Flood models of the National Cartography System for floodable zones vs. actual floods

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Hazard maps are one of the key tools for managing flood risk. They are so important that Directive 2007/60/EC on the assessment and management of flood risks and Royal Decree 903/2010 of 9 July, which transposes it into the Spanish legal system, actually devote one of the three phases in the planning process to drafting them.

The floodable zones calculated have serious limitations with respect to the flood that would occur in a specific event and, even though current techniques and models are very accurate, a real-life flood in an event can vary considerably relative to what has been calculated.

Whatever the case, floods happen and, when there is a hazard map for a specific place that suffers the event, it can be calibrated by taking data in the field and identifying any evidence that enables demarcation of the extent of the flood, or even determination of the depths which it has attained.

The maps include geographic zones that are capable of being flooded under scenarios of a low, medium and high probability of flooding, which, in Spain, have been specified with return periods of 500, 100 and 10 years respectively. A return period of n years for an event means that, on average, it is exceeded every *n* years. The probability of this event being exceeded in any year will be 1/*n*. Thus, for example, a flood with a 100-year return period is one which, on average, is exceeded once every 100 years and every year has a probability of occurring of 1/100, i.e. 1%. Drawing up these maps is basically done by means of a hydrological study and a hydraulic study. In the first case, an estimate is made of the flows which may come to run through a certain point of the watercourse being studied for each return period based on existing data sets of rainfall measurements and models which convert the rain into a flow for a specific basin. The hydraulic study simulates how this flow runs along the watercourse and, in the case of an overflow, along its banks. This is used to obtain maps that chart the area that would be flooded, the depth or level that the water would reach at each point and even the speed at which it would flow.

The floodable zones calculated have serious limitations with respect to the flood that would occur in a specific event and, even though current techniques and models are very accurate, a real-life flood in an event can vary considerably relative to what has been calculated. Firstly, it is not possible to take into account the effect of erosion, slides, sedimentation, etc. On the other hand, neither is it possible to take account of the effects which certain elements, such as fallen trees, vehicles or sediment carried along, might cause via obstruction and branching or leakage of the flow. Finally, in large floodable areas, where there are major urban settlements, the problems associated with managing to give a suitably faithful representation in the hydraulic model of all the artificial elements that have a bearing on the characteristics of the flow, as well as the computational limitations themselves which stem from a vast amount of data being processed, can also mean that the results of flooding diverge from those model-forecasted.

Whatever the case, floods happen and, when there is a hazard map for a specific place that suffers the event, it can be calibrated by taking data in the field and identifying any evidence that enables demarcation of the extent of the flood, or even determination of the depths which it has attained. Photographs and videos, the press, social networks and the internet can also be used. In this way, we can check on whether the model is valid. Nowadays, in certain favourable situations, it is also possible to take pictures of the flood in real time from the air using light aircraft, helicopters or drones, although, in the case of floods over a large area, these might be unable to fly over the whole flooded zone. The process be the other way around, using historical precedents of this kind to build up the model for a zone that has not yet been studied but where there has been flooding.

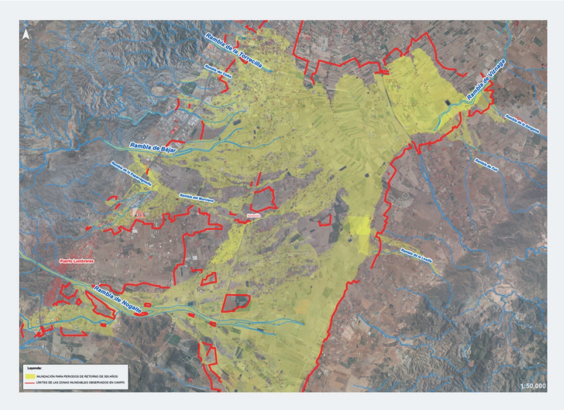

Figure 1. Puerto Lumbreras and Lorca. Comparison between the floodability model for a 500-year return period (in yellow) and the limits observed in the actual flood (in red).

Figure 2. Image from the satellite Sentinel (European Space Agency, or ESA) of the Cartagena countryside on 13 September 2019. Next to the sea is the population centre of Los Alcázares, with San Javier to the northeast and Torre Pacheco to the southwest.

