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Flood risk management based on 2D TELEMAC computations: an example with Swiss hazard maps

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***Abstract*— A case study in Switzerland is considered, where hazard/flood maps are established as part of the planning of flood protection measures. Due to the commune's location within a flat plain divided by a railway dike, it could be shown that the settlements and infrastructures are much more endangered by floods than originally thought. Using the theme "land cover" of the digital cadastral survey, a digital terrain model (DTM) and bathymetry data, break lines were generated to build a triangular mesh. Culverts, tubes, and bridges are an important element of hazard mapping, as they can alter or create new flow paths not only as common bottlenecks in the channel (overflow), but also outside in flooded settlement areas where pedestrian/road underpasses and tunnels are present. However, the modelling of culverts and tubes has revealed that they are no longer suitable from a certain size of the channel, as the flow passes by the point which defines the culvert. Thus, several workarounds were tested to improve the reliability of the culverts/tubes. Recorded floods have shown that buildings are not necessarily an impermeable obstacle for the flowing water. An approach was developed to consider buildings as floodable as well as impermeable, as it could be observed that larger building complexes may by traversed by floods and alter the flow paths in this way. If these aspects are taken into account, an informative hazard map may be established.**

I. INTRODUCTION

Switzerland is regularly affected by natural hazards, especially floods (Fig. 1). The impacts of climate change are expected to lead to an increased danger where more frequent and intensive flooding can be expected in winter and spring. The risk of flooding will also increase in areas that have so far been spared from such floods. To enable an adequate response to natural hazards, their posed danger must be identified. Key elements are inundation maps, which indicate the threatened settlements and infrastructures, the extent of the associated flooding danger and the probability of hazard occurrence. The extent of the danger is derived from the intensity of the inundation and the associated probability (return period). Our hydraulic engineering company is active throughout Switzerland in the field of hazard/inundation mapping, using 2D TELEMAC.

Fig. 1: Flood overflow from and discharge under a road bridge [1]

The natural hazard protection is based on the principles of integrated risk management, aiming at an optimal combination of different protective measures and reducing existing risks to an acceptable level. The risk results from the possible extent of damage and the associated probability of occurrence. The risk resulting from inundation has increased in recent decades. The main reason for this is the greater potential for damage resulting from the growth of the population, the expansion of settlement areas into threatened regions and the increase in value of public infrastructures. Two important questions arise in the context of planning flood protection measures:

- How much can the risk be reduced (impact of the project)?
- What is the ratio of the risk reduction achieved to the costs caused by the measures (economic efficiency)?

To answer these questions, a hazard map for the initial state and a possible project state with protective measures must be elaborated. The hazard map documentation consists of a hazard map, a flow velocity map $\boldsymbol{u}$, a flow depth map $\boldsymbol{h}$ and an intensity map (max ($\boldsymbol{h}$; $\boldsymbol{u}*\boldsymbol{h}$)) for specific return periods 30, 100, 300 and 1000 years.

Depending on the region, Switzerland has a very diverse and dense river network with a density of up to 2.9 km/km^2 (on a scale of 1:25'000) [2]. Both, small mountain streams and larger rivers or currents have to be investigated. Using a concrete project example, we will show the procedures of hazard mapping for a particular river in Switzerland, with emphasis on the application of 2D TELEMAC.

II. METHODS AND MATERIALS

Fig. 2 shows the schematic procedure and materials used for hazard mapping.

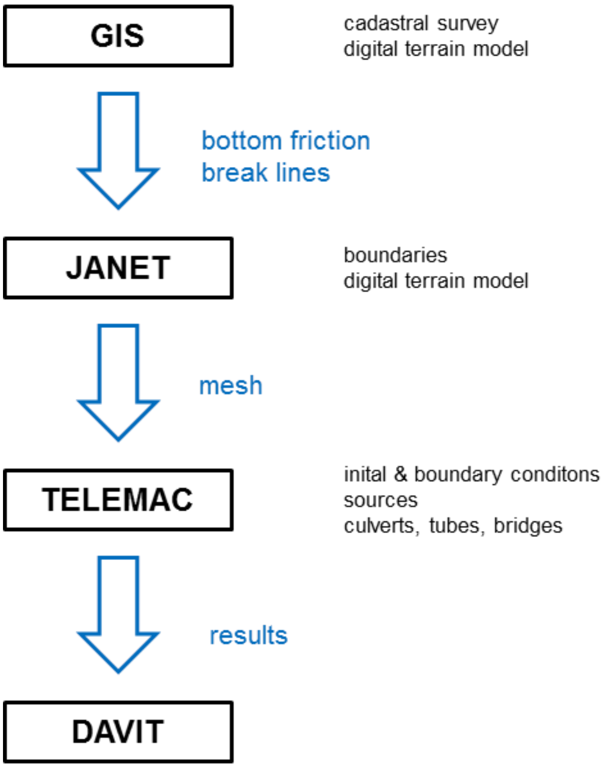

Fig. 2: Procedure with software and materials used for hazard mapping

A. *Mesh*

The topography of the mesh is based on a Digital Terrain Model (DTM), usually captured with Airborne Laser Scanning. The resolution of the DTM grid typically ranges between 0.25 and 2 meters. It is crucial that the Laser Scanning takes place in the leafless vegetation period to ensure the DTM covers the earth surface without shrubs and trees (especially next to water bodies). The DTM may be enhanced with bathymetry data to include important low transverse structures of the channel bed, such as sills (Fig. 3).

