

Elaboration and implementation of a global flood management strategy of the river Meuse – France

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ABSTRACT: The disastrous flooding in December 1993 and January 1995 lead the elected officials of the regions Lorraine and Champagne-Ardennes to create the Etablissement Public d' Aménagement de la Meuse et de ses Affluents (EPAMA). The first mission of this public body was to start, in 1998, a complete modelling study of the stream of the Meuse (nearly 450 kilometers of valley) in order to define a global flood management strategy.

The precise analysis of the origin of floods, the hydraulic's parameter (thanks to a pseudo 2D "cell" model) and the flooding risk allowed purposing a development scenario aiming to reduce the risks on the whole French valley of the Meuse and more specifically on the most vulnerable sites, without consequences downstream.

An economical part precised the cost of the flooding and the cost of the solutions.

The selected strategy mixes 8 flood dynamic slowing areas which permit to reduce the water height on the whole valley and 15 localized protections of vulnerable places.

Easy dynamic slowing area is made of a earth fill dam closing the flooding field. The dam, opened in the minor bed, is an obstacle to the flood. This hole is a mean to minimize the consequences on small floods and on low water. This dam, nearly 4 or 5 meters height, could be overtopping for exceptional flood.

For a one hundred years occurrence flood, the development scenario reduces the flooding heights to one meter on the most vulnerable locations. This reduction lowers the cost due to the flood damages in a scale close to the forecast investments. The annual flood cost is reduced by 40%, which represents 21 millions euros for works estimated to about 80 millions euros.

The project of creating a flood dynamic slowing area upstream Mouzon (Ardennes) is part of the global Meuse floods reduction strategy.

This dam reduces the flood height downstream and balances the negative impacts of the protections built in the cities of Charleville-Mézières and Givet.

This project is based on a multidisciplinary approach. A detailed hydraulic's modelization of the streams helped to establish the effects of the storage on the water heights, on the stream velocity and on the increase of the inundation lengths of time. The consequences of this storage on the human activities, on the environment, on the landscape and on customs have been evaluated too. It was needed to protect some residential areas in the retention area. This process came with a wide dialog with the inhabitants of the dam's neighbourhood.

This project will reduce the flood heights by 60 centimeters in the cities of Charleville and Givet and the damage costs by 30%–40%.

1 GLOBAL CONTEXT

1.1 *Watershed*

The Meuse is a 900 km long european river. Its watershed, with a surface of 32,000 km², covers five countries, including France (over 10,000 km²), Belgium (over 12,000 km²) and The Netherlands (over 6,000 km²) (Figure 1).

The source of the Meuse is located at Pouilly en Bassigny (France, 384 meters height).

Its french watercourse is 450 km long, almost the half of the total length. It is navigable from Trousey (Meuse, France).

The population of the french watershed gathers 500,000 inhabitants.

1.2 *Flow regime*

The Meuse floods have a pluvial origin, characterized by important summer low waters and high winter floods, due to rain falls.



Figure 1. Map of watershed of the Meuse.

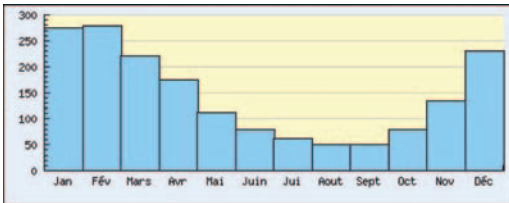


Figure 2. Monthly flow variations in m³/s at the monitoring station of Chooz (watershed of 10,120 km²).

For example, at the watery station of Chalaisnes (Meuse, France), draining a 1,717 km² basin, the minimal flow is estimated at 1.5 m³/s and the flow of 100 years recurrence interval is estimated at 623 m³/s.

The watery station of Chooz (Ardennes, France) measures a 10,120 km² watershed. The minimal flow is evaluated at 24 m³/s and the 100 years recurrence interval flow at 2,000 m³/s.

1.3 The highest floods of the Meuse

The Meuse was recently stricken by two high floods: the one of January 1995, which mainly affected the



Figure 3. The 1995 flood in Charleville-Mézières (Ardennes, France).

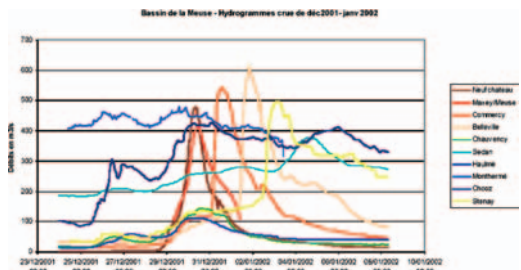


Figure 4. December 2001 flood hydrograph – origin: flood report DIREN Lorraine.

