Supplementary Material

Evaluation of green and grey flood mitigation measures in rural watersheds

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S1. Existing and Proposed Flood Protection Measures in the Tamnava Watershed

This section provides a description of the existing and proposed flood protection system in the Tamnava watershed. The description of the flood protection system is based on the information available in the UNDP study [1].

The existing flood protection system consists of the levees, while the proposed system includes raising some of the existing levees and the detention basins. The levee system is presented in Table S1: namely, features of the existing systems are outlined together with the proposed heightening under the green and green-grey flood mitigation scenarios described in the paper. Some elements of these levees, such as crests and berms, are made of concrete, especially in the settlements (see Figure S1).

The three proposed detention basins in the Tamnava watershed will be formed by building earthen dams in the upper reaches of the Tamnava, Ub and Gračica Rivers. The locations of the proposed detention basins are selected to avoid overlapping with major traffic infrastructure, industrial facilities or settlements (except for few isolated households that will be relocated). The dams are designed as rock fill structures with clay cores. During flood events, excess water in the detention basins will be discharged within 10-15 days through open sluice ways. It should be emphasized that the UNDP study [1] presents merely a conceptual description of the three dams, while their detailed design will be produced in later stages of the project. The details on the dams that were available in the UNDP study are outlined in Table S2.

Table S1. Levee system in the Tamnava watershed (source: UNDP study [1]).

River	Section	River Bank	Station (start end)	Levee Length (m)	Elevation of the Levee Top (m a.s.l.)	Average Levee Height (m)	Design Flood	
							Existing system	Proposed system
Tamnava	Confluence with Kolubara – Ćemanov most	Left	0+000 13+850	13,850	81.80 / 89.85	3	100	1000
	Confluence with Kladnica – Brgule	Right	0+000 4+554	4,554	82.50 / 84.80	2.5	100	100
	Brgule – Confluence with Ub	Right	4+833 8+581	3,748	85.40 / 87.00	3.5	25	100
	Confluence of Ub – Ćemanov most	Right	8+581 12+083	3,502	87.00 / 89.20	2.5 – 3	100	100
	Ćemanov most – Takovo bridge	Left	12+083 17+743	5,660	89.15 / 93.60	2.8	50	100*
	Ćemanov most – Takovo bridge	Right	12+083 17+743	5,660	89.39 / 93.60	2.8	50	100*
	Upstream of the Takovo bridge	Both	N/A	2,600	N/A	N/A	50	100
	The town of Koceljeva	Both	0+000 2+400	2,400	121.50 / 127.80	N/A	50	100
	Donje Crnjiljevo	Left	0+000 1+000	1,000	171.96 / 177.92	1	50	50
Ub	Confluence with Tamnava - Šarbane	Right	0+000 3+830	3,830	85.98 / 88.27	2	25	100*
	Confluence with Tamnava - Šarbane	Left	0+000 3+830	3,830	87.00 / 89.20	2	25	100*
	Šarbane – brickyard	Both	3+924 8+300	4,376	87.82 / 92.54	1-2	25	100
	The town of Ub	Both	8+300 12+533	4,233	92.54 / 96.86	1	100	100
	Upstream of Gunjevac bridge	Both	12+533 13+450	917	N/A	N/A	25	N/A
Gračica	Upstream of the confluence	Both	0+000 0+600	600	N/A	N/A	N/A	100[U]

* Riverbed widening and removing obstacles from the riverbed in these sections is planned.

[U] Only in the area of the town of Ub.

N/A – data not available.

Figure S1. Levees in the Tamnava watershed (photos made by R.P.).

Table S2. The three detention basins in the Tamnava watershed.

Detention Basin	Kamenica at Tamnava	Pambukovica at Ub	Gračica at Gračica
Preliminary location	62.5 km upstream of the confluence with Kolubara; 8.5 km upstream of the town of Koceljeva	30.5 km upstream of the confluence with the Tamnava River	12 km upstream of the confluence with the Tamnava River
Drainage area (km^2)	132.6	113.1	23.1
Total storage volume (10^6 m^3)	11.2	10.8	3.8

S2. Hydrodynamic Model for the Tamnava watershed

This section provides information on the hydrodynamic model developed within the scope of the UNDP study [1] for flood simulations in the Tamnava watershed. The model is calibrated to reproduce water stages and flooding extents observed during the flood event in May 2014 (referred to as MODEL 2014 in the paper). Table S3 presents details on the calibrated MODEL 2014, together with the calibrated Manning roughness coefficients in the reaches of the Tamnava, Ub and Gračica rivers. All data given in the table are retrieved from the UNDP study [1]. Additionally, according to this study, the estimated Manning roughness coefficients in MODEL 2014 were fine-tuned (by including other flood events into model calibration) in the river sections that were most affected by levee breaching/overtopping during the 2014 flood.

The observed hydrographs during the flood event in May 2014 versus the simulated ones by the MODEL 2014 are shown in figures S2 through S4.

Table S3. Characteristics of the hydrodynamic model of the Tamnava, Ub and Gračica rivers for the May 2014 flood event (MODEL 2014; adapted from [1]).

