Numerical modelling of plastic transport and accumulation at the Austrian Danube River

Pessenlehner, S.[1],

Liedermann, M.[1], Tritthart, M.[1], Habersack, H.[1]

03.04.2019 – SedNet Conference, Dubrovnik

[1] Institute of Hydraulic Engineering and River Research (IWA)

Department of Water, Atmosphere and Environment

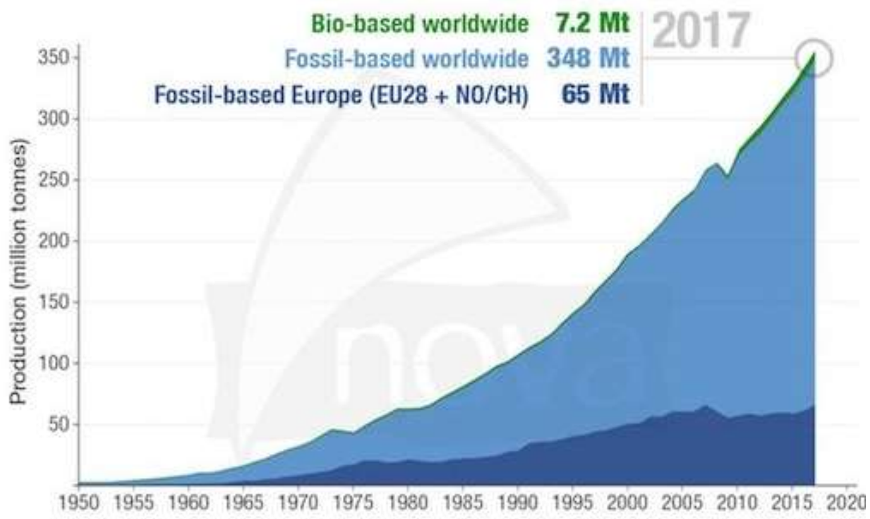
University of Natural Resources and Life Sciences, Vienna, Austria

Email: sebastian.pessenlehner@boku.ac.at; Phone: +43 1 47654-81924

European Regional Development Fund

Introduction

- Worldwide plastic production increase:
  1,7 Mio. t (1959) to 348 Mio. t (2017) (PlasticsEurope, 2018)
- Most important plastics: PP, PE, PS, PU, PET, PVC (PlasticsEurope, 2018)
- Total degradation of plastics in nature very slow



Source: PlasticsEurope 2018

Source: BBC, 2017

Introduction – Project area

- More than 80 % of marine plastics is related to land-based sources

- Rivers nowadays are known to be the main contributors for plastic debris to the ocean **BUT → almost no studies in freshwater systems**

- Increasing quantities of **macro plastic waste** (particles > 5mm) near the banks and within the inundation areas of the **Nationalpark Donau-Auen** (collecting activities)

- Launching of a project to deal with macro plastic waste in and along the Danube between Vienna and Bratislava

Aims of PlasticFreeDanube

- Methodologies, data and a manual for assessment and monitoring plastic pollution in the fluvial ecosystems
- Action plan for the management of plastic waste and implementation of pilot measures against plastic pollution in the Danube
- Awareness raising (public & stakeholders) about plastic litter pollution in rivers

Modelling and monitoring of plastic pollution in the fluvial ecosystems

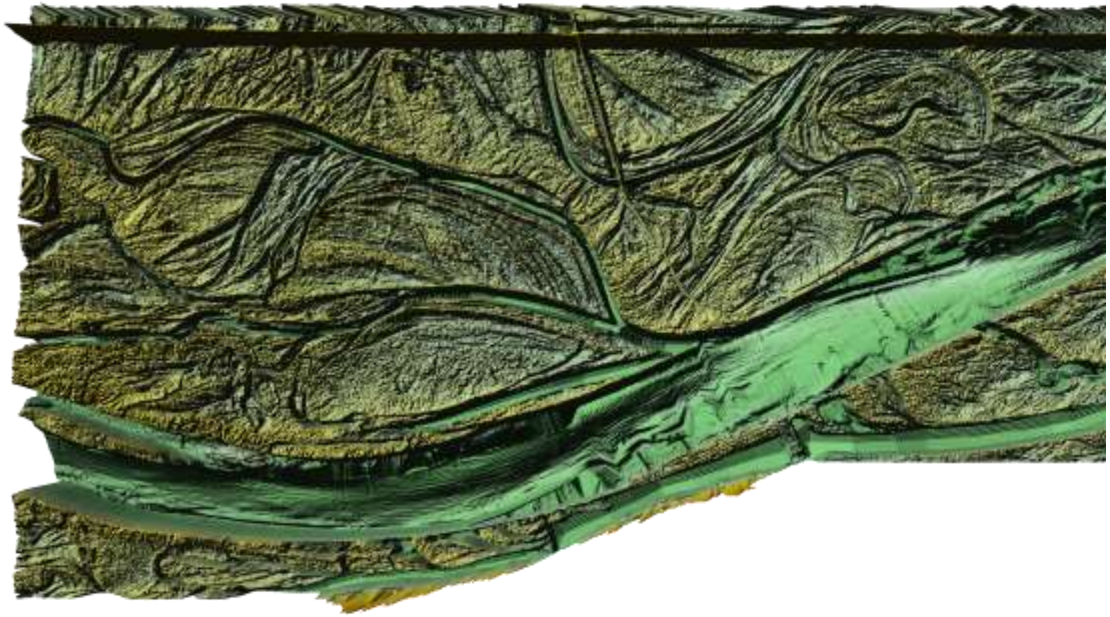
- Detection of accumulation zones
- 3D Hydrodynamic Modelling
- Particle Tracing → Characterization of accumulation zones (bank near & innundation area
- Possible construction ideas to reduce sampling actions

Methods

Detection / Characterisation of accumulation zones – Morphodynamics

Digital Terrain Models based on:

- Laser Scan 2010 / Single Beam 2015 / Terrestrial Survey 2006

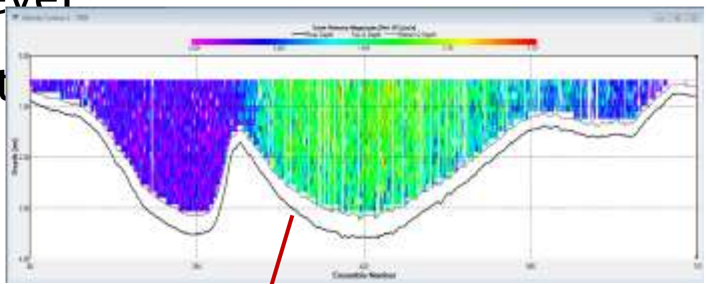


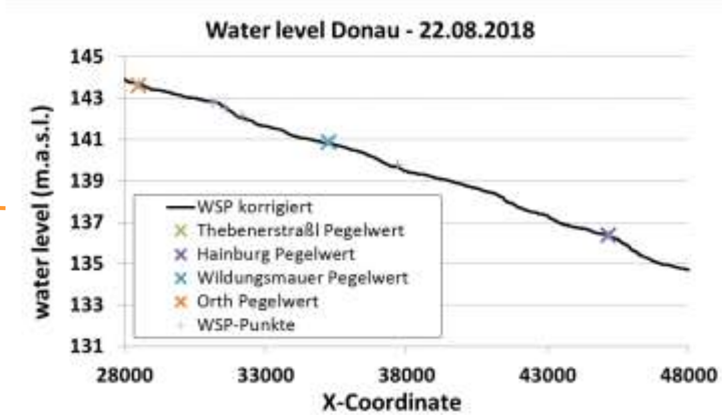
Methods

Detection / Characterisation of accumulation zones – Flow field

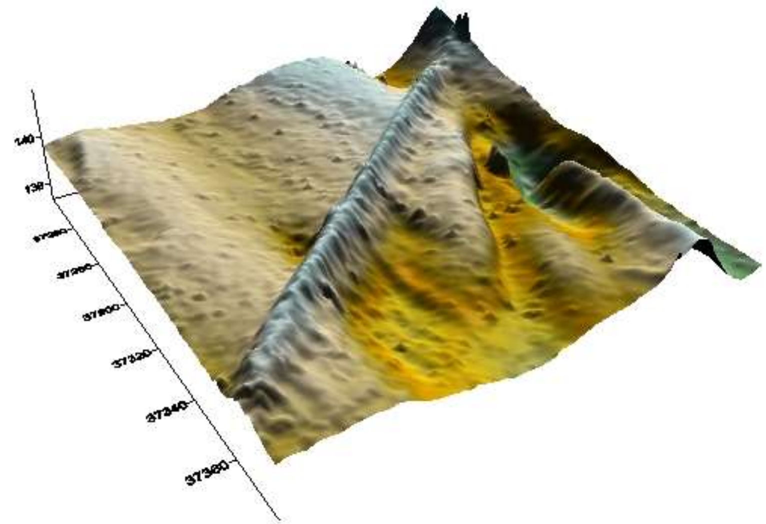
- ADCP discharge & flow velocity
- GSP water level measurment

