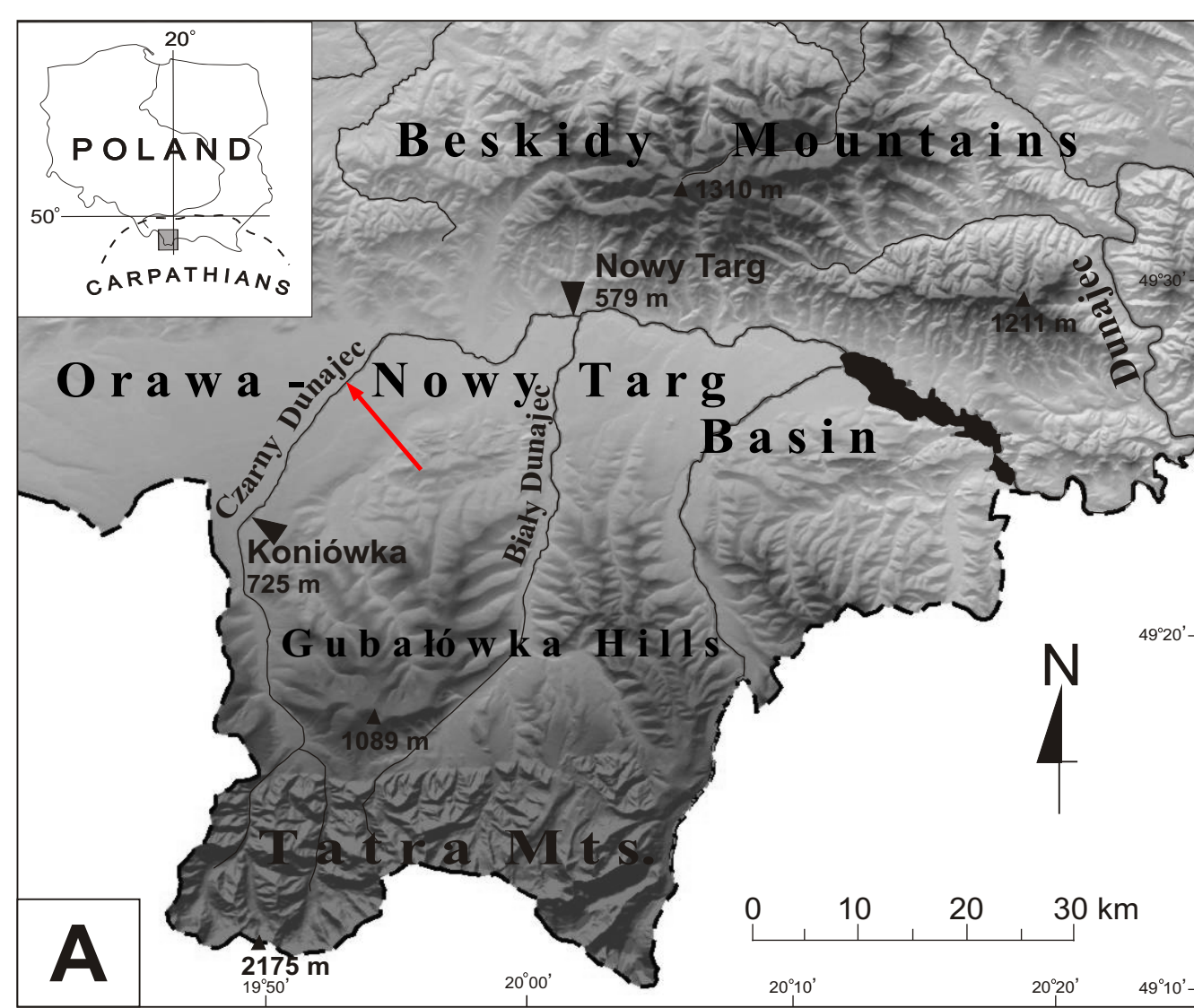


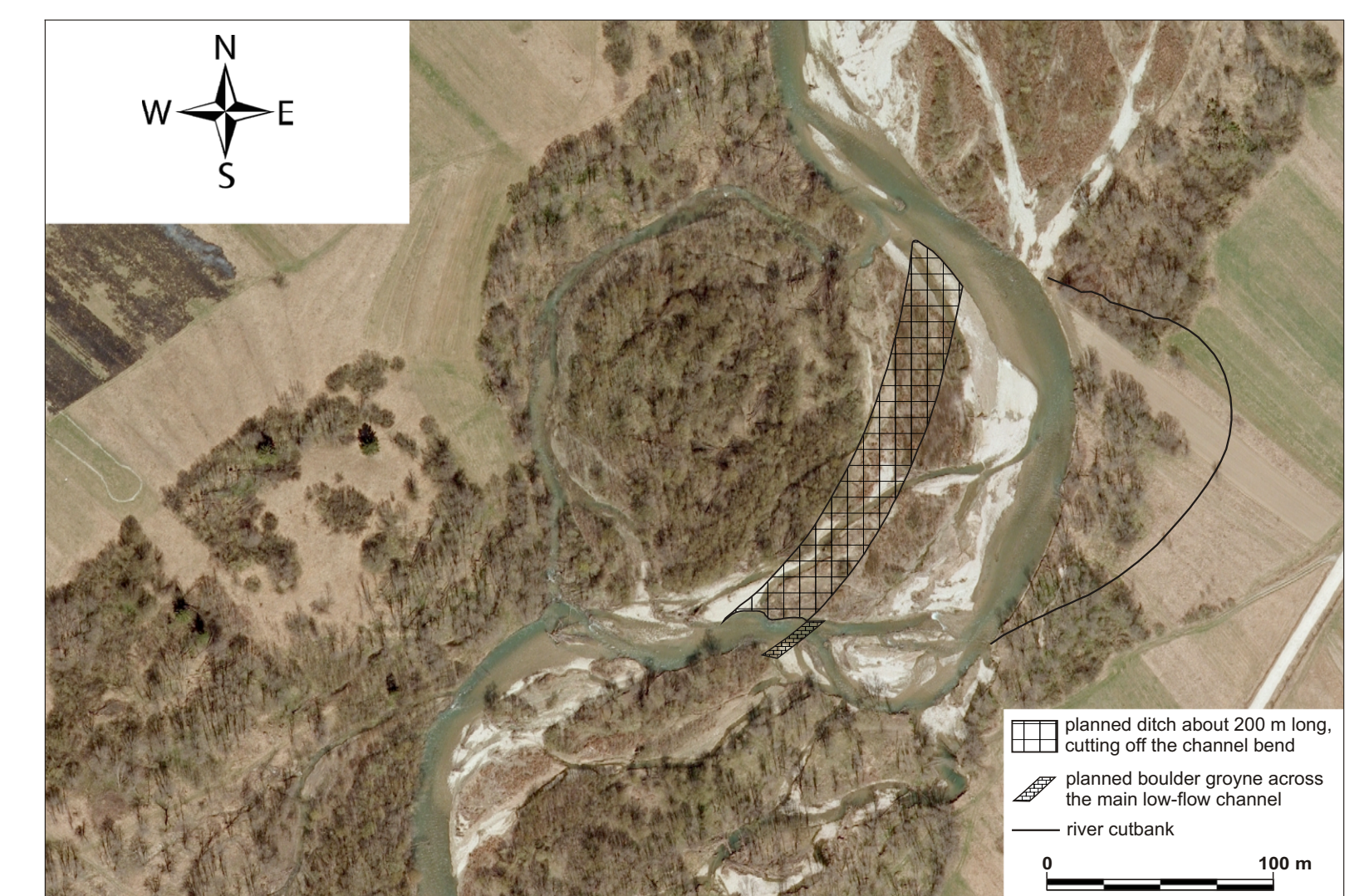
Environment-friendly reduction of flood risk and infrastructure damage in a mountain river: case study of the Czarny Dunajec

Bartłomiej Wyżga (Institute of Nature Conservation, Polish Academy of Sciences, Poland, wyzga@iop.krakow.pl), Paweł Mikuś, Antoni Amirowicz, Mateusz Przebieda (Institute of Nature Conservation, Polish Academy of Sciences, Poland), Artur Radecki-Pawlik (Department of Hydraulic Engineering and Geotechnique, University of Agriculture in Kraków, Poland), Paweł Oglęcki (Department of Environmental Engineering, Warsaw University of Life Sciences, Poland), Joanna Zawiejska (Institute of Geography, Pedagogical University in Kraków, Poland)



1 Location of the Czarny Dunajec River in southern Poland and location (indicated by the red arrow) of the environment-friendly flood risk solution.

