Simulation of flood diversion and slowing in the Red river basin

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1. Introduction

The Red river basin is the largest basin in Vietnam with danger floods occurred every year. The main objective of flood control measures in the basin is to keep the water level at Ha Noi under the permitted level. At present, dams are the main expected measure for flood control in the basin. Detention basins or other hydraulic structures are considered as secondary measures and only used in urgent cases. In this study, the current situation of *Day river flood diversion and slowing project* is investigated and one-dimensional dynamic hydraulic flood routing is chosen for simulation purpose. The context of application is the danger flood occurring in the Red river basin and it is diverted into the Day river. The paper tries to describe the development of flood flow in the river network when diverging flood. Conclusions about effectiveness of the operation plan, real capacity of flood diversion and social issues related to such flood control plans are given from results of the study.

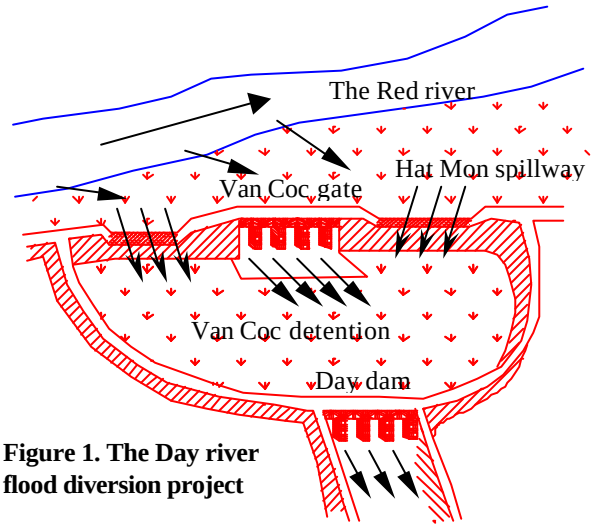

Figure 1. The Day river flood diversion project

2. Governing equations

a. Channel flow

Gradually varied flow unsteady flows in open channel are described by the de Saint Venant equations for one-dimensional free-surface flow:

$$\frac{\partial y}{\partial t}+\frac{1}{b_s}\frac{\partial Q}{\partial x}=0 \qquad (1)$$

$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{\alpha Q^2}{A}\right)+gA\frac{\partial y}{\partial x}+gAS_f=0 \qquad (2)$$

where t is time, x is the distance along the longitudinal axis of watercourse, A is cross-sectional area, y the water surface elevation, α is momentum correction coefficient, b_s is the storage width, g is gravitational acceleration and S_f is friction slope.

The friction slope can be evaluated using Manning's formula

$$S_f=\frac{n^2 Q|Q|}{A^2R^{4/3}} \qquad (3)$$

in which n is the Manning coefficient of frictional resistance, R is the hydraulic radius.

For a river network, a compatibility condition must be satisfied at a junction:

$$\sum_{k=1}^{m} Q_k=0 \qquad (4)$$

$$y_1=y_2=\ldots=y_k=\ldots=y_m \qquad (5)$$

where m is the total of the links, which emanate from the junction, Q_k is the discharge of the kth link.

b. Flow in flood-slowing region and reservoir

Overbank flow will inundates the flood plain or fields. In the case of flood diversion and slowing, flood flow may overtop the dyke at some pre-defined locations and run over into ponds or cells. The continuity equation for cell j in the form of quasi two-dimensional flow is used [3]:

$$A_j(y_j)\frac{dy_j}{dt}=\sum_k Q_{j,k}(y_j,y_k) \qquad (6)$$

where A_j is horizontal water surface area of cell j, y_j is water stage in the cell j and k is the index of the cells adjacent to the cell j.

c. Internal boundaries

Hydraulic structures along or adjacent to the watercourse such as dams, weirs, bridges or waterfalls are considered as internal boundaries. In this case, the reach is considered as the one between two cross sections $(j, j+1)$ just upstream and downstream of the structure. Two equations equivalent to the Sain Venant equations are required. They are:

$$Q_j^{i+1}-Q_{j+1}^{i+1}=0 \qquad (7)$$

$$Q_{j+1}^{i+1}=f(y_j^{i+1},y_{j+1}^{i+1}) \qquad (8)$$

Equation 8 is usually an empirical rapidly varied flow relation for computing the discharge. In this paper, because of using Preissmann's implicit scheme, the Eq. 8 may be rewritten by supposing that all functions f are differentiable so that:

$$f=f^{i+1}\approx f^i+\frac{df}{dy}\Delta y+\frac{df}{dQ}\Delta Q+H.O.T \qquad (9)$$

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This is the Taylor series expansion of the function *f* at the time (*i+1*)*Dt* (*H.O.T: High Order Term*).

3. Numerical simulation of the Day river flood diversion project and results

The project includes there main parts: Van Coc gate and Hat Mon spillways; Van Coc detention pond and Day dam (figure1). The Day river has a length of 230 km and catchment area of 5800 km^2. The river and its flood plain are important parts in the project with the mission of transporting the water from flood diversion the sea. The flood plain as well as ponds or lower cells located inside of dykes may be inundated when flood diversion because there are some predefined locations for flood spill over on dykes.

