M2R Hydrohazards internship report

Elaboration of a flood warning system on the downstream Brenne basin

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Acknowledgement

Thanks to Vincent RIBOT (my supervisor) and the SIRTAVA staff, for trusting me
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Sandrine ANQUETIN and my Greek and French teachers in Volos and Grenoble Universities

Brenne pictures during the 2001 flood

Résumé:

Ce rapport de stage présente le travail réalisé, au sein de SIRTAVA dans le cadre des actions du PAPI, pour mettre en place un système d'alerte aux crues sur la partie aval du bassin de la Brenne, en Côte d'Or.
Le bassin de la Brenne, bien que vulnérable face aux inondations, n'est pas couvert par un service de prévision des crues. Cependant, des stations hydrométriques sont présentes à l'amont de la zone menacée par les inondations. Il est donc possible de se servir d'elles pour élaborer un système d'alerte aux crues.
Pour cela, l'ensemble des données hydrométriques disponibles depuis la mise en service de ces stations a été étudié, afin de connaître le comportement et les caractéristiques de ces crues. Dans le but de sélectionner, ensuite, des stations pour porter le système d'alerte et déterminer les seuils responsables des premiers dommages.
Deux stations amonts ont été choisies pour être intégrées au dispositif, ainsi que deux seuils d'alerte et un seuil de pré alerte. Afin que les communes menacées disposent de suffisamment de temps pour s'organiser à faire face aux inondations.
L'organisation de ce système d'alerte a été élaborée en collaboration avec les différents acteurs de ce bassin versant.

Abstract:

This internship report presents the work realized in SIRTAVA within the framework of actions of the PAPI, to establish a warning system for floods, on the downstream part of the Brenne basin, in the Côte d'Or County.
The Brenne basin, although vulnerable to flooding, is not covered by a service of flood forecasting. However, hydrometric stations are present in the upstream of the area threatened by flooding. It is therefore possible to use them to develop a warning system for floods.
For this, all the hydrometric data available from the setting of these stations have been studied, in order to determine the behaviour and characteristics of these floods. The goal was to select the stations to carry the warning system, and to determine the thresholds responsible for the first damages.
Two upstream stations were selected to be included in the device, as well as two alert thresholds and an early-warning threshold, so that the threatened communes have enough time to organize themselves to face the floods.
The organization of this warning system was developed in collaboration with the various actors of this watershed.

περίληψη:

Η παρούσα εργασία διεξάγεται στα πλαίσια του γαλλικού προγράμματος πρόβλεψης πλημμυρών PAPI (Programmes d'Actions de Prévention des Inondations) της εταιρείας SIRTAVA, με σκοπό την καθιέρωση συστήματος έγκαιρης προειδοποίησης πλημμυρών, στα κατάντη της λεκάνης απορροής Brenne η οποία ανήκει στην περιοχή Côte d'Or. Σε αυτή την περιοχή, αν και ευάλωτη σε πλυμμήρες, δεν υπάρχει κάποιο σύστημα έγκαιρης προειδοποίησης πλημμυρών, ενώ οι υδρομετρικοί σταθμοί στα ανάντη της λεκάνης απορροής, απειλούνται συνεχώς από έντονες πλημμύρες. Αυτοί οι σταθμοί, είναι πιθανό να χρησιμοποιηθούν, ως σταθμοί έγκαιρης προειδοποίησης πλημμυρών. Για το σκοπό αυτό, τα υδρομετρικά στοιχεία διαθέσιμα από τους υδρομετρικούς σταθμούς, έχουν μελετηθεί εκτενέστερα, ώστε να παρέχουν έγκυρες πληροφορίες σχετικά με τα χαρακτηριστικά των υφιστάμενων πλημμυρών. Σκοπός της παρούσας εργασίας, είναι η συλλογή κατάλληλων υδρομετρικών σταθμών για την καθιέρωση έγκαιρων συστημάτων προειδοποίησης πλημμυρών καθώς και η εύρεση ενός κατώτερου ορίου βάσει του οποίου θα παρέχονται πληροφορίες σχετικά με την εκδήλωση των πλημμυρών. Δύο σταθμοί επιλέχθηκαν, για την δημιοργία συστήματος έγκαιρης προειδοποίησης πλημμυρών μαζί με την εύρεση ορίου ώστε να παρέχεται έγκυρη ενημέρωση και πρόληψη για την αντιμετώπιση πλημμυρών. Η οργάνωση και καθιέρωση των συστημάτων έγκυρης προειδοποίησης πλημμυρών, πραγματοποιήθηκε με την συνεργασία των ανθρώπων της περιοχής.

Foreword:

The SIRTAVA (Syndicat Intercommunal pour la Réalisation des Travaux d'Aménagement de la Vallée de l'Armançon) is an inter-communal union, created in 1981 to realize development works of the Armançon valley. Its first aim was to fight against floods.
It is composed of 118 commune members, that corresponds to 68000 residents, all along the 1255 km of the Armançon river and its tributaries.
This union committed in 1998 to lead a watershed politic through the SAGE (Schéma d'Aménagement et de Gestion des Eaux). It is a planning tool of water resources and aquatic environment.
In 2004, the SIRTAVA became one of the PAPI programs (Programme d'Actions et de Prévention des Inondations). It is an operational tool to set up a flood prevention politic at the watershed scale.
Since 2009, the SIRTAVA ensures the animation of the downstream Armançon global contract.
During the 5 months of my internship, I was integrated into the SIRTAVA's watershed pole, in the framework of the PAPI's actions.

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1. Introduction

Situated in North Eastern France, in the Côte d'Or county, the Brenne river is a tributary of the Armançon river, which is the river managed by the SIRTAVA. The Brenne river frequently overflows, causing principally material damages (see Figure 1).
Despite significant issues (500 habitations and several sensitive establishments) evaluated as situated in the flood zone (ASCONIT Consultant, 2007; Hydratec, 2007), the Brenne watershed is not covered by a SPC (Service de Prévision de Crues), the French flood forecasting service, due to its situation in upstream watershed. Indeed, this location and therefore the flood kinetic make difficult to realise forecasts.

To cope with floods, currently, elected officials or riverside residents keep watch on water level, themselves, when the meteorological context is abnormal. Therefore, they have to well assess the situation. This organisation induces a risk increase caused by the possibility to not detect the water rise or to see it too late, and giving a lot of concern among residents.

Due to the flood vulnerability of the Armançon basin, this region was accepted to be one of the forty-two PAPI (Programmes d'Actions de Prévention des Inondations), the French Flood Prevention Action Programs, launched by the government in 2002.
These programs are composed of four sections:

- Improvement of the risk conscience thanks to communication, information and formation actions.
- Improvement of precipitation monitoring, forecasting and warning systems and of the crisis management.
- Elaboration of flood risk prevention plans.
- Implementation of flow deceleration actions, upstream of threatened zones.

Within the framework of Armançon PAPI, the SIRTAVA would like to elaborate a flood warning system for the downstream Brenne basin, where the main issues are situated.

Previous studies already worked to elaborate forecasting and/or warning systems, in this region: S. Goguely (2000) found an equation to forecast streamflow from precipitations with as prerequisite high soil moisture whereas SOGREAH (2008) searched a technical organisation using a streamflow - streamflow modelling.
But none of these projects has been realised, as the available technical and human means were not sufficient. Indeed, there are no structures able to do monitoring, therefore to interpret complex data at any time.

Consequently, the flood warning system will have to be simple, and not require scientific interpretation from people who will receive the warning messages.
It will not take into account rainfall, because to be significant on flood development, precipitations have to be compared to soil moisture and temperature.
It will only give information about water level, from hydrometric stations situated upstream.
This report presents the elaboration of this flood warning system. Section 2 introduces the Brenne watershed and its main characteristics. Section 3 develops the methodology applied to elaborate the warning system, with a first phase to select the relevant hydrometric stations, a second phase to determine the warning thresholds and to finish a phase to design the organisation of the warning system. Section 4 presents the results and their interpretations, to then conclude in a section 5 by presenting the running of the flood warning system elaborated.

Figure 1. Main characteristics of the Brenne basin

2. Brenne basin

The main Brenne basin information is presented in this section, in order to explain the context of the study.

2.1 Brenne basin description

The Brenne is the main tributary of the Armançon with its watershed of 800 km^2. It takes its source at an altitude of 563 m, in the Sombernon commune.
This region is undulating with high slopes and altitudes from 100 m, in the bottom valleys, to 600 m at the tops (see Appendix 1).
The Brenne basin is characterised by a dense hydrographic network, however, it possesses two main tributaries: the Oze and the Ozerain, which are similar as far as their watershed size and elongated shape are concerned (see Figure 1).

2.2 Land use and vulnerability

A rural landscape characterises this region, 97% of the area is little or not developed. Pastures and forests are the main land uses (see Appendix 2), consequently, soils are not much modified. Urban zones are sparse, mainly localised on the valley floor. This geographical situation of towns makes them vulnerable to river overflows (see their order of natural disaster in Appendix 3).
The primary urban zones are the Venarey - Les Laumes and Montbard communes, with respectively 3 046 and 5 582 inhabitants (INSEE, 2009). Consequently, the main issues are situated in these towns : 190 homes located in the flood zone in the Venarey-les Laumes town and 130 in the Montbard town (ASCONIT Consultant, 2007). Furthermore, 5 schools, the hospital, the police station and the emergency services are even included in the flood zone of Montbard.
The flood zones have been evaluated in reference to the 1910 flood corresponding to an event just higher than centennial event.

2.3 Climate and hydrogeology

On the Brenne watershed, Oceanic climate prevails with predominant precipitations during winter and spring. Accumulated precipitations during one year vary from 800 to 950 mm and a rainfall gradient South-West/North-East is observed (see Appendix 4).

Precipitation events coupled with the Brenne basin geology will determine watercourse response, according to the soil's permeability.
The lower parts of the Oze, Ozerain and Brenne valleys, composed of Liassic marls, are low permeable, whereas the higher parts, constituted by Bajocian limestone, have a high permeability (see Appendix 5). Thus, the hydrologic behaviours of these two zones are very different.
On the Liassic marl zone, runoff is dominant and response times are very short. While on the Bajocian limestone zone, water can infiltrate until soil saturation, then water goes directly to the river by runoff. Therefore, until soil saturation, response time is long then it decreases quickly when runoff starts. Thus, two kinds of responses occur and will determine the flood formation.

Picture 1. 2001 flood aerial view of Montbard

Picture 2. 2001 the Brenne in Montbard during the flood

Picture 3. 2011 the Brenne in Montbard

2.4 Hydrology and hydrography

The Brenne river has a linear length of 75 km and an average slope of $4_0/_{00}$. It is submitted to a river regime influenced by rains, consequently oceanic. It possesses a high inter-annual variability, with high water level during winter and low water level during summer (see Figure 2).
It has got a lot of tributaries, the Oze, Ozerain, Ru de Vau, Drenne, Dandarge and the Lochère are the mainly, with linear lengths from 42 to 10 km.

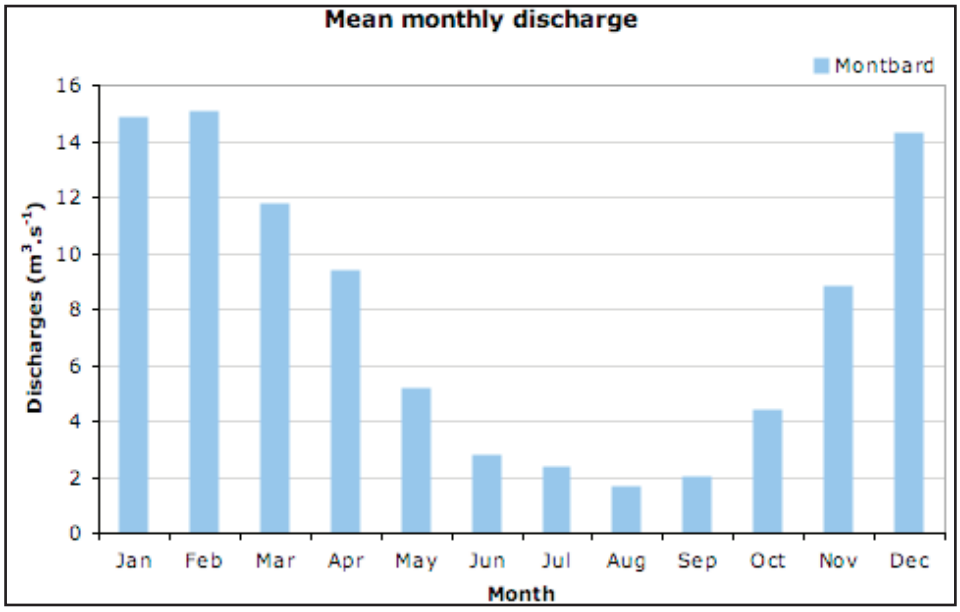

Figure 2. Histogram of the mean monthly discharges of the Montbard station

2.5 Flooding typology

In this region, floods are mainly generated by river overflows and occur during winter, between November and April, after a long rainfall period, when the soil is saturated. These events are associated to low precipitations but with a large spatial extent. Therefore, flooding generally impacts the whole watershed and not only one sub-watershed.
On the other hand, during summer storms with localised high precipitations intensities, floods are concentrated in one zone. Impacts are principally generated by runoff, and river peak flows are less important than during winter (SOGREAH, 2008).
These floods are fast, due to their upstream situation. However, the elongated shape of the Brenne watershed and its sub-watershed induces floods which are more spread in time than with compact watershed of equivalent size (see Figure 3).

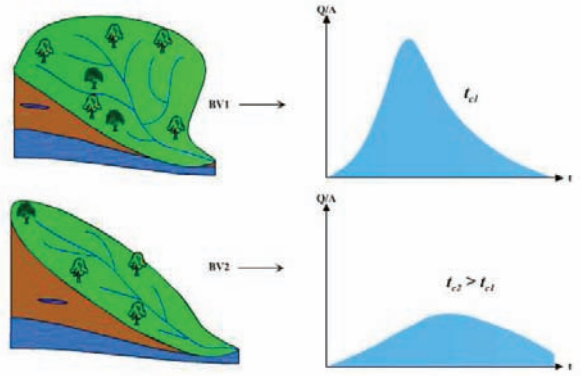

Figure 3. Impact of the watershed shape on the watercourse response (A. Musy, EPFL)

2.6 Past events

Flood marks on old buildings testify of past floods, which have impacted cities. January 1910 and September 1866 are the two biggest known flood periods, with flood return periods greater than 100-year.

The two last damaging events occurred on April 1998 and March 2001. Table 1 presents their discharges and return periods (Hydratec, 2007). The flood return periods have been evaluated using a Gumbel distribution and the Gradex method.

Station	April 1998		March 2001		Centennial event
	Discharge ($m^3.s^{-1}$)	Return period	Discharge ($m^3.s^{-1}$)	Return period	Discharge ($m^3.s^{-1}$)
Brain	32,7	15-year	32,7	15-year	49,2
Darcey	40,1	6-year	50,5	15-year	87,2
Montbard	133	19-year	127	14-year	249

Table 1. Return periods and discharges (Hydratec, 2007)

2.7 Hydrometric stations

Four hydrometric stations are in use over the Brenne basin (see Figure 1). Table 2 resumes their main characteristics.

The DREAL Bourgogne (Direction Régionale de l'Environnement, de l'Aménagement et du Logement), the regional state service of the French Ministry of Ecology, manages a lot of hydrometric stations in order to perform a global environmental policy.

The DREAL Bourgogne has computed for its own stations the discharge return periods using a Gumbel distribution. Return periods are computed according to the length of the recording period. The flood frequencies of the Hauteroche station were not evaluated due to the short validity period.

The data used in this report correspond to the instantaneous discharges recorded by these hydrometric stations and supplied by the DREAL Bourgogne and the Côte d'Or General Council. Data from Dreal Bourgogne are discharges at variable time steps (QTVAR – recording of data each time there is a variation of discharge or water level) whereas General Council produces hourly data.

2.8 Hydraulic structures: the Grosbois reservoir

This rural area doesn't possess any important hydraulic structure, except the Grosbois reservoir situated upstream to the Brenne river.

It was built in 1838, to feed the Bourgogne canal during dry periods. For this purpose, it fills during winter until its maximum capacity (generally in March), without accurate management.