Ardennes department, and the one of December 2001, a upstream flood which hit the Vosges and the Meuse departments.

1.3.1 The 1995 flood

The 1995 flood was the result of the conjunction of two flood peaks (concomitance Meuse-Chiers and Meuse-Semois), produced by several continuous great rainfalls.

A maximum discharge of 1,000 m³/s has been recorded at Charleville-Mézières (Ardennes, France) and an other of 1,600 m³/s at Chooz. Its recurrence interval is estimated at 50 years.

Over 315 towns were declared stricken, the navigation was stopped during 3 months, over 800 firms were affected and over 10,000 employees were unemployed. The overall cost in the Ardennes department was evaluated to 225 millions euros.

1.3.2 The 2001 flood

The 2001 flood was the consequence of on very intensive rainfall on a snowbound ground. The accumulation of the falls on two days reached 146 mm in

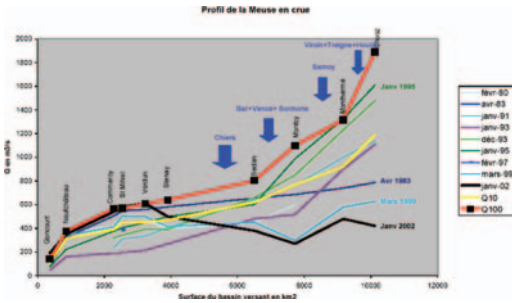


Figure 5. Longitudinal profile of the Meuse's flows – origin: flow report DIREN Lorraine.

Gérardmer (Vosges, France). Combined with a significant reheating, these rainfalls brought a fast rise of the levels over the uphill of the watershed. Then the flood wave spread easing toward the downhill.

This flood was characterized by a poor volume, since it came after a single rainfall.

The flow reached $580 \text{ m}^3/\text{s}$ in Saint Mihiel (Meuse, France), namely 228 l/s/km^2 , a value close to the centennial flood. Downhill, the recurrence interval is lower than the decennial flood in the Ardennes department.

1.3.3 Conclusion

The Meuse floods in France can be characterized by 3 kind of flood:

- The simple uphill floods, strong in the Vosges and Meuse departments, which ease along the Meuse couloir (1983 or 2001 floods).
- The downhill floods, created by intensive rainfalls on the Ardennes massif (1993 flood).
- The global floods, with several sequential peaks and a very high volume. They are produced by several successive rainfalls leading to the concomitance of the Meuse and its main affluents (1995 flood).

2 INSTITUTIONAL CONTEXT AND GLOBAL STRATEGY

2.1 The EPAMA

The Etablissement Public d'Aménagement de la Meuse et de ses Affluents (EPAMA) has been created after the important floods of the Meuse in 1983, 1993 and 1995. Its aim is to define a coherent and solidary global flood management strategy of the river.

The EPAMA is a public organization gathering waterside regions (Lorraine, Champagne-Ardennes), departments (Haute-Marne, Vosges, Meuse, Ardennes) and cities of the Meuse.

The actions suggested by the EPAMA include three main concerns:

- First, the protection, with works to lessen the floods and to keep safe people, goods and private and public interests in the most urbanized and industrialized areas.
- Then, the prevention. The purpose is to improve the flood report and crisis management systems, in order to limit the harms by giving time to public services, firms and private persons in risky zones to organize themselves. In parallel, we try to contribute to the development of a urbanism management which avoids the buildings in risky sectors.
- Finally, the rehabilitation of the river and the protection of the environment, especially by preserving the watery areas.

The EPAMA is the most relevant institution to give the requisite arbitrations to lead a resolute, coherent and solidary policy for an integrated management of the watershed. The coordination with the downhill countries (Belgium and The Netherlands) is ensured by the involvement of the EPAMA in the International Commission for Protection of the Meuse.

In 2004, the flood prevention program suggested by the EPAMA has been selected among the four best ones in France and thus profits a special state founding.

This program provides actions:

- For the flood prevention (improvement of the flood local management).
- For the protection, with works (studys and buildings of flood dynamic slowing areas).
- For the reduction of the vulnerability (firms location analysis).
- For the improvement of the flood history (cartographic atlas spreading and historical flood landmarks installation).

Between 1998 and 2001, the goal of the EPAMA was to realize a complete global knowledge and modelling study of the flows of the Meuse in order to:

- Have a better view of the risks and the interests linked to the floods.
- Search the most adapted buildings to reduce the flood effects.
- Improve the existing flood prevision tools.

