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**THE SEINE RIVER FLOODING IN THE ILE-DE-FRANCE REGION: WHAT ACCOUNT IS TAKEN
OF CLIMATE CHANGE IN THE DECISION-MAKING PROCESS?**

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THE SEINE RIVER FLOODING IN THE ILE-DE-FRANCE REGION: WHAT ACCOUNT IS TAKEN OF CLIMATE CHANGE IN THE DECISION-MAKING PROCESS?¹

Pierre-Alain Roche²

Over the past few years the authorities have rightly expressed renewed concern over the major risks of flooding posed in the event of the Seine and its main tributaries overtopping in the Paris region. The scale of these risks is indeed enormous and merits a closer examination of the impact of the climate change debate on the decision-making process. We will discuss how flooding risk mitigation policies could be affected by climate change after presenting the current situation.

1. Flooding of the major rivers in the Ile-de-France region

Flooding of the Seine and its tributaries in the Ile-de-France region occurs from mid-December to April, with a particularly high risk in January and February. Late and milder flooding in May can pose significant problems, however, due to the fact that dam reservoirs are almost full at that time of the year. These slow-moving river floods take 3-4 days to reach the Paris conurbation in the case of the Yonne and 6-8 days in the case of the upstream sections of the Seine and the Marne. The maximum impact is produced when several river floods resulting from successive periods of rainfall reach the Paris conurbation at the same time.

The most extreme river flood recorded was in February 1658 (34 cm above the level of the 1910 flood). In the 17th century there were three severe floods in 9 years and 5 major floods. In the 18th century there were 6 major floods, 13 in the 19th century and 9 in the 20th century including the memorable flood of 1910, almost a hundred years ago. Since 1910, there have been two major floods, one in 1924 and the other in 1955. There has been no river flooding on a comparable scale in the Ile-de-France region since 1955, due to the fact that since 1955 the Seine basin has not experienced any very intense rainfall or hydrological events.

2. The impacts today of river flooding on a scale comparable to the 1910 flood

The first physical damage from rising river levels consists in the seepage of water from the Seine through quay walls and a gradual increase in the height of the water table supplied by the Seine in sub-surface formations. There are many engineering works located below ground level (miscellaneous pipes and conduits down to 3 metres below ground level, car parks and sub-surface urban infrastructure down to

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The opinions expressed in this paper are those of the individual authors and do not necessarily reflect the views of their organisations or of the OECD.

15 metres, RER³ tunnels down to 30 metres). The flooding of the telephone switchboard at the Quai des Orfèvres in 2001 as a result of a relatively modest increase of 5.2 metres in the level of the Seine revealed the type of impact such flooding could have on infrastructure. Above a level of 7.3 metres, flooding as such would start upstream in the 12th and 13th *arrondissements* and by direct overtopping in the 4th, 7th and 15th *arrondissements*. And that's just in Paris...

The socio-economic impact on the conurbation of flooding to the 1910 level would be substantial due to the large number of people who would be affected by the flooding (the DIREN⁴ estimates 880 000 people: 260 000 in the Val de Marne *département* and 255 000 in the Hauts de Seine *département*), the large number of companies similarly affected (170 000, according to estimates by the Paris Chamber of Commerce and Industry), and the presence of many governmental, political, financial or economic decision-making centres in a capital city.

Although our modern urban society functions in a far more sophisticated way than the Paris of 1910, it is also far more vulnerable to flooding in that we clearly depend heavily on electricity, telecommunications and transport. In 1910, trains could still run despite the tracks being under a few centimetres of water; our current electro-mechanical systems, particularly computer systems, would be inoperable under such conditions and would all have to be inspected once the floodwater had subsided and in most cases replaced. In 1910, Parisians could keep themselves warm during what was a particularly cold month of January by continuing to fetch coal up from their cellars to burn in their fireplaces. Today, living in an unheated apartment with no electricity (since district heating systems and boilers regulated by electrical control systems would be out of commission) would be far more difficult.

