# *Surveillance of the banks of reservoirs on the Drava River in Slovenia after extensive floods*

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# *Introduction*

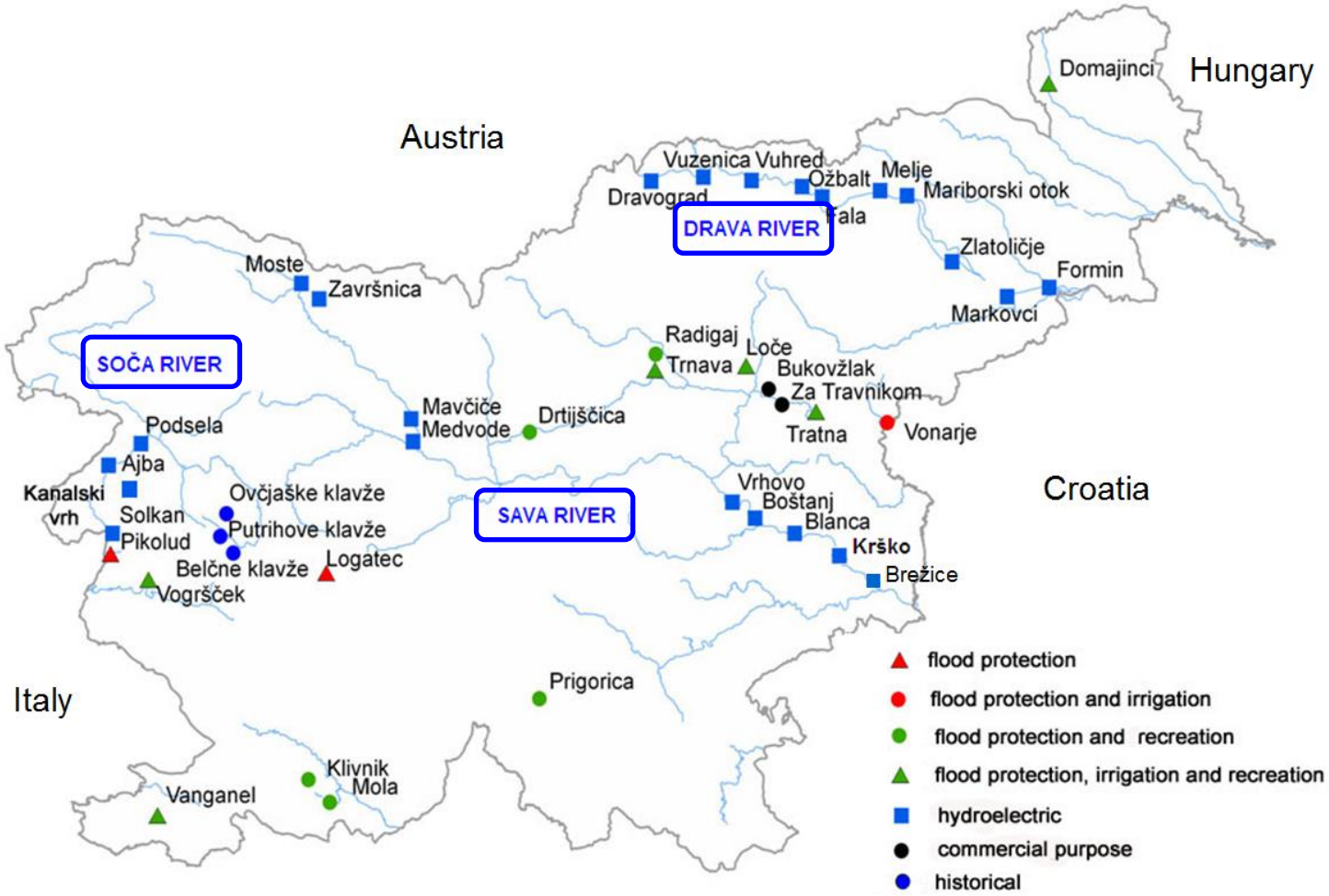
There are over 40 large dams in Slovenia - concrete and embankment dams.

Intended for water retention for various purposes: electricity generation, floods mitigation, irrigation, industrial water use and recreation.

Also some historical dams and dams used for other commercial purposes.

Most water reservoirs in Slovenia used for several purposes.

On the three largest rivers in Slovenia: 21 reservoirs with actual priority use for electricity generation, but also used for other purposes.




