

**Flood control measures in União da Vitoria and Porto União:**

**structural x non-structural measures**

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**Abstract:** In recent years (1983 and 1992), União da Vitoria and Porto União in Brazil suffered severe floods, after a long period (50 years) of normal to low floods. The economic losses to some industries, businesses and homes created a depression and psychological impact to most of the population. The population believed that the main cause of the floods were the impact of Foz do Areia Dam, a Hydropower Plant located downstream of the city. It created a major conflict for more than ten years between the population and the State Power Company.

In this paper are presented the main flood causes, hydropower impact and structural and non-structural measures studied, in order to cope with the problem.

**Keywords:** Urban Floods, structural measures, non-structural, flood zoning

## 1. INTRODUCTION

The cities of *União da Vitória* and *Porto União* (figure 1) are located on the banks of the Iguaçú River, State of Parana, Brazil, where, for about 50 years (1930 to 1982, see figure 2), only low or medium floods occurred. In the early 80's the *Foz do Areia* Dam was built, about 100 km downstream.

The backwater curve for the dam design flood may reach the cities, depending on its operation water level. During the dam design, two alternatives were studied to cope with this influence, protection levees or operational rules to prevent the increase of the flood levels in the cities. The first operational level chosen was 744 m. Studies carried out by Parana State Power Company (owner and operator of the dam) in 1982 and 1985, showed that 744 m was a high level, and recommended 742 m at first, and later 741.5 m.

In 1983 an extreme flood occurred, which caused severe economic losses. The flood level was the highest of 107 years (estimated return period of 170 years, and a duration of 62 days), and the estimated losses were US\$ 78,1 millions.

At that time the population blamed the Power Co. for the Dam operation and high flood levels. It was estimated the flood recurrence as being about 1000 years, using continuous records (1930-1983). This calculation, however, did not consider historical marks (figure 2), and this led

to overestimation of the return period. When historical marks (found after some research done by local personal) were included in the statistical analysis, the return period decreased to 170 years. In 1992 another flood came, smaller than the last, but of similar magnitude and impact (return period of 30 years, duration of 65 day and US\$ 54,6 millions losses). As the people had been told that the risk was very small, and, in less than ten years, the cities were again flooded, their reaction was very strong, and distrust towards previous studies and official statements was widespread.

A NGO (Non Governmental Organization) called *CORPRERI* (Regional Permanent Commission for Flood Prevention of Iguaçu River) was created by the population to deal with the flood problem. This organization has been the representative of the cities in the discussion with the Parana State Eletric Power Company (COPEL).

This study was performed for this organization, to disclose the causes of the high stages, the influence of the dam, and recommended solutions and measures to cope with floods.

## **2. Floods evaluation**

### **2.1 Risk analyses**

Recorded discharges started in 1930 and had 68 years. These flows are not representative for low flood risk since during this period there were high and

median frequency floods. A research done on the historical documents allowed the estimation of three major floods occurred from the end of the last century until 1997. A Log-Pearson III statistical distribution was fitted for the composed series of continuous recorded flows and historical flood levels using the procedure described by Beard (1974). Some of flood risk and the recorded values are presented in figure 2.

## **2.2 Simulation of Iguaçú River with Dam operation**

In order to answer most of the question posed by the population a hydrodynamic model was applied (Tucci, 1978) taking into account the characteristics of the flood valley and main channel in the reach between the cities and the dam. Usually the flood plain is represented only by a storage function assuming an infinite roughness. Since depths in the flood plains can reach more than 5 m, there are flow dynamic effects in this part of the river system. The model used to describe the dynamic effects was the Lateral Distribution Method described by Wark et al (1991) and Villauneva, (1997) to compute conveyance and velocity distribution coefficient for each section.

The boundaries conditions used for the simulations (fitting and scenarios analysis) were the discharges in the cities (upstream boundary) and the level at the Dam (downstream).

Model fitting was made through the comparison of simulated and

recorded levels at União da Vitória (section M8, figure 1) and discharge and level at Porto Vitória (figure 1) for 1983 and 1992 events. The discharges in those floods varied between  $240 \text{ m}^3\text{s}^{-1}$  to  $5,000 \text{ m}^3\text{s}^{-1}$  (figure 3).

### **3. Flood impacts**

The first question to be answer was the influence of the dam operation in the cities floods and the causes of the high levels. Some other questions were raised by the population which were related to other solutions for the flood alleviation such as improvement on the channel conveyance and bridges impacts.

#### **3.1 Influence of the Dam operation during 1983 and 1992 on the floods of the cities**

Using the two major floods, 1983 and 1992 two different downstream boundary conditions were used in the model: (i) the actual operational levels at the time of the flood; (ii) safe operational level at the dam, fixed at 741.50 m by previous studies.

The results showed that the operational procedure in 1983 increased the flood levels at the cities by 14 cm in the first part of the flood but did not show any influence during the flood peak. During the flood of 1992 the operational levels at the Dam did not influence the flood levels at the cities.

### **3.2 Influence of river conveyance**

Some of the potential alternatives to decrease the flood levels were to modify the characteristics of the river at some critical reaches downstream from União da Vitória. These river modifications are: rectification and enlarging of some bends, duplication of the channel and by-pass of the curve immediately downstream from the cities, and even deepening of the channel stretch between the Porto Vitoria rapids and the cities (about 50 km long).

