

**EXTREME FLOODS IN "THE HEARTH OF EUROPE":
THE CASE OF THE 1995 MEUSE FLOOD**

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Abstract. In January 1994 and January 1995 extreme water levels and discharges occurred in the Meuse River in the "Heart of Europe" due to unusual weather patterns over Southern Belgium. The return period of the referred floods was estimated to be about twenty years. It appears that the return period of unusual floods have been decreasing over the years due to antropogenic effects. The impacts of the 1994 and 1995 floods have been different over different parts of the country. In the Southern hilly region (the Ardennes), part of the valley was flooded without exceptional damage, while in the Northern flatter part no flooding beyond the usual floodplain occurred in 1995, except for some problems due to rising of groundwater tables. A global strategy is necessary to manage floods in the Meuse River in the future. Existing flood forecasting models must be kept operational. A number of emergency strategies should be established. In addition, before any new measures are undertaken, such as those related to gravel mining and widening of riverbed, careful studies should be done to predict reliably the marginal effect of any new measure.

1. HISTORY OF THE MEUSE FLOODS

The Meuse valley has been inhabited since historical times. In the Middle Ages, it was a center of trade between Germany, Flanders, and France. Liège, situated on the Meuse Valley, has been the territory of Prince Bishops since the 11th century and had been an independent region until 1794. According to recorded history, the Meuse valley has, quite regularly, been subject to flooding during the last millenium (Demarée et al., 1994). The earliest documented flooding of the "Ile a Liège" was in January 1374. Also, destructive floods in Namur occurred in January 1643 and December 1740, making the inhabitants fear for a total destruction of the city. Since 1876, a dense network of pluviometers was installed over the whole Belgian territory. Thus the flood of 1880 was the first with well-documented hydrometeorology. Until recently, the flood of January 1926 was considered as being the worst one within living memory. Apart from flooding events, periods of severe droughts have been reported, e.g. in 1198 and 1976.

The water discharges of the River Meuse are basically generated by rainfall on the catchment. Since the subsoil of the upper part of the catchment in the "Ardennes" is hardly permeable, heavy rainfall on the catchment quickly generates high flow rates down the river, which regularly causes flooding. The discharge of the river Meuse at Liege varies between 10 and 3,500 m³/s.

2. THE 1995 FLOOD OF THE RIVER MEUSE

The 1995 Meuse flood was perceived by the general public as an extreme flood event. This was largely due to the fact that it succeeded another "extreme" flood occurred the year before (1993-1994). Although the maximum discharge in 1995 was roughly 3,100 m³/s and the related water levels were believed to be the 1 in 50 years values, it has not been easy to make the people understand that such extreme floods could actually occur during two consecutive years.

Another reason why the 1995 flood frightened the local people was that although the peak discharge was similar to the one in 1993-1994, the flood duration was much longer than that in the previous year. In the Netherlands, the high water levels persisted above the low-lying surrounding borderland for more than two weeks. The frail and ramshackle dikes, which badly needed repair and strengthening, were permeable so that the water leaked through them. This may actually have hampered collapse (refer to Fig. 1). The strengthening of the dikes had been planned for a long time, but environmentalists who did not agree that enlarging the dikes necessarily went along with dike heightening and strengthening had halted the works. Also the fact that other rivers flooded in other places in Europe (for example the Rhine River, which is nearby), contributed to the general feeling of fear.

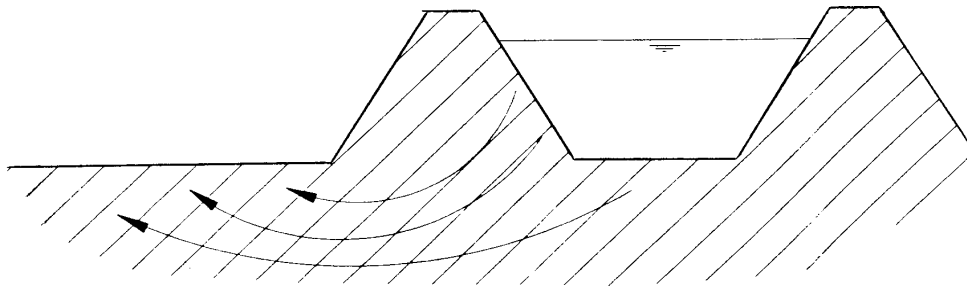


Figure 1. Leakage through permeable dikes or under impervious dikes through an impervious subsoil