Calibration and validation



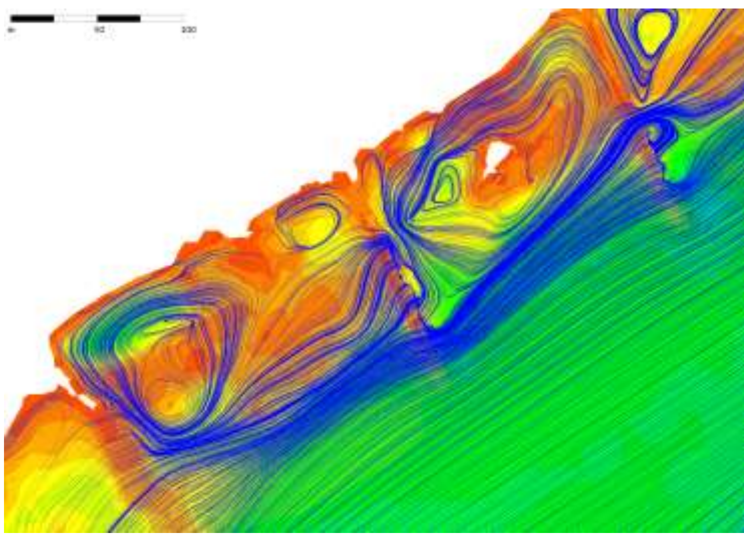


Tasks and Methods



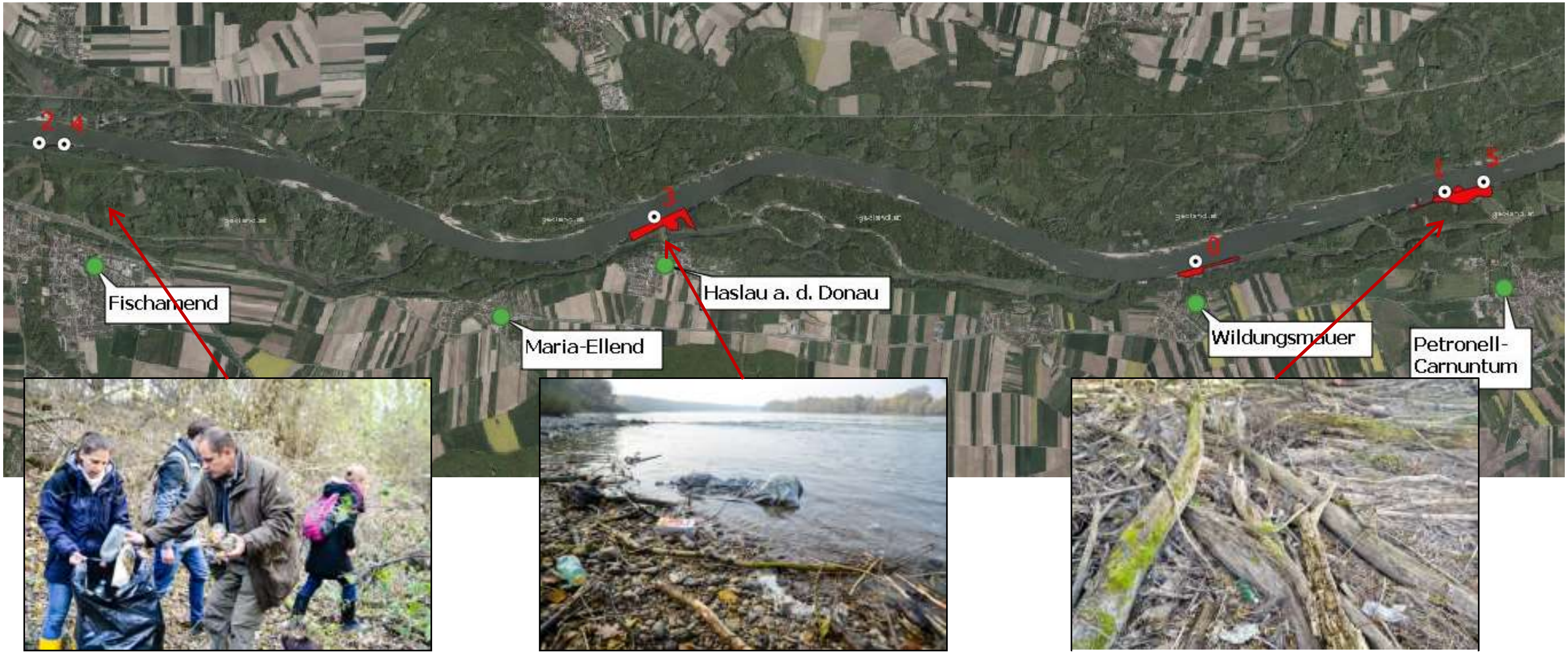
Modelling of accumulation zones

- Hydrodynamic Modelling of the flow field
- Particle tracing in complexe structures
- as



Accumulation Zones → Determination

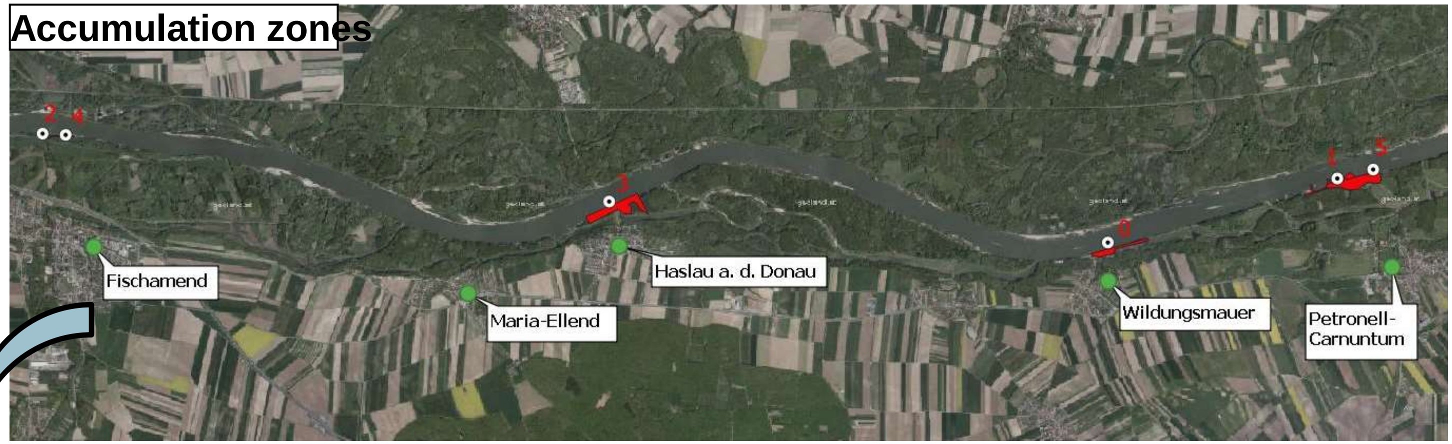
Data from Excursions and waste collection campaigns of the “National Park Donauauen” used to determine modelling reaches → Gathered in a GIS map

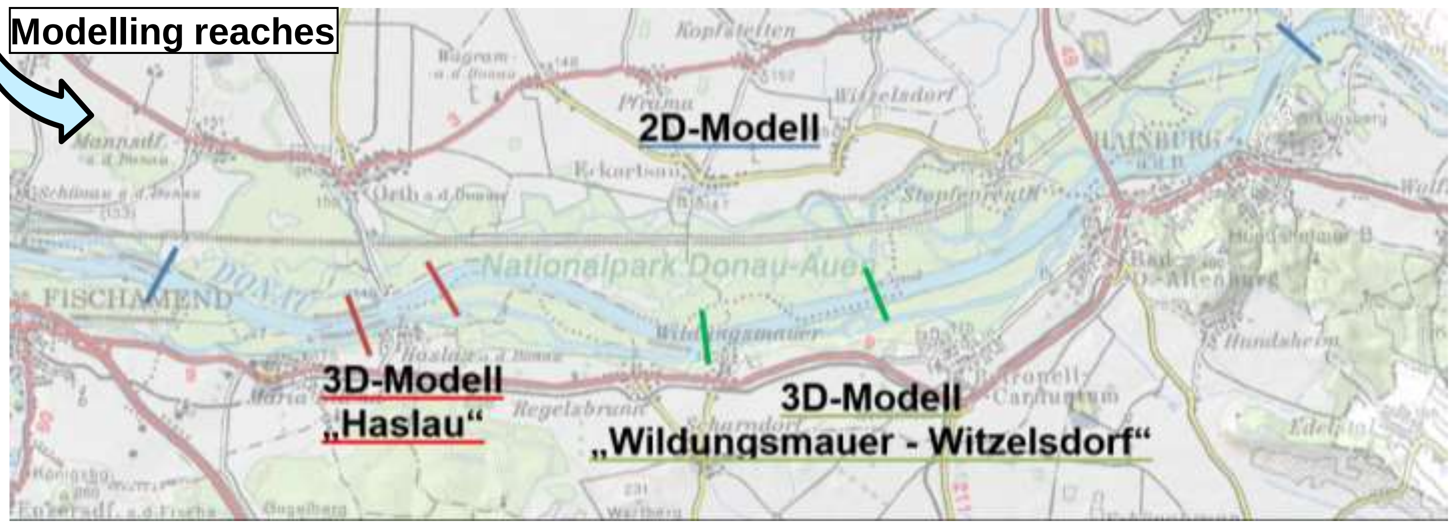


Anabranch/innundation area | **Shore line /bank near** | **Woody debris**

Accumulation Zones → Modelling Areas

- 3D numerical model Haslau (2,5 km)
- 3D numerical model Wildungsmauer–Witzelsdorf (4,2 km)
- 2D large scale model Vienna–Bratislava (25,6 km)

