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DORIANO CASTALDINI (*) & MAURIZIO PELLEGRINI (*)

A REVIEW OF THE FLOW REGULATION SYSTEM ON THE SECCHIA AND PANARO RIVERS (MODENA AREA, ITALY) (**)

Abstract: CASTALDINI D. & PELLEGRINI M., *A review of the flow regulation systems on the Secchia and Panaro rivers (Modena area, Italy).*

The Secchia and Panaro rivers form a scissors-like course around Modena. These two rivers have periodically caused flooding in the area of Modena. The more recent floods took place mainly between 1960 and 1973 and were largely determined by changes in the flow and transfer velocity of the volume of water in the beds. Flow regulation devices were planned and constructed in areas adjacent to the courses of the two rivers in order to control these hydrological hazards in the area of Modena.

The flow regulation systems have been in operation since 1979 (for the Secchia R.) and 1985 (for the Panaro R.). They have constructed in the toe areas of the Secchia and Panaro rivers fans within channels that are approximately 2 km wide and that are bordered by banks several metres high.

The flow regulation systems are located in a geomorphological situation that is optimal for storing large volumes of water without necessitating major works for such purposes. The two structures consist principally of a regulating dam built across the bed and a storage basin bordered by embankments.

Their most important function is to reduce the flood peak, that is, they intervene on only a limited scale.

The flow regulation systems for the Secchia and Panaro rivers have not yet been tested as to their efficiency under flood conditions for which they were built. The systems were planned for major flood events, however, none have occurred since their completion.

KEY WORDS: Flood hazard, Flow regulation system, Secchia river, Panaro river, Modena (Italy).

Riassunto: CASTALDINI D. & PELLEGRINI M., *Rassegna sulle casse di espansione dei fiumi Secchia e Panaro (Provincia di Modena, Italia).*

I fiumi Secchia e Panaro scorrono ai lati di Modena descrivendo una specie di forbice. Il Secchia ed il Panaro con le loro acque hanno periodicamente allagato vaste aree in prossimità di Modena. Le alluvioni più recenti, che si sono verificate principalmente tra il 1960 e il 1973, sono state prevalentemente determinate da cambiamenti di flusso e di velocità di corrivazione del volune d'acqua nei letti fluviali. Per difendere l'area di Modena dal rischio da alluvioni sono state progettate e costruite due «casse di espansione», in aree adiacenti ai corsi dei due fiumi.

Le «casse di espansione» del Secchia e del Panaro (in funzione rispettivamente dal 1979 e dal 1985) sono state ubicate al piede dei conoidi dei fiumi suddetti all'interno di solchi larghi circa 2 km e delimitati lateralmente da scarpate fluviali alte qualche metro. Sono situate in una situazione geomorfologica che è ideale per invasare grandi volumi d'acqua senza enormi opere di contenimento.

Le casse di espansione consistono principalmente in un manufatto regolatore costruito traversalmente al letto del fiume e in un bacino d'espansione bordato da argini. Lo scopo principale delle casse di espansione è quello di regolare l'onda di piena cioè di intervenire su una capacità d'acqua molto limitata, ma con un'altezza idrometrica elevata. Le casse di espansione del Panaro e del Secchia non sono ancora state collaudate in relazione ai maggiori eventi di piena per cui sono state costruite, ma che non si sono più verificati dall'epoca del loro completamento.

TERMINI CHIAVE: Rischio da alluvioni, Casse di espansione, Fiume Panaro, Fiume Secchia, Modena (Italia).

The Secchia and Panaro Rivers are the last affluents on the right side of the Po River; they collect water from the central section of the Emilian Apennines (the Secchia River has a mountain-basin of 1292 km^2; the Panaro River mountain-basin extends over an area of 1035 km^2) and they flow through the outskirts of Modena, the Secchia to the east of the city, and the Panaro to the West. After forming a scissors-like course around Modena, they flow tortuously to the NE between high banks until their confluence with the Po River. At the points where they flow on to the plain, the rivers coming from the Apennines formed large alluvial fans during the Quaternary; these are characterized by sandy gravels alternating with silty and clayey deposits, both at the surface and at depth.