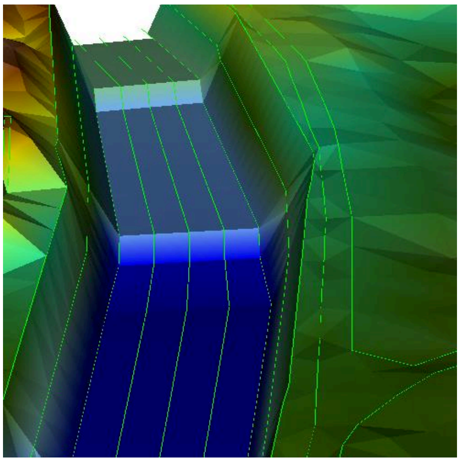

Fig. 3: River bathymetry data, showing the river bed with sills

The break lines are extracted from the land cover data of the digital cadastral surveying using a python-based script in GIS. The cadastral survey is a national product, providing data relating to landownership divided into eleven themes (Fig. 4). The theme “land cover” data contains accurate data on ground cover, such as buildings, roads, bodies of water, forest, etc.

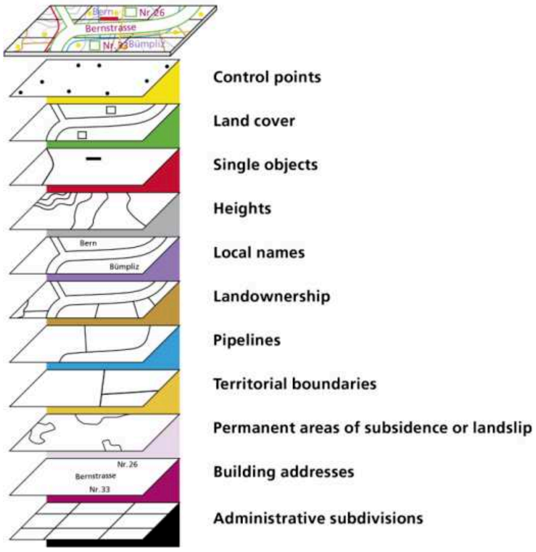

Fig. 4: The eleven information levels of the cadastral survey [3]

The break lines are used to define streams, ridges, shorelines of lakes, building footprints, dams (e.g. of rivers or railways) and other locations of abrupt surface change and/or a change in the land cover (smooth vs. rough). Normally, the extracted break lines have to be generalized to reduce the vertex count in lines that were captured in too much detail by the survey, such as traffic hubs or walls. Walls represent a vertical fault with more than one z-value at a given x-y-location, which cannot be stored in the mesh when using 2D TELEMAC (Fig. 5).

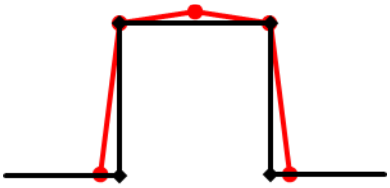

Fig. 5: An example for a wall (cross-section): captured by the survey (black) and adapted for the implementation in 2D TELEMAC (red)

Instead, it is possible to represent a nearly vertical wall with two parallel break lines: one containing surface z-values at the top of the wall, and a second with z-values at the bottom. Usually, an additional break line is added in-between the top break lines with z-values slightly higher than the top break lines. This in-between break line prevents water from overtopping when the water surface reaches (but does not exceed) the upper edge of a protective wall (e.g. next to a river).

The mesh is generated based on the break lines and the DTM using JANET by smile consult GmbH.

B. Roughness

The bottom friction zones are extracted from the land cover data and categorised accordingly to its roughness. The following seven roughness zones are usually defined:

ROUGHNESS ZONES

Nr.	**Roughness table**	
	Specification of land cover	***Roughness value***
1	River bed	27 $m^{1/3}/s$
2	River embankment	25-30 $m^{1/3}/s$
3	Forest	15 $m^{1/3}/s$
4	Humus (meadow, pasture, etc.)	25 $m^{1/3}/s$
5	Paved areas (e.g. streets)	35 $m^{1/3}/s$
6	Buildings*	0-1 $m^{1/3}/s$
7	Non-vegetated areas	20 $m^{1/3}/s$

* Only footprints of buildings.

