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Flood risk investigation in the Varbica river watershed, acc. Directive 2007/60/EO, regarding flood risk assessment and flood management

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Goal and tasks

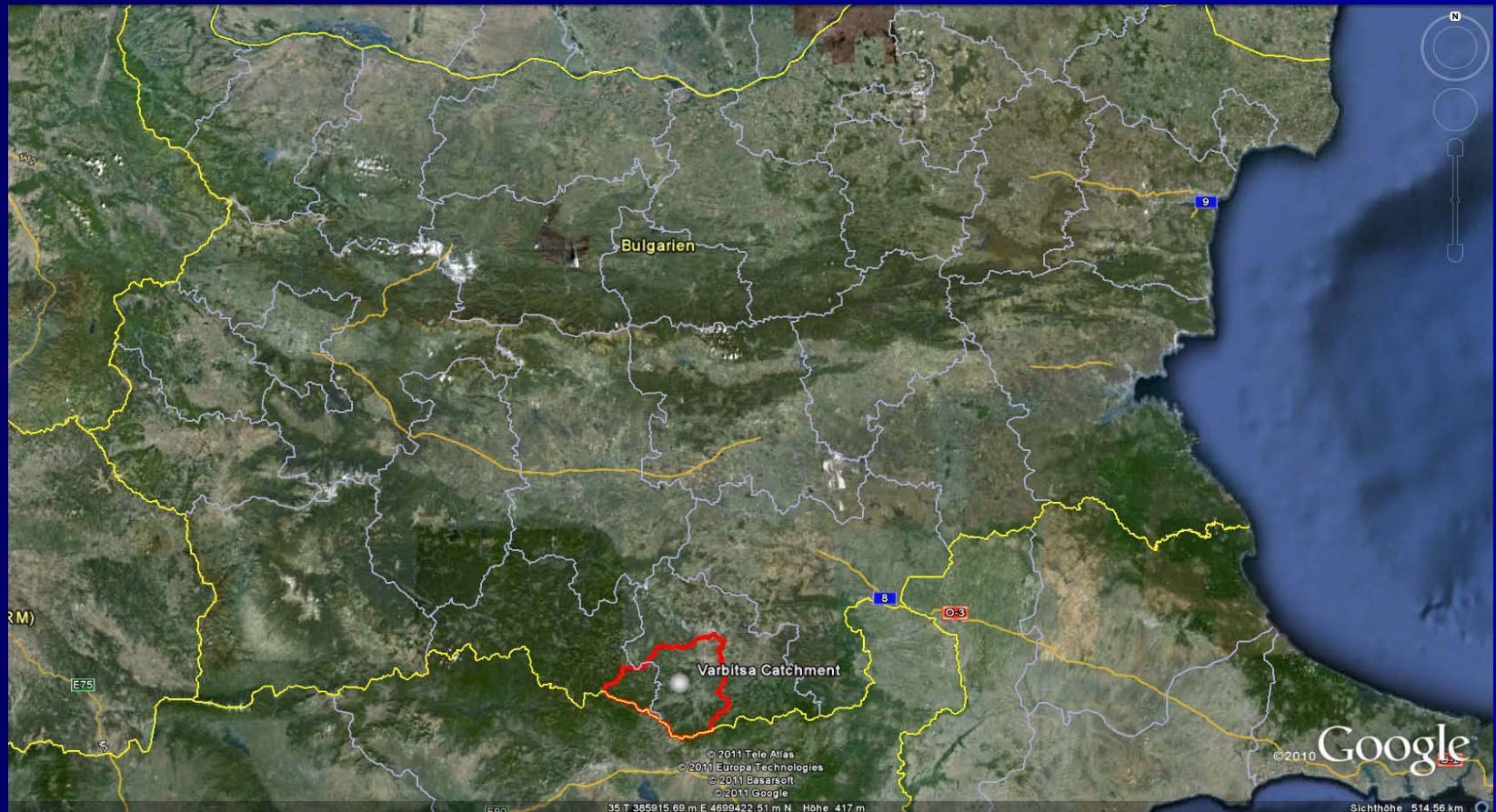
- The objective of development was the preparation of a simplified methodology for flood risk assessment on the watershed area of Varbica river -South Bulgaria.
- The development of the methodology is based on preliminary analyses carried out of the relevant data.
- The results can be checked and assessed, this enabling to use the methodology in other risk flood cases.