The Secchia river fan, with its head in the vicinity of Sassuolo (fig. 1), is asymmetrical with respect to the present course of the river, which has shifted to the western margin. Its length is about 20 km and the maximum width is 14 km. The fan is almost flat and presents, longitudinally, a double gradient: there is an average slope of 0.7% in the upper part and 0.3% in the lower part. Overlying marine clays of the Pliocene-Quaternary, the fan is made up of four overlapping lithological units, three of which are identifia-

(*) *Istituto di Geologia, Università di Modena - Corso Vittorio Emanuele II, 59 - 41000 Modena.*

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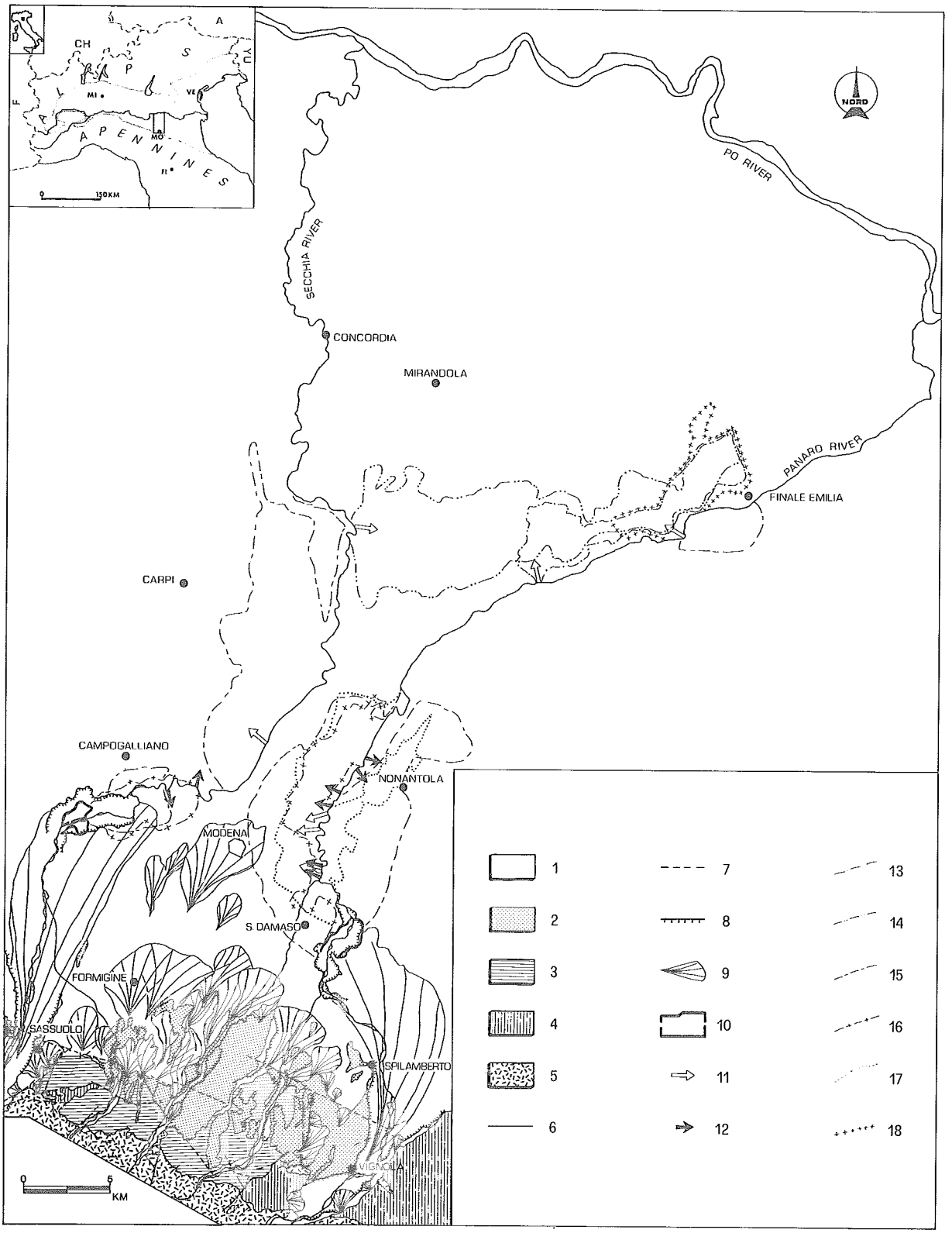

