Interreg
Danube Transnational Programme
DAREFFORT

Evaluation report of the pilot action
WP5 - Deliverable D 5.3.1.

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Introduction

This technical report represent the Deliverable D 5.3.1 – Evaluation report of the pilot action, as result of the Activity 5.3. Sharing model calculation capacity for flood forecasting.

The Danube River Basin is the most international river basin in the world, including territories of 19 countries, with many important tributaries. Occurrence of severe floods in the Danube river basin in the last two decades (2002, 2005, 2006, 2009, 2010, 2013 and 2014), highlighted the need for a more effective and better harmonized regional and cross-border cooperation in the field of flood forecasting, especially during extreme flood events.

In general, the cooperation between hydrological services in transboundary river basins, use one of the following two approach:

- Exchange of real time observation data (water level, discharge, etc.) and hydrological forecasted data for representative river sections, based on data exchange agreement;
- Implement and operate a common Flood Forecasting an Warning System, covering the entire, or the most important part of the transboundary river basin.

Implementation of Activity 5.2 pilot action main objective was to investigate and evaluate the possibility of using a new innovative cooperation approach, between forecasting services of two neighbouring countries, respectively by giving external access to a downstream neighbouring country (secondary Forecast Center) for using and running independently a hydrological forecasting model, which is part of the forecasting system of the upstream country (main Forecast Center).

This is in fact a combined approach, of the two standard cooperation solutions between different Forecasts Center within a transboundary River Basin, with the advantage of avoiding the difficulties of implementation and maintenance of a complete common Flood Forecasting System, while keeping the possibility for the secondary Forecast Center to use the shared hydrological forecasting modellin components.

1 General description of the pilot area

The geographic scope of the pilot action, is represented by the Danube sector between Bogojevo and Iron Gate Reservoir, an area of great importance for both Serbia and Romania, taking into consideration that on this sector the Danube River receive major inflow contribution from his tributaries, and that the Iron Gate Reservoir is jointly operated by the two countries.

This Danube sector (Figure 1), is very important also for the flood formation on the Lower Danube, due to the influence of superposition of flood waves on the Danube, and the flood waves on his main tributaries on this sector (Tisza, Sava and Velika Morava).

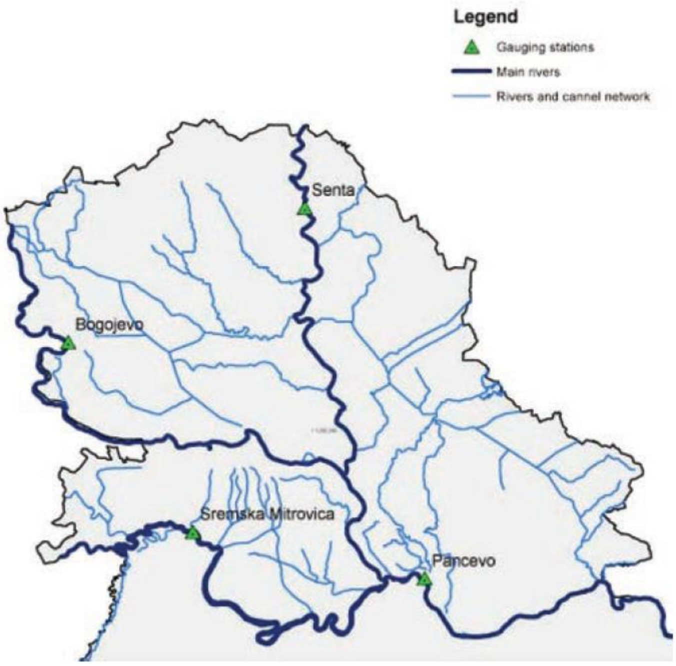

Figure 1: A schematic presentation of the selected Danube River reach

The analysis of the multiple-coincidence of flood waves on the Danube and its tributaries provide very interesting and usefull results, demonstrating also the importance of a good simulation of the superposition and routing processes on this Danube sector for real time forecasting activities (Figure 2).

As example, a 100-year flood on Danube at Pančevo, may be generated by multiple-coincidences of different combinations of floods on the other upstream representative sections (Prohaska et al., 2012):

- 50-year Danube at Bogojevo, 10-year Tisa at Senta, and 2.2-year Sava at Sremska Mitrovica;
- 100-year Tisa at Senta, 33-year Sava at Sremska Mitrovica, and 5-year Danube at Bogojevo;

- 100-year Sava at Sremska Mitrovica, 10-year Tisa at Senta, and 3-year Danube at Bogojevo;
- And, potentially many other coincidence combinations.