Tab. 1: The seven roughness zones, extracted from the land cover data

Fig. 6 shows an example of how the roughness zones are defined according to the land cover data in Tab. 1.

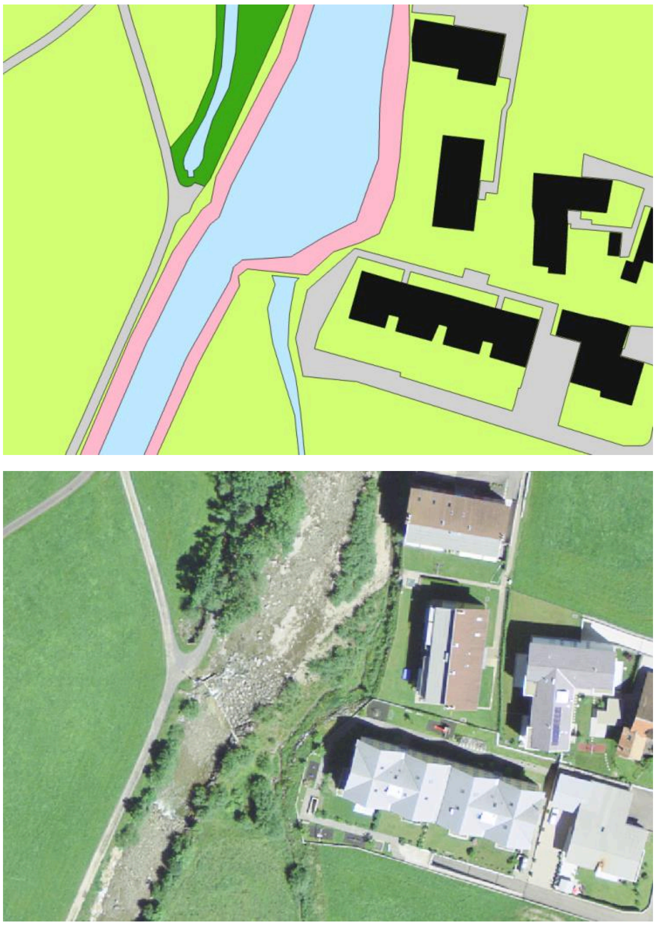

Fig. 6: The roughness zones categorised according to the land cover (above) and the corresponding Orthophoto (below) (Orthophoto: [4])

C. Initial and boundary conditions

Boundary conditions are defined for the inflow at the inlet and the outflow at the basin outlet of the investigated river, and if necessary, at the basin outlet of eventual flood corridors outside of the main channel. Around the boundary points, pools are created with a bottom height lower than the rest of the domain (to avoid dry boundaries).

A computation is performed, where a constant elevation is initialized at the boundaries. Next, the pools are filled up to the corresponding pool's top edge in this computation. As a result, the entire domain is dry but the pools are wetted. This computation is later on continued with prescribed flow rates at the inlet and prescribed elevation(s) at the outlet(s) for simulating the floods.

The prescribed elevation at the basin outlet is constant in time and sometimes defined by a receiving watercourse or by a lake. The prescribed flow rates at the inlet are variable in time and are prescribed by hydrographs. In some cases, the hydrographs can be derived from the measurement data of past flood events. Usually, as no gauging station is present at the point of interest, synthetically generated hydrographs are used. These are based on the characteristics of the catchment area and the amount of precipitation.

D. Water sources (Tributaries)

Water sources are placed at junctions where the river is joined by lateral tributaries increasing its discharge. The hazard maps of the tributaries are elaborated separately. The discharge of the tributaries is time-dependent and prescribed by hydrographs. A first computation is performed without any input at the junctions (only input at the inlet of the domain) and its results are used to identify the travel time of the flood peak along the river between the junctions. Based on this information, the hydrographs of the tributaries are adapted in order to achieve a flood with peaks converging.

E. Culverts, Tubes, and Bridges

In most cases, culverts, tubes, and bridges constitute weak points of the river and as a result of their bottleneck effect, may lead to overflow and altered or even new flow paths, especially within settlement areas. For this reason, the behaviour of these structures must be taken into account in flood modelling to produce a meaningful hazard map:

- Identification of weak points / bottlenecks such as culverts and bridges by means of a general plan, an Orthophoto and use of Google Street View.
- Surveying the geometry of the weak points (length, width, height, total cross-sectional area, constriction, slope, bank heights, material and /or roughness) and assessing the probability of clogging at the weak points by driftwood, debris or other material.
- Definition of the weak points; information about culvert/tube characteristics is stored in the CULVERT DATA FILE.
- The culverts and tubes are then calibrated. By conducting several simulations and adjusting the

characteristics of culverts and tubes (cross-sectional area, losses), the flows computed by 2D TELEMAC are checked and matched with the capacity calculated in a one-dimensional steady flow model (e.g. HEC-RAS).