The locations of large dams in Slovenia

# *Water reservoirs on the Drava River in Slovenia*

The Drava River (725 km) flows through southern central Europe.

Tributary of the Danube River.

Source of the river is in northern Italy at 1450 m a. s. l.

It connects Alpine and Pannonian biogeographical regions.


Course of the Drava River

On the Slovenian section of the Drava River (133 km) eight HPPs are located: six HPPs located directly in the river course; the other two HPPs situated in derivation channels of the river.

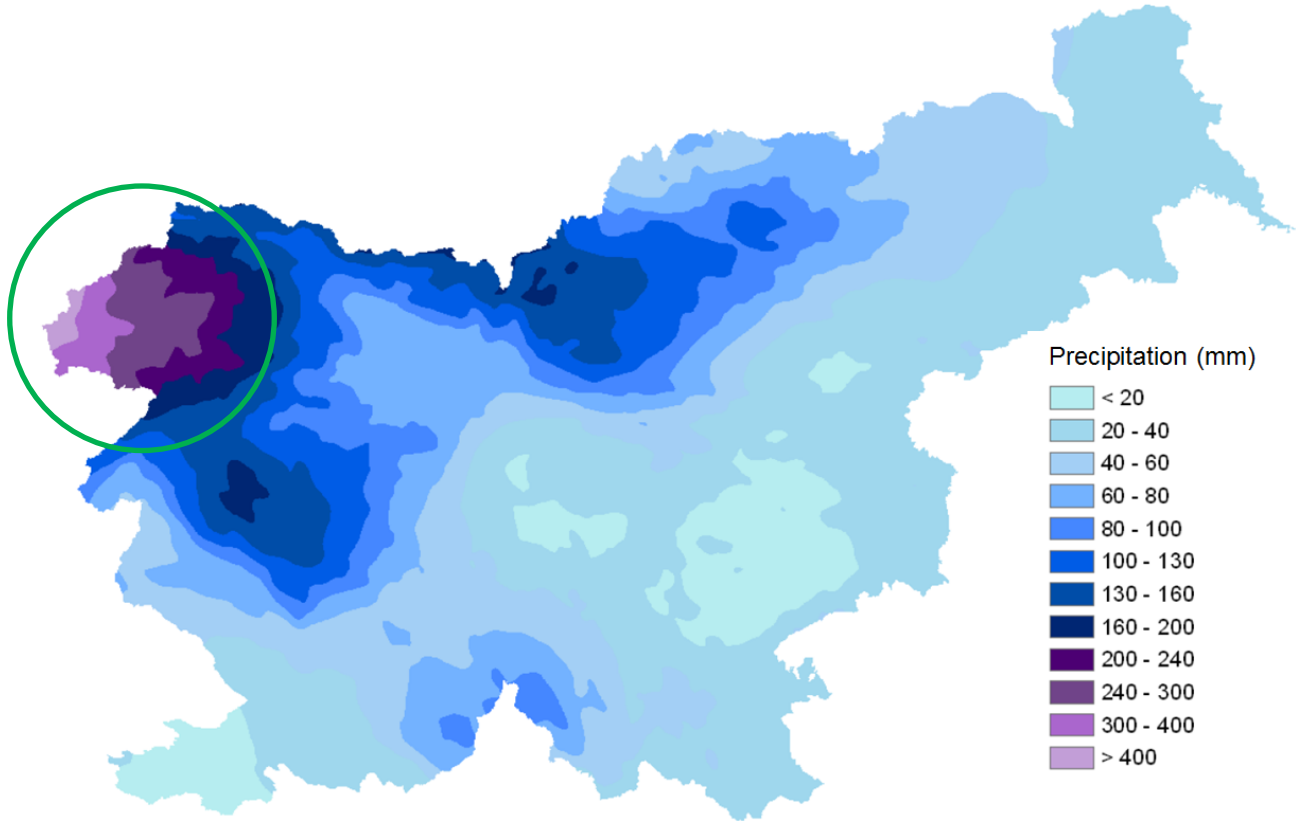
10 concrete gravity dams (heights: from 17 to 54 m) built from 1918 to 1978 created 8 multipurpose reservoirs.


Location of HPPs on the Slovenian section of the Drava River

# *Extreme event – Extensive floods in November 2012*

After a very long drought (from autumn 2011 to autumn 2012) – the first abundant precipitation was at the end of October 2012.