Flooding in narrow valleys in the southern part of the country (the Ardennes) is not very unusual. In fact, since the banks of the river are densely populated and extensively exploited for tourism, including camping and caravan sites in or very close to the winterbed, local "inundations" occur quite frequently. The flooding of 1955 was reportedly not very much worse than what typically occurs annually. There certainly was no flooding of major cities like Liège or Namur (as occurred in 1643 and 1740, respectively.) The high waterlevels north of Liège, in particular along the border between Belgium and the Netherlands (the so called "grensmass"), did not cause any serious problem. In fact, since some weaker points in the winterdikes were repaired after the 1993-1994 flooding, there was no flooding at all. Some locations (e.g. a ferry and the adjacent local pub), that in fact are located within the winterbed, were flooded, but one can hardly call that an inundation. Since the duration of the 1995 flood was much longer than that in 1993-1994, some parts of the low-lying lands of the valley (partly due to subsidence) outside the winterdike were temporarily covered with water due to the rising groundwater, which percolated through the pervious subsoil and thus looked as "flooded" (refer to Fig 1).

Both the 1993-1994 and the 1995 floods were caused by rather unusual weather conditions: a low pressure system, moving from West to East over southern Belgium, caused the rains to travel over the Ardennes from the South West to the North East, thereby following roughly the course of the River Meuse and its southern tributaries the Sambre, the Semois, and the Lesse. Tributaries joining the River Meuse especially on the North and the East (e.g. the Ourthe) did not show very unusual high discharges. Usually low-pressure systems move North of Belgium, inducing NorthWesterly winds, eventually causing flooding from the North Sea (e.g. floods in 1953 and 1976).

3. STATISTICS OF THE 1995 MEUSE FLOOD

The return period of the 1995 flood discharges has been determined based on the extreme high water data available since 1643. The lognormal, Pearson III, and Log-Pearson III distributions gave very similar results. It may be shown that the 1995 (and also the 1926 and 1993-1994) flood at Hocht has a return period of 42 years, if the 1993-94 and the 1995 floods are not included in the analysis. On the other hand, the return period is 25 years, if only the 1995 flood is excluded, while it is 17 years, if all recent data are included in the analysis. Furthermore, if the 1643 flood discharge is excluded (the value of which may be uncertain for obvious reasons) the return periods for the 1995 flood become respectively, 65, 40, and 23 years.

The foregoing calculations were made considering: (i) Manning's equation was used to convert the recorded flood levels into discharges, and (ii) the subsidence since 1880, which caused a general lowering of 2.4 m of the average winterbed. The absolute values of the obtained return periods may thus be questionable, but the results show that including the two recent extreme floods in the analysis changes the expected return periods considerably.

4. CHANGES IN FLOODING REGIME/HYDROMETEOROLOGY OF THE MEUSE

The valley of the River Meuse has been subject to many changes and severe environmental stress in the last century. The river was canalized during the last decades of the XIX-th century. In particular, in the southern region many weirs and locks were required because of the relatively steep gradient. The XIX-th century project was not capable of accommodating modern navigation. Therefore, the water levels upstream of the weirs were increased above the design values, thereby increasing the risk of flooding. Now, safety depended largely on the timely and accurate regulation of the weirs. However, timely operation under flood conditions was difficult with the old needle and shutter weirs. Sometimes local flooding occurred simply because of the wrong or late operation of the weirs.

In the northern (flatter) region of the country (the "grensmaas"), along the Belgian-Dutch border, many other changes have taken place. They are summarized below:

- General Subsidence Due to Mining. The Meuse is close to the Belgian coal mines at Eisden (closed in 1992) and the Dutch "Staatsmijnen Maurits" (closed in the 1960's). Subsidence due to mining went on for many years after the mining activity stopped. At some places close to Liège, the subsidence is of the order of 6-8 meters, with a maximum of 12 meters. Subsidence due to mining causes a relative rise of the water level (at constant discharge).