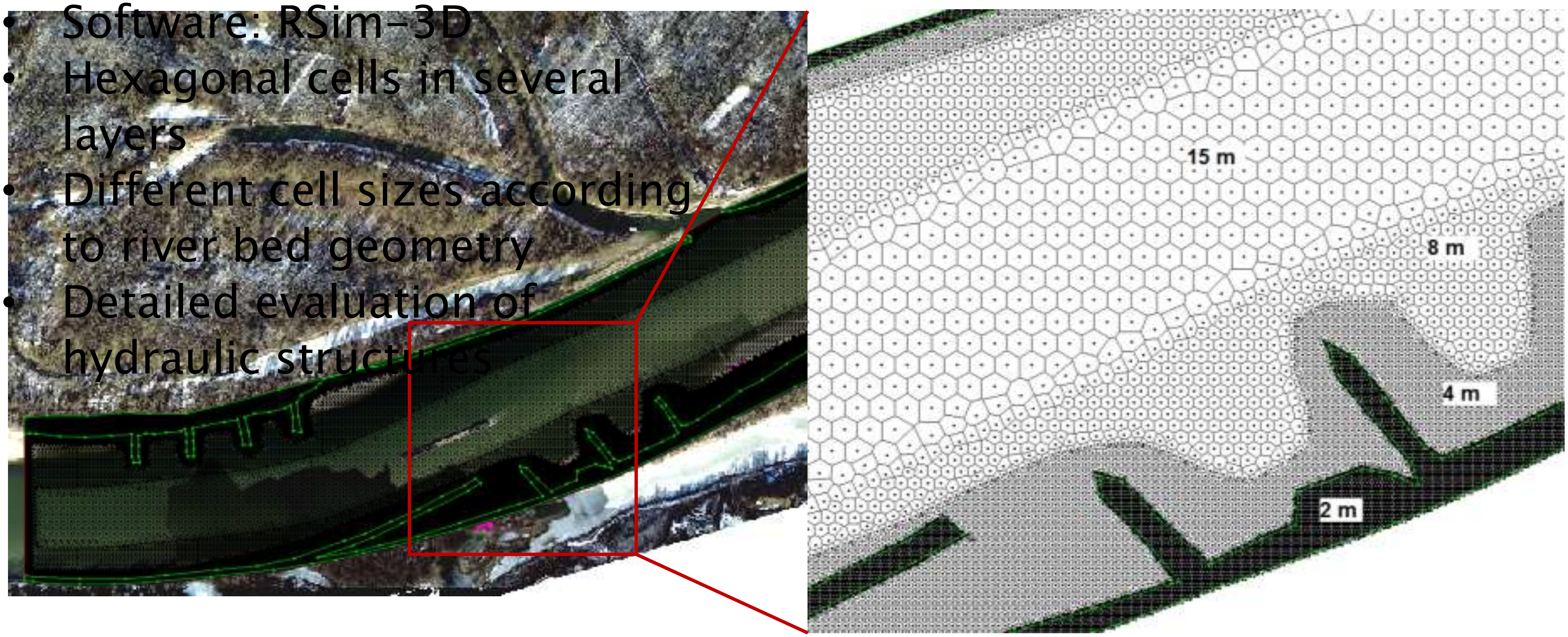




Hydrodynamic Modelling

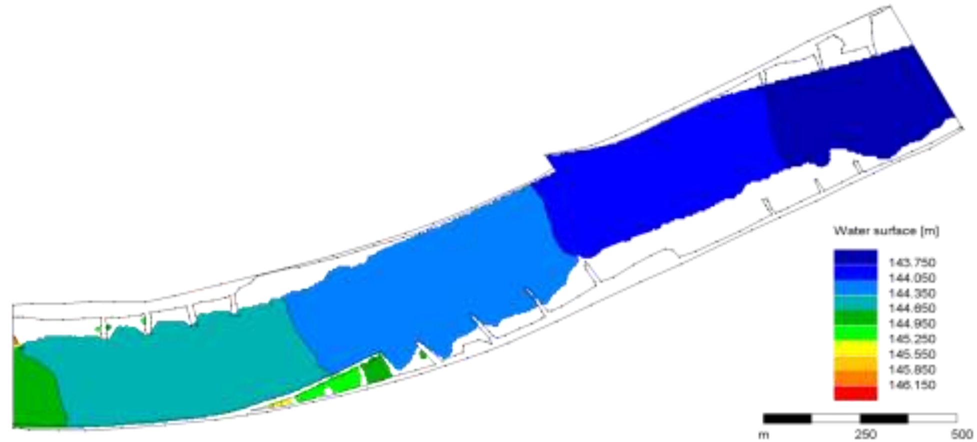
Setup of a hydrodynamic model of the accumulation zone Haslau

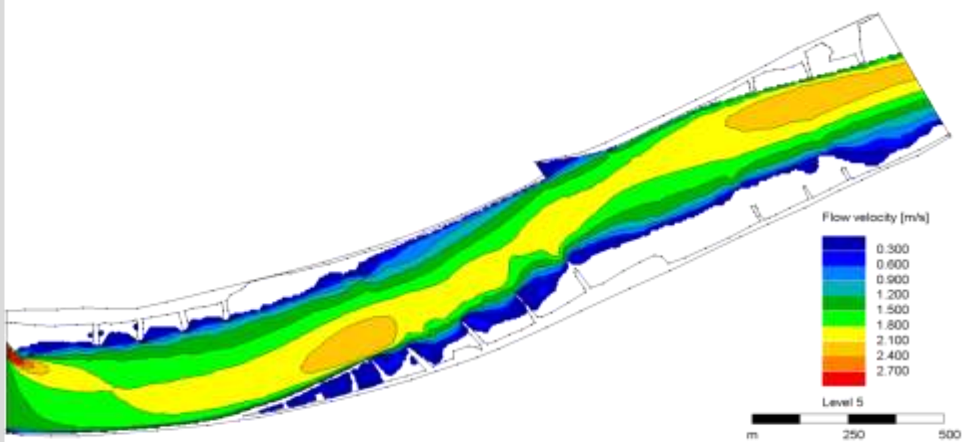
- Software: RSim-3D
- Hexagonal cells in several layers
- Different cell sizes according to river bed geometry
- Detailed evaluation of hydraulic structures