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Location of the investigation – Varbica river watershed

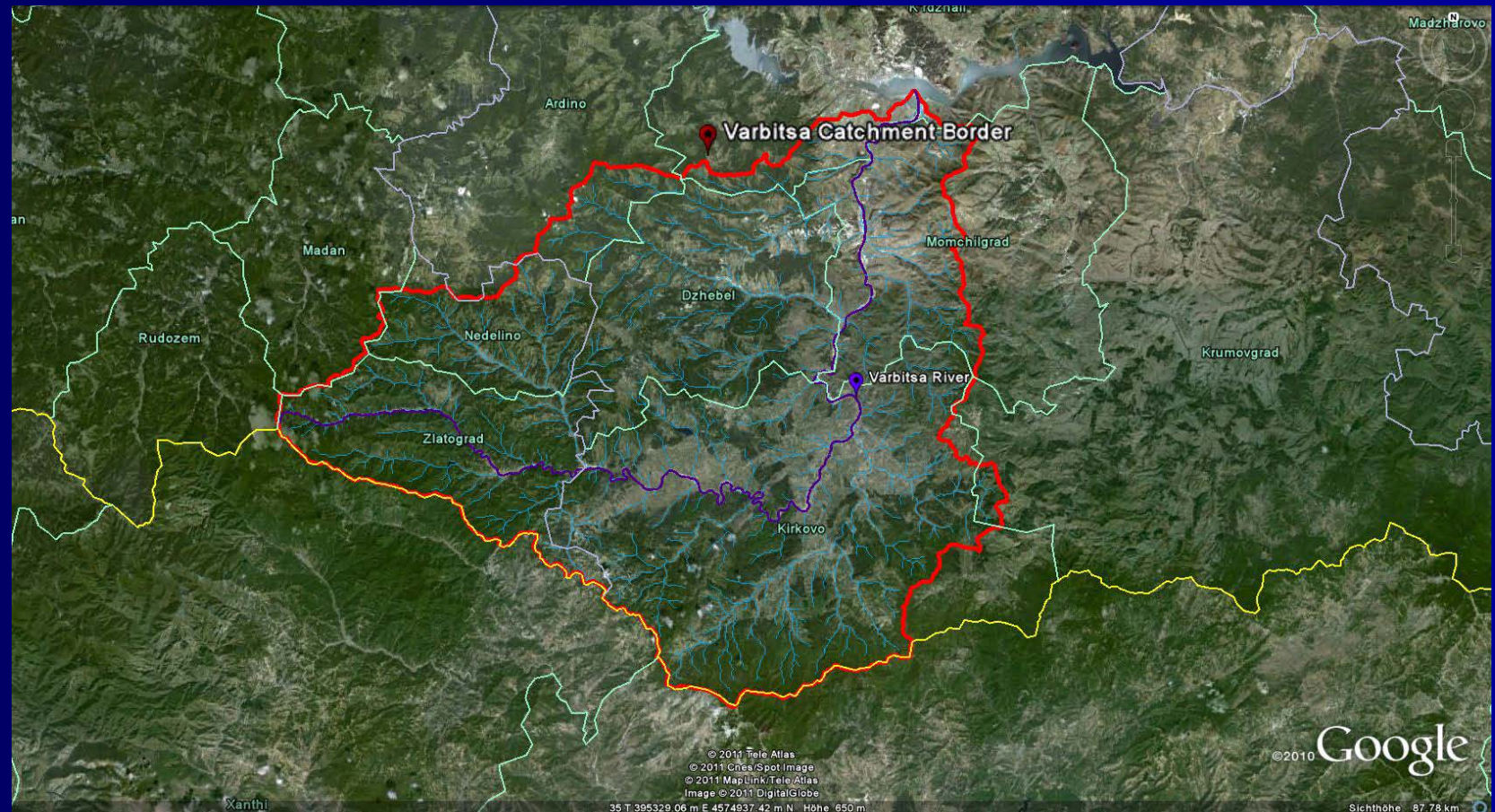




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Location of the investigation – Varbica river watershed





Characteristics of the terrain

- Watershed area 1 200 km².
- 65% covered with forest or bushes and 35% agriculture land
- Terrain altitude from 220 m to 1 440 m
- Length of the main river stream 98 km, from the mountain spring to the Studen Kladenec Dam
- Two measurement station for the river level (Dzebel and Varli dol)
- High terrain altitude with steep slopes
- The combination from areas with rare vegetation and high intensity of the precipitation contributes to the formation of torrential rainfall
- Deforestation and river bed excavation for construction materials, lead to erosion of the Earth's surface and transport of sediments; These processes are increased by the fact that in the area are observed torrential rainfalls. This increase the risk for obstruction of the drainage facilities and culverts, as well as the increase of the sediments content on the bottom of the river and a dam.



Conception of the model

- Plain representation of the entire river watershed in 2D-model.
- Unstationary simulation of the river stream with a starting water level „0” corresponding to the effective height of the sediments on the bottom
- Simultaneously modeling of the water flow distribution on entire watershed and the water discharge into the Varbica river.
- Presentation of results as graphs for the amendment of the water level in control cross-sections
- Affected areas are generated by the data block for the maximum water depth throughout the whole simulation time.



