1 Introduction

In this document is described the methodology employed and the difficulties encountered by the Team 1 of the University of Zaragoza to carry out the simulation of a real flooding event in a valley including a urban area. The event selected to simulate is the Tous Dam Break happened in October 1982, that caused a major flood that propagated along the Júcar river valley and affected the small town of Sumacárcel, situated about 4.5 km downstream the dam. A general view of the valley is shown in the Figure 1.

This event has been selected as the case study for the Flood Propagation area of the IMPACT project because it encompasses both the wave travel along a natural valley and moreover the effects of an extreme flood in a urban area.

Finally, the numerical results obtained from the simulations will be analyzed in order to check the capability of the numerical model to reproduce real flooding events in a practical way, in terms of computational time, accuracy of the results compared with field data and uncertainty level due to non-fixed parameters.

![Figure 1: Overall view of the valley (1998 bathymetry).](image)

2 Numerical / Geometrical model

The 2-D shallow water equations are solved using an explicit second order finite volume model. The numerical fluxes are calculated by means of the Roe scheme and the Manning approach is used for the friction terms.

Owing to the complexity in the introduction of the city in the whole valley model, it seemed convenient to make the problem more flexible from a geometrical point of view. In order to reach this objective, the model, originally developed for structured meshes with quadrangular cells, has been adapted for unstructured meshes during the execution of this project as it is stated in later sections.
3 Test Case data summary and comments

The data distributed to the different modelers to perform the simulations of the Tous case study can be divided into several areas (see for more detail: “IMPACT Project Flood Propagation Case Study: The Flooding of Sumacárcel after Tous Dam Break”, Alcrudo&Mulet 2004):

1- Topographic data
2- City representation
3- Boundary conditions
4- Roughness coefficients
5- Requested results

3.1 Topographic data

Two data sets (Digital model of the terrain, with 5 m spatial resolution) have been used to carry out the simulations. The older one is dated several weeks after the disaster, in 1982, and the other one is from 1998. There are clear evidences that the sediment movement caused by the flooding was of huge importance looking at the differences between both bathymetries. The differences reach values of almost 10 meters in the river bed, and up to 5 meters in both river banks. The differences between both bathymetries are shown in the Figure 2 represented by colors, where it is easy to notice the soil deposition in the river bed and the erosion in both river banks caused by the flooding.

Figure 2: Differences between bathymetries.
Both bathymetries have been used for the simulations in order to estimate the influence of the topography uncertainty in a real flooding event, as it is known that the real topography was something between the two data sets available.

3.2 City representation

The buildings that make up the city are listed as polygons by their vertex coordinates, with a specific height. The inclusion of this data in the model presents several difficulties, mainly because the narrowness of the streets, that involves small cells in the mesh, and then, short time steps during the calculations. So, the selection of an appropriate building representation is needed in order to obtain results in an affordable lapse of time and also to describe the urban flow adequately. In the Figure 3 it is shown a picture of a mesh with the buildings included as bottom elevation.

![Figure 3: Buildings represented as bottom elevation.](image)

3.3 Boundary and initial conditions

The upstream boundary condition is set by the normal outflow hydrograph provided by CEDEX (Ministry of Public Works, Spain), which has a peak of 15000 m$^3$/s and last more or less two days (See Figure 13). The modelers have to impose it as an inflow boundary condition at the upstream part of the river reach considered. The downstream boundary condition is not fixed, and each modeler has to choose the location (enough far downstream the city of Sumacárcel to avoid the urban flow be influenced by the location) and also the numerical boundary condition that best suits the flow characteristics in that section.
The initial condition is set as dry valley, because it can be considered not significant the amount of water stored in the valley before the dam collapse in comparison with the water volume represented by the outflow hydrograph used as inflow condition.

### 3.4 Roughness coefficient

The roughness coefficient is a non-fixed parameter in the Tous Case Study. We have value ranges provided from official reports for the overall valley friction and also for the orange orchards present in the surroundings of Sumacárcel, which seem to have main influence in the urban flood turn out. It seems to be adequate to carry out a sensibility analysis to find out the influence of friction uncertainty in a real event.

The available ranges for the friction parameters are described in the Table 1 below.

