PILOT PROJECT ON INTEGRATED FLOOD MANAGEMENT IN THE CUAREIM/QUARAÍ RIVER BASIN (URUGUAY/BRAZIL)

EXECUTIVE SUMMARY

1. INTRODUCTION

The pilot project on Integrated Flood Management (IFM) in the basin of the Cuareim river (as it is referred to in Uruguay, "Quaraí" in Brazil) is coordinated in Brazil by the Instituto de Pesquisas Hidráulicas (IPH) and in Uruguay by the Dirección Nacional de Hidrografía (DNH). This project has been financially as well as technically supported by the Associated Programme on Flood Management (APFM), which is a joint initiative of the World Meteorological Organization (WMO) and the Global Water Partnership (GWP).

The ultimate target for the basin is the design and implementation of an integrated flood management system in the Cuareim/Quaraí river basin (Uruguay/Brazil). Integrated Flood Management should be understood as flood management within the context of Integrated Water Resources Management (IWRM), i.e. the coordinated development and management of water, land and related resources. Activities aimed at achieving this final objective have been rolled out or are being planned within the context of this project.

During the initial stage of the project, an assessment of the current situation was carried out and the following have been identified to be some of the key IFM components in the Cuareim/Quaraí river basin: identification of measures to promote joint flood management within this transboundary basin; definition of flood risks and corresponding urban zoning and the assessment of flood-prone rural areas; the design and implementation of a preliminary flood prediction system; education and dissemination of flood information to local inhabitants; a socio-economic and environmental assessment of the flood-prone area and of the existing emergency plan; enhanced links and coordination between the two countries.

2. OVERVIEW OF THE STUDY AREA

The Cuareim river forms part of the Plata river basin (Figure 1). It is a left-bank tributary of the Uruguay river and marks the border between Uruguay and Brazil. The Cuareim river drainage basin covers approximately 14 800 km^2, of which some 6 700 km^2 (45 percent) are located in Brazilian territory and approximately 8 100 km^2 (55 percent) in Uruguayan territory.

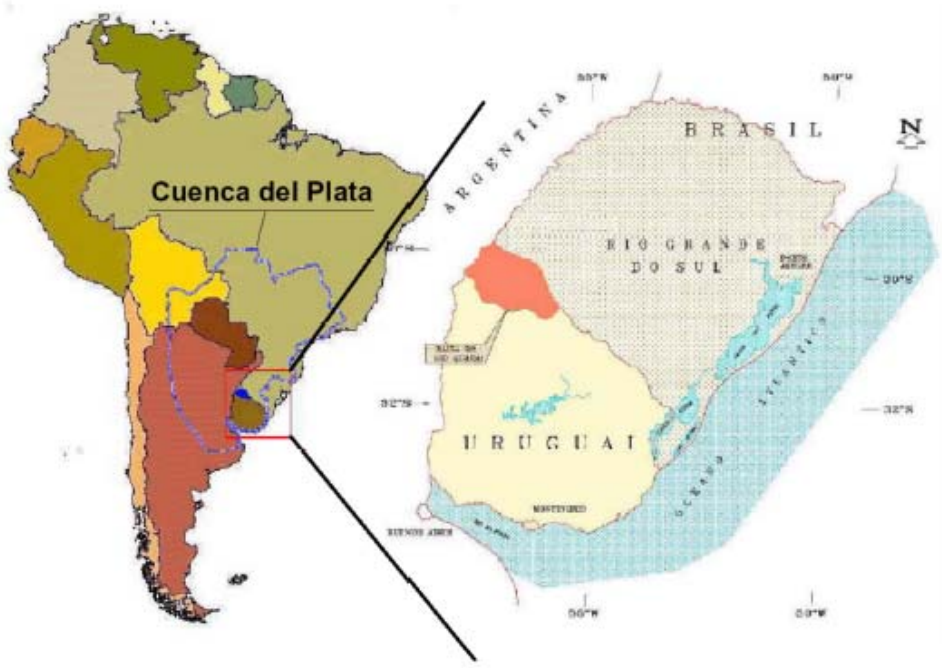

Figure 1. Location of the Cuareim/Quaraí river basin

The total length of the main channel of the Cuareim river is 351 km, with a height difference of 326 m between its source and mouth (Datum Torres-SGE/Brazil) and a mean slope of 0.93 m/km. The most pronounced slopes can be found in the first quarter of the river's course.

