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Implementation of a Unique Real Time Flash Flood Forecasting System in Martinique (France)

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In France and specially in the Caribbean islands, the serious damages caused in urban areas by the recent flash floods showed the importance of efficient and adapted reactions of the municipality. Faced to a flash flood crisis, decisions should be taken based on the current information available that are often very limited due to the lack of time to obtain, manage and analyse them.
Therefore, the Conseil Général of Martinique decided to develop an operational, integrated and innovative tool SDAC (Système Départemental d'Alerte de Crues) to be able to forecast and manage urban flooding in real time. The modelling system is based on predicted precipitations from rain gages (radar imaging will be integrated soon), a rainfall-runoff model, a hydraulic model developed for urban area and a risk definition representing the flood importance.

This innovative system has been initially implemented on 4 watershed of the island in 1999, including the Lezarde basin particularly vulnerable to floods that induce important damages on the road system as well as on the economic activities of the island (airport, commercial center…). In 2005, the system was significantly improved and innovative steps were done to reach different objectives: (i) to improve the robustness and precision of the flood

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forecast (ii) to improve the alert system for small watersheds (iii) to represent in details the flooding zones in the urban areas using GIS (iv) to insure alert messages reception that allow prevention actions (v) to make the forecasting data and maps available on internet for public information.
The system is currently operational and very promising since the results proves the significant advancement obtained when combining the growing computer power and the increasing urban hydrological knowledge.

The next step in 2009 is to include the radar data and the sea level data in real time in order to (i) enhance the anticipation of rainfall that can produce flood and (ii) take into account the sea level hydraulic constraint that could be significant for some basins during a big storm.

11.1 Context for the SDAC system

Frequently, very intense storm events induce catastrophic floods in the Caribbean islands, and especially in Martinique (France). The particular morphology of the island drained by medium to small rivers called "ravines" that are generally dry, and the urbanization that took place on their downstream part close to the coasts create the combination of the flood risk and the vulnerability (people, goods, services and the island airport) that contributes to particularly important human and economic risks.

In 1999, the Conseil Général of Martinique that is in charge of the road network management decided to take actions by the development of a flood warning system SDAC (Système Départemental d'Alerte de Crue). This first version of the system was based on a network of rain gauges and river water level recorders located on the island. In this project, various entities are collaborating: Météo France, the state ministries, the different municipalities [3].

In 2006, the Conseil Général decided to significantly improve the system through various actions:

- Update the data acquisition process
- Implement real time hydrological modeling
- Develop warning and actions procedures in their security plans
- Make the forecasted flooding maps available on internet

11.2 The objectives of the SDAC system

The objectives of the SDAC system are as follows:

- the follow-up and the hydrological forecast for the anticipation of the flood events,
- the management of flood alarms and warnings,
- the management of the security plans.

This ready-to-use system includes the complete equipment required for the crisis control room (furniture, data-processing equipment, software, communication equipment, automatic calling system, secured power, guarantee and maintenance) as well as in-situ video control.

The SDAC was developed by the association between Egis Eau and CS SI. Egis Eau was in charge of the hydrological and hydraulic modeling parts, as well as the risk study and the flooding maps development. The informatics company CS SI was in charge of the informatics part (supply, software development, data processing and SIG tools management).

Four different watersheds, located on each sea coasts of the island are under control by the system (Figure 11.1):

- the Lézarde river (132 km2,
- the Rivière Pilote (36 km2)
- the DesRoses river (22 km2)
- the Carbet river (23 km2)

Around 70,000 people are living on the 4 watersheds that are covered by close to 1,000 km of roads.

Figure 11.1 The 4 basins considered by the SDAC system .

11.3 The functions of the SDAC system

11.2.1 Data acquisition

The data of 20 rain gauges and 15 water level recorders that are managed by the Conseil Général are collected every 15 minutes by phone lines. The time step of the data is 6 minutes.