Most of this alternatives simulated were at Ressaca bend (M6, figure 1) , the bridge embankments (M8 and M7 in figure 1) and the Porto Vitoria rapids. The deepening of the channel had already been analyzed and discarded in a previous study (JICA, 1995).

As a general conclusion of the analysis, it can be said that, even though the critical points contribute to increasing the levels, none of them is alone responsible for the high levels. Not even their joint effect increases the floods critically.

The main problem is the lack of river flow conveyance for the floods in the sections along the cities and some contractions. Other factors such, as river bends and contractions far downstream have little influence.

In fact, discharges for both floods considered (1983 and 1992) were very high, and the 1983 flood was the historical maximum. The historical records,

however, show that flood levels of similar magnitude had already occurred.

The problem stems mainly from forgetting the previous floods, probably because of several decades without any major one. This led to the occupation of the river valley (quite a common situation), which, in due time, was again claimed by the river.

#### **4. Flood alleviation measures**

Non-structural such as: Flood zoning and flood warning were studied together with the structural measure of levees on the lower banks proposed in a former study for the cities (JICA, 1995).

##### **4.1 Non-structural measures**

###### **Flood zoning**

In order to define the flood levels for the land use map, levels were calculated for each of the available cross sections, for several return periods, using the mathematical model. A 1:2,000 map was used. Flood level lines were established for 5, 10, 50 and 100 year return periods (considering historical marks). Figure 4 shows a view of the flood map.

Three zones were established for the flood control areas:

**Preservation area:** below 744.50, reserved for environmental protection and parks. This area was bought by the Power Company, Dam owner. A park was constructed in the urban part of the land after an agreement between the communities and the Company.

**Water resources protection area:** between the former area and the 10 year levels. Remove public building such as school and hospital from this area; progressive taxes be imposed for any use but the recommended ones: parks, sport fields, agriculture, and others. There were recommended tax reduction for these uses.

**Low density area:** less restrictive than the former, but needing special care and protection against flood damage in the buildings.

### **Flood forecasting**

The flood zoning must also have a real time flood forecasting system, working together with the Civil Defense Authority. The proposed actions were the following: (i) definition of an alert system: mathematical model, forecasting range and alert steps; (ii) County Civil Defense Authority must be created, so as to be prepared to act, with well pre-established plans, during



the floods; (iii) emergency plans must be prepared for the different parts of the city.

Three forecasting conditions have been recommended: (i) **watch condition:** from that level on, the behavior of the river must be accompanied carefully. Real time forecasting begins at this condition; (ii) **alert condition:** when the 744.0 m level is to be reached within 12 hours; (iii) **emergency condition:** when the 745.5 m level is to be reached within 12 hours;

#### **4.2 Structural measures :**

Most of the structural solutions studied, related to the river conveyance, were not feasible due to the high intervention cost. They recommended a feasibility study for this system and concluded that was the acceptable combination of protection and cost. The levee system would be constructed protecting the areas above 10 year return period.

This engineering system will change the cities characteristics and protecting it from low risk floods. The analysis done in this study led to some questions which the population has to answer before it decided for this system:

- a system of that kind must be under the jurisdiction of the city authorities. This implies a cost that need to be supported by taxes. The investment maintenance costs are high which may create a major impact in the city economy.

- the protection will benefit mainly the areas between the 10 years flood level and the 1983 flood level. Will all the population be willing to pay for the benefit of only part of them?;
- the impact of the levees on the flow conditions upstream and downstream of them must be carefully studied;
- not only the technical and economical aspects of the levees must be considered, landscape and urban environment issues also need also to be included. Questions such as this have to be answered: Would you like to live with a 6 m wall, all along the city, which will protect levels above 10 year flood or create a new urban development toward more safe areas and use zoning measures?

Until now the decision has been to use non-structural measures in order to cope with flood conditions. But for political reasons there are pressure to show some structural measure which in this case represents high costs.

## **5 Conclusions**

On the matter of causes and influences of the flood stages at União da Vitoria and Porto União, the study showed that the high stages were due to the characteristics of the river and to the high discharges, without any major

influence of local features downstream, the influence of river bend and contractions being very small.

Also, the influence of the operation levels of Foz do Areia dam is very small, provided that the level is kept under 741.50 m.

The analysis of the problem leads to some interesting conclusions regarding its origin and development. A long period without severe floods induced a sensation of false security in the people, who began settling in the flood valley. Also as a result of this false security, no flood protection measures or planning were adopted. When the 1983 flood showed that there was an actual risk, it was disregarded, based on seemingly dependable (50 years data) statistical analysis. This analysis, however, did not take into account existing and very valuable information (the historical flood marks). When another severe flood came along in 1992, the population was upset, and distrusting the technical studies. This problem was aggravated because of communications problems with the responsible institutions. It must be stated that, except for the statistical analysis, the existing technical reports were basically right in their diagnosis and conclusions.

The lack of flood protection planning and preventive measures has caused losses as per evaluation at about US\$ 150 millions, and the solution will have a similar cost, not to mention the indirect impacts in both cases.

Several decades without severe floods are not an uncommon situation, it

is logical that floods with high return periods do seldom happen. The consequences of long lags between this kind of floods are also common: occupation of the river valley and disregard for protection measures.

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