The area exhibits a variety of lithological units forming part of the Paraná basin. Volcanic igneous rocks (basalts) with exposures of sedimentary rocks occur frequently, such that protruding outcrops of basic volcanic rocks can be found in sediment sequences. The shallow soil layer (around 0.5 m) across most of the basin area means that storage capacity is low. On the one hand, this results in a rapid response and extensive overland flow during intense rainfall, and on the other, causes a marked summer water deficit owing to the high rate of evaporation during that period. The basin has a high runoff coefficient (C) (Annual mean C of around 0.46 at Artigas), an extremely low storage capacity and virtually no percolation, resulting in a near-complete absence of base flow, whose contribution to runoff volume is negligible.

Annual mean rainfall is between 1300 and 1500 mm and annual evaporation is 1600 mm. A high degree of monthly variability in rainfall can be observed (over 80 percent), whilst rates of annual variability are low (under 30 percent). This situation has prompted the construction of dams for water storage and to overcome the monthly variability mentioned above, whilst taking advantage of

the acceptable stability of annual rainfall volumes. Dam construction was frequent during 1990s and can be linked to the major expansion of rice production.

Flood frequency analysis shows that 80 percent of floods peak at a level that will not provoke flooding in the cities of Artigas (capital of the department of Arigas, Uruguay) and Quaraí (administrative centre of the municipality of Quaraí, Brazil). The river starts to overflow its banks at Artigas above a height of 6.80 m (staff gauge DNH 84.0), with evacuations beginning when it exceeds 8.30 m.

Demand for water within the Cuareim river basin comes principally from rice irrigation. Rice is cultivated mainly in the lower part of the basin. Some plantations can also be found in the upper basin, although this region is largely given over to livestock husbandry. Other demand includes water for human consumption in the cities of Artigas, Quaraí, Barro de Quaraí and Bella Unión, livestock watering and irrigation for other crops (in the Bella Unión area). However, these represent a very small segment (around five percent) of the demand for water within the basin.

3. COORDINATED TRANSBOUNDARY RIVER MANAGEMENT MECHANISM

Uruguay and Brazil, through the treaties and agreements they have each signed, have stated and reiterated that it would be both necessary and advantageous to undertake joint water resources activities capable of yielding benefits for citizens throughout the Cuareim river basin. The principal factors in support of a system of coordinated management are as follows:

- Growing competition for use of water resources;
- Increasing occupation of flood-prone areas for dwellings and production, both in population centres and rural zones;
- The variety of users and the extensive infrastructure for harnessing water within the basin, either through direct abstraction from streams or via the damming of such streams, creating conditions for potential conflict as a result of interference with the catchment and disturbance of the flow of the main stream channel;
- The use of streams within the basin for the disposal of effluent and waste products from industrial or other processes and of sewage from population centres;
- The increasingly serious impact of extreme natural phenomena such as drought and flooding, in addition to the effect of global climate change phenomena; and
- The recommendations of international conferences and forums on water, encouraging countries to establish mechanisms and procedures for the shared management of transnational basins.

4. ACTIVITIES UNDERTAKEN

Based on the assessment, which identified the current situation and the principal factors for coordinated management in the Cuareim/Quaraí river basin, among others, the following activities have been implemented in this pilot project:

- Analysis of water availability within the basin, with consideration of concessions for use of the resource;
- Establishment of a shared database on flood management;
- Flood characterization;
- Assessment of flood management options;
- Characterization of the socio-economic impact of urban and rural flooding.
- Zoning of flood inundation in rural and urban areas and its dissemination;
- Establishment of an early warning system;
- Environmental study of the basin for the purposes of water resources management;
- Proposal for improvements to the hydro-meteorological network in order to enhance water resources management and flood prediction;
- Establishment of coordinated transboundary management mechanisms

Analysis of water availability within the basin, with consideration of concessions for use of the resource

Monthly water availability analysis was conducted, taking into account the granting of water use concessions within the basin. It was found that in the majority of sub-basins, rice cultivation is limited by water availability. Volumes of water for irrigation from the river are affected by the monthly distribution of water. As a result, there is a need for modelling with a daily time step in order to assess the volumes available for irrigation. To this end, funding for the studies in question was sought and obtained. These studies will be made possible by the “TWIN LATIN” (Twinning European and Latin American River Basins for Research Enabling Sustainable Resources Management) project, financed by the European Commission through the Sixth Framework Programme for Research and Technological Development.