<table>
<thead>
<tr>
<th>SOIL TYPE</th>
<th>FRICTION COEFFICIENT (MANNING) S.I. units</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIVER BED</td>
<td>0.025-0.045</td>
</tr>
<tr>
<td>ORANGE TREE ORCHARD</td>
<td>0.05-0.1</td>
</tr>
</tbody>
</table>

Table 1: Estimated friction coefficients.

The suggested areas surrounding Sumacárcel that must be modelled with increased friction values are represented in red in the Figure 4 below.

Figure 4: Buildings represented as bottom elevation.
3.5 Requested results

The Test Case Study can be formally divided into two areas: Urban flooding and Flood propagation in natural topographies. For Urban flooding area, the requested results are the water levels at 21 locations inside the city, where there are field measurements of the maximum water levels reached during the event. The location of the gauges inside the city can be seen in the Figure 5.

![Figure 5: Gauge location in the city.](image)

For Flood propagation area, the expected results are the water levels at 6 control points distributed along the valley and the flow rate through 3 sections, besides the water depth envelopes of 0.5 m and 2 m for the whole valley. In the Figure 6 the control points and sections are shown.
4 Methodology

The work carried out by the Team 1 of the University of Zaragoza for the Test Case Study can be divided into several main parts:

1- Preliminary simulations  
2- Sensitivity analysis  
3- City model analysis  
4- Geometric model analysis

4.1 Preliminary analysis

The preliminary analysis of the Test Case was aimed at having an overall impression of the problem, select the more appropriate boundary conditions and also to locate the flooded urban area. To attain this objective preliminary simulations were done for both available bathymetries for the whole valley, not including any city model. The runs were performed in calculations meshes with the following features:

- Structured meshes with 1 domain  
- ~ 15000 cells  
- 20 x 20 m typical dimensions of the cells

A view of a calculation mesh employed for preliminary simulations with the 1998 bathymetry can be seen in the Figure 7.
The most complicated issue was the selection of the downstream boundary condition location. A section with supercritical conditions was searched because it was the simplest way to impose the downstream condition without affecting the flow upstream. After large trials, two sections (one for each bathymetry) with nearby supercritical conditions were selected.

The application of the upstream boundary condition did not present any complication. The hydrograph provided as data, was imposed as inflow in the breach for the old bathymetry, and as overtopping the dam for the new bathymetry. This is shown in the Figures 8 and 9 respectively.
Figure 9: Upstream boundary condition for 1998 bathymetry.

As the first intention was to perform simulations including the whole valley as well as a city model, different possibilities were considered. The most attractive ones were to model the city as bottom elevation (it only requires a big cell concentration in the urban area to represent the streets of the city adequately, but the simulation takes a long time) or model the streets of the city as vertical walls (it requires more meshing effort but the amount of cells are lower and thus the simulation can be completed in a affordable time). The city model selected was the vertical walls model, because it was the most “economical” model from a computational point of view, as the main factor in this Test Case was the long duration of the event. So, a simplified city model representing the streets as vertical walls was made covering the flooded area calculated in the preliminary simulations, as it can be seen in the Figure 10.

Figure 10: Simplified city model: Streets as vertical walls.
The minimum number of cells per street in the transversal direction was set as two, and the mesh was made preserving as far as possible the cell uniformity.

### 4.2 Sensitivity analysis

The sensitivity analysis was performed in order to estimate the influence of variations in non-fixed parameters (friction values) and initial data (inflow hydrograph, topographic description) in the event evolution. To carry out this sensitivity analysis, calculation meshes covering the whole valley and including the simplified city model selected from the preliminary results, were used. An overall view of the mesh used for the sensitivity analysis with the 1998 bathymetry is shown in Figure 11.

![Simplified City Model](image)

**Figure 11:** Mesh used for sensitivity analysis with a simplified city model included (1998 bathymetry).

The main features of the mesh used for the sensitivity analysis are described below:

- Structured meshes with 42 domains
- ~ 20000 cells
- 15 x 15 m typical cell dimensions in the valley
- up to 1 x 1 m cell dimensions in the urban area
- minimum of 2 cells per street width

Although in previous reports only two increased friction zones were indicated, it seemed interesting to include more zones modeling cultivated areas upstream the city. This new approach can be useful to consider the influence in the flood of cultivated zones located in both river banks along the valley. The cultivated zones were extracted from aerial pictures taken just several days after the event. In the Figure 12 a picture is shown with the cultivated zones introduced in the model along the valley in red.
A summary of the runs performed for the friction analysis is stated below in the Table 2.