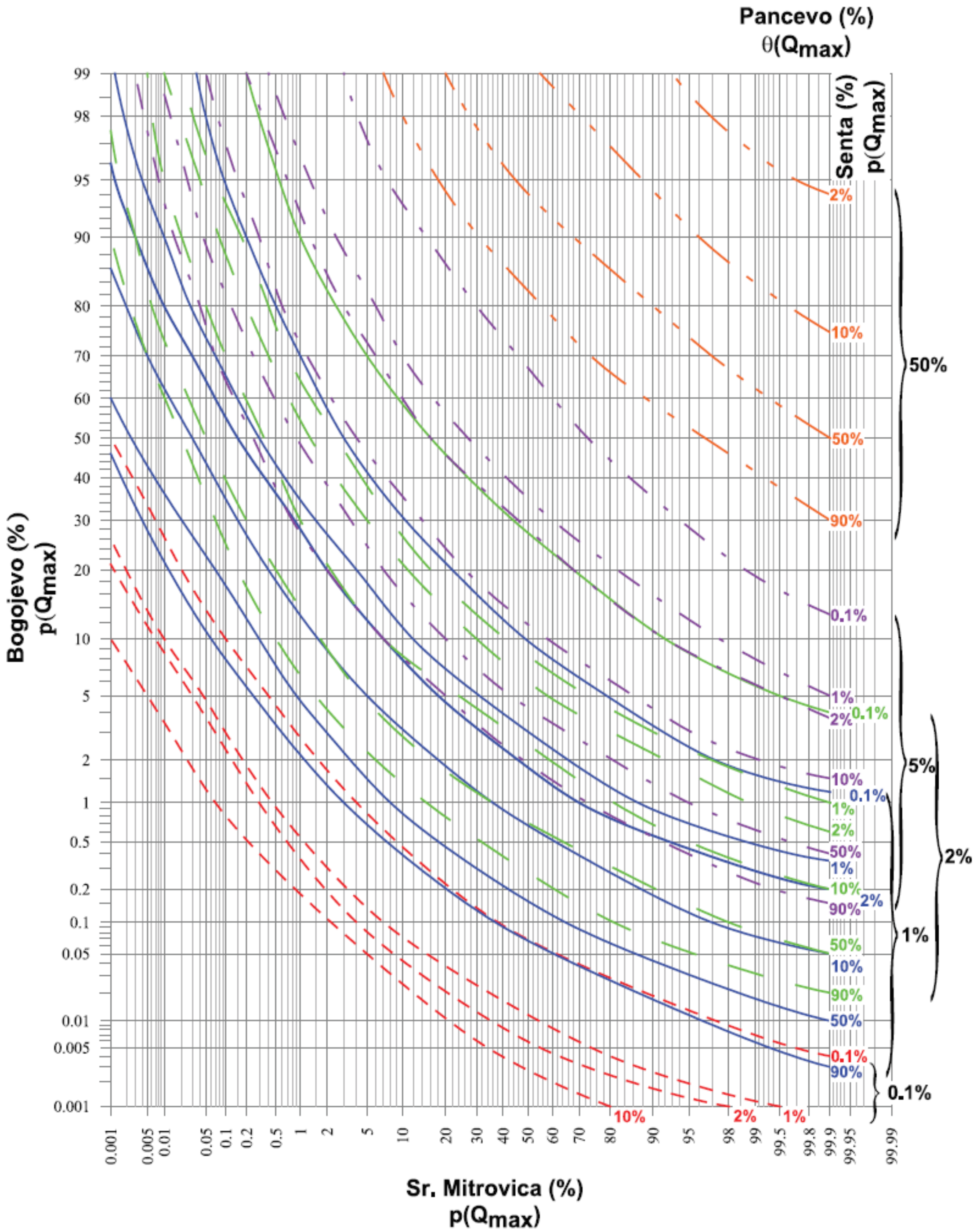

Figure 2: Multiple-coincidence of different return-period floods on the Danube River at Pančevo as a function of floods on the Danube at Bogojevo, the Tisa at Senta and the Sava at Sremska Mitrovica (Prohaska et al., 2012)

Also, an analysis of the Danube sectors with the main tributaries upstream Bazias section (entrance of the Danube in Romania), demonstrate the importance of pilot area within the entire Danube River Basin (Table 1).