Main database for the model

- For the watershed area of the Varbitsa River has relatively small amount of database, because of lack of perennial water management.
- In the whole watershed area has only two measurement stations whose records may submit only a fragment hydrological data for the river flow. For this reason, it is not possible good statistical analysis for water discharge to be made.
- The same applies to the records of the rainfall measurement stations in the watershed area.
- Information on protected areas in accordance with Directive 2007/60/EC-as installations and facilities in accordance with Directive 96/61/EC, world cultural heritage sites and other protected areas-are not available.



Hydrological data

Text documents to:

- Annual water discharge rate
- Max. Water discharge from a few past floods *
- (partly with water level and water discharge)
- Average amount of precipitation
- For some past events, runoff, amount of precipitation and water discharge *

* The amount of data for past events are not continuous and are incomplete.



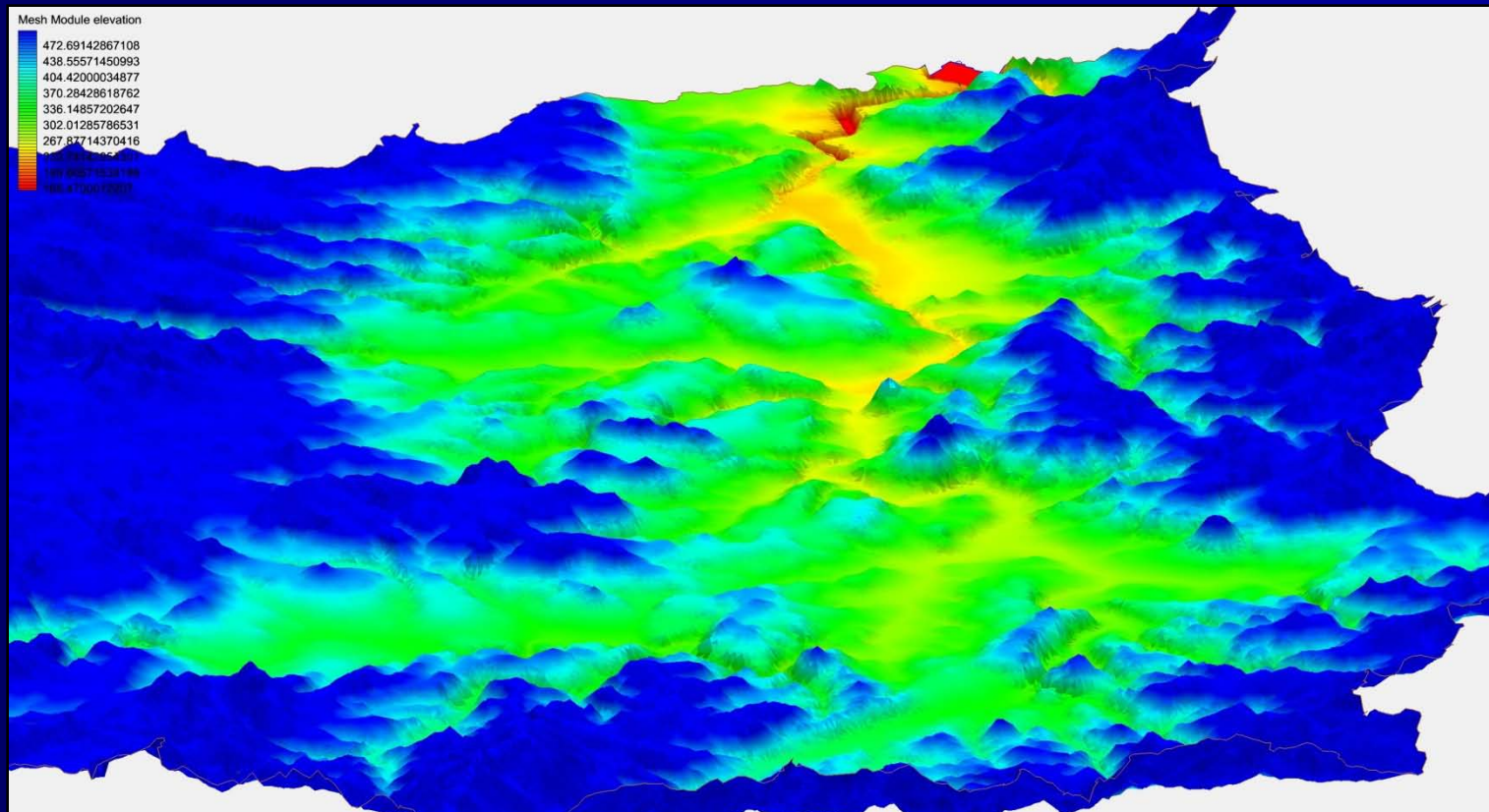
GIS data

- Layer land cover
- Grid terrain file raster 100x100m
- Layer river including channels.
- Layer dams and lakes
- Layer boundaries of the secondary sub-watersheds
- Layer roads
- Layer settlements
- Layer relief
- Layer attitude
- Layer slope inclination
- Layer slope direction