<table>
<thead>
<tr>
<th>SIM</th>
<th>NUMBER OF CELLS</th>
<th>VALLEY FRICTION</th>
<th>ZONES FRICTION</th>
<th>CITY MODEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>~ 20000</td>
<td>0.025</td>
<td>0.05</td>
<td>VER. WALLS</td>
</tr>
<tr>
<td>A2</td>
<td>~ 20000</td>
<td>0.025</td>
<td>0.1</td>
<td>VER. WALLS</td>
</tr>
<tr>
<td>A3</td>
<td>~ 20000</td>
<td>0.045</td>
<td>0.05</td>
<td>VER. WALLS</td>
</tr>
<tr>
<td>A4</td>
<td>~ 20000</td>
<td>0.045</td>
<td>0.1</td>
<td>VER. WALLS</td>
</tr>
</tbody>
</table>

Table 2: Runs performed for friction analysis.

Besides the friction analysis, with the whole valley and also the simplified city model a sensitivity analysis has been carried out varying the inflow hydrograph only using the 1982 bathymetry. The hydrographs used for these simulations were provided by the breach modelers and they can be named Upper, Medium or Lower, depending on the flow rate peak. In the Figure 13 the hydrographs used for the uncertainty analysis as well as the normal hydrograph are shown.
The first thing that hits after seeing the previous Figure is the appreciable difference in the peak shape between the uncertainty hydrographs calculated by the breach modelers and the normal hydrograph. The uncertainty hydrographs have a more marked peak than the normal one. This could mean that the real hydrograph was more peaky than the normal one provided.

The summary of the cases calculated for the hydrograph uncertainty analysis is stated in Table 3 below.

Table 3: Runs performed for hydrograph uncertainty analysis.

4.3 City model analysis

After carrying out the sensitivity analysis it was found interesting to check the model accuracy using other city representations, for example, represent the whole city as an increased friction spot included in the valley, or represent the buildings as bottom elevation or high friction.

As the computational time needed to complete the simulations with the buildings represented as bottom elevation or high friction was too large, because the small cells required in order to model adequately the city streets, it was indispensable to use some kind of trick. The selected trick was to split the valley in two zones, one covering the whole valley (coarse mesh) and another covering only the city area (refined mesh). The mesh characteristics used for both zones were quite different. These characteristics are detailed below:
**COARSE MESHES:**

- Structured meshes with 5 domains
- ~ 17500 cells
- 15 x 15 m typical cell dimensions in the valley
- Covering the whole valley

**REFINED MESHES:**

- Structured meshes with 3 domains
- ~ 26000 cells. Up to 1 x 1 m cell dimensions in the urban area for bottom elevation.
- ~ 15200 cells. Up to 2 x 2 m cell dimensions in the urban area for high friction.
- Covering only the city area.

The data interchange between both meshes (coarse and refined mesh) is done at the upstream part of the refined mesh and the downstream boundary condition is imposed as supercritical outflow.

The summary of the runs carried out with the coarse mesh is shown in Table 4.

<table>
<thead>
<tr>
<th>SIM</th>
<th>NUMBER OF CELLS</th>
<th>VALLEY FRICTION</th>
<th>ZONES FRICTION</th>
<th>CITY MODEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA1</td>
<td>~ 17500</td>
<td>0.025</td>
<td>0.025</td>
<td>FRICTION</td>
</tr>
<tr>
<td>CA2</td>
<td>~ 17500</td>
<td>0.025</td>
<td>0.1</td>
<td>FRICTION</td>
</tr>
<tr>
<td>CA3</td>
<td>~ 17500</td>
<td>0.025</td>
<td>0.1</td>
<td>BOTTOM</td>
</tr>
<tr>
<td>CA4</td>
<td>~ 17500</td>
<td>0.025</td>
<td>0.025</td>
<td>NONE</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SIM</th>
<th>NUMBER OF CELLS</th>
<th>VALLEY FRICTION</th>
<th>ZONES FRICTION</th>
<th>CITY MODEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB1</td>
<td>~ 17500</td>
<td>0.025</td>
<td>0.025</td>
<td>FRICTION</td>
</tr>
<tr>
<td>CB2</td>
<td>~ 17500</td>
<td>0.025</td>
<td>0.1</td>
<td>FRICTION</td>
</tr>
<tr>
<td>CB3</td>
<td>~ 17500</td>
<td>0.025</td>
<td>0.1</td>
<td>BOTTOM</td>
</tr>
<tr>
<td>CB4</td>
<td>~ 17500</td>
<td>0.025</td>
<td>0.025</td>
<td>NONE</td>
</tr>
</tbody>
</table>

Table 4: Runs performed with coarse meshes.

