RIVER BRENTA DEFENCE BY CONTROLLED FLOODING

Michelle Ferri[1] & Fabio Giuriato[1]

ABSTRACT

The way to tackle the even more frequent and harmful floodevents, is to adopt efficient forecasting and risk prevention methods. This can be obtained only through a deep understanding of causes and dynamics involved in such events.
The local Water Authority of North Eastern Italy, which is in charge of the planning and coordination of flood defence, water use and protection of water resources, has developed an accurate and robust of the hydrologic response model. The model, of the geomorphologic - MonteCarlo type, reproduces stochastic and real hydrographs and thereby the return period of peak flows and of any other feature of engineering interest, including shapes and volumes.
The salient geomorphic features of the basin is recovered by digital elevation model while the land cover analysis is based on data from remote sensing. The model captures the essential physics of the relevant processes, rather than merely reproducing a correspondence between inputs and outputs within a finite set of observations. So predictive capabilities and robustness of the model are showed.
The main forecasting measures adopted in the regarding Plan for Brenta river hydraulic defence are presented: identification of the maximally effective gate operations for flood mitigation using the storage capacity Corlo reservoir, development of the hydro-meteorological networks, real time interconnection of the hydro-meteorological control system and definition of the alerting procedures based not only on the notification of adverse weather conditions, but also on the knowledge of the land vulnerability according to established rainfall scenarios.
The operation rules of the Corlo reservoir were optimized to meet the different requirements of use. From the operative point of view, a meaningful improvement in flood defence has been observed when a new gate geometry in association with a suitable meteorological prediction is introduced: if the bottom outflow capacity is increased from 150 to 550 m3/s, all dam gates can be closed after inflow discharge is more than such value; as a consequence the Cismon peak's time is anticipated regarding that one of the Brenta river and the new different phase of the tributaries flood peak reduces to 1350 m3/s the maximum discharge expected at the following draft.
The new gates configuration and a robust meteorological forecast allows a not imposed low constant water level (240 m.s.l.m) in the period 1 september -30 november; contrarily the dam manager could operate a fast drawdown level in the case of predicted critical rainfall.

Keywords: flood defence, hydrologic response model, water reservoir, forecasting measures

[1] Autorità di Bacino dell'Alto Adriatico, Dorsoduro 3593, 30123 Venezia, Italy, phone: +39 041 714444; fax: +39 041 714313; e-mail: ferri@idra.unipd.it

INTRODUCTION

Progresses and improvements in the field of hydrological research led to significant achievements and developments for what concerns flood management system. The possibility of creating a mathematical model based on the deep knowledge of physical phenomena, is of utmost importance in river engineering.

The Alto Adriatico River Basin Authority in charge of planning and coordinating flood defence, water use and protection of water resources developed with the International Centre of Hydrology in Padova, an accurate and robust mathematical model of the hydrologic response for the river Brenta closed at Bassano del Grappa (Northen Italy).

The model gives the opportunity to evaluate planning decision in order to reach flood defence. Moreover it permits the identification of the effects produced by reservoirs using its storage capacity for flood mitigation.

The aim was to integrate the flood risk management including the reservoir operation strategies into the river catchments management. In fact in the case of a multipurpose reservoirs, as in Brenta river, there are competing purposes: flood protection needs an initially large empty flood control storage resulting in a low water level. Contrarily recreation, water power and water supply needs a high water level because of required supply safety and the need of water extraction in different water levels to guarantee the water quality.

THE CATCHMENT BASIN OF THE BRENTA RIVER

The Brenta river originates from the Caldonazzo lake initially flowing eastward past Levico and beginning south downstream of its confluence with Grigno torrent. Further south, the river is joined by Cismon torrent and at Valstagna bends south-east down to Bassano del Grappa. From Bassano to Carmignano, the Brenta sweeps in a westward arc over a broad gravel bed before meandering toward the outskirts of Padua. Past Padua, the Brenta flows toward Chioggia and into the Adriatic, diverted from its original course into the Venetian Lagoon in order to control siltation and swamping effects.