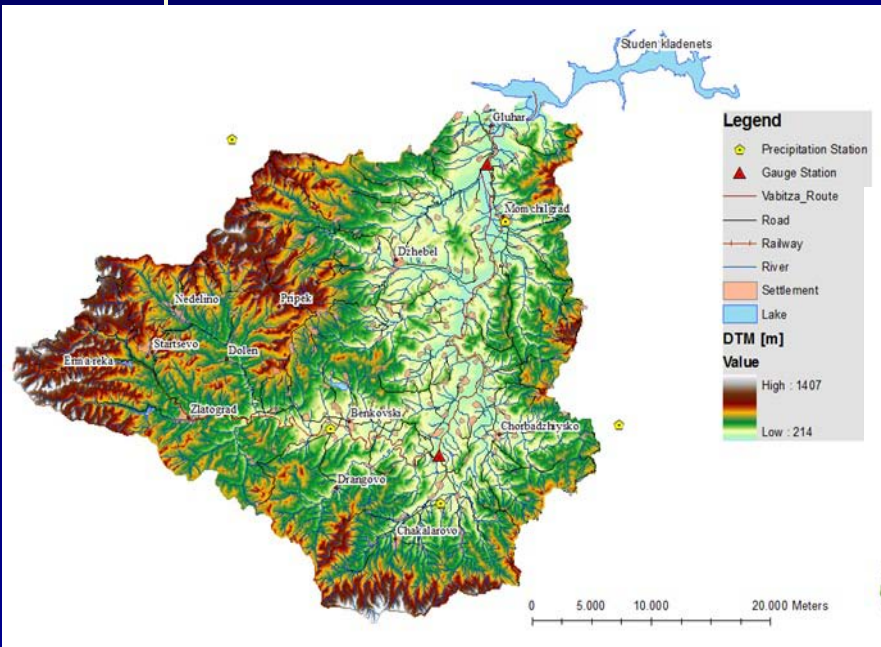
GIS data

Digital terrain model

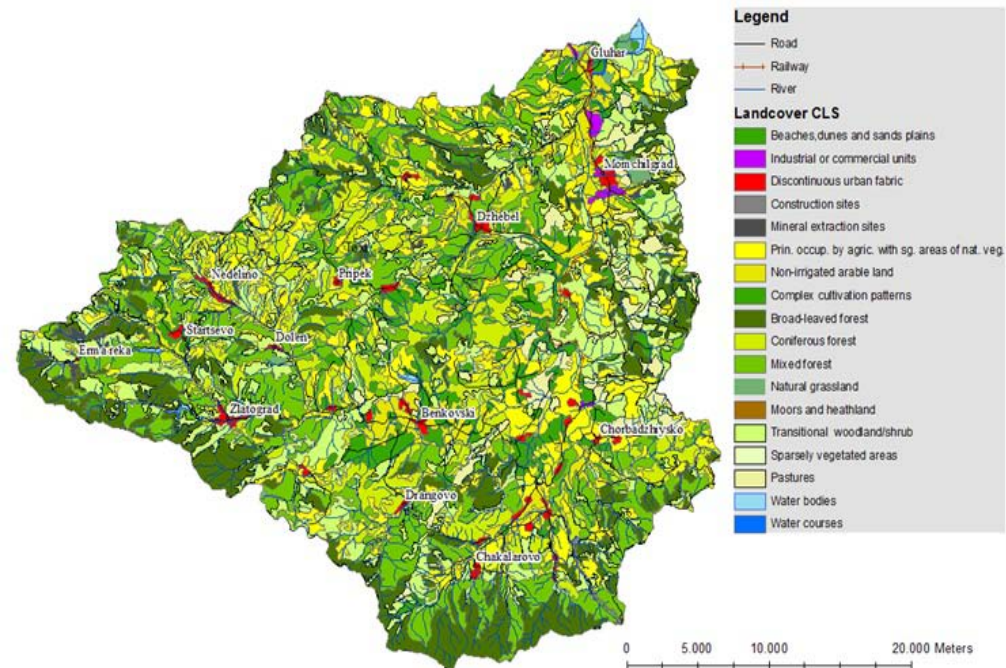


GIS data

➤ Location. Infrastructure facilities, measurement station, settlements, lakes



CORINE project – land cover/ use data





Methodical development of the model

- This approach is based on the methodology of the work under project «Simplified calculation of the danger flood areas in North Rhine-Westphalia». By using this method it is possible without detailed information for water discharge on the watershed area to generate a distribution of surface water discharge.
- Applying 2D-model with series simulation of rainfall from the available data for rainfall.
- Simplified 2D simulation, by adoption of the terrain altitude from the GRID terrain model.
- The supplied GIS layer for the location of the small rivers did not fit into the details of the digital terrain model (e.g. river flows in a slope instead of in the valley), from the digital model is derived a new corrected layer for rivers location.



