EXTRACTING 1D RIVER CROSS-SECTIONS OUT OF 2D FLOODING STUDIES

EXAMPLE FROM STYRIA AND BURGENLAND - AUSTRIA

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ABSTRACT

The present paper illustrates an Austrian development for extracting river cross section out of 2D flooding studies. The tools created at Joanneum Research are standalone tools or embedded in the Geographic Information System (GIS) ARCGIS. The data are implemented in the new Raab Flood Forecasting System for Styria and Burgenland. Many more cross sections could be implemented in the system by using these tools. This allows a much better schematisation of the river network because river slope and local wideness are more precisely integrated in the hydraulic model. Finally, because cross sections are saved in a database for Styria it is also possible to follow morphological evolution for the main river channel.

Keywords: River cross section, Geographic Information System (GIS), Flood Forecasting System, Hydraulic modelling.

INTRODUCTION

The knowledge gained through flooding studies is the basis for land-use planning especially at the communal scale. Flood extension maps and flood risk maps should be considered as expertise documents for further administrative actions especially for building planning. This concerns the protection of existing private or public objects, and the respect of free open spaces for flooding discharge. Keeping such spaces free instead of a retrospective rehabilitation became in the meantime also a goal of different juridical regional regulation in Austria. It is also in full agreement with the widespread slogan of "more space for rivers" that denotes the actual mentality changing: rivers are not constrained in man-made structures anymore but it is the goal to give rivers their natural, as far as possible original, independence.
The European Union – Flood Directive should be considered in this respect as the official documents for defining flood risks and minimizing flood damages. A new approach according to this text is the obligatory consideration of extreme events that are, for example in Austria, covered with HQ300 (flood events with a return period of 300 years). In Styria flood extension for a 300 years event are modelled since 2005 using 2D flooding studies. Flooding representation for extreme events shall promote the idea that full (100 %) flood protection doesn't exist, i.e. there exist always a rest risk of being flooded. Taking into account these residual risks will guide prevention measures that must be taken. It should be noted that in Austria, flood modelling is done assuming water without any load (sediment transport). This is because the parameters for modelling sediment transport are associated with important uncertainty so that at the moment potential load danger due to hits are "only" described and not modelled.

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The European Union – Flood Directive clearly suggest developing, beside flood studies, also flood forecasting systems for reducing flood damages. Such systems need to be very effective regarding calculation time. Thus, the complex and precise 2D hydrodynamic methods cannot be used because they are too time consuming. Nevertheless, 2D flooding studies deliver very important and detailed topographic up to date data that should be included in forecasting systems. Furthermore, past 1D hydraulic studies frequently lack geographical information. River cross sections are often localised using chainage (distance from confluence) only. Such information is difficult to use because river length changes in time especially due to human modifications. For these reasons a tool has been developed at Joanneum Research together with the hydrological service from the Austrian region Styria and Burgenland. This tool implemented in the ARCGIS GUI (Graphical User Interface) gives the possibility to geographically locate precisely the river cross sections. This is a huge advantage when such information must be replaced in a 1D flood forecasting model for defining flood extension for example. The tool has been applied using the most important flooding studies from the Austrian part of the Raab watershed. This is because a Flood Forecasting System has been developed from 2009 to 2011 for the Raab River in Austria and in Hungary. It is also applied to all flooding studies from the Mur watershed in Austria in the frame of a Master thesis in Physical Geography (Dalmatiner B., 2011).

The tool application for extracting river cross sections saved in a database and further used in the hydraulic model from the Flood Forecasting System Raab is illustrated in the next chapter. The second chapter illustrates some of the most common problem when using data from older flood studies. In next two chapters are presented the concept and the method for extracting river cross sections out of 2D flood studies. Results and conclusion are presented in the last chapter.

THE RAAB FLOOD FORECASTING SYSTEM

The development of the Raab Flood Forecasting System is a project with European dimensions. The Raab watershed extends over two countries: Austria and Hungary, whereas the last one is located downstream compared to Austria. There are four regions which the whole Raab catchment covers, the federal states of Styria and Burgenland in Austria, the regions of West Transdanubia (Szombathely) and North Transdanubia (Györ) in Hungary. The Austrian part of the watershed corresponds to the mountainous area whereas in Hungary the meandering Raab river is flowing in a large and complex floodplain. Due to these geographical characteristics the probability for a flood genesis is much more significant in Austria than in Hungary but the related flooding risks are distributed over the entire watershed.