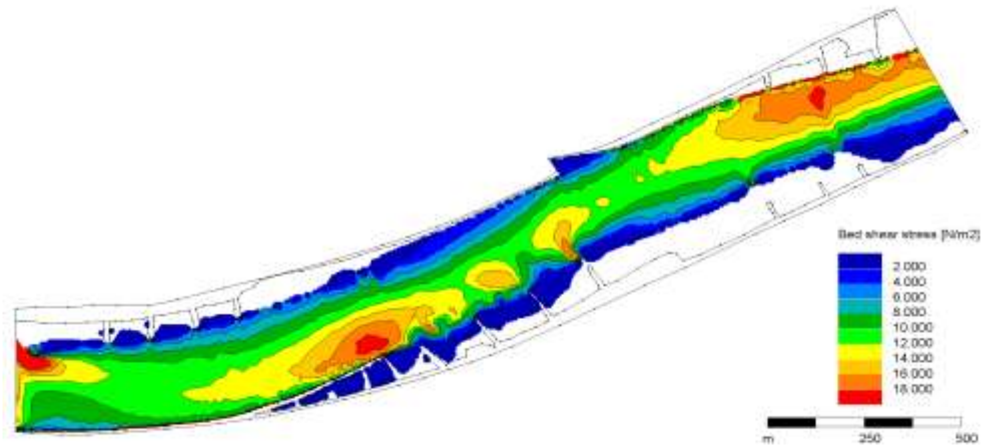


Numerical Model – 3D Model Haslau

Result RNQ: 980 m³/s

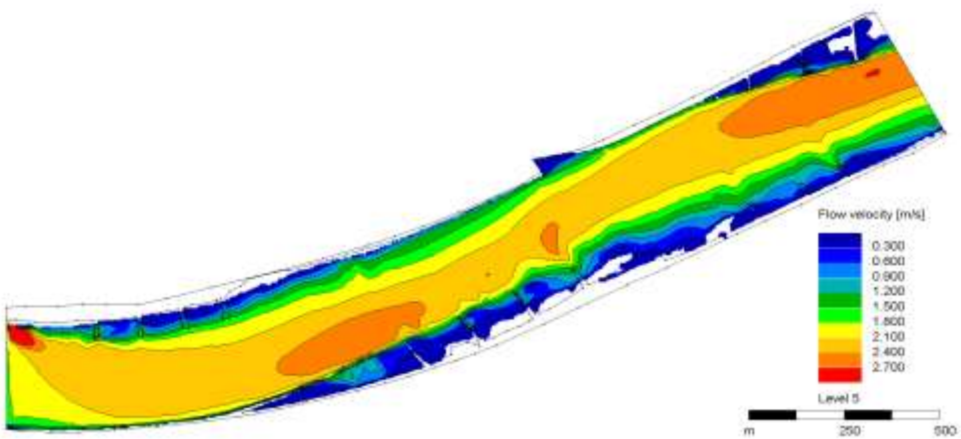


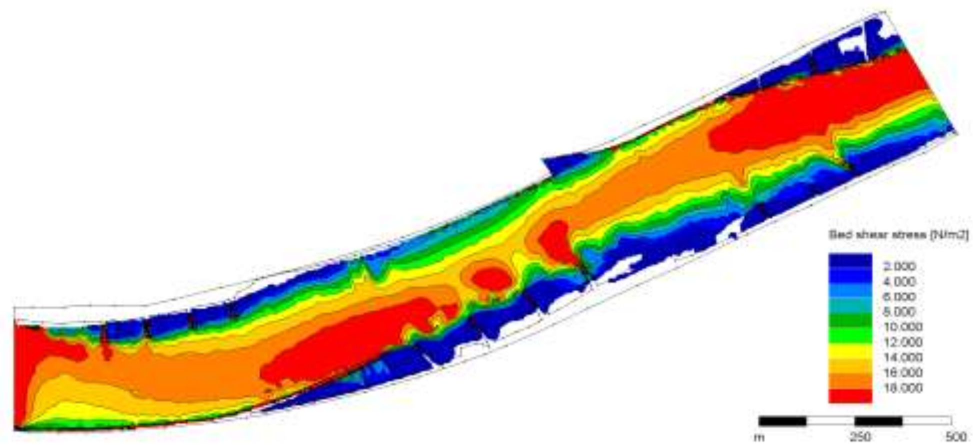




Numerical Model – 3D Model Haslau

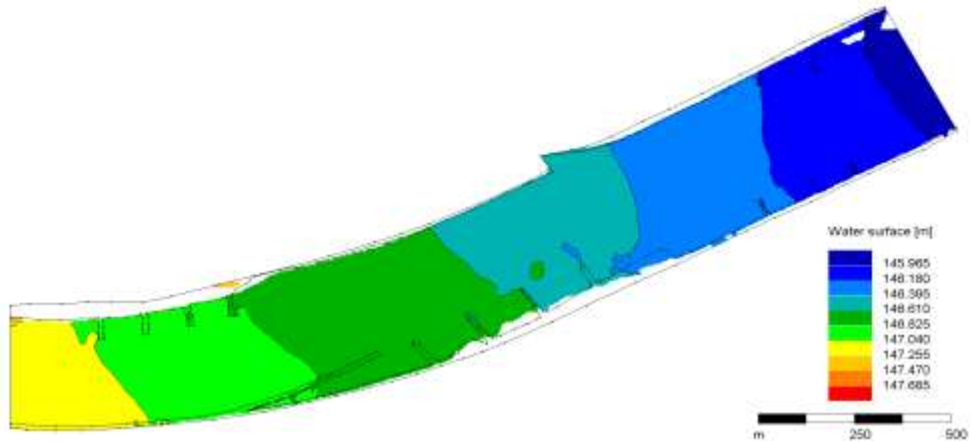
Result MQ: 1930 m³/s

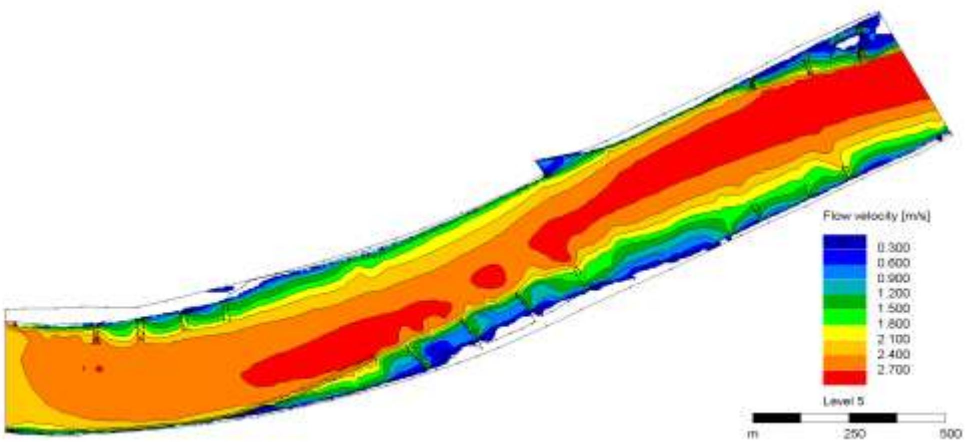


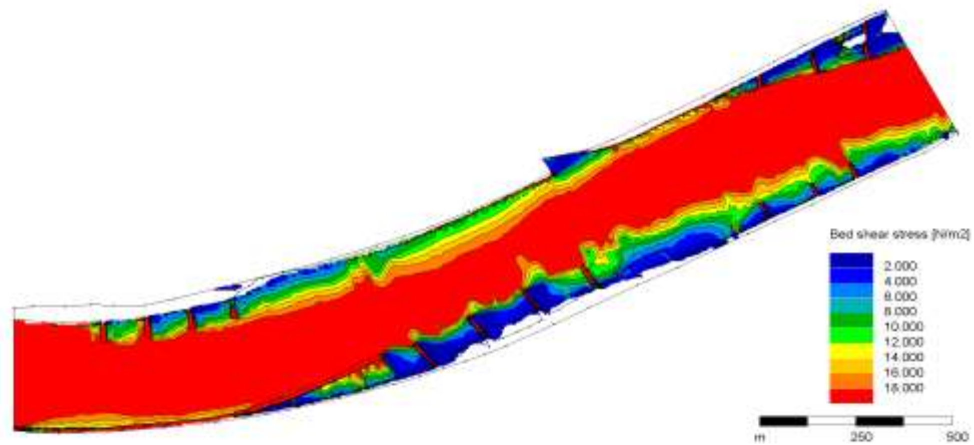


Numerical Model – 3D Model Haslau

Result Q: 3000 m³/s

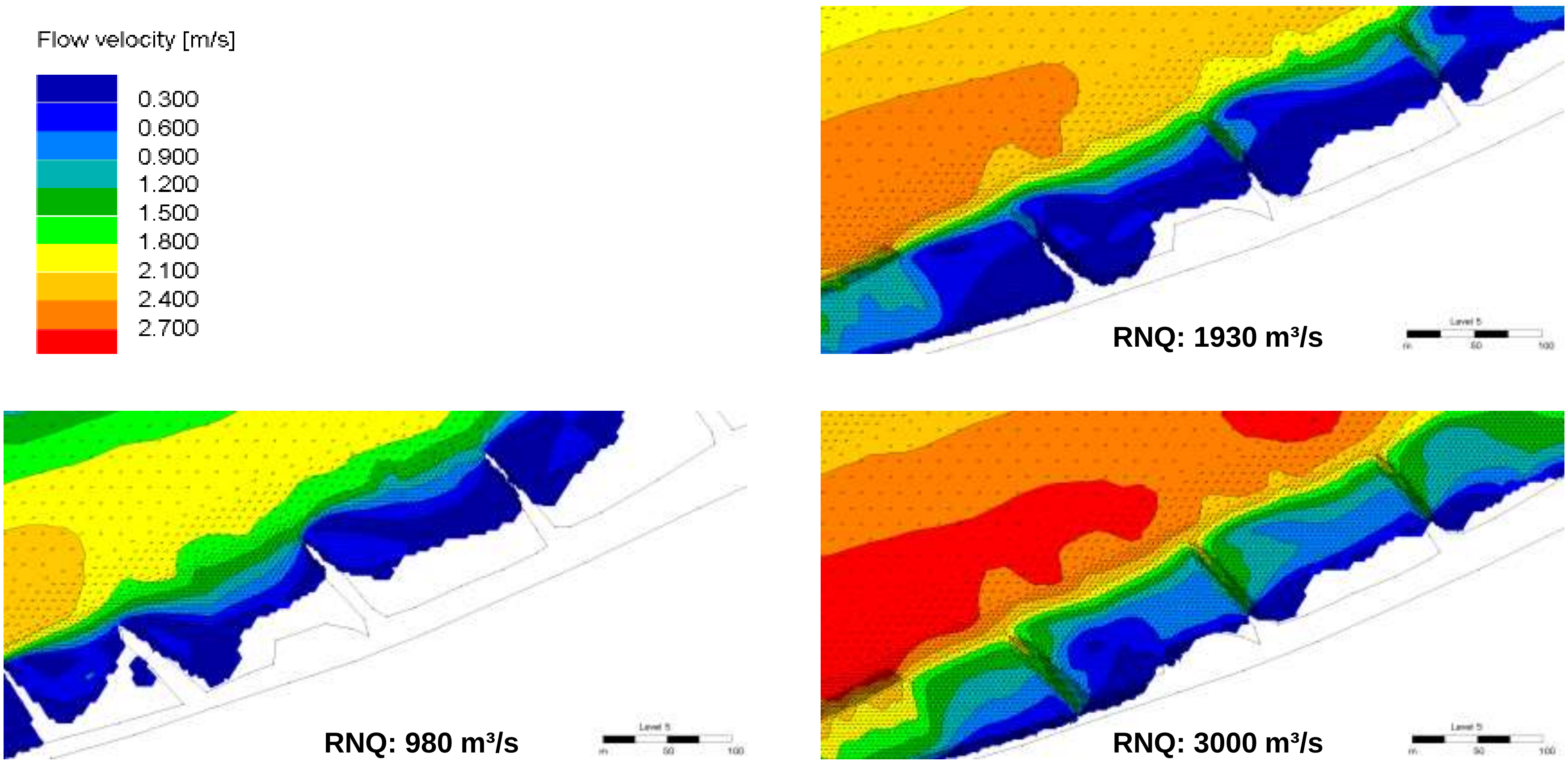






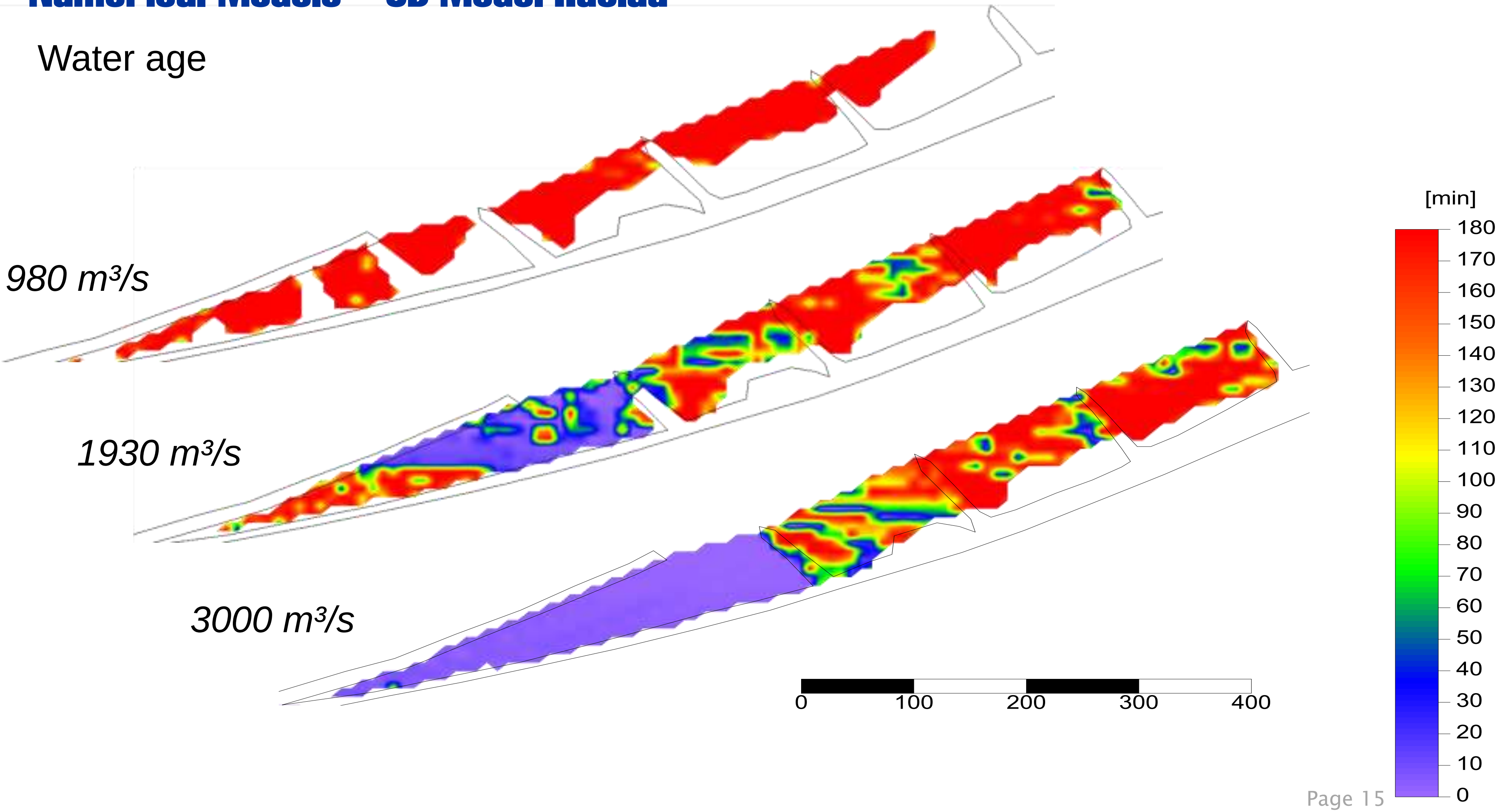
