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Team 01: Week 2

HYDROEUROPE

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HydroEurope

WP4: Accidental Water Pollution

Case Study La Tordera (Spain)

Team 01: Report Week 2:

Modelling and Analysis of water pollution

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Summary

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1 Introduction

1.1 Brief introduction of the area

La Tordera catchment is located in Catalonia, on the northwestern Mediterranean, an area characterised by the effects of the dry summer climate (also called Mediterranean climate) and by the high risk of storm impact. The catchment has an area of 864 km², spanning over the regions of Vallès Oriental and La Selva. The river itself has a length of 60 km, starting at an altitude of approximately 1700 meters and ending at sea level.

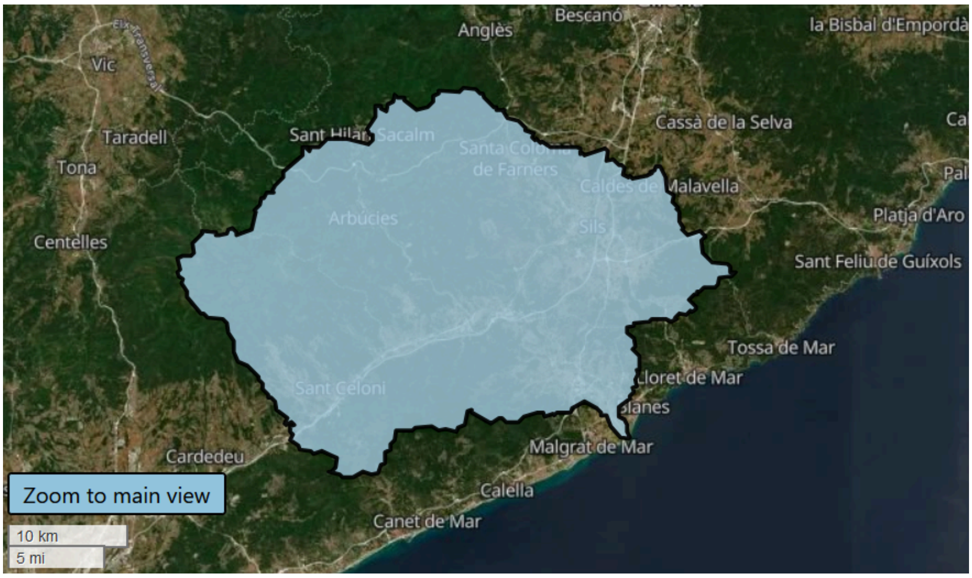

Figure 1: General overview of La Tordera catchment.

1.2 Background on water pollution

The sources of water pollution in La Tordera mainly come from industrial and urban areas. The wastewater discharge from some cities and factories, which is not disposed of sufficiently, influences the water quality. The wastewater discharge is mainly from textiles, food processing, and agriculture. Although there are sewage treatment plants in this catchment, the efficiency is not high, especially during strong rainfall. The bypass flows without treating the flow into the river, which may bring pollution.

In addition to that, it should be noted that agricultural pollution also plays an important role in water quality, as the surface runoff on agricultural lands can bring pesticides, fertilizers and sediments into the river, generating or increasing eutrophication processes. In that sense, it should be noted that, in addition to the inherent environmental consequences, it may also pose economical risks, as fishery is one of the main water usages of this area and toxic chemical levels risk banning this activity for health reasons.

Although it is always a thing to be monitored, water pollution is especially of concern in case of a flooding event. Sewage leakage is the serious problem of this catchment, though it occurs occasionally, particularly when the facilities of sewage treatment fail and heavy rain occurs. These events may release amounts of pathogens, organic biochemical oxygen demand (BOD) and

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chemical contaminants, which lead to reducing the water quality in a short time. This issue becomes more significant during the dry season because of the decrease in dilution capacity.

In that sense, the Blanes Wastewater Treatment Plant located halfway along the Tordera provides a potential pathway for pollution to enter the river, affecting water quality and downstream ecosystems. Given the treatment plants close proximity to the river, there is an increased risk of pollutants being discharged into the river during extreme weather events. This area is therefore identified as the pollutant pathway for future modelling during the simulation of these high discharge fluvial events.

Figure 2: Blanes WWTP, adjacent to La Tordera water course.

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2 Overview of the Iber hydraulic model

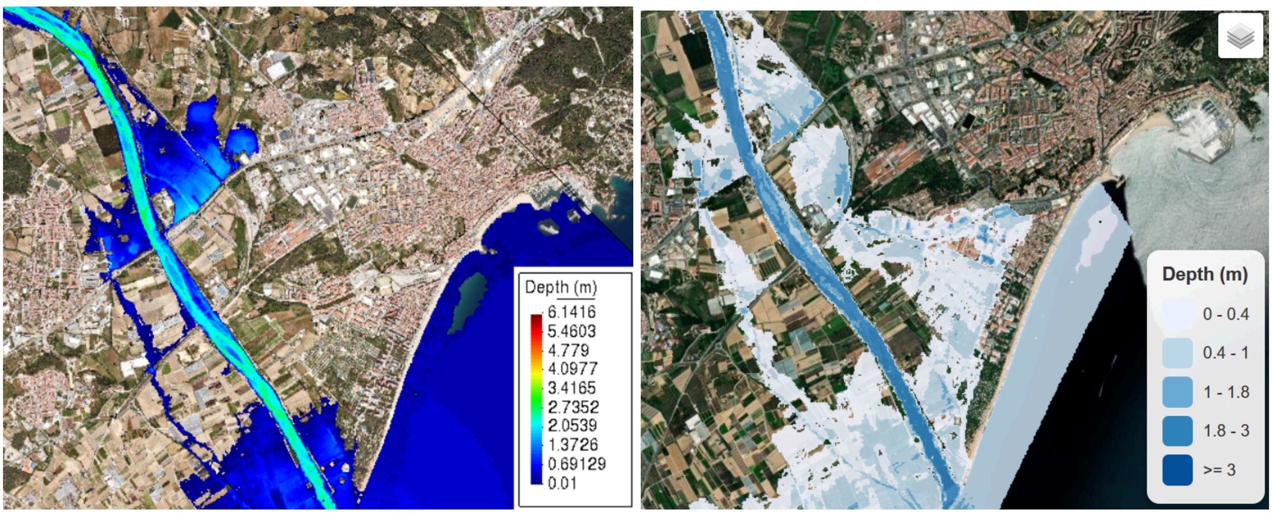
2.1 Initial model

This model refers to the one described during the Report 2 (Team 01: Report Week 1).

2.1.1 Overview of the first modelling attempt

The model developed during the first week, from which there were no results to be discussed, as the computation made it impossible to obtain results in due time, finally finished doing the calculations needed. From it, the following results in terms of water depth were obtained:

Figure 3: Initial hydraulic model created with Iber. Maximum water depth.



Figures 4 and 5: Comparison of results for the Iber model generated (left) and the simulation shown in the HydroEurope Project webpage (right).

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As it can be seen, there are, however, some problems, as the model produced does not accurately reflect the real results registered during the Gloria storm (here described in Figure 5 as the simulation shown in the HydroEurope Project webpage. Therefore, there are some key findings and limitations that need to be addressed.

2.1.2 Key findings and limitations

Initial observable comparison of the initial 2D modelling attempt with the observed 2020 Gloria flood event presents potential for improvement for the modelling attempt. Key limitations of the initial model were identified to improve the results. The most notable discrepancies that were identified during this stage was the localised flooding in the north of the city and the lack of flooding south of the GI-682. The general areas in which the fluvial flooding occurs is consistent across both the observed and simulated, however both the intensity and extent vary. In the simulated run, the volume of water is way more north of the GI-682, characterised by deeper and more spatially spread flooding. It does not, however, reflect the real observed flooding experienced directly south of the GI-682. Additionally, the model took a longer-than-expected time to run, indicating potential inefficiencies in the input data resolution or computational setup.

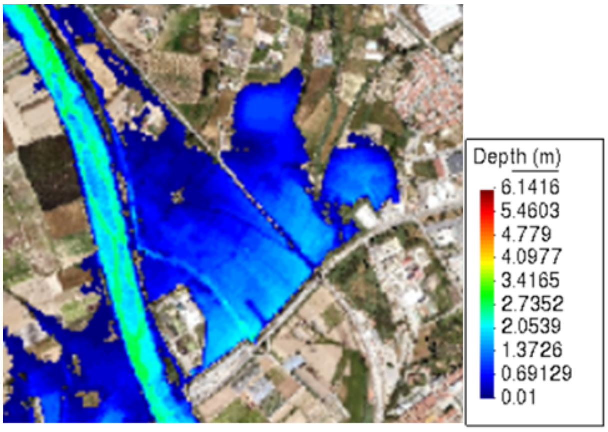

Figure 6: Drastic variations in flood depths north and south of the GI-682 in simulated results.

This downstream flooding was localised and contained largely due north of the GI-682 raised highway is indicative of a potential physical barrier obstructing any further flow. This was further investigated and unveiled a key limitation in the current model setup. In this area, the DEM and consequential mesh takes the highest point in the terrain for its reference. Any areas in which there is area below the underpass is not picked up by the model, and is therefore represented as a solid obstructive area where in reality, flow would be able to freely move along the subsurface to the otherside of the highway without the requirement to meet the elevation of the summit of the highway.

Another significant limitation of the initial Iber model is its high computational demand. Given the time constraints of the project, prolonged simulation runtimes can be inefficient, limiting opportunities for fine-tuning and sensitivity analysis. Optimising the model to reduce computational time would enhance result quality by allowing for more iterative refinement.

The initial land use of the model was also not representative of the actual catchment, and may be attributable to the inaccurate results. The observed flow visibly varies depending on the terrain, presenting observable differences at a neighbourhood level. This was not reflected within the model, meaning more attention to the land use types would be required in future models.

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2.2 Model refinement

2.2.1 Modification of the mesh

Due to the difficulties found during the creation and run of the first hydraulic model, it was decided to re-do the meshing of the subcatchment.

On the Iber model, the main approach to this was double, as it needed to solve the main two problems that were found in the first model created with Iber: the large amount of time needed for the computation process and the need to remedy the blockage of the flooding created by the DTM in the road GI-682, connecting Blanes and Palafolls, as the DTM does not account for the existing culverts located under the road. That way, it was decided that it was needed to improve the resolution of the mesh on the area concerning the road GI-682, but this would translate into a higher computational cost, as the increase of elements that it would pose would decrease notably the efficiency of the model.