The Brenta runs 174 km in length, the first 70 km from the source to Bassano flowing through mountainous terrain rich of historical takeovers, the remainder, from Bassano to the sea, across flatlands full of industrial areas.

The flood generating area of the watershed of the Brenta river, with an extension of 1570 square kilometres, terminates at Bassano (Figure 1); thereafter the river progresses across an alluvial plain. The Cismon is the most important tributary due to its large catchment area, matching that of the main course of the Brenta, privileged with a high level of rainfall and abundant runoff from snowpack on the mountains in the Northern part of the basin. The ability of the Cismon to supply copious water, a fact well known to local residents, gave rise long ago to the saying: “El Brenta no saria Brenta se el Cismon no ghe dasse una spenta…” – The Brenta would not be the river it is, without a “shove” from the Cismon.

The area contains a large number of dams for hydropower production (Figure 1). The most important of these, for storage capacity, is the Corlo reservoir. This is a multipurpose reservoir for irrigation water supply, recreation and downstream low water regulation during dry seasons.

The system behaviour knowledge needs a wide range of input and control data as rainfall observations, water level and discharge measurements of the extreme flood events which were made available from ARPAV (Regional Environmental Protection Agency).

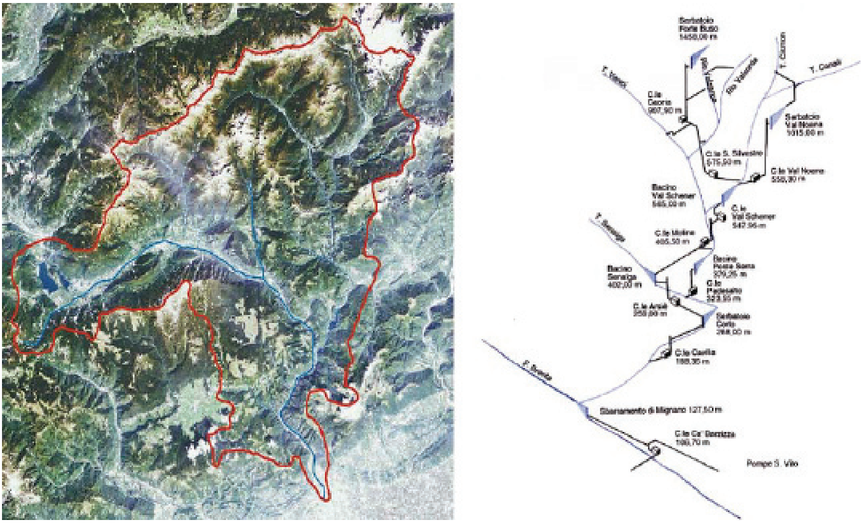

Fig.1: The catchment basin of the Brenta river with dams for hydropower production.

THE MATHEMATICAL MODEL

The hydrological model is aimed at incorporating state of the art information, from remote sensing and ground measurements, to address, in the framework of the formulation of transport by travel time distribution and of real and Montecarlo rainfall patterns in space and time, runoff production.

The geomorphologic theory of the hydrologic response is based on the definition of the probability density function associated to travel time in different states, hillslopes and channels, assuming that different states are statistically independent (*Rodriguez-Iturbe & Valdes*, 1979; *Gupta & Waymire*, 1983; *Mesa & Mifflin*, 1988; *Rosso*, 1984; *Troutman & Karlinger*, 1985; *Karlinger & Troutman*, 1985; *Rinaldo et al.*, 1991; *Rinaldo & Rodriguez-Iturbe*, 1996). Travel time distribution in the channels is derived from a parabolic model of flood wave propagation that includes both cinematic than storage effects (*Rinaldo et al.*, 1991). Complete use is made of the geomorphologic structure of the basin relevant to the above processes: the detailed geomorphologic features of the basin are recovered through manipulation of a digital elevation model with a clearance of 20x20 m (Figure 2 shows Brenta DEM which has been superimposed to Landsat image).