Numerical Model – 3D Model Haslau

Detail –velocity vectors surface layer



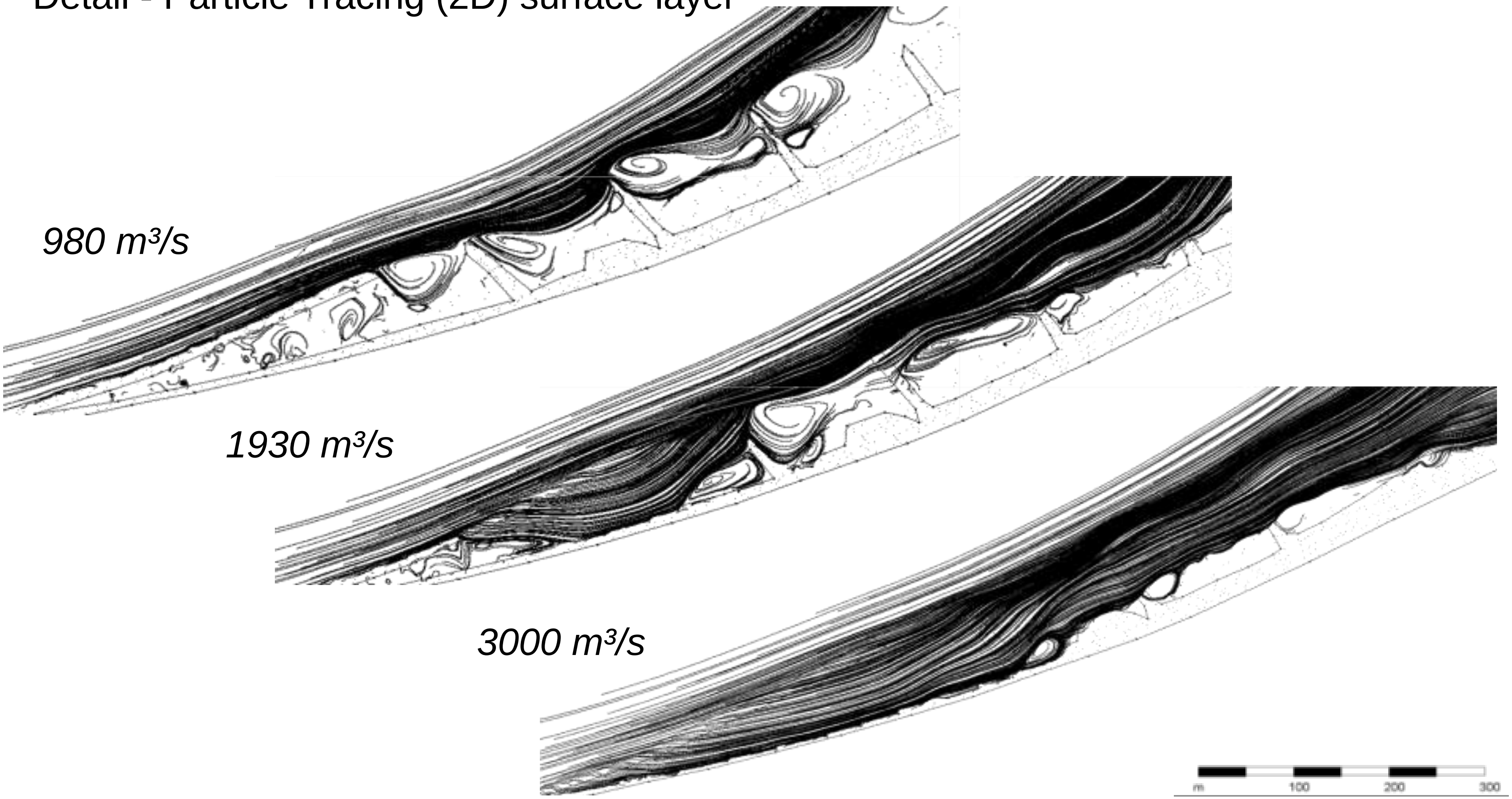
Numerical Models – 3D Model Haslau

Water age



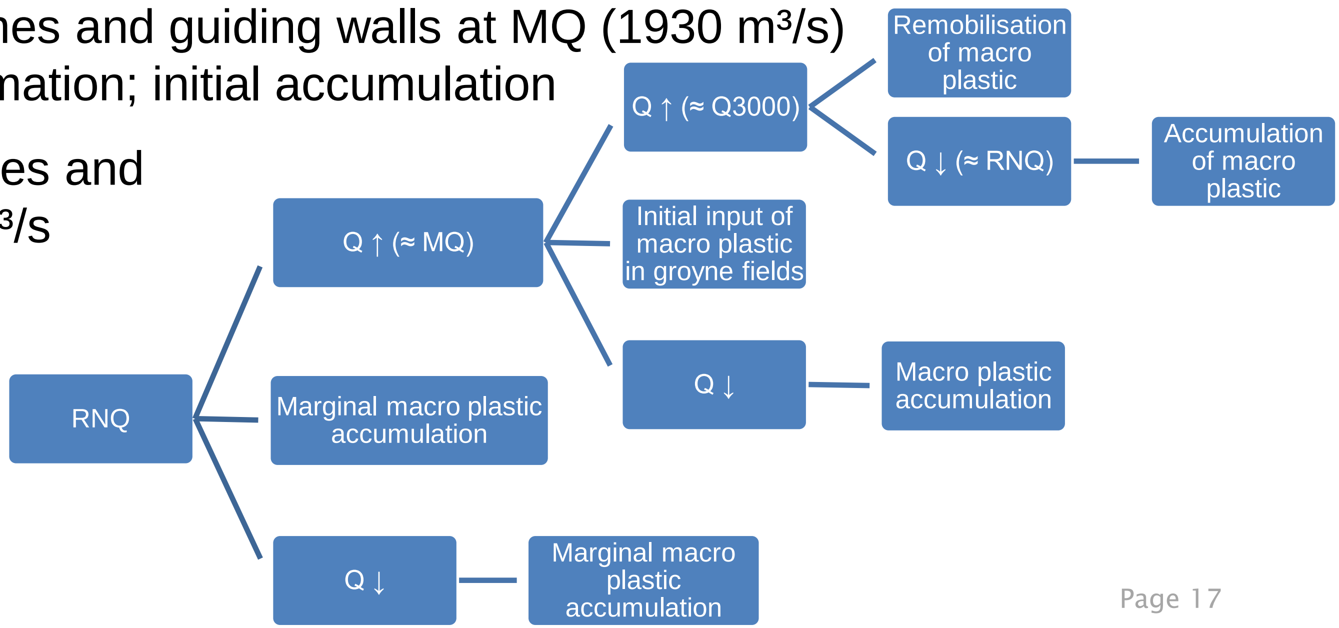
Numerical Models – 3D Model Haslau

Detail - Particle Tracing (2D) surface layer



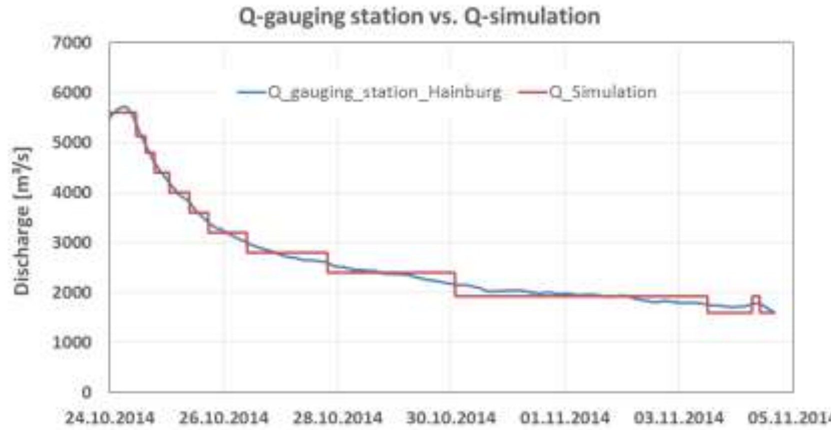
Conclusions – 3D Numerical Model Haslau

- Significant vortex formations and high water age at RNQ (980 m^3/s)
  ➔ marginal macro plastic accumulaiton
- Scenario water level lowering to RNQ