Studies conducted in the 1990s gave the authorities an initial warning by estimating the damage from a flood comparable to that of 1910 at 4.6 billion euros (1990 scenario). These same studies also estimated that the disruption caused by a rise in the level of the Seine equal to that reached during the 1910 flood would affect:

- 70% of metro traffic for 30 to 50 days;
- 50% of RER traffic for 30 to 50 days;
- over 200 000 electricity subscribers;
- over 1 million telephone subscribers;
- around 100 000 gas subscribers;
- 5 household waste processing plants;
- 5 district heating plants;
- 50% of drinking water supplies.

The most recent estimates have raised this figure to 12 billion euros. The reason for this increase is that in addition to direct damage there are also the costs resulting from the loss or disruption of a large

^{3.} *Réseau Express Régional* (Regional Express Network).

^{4.} *Direction Régionale de l'Environnement* (Regional Directorate for the Environment).

number of public services. The failure of an EDF⁵ transformer affects a much larger area than the area actually flooded; the same is true of all utility networks (telecommunications, district heating, drinking water, drains and sewers, etc.), and obviously, transport networks too (RATP⁶, SNCF⁷, together with bridges, roads and motorways). Like a house of cards collapsing, knock-on effects would spread the impacts of the flooding to areas far removed from those actually under water; the estimated costs of “indirect” damage constantly rise the more they are studied in greater detail.

3. Dam reservoirs and existing and planned defences

3.1 Localised defences: flood defence walls, embankments, etc.

Paris and its neighbouring *départements* are protected by flood defence walls and, in the case of neighbouring *départements*, embankments. Paris has also significantly raised the height of its quay walls. The level of protection afforded by these defences therefore varies. While most of the flood defence walls in the Val-de-Marne *département* have been raised to the level of the 1924 flood (almost a metre and a half below that of the 1910 flood), they do not secure the entire length of the Seine or the Marne and leave many points where water can escape from the river channel through pipes and conduits.⁸

Table 1. Degree of containment by river dykes

River valleys concerned	Historical flood levels	Period of flood cycle (in natural flow)
Seine in <i>départements</i> 77, 78, 91 and 95	1955	30 years
Seine in <i>départements</i> 92, 93, 94 and Marne valley in <i>département</i> 94	1924	30 years
Seine in Paris	1910	100 years
Marne in <i>départements</i> 77 and 93	1970	8 years
Oise	1926	40 years

3.2 Protection at the level of the Seine river basin: dam reservoirs

Dam reservoirs (Table 2) located at the head of the Aube, Marne, Seine and Yonne river basins help to reduce the level of floodwater upstream of the Paris region, in conjunction with natural flood attenuation areas (middle stretch of the Marne valley, La Bassée, etc.).

Table 2. Dam reservoirs in the Seine basin

Engineered defences	Year commissioned	Volume (cubic metres)	Surface area of river basin controlled
Pannecièrre-Chaumard (Yonne)	1949	80 million	220 km ²
Seine	1966	205 million	2 400 km ²
Marne	1974	350 million	2 950 km ²
Aube	1991	170 million	1 700 km ²

5. *Electricité de France* (French Electricity Board).

6. *Régie Autonome des Transports Parisiens* (Paris Transport Authority).

7. *Société Nationale des Chemins de Fer Français* (French Railways).

8. Most of the drainage and sewer networks are not fitted with check valves, as they are in countries where flooding is more frequent (e.g. Hungary).

If account is taken of the additional volumes of water supplied to the Seine reservoir lakes (Grands Lacs de Seine) by the Crescent and Bois-de-Chaumeçon dams (Yonne river basin) managed by EDF, the total volume amounts to 830 million cubic metres of water. The total volume of the 1910 flood amounted to several billion cubic metres of water (from 3 to 6 billion cubic metres of water according to estimates).

