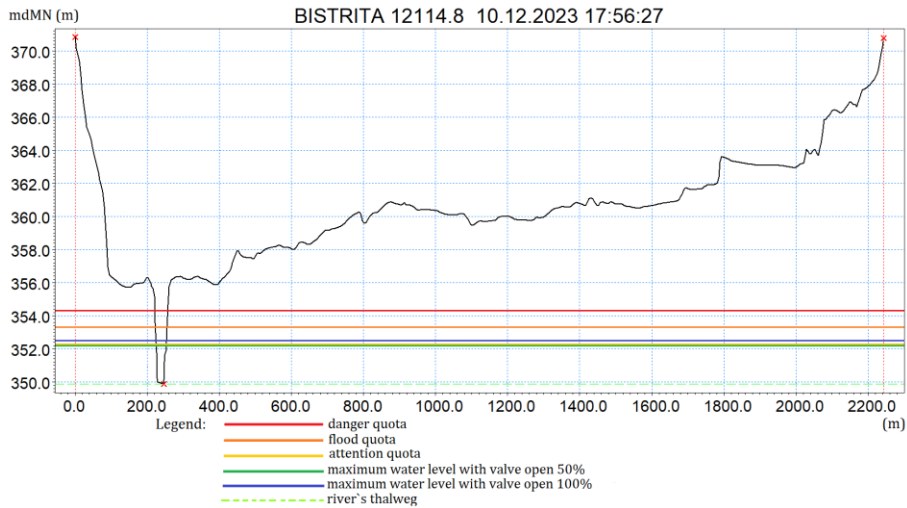


Figure 7.14 Graphical representation of the water level in the riverbed of the Bistrița Ardeleană river, result for the secondary bottom outlet during the period with increased flows in the transverse profile of the Bistrita h. s., with valve opening 50% and 100%

The results of hydraulic modeling for the third hypothesis, when the discharge of water from the reservoir is carried out simultaneously through both bottom outlets with the valves open 100%.

The results for the situation in which the discharge of water from the reservoir is carried out simultaneously through both bottom outlets during the period with low flows

At the Bistrița Bârgăului hydrometric station, the water level exceeds the flood quota by 37 cm (Figure 7.15), while at the Bistrița hydrometric station, the resulting water level is below the attention quota (Figure 7.16).

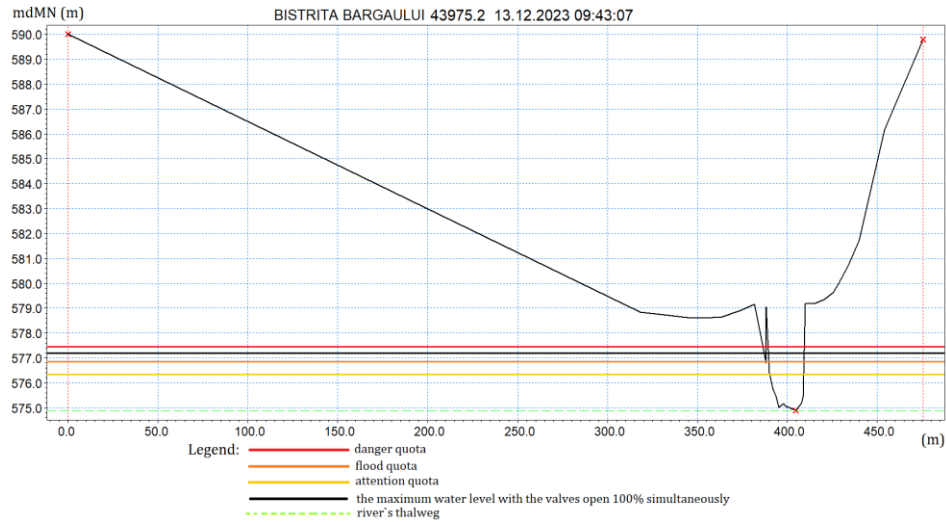


Figure 7.15 Graphical representation of the water level in the riverbed of the Bistrița Ardeleană river, for the simultaneous discharge of water from the reservoir through bottom outlets during the period of low flows, at the Bistrița Bârgăului h. s.

