CONCLUSIONS

The hydrologic impacts of eliminating flood basin storage are clearly depicted by comparison of the pre-flood control and post-flood control valley inflow and outflow hydrographs. In their natural state, the flood basins stored high fall and winter flows (reducing basin outflow from November through March) and released these flows in the spring and summer (increasing basin outflow from March through July). This redistribution of annual flows was important to ecological processes in the river and estuary system.

REFERENCES

CDWR (California Department of Water Resources). 1994. *California Central valley Unimpaired Flow Data: October 1920 through September 1992.* California Department of Water Resources, Sacramento. 54pp.

CDWR (California Department of Water Resources). 1995. *Historic Outflow Data: Model Run 1995c06a.* California Department of Water Resources, Sacramento.

Gilbert, G.K. 1917. *Hydraulic-Mining Debris in the Sierra Nevada.* Government Printing Office, Washington, D.C., 154pp.

Hall, W.H. 1886. Physical Data and Statistics of California: tables and memoranda. State Engineering Department of California, Sacramento. 451pp.

Roos, M. 1973. Drought Probabiliyt Study Sacramento River Basin (Progress Report). California Department of Water Resources, Sacramento. 90pp.

USCOE (U.S. Army Corps of Engineers). 1916. *Supplemental Report on Flood Control of the Sacramento River (House Report No. 616)*, Government Printing Office, Washington D.C.169pp.

Hydrodynamic approaches to design balancing ponds

M.J.J. PIROTTON
University of Liège, Institute of Civil Engineering,
Dept. of Applied Hydrodynamics and Hydraulic Constructions
6, Quai Banning, B.4000 Liège, Belgium

ABSTRACT

This paper aims to summarize the global hydraulic studies carried out in order to prevent the floodings of a small river located in the western part of Belgium. A first stage is devoted to compute the hydrograph resulting from extreme rainfalls on the catchment, using a distributed physically based model. Its numerical propagation on the studied site reflects the actual situation in the vicinity of the river site. Due to natural reservoirs, the flood peak is dampened and its base extended, i.e. the flood subsides. This peak reduction is first fitted to the reality by unsteady computations that handle the lateral exchanges between the planned floodplains and the main river. Besides, they led to optimise the location and the size of the planned lateral reservoirs as well as to forecast their impacts on the surroundings. This paper summarizes simplified approaches that saved much computational effort.

INTRODUCTION

« L'Espierres » is a small river flowing through the border between France and Belgium. This tributary is parralel to a navigable waterway for small ships along 8 kilometres before joining the Scheldt river. Because of the significant difference of water quality, mixing is not permitted between both flows. When floods occur in the Espierres river, the resulting flood stage implies a complete cross-section filling. Gradually, water spreads on the floodplains and flows into the bordering canal. Two basins were planned in Belgium in order to protect the near by sites of the river. The simulations have to reflect the ability of the lateral weirs to diverge the prescribed volumes and to forecast the smoothing of the hydrograph propagating along this 8 km long section.

HYDROLOGICAL PHYSICALLY BASED MODEL

We focus here on the thin water layer propagating on natural tridimensional slopes in order to compute the lateral discharge for each river element. This additional inflow that propagates in the main drainage path is then computed in a final stage with the specific software further described.

It is commonly supposed that a dynamic equilibrium exists between friction and gravity components in the flow direction. Resulting from the scale difference between the spatial dimension and water layer thickness, we assume biunivoque relations between the speed components and the water depth.

The resulting non-linear equation has been entitled kinematic wave approximation and was proposed for the first time in the hydrology field by Woolhizer and Ligett.

$$\frac{\partial h}{\partial t} + \frac{\partial (a_i h^{m+1})}{\partial x_i} + B(h) = 0 \qquad \text{on the domain D} \qquad (1)$$

with the following notations :
- $h(x_i,t)$: the water depth
- $B(h)$: the general function including the infiltration speed into the soil, the intensity of rainfalls and other effects of exchanges and losses
- a_i : functions including topographical data, surface and flow characteristics

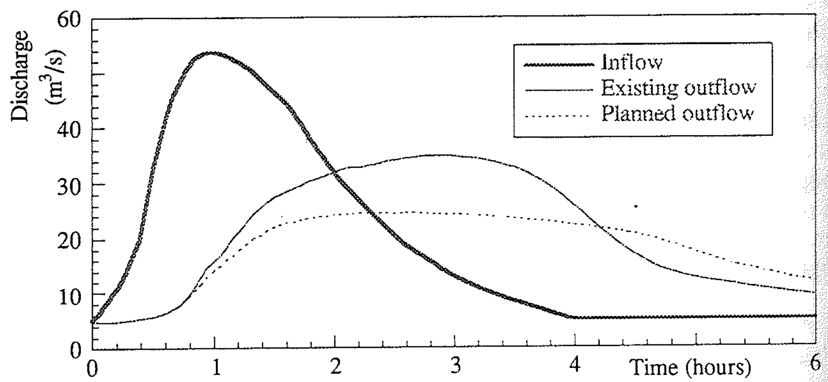

Figure 1 - Flood subsidence between the entrance and the outlet

The analysis of theoretical solutions assesses that hydraulic jumps arise on complex topographies at the scale of the thin water layer. The physical relevance of those kinematic shocks suggests the unique formulation of the weak solution of the problem. In order to prevent the occurrence of multi-peaked solutions highlighted by significant errors in the global volume balance (classical Galerkin method), a shock capturing finite element approach is used which introduces discontinuous test functions (see [1]).