In that sense, it was also decided to crop the model, reducing the catchment studied by taking into account the area affected by the flooding during the storm Gloria instead of a bigger area as done in the previous model, hoping that this would reduce the computational costs, or, at least, counterbalance the loss of computational efficiency due to the augmentation of resolution in the area of the blockage of the flooding due to the road. The resulting mesh size distribution is presented in the figure below:

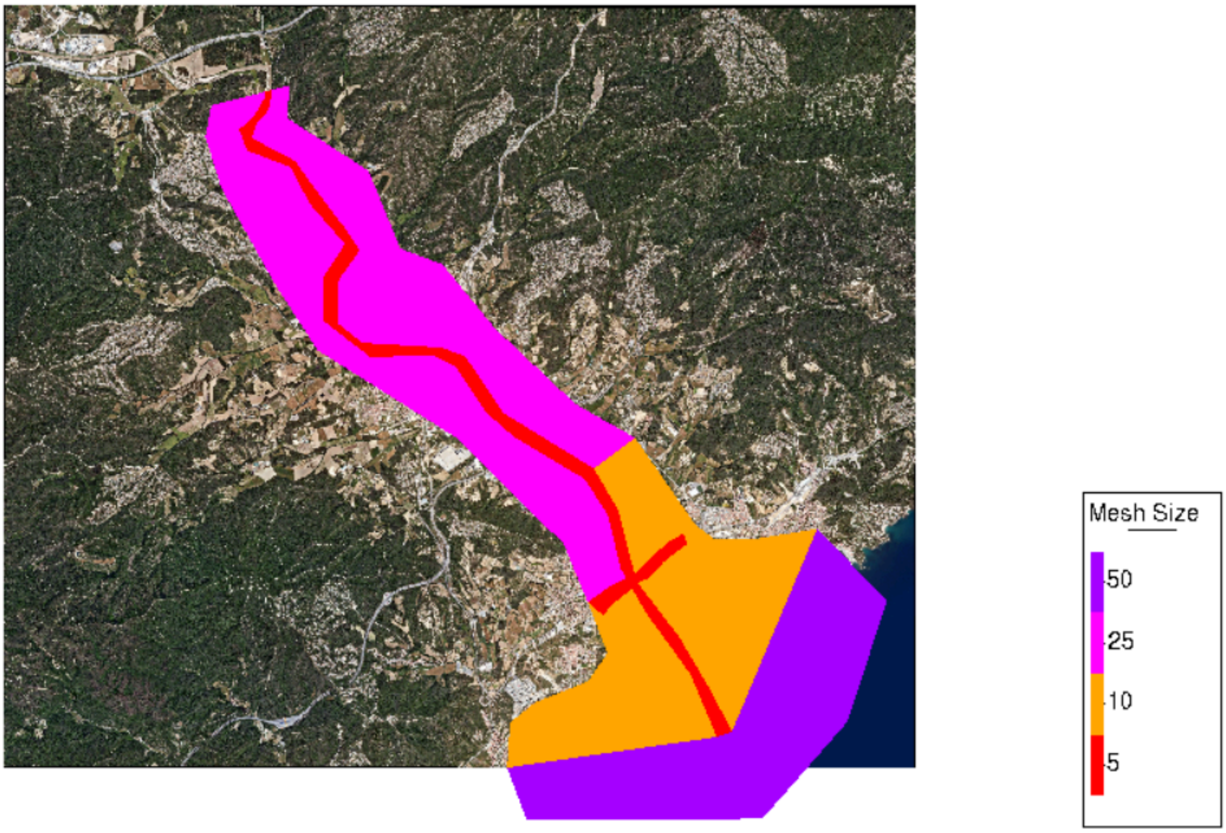

Figure 7: Mesh sizes of the new Iber model.

However, the cropping of the model and the augmentation of the meshing resolution in the conflictive area, was only the first step. That way, it was followed by the exhaustive study of the area, by the aid of Google Maps, in order to locate the existing places in which culverts are located but they are not considered in the DMT provided.

In that sense, the following points were located:

Figure 8: Location of culverts and other existing water bypasses not detected by the DTM.

That way, as it can be seen, there are two major actuation areas, one located on the left bank of the river and one located on its right bank. Its absence in the DTM caused the water to stagnate on the northern part of the GI-682 road, containing the flooding of the area. In order to remedy that, there was the need to create a way for the water to pass through the described road.

Due to the difficulties that the initial option of modifying the shapefile presented, it was decided to alter the meshing scheme in order to account for these existing bypasses. The methodology used to do so was, in fact, quite simple: with the meshing of the model tilted, in order to better see the elevation problems, points before and after the blockage were identified, writing down its respective altitude. After this, the theoretical altitude of the existing culverts and tunnels were approximated according to the data taken. With it, the altitude of the points related to a culvert was changed in order to account for the different bypasses, creating trenches along the road.

Below it can be seen the modifications done in the mesh in case of the actuation area related to the area of actuation in the right bank of the river:

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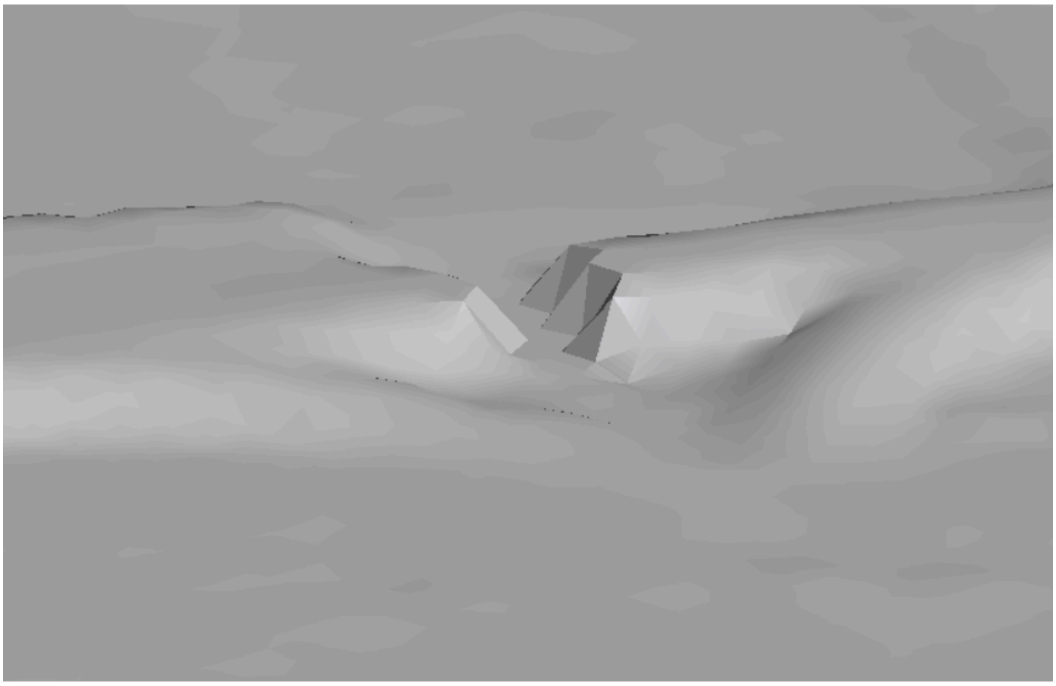

Figure 9: Modification of the mesh provided from the DTM in order to account for existing culverts.

After all these different processes altering the mesh in order to further adapt the model to the necessities of the problem, it was considered enough accurate, balancing both the quality of results and the computational cost needed (specially due to the time concerns of this project), considering it good enough in order to obtain the desired results.

2.2.2 Modification of the land uses considered

Apart from that, the other major actuation to be done in order to refine the first model obtained with Iber was related to the land use distribution of the soil.

In order to improve the overall quality of the model generated, it was decided to use the automatic assignation option provided with Iber, in order to extract, directly and in a much more reliable and accurate way, the land uses of the soil, needed for the computation of the Manning coefficient.

There was, however, one major downside of this process, and the main reason it was avoided in the first place: although the landuse data was accessible, there were too many categories considered, making the comprehension and discussion of results and the overall analysis of the problem too complicated.

To remedy that, the land-use data was modified in order to merge different types of land use into 9 different categories:

- River
- Urban vegetation
- Concrete
- Residential
- Sports areas
- Agroforestry areas

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- Green urban areas
- Beaches

The final layout of landuse distribution can be seen in Figure 9:

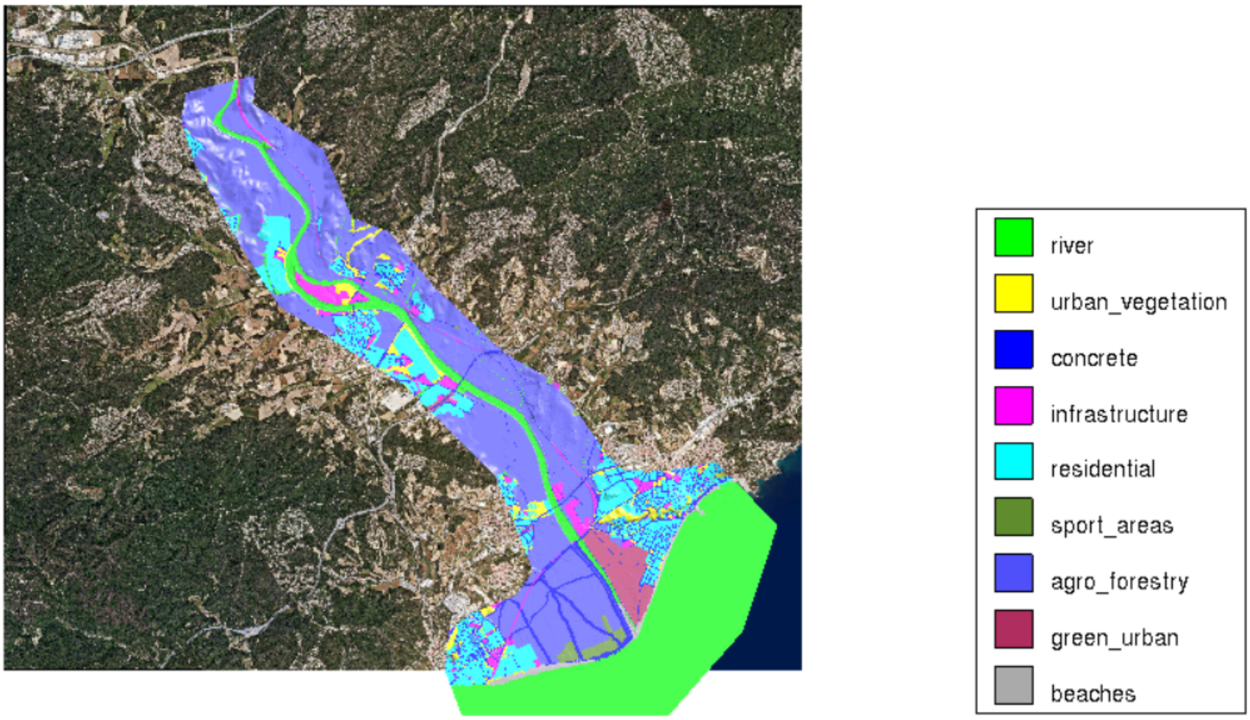

Figure 10: New land use distribution proposed.