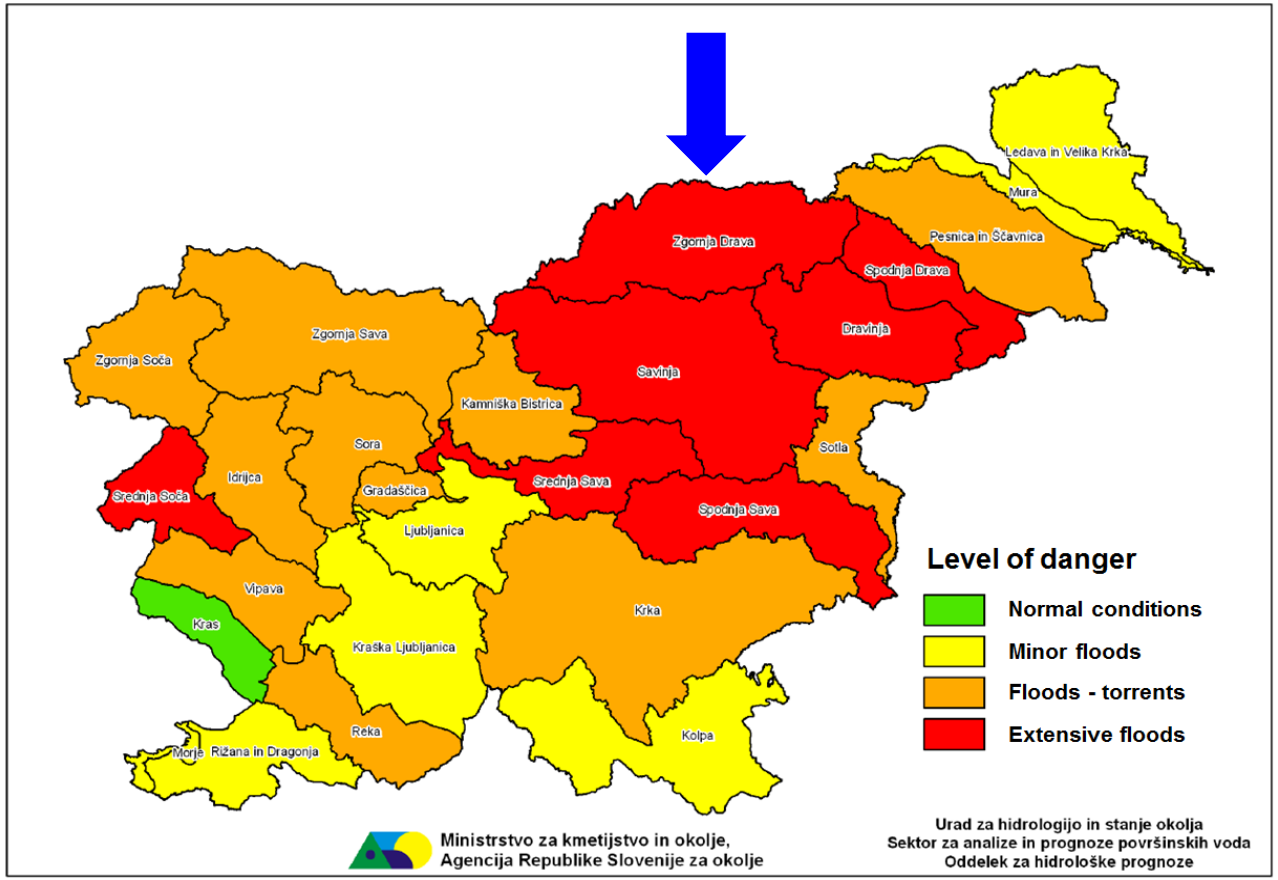
The next abundant precipitation appeared a week later (on 4th and 5th November 2012).




Spatial distribution of 48-hour precipitation

The precipitation caused that – due to the pre-saturation of the soil with water and also due to the melting snow that fell in late October – the flows of most rivers began to increase rapidly.

The consequences of this event: floods of many rivers in Slovenia.

