Le Havre is located at the north of France on the Seine estuary (Normandy region). *Le Havre* metropolitan area is 293.851 inhabitants for 678 km². More than 60% of inhabitants live in *Le Havre* city (178.769 inhabitants in 47 square kilometer) (INSEE, 2010). And it is the second largest Harbor in France.

In France Flood Risk Management organization is a top-down and multilevel organization[30]:

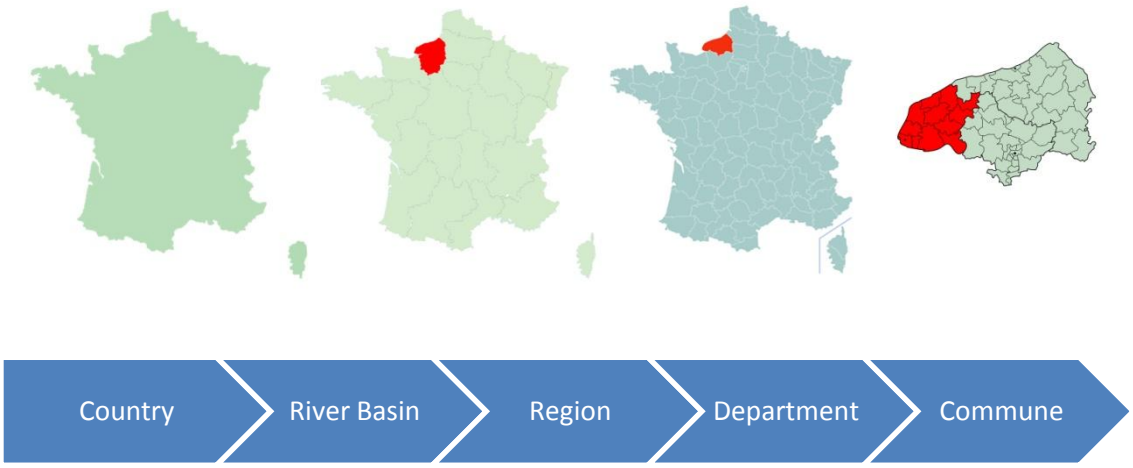


Fig. 7 Different levels of administration in France (*Source: FRM Actors,Kamal Serrini 2013)*

According to the administration level in France, Le Havre is located in the north of France, belong to the Normandy region "Haute Normandie", and taking part in "Communes de L'agglomeration Havraise" which is made up of a group of 17 communes[31].

In 1995 was created PPRi[32] *(Plan de Prévention des Risques d'Inondation)* based on the framework of PPRNP *(Plans de Prévention des Risques Naturels Prévisibles).* The state administration aim was to create a single planning document that would replace all the PSS, *Art. R111-3* perimeters and PER *(Plan d'Exposition aux Risques Naturales Prévisibles)* that existed. None of those procedures had really been successful and implemented locally. Hence, the PPRi aim is to be a simpler tool to identify flood prone areas and impose planning regulations on them (M. Amalric, S. Bernier, M. Fournier, J. Serrano, L.Verdell 2008).

The state administration is responsible and carries out the studies and mapping of the PPRi. Hence, it is a planning document (maps and rules) which constraints local planning documents). The prefect's administration (head of the

[30] See this organization in index 4.
[31] See the map on index 5.
[32] See index 6.

state administration at the departmental level) identifies the areas where a PPRi should be planned[33].
Then, the state administration through the DDE *(Direction Départementale de l'Equipement)* carries out the project. A negotiation phase is planned with the local authorities and a public inquiry before the PPRi is approved by the prefect[34] (M. Amalric, S. Bernier, M. Fournier, J. Serrano, L.Verdell 2008).

At the local level, concerns to the observation of the constraints imposed by the PPRi as well as the willing to develop the territory, there is a main instrument as the PLU *(Plan Local d'Urbanisme)*[35] which is a strategic document must follow what defined in the local PPRi that cancelled the former procedures (M. Amalric, S. Bernier, M. Fournier, J. Serrano, L.Verdell 2008).

3.1 Stakeholders of *Le Havre* in Flood Risk Mitigation.

CODAH. *(La Communautè de l'agglomération Havraise)*

CODAH is defined by 17 communes being *Le Havre* one of them. The aim is to help the population in several areas such as waste management, water management, transport, and information about major risks, hygiene and health, housing, economy, tourism, sports infrastructure. Related to the floods risk CODAH leads the development of guides about flood risk into the city addressed to the community.

SMBV *(Syndicat Mixte des Bassin Versants de la Pionte de Caux)*

It is a public entity which was created by the administrative body of Normandy region in 2000 focusing in mitigating flood risk concerning the Lezarde area. During the late 1990s as well as the 2000s, public policy for flood management has decided to renew and build several small retention basins (around 120 basins), but also to elaborate flood reduction strategies at inter-city level (inter-municipal institution) (Start-Flood 2012).

This entity is working with two more communes: *La Communauté de Communes de Saint-Romain-de-Colbosc, La Communauté de Communes de Criquetot-l'Esneva.*

TOWN HALL

The urban department in the town hall is addressing PLU *(Plan Local d'Urbanisme)* which is focused to identify flood risk areas into the city and provide it of rules such as: minimum height for ground floors, and forbidden areas to build underground parking.

[33] The PPRi has defined four different levels of risk: low, medium, high and very high risk. See Index 7.
[34] The PPRi was prescribed on 26 June 2003 and recently on 8th of Mai was approved as law.
[35] The PLU replace to the POS *(Plan d'Occupation du Sol)*

Likewise we found others mitigation measures which are being carried out from other stakeholders:

The *University of Le Havre* is developing different tests to verify or contrast water sea levels in order to better understand flood events that happened during 1982, 1983 and 1984 in *Saint François* neighborhood.

The ORSEC *(Organisation de la Réponse de Securité Civile)* has been developing, through hydrodynamic modeling, statistics to analyze the sea behavior during the last decade that; as main results they have proposed a chart according to sea tide: *Optimistic* when water from the sea overflows around 40 cm height, *Pessimistic* when water from the sea overflows around 60 cm height, and *Extreme* when water from the sea overflows around 1 meter height.

The MDS (Spread of Modeling Methodology) focusing on designing a communication process in terms of sea submersion, therefore they are promoting tools to spread information about sea overflow and their phenomena or different consequences.

3.1.1 Last Flood Events in *Le Havre*

Just as a historical date: *Le Havre* was established in 1517 and the first flood event happened in 1525. Therefore we can see that this area has lived with the water since its foundation, as well as with several other factors such as rainfall, the river, the sea, and the stream.

As past flood events we have:

- **01 June 1984** *Saint François* neighborhood was overflowed due to sea submersion; overflow height reached 1 meter.
- **04 July 2000** Downtown in *Le Havre* was overflowed due to rainfall; overflow height reached 1 meter.
- **01 June 2003** Overflow by marine submersion in *Saint François*, at that moment damages were almost catastrophic.
- **2009** Water came fast and went back fast to the sea having damage in housing and commercial buildings as results.
- **08 September 2010** *Montivilliers*; two hectares were overflowed due to rainfall.
- **03 August 2012** Overflows around *Le Havre* and basin.

Taking types of floods[36] into consideration nowadays we find as main flood events in *Le Havre*: overflows, runoffs and sea submersion; where pond, stream, filtration capacity of land are involved it. Moreover, the whole area close to the sea has been affected by flood since many years ago; *"each year in the last couple of decades we can see floods event happening due to level sea considerations not being taken in the majority of the buildings"(*CODAH 2013).

Although those flood events in this part of the city did not have damaging consequences, it has become frequent to have floods in the parking areas, overflows of some centimeters in the Public Square of the neighborhood, and closed roadways because of overflows. In this way, stakeholder as the CODAH intends to involve the community through informative programs.

4. STATE OF ART

4.1 Findings and Reflections

4.1.1 Findings

Taking argued above into account, firstly related to the flood mitigation approach and secondly our case study, we focus on the current scenario in *Le Havre* in terms of flood mitigation.

In this way, and after being analyzed the types of level of risk in *Le Havre*, we are going to find natural and human factors which are increasing flood risk. In addition, according to the localization of *Le Havre*, it is mainly affected by the sea and the river as well as a high rain level during the whole year. As result, there is a variety of scenarios around the city and surrounding where can be identified different issues related to the flood events in each of them.

We are going to choice three cases in order to identify those differences and to have a general point of view of the issue. Therefore, these scenarios will be analyzed in terms of morphology and architectural issues and, at the same time, their challenges concerning flood risk mitigation.