Table 1: Danube sectors with important tributaries, upstream Bazias section (Prohaska et al., 2019)

Node	Recipient	Hydrological station		Tributary	Hydrological station
		QIN	QOUT		qTR
1	Danube	Hofkirchen	Achleiten	Inn	P-Ingling
2		Vienna	Bratislava	Morava	Moravsky Jan
3		Bezdan	Bogojevo	Drava	Donji Miholjac
4		Bogojevo	Slankamen	Tisa	Senta
5		Slankamen	Smederevo	Sava	Sremska Mitrovica
6		Smederevo	Veliko Gradište	Velika Morava	Ljubičevski Most

2 Design and concept of operation

The design and concept of operation are based on the following assumptions:

- The selected modeling component that will be shared is represented by a hydraulic routing model, for the Danube sector between Bogojevo and entrance in the Iron Gate I reservoir (Bazias section).
- For the implementation of this specific hydraulic routing model the Hydrologic Engineering Center's (CEIWR-HEC) River Analysis System (HEC-RAS) software will be used.
- The model is one of the components of the operational models used by the National Hydrologic Forecast Centre from Serbia (main Forecast Center), with complete access to the detailed model configuration and results in different sections.
- The National Hydrologic Forecast Centre from Romania (secondary Forecast Center), as a downstream country, will be able to access and run this model as a “black-box”

model, for analyzing different what-if scenarios evolution from upstream Danube, Sava, Tisa and Morava, in order to have the possibility to estimate with greater lead time the possible evolution of the inflow to Iron Gate Reservoir.

- The model can be used by the secondary Forecast Center also for other operational tasks / activities, like extending the lead time of the forecasts for the representative section for the downstream sector (in this case the Bazias section).
- The secondary Forecast Center does not have access to the detailed configuration and simulation results of the model on the territory of the upstream country, where the main Forecast Center have the responsibility for elaboration of hydrological forecasts and warnings.
- The access and use of the model by the secondary Forecast Center does not have any impact on the operation, and use of the model by the main Forecast Center.

For the implementations of the pilot action, an experimental environment was configured on the hardware infrastructure of NIHWM National Forecast Center. All the software used for the implemntation were open source or license free software packages.

Figure 3: Schematic representation of the main functional components and of the concept of operation

3 Implementation of a HEC-RAS hydraulic routing model for the pilot area

Within the pilot action a specific implementation of a hydraulic routing model was done, in order to be used for testing the new concpet for sharing a forecasting model between the two national forecasting services.

The 1 D hydraulic routing model was implemented for the Danube sector between Bogojevo and Iron Gate Reservoir, and include the main Danube tributaries on this sector: Tisa, Sava and Velika Morava.

The model implementation was done using the Hydrologic Engineering Center's (CEIWR-HEC) River Analysis System (HEC-RAS) software, which allows the user to perform one-dimensional steady flow, one and two-dimensional unsteady flow calculations, sediment transport/mobile bed computations, and water temperature/water quality modeling.

The model was tested and validated using slected historical flood events, from the years: 2006, 2010, 2013 and 2014.

Figures 4 – 8 present some examples of model configuration within the pilot area, for selected representatives areas, and Figures 9 – 10 present some selected model simulation results, from the 2014 historical flood event.