The package works on any digital terrain model. It handles spatial and temporal variations of rainfall and soil properties. Partially dried elements deal with the effects of infiltration. Discretising the natural 5,000 ha catchment slopes submitted to significant rainfalls, we compute the ensuing hydrograph that

propagates in the main drainage path. The temporal evolution of the upstream imposed discharge is illustrated on figure 1.

OPEN-CHANNEL FLOW

As far as the problem is handled in a steady way, unrealistic friction factors issue from a reasonable fitting between computed water profiles and measured values. This stage suggests two major remarks. Firstly, local overflowings are so important that we have to face the understanding of the flow in compound channels, the importance of which is frequently reported in the literature. Secondly, the computed inflow could be locally overestimated. Since the global balance confirms the accuracy of the hydrological approach, it seems essential to account transient influences that smoothen the hydrograph along its propagation. The smoothing would not result from the roughness properties but much more from the exchanges between the main path and lateral areas.

The sketches on the figure 2 highlight two potential circumstances that affect the suitable reasoning to achieve about lateral exchanges.

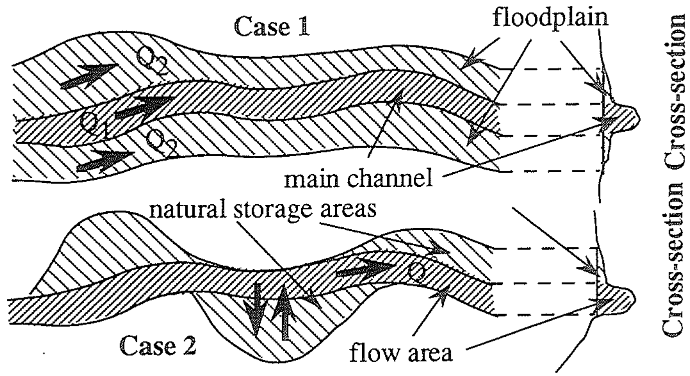

Figure 2 - Hydraulic influences between the main channel and the floodplain

In the first case, the typical shape of the cross-section on the whole is spatially uniform enough to conceive that each sub-section is hydraulically homogeneous, inducing two main streams. Several recent papers explain why common methods based on conveyance considerations lead to substantial errors, as well as why the right approach has so far to be found.

In the second event, the open water course is locally disturbed, especially on the floodplain, by topographic unevenness and manmade structures. All these hazards prevent the discharge to develop freely on the floodplain. It acts as lateral storage areas, with hydraulic death zones where water movements occur only in the transverse direction. The occurrence of culverts in the Espierres river in order to flow beyond embankment fills for highways or railways and the variable height of river banks imply that this last event has to be preferred.

Dealing with the complete set of over-depth integrated quasi-bidimensional Navier-Stokes equations, the river software reproduces all transient flows occurring in nets of natural rivers. They result from lateral exchanges with floodplains through a suitable statement of the term of lateral inflow or outflow.

The coexistence of several flow rates with shocks and bores in ramified nets of variable cross section arms requires the development of suitable capturing methods. The implemented scheme belongs to the class of implicit Petrov-Galerkin methods with dissymetric continuous test functions. The degree of decentering is optimized according to the local flow conditions. This shock capturing technique performs reliable simulations of unsteady sharp transitions, as verified for dam-break flood-wave simulations and jumps propagations.

Concerning the reservoir flood routing, only storage phenomena are considered. The influence of impulsive motion of the inflow is neglected and water surface is assumed to be horizontal. As illustrated on figure 4, the interface between both sub-sections acts as an imaginary solid sharp wall. Thus, we extend the available stage-discharge curve of lateral diversion weirs to this situation with an efficiency factor to be fitted. Besides, the code takes into account backwater effects of the different culverts, including pressure surge computations.