Every winter the dams attenuate small and medium-sized river floods and fill up to provide additional flow when water levels fall in the summer and early autumn. In the event of an extreme flood, these reservoirs, by reducing the height of the surge, should lower the level of the Seine to 60 cm below the height at which the Seine peaked during the 1910 flood in Paris (which should ostensibly make it possible to prevent a third of the damage caused during the 1910 flood). In addition, these reservoirs are located in the upper catchment of the basin and control merely 17% of the surface area of the basin. There are two scenarios, unfortunately all too realistic, in which the impact of the dam reservoirs would be diminished:

- further to a series of several periods of very heavy rainfall, several successive floods start to move down a given waterway: the first increase in river level due to flood water can be effectively reduced by filling the dam reservoir, but doing so will reduce its capacity to contain the increase in river level caused by the following floods;
- since they are designed to help maintain minimum water levels, dam reservoirs are half full in early March and are almost full by as early as April; as a result, their ability to reduce river levels at such times would be inadequate in the event of major river flooding late in the season, that is to say in early spring.

Other dam reservoir projects have been considered, for example the Saulx reservoir (or the Côte de Champagne lake), a dam to divert tributaries of the Marne, and a number of conventional projects, either open or on platforms requiring pumping stations near to, or on, the Yonne and its tributaries. These projects are no longer on the agenda. Engineering structures designed to slow down runoff dynamically are currently being studied, notably in the La Bassée sector in the Seine-et-Marne *département*. The aim is to create storage for floodwaters from the Seine upstream of its confluence with the Yonne in order to delay floodwater surges to prevent floodwaters from the two rivers reaching Paris at the same time. This system should make it possible to reduce the level of the Seine in Paris by 20 to 30 cm. Whether or not these defences will be compatible with wetland conservation remains to be seen once studies currently in progress have been completed.

To sum up, the defences currently in place provide effective protection against frequent floods and significantly lower the risks of larger floods and the associated damage. It would hardly seem possible under current decision-making procedures to contemplate making any particularly significant changes to this level of protection, even though efforts are being made to improve this system of defences.

4. Prevention by controlling land use

Besides the engineered defences designed to protect against the devastating effects of flooding, the most obvious way to protect against floods is to avoid building in floodplain areas and to preserve floodplains. This time work is at last well in hand on the preparation of flood risk prevention plans, and by the end of 2003 most of the areas at risk from the major rivers in the Ile-de-France region now have a plan that has either been approved or is in progress. Several *départements* have even moved on to second-generation plans either because additional studies have provided more detailed data (Val de Marne), or in response to a ruling by their administrative tribunal (as in the case of 8 communes in the Val d'Oise). The plan for Paris was approved in 2003, and the most recent plan is that for the Hauts de Seine (approved on 9 January 2004); the plan for Les Yvelines (first stage) has now reached under final discussion with local elected government officials.

These salutary measures, while reassuring (in that they avoid aggravating the situation), were taken once the areas at risk of flooding were already very highly developed; they do not fundamentally change the level of collective risk exposure.

5. Emergency preparedness

The authorities realised late in the day that major flooding of the Seine and its tributaries in the Ile-de-France region would be a national disaster which would plunge the country in a major state of emergency: there would be hundreds of thousands of refugees to shelter and feed for several weeks, the economy would grind to a halt, etc. If we simply consider the political repercussions of the heat wave in the summer of 2003, or those of the floods in Germany or the lengthy shutdown of the Prague underground system, there can be no doubt that an event such as the flood of 1910, apart from its dramatic immediate and direct impacts, would generate a huge political backlash that no government or municipal authority could possibly survive.

As noted earlier, it would be futile to imagine that there is any engineered defence which can substantially lower the risks; all that we can do is simply live with those risks. The only way forward is to reduce our vulnerability and improve our crisis management. We need to identify the functional weak points in the system and put in place an effective organisation to marshal the resources required. Specialised emergency plans are designed to address these concerns.