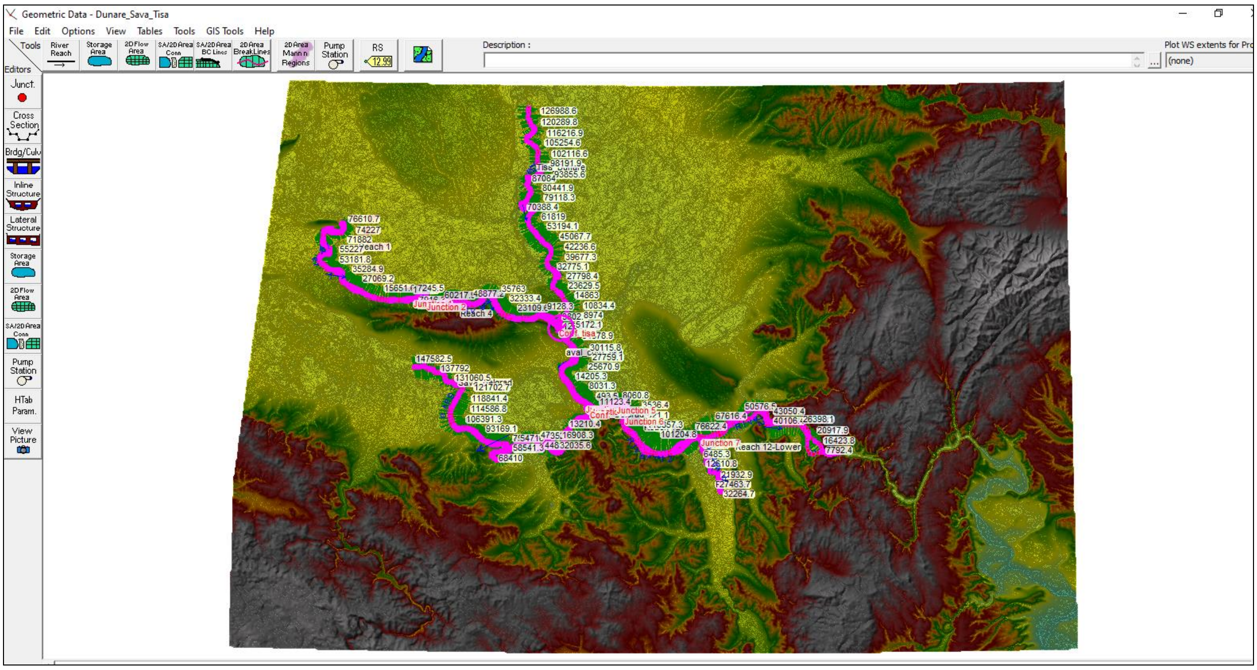

Figure 4: Pilot area general view within HEC-RAS geometric editor

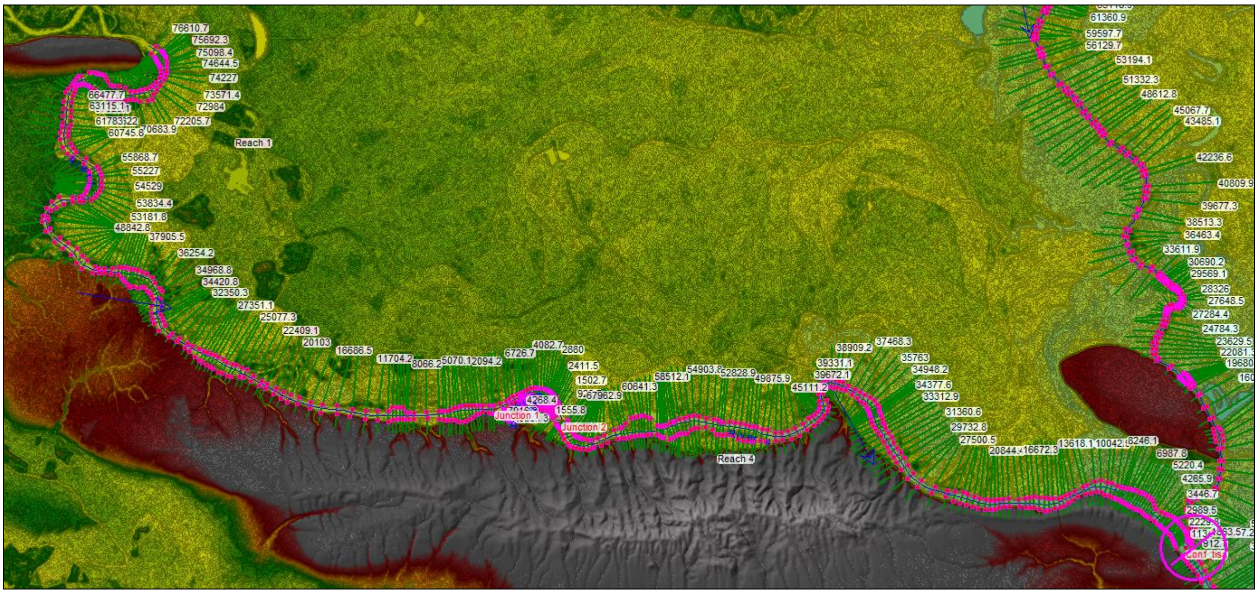

Figure 5: HEC-RAS geometric editor detail on Danube River sector between Bogojevo and confluence with Tisa River