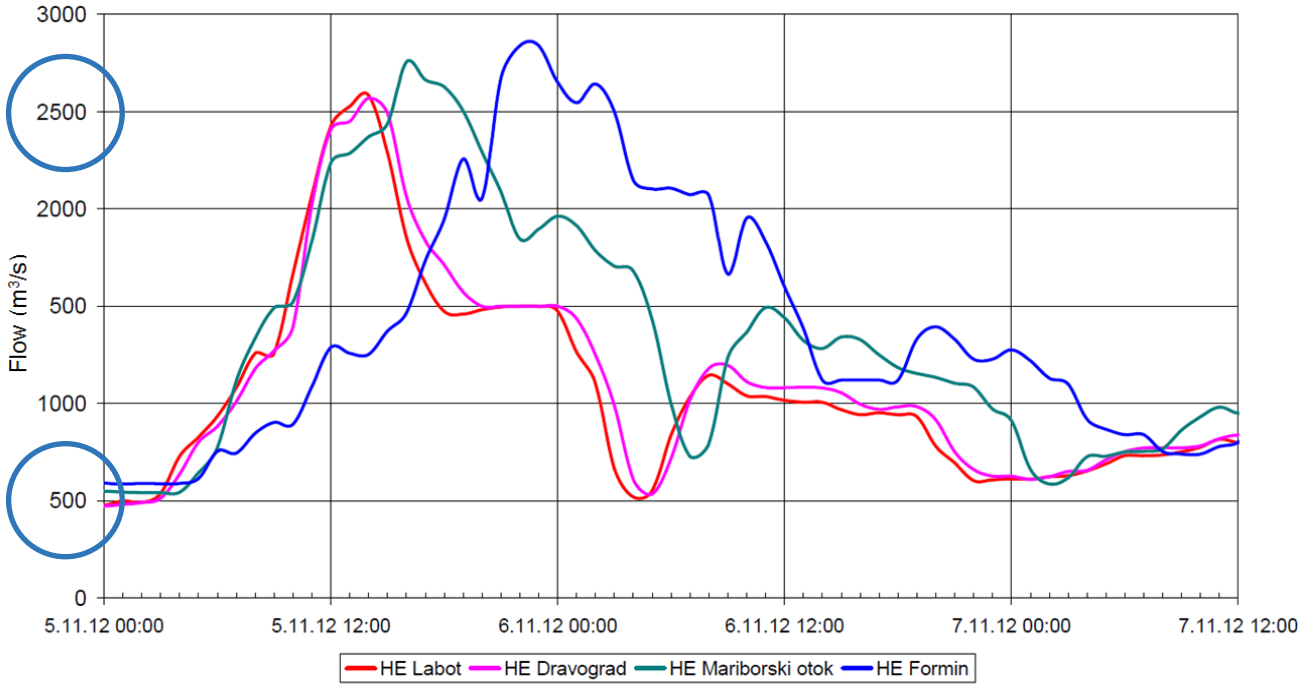



Flood forecast for the afternoon of 5th November 2012 (issued at Slovenian Environment Agency)

The worst floods caused by the Drava River (in the middle and lower reaches of the river), which – also due to the extremely increased inflow from Austria on 5th November in the morning – rose sharply and reached record flows.

Extensive floods of the Drava River (6th November 2012)

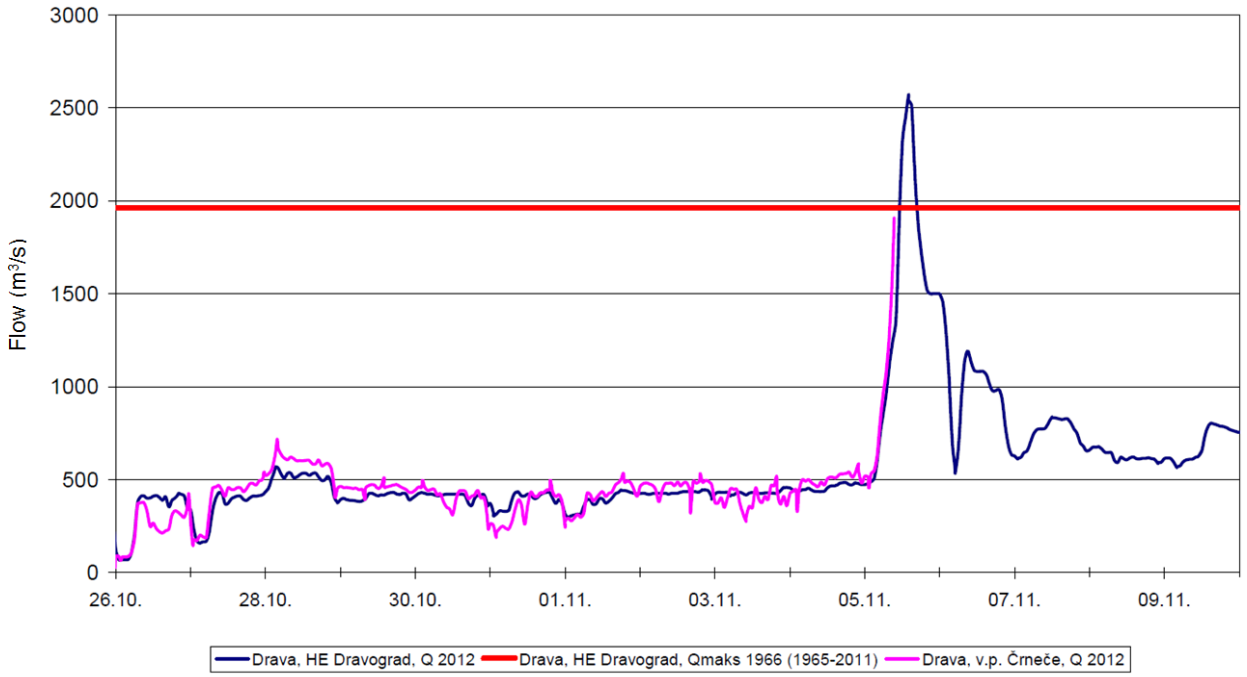
The extremely high flows of the Drava River (more than 2600 $m^3/s$ at the Dravograd Dam, at border with Croatia the flow was even estimated at about 3000 $m^3/s$) greatly exceeded the flow of the river just before this event (about 500 $m^3/s$ at the Dravograd Dam).