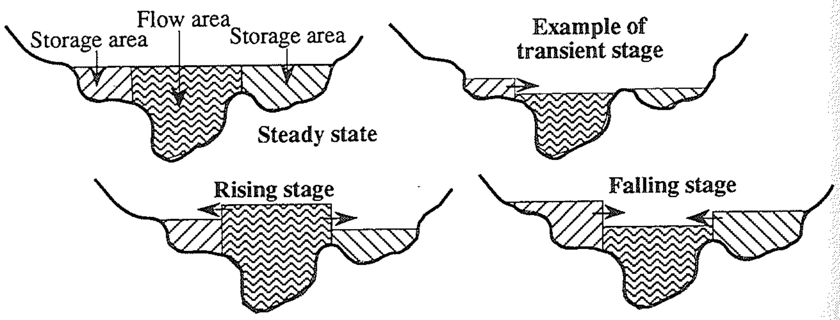

Figure 3 - Illustration of the transient exchanges

EXISTING SITUATION AND FORECAST IMPROVEMENTS

An excellent fit between computed values and gauged data is obtained with a physical relevant roughness coefficient that corresponds to referenced values for the same conditions. Figure 4 suggests the significant smoothing of discharge along the propagation, due to the natural storage in the surrounding fields.

After many computations, reservoirs were designed to lie on a respective maximum area of 6 ha and 11 ha. The figure 5 shows the location of the basins and the planned lowering of the maximum water profile. The weir sill is 200 m long for the first basin and 500 m long for the second one. In order to maintain wetted areas behind the weirs, a slight difference of level is maintained between the bottom of the reservoirs and the sills, with a delayed emptying by gates.

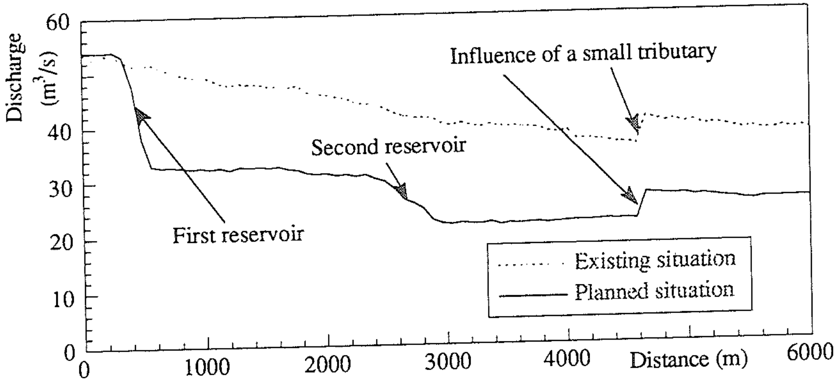

Figure 4 - Maximum discharge at each cross-section

The sole roughness of the main channel cannot induce any subsidience of the flood during its propagation, as suggest in figure 4 the constant levels of maximum discharges linking the characteristic stairs. No lowering occurs between both reservoirs where the flow is maintained in the main channel .

Figure 5 highlights the fundamental difference of results between a steady analysis and transients computations since the prospected modifications bring no significative effects upstream of the reservoirs.

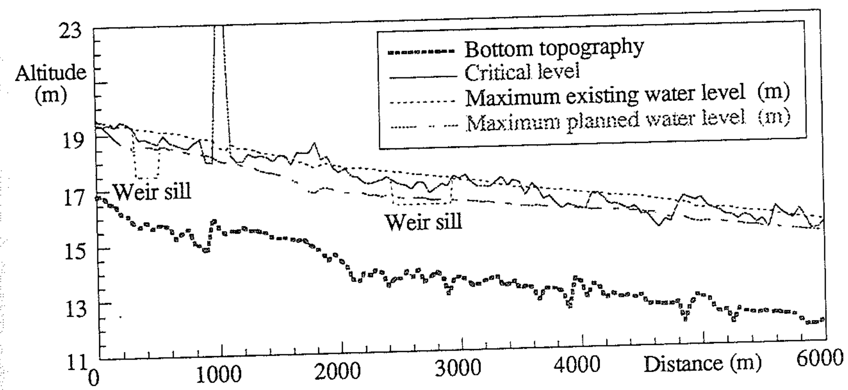

Figure 5 - Maximum water level at each cross-section

Figures 6 explains the gradual work of the fisrt weir for every 50 m spaced section of the sill. The computation proves that the downstream part is more efficient, inducing more lateral exchanges, as often theoretically demonstrated.

Computations assessed that discrepancies of the efficiency factor for this kind of diversion had minor effects on the global exchange balance, due to the characteristic time of the hydrograph. A middle value was selected in accordance with the works of Sinniger et al [2] for classical lateral thin crested weirs.

