

# Hydrotechnical assessment of the flow of the Hnilec river in the town of Gelnica

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**Abstract.** It is important to develop a hydrotechnical assessment of the existing habitat in the river system for potential proposals for flood protection solutions. The basic factors in the assessment are accurate and up-to-date geodetic assessment, terrain reconnaissance, history of the area and hydrological data necessary for the calculation. In the past, minor improvements to the banks of the Hnilec River were conducted in the vicinity of the town of Gelnica, but these were not large-scale improvements to the entire riverbed. A plausible reason for the non-implementation of large-scale modifications is the dense construction of dwellings in close proximity to the riverbed, the confluence of the railway line with the river and road bridges. The objective of the assessment is the evaluation of critical sections, description of threats in the treated area and the possibility of pointing out the improvement of hydrotechnical parameters to mitigate flood conditions. If it will not be possible to apply flood defence measures in the town residential area, it is necessary to point out another potential solution.

## 1 Introduction

Floods are among the most powerful forces on earth. Human societies worldwide have lived and died with floods from the very beginning, spawning a prominent role for floods within legends, religions, and history. Inspired by such accounts, geologists, hydrologists, and historians have studied the role of floods on humanity and its supporting ecosystems, resulting in new appreciation for the many-faceted role of floods in shaping our world [1]. Flooding is an issue that affects all countries and each year they cause considerable damage to people's lives and properties. This leads to that many floodplains are excluded from sustainable urban development. Therefore, the development of innovative approaches to flood management and mitigation are required for sustainable urban development [2]. Flood protection is activity aimed at reducing the flood risk in flood-prone areas, preventing flooding caused by floods and mitigating the adverse consequences of floods on human health, the environment, cultural heritage and economic activity. The preliminary flood risk assessment determines geographical areas in the territory of the Slovak Republic in which there is a potentially significant flood risk or in which it can be assumed that its occurrence is likely [3]. For the needs of defining the flood risk, it is necessary to develop a water level

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regime of the area under consideration, which is represented by a map with flood lines. Flood maps is a simplified common name for flood hazard maps and flood risk maps. Flood risk maps are drawn up for geographical areas in which the existence of a potentially significant flood risk was identified in the preliminary flood risk assessment and areas in which the probable occurrence of a significant flood risk can be assumed. The flood risk map shows the range of floods that would cause floods with an average recurrence time from once every 5 years to once every 1000 years, or another flood with an exceptionally dangerous course. Flood risk maps contain data on the potentially adverse consequences of flooding caused by floods, which are displayed on flood hazard maps. The flood risk maps contain data on the estimated number of inhabitants potentially at risk of flooding and on the types of economic activities in the area potentially at risk of flooding [4]. After the flood threat has been proven, it is also necessary to define the value of the safety discharge that can flow through the treated area and at what water surface elevation.

## 2 Material and methods

This section will be devoted to the description of the Hnilec river in the town of Gelnica, its past, memorable floods that still affect the town today.

### 2.1 Study area

*Hnilec* river springs on the northern slope of *Kráľová hoľa*. On its upper course, the Hnilec river has the character of a mountain torrent, which cuts through a picturesque valley on the border of the *Slovak Paradise* and the *Slovak Ore Mountains*. In the treated territory of the town of Gelnica, the river is massive, but the slope does not decrease, it flows through numerous stony rapids. The Hnilec river maintains the mentioned character of rapid flow up to its mouth in *Hornád* river [5].

The centre of the entire Hnilec valley is *Gelnica*. The city is surrounded by a range of forested hills, and it stretches along both banks of the Hnilec river. The prehistory of the Hnilec valley is told by archaeological findings that document settlement in the Stone Age and the Bronze Age. The development of the royal mining town is confirmed by the construction of the castle in 1234 and the foundation of the Dominican monastery in 1288. The oldest city seal is preserved on a document from 1497, which is located in the castle archive in Vienna. Not only silver and copper, but also gold, mercury, lead and iron ore were mined in the Gelnica mines and its surroundings.

Modern Gelnica, with its own natural beauty and cultural-historical monuments, reminiscent of the heyday of the free royal mining town, has retained its ancient character despite the modern quarter. The city and its surroundings have recently become an exposed centre of tourism [6].



**Fig. 1.** Comparison of the historical map of 1915 and the current situation.

## 2.2 Recent history of the floods

The biggest flood that was recorded in the town of Gelnica occurred on June 2<sup>nd</sup> in 2010. Floods paralyzed the town for several days. The centre of the town was flooded, the local elementary school had to be closed for three days due to water in the basement. The people of Gelnica were supplied with drinking water from cisterns for a week because of the drinking water substation in *Perl* valley was flooded. In Gelnica, after the flood, the bridge in the city centre was impassable, and the second one, which had not been used for years, fell into the Hnilec river during the floods [7]. The second significant, but not so destructive flood occurred on October 14<sup>th</sup> in 2020 [8].

