



Side-arms and floodplains along large rivers  
LIFE+ project closing conference

## Morphodynamic equilibrium: the key approach for sustainable restoration of large rivers

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# The main content of the presentation

Some experiences and the results from the projects focusing the river/ floodplain restoration on the **Danube and Morava rivers** - achieved within the projects:

- **MoRe** - The Morava River Restoration: Plan of measures prepared in agreement with EC Water and Nature Protection Directives (ERDF – Slovak – Austrian project)
- **DuReFlood** - Danube floodplain rehabilitation to improve flood protection and enhance the ecological values of the river in section between Szap and Szob (ERDF – Slovak - Hungarian)
- **Impact of restoration scenarios on the development of the Danube river bed**  
(Preparation by the Hungarian Party of the Hungarian-Slovak Joint SEA .....

**Key approach**

**Re-introducing of flow dynamics and sediment transport that is recognized as the most vital step to achieve sustainable restoration of large lowland rivers with active sediment transport**

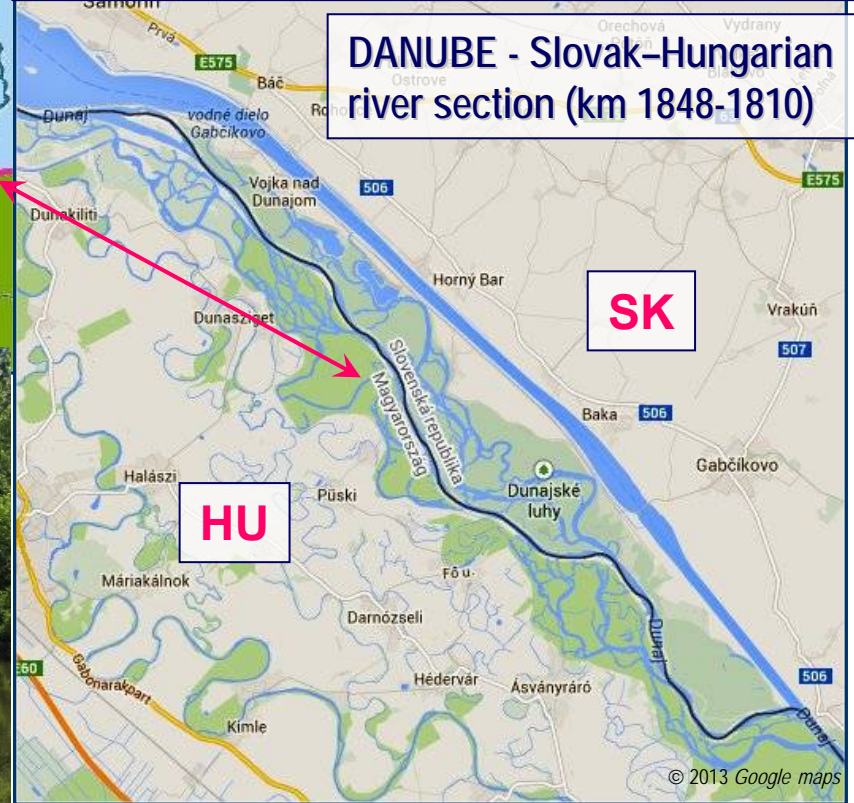


# DANUBE & MORAVA- Where we are?

MORAVA - Slovak-Austrian river section (km 0 – km 70)



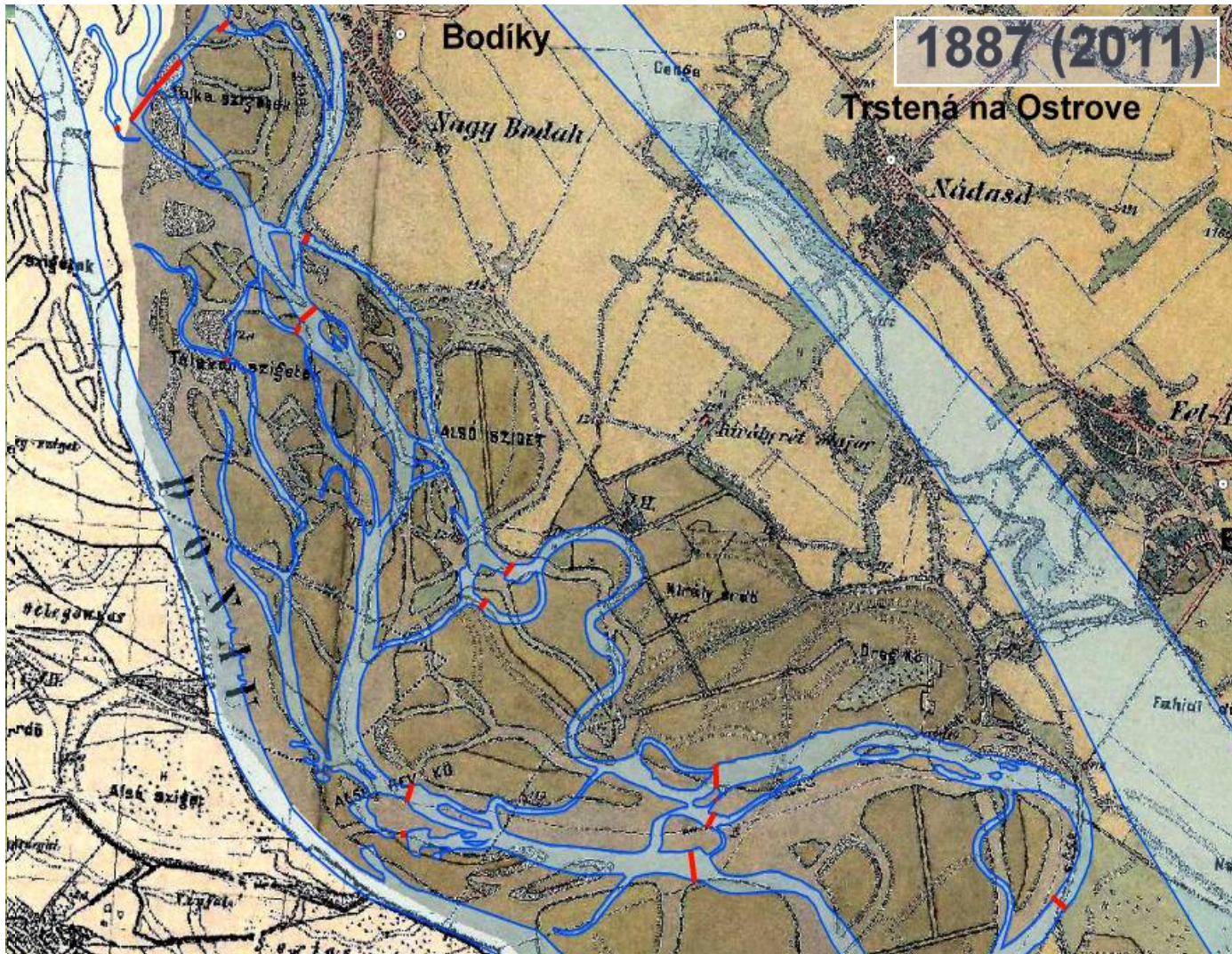
DANUBE - Slovak-Hungarian river section (km 1848-1810)





# OLD DANUBE - from history to the present

**Danube downstream of Bratislava** - unique anastomosing area with high morphological diversity, characterized by a system of side arms connected with the main channel.