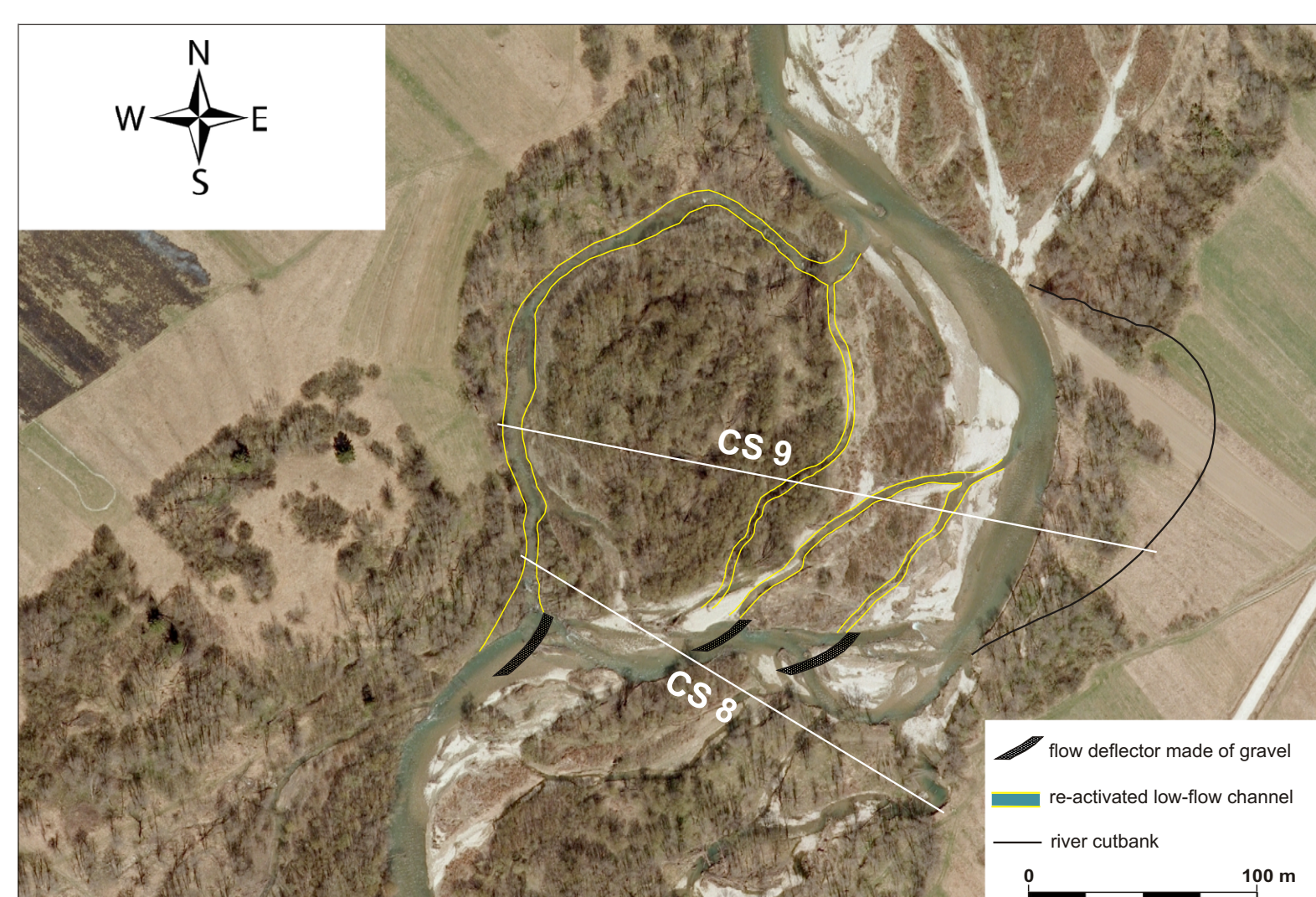
The Czarny Dunajec drains the Inner Carpathians in southern Poland (1). Its unmanaged, multi-thread reaches exhibit high hydromorphological quality, support a relatively rich biocoenosis and trap substantial amounts of woody debris, preventing its further transfer to urbanised valley reaches (3). To arrest erosion of a laterally migrating channel and protect a nearby road, water authorities planned construction of a ditch with reinforced banks and damming the main channel with a boulder groyne (2). The channelization would deteriorate the ecological status of the reach and increase flood risk to downstream reaches. A different solution to limit the erosion risk to the road was thus proposed, aiming to open the inlets to inactive braids located by the neck of the bend of the main channel (4). Directly below the inlets to the reactivated side channels, gravelly deflectors were constructed to divert the flow into the channels and prevent the water from entering the main channel (5). The scheme, re-establishing the flow in the steeper side channels, was applied in the autumn 2001 with the budget of 9000 euro.