If driftwood is mobilised in the upper reaches of a forest-covered catchment area, this can lead to partial or complete clogging at weak points downstream. The proportion of clogging of the cross-section depends on the flow velocities and the type and quantity of driftwood. Thus, the cross-section area of the culverts or tubes is reduced by the percentage clogged. For both cases, a simulation is conducted without consideration of floating solids (pure water, primary process) and one with floating solids and possible clogging (secondary process).

In addition to culverts and bridges, pedestrian or road underpasses and tunnels can also play an important role. Underpasses and tunnels can change the flow paths of an inundation and flood areas where flooding is not expected at first glance. They must therefore also be taken into account and defined as culverts or tubes.

F. *Model Parameters*

The computations are run with TELEMAC v7p1 on Linux Ubuntu Mate (16.04.01) with 80 processors on five servers. The Time step is an important parameter: it should be as long as possible (to keep the computation time short), and as short as necessary to meet the CFL criterion (usually determined by the shortest element in the grid where small structures such as walls have to be represented).

Since we have experienced unstable flow directions next to the channels and water emerging and disappearing in flat plains next to the channels in several simulations for various projects, different parameter sets were tested within the scope of this project case. Tab. 5 (at the end of the paper) lists all the parameter sets tested.

III. PROJECT CASE

A. *Project Area*

The project area consists of one main river and several tributaries in a commune with two separated settlement areas, one in the south and one in the north. The project area is divided into two parts by an important railway-line on a dike: a western part with settlements and infrastructures, a natural eastern part (Fig. 7). The capacity of the culvert through the railway dike is a limiting factor. Various events have confirmed that there is a flood protection deficit.

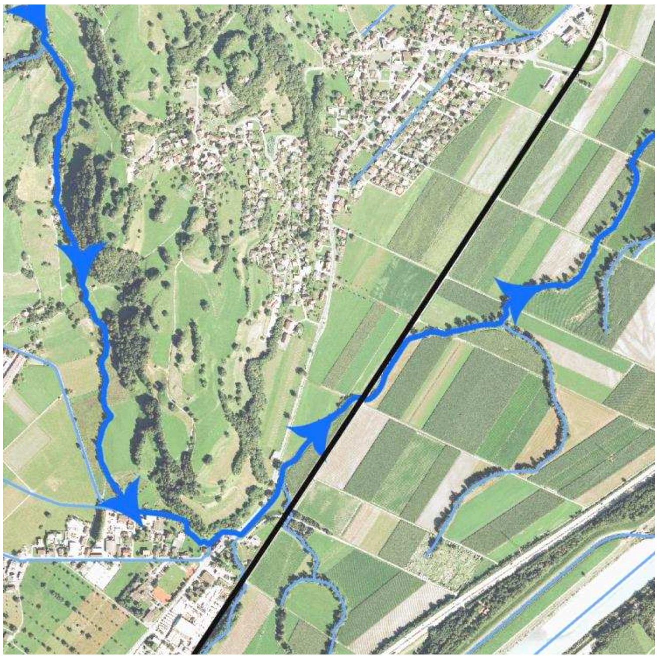

Fig. 7: Orthophoto showing the settlement areas, the main river (flow direction from left to right) and the railway-line on a dike (black line) (Orthophoto: [5])

B. *Modelling & Challenges*

1) Tributaries (Water sources): The peak flow data for the investigated river at the different junctions of the tributaries are shown in Tab. 2 (for the return period 100 years).

HYDROLOGY

Location	Peak discharge in River	Δ peak discharge at junction	Catchment Area
	m^3/s	*m^3/s*	*km^2*
Inflow (0)	17	-	4.3
Junction 1	18	1	4.5
Junction 2	25	7	7.9
Junction 3	26	1	8.3
Junction 4	28	2	9.5
Junction 5	29	1	9.7
Junction 6	31	2	10.0

Tab. 2: Peak discharges in the river at the different junctions for the return period 100 years

The discharge increases by more than 50% along the river by the tributaries. The aim is to determine the hazard posed by the river for the return periods 30, 100, 300 and 1’000 (extreme flood); both with and without taking into account the risk of clogging at selected culverts/tubes. The hazard maps of the tributaries were elaborated separately. Other hazard processes such as surface runoff are not taken into account.

The discharge of the river was supplied by an inflow boundary. On the other hand, there are six lateral tributaries along the river, which were taken into account through sources at the junctions. At each junction, the peak discharge and a corresponding hydrograph were defined for the (increasing) catchment area. Building the difference of the hydrographs between the junctions x and x-1 (x = 1-6), the hydrograph for the junction x is obtained. The hydrographs of these sources were adjusted in timing to make the runoffs along the river superimpose, peaking in the values listed in Tab. 2.