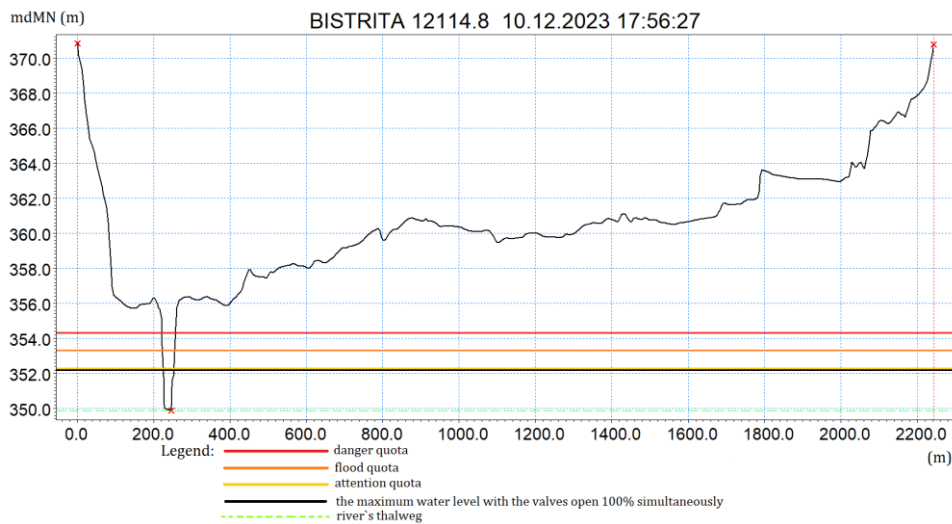


Figure 7.16 Graphical representation of the water level in the riverbed of the Bistrița Ardeleană river, for the simultaneous discharge of water from the reservoir through bottom outlets during the period of low flows, at the Bistrita h. s.

The results for the situation in which the discharge of water from the reservoir is carried out simultaneously through both bottom outlets during the period with increased flows resulting from heavy precipitation and yielding water from the snow layer.

With the valves open 100% simultaneously, the water level at the Bistrita Bârgăului h. s. exceeds the danger quota by 21 cm (Figure 7.17). At the Bistrita h. s., the water level exceeds the attention quota by 87 cm (Figure 7.18).

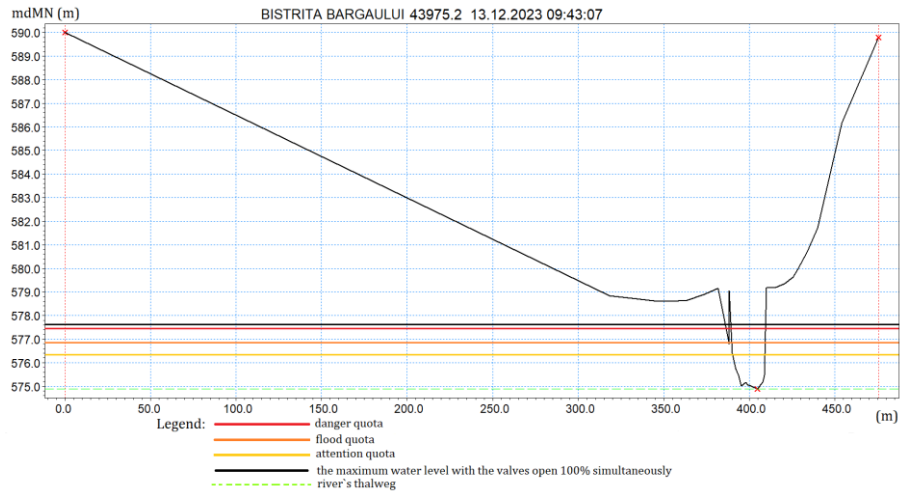


Figure 7.17 Graphical representation of the water level in the riverbed of the Bistrița Ardeleană river, for the simultaneous discharge of water from the reservoir through bottom outlets during the period with increased flows, at the Bistrița Bârgăului h. s.

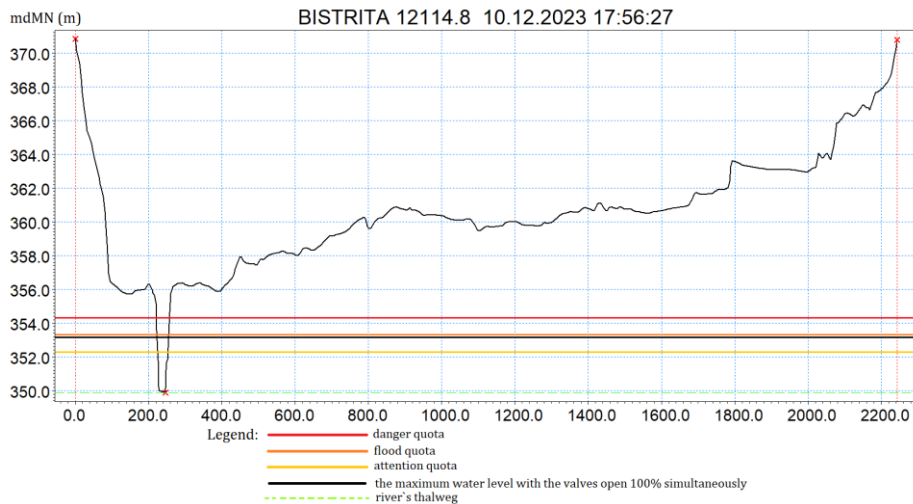


Figure 7.18 Graphical representation of the water level in the riverbed of the Bistrița Ardeleană river, for the simultaneous discharge of water from the reservoir through bottom outlets during the period with increased flows, at the Bistrița h. s.

8. General Discussions

The changes in the morphological evolution of the Bistrița Ardeleană riverbed downstream of the Colibița complex hydrotechnical construction can be observed shortly after its commissioning.