2 Situation in the so far unmanaged, multi-thread section of the Czarny Dunajec River resulting in the erosional threat to a local road, and channelization works planned in the section by water authority. The location of erosional cutbank in the summer 2011 is shown on the background of the orthophoto from 2009.



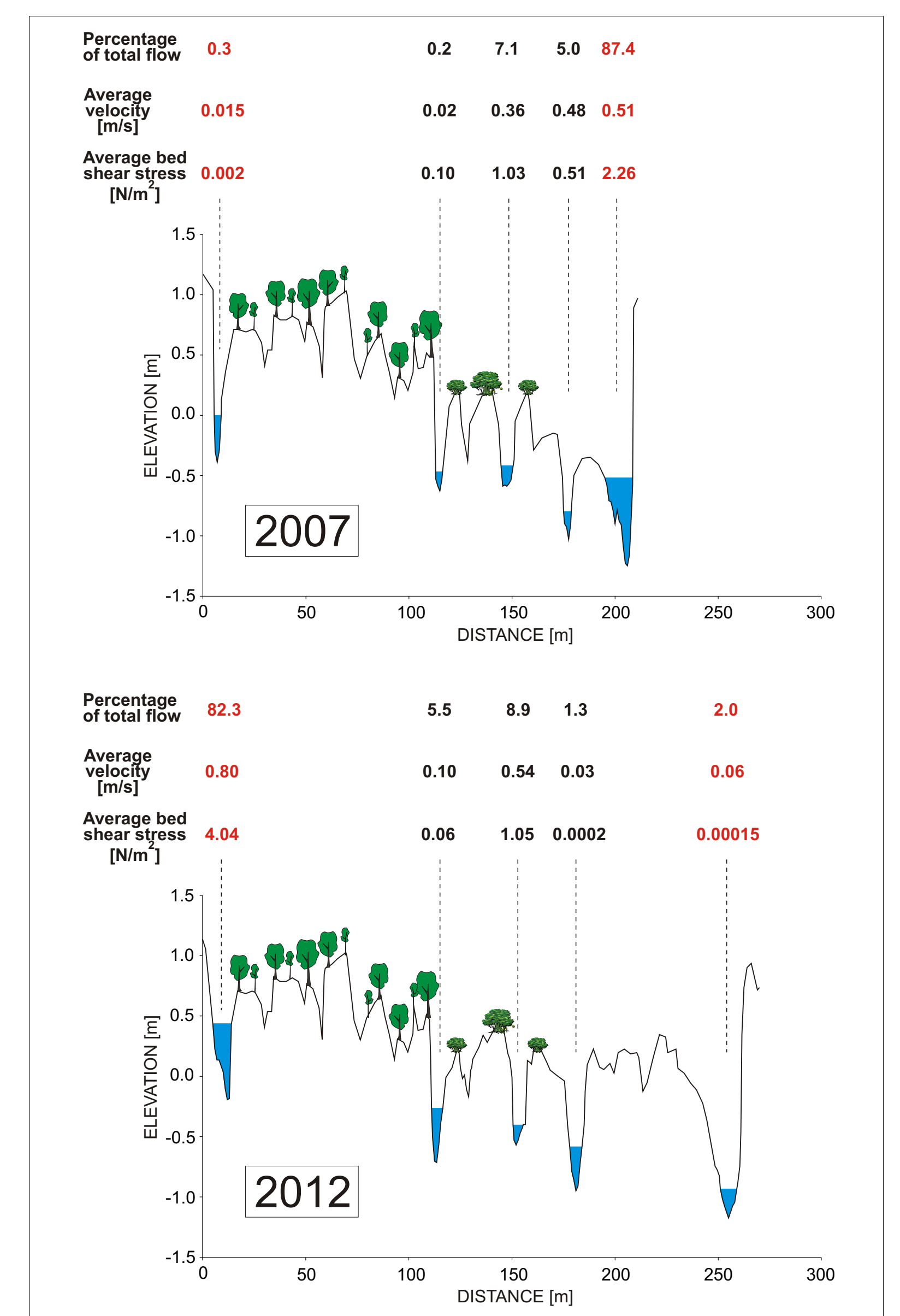
3 Narrow braids in the multi-thread river section operate as natural traps for the woody debris transported by flood flows, preventing its further transfer to urbanised valley reaches.