2.2 The global flood management strategy

This study is based on the use of a watery model rainfall over the whole french watershed of the Meuse and a watery "cell" model between Neufchateau (Vosges, France) and the belgian border, namely a modelised stream over 400 km.

The needed topographic data were obtained thanks to aerophotographies of the valley.

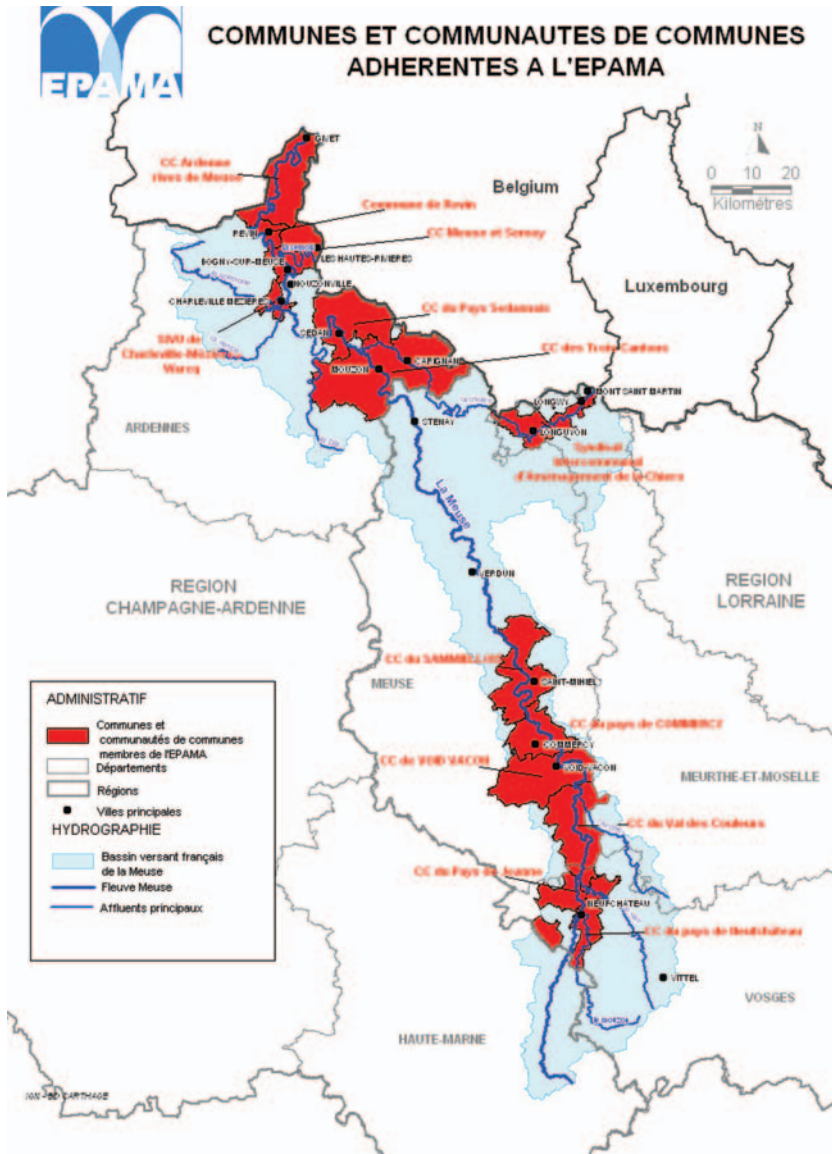


Figure 6. Constitution of EPAMA.

Its first goal was to better know the origin of the major floods and to study their effects. An atlas of the areas which could be drawned has been created, with a 1/10000e scale in urban sectors and with a 1/25000e one in the other sectors. An economic study based on the damage costs of the 1983, 1993 and 1995 was carried out: the cost of a centennial flood has been estimated to 380 m€ for the french valley of Meuse.

Three scenario of major flood reduction has been studied:

- Building of a big dam in the Meuse department: efficient and expensive solution, which does not allow to protect all the vulnerable sectors of the watershed.
- Development of storages on the Meuse's affluents: uneffective solution, especially in the Meusian couloir.