It controls a 31km^2 drainage area and it can store 7,7 million of water cubic meters (9.2 million of m^3 at most).

This reservoir was not built to control flood. However, it decreases flood discharge in upstream areas, for flood of small return period (Hydratec, 2009).

Picture 4. 1910 flood in Montbard

Station	River	Drainage area (km^2)	Annual Mean discharge ($m^3.s^{-1}$)	Specific discharge ($l/s/km^2$)	Validity period	Manager	Return period of flood flow (from Banque hydro) ($m^3.s^{-1}$)
Brain	Brenne	136	1,1	8,1	1993-2011	DREAL Bourgogne	2-year = 21 5-year = 29 10-year = 34 20-year = 39
Darcey	Oze	205	2,5	12,2	1993-2011	DREAL Bourgogne	2-year = 27 5-year = 37 10-year = 44 20-year = 50
Hauteroche	Ozerain	86,8	0,8	8,7	2001-2011	Côte d'Or General Council	Not specified
Montbard	Brenne	732	7,7	10,5	1988-2011	DREAL Bourgogne	2-year = 77 5-year = 100 10-year = 120 20-year = 130 50-year = 150

Table 2. Hydrometric stations characteristics

3. Methodology

The methodology applied to elaborate the flood warning system is divided in two approaches. The first one corresponds to hydrologic analysis phases. The aim is to better know the flood characteristics, in order to choose the relevant hydrometric stations to perform the water level monitoring, and determine the warning thresholds.
The second approach corresponds to the reflection about the setup of the warning system, to assess the responsibilities and decide which system could be appropriate.

3.1 Hydrologic analysis phases

During the whole hydrologic analysis, the Montbard station was used to evaluate the floods impacts. It gives information concerning the downstream part whereas the Brain, Darcey and Hauteroche stations were used to analyse the hydrologic behaviour at the upstream part.

3.1.1 Research of the hydrometric stations to perform water level monitoring

To select the hydrometric stations able to monitor the water level, past floods were studied in order to know the main flood characteristics.
The events have been selected according to their intensity, so that their behaviours are similar to events causing damage. All events from 1993 (the upstream station start-up date), with a return period greater or near 5-year, were analysed.

• To know the link between stations and to verify if flows recorded at the upstream stations are consistent with the downstream behaviour, correlation coefficients have been computed. This shape statistical parameter measures the linear correlation between upstream stations flows and the Montbard station's discharge. Its optimal value is 1.
The correlation coefficients were computed for each flood event period. This period is defined as going from a date just before the water rise until the end of the flood (see Figure 4). Linear interpolations were made, to study the time series at an hourly time step.

• Water contributions of the upstream stations during flood events were compared to the recorded waters at the Montbard station. Study of these water volumes drained at each station will determine which sub-watershed station contributes the more on the recorded flood at the Montbard station. To compute these volumes, the whole drained waters during the flood event period are taken into account.

• Propagation times between station's flood peaks were computed for each event, in order to estimate the warning times.
Furthermore, a link between flood frequency and propagation time was searched. In this aim, delays between two stations were evaluated for discharges corresponding to different return periods (see Figure 4).

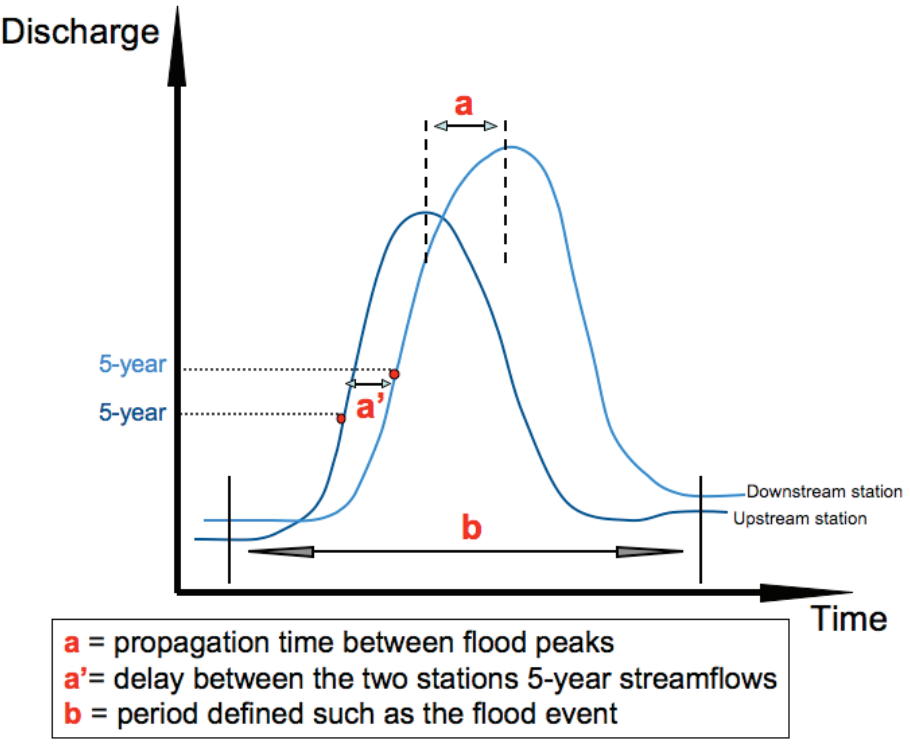

Figure 4. Hydrograph diagram illustrating the different flood time periods

3.1.2 Research of the warning thresholds

The methodology used to determine the warning thresholds was to first find the downstream water level responsible for the first damages, then to determine the corresponding upstream streamflow.

In this aim, all the communes threatened by floods, on the downstream Brenne, were listed and the majority of mayors or SIRTAVA's delegates of these towns were met.
During these meetings, many questions were asked to collect the main information concerning floods and to complete the following form (see figure 5).

With this approach, the frequency of damageable flood for these towns could be estimated, to then find the corresponding upstream discharges.

3.2 Organisation phases

To find an organisation of the warning system, the regulatory framework was studied. It permitted to know what is allowed and the responsibilities engendered by a warning system.
Furthermore, a cooperation work with the different actors of this territory was realised. The meetings with the mayors helped to understand and to take into account their functioning and their needs. It gave a local point of view, whereas the work with the state services: the Côte d'Or Prefecture; the DREAL Bourgogne and the SPC, gave a point of view more official, as their goal is to coordinate this system with other services. Moreover, the Dreal Bourgogne supplied information concerning the hydrometric stations functioning.

Interview date:

Commune:	
Interlocutor(s): (Name, function)	

Flood zone:	
Habitats	
Activities	
Equipments	
Sensitive establishments	
Transport infrastructures	
Networks	

Questionnaire to the communes threatened by floods, on the downstream Brenne basin

1- Is there a flood prevention plan in your commune? (PPRi?)

2- Is there a communal safeguard plan in your town? (PCS?)

3- Last flood consequences?

1998:
2001:
2010:

Where did the first overflows happen?

4- Is there a particular management during flood event?

Any monitoring persons?

Water level monitoring?

Staff gauge?

Knowledge/list of people or companies situated in flood zone?

Breedings or pastures situated in flood plain?

5- What do you expect of a warning system?

Telealert?

Mass phoning system?

6- Flood marks?

Figure 5. Questionnaire to the communes threatened by floods

4. Results and interpretations

4.1 Hydrometric stations analyse

4.1.1 Selected floods

11 flood periods have been selected, from 1993. Table 3 presents the peak flows of each station, in order to know their order of magnitude (see above Table 2).

Studied floods	Brain peak flow ($m^3.s^{-1}$)	Hauteroche peak flow ($m^3.s^{-1}$)	Darcey peak flow ($m^3.s^{-1}$)	Montbard peak flow ($m^3.s^{-1}$)
Oct-93	26,5	No data	38,5	79,9
Jan-95	23,9	No data	35	94,4
Nov-96	24,6	No data	38,3	102
Apr-98	32,7	No data	40,1	133
Jan-99	19,5	No data	33,4	87,2
Feb-99	23,6	No data	41,5	103
Mar-01	32,7	92,2	50,5	127
Jan-04	22,6	43	45,6	97,8
Mar-06	24	11,5	36	95,4
Dec-10	21,8	11,1	28,6	90,5
Dec-10	28,4	11,5	31,9	97,7

Table 3. Peak flows of the selected floods

Figure 6 and 7 present the hydrographs of the two last bigger damageable floods: April 1998 and March 2001. The whole hydrographs of these floods are on Appendix 6.

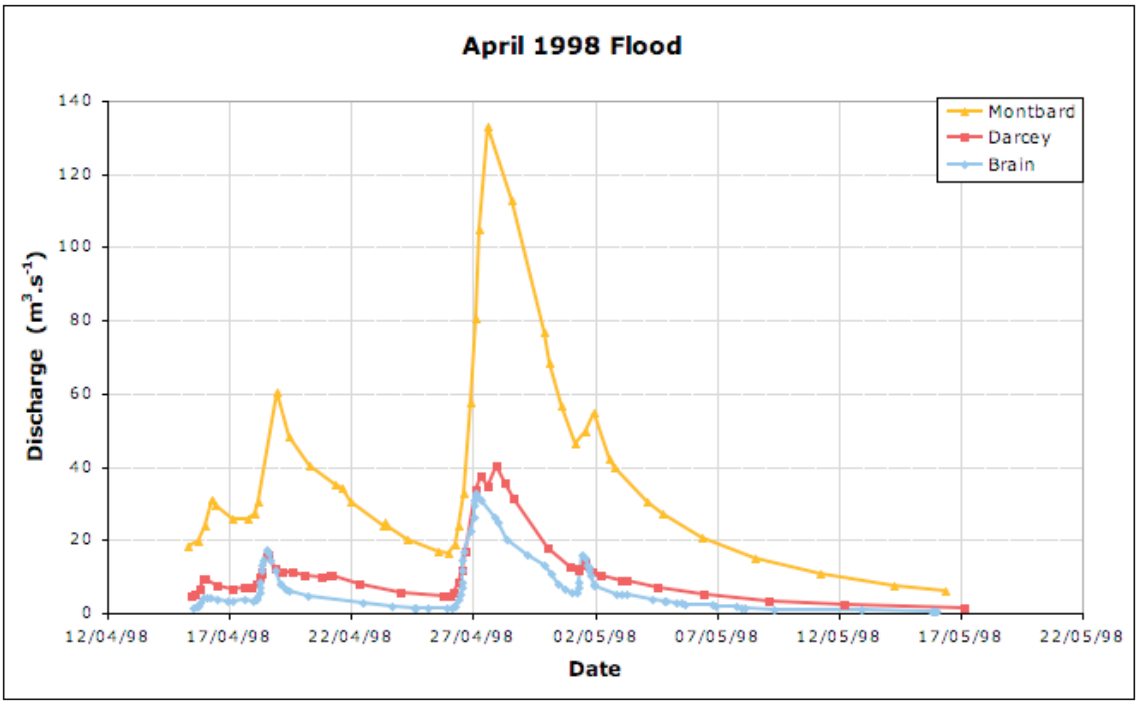

Figure 6. April 1998 hydrograph

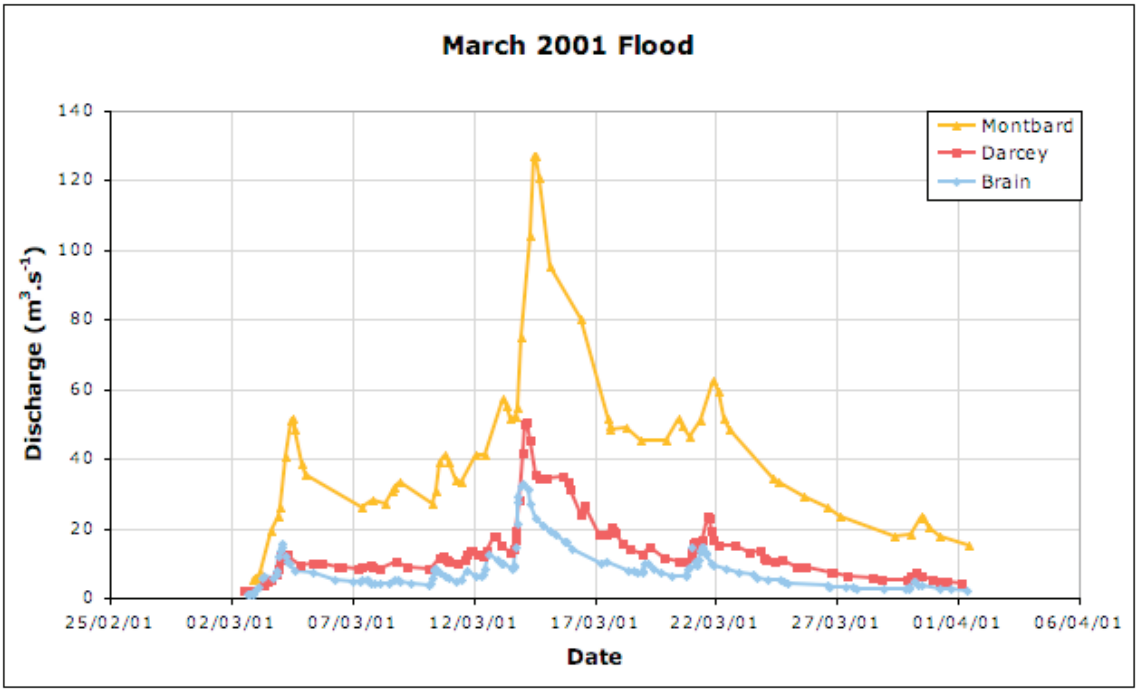

Figure 7. March 2001 hydrograph

4.1.2 Correlation coefficients

The linear correlation coefficients between upstream station discharges and Montbard station discharge are presented in Table 4, for each flood period.

Analysed floods	Correlation of the discharge values		
	Montbard - Brain	Montbard - Darcey	Montbard - Hauteroche
Oct-93	0,68	0,92	No data
Jan-95	0,71	0,96	No data
Nov-96	0,76	0,96	No data
Apr-98	0,91	0,98	No data
Jan-99	0,90	0,91	No data
Fev-99	0,88	0,95	No data
Mar-01	0,88	0,95	0,656
Jan-04	0,91	0,98	0,938
Mar-06	0,85	0,96	0,900
Dec-10 – w 49	0,74	0,98	0,891
Dec-10 – w 51	0,66	0,96	0,863
Average	**0,81**	**0,95**	**0,85**

Table 4. Correlation coefficients

The three upstream stations generally have good correlations with the Montbard station. In fact, the most of the correlation coefficients are situated around 0,8 to 0,9.

These results testify of the similar watercourse reactions during a flood event and of the homogeneity of the studied area: geology, land use, relief… (see above Brenne basin). Furthermore, it shows that during important events, flooding affects the whole watershed and not only one sub-watershed.

The Darcey station possesses the best correlation with values upper to 0,9. Consequently, discharges recorded at the Darcey station are the more representative of the Montbard streamflow.

The Brain and Hauteroche stations have similar average values, however the Hauteroche station

is difficult to compare due to the few recording years.
Moreover, the good correlations also show the concomitant character of these floods. Indeed, the worse results obtained at the Brain station for the 1993, 1995, 1996, 2010 floods and at the Hauteroche station for the 2001 flood, become higher than 0,8 if the time series is shifted of few hours, by delaying them.
This flood concomitancy is also observed on the different flood hydrographs: figures 6, 7 and Appendix 6.

4.1.3 Water contribution

The study of the water drained at each station permits to know the water contribution of the upstream stations, on the flood generated at the Montbard station. The water volumes drained have been computed from a date just before the water rises until it returns to base flow. Table 5 presents these results.