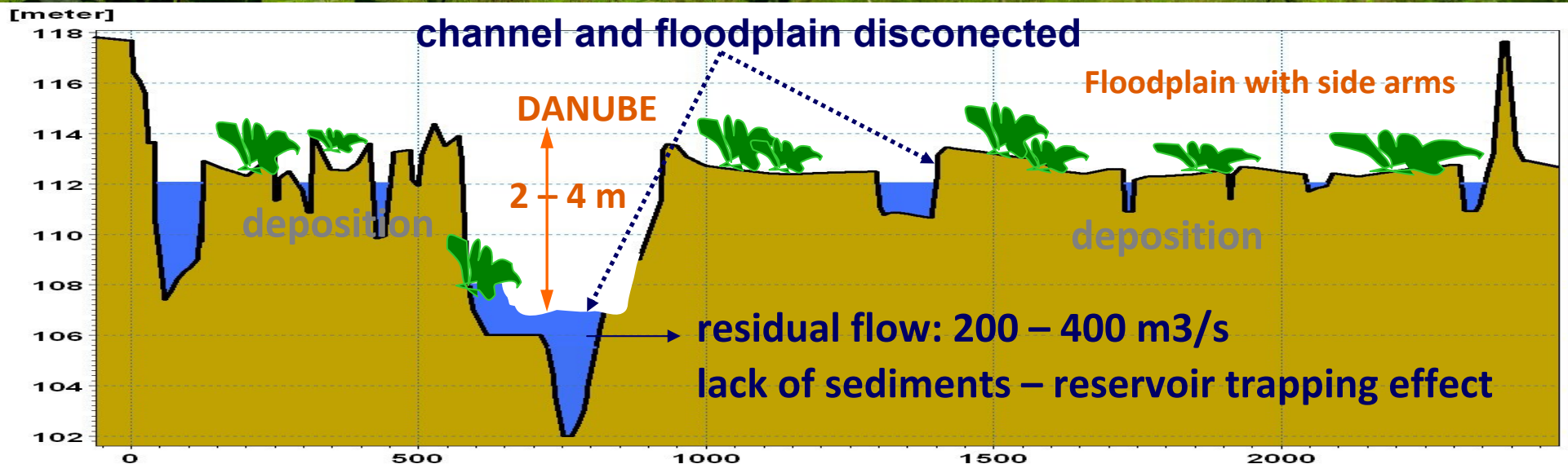
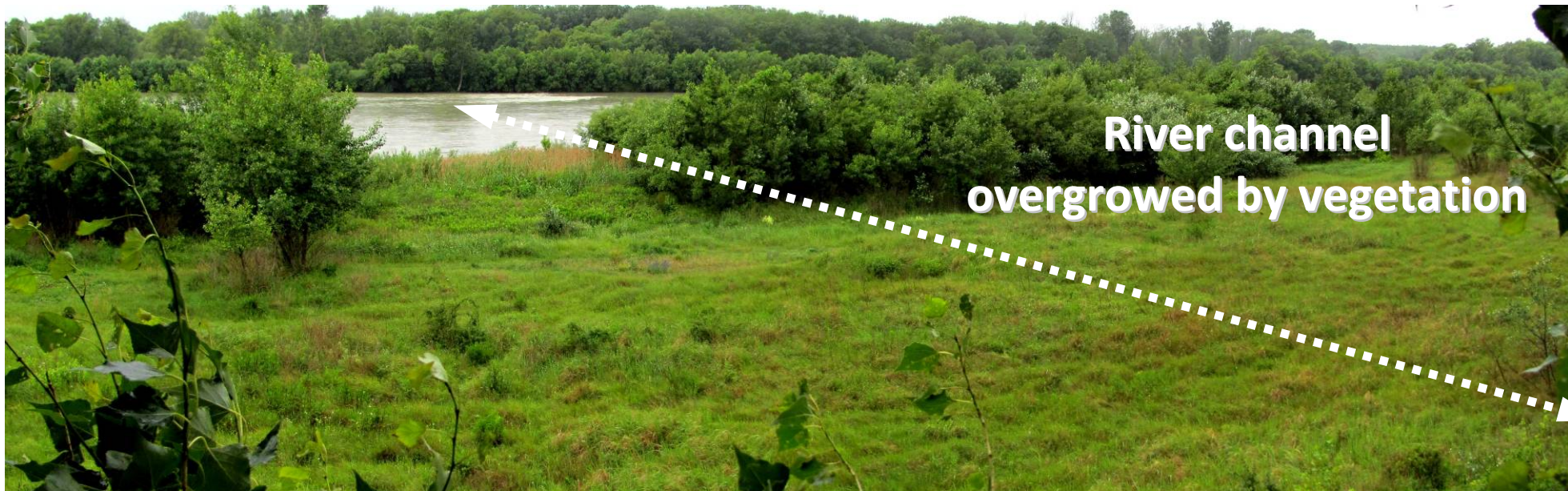


## HUMAN IMPACTS:

- 19th- 20th century:
  - flood protection
  - river regulation for navigation purposes
- Since 1992:
  - HPP Gabčíkovo
  - changes in flow regime
  - and sediment transport



# OLD DANUBE – PRESENT STATE



# RESTORATION CONCEPT - RIVER CHANNEL WIDENING

....based on the premise of natural bank erosion triggered by bank pavement removal, transport/deposition of eroded sediments along the river bed  
*(proposed and discussed by Martin Jaeggi - HU feasibility study)*

Expected result: Successive aggradations of the river bed over a certain period could provide reconnection of the main channel with side arm system



TEST – 10 km river section - to demonstrate whether eroded material could create sufficient deposits in the river bed to restore the former hydrological connectivity

