WEATHER AND WATER MONITORING IN THE PO BASIN - FORECASTS, MODELING AND ORGANIZATION FOR THE DEFENSE AGAINST RIVER FLOODS

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Abstract

The Po river is the main Italian river and its basin is approximately 660 km long.
Its area covers over 70.000 km2 with a population of 16 million people and accounts for 50% of gross domestic product.
Flood defence of such an important social-economic community is achieved through construction and maintenance of levees systems, flood retention tanks, forecasting and prevention activities.
In recent years AIPo has made large investments of financial and human resources to create water modelling systems able to simulate and forecast the evolution of floods phenomena in order to organize the flood emergency service and civil protection activity for citizens.
The forecasting system processes data delivered by a real - time monitoring network consisting of more than 1500 sensors (rain gauges, snow gauges, hydrometers, thermometers) by means of hydraulic and hydrologicalmodels, providing detailed forecasting of the flood phenomena.

THE AGENCY ACTIVITY

The Po River is the main Italian river both for the length of the main course, approximately 660 km, and for its water flow fed along its course by 141 tributaries.

These are the characteristics of the closing section

Closing section of the basin	*Subtended basin*		*Drought flow*	*Average annual water flow*	*Maximum recorded water flow*
Pontelagoscuro	70,091 km^2		300 mc/sec	1500 mc/sec	12,500 mc/sec

Its area covers over 71,000 square kilometers, a quarter of the entire national territory, affecting 3,200 municipalities in six regions: Piedmont, Valle d'Aosta, Lombardy, Veneto, Liguria, Emilia-Romagna, and the Autonomous Province of Trento.

The importance of the basin is not so much due to its size which is small in comparison to the major European rivers, but to the strong anthropization of the territory where it flows. The density of the area, the manufacturing activities, the infrastructure and use of water resources make the Po basin an exceptionally diverse area and a focal point for the Italian national economy

In fact, this area accounts for 40 percent of gross domestic product, 37 percent of the domestic industry, which supports 46 percent of jobs, 55 percent of livestock in only 5 provinces, and 35 per percent of the agricultural production. The consumption of electricity is 48 percent of the national consumption.

The population living in the basin is about 16 million people.

This intense anthropization has determined a growing demand for the implementation of safety measures in the area in the last century with consequent construction of containment works (the length of embankments has increased from 1574 km in 1878 to 3470 km in 2010). The growing use of passive defenses instruments reduced the frequency in which the banks were broken by the river thus preventing significant portions of the floodplain from being affected by the overflow dissipation and also increasing the levels and runoffs along the main course of the river over the years. This resulted in the progressive increase of top embankments.

It is clear that the strategy cannot be pursued indefinitely both for natural structural limits of the embankments and for its ineffectiveness in reducing the risk at basin scale.

The objectives set out, on which it is necessary to work at different levels for the hydraulic re-balancing of the river, are therefore structural and non-structural. The aim is to improve both the shape (by improving the morphological configuration, balancing the dynamics of sediment transport and increasing, when possible, the reservoir capacity to attain the goals set by the Directive regarding runoff flow limit) and the use of the resource (by rationalizing the use of water resources at the basin scale and for land use).

Water modeling system

Among the most important non-structural activities that the Agency has carried out in the last five years in order to pursue these strategic objectives there is the creation of a water modeling system for the management of extreme events (droughts, floods).

This project, which will be completed in 2010, consists of two modules, one for flood management and one for drought management integrated into a single work environment developed by the Dutch group Delft Hydraulics called FEWS.

According to the concept of the system environment by Delft-FEWS an open system will be provided to allow the use of a large number of existing simulation models. The modular and highly configurable nature of the system environment makes it possible to effectively use both simple and very complex forecasting models, which use a large number of hydrological, hydraulic and water management models (already used by emergency management centers in England, Germany, Switzerland, The Netherlands).

Flood forecasting model

The main aim is to create a single forecasting modeling system on the main course of the Po river, applicable to the entire Po basin, which is automatically connected to hydrological-hydraulic modeling systems for real-time forecasting operated by Regional Functional Centres of the Po Basin area and which can transmit the data needed by the competent bodies to organize the flood emergency services and civil protection activities during emergencies.

The integrated system will be conveniently used to provide the authorities, the institutional and regional bodies responsible for emergency management with the information regarding the beginning and development of water and hydro-geological risk, related to the occurrence of particularly intense weather-hydrological events which can provoke damages in the affected areas and endanger the population.

The modeling system for flood forecasting, which is very advanced in Europe, consists of three models of rainfall-runoff, using two conceptual schemes (MIKE11 NAM Danish Hydraulic Institute Water & Environment1, HEC HMS U.S. Army Corps of Engineers – Hydrologic Engineering Center2) and one that employs a distributed scheme (Topkapi-Università di Bologna Italy3) in the interpretation of physical processes. These models take into account the influence of topography, quantity and intensity of rainfall, soil moisture content, soil type and its use. To obtain a proper operational use of codes of rainfall-runoff transformation, appropriate validation techniques are used, sampling and reconstruction of the input data for the numerical transformation process. There is also a significant presence of combination techniques of multi-sensor observations in the estimation of precipitation fields.