For this purpose a computation with sources switched off was carried out. Based on the acquired propagation time of the flood peak between the junctions, the hydrographs of the sources were temporally shifted to adequately reflect the propagation of the flood event.

2) Culverts, Tubes, and Bridges: The model contains 18 culverts, some of which have a capacity of 2 m^3/s. However, the focus is on the culvert at the railway dike (Fig. 8), which is the key point in the system, as it divides the project area in two due to its elevated position relative to the flat plain. The modelling has shown that the culvert has a very limited capacity of 6 m³/s (Fig. 9) and cannot discharge the 30 m^3/s design flood through the dam.

Fig. 8: Culvert through the railway dike [6]

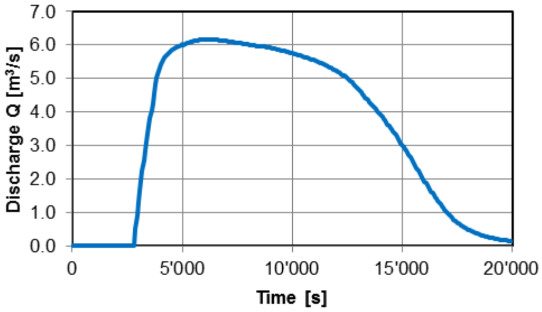

Fig. 9: Time-series of discharge through the culvert during the simulation

Problems have occurred with the modelling of larger culverts/tubes in a wider channel bed because they are only described as couples of points in the grid between which flow may occur (as a function of the respective water level at these points). It has been established that in wider channels the major part of the discharge does not flow to the receiving point of the culvert but flows past it and leads to overflow, although the capacity of the culvert would actually still be sufficient. Since the modelling of the culverts did not lead to the desired results, further workarounds had to be found: (1) the coupling points of the culverts were lowered, (2) multiple parallel culverts were used, and finally (3) no culverts were used but open channels with built-in bottlenecks to reproduce the cross-sectional area of the culverts.

- The coupling points of the culverts were lowered to change the flow field by aligning the streamlines to the receiving point of the culvert. However, the flow field was only marginally improved with this measure.

- Several parallel culverts were defined, which have the same cumulative capacity as the actual culvert. The intention was to distribute the runoff to multiple receiving points to prevent it from over-flowing. However, counter-current flow and general instabilities have occurred at the downstream points of certain culverts, which have falsified the results.

- No culverts were used but open channels with built-in bottlenecks to simulate the cross-sectional area of the culverts. However, the modification of the open channel to replicate a culvert is very time-consuming and error-prone. In the case of longer culverts, the problem arises that the water that has been spilled out upstream of the culvert can flow back along the route of the culvert, even though the culvert would actually be underground.

3) Roughness: Determining the roughness based on the land cover data is a simple and reliable method. It opens up the possibility of carrying out computations with different roughness values for specific land covers.

4) Consideration of buildings: The buildings are primarily modelled as impenetrable obstacles. However, analyses of past flood events have shown that buildings are not always an impenetrable obstacle to runoff and in certain cases can be crossed by floods. Particularly in larger buildings, different flow paths occur depending on whether they were modelled as impenetrable or crossable obstacles.

For this reason, usually two computations for the roughness values of buildings are performed:

- Strickler = 0 m$^{1/3}$/s, to model the buildings as impermeable obstacles in the grid, and

- Strickler = 1 m$^{1/3}$/s, to model the buildings as permeable/traversable for floods

Industrial complexes constitute a special case as some buildings may have openings, e.g. in the form of a stock hall. Such a complex can be traversed using the second method, which may have the effect of slowing down the flood wave and possibly reducing the peak discharge.

If buildings in a sink are flooded, (1) the damming at the building shell can be determined using the first method and (2) the traversing flow through the buildings, as soon as the openings no longer withstand the water pressure and break, can be determined using the second method (Fig. 10).

Fig. 10: Complex modelled as impermeable obstacle, Strickler 0 $m^{1/3}/s$ (above) and as permeable, Strickler 1 $m^{1/3}/s$ (below) (Background: [5])

Calibration and Verification: By adjusting the parameters (Strickler), the calculated water levels of an observed flood event are checked and matched to the gauging measurements recorded. Tab. 3 shows the measured and the calculated values for water depth and discharge of another project case/river with a gauging station.

MEASUREMENTS VERSUS CALCULATIONS

Variable	Measured at gauging station	Calculated 2D TELEMAC
Water level [MASL]	404.83	404.72 (water depth = 3.6 m)
Discharge [m^3/s]	110+/-10*	115

* The discharge at the gauging station is derived from measured water level and known stage-discharge curve. This derivation is associated with a certain uncertainty in the high water range, as the stage-discharge curves are usually extrapolated.

