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THE FLOOD OF THE RIVER TURIA AT TERUEL IN JUNE 1933: AN ASSESSMENT

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I. INTRODUCTION AND AREA OF STUDY

Flooding can result when river levels rise substantially. The results of floods are mostly determined by the exposure of goods and people. In recent decades early warning systems have improved and some governments in nations with sufficient economic resources have prepared flood management plans for drainage basins. Such actions help mitigate the effects of floods but can never eliminate these effects. Moreover, the elimination of flooding could be one of the worst environmental effects that a river can suffer.

The monitoring and study of floods is necessary because they form part of the essence of rivers and flooding may cause major socio-economic damage. The behaviour and effects of floods have been studied in various regions, including the Iberian Peninsula.

The key information about a flood regarding volume and development comes from height measurements made in flow gauging stations. In the case of Spain, these figures are compiled in the Gauging Yearbook (*Anuario de Aforos*) which (at best) disaggregates temporal information into day periods. In the 1980s numerous water authorities introduced automatic hydrological information systems and so much more information became available – including data for periods of 1 hour, 15 minutes, and even 5 minutes.

Gauging yearbooks and automatic systems have provided considerable information on the frequency and volume of floods during the second half of the twentieth century and into this century. Systematic gauging theoretically began around 1911 in many basins and rivers in Spain; however, the data is discontinuous for the first half of the twentieth century. Therefore, other documentary sources are needed to detect floods and discover their effects for this and earlier periods. Newspapers and magazines are revealed as a source of basic information for the study of floods during the second half of the nineteenth century and the first half of the twentieth.

From the evidence obtained in various newspapers of the time, our hypothesis is that the River Turia experienced a flood in June 1933 that was among the largest ever recorded in the area of Teruel. The main objective of this paper is to estimate the size and scope of this flood. In addition, we study its causes and make a comparison with floods for which there is detailed data available from gauging stations installed along the Turia and Alfambra rivers near Teruel.

The study area is therefore limited to an area near Teruel, including the areas where the rivers Guadalaviar and Alfambra meet, the first section of the River Turia (emerging from the previous confluence), its plain flood, and several tributaries.

II. MATERIALS AND METHODS

The documentary sources and methods used for this work are diverse. The flood was detected from a reference in the Madrid-based '*ABC'* newspaper on 6 June 1933. The search for more references about this flood, as well as subsequent floods from the mid-twentieth century, was made in the Historical Press Virtual Library of the Spanish National Library and the Virtual Library of the Library of Aragon, as well as municipal newspaper libraries in Teruel and Zaragoza. News stories have been gathered from the largest circulation newspapers in Aragon (*Heraldo de Aragon*, *El Periodico de Aragon*) and Teruel (*Lucha - Diario de Teruel*).

To determine the cause of this flood we examined the '1933 Summary of Meteorological Observations' prepared by the National Weather Service (*Servicio Meteorológico Nacional*) which was then part of the Air Ministry. As another main source, we used the Spanish Weather Service bulletins published by the Spanish Geographic, Cadastral, and Statistics Institute. Both sources published rainfall figures and weather forecasts.

We consulted the minutes of sessions of Teruel city council as preserved in the municipal archive (from 1922 onwards). Our research has enabled us to determine whether the flooding was of sufficient importance to be discussed in municipal sessions. An examination of these sessions also produced complimentary data.

The most direct and comprehensive data describing the hydrological behaviour of the Alfambra and Turia rivers in the study area was produced by the gauging stations (belonging to the ROEA network) located in the city of Teruel. One is located on the River Alfambra (8027); and the other on the River Turia (8015) shortly after the confluence of the rivers Guadalaviar and Alfambra. These records are published in the Gauging Yearbook (sig.mapama.es/redes-seguimiento/visor.html). Moreover, both of these gauge stations are included in the Automatic Hydrological Information System for the River Júcar basin. This system includes gauge and precipitation data with hourly and five-minute levels of detail. Records from the gauging yearbooks and the automatic system for the Júcar basin indicate the volumes involved in major floods.

The study area is defined as an area of major flood risk in the National System of Flood Zone Mapping (*SNCZI* in Spanish). The availability of this flood zone mapping data in shapefile format enables us to use ArcGIS 10.2 software to compare the sectors of the floodplain under water for various return periods and the June 1933 flood (as described in press and municipal records).

For an estimation of the flood flow in June 1933 we selected as a point of analysis the Iron Bridge *(Puente de Hierro*) for which we had several photographs from the era and subsequent years. Two references in the press indicated the height of the flood water at the bridge. As the bridge remains standing today and retains its openings, a set of measurements enables us to estimate the peak flow under the bridge in the 1933 flood. To make a flow estimation, we used a geomorphological method based on Manning's formula (Gallart, 1988; García Ruiz et al., 1996) with hydraulic radius data describing the cross-section, slope, and roughness. This methodology proved very useful in previous applications (Ollero, 2014).