The center where the data are collected is in the Conseil Général building in Fort de France (Figure 11.2). A set of video-cameras completes the acquisition system by providing real time pictures of the most sensible points of the rivers.

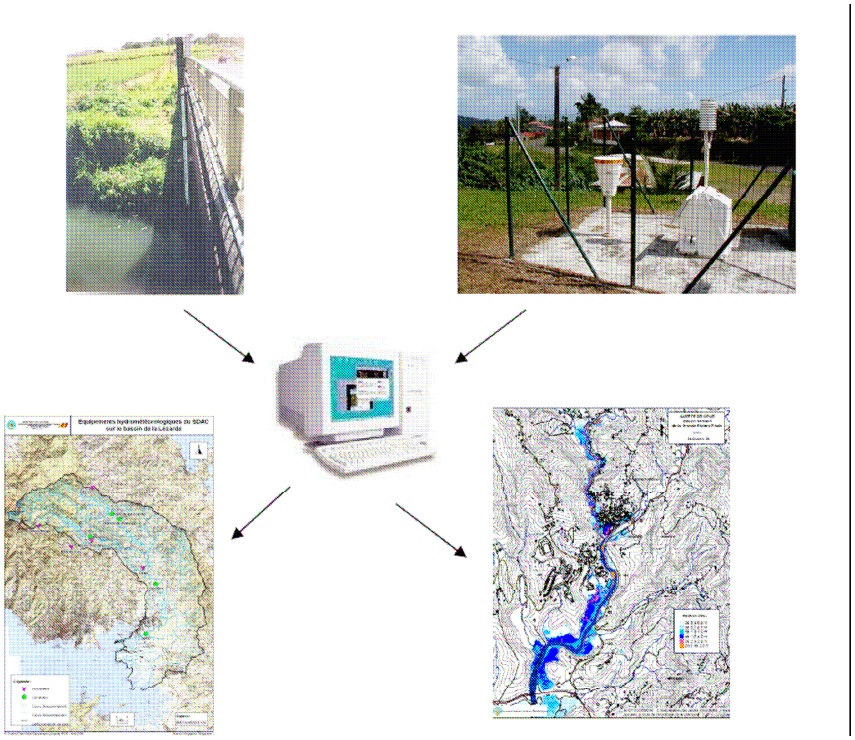

Figure 11.2 Main functionalities of the SDAC system: data acquisition and maps presentation of the resulting forecasts .

11.2.2 Hydrological computations

Based on the observed rainfall quantities, the system computes flow forecasts at various points of the rivers and especially at the entry of the most urbanized areas. These estimated flow values are produced by rainfall-runoff models that are calibrated based on past observed events. The various behaviours of the rural and urbanized watersheds are represented. The simulations take into account the existing storage basins. The hydrological predicted values are updated every 15 minutes. The models used for the real time forecasts is composed of (i) the GR4 model developed by the CEMAGREF for the rural parts (a 2 linear reservoirs models with 4 parameters to calibrate [4,5]) and (ii) the RERAM model for the residential areas (the French Desbordes rainfall-runoff model [2]).

The hydrological calculations are based on a model structure built from a sub-basin delimitation associated with a tree structure network, in which the hydrographs are routed. In real time, the flow values are estimated at the critical overflow points, i.e. at the entrance of the vulnerable sectors. These points of overflow that are located just upstream of the urbanized areas, are represented on figure 11.3.

The computation time necessary for a complete cycle of forecasts simulation is around couple of minutes, which is absolutely compatible with the speed requirements of the system.

Figure 11.3 Structure of the model with the main computations points for the River Desroses basin.

11.2.3 *Identification of the most probable flood hazard scenario*

The reduced capacity of the river channels associated with the important vulnerable sectors in their urbanized part leads to catastrophic overflows in populated areas. Such flows, that are then disconnected from the river flows, are hydraulically complex (significant speed, crossroad divergences, presence of obstacles to the flow...). A simulation of these flows can be realized with a pseudo 2D modeling, STREAM (software developed by Egis Eau [6]), that can be implemented in real time because of the rather short

computing time required. This modeling approach is based on a finite element resolution of the flow (Figure 11.4).