The cases are *Grand Hameau, Saint Nicolas*, which are neighborhoods in *Le Havre* city and *Montivilliers*[37] which is a municipality beside to the *Le Havre*.

Analysis will be showed in the next chart (figure 8):

[36] See in Index 1.
[37] See Index 5

	MONTIVILLIERS	GRAND HAMEAU	SAINT NICOLAS
SCENARIO	 *Curande* stream around it. *Lézarde* river around it.	 Water ways in the project.   Built-up in surrounding areas.	 Seine Estuarine and basin around it. 
ASPECTS RELATED TO MITIGATION MEASURES	– Basin built to save rainwater by SMBV and CODAH. – In 2011 around 116800 m3 of rainwater is saved by the basin everywhere in the region. – Since 2010 a program to limit the spread of household waste has been developed; it was carried out by Mairie in partner with SMBV *(Syndicat Mixte des Bassins Versants de la Pointe de Caux)* – After damage happened in 2003 a program from the municipality to study the vulnerability of the buildings and, if necessary, destroy them was launched. Then those areas are supposed to be hydraulics areas managed by CODAH. – Setting up a permanent service in site to supervise rise up water level. – Points of references have been put in flood risk areas around the village by SMBV, so that people can identify them easily.	– CODAH is promoting the awareness of risks with a pedagogic program called *The Risk Culture (La culture du Risque)* which is addressed to the community through schools, university, newspapers. – In 2007 CODAH invested an amount of 183.000.000 Euros to build basins around Le Havre region as well as to improve evacuation network from rainwater like ditch for instance. – PLU *(Plan Local d'Urbanisme)* identifies flood risk areas in the region and establishes rules according to the level of risk for each of them. For instance, minimum height to built ground floor, forbidden areas to build underground parking, and so on. – In 2007 the ongoing *"Le grand Hameau – L`eco-quartier du Havre"* urban project, from Le Havre town hall was launched. The project aims to innovate about water rain management, with different proposals such as: use of mineral material in public space, green roofs, waterways networks, basin and waterways which will be involved in the landscape design. We remarks mainly two issues of the project: 1. Waterways networks underground and on the ground which will address rainwater to basins. These waterways on the ground have 60 cm of maximum depth. 2. Main basin on the main point of area, due to topography at this point water is coming there by streaming. However, according to the expectations others small basin will be built in different part of the project to give support the main one.	– PLU (*Plan Local d'Urbanisme*) identifies flood risk areas related to submersion marine on the region and establishes rules according to the level of risk for each of them. – *Le Havre* town hall in 1986 built up a retaining wall next to the *Saint François* neighborhood in order to protect it against tide. – Le Havre town hall and CODAH launched a pedagogic program called *The Risk Culture (La culture du Risque)* which promotes information about main aspects related to the submersion marines such as wind, tide height; that people must take into account in order to recognize risk. – PLU (*Plan Local d'Urbanisme*) has established strong rules related to the minimum height to built ground floor, and forbidden areas to build underground parking. – Le Havre town hall through PLU *(Plan Local d'Urbanisme)* Is renewing part of sewage system since the last couple of years ago
	MONTIVILLIERS	GRAND HAMEAU	SAINT NICOLAS

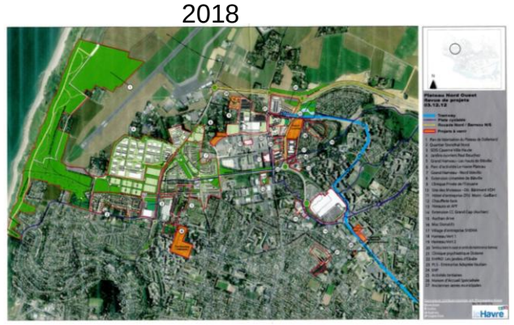
MORPHOLOGICAL AND ARCHITECTURAL ISSUES	Mainly from the destroying measures on risk areas, the urban form presents new empty space which is supposed to be used for hydraulics areas but in some of them it does not work, therefore those spaces are restricted to be built on but they do not have any use. According to the data gathered from CODAH and the municipality (look at website) we can conclude as next: 1. Since a couple years ago they have proposed considerations, recommendations, or strategies in terms of mitigation of flood risk based on several flood events happened before. 2. During the last ten years, many basins have been built taking place mainly on flood risk areas. <u>Urban Growth</u>  1968  2001	The major part of this area is considered as expansion area, which means that the whole urban project involving it will take up empty space of the city which is going to continue its growth. Nowadays we have an agricultural and expansion area which is being developed: the *Grand Hameau - Eco quartier* project[38]. In the project a basin as main design element in reference to large scale has been considered. Therefore there is a basin network proposed into the plan which is going to be underground and over the level ground saving rainwater. <u>Urban Growth</u> 2012  2018 	This area is considered as an urban renewal; therefore we can see old and new buildings around it which are producing two main issues: 1. Changing the height of buildings, turning places from one floor to social housing with fourth floors. 2. Needing to create empty spaces on the area such as urban parks, squares and so on, dedicated to the population. <u>Urban Growth</u>  2003  2012
CHALLENGE	Categorize all of the information gathered about mitigation measures from different stakes in each scale; in order to verify it if all of them can be applied nowadays.	Mitigation strategies at large and medium scale could get innovating changes that at the same time will involve the whole population who live in the neighborhoods including them into the general plan.	At the neighborhood there is only a restriction to use public space related to technological risk, none to the flood risk. In this way, it is necessary to take into account flood events happened from the sea in the past and as well as its fast growth ongoing. There is still acknowledging about the effects at structure, electric, and environmental level causing for the sea water in a flood event. How to improve that or how to approach to this knowledge?

Fig. 8 Analysis of 3 cases in *Le Havre.*

[38] See index 8. The urban plan and design is leaded by Town Hall through dealership given to *SHEMA*, which is half private and half public company.

4.1.2. Reflections

Is important to highlight that the fact of "flood risk" is involving the population both directly and indirectly at the same time, it depends on each case study. That means that when we see *Saint Nicolas* and *Montivilliers*, those are related to neighborhoods where people have lived since long time ago, meaning that they have a previous approaching to knowledge of risk, even experiences (it does not mean that it is enough or the whole of it), due to flood disaster that have already happened in both cases. On the another hand in *Grand Hamaeu* people started to come since a few years ago without becoming a consolidate neighborhood yet, it means that people are not totally involved in it or they do not have any experiences with flood risk as in other cases.

Taking previous reflection into account, the methodological approach about mitigation measures should be taken facing in different ways; for instance at the first case (*Montevilliers* and *Saint Nicolas*) we have a mixture between social buildings and private houses (That means a mixture of middle and high classes) which should be provided with technical measures to mitigate risk at building scale. In this way it is important to cover the whole population, to take actions with them at the same possibilities in terms of adoption and implementation[39]. One example is when there is high-level technical proposals into the houses such as green roof or saving water rain in buildings; it is going to represent high amount of money and most of the times it needs monitoring or following during some parts of the process. Therefore the state must be able to do it feasible to all inhabitants in risk (it does not mean it should be the same resources either design features, design rules, etc.) (D. Milleti 1999).

In the case of *Grand Hameau*, at the start of the project, was taken into account the flood risk issue, for which the project itself has been developed different strategies in terms of flood mitigation.

According to the previous discussion, we are focus in one case which provides us tools to understand the flood mitigation processes ongoing. In this way we have chosen to address the *Montivilliers'* case due to it presents a combination of factors in the cope of flood risk, among the flood urban areas and the mitigation strategies that are being developed within last decade. In a way it will give us valuable support to go deeper in the topic of flood mitigation in order to elaborate relevant results.

[39] At the framework of decision making processes "adoption" and "implementation" have a crucial position due to it will involve personal stakes, let say inhabitants; organizational stakes let say local communities, and national governmental stakes. Therefore, it should be taken as process where feedbacks among all of the actors mentioned before exist. (D. Mileti 1999)

4.2 How can mitigation strategies be interpreted ongoing? Special case in *Montivilliers*

On the scope of flood risk policies in France[40], during the last decade *Montivilliers'* municipality has developed an important plan about how to adopt and improve strategies in order to reduce the vulnerability facing flood events. This work has been carried out mainly by SMBV and CODAH at different scales on cities and supported, among others, by the Ministry of ecology, the sustainable development, transportation and housing.

In this context we have two main considerations: first, during the late 1990s and the 2000s, public policy for flood management has decided to renew and build several small retention basins (around 120 basins). The watershed valley "*La Lézarde"* it elaborates flood reduction strategies at the inter-city level (intermunicipal institution) (Start-Flood 2012). (See figure 1 and 2) Secondly, several documents have been launched in the same period from the stakes mentioned before, which are focusing to provide recommendations for households in order to mitigate flood risk at building scale in terms of minimizing the structural damages to reduce delay, become normal again and keep households safe[41] (Ministry of ecology 2011).

