

## The Effects of Damming and Recent Climatic Changes on the Sediment and Water Discharge of the Ebro River (Northwestern Mediterranean)

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The Ebro River is one of the most important fluvial systems that discharge into the Northwestern Mediterranean Sea. During the last few centuries this fluvial system has been greatly affected by human activities. Deforestation of its drainage basin became very intense from the 15<sup>th</sup> century onwards, making the deltaic system prograde very rapidly. Construction of irrigation systems became important at the end of the 19<sup>th</sup> century and the beginning of the 20<sup>th</sup> century and in addition, many dams have also been built during this century. These facts have dramatically changed the sediment dynamics and the hydrodynamics of this fluvial system. The area most affected by these changes is the lower part of the river and especially the delta and the river mouth, where the marine-fluvial interaction controls the evolution of the delta.

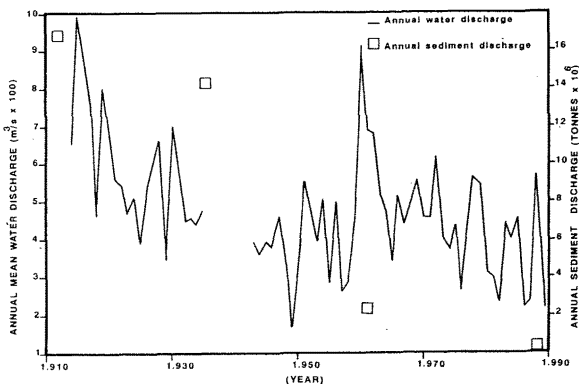


Fig.1. Annual Water and sediment discharge of the Ebro River during the 20<sup>th</sup> century

The water discharge of the Ebro river is quite irregular during the year. The annual distribution of water discharge in the lower part of the river shows that the higher values occur between November and March and the lower values in summer. During this century the annual mean water discharge of the Ebro River has been very irregular. Maximum mean water discharge was 992 m<sup>3</sup>/s in 1915 and the minimum was 165 m<sup>3</sup>/s in 1949. The mean distribution shows a decreasing trend from 1914 to the present with some stages of high water discharge. These stages correspond to 1915 and 1960. Another stage may have taken place in 1937 when a strong flood led to a change in the location of the river mouth. Unfortunately there are no data for the end of the thirties. The decreasing trend in the annual water discharge has been quite continuous from 1960 to the present. The eighties have been especially dry years. In 1982, 1986, 1987 and 1989 the mean was lower than 250 m<sup>3</sup>/s. The decreasing trend in annual mean water discharge can be attributed to the human management of the river water and to climatic changes. Dams have also contributed to mitigate the river floods. Floods of more than 3000 m<sup>3</sup>/s took place before the construction of the dams, but after the regulation of water discharge induced by the dams, these big floods have ceased to occur.

Historical data allow the estimation of sediment discharge in the late 19<sup>th</sup> century. In 1891, before the construction of the dams, suspended load transported by the river was about 25x10<sup>6</sup> tons per year. Like the water discharge, the transport of suspended sediment without river damming was quite irregular during the year. During the higher water discharge floods, the river could transport more than 10<sup>6</sup> Tm/day. Between 1906 and 1930, some significant dams (200 Hm<sup>3</sup>) were built in the upper part of the Segre River and several small capacity reservoirs (0.3-28 Hm<sup>3</sup>) were built in some of the Ebro River tributaries. The average amount of suspended sediment transported by the river decreased to 17x10<sup>6</sup> tons per year in 1911 and to 14x10<sup>6</sup> tons per year in 1935. A really significant reservoir was not constructed until the forties, when the Ebro dam (540 Hm<sup>3</sup>) was built in the upper part of the river. During the forties and the fifties several reservoirs with a capacity ranging from 50 to 200 Hm<sup>3</sup> were constructed. In 1959 another important dam, the Yesa dam (470 Hm<sup>3</sup>) was located in the upper part of the Aragon River (one of the most important tributaries of the Ebro River). At the beginning of the sixties, the amount of suspended sediment discharged by the river was 2.2x10<sup>6</sup> tons/year. The largest dam in the Ebro system (the Mequinenza dam) was built in the lower part of the river in 1966. The Mequinenza dam has a capacity of more than 1000 Hm<sup>3</sup>. In 1969 the Ribarroja dam (136 Hm<sup>3</sup>) was built a few kilometers downstream of the Mequinenza dam. In 1968 another important dam was constructed in the Cinca River, the Mediano dam, whose capacity is 436 Hm<sup>3</sup>. During the eighties the Ebro river discharged only between 120.000 and 150.000 tons per year (Fig.1). This means that at the present time the Ebro River is discharging into the Mediterranean less than 1% of the suspended sediment that this river discharged into the sea before the construction of the dams (Palanques, 1987; Palanques et al., 1990).

This huge reduction of the sediment input is mainly the result of the accumulative sediment retention in each of the dams built along the Ebro river and its tributaries and it is also the result of the location of the Mequinenza and Ribarroja dams. These dams are located only a few kilometers upstream of the delta and they retain more than the 75% of the suspended sediment input and the totality of the bed load input that they receive (Palanques, 1987; Palanques et al., 1990). The decrease of the river water discharge also contribute to the reduction of the river sediment discharge. Moreover, dams prevent the big floods that could transport huge amount of sediment to the sea. At present, the Ebro river discharges mainly very fine sediment to the marine environment, the bed load transported along the lower part of the river is insignificant and the Ebro delta coast receives practically no sand sediment supplies from the river so the action of the marine processes on the delta coast dominates the present evolution of the delta. It is not possible to interpret the geological record of the recent Ebro sedimentary deposits from present day river conditions.

### REFERENCES

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