The project “Flood Forecasting Raab” gives a concrete example of international cooperation in the field of flood management. The development of the system was supported by the European Union in the frame of an bi-lateral European project - (Cross-border Cooperation Programme Austria - Hungary 2007-2013 - AT-HU-03-011/A), project ProRaab(a). Furthermore the Austrian government as well as the Hungarian government contributed to the financial support of this project. In this first phase, focus has been given to the system building, its structure and stability and to implementation of available hydro-meteorological data. Nevertheless, great efforts have been done to integrate hydraulic structures and up to date description of the river channel and the floodplain.

The structure of the system (Figure 1) is built on an International Flood Forecasting Centre in Graz and four regional centres in Styria, Burgenland and Hungary - Szombathely and Hungary - Györ. It illustrates how a trans-boundary flood forecasting system can operate. The main element is the International Flood Forecasting Centre installed in Graz (Austria) where all the necessary online data and meteorological forecasts are automatically collected and formatted for the simulations. Each hour, a simulation starts with a time of forecast of six days whereas the main results are published on the internet. Furthermore, four times a day also ensemble forecasts are computed based on the ensemble weather forecasts of ECMWF (European Centre for Medium-Range Weather Forecasts). The complete model setup and the results are transferred to the four regional centres. At these regional centres it is possible to analyse detailed results and to develop local scenarios using for example modified meteorological forecasts, different meteorological inputs in terms of forecasted rainfall or forecasted air temperature or other initial conditions.

The Raab Forecasting system is based on the MIKE 11 (1D hydraulic model; DHI, 2005) modelling system for hydraulic purposes also including the hydrological model NAM (NAM is a lumped rainfall – runoff model) and the MIKE Flood Watch real time decision support system. This combined forecasting system is a well proven approach, which has been applied successfully for example in the "Trans-boundary Flood Forecasting Project in Austria, Slovenia, Hungary and Croatia" - Ruch & Jorgensen, 2005). The river Raab raises in the Teichalm area (approx. 1150m above the Adriatic Sea) in the eastern part of Styria and it joins to the Mosoni-Danube in a Hungarian town, Győr. The whole catchment area is 14911 km2. The Austrian part of the Raab catchment is 1078 km² in Mogersdorf (Burgenland), which is bordering on Hungary.