It should be noted, however, that there were areas outside the landuse data provided that were included in the model, mainly the sea areas, which are however considered on the model. That is why, before the automatic assignation was done, a first initial assignation was manually made, assigning all the polygons as a river, to avoid null areas which could cause an error during the computation of the model.

2.2.3 Timestep modification

Finally, the timestep was also adjusted from the previous iteration. The timestep on the original simulation was set to 2 hours, with reductions in the computational demand being the intent behind the decision. However, when exploring frame by frame results of the flooding, the resolution of this selection was found to be too coarse. Not enough resolution was provided to fully understand the peak of the flood event, and to understand the extent and spatial distribution of the flooding given its flash flood nature.

This is presented in the below figure 11, showing two consecutive timesteps with too great of a difference to appropriately infer hydrodynamical processes accurately. The timesteps were therefore reduced to 1 hour (3,600s) from 2 hours (7,200s) for future simulations despite coming at a slight computational cost.

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Figures 11 and 12: Simulation results showing too high of a variation between two consecutive timesteps ; t =194400s (left) and t = 19800s (right).

2.3 Updated model results

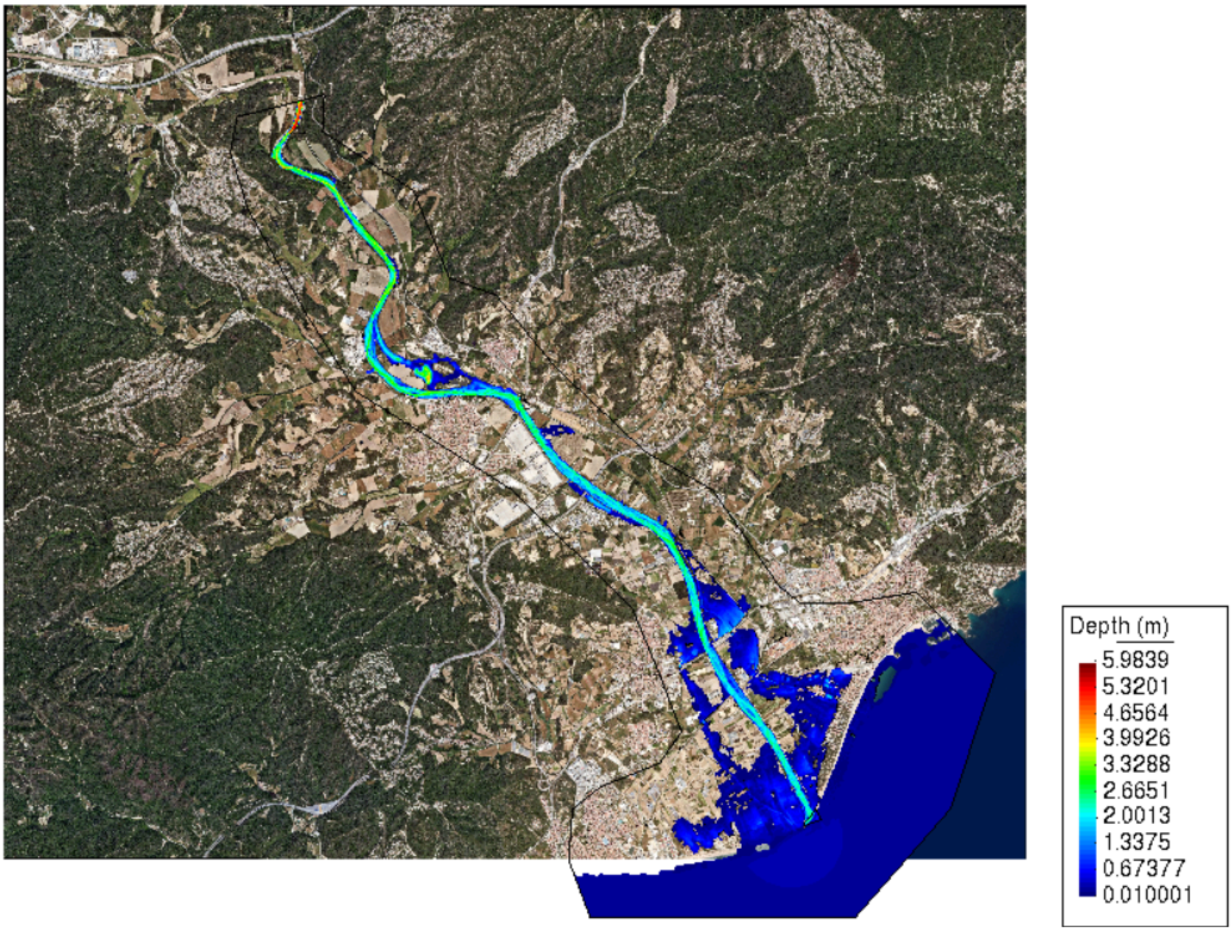
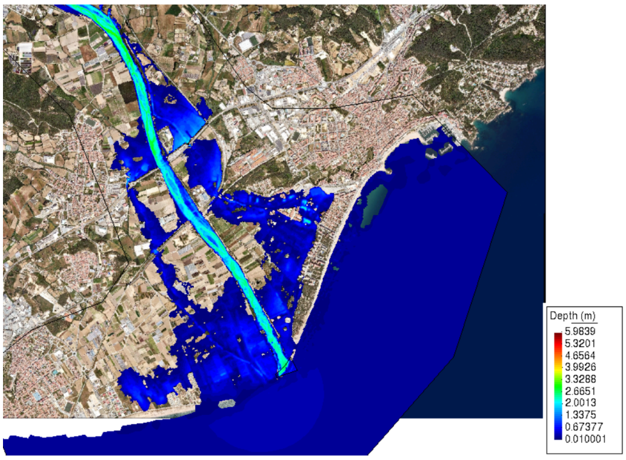
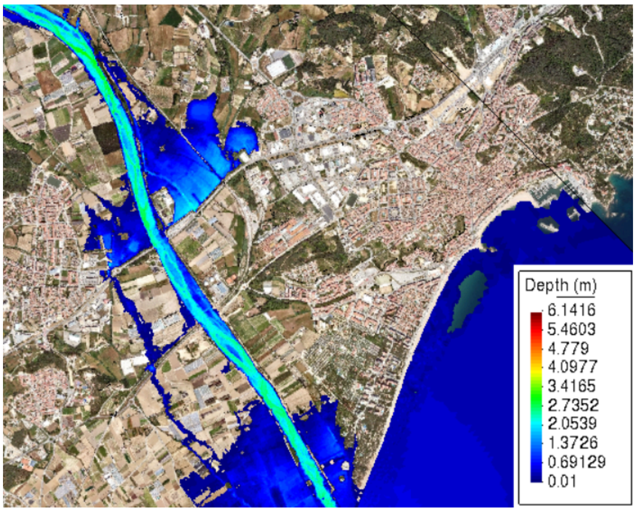


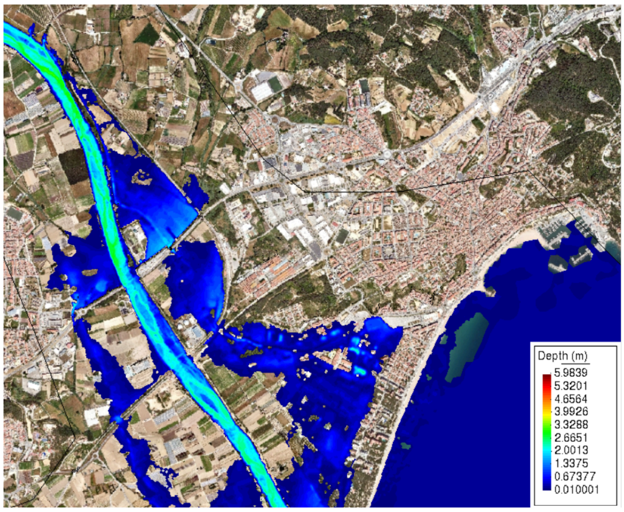
Figure 13: Updated hydraulic model created with Iber. Maximum water depth.



Figures 14 and 15: Comparison of results for the updated Iber model (left) and the simulation shown in the HydroEurope Project webpage (right).

2.3.1 Comparison with initial results





Figures 16 and 17: Comparison of results for the updated Iber model (left) and initial Iber model (right).