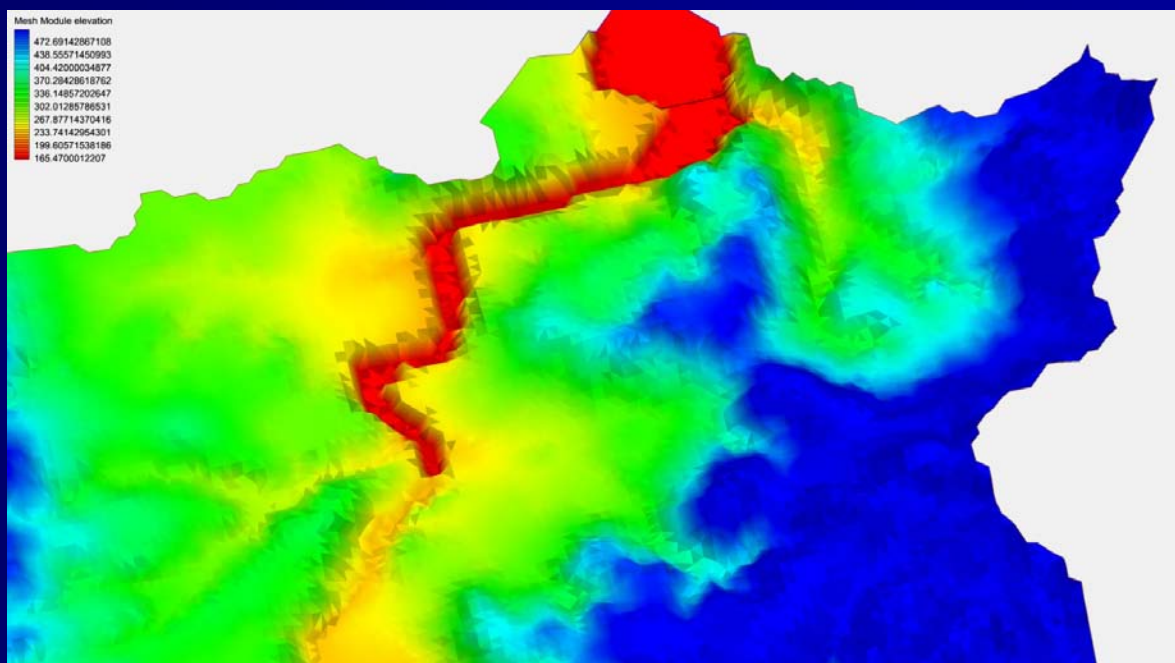
- 2D-model allows simplified representations of complex processes of the flow and allows for each point on the model to specify the relevant values (water depth, velocity, flow direction).
- The model ignores the existing culverts and flood protection facilities. The simulated events respond to the high waves, which could happen more frequently than HQ100. The calculated areas in this way respond of extreme floods, or situation which would lead to flooding bridges and culverts.
- As a value for HQ100 is used the maximum recorded and documented value for river water discharge at station Dzebel-2.640 m³/s, it is also used for the calibration of the model.



Simulations

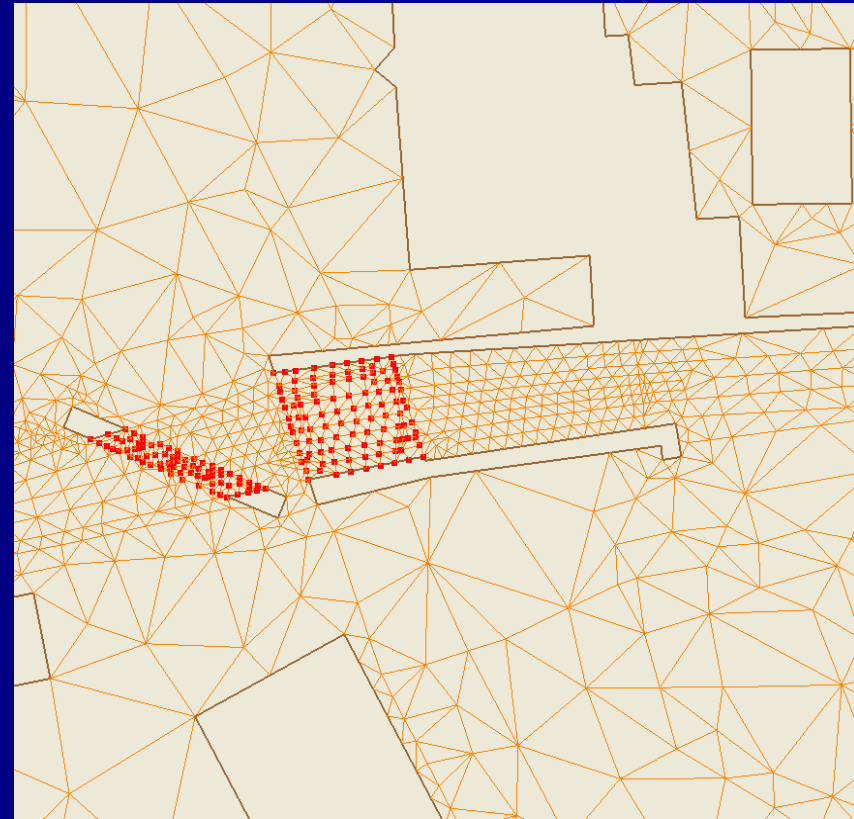
- Set is a uniform distribution of 50 mm sediments high for the entire river streams. The properties of the sediments material are accepted as homogeneous for the entire watershed
- Simulators are made with Hydro_AS-2D.
- In rise of the water depth (in meters) in any time interval in the simulation model, noticed a small area with extremely large water depth.
- The data for the terrain level in a digital terrain model in the area where Varbica river flows into the dam are probably wrong. All have the same, too low value, leading to a jump of about 62 m difference in height to the river bed.