Analysed floods	Upstream station volume / Montbard volume		
	Brain volume / Montbard volume (%)	Darcey volume / Montbard volume (%)	Hauteroche volume/ Montbard volume (%)
Oct-93	14,8	30,8	No data
Jan-95	10,8	31,9	No data
Nov-96	11,6	33,1	No data
Apr-98	20,3	29,8	No data
Jan-99	10,3	30,8	No data
Feb-99	18,4	31,5	No data
Mar-01	19,6	33,4	22,5
Jan-04	13,1	31,7	10,5
Mar-06	13,5	30,7	11,3
Dec-10 – w 49	11,4	29,2	10,2
Dec-10 – w 51	12,7	29,1	10,2
Average	**15,5**	**30,4**	**13,6**
Station watershed surface / Montbard watershed Surface (%)	**18,6**	**28**	**11,9**

Table 5. Water participation of the upstream stations according to Montbard recorded volume

The water contributions of the upstream stations are proportionately similar to the sub-watershed stations surface. Thus, recorded waters at the Darcey station represent the bigger part of the recorded waters at the Montbard station. This result is in agreement with the specific discharges of each station, presented in Table 2, and with the similar geology observed in this watershed.
The water participation of the Brain station, according to its sub-watershed size, is lower than Hauteroche water participation. It is maybe due to the Grosbois reservoir influence, which fills during winter period.

4.1.4 Propagation times

Table 6 presents the propagation times, evaluated from the flood peaks of each event.

Studied floods	Propagation time observed (h) between flood peaks		
	Between Brain and Montbard	Between Darcey and Montbard	Between Hauteroche and Montbard
Oct-93	17:56:00	13:08:00	No data
Jan-95	14:18:00	8:14:00	No data
Nov-96	11:35:00	10:36:00	No data
Apr-98	11:36:00	6:45:00	No data
Jan-99	9:47:00	7:52:00	No data
Feb-99	13:45:00	7:25:00	No data
Mar-01	11:36:00	8:48:00	12:41:00
Jan-04	13:28:00	5:40:00	15:30:00
Mar-06	19:35:00	8:55:00	19:31:00
Dec-10 – w 49	17:37:00	9:35:00	14:37:00
Dec-10 – w 51	13:40:00	7:38:00	12:30:00
Average	**14:04:49**	**8:36:00**	**14:57:48**

Table 6. Observed propagation times

The propagation times obtained for the Darcey station are smaller than the Brain and Hauteroche propagation times. Indeed, it is the nearest station of Montbard. Consequently, the Darcey station will give the shortest warning delay.
The Brain and Hauteroche stations are situated at equal distance of the Montbard station and they give similar average values of propagation time.

Then propagation times were computed at different streamflow frequencies, in order to search a link between propagation time and flood return period (see Figures 8 and 9). This approach permitted to see if the water level has an impact on the flood propagation.

The study of the correlation between propagation time and flood frequencies did not indicate any link between these two parameters. The flood wave doesn't seem to propagate faster or slower according to the flood return period.
Moreover, for a same discharge, a high variability on the delays between two stations is observed. Whereas if there was a link between flood velocity and the discharge return period, a cluster around a particular value would have been observed. Some of them are negative, so it will have to be taken into account for the warning system.

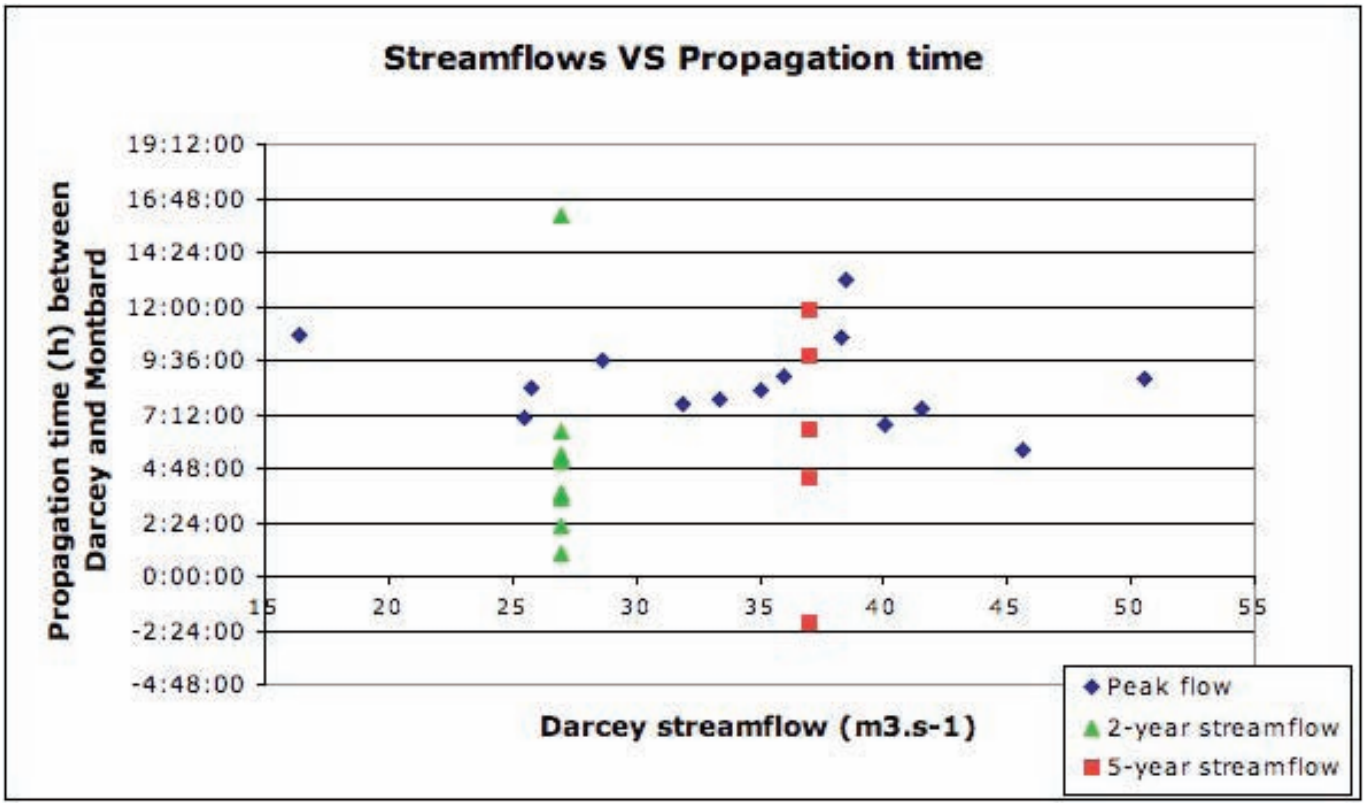

Figure 8. Propagation time between Darcey and Montbard according to Darcey streamflow

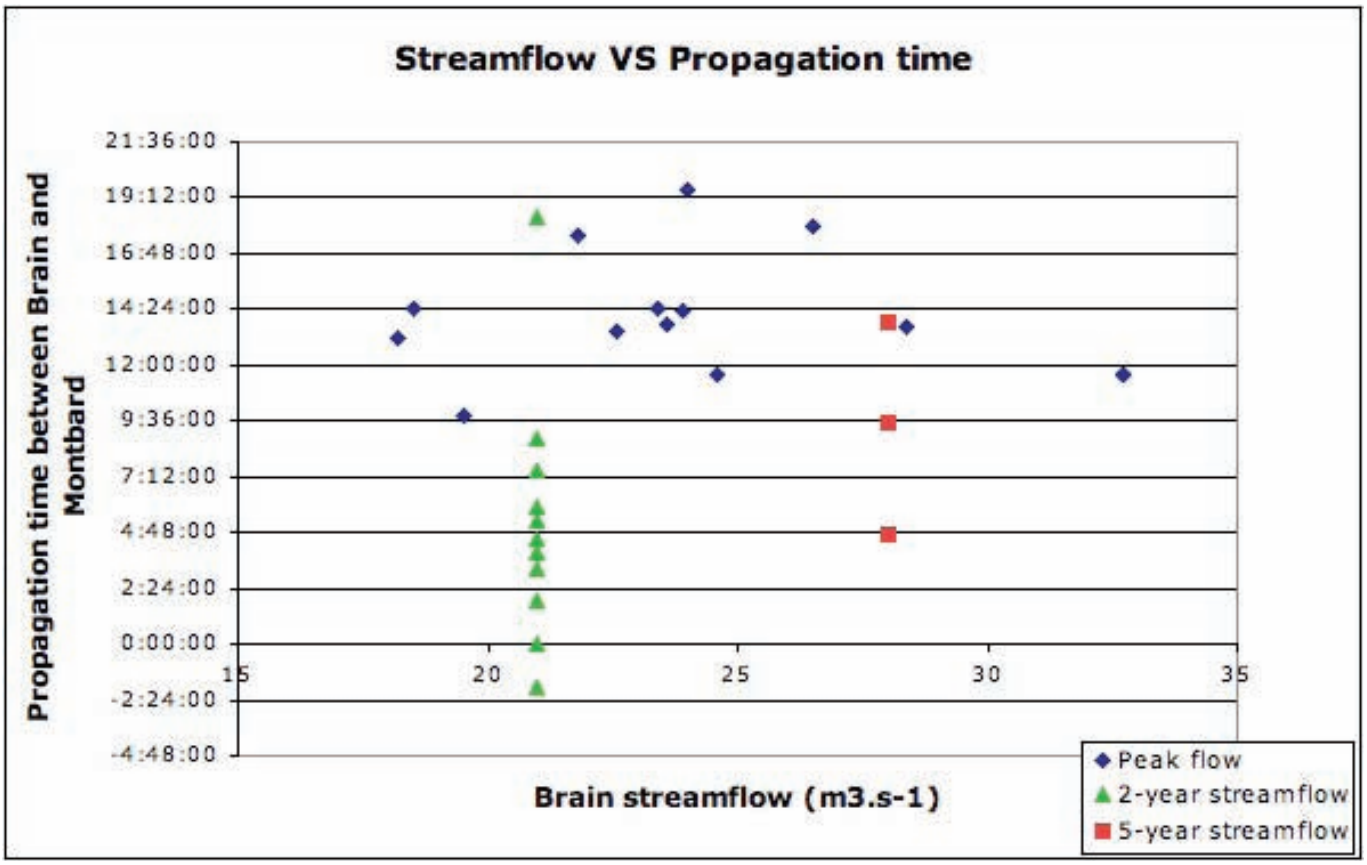

Figure 9. Propagation time between Brain and Montbard according to Brain streamflow

Theses results show the initial conditions influences on the propagation time. Indeed, according to the previous meteorological conditions, consequently, on the soil saturation and the snow cover, the lag time and the water rising will be very different (see above hydrogeology).
Furthermore, the situation on the watershed top and the high drainage density make the water rising very dependant on the spatial variability of the rainfall intensity.

4.1.5 Selection of the relevant hydrometric stations

The previous analyses of the hydrometric stations allowed to know the advantages and disadvantages of each station.

• The Hauteroche station possesses the smallest watershed: 12% of the Montbard station watershed surface. There are only 11 recording years, which doesn't allow to make statistical analyses of the hydrometric station. Moreover, this station is managed by the General Council and seems to be less accurate and less reliable than DREAL Bourgogne's stations. Indeed some of its recorded discharges are suspect, such as the March 2001 flood peak of 92,2 $m^3.s^{-1}$ (see Table 3).
Nowadays, this station doesn't seem relevant to be included in the warning system. It will not be taken in account for the end of the study.

• The Brain station possesses a small watershed: 18,6% of the Montbard station watershed surface. However, its propagation time, longer than that of the Darcey station, could be interesting for the warning system. But the upstream Grosbois reservoir presence and its unfamiliar influence with Brain discharges, make this station uncertain to be the only source detection of the water rise.

• The Darcey station has the biggest watershed of the 3 upstream stations: 28% of the Montbard station watershed surface. Furthermore, it possesses the highest specific discharge and water participation, its correlation coefficients with the Montbard discharges are the better, thus, it corresponds to the hydrometric station the more representative of the Montbard conditions.
It is the station the more relevant to be included in the warning system.

4.2 Warning threshold analyse

4.2.1 Communes meetings

Meetings with mayors or SIRTAVA delegate allowed to collect a lot of information about floods: town vulnerability, flood damages, the first zones impacted, their organisation, … The whole interviews are included in Appendix 7.
Table 7 presents the whole communes threatened by floods in this area and their issues situated in the flood zone.

Communes	Number of homes situated in flood zone (estimation)	Sensitive and decision structures situated in flood zone	Activities in flood zone	Roads in flood zone	Commune met for the study
Pouillenay	~ 10	Town council; Fire station		D9	Yes
Mussy-la-Fosse	0				No
Venarey-les-Laumes*	190	Town council; Police station; Rescue center; Technical service	21 companies	Jean Jaurès avenue; Pont Romain street	Yes
Grignon	0		3 cow breeding	D119	Yes
Seigny	1		3 cow breeding	D119	Yes
Benoisey	0				No
Courcelles-lès-Montbard	0			D119	No
Fain-lès-Montbard	0			D119	Yes
Nogent-lès-Montbard	2		1 cow breeding	D119	Yes
Marmagne	0		1 farmer		Yes
Montbard*	130	Hospital; 2 nursery schools; 2 schools; 1 technical school; Rescue center; Police station	66 companies	Docteur Bruhnes street; town streets; RD980	Yes
Saint Rémy	~ 20		1 restaurant Farmers	D 905	Yes
Buffon	2		Small et Large Forge (historical building) 2 farmers	Pont street	Yes
Rougemont					No
Aisy-sur-Armançon*	70	0	1 bakery 1 wine shop 2 farmers	D956 D 957 (town streets)	Yes

* according to ASCONIT Consultants (2007)

Table 7. Inventory of the flood issues, in the downstream Brenne communes

The aim of these meetings was also to determine the water level responsible for the first damages. It emerged from these interviews that the 23rd/24th December 2010 peak flood corresponds to overflows at the limit of the first damages.
Indeed, according to the elected members of the most vulnerable communes: Aisy-sur-Armançon, Saint Remy and Venarey-les Laumes, a few more centimetres would have been enough to flood the first houses.

These pieces of information are confirmed by the flood impact census of the 2010 flood, where a few roads and cellars have been flooded (see Appendix 8). This flood impact census was realised by the emergency and fire departmental service (SDIS – Service Départemental et d'Incendie et de Secours), the road departmental service and the technical service of each commune.

4.2.2 Flood characteristics of December 23rd/24th 2010

Following the commune meetings, the December 23rd/24th 2010 peaks discharge of the Brain and Darcey stations have been selected first as the upstream warning threshold, and the peak discharge of Montbard station was used as the downstream damageable threshold. The characteristics of the December 2010 flood are presented on Table 8 and its hydrograph on Figure 10.
The peak flow study of the December 2010 flood shows that the Brain and Montbard discharges are almost similar to the 5-year streamflow. The Darcey discharge has a lower occurrence.

23rd/ 24th December 2010 – Flood characteristics			
Hydrometric station	**Peak flow hour and date**	**Peak flow discharge ($m^3.s^{-1}$)**	**Characteristic streamflows (from Banque hydro)**
Brain	23/12/10 13:30	28,4	2-year = 21 $m^3.s^{-1}$ 5-year = 29 $m^3.s^{-1}$
Darcey	23/12/10 19:32	31,9	2-year = 27 $m^3.s^{-1}$ 5-year = 37 $m^3.s^{-1}$
Montbard	24/12/10 3:10	97,7	2-year = 77 $m^3.s^{-1}$ 5-year =100 $m^3.s^{-1}$

Table 8. Flood characteristics of the 23rd and 24th December

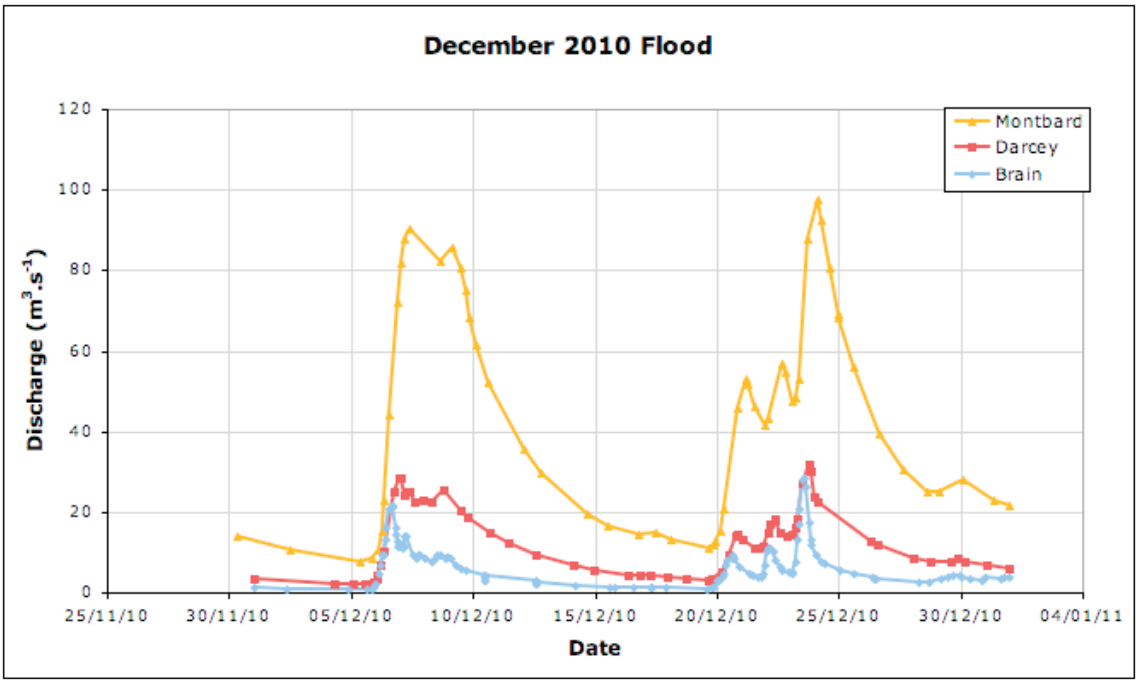

Figure 10. December 2010 hydrograph

The census of the whole events that have exceeded the selected thresholds, from stations setup, shows that the Darcey warning threshold of 32 $m^3.s^{-1}$ is too low and is not necessarily representative of the Montbard damage threshold reach.
Thus, this threshold was rose at 37 $m^3.s^{-1}$: the Darcey 5-year discharge.