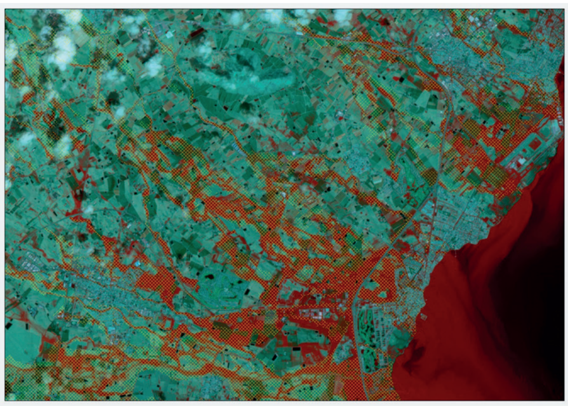

Figure 3. Image from the satellite Sentinel (ESA) of the Cartagena countryside on 13 September 2019, which has been altered by the OPH at the CHS and compares the flooded zone (in red) with the CHS model for a 50-year return period (using the yellow grid).

Following what has been known as the St Wenceslas flood of 28 September 2013, it was possible to do this with the maps drawn by the Segura Basin Authority (the CHS, for the Spanish) for the National Cartography System for Floodable Zones (the SNCZI, for the Spanish). Figure 1 shows a comparison of the floodable zone for a 500-year return period according to the model and, with red lines, the limits of the flooding actually observed between Puerto Lumbreras and Lorca.

Nonetheless, sometimes satellite images that cover wide areas can also become available. This was true for the floods in Murcia on 12 and 13 September 2019.

The image from the satellite Sentinel, belonging to the European Space Agency (ESA), captured the Cartagena countryside on 13 September 2019, as Figure 2 shows. In it, next to the sea is the population centre of Los Alcázares, with San Javier to the northeast and Torre Pacheco to the southwest. In Figure 3, which features some work done to the original Sentinel satellite image by the Hydrological Planning Office (OPH, for the Spanish) at the CHS to highlight the flooded zones in red, we can see the fit with the model made by the CHS for the SNCZI for a 50-year return period. In view of this, we can approximate the return period for the actual event at around 50 years. Even so, bearing in mind that the Sentinel image is at a certain specific moment and that it does not necessarily show the maximum extent of the flood reached, we can see slight differences between the model and actual events insofar that zones are apparent that were in fact flooded yet which the models do not show even for 500-year return periods. There can be several reasons for this besides the limitations of models themselves. It should be pointed out that the flooding in this zone is very much influenced by the rain in situ, in other words, besides the flows from upstream, by the large amount of rain that falls on the land and which, due to the minimal sloping, builds up rapidly. This effect is hard to model, which is why zones can appear that become flooded either in part or solely on account of the rain in situ. This can be seen from Figures 4 and 5, where it is clear that the zones that were flooded are at lower heights than the surrounding area itself, with a build-up of the rain falling directly on them and no scope for drainage or run-off: plots of land below the ground level of roads in the process of urban development, undeveloped plots cut off by waste-fill, pools, etc. Moreover, in a region as flat as the one affected, the digital landscape model (DLM) with which the hydraulic study has been made might not have picked up slight differences in height (of only a small number of centimetres) which do ultimately have an influence in real life. Likewise any topographical modification after the DLM used can have a bearing. Similarly, even during the event, circumstances can arise that alter the situation as regards the modelled behaviour, such as, for example, breaking up of walls, ridges or embankments caused by surge flows, which were actually included in the model, but not breakage to them.

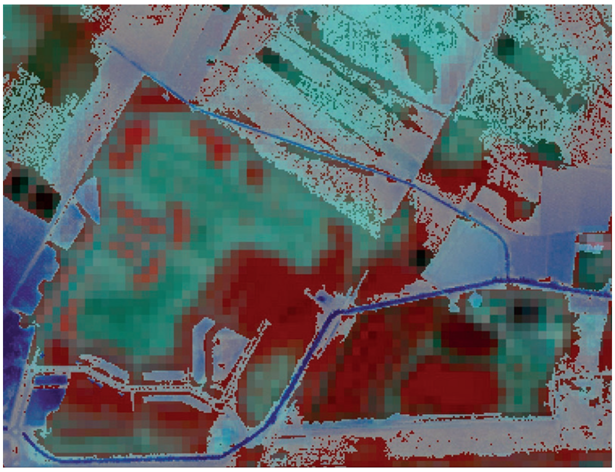

Figure 4. Image from the satellite Sentinel (ESA) of the Cartagena countryside on 13 September 2019, which has been altered by the OPH at the CHS and compares the flooded zone (in red) with the CHS depths model for a 100-year return period (using blue scaling).

Figure 5. Orthoimage featuring the CHS depths model for a 100-year return period (using blue scaling) and which shows that there are zones which were actually flooded which experienced this due not to flows, but instead to rain in situ, given that these are cut-off zones at heights below the surrounding area itself such as, for example, plots of land below the ground levels of roads in zones half-developed for housing purposes.