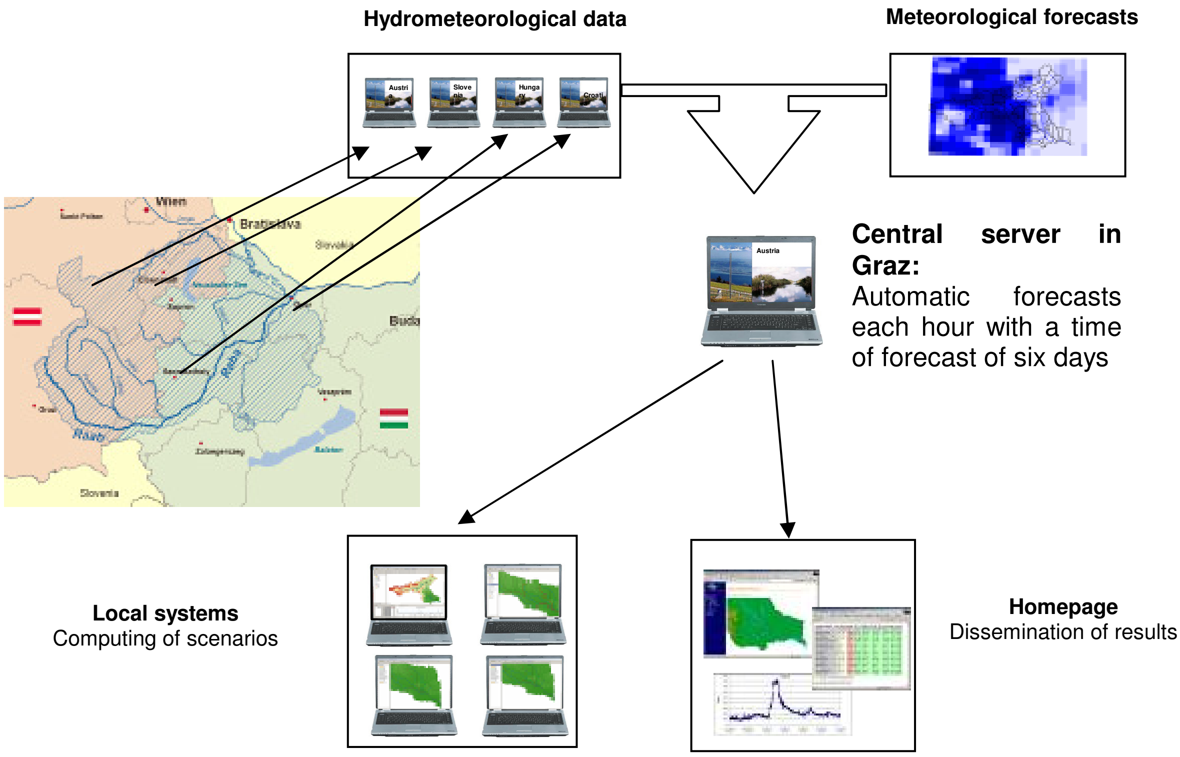

Fig. 1 Structure of the international system

PROBLEMS FACED WITH OLDER 1D FLOOD STUDIES DATA

In Figure 2 is illustrated a modern way to locate river cross section. Rapid development of information technologies allows non-specialists to grasp huge amount of geographical data. Figure 2 illustrates a simple example of how river cross section could be checked in the internet by using tools like Google Earth. It is of paramount importance that the right cross section is located on the right place. But, using data from "older" 1D flooding studies often means that problems related to missing or wrong information arise. Here is given an overview of possible problems whereas a complete description is described in Ruch et al. (2011).

1. It may occur that cross section lines (traces) are not all located in one file only but on different CAD-layers. This means that the cross section identification number (ID) is not unique and one ID can be given several times.
2. Lines representing cross section should have been digitalized so that one line represents one cross section. Unfortunately it happens that some cross sections are built out of few lines. The consequences are that the complete dataset must be worked out manually and cannot be processed automatically.
3. Cross sections are made out of measured points. It can happen that the points from cross section are digitalized from left to right or from right to left or both in some case. But the digitalization direction should be constant, in our case from left to right in flow direction.

4. Some lines are missing cross section geographic information from cross sections on the maps whereas these lines exist and are used for the hydraulic calculation and vice and versa. Thus there is no correspondence between the geographic file and the hydraulic file and data must be checked manually.
5. The profile length in the AutoCAD file is different from the profile length used in the hydraulic calculation. This means that the profile is certainly drawn without any link to real existing morphological characteristics from the cross section lines.
6. Some cross section lines (traces) are AutoCAD-simple drawings without any geographical information. Such datasets can only be processed manually and during a relative long time.
7. Chainage is not the constant and may vary from one study to another one. Such information are particularly irritating because there no “standard” is defined