# CHANNEL WIDENING – ASSUMPTIONS

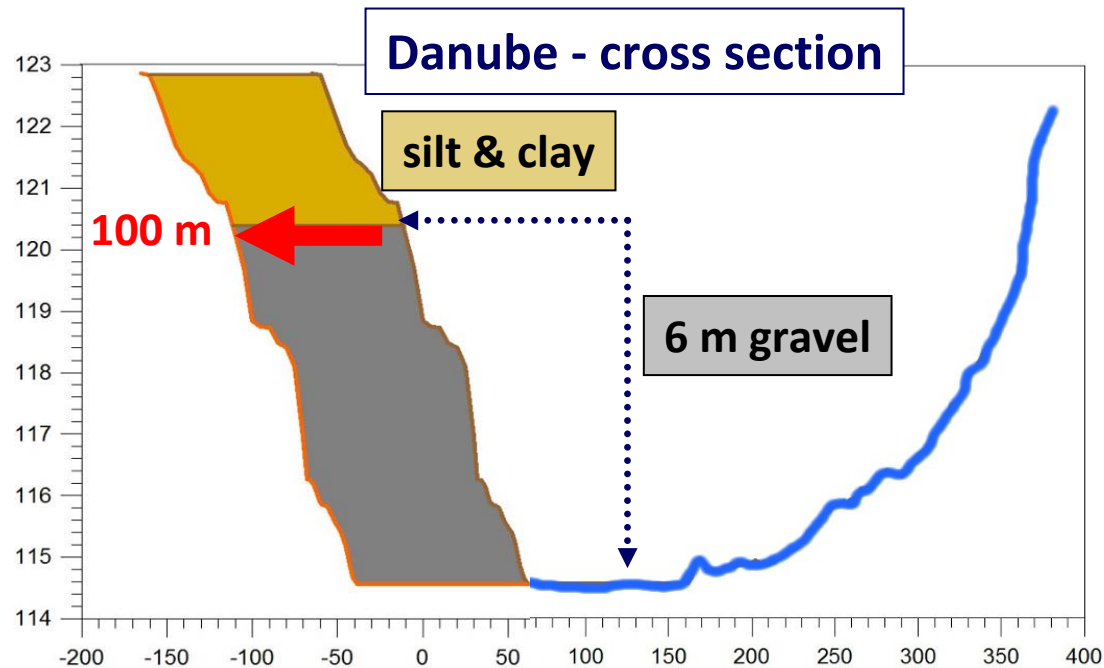
1D numerical model (MIKE 11) was used to test this concept

## Model - test assumptions:

- simulation period - 40 years
- the river section - 10 km (between km 1830 –1840)

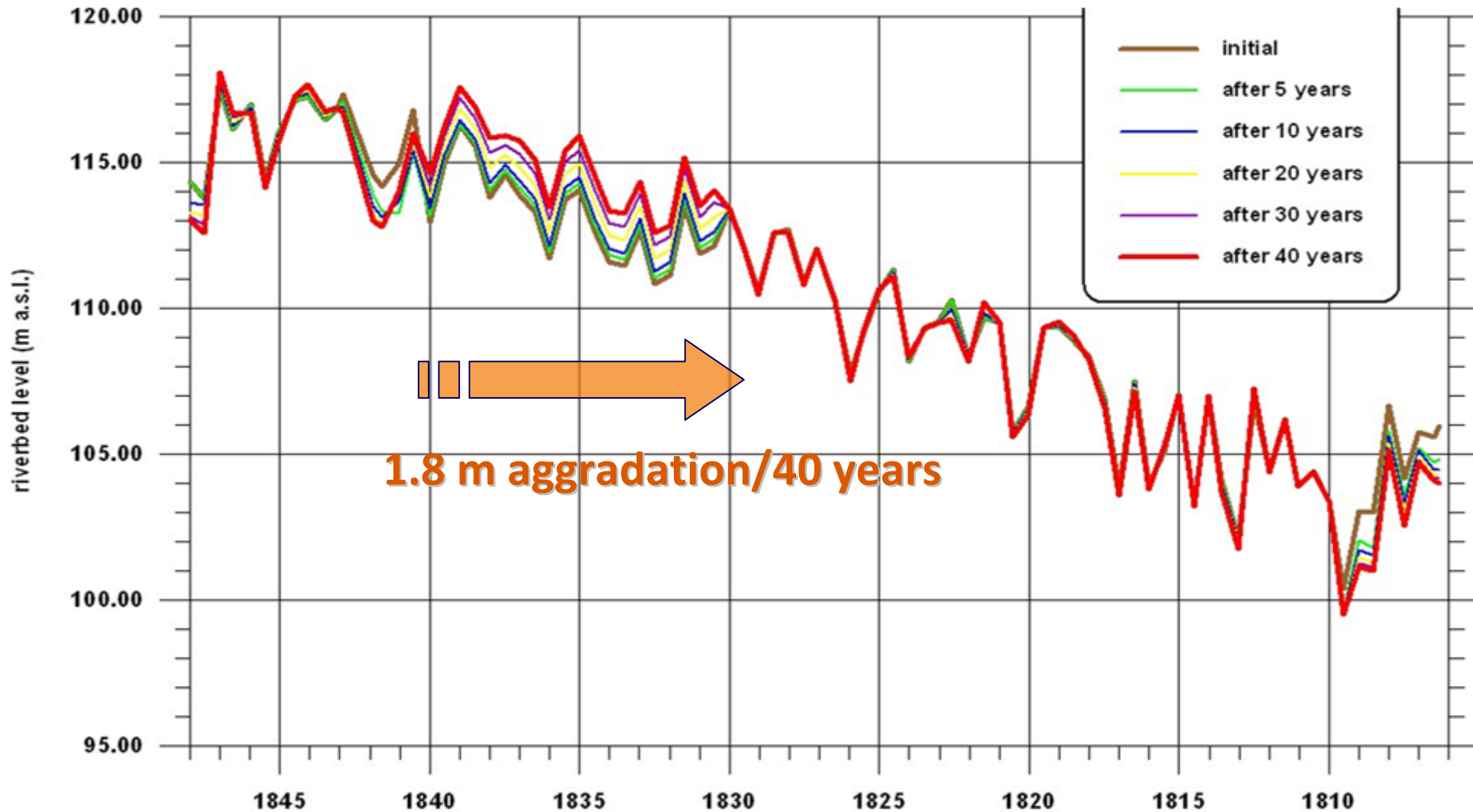
## Geometry:

- Channel widening remained stable during simulations
- Topography modification - shifting of the steeper bank by 100 m