2.3.2 Additional notes from the updated model

One of the many functionalities that Iber has during the hydraulic modelling stage is the direct production of flood hazard maps of the event, according to the criteria used by the Agencia Catalana de l'Aigua (ACA). In that sense, results obtained are shown below:

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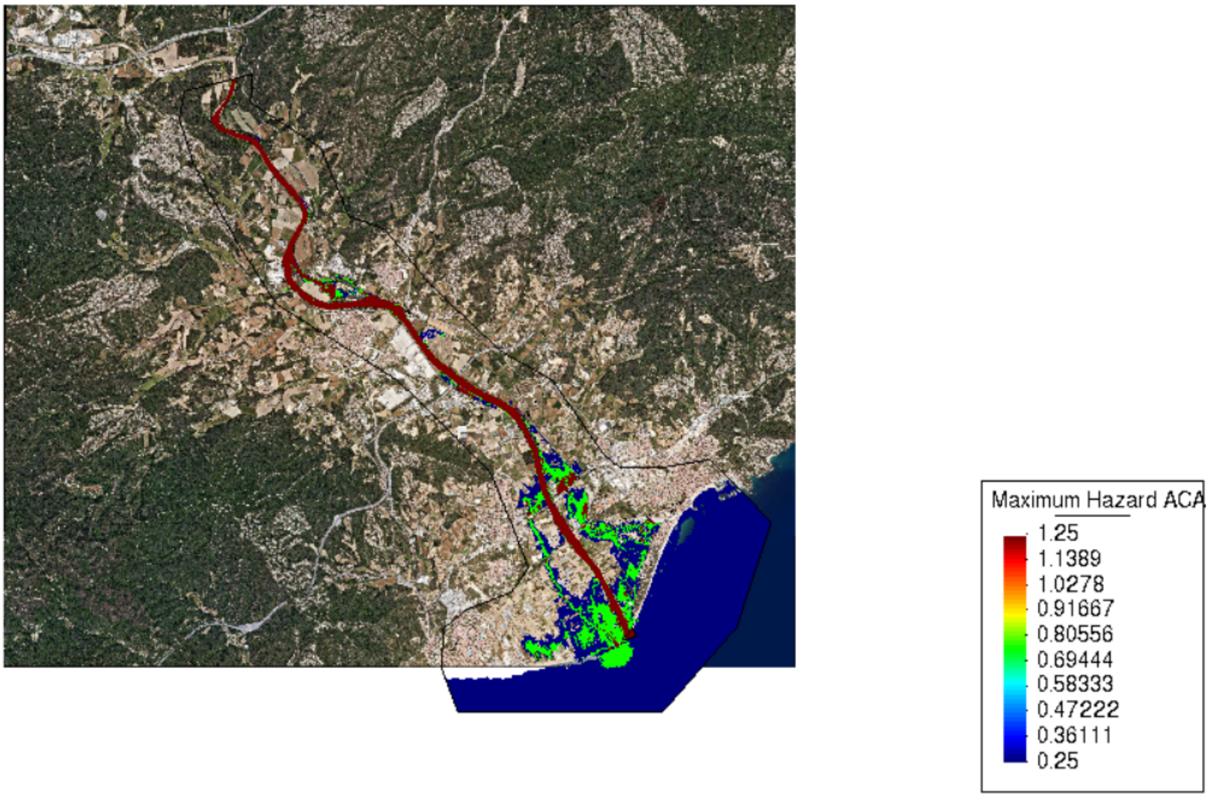

Figure 18: Map of Maximum Hazards generated by Iber.

The methodology used by ACA in order to assess flood hazard and create flood hazard maps is described in the document *Propuesta de mínimos para la realización de los mapas de riesgo de inundación. Directiva de inundaciones - 2º Ciclo,* published by the *Ministerio para la Transición Ecológica* (MITECO).

3 Overview of the Telemac hydraulic model

3.1 Initial model

This model refers to the one described during the Report 2 (Team 01: Report Week 1).

3.1.1 Overview of the first modelling attempt

In TELEMAC, hydraulic modeling can be performed in either steady-state or unsteady mode, depending on the nature of the flow being simulated. A steady-state model assumes that flow conditions, such as discharge, velocity, and water depth, remain constant over time. This type of modeling is useful for analyzing equilibrium conditions. It is computationally simpler and requires less simulation time compared to unsteady modeling. An unsteady model, on the other hand, accounts for time-dependent variations in flow conditions. It simulates changes in discharge, water levels, and velocity over time, making it essential for studying dynamic phenomena like floods. While more computationally demanding, unsteady modeling provides a more realistic representation of natural water systems.

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For this second model, we need the simulated hydrograph derived from the HEC-HMS results. This provides much higher flow values than those observed. We should therefore see a significantly higher flood than that of the Iber model. The results of steady-state modeling were discussed in the previous report. Last week, the modeling was wrong and unrealistic, with the river height at around 30 m, which is totally impossible. The error stemmed from the use of the wrong formula in TELEMAC. Instead of 3 for the Strickler coefficient, it was 4 for the Manning coefficient. The result was impossible because Strickler's coefficient is 1 over Manning's.

3.1.2 Key findings and limitations

We now turn to the results of unsteady-state modeling. The simulated flow is much higher than that of the previous model. The rise in water level follows a gradual evolution in line with the hydrograph: for a large part of the time, the river remains in its bed with water heights of around 2.5 m. When the hydrograph peaks, the river begins to overflow its banks. The second branch of the river also fills up when the first bed reaches a significant water level. Water accumulates in the lower reaches of the river, where the topography is lower and the water can no longer flow efficiently. The river's second bed also quickly becomes saturated as flow increases. Downstream homes and businesses are at greater risk, as they can be submerged by up to 1.2 m of water, causing considerable damage. However, despite the high water level, the riverbed manages to contain the flow upstream, limiting overflow in this area.

This downstream flooding was localised and contained largely due north of the GI-682 raised highway, indicative of a potential physical barrier obstructing any further flow. This was further investigated and unveiled a key limitation in the current model setup. In this area, the DEM and consequential mesh takes the highest point in the terrain for its reference. Any areas in which there is area below the underpass is not picked up by the model, and is therefore represented as a solid obstructive area where in reality, flow would be able to freely move along the subsurface to the otherside of the highway without the requirement to meet the elevation of the summit of the highway.

3.2 Model refinement

3.2.1 Modification of the mesh

For TELEMAC, a similar technique has been used compared to the Iber model. However, we note that the model is inconsistent at one particular point, where water stagnates when, in reality, it should flow. This is mainly due to the presence of a freeway crossing the Tordera on a bridge. As a result, the modeled topography is higher than it should be at this point, preventing natural stream flow. In reality, however, underneath this concrete structure is a railroad track and an additional passageway for cars. This element can be integrated into the BlueKenue modeling. To do this, it is necessary to modify the mesh by adjusting the topography at certain points. One method is to average the terrain values before and after the elevation to be corrected.

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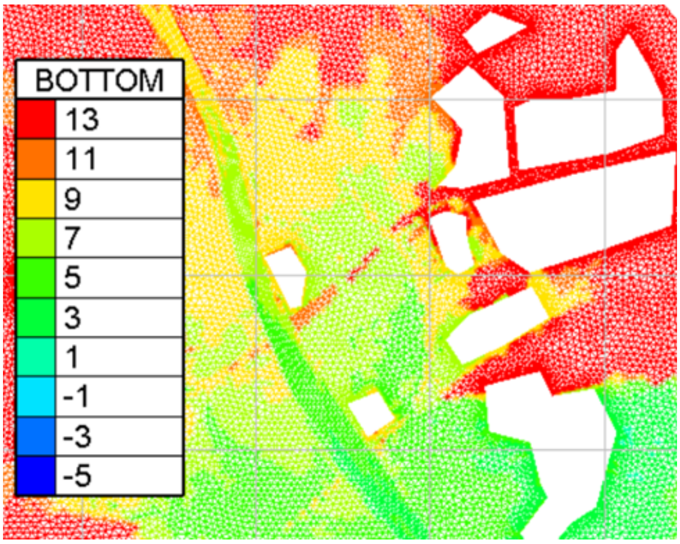

Figure 19: Mesh with the new topography

To overcome this problem, the creation of culverts is necessary, as explained in the section on Iber. The topography of the new mesh has been modified, with the creation of two openings that act as culverts. These will allow water to flow more smoothly, facilitating its conveyance to the sea, making our model more realistic and faithful to real-life conditions. Consequently, it is imperative to redo our simulations taking these new parameters into account, as they significantly influence our dynamic simulation (unsteady simulation).

3.3 Updated model results

In the downstream section, the results are significantly different. While the flow and water levels in the river remain broadly similar, the differences are mainly in the spread of the flooding. The surface area affected is no longer the same: the water, which was previously blocked before the bridge, now flows through the culvert, allowing a more natural spread of the flow.

This modification has significantly altered the hydraulic dynamics of the system. The culvert improves the hydraulic connectivity between upstream and downstream, reducing water stagnation and preventing excessive accumulation before the bridge. As a result, the velocity of the flow changes, potentially accelerating the flood propagation in some areas. The flood peak may also be reached earlier in the downstream section. Additionally, the impact on flood areas is notable. The redistribution of water means that while some previously flooded zones may experience reduced water depths, new areas in the downstream section are now at risk. Infrastructures such as residential areas and agricultural land close to the coast could suffer from increased flooding due to altered flow patterns.

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Figure 20: Flooding Map of the Tordera

In Figure 20, the velocity is higher in the Tordera riverbed, and as the water leaves the channel, its speed decreases significantly. Floodwaters spread at velocities of less than 1 m/s, compared to an average of 4 m/s within the riverbed. A notable difference in velocity is observed in the area near the culvert. Since the flow can now pass through two distinct points, water accelerates towards the culvert, improving drainage efficiency. This modification alters the flow distribution and could influence sediment transport and deposition patterns, potentially reshaping the flooded areas over time. A hypothesis can also be made regarding water pollution transport. If a pollutant were introduced into the river, its movement toward the flooded areas would be slower due to reduced velocity outside the riverbed. However, the modification of the flow paths could increase the surface area impacted by contamination, affecting a larger region than before. Further investigation could assess whether pollutants accumulate in low-velocity zones, leading to long-term contamination risks and evacuation toward the sea.