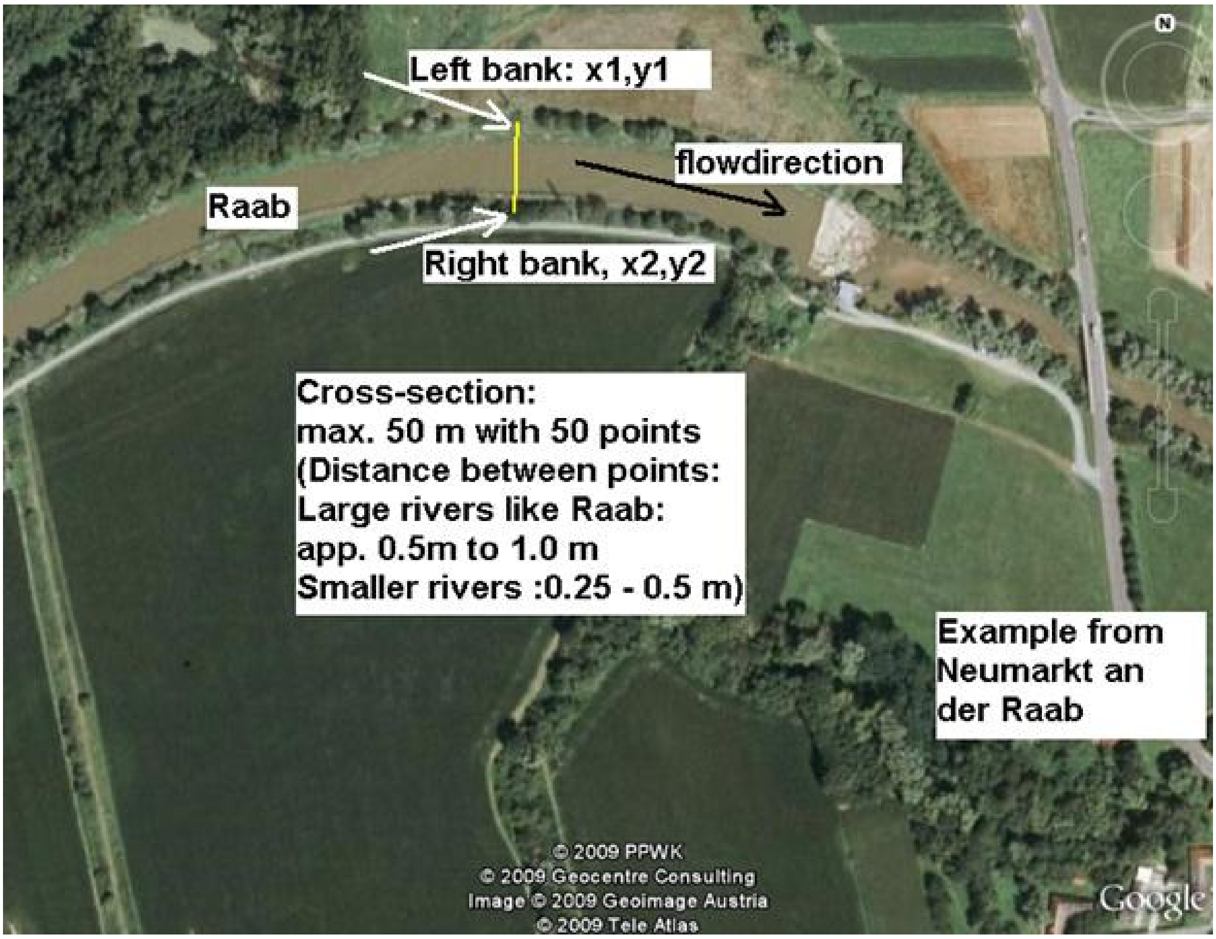

Fig. 2 Cross section demand in a modern Flood Forecasting System (example from the Raab river).

GENERATING RIVER CROSS SECTIONS – THE CONCEPT

Using existing 2D flooding studies data for river cross section extraction leads to several methodological options illustrated in Figure 3. The one developed for this work is the option 1 together with part of option 2.2. The DEM (Digital Elevation Model) mostly created out of radar and terrestrial measurements is first transformed in an ARCGIS format: the Polygon M shape file (shape file with 3 dimensions for polygons), i.e., the irregular mesh structure is transformed in a regular DEM geometric file.

The tool allows extracting river cross sections anywhere as mentioned for option 1 below. Nevertheless it was decided to extract the profiles where terrestrial measurements were available (option 2.2). For each measured profile a geo-referenced polyline is available which corresponds to the geographical 2D tracks (lines) of the measured points. Importing these lines together with the

Polygon M shape file and further using the new tool, it is possible to extract river cross sections in an internal binary format "BQP". For the Styria region these cross sections are saved in a Database that will allow a better analyse of river bed dynamic in time. This option is not chosen from the region Burgenland so that cross sections are not saved in the database.
After that, all generated river cross sections are transformed in a Mike11 importable format. This is because Mike11 is the hydrodynamic model used in the Flood Forecasting System Raab (The Raab river flows in both Austrian regions to Hungary).