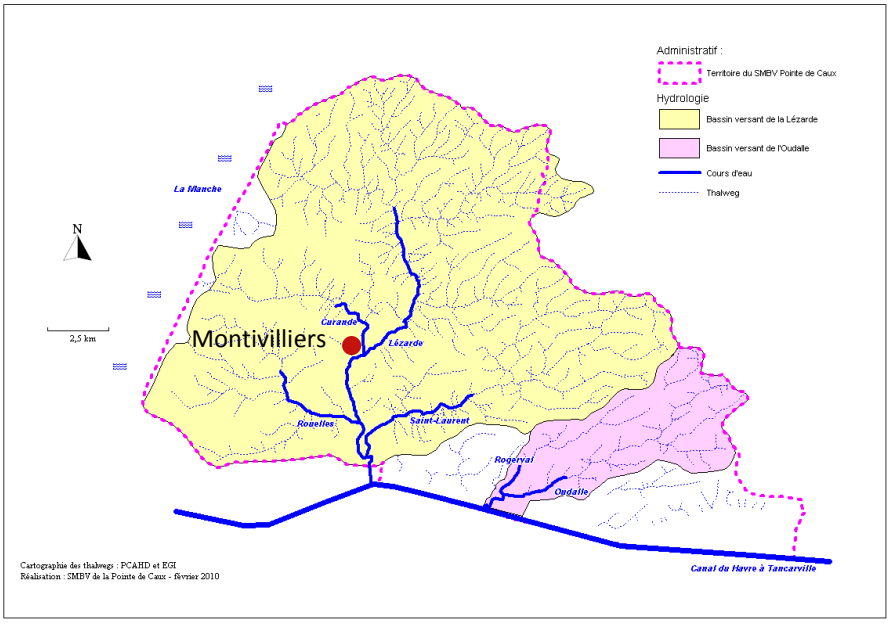


Fig. 9 Structuring axes runoff from watersheds of the community of Havre (source: SMBV, 2011)

The watershed area of the community of Le Havre is incised valleys plateau. The steady flows occupy only the terminal portion of these valleys. Upstream, the valleys are called "dry": the water flow is happening there in case of rainy weather. Valley bottoms or valleys are otherwise called troughs.

[40] According to the report about "French policy to reduce the risk from disasters" published by *Ministry of ecology, sustainable development, transport and housing in 2011,* reducing vulnerability is considered as one of the seven pillars of French prevention policy.

[41] According to the PPRi there is a classification which to allow considering the situation about building facing its vulnerability. See Index 9.

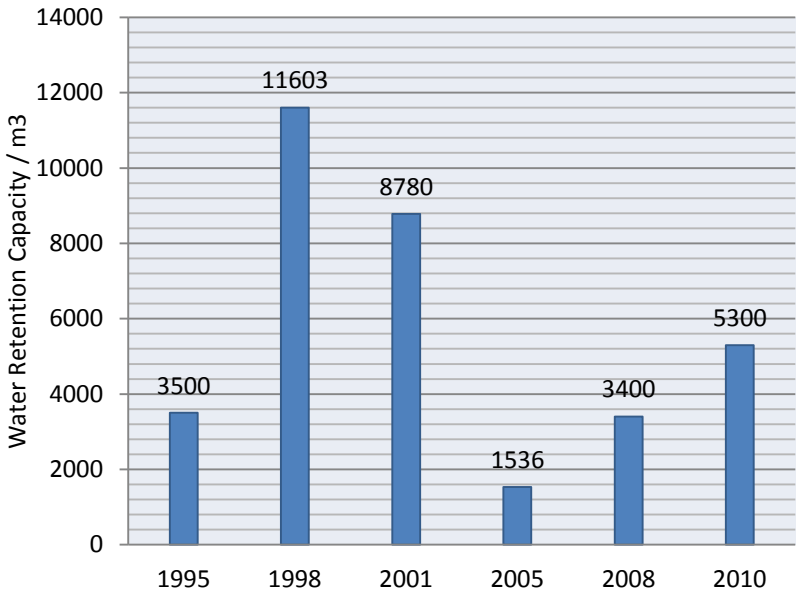


Fig. 10 Basins' water capability, it has built during last couple of decades in the of *Montivilliers'* municipality.

Since the beginning of eighties SMBV has been responsible for to build retention basins around Montivilliers' municipality, it is framed on the program called "rainwater structural works".

As a first step on this methodological approach, I have analyzed all of the data gathered according to the mitigation measures from different stakeholders involved in *Montivilliers*[42]. After that, and taking into account the major part of the references I read, I am going to clearly report three main scales which will allow an approach to flood risk that becomes more powerful in the France discourse about risk. As we can see, the PPRi report always identifies the building or lot scale as *"l'échelle du parcelle*", the neighborhood scale as "l'*échelle du quartier*" and the catchment scale as *"Agglomération"* (CODAH 2011). In a way from my viewpoint, it is a clear manner to face floods at different levels allowing us to get a broad scenario as at the same time we enter into further details. It is considered that at the beginning, as well as throughout the fieldwork, we have:

- *Catchment Scale*

  At the level of river basin, catchment scale focuses on providing measures to reduce flood risks through large infrastructure as dicks or barriers. Provision of temporary water storage capacity during flood events, to reduce peak flows can be adopted through the retarding basins as well as holding water in the upper parts of catchments which reduce downstream flooding (TCPA 2007).

[42] See all of the mitigation measures in Index 10.

- *Neighborhood Scale*

  At the level of river basin, neighborhood scale focuses on understanding and managing flood pathways and protecting areas at risk. In this way we should consider measures as permeable pavement, gravel or grass so that water can soak away and provide of green open space which could become a potential storage area, using for example infiltration ponds. Likewise green roofs reduce runoff and improve pressure on drainage systems during heavy rainfall (TCPA 2007).

- *Building Scale*

  At the level of river basin, building scale focuses on minimizing exposure to flooding whilst incorporating structural solutions to reduce vulnerability. Existing buildings can take advantage of new materials and products to manage flood risks. Some of the main resilient measures in the building are materials and removable household products. Nowadays, measures such as Green roofs are constantly increasing. This will help to reduce runoff and ease pressure on drainage systems as well as managing flood pathways and removing 'ditch', which during heavy rainfall can drain away (TCPA 2007).

Therefore, as main result we can see that most of the mitigation documents concerning *Montivilliers* are addressing mainly the building scale, producing so much information about it. In a way, this could be advantageous in terms of implementation approach [43] . Nevertheless, it is not because all of the recommendations that are not involved as feedback process where the owners can interact with persons who promote it, otherwise they should assume whole execution of measures, having as consequences that most of the owners do not carry out that.

According to what I have studied, an experimental survey[44] was carried out by the CODAH in 2012 on inhabitants, who were affected by flood events that happened in 2003. The target was damages caused at that time can propose them some infrastructure measures to minimize damages facing a future overflow. Currently, the results of this survey are still under review by the CODAH, but also the first perception was related to lack of application of these measures by the owners.

[43] At the framework of decision making processes "adoption" and "implementation" have a crucial position due to it will involve personal stakes, let say inhabitants; organizational stakes let say local communities, and national governmental stakes. Therefore, it should be taken as process where feedbacks among all of the actors mentioned before exist. (D. Mileti 1999)

[44] See whole survey in Index 11.

In this way, one consideration can be that those recommendations in the building scale do not have a clear link among the catchment and neighborhood scale measures, having as consequences the lack of suitable knowledge about how to implement that by the inhabitants.

Another consideration related to this scale has to do with the vulnerability measures that have started to obtain a certainly relevant policy plan after flood events happened in 2003 (See figure 11) mainly through PPRi. Nevertheless in the neighborhood as in the catchment scale they already began to be analyzed a few years before that.