FIG. 1 - Geological map of the Apennine margin and the Modena plain with indications of the areas flooded by the Secchia and Panaro rivers (The geological map is from GASPERI, 1987; the flooded areas from MORATTI, 1988).
1) Alluvial fan and plain deposits (Holocene); 2) Alluvial fan deposits (Pleistocene); 3) Marine clays, sands and beach gravel at the top (Upper Pliocene (?) - Lower Pleistocene; 4) Marine clays (Pliocene); 5) Pre-Pliocene substratum; 6) Fault; 7) Buried or probable fault; 8) Scarp edge; 9) Alluvial fan; 10) Embankments of the flow-regulation systems; 11) Crevasse; 12) Overflow; 13-18) Borders of the flooded areas due to the crevasses and overflows of the Secchia and Panaro rivers which occurred on the following dates; 13) November 1952; 14) April 1960; 15) November 1966; 16) September 1972; 17) September 1973; 18) November 1982.

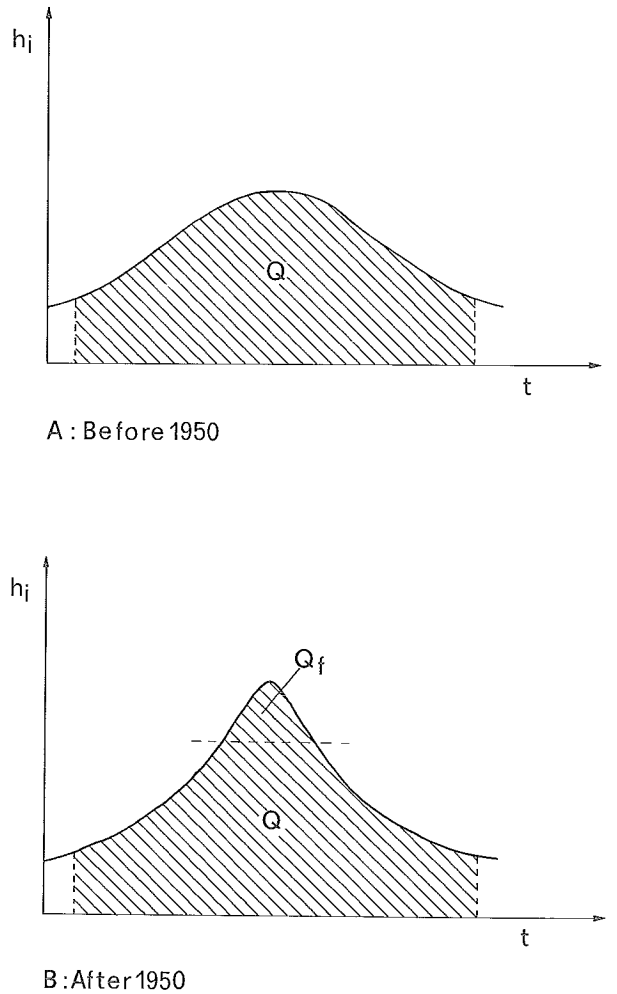

FIG. 2 - The Secchia and Panaro river flood hydrographs.
hi: hydrometric height; t: time; Q: total discharge; Qf: discharge regulated by the flow-regulation system.

ble on the surface and one of which is buried (COLOMBETTI & *alii*, 1980; GASPERI, 1987).