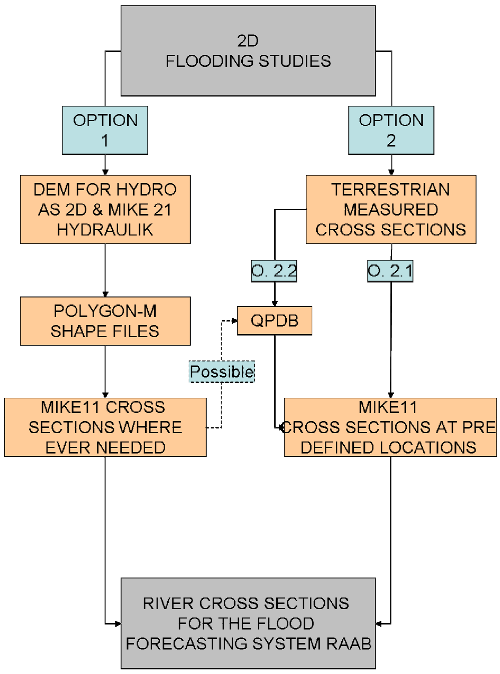

Fig. 3 Possible options for extracting river cross sections out of 2D flooding studies.

GENERATING RIVER CROSS SECTIONS – THE METHOD

The extraction of river cross sections out of 2D flood studies requires using several software developed at Joanneum Research. First of all, using the software „FEModelTool" allows to convert the 2D hydraulic calculation point network used during the 2D modelling in a PolygonZM-Shape-File (ARCGIS software). In the next step it is necessary to define the cross-section lines. This step is not further explained in this paper as it is a 100 % Geographic Information System manipulation that can be done elsewhere. The goal of this step is simply to obtain geographic traces of all the cross sections that should be extracted out of the hydraulic DEM transformed in a PolygonZM format. These lines are saved in ARCGIS as Polyline-Shape-file. For the following step, cross sections lines overlay the PolygonZM-Shape-File so that using the ArcMAP-Extension „QProfGIS" it is possible to extract geomorphologic points for each cross section. At least, it is then possible to visualise the created cross sections using the software „QProfExplorer" and further to export the profiles in a particular format. It is to note that only Excel or Mike11 formats can be exported at the moment. The different steps are illustrated with more details bellow.

1. FEModelTool: From the hydraulic calculation point network file to the PolygonZM-Shape-file. As already mentioned the„FEModelTool" software is used to convert the hydraulic calculation point network file into the PolygonZM-Shape-file. Actually, this software is able to read hydraulic files from Hydro-AS2D (*.2dm) and Mike21 (*.mesh). It is to note that Mike21 is the 2D modelling software whereas Mike11 is the 1D modelling software both from DHI. An example of this transformation is given in Figure 4.