- Consequently, the results of calculations for this area are not realistic. However in this area are not situated critical infrastructure or settlements, so that we abandoned correction of the digital terrain model, and thus the 2D-model.



Hydrodynamic model Hydro_AS-2D

- The model is based on the use of average depths
- The calculations are based on the grid, which consists of triangular and quadrilateral elements.
- The results are: water depth, flow rate, water level (water mirror), tangentially tension, flood duration, flood distribution, hydrographs, animation, etc.





Model structure

- Preliminary processing of the data from digital terrain
- Adjustments of the digital terrain model (fill in the hollows into the river bed)
- Calculation of the slopes and direction of the water flow for each cell
- Removal of groundwater from the main water streams
- Linking the terrain level data with the data for the rivers. Manual data adjustments
- Conversion and export of the surface raster data and river data (3D line), as attribute points data
- Import of the data into the simulation software for and design of attribute points data in terrain grid.
- Inadequate triangular terrain raster structures and all existing hollows in the terrain, have been adjusted manually



- As a result from model hydrographs can be included and defined many control cross-sections of the most important points along the River (measuring stations, the location of large cities, critical infrastructure location).
- The defined rainfall amounts are used as the initial conditions (getting the water level in each point of the model), also like effective rainfalls.
- For a better presentation of the processes of the flow are used the land cover/use data.
- Internal parameters of the model Hydro_AS-2D are determined by optimization and iterative flow measurement.
- The final calculations are carried out with constant time step through simulation of 60 hours



Result probability

- The balance of the volume show that the added water into the model is without loss as a result of digital errors, and that there are no errors in the calculation.

Precipitation amount	50 mm	110 mm
Capacity used for input model data [m ³]	59.950.000,00	131.890.000,00
Read capacity [m ³]	48.721.382,82	119.414.509,35
Residual capacity in the model[m ³]	11.213.087,17	12.710.681,69
Declination[%]	0,03	0,18

- The curves show that outbound flow at the end of the simulation time is only slightly reduced. The part of the water, which is still in the system, is a result from the loss in the river bed. Another case in which a water preserve could appear, is when the inclination is against a watertight boundary of the model.