4.2.3 Validation of the selected warning thresholds

To validate the selected thresholds of 29 $m^3.s^{-1}$ at Brain and 37 $m^3.s^{-1}$ at Darcey, all the events which have exceeded the selected thresholds have been studied. As the warning delay seemed to be too short in some cases (see Table 9), an early warning threshold of 27 $m^3.s^{-1}$ was added at the Darcey station, corresponding to its 2-year discharge. Indeed, for the April 1998 flood, the damageable threshold was reached before the trigger of the Darcey warning threshold.

The combination of the Brain warning threshold and the Darcey early warning threshold aims to make this warning system stronger and to alert the communes earlier.
Moreover, the Brain station allows the system to have a larger spatial extent of upstream flood detection: 46,6% of the Montbard watershed area. And although the Brain station is influenced by the Grosbois reservoir, infrequent floods are well detected.

Table 9 presents all the events which would have triggered the warning system if it had been operational. The green colour represents floods correctly detected by the system, namely, when a warning message would have been sent before the Montbard damageable threshold reach. The red colour represents the only case when the system does not work, whereas the downstream damage threshold was reached. The yellow and orange colours represent respectively the false early warning and false warning.

Summary table of the crossing thresholds						
Exceeding threshold date	Brain streamflow ($m^3.s^{-1}$) warning threshold=28	Darcey streamflow ($m^3.s^{-1}$) early warning threshold=27 warning threshold=37	Montbard streamflow ($m^3.s^{-1}$) damageable threshold=97	Warning delay Darcey/Montbard from early warning from warning	Warning delay Brain/Montbard from warning	Exceeding threshold hour and associated message
14/10/93 period	26,5	38,7	79,9			1 early warning message from Darcey at 7:45 1 warning message from Darcey at 12:19
7/01/94 period	26,7	30,7	86,3			1 early warning message from Darcey at 3:05
11/01/95 period	23,9	35	94,4			1 early warning message from Darcey at 6:37
30/11/96 period	24,6	38,3	102	11:39:00 9:51:00		1 early warning message from Darcey at 4:16 1 warning message from Darcey at 9:45 Damageable threshold reaches at Montbard at 19:36
27/04/98 period	32,7	40,1	133	5:43:00 -2:05:00 [1]	4:42:00	1 early warning message from Darcey the 26 at 22:22 1 warning message from Brain the 27 at 0:34 Damageable threshold reaches at Montbard the 27 at 5:16 1 warning message from Darcey the 27 at 7:21
29/01/99 period	19,5	33,4	87,2			1 early warning message from Darcey the 28 at 23:06
20/02/99 period	23,6	41,6	103	13:21:00 4:24:00		1 early warning message from Darcey the 26 at 22:22 1 warning message from Darcey the 27 at 7:21 Damageable threshold reaches at Montbard the 27 at 22:10
13/03/01 period	32,7	50,5	127	7:25:00 6:31:00	9:34:00	1 warning message from Brain the 13 at 20:29 1 early warning message from Darcey the 13 at 20:42 1 warning message from Darcey the 13 at 23:32 Damageable threshold reaches at Montbard the 14 at 6:03
30/12/01 period	20	No data (recording problem)	98			Damageable threshold reaches at Montbard at 10:04
17/01/04 period	22,6	45,6	97,8	8:34:00 11:50:00		1 early warning message from Darcey the 17 at 2:52 1 warning message from Darcey the 17 at 6:03 Damageable threshold reaches at Montbard the 17 at 17:53
20/01/04 period	15,3	28,7	75,3			1 early warning message from Darcey at 20:33
9/03/06 period	24	38,3	95,4			1 early warning message from Darcey the 9 at 3:33 1 warning message from Darcey the 10 at 5:56
6/12/10 period	21,8	28,6	90,5			1 early warning message from Darcey the 6 at 21:22
23/12/10 period	28,4	31,9	97,7	8:51:00	13:52:00	1 early warning message from Darcey the 23 at 11:25 1 warning message from Brain the 23 at 12:40 Damageable threshold reaches at Montbard the 24 at 2:32

Table 9. Study of crossing threshold periods

[1] The rainfall map of the April 1998 flood (see Appendix 9), indicates that the peak rainfall was situated near Montbard. This explains the negative warning delay between Darcey and Montbard.

The following table counts the different alerts emitted by the upstream stations according to the Montbard observations.

		Montbard observations		
		No crossing of the damageable threshold	Crossing of the damageable threshold	Total
Upstream stations information	No warning		1 [3]	1
	Early warning	5	0 [4]	5
	Warning	2 [2]	6	8
	Total	7	7	14

Table 10. Warning contingency table

[2] Corresponds to the October 1993 and March 2006 floods. For the 2006 flood, some pictures testify of inundations during this period at Venarey-les Laumes.
[3] Corresponds to the December 2001 flood. When there has been a recording dysfunction at the Darcey station.
[4] Only the early warnings not followed by a warning are counted.

Over 17 years analysed and 14 floods studied, this warning system gives:

- 75% of hits or good warning
- 45% of false early warning
- 14% of missed event.

For the 14 studied floods, delays between warning threshold exceedance and damages threshold have been studied.

- Delays, between warning from the Brain or Darcey stations and Montbard damages threshold, vary from 4h25 to 13h52.
- Delays, between Darcey early warning and Montbard damages, vary from 5h43 to 13h21.

These delays seem to be sufficient, however, they have the disadvantage to be really heterogeneous. It will be not possible for people, who will receive the alert, to know when to be ready to cope with the event.

4.3 Organisation phase analyse

4.3.1 Regulatory framework

The study of the regulatory framework around the flood risk management allows to know the role of the different actors of this territory, their responsibilities and how their actions have to be coordinated.

Mayors missions, fixed by the communities code, give them a preponderant role beside their population, in term of crisis management.
Mayors have to act, in the limit of their means, with or without flood forecasting. The commune responsibility or their own responsibility are involved if they do not act.
Thus, if no information is provided to riverside residents whereas the situation is alarming, serious misconduct can be invoked.
Therefore, the setting up of a warning system will help mayors to better manage flood crises but it will also increase their responsibility.

The 2003 risks Law, reminds the State role regarding the monitoring, forecasting and information transmission about floods (Law n°2003-699 of July 30th 2003, article 41/ article L. 564-1 of environmental Code). It results in the reorganisation of the flood announcement services and their new denomination in flood forecasting services. It also aims to give more information to the mayors of the covered sectors and to allow them to better manage the risk.
However, these services do not concern all communes as in the case of the Brenne basin, which is not covered by the SPC Seine moyenne – Yonne – Loing. In this case, the territorial community can elaborate a system to monitor floods, under their responsibilities and for their needs (Environmental code, L564-2 et L564-3).
The March 2005 circular, about the director schema of the flood forecasting (SDPC) and of the flood monitoring and forecasting regulation (RIC), aims to promote and facilitate the work of communities in the case of small watersheds with short response time. Indeed, local warning systems in these cases are more appropriate, due to their quick reaction.
These kinds of systems have to pass prefectorial bylaws, to be validated by the State representatives in the department, in order to provide coherence between the different systems.
The inscription of systems managed by communities at the SDPC is provided by the application decree of the 2003 natural risk law (January 2005 decree). Moreover, these systems have to be governed by a RIC, which stated the information that have to be transmitted at the civil security responsible and the technical rules ensuring the coherence of the different systems.
The law establishes the principle of the free supply to the territorial community of the collected data and of the forecasts realised by the State, its public institutions and the hydraulic structure managers. And vice versa, the territorial community has to supply for free their collected information and their forecasts to the authorities having a police power.

4.3.2 Works with the different actors of the basin

• The cooperation work realized with the DREAL Bourgogne, which manages the hydrometric stations, allowed to collect all the data concerning these stations. Moreover, they followed our work, to validate our scientific approach and gave us their agreement in order to use their stations (an agreement will have to be passed with them). They provided information about the hydrometric stations functioning and the equipments that can possibly be implemented at the stations, in order to make them usable for the flood warning system.
The DREAL Bourgogne has the possibility to cheaply equip selected hydrometric stations with an automatic remote transmission system, using the GSM network (Global System for Mobil communications). This system permits to transmit automatically a SMS (Short Message Service) when a water level is exceeded. However, to not saturate the GSM network during a flood event and to save the battery of the hydrometric stations, the system will need send only warning messages at one or two phones. Indeed, during flood events, the DREAL's stations already transmit the recorded discharges at the DREAL Bourgogne and at the SPC. Thanks to this organisation, these services can realize a monitoring of the situation and provide flood forecasts at the regional scale.

• The work realized with the SPC, aims to validate our scientific approach, in order to coordinate the Brenne warning system with the other devices and to incorporate it to the SDPC and RIC. Following the oral validation of the scientific approach, a formal request will be send quickly, to validate the warning system.

• The cooperation work realized with the Côte d'Or Prefecture, and more especially with the civil security service, permitted to determine which kind of warning system the prefecture could accept. Indeed, the prefecture has to coordinate the different flood monitoring systems and it is the only state service that is allowed to trigger the alerts. So, to make our system a real warning system, it has to be validated by the prefecture and suitable with its functioning.
The civil security service, with the favourable opinion of the DREAL Bourgogne and the SPC, accepted to incorporate our warning system to their services.
The prefecture will transmit the flood warning messages of the Brain and Darcey station to the threatened communes, using their GALA (Gestion de l'Alerte Locale Automatisée) system. This system corresponds to pre-recorded voice messages that are sent to all the threatened communes. These calls keep trying to contact different numbers of elected officials until someone receipts it.
To be able to receipt the Brain and Darcey alerts and incorporate them to the GALA system, the prefecture have to receipt them by mail or by fax.
Consequently, a private provider will have to ensure the retransmission of the SMS warning message, sent by hydrometric stations, to the Côte d'Or prefecture which has to receipt them by mail or fax.

5. Functioning of the flood warning system

To conclude, the device elaborated thanks to the combination of the all-previous elements will consist in a flood warning system. These alerts will be retransmitted to the communes concerned by the Côte d'Or prefecture through its automatic calling system, under the form of a pre-recorded message. For this, it will have to be included to the RIC and the SDPC.
When the communes will receive the warning message, elected officials will have to inform their citizens, by their own ways. The complete warning chain is presented in Figure 11.

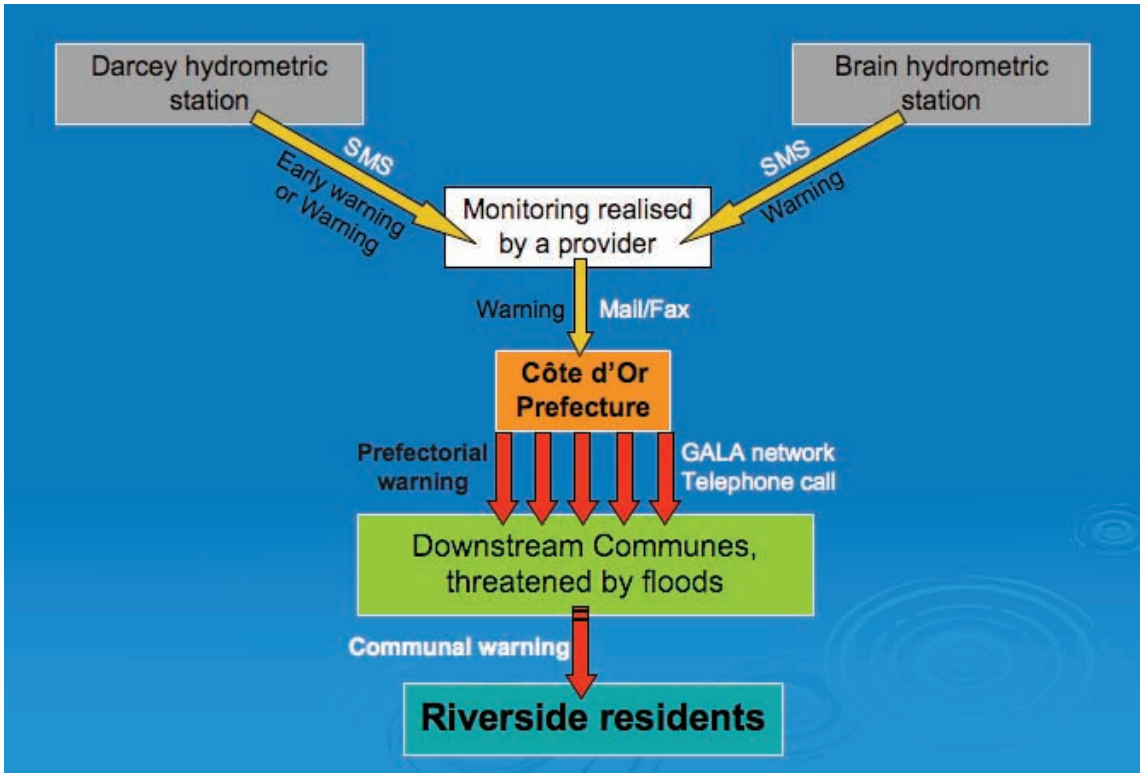

Figure 11. Diagram of the warning chain

Different warning scenarios could be encountered, according to the hydrometric context. In case of exceeding of the upstream warning thresholds, the communes will receive a pre-recorded alert message from the prefecture, corresponding to the situation. The following diagram presents the different scenarios.

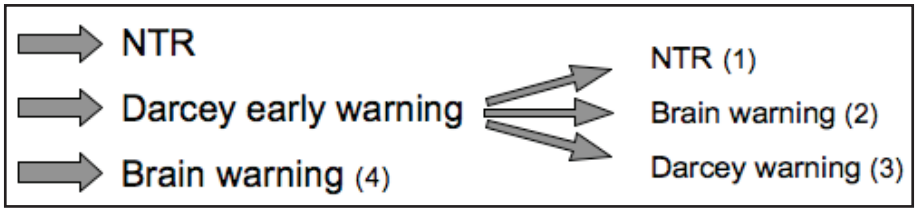

Figure 12. Diagram of the different warning scenarios

(1) The 27 $m^3.s^{-1}$ threshold is exceeded first at Darcey. Communes receive the following pre-recorded message: “Darcey, the early warning threshold of 27 $m^3.s^{-1}$ is exceeded”. Then, none other threshold is exceeded (NTR - Nothing To Report). The warning chain is stopped at this moment.

(2) The 27 $m^3.s^{-1}$ threshold is exceeded first at Darcey. Communes receive the following pre-recorded message: “Darcey, the early warning threshold of 27$m^3.s^{-1}$ is exceeded”. Then, the 28 $m^3.s^{-1}$ threshold is exceeded at Brain. Communes receive the following pre-recorded message: “Brain, the warning threshold of 28 $m^3.s^{-1}$ is exceeded”. The warning chain is stopped at this moment.