  ➔ high probability of macro plastic accumulation
- Partial overflow of groynes and guiding walls at MQ (1930 m^3/s)
  ➔ Moderate vortex formation; initial accumulation
- Entire overflow of groynes and guiding walls at 3.000m^3/s
  ➔ Remobilisation of macro plastic

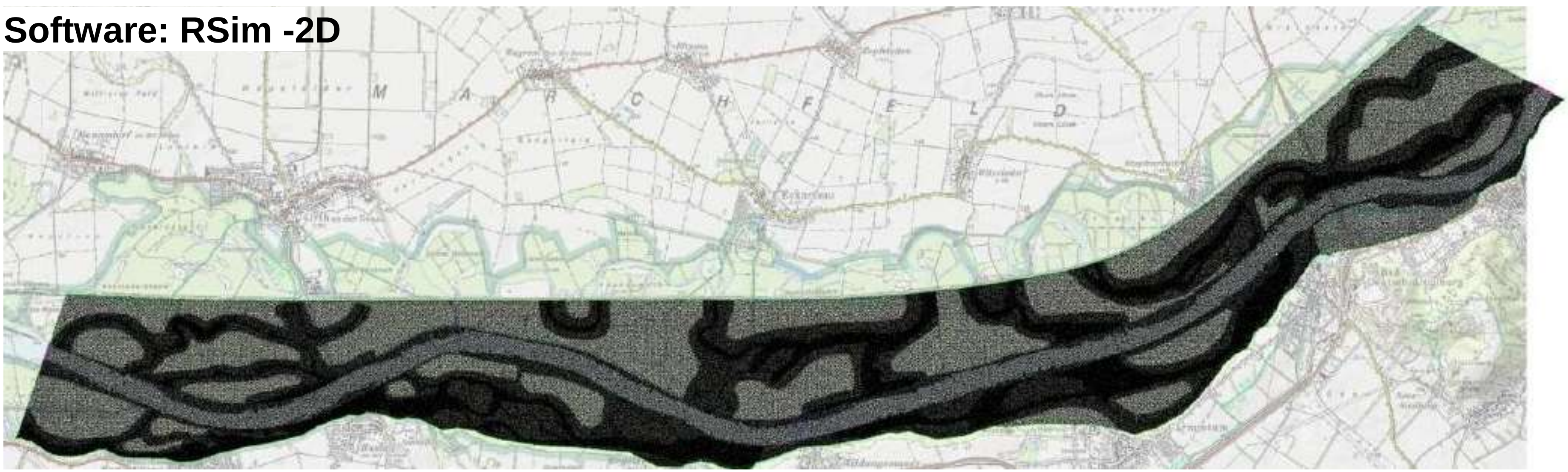


Numerical Model – 2D Large Scale Model Vienna - Bratislava

- Evaluation of macro plastic transport in the innundation area
- Implemented concept model considering drainage effects
- Quasi-stationary discharge used for particel tracing