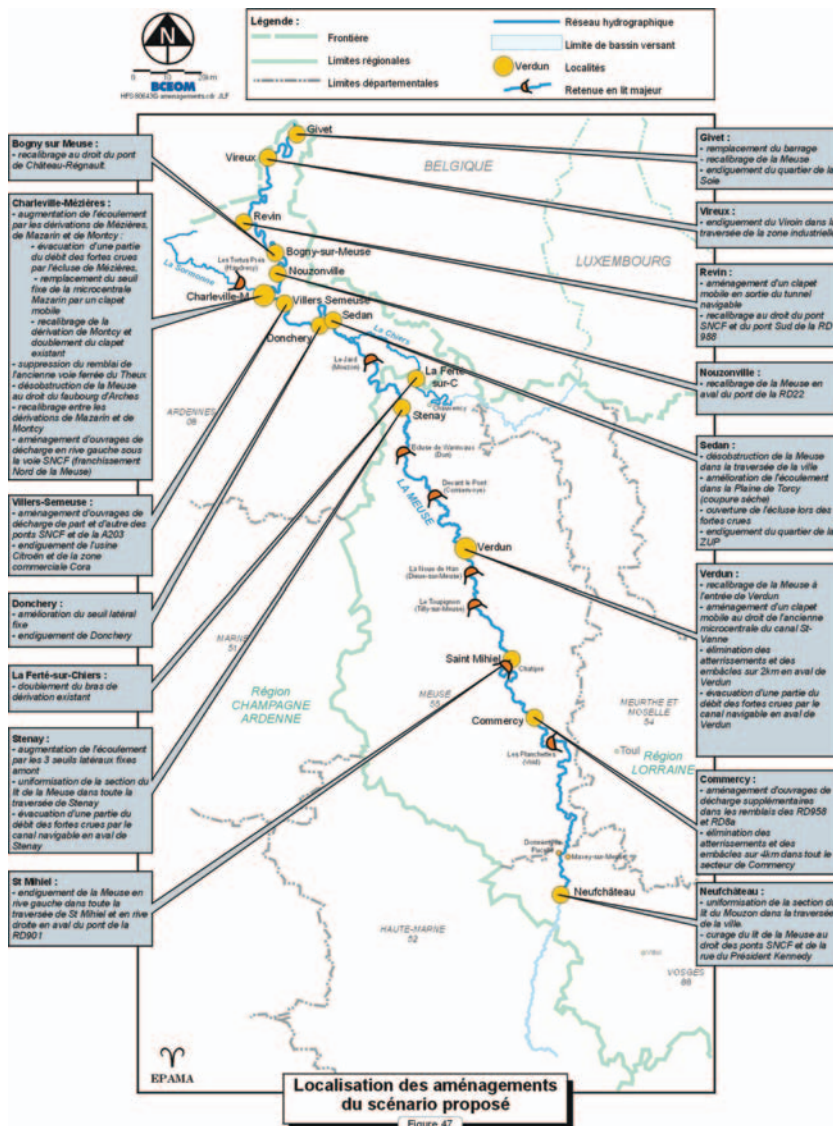


Figure 7. Flood reduction strategy selected by the EPAMA.

- Combination of dynamic slowing areas and situated protections: allows to reduce the floods on the whole watershed.

The chosen strategy to reduce the flood riskiness combines two main development types:

- Global developments (“dry storages”) whose aim is to reduce the flows and the submersion heights in the valley, uphill works, by regulating the floods.

- Local developments (curl cut, re-adjustings, destruction of buildings blocking the flows, dam buildings), in order to increase the flow capacity and thus to locally reduce the submersion heights or to put the most exposed areas out of danger.

Thanks to the results of the study, the EPAMA selected a management scenario combining a global development with 8 dams in the overbed and local developments on 15 locations.

2.3 Flood dynamic slowing areas principle

2.3.1 Description of a flood dynamic slowing area

A dynamic slowing area is a sort of “dry” storage, which works only for the Meuse’s strongest floods. It creates an additional storage in the natural drowned sectors of the valley.

The development consists of the creation of a ground dam obstructing the flood field and opened in the minor bed, like illustrated in the following schemas.

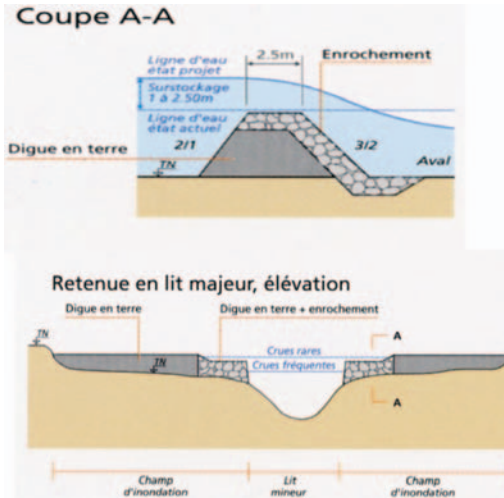


Figure 8. Cross section and axial section of a dam.

