XXXIX Cycle Doctoral Proposal

Project: FAME - Floods Active Management during Emergency

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In lowland territories all over the world, Flood Management (FM) is still mainly based on passive structural measures, such as floodwalls, channelization, flood control dams and - above all - levees (Wenger, 2015). The continue raising of the levees tries to counter increased flood hazard consequent to urbanization, deforestation, soil compaction by agriculture and climate change (Blöschl, 2022). However, despite being traditionally adopted for their effectiveness in reducing flood frequency, levees imply as a flip side also an increased flood risk downstream (De Marchi, 1952). Flood risk can be in fact transferred across space due to the increasing of flow discharges and increased over time. Floods exceeding the levees design crest can unfortunately lead to overtopping and failure of the embankment (*Figure 1*), thus exposing communities to far more destructive consequent flooding (Liao et al., 2023).

Figure 1: The levee breach on the Secchia river at the end of the evolution

The structural and maintenance interventions currently planned to improve the safety of the embankments (swelling and elevations of the embankment shape, diaphragm walls, blockages of the dens of burrowing animals, etc.) therefore configure an approach not free from contraindications, especially in urbanized flood prone areas.
The recent levee breaches occurred in in Emilia-Romagna (Secchia river, January 2014; Enza river, December 2017; Reno river, February 2019; Panaro river, December 2020) have clearly highlighted that a paradigm shift is urgently needed due to the difficult maintenance of an embankment system characterized by a length of more than two thousands of kilometres, such as that of the Po river basin.
In the case of a breach triggered by overflowing (as is the recent case on the Enza river) the damage could have been drastically reduced if limited stretches of unerodible embankments in suitable locations had been designed and built, so as to force the waters to overtop there the levee, properly lowered with respect to the surrounding crest heights. To avoid overtopping in case the flood could be contained in the river bed at the level of the non-lowered embankments, these stretches could also be equipped with sluice gates or, more simply and economically, with temporary raising/sandbags to be removed during the course of an event. This would allow to avoid undesired, albeit modest, flooding during events characterised by medium frequency of occurrence. If, on the other hand, the flood

could not be contained in the riverbed, these stretches would behave as unerodible spillways, preventing from the overflow of neighbouring erodible stretches of the embankments and, consequently, avoiding the occurrence of uncontrolled flooding. The volume that would be overflowed in this case would be strictly limited to the quantity that cannot be contained in the riverbed, much less than that which would overflow as a consequence of an uncontrolled levee breach. This is not an original idea, since something similar is already present in the proposals made by Giulio De Marchi after the catastrophic Po river flood in 1951 (De Marchi, 1952). However, compared to seventy years ago, the assessment of the evolution of flooding and of the territories that would be involved, the optimal location and design characteristics of the prefigured control devices can nowadays be easily identified with high reliability thanks to the high-performance 2D Shallow Water Models (SWE) currently available (Vacondio et al., 2016, 2017). There are many aspects to take into consideration in order to achieve effective active flood management: 1) the identification of the embankment stretches most subject to risk of overflowing and consequent collapse; 2) the evolution of the flooding and the territories involved; 3) the estimation of the expected damage for human life, cultural heritage, economic activities, infrastructure and the environment. The study of necessary interventions outside the riverbed to protect areas of high vulnerability should also be accomplished, together with the control during the event of multiple devices insisting on the same watercourse. These elements presuppose the possibility of operating in real-time, which in turn requires the implementation and refinement of computationally efficient mathematical models (Aureli et al., 2020; Aureli et al., 2021; Dazzi et al., 2022).
On the basis of these assumptions and the proposed interventions, "*...flood defense would lose its rigid and passive character, which allows for simple tactical operations of relief and local defenses, and would instead provide, to those who have to manage it, a certain possibility of strategic manoeuvres, to avoid major disasters*" (translated word for word by De Marchi, 1952).

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