The flood wave along the Drava River in Slovenia

These extremely high flows also exceeded 100-year return period of flood event.

It was found out that the damage caused by the extensive floods on 4th and 5th November 2012 was the largest recorded damage due to natural disasters in the history of independent Slovenia.




The flow of the Drava River at Dravograd HPP and the maximum flow 1965-2011

# *Extraordinary surveillance of the banks of reservoirs*

## *Performance of visual inspections*

A detailed extraordinary visual geotechnical inspections of the river banks and levees of derivation channels, to determine any instability of them, carried out immediately after this extreme event. Topographic maps with recorded damage of the previous regular inspections of river banks, in which newly identified damage was registered, used as a basis for the inspection. The damaged areas were also carefully photographed.

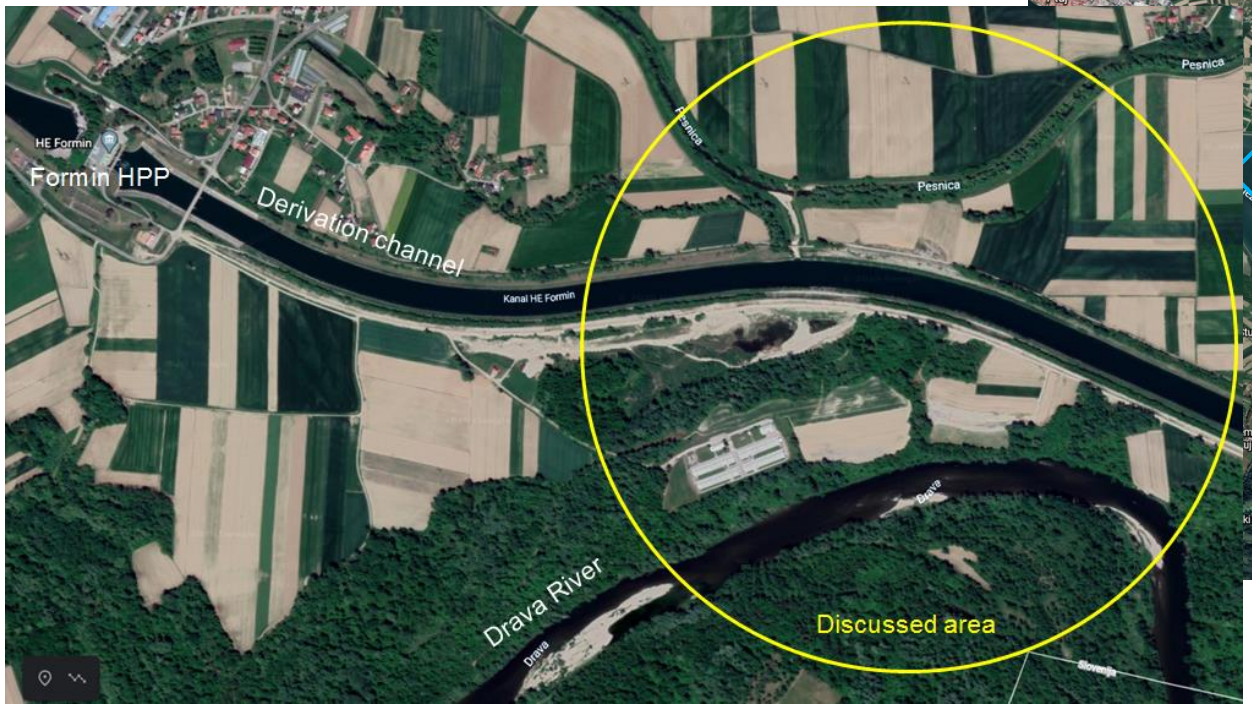
After that, extraordinary reports prepared, where a detailed inventory of all noticeable damage was made and suggestions for preferential rehabilitation of damage were given.