This embankment forms an obstacle for the flood and makes a backwater. It is sized for the exceptional floods, which are the most damageable for the whole watershed.

The opening in the minor bed minimizes the effects of the dam on the small floods and on the low waters.

No additional device (like a valve) is forecast, because of obvious security and management simplicity reasons: the regulation of the flows happens naturally through the opening in the minor bed.

2.3.2 Dam principles

Without flood, the dams has no effect on the flows.

During floods, the obstacle created by the building temporarily increases the uphill water levels. The water height and the drowned surface are higher. Thus, the water volume stored in the major bed increases.

This additional storage allows to «spread out» the flood: the downhill peak flow, water heights and drowned surface are lower. Thus we can reduce the risks for the downhill urbanized sectors.

After the flood, the major bed uphill the dam empties and the natural flow conditions are recovered. The human activities (mainly agricultural) can be resumed.

2.3.3 Results of the selected strategy

This development gives a water heights’ decrease between 9 and 45 cm for a centennial flood and until 1 meter in the most unprotected sectors (Charleville-Mézières, Verdun, Sedan, Givet, ...).

The investment cost of the scenario is estimated to 80 m€ It allows a saving on centennial flood cost of 149 m€ that to say a decrease of 40% of these costs.

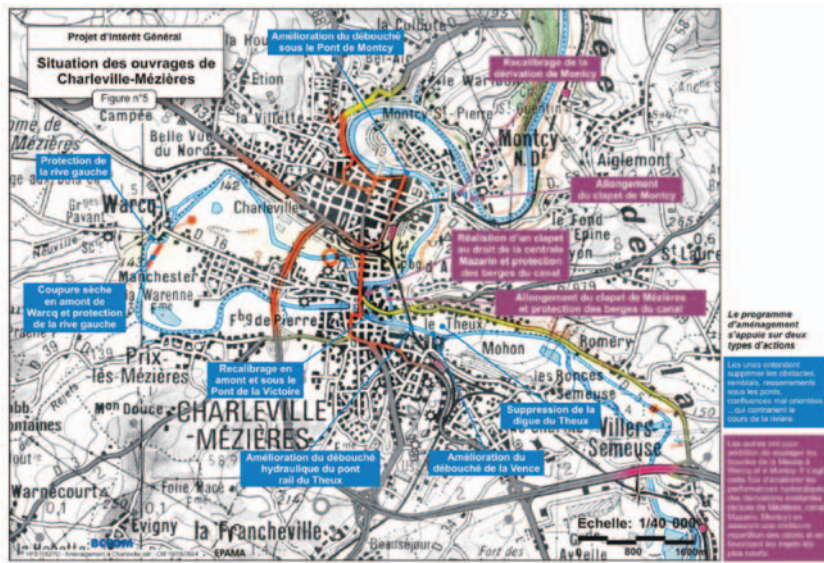


Figure 9. Local building program for Charleville-Mézières (Ardennes, France).

3 FIRST MEUSE DEVELOPMENT STAGE IN THE ARDENNES

After the global flood management strategy study, performed by the EPAMA between 1998 and 2001, the plan signed by the state and the Champagne-Ardennes region gave the priority to the protection operations concerning the densely populated regions of Charleville-Mézières and Givet, including the building of a flood dynamic slowing area uphill Mouzon (Ardennes, France).

This project contains the making of local protection buildings in the different cities. These protections (resizing and modernization of a navigation dam, containment, curl cut) locally lower in a significant way the water heights during a flood and reduce the size of the drowned areas. But they bring secondary effects, like the acceleration of the floods and the increase of the uphill heights.

Feasibility studies for these protections were started from 2002 for the cities of Charleville-Mézières and Givet, under the control of the SIVU of Charleville-Warcq and VNF.

