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Comparison of 2D HEC-RAS Modeling with the Observed September 2024 Flood in Poland: A Case Study of the Bóbr River in Bolesławiec

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1. INTRODUCTION

As part of the work on the Technical and Economic Analysis of the Construction of a Small Hydropower Plant in Bolesławiec, commissioned by Przedsiębiorstwo Wodociągów i Kanalizacji Sp. z o.o. Bolesławiec, a hydrodynamic model of a section of the Bóbr River was developed (Kostecki et al. 2024). This abstract highlights the key information of the research, which involved 2D modeling using HEC-RAS software to analyze flood propagation during the September 2024 flood event on the River Bóbr in Bolesławiec, Poland. The modeling results are compared with real-world conditions recorded during that period.

2. MODEL DESCRIPTION

The main purpose of the primary work was to analyze the impact of a Small Hydropower Plant in Bolesławiec, located at kilometer 145+000 of the River Bóbr. To conduct this analysis, a geodetic survey was carried out on the section between kilometer 144+700 and 145+200, covering 10 cross-sections (Short Model) as shown in Fig. 2. Additionally, a site inspection was performed, and the basic dimensions of bridges located downstream of the analyzed section were inventoried. The surveyed cross-sections were used to update the publicly available Digital Terrain Model through interpolation along the river axis, using a tool in HEC-RAS. The characteristic flows and flows with specified probabilities of occurrence were determined based on data from the “Dąbrowa Bolesławiecka” gauging station, located 7 kilometers downstream of the study area (Kostecki et al. 2024).

For model calibration, Flood Hazard Maps were utilized, particularly data from three points within the analyzed section. Due to challenges in obtaining reliable results, multiple calibration tests were conducted. One of the proposed solutions involved extending the model’s range from approximately kilometer 143+800 to kilometer 148+000 (Full Model) as shown in Fig. 1. The

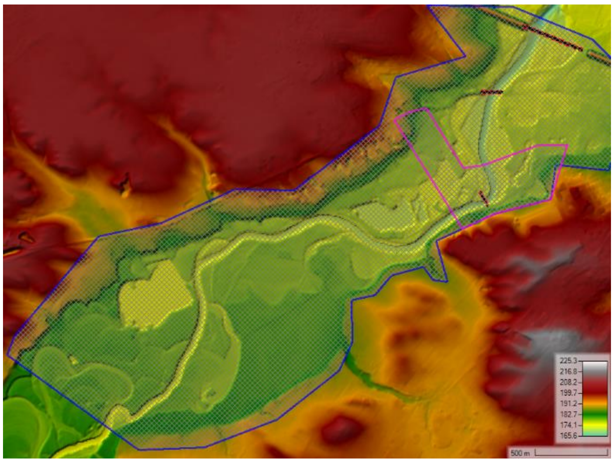

Fig. 1. Model map. Short Model – pinkcontour, Full Model – blue contour.

Fig. 2. Short Model map. Short Model – pink contour, black lines – locations of measured cross-sections, orange dots – locations of calibration points.

river bathymetry for the additional sections was extrapolated with the assumption that results for this portion may be less reliable. Implementing this solution allowed for the inclusion of two bridges located downstream of the analyzed section. The upstream boundary condition was defined as a "flow hydrograph" and the downstream boundary condition was defined as "normal depth" (the boundary condition where the energy slope is set). Two different sets of equations were tested: Diffusion Wave Equations (DWE) and Shallow Water Equation (SWE). Calibration results for Q1%, based on the Flood Hazard Map (ISOK 2025), are presented in Table 1. The bed friction was set as Manning *n* value: 0.035 for river bed, and 0.120 for floodplains. The grid size of the model ranged from 2 m by 2 m in the main channel to 15 m by 15 m in the floodplain areas.

3. CALIBRATION RESULTS

Table 1
Calibration results

	Location (kilometer of the River Bóbr)			144+916	145+177	145+204	
Model variants	Calibration tests			Water surface elevation [m a.s.l.]			Δ [m]
0	ISOK flood hazard map Q1%			174.38	174.87	174.99	–
1	Short Model	DWE	Downstream normal depth 0.002	173.669	174.314	174.926	0.52
2	Short Model	DWE	Downstream normal depth 0.001	174.343	174.728	175.033	0.09
3	Short Model	SWE	Downstream normal depth 0.002	173.663	174.696	175.075	0.43
4	Short Model	SWE	Downstream normal depth 0.001	174.354	174.941	175.190	0.12
5	Full Model	DWE	Downstream normal depth 0.002	174.408	174.768	175.080	0.08
6	Full Model	DWE	Downstream normal depth 0.001	174.400	174.764	175.038	0.07
7	Full Model	SWE	Downstream normal depth 0.002	175.254	175.538	175.746	0.77

where:

$$\Delta_{\mathrm{k}} = \sqrt{\frac{1}{n}\sum_{i=1}^{n=3}\left(WSE_{k,i} - WSE_{ISOK,i}\right)^2} \tag{1}$$

WSE – water surface elevation [m a.s.l.], *k* – variant number, *i* – location.