Different criteria of network extraction have been applied (*Tarboton et al.*, 1991; *Dietrich et al.*, 1993; *Cabral & Burges*, 1994; *Rodriguez-Iturbe & Rinaldo*, 1997) but we show that the travel time distribution is quite independent from the extraction methodology (*Ferri et al*, 2004).

Path probabilities (*Gupta & Waymire*, 1983) are deducted directly from the synthetic or sperimental distributions of the precipitations. The evolution in space and time of meteorological events is described through a geostatistical interpolation of recorded data (*Bellin & Rubin*, 1996)

The resulting model is lumped in the parameters but distributed in the description of the geometry.

The land cover analysis and runoff production schemes are based on data from remote sensing. In particular the recognition of some sample areas in the catchment allowed the use of a supervised classification procedure, based on the spectral angle mapper algorithm (*Kruse et al*., 1993). The knowledge of the spatial distribution of soil cover is fundamental to determinate parameters which control run off production: soil permeability and evapotraspiration spatial distribution. To determine effective rainfall, the Soil Conservation Service method (SCS) has been used.

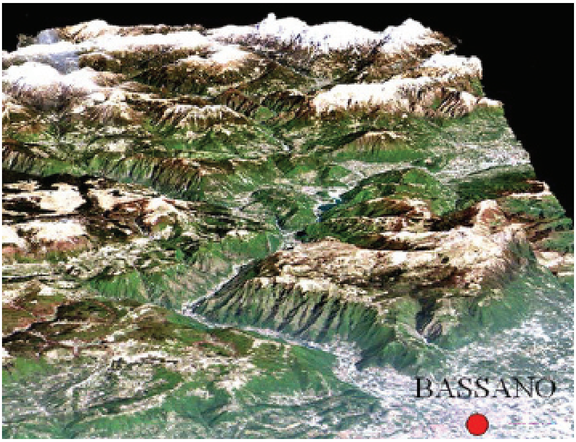

Fig.2: DEM for Brenta catchment basin.

Much information on dam characteristics and hydrological and hydraulic parameters have been collected to account for the effect of water reservoir presence. In particular, to solve the continuity equation for each dam, the geometry of each gate and the correct relationship between discharge, water level and gate operations were determined. Finally, flood hydrographs discharge during important flood events have been recovered.
Previous important flood events among them the 2002 event have been used to calibrate the model. In fact an obvious requirement prescribes that the model be capable of reproducing, with specified accuracy, the observed system behaviour. Figure 3 shows the comparison in two different sections (Corlo and Bassano) between observed and simulated flood for different events in shape and volumes (*Rinaldo et al*., 2002).
The model captures the essential physics of the relevant processes, rather than merely reproducing a correspondence between inputs and outputs within a finite set of observations. So predictive capabilities and robustness of the model are evident.
The hydrological model has been coupled to a Montecarlo model (*Rinaldo et al*., 2002) which allows to generate an unlimited sequence of events of different duration. This is allows the relaxation of unphysical or unrealistic assumptions, like, typically, statistical stationarity of the response of a drainage basin, for example subject to continuous changes in soil use.
To connect the damages due to the inundation with the precipitation-runoff-model a one-dimensional hydrodynamic model has been introduced into the calculation. It solves the one-dimensional shallow water equation and can be used for both steady state and dynamic water level calculation. The profiles of river cross section were determined by terrestrial surveying; additionally laser scan data were used for the whole watershed and the flood plains. Backwater effects of bridges and weirs as well as more complex cross sections have been considered. Another calibration was necessary for the hydrodynamic model: it can be stressed that, after such calibration, the mean difference between observed and calculated maximum

water levels at the hydrometric stations of Brenta was about ±5cm.