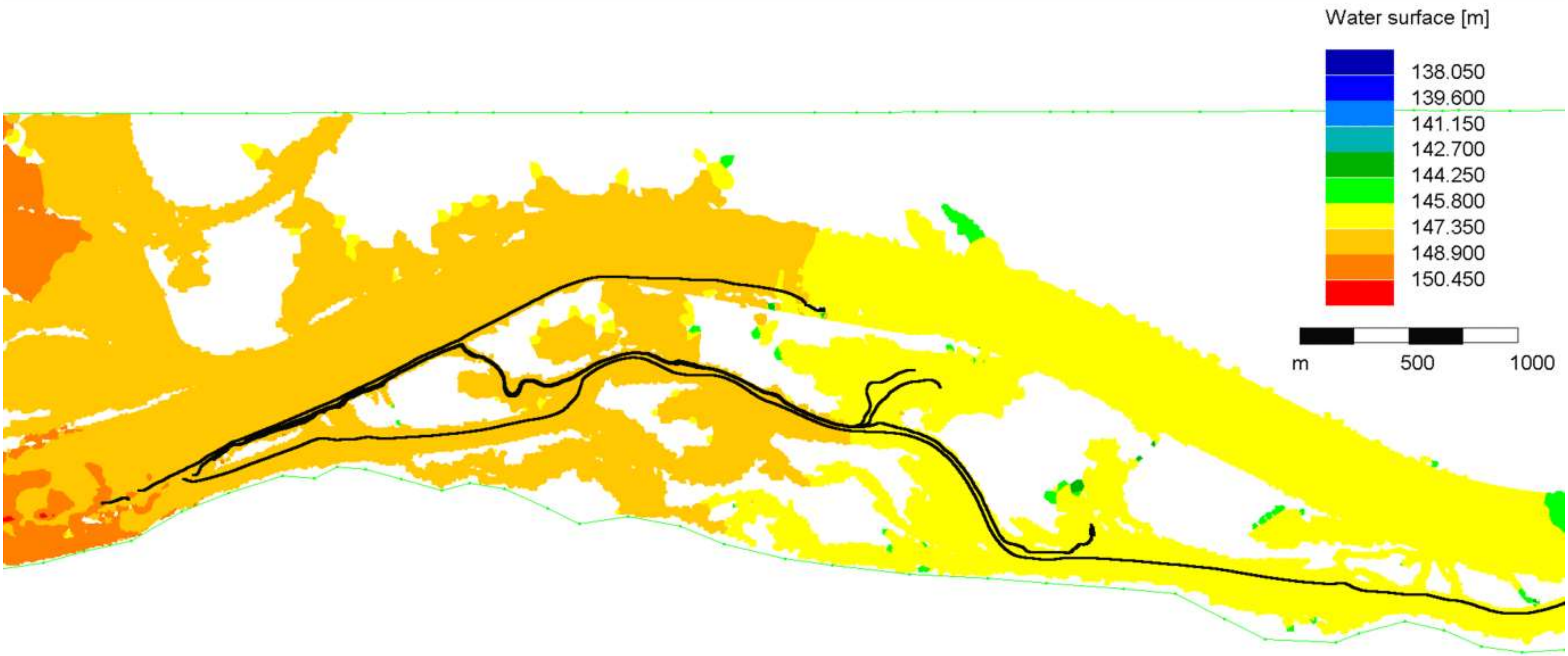


Software: RSim -2D



Numerical Model – 2D Large Scale model Vienna - Bratislava

Particle Tracing (2D) – Innundation area

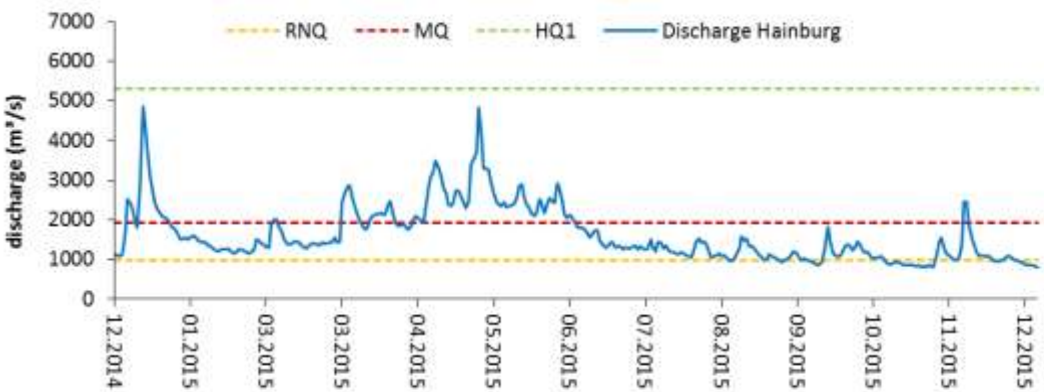


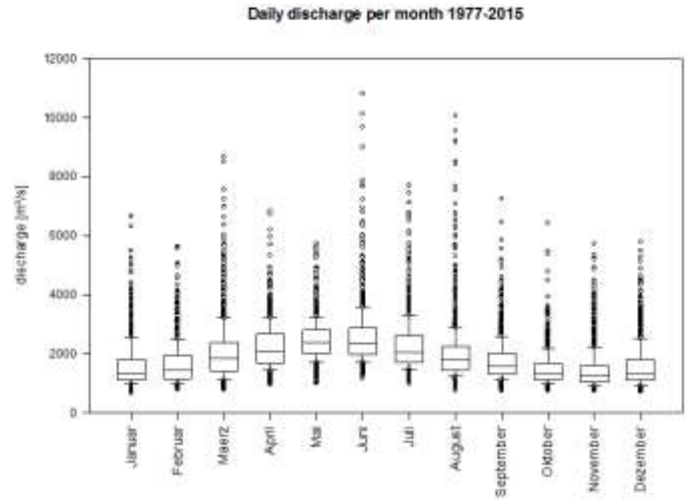
2D Numerical Model

Characterisation of accumulation zones

- **Bank near/shore line accumulation**
  - occuring at frequent water levels
  - influenced by wave splash

Statistical analysis of hydrologic data

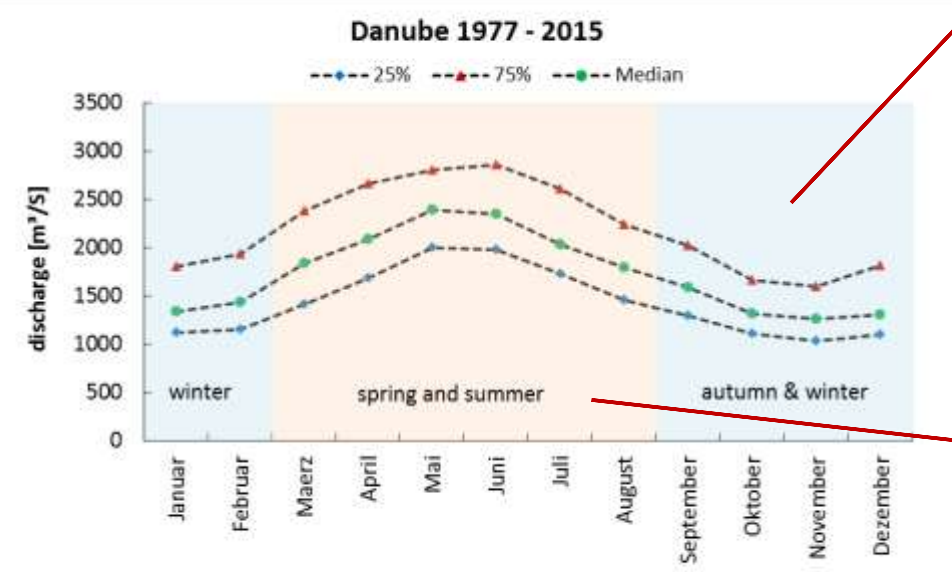




Numerical Model

Characterisation of accumulation zones

- **Bank near/shore line accumulation**
  - Classification of discharge periods based on 25% and 75% quartiles



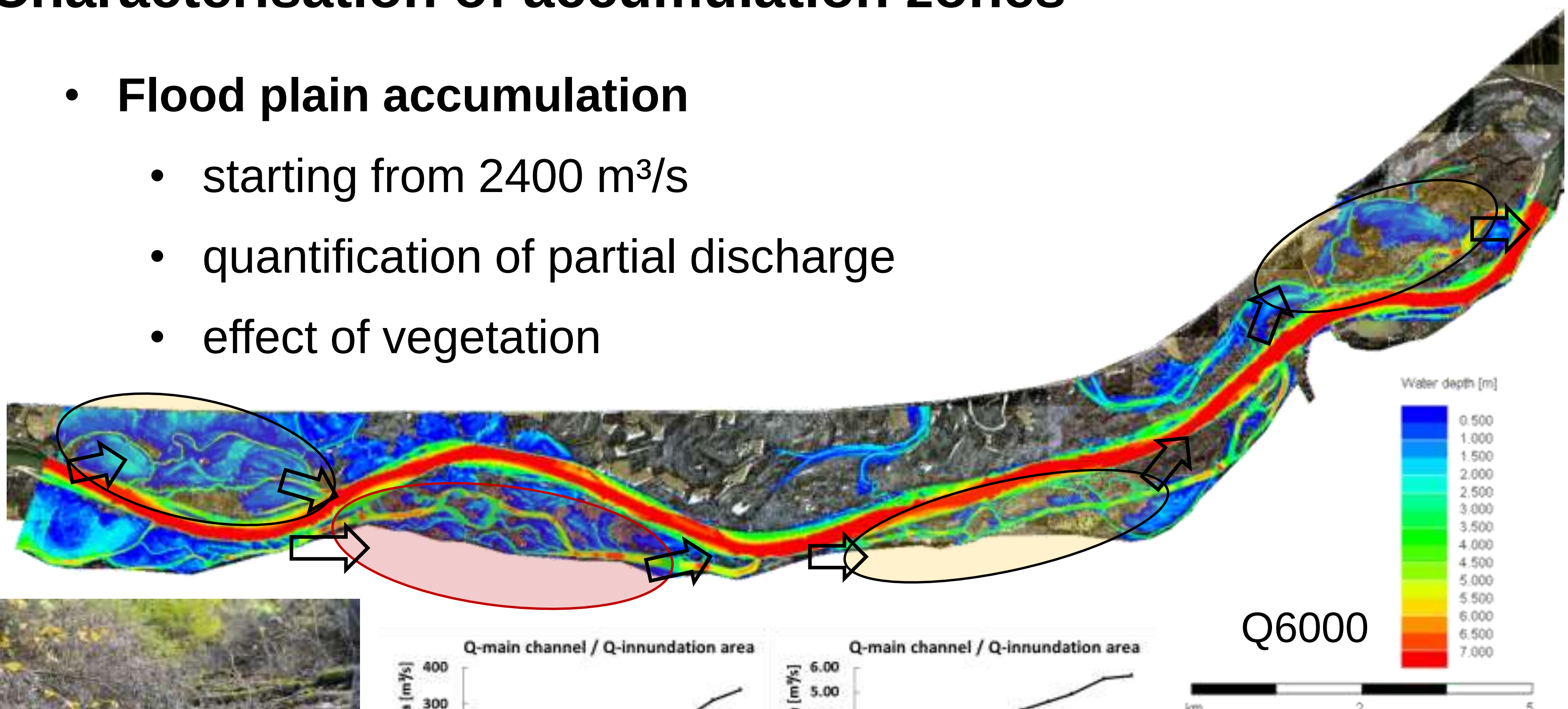
Autumn & Winter: Q1000 – Q2000

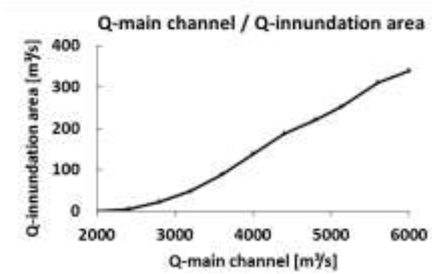
Spring & Summer: Q1450 – Q2850

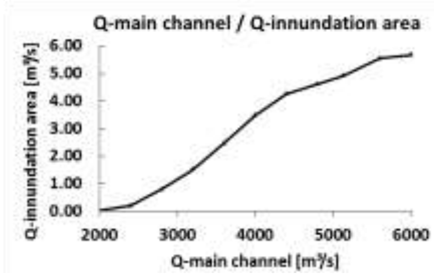
Numerical Model

Characterisation of accumulation zones

- **Flood plain accumulation**
  - starting from 2400 m³/s
  - quantification of partial discharge
  - effect of vegetation