At the same time, the EPAMA lead a feasibility study for a flood dynamic slowing area uphill Mouzon

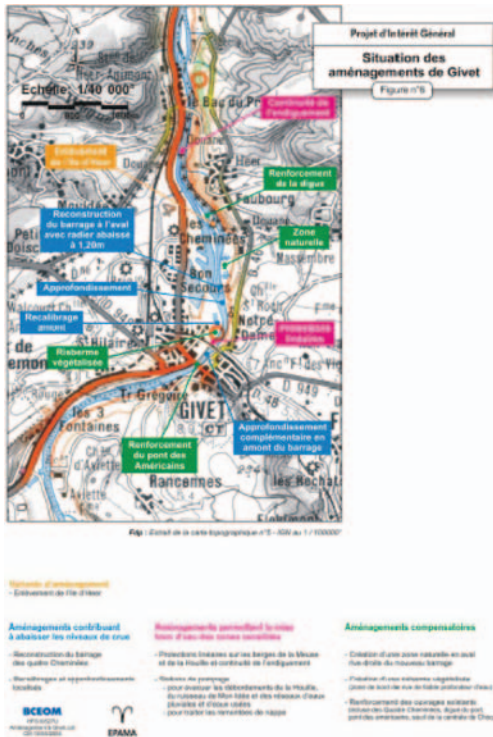


Figure 10. Local building program for Givet (Ardennes, France).

whose the main goal will be to compensate the bad effects of the local protections.

4 THE FLOOD DYNAMIC SLOWING AREA UPHILL MOUZON

4.1 Environment

The flood dynamic area is located in a rural sector where the effects of the increase of the water heights will mainly involve agricultural zones.

The major bed is already very drownable in this sector. The valley is U shaped and the major bed is about 600 meters wide there.

The navigable minor bed is 50 m wide. The water height is upheld thanks to a sill located 300 m downhill the dam.

The centennial flood flow is estimated to $640 \text{ m}^3/\text{s}$ and the one for the most important flood recorded in the sector is equal to $581 \text{ m}^3/\text{s}$ (flood of April 1983, 45 years recurrence interval).

4.2 Backwater study

The working of the dynamic slowing area (stored volume and efficiency) is linked to the backwater created by the overflow outlet.

The backwater was first evaluated thanks to the Bradley method. This well-known method is based on the use of the Bradley abacus to size the road crossing.

The resulting chart is shown below (Figure 12).

In order to check the working of the building and to measure the speeds in the overflow outlet and along the banks, a physical model of the dam has been realized at the 1/50e scale. It represents a 1200 m long part of the valley.

The behavior of the building has been studied with flows ranging from 200 to $900 \text{ m}^3/\text{s}$ and different opening sizes of the overflow outlet.



Figure 11. View of physical model.

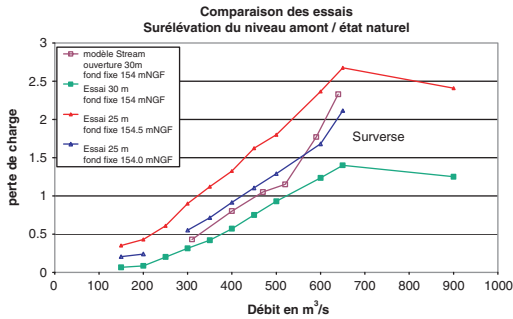


Figure 12. Results from physical models and method of Bradley.

The results given by the two methods are quite different. The backwater found with the model is lower than the one procured by the Bradley abacus (difference of one meter or so).

The study of the physical model brings to conclude that the found friction head is sensitive to the opening size of the overflow outlet in the river minor bed: a gap of 17% on the overflow outlet width leads to a change of the developed friction head in a scale of 40%.

The differences between the two methods could be explained by a move in torrential flow. The velocity reach 5.7 m/s for a flood of 600 m³/s.

Moreover, the speed profile in the overflow outlet is very asymmetric, because of the curvature of the Meuse and the very decentred location of the outlet. 25 m downstream, the velocity reach 1 m/s on left bank, 4.8 m/s on middle, 2.5 m/s on right bank.

4.3 Sizing of the dynamic slowing area

The conclusions of the study and the constraints of the site (navigation, uphill residences) led to set the size of the overflow outlet at 30 m in the minor bed.

The construction is made of a ground dam, protected by rockfills and blocking the whole major bed and a part of the minor bed.

It is about 3.5 m high and 10 m wide on the top. A dump valve is used to restore an auxiliary arm of the Meuse.

The backwater created by the building creates a height increase of 1.5 m near it for a centennial flood. This effect is completely cancelled 12 km uphill the dam. Thus the stored volume is evaluated to 3 mm³ (the total flood's volume is appraised to 60 mm³).

The submersion durations are increased by 10 days at the dam and by few hours uphill.

Downhill, the water height is decreased by 5 cm if compared to the current state. This dam balances the negatives impacts of the protections built in the cities of Charleville-Mézières and Givet.

4.4 Consequences and remediations

The choice of the location of the dam is the result of several local constraints.

The dam must be as close as possible of the city of Mouzon in order to have the maximum storage capacity and thus the best efficiency.