In these cases with coarse meshes, the city included as friction is equivalent to a big spot in the valley with increased friction as it is shown in Figure 14. The building locations have been modeled as a Manning coefficient of 1 (ten times more than the cultivated zones). If the city is included as bottom elevation, due to the low resolution of the mesh, the streets are not represented, and the whole city is a elevation on the left river bank.
The summary of the runs carried out with the refined mesh is shown in Table 5.

<table>
<thead>
<tr>
<th>SIM</th>
<th>NUMBER OF CELLS</th>
<th>VALLEY FRICTION</th>
<th>ZONES FRICTION</th>
<th>CITY MODEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA1</td>
<td>15200</td>
<td>0.025</td>
<td>0.025</td>
<td>FRICTION</td>
</tr>
<tr>
<td>RA2</td>
<td>15200</td>
<td>0.025</td>
<td>0.1</td>
<td>FRICTION</td>
</tr>
<tr>
<td>RA3</td>
<td>26000</td>
<td>0.025</td>
<td>0.025</td>
<td>BOTTOM</td>
</tr>
<tr>
<td>RA4</td>
<td>26000</td>
<td>0.025</td>
<td>0.1</td>
<td>BOTTOM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SIM</th>
<th>NUMBER OF CELLS</th>
<th>VALLEY FRICTION</th>
<th>ZONES FRICTION</th>
<th>CITY MODEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>RB1</td>
<td>15200</td>
<td>0.025</td>
<td>0.025</td>
<td>FRICTION</td>
</tr>
<tr>
<td>RB2</td>
<td>15200</td>
<td>0.025</td>
<td>0.1</td>
<td>FRICTION</td>
</tr>
<tr>
<td>RB3</td>
<td>26000</td>
<td>0.025</td>
<td>0.025</td>
<td>BOTTOM</td>
</tr>
<tr>
<td>RB4</td>
<td>26000</td>
<td>0.025</td>
<td>0.1</td>
<td>BOTTOM</td>
</tr>
</tbody>
</table>

Table 5: Runs performed with refined meshes.

An example of refined meshes used to represent the city as high friction or bottom elevation can be seen in Figures 15 and 16 respectively.
Figure 15: City introduced as high friction in a refined mesh.

Figure 16: City introduced as bottom elevation in a refine mesh.
4.4 Geometric model analysis

The difficulties found in the meshing process when using structured meshes caused the interest in trying different geometric models. So, the original model for structured meshes has been adapted to use unstructured meshes with quadrangular cells. With this new geometric model a case for the refined mesh representing the city as bottom elevation has been carried out, only with the 1998 bathymetry. In order to reduce the calculation time this case was run in first order.

The general characteristics of this case are described below:

- Unstructured mesh
- ~ 20000 cells
- Cells up to 0.8 x 0.8 m in the city area
- Cultivated zones represented as a friction coefficient 0.1 (Manning)
- Buildings represented as bottom elevation

In the Figure 17 it is shown the mesh used for the unstructured case, in which is very clear the high cell concentration in the city area, specially in the flooded area obtained from preliminary simulations.

![Figure 17: Mesh used for the unstructured calculation.](image)

In the Figure 18, in which the buildings that made up the urban area are easily seen.

A more detailed view of the city area is detailed in the Figure 18, in which the buildings that made up the urban area are easily seen.
4 Numerical results

The numerical results exposed in this section will be divided into several parts, i.e.:

1- Test Case Study
2- Sensitivity analysis
3- City model analysis
4- Geometric model analysis

4.1 Test Case Study

In this section the numerical results obtained from the simulations considering the whole valley and the simplified city model stated below (buildings as vertical walls) are described. In each graphic, two data sets were shown, one with the 1982 bathymetry and another one with the 1998 bathymetry. All the results are presented in terms of water elevation instead of water level, because of the difference in the ground level between both bathymetries. In the Figure 19 a graphic with the subtraction of both bathymetries ground levels is showed. In almost all the gauges the ground level for the 1982 bathymetry is higher than the 1998 bathymetry due to the deposition of material caused by the flooding, specially in the gauges located nearby the river bed.
Figure 19: Differences between bathymetries in the location of the gauges.