- Gravel Mining. The River Meuse has produced good sand and gravel since 1914-1918. Production gradually increased from about two 10^6 tons to seventeen 10^6 tons annually. Gravel mining (in the winterbed) causes a lowering of the flood levels (at constant discharge).
- Canalization/River Regulation. At some places the available width between the winter dikes is too narrow (Jodogne, 1965). In the Netherlands, it was recently decided to enlarge the riverbed along the Belgian border considerably. This measure, which is intended to restore the storage capacity of the bed, seems to have beneficial "environmental" and "recreational" effects by creating pools and wetlands capable of accommodating fauna and flora. In addition, the water supplies to the Albert and Juliana canals cause a reduction of the low water levels during the summer.
- Increased Urbanization of the Valley. Urbanization causes an increase in water discharges. Due to river regulation works and mining, the mean winter water level has dropped over 2.40 m at Maaseik and over 0.88 m at Lanaken since 1990. As compared to 1880 levels, the mean summer water levels are 2.90 m lower at Maaseik and 1.30 m lower at Lanaken. The average water level has dropped 3.0 m at Maaseik and 0.40 m. at Lanaken. In addition, (i) the mean water levels have lowered, but the maximum (annual, bi-annual) water levels have not been reduced, (ii) the frequency of high water has not been reduced, and (iii) the duration of high waters has been reduced (usually by 5 to 12 days).

It is seen that many natural and antropogenic changes have been inflicted upon the river. The river's response to them is very complex. The time lag between cause and effect makes it quite difficult to separate the partial effects caused by different factors. The differences in adjacent river gauging stations are sometimes quite big even though the distance between the stations is small (Lanaken and Maaseik are only 30 km apart!).

Figure 2 shows the winter half-year precipitation totals over the Meuse catchment at Visé (Demarée, 1994, 1995). There is a large variability with rainy and less rainy decades; particularly, the 1970's have been less rainy and are followed by the rainy years of the 1980's and 1990's. A shift in the mean of the winter areal precipitation can be detected around 1910 by using Pettit's test with a 1% significance level. According to Demarée (1995), this may be attributed to instrumental changes. The apparent shift around 1980 is not detected by Pettit's test, not even at the 10% probability level. No trend analysis has yet been performed. Figure 3 shows the annual peak discharges of the Meuse at Borgharen since 1911. The 15 years moving average analysis shows a decreasing trend in the 1960's followed by an increasing trend beginning around the early 1970's. A linear regression analysis shows a weak increasing trend over the whole study period 1880-1995.

5. CONCLUSIONS AND RECOMMENDED RESEARCH

In January 1994 and January 1995 extreme water levels and discharges occurred in the River Meuse because of unusual weather patterns over southern Belgium. The floods had an expected return period of approximately 20 years. It seems that the return periods of these unusual events have been decreasing over the last few years. This may be due to antropogenic factors. The effects of these floods are quite different in the southern hilly region of the country and the flat northern area. In the southern region (the Ardennes), part of the valley was flooded

without exceptional damage and no major cities were flooded. In the northern area, no flooding occurred outside the floodplains in 1995 except for some inundation of meadows due to rising ground water.