Establishment of a shared database on flood management

Information on existing hydraulic infrastructure within the basin for harnessing its water resources was compiled from organizations in both countries. Additional information came from a dam survey (location, size of reservoir and size of dam drainage area) undertaken with the help of LANDSAT satellite images and a digital terrain model of the basin. This enabled a preliminary list of hydraulic infrastructure within the Cuareim river basin to be drawn up.

The range of basin information compiled included maps, topographic data, satellite images, meteorological and hydrological information, information on cultivated areas, the register of dams and headraces and demographic information and enabled the project studies to be carried out in an integrated fashion.

Flood characterization

Basin flood events were characterized. Upstream of the cities of Artigas and Quaraí, the physical features of the basin dictate that it is “rapid-response basin”, with a 28-hour concentration time and very shallow soil exhibiting numerous basalt outcrops. Attempts were made to identify the form of storm hyetographs, which were found to be unimodal. However, it was not possible to find a “typical” hyetograph, since there is a high degree of dispersion between them.

The Cuareim river overflows its banks on reaching a height of 6.8 m (datum level of staff gauge DNH 84.0) and evacuations are begun when water levels exceed 8.3 m. Ten thousand inhabitants in Artigas and 1 200 in Quaraí are affected by flooding.

Extreme flow was adjusted using GEV distribution, with the result showing that the 8.3 m level (datum of DNH staff gauge 84.0) corresponding to the commencement of evacuations has an associated return period of under two years.

Assessment of flood management options

Fears were voiced during various workshops and activity days with the local population and every effort was made to provide a technical response to such concerns. Concerns were raised in relation to the possible effect that structural undertakings might have on flooding. In particular, there was repeated concern expressed as to whether a deepening of the channel of the Cuareim river would yield positive results in terms of the consequences of flooding in Artigas and Quaraí.

A hydrodynamic modelling tool was used to establish the impact on maximum flood levels of deepening the channel of the Cuareim river by one or two metres, with only a minimal difference being found in the size of the affected area. At the same time, deepening of the channel would involve earth-moving activities of such magnitude that this would no longer be an economically viable option.

In order to dispel concerns regarding the effect of structural measures on flooding, various alternative approaches are being assessed as part of the postgraduate Master’s course in Applied Fluid Mechanics/Engineering offered by the Institute of Fluid Mechanics and Environmental Engineering (IMFIA, Uruguay). The results are still being awaited, since the course has not yet come to an end.

Characterization of the socio-economic impact of urban and rural flooding

The population affected by floods, along with local organizations and institutions, expressed major concerns regarding the negative impact of flooding. This was particularly the case in urban areas. Flooding affects school attendance to a significant extent (40 percent in Artigas, 30 percent in Quaraí), with a similarly serious effect on the labour market (45 percent in Artigas, 50 percent in Quaraí).

One of the main conclusions drawn from the socio-economic study is that the population of the flood-prone area of Artigas continues reside there because of the feeling of 'belonging' instilled through home ownership (more than 60 percent of the population are owner-occupiers), the sense of solidarity between residents, which is cemented when faced natural hazards, and the lack of alternative housing options offering equal or better conditions and similar fixed costs. In Quaraí, the factors behind the continued habitation of the flood-prone area relate mainly to the absence of other housing options open to the population in question (38.4 percent) and the fact that change proves costly to residents from an economic point of view.

Twenty-seven percent of those questioned in Artigas are prepared to sell their home (respondents estimated the value of their property at $ 3 500), whilst 56 percent of respondents in Quaraí would do the same (respondents estimated the value of their property at $ 4 000).

Economic activity within the flood-prone area of Artigas was found to comprise commercial microenterprises or small-scale industry. Losses from these activities are similar to losses on property, amounting to around 10 000 Uruguayan pesos (approximately $ 400). Seventy-five percent of enterprises state that they would be prepared to relocate if they had access to an average $5 000 of investment. Small workshops and commercial activity are widespread in Quaraí. Of these, 56.5 percent would be prepared to relocate. Half of respondents estimate investment at $ 8 000, with the exception of one female respondent, who gave an estimate of $ 60 000.

According to the survey, the flooded population is not aware of an organized emergency management system during flood events.

In the rural zone of Artigas, it was found that in general, losses caused by flooding do not exceed the potential loss caused by climatic factors, as estimated and accounted for by every crop and livestock farmer. Comments have also been received concerning the drought in Artigas, which is generating losses considered equal to or greater than the difficulties caused by flooding. Within the framework of integrated water resources management, it would be interesting to study how floods might be harnessed to mitigate the effects of drought.