The available experimental data is only compared with the numerical results in the gauge locations where the difference between bathymetries is less than 0.5 m, i.e., in gauges 3, 7, 9, 10 and 11. The ground level for the experimental results is then fixed as the average between both bathymetries. The numerical results for all the gauges, control points and sections along the valley are exposed below from the Figure 20 to Figure 49. In red the results with the 1982 bathymetry and in green the results with the 1998 bathymetry.

Figure 20: Water elevation. Gauge 1.
Figure 21: Water elevation. Gauge 2.

Figure 22: Water elevation. Gauge 3.
Figure 23: Water elevation. Gauge 4.

Figure 24: Water elevation. Gauge 5.
Figure 25: Water elevation. Gauge 6.

Figure 26: Water elevation. Gauge 7.
Figure 27: Water elevation. Gauge 8.

Figure 28: Water elevation. Gauge 9.
Figure 29: Water elevation. Gauge 10.

Figure 30: Water elevation. Gauge 11.
Figure 31: Water elevation. Gauge 12.

Figure 32: Water elevation. Gauge 13.
Figure 33: Water elevation. Gauge 14.

Figure 34: Water elevation. Gauge 15.
Figure 35: Water elevation. Gauge 16.

Figure 36: Water elevation. Gauge 17.
Figure 37: Water elevation. Gauge 18.

Figure 38: Water elevation. Gauge 19.
Figure 39: Water elevation. Gauge 20.

Figure 40: Water elevation. Gauge 21.
Figure 41: Water elevation. Point A.

Figure 42: Water elevation. Point B.
Figure 43: Water elevation. Point C.

Figure 44: Water elevation. Point D.
Figure 45: Water elevation. Point E.

Figure 46: Water elevation. Point F.
Figure 47: Water flow rate. Section 1.

Figure 48: Water flow rate. Section 2.
The results shown before have some interesting characteristics:

- The water elevation in the urban area is about 1.5 m higher with the 1982 bathymetry. The dredging of the river bed after the construction of the new Tous Dam cause these differences and it is easy to verify that the city is now more secure than before the river conditioning.

- The maximum differences in water elevation in the control points along the river are located in the nearest probe to the dam (Point A). In this point the water elevation with the 1982 bathymetry is around 2.5 m higher than in the 1998 one. This difference seems no to be in agreement with the flooding event, because in this river reach the erosion was very important and then, the ground level for the 1982 bathymetry is lower than in the new one. But, it is probable that the closeness of upstream boundary causes effects in these control points depending on the way the condition is imposed. In the 1998 bathymetry the flow is imposed as overtopping, and so, the energy is higher and the velocities too, while the eater flow rate is the same for both bathymetries

- The differences in water elevation for one specific bathymetry are about 1 m for the old one and around 2 m for the new one between the upper and lower part of the city. The differences are specially important for the new bathymetry due to the combination of a simplified city model that represents the streets as narrow channels and the topographic characteristics of the new DTM in the upper part of the city.

- The flow rate through the sections is the same for both bathymetries and the maximum peak is similar to the peak of the inflow hydrograph. The water elevation is adapted to the
flow rate imposed as boundary condition because the storage of water in the valley is very little.

- The numerical results in the urban area seem to agree with the experimental data in terms of peak values for the gauges 3, 7, 9, 10 and 11. Particularly, the numerical results for the old bathymetry are generally higher than the experimental data, which is logical if we think that the ground level is higher than the original one, whereas the numerical results for the 1998 bathymetry are lower than the experimental data, which is also logical because of the conditioning of the river bed.

- The emptying rates for the gauge 7 are lower than the available data. This could mean that the real hydrograph was closer to the hydrographs calculated by the breach modelers, which have a more picky shape.

4.2 Sensitivity analysis

In this section it is described the influence of the friction parameter selection and also the effects of variations in the inflow hydrograph. Not the results in all the gauges and control points will be presented because the huge amount of data and only the main features of the sensitivity analysis are presented in this paper. The Figures 50 and 51 represent the results in water level obtained in the gauge 1 varying the friction values between the ranges stated before, for the 1982 bathymetry and the 1998 bathymetry respectively.