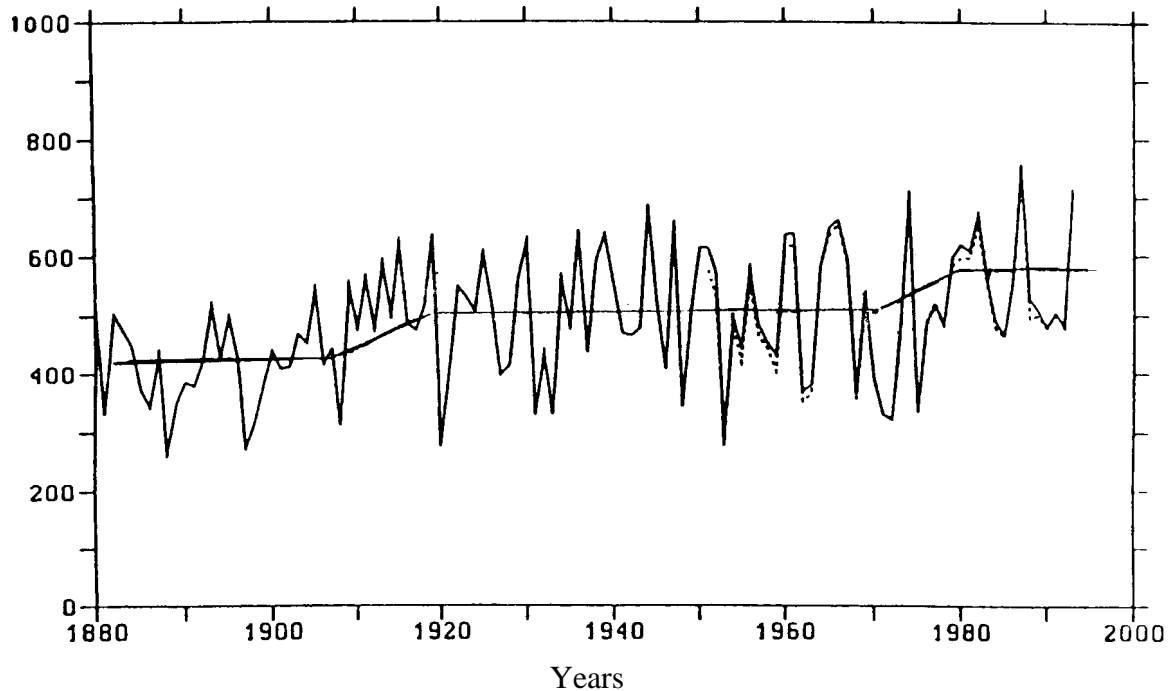


Figure 2. Winter half-yearly precipitation totals over the Meuse catchment at Visé

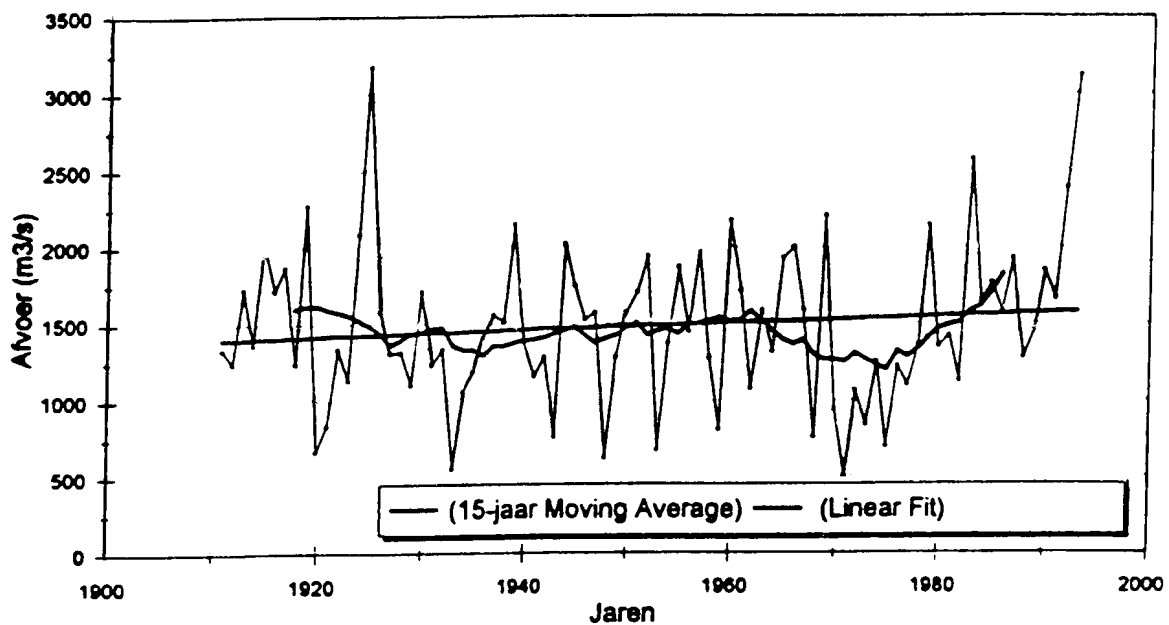


Figure 3. Annual peak discharges of the Meuse at Borgharen

The future flood management on the River Meuse requires a *global control strategy*. Cooperation between the Walloon Region, the Flemish Region, and the French and Dutch authorities will be needed. Existing models for online flood forecasting must be kept operational. A number of emergency strategies should be established prior to the next flooding event. Before any new measures are undertaken concerning gravel mining, widening of the riverbed, etc., careful modeling should be done to predict as accurately as possible the "marginal" effect of any new measure on the river flood regime.

6. REFERENCES

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