The results from variants 1 to 4 show significant changes in water levels when the normal depth was adjusted from 0.001 to 0.002. Since the actual value of the normal depth is difficult to determine precisely, the Full Model was considered significantly more reliable due to the distinctly smaller differences between variants 5 and 6. The application of the Shallow Water Equation (SWE) yielded less accurate results, particularly for the Full Model (variant 7). Additionally, SWE proved to be six times more computationally demanding than the Diffusion Wave Equations (DWE).

In conclusion, the Full Model DWE was deemed the most suitable approach as it provides satisfactory accuracy compared to ISOK, is not sensitive to changes in the boundary conditions, and is less computationally expensive than the SWE model.

4. FLOOD EVENT

In September 2024, a flood caused by the Genoa low-pressure system resulted in catastrophic consequences, leading to the declaration of a state of natural disaster (Rozporządzenie RM 2024). The River Bóbr experienced exceptionally high water levels, significantly impacting the town of Bolesławiec, which is represented in the numerical model. Using data from the Polish Institute of Meteorology and Water Management (IMGW) gauging station at Dąbrowa Bolesławiecka (Hydro IMGW-PIB 2025), the model was validated against the actual flood situation. The flow rates were input to reflect the real conditions without introducing any additional modifications

The obtained results satisfactorily align with the actual situation. Figure 3 shows that the flood-affected area in the model closely matches the real-world extent. This is particularly evident in the western region, where a large building with a red roof was impacted by the flood, while neighboring buildings situated slightly higher remained outside the inundation zone.

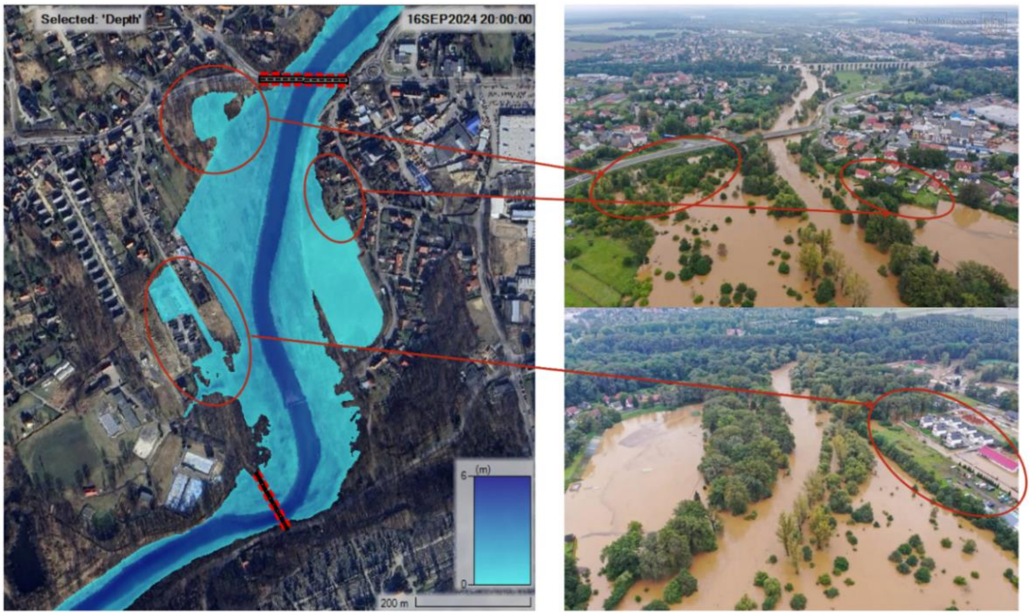

Fig. 3. Comparison of the results for the September 2024 flood, performed using the Full Model DWE, with the actual flood situation shown in the photos presented in Miasto Bolesławiec (2024).

5. CONCLUSION

The presented model successfully passed verification against the September flood, confirming the effectiveness of this tool. The calibration technique employed, based on results from the ISOK Flood Hazard Maps and the extrapolation of riverbed geometry data, proved effective and reduced the uncertainty associated with assuming a single normal depth value for the downstream boundary condition. Satisfactory results were achieved, even in areas extending beyond the more accurately modeled section of the river.

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