The Panaro river fan, the head of which is located in the vicinity of Vignola, is also asymmetrical with respect to the present course of the river. The latter flows in a marginal position and has shifted westward. The fan is about 15 km long and its width is 7-8 km at the toe. Similarly to that of the Secchia, it presents a double slope of 0.7% in the upper part and 0.3% in the lower part. Both on the surface and at depth, the Panaro River fan is characterized by the presence of sandy gravels alternating with finer deposits. These alluvial deposits overlie a prevalently clayey marine substratum with infrequent sandy-pebbly intercalations or, more frequently, intercalations of conglomerates of Pliocene-Pleistocene age (PELLEGRINI & *alii*, 1978). The substratum shows marked tectonization which has also affected the alluvial cover itself.

The present morphological patterns of the Secchia and the Panaro river beds were defined in relatively recent times, starting from about 1950. Prior to 1950, they were definitely *pensile* beds and filled with gravelly material. Extraction of gravelly material for technological use (construction, roads, etc.) has triggered erosion and has resulted in a lowering of the bed levels by as much as 15 m in some spots (PELLEGRINI & *alii*, 1979). The more evident effects of the phenomenon are seen in the exposure of the bases of the piles of several bridges. Due to the lowering of the Secchia river bed in the vicinity of Rubiera, for example, sizable girders had to be added to the Via Emilia bridge and the bridge on the Milano-Bologna railway, to ensure their stability.

The channeling of the bed resulting from these erosion phenomena has caused a change in the flood hydrographs for the rivers (fig. 2). The frequent repeated floods that took place mainly between 1966 and 1975 were largely determined by changes in flow velocity and discharge.

The waters of the Secchia and Panaro Rivers have periodically caused flooding in the area of Modena (fig. 1). The more recent floods of the Secchia occured in April 1960 (flooded area (f.a.): 8,900 ha), November 1966 (f.a.: 7,000 ha), and September 1972 (f.a.: 1,320 ha). Those of the Panaro River occurred in November 1952 (f.a.: 3,000 ha), November 1966 (f.a.: 9,400 ha), September 1972 (f.a.: 2,540 ha), September 1973 (f.a.: 5,700 ha), and November 1982 (f.a.: 2,300 ha).

Two «flow-regulation systems» were planned and on constructed in areas adjacent to the courses of the two rivers in order to control these hydrogeological hazards in the area of Modena.

The Secchia river «flow-regulation system» is situated near Rubiera in the toe area of the Secchia River fan where the river flows inside an incision that is approximately 2 km wide and separated from the surrounding plain level by a scarp which is about 2 m high. This structure, which has been operating since 1979, is a device designed to control flood waters in the Secchia River, at the beginning of the embanked reach. In this area, the massive removal of material both from the bed and from quarries in the land adjacent to the river, had created an enormous varix.

A dam 9 m high was constructed across the river bed, with the two purposes of permitting free runoff at low water and small increases in flow rate, while holding back a considerable portion of the flood waters, first in the channel and secondly, over a certain level, in a large quarry by means of an overflow device (CERUTTI & *alii*, 1978). To increase the capacity of the storage area, the latter was bordered with an embankment of up to 6 m in height above the level of the surrounding land and of 8 km in length. This makes it possible to store about 7 million m^3 in the channel and 9 million m^3 in the lateral basin corresponding to the quarry area. With such volumes, the regulating capacity appears to be about 20 per cent under the worst conditions (from 1,160 to 920 m^3/s).