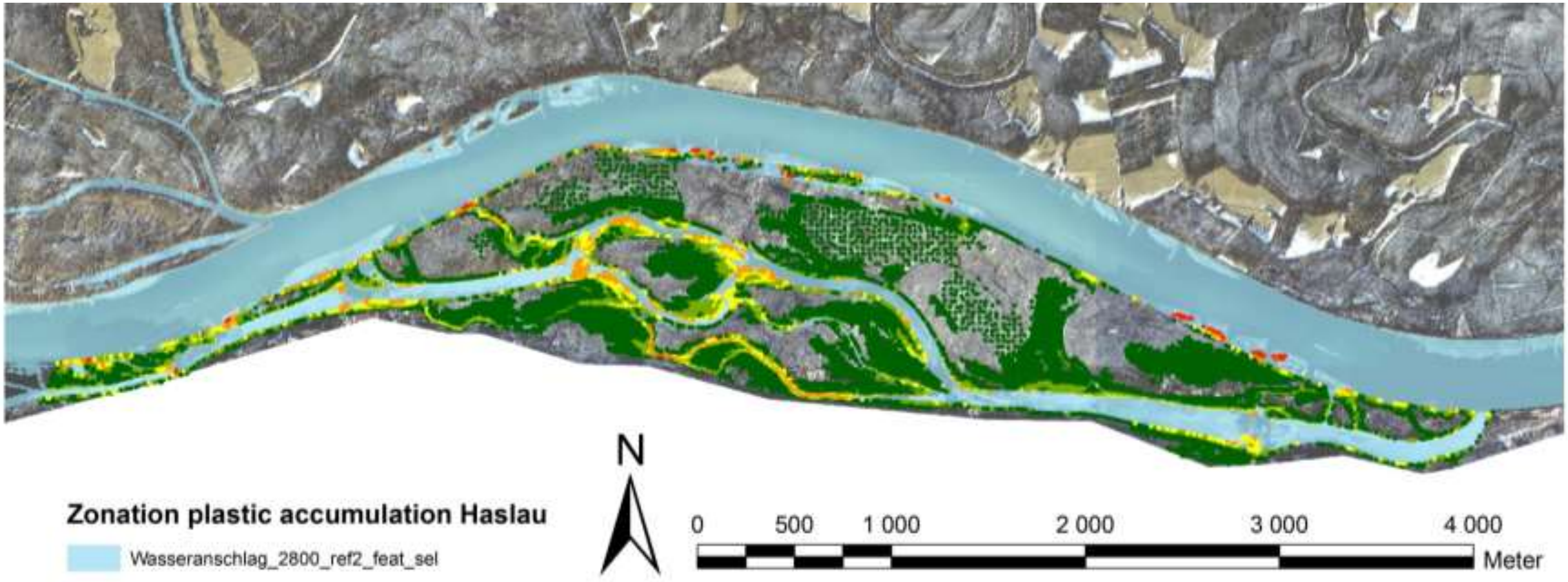


Numerical Model

Characterisation of accumulation zones

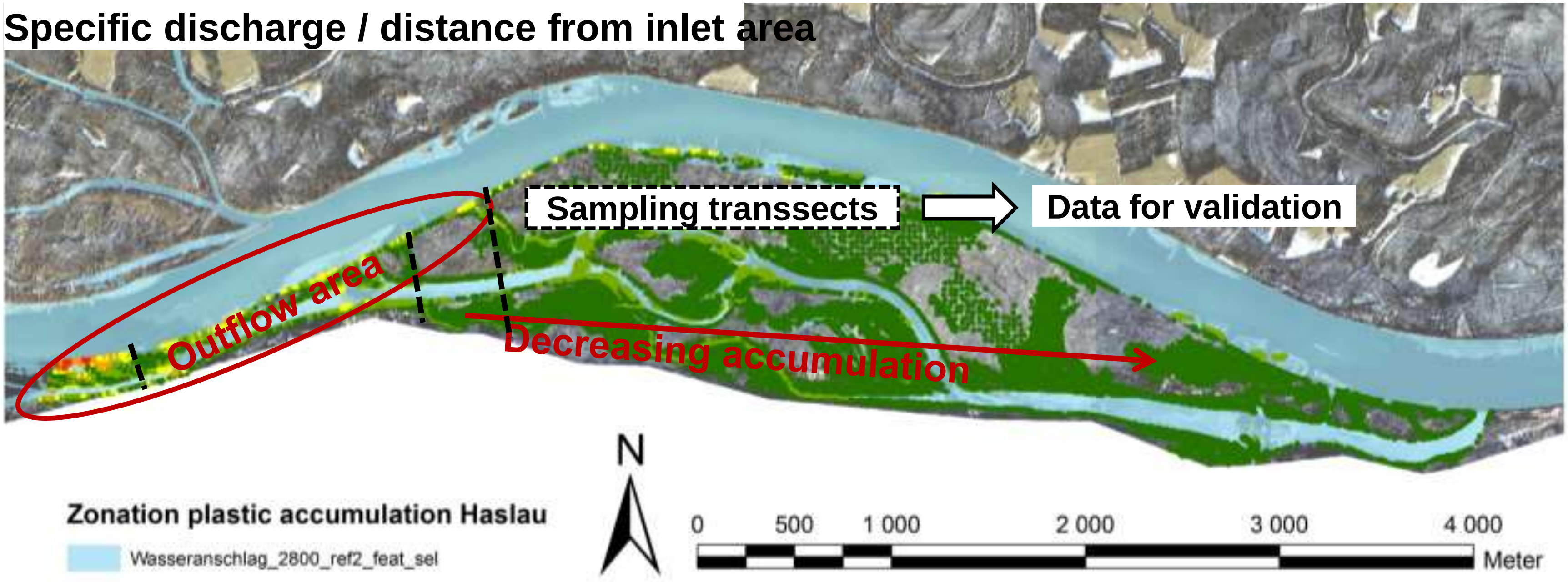
- **Flood plain accumulation**
    - High accumulation potential related to specific discharge

Specific discharge (m^3/m^2) in the innundation area Haslau at Q6000 m^3/s



Numerical Model

- **Flood plain accumulation**
  - High accumulation potential at the outflow area
  - Decreasing accumulation potential depending on the distance from the outflow caused by filtration effect of vegetation



Interreg Slovakia-Austria
European Regional Development Fund

PlasticFree Danube

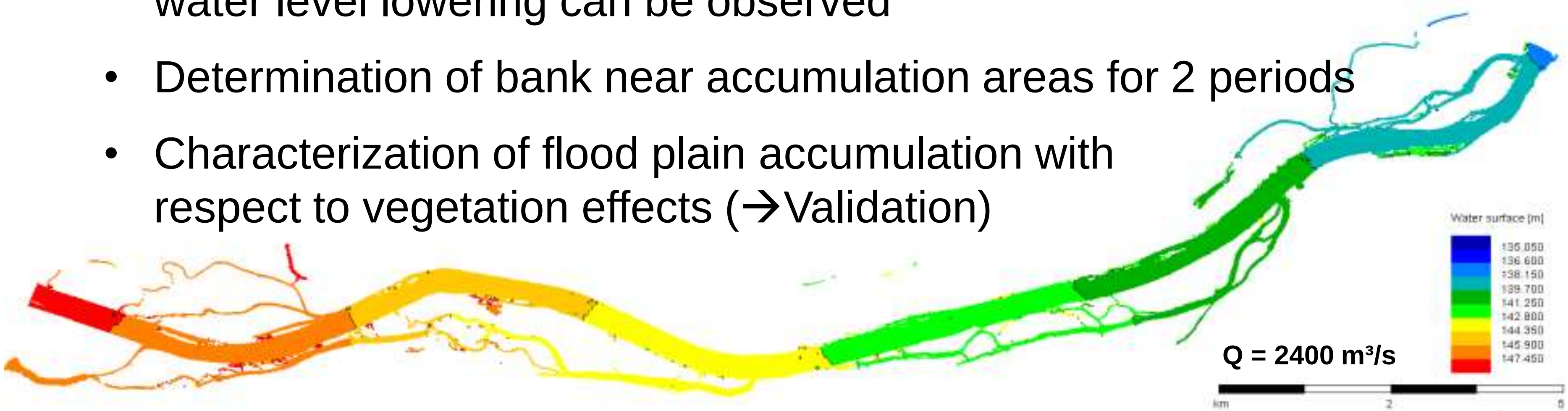
SedNet

EUROPEAN UNION

Conclusions – 2D Large Scale model Vienna - Bratislava

2D large scale model Wien-Bratislava

- Simulation of quasi-stationary discharge suitable for particle tracing
- Particles are likely to drift into side arms (connected from 2.400 m^3/s)
- Accumulation of particles in sink areas of the floodplain during water level lowering can be observed
- Determination of bank near accumulation areas for 2 periods
- Characterization of flood plain accumulation with respect to vegetation effects (→Validation)




Protect Nature – avoid pollution!