



## **Unexpected drying of the river bed after floods and weak earthquakes – case of the River Iška in the central Slovenia**

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In September 2010 central Slovenia has suffered floods with return period of around 100 years. Floods occurred also in the watershed of River Iška positioned on the southern rim of Ljubljana Moor (Ljubljansko barje) approximately 15 km south of the capital city of Slovenia. The River Iška discharges into larger river Ljubljanica. At the gauging station positioned in the upper middle part of the watershed the total recharge area is 69.7 km<sup>2</sup>. Until 2008 average discharge was 1.48 m<sup>3</sup>/s and average yearly precipitation in the watershed was between 1400 and 1500 mm. In the upper part watershed is represented by the steep slopes and large part of the river is positioned in the gorge predominantly consisting of Triassic dolomite and limestone. Lower part is represented by alluvial fan of gravel with high permeability and terminal part is represented by regulated wetland area. In September 2010 due to the interferences of high waters at the confluence River Iška has flooded its lower part.

High water in Iška starts on 17.09.2010 and the maximum discharge of 59.3 m<sup>3</sup>/s was reached on the midnight between 19.09.2010 and 20.09.2010. The measured peak discharge represents a record value since the starting of the gauging station in 2001. On 21.09.2010 at 0:19 UTC two weak shallow earthquakes (ML=0.5 and ML=0.2) occurred 43 seconds apart with the epicentres in the valley bottom. They were felt by some inhabitants who reported also a rumbling noise (brontides). Several shallow earthquakes with epicentres in the wider surrounding followed in next 15 days. On 23.09.2010 the river bed dried completely. It was dry for nearly two days until 25.09.2010 when due to heavy rain water in the river bed appeared again. The epicentres of the first two earthquakes are positioned in the place where river started to sink.

Drying of the Iška's river bed in its middle part is a very rare event. The last recorded one happened before World War II, more than 70 years ago. Therefore, drying of the bed after intensive discharge and floods was followed by all the media and wider public interest was attracted. Many controversial questions have been raised.

Drying of the bed is the consequence of several events and natural conditions of the river bed. In normal situation the river bed is clogged with fine sediments of sand and marl. The alluvial fan of the river is represented with high permeable gravel pack and positioned on the karstified limestone where open fissures are present. The limestone also outcrops on the river bank. During the flood event of September 2010 high waters remove the clogged river bed and several springs in limestone on the bank were also recorded above river's water table. After the end of the rainfall, springs on the banks dries and river starts to sink in the cleared river bottom. Mapping of the river bed showed that due to low permeable river bed river water, before the flood, hang above the groundwater bellow. With the removal of the low permeable bed and lowering of high groundwater head from the karstified limestone aquifer in the bottom, river water started to sink.

The role of earthquakes remains open. However, seismological analyses have shown that the first ideas about cave-in of the river's limestone base (collapse earthquakes) is unlikely mechanism. All earthquakes are interpreted as shallow tectonic events. Since they occurred at the position of a known fault, they could be accompanied by small tectonic movements.