Although rural surveys were not conducted in Brazil, the impact of flooding can be estimated on the basis of the damage figures set out in the report supplied by the Quaraí Prefecture. This puts agricultural losses (cereals and grain) at 9 000 tonnes worth of production, which in September 2001 was the equivalent of 2.9 million reais.

Zoning of flood inundation in rural and urban areas and its dissemination

The aim of urban modelling was to calibrate, validate and utilize a hydrodynamic model of the urban section of the Cuareim river, with a view to determining a series of flood risk zones in the cities of Artigas and Quaraí.

This study resulted in the preparation of a file of 15 diagrams illustrating the following information: the different maximum flooded areas for return periods of two, five, ten, 20, 50 and 100 years plotted on the Artigas/Quaraí town plan; the maximum flooded area of Artigas/Quaraí for each return period on both a town plan and a satellite image; a comparative plan showing the maximum level recorded by IMA for the June 2001 flood (return period estimated at 42 years) and the maximum flooded area corresponding to a 50-year return period; a comparative plan showing the maximum level recorded by IMA for the June 2001 flood and the maximum level established on the basis of a simulation of the same event using the hydrodynamic model in operation, demonstrating that for the objectives being proposed, the simulation approximates very closely with reality. This file has been distributed to various authorities including the mayor's office (Intendencia Municipal) of Artigas and the Uruguayan National Emergency System and Servicio Geográfico Militar.

Difficulties were experienced with regard to the creation of a rural flood map. A lack of information meant that it was not possible to calibrate or validate the model, such that the results obtained are preliminary. It can be deduced from this analysis that floods of a magnitude corresponding to a return period greater than 30 years could begin to impact negatively on rural production.

Establishment of an early warning system

The cities of Artigas and Quaraí do not currently have in place any kind of system to provide early warning of flooding by the Cuareim river. Rather, the population of low-lying areas is taken by surprise and evacuations take place during the flood itself. This study took the first steps towards developing and implementing an early warning system (EWS) for the city of Artigas, based exclusively on hydrological statistics tools.

The study yielded an Excel (Macro) -based forecasting tool enabling river stage, and consequently possible overflow and flooding, to be predicted. The design of this preliminary forecasting system will help prepare the ground for a future emergency plan.

In order to improve the early warning system mentioned above, and bearing in mind that the basin has a rapid response time, there is a need to make use of coupled precipitation-hydrological prediction methods in order to increase prediction times.

In this vein, an analysis of the quality of rainfall estimation was carried out using the ETA-CPTEC model, with degree of accuracy analyzed against observed rainfall in the Cuareim river basin and in relation to the time range of the forecast. The results of the study show that caution should be exercised when using meteorological rainfall forecast data derived from the ETA-CPTEC model as input for stage prediction models.

Environmental study of the basin for the purposes of water resources management

An environmental monitoring plan for the Cuareim river basin (left bank) was designed with a view to managing its water resources. This came in addition to the existing body of environmental studies of the left bank of the Cuareim river and enabled an environmental monitoring plan for the entirety of the basin to be obtained.

A single document was prepared, containing all the information held by the various stakeholders (DNH, OSE, DINAMA, IMA, NGOs such as Artigas ’86 and political, social and technical players). In addition, a review was carried of literature on the chemical products frequently used within the basin in agriculture and livestock dipping, of concern to the inhabitants of the area. Furthermore, fieldwork was undertaken, including water quality analysis and visits to various places of interest, providing the data input essential in order to ensure that the technical vision formulated in a boardroom remains rooted in reality.

The fruit of this work is a document laying the foundations and setting out a proposal for an environmental monitoring plan (12 points have been selected throughout the left bank of the basin). The document includes directions on how to take and analyse water samples (sample containers and their preparation and care, instructions on collecting water, how to organize a sampling campaign, variables to be analysed at each selected location, frequency of sampling) as well as information to be gathered on population, arable land, head of livestock in the basin, agrichemicals in use, etc.

Proposal for improvements to the hydrometeorological network in order to enhance water resources management and flood prediction

Information was compiled and a proposal for improvements to the hydrometeorological network to enhance water resources management and flood prediction capacity was put forward. In order to improve water resources management in the sub-basins currently or potentially subject to the greatest intervention, it is proposed that systematic discharge measurement be carried out in the

lower basin (Paso de la Cruz station, 35 km upstream of Bella Unión). This will yield information on the impact of human activity, as well as enabling the management model for the basin as a whole to be adjusted. It is recommended that a gauging station be installed within the Arroyo Yucutujá basin in order to generate sub-basin data for use in resource management. Water level recorders should also be installed to allow maximum discharge rates to be monitored.