The weir on the Secchia is the principal structure of the whole scheme, consisting of an overflow dam 150 m long with the addition of four conduits to allow regular flow at low waters. Similar to a gravity-dam, it is constructed in con-

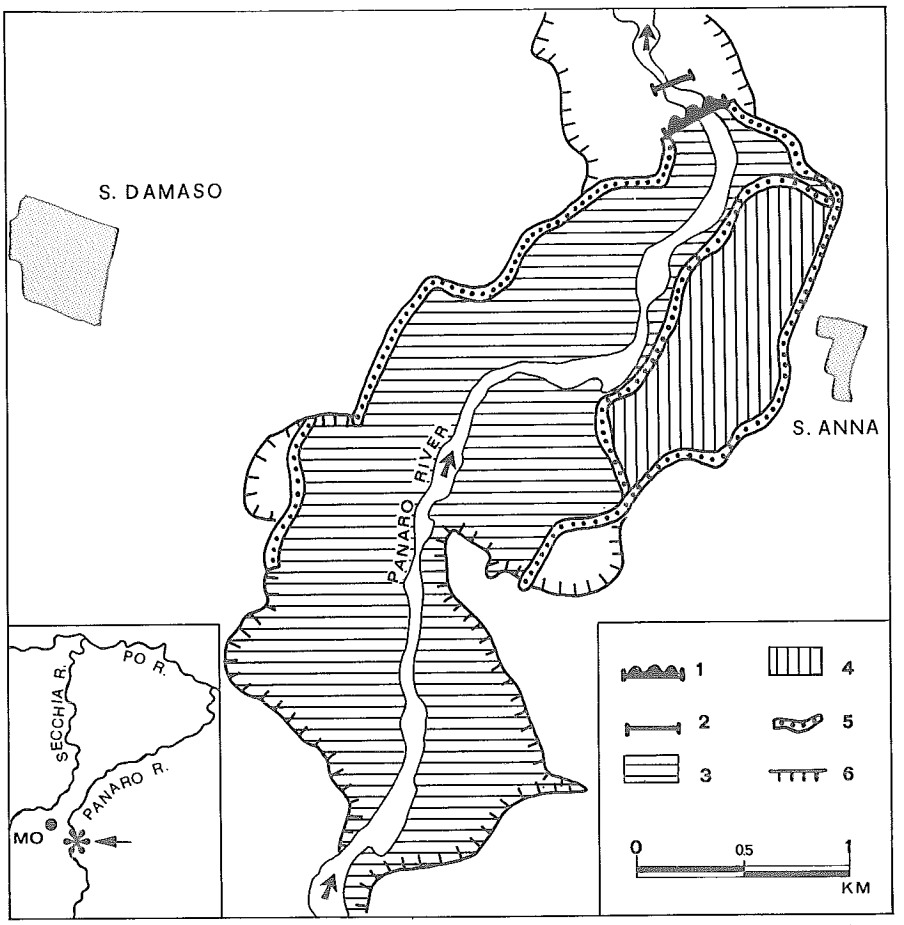

FIG. 3 - Panaro river «flow-regulation system» (from: PROVINCIA DI MODENA, 1987, with modifications)
1 - Main weir (or regulation systems); 2 - Downstream barrier; 3 - Storage basin; 4- Auxiliary storage basin; 5 - Embankments; 6 - Fluvial scarp edge.