Tab. 3: Measured/observed values at gauge vs. calculated values

Our models typically present important topographic gradients, tidal flats and steep banks. The objective is to find a parameter set which presents…

- reasonable water lines in flat (~1 ‰) channels, steep (~10 ‰) channels and in the flood plain
- reasonable flood propagation in the flood plain, no water disappearing in the flood plain
- no flow direction artefacts in the channel producing erroneous discharge to the plain (unrealistic flow directions going upwards the embankment resulting in a discharge from the channel to the plain, even though the water level is way below terrain)

Different parameter sets were tested (Tab. 5 at the end of the paper) based on the recommendations from the user manual [7] and posted in the forum (www.opentelemac.org). The recommendation with tidal flat are TYPE OF ADVECTION = 1;5;14 or 14;5;14. Based on this, two runs different keywords mentioned in the recommendations were modified singularly and the results evaluated. The meaning of the keywords can be found in the TELEMAC-2D reference manual [8]. The results are presented in Tab. 4. It has emerged that the parameter set T14 is best suited for our field of application. It consists of a TYPE OF ADVECTION = 1;5;14 and a TREATMENT OF NEGATIVE DEPTHS = 1.

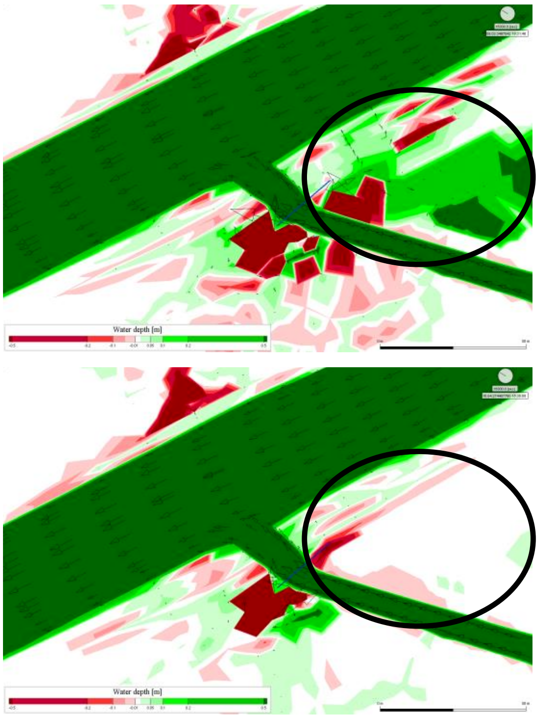

Fig. 11: Water depth in the main channel and the tributary of another project case to illustrate the positive water depth = green and the negative depth = red. The results yielded with parameter sets T10 (above) and parameter set T11 (below).

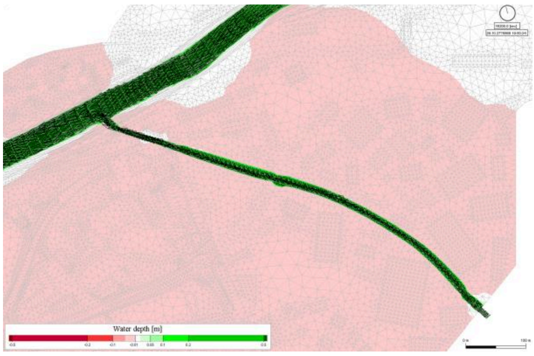

Fig. 12: Water depth of another project case to illustrate the positive water depth = green and the negative depth = pink propagating over the plain.