(3) The 27 $m^3.s^{-1}$ threshold is exceeded first at Darcey. Communes receive the following pre-recorded message: “Darcey, the early warning threshold of 27 $m^3.s^{-1}$ is exceeded”. Then, the 37 $m^3.s^{-1}$ threshold is exceeded at Darcey. Communes receive the following pre-recorded message: “ Darcey, the warning threshold of 37 $m^3.s^{-1}$ is exceeded”. The warning chain is stopped at this moment.

(4) The 28 $m^3.s^{-1}$ threshold is exceeded first at Brain. Communes receive the following pre-recorded message: “Brain, the warning threshold of 28 $m^3.s^{-1}$ is exceeded”. The warning chain is stopped at this moment.

In order to finalize the warning system setting up, different points have to be realized:

• An agreement will have to be passed with the DREAL Bourgogne to use and equip their stations with an automatically remote transmission system, using the GSM network.

• A private provider will have to be found. Its mission will consist in receipt SMS warning messages from the hydrometric stations and retransmit them by fax or by mail to the prefecture.

• A campaign will have to be realized, in the downstream Brenne, by the Prefecture services in order to collect all the elected officials’ numbers and implement a special campaign for this warning system.

• The warning chain and the information modalities will have to be formalized in the RIC and SDPC.

• Elected officials of the communes concerned will have to be accurately informed about the warning system and its functioning, in order that they know the different scenarios, the limits of this warning system and how to well react during a flood event.

Thereafter, the Brenne warning system will have to be continuously updated.
Indeed, the list of the elected officials who will be alerted in case of flood risk will have to be regularly updated.
Moreover, flood feedbacks will permit the system to become more reliable and show what points could be improved.
I think that one point could really make this system more efficient : residents of this region should access for free at a website where they could see the evolution of the upstream discharges in real time.
Nowadays, the continuous transmission of data from hydrometric stations seems to be difficult to organize; however, it seems that one will try to achieve this quality of information in the forthcoming years.

Personal conclusion

In the framework of my Hydrohazards master, the internship realized within the SIRTAVA allowed me to apply my knowledge learned during my studies.
Through this training, I discovered the latest practical applications elaborated by the French government in order to fight against floods, such as the PAPI programs, the SPC... and the volition to manage flood at a global scale, for example with the European Flood Directive.
Furthermore, I discovered the professional world and the community functioning. These 5 months were very rewarding.

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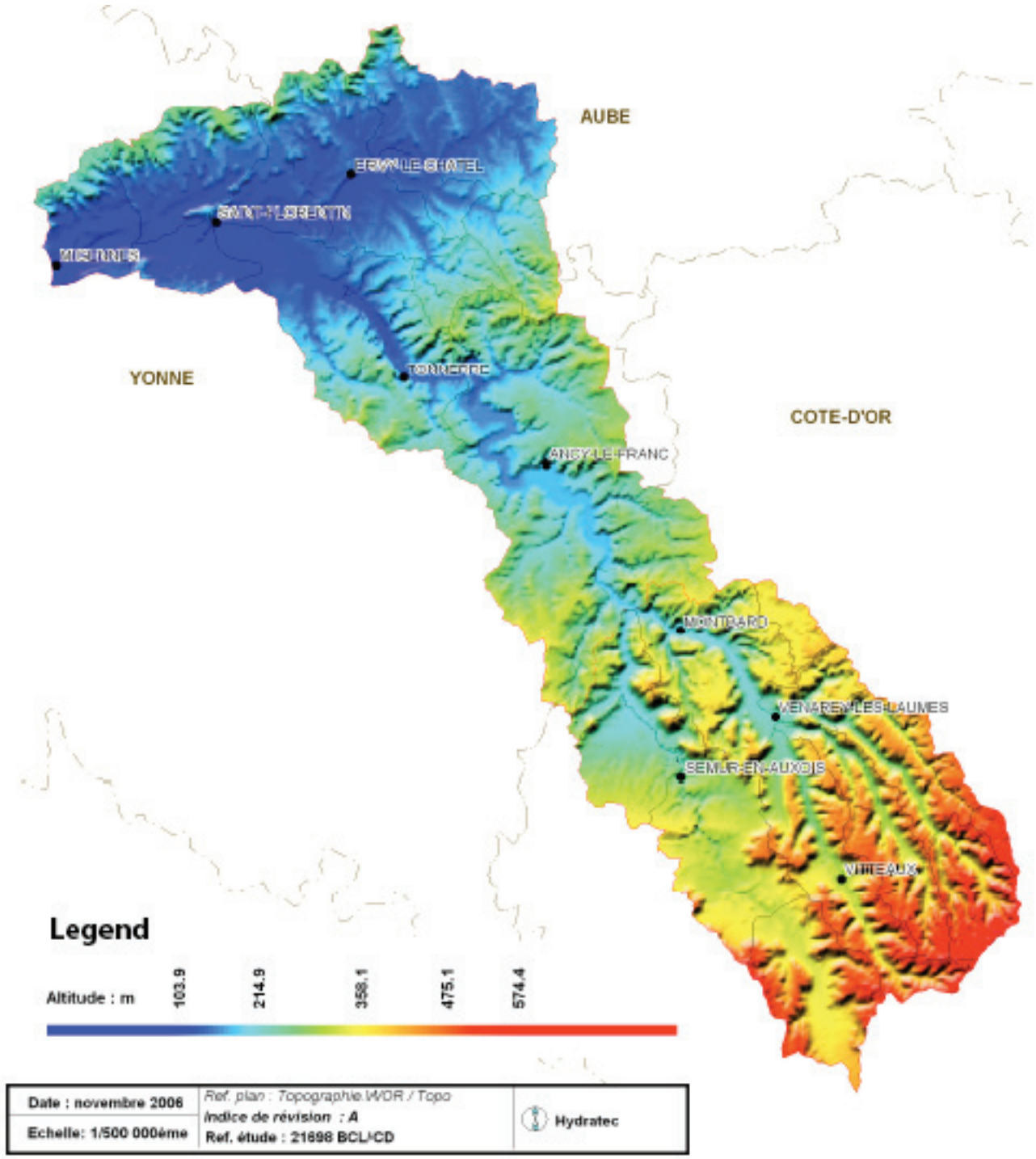
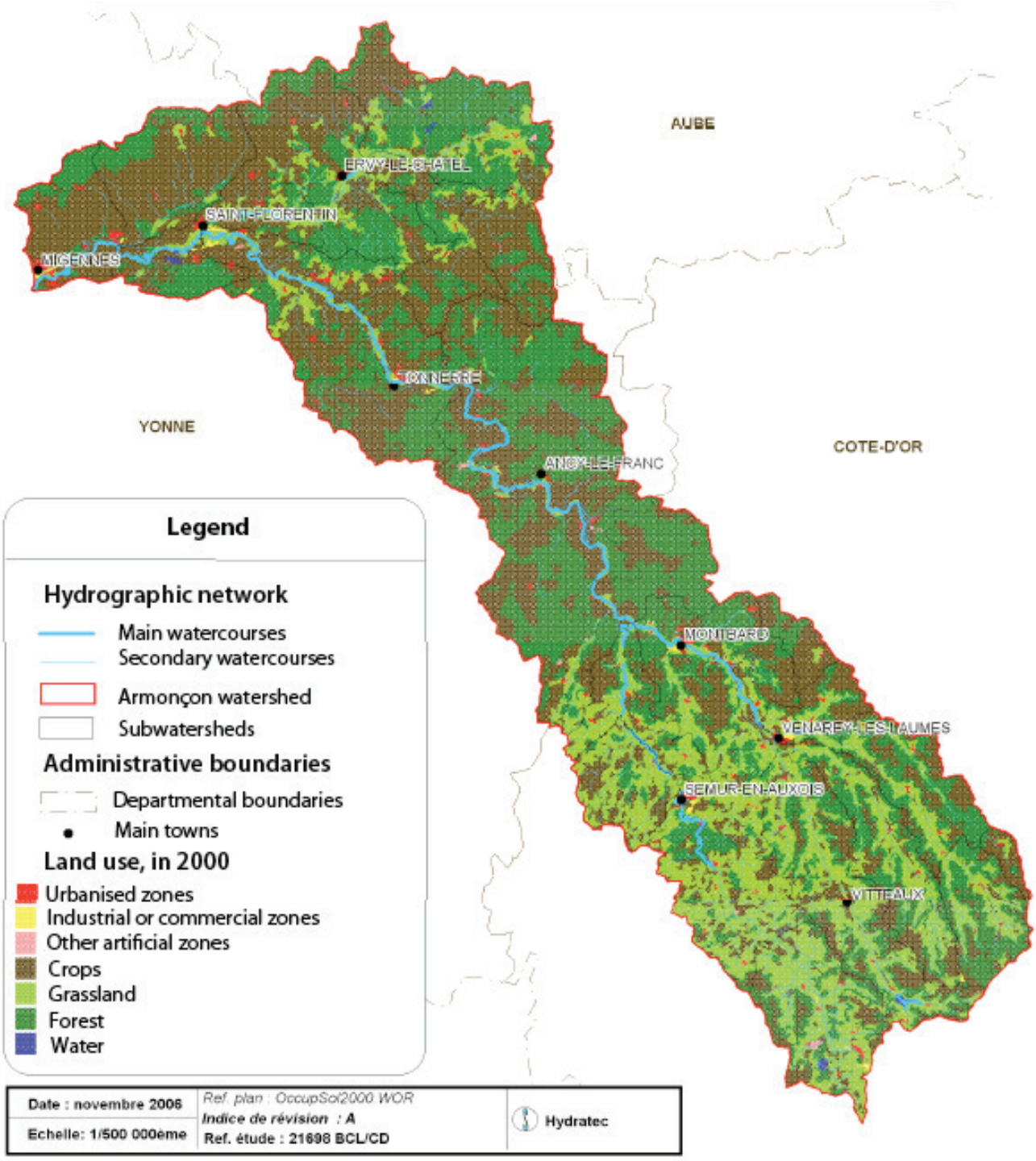
Appendices

• Appendix 1. Topography of the Armançon watershed (Hydratec, 2007)



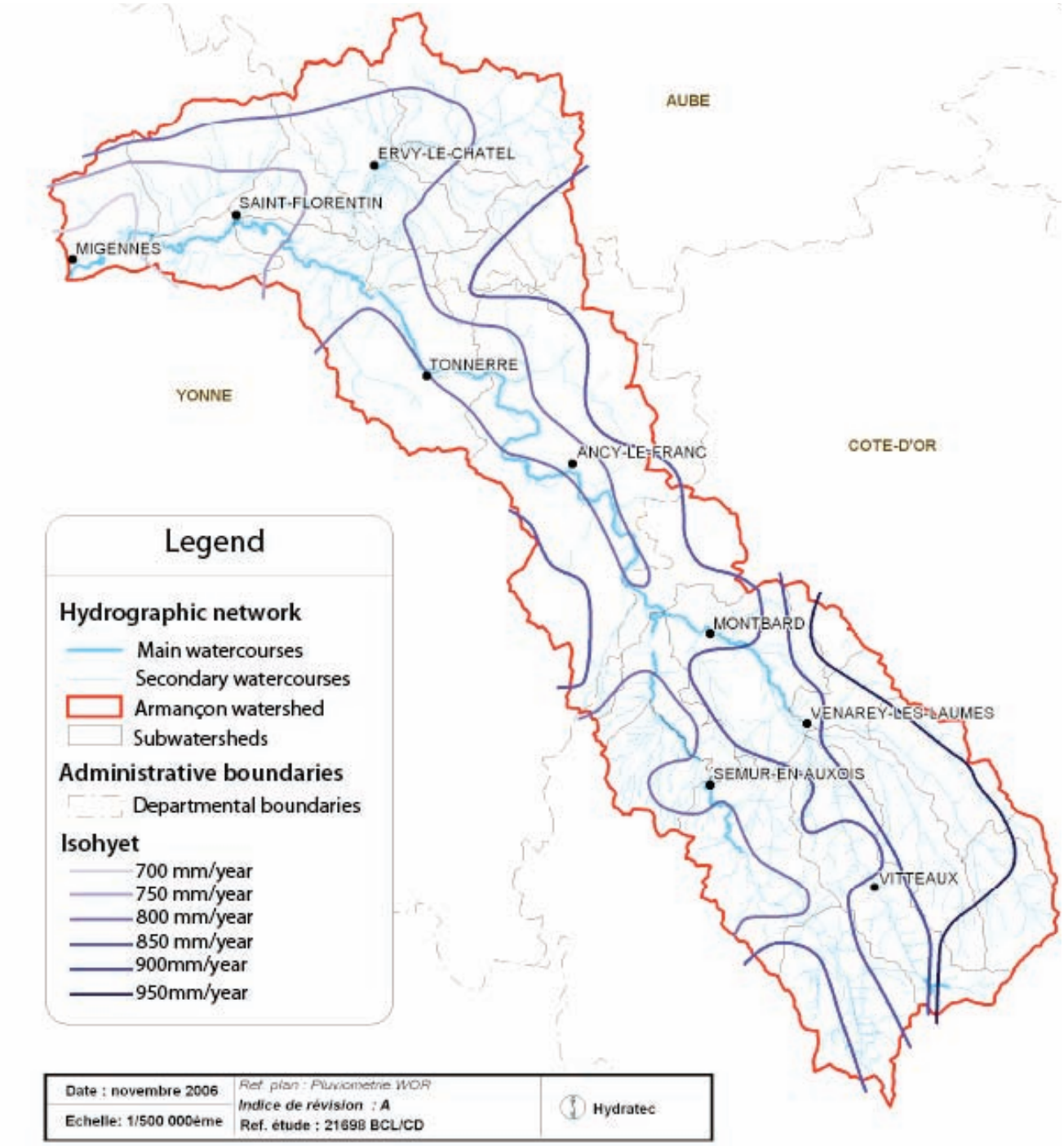
• Appendix 2. Soil occupation (Hydratec, 2007)



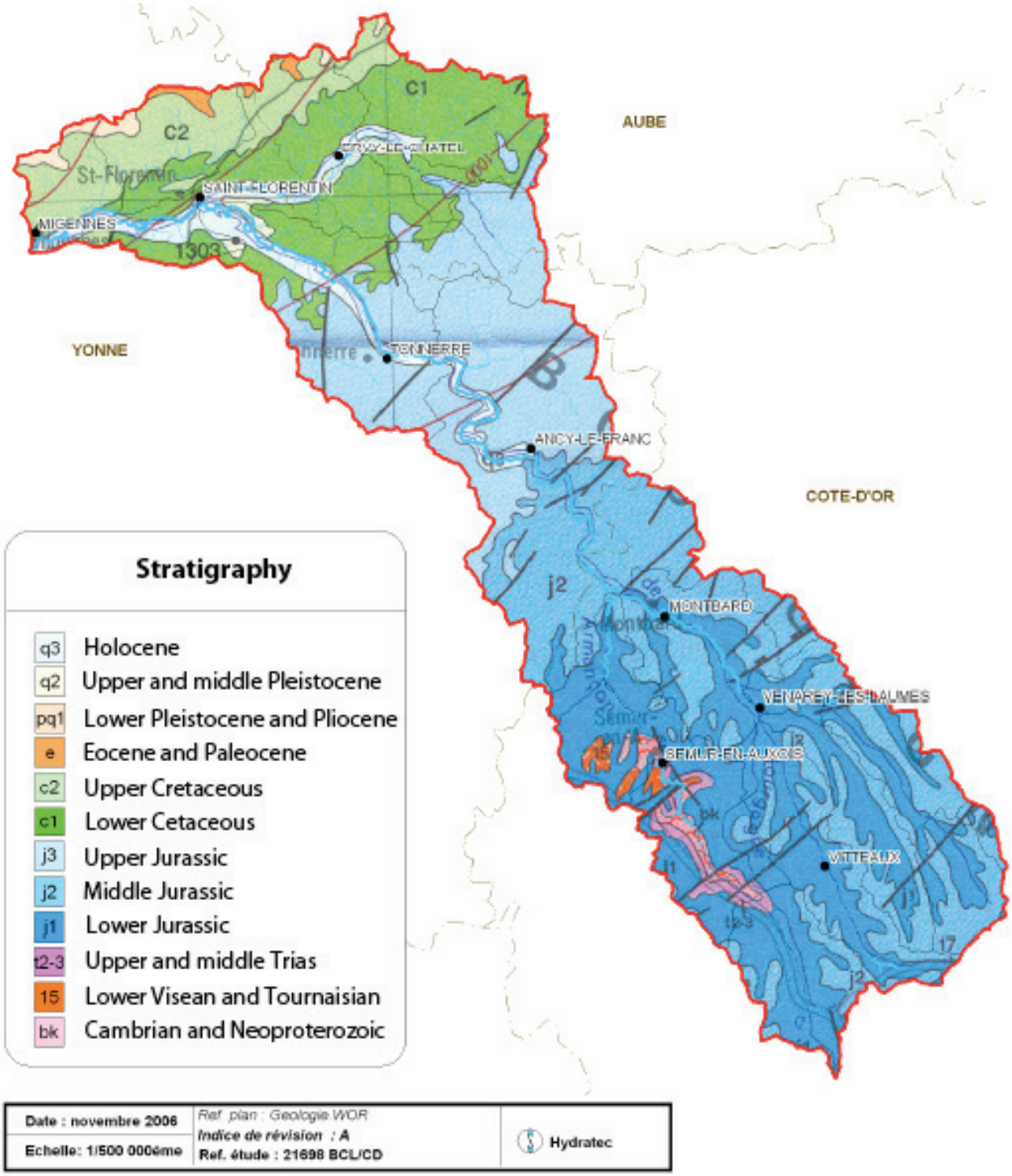
• Appendix 3. Order of natural disaster, of downstream Brenne communes