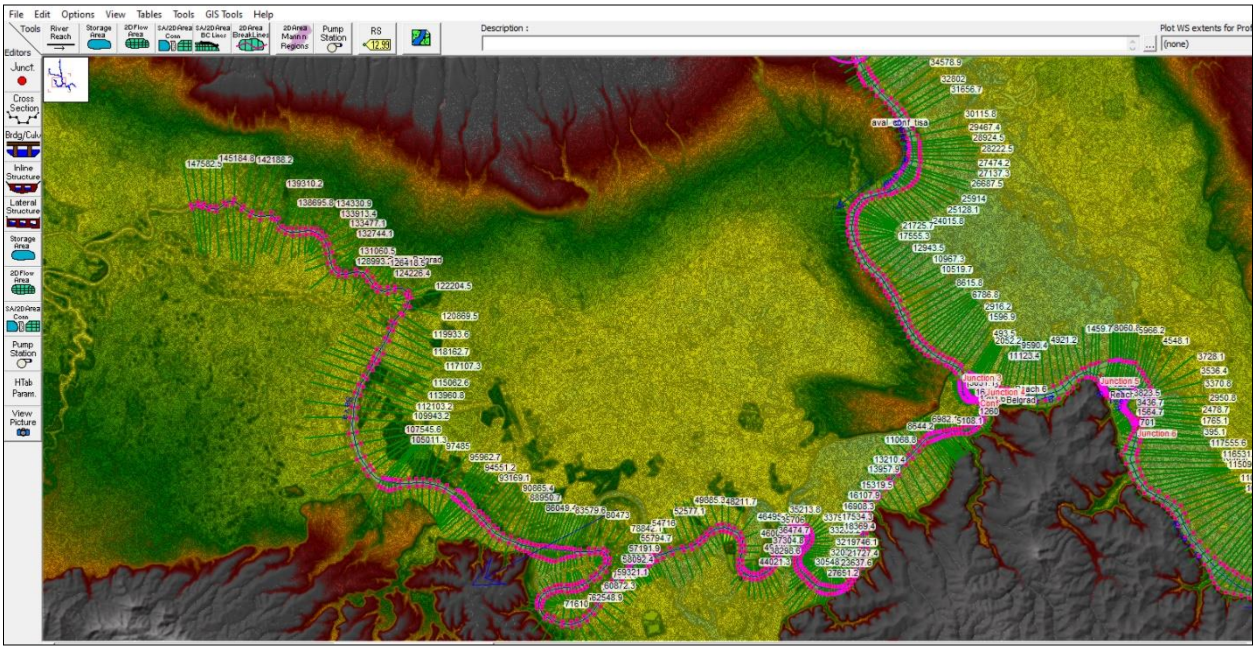

Figure 6: HEC-RAS geometric editor detail on Sava River sector between Sremska Mitrovica and confluence with Danube River