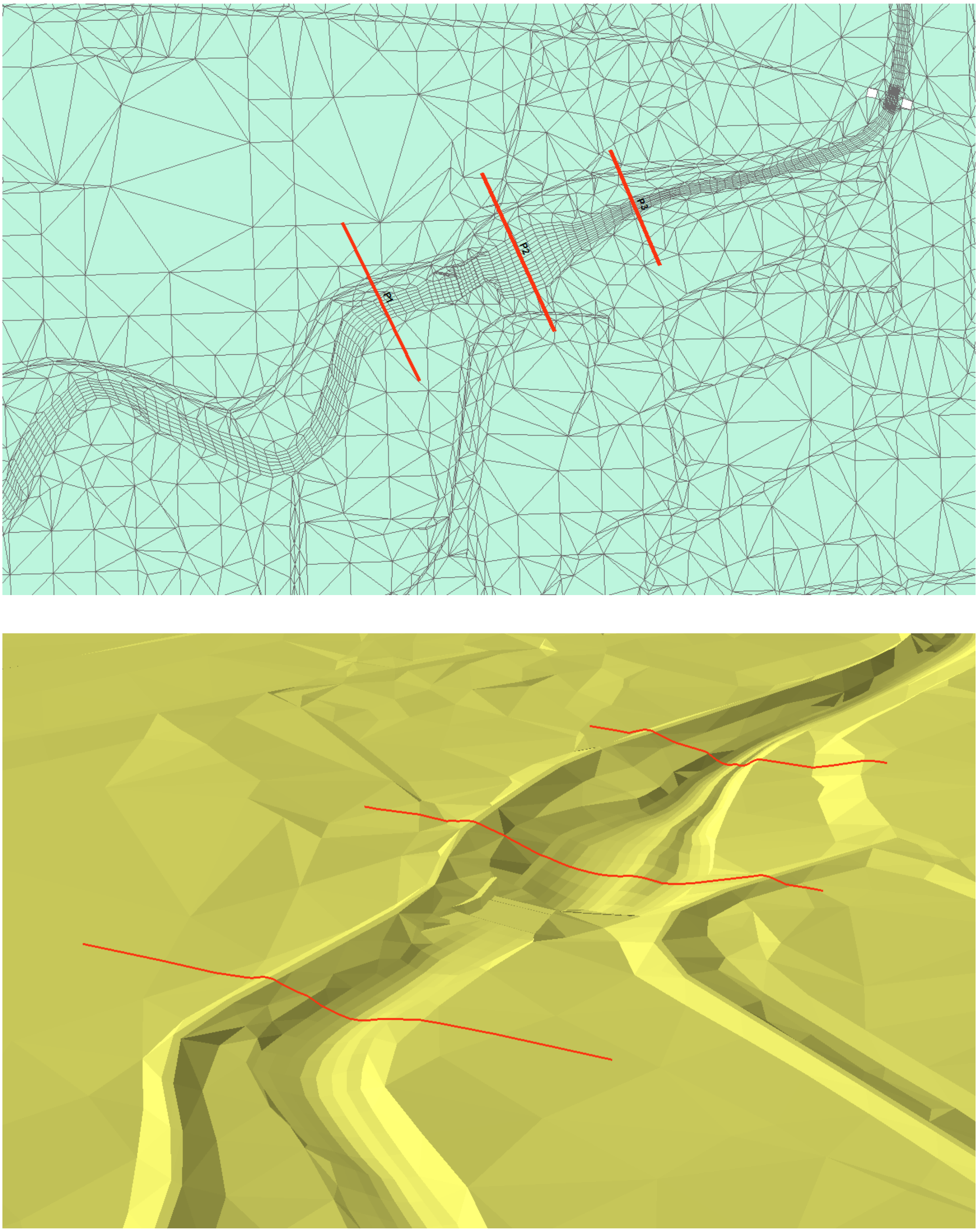

Fig. 4 above: 2D view of uploaded 2D hydraulic calculation point network in the „FEModelTool“ software, bellow: 3D view of resulting PolygonZM-Shape-file after transformation. Note that the red lines correspond to cross section trace

2. QProfGIS: making river cross section out of the PolygonZM-Shape-files. QProfGIS is used to define river cross out of the PolygonZM-Shape files. This tool is a GIS-Extension embedded in ArcMap. For making calculation of cross sections it is necessary to import the cross section traces in the format Polyline-Shape (see Figure 5). If no Shape-file with the cross section traces is

available, it is necessary to digitalise these lines manually. This allows extracting cross sections anywhere on the PolygonZM-Shape file. Nevertheless, lines (traces) should be delivered with the flooding study because they are normally part of the 2D flood studies results for terrestrial measured section. Therefore they should be included in the result data of each modern/actual 2D flood study.

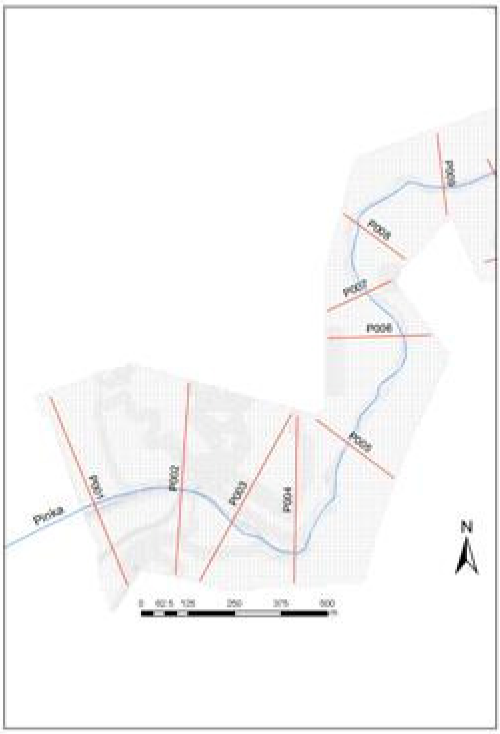

Fig. 5 Uploaded 2D hydraulic calculation point network in the „FEModelTool“ software.