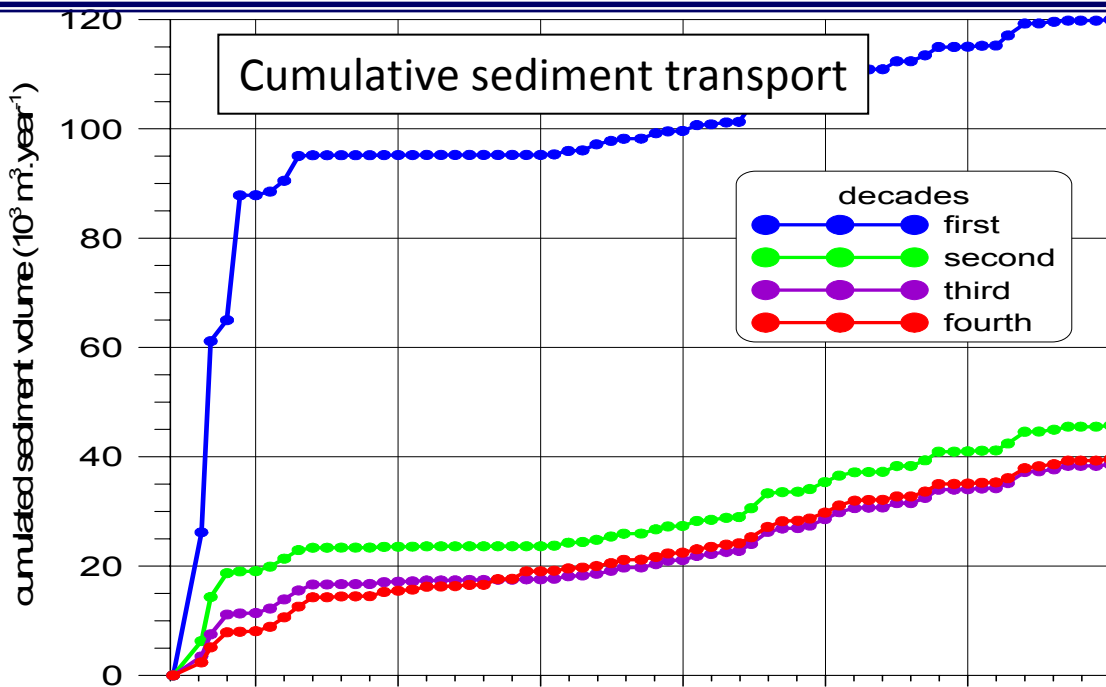
# CHANNEL WIDENING – RESULTS

1D model - Sato-Kikkawa-Ashida equation river bed changes - 40 years





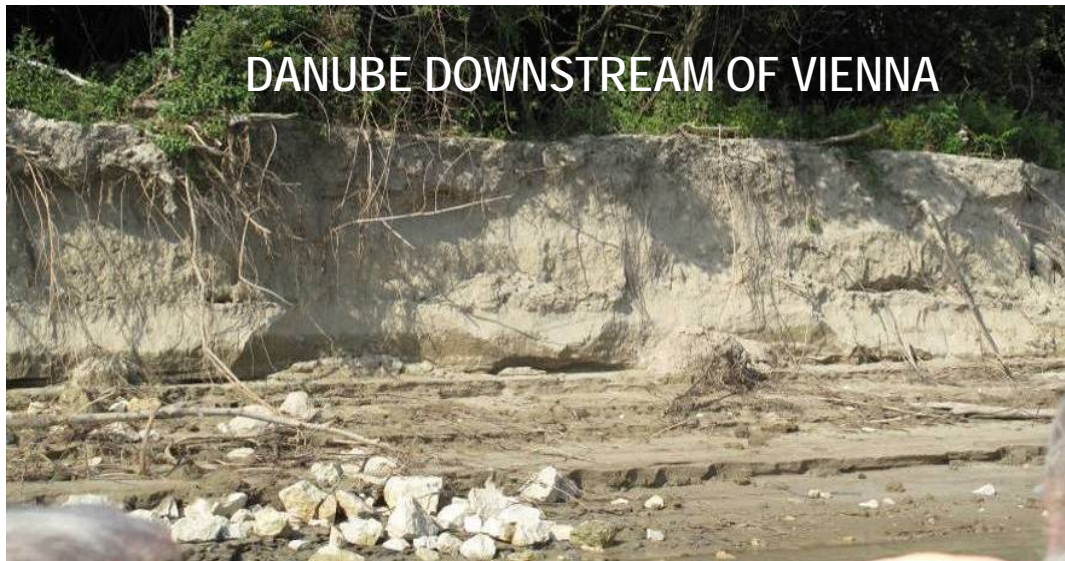
# WIDENING - RIVER BED STABILIZATION



**First period** - some degree of the river bed destabilization in terms of geomorphic perspective

**Cumulative sediment transport over 40 years period** indicates the river bed stability could be achieved during **the third decade**.

**TEST: 1D model** proved realistic basis for channel widening concept.



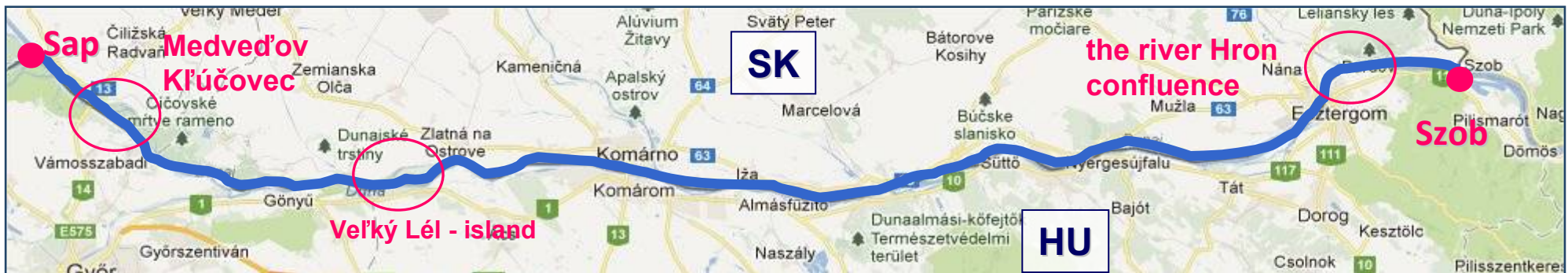
Next analyses are needed to study complicated bank erosion processes more detail (2D, 3D models for bank erosion & sediment transport).

**Main constrains:** residual flow (increase Q and variability) dense vegetation, SK & HU agreement

**DuReFlood** - Danube floodplain rehabilitation to improve flood protection and enhance the ecological values of the river in section between Szap and Szob

**Main objectives:**

- ✓ Flow dynamics of flood discharges - present situation and improvement of flood protection
- ✓ Evaluation of morphodynamics in relation to side arms reconnection



Project partners: Edukovizig – Győr

Water Research Institute

Budapest University of Technology and Economics

Slovak Watermanagement Enterprise





...following activities done by BROZ and in close cooperation  
proposal of further restoration measures





