

## Preparing FAIRway 2 works in the Rhine-Danube corridor

### General concept for hydraulic and morphological modelling of the common Serbian-Croatian stretch of the Danube River

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Author IMI

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## Geographical area

The area which is the subject of the hydraulic and morphological modelling is the Serbian-Croatian common stretch of the Danube River, from the rkm 1,433.1 to the rkm 1,295.5.

## Components

The following components of the process will be performed:

- 1D hydraulic model for the entire Serbian and Croatian common Danube stretch,
- Redefinition and prioritization of navigational bottlenecks,
- Definition of parameters for and execution of the multi-criteria analysis,
- Definition of alternative solutions for prioritized sectors and hydrodynamic and morphological modelling, and
- Development of the integrated study on alternative solutions and definition of next steps for future investments.

### Component 1 - 1D hydraulic model

1D steady flow hydraulic model for the whole common stretch of Danube River will be prepared, for the selected characteristic hydrological occurrences agreed and approved by the Stakeholder's Forum. The model shall serve in redefinition of navigational bottlenecks at common stretch and prioritization of identified bottlenecks in order to perform 2D hydrodynamic and morphological modelling of selected bottlenecks. The updated ENRs on selected gauges shall be checked by the 1D model.

The 1D model shall be developed as follows:

- Gathering all the input data,
- Configuration of the 1D model,
- Calibration of the 1D model, and
- Evaluation and monitoring of the results.

There is no preference regarding 1D modelling software. However, a technical justification of the selected modelling software must be provided.

## **Component 2 - Redefinition and prioritization of navigational bottlenecks**

The technical expert group consisted of representatives of Serbia and Croatia established a prioritization of critical bottlenecks on the mutual Danube stretch in 2014, where 17 critical sectors were identified. Out of 17 bottlenecks, 7 critical locations were identified as “most critical”. Due to constant changes in the riverbed, new critical sectors might emerge and already identified ones might be solved.

The Catalogue of bottlenecks has been prepared and it is continuously being updated by the waterway administrations. These bottlenecks are prioritised, which means that all of them are already categorised from highest to lowest priority.

Catalogue will be analysed, and using inputs and outputs of the 1D modelling, information on fairway location and other relevant data, navigational bottlenecks will be redefined in terms of their location and priority, including their characterisation in terms of the type of bottleneck.

Redefinition of the bottlenecks shall take into account recently observed changes in riverbed morphology.

Finally, the list of the bottlenecks for which the alternative solutions will be proposed shall be agreed.

## **Component 3 - Definition of parameters for the multi-criteria analysis**

After the redefinition and prioritization of navigational bottlenecks has been performed, the multi-criteria analysis for selection of the optimal option for each bottleneck shall be defined and agreed within the Stakeholder’s Forum.

The multi-criteria analysis relies on inputs from experts and stakeholders. These inputs shall be summarized to arrive at a collective decision, or choice, regarding the selection of a weighted set.

Criteria and sub-criteria shall be applied to each modelled option. Criteria shall take into account at least navigational, environmental, technical and financial issues. All proposed criteria, sub-criteria and weights shall be discussed and agreed with Stakeholder’s Forum.

## **Component 4 - Definition of alternative solutions for prioritized sectors and hydrodynamic and morphological modelling**

After the redefinition and prioritization have been performed, alternative solutions per each bottleneck selected shall be defined (including “do nothing” option). It shall be agreed and confirmed by the Stakeholder’s Forum which alternatives will be modelled, having in mind that a sufficient number of model simulations, shall be performed, in order to reach the quality level which will be acceptable and preferable for all involved parties.

In principle, the 2D modelling shall include the following steps:

- Collecting and analysis of existing data;
- Geodetic and hydrographic surveys;
- First series of hydrodynamic and sediment surveys;
- Preparation of 2D model for existing situation;
- Calibration of the model;
- Second series of hydrodynamic and sediment surveys;
- Model verification;
- Preparation of model for considered (at least two) variants;

- Analysis of considered variants.

Data collected during the interlinked monitoring activity will be used for all modelling activities.

A 2D mathematical hydrodynamic cohesive and non-cohesive sediment flow and transport model shall be prepared, too.