3. When the river cross sections are calculated they can be saved in the neutral and binary BQP format/file developed at Joanneum Research. Each cross section saved in a BQP format can further be visualised, controlled and exported using the Tools „QProfExplorer“ for management of the data and „QProfView“ for visual inspection of the data. A visualization example using the software „QProfView“ is given on Figure 6. Depending on which information is available from the original 2D flood study, it is possible to show Manning's numbers for the main river channel and for the right-side flood plain and for the left-side flood plain, Bankfull discharge on the right and on the left sides. Such information are very important for the re-use of the cross-sections in other modeling systems.

RESULTS AND CONCLUSION

The number of river cross section imported in the Flood Forecasting System Raab can be greatly augmented when using data gained from 2D flooding studies. This allows a much more detailed description of the Austrian river network in the Flood Forecasting System Raab (Figure 7). Furthermore, these data are mostly of high quality and up to date. Therefore it is possible to import a good and actual structure of the river bed and floodplain into the hydrodynamic model. In the present case data from flood studies coming from the Raab catchment have been used. This is because these data are necessary for a better hydrodynamic schematisation in the Raab Flood Forecasting System developed from 2009 to 2011. The full system incorporates two countries (Austria and Hungary) but four different administrations, two in each country (the federal states of Styria and Burgenland in Austria, the regions of West Transdanubia (Szombathely) and North Transdanubia (Györ) in Hungary).

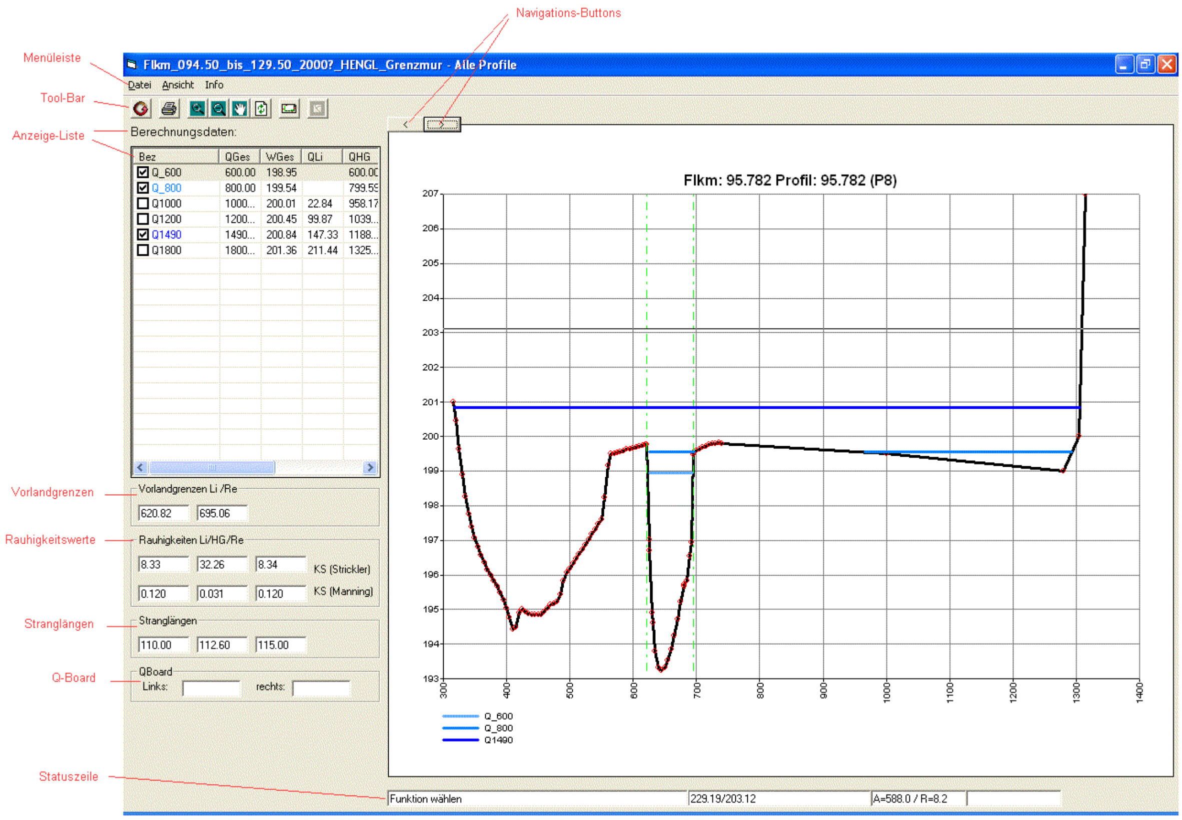

Fig. 6 Uploaded 2D hydraulic calculation point network in the „FEModelTool“ software.