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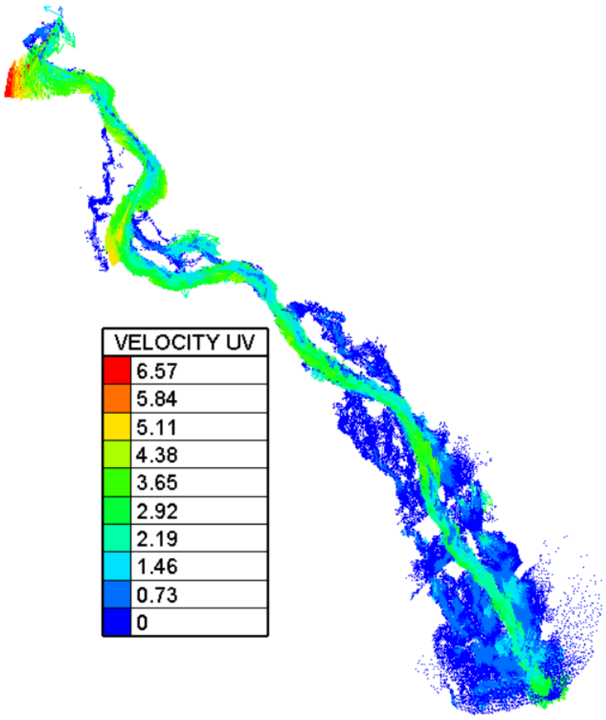

Figure 21: Velocity of the water during the peak of Gloria's events

3.3.1 Comparison with initial results

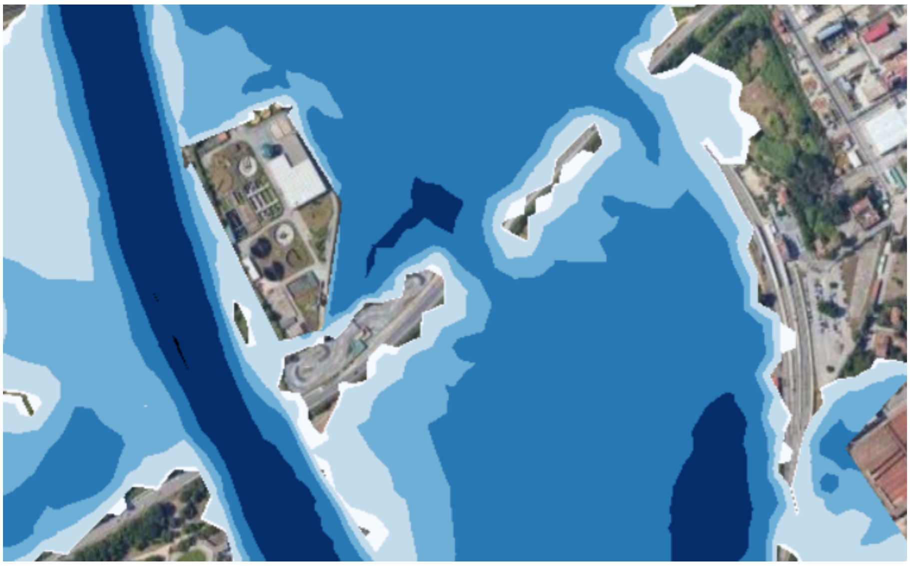

Figure 22: Culverts under the road

A comparison with real-world observations would be useful to validate these findings. Historical flood events, topographic surveys, and hydrological measurements could help assess whether the updated model better represents reality. Further adjustments, such as refining the culvert's dimensions or incorporating additional drainage structures, could enhance the accuracy of the simulation. On the figure X, the buildings are not underwater, thus our simulation computes in a correct way.

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4 Hydraulic modelling. Comparison of scenarios.

This is the map of the variation of flood every three hours since peak flood (graph A) (graph B presents the flood extent from peak flood three hours, graph C presents the flood extent from peak flood six hours, etc.). It is clear to show the decrease of flood and variety of flood extent and recession.

Graph A illustrates the peak flood, which is the maximum inundation extent when the flood occurs. The gradient of blue colour means the different depth of water. The dark blue represents the maximum depth, which is five or over five meters. The light blue shows the minimum depth, which is 0.025 or less than 0.025 meters. The flood mainly impacts the river and plain, while extending to urban and coastal areas.

The graph B to E presents the evolution of flood extent after peak flow. As the time goes by, the floodwater gradually recedes whilst the inundation area and depth all decrease.

It is evident that when the flood reaches its peak, the river bank and low-elevation urban areas face severe risks of flooding and damage. The deepest areas are concentrated on the river channel and coastal region.

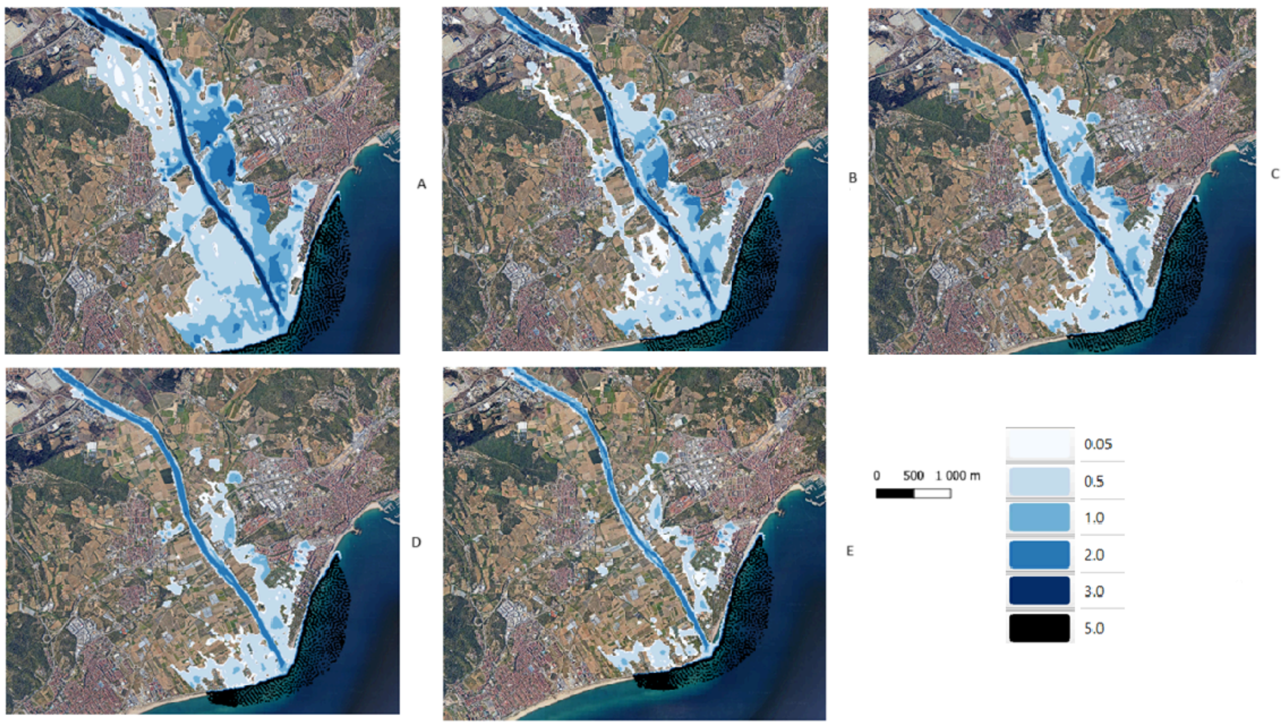

Figure 23: Comparison of flood extend and recession every three hours in meters.

During the flood water recedes process, the inundation areas are reducing and the shallow water was the first to dry up. However, there are some areas that still have standing water, which means the impact of flooding still exists.

Using a simulated hydrograph with higher values than those observed can lead to significant differences in the visualization of results, particularly with regard to the intensity and extent of modeled phenomena. A simulated hydrograph that generates flows higher than those observed in reality can lead to an artificial increase in the volume of water in the model, which can induce more severe flooding and greater expansion of the affected areas. This difference is visually reflected on flood maps, where the flooded area is larger and the water level higher. In contrast, an

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observed hydrograph, reflecting actual measured flows, will show a more moderate distribution of water heights, offering a more faithful representation of actual conditions. Consequently, viewing simulated results with an overestimated hydrograph could lead to erroneous conclusions as to the extent of the flood risk and its impact on infrastructure or residential areas. It is therefore essential to properly calibrate simulations so that results correspond to actual observed conditions, thus guaranteeing a realistic representation of hydrological phenomena.

Simulation results reveal significant differences between Iber and TELEMAC, both in terms of flow dynamics and pollutant dispersion.

From a hydraulic point of view, Iber is based on a more simplified approach, using numerical schemes adapted to shallow flows and fluvial environments. TELEMAC, on the other hand, offers a more advanced resolution of the Saint-Venant equations in 2D, enabling more detailed consideration of turbulence effects and the complex interactions between the riverbed and the flow. This difference translates into variations in the distribution of water heights and flow velocities, directly influencing the extent of flooding, in addition to the difference in hydrographs. Another important distinction is the inclusion of infrastructure. TELEMAC enables more detailed representation of structures such as bridges and culverts, which influence water flow and stagnation. In Iber, the impact of these elements may be less marked due to the spatial resolution and numerical schemes employed. As a result, differences in flow velocity and water height have been observed around infrastructure zones, which may influence the accuracy of flood modelling.

5 Water quality model creation

5.1 General approach

As told in subsection *1.2 Background on water pollution*, the Blanes WWTP is the main focus of concern on the area for water quality in case of a flooding event, as, if flooded, all the wastewater contained could spill to the catchment and pollute the waters.

In that sense, in order to make a water quality assessment of the area, an arbitrary discharge point was taken near the WWTP, creating a spill during the flooding events.

5.2 Iber Model

5.2.1 Basic data and model creation

Given the possible impacts and variation of pollutants that may access the river, a number of fluvial pollution metrics were measured. These metrics were:

- Dissolved Oxygen: Indicating the rivers ability to support aquatic life.
- CBOD (Carbonaceous Biochemical Oxygen Demand): Measures the oxygen present for microbial decomposition of organic matter.
- Nitrogen (NH_3 + NO_3): Contributes to eutrophication and excessive algal growth.

It is important to note that, apart from that, in the Iber model coliforms were also analysed, as it represents a typical water quality parameter to monitor in case of wastewater discharge.

For the upstream boundary conditions, values for each of these pollutants were given based on approximations for the catchment. Initial conditions of the entire river reach were set to mirror the natural baseline conditions of the levels of pollutants. These values were again taken from basic approximations for similar rivers. The below table presents these initial values.

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	Dissolved Oxygen (kg/m3)	CBOD (kg/m3)	NH3 (kg/m3)	NO3 (kg/m3)
Upstream boundary conditions	0.0083	0.002	0.0002	0.0005
Initial reach conditions	0.0083	0.002	0.0002	0.0005

The wastewater source was then incorporated into the simulation, representing the expected pollutant load entering the river adjacent to the identified wastewater treatment plant. This was designed to replicate conditions during a flooding event. To further enhance the realism of the simulation the pollutant discharge was set to occur at **170000s**, aligning with the onset of the flood event.