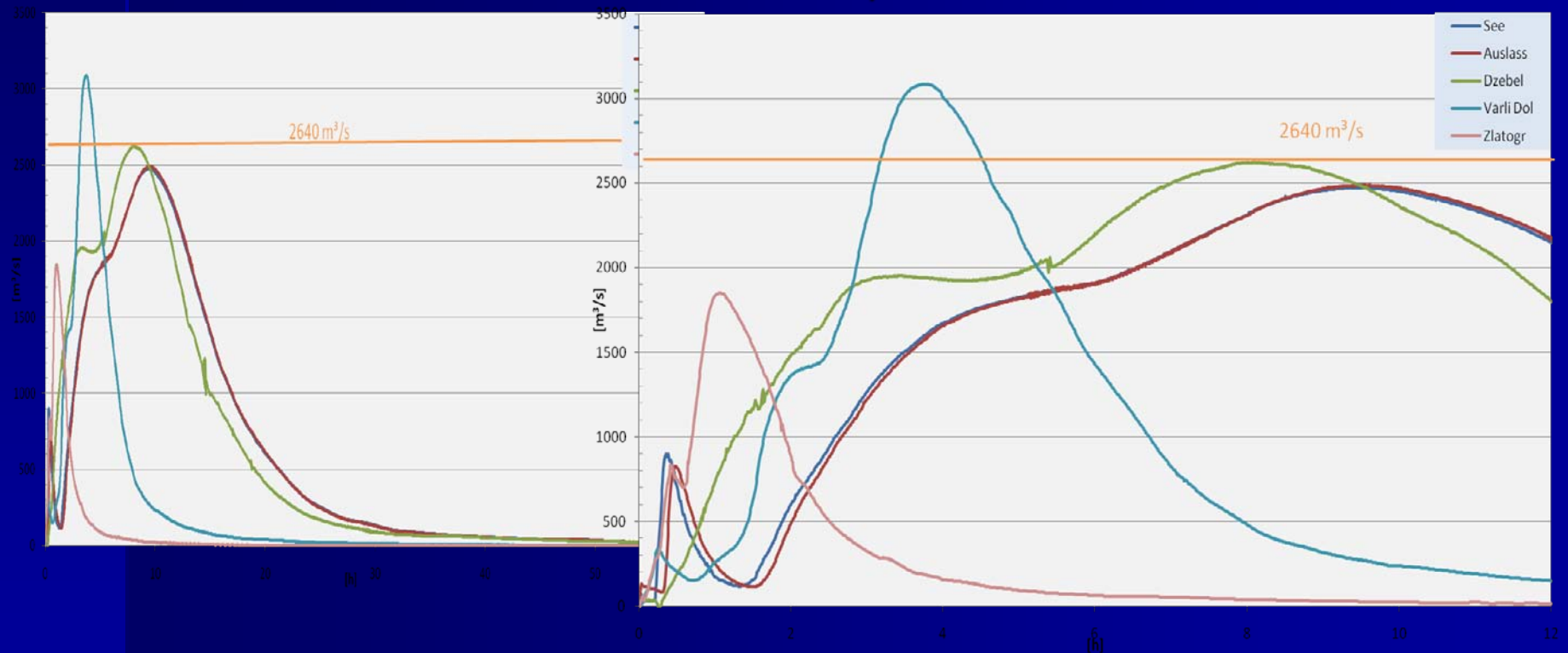


Result assessment on the base of historical recorded events

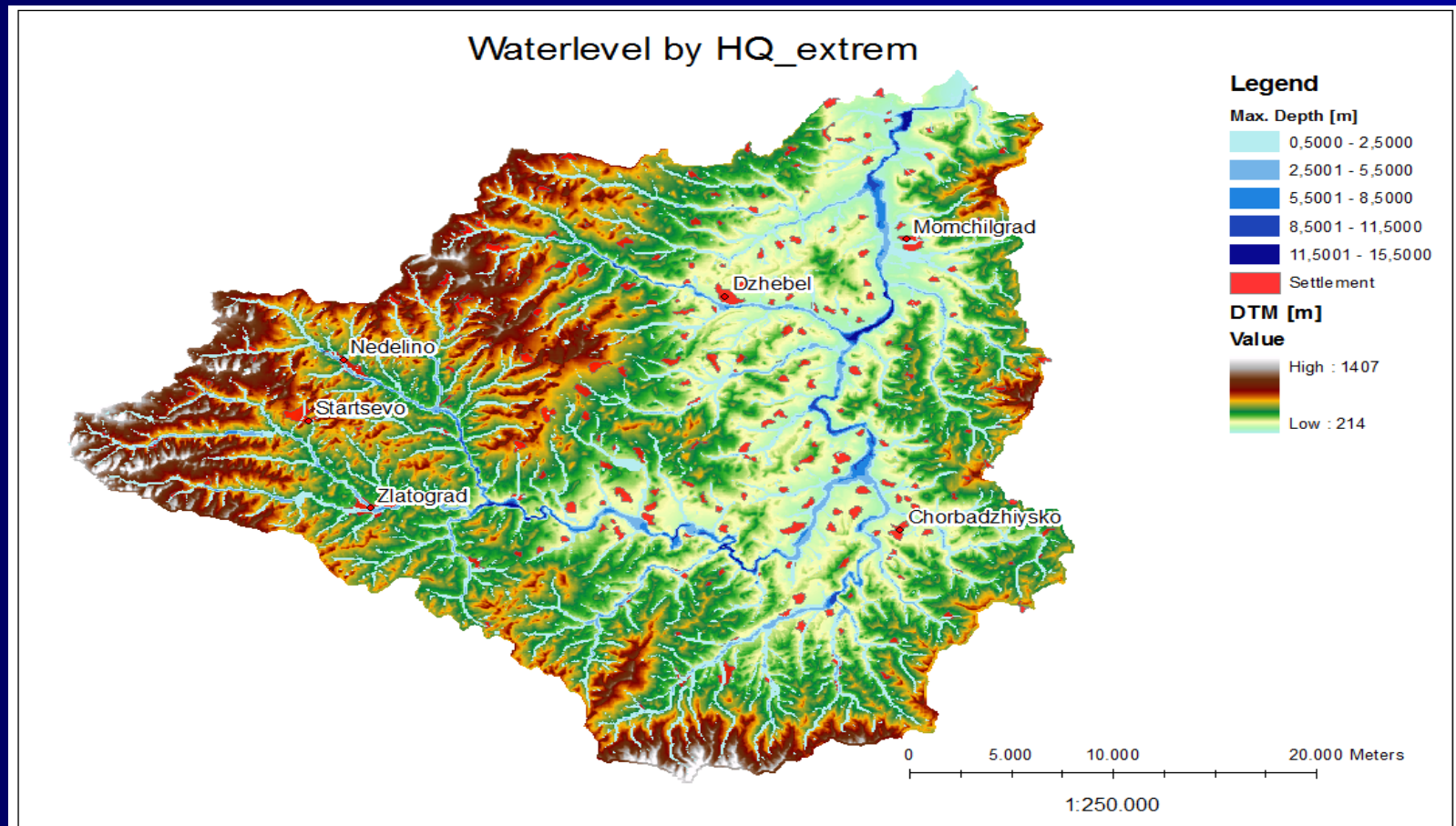
- All available documentation regarding water discharge, rainfall, and floods is often incomplete and does not contain a suitable data format (Q, H, location, date).
- Therefore, it is impossible to calculate the statistical water discharge distribution by standard methods.
- In literature — for the last 80 years was recorded the largest river water discharge at Dzebel measurement station with value 2.640 m³/s.
- For the purposes of the simplified approach for risk assessment, without taking account of the groundwater, this value can be assessed and having greater than HQ100
- On this basis is determined the flood risk assessment for the Varbica river watershed