Numerous landslides and landslips identified, damage due to erosion in the zone of water level fluctuations, damage to nearby buildings and retaining structures, also damage and threat to nearby transport infrastructure.

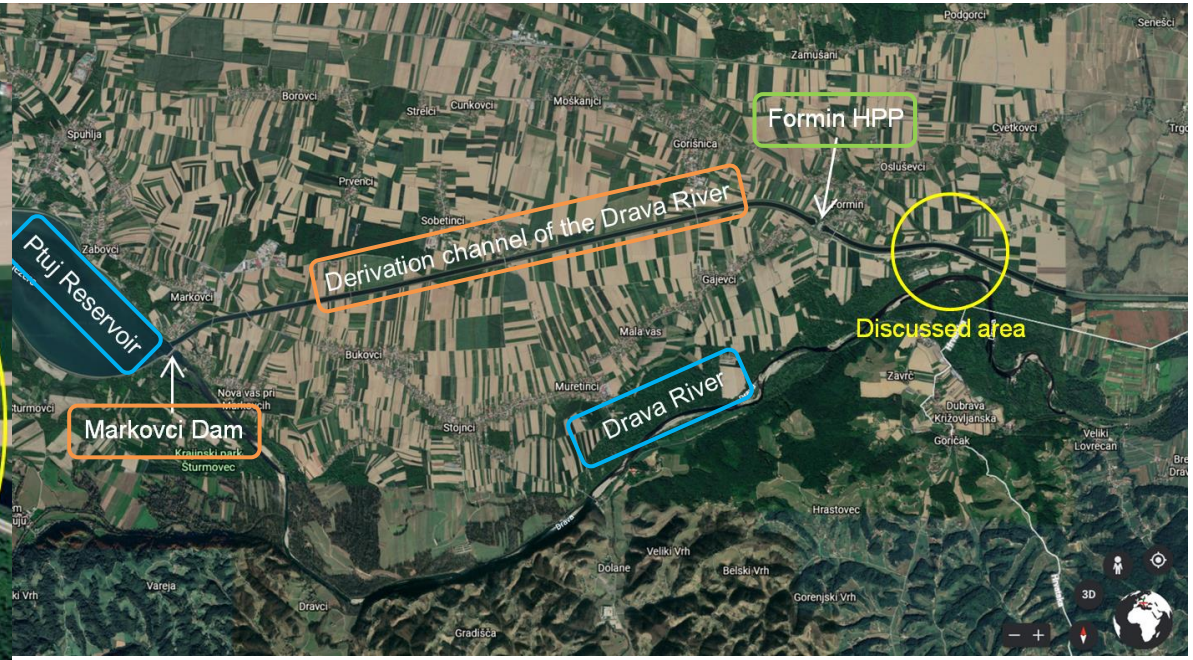
Found out that the most damaged areas should be rehabilitated as soon as possible.