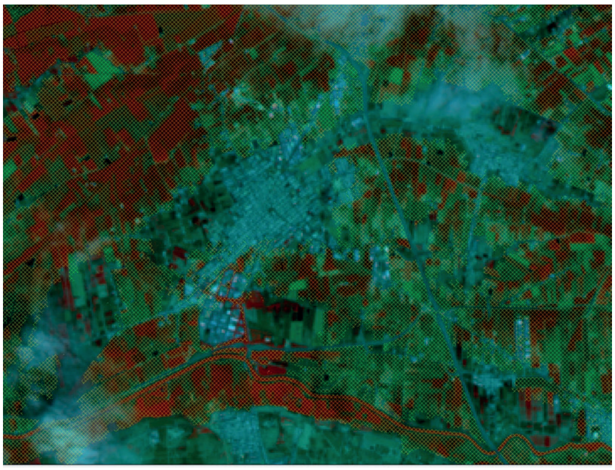

Figure 6. Image from the satellite Sentinel (ESA) of the Almoradí population centre (Alicante, La Vega Baja del Segura) on 13 September 2019, which has been altered by the OPH at the CHS and compares the flooded zone (in red) with the CHS model for a 500-year return period (using the yellow grid).

It is also possible to witness how the models fit in La Vega Baja del Segura. In Figure 6, in the centre of which appears the Alicante population centre of Almoradí, using the same treatment of the original Sentinel image already mentioned, the model shown is the one produced by the CHS for the SNCZI for the 500-year return period (in yellow), that extends beyond the zone actually flooded but is still quite a good fit, for which reason, it could be that the flooding return period in this section is between 100 and 500 years.

In greater detail and using images taken from helicopters, the models can be compared in the population centre of Orihuela (in the Sentinel image it appears covered by clouds). In Figures 7 and 8, a parking lot and a football pitch can be observed by way of reference. The figures afterwards show the models for depths in the same zones for return periods of 50 and 100 years, which is the range within which the actual event ought to be. Slight differences are discernible, perhaps because this is very flat terrain and given that the parking lot has had one or two alterations since the images were taken to produce the DLM.

Figure 7. Photo taken during a flight by the Valencian Regional Government's civil protection department over the population centre of Orihuela to the east of the city centre. In the top left hand corner, you can see the course of the river Segura.

Figure 8. Photos taken during a flight by the Valencian Regional Government's civil protection department over the population centre of Orihuela to the east of the city centre. In the image at the bottom, you can see the railway track and, in the image at the top, down on the right hand side, the football pitch mentioned.

Figure 9. Orthoimage featuring the depths model for a 50-year return period, with the parking lot (Aparcamiento) and the football pitch (Campo de fútbol) which can be seen in Figures 7 and 8 highlighted in red.

Figure 10. Orthoimage featuring the depths model for a 100-year return period, with the parking lot and the football pitch which can be seen in Figures 7 and 8 highlighted in red.

Finally, there is a model for El Pilar de la Horadada (Alicante). Although it has not been published yet on the CHS's flood zone viewer (https://www.chsegura.es), it has been possible to partially confirm its reliability, since the model showed the risk of flooding for the tunnels on the AP-7 highway as it passes through this population centre. Images 11 and 12 show the complete model output for the area, as well as the detail of the tunnel zone.

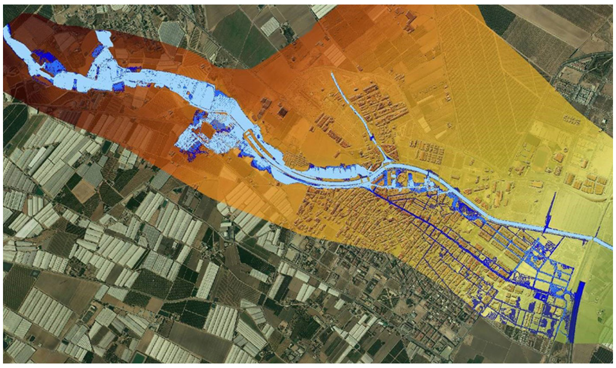

Figure 11. Orthoimage featuring the depths model for a 500-year return period. The AP-7 highway runs along the west and the entrance to the tunnel can be seen in the lower right hand corner of the image.

Figure 12. Detailed view of the AP-7 highway tunnel in which its southern entrance can be observed, which has been flooded by the overflowing of the watercourse, which continues downstream and passes right over the tunnel. Just at the entrance, the depth obtained by the model is 1.6 m.

It can therefore be concluded that, although it has certain limitations, the mapping of floodable zones produced in recent years for the SNCZI shows the hazardousness of those zones which it has thusfar been possible to map with a notable degree of accuracy, as has unfortunately been confirmed over time as the floods have occurred. It is thus important to disseminate information about the fact that such maps exist and to promote the use of them in any zoning process, whether this concerns territorial or urban planning, civil protection, infrastructure design, etc.