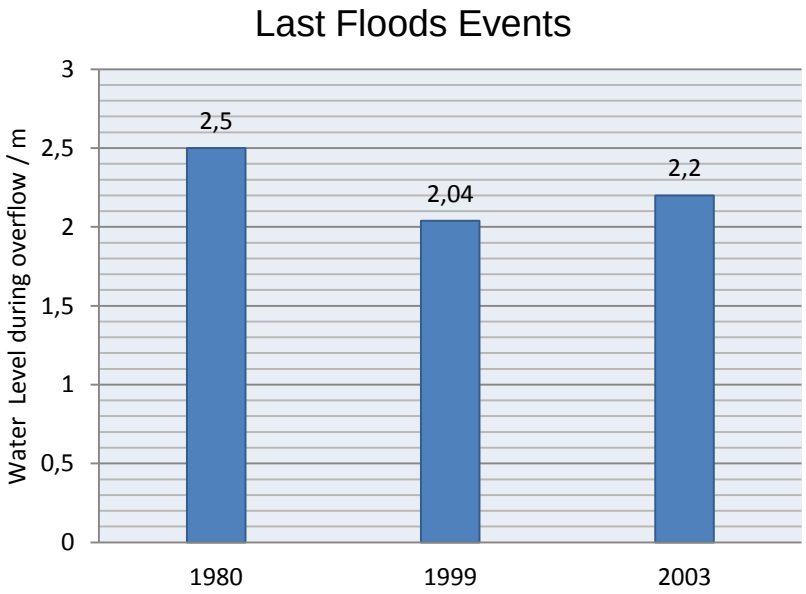


Fig. 11 Main last flood events happened in the *Montivilliers'* municipality.

In the framework of tendency *one overflow event per each 10 years; different actions facing floods is going to carried out during ninethies90, it will become recognize in the cope flood prevention policies through PPRi which was prescribed on 26 June 2003*[45]*. It involve watershed in the Lézarde river, coastal maritime and seine reverie.*

On the other hand at the catchment scale we are going to find that all of the mitigation measures are addressing the basins and expansion areas which have began to apply a few years ago. Despite the usefulness of these measures in terms of vulnerability reduction, they are hard to manage.
Some testimonies show that this fear takes an important consideration nowadays from stakes as CODAH:

"*It is a green space? Who will manage it? Which kind of construction could take place?"*

[45] The PPRi was prescribed on 26 June 2003 and recently on 8th of Mai was approved as law.

Taking previous questions into account as well as discourse argued above about “implementation”, an opposite scenario arises with the same consequences, meaning that most of the measures commented at this scale have been implemented but having a lack of integration with the inhabitants. In part it happens, in this case of basins for instance, they were created in the past on surrounding areas which have grown (see figure 12) so fast during the last decade through built-up areas that appear around them (see figure 13). Hence, this mixture that is found nowadays in built-up areas around basins helps us to keep that sense of living on water and should obtain an important position on political agenda, concerning not only flood risk areas, but also flood prone areas and further flood protected areas (V. Wattenberg, T. Brinkhof, J. Spits 2008).

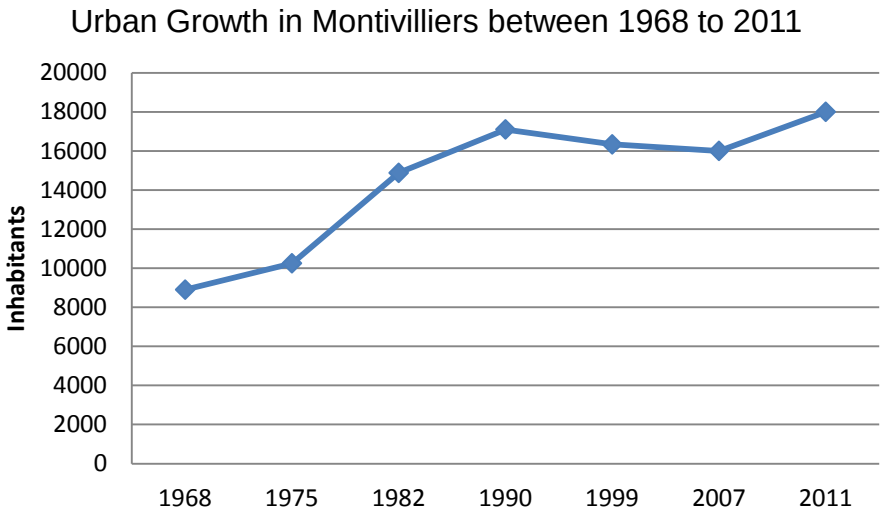


Fig. 12 Growth rate in *Montivilliers’* municipality. (Source: INSEE 2011)

In the framework of tendency *one overflow event per each 10 years; different actions facing floods is going to carried out during 90, it will become recognize in the cope flood prevention policies through PPRi which was prescribed on 26 June 2003. It involve watershed in the Lézarde river, coastal maritime and seine reverie.*

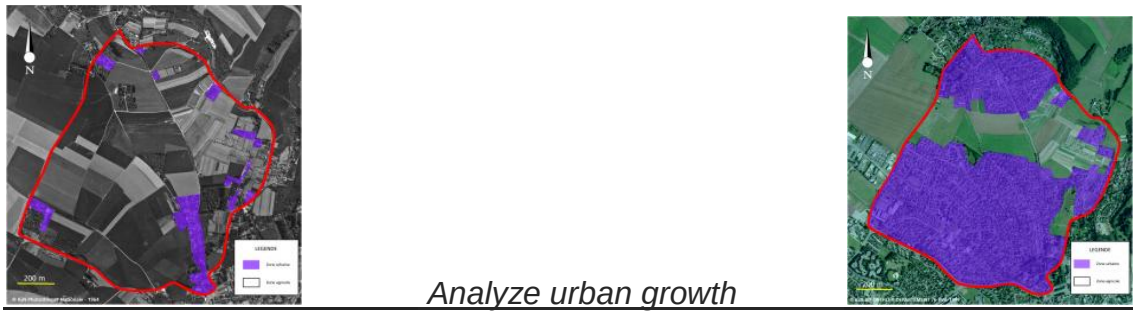


Fig. 13 Urban Growth between 1968 to 2001 in *Montivilliers’* municipality. (Source: SMVB 2011)

In *Montivilliers* since the last decade built-up (urbanizations over flood risk area without monitoring process) areas have increased.

In an international context it is well known that during the last couple of decades the attitude from struggling against water has been changed for an approach towards to live with it (living with water). At this point from known cases in countries as Netherlands or Germany we can perceive two positions about to build in floodplains areas which are going to help us to understand better this situation. On one hand it could be considered as viable once they strengthen the interrelation between safety, economy or sustainability, this belief is recognized under “water as companion” become a perspective where buildings can be considered to be solutions serving multiple purposes within complex problems (see figure 14). On another hand there is a belief that the river should keep the function of a river, and buildings are regarded as hydraulic obstructions and threatened objects. Buildings are then considered to be an unwise decision (V. Wattenberg, T. Brinkhof, J. Spits 2008). This contradiction in beliefs seems to be about disputes over water management versus spatial planning within the domains of risk management. In parallel, it shows the diversity of a broadly accepted philosophy such like “water as a companion” (V. Wattenberg, T. Brinkhof, J. Spits 2008).

Fig. 14 Residential area in *Trabrennbahn Farmsen* (Hamburg, Germany) 2000.

The storm water management train is clearly organized and well implemented. In the open water system the storm water is retained and on its way to the retention ponds, it is able to percolate into the soil. Therefore it contributes significantly to the redevelopment of a natural water cycle.

Finally, as far as the neighborhood scale is concerned, there are mitigation measures mainly based on filtration processes, carried out through easy techniques, highly related to the natural landscape, and moving towards sustainability, if applied successfully. Moreover, it is possible to be integrated into the storage water system due to some of these measures, which can storage temporarily water when at the same time its filtration capability improves. Specifically, the measures proposed at this scale also offer a talent on how to adapt it or extend it to another scale taking in consideration both, for instance in the case of water way is clearly that they can be connected to the retarding basins as well as take water from the dew pond which would carry out rural housings. In this way, we can see as the concept of water management, through the water conservation and drainage concept appears to take an important role in a flood mitigation strategies.

Therefore having a broad consideration about mitigation strategies ongoing in *Montivilliers*, and through careful examination procedure on literature review we have chosen all of the measures found mainly in SMVB, CODAH and Ministry of ecology. Then, according to the scales (Catchment, Neighborhood and Building scale) and its inter-relation with the water management process, we are going to categorize them.

