Hydraulic Modelling for Environmentally Friendly Small Hydropower: Innovations and Applications

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The main purpose of the study is to show, using a real example of mini hydropower plant the role of computer modeling in assessing its environmental impact and determining the possible consequences of extreme flood discharges in case of improper design of structures

a)

b)

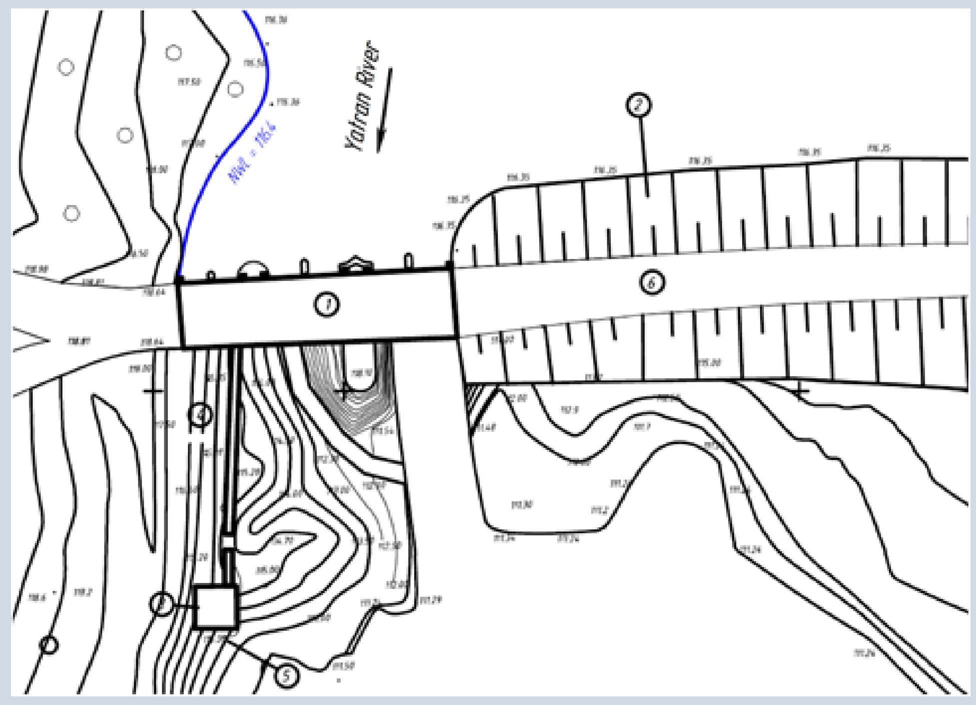

Fig. 1.Perehonivka mini hydropower plant: a) photo from the air, b) design of structures composition:
1 – water spillway,
2 – earth dam,
3 – power house,
4 – inlet canal
5 – outlet canal,
6 – road

Study area

The study area is the Perehonivka mini-hydropower plant on river Yatran (Fig 1a). It was built in the 1950s. In 2014 it was reconstructed that included upgrading the hydraulic structures that make up the hydroelectric complex (earthen dam, concrete spillway dam, inlet and outlet canals, and powerhouse) (Fig. 1b), selection of modern hydropower equipment, minimization of harmful effects on the river fish fauna, protection of the adjacent territory and the Perehonivka village from flooding by the Yatran River.

The Yatran River belongs to the Southern Buh River basin. Its length is 70 km, and the catchment area at the mouth is 2,170 km^{2}. The average long-term flow rate is 3.07 m^3/s. The maximum values of flow rates have reached 840 m^3/c (Fig. 2).