## Improvement of ecological status of the Danube side arm system

**Velký Lél – island**

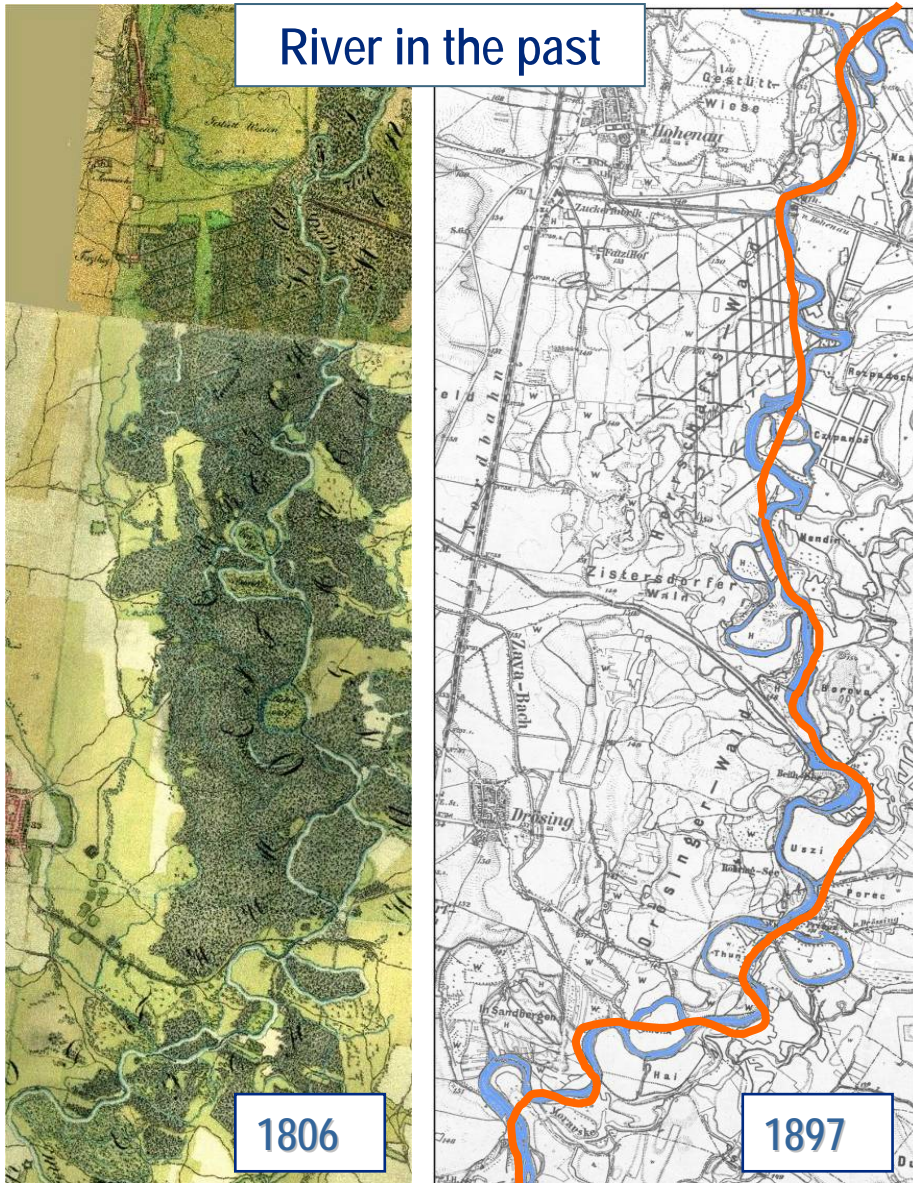
**The Hron river confluence**

The figure consists of a central map and several photographs. The map shows the Danube river system with a side arm. Key locations marked include Velký Lél island, Záhřevský luh, and the confluence of the Hron river. The map also shows the border between Slovakia and Hungary, with labels for 'Slovenská republika' and 'Magyarország'. Specific roads like '664', '11', '111', '112', '113', '114', '115', '116', '117', '118', '119', '120', '121', '122', '123', '124', '125', '126', '127', '128', '129', '130', '131', '132', '133', '134', '135', '136', '137', '138', '139', '140', '141', '142', '143', '144', '145', '146', '147', '148', '149', '150', '151', '152', '153', '154', '155', '156', '157', '158', '159', '160', '161', '162', '163', '164', '165', '166', '167', '168', '169', '170', '171', '172', '173', '174', '175', '176', '177', '178', '179', '180', '181', '182', '183', '184', '185', '186', '187', '188', '189', '190', '191', '192', '193', '194', '195', '196', '197', '198', '199', '200' are also indicated. The photographs show various riverbank conditions: a lush green bank, a wide sandy bar, a calm river with forested banks, and a river with a large fallen tree trunk in the water.



# MORAVA RIVER – from history to the present

River in the past



1806

1897

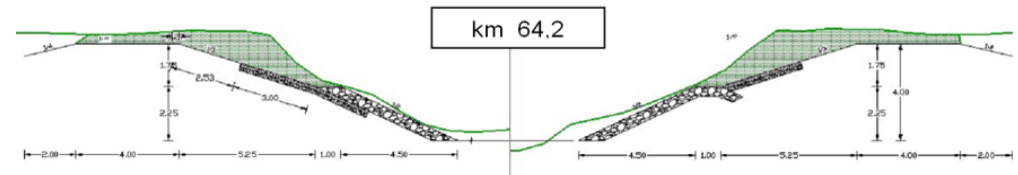
...after regulation:



cut-off meander



river channel

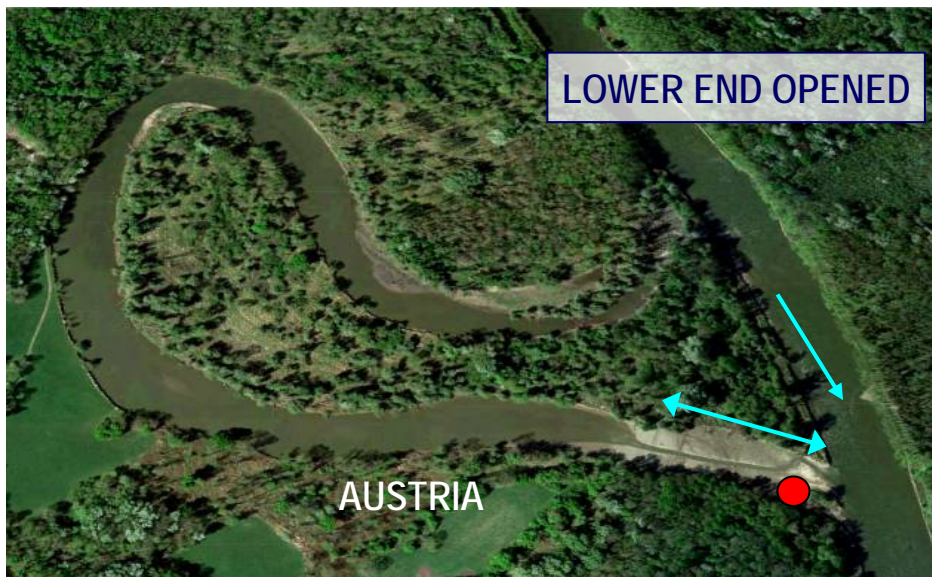
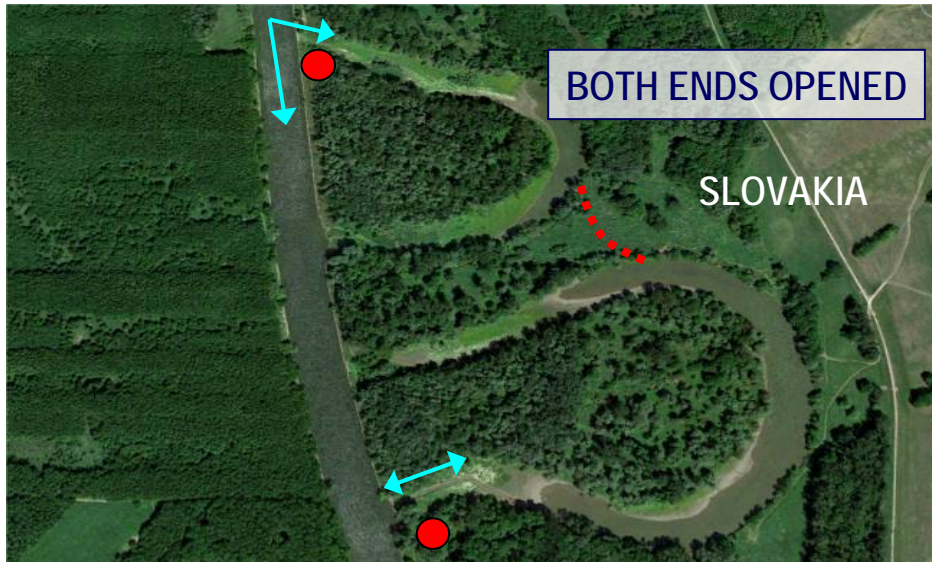