![Figure 50: Friction analysis. 1982 Bathymetry. Gauge 1.](image-url)
In the Figures before, the friction parameter (Manning coefficient) adopted for the valley is named $N_v$, and the friction parameter adopted for the cultivated zones is named $N_z$. It is very clear in the graphics that the influence of the selection of the friction parameter for the whole valley does not affect too much the numerical results, while the variation of the friction coefficient for the cultivated zones between the ranges proposed cause an increase of about 2 m in the water levels for both bathymetries. The gauge 1 can be taken as a guide for what happen in the rest of the city.

The results for the hydrograph uncertainty analysis are showed in the Figure 52 below.
The uncertainty due to variations in the inflow hydrograph can be estimated as 2 m for the urban zone taking the gauge 1 as a reference. The shape of the water level evolution obtained with the uncertainty hydrographs provided by the breach modelers is more adjusted to the field data because the filling up and emptying rates are higher, specially for the upper and the medium hydrographs.

4.3 City model analysis

In this section the graphics presented are concerning the effects of the city model selection in the numerical results. In the Figure 53 the results with the coarse mesh are compared with the results obtained with the simplified city model representing the streets as vertical walls for the 1982 bathymetry.

It can be appreciated in the previous graphic that the inclusion in the model of a big “spot” representing the city as increased friction without including the cultivated zones has no important effect in the numerical results. If the cultivated zones are included, then the water levels reached with the city represented as high friction are a bit higher than the water levels obtained with the simplified city model. The water level with the city represented as bottom elevation is much lower than the obtained with other models. This is because the city streets are not represented adequately since the mesh density is poor.

The results with the refined mesh compared with the simplified city model, for the same gauge shown before, are exposed in the Figure 54.

The results with the refined mesh are quite similar to those obtained with the coarse mesh or the city modeled as vertical walls. The main issue is again the inclusion or not of the cultivated zones in the model and not the selection of the city representation. The flooding is not being appreciably affected by the city, because the town is not located in the main flow and the city flooding is lateral. If the city would be situated in the left
river bank, where nowadays the orange orchards are placed, the flood would be affected in a critical way by the city. This could be an interesting experiment to carry out in the future.

Figure 54: City model analysis. Refined mesh. 1982 Bathymetry. Gauge 7.

4.4 Geometric model analysis

The numerical results shown in the Figure 55 below are a comparison between two different geometric models. The original one uses structured meshes, while the new one, developed during this project, is adapted to use unstructured meshes. There are not important differences in the results between models. The results modeling the city as bottom elevation or high friction yield higher water levels (about 0.5 m) than the results with the city as vertical walls. Moreover, it can be observed some level of oscillation with the structured model if the city is represented as bottom elevation whereas the oscillation is not present if the unstructured model is used. The reason for this is that the unstructured model has been run with first order accuracy (in space and time) to reduce the calculation time while the structured model has been run in second order. As it is apparent from the graphs shown, the formal order of accuracy of the numerical scheme does not have a strong influence in the quality of results.
5 Conclusions and recommendations

A significant amount of modeling work has been performed at University of Zaragoza during Impact project Flood Propagation Case study. This effort has clarified many fundamental issues and highlighted the following points:

- The Tous Dam break and subsequent flooding downstream, and in particular the town of Sumacárcel was indeed a catastrophic event. However the progression of the flood inside the urban area was not an inertial phenomenon as would have been desirable from the project perspective. This would have been the case, if for instance the town of Sumacárcel were located on the opposite bank of the river Júcar (It is not surprising that many years of fight against floods have led to a sort of natural optimization process).

- The modeling technology developed during Impact project and applied to this case study has proven successful not only in reproducing the qualitative aspects of the flood but also the measured levels of flooding within the streets with acceptable accuracy. Even though the models were designed more to cope with floods in which inertial effects are important.

- The amount of work needed to set up and run a model on a real event of this duration is very important. Not only the model computer time is very long (on the order of days and even weeks) but also the effort and time that a team of experienced engineers need to set up and pre-process all the required information is very considerable

- It would be advisable that the steps needed to run a model can be categorized in form of a check list or modeling protocol. From data gathering and collation to area meshing, calibration (if possible) and predictive runs each of the tasks performed should be listed and described. Then the whole process can be analyzed and checked for bottle necks that could lead to improvement and optimization. This is necessary if turnaround times are to be reduced to acceptable limits.