But the dam must be outside the protection perimeters of the drinkable water catchments of the city, in a sector with little effect on the fauna and the flora. The maximal height increase must enable the protection of the interests located inside the storage area (urban sectors, navigation facility, ...).

The following schema summarizes the set of the constraints and the location of the dam.

A global study based on elaborated modelling tools, investigations and the making of a physical model of the dam has allowed to find the interests in the project area and to purpose the suited remediations:

- *Existing buildings:* the villages of Letanne and Pouilly-sur-Meuse are already drownable and are affected by the height increases of the project (respectively by 18 cm and 5 cm for a centennial flood). We decided to build local dams and to uplift the road to protect them.
- *Drinkable water supply:* the project is located inside distant protective zone of water catchment. There is no impact on groundwater levels, and a piezometric following could be carried on.
- *Navigation:* Meuse is navigable on the location of the dam. The overflow outlet allows navigation. The dam has no impact on stream line for navigation's flood.
- *Environment:* Fauna and flora are very diversified. Measurements were carried out in the flood dynamic slowing area. A dump valve on an auxiliary arm of the Meuse let fish circulation. A following of the gradual change of species would be carried out.
- *Steep bank:* Velocity reaches 5 m/s. Mineral and planting protections are necessary.
- *Landscape:* Grass and bush integrate the embankment in landscape.
- *Local project:* A road runs on the top of the dam. Its relieves congestion in the city of Mouzon.
- *Agriculture:* Financial compensations for cultivation damages during the flood were negotiated with local farmers. A valve on the auxiliary arm of the Meuse reduces the impact of the dam during small flood.

4.5 Meetings

All actors and organizations affected by the project (elected people, state employees, farmers, wildlife protection organizations, ...) met three or four times each year to study the progression of the project.

Specific meetings were arranged, for example with the towns of Letanne and Pouilly concerning local protections.