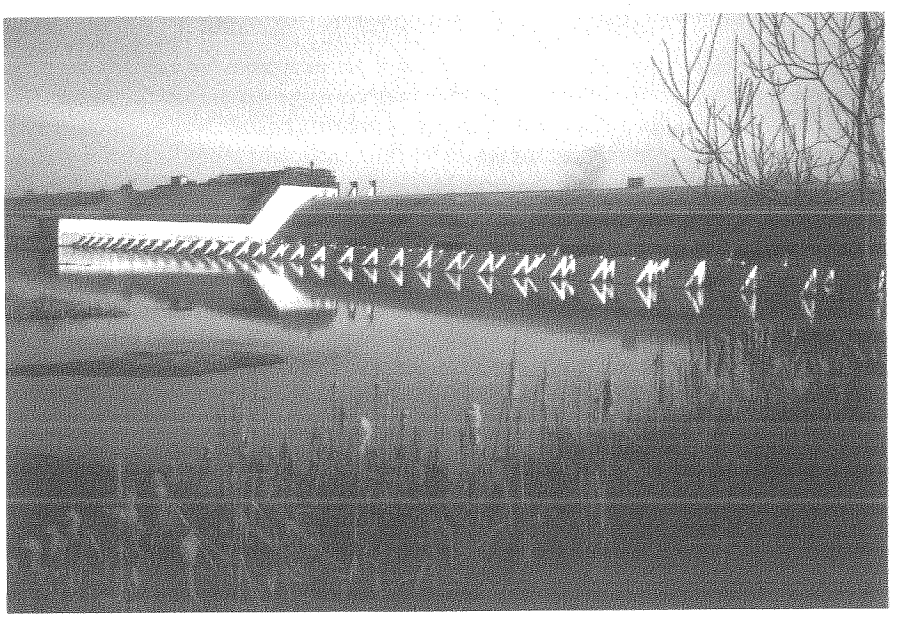

FIG. 4 - Downstream section of the main weir of the Panaro river flow-regulation systems (photo by Castaldini, March 1989).

crete with joints about 30 m apart and stands on continuous foundations consisting of diaphragm walls about 15 m below the level of the conduit, and reaching into a layer of clay.

The overall surface area involved in this construction is slightly less than 200 ha. The storage capacity is relatively moderate in comparison to the total discharge for each flood event. The most important purpose of the flow regulation system is to reduce the peak of the flood, that is, they intervene on a very limited capacity (see fig. 2B), but at an elevated hydrometric height (MORATTI & PELLEGRINI, 1977).

A stilling basin has been constructed downstream from the regulation structure and it is characterized by original forms (PELLEGRINI, 1984).

The Panaro river «flow regulation system» (fig. 3), operating since 1985, is situated slightly to the East of S. Damaso in the toe area of the Panaro River fan, within a channel that is 1.5 km wide and bordered by channel banks that are 4-5 m high. In fact, it is located in a geomorphological situation that is optimal for storing large volumes of water without necessitating major works for such purposes.

The Panaro river flow regulation system principally consist of the following structures (PROVINCIA DI MODENA, 1987):

a) a main weir (fig. 4): transversal structure of about 150 m in length which, in addition to allowing overflow, permits discharge through 9 lower conduits. During periods of low water, the water is discharged through apertures located at the level of the river bed. In the event of floods, no more than a limited amount can be discharged through these same apertures. Excess water is stored up-stream from the main weir, producing an increase in the water levels and regulating the flow downstream.

b) a storage basin: The basin is represented by an area of 350 ha providing temporary storage of the water contained by the regulating structure up to a capacity of over 15 million m^3. The basin is almost completely bordered by embankments about 6 km long that were constructed to increase the capacity of the storage area.

c) a downstream barrier: This is a transverse structure, about 350 m in length, constructed downstream from the main regulating dam and which serves the purpose of maintaining the river bed level, thus ensuring protection against bed erosion.

d) a selective barrier: The structure is situated in the vicinity of Spilamberto. This barrier consists of a transverse net which serves to prevent large plants and trees from blocking or interrupting the discharge from the apertures in the regulating structure, and thereby modifying the hydraulic functioning of the main weir.

e) an auxiliary storage basin: The main function of this is to provide an area of 4 million m^2 for extra flow in the event of an emergency.

The flow regulation systems for the Secchia and Panaro rivers have not yet been tested as to their efficiency under the flood conditions for which they were built. The systems were planned for major flood events, however, none have occurred since their completion. At any rate, similar structures are now being built on other watercourses in the Region of Emilia Romagna.

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