RESULTS

Test	**Modifications of keywords to T1**	**Courant number**	**Computation rate**	**Total volume lost**	**Water line**	**Artefacts because of steep banks**	**Conclusions**
		-	-	***m³/s***			
T1		1.96	0.09	-0.31	Smooth	Local erroneous discharge to the plain because of artefacts in the flow direction	Strong oscillation of the water line, computation rate is poor as well as the water balance in comparison with T1. Rejected solution because of quality of the results and performance.
T2	TYPE OF ADVECTION = 14;5;14 NUMBER OF SUB-ITERATIONS FOR NON-LINEARITIES=10 instead of 1	1.41	0.74	-16.2	Strong oscillations	Similar to T1, little more discharge to the plain	Rejected solution because of quality of the results.
T3	Based on T2, DISCRETIZATION IN SPACE to 11;11 instead of 12;11 and TREATMENT OF NEGATIVE DEPTHS = 2 instead of 0	0.38	0.09	0.00	Similar to T1	more artefact around the steep banks as T1	Shows similar results and performances as T2, but with a better water balance. Rejected solution because of quality of the results and performance.
T4	Based on T3, NUMBER OF SUB-ITERATIONS FOR NON-LINEARITIES=10 instead of 1.	0.38	0.74	0.00	Similar to T2	more artefact around the steep banks as T1, even as T3	Shows similar results of the water lines as T2 but with a performance equal to T1 and a good water balance. Rejected solution because of quality of the results.
T5	TYPE OF ADVECTION = 14;5	0.38	0.09	0.00	Similar to T2	Similar to T3	-
T6	TREATMENT OF THE LINEAR SYSTEM = 1 instead of 2	-	-	-	-	Could not be run	Shows erroneous water line at the confluence, a poor courant number and a poor water balance. Rejected solution because of quality of the results.
T7	DISCRETIZATION IN SPACE = 11;11 instead of 12;11	2.31	0.06	-6.97	Oscillations and high level in comparison to the other runs	Very important number of erroneous discharge. Even building (400 m higher than the plain) are flooded	-
T8	OPTION FOR DIFFUSION OF VELOCITIES= 2 instead of the default value 1	-	-	-	-	Could not be run	Shows similar water lines and computation rate as T1, slightly better courant number as T1 but poorer water balance. Rejected solution because of quality of the water balance
T9	MASS-LUMPING ON H and MASS-LUMPING ON VELOCITY = 0 instead of 1	1.66	0.09	7.25	Similar to T1	Similar to T1	Shows strong artefacts at the confluence. Rejected solution because of quality of the results.
T10	FREE SURFACE GRADIENT COMPATIBILITY = 1 instead of 0.9	1.91	0.09	-0.35	Smooth and lower level in comparison to the other runs	Instabilities at the water mouth between large main river and tributary. (Fig. 11).	Shows similar results as T1 with better courant number. The water balance is slightly inferior. The performance is equal. Rejected because other combination shows better results
T11	FREE SURFACE GRADIENT COMPATIBILITY = 0.8 instead of 0.9	0.39	0.09	-0.87	Similar to T1	Similar to T1.	Shows similar results as T1 with a poor water balance. (Fig. 11).
T12	SOLVER = 7 instead of 1	1.96	0.10	-3.45	Similar to T1	Similar to T1	Shows strong artefacts at the confluence. Rejected solution because of quality of the results.
T13	OPTION FOR THE TREATMENT OF TIDAL FLATS = 3 instead of 1	0.38	0.09	0.10	Smooth and higher level in comparison to the other runs	Instabilities at the water mouth between large main river and tributary	Shows a smooth water line. In the steep channel the water line is high but comprehensible. In the flat channel the difference is no so important. No erroneous discharges along steep banks are observed. But desired flood propagation in the plain could be underestimated.
T14	TREATMENT OF NEGATIVE DEPTHS = 1 instead of 0	0.38	0.08	-0.85	Smooth and higher level in comparison to the other runs, even than T13	No artefacts, important development of negative depth in the entire plain.	Fig. 12

Tab. 4: Results of tested parameter set

C. Results of modelling the Project Case

1) Initial state: So far, it has been assumed that the uncultivated area to the right of the railway dike would be flooded and that the settlement areas in the northeast of the commune would not or only to a small extent be affected by flooding. However, the new simulations have shown that the culvert through the railway dike has a limited capacity to 6 m^3/s as a result of which the design flood of 30 m^3/s cannot be discharged to the other side of the dike. The inundation maps show that the majority of the flooding is on the left side of the railway dike and that the northern settlement area is considerably more endangered than originally thought (Fig. 13).

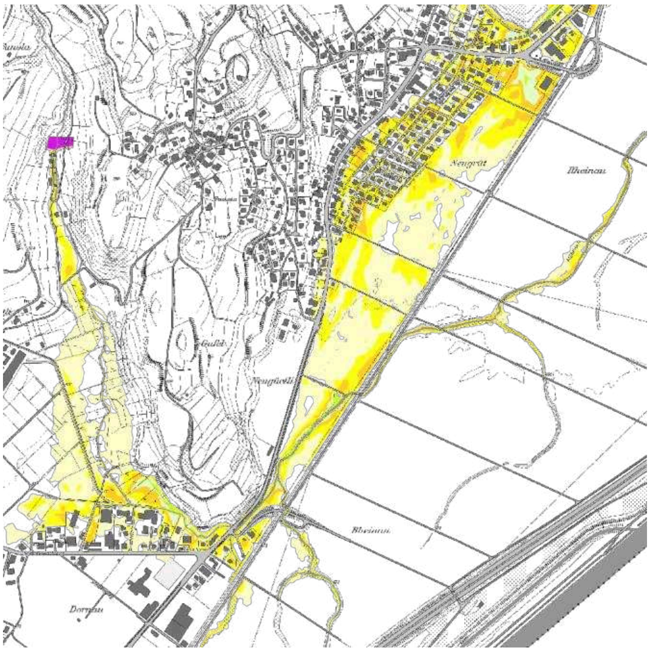

Fig. 13: Inundation map (return period 100 years) (Background: [5])

2) Project state: On the right side of the railway dike would be enough space for a natural retention area, but it is difficult to conduct the discharge to the other side of the dike because (1) the slope is extremely flat and leads to a significant backwater effect, and (2) the capacity of the culvert is not sufficient. The expansion of the railway culvert including the downstream channel to a capacity of 30 m^3/s is technically complex and economically unfavourable considering the large span required below the railway dike. The flood area on the left must therefore be limited to a man-made retention basin to be able to protect the settlement areas in the north from flooding.