Results

- From the model at Dzebel measurement station is measured the max. water discharge $2.624 \text{ m}^3/\text{s}$, which is exactly 99% from the real record at the station $2.640 \text{ m}^3/\text{s}$



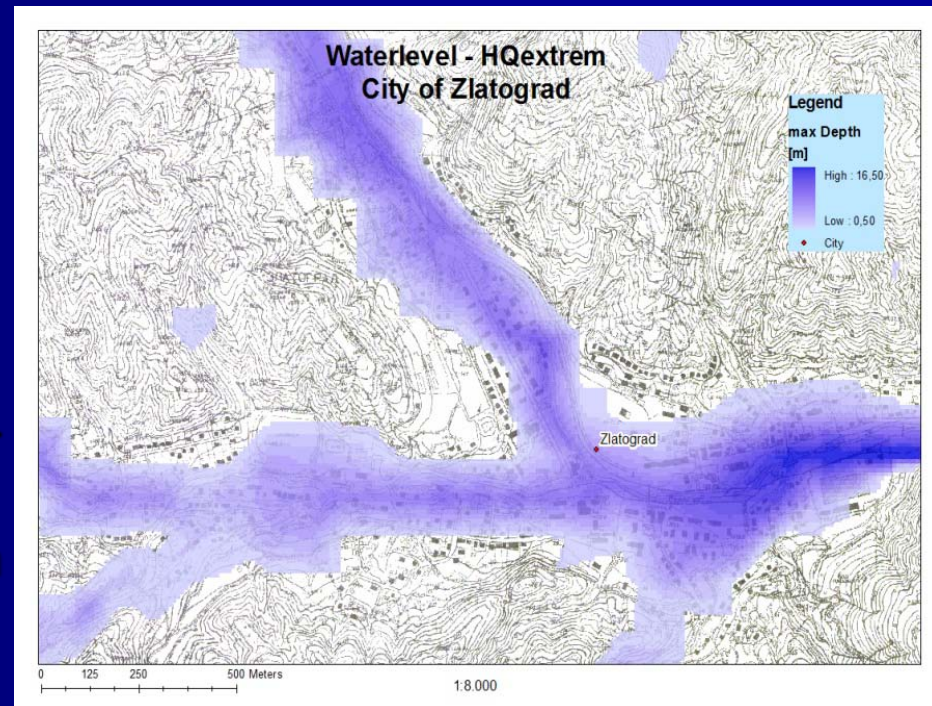
Water level by HQ extreme





Visualizations

- High river water wave through whole watershed
< watershed high wave.avi >
- 3D visualization of the rivers flow
<3D watershed high wave.avi>
- High river water wave through city of Zlatograd
< Zlatograd high wave.avi >





Application of the Hydro_AS-2D model

- Modeling of water flow in complex solutions into flooded river valleys. Development of preventive measures against floods with the planning of protective measures and facilities
- Dam wall destruction modeling and the spread of the water wave, leading to floods.
- Solve problems with preventive dam volume, flood protective facilities for the reception of high waves, etc.
- Transport of deposit materials and the expected deposit location in the river .





- The assistance of civil protection experts for the drawing up of effective emergency and contingency plans.
- Prediction of high waves and predicting the potential value and the type of damages. Techno-economic comparison of variants for the selection of the optimal strategy for flood protection.
- Detailed analysis and assessment of the benefits, risks and potential of a settlements location in case of flood.



Following activities

- Simulation of other flood scenarios.
- Confirmation/validation of the results through documents from past floods from local services.
- Impact analysis of high wave upon agricultural areas, commercial and industrial objects
- Damage location identification
- Preparation of flood hazard and risk maps
- Final calibration of the model with new GRID model (50x50m) and with more detailed recorded data (H and Q) from past floods



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THANK YOU FOR YOUR ATTENTION



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