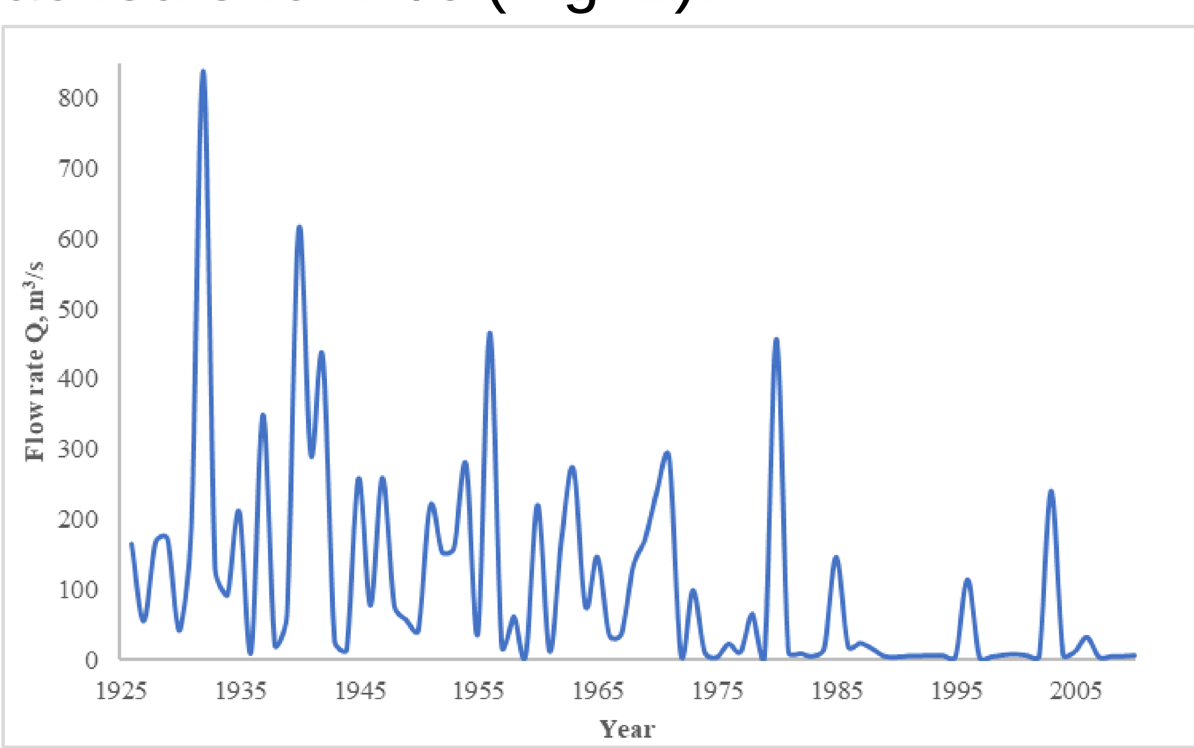

Fig. 2. Flow rate of floods in the location of Perehonivka HPP

Method of hydraulic processes modelling

The Perehonivka HPP was analyzed under two flow scenarios: regular turbine operation (4.6 m^3/s) and combined turbine and spillway operation during a 5% probability flood event (397 m^3/s) by mean of 2D modelling in HEC-RAS.

Results and discussion

a) b)