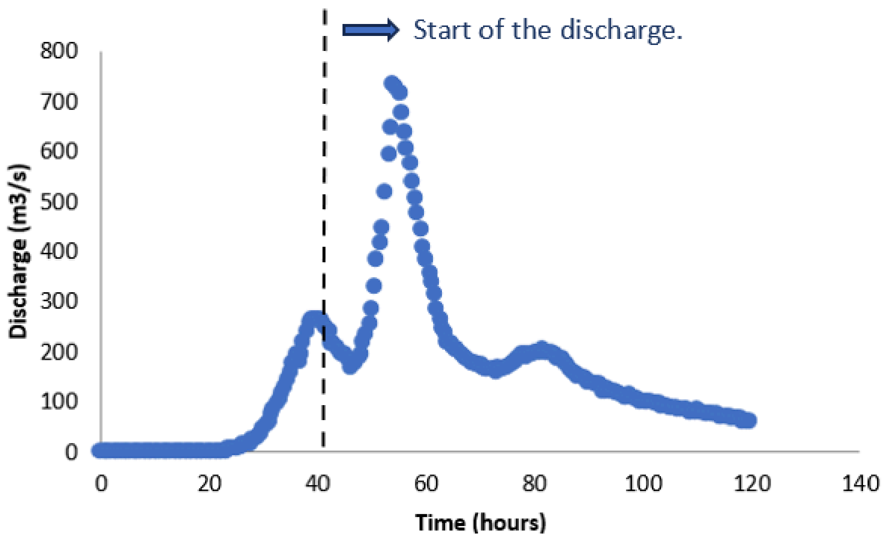

Figure 24: Hydrograph showing the starting point of the discharge considered.

The amount of pollution from the wastewater treatment plant was determined by ____. It was attributed a discharge of 0.328 m3/s and a temperature of 25 C to replicate real conditions of a spill from a wastewater plant. The below table presents the pollution discharge amounts added at the pollution event.

	Dissolved Oxygen (kg/m3)	CBOD (kg/m3)	NH3 (kg/m3)	NO3 (kg/m3)
Pollution event	0.0083	0.08	0.015	0.0005

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5.2.2 Assumptions, simplifications and other remarks from the Iber water quality model

Although the initial plan was to compare the two different scenarios obtained with the hydrograph created by the observed data of Gloria Storm and the hydrograph obtained by the simulated data created during the HEC-HMS hydrological modelling, this was not feasible due to time constraints. In that sense, it was proposed that, due to the high uncertainty of the problem, it may be a better approach to create a third scenario that could prioritise computational efficiency over accuracy of results, as, again, due to the high amount of uncertainties of the case of study, there is no need for higher accuracy on the results.

In that sense, a new model was created for the water quality analysis, using hypothetical values (although with a physical meaning and which could be perfectly possible in a wastewater discharge of these characteristics. During the configuration of the model, the main approach was to opt for a coarser model, in order to gain more efficiency during the computational calculations process, and with less timesteps, finalizing the modelling of the scenario when it accomplishes steady state. Peak discharge was also limited, using a value of 500 m3/s.

5.3 Telemac Model

The TELEMAC and Iber simulations were carried out by integrating the same four types of pollutants in order to assess their dispersion and impact on water quality. The main difference is that one has been simulated with the true hydrogram and the other by the one from HEC-HMS. The study of these pollutants enables us to better understand their transport and evolution in the aquatic environment, particularly as a function of simulated hydrodynamic conditions. These results are essential for anticipating environmental risks.

To maintain consistency, the same pollutant metrics and baseline conditions were used throughout the simulation. In the modeling process, a specific node number 70681 was designated as the global reference for the source location, ensuring a precise definition of the pollutant discharge point. Additionally, a linked text “Source.txt” file was implemented to incorporate the concentration and flow rate data, allowing for an accurate representation of the pollutant release dynamics. With these modifications, in the unsteady case, we can effectively visualize the evolution of the four pollutants from the source point over time. This approach enables a more comprehensive analysis of pollutant transport and dispersion under varying hydrodynamic conditions.

6 Water quality modelling: Analysis of results

6.1 Iber model results (observed data)

After finalizing the model specifications, we ran the Iber model for the water quality analysis of specified pollutants, these pollutants were selected based on the tutorials provided to form the model, and the purpose of this was to train our model on a pollution scenario therefor we took simplified values and limited pollutants, which can be increased more in the future. The figures 26 - 29 show maps obtained from Iber for the different pollutants and their concentration spreads during the flood.

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Figure 25: Water quality Iber model. Coliforms.

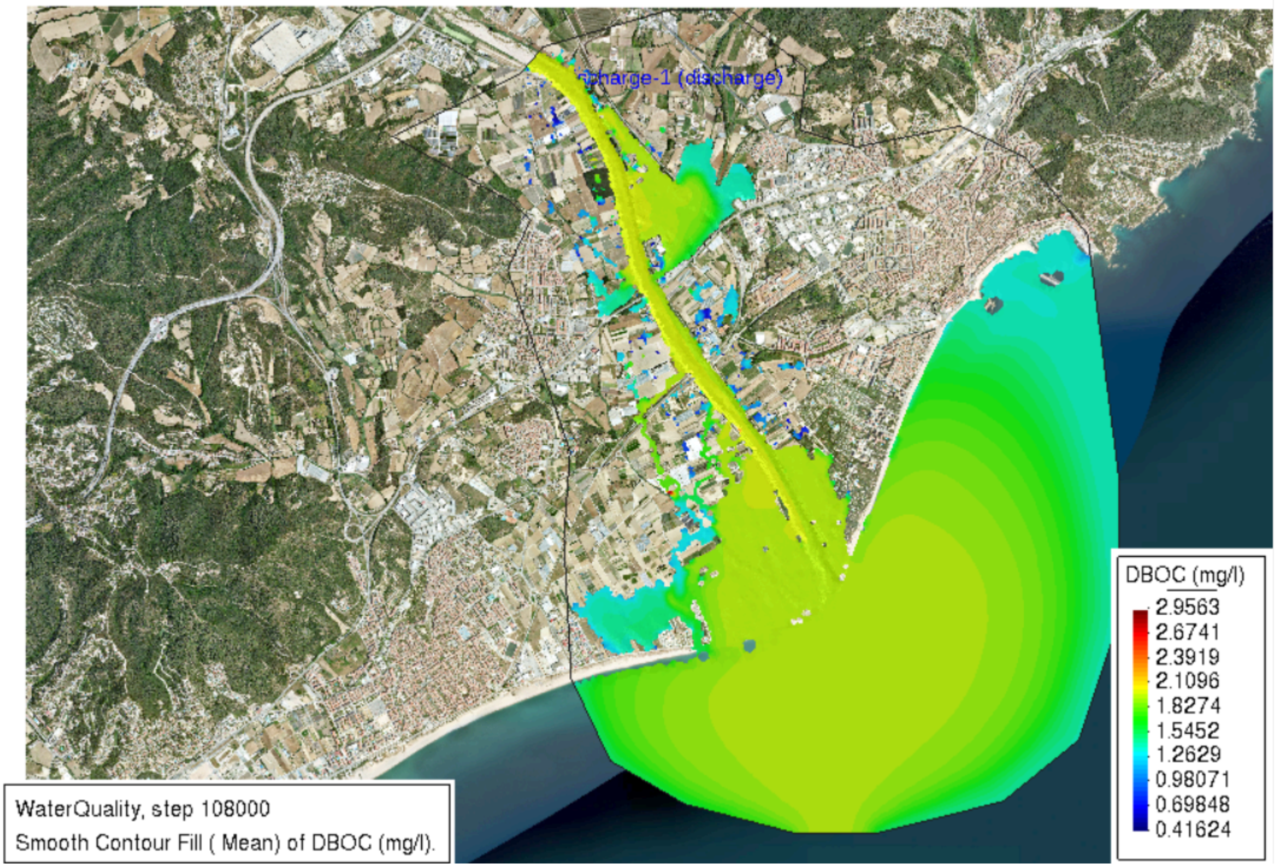

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Figure 26: Water quality Iber model. CBOD.

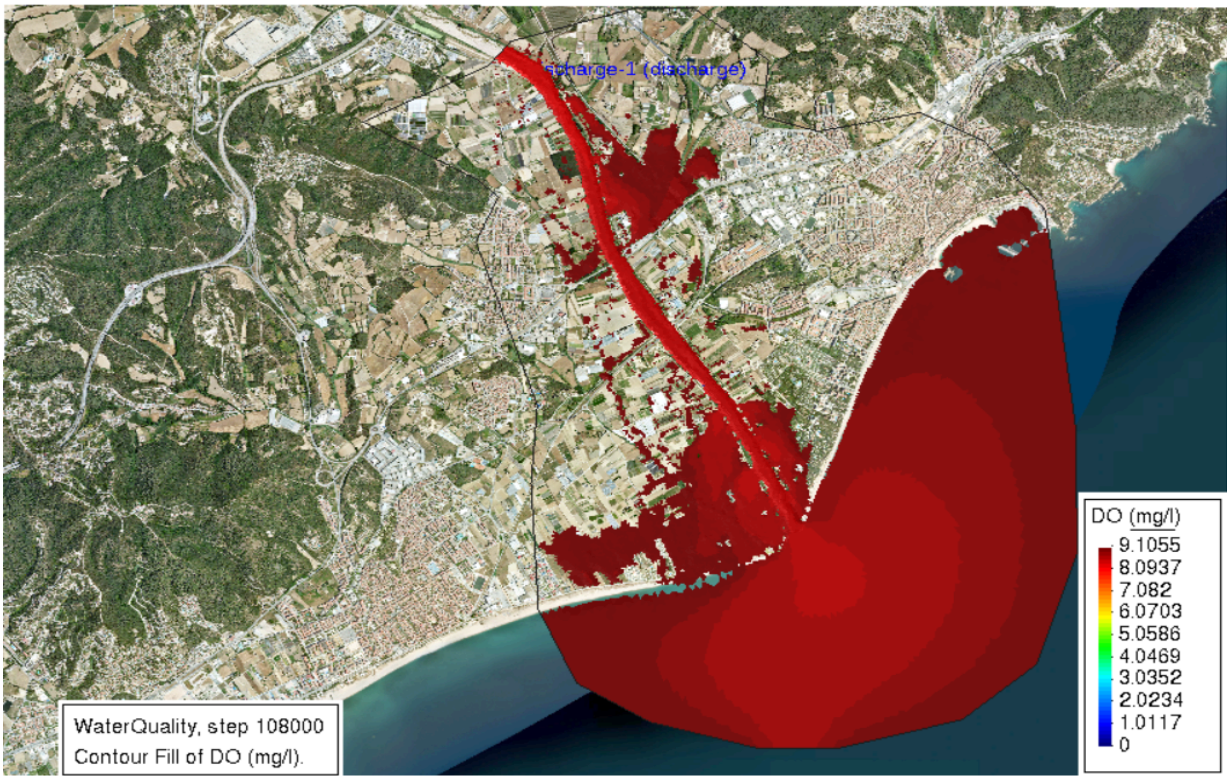

Figure 27: Water quality Iber model. DO.