III. RESULTS AND DISCUSSION

III.1. The direct cause: rainfall

As is often the case, the cause of this flood was intense and persistent rainfall. The National Weather Service bulletins provided specific data on this rainfall and described a series of storms moving in a southerly direction across the Iberian Peninsula.

The rain began on 3 June (21 mm) and continued with considerable intensity during the 4 and 5 June and with less intensity on the 6 and 7. The greatest intensity (78 mm) was reached for a period of 36 hours on 4 and 5 June. Over a period of three days (3 to 5 June) a total of 99 mm of rain fell. This data relates specifically to the observatory at Teruel, yet widespread rains across the Peninsula suggest that rain fell throughout the river basin.

III.2. The flood of 1933 in context of the Turia and Alfambra river floods at Teruel

The gauging yearbook offers a wide data time series that include the maximum instantaneous monthly and annual flow values together with average daily flow data. As a result, it is possible to closely track floods on the Alfambra and Turia rivers near Teruel.

We selected the floods on the River Turia for which the gauge flow station at Teruel indicated a flow greater than 50 m^3/s and floods on the Alfambra where the station measurements exceeded 40 m^3/s with the intention of checking whether these floods were mentioned in the most important local newspapers: the *Lucha - Diario de Teruel* and the regional newspaper – the *Heraldo de Aragon*. The five floods on the River Alfambra that exceeded peak flows of 50 m^3/s were all reported in the newspapers. Reports of flooding were less regular for the River Turia, although most of the floods exceeding 60 m^3/s were mentioned.

All this suggests that the June 1933 flood reached levels similar to other major floods on the Alfambra and Guadalaviar rivers, as news was published in local papers and other newspapers across the Peninsula.

III.3. References and effects of the June 1933 flood

In the local press there was a mention of the flooding in *Acción* and *República* from 6 to 10 June. The *Heraldo de Aragon* was the regional paper that gave the most coverage with daily updates between 6 and 9 June. *ABC*, a Madrid-based national newspaper, reported on the flooding on 6 June. *La Libertad*, another national paper published in Madrid, also reported the flooding. Finally, numerous daily newspapers from various provinces (but mainly from the Mediterranean coast) reported the flooding – including: *Diario de Alicante*, *El Día* and *El Luchador,* (Alicante); *La Correspondencia* (Valencia); *El Defensor de Córdoba* and *La Voz,* (Cordoba); *Diario de Almería (*Almeria); *La Voz de Menorca (*Menorca).

Several of these reports mention the very protracted nature of the rainfall, with more than 40 hours of uninterrupted rain. The reports mention the overflowing of the Alfambra, Guadalaviar, and Turia rivers and a number of effects:

- Uprooted trees and sweeping away of animals and buildings.
- Flooding of meadow fields and destruction of crops.
- Interruption of traffic on the road to Zaragoza and train lines.
- Large-scale destruction along the *avenida de Zaragoza* in Teruel.
- Flooding of the square in front of the Convent of San Francisco.
- On the right river bank, the flood reached the public laundry and the premises of the drinking water supply company *Aguas Potables de Guadalaviar*.
- Flood water reached the lower supports of the Iron Bridge and was within 50 cm of reaching the platform according to *Acción* (and even 'splashed the platform' according to *República*).
- The Doña Elvira Bridge (or *Puente de Tablas*) was dragged away by the current.
- Flooding and evacuation of houses near the Doña Elvira Bridge and railway station.

Proceedings of the City of Teruel council sessions confirm these effects and show that the national government was asked to help flood victims. Council proceedings emphasised the losses of vegetable and cereal crops and the need to repair the Dona Elvira bridge.

III.4. National System of Flood Zone Mapping (SNCZI)

In recent years the various river basin authorities have made a preliminary flood risk assessment of their rivers, and mapped flood hazards and flood risks as required by European Directive 2007/60. The results have been centralised within the National System of Flood Zone Mapping (SNCZI) and flood-risk areas are recorded with return periods of 10, 50, 100 and 500 years.

In this paper, we have considered water coverage corresponding to floods of very high frequency (Q10), high frequency (Q50), and medium frequency (Q100). These flood lines are shown superimposed on an aerial photograph from the year 2012. The resulting image shows the considerable difference between the land area under water in a very high frequency flood in comparison with high and medium frequency floods.

The aim here is to relate flood levels with the effects described in the 1933 flood. The reported flooding (various meadows, part of the *avenida de Zaragoza*, a stretch of railway tracks and road, and the square and houses around the convent of San Francisco) correspond to high frequency (Q50) and even medium frequency (Q100) flooding. This confirms, the importance of the 1933 flood.