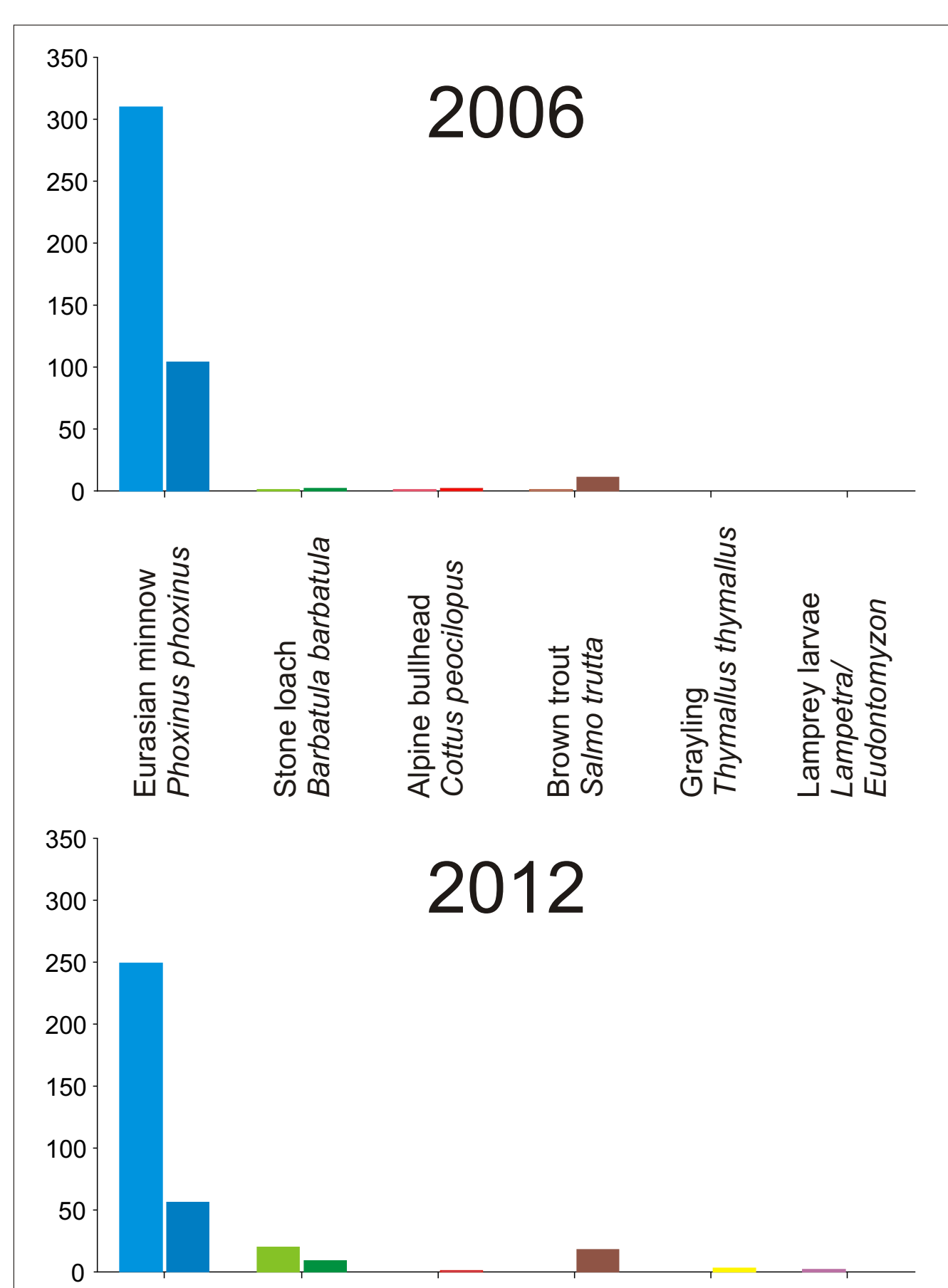
4 Environment-friendly solution to the erosion threat to the local road, implemented in the autumn 2011. Inlets to blocked braids farther from the road were opened and gravelly flow deflectors were formed in the main channel in order to direct flow to the re-activated braids.