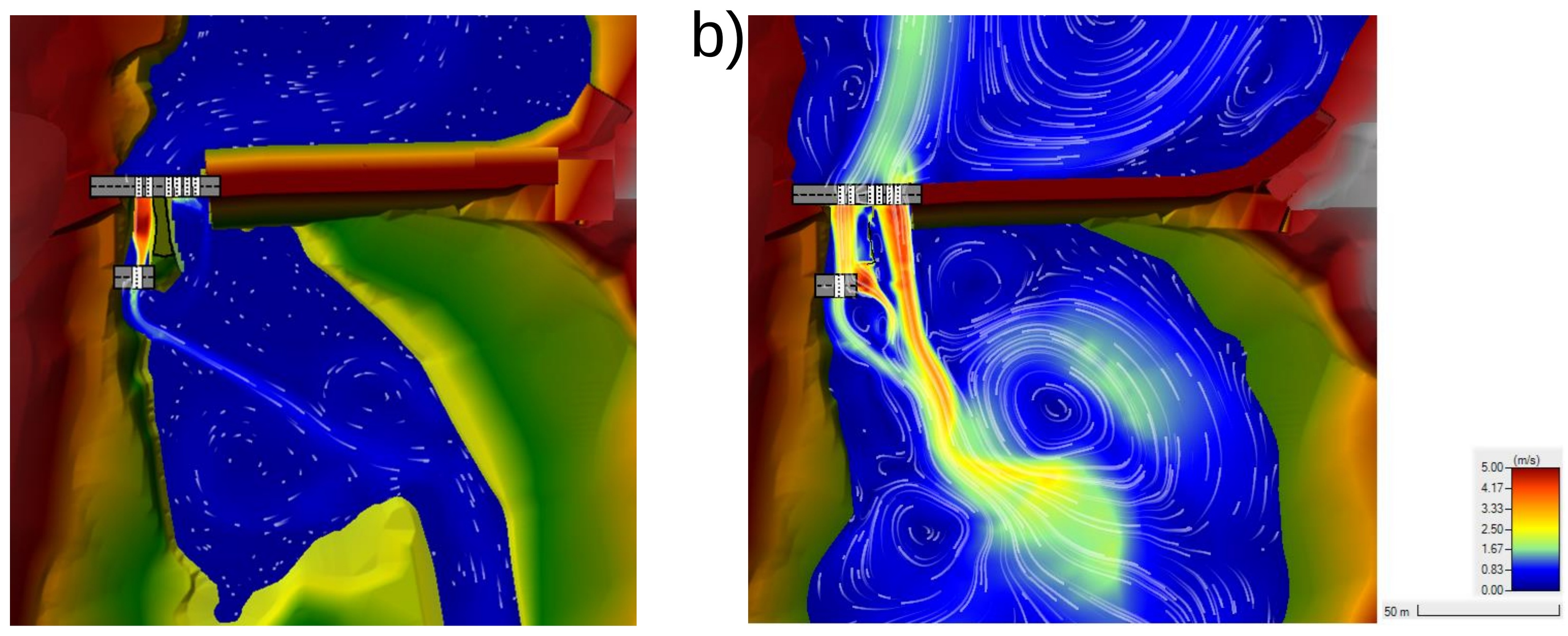

Fig. 3. Velocities values of modelling: a) during turbine operation with Q = 4.6 m^3/s, b) during turbine and spillway operation with Q = 397 m^3/s

a) b)

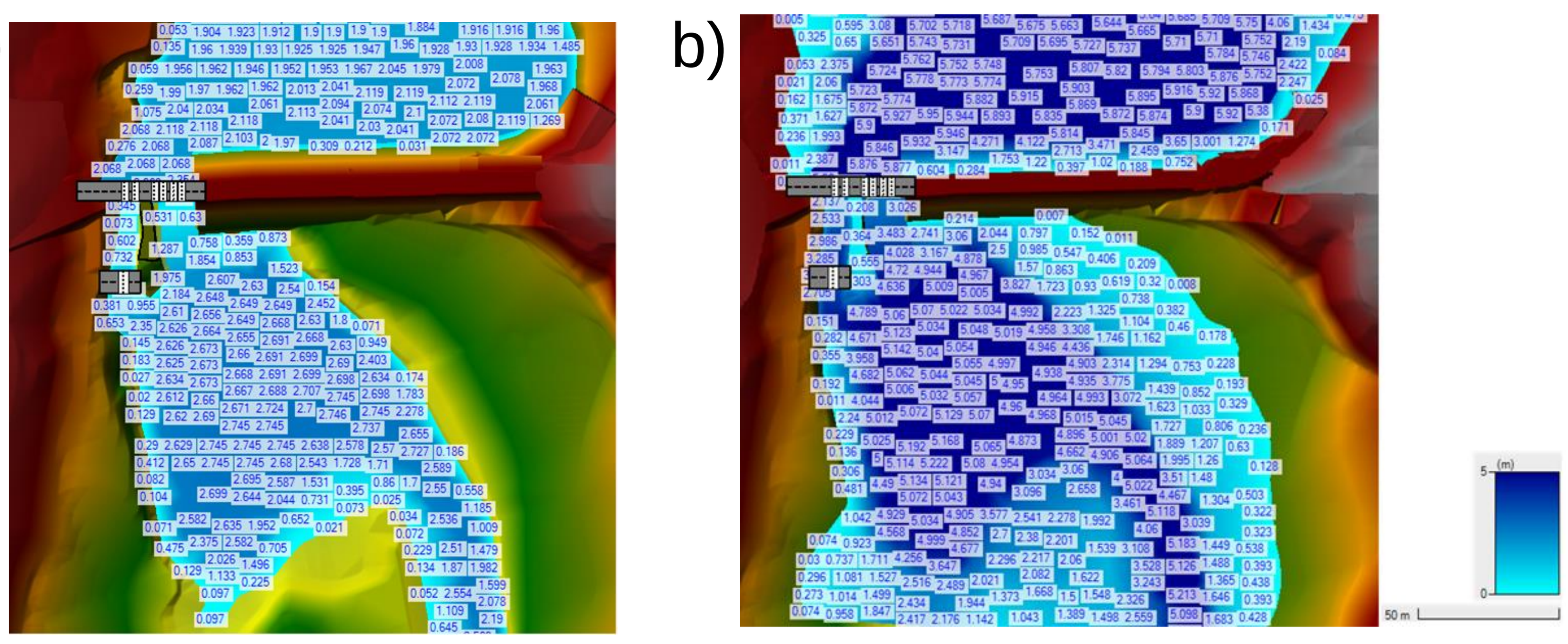

Fig. 4. Depth values of modelling: a) during turbine operation with Q = 4.6 m^3/s, b) during turbine and spillway operation with Q = 397 m^3/s

Conclusion

The study highlights the importance of detailed hydraulic modelling in evaluating and improving small hydropower plants' operational safety and efficiency. The results demonstrated that while the current system handles turbine operation under normal flow rates effectively, it becomes highly stressed during flood events, with water levels exceeding the canal banks and potential overflow beyond the design limits.