- uniform channel - poor habitat diversity
- no lateral movement
- limited hydrological connectivity
- changes in flow dynamics and sediment transport
- incised river bed and floodplain deposition
- separation of the river and floodplain processes

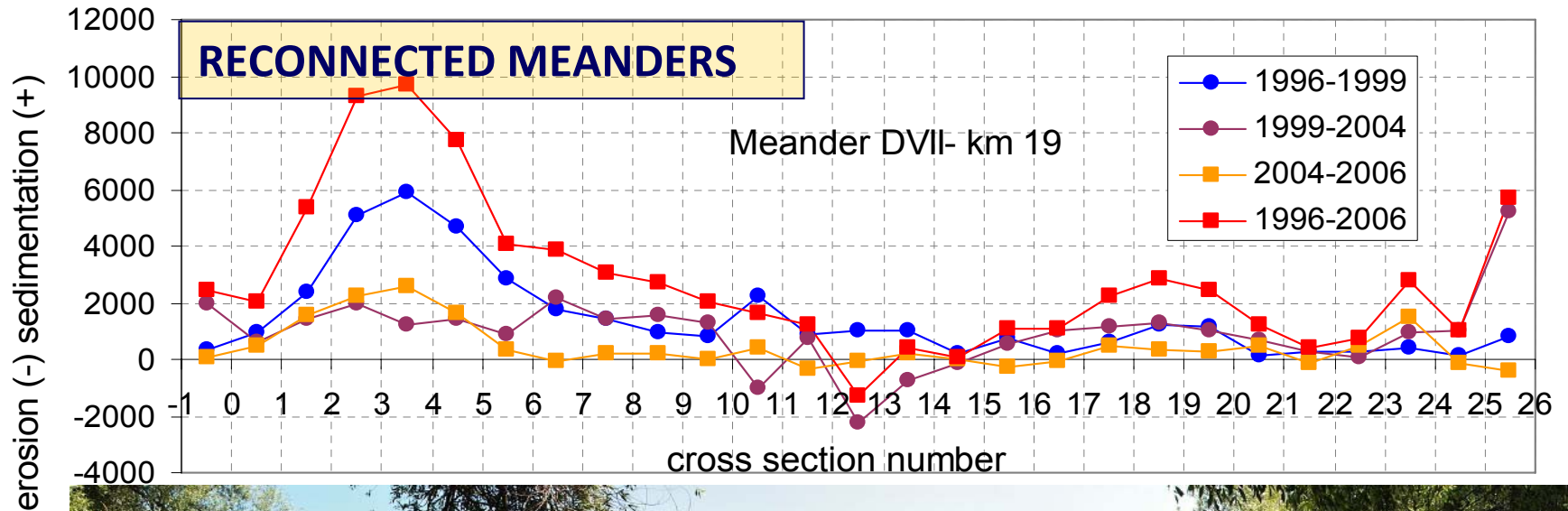


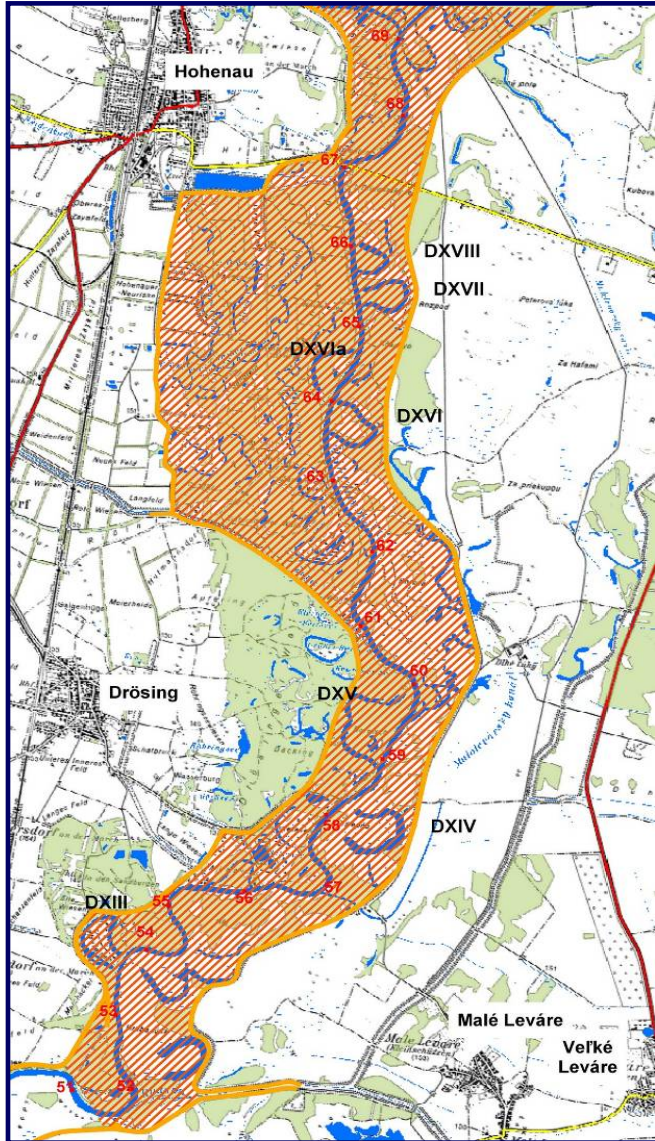
Successive abiotic and biotic degradation











## SK & AT PROJECT



...concentrates on the preparation of the detail concept and plan of all restoration measures for the river channel and floodplain within the pilot river section (16 km).

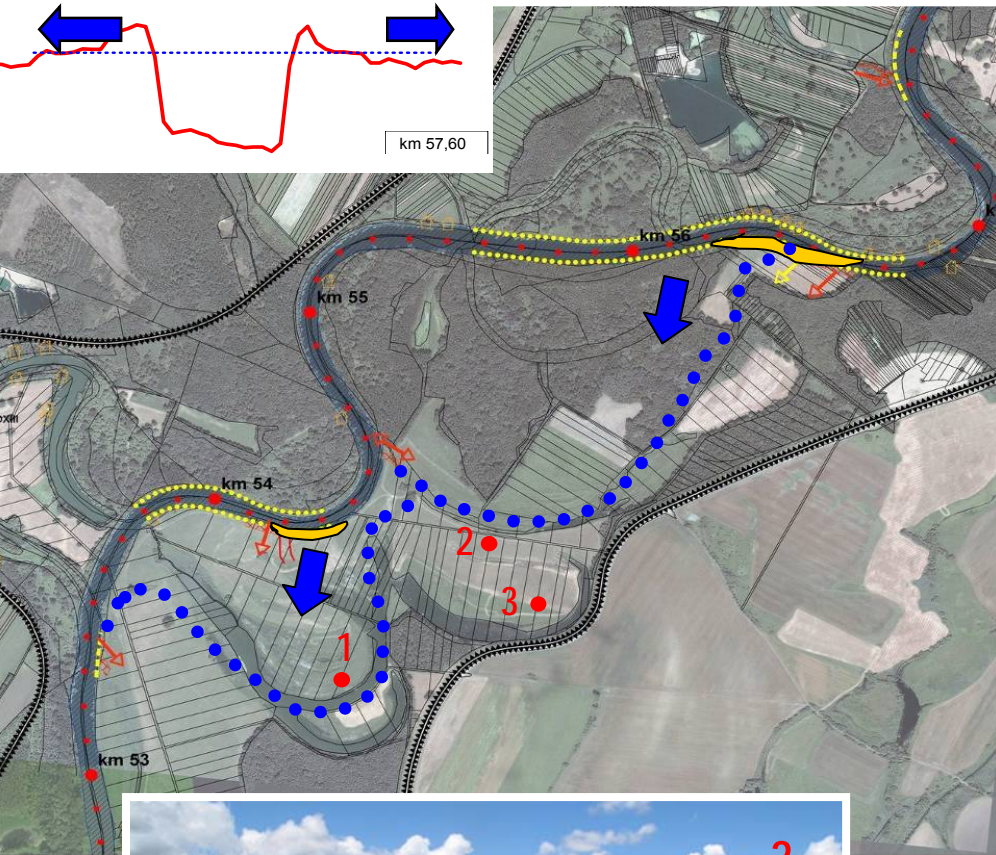
*Main project objective (based on BGM II):*