Communes	Order of natural disasters - Floods (Arrêtés CAT NAT)							
	Start date	Finish date	Start date	Finish date	Start date	Finish date	Start date	Finish date
Pouillenay	16/06/1986	17/06/1986	25/04/1998	28/04/1998				
Mussy la Fosse	16/06/1986	17/06/1986						
Venarey-les-Laumes	14/03/2001	16/03/2001	25/04/1998	28/04/1998				
Grignon								
Seigny	17/05/1985	19/05/1985	13/03/2001	15/03/2001				
Benoisey								
Courcelles-lès-Montbard								
Fain-lès-Montbard	17/05/1985	19/05/1985						
Nogent-lès-Montbard								
Marmagne	08/05/1988	11/05/1988	25/04/1998	28/04/1998	07/05/2001	07/05/2001		
Montbard	25/04/1998	28/04/1998	14/03/2001	16/03/2001	07/05/2001	07/05/2001	03/07/08	03/07/08
Saint Rémy	14/03/2001	15/03/2001	25/04/1998	28/04/1998				
Buffon	14/03/2001	16/03/2001	25/04/1998	28/04/1998				
Rougemont								
Aisy-sur-Armançon	25/04/1998	29/04/1998	14/03/2001	15/03/2001	05/07/2001	05/07/2001		

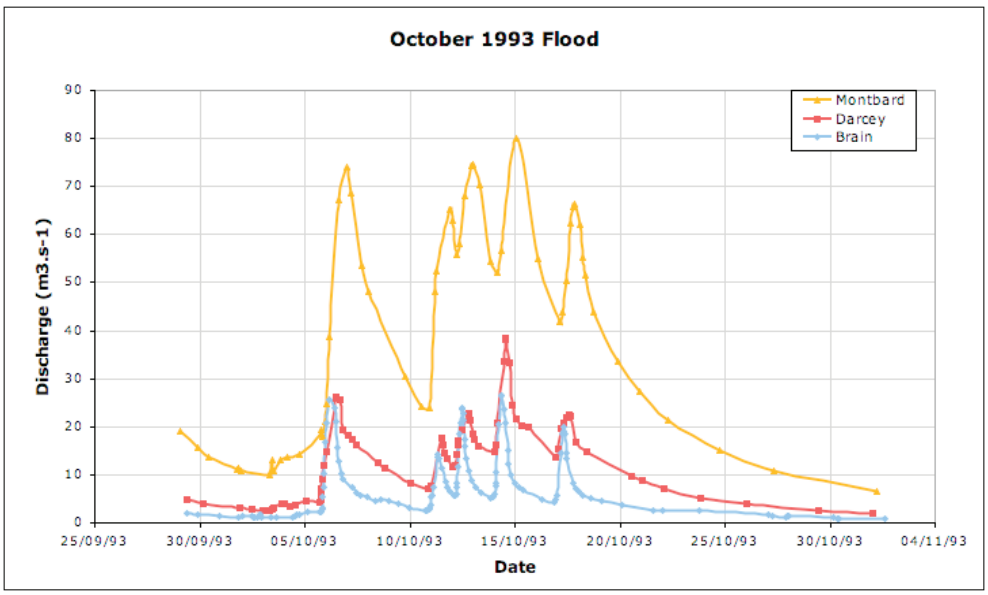
• Appendix 4. Armançon annual rainfall (Hydratec, 2007)

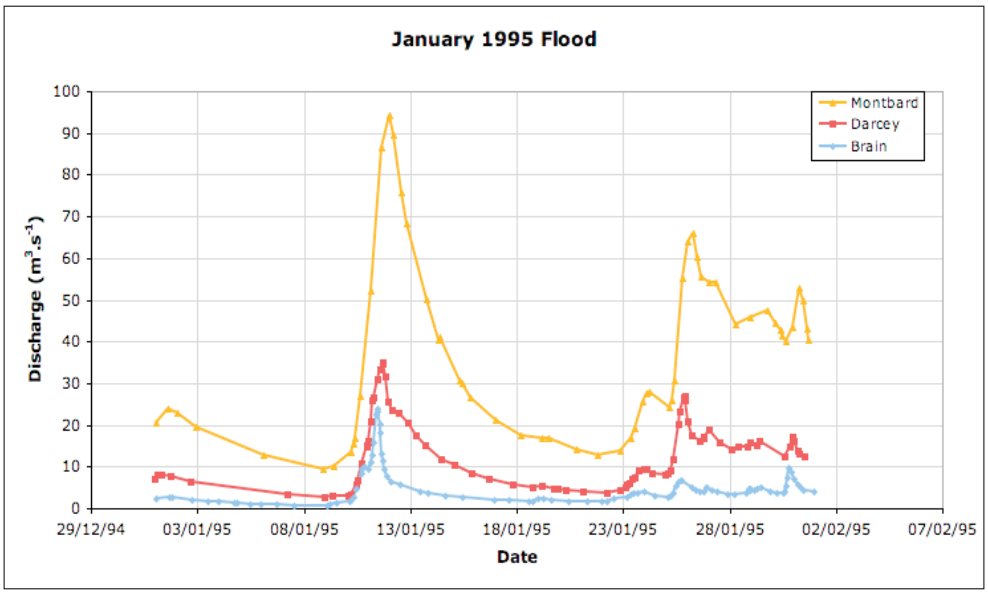


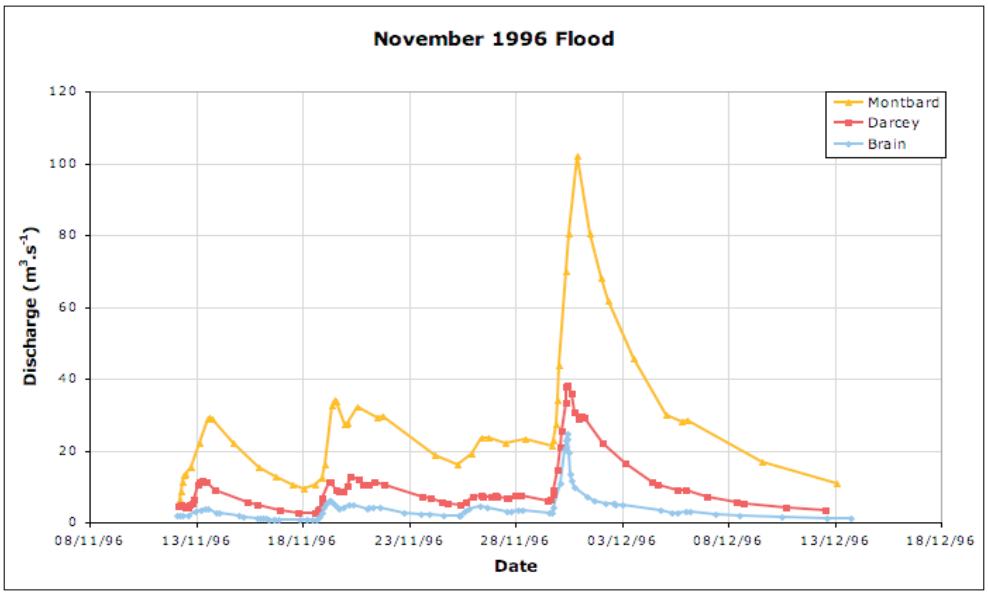
• Appendix 5. Armançon geology (Hydratec, 2007)

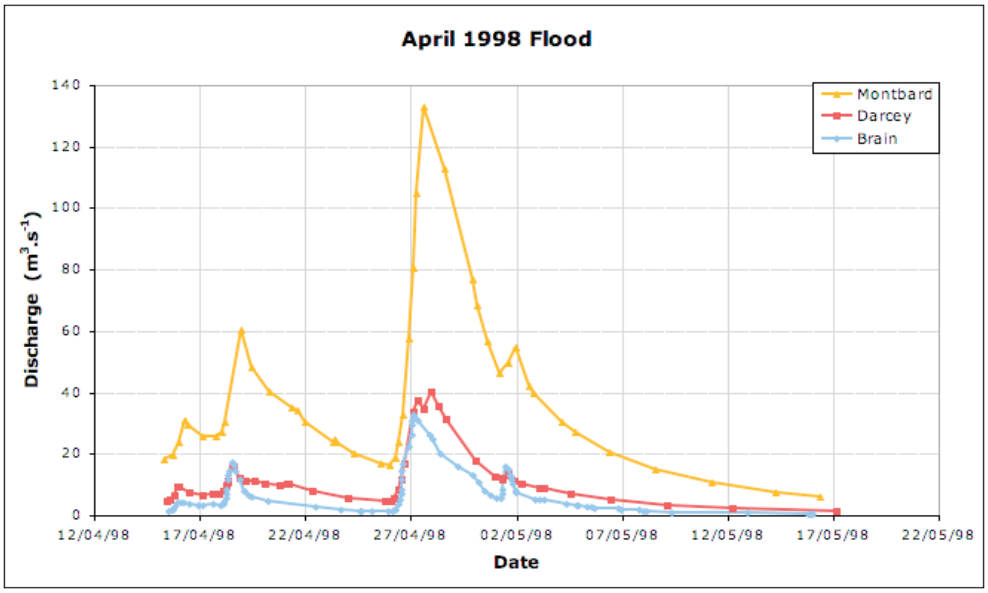


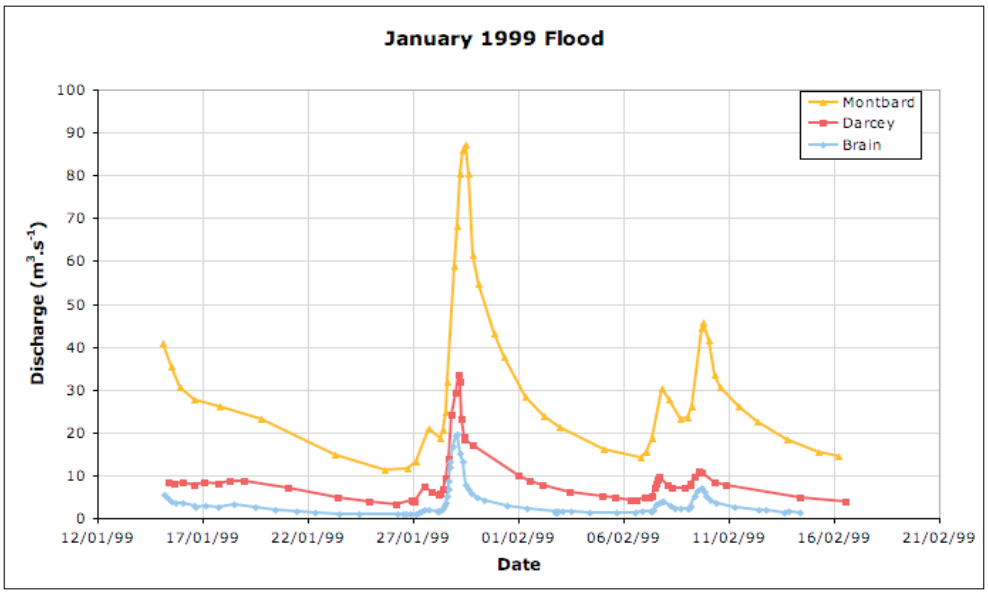
• Appendix 6: Selected flood hydrographs

