

Floods of the Segre River in Lleida (NE Iberian Peninsula) since 1500 AD



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The Segre River is one of the main tributaries of the Ebro River, one of the greatest rivers in NE Iberian Peninsula (Figure 1).

The Segre River drains the eastern sector of the Pyrenees. Its catchment's area (12,500 km²) is 13.5% of Ebro's and its contribution to Ebro's mean annual runoff is 19%.

However, knowledge about Segre River is limited to a short, incomplete systematic series of measurements of the 20th century and to a list of historical floods.

Our objective was to reconstruct the peak flows of the 20 known historical floods occurred in Lleida since 1500.

The software used was the one-dimensional HEC-RAS v.4.1 under gradually varied, steady, mixed flow in a 7750 m long reach with 18 cross sections (Figure 8).

The digital elevations model (DEM) was manipulated to adapt to the time of each flood the many changes in the river bed morphology and its obstacles (bridges, walls) (Figure 2).

Information about changes in morphology and roughness and about floods was varied and abundant (written accounts, maps, drawings, photos; Figures 2-8). Roughness coefficients were estimated as: 0.045 (channel), 0.05 (banks and flood plain) and 0.1 (town).

The results (Table 1) show that at least 20 floods since 1500 reached or exceeded 3000 m³ s⁻¹, which is the flooding flow for the right bank (the highest and historically most populated). Three periods with different flood frequency can be distinguished: 1500-1625 (9 floods or 7.4 floods per century), 1626-1725 (0 floods) and 1726-2014 (11 floods or 3.8 floods per century). The two heaviest reconstructed peak flows are 13300 m³·s⁻¹ (1597) and 12000 m³·s⁻¹ (1787), between 120 and 130 times greater than the mean flow, and with K indexes of 5.2.

Segre's contribution to peak flows in Tortosa (near Ebro's mouth, Figure 1) can reach 100% and is usually above 50% during the heaviest floods.

The Old Bridge (in its different versions across history) is a big obstacle that increases water level by as much as 2.5 m during the heaviest floods.

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References

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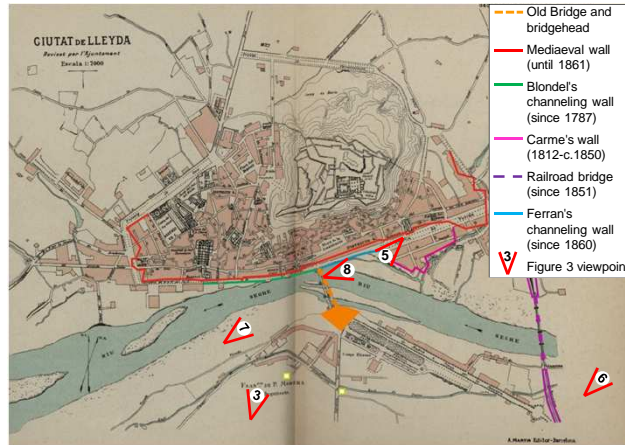
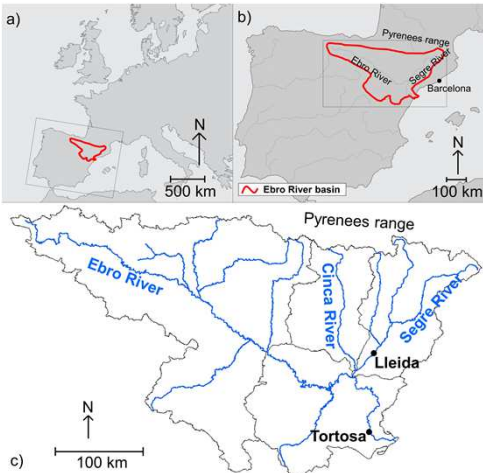


Figure 5. Old Bridge destroyed by 1907 flood. Source: Herrera-Ges, Arxiu Bisbat.



Figure 6. 1937 flood. Source: Riegos y Fuerzas del Ebro.



Figure 7. 1982 flood. Source: Rey Cascales, Dilagro.



Figure 8. Upstream view of Lleida and the Segre from the Old Bridge in 1910. Source: A. Toldrà

Table 1. Results of the peak flow reconstructions

Date of flood (dd/mm/yyyy)	Peak flow in Lleida (m ³ s ⁻¹)	Percentage over peak flow in Tortosa ⁽⁴⁾ (%)	Return period ⁽⁵⁾ (yr)
28/09/1504	>5750 ⁽¹⁾	No data	90
1536	>5750 ⁽¹⁾	No data	90
23/04/1544	3300 ⁽¹⁾	No data	30
1553	5750 ⁽²⁾	No data	90
1586	10800 ⁽¹⁾	No data	200
19/05/1597	13300 ⁽¹⁾	No data	920
1604	>5000 ⁽¹⁾	No data	50
08/11/1617	6400 ⁽¹⁾	85	145
11/10/1625	4800 ⁽¹⁾	No data	40
1726	>3500 ⁽¹⁾	No data	35
17/12/1766	4800 ⁽¹⁾	100	40
14/06/1773	>5750 ⁽¹⁾	No data	90
08/10/1787	12000 ⁽¹⁾	93	330
06/01/1826	3000 ⁽¹⁾	No data	25
24/05/1853	5900 ⁽²⁾	67	115
21/10/1866	5000 ⁽¹⁾	62	50
23/09/1874	3200 ⁽²⁾	71	30
25/10/1907	5200 ⁽²⁾	48	55
29/10/1937	3600 ⁽³⁾	39	35
09/11/1982	3400 ⁽³⁾	36	30

⁽¹⁾ Modelled with HEC-RAS from an approximate flood mark (error > 50 cm)
⁽²⁾ Modelled with HEC-RAS from an exact flood mark (error < 50 cm)
⁽³⁾ Calculated by the Ebro Basin Authority (CH Ebro)
⁽⁴⁾ Tortosa is 30 km upstream Ebro River's mouth (Figure 1)
⁽⁵⁾ Calculated with a plotting-position formula (Hirsch & Stedinger, 1987)

Figure 1. Location of the Ebro basin within Europe (a) and within the Iberian Peninsula (b), and location of the Segre River and the town of Lleida within the Ebro basin (c). Source: Own elaboration from a map Copyright © 2009 National Geographic Society, Washington, D.C.

Figure 2. Map of Lleida in 1908 with the major changes in the river bed morphology and the viewpoints of Figures 3 and 5 to 8. Source: F.P. Morera, Lleida City Council



Figure 3. Detail of a drawing of Lleida in 1563 by artist Anton van den Wyngaerde, with the Segre River, the Old Bridge and the houses by the river.



Figure 4. Modelled reach with the 18 cross section over the digital elevation model