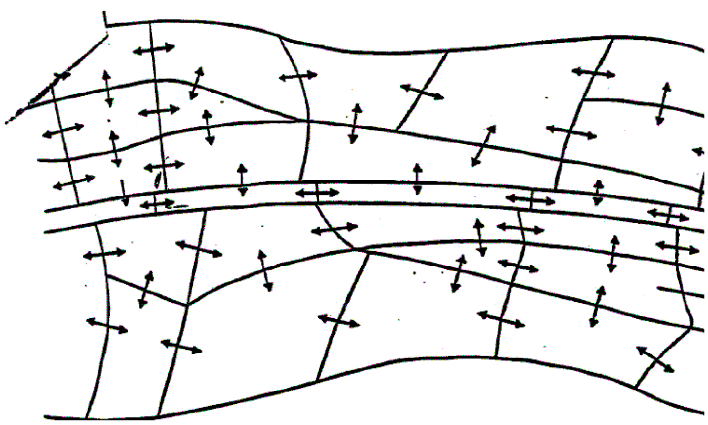

Figure 11.4 Concept of the pseudo-2D hydraulics STREAM software.

However, to gain even more time, it was decided to create a series of various scenarios based on the results of the pseudo 2D model that was developed for each downstream rivers.

As a consequence, the SDAC system is based on the identification in real time of the most probable flood risk scenario based on a series of preset scenarios that were already elaborated. The selection criteria for the scenario based on the observations and forecasts hydrological are the flows at the principal points of forecast, associated with a warning level of the security plan of the Conseil Général. For the various forecasting times, precise flooding maps are associated with each scenario in order to represent observed and probable flood hazard and risk in the areas (Figure 11.5). These maps were developed by CALYPSEAU, a GIS tool (software developed by Egis Eau [1]) that is using the STREAM model results and the DTM data (topographic information).

Depending on the river structures, various number of scenarios are possible for each four basins. Each scenario gives the water level ranges in the flooding zones and are directly related to actions procedures (roads closing, public building alarm…).