**Re-introducing of lateral connectivity between the main river channel and floodplain keeping the morphodynamic balance**



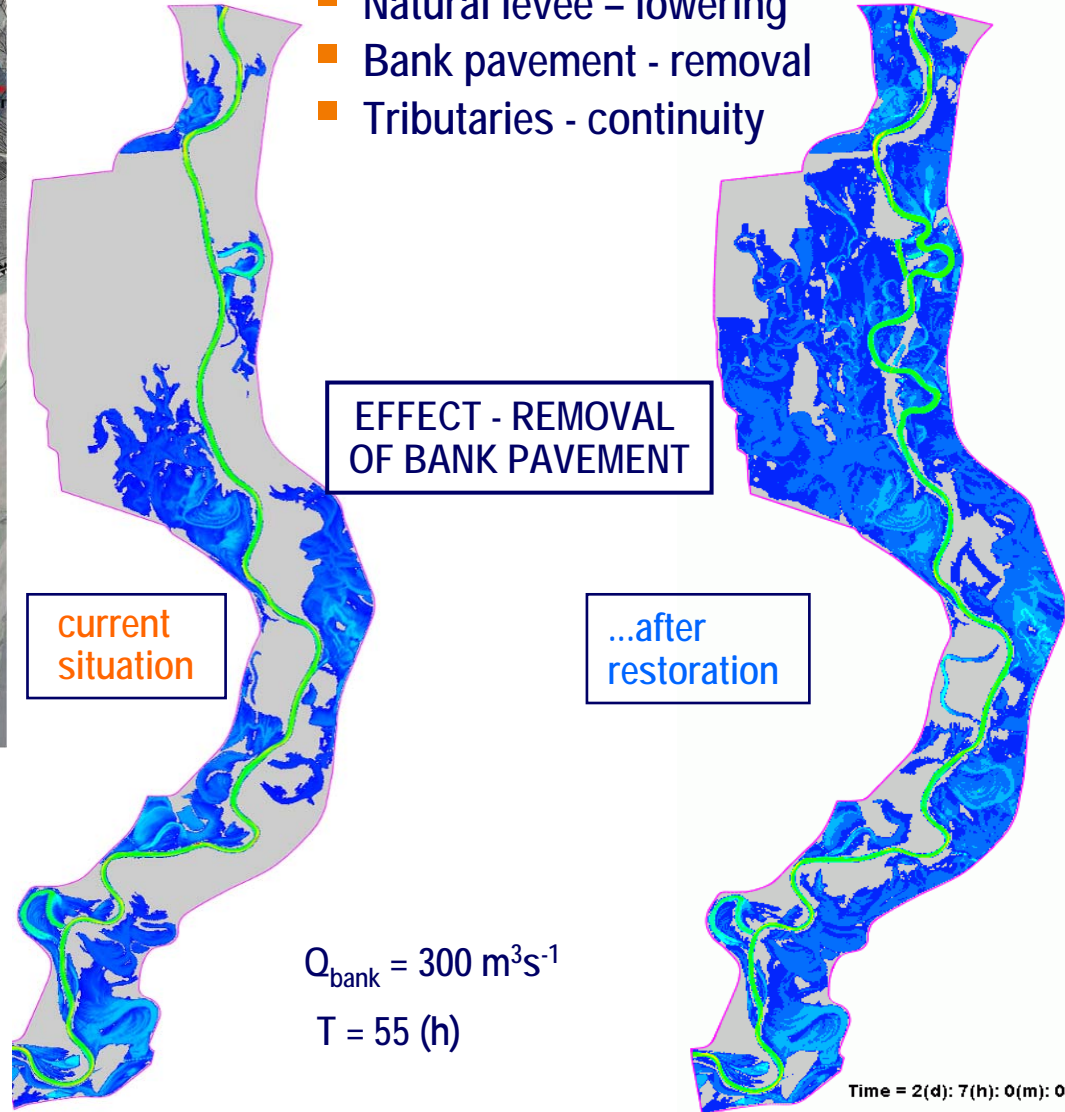


# SMALL SCALE RESTORATION MEASURES



THE AIM: reintroducing of natural dynamics

- Natural levee - lowering
- Bank pavement - removal
- Tributaries - continuity



EFFECT - REMOVAL OF BANK PAVEMENT

current situation

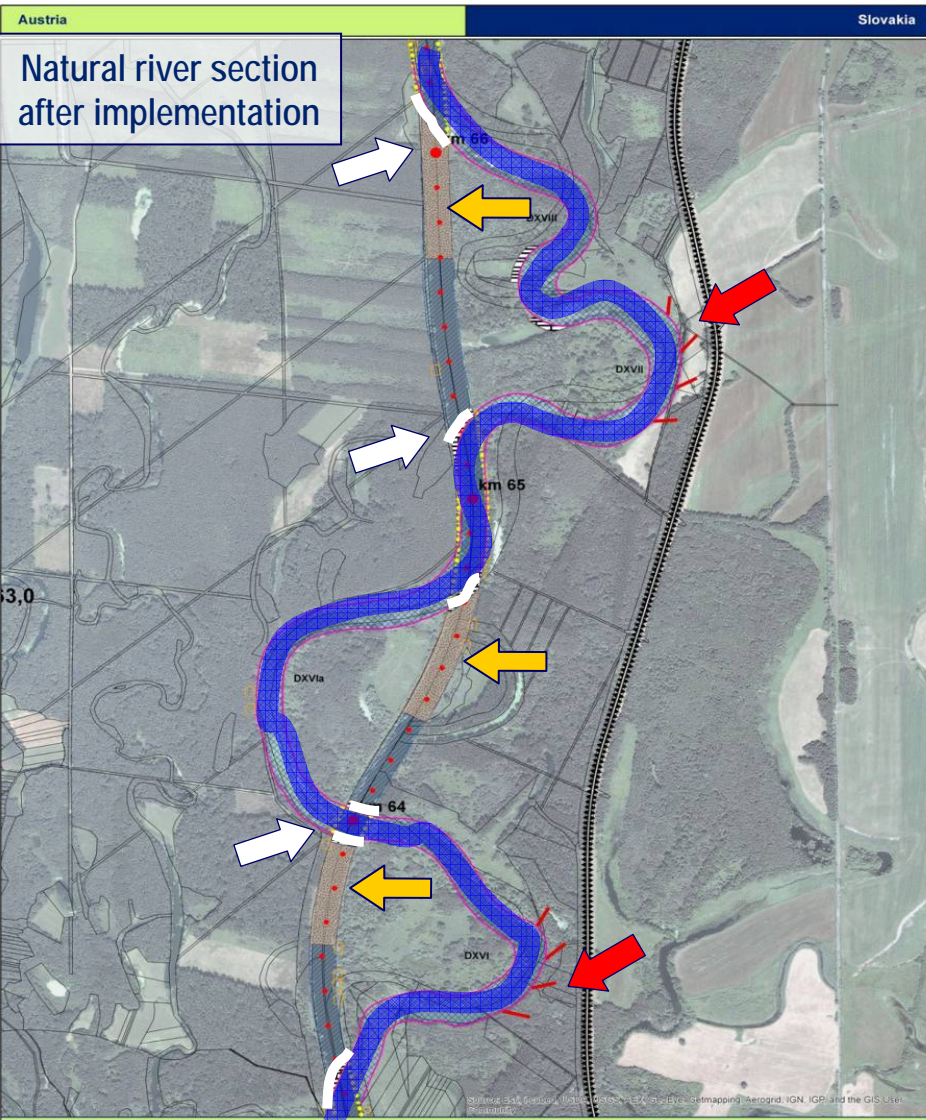
...after restoration

$$Q_{\text{bank}} = 300 \text{ m}^3\text{s}^{-1}$$

$$T = 55 \text{ (h)}$$

Time = 2(d): 7(h): 0(m): 0(s)





Integration cut-off meanders into the river system to restore original morphodynamics and create free flowing natural river section

SCENARIOS: types, dimensions, localities & combination of restoration measures

OPTIMIZATION



MIKE11, CCHE2D, km 69-km 53 - flow pattern, sediment transport, river bed morphology

Physical model: km 64- km 66 - reconnection variants - flow pattern, river bed morphology



MORPHODYNAMIC EQUILIBRIUM

Respecting:

- ecological criteria - habitat diversity
- flood protection -  $Q_{100}$  water level
- ice regime





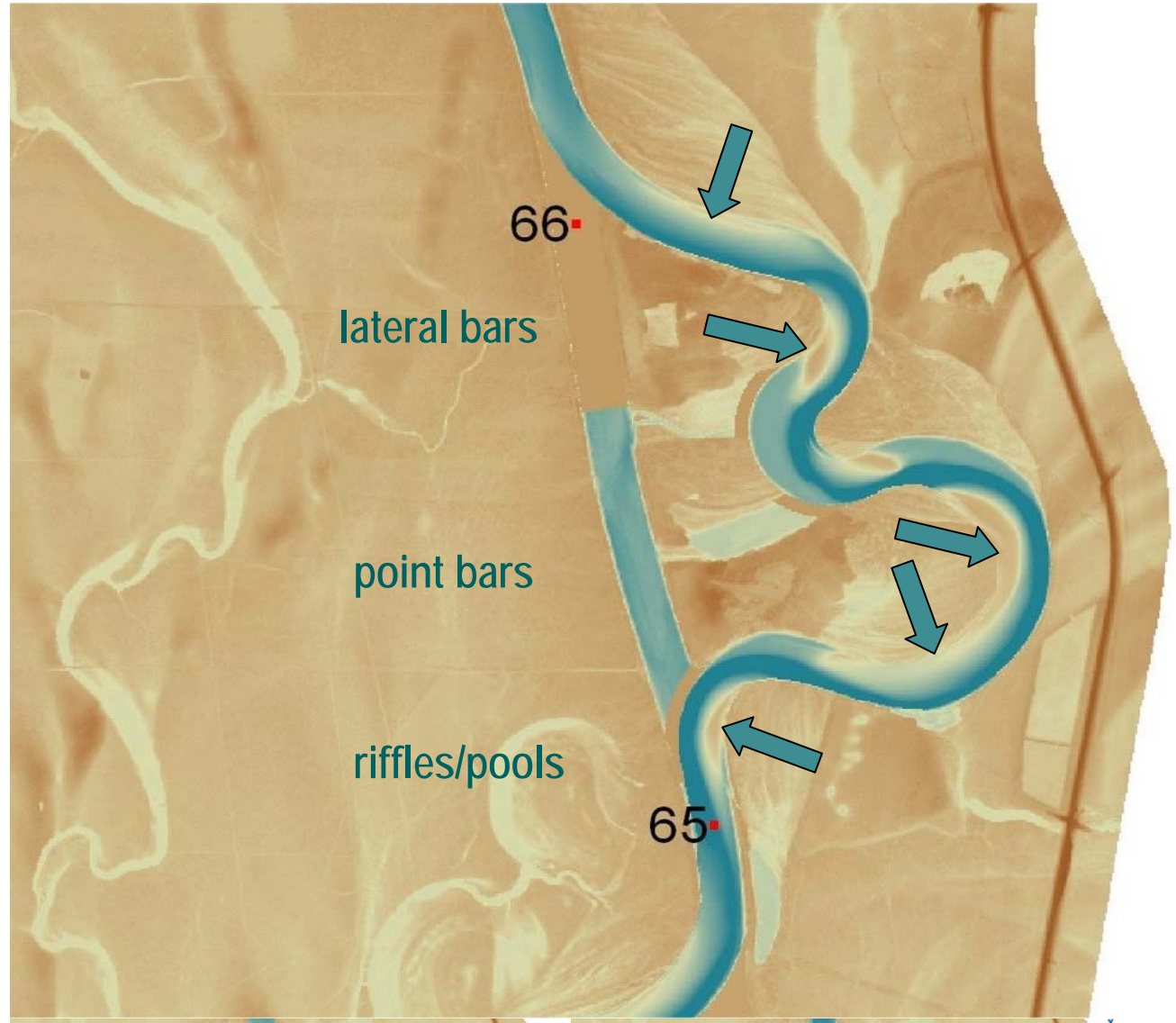
# MEANDERS INTEGRATION - OPTIMIZATION





## Changes in the channel morphology - habitat diversity

current situation





# Natural dynamic section of the Morava river (Osypané brehy) in CR





# SUMMARY ... final remarks

**Flow and sediment create the channel habitats that are later on biologically colonized**



- Implementation of large scale measures that are not based on physical processes are often ineffective and too costly (mainly on large rivers with active sed. transport)
- Local measures- implemented without wider restoration strategy for longer river section have usually limited effectiveness (they are not sustainable)...
- Numerical and physical models in combination with field data are effective tools to optimize effectiveness of the restoration scheme respecting ecological requirements
- Morphodynamic equilibrium = sustainable restoration, maximize ecological benefit

**... final but important remark 😊**

Respecting the river processes in restoration schemes enables to recreate hydromorphological conditions, which allow the river to create expected habitat diversity itself that can be very close to the natural state





**Thank you ...**