The hydraulic propagation along the main water courses was implemented using three hydrodynamic chains implemented by MIKE11 HD4 (Danish Hydraulic Institute Water &

[1] MIKE 11 NAM from the Danish Hydraulic Institute Water & Environment is a deterministic hydrological model of rainfall-runoff transformation, physically based, lumped, consisting of a set of mathematical relationships related to each other in order to describe quantitatively the terrestrial phase of the water cycle. The continuous model simulates the variation of water content (in liquid or vapor) of separate reservoirs and mutually connected, which represent the physical elements of the main basin. Reservoirs reproduce the following processes: accumulation and melting of the snow, interception, infiltration, storage in the aquifer.

[2] HMS is a code designed to simulate the processes of rainfall-runoffs within a river basin, applicable to the most diverse geographical conditions and for different hydrological problems: from the determination of the flash flood typical of a water body in a large basin, to the runoff affecting medium size natural or urban areas: HMS is a deterministic model, conceptual or empirical (depending on options used), with lumped or distributed parameters. HMS divides the rainfall/runoff transformation into four different phases: calculation of the effective volume, hydrograph determination of superficial runoff, calculation of deep runoff, flash flood translation. For each of these stages different methodologies can be used for the calculation.

[3] Topographic Kinematic Approximation and Integration) is a model of a distributed, structured into three modules which represent the soil component, the surface runoff and the runoff components along the drainage network, each of which adopts a kinematic wave propagation scheme. In the model the soil plays a key role, since it is the water balance in the soil that regulates the dynamics of the production of surface runoff, so the storage of water in the soil is the main system status variable. According to the soil saturation attained, the mechanism of surface runoff is triggered. Both soil and surface runoff fuel the drainage network.

[4] MIKE 11 HD of the Danish Hydraulic Institute Water & Environment is a general program for simulating flows in one-dimensional conditions, stationary and non-stationary, of vertically homogeneous fluid in any system of channels or river courses. In particular it is possible to take into account : lateral floes, fast or slow current conditions, free flow or regurgitated at the spillways; different operating rules of operation of reservoirs or dams, local resistance and losses of

Environment), HEC-RAS (from the U.S. Army Corps of Engineers – Hydrologic Engineering Center5) and Sobek (Delft-Hydraulics6).

Weather forecasts involved in the system are both deterministic, with the LAMI model that provides two Lokal Modell runs a day, integrated for 72 hours to 7 km horizontal resolution (whose boundary conditions are extracted from the GME of DWD global model and the initial conditions are produced by a continuous assimilation cycle during which LM acquires data provided by the Italian Air Force General Office of Meteorology) and probabilistic, with the COSMO-LEPS, which provides a run a day with the help and cooperation of the ECMWF system (European Center for Short Term Weather Forecasts) based on the integration of 16 Lokal Modell, 10 km of horizontal resolution on a European domain of integration. The run of the 16 models is initialized and driven by 16 members of Ensemble selected from those of ECMWF-EPS) and real-time monitoring network consisting of more than 1500 sensors (rain gauges, snow gauges, hydrometers, thermometers).

All weather information provided and observed from the various measurement or simulation systems, are properly converted into a common format for hydrological and hydrodynamic modeling chains that constitute the integrated system.

To understand the level of detail and complexity of the system outlined, almost 11,000 cross-sections, 2500 works (bridges, flow adjusting sections, holms etc) have been implemented.

Model for the forecasting and management of droughts

In the same system environment a forecasting modeling system has been developed as well as system for simulation and control of droughts of the Po river, capable of providing adequate support for decisions to be made at the basin level. The modeling system allows:

flow; flow adjusting sections; quasi-two-dimensional flow conditions, action of wind, hubs (bifurcations and convergences).

The general equations of De Saint Venant were transformed into a system of equations implying finite differences according to a calculation grid with points Q and h alternating, in which the flow Q and the water level h, are respectively determined at each time step (Abbott scheme to 6 points)

[5] HEC-RAS solves the equations of De Saint Venant distinguishing between the riverbed and alluvial zones, using a calculation grid with points Q and H coinciding, in which the flow Q and the water level h, respectively, are determined at each time step according to the numerical scheme of Preissmann .

[6] The Delft-scheme solves the system of De Saint Venant equations through a grid of calculation points Q h alternating, in which points h (water level) are defined at the connection of nodes and calculation nodes, points Q (flow) are always positioned midway between two near points h.

- The simulation of use and availability of water resources under different conditions of water regime;

-the definitions of schemes for the water balance and a methodology for the management of water resources.

The system can be used for:

1. Long-term basin planning : preparation of basin plans in the medium and long term, such as time frames from 10 to 25 years

2. Planning resource allocation in the short term (six month or annual): preparation of seasonal operational plans for the basin

3. Preparation of seasonal operations: during the seasons based on the actual situation on the field, on the precipitation and on updated forecasts it is possible to plan the resource allocation for the following weeks or months.