Urban growth in this part of the city of Teruel since 1933 means that there is now a substantial increase in exposure and that a similar flood today would cause more damage.

The national flood zone mapping system establishes the maximum instantaneous flows for return periods and river sections. The flood peak with a 25-year return exceeds a maximum instantaneous flow of 90 m^3/s, and the 50-year return exceeds 100 m^3/s. It can therefore be determined that the flood of 1933 almost certainly exceeded 100 m^3/s, which means that it was one of the largest floods on the River Turia at Teruel. This flood level was only achieved three times between 1956/57 and 2011/12 (the time period for which records exist of instantaneous peak flows).

III.5. Estimation of circulating flows

We have attempted to estimate the maximum flow rate in the Turia River during this flood, based on claims that the water was scarcely 50cm from the platform of the Iron Bridge (*Acción*), a report that was confirmed by another reference to the flood 'splashing the bridge platform' (*República*).

We measured the current cross-section of the Iron Bridge and examined old photographs to estimate the cross-section in 1933. The current cross-section (including the lateral stone arches) is 79.37 m^2. The following differences can be observed when comparing the current bridge with the bridge in June 1933:

– There is now considerable – mainly herbaceous – vegetation under the bridge. In 1933 the vegetation in the water was 27 metres downstream from the bridge. The riverbed was gravel and lacked vegetation and other obstacles.
– The riverbed in 1933 was regular and homogenous.
– Unlike the current situation, the stone arch on the left bank was more open than the right arch.
– In the right half of the channel under the bridge, the depth was 110 cm greater than today, (according to the blocks visible on the bridge pillar). The depth of the lowest channel was also about 20 cm greater in 1933 than today.

From the evidence provided by the photos, the cross-section of the bridge in 1933 can be estimated at about 110 m^2 – or about 27% larger than the current cross-section. The flood level of 1933 fell about 50 cm short of the bridge platform. This implies that the section occupied by the flood was about 95 m^2. The hydraulic radius was 2.02. The local slope in 1933 is impossible to estimate, and so we applied the same slope as at present (0.0030675 m/m). The peak flow of the flood, applying the formula of Manning, would have reached 140.2 m^3/s. This value corresponds to the 100-year flood maximum flow indicated by the national flood zone mapping system. It must be remembered that this is the peak flow under the bridge, and it is possible that an overflow of the river banks may have meant that the flow was even greater (however, there is not enough information to determine if the entire flow was under the bridge).

IV. CONCLUSIONS

Newspapers are very suitable and valid for detecting floods. News reports give us clues about their magnitude and evolution, as well as data on the extent of the flooded areas and major socio-economic effects. This information becomes more valuable if we can make comparisons with other extraordinary floods in which flow levels were recorded – even more so if such floods occurred in areas where flood zone maps have been made that show return period flood levels. Press information can help us complete the national catalogue of historic floods.

The flooding of the River Turia in the area of Teruel was recorded in local, regional, and national newspapers. These reports described a level of damage that suggests a major flood and this is confirmed by actions taken by Teruel city council. The size of the 1933 flood is also confirmed by media coverage given to other events. Only some of the larger floods reflected in the records from 1956 to the present were covered by local and regional newspapers.

The flood was caused by heavy rainfall deposited by storms crossing the Iberian Peninsula from the north. Up to 99 mm fell in in three days, 78 mm of which fell in 36 hours in Teruel. The effect was immediate on the Alfambra, Guadalaviar, and Turia rivers, and the usually dry river beds that cross the city of Teruel. Peak flood levels were reached on the morning of 5 June.

The widespread effects of the flood were numerous: flooding of fields and destruction of crops; disruptions on the road to Zaragoza and train lines in the city of Teruel; damage to property in the *avenida de Zaragoza*; flood-damage around the convent of San Francisco; uprooted trees; the sweeping away of animals and buildings; and the collapse of the Doña Elvira bridge. According to data collected in various documentary sources, the flooded areas correspond in the national system of flood zone mapping to a flood with a return period of between 50-100 years.

By bringing together the above data we can say that the flood of June 1933 was one of the largest registered on the River Turia in Teruel and comparable only with the largest of the floods for which maximum instantaneous flow records exist. We can estimate the peak flow at around 140 m^3/s by referring to the map showing maximum flows (MAPAMA) under the Gumbel formula and using a geomorphological methodology for estimating flows.

A comparison between aerial photographs from the American flight series A (1945 to 1946) and aerial photographs from 2012 shows that the damage caused by a flood of equal magnitude to that of June 1933 would now be much greater because of new constructions around the *avenida de Zaragoza* and the convent of San Francisco. In addition, the capacity of the River Turia at specific points – such as at the Iron Bridge – is smaller now than in 1933.