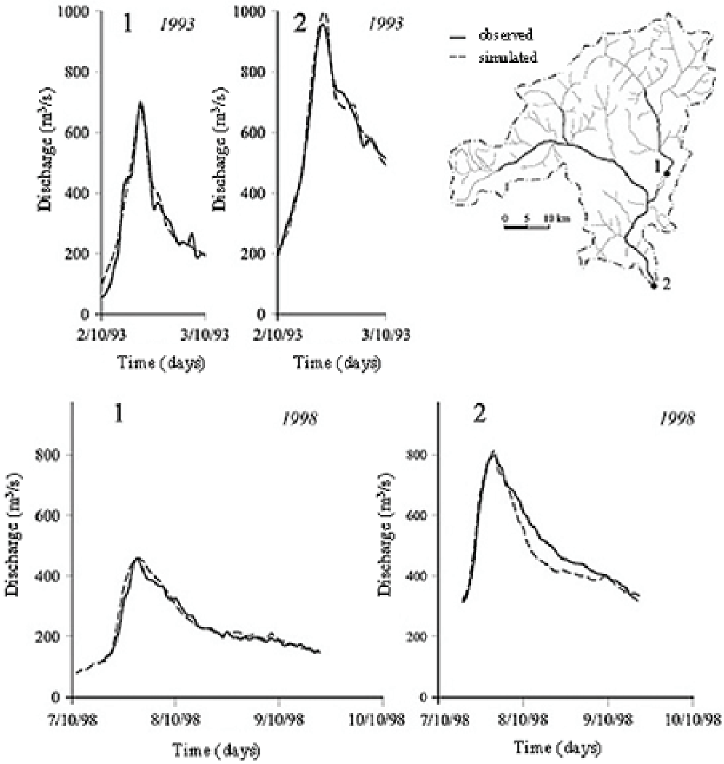

Fig.3: Predicted and measured flow for different flood event at Corlo and Bassano (*Rinaldo et al*., 2002).

RESULTS

The geomorphologic-Montecarlo model allowed the production of stochastic hydrographs and thereby the reconstruction of the return period of peak flows and of any other feature of engineering interest, including shapes and volumes for the natural Brenta system that is river network without dams or any other structure capable to modify flood generation and propagation. Other important information for Brenta behaviour knowledge can be obtained by the reconstruction of the most recent flood disaster in November 1966, when a peak value of 2700 m^3/s was esteemed (Figure 4).
The comparison of said waves with Brenta cross sections shows a flow capacity of about 1500 m^3/s for Canal del Brenta. Of particular relief it is instead the present hydraulic suffering in correspondence of the lived one of Valstagna where a flow capacity of 950 m^3/s was valued (Figure 5).
After these results, a new set of different cross sections that considers a wider channel form as well as deeper bed form in Valstagna, were performed. The increase of conveyance that can

result from these new sceneries was estimated 400 m^3/s more (*Gamba et al*., 2004).
These solutions can be added to other set of projects in the upper part of the basin for planning a partial or complete reduction of the risk.
Amongst the proposable actions for flood defence foreseen, structural interventions, that is, real civil engineering works and non-structural interventions, namely those which include behavioural rules useful in mitigating dangerous conditions can be considered.