A proposal for improvements to the hydrometric network was also produced with a view to implementing a flood early warning system. In order to gain a clearer picture of the spatial distribution of storms, the installation of two rain gauging stations has been proposed, along with three water level recorders, respectively transmitting real-time hourly rainfall data and instantaneous stage levels to the CTM network (Cuaró receiver).

The proposal for improvements to the hydrometric network was considered as part of the funding request lodged through the TWIN LATIN project.

Establishment of coordinated transboundary management mechanisms

In order to seek mechanisms for coordinated transboundary management, the public policy, legislation and institutions connected with the management of the Cuareim basin were identified.

There is a high degree of similarity between the legal frameworks of Uruguay and Brazil, chiefly in terms of their principles and the objectives, which both are pursuing on the basis of water resources management, and in terms of the value placed on the resource and its proper usage.

Each country also has institutions with a dedicated and clearly defined mandate to ensure proper management of the resource. Whilst the internal organization of each country may differ, given that one state is unitary (Uruguay) and the other federal (Brazil), there is nothing to prevent the necessary coordination mechanisms being established between the respective bodies. In the context of the Cuareim river basin, bilateral bodies with defined powers and appointed representatives are in operation. They have been granted responsibility for harmonizing proposed plans and activities, ensuring that these are consistent with legislation in force and tailored to the institutions with the capacity to implement them. The above serves as an excellent starting point for the harmonization of both countries' shared basin management undertakings and for the implementation of the policies and legislation already mentioned, provided that this objective is in the interests of each State.

The key matter of implementing legislation has received insufficient attention. At best, its complexity has been underestimated. Difficulties surrounding the integrated management of the Cuareim river basin derive not from legal or institutional shortcomings, but rather from failings in the implementation of planned mechanisms.

Taking this reference framework derived from current treaties and agreements as a starting point, this study came up with the proposal to create an instrument for coordinated transboundary management, the Cuareim River Basin Agency. This proposal will be submitted for consideration by the authorities in both countries. The analysis carried out during the study has already been used as input for the GEF-funded project entitled “Programme for the Sustainable Management of Water Resources in the Plata river basin, with respect to the Hydrological Effects of Climatic Variability and Change”, involving the execution of a pilot demonstration project in the Cuareim river basin.

5. EXPERIENCES AND LESSONS LEARNED

This study took place within a transboundary basin with the participation of experts and employees from a diverse range of organizations in both countries. On that basis, it can be concluded that the experience was, on balance, a positive one.

Difficulties faced in implementing the pilot project in the transboundary context

With regard to progress towards an integrated water resources management system, the project suffered from the fact that the principal stakeholders in each country have different mandates. Whilst the Dirección Nacional de Hidrografía (DNH, Uruguay) is legally responsible for water resources management in terms of quantity (but not quality) at a national level, the Instituto de Pesquisas Hidráulicas (IPH, Brazil) forms part of a research institution without resource management responsibility. Moreover, Brazil has a number of bodies operating in the sphere of water resources management at a federal, state and municipal level, further complicating the issue. Nevertheless, contact, information and project mainstreaming for every institution playing some part in water resources management has been undertaken by both IPH and DNH. In this way, significant progress has been achieved in terms of the release and exchange of available information, analysis of the issue and sharing of cross-cutting knowledge between experts within the institutions involved. Such progress will set the scene for continued efforts towards achieving joint management. To conclude, it can be seen that in spite of the difficulties mentioned above, satisfactory progress has been made.

With regard to the question of knowledge development and hydrology, the contribution of both IPH and the Institute of Fluid Mechanics and Environmental Engineering (IMFIA, Uruguay) has been thoroughly useful, with experience and knowledge shared and also partially disseminated to the other participating institutions.

As far as the topographic surveying element of project execution is concerned, difficulties were initially experienced in gaining access to private premises. This problem was subsequently resolved by issuing notice prior to the start of survey campaigns.

Future challenges

It was possible to establish links between the local population and the authorities in each country through workshops, workdays, surveys, interviews, information and education material, and exchange of information and joint projects. In time, such links will need to be further cemented. A final workshop is being organized with the general public and the local authorities in order to ensure the large-scale dissemination of the results of this project.