As result, we approach through next chart to flood mitigation measures in *Montivilliers* (see figure 15):

MEASURE ADAPTATION	
A	Adapted Measure
NA	Non-adapted measure

ACHIEVE	
P	Primary
S	Secondary

		CATCHMENT SCALE	NEIGHBORHOOD SCALE	BUILDING SCALE	Sloping land >5%	Lower ground waterproof	Lower draining level	Reduced area parcel	To reduce damages	delay return to normal	Keep household Safe
					Land properties/characteristics				Expects		
WATER CONSERVATION		Flood Retarding Basins								P	
		Flood Barrier or Dams								P	
		Field Expansion Rise								S	P
			Dew Pond		NA	A	NA	NA		P	
DRAINAGE			Waterway		A	A	A	A*		P	
			Dew Pond		NA	A	NA	NA		P	
			Permeable pavement		A*	A	A	A		P	
				Ditch	A	A	A	A*		P	
				Draining trench	A	A	A	A		P	
INFRASTRUCTURE	Temporary methods to protect the housing. Height <1mt.			Cofferdams					P	P	P
				Sandbag					P	P	P
				Wrapping					P	P	P
				Shutter vents					P	P	P
				To protect the front porches located in the axis of the stream					P	P	P
				Refuge area into the housing							P
				Wastewater management					P	P	P
	Adaptation of the different kind of materials inside at home. Height >1mt			Walls					P	P	
				Dividing walls					P	P	
				Coatings wall					P	P	
				Floors					P	P	
				Woodwork					P	P	
				Weather-proofing					P	P	
				Protection of climate control equipment					P	P	
				Redistribution and / or modification of electrical circuits					P	P	P
				Protection of elevators					P	P	P
				Prevention of damage to networks					P	S	P
				Prevention of damage caused by oil tanks.					P		P
				Protection of persons in presence of swimming pools.							P
				Protection of crawl spaces.					P	P	

A* These measures are not adapted enough but can be implemented.

Fig. 15 Flood Mitigation Measures in *Montivilliers* (Designed by the author).

The measures have been collected through careful examination process on data of literature review mainly from the SMVB, CODAH, and Ministry of Ecology. On the chart only structural mitigation measures have been taken. We can see in detail on Index 10.

4.2.1 A holistic approach adopting measures

The flood events that happened in 2003 were a main factor to develop an important progress in terms of measures and strategies facing flood risk. As mentioned above, in this context one of the most important initiatives was carried out by the SMBV with the construction of basins around the community area. But at this point is important to remark that these basins started to built on countryside areas and with a high retention capability *o*f rainwater, while nowadays due to the urban growth the basins are decreasing in terms of retention capability (see figure 10). Moreover urban sprawl has as consequences that built-up areas are closer to the basins than before. Thus we have in term of urban scenarios, on one hand a scenario where the city should improves its resilience (adaptability) conditions against floods but on the other hand there is a second scenario which will be related to the question about how the basin is adapted to the new settlements that are being built (A. Röhring, L. Gailing 2011).

In our approach we will take into account the first from the two previous scenarios only one scenario, due to our focus to be taking the mitigation measures which are already done or proposed from stakeholder and to apply it. It will be more useful in order to enhance the mitigation strategies going on; otherwise the second scenario presents one more way of suggesting new uses about that space and furthermore it can be an empirical approach deal with spatial inter relation between measures and settles that gave the built up that comes to the measure. On the other hand in our research, the measure comes to the built up.

At the same time, large measures have been developed about how to mitigate flood risk at the building scale, producing numerous documents about that. All of them come from different stakeholders such as the national, the municipality level based on professional knowledge as well as experience getting in past flood events. It becomes a handbook guide of solutions which do not have strong or specific properties what allow them to get involved with the rest of scales. These measures can therefore be defined as from a theoretical perspective on the basis of conceptual and experience or based on statistical analysis, which will be adopted according to the risk of level of different areas into the city and implementing it directly by the owners.

The methodology presented by this section is a synthetic approach to the mitigation analysis of built environments[46] carried out around the city. The main

[46] Research on built environment deals with a complex and interdisciplinary subject; for example specific analyses and assessments will only be possible when the urban built environment is defined in categories like housing, office, and industrial building, and in a more detailed form such as housing periods and types. We would then be able to identify main features in order to get measures and carry them out (A. Blum, K. Gruhler 2011).

objective of the approach is to determinate how it can create resilience condition on the town applying the mitigation measures proposed by stakeholders through of empty space [47] based on urban morphology of *Montivilliers*.

Through an urban analyze we will identify different typological urban form produced into the city, and then this will allow us to identify different patterns of occupation of land focus on the "empty vs fill space" criteria.

The mitigation approach consists of three main components:

- The special identification of typologies based on urban features in municipality of *Montivilliers* and the choice of the most representative ones.
- The analysis of areas taking into account high and medium risk of level[48] which will represent a holistic approach to the flood risk going on.
- The hypothesis on how these cases could became if some of the mitigation measure would carry them out.

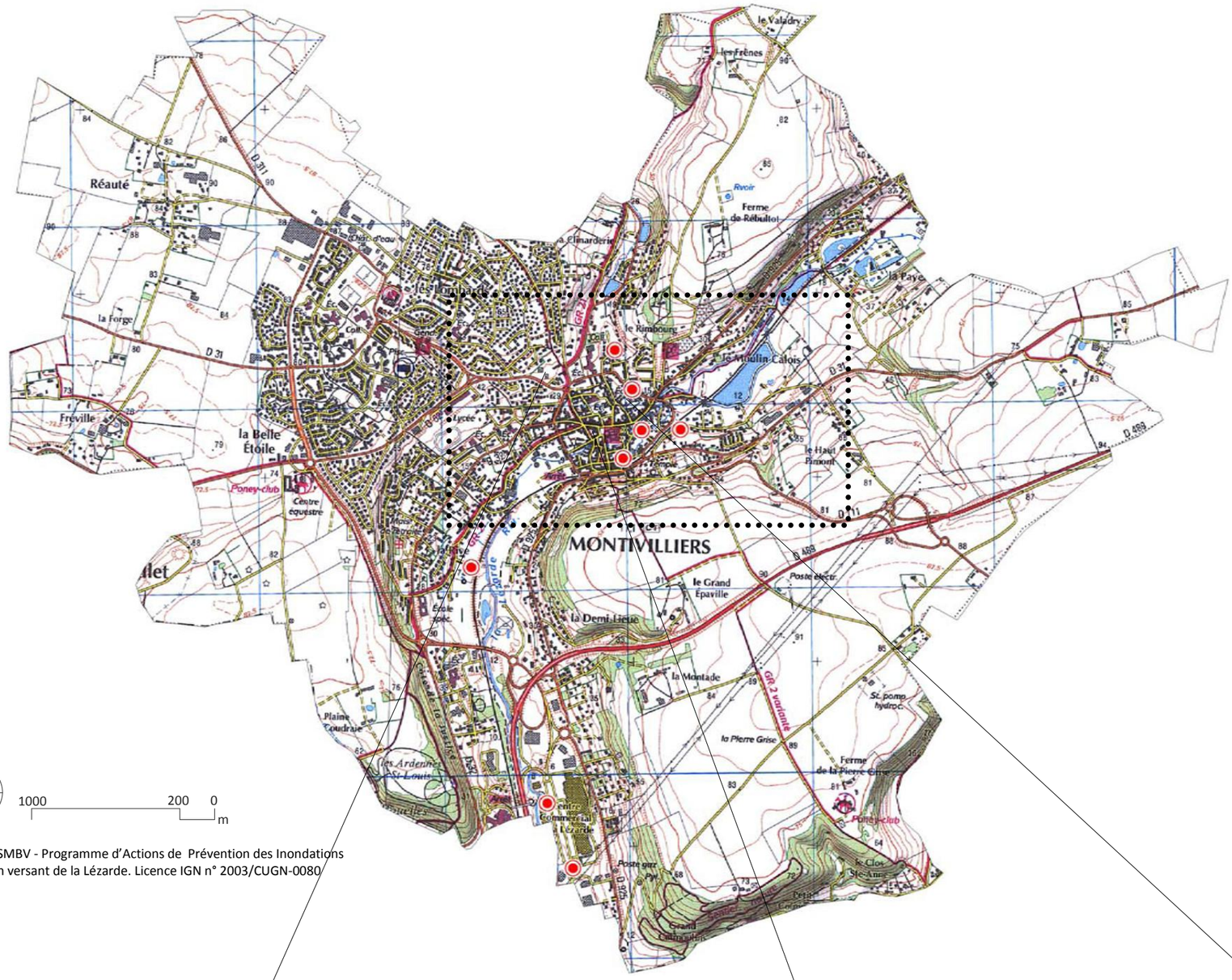
The first step based on urban morphology theory[49] is takes place in terms of "empty vs fill space", due to which understanding the cities with a broad view is possible. At the same time the urban form gives an idea about how it was structured, and how it works. In other words "the *skeleton system"* of the city (M. de Solà 1972). Considering it part of many discussions from several authors within the years, it can be considered that in the past there was holistic interest in to think the city but over the years it has undergone a metamorphosis to become quite contemporary concept known as "re-thinking the city". Specially in Europe, countries carry out urban develop process under this concept; arising new ways based on point of view as sustainable development, urban regeneration as well as hazards risk in urban areas. This latter subject it has been explained by Mark Pelling as *the co-evolution of urbanization and risk*, the nature of disaster risk is constantly being redefined as changes to urban landscapes and socio-economic characteristics are unfolded. Urbanization affects disasters just as profoundly as disaster can affect urbanization (M. Pelling 2003).