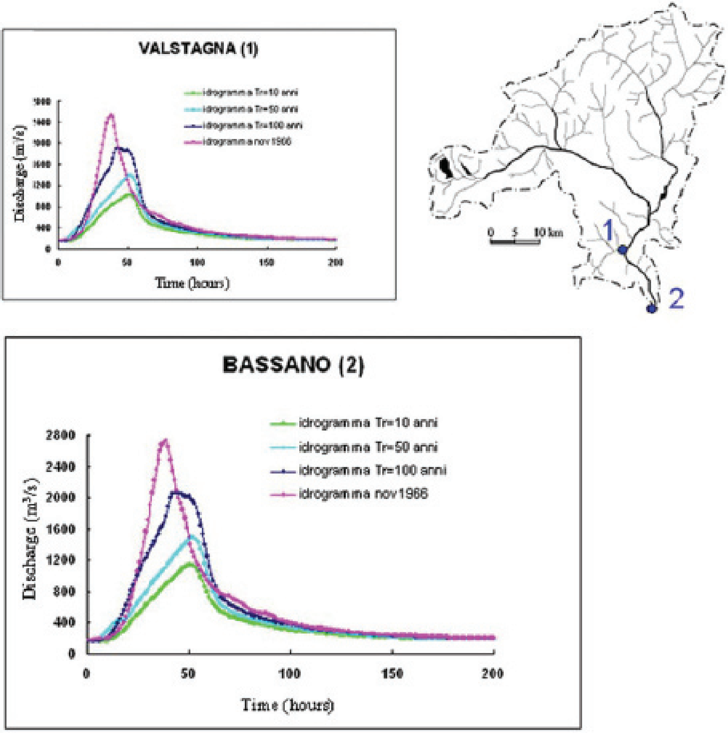

Fig.4: Flood event in Corlo (1) and Bassano (2)generated with different return period.

An example of non structural intervention is the temporary use of hydro-electric reservoirs existing in the mountain basin: on the river Cismon which governs Brenta floods, as already explained in the previous sections, Corlo reservoir can be used to test the reduction of the peak discharge in autumn season. In order to evaluate the effects produced using its all storage capacity without any other structural measure, geomorphologic-montecarlo model was successfully used: simulations were performed with artificial flood events characterized by a recurrence period of about 5 to 100 years and beyond and the series of historical flood events.
Referring to the results shown in Figure 6, the availability of additional volumes in the reservoir, obtained by lowering the level in the lake before the flood event allows the safe containment of the 70yrs flood event.

Another important application, the identification of the maximally effective gate operations for flood mitigation in association with a real time interconnection of the hydro-meteorological control system was also addresses. If the dam Corlo gates are opened in perfect matter just before the discharge in Cismon reaches its maximum the peak reduction is less than 50 m3/s for the100 years return period event. Due to inexact forecast and an early opening on the inlets the retention effect could be completely lost.

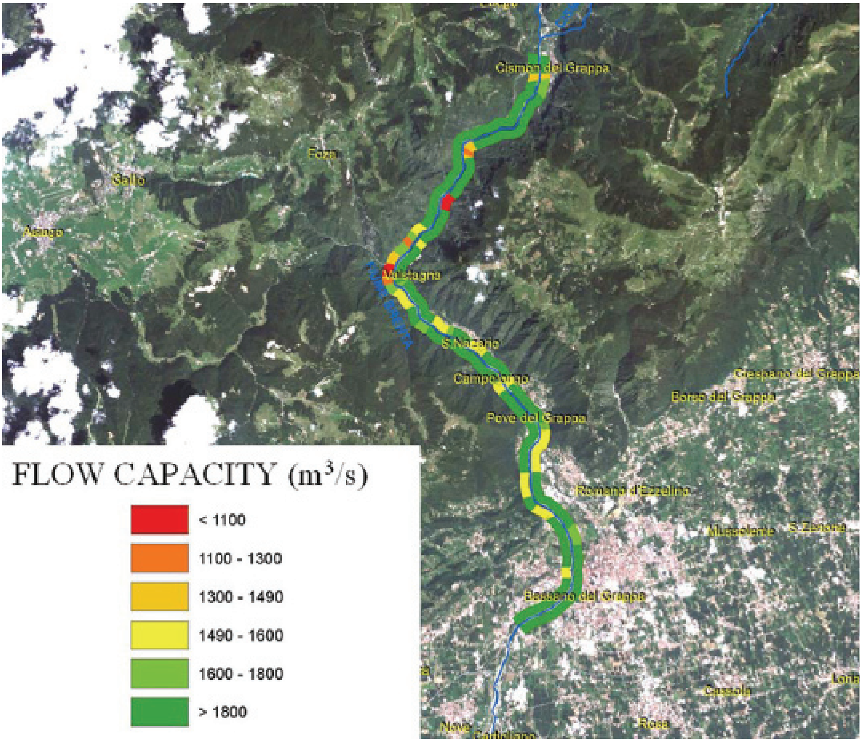

Fig.5: Flow capacity of Brenta river.