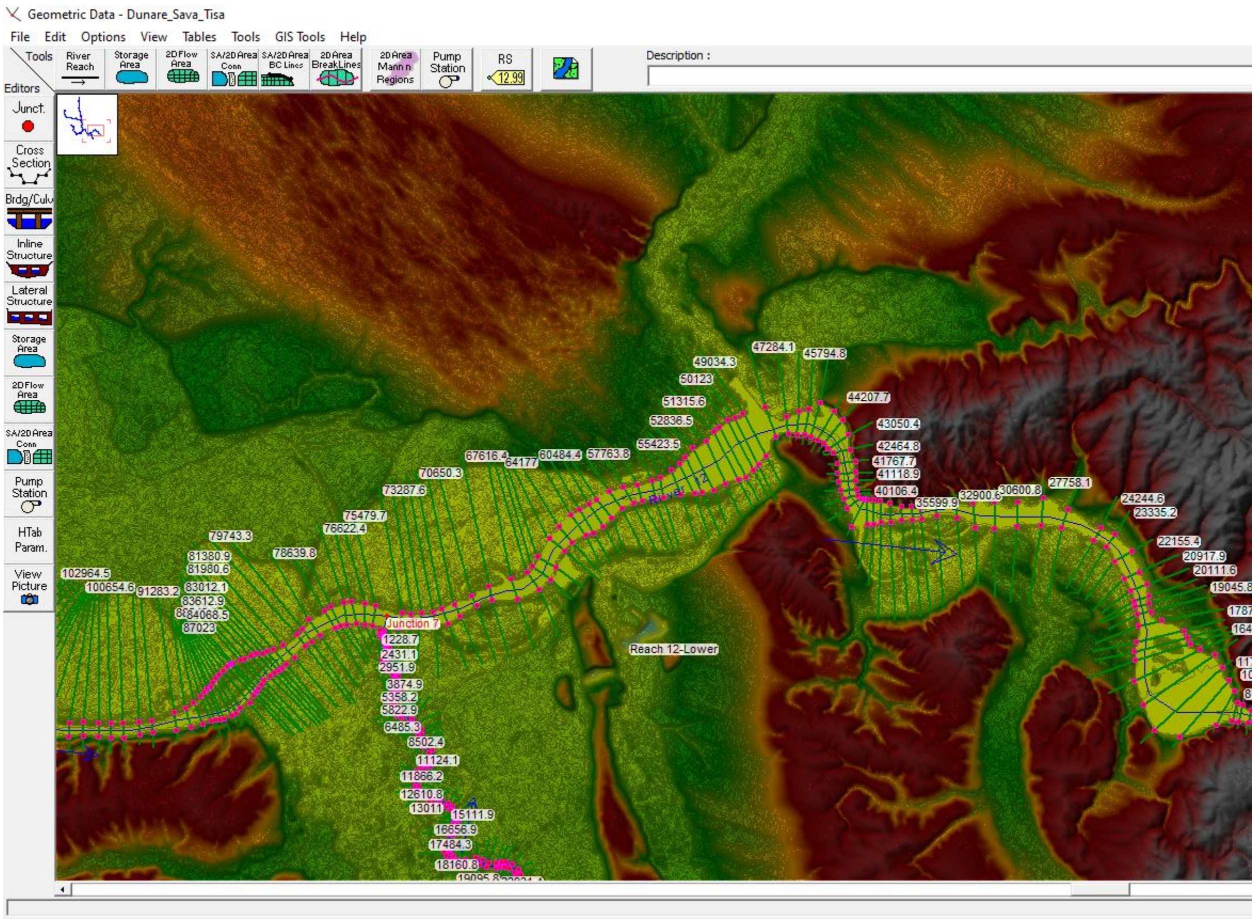

Figure 7: HEC-RAS geometric editor detail on Velika Morava River sector and confluence with Danube River