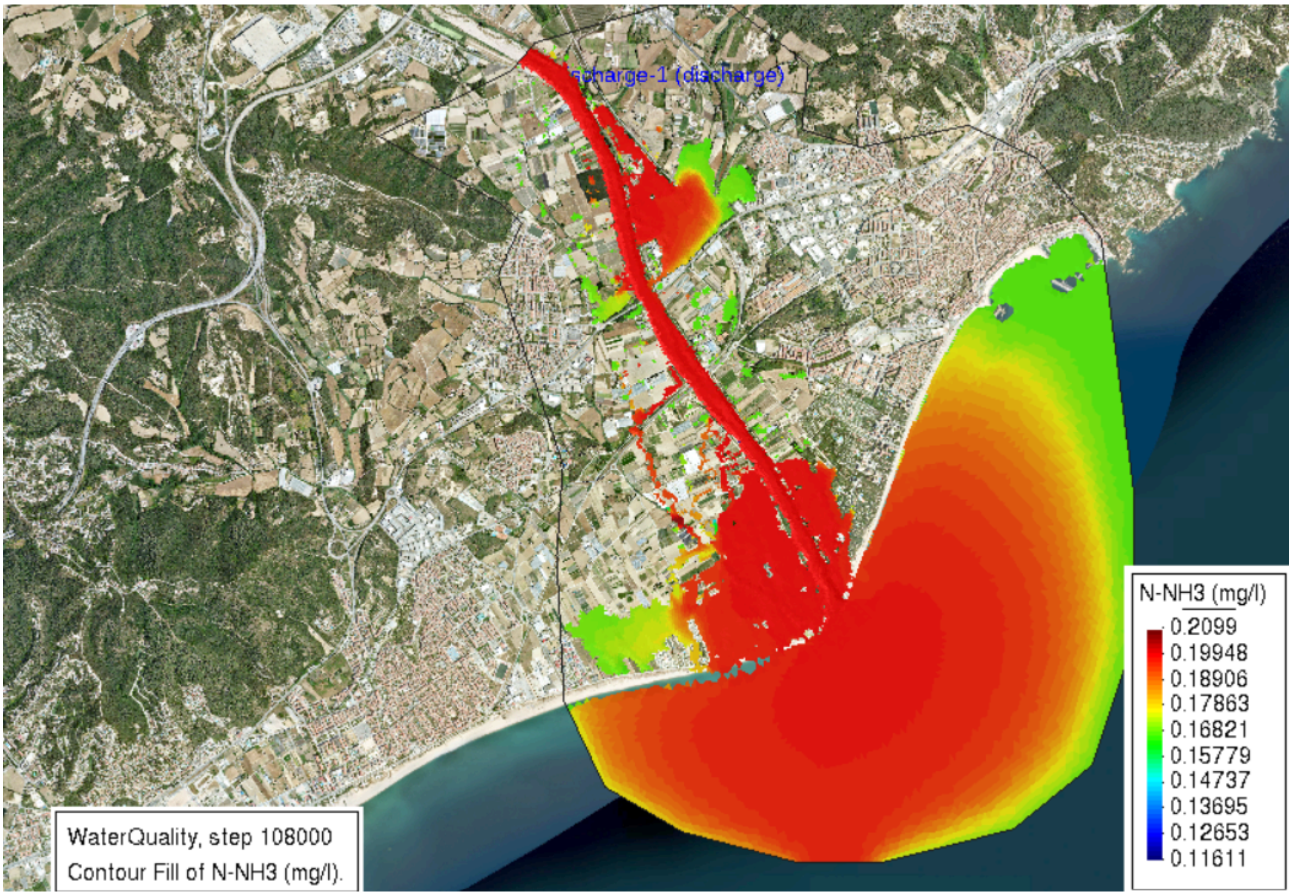

Figure 28: Water quality Iber model. N-NH3.

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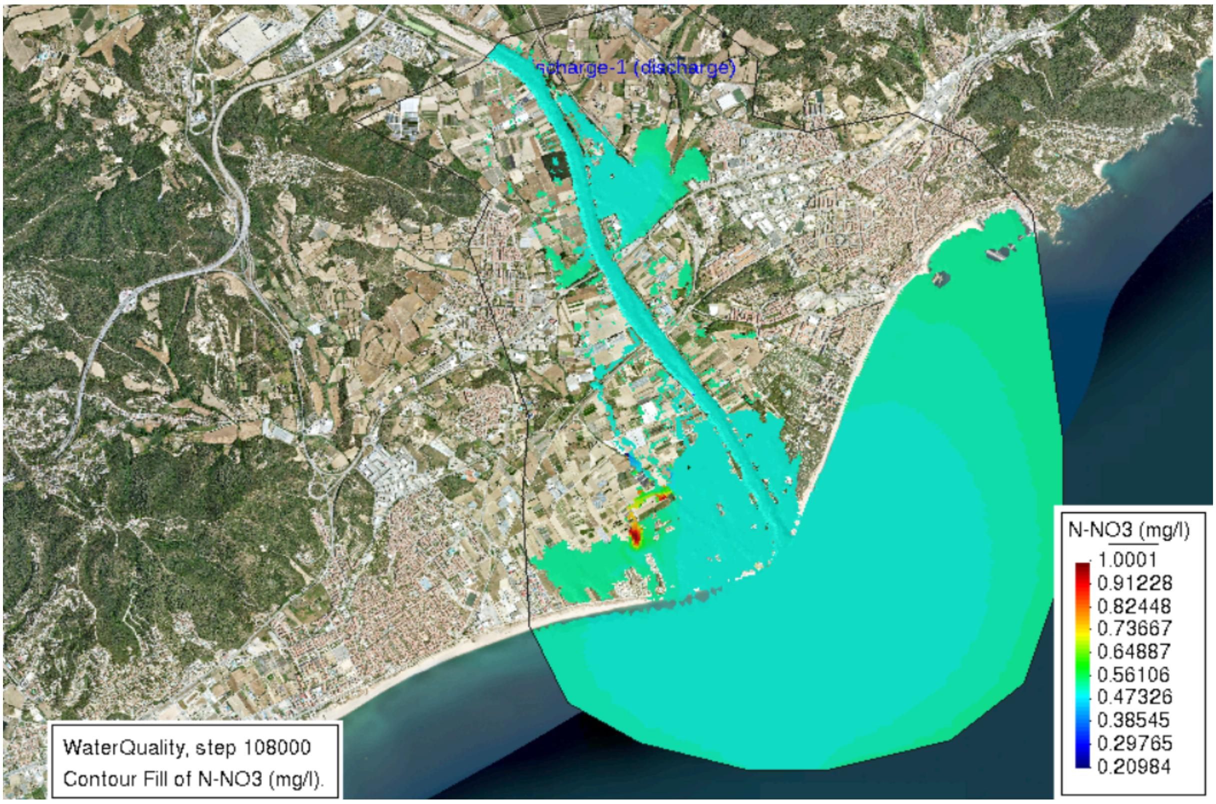

Figure 29: Water quality Iber model. N-NO3.

Pollutants	Observations	Reasoning/comments
Coliforms	The coliform values observed go as high as 3093 cfu/100 ml	Standard values range around 120-160 cfu/100ml, and these observed values are extremely high, which indicates high fecal matter that could be dangerous to human and ecosystem health.
CBOD	These range from 1.3 - 1.9 mg/l	These values by standards range from 2 - 5 mg/l, and our observed values show that it is normal
DO	Dissolved oxygen values range around 8.5 mg/l	The standard DO value is 3-8 mg/L and our observed values fall in between the range, which suggest good dissolved oxygen content, however the DO near the discharge is low as compared to away from the source, this could be as high coliform/bacterial content consumes more DO result in its decline of concentration in that area, but for concrete result, further analysis is required
N-NH3	Ranges from 0.1 - 0.2 mg/L	These values are within the range and very low.
N-NO3	Averages around 0.5 mg/l	These values are within the range and very low.

It is important to note that these input concentrations were assumed from tutorial/literature hence do not represent real world scenario, however it can be used to observed trends on how the ranges of the pollutants vary and ofcourse in training the model.

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6.2 Telemac model results (simulated data)

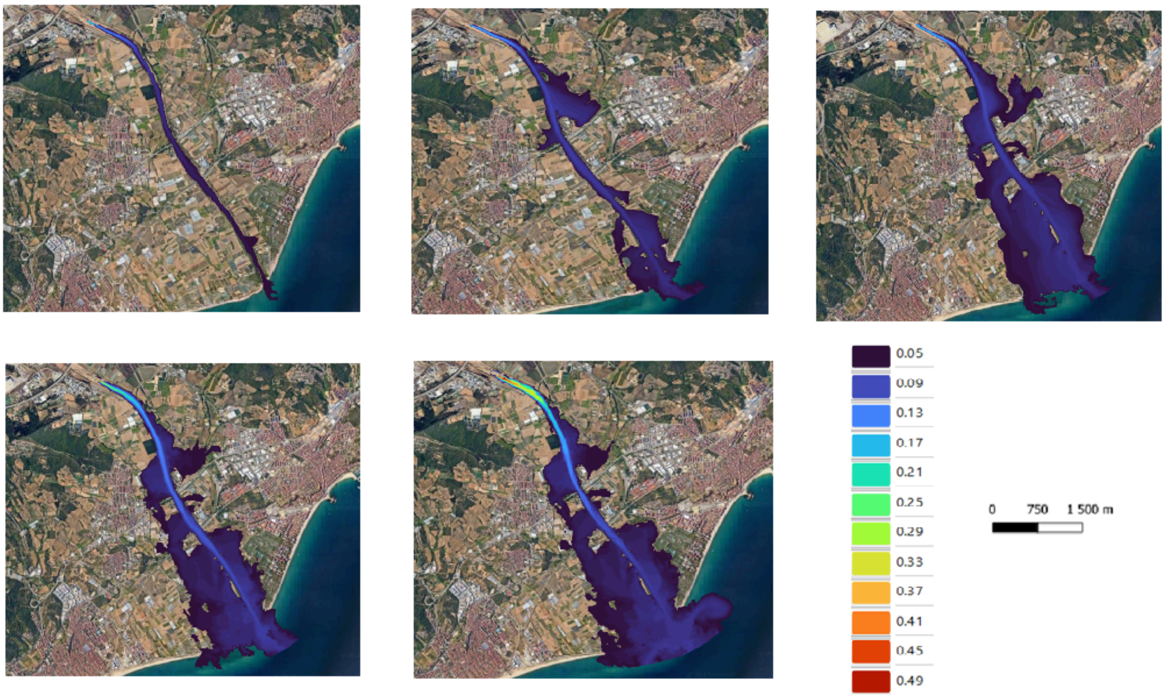

Figure 30 : Evolution of the pollutant CBOD during the flood in mg/L

Simulations carried out with TELEMAC and BlueKenue allow us to observe the evolution of several pollutants in the river and coastal system. The dispersion of contaminants varies according to their nature, hydrodynamic conditions and local topography. The results also show that certain stagnation zones are conducive to pollutant accumulation, particularly in areas with weak currents or near infrastructures such as bridges and culverts. Here, water flows more slowly, delaying the dilution of substances and increasing the risk of local pollution. From a spatial point of view, some pollutants spread rapidly into the sea, while others remain more concentrated near the river outlet.