The equations in section 2 are used to simulate the flood flow development when diverging floods of the Red river into the Day river through the Day river flood diversion project. The implicit, finite-difference Preissmann's scheme has been chosen to code in C. The flood from 9 to 31, August 1996 is taken into calibration process. This flood is big flood in the Red river and it is the historical flood in Da river. The water level at Ha Noi in this flood is 12.43m. Upstream boundaries are discharge hydrographs at Hoa Binh, Yen Bai, Vu Quang, Hung Thi and Ba Tha. The downstream boundaries are water level hydrographs at Nhu Tan, Phu Le, Ba Lat, Dinh Cu, Tien Tien and Pha Lai. The investigated and measured topographical data from 1992-1999 are used in simulation. Some results are shown in figure 2 and figure 3. The error in discharge is 4-15% and the maximum error in water stage is 42 cm. The results are acceptable in the next process: simulating the development of flood flow in the case of flood diversion into Day river. The supposed floods in three main tributaries of the Red river will cause a big discharge at Son Tay (about 37800 m^3/s). This value of discharge approximates the discharge value of a real flood occurred in the Red river basin in August 1971.

4. Conclusions

The problem of flood diversion into Day river has been considered with one-dimensional unsteady flow model. A danger situation of flood is supposed and development of the flood has been simulated. With this situation, it can be said that:

- The Day river flood diversion project can reduce 0.65m in water stage at Ha Noi (figure 4) but the water level at Ha Noi still at high level and can threat the dyke system around Ha Noi. By only the Day river flood diversion project, it cannot reduce the water level at Ha Noi under required level (13.4m).
- The structures of the project seem working as design. The flood diverted from the Red river by the Day river flood diversion project can cause the inundation in flood plain as well as in flood slowing area. The average depth and average time of inundation in the Chuong My - My Duc flood slowing area are 3.5m and 5 days, respectively.

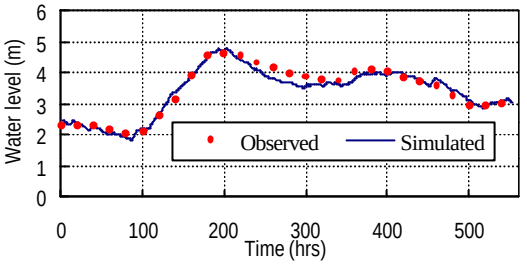
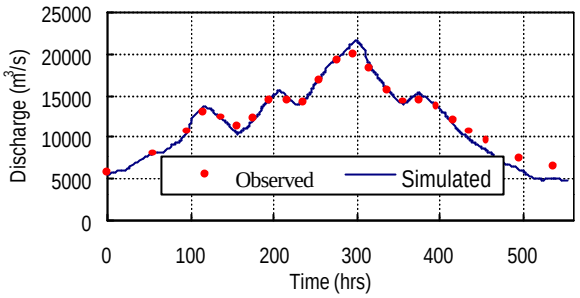


Figure 2. Water level hydrograph at Tan Lang station (flood from 9 to 31, August 1996)



Figue 3. Discharge hydrograph at Son Tay station (Flood from 9 to 31, August 1996)

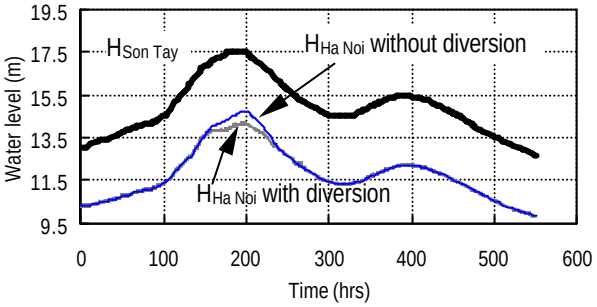


Figure 4. Water level at Son Tay and Ha Noi in supposed flood

- The channel condition of the Day river has been changed rapidly, especially in flood plain. Human's activities such as houses building and cultivating in the flood plain cause obstructing the flood flow along the river.

When a very big flood occurred, the Day river flood diversion and slowing project cannot work as designed mission without the improvement of flood plain. In the term of technical issues, specifically is hydrology; the flood diversion has to be considered in the context of flood regime in other tributaries of the Day river. Flood diversion from the Red river can cause serious inundation for a long time in the downstream of the Day river when combining with flood from other tributaries as well as flood tide from the sea.

References

1) Binnie, SMEC, AACM, Delft (1995). Ministry of Science, Technology and Environment, Vietnam. 2) Cunge, J.A., F.M. Holly, Jr and A. Verway (1980) Pitman, Boston, Mass. 3) M.G. Anderson and T.P. Burt (1985). Wiley, New York. 4) Center for Hydrologic Research (2000), Institute of Meteorology and Hydrology,Vietnam.