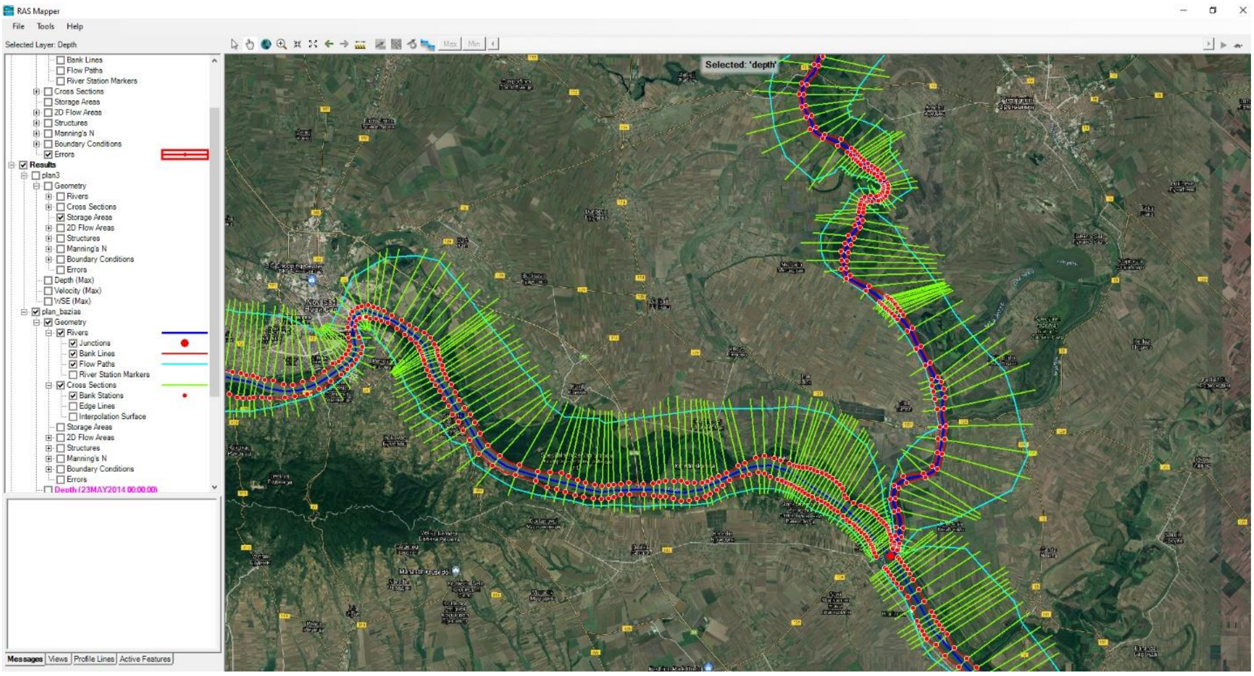

Figure 8: RasMapper analysis of the Hec-RAS model

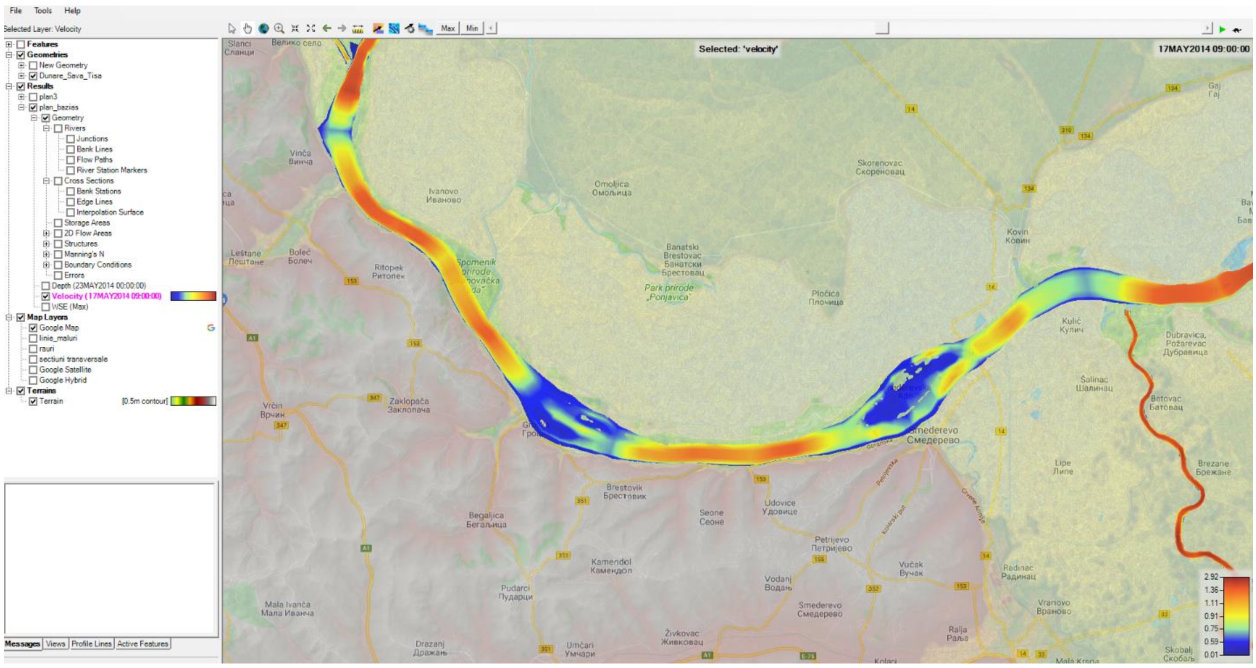

Figure 9: Simulated flow velocities on the Danube sector near Smederevo

- 17 th of May 2014

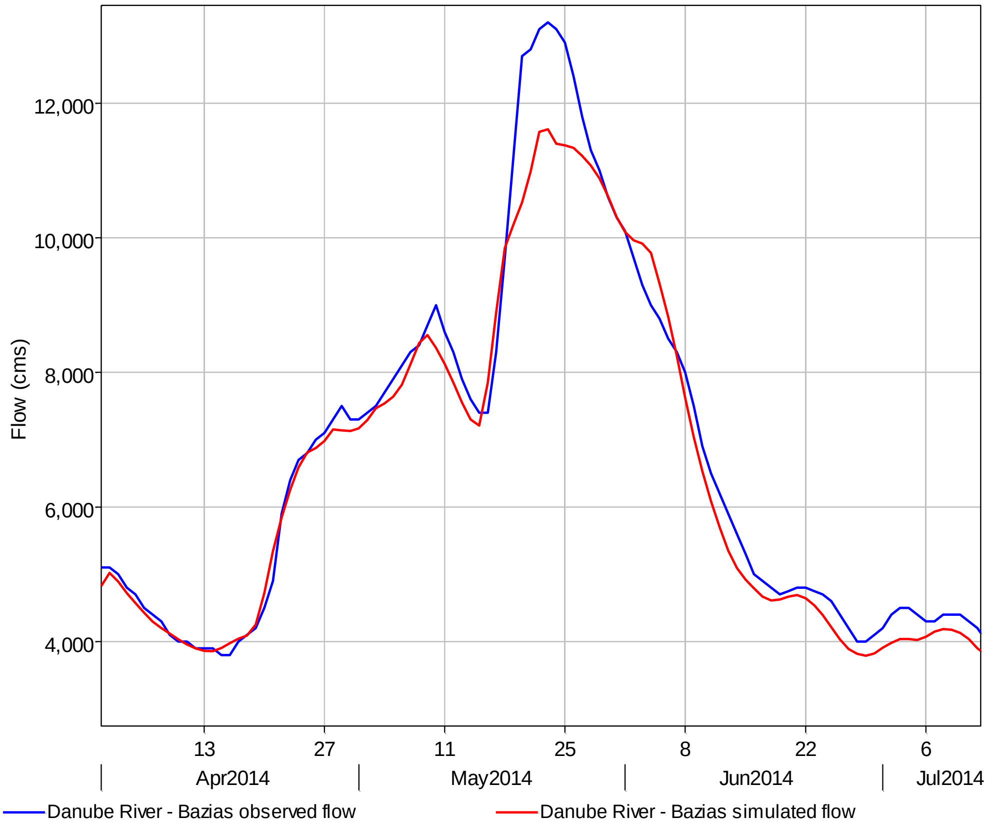

Figure 10: Simulated and observed discharge hydrographs,

on the Danube River – Bazias section, April – July 2014

It should be mentioned, that the observed discharge hydrographs values for the Bazias section on the Danube are in fact estimated values, by hydrological computation. Standard observed discharge derivation using a rating curve is not used for this section due to the influence of the Iron Gate reservoir on the water flow regime.

4 Conclusions and recommendations

The pilot action was successfully and the experiences show good potential for using the results and in general this approach in the future, after the project end, for improving the flood forecasting capabilities in both cooperating countries.

Also, based on the pilot action experience, we recommend the extension of this approach also for other sectors within the Danube River Basin, with the following reccomendations:

- This specific way of sharing a hydraulic routing model (or a hydrologic routing model) between a main and a secondary Forecast Center could be used in principle for any Danube River sector.
- We recommend this approach with priority for the important river sectors on the Danube or on the tributaries of the Danube, where we have a great influence during flood events from the existing important reservoirs.
- For these specific cases, with great influence on the flow regime from a reservoir operations, the sharing component model could be in fact just the hydrologic model corresponding to a specific reservoir. The great advantage in such cases, will be that the secondary Forecast Center gain the possibility to take into account the influence of the reservoir, but whitout the need to have access to all the detailed reservoirs characteristics data, parameters and information used for configuration of the reservoir model.
- On a longer time scale, if such sharing solution will be accepted and adopted, we could arrive to have a network of integrated National and/or Regional Hydrological Forecasting Centers, sharing and using in common selected modelling components, using a distributed hardware and software structure.