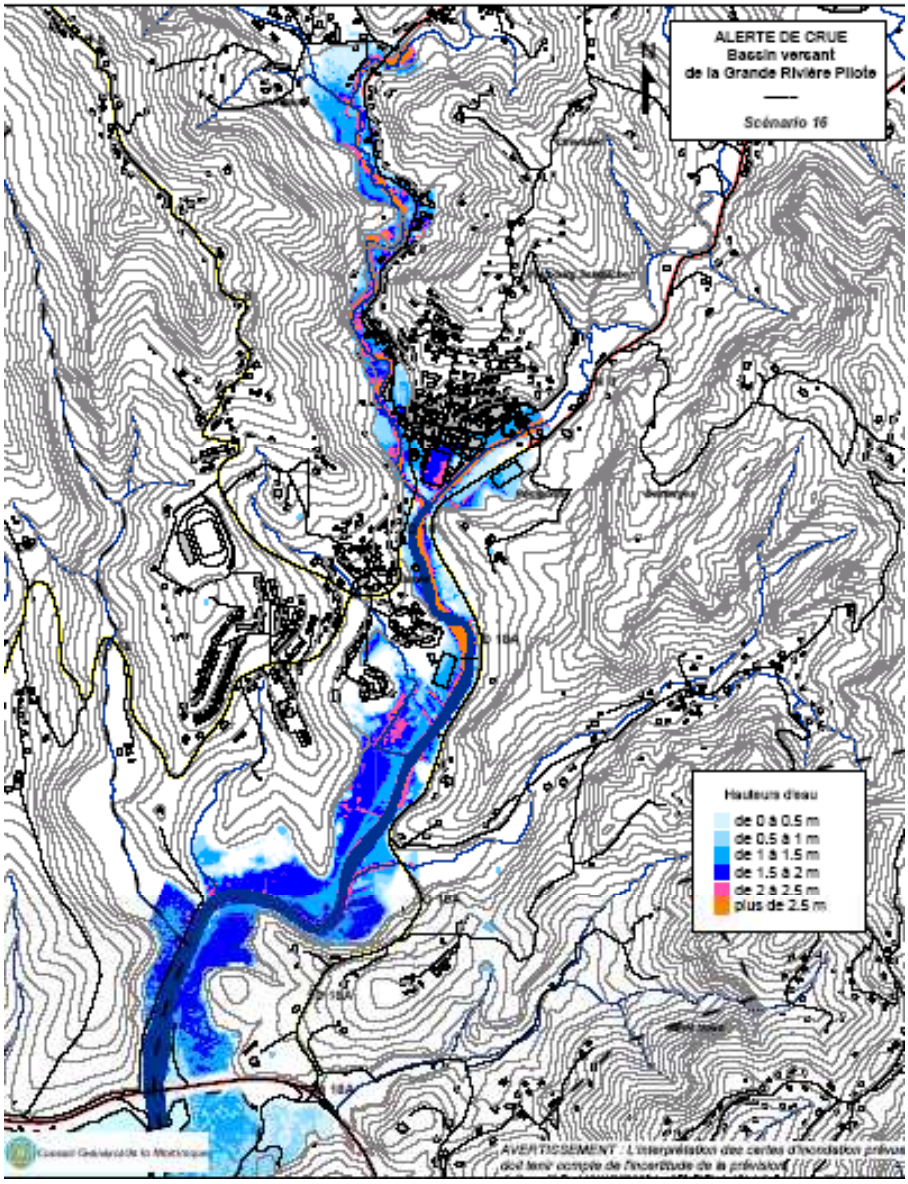

Figure 11.5 Example of a scenario for the Grande Rivière basin.

11.2.4 *Implementation of the security plan*

The various warning levels of the system are as follows:

- vigilance of the staff,
- moderate overflows of the storm network, located flooding;
- beginning of the river overflows;
- generalized and serious floods with significant human risks.

The changes of the warning level are proposed by the system. The SDAC system allows to manage the phone calls and the email emission related to the actions of the security plan according to the warning level. The phone calls are managed on the basis of phone call scenarios. The lists can be filtered according to the current date (week-end/week, holidays) and time (opening schedules). In addition, a validation of warning message being well received is given by the system.

To inform the population, some operational actions are also based on he system results:

- visual signal on the roads (Figure 11.6)
- barriers in dangerous areas

Figure 11.6: Road visual signal to inform the population.

11.2.5 *Web site*

Another very important communication tool is the the Conseil Général web site that makes all system information available in real time :

- observed data (rainfall and water level of the rivers)
- predicted date, hour and location of the warning
- predicted flooding maps (password needed)

On the web site, the images of the video cameras placed on vulnerable sectors are also available in real time.

11.4 *Perspectives of the system*

Based on the context evolution and the progress of informatics capabilities, the following perspective directions are considered for the evolution of the system:

- Implementation and use of the radar data produced by Météo France. The radar in Martinique is in the calibration phase and should be operational in 2009. The observed and predicted rainfall quantities will be then implemented and used by the SDAC system to enhance the rainfall information and therefore the system precision (real time warning systems using such data already exist in France).
- For a more detailed representation of the sea level constraints, the model will be adapted based on data collected in real time by sea level sensors that will be installed in 2009. This adaptation could lead to interesting modifications of the hydrological model to integrate in real time the downstream constraints of the flows. Three sensors will be installed in the different seas of the island to represent all local conditions.

The growing technological progress associated with the experience feedbacks obtained in practice from the various operational system will contribute to extend the development and success of such real time flood warning systems.

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