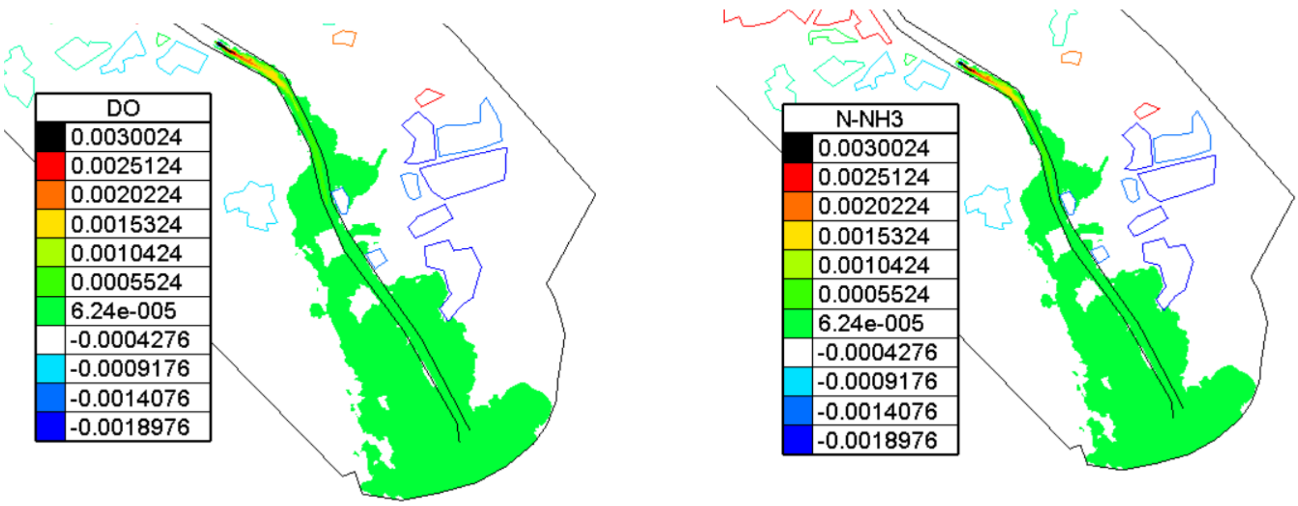

Figure 31 : Evolution of the pollutant DO(left) and N-NH3(right) during the flood in mg/L

Figure 32 : Evolution of the pollutants during the flood in mg/L

In the case of the last three pollutants, we observe identical concentrations, which could indicate a problem in our modelling. Normally, each pollutant should follow a different dispersion dynamic, influenced by its properties, such as solubility, degradation rate or chemical reactions in water. This concentration uniformity may result from incorrect parameterization of transport coefficients, errors in boundary conditions, or failure to take degradation processes into account. An in-depth analysis of the parameters used, and a comparison with real data, would help to identify the origin of this anomaly and improve the reliability of the simulations.

In each case, the models show that the sea has been contaminated and that the pollutant has spread over the entire water surface. Although the concentration gradually decreases as one moves away from the river outlet, the pollutant is still present throughout the coastal zone. This dispersion is influenced by marine currents, natural dilution and pollutant diffusion, but despite these processes, significant concentrations remain, which can have an impact on water quality and marine ecosystems.

A comparison between TELEMAC and Iber reveals differences in the modeling of pollutant transport. TELEMAC simulates a wider dispersion, suggesting more detailed consideration of diffusion and advection processes. Conversely, Iber shows a wider and more extensive dispersion, as it is based on simpler and less precise calculations.

6.3 Comparison of observed vs. simulated data

Before comparing the obtained data on observed and simulated flow of accidental pollution diffusion, it is important to note that the pollution maps generated from the models display five types of pollutants in Iber and four in Telemac. To ensure consistency and a meaningful comparison, we focused on the four common pollutants present in both models. This approach allows for a direct evaluation of their dispersion patterns and concentration variations across the two simulations.

We do not intend to compare the two modeling approaches directly, as they were conducted using different software. Instead, our focus is on analyzing the results obtained by comparing the

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observed data with the simulated data. This approach allows us to assess the accuracy and relevance of the simulations without being influenced by the differences in modeling methodologies.

Here is a comparative analysis of the water quality maps for different pollutants (CBOD, DO, N-NH3, N-NO3) between the Iber and Telemac models:

6.3.1 Comparison of Observed and simulated Data for Each Pollutant

6.3.1.1 Carbonaceous Biochemical Oxygen Demand (CBOD)

- **Observed Data Model**: The CBOD concentration from the Iber model shows clear dispersion of pollutants downstream from the wastewater discharge point. The spatial spread of contamination is extensive, with higher concentrations observed near the spill source.
- **Simulated Data Model**: On the Telemac model, in contrast, shows a broader diffusion pattern. The pollutant appears more diluted due to the different hydrodynamic conditions, particularly the simulated hydrograph used.
- **Comparison**: The observed data model results suggest more localized contamination, whereas Telemac indicates a wider spread. However, the ocean pollution seems higher on Iber which makes us think that there is a special interest in observing ocean pollution dispersion.

6.3.1.2 Dissolved Oxygen (DO)

- **Observed Data Model:** DO concentrations drop significantly near the discharge point, illustrating the impact of organic matter on oxygen depletion. The decrease in DO is visible in specific zones but stabilizes further downstream.
- **Simulated Data Model**: The Telemac model similarly shows DO depletion near the discharge but at a slightly different magnitude. The lower DO values extend over a broader area, indicating a different dilution effect.
- **Comparison**: Both models show expected DO depletion near the pollution source, but Telemac results extend further downstream. This suggests a more diffusive transport of pollutants with the simulated data.

6.3.1.3 Ammonia Nitrogen (N-NHO3)

- **Observed Data Model:** The Iber model highlights a clear increase in ammonia nitrogen near the wastewater discharge, with contamination reducing progressively downstream. The concentration remains relatively high close to the pollution source.
- **Simulated Data Model**: In Telemac, the ammonia nitrogen concentration appears to be more uniformly spread, with less noticeable high-concentration zones near the discharge point.
- **Comparison**: Iber suggests localized pollution accumulation, while Telemac presents a more homogenous dispersion. This difference may stem from how each model represents flow turbulence and pollutant mixing or from the difference between the observed and simulated data values.

6.3.1.4 Nitrate Nitrogen (N-NO3)

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- **Observed Data Model:** : The Iber model shows a defined pollution plume with nitrate spreading progressively downstream but still maintaining localized high concentrations.
- **Simulated Data Model**: The Telemac model suggests a much more uniform spread of nitrates, indicating a potential overestimation of diffusion effects.
- **Comparison**: The discrepancy in NO3 distribution between the models suggests differences in how pollutant transport is handled. Iber seems to provide more realistic localized contamination zones, while Telemac assumes a more even spread.

6.3.2 Accuracy of the Models and Key Findings

The comparison between observed and simulated data for water quality indicators (CBOD, DO, N-NHO3, and N-NO3) highlights key insights into the accuracy of the models in representing pollutant transport dynamics. The observed data indicate localized areas of high pollution concentration near the discharge point, with gradual dilution downstream. In contrast, the simulated data, particularly from Telemac, suggest a broader and more uniform dispersion, which may not fully capture the localized accumulation observed in reality. For CBOD and DO, the simulated data generally reflect expected trends, with oxygen depletion near pollution sources; however, the extent of the impact varies between observed and modeled results, suggesting potential differences in flow turbulence representation. The ammonia and nitrate simulations also show differences in spatial distribution, with observed data indicating more concentrated pollution zones compared to the more evenly spread contamination seen in the models. These discrepancies suggest that while both models provide valuable insights, refinements in pollutant transport mechanisms and calibration with real data are necessary to enhance their reliability. The observed data should serve as a benchmark for further adjustments to improve predictive accuracy and better represent real-world pollution behavior.

6.4 Limitations and uncertainties

One of the main limitations of this study lies in the comparison of observed and simulated data across two different modeling software, which introduces inherent uncertainties. The simulation process in HEC-HMS required significant time and data input, which may have influenced the accuracy and completeness of the results. Additionally, several assumptions were made during data preparation, and further investigation is needed to validate these assumptions and assess their impact on model performance. Another limitation is the fixed discharge source point used in the simulations—testing multiple locations would provide a more comprehensive understanding of pollutant dispersion dynamics. Moreover, incorporating pollution mapping through Waqtel (Telemac) could enhance spatial visualization and improve interpretation of pollutant transport. Lastly, verifying data accuracy through thorough documentation review remains essential to ensure the reliability of the input data and model outputs. These factors highlight the need for further refinement and validation to strengthen the study's conclusions.

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7 Conclusion

The analysis of flood maps and pollutant diffusion highlights key discrepancies between observed and simulated data, emphasizing the need for refinement in water quality modeling. Flood maps show significant variations in inundation extent and pollutant transport due to differences in hydrograph sources, with observed data revealing more localized contamination while simulated data, especially from Telemac, indicate broader dispersion.

This suggests potential overestimation of diffusion in the models, impacting pollution risk assessments. To improve water quality monitoring, reducing assumptions, increasing simulation time, refining boundary conditions, testing multiple discharge points, and validating results with real measurements are essential.

Future directions should focus on obtaining more accurate hydrographs for HEC-HMS, reassessing assumed parameters, testing different pollutant discharge locations, integrating pollution mapping with Waqtel in Telemac, and ensuring data reliability through thorough documentation review. These improvements will enhance model accuracy, providing better insights for pollution management and mitigation strategies. Thus, to improve the reliability of the simulations, a comparison with field data would be essential to properly calibrate the models and identify which one most faithfully reproduces the hydraulic and environmental reality of the Tordera.

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