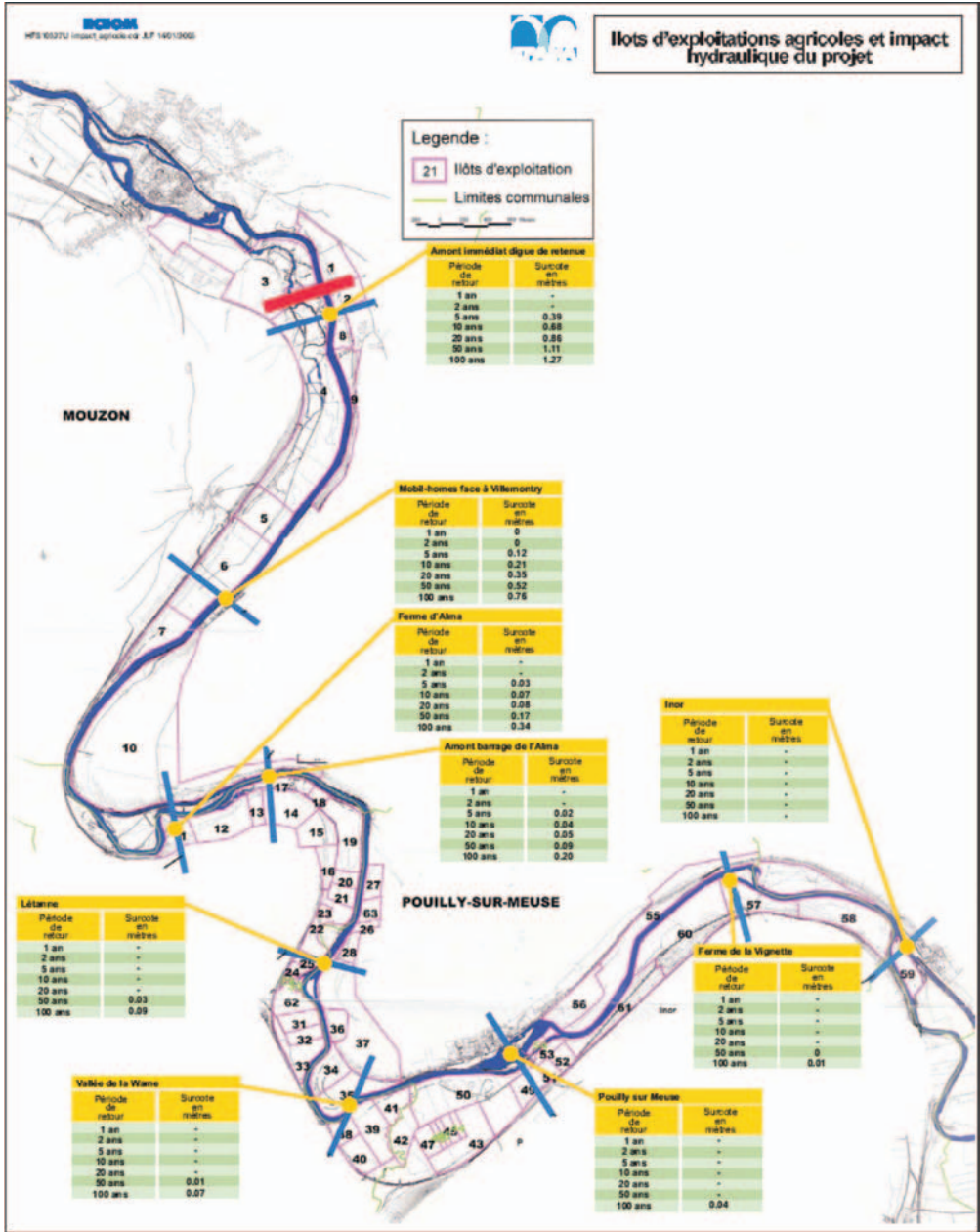


Figure 13. Impact on water stage.

The project was introduced to local people by an open meeting and a public exhibition.

A group gathering agriculture offices of Ardennes, Marne and Meuse departments and the EPAMA work on the compensation principle.

4.6 Advantages of the first development stage in the Ardennes

This program (local building program for Charleville and Givet and flood dynamic slowing area upstream Mouzon) will reduce the floods heights by 60 cm in

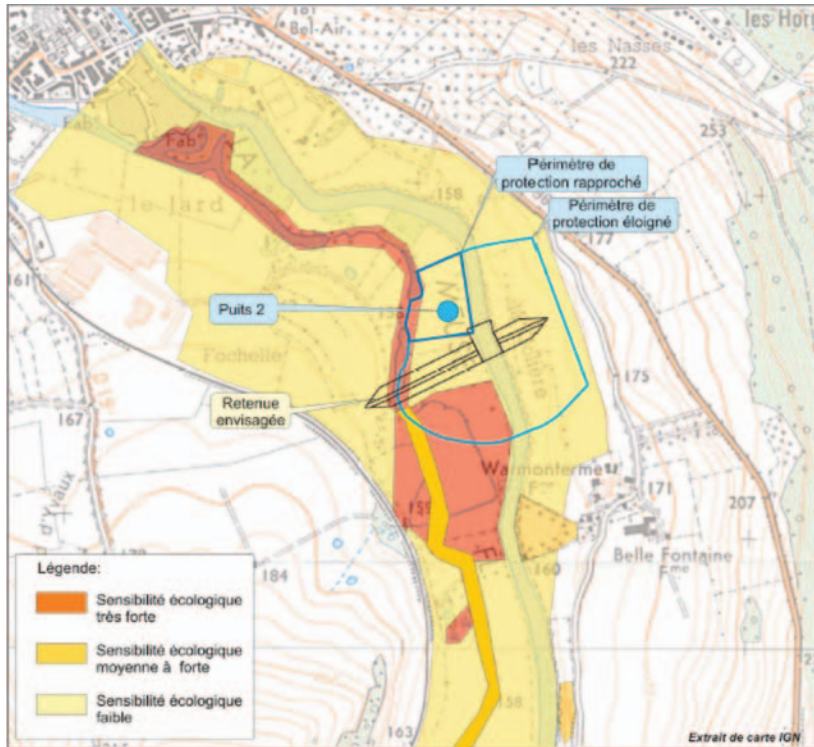


Figure 14. Location of the flood dynamic slowing area of Mouzon.

the cities of Charleville and Givet. From an economic point of view, the damage costs will be reduced by 29 m€ in Charleville (today the cost is estimated at 101 m€ in Givet).

The cost of this building is evaluated at 40 m€ for local building program in Charleville and Givet and 10 m€ for the construction of a flood dynamic slowing area.

5 CONCLUSION

Presently, two other flood dynamic slowing areas have been studied in Meuse's department.

The development of a dam upstream Mouzon is forecast in 2006, after public investigations.

This strategy leads to a global flood management. The consequences on the environment are poor and allow usual activity in the Meuse valley.

However this sort of dam is new, and there is no return on the performance during flood.

Complex studies and measures of the initial conditions are necessary. A wide dialog with the inhabitants of the dam's neighbourhood is needful.