There is no preference regarding 2D modelling software. However, a technical justification of the selected modelling software must be provided. The minimum requirements of the selected mathematical modelling software are:

- The model must be based on the integrated Navier-Stokes equations for free surface flows, using a flexible mesh of elements;
- Information on depth/water levels, discharge and flow velocities for each calculation point at any desired moment of the calculations shall be available;
- It shall be able to simulate sediment transport and morphological modifications along with the hydrodynamic simulations. The module used for the sediment transport mathematical model shall include cohesive and non-cohesive sediment transport;
- The flexible mesh shall be dense enough in order to present results with reasonable details;
- It shall describe the effects of the proposed works and their effect on sediment transport, river morphology, the existing infrastructure, upstream and downstream environmentally affected areas etc.;
- It must be possible to use the model's outputs in a GIS system.

Multi-criteria analysis shall be performed for each bottleneck and best solution shall be selected in line with parameters adopted.

Existing environmental documentation and existing measurements will be collected (provided by the Contracting authority). In addition, zero state analysis will be carried out on water quality, biological species and habitats (fish, birds, macrozoobenthos, habitats, vegetation). It will be the basis for EIA report preparation in the following phase of the project preparation. Environmental monitoring programme will be proposed for implementation before the construction of the selected solution, as well as during construction and after construction.

## **Component 5 - Development of the integrated study on alternative solutions**

An integrated study on alternative solutions will be prepared, containing results of 1D hydraulic modelling, defined critical sectors for navigation, prioritized critical sectors for navigation, parameters of the mutually agreed multi-criteria analysis, alternative solutions, results of modelling of alternative solutions, application of the multi-criteria analysis, elaboration of favourable selected solutions which will improve navigability but will also help to meet the requirements of the EU Water Framework Directive to ensure that rivers achieve 'good chemical and ecological status', addressing the climate change issue and including all activities of the Stakeholders' Forum in all phases of the process. The study will contain most of elements for further progress and coordinated implementation of further steps.

The study will analyse environmental aspects especially impacts of the alternative solutions on: aquatic ecosystems (habitat loss or degradation, spawning, fish migration), birds, sediment and water quality (impact on physical-chemical and biological quality indicators), hydromorphology (water levels, flow velocities, riverbed morphology). The study will also include Climate change vulnerability assessment, i.e. Impact of extreme hydrological phenomena on vulnerability of the alternative solutions.

## Expected results

Expected results are as follows:

- Developed 1D hydraulic model of the whole common Croatian and Serbian river stretch of the Danube River for the selected flows, which shall be confirmed by the Stakeholder's Forum and the Contracting Authority (CA). Updated existing Low Navigation Water Levels (ENRs) at selected water level gauges (at least recognised by the Danube Commission and agreed with the Stakeholder's Forum). The 1D hydraulic model can be used as a supporting tool in recalculation of the ENR.
- The results should be checked with the general trend of decreasing water levels as the river bed deepening through incision due to old and existing river regulation is estimated already in the magnitude of 1 m in the past 70 years (comp. presentation of E. Tamas, uni Budapest at 43. IAD conference 2021).
- Redefined navigational bottlenecks in order to check and, if necessary, update existing bottlenecks at mutual sector, based on 1D modelling results;
- Prioritized identified bottlenecks in order to perform hydrodynamic and morphological modelling of selected bottlenecks;
- Defined parameters for the multi-criteria analysis, where proposed parameters will be discussed and agreed within the Stakeholders' Forum;
- Defined alternative solutions for prioritized sectors and 2D hydrodynamic and morphological modelling. All proposed alternatives shall be discussed within the Stakeholders' Forum. It is foreseen to have a sufficient number of model simulations, in order to reach the quality level which will be acceptable and preferable for all involved parties;
- Developed integrated study on alternative solutions containing results of 1D hydraulic modelling, defined critical sectors for navigation, prioritized critical sectors for navigation, parameters of the mutually agreed multi-criteria analysis, alternative solutions, results of modelling of alternative solutions, application of the multi-criteria analysis, elaboration of favourable selected solutions, addressing the climate change issue and including all activities of the Stakeholders' Forum in all phases of the process. The study will contain most of elements for further progress and coordinated implementation of future measures.