Some examples of damaged banks of reservoirs

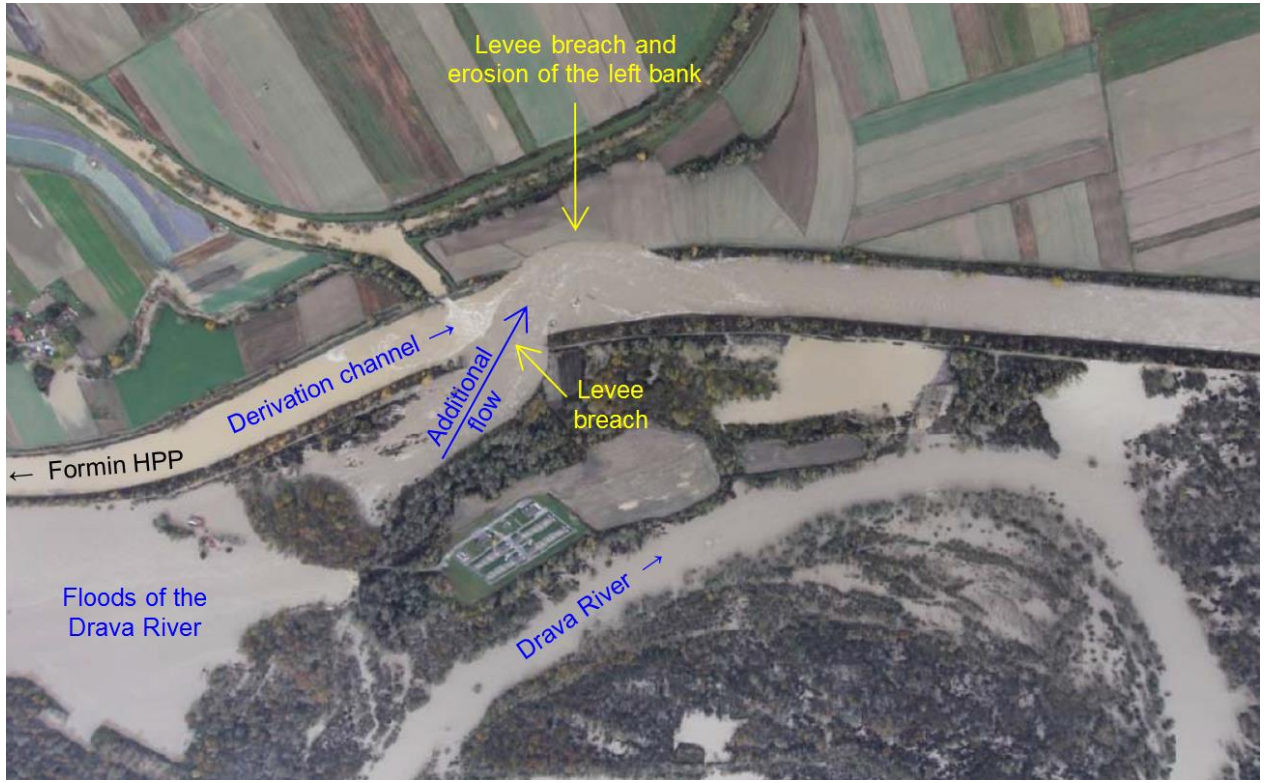
# *The area with the most extensive damage*