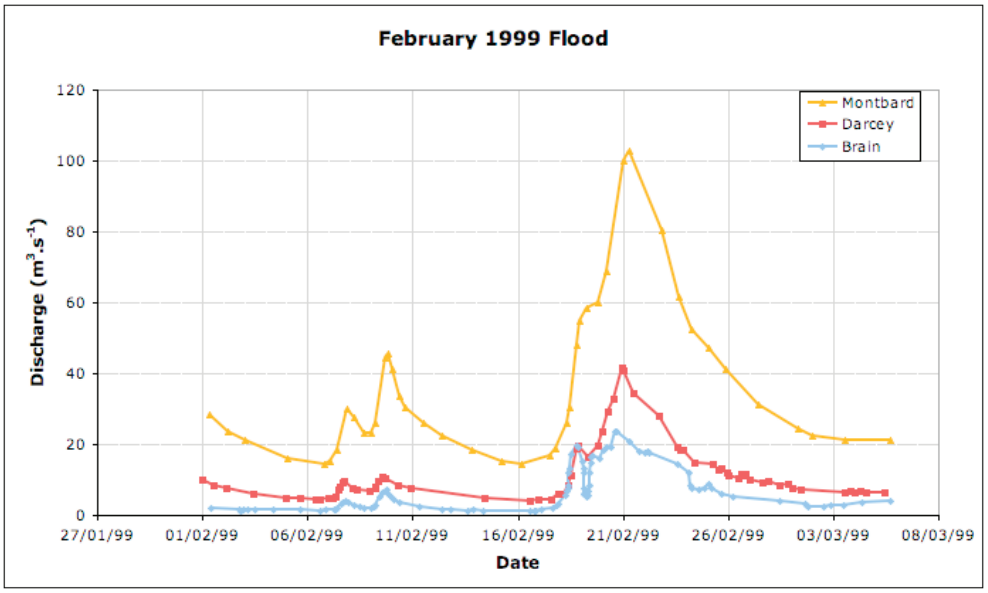


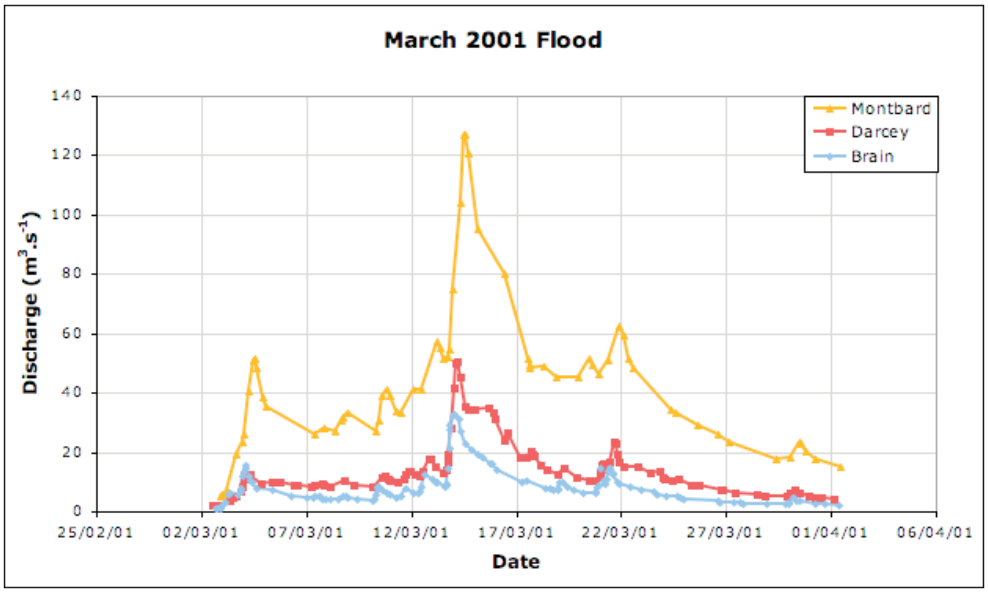


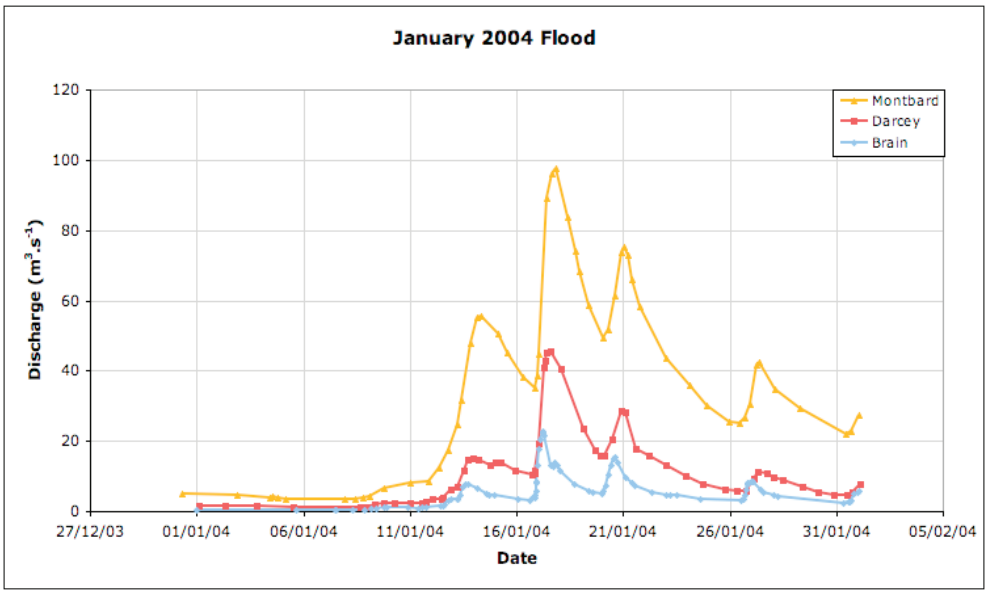


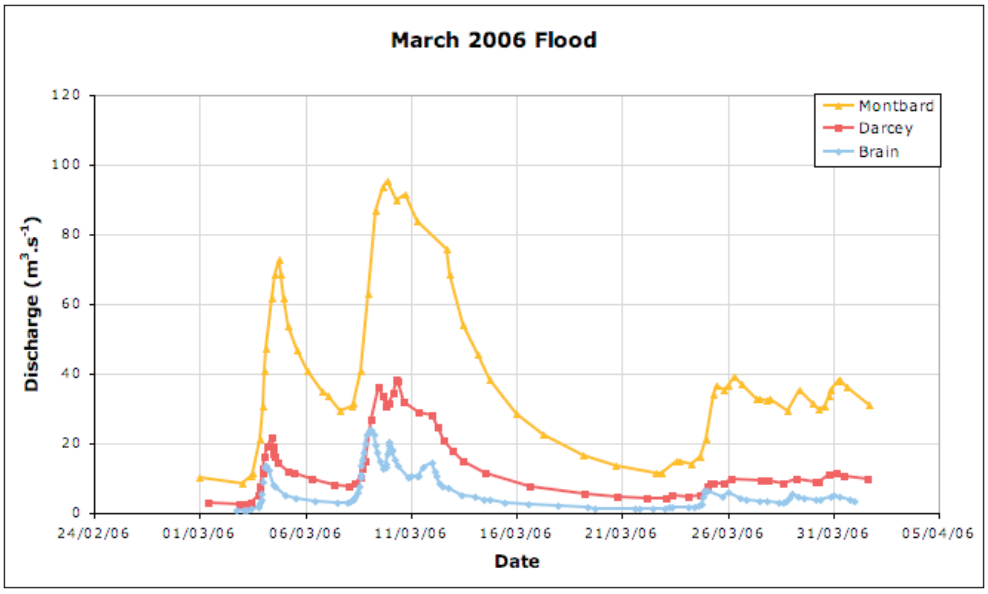


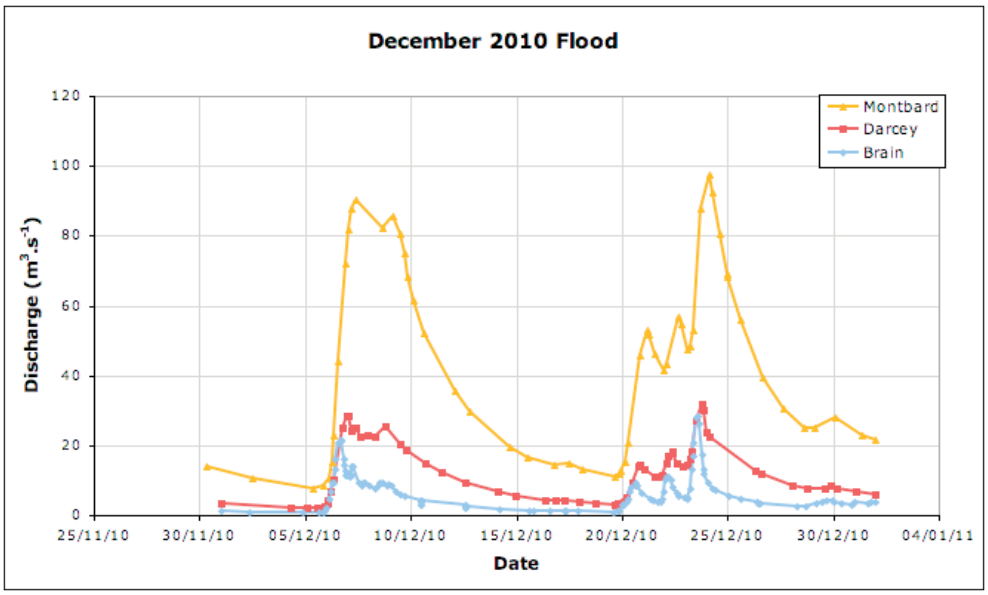












• Appendix 7. Meetings with communes

Date entretien(s): 29/09/11

Commune:	Aisy-sur-Armancon
Interlocuteur(s):	
(Nom, Fonction)	Mr Burgraf, Maire Mr ?, Cantonnier

Zone inondable:	
Habitat	~ 70 maisons
Activités	1 boulangerie; 1 marchand de vin; 2 exploitations agricoles
Equipements	Cimetière et église
Structures sensibles, décisionnelles,..	
Infrastrucures de transports	D956 (route qui longe l'armançon); Rue Marthe Saillard
Réseaux	1 poste EDF

Questionnaire d'enquête auprès des communes menacées par les inondations sur le bassin de la brenne

1- Votre commune est elle couverte par un PPRi (Plan de Prévention du Risque inondation)?
Oui

2- Votre commune s'est elle dotée d'un PCS (Plan Communal de Sauvegarde)?
Oui

3- Conséquences des dernières inondations?
1998: des personnes ont été évacuées de chez elles par les pompiers

2001: (moins important que en 1998) Des caves inondées et des rez-de-chaussées.
2010: limite avant des débordements dommageables (5cm avant que les caves soient inondées)

Où s'effectuent les premiers débordements problématiques?

D956 et rue de l'église

4- Organisation en période de crue?
Avant 2006, la station hydrométrique de Aisy était jugée peu fiable donc ils surveillaient eux même le niveau d'eau. (Voir problème de fonctionnement, document Mme Goux). Depuis 2006, la station hydrométrique est gérée par la Dreal + le cantonnier relève tous les matins la hauteur d'eau (et l'envoie à la DREAL). Lorsque la hauteur d'eau >90cm ou augmente de plus de 20cm entre 2 relevés, la fréquence de mesure passe à 3 fois/jour. Quand il y a un risque d'inondation, la prefecture les appel (système GALA): message pré-enregistré à destination du Maire. S'il ne répond pas, l'appel est reconduit vers les adjoints puis la secrétaire de la Mairie (ils ont déjà raté des appels, le Maire n'a pas de portable). En général, quand la préfecture les prévient, ils sont déjà au courant que la situation est anormale. Les habitants ont l'habitude de surveiller le niveau d'eau et ceux qui ont internet consulte le site de vigicrue et transmettent l'information aux autres. Le Maire a des repères visuels empiriques de seuil d'alerte. Quand le niveau d'eau les atteint, il passe dans les maisons qui sont les premières inondées et prévient les pompiers de Cry pour qu'ils viennent aider les personnes les plus vuln
Personnes d'astreintes? Pas réellement de personne d'astreinte

Surveillance du niveau d'eau? Par le cantonnier ts les matins et par le Maire en période inhabituelle (voir feuille relevé des hauteurs d'eau crue 1998)

Echelle limnimétrique? Oui (2). Une sur le pont de la D956 et une à l'aval.

Connaissance/liste des personnes ou entreprises en zone inondable?
Liste. En cas de crise, le Maire fait du porte à porte pour prévenir les gens.
Elevage en lit majeur? Oui, le Maire les prévient.

5- Qu'est ce qu'ils attendent d'un système d'alerte?
Etre prévenu plus tôt + inquiétude par rapport au barrage de Pont-et-Massène
Téléalerte? Oui, pourquoi pas

Système d'appel en masse? Non, petit village (pas beaucoup de personne à prévenir)

6- Repère de crue?
1850 près de la gare (noté dans le PPRi)
1998 rue de l'église (noté dans le PPRi). Mr le Maire aimerait mettre un repère.

Date entretien 1/12/11

Commune:	Buffon
Interlocuteur(s): (Nom, Prénom, Fonction)	Mr Berthiot, Maire

Zone inondable:	
Habitat	2
Activités Equipements Structures sensibles, décisionnelles,..	1
Infrastrucures de transports Réseaux	rue du pont

Questionnaire d'enquête auprès des communes menacées par les inondations sur le bassin de la brenne

1- Votre commune est elle couverte par un PPRi (Plan de Prévention du Risque inondation)?
Non

2- Votre commune s'est elle dotée d'un PCS (Plan Communal de Sauvegarde)?
Non

3- Conséquences des dernières inondations?
1998: arrêté CAT NAT; le 27 avril 1m52 d'eau au lavoir, 1m50 à la Grande Forge. Des personnes ont été héllitreuillées (Petite Forge)+ voiture submergée
2001: arrêté CAT NAT; dégradation des routes et de la Grande Forge. 1m10 d'eau à la grande forge et 1m32 au lavoir.
2010: Rien à signaler

Où s'effectuent les premiers débordements problématiques?

Les premiers débordements se font au niveau de la petite forge et du lavoir. Puis rue du pont.

4- Organisation en période de crue?
Pas d'organisation particulière. Ils ne préviennent pas spécialement la petite ou la grande forge (prévenus par d'autres personnes?)
Personnes d'astreintes?
Non juste le système GALA
Surveillance du niveau d'eau?
Non
Echelle limnimétrique?
Non
Connaissance/liste des personnes ou entreprises en zone inondable?
Ils savent que la petite forge et la grande forge sont en zone inondable.
Elevage en lit majeur?
2 exploitants

5- Qu'est ce qu'ils attendent d'un système d'alerte?

Téléalerte? Oui
Système d'appel en masse? Non

6- Repère de crue?
Oui au lavoir et à la grande forge

Date entretien	3/11/11
Commune:	Fain-lès-Montbard
Interlocuteur(s): (Nom, Prénom, Fonction)	Mr Pernet, Maire

Zone inondable:	
Habitat	0
Activités	
Equipements	
Structures sensibles, décisionnelles,..	
Infrastrucures de transports	D119
Réseaux	

Questionnaire d'enquête auprès des communes menacées par les inondations sur le bassin de la brenne

1- Votre commune est elle couverte par un PPRi (Plan de Prévention du Risque inondation)?
Non

2- Votre commune s'est elle dotée d'un PCS (Plan Communal de Sauvegarde)?
Non

3- Conséquences des dernières inondations?
1998: Rien à signaler
2001: Rien à signaler
2010: Rien à signaler

Où s'effectuent les premiers débordements problématiques?

Sur la D119 'seul endroit de la commune qui est concerné par le risque inondation

4- Organisation en période de crue?

Personnes d'astreintes?
Non juste le système GALA
Surveillance du niveau d'eau?
Non
Echelle limnimétrique?
Non
Connaissance/liste des personnes ou entreprises en zone inondable?
Pas d'habitation en zone inondable
Elevage en lit majeur?
Non

5- Qu'est ce qu'ils attendent d'un système d'alerte?

Téléalerte? Non
Système d'appel en masse? Non

6- Repère de crue?
Non

Date entretien 2/11/11

Commune:	Grignon
Interlocuteur(s): (Nom, Prénom, Fonction)	Mr Hanson, Maire Mr Mignard, délégué

Zone inondable:	
Habitat	0
Activités	3 éleveurs (Mr Mignard en fait parti)
Equipements	
Structures sensibles, décisionnelles,..	
Infrastrucures de transports	D119
Réseaux	

Questionnaire d'enquête auprès des communes menacées par les inondations sur le bassin de la brenne

1- Votre commune est elle couverte par un PPRi (Plan de Prévention du Risque inondation)?
Non

2- Votre commune s'est elle dotée d'un PCS (Plan Communal de Sauvegarde)?
Non

3- Conséquences des dernières inondations?
1998:

2001: Ils ont dû évacuer les vaches des prés
2010: route coupée

Où s'effectuent les premiers débordements problématiques?

Au niveau de la D119, elle est inondée tous les ans. Si les crues sont plus importante, ca remonte jusqu'à la station de pompage.

4- Organisation en période de crue?

Personnes d'astreintes?
Le Maire et ses adjoints (ils ont donné leur numéro de téléphone à la préfécture)
Surveillance du niveau d'eau?
Les éleveurs surveillent eux même la monté des eaux.
Echelle limnimétrique?
Non
Connaissance/liste des personnes ou entreprises en zone inondable?
connaissance des éleveurs concernés par les inondations
Elevage en lit majeur?
Oui

5- Qu'est ce qu'ils attendent d'un système d'alerte?
Pouvoir prévenir les éleveurs
Téléalerte? Oui
Système d'appel en masse? Non

6- Repère de crue?
Non

Date entretien 8/11/11

Commune:	Marmagne
Interlocuteur(s): (Nom, Prénom, Fonction)	Mr Drappier, Maire Mr Dumont, Délégué

Zone inondable:	
Habitat	
Activités	
Equipements	
Structures sensibles, décisionnelles,..	
Infrastrucures de transports	
Réseaux	

Questionnaire d'enquête auprès des communes menacées par les inondations sur le bassin de la brenne

1- Votre commune est elle couverte par un PPRi (Plan de Prévention du Risque inondation)?
Oui pour le ru de tuyon

2- Votre commune s'est elle dotée d'un PCS (Plan Communal de Sauvegarde)?
Non

3- Conséquences des dernières inondations?
1998: arrêté CAT NAT, inondation causée par le ru de tuyon
2001: arrêté CAT NAT (en Mai) inondation caussée par le ru de tuyon
2010: Rien à signaler

Où s'effectuent les premiers débordements problématiques?

Les inondations ne sont causées que par le rue de Tuyon

4- Organisation en période de crue?

Personnes d'astreintes?
Non juste le système GALA
Surveillance du niveau d'eau?
Non
Echelle limnimétrique?
Non
Connaissance/liste des personnes ou entreprises en zone inondable?
Pas d'habitation en zone inondable
Elevage en lit majeur?
Il y a des exploitants qui ne sont pas de la commune

5- Qu'est ce qu'ils attendent d'un système d'alerte?