- The sharing of modeling component could be extended in principle also for rainfall-runoff models, but in this case the implementation will be more complex and diificult, and could provide benefits only if a common rainfall-runoff model is adopted by the cooperating Forecast Centers. For the implementation, the reccomended solution will be to use also in all the cooperating Forecasting Centers the same platform for models integration, with advanced functionalities, for instance using the Delft-FEWS platform, or other similar specific software system.
- As final recommendation, we consider that the sharing of hydraulic routing components, potentially between all the Forecast Centers within the Danube River Basin, could provide great benefits if they will be coupled and used in combination with the rainfall-runoff ensemble simulations outputs from a regional system (e.g. EFAS). This approach could also significantly reduce the needed resources and time of implementations for further developments of the National Flood Forecasting Systems.

For the long-term sustainability of this project activity results, NIHWM and RHMSS partners are preparing a technical cooperation agreement, in order to continue the common activities for improving the configuration of the hydraulic routing model implemented within this Pilot action, and also for preparing for the next step, respectively to implement and use these results in the real time flood forecasting activities, in both countries. This agreement will be finalized and signed in the next period, after reaching a common agreements on the future cooperations activities.

References

Prohaska S., Ilić A., Tripković V. (2012), *Methodology for Assessing Multiple-Coincidence of Flood Wave Peaks in Complex River Systems*, Water Research and Management, Vol. 2, No. 1 45-60.

Prohaska S., Ilić A. (2019*), Coincidence of the flood flow of the Danube River and its main tributaries*. In: Pekárová, P., Miklánek, P. (eds.), Flood regime of rivers in the Danube River basin. Follow-up volume IX of the Regional Co-operation of the Danube Countries in IHP UNESCO. IH SAS, Bratislava, 215 p. + 527 p. app., DOI: 10.31577/2019.9788089139460.