The results presented here are part of the Austrian developments. It is to note that the data are incorporated in a database in Styria only, i.e. in Burgenland data can be found in the hydrodynamic model only. An important effort for collecting older data and finding proper geographic location has been made in Styria. Saving the data in the database allows comparing cross section measured during different studies. This is a great application that permits to analyse morphologic evolution especially of the main river channel. Such information are very important aspect for recent developments in river ecology like re-naturalisation projects (Hornich & Turk, 2007). Such application should increase intensively in the near future because morphological river evolution will become more natural again. But it will become more and more important to control these developments through their proper morphological description.

In the same work, it has been illustrated that cross sections retrieved using the Joanneum Research tools and the measured ones don’t differ very much. Therefore, it should be recognised that the section accuracy is by far high enough for using in flood forecasting systems. Uncertainties included in flood forecasting systems are originating for a very large part somewhere else in such systems. Modelling spatial flood extent is related to flooding processes in the main river channel and needs therefore very accurate topographical information also from the cross sections.

Finally, future tests shall be made to incorporate other information gained by the flooding studies. For example simulated flood extension for several return period (e.g. HQ30, HQ100 or HQ300) could be used to better calibrate the 1D hydrodynamic model used in the new system. Also new developments using systems of pre-defined or pre-simulated flood extensions (water levels) as well as water velocity both related to discharges for 30, 100 and 300 years floods and intermediate values, e. g. in 5 years steps, are examined.

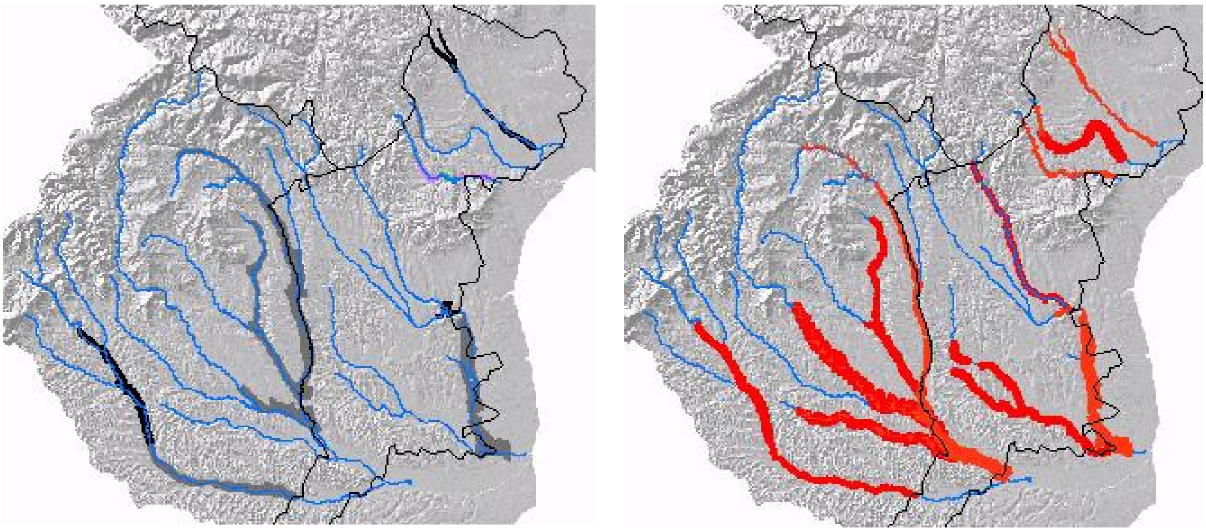

Fig. 7 2D flooding studies (left) used to extract river cross sections for the Flood Forecasting System of the Raab (Austrian part of the watershed). The total river cross sections used in the hydrodynamic model are shown on the right side.

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