Téléalerte? Non
Système d'appel en masse? Non

6- Repère de crue?
Non

Date entretien 12/10/11

Commune:	Montbard
Interlocuteur(s): (Nom, Prénom, Fonction)	Mr Petit, Directeur des Services Techniques

Zone inondable:	
Habitat	130 logements
Activités	66 établissements
Equipements	administration; complexe sportif; bibliothèque; MJC; cinéma
Structures sensibles, décisionnelles,..	Hôpital; 2 écoles maternnelles; 2 écoles primaires; 1 lycée technique; centre de secours; gendarmerie
Infrastrucures de transports	voie d'accès à la ZI Saint-Roch (rue du docteur Bruhnes); rues du centre ville; RD980
Réseaux	poste EDF relais de Montbard; 6 postes EDF; la STEP; captages AEP

Questionnaire d'enquête auprès des communes menacées par les inondations sur le bassin de la brenne

1- Votre commune est elle couverte par un PPRi (Plan de Prévention du Risque inondation)?
Oui

2- Votre commune s'est elle dotée d'un PCS (Plan Communal de Sauvegarde)?
Pas encore

3- Conséquences des dernières inondations? Mr Petit travaille à Montbard depuis 10ans

1998: Mr Petit n'a pas connu les inondations de 1998. Hélitreuillage (maison isolée) vers la prairie (n°1 sur la carte de Montbard). Hauteur d'eau notée = 2m80 (échelle limnimétrique).
2001: Mr Petit n'a pas connu les inondations de 2001. Hauteur d'eau noté = 3m10 (échelle limnimétrique).

2010: Hauteur d'eau pas sinificative (côte 1,79m sur l'échelle limnimétrique) lors du premier pic de crue. Mr Petit n'était pas présent lors du 2ème pic de crue (entre le 23 et le 24 Décembre). Information à compléter pour le 2ème pic de crue.

Où s'effectuent les premiers débordements problématiques?

Les premiers débordements s'effectuent au niveau de la rue du Docteur Brunhes (n°2 sur la carte), les premières habitations (1 menuisiers + 1 magasin électro-ménagé) sont rue Auguste Carré. Puis les inondations arrivent au niveau du quartier des Castors.

4- Organisation en période de crue?
Comme Mr Petit n'est là que depuis 10ans, il n'a pas vécu d'inondation. Il ne sait donc pas précisement comment se déroule les évènements. Il sait les routes à couper et les gens à prévenir. Mais il compte aussi beaucoup sur le bon sens des gens. Vu que la monté des eaux est en général lente, il pense qu'ils ont le temps de s'organiser. Par contre, il ne sait pas comment l'hopital gère cette situation et ils n'ont pas prévu d'établissement d'acceuil.
Personnes d'astreintes? Mr Petit est d'astreinte en permanence

Surveillance du niveau d'eau? A partir du moment où la hauteur d'eau devient significative, il vérifie régulièrement la hauteur et les note dans un carnet (depuis 1968, voir photocopie).

Echelle limnimétrique? Oui, au niveau du pont Anatole Hugot.

Connaissance/liste des personnes ou entreprises en zone inondable?
Ils n'ont pas de liste des personnes habitant en zone inondable mais ils connaissent les gens à prévenir.
Elevage en lit majeur? Mr Petit connaît les éleveurs, mais ne sait pas s'ils sont prévenus en cas d'inondation.

5- Qu'est ce qu'ils attendent d'un système d'alerte?

Téléalerte? Oui
Système d'appel en masse?

6- Repère de crue?
Oui au niveau de l'Hotel de l'Ecu

Date entretien 2/11/11

Commune:	Nogent-lès-Montbard
Interlocuteur(s): (Nom, Prénom, Fonction)	Mr Lhomme, Maire

Zone inondable:	
Habitat	2 pavillons juste à la limte du canal
Activités	1 éleveur, mais il y a aussi d'autres éleveurs qui ne sont pas de la commune
Equipements Structures sensibles, décisionnelles,..	
Infrastrucures de transports	D119
Réseaux	Zone de captage (au niveau du moulin)

Questionnaire d'enquête auprès des communes menacées par les inondations sur le bassin de la brenne

1- Votre commune est elle couverte par un PPRi (Plan de Prévention du Risque inondation)?
Non

2- Votre commune s'est elle dotée d'un PCS (Plan Communal de Sauvegarde)?
Non

3- Conséquences des dernières inondations?

1998:

2001: Tête de puit touché, restriction d'eau à la suite des inondations

2010: Un peu d'eau au ras des maisons. Des personnes se sont retrouvés bloqués sur la route D119 (ils n'avaient pas regardé les panneaux qui disaient de ne pas y aller).

Où s'effectuent les premiers débordements problématiques?

Au niveau du pont sur la D119

4- Organisation en période de crue?

Personnes d'astreintes?
Non (mais la préfécture à le numéro du Maire et de ses adjoints)
Surveillance du niveau d'eau?
Non
Echelle limnimétrique?
Non
Connaissance/liste des personnes ou entreprises en zone inondable?
Le Maire connaît les 2 habitations en zone inondable ainsi que l'éleveur.
Elevage en lit majeur?
Oui

5- Qu'est ce qu'ils attendent d'un système d'alerte?

Téléalerte? Oui
Système d'appel en masse? Non

6- Repère de crue?
Non

Date entretien 4/11/11

Commune:	Pouillenay
Interlocuteur(s): (Nom, Prénom, Fonction)	Mr Audry, délégué Mr Rigaud, Maire

Zone inondable:	
Habitat	4 habitations peuvent être inondées pour les crues fréquentes (mais les caves).
Activités	
Equipements	
Structures sensibles, décisionnelles,..	
Infrastrucures de transports	D9
Réseaux	

Questionnaire d'enquête auprès des communes menacées par les inondations sur le bassin de la brenne

1- Votre commune est elle couverte par un PPRi (Plan de Prévention du Risque inondation)?
Non

2- Votre commune s'est elle dotée d'un PCS (Plan Communal de Sauvegarde)?
Non

3- Conséquences des dernières inondations?

1986: Arrêté CAT NAT à Les Prés Hauts + eau sur la place de la Mairie
1998: Arrêté CAT NAT pour la ferme Blie (chemin raviné par les fortes pluis)
2010: Pas de conséquences

Où s'effectuent les premiers débordements problématiques?

Au niveau du pont au dessus de la Brenne

4- Organisation en période de crue?

Personnes d'astreintes?
Le Maire et ses adjoints ont donné leur numéro à la Prefecture
Surveillance du niveau d'eau?
Non
Echelle limnimétrique?
Non
Connaissance/liste des personnes ou entreprises en zone inondable?
Non
Elevage en lit majeur?
Oui

5- Qu'est ce qu'ils attendent d'un système d'alerte?

Téléalerte? Oui
Système d'appel en masse? Non

6- Repère de crue?
Oui, 2 dans la caserne des pompiers

Date entretien 26/10/11

Commune:	Seigny
Interlocuteur(s): (Nom, Prénom, Fonction)	Mr Villarmet, Maire

Zone inondable:	
Habitat	1 moulin
Activités	3 éleveurs
Equipements	
Structures sensibles, décisionnelles,..	
Infrastrucures de transports	D119c (près du moulin)
Réseaux	

Questionnaire d'enquête auprès des communes menacées par les inondations sur le bassin de la brenne

1- Votre commune est elle couverte par un PPRi (Plan de Prévention du Risque inondation)?
Non

2- Votre commune s'est elle dotée d'un PCS (Plan Communal de Sauvegarde)?
Non

3- Conséquences des dernières inondations?
1998:
2001: inondation du moulin (arrêté CAT NAT)
2010: inondation de la D119c

Où s'effectuent les premiers débordements problématiques?

Sur la route près du moulin (D119c)

4- Organisation en période de crue?

Personnes d'astreintes?
Astreinte du Maire et de ses adjoints
Surveillance du niveau d'eau?
Non, il n'y a pas d'enjeux inondables sur la commune de Seigny
Echelle limnimétrique?
Non et ils ne pensent pas que se soient nécessaire
Connaissance/liste des personnes ou entreprises en zone inondable?
Les habitants du moulin et les éleveurs sont connus.
Elevage en lit majeur?
Oui

5- Qu'est ce qu'ils attendent d'un système d'alerte?

Ils ne sont pas intéressaient par un système d'alerte, il n'y a pas d'enjeux a Seigny
Téléalerte? Non
Système d'appel en masse? Non

6- Repère de crue?
Non

Date entretien: 30/09/11

Commune:	Saint Rémy
Interlocuteur(s): (Nom, Prénom, Fonction)	Mr Bilbot, Maire Mr Sitterlin, Délégué

Zone inondable:	
Habitat	~ 20 habitations
Activités	restaurant au niveau du rond point + exploitation agricole
Equipements Structures sensibles, décisionnelles,..	
Infrastrucures de transports	Rue de Dijon (D905)
Réseaux	

Questionnaire d'enquête auprès des communes menacées par les inondations sur le bassin de la brenne

1- Votre commune est elle couverte par un PPRi (Plan de Prévention du Risque inondation)?
Non

2- Votre commune s'est elle dotée d'un PCS (Plan Communal de Sauvegarde)?
Non

3- Conséquences des dernières inondations?
1998: Ils ont eu le temps de réagir, les gens ont pu monter ou surélever leurs meubles. Niveau max d'eau atteint = 80cm rue de dijon

2001: Pas d'eau chez les gens
2010: Eau au sommet des arches du pont (limite avant les débordements sur la route). Pas d'inondation chez les gens.

Où s'effectuent les premiers débordements problématiques?

Route de Dijon (rond point) et chez Mme Barcelos (derrière la Mairie).

4- Organisation en période de crue?

Appel de la préfècture à la Mairie (message pré enregistré). 6 personnes peuvent être contactées (Maire, adjoints, secrétaire). Pour le moment, ils n'ont jamais raté d'appels. + le cantonnier surveille le niveau d'eau quand la rivière est élevée. Quand le niveau d'eau atteint un repère visuel naturel (seuil d'alerte), ils font du porte à porte pour prévenir les gens et les aider => entre aide entre les riverains + conseillés municipaux (pas de pompiers).
Personnes d'astreintes? Pas officiellement de personnes d'astreintes

Surveillance du niveau d'eau? Le cantonnier surveille le niveau de la rivière à partir du moment où elle est élevée. Quand l'eau atteind le niveau des arches du pont, il surveille toutes les heures la hauteur d'eau.

Echelle limnimétrique? Oui sur le pont rue de Semur

Connaissance/liste des personnes ou entreprises en zone inondable?

Connaissance des gens en zone inondable, en période de crue, ils font du porte à porte.
Elevage en lit majeur? La gendarmerie prévient les éleveurs.

5- Qu'est ce qu'ils attendent d'un système d'alerte?

Téléalerte? Ils trouvent la démarche intéressante mais ne ressente pas la nécessité
Système d'appel en masse? Non, pas beaucoup de personnes concernées

6- Repère de crue?
1910 au niveau du rond point rue de Dijon

Date entretien: 30/09/2011 et 14/10/2011

Commune:	Venarey-Les-Laumes
Interlocuteur(s): (Nom, Prénom, Fonction)	Mr Rogosinski, Adjoint au Maire Renaud Dedenon, Technicien

Zone inondable:	
Habitat	190 maisons
Activités	21 entreprises
Equipements	Stade, gymnase, terrains de tennis, salle des fêtes, camping
Structures sensibles, décisionnelles,..	Mairie, Gendarmerie, Centre de secours, locaux des services techniques
Infrastrucures de transports	Avenue Jean Jaurès; rue du Pont Romain
Réseaux	Poste de détente GDF et 6 postes EDF

Questionnaire d'enquête auprès des communes menacées par les inondations sur le bassin de la brenne

1- Votre commune est elle couverte par un PPRi (Plan de Prévention du Risque inondation)?

Oui

2- Votre commune s'est elle dotée d'un PCS (Plan Communal de Sauvegarde)?

Oui

3- Conséquences des dernières inondations?

1998: Sous-sol + rez de chaussées inondés + qq interventions de pompiers pour surélever les meubles
2001: Même conséquences que en 98.
2010: Pas de dommges, sauf à la plage du Nid à la Caille. Qq caves inondées (par remontée de nappe). Crue débordante mais pas de problèmes. Bon seuil d'alerte, se joue à qq cm.

Où s'effectuent les premiers débordements problématiques?

Rue de la Paix, puis rue de l'Oze et Avenue Jean Jaurès

4- Organisation en période de crue?

Permanence des élus adjoint depuis 2001, si il y a un problème d'inondation, la personne de permanence prévient le Maire et les autres élus. Puis les services de sécurité civile quand le niveau d'eau devient critique. Ils ont des repères naturels pour surveiller la monté des eaux. Ils regardent toutes les heures le niveau (voir ttes les 1/2h). Quand le niveau d'eau atteint le parquing (au niveau du pont romain), ils alertent les riverains (en général, les gens sont au courant car ils surveillent aussi). A ce moment, ils ont 1h pour s'organiser. => mobilisation des élus et de personnes volontaires pour aider les plus vulnérables. Plus possibilité d'appeler les gens (liste).
Personnes d'astreintes? Oui, permanance des élus adjoints.

Surveillance du niveau d'eau? En période de crise, Mr Rogosinski surveille le niveau d'eau avec des repères visuels naturels.

Echelle limnimétrique? 2 échelles limnimétriques (rue du Luziau et rue Marcelin Berthelot) mais elles ne sont pas facilement accéssibles

Connaissance/liste des personnes ou entreprises en zone inondable?
Liste des personnes à prévenir (avec des zones prioritaires) + des entreprises.
Elevage en lit majeur?
Oui, mais ils ne sont pas encore pris en compte dans les personnes à prévenir

5- Qu'est ce qu'ils attendent d'un système d'alerte?

Etre alerté que le niveau devient critique même s'ils n'ont pas beaucoup de temps pour s'organiser
Téléalerte? Oui
Système d'appel en masse? Surement trop cher, ils passeraient dans les rues concernées avec un camion équipé d'un haut parleur + qq appels.

6- Repère de crue?

Voir Mr Chesneau

• Appendix 8. Flood impact census of the 2010 flood

Bassin versant	Affluent	Commune	Dpt	Objet	Détail	Date
L'Oze	La Drenne	Saint-Hélier	21	1 route inondée	Rue de l'Eglise coupée par 15 cm d'eau	le 20 de 8 h à 12 h
L'Oze		Thénissey	21	Divers	Mise en fonctionnement de résurgences au niveau du cimetière (sources folles)	
L'Oze		Turcey	21	1 route inondée	Rue de L'Oze	le 06 momentanément
L'Oze	Le Ru de la Combe de Pâques	Villote-Saint-Seine	21	1 bien inondé	1 RDC	24
L'Ozerain		Villeberny	21	1 route inondée	VC n°4 entre Tiers du Bas et Jailly-les-Moulins	
La Brenne		Benoisey	21	1 route inondée	RD 119	23
La Brenne	Le Dandarge	Champ d'Oiseau	21	1 bien inondé	1 cave par remontée de nappe	23
La Brenne		Fain-les-Montbard	21	2 biens inondés	- 1 cave par débordement - 1 cave par remontée de nappe	13
La Brenne		Grignon	21	1 route inondée	RD 119	23
La Brenne	Le ru de Quionquère	La Roche-Vanneau	21	1 route inondée	RD 119 en amont de Leugny	
La Brenne		Marmagne	21	1 bien inondé	1 local industriel par remontée de nappe	24
La Brenne		Montbard	21	1 route inondée	Carrefour rue du Docteur Brunhes / rue Saint Roch en partie 1 journée	
La Brenne		Montbard	21	Observation	- Cote max 1,79 m observée à l'échelle du pont rue A. Hugot. - Promenade de la Brenne inondée. - Terrain de rugby inondé.	
La Brenne		Montbard	21	2 biens inondés	- RDC par remontée de nappe - Cave par remontée de nappe	23
La Brenne		Nogent-les-Montbard	21	1 route inondée	RD 119	24
La Brenne		Pouillenay	21	2 biens inondés	- 1 sous-sol par débordement - 1 sous-sol par remontée de nappe	- 09/12 - 23/12
La Brenne	Ru de Sainte-Barbe	Saint-Rémy	21	1 route inondée	Rue de l'Etang en amont de la voix SNCF	
La Brenne		Venarey-les Laumes	21	2 biens inondés	- 1 cave suite à remontée de nappe - 1 sous-sol suite à remontée de nappe	- 7 - 23
La Brenne		Vitteaux	21	1 bien inondé	1 garage	23
L'Armançon		Buffon	21	3 biens inondés	3 maisons isolées par débordement	7

• Appendix 9. Rainfall map (mm) of the 1998 event