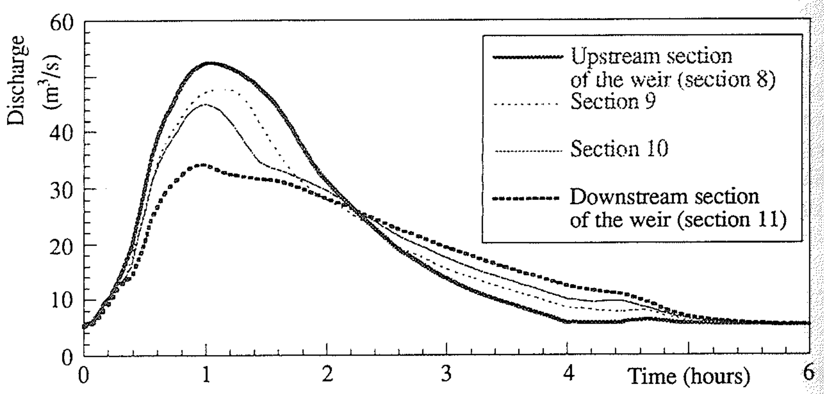

Figure 6 - Temporal evolution of discharge along the upstream weir

CONCLUSION

This article proved that we have to evolve towards transient computations in order to reproduce current floodings situations, to ensure a fit design and an adequate management. In several actual cases, the smoothing of the initial hydrograph can be mainly explained by lateral exchanges between the main channel and the floodplain. Natural as well as manmade obstacles prevent in practice a secondary flood to freely develop on floodplains. A first approach consists therefore in considering these areas as death zones. They maintain their water level by lateral exchanges which imply only transverse discharges.

The computation for a small belgian river assessed that they are correctly modelized by lateral weirs laws since the dynamics of these diverted flows can be neglected. With the assurance of reliable simulations gained by comparison with gauged measurements, simulations were then devoted to forecast the lowering of the water profile after the buildings of flooding basins in order to set up an economical design.

REFERENCES

[1] PIROTTON M.J.J., *A Global Approach of the Unsteady Surface Flows Computations Including Shocks, by Finite Elements*, "Numerical Methods in Engineering Simulation", editors : M. Cerrolaza, C. Gajardo, C.A. Brebbia, Computational Mechanics Publications, pp. 45-52, Mérida, Venezuela, 1996.

[2] SINNIGER R.O. ET HAGER W.H., *Constructions Hydrauliques, Ecoulements stationnaires*, Presses Polytechniques Romandes, Lausanne.

THE THREAT OF FLOODING AND THE PROBLEM OF PROTECTION OF TERRITORIES IN THE DELTA OF THE URAL RIVER IN VIEW OF THE RISING OF THE CASPIAN SEA LEVEL

V.F.POLONSKY, L.P.OSTROUMOVA,[1] Y.G.VIKULOV, R.R.MULIKOV[2]
1-State Oceanography Institute, 6 Kropotkinsky Per., Moscow, Russia
2-Department of Ecology and Bioresources, 10-a Abay Ave., Atyrau, Kazakhstan

ABSTRACT

Researchers investigated the processes of distribution of backwater from the sea to the mouth portion of the Ural River, wind-induced surges, hydromorphological characteristics of the delta. They also developed methods to estimate changes in the water level regime in the mouth portion of the Ural River in the presence of fluctuations in the level of the Caspian Sea, assessed the threat of flooding of various regions and objects in the delta of the Ural River, provided a hydrological substantiation for protective measures taking into account possible changes in the background level of the Caspian Sea.

INTRODUCTION

The range of fluctuations in the level of the closed water body, Caspian Sea, amounted to approximately 5 m within the recent millennium, with its most acute rises and drops taking several decades, featuring the rate of change of 10 to 30 cm per year. The periods of a relatively stable condition of the sea level appeared to be more prolonged. In the presence of significant fluctuations of the Caspian Sea, the territories adjacent to the sea edge and the deltas of rivers flowing into it are flooded and dry out from time to time. Especially complicated are these processes in river deltas, because flooding of residential areas here may occur not only from the sea, but also tens of kilometers from it - from the river - where reaches backwater from the sea. Owing to the sea level rise which occurred in 1979-95 - by 2.4 m, to the -26.6 m BS mark in the Ural River delta - there emerged an acute problem of protecting the large industrial center of Kazakhstan - the city of Atyrau - as well as the territories and objects adjacent to it. A scientific substantiation of protective measures shall include complex research and development of methods of calculation of levels in the mouth portion of the Ural River in the presence of a complicated interaction of the background sea level, discharge of the Ural River, wind-induced surges, taking into account morphological particulars of the delta and the mouth off-shore zone. In this case, besides the data of hydrometeorological stations, to assess discharge distribution in the delta braiding system, adjust level surfaces along the delta area, and investigate regularities of surge penetration into the delta, researchers used the findings of special expeditions arranged in 1989-93. Besides, level recorders were placed on a large scale along the area of the Ural River delta, and measurements of the braiding network of the delta were made. These data permitted to develop empirical methods to calculate level changes in the delta of river and sea origin, as well as to parametrize and verify the joint hydrodynamic model of the Caspian Sea, the mouth off-shore zone, and the delta of the Ural River.