[47] Has been taken public and private space on whole analyze.
[48] It is based on the flood Risk map of Montivilliers by the PPRi.
[49] A.E.J Morris.

Second step, based on categorization of flood mitigation measures[50] (see figure 15), our next step will be to contrast the efficiency and dynamics of them. To do that, we are going to adopt some flood mitigation measures in the current area in *Montivilliers* through graphic exercise where we will able to identify the strengths or/and weakness of them.

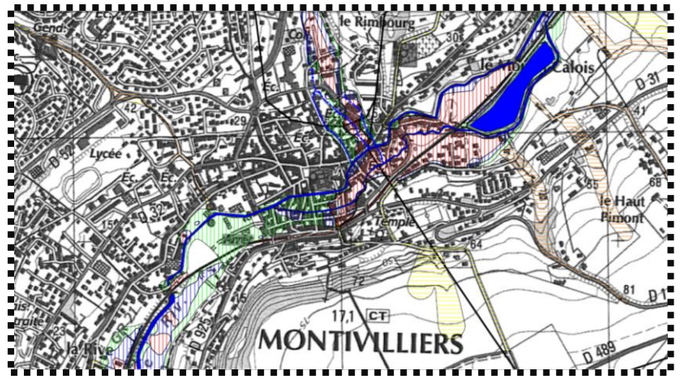
According to the previous consideration, we are going to explain how was carried the approach out, applying these measures in three different scenarios:

[50]Nowadays, several authors argue concerning flood mitigation: *it should extend to strategies in which actors are integral part of the system and either influences its resiliency to the places* (A. Röhring, L. Gailing 2011).



Source: SMBV - Programme d'Actions de Prévention des Inondations du bassin versant de la Lézarde. Licence IGN n° 2003/CUGN-0080

FLOOD MAPS ACCORDING TO PPRi



Source: DDTM Seine-Maritime | IGN Scan25®2005 | SAFEGE®2008
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EMPTY vs FILL SPACE

Empty Space

Fill Space

Streets

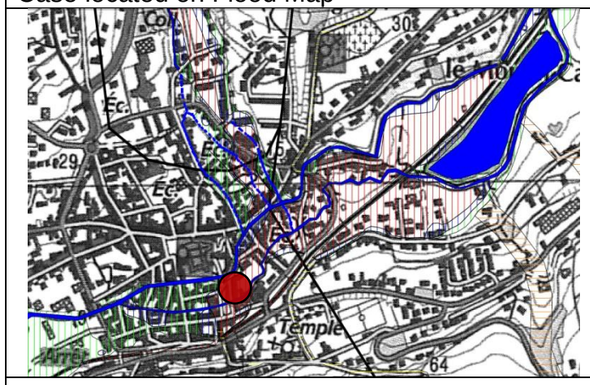
BLOCK TYPOLOGYS

Typology 1
Rural Housing
More than 50% empty space

Typology 2
Urban Buildings
More than 50% fill space

Typology 3
Mixture between Typology 1 and 2.

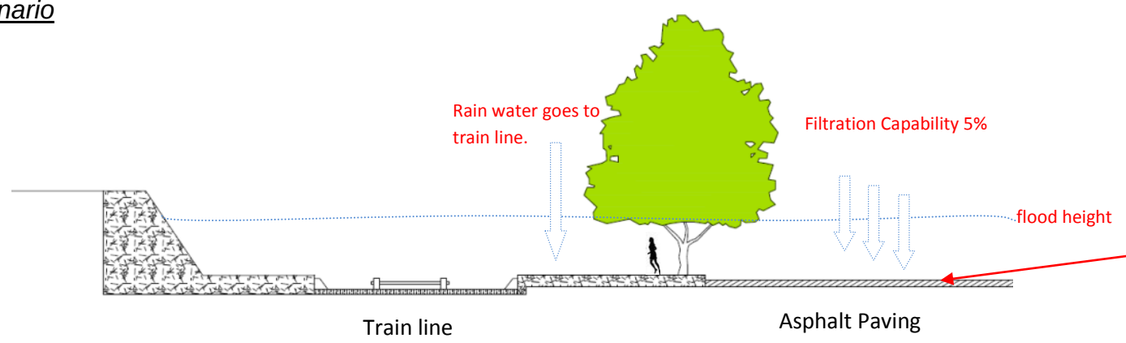
SCENARIO 1

Case located on Flood Map	Block Typology	Empty Space to Analyze	View
			
High Risk Medium Risk	Typology 2. Urban Buildings	Public space Private space	

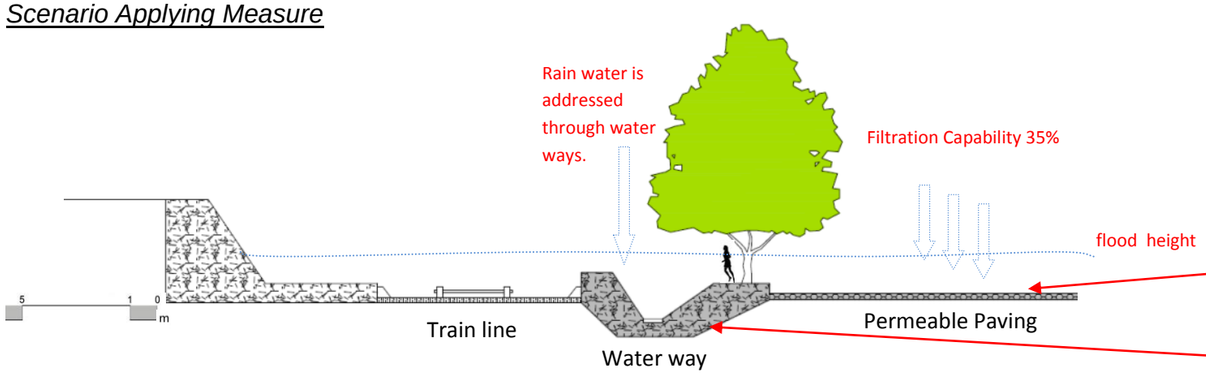
Empty Space to Analyze	
Empty Area	**Total Area 4108m2** Public: 3830m2 Private: 278m2
Use of the space	Parking Area
Material on the ground	Asphalt Paving
Green areas	Dense vegetation with tree around 8 – 10 height. Tree 4 m height on the parking.
Water level during last flood event	2,50 m
Construction around it.	Housing Residential Building
Use of the buildings	Commercial and housing
Max. Height of building	12m (4 levels)
Topography	Land flat
Water table	

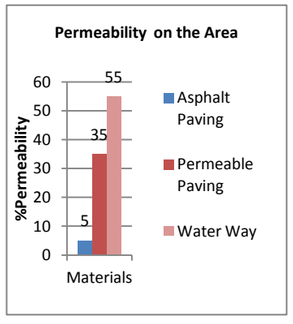
Measures adopted according to the chart (Fig. 15).	
Slope land <5%	**Permeable Paving Water way**
Low water table level	

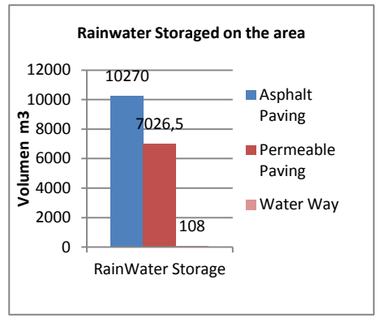
Scenario

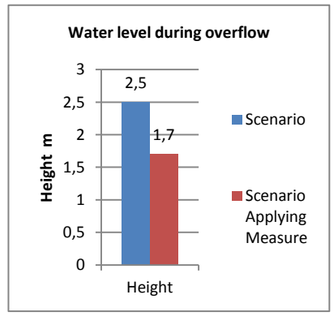


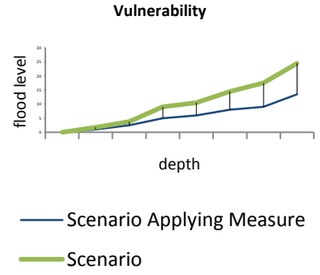
Scenario Applying Measure







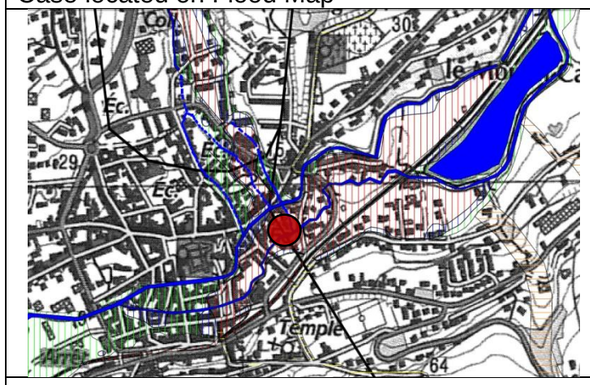
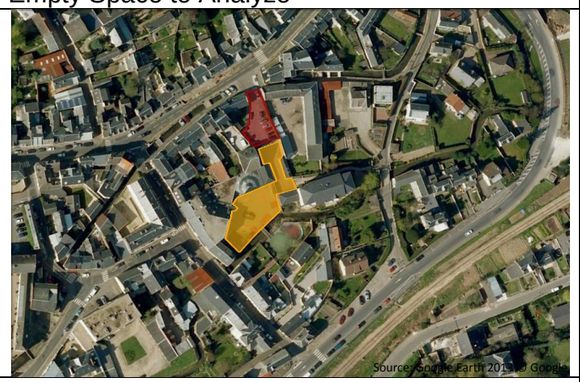




This analyzes shows as results: having applied the mitigation measures and using the same conditions happened during flood event in 2003, the flood risk have been reduced 32%.