## 2.3 Input data

For the needs of hydrotechnical calculations and the drawing of flood lines, hydrological data and the development of a geodetic background in the form of a raster map are necessary.

### 2.3.1 Hydrological data

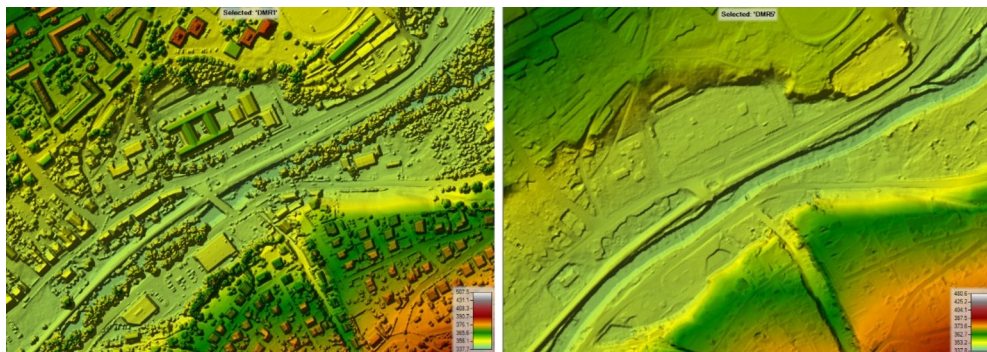
Hydrological data represent maximum flows reached or exceeded on average once every N-years. In the specific case, these years are 1, 2, 5, 10, 20, 50 and 100.

**Table 1.** Maximum flows reached or exceeded on average once every N-years.

N-year	1	2	5	10	20	50	100
Flow (m <sup>3</sup> s <sup>-1</sup> )	49	72	105	132	160	192	220

### 2.3.2 Raster map

The current state according to the geodetic survey from March 2024 was used as the basis for the calculation model. For the purposes of the calculation, the 3D relief model also contained broader relationships and a more comprehensive focus of the surroundings, which were supplemented with terrain maps from the GIS database of Slovakia. Figure 2. illustrates comparison of DSM1 (digital surface model) and DMR5 (digital terrain model) in resolution 1 m/pixel acquired from airborne laser scanning. DMR5 also includes riverbed survey [9].



**Fig. 2.** Comparison of the historical map of DSM1 (left) and DMR5 (right).

## 2.4 Hydrotechnical evaluation

The calculation of the course of the levels was conducted using the Hec-Ras 6.3 program developed by the US Army Corps of Engineers. One of the possibilities of this program is the calculation of uniform and non-uniform steady flow in a non-prismatic flow. The basis of the program is a one-dimensional mathematical model of continuous flow in channels and natural beds. The one-dimensional computational model used allows uneven flow to be solved in the regime areas of rivers and streams, to solve simple and complex riverbeds, with the possibility of dividing their profiles into sub-parts. This makes it possible to apply the calculation algorithm to tracks with floods. Part of the program circuit is also the possibility of determining the approximate value of the opposite mutual depth of the water jump in the event that the flow regime is supercritical or subcritical. The calculation of objects on the stream is also part of the program. The basis of the solution of the program part is the gradual approximation method, or method by sections. The solution is realized by iterative procedures.

## 3 Result and discussion

The official flood risk maps, which also include the Hnilec river in the second cycle, depict the overflow of water from the riverbed already at the  $Q_{10y}$  flow rate. We also achieved remarkably comparable results, but there are few ambiguities and differences in the rendering of flood lines. The railway line runs parallel to the left bank of the riverbed. Part of the embankment of the rail of the given track are discharge objects (culverts), that release internal (urban) rainwater into the stream. In most cases, these culverts are not regulated and do not have a closure in the form of a sluice gate, so the rising water surface elevation during a flood can flow under the railway line and endanger the wider territory as shown in Figure 3.



**Fig. 3.** Culvert 1. (left) and Culvert 2. (right) from evaluation.



**Fig. 4.** Flood risk map (source: [https://mpt.svp.sk/svp\\_vmapportal](https://mpt.svp.sk/svp_vmapportal)).

## 4 Conclusion

Even small regular floods, or the results of the models show that the flood situation in the town of Gelnica is bad. The cramped conditions around the stream, the parallel railway track and the historic stone bridge in the city complicate the situation of the proposal of flood defence measures directly in the town residential area. One possibility is to transform the flood wave above the city and limit the flow of the flood water entering the city. For such a safe and regulated flow, we need to have defined maximum water surface elevation for critical infrastructure such as bridges or the height of the impervious layer of the embankment of the railway line. Another factor in defining the flow is the continuity of flood protection in the area under the municipalities, as the village of Jaklovce is in close proximity to the town of Gelnica. It will be possible to define the final safe flow only after a similar model has been developed for Jaklovce.

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