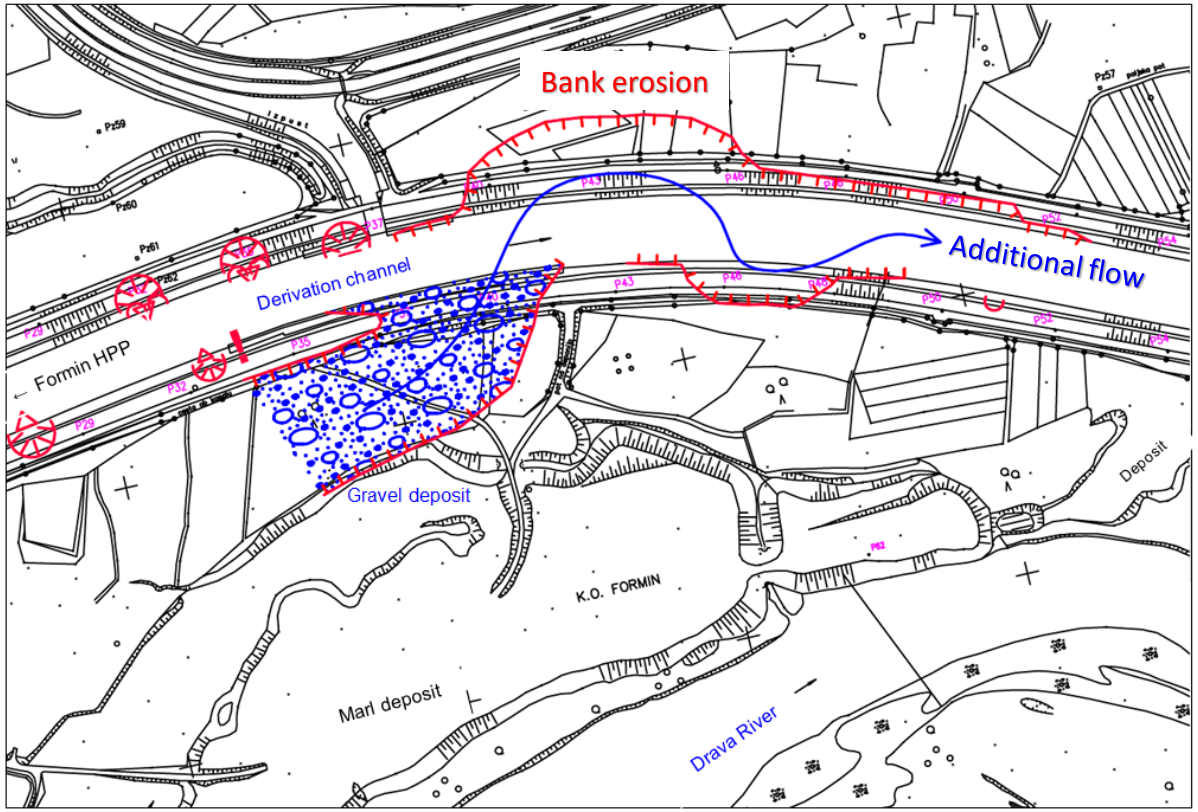

Detailed location of the discussed area




General location of the discussed area

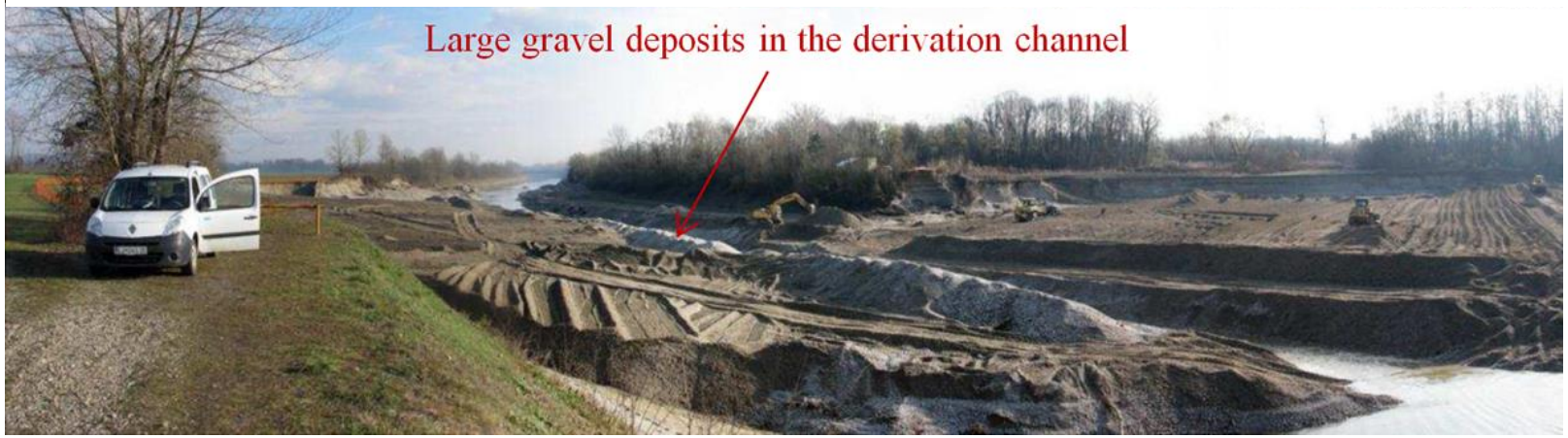



The area with the greatest damage




Topographic map with registered damage

Gravel deposits dammed water in the channel, caused rising of the water level in the channel and consequently flooding of the machine hall area of the upstream located Formin HPP.




Erosion of the left bank of the channel and large gravel deposits


Due to the high risk of additional damage and deterioration of the stability of the damaged banks of derivation channel, the main rehabilitation works began immediately after the detailed inventory of all noticeable damage was made, and they were completed quickly and successfully.

# *Conclusion*

In the future: necessary to perform regular and extraordinary surveillance of the banks of reservoirs and levees (detailed visual inspections, terrestrial measurements and also increasingly accessible use of space technologies) drawing attention to damage that needs immediate rehabilitation and thus preventing the occurrence of eventual catastrophic consequences.

In addition: a lot of attention needs to be paid also to water management in reservoirs in the near future, as extensive floods - also due to inadequate water management - can cause disastrous consequences, such as the loss of many lives, major economic losses and severe ecological effects.

# Merci pour votre attention!