This result can be interpreted as a low dependence of minimal outflow discharge from inflow hydrograph and operation rules: for what concerns the actual gates configuration, the peak discharge reduction ability of Corlo is not particular sensitive on opening time of the outflow organs. However it's possible to reduce in meaningful way hydraulic risk with relative low problem in both time and money necessary to realise the work foreseen.

Finally the optimized final river engineering plan was implemented by defining as an optimization objective for instance the minimization of hydraulic risk.

The operation rules of the Corlo reservoir were optimized to meet the different requirements of use. From the operative point of view, a meaningful improvement in flood defence has been observed when a new gate geometry in association with a suitable meteorological prediction is introduced: if the bottom outflow capacity is increased from 150 to 550 m^3/s, all dam gates can be closed after inflow discharge is more than such value; as a consequence the Cismon peak's time is anticipated regarding that one of the Brenta river and the new different phase of the tributaries flood peak reduces to 1350 m^3/s the maximum discharge expected at Valstagna.

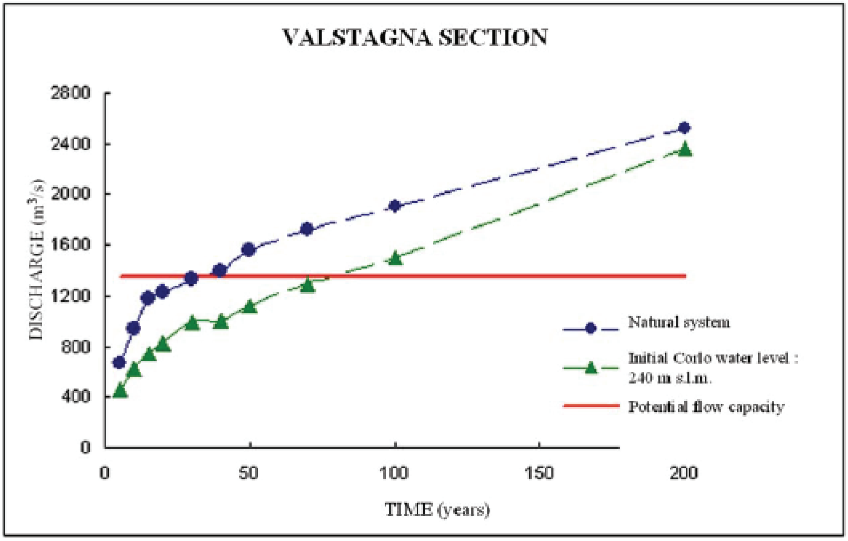

Fig.6: Discharge in Valstagna for different return period in natural condition and with Corlo at 240 m s.l.m. as initial water level.

The new gates configuration and a robust meteorological forecast allows a not imposed low constant water level (240 m.s.l.m) in the period 1 september -30 november; contrarily the dam manager could operate a fast drawdown level in the case of predicted critical rainfall. The feasibility of such actions requires the development of studies about shore stability.

CONCLUSION

River Basin Plan is a container where all the interventions concerning the protection of water resources and defence from flood are planned and co-ordinated. The technical solutions which are chosen with the corresponding rules and the relative priorities of intervention gives us the project plan.

During the functional phase of the preliminary planning process, the Alto Adriatico River Basin Authority has developed an accurate and robust mathematical model of the hydrologic response for the river Brenta closed at Bassano which can be used as a powerful flexible instruments to study new solutions for planning a defence by controlled flooding.

Simulations shows that the temporary use of hydro-electric Corlo reservoir existing in the mountain basin can successfully help to resolve the hydraulic safety problem of the river Brenta.

Here therefore confirmed that among all the possible solutions, a non structural intervention with a low costs of realisation, a fast time for implementation, very places itself in the interventions of short period of a plan of hydraulic emergency in the wait to realize in the mean and long period the eventual definitive structural ones.

A practical solution to reach a complete reduction of the hydraulic risk considering inundation damages as well as other social and ecological impacts has been proposed.

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