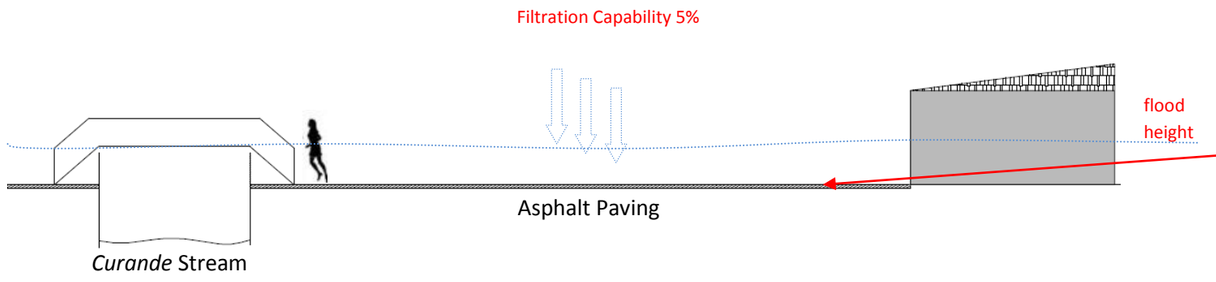
These quantities were calculated take into account list of standards material from France and UK, based on data and literature review about kind of permeable grounds and new kind of materials related to flood risk (See Index 12 – 13).

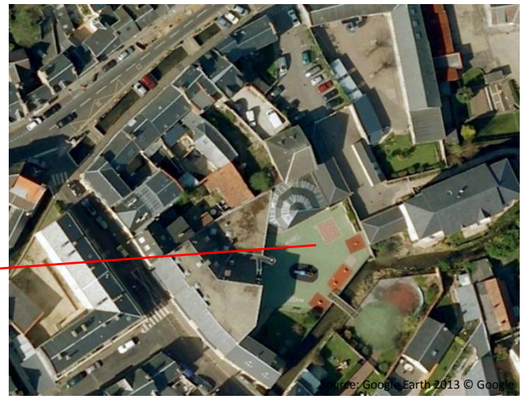
SCENARIO 2

Case located on Flood Map	Block Typology	Empty Space to Analyze	View
			
High Risk Medium Risk	Typology 2. Urban Buildings	Public space Private space	

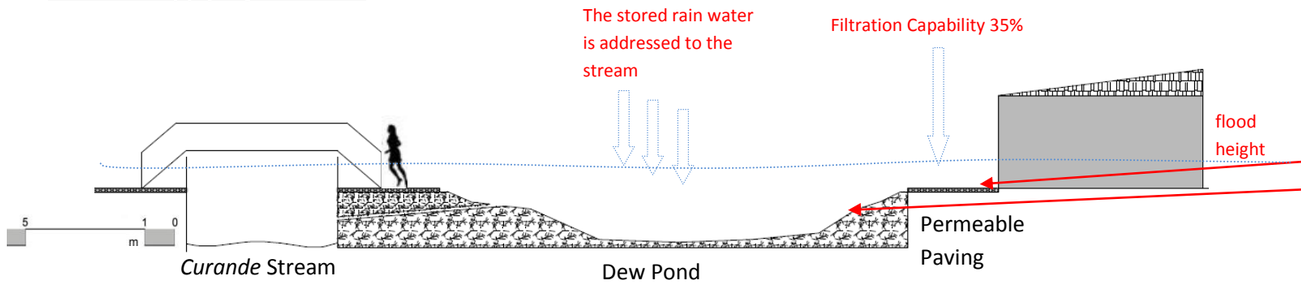
Empty Space to Analyze	
Empty Area	**Total Area 1163m2** Public: 363m2 Private: 800m2
Use of the space	Parking Area Leisure
Material on the ground	Paving Paving synthetic
Green areas	Lack of it
Water level during last flood event	1,15m
Construction around it.	Housing Residential Building
Use of the buildings	Housing
Max. Height of building	18m (5levels)
Topography	Land flat and slope
Water table	

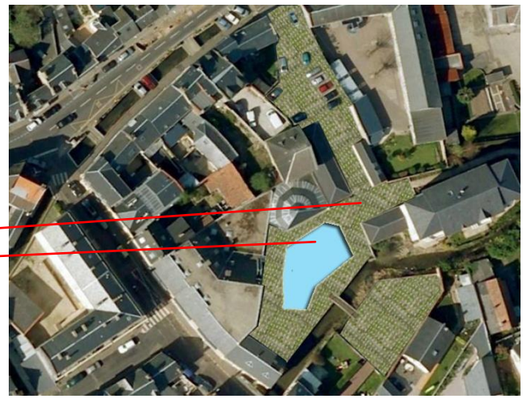
Scenario



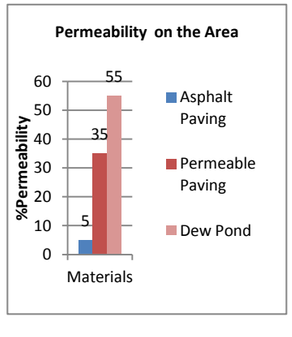


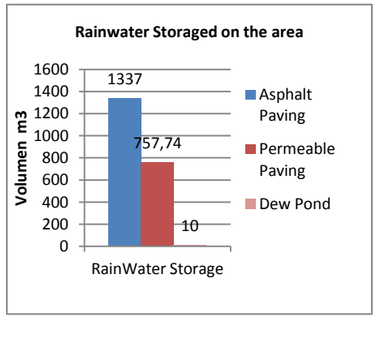
Scenario Applying Measure

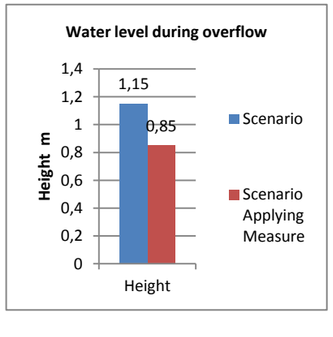


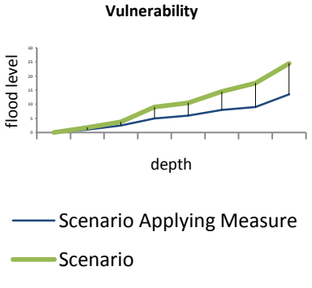


Measures adopted according to the chart (Fig. 15).	
Slope land <5%	**Permeable Paving Dew Pond**
Low water table level	





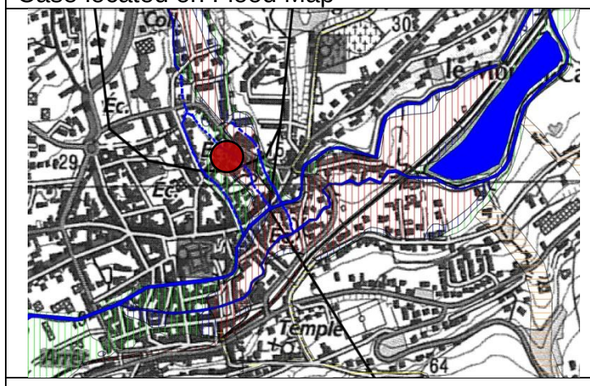




This analyzes shows as results: having applied the mitigation measures and using the same conditions happened during flood event in 2003, the flood risk has been reduced 26%.