IV. CONCLUSIONS

With the described methods for hazard/flood mapping by using 2D TELEMAC good results can be achieved. It allows an efficient delimitation of hazard areas under consideration of different aspects such as culverts, buildings, etc. This is essential for large-scale assessments with many origins of danger.

Nevertheless, the modelling of larger culverts or tubes has revealed a number of problems: (1) The culvert or tube geometry cannot be reproduced adequately and some simplification is required, (2) the definition of the culverts with the node numbers is not optimal, because an adaptation of the model grid after verification of the results in the field requires the adaptation of the CULVERT/TUBE DATA FILE, and (3) the calibration of the culvert is time-consuming and error-prone. The tested workarounds did not really improve the situation. It might be advisable to model the larger culverts or bridges as modified weirs that are considered as linear singularities across the channel (in contrast to the culverts or tubes, which are defined as punctual singularity).

To improve the quality of the results and to reduce the effort for the analyses, the Python scripts and workflows used are constantly being further developed. An important aspect is to adjust the mesh resolution to the size of the channels, which reduces numerical problems such as negative water depths and the occurrence or disappearance of water. However, the problem can be observed in small channels with steep slopes or walls in particular. For these cases, no solution could be found so far so that a time-consuming review of the results is still necessary.

REFERENCES

[1] Tiefbauamt Stadt Schaffhausen

[2] Bundesamt für Umwelt BAFU (2019, August 31). Auswertungen zum Gewässernetz. Retrieved from URL https://www.bafu.admin.ch/bafu/de/home/themen/wasser/zustand/karten/gewaessernetz-der-schweiz.html

[3] Cadastre.ch (2019, August 31). Information levels & data. Retrieved from URL https://www.cadastre.ch/en/av/result/layer.html

[4] Abteilung Geoinformation, Kanton Schwyz

[5] Amt für Raumentwicklung und Geoinformationen, Kanton St. Gallen

[6] Naturgefahrenanalyse, Kanton St. Gallen

[7] User manual Telemac-2D Software, release 7.0, 12/2014

[8] Reference manual Telemac-2D Software, release 6.2 07/2013

COMPUTATION PARAMETERS

Runs	**Computation parameters**												
	Type of Advection	***SUPG Option***	***Number of sub-iterations for non-linearity***	***Discretization in space***	***Option for Diffusion of Velocities***	***Mass-Lumping on H***	***Mass-Lumping on Velocity***	***Treatment of the linear system***	***TIDAL FLATS***	***Free surface gradient compatibility***	***Solver***	***Option for treatment of tidal flats***	***Treatment of negative depths***
T1	1;5;14		1	12;11		1	1	2	YES	0.9	1	1	0
T2	14;5;14		**10**	12;11		1	1	2	YES	0.9	1	1	0
T3	14;5;14	0;0;0*	1	11;11		1	1	2	YES	0.9	1	1	**2**
T4	14;5;14	0;0;0	10	11;11		1	1	2	YES	0.9	1	1	2
T5	14;5	0;0;0	1	11;11		1	1	2	YES	0.9	1	1	0
T6	1;5;14		1	12;11		1	1	**1**	YES	0.9	1	1	0
T7	1;5;14		1	11;11		1	1	2	YES	0.9	1	1	0
T8	1;5;14		1	12;11	2	1	1	2	YES	0.9	1	1	0
T9	1;5;14		1	12;11		**0**	**0**	2	YES	0.9	1	1	0
T10	1;5;14		1	12;11		1	1	2	YES	**1**	1	1	0
T11	1;5;14		1	12;11		1	1	2	YES	**0.8**	1	1	0
T12	1;5;14		1	12;11		1	1	2	YES	0.9	**7**	1	0
T13	1;5;14		1	12;11		1	1	2	YES	0.9	1	**3**	0
T14	**1;5;14**		**1**	**12;11**		**1**	**1**	**2**	**YES**	**0.9**	**1**	**1**	**1**

* With adaption to the recommendation 2;0 (User manual) run breaks off.

Tab. 5: Computation parameters: if no value is specified, default values were used. The recommendations in the User Manual and the TELEMAC-forum were regarded. Equations for all sets: SAINT-VENANT EF. THRESHOLD FOR NEGATIVE DEPTHS = default values