In the cross-sectional profiles analysed, no significant erosions of the riverbed were found, either horizontally or vertically, which could endanger socio-economic, administrative, household or road infrastructure objectives. However, this conclusion cannot be applied to unimproved sectors of the watercourse.

One of the localities with a critical sector that can endanger agricultural land, households and road infrastructure is Unirea. For this critical sector, two hydraulic models were made, one for a flow rate of $Q = 54.5 \text{ m}^3/\text{s}$, respectively for a flow rate of $Q = 178 \text{ m}^3/\text{s}$. With the help of modeling, the hydraulic parameters such as the average water velocity and water depth were determined in the 9 transversal profiles made through the riverbed.

It is evident that at the velocities and depths resulting in the two modeling scenarios, a significant proportion of particles from the riverbed, with a diameter smaller than 25 mm and representing approximately half of the granulometric sample, are set in motion. This leads to the emergence of the hydromorphological process of bank erosion and deepening of the thalweg.

Another urgent problem for the sustainable development of the Bistrița Ardeleană river is the hydrotechnical constructions with the role of defence against floods promoted 40 years ago, which have caused significant modifications to the riverbed. These hydrotechnical constructions have sectioned the aquatic ecosystem resulting in the loss of longitudinal connectivity.

One solution to restore the longitudinal connectivity of the aquatic ecosystem is to remove, replace, or resize the weirs. For such a scenario, the results of two hydraulic modeling studies were analysed. The first scenario examined hydraulic parameters for the current situation, while the second scenario analysed hydraulic parameters in a situation where the weir is resized and three more low-height weirs are built downstream of it.

In order to be sure of the real potential of creating a hazard downstream of the Colibița dam or reservoir, at the time of the evacuation or release of some water flows, we took into account that there is a certain flow in the minor riverbed of the Bistrița Ardeleană. Thanks to the technical characteristics of the riverbed, the flows and levels resulting from the hydraulic modeling, we were able to identify the real potential for a hazard to occur due to the controlled discharges of water from the reservoir.

9. Final conclusions

General conclusions

The doctoral research "Studies and research on the sustainable development of the Bistrița Ardeleană watercourse" aimed to investigate and highlight the effects of conventional hydraulic constructions and to offer alternative technical solutions for water resource management concerning the restoration of longitudinal and transversal connectivity of ecosystems or securing critical riverbed sectors.

In order to stop the bank or thalweg erosions in the critical or unstable sectors along the Bistrița Ardeleană water course, they can be made safe with the help of bioengineering, more precisely with green or alternative methods. These alternative hydrotechnical constructions use natural elements that have positive effects on the ecosystem such as: it significantly increases the diversity of the aquatic ecosystem, the accumulation of alluvium and the removal of excess moisture accumulated in the soil on the two banks of the river.

Removing or resizing weirs will significantly contribute to the longitudinal connectivity of ecosystems.

Following the data obtained from the hydraulic modeling of the current situation and the proposed solution, differences in water velocity and depth were observed in the analysed section. Differences in water velocity and depth would have a favourable effect from a morphological and ecological point of view. The technical solution to replace the weirs would contribute to restoring the fragmented aquatic ecosystem.

According to the hydraulic modeling carried out for the release of a volume of water from the Colibița reservoir through the dam's bottom outlets with the valve open at maximum capacity (100%) it can be done without endangering the urban settlements during periods of low precipitation, low flow rates or levels in the minor riverbed of the Bistrița Ardeleană river.

The release of a volume of water from the reservoir through one of the dam's bottom outlets with a 100% open valve, superimposed with the increased flows and levels in the minor riverbed at the Bistrița Bârgăului hydrometric station, the water level exceeded by 41 cm, flood quota in the cross section of the station.

In conclusion, it is crucial for local authorities and public institutions involved in water resource management or emergency management to have a realistic understanding of the potential hazards downstream of the dam.

The originality and innovative contributions of the thesis

The research conducted as part of the doctoral studies, which includes determining local hydraulic parameters for analysed riverbed sectors, assessing riverbed instability due to

hydromorphological processes, establishing hydrometeorological conditions required for safely releasing water volumes from reservoir for urban settlements, and determining hydraulic parameters in the transverse profile of two hydrometric stations, was carried out in the hydrographic basin of the Bistrița Ardeleană river with the aim of fostering its sustainable development. This research demonstrates a high degree of originality and novelty due to:

- conducting a study on the morphological evolution of the Bistrița Ardeleană riverbed, in the cross-sections of two hydrometric stations, before starting the construction of the complex hydrotechnical arrangement, as well as after putting it into operation;
- conducting out research on the sustainable development of the Bistrita Ardeleană river in order to stop the erosion of the banks and thalweg;
- undertaking a comparative study regarding the sustainable development of the Bistrita Ardeleană river by resizing the weirs;
- carrying out the flood risk assessment following the release of some volumes of water from the Colibița reservoir through the dam's bottom outlets, utilizing 1D hydraulic modeling.