River	Comp. time step	Number of cross-sections (mean distance between the sections)	Boundary conditions			Flooding extent used in calibration	River reach	Manning roughness coefficients	
			Upstream	Inner	Downstream			Main channel	Flood -plain
Tamnava	1 min.	85 (730 m)	Simulated hydrograph at Kamenica detention basin	Simulated hydrographs at location of tributaries	Simulated stage at the confluence with Kolubara	Yes	r1	0.06	0.08
							r2	0.035	0.06
							r3	0.035	0.06
							r4	0.032	0.06
							r5	0.035	0.06
Ub	1 min.	44 (700 m)	Simulated hydrograph at Pambukovica detention basin	Simulated inflow from the contributing drainage area	Simulated stage at the confluence with Tamnava	Yes	r1	0.035	0.06
							r2	0.03	0.08
							r3	0.035	0.07
Gračica	1 hour	95 (200 m)	Simulated hydrograph	Simulated inflow from the contributing drainage area	Simulated stage at the confluence with Tamnava	No	r1	0.035	0.06

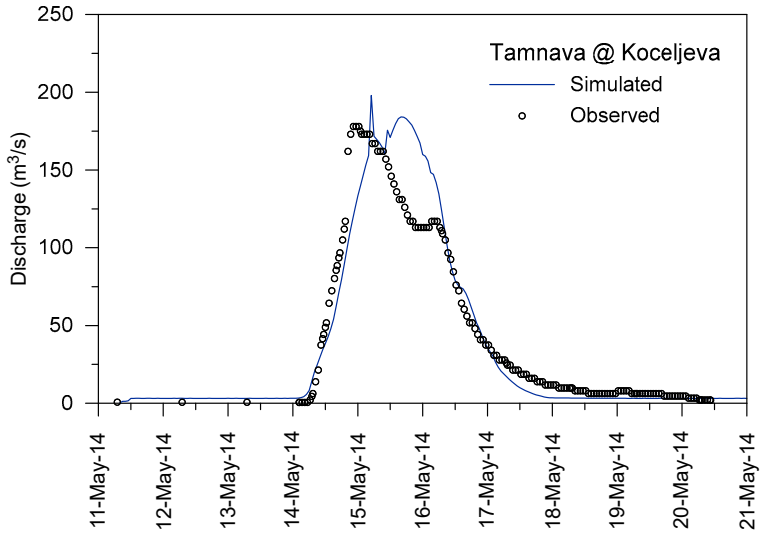

Figure S2. Simulated and observed hydrographs during the flood event in May 2014: the Koceljeva stream gauge at the Tamnava River.

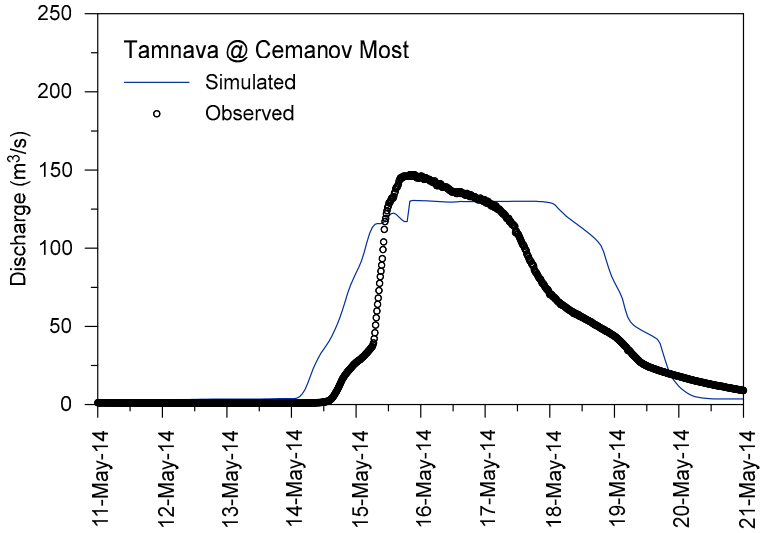

Figure S3. Simulated and observed hydrographs during the flood event in May 2014: the Ćemanov Most stream gauge at the Tamnava River.

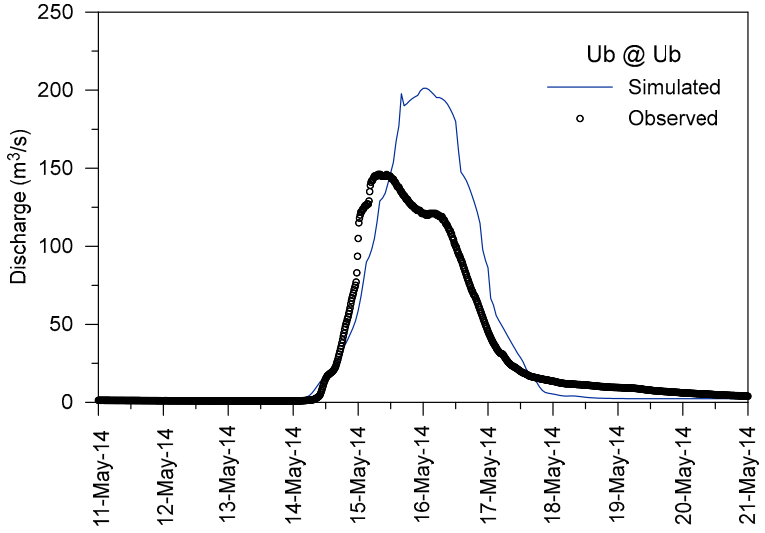

Figure S4. Simulated and observed hydrographs during the flood event in May 2014: the Ub stream gauge at the Ub River.

References

1. UNDP Serbia. *Studija unapređenja zaštite od voda u slivu reke Kolubare (Study of the Upgrade of the Flood Protection System in the Kolubara Watershed)*; Institute "Jaroslav Černi" for the United Nations Development Programme in Serbia and Public Water Management Company "Srbijavode"; Belgrade, 2016. Available online: https://studijakolubara.srbijavode.rs/izvestaji_o_rezultatima_studije/Друга-фаза/preliminarni_izvestaj/ (accessed on 10 September 2020).