These quantities were calculated take into account list of standards material from France and UK, based on data and literature review about kind of permeable grounds and new kind of materials related to flood risk (See Index 12 –

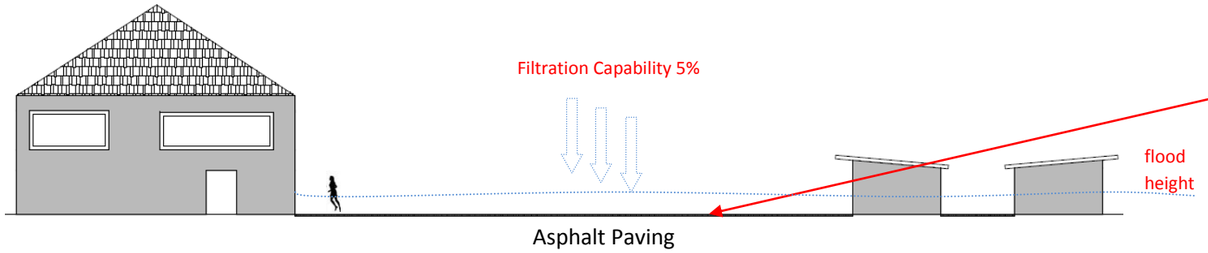
SCENARIO 3

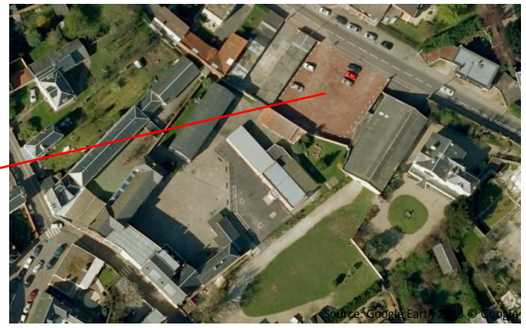
Case located on Flood Map	Block Typology	Empty Space to Analyze	View
			
High Risk Medium Risk	Typology 3. Mixture of Buildings	Public space Private space	

Empty Space to Analyze	
Empty Area	**Total Area 2254m2** Public: 792m2 Private: 1462m2
Use of the space	Parking Area
Material on the ground	Paving Paving without asphalt
Green areas	Lack of it
Water level during last flood event	0,71m
Construction around it.	Housing School
Use of the buildings	Housing
Max. Height of building	10m (3 levels)
Topography	Land flat
Water table	

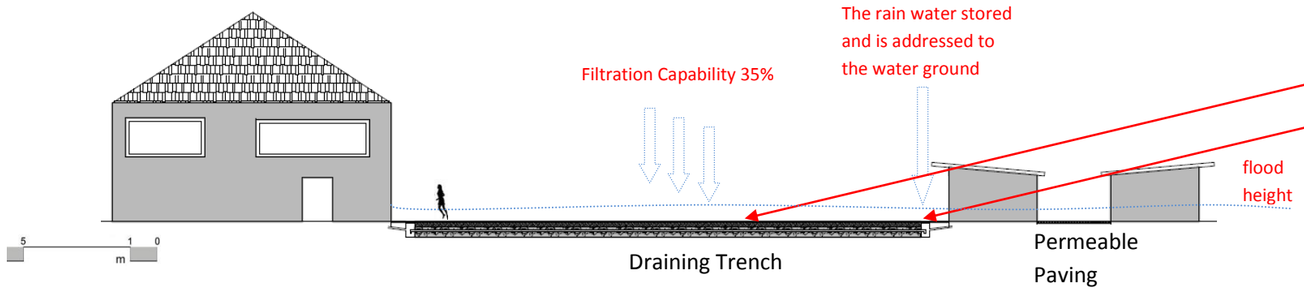
Measures adopted according to the chart (Fig. 15).	
Slope land <5%	**Permeable Paving** **Draining Trench**
Low water table level	

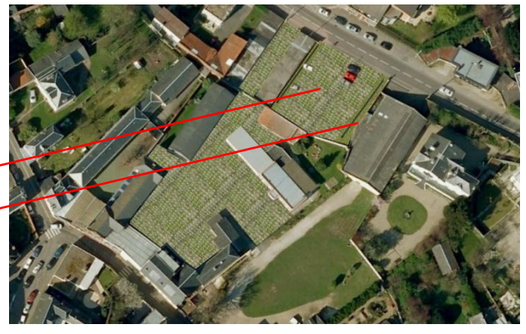
Scenario

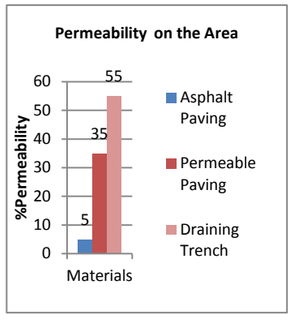


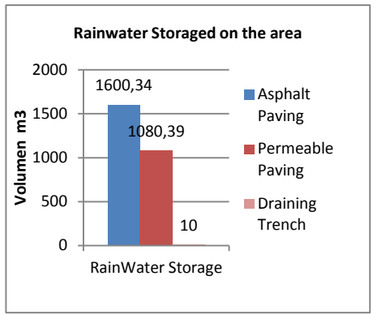


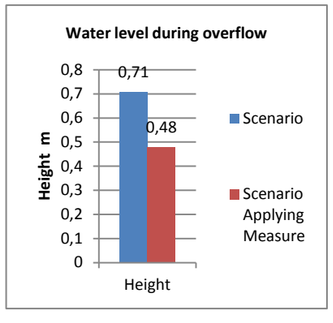
Scenario Applying Measure

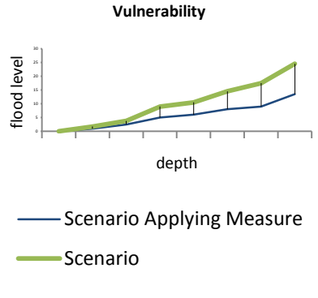












This analyzes shows as results: having applied the mitigation measures and using the same conditions happened during flood event in 2003, the flood risk has been reduced 33%.

These quantities were calculated take into account list of standards material from France and UK based on data and literature review about kind of permeable grounds and new kind of materials related to flood risk (See Index 12 –

Concerns previous exercise, we decided to apply mitigation measures at neighborhood scale taking into account two main considerations: first, mitigation measures found at this scale (waterways, dew pond permeable paving, ditch and draining trench) are not implemented in most of parts of the *Montivilliers*. Second, we found also around *Montiviliers* several empty areas, both public and private, such as parking, squares, and parks; which are producing different urban form into the city.

According to that arises the question about *how to involve these areas with the flood mitigation process?*

As main result, we can see as the vulnerability was reduced at average of 30% having applied the mitigation measures in all of the scenarios.

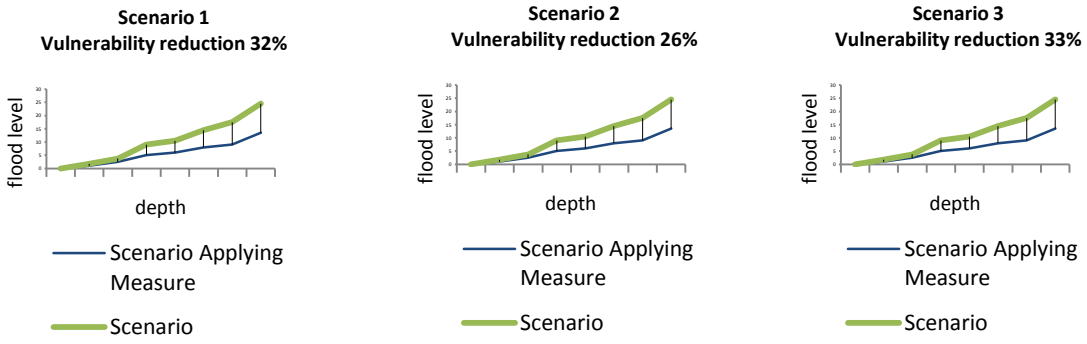


Fig. 16 Vulnerability reduction for each scenario.

We can consider that the neighborhood scale has a talent to involve stakeholders of both catchment and building scale due to it allows carry projects out that will serve as meeting point between professionals and inhabitants promoting to work together on flood mitigation.

As an example, the implementation of new material as permeable paving on the ground can take part at the municipality or regional level regarding the features of public and private space. But also it will involve directly to the community, due to in a way they could be able to make it, through participation process for instance (See figure 17).

Scenario

Scenario Applying Measure

Fig. 17 Holistic view on *scenario 1* having applied mitigation measure.

The flood mitigation measures have a talent to create participative process at different scales through of projects related to flood mitigation currently, as for example urban farming.