5 Re-opened inlet to a braid running inside the bend of main river channel. The arrow indicates the direction of flow along the bend of main channel. A gravelly deflector directs water to the re-activated braid and prevents it from flowing to the main channel.



6 Morphology of the active zone of the Czarny Dunajec and hydraulic characteristics of particular low-flow channels in cross-section 9 in 2007 and 2012. Until 2011, the right braid conveyed most flow and exhibited high values of velocity and bed shear stress, leading to its progressive lateral shift. With the implementation of flood risk solution, the main water current was shifted to the left braid, most distant from the road.



7 Average composition of fish assemblages recorded in cross-sections 8 and 9 during the electrofishings performed in 2006 and 2012, i.e. before and after the implementation of the environment-friendly flood risk-reducing solution. Lighter and darker colours indicate juvenile (YOY) as well as subadult and adult fish individuals, respectively.

Taxon	2007		2012	
	CS 8	CS 9	CS 8	CS 9
<i>Crenobia alpina</i>	x	x		
<i>Dendrocoelum lacteum</i>			x	x
<i>Dendrocoelum carpathicum</i>		x		
<i>Nematoda</i>		x		
<i>Lumbricidae</i>		x		
<i>Pisicola</i> sp.			x	x
<i>Erpobdella</i> sp.			x	x
<i>Aeshna</i> sp.			x	x
<i>Ephemera</i> sp.			x	x
<i>Baetis</i> sp.			x	x
<i>Ephemerella ignita</i>		x	x	x
<i>Heptagenia</i> sp.	x	x		
<i>Agapetus</i> sp.	x	x		
<i>Leuctra</i> sp.	x	x		
<i>Caenis</i> sp.	x	x	x	x
<i>Perla</i> sp.	x	x	x	x
<i>Perlodes</i> sp.	x	x	x	x
<i>Platambus maculatus</i>			x	x
<i>Gyrinidae</i>			x	x
<i>Nolidobia ciliaris</i>			x	x
<i>Goera</i> sp.	x	x		
<i>Hydropsyche</i> sp.	x	x	x	
<i>Philopotamus</i> sp.	x	x		
<i>Rhyacophila</i> sp.	x	x		
<i>Limnephilus</i> sp.			x	x
<i>Liponeura</i> sp.				x
<i>Chironomidae</i>		x	x	x
<i>Simuliidae</i>			x	x
<i>Tabanus</i> sp.		x	x	x
<i>Tipula</i> sp.		x		
<i>Theodoxus fluviatilis</i>			x	x
<i>Ancyclus fluviatilis</i>	x	x		
<i>Physa</i> sp.			x	x
<i>Valvata piscinalis</i>			x	x
Total number of taxa	13	19	19	22

8 Composition and richness of benthic macroinvertebrate assemblages recorded in cross-sections 8 and 9 during the surveys performed in 2007 and 2012, i.e. before and after the implementation of the environment-friendly flood risk-reducing solution.

After the scheme implementation, the river cross-sections located at the upstream end and in the middle of the main channel bend (4) were surveyed to compare the hydraulic characteristics of flow (6) and the composition of fish (7) and benthic invertebrate communities (8) with those recorded prior to the project. The hydraulic measurements confirmed that the scheme allowed to shift the main water current, with the highest average velocity and bed shear stress, from the right braid closest to the road to the left, most distant one (6). This should lead to a natural cut-off of the main channel and its abandonment during the next flood. The biotic surveys documented an increase in the number of fish species (7) and benthic invertebrate taxa (8) in comparison with the situation before the scheme implementation.

The implemented solution:
 – effectively changed the hydraulic pattern
 – enhanced ecological functions of the multi-thread channel
 – maintained the role of the reach as wood debris trap
 – was significantly less expensive.