Some recommendations are simply common sense and call for measures whose costs, although high, still remain tiny compared with the benefits they would provide in the event of flooding. The RATP, for example, knows precisely which underground station entrances would need to be protected within three days of a flood warning being issued and how now implemented the emergency plan on which work first started in 1998. Under this plan, there are 400 access points to the RATP network that would need to be sealed off in the event of flooding; the plan nonetheless assumes that it would be physically possible to install such defences within the time allotted. Asking a question will give you an answer, and the answer is no, there would not be enough time unless the defences were pre-fabricated and stored at a suitable location, which was precisely what the RATP did in 2003. Telephone switchboards and critical EDF transformer stations have been identified in advance, all the public services know what procedures to implement in response to given increases in water levels, etc. It does not require much planning to realise that sensitive objects that cannot be rapidly transported should be transferred elsewhere (museum storerooms which in the event of a flood would have mobilised all the emergency resources available in Paris). The media have drawn public attention to the inadequacies and inconsistencies which translate a criminal lack of preparedness on the part of all public actors, and have had a salutary impact by forcing those actors to face up to their responsibilities.

It is without doubt one of the most difficult and complex exercises that exists in civil protection. The RATP, SNCF, RFF⁹, EDF, RTE¹⁰, France Télécom, GDF¹¹, Paris hospitals, social services, museums, prefectures, the authorities in charge of water, sewerage, waste collection and treatment, and the communes and *départements* concerned, not to mention the fact that the manpower provided by the army, on which the French government traditionally relies in such circumstances, has now been reduced by the ending of national service.

⁹. *Réseau Ferré de France* (French Rail Network).

¹⁰. *Réseau de Transport d'Electricité* (Electricity Transmission Network).

¹¹. *Gaz de France* (French Gas Company).

To be effective, flood warnings of more than the current 24 hours are needed. The aim of the new flood warning service due to put in place is to increase the forecasting time from the current 24 hours to 72 hours while maintaining the same degree of reliability, which is a perfectly realistic proposition.

It is difficult to place a figure on savings that such measures are likely to afford, but it is clear that a few tens of millions of euros spent on appropriate measures could reduce the material damage of a disaster by a quarter or a third, that is to savings running into billions of euros.

6. Current lack of appropriate defensive measures

The situation described above may be briefly summed up as follows:

- Despite substantial efforts to put defences in place, the greater Paris area is poorly equipped to cope with this foreseeable risk, which is both well documented and easy to assess;
- While this lack of appropriate defences is clearly due in part to the lack of foresight evident in the relatively recent extension of housing development to floodplain areas, it can basically be attributed to the fact that the entire conurbation is built around a river; in the case of the oldest infrastructure, the vulnerability of Ministerial buildings and the recent realisation that the major decision-making centres of the country are flooded in the event of a major rise in the level of the Seine, is not related to a recent colonisation of the 7th arrondissement;
- In this case, it is the complexity and vulnerability of modern urban systems and networks which turn what is, all in all, a tolerable situation into a humanitarian disaster;
- While admittedly the virtuous development measures and land use strategies that have been introduced are helpful and should be warmly welcomed, they will not have any significant impact on either the situation or the issues at stake;
- While work has begun on improving the suitability of the defences for urban networks and the emergency management system, most of the efforts that are needed to reduce the potential costs and socio-economic impacts of a flooding event have yet to be made and the economic efficiency of such efforts is both obvious and enormous.

What we therefore have before us is a lack of suitable defences at the:

- structural level: the perceived benefits of the successive development of floodplain areas have created a city which fails to occupy such areas in the proper manner; if we knew today how to rebuild that city, this is not the form of town planning that would prevail;
- functional level: the city still continues to operate without taking due account of the risk to which it is exposed and it artificially compounds the adverse consequences of flooding simply through its own inefficiency. The actors are now aware of this risk and are drawing up an action plan, but in 2004 the lack of appropriate defences is clear for all to see;
- organisational level: the lack of preparedness with regard to crisis management adds disorganisation and potentially inadequate decision-making to the vulnerability of urban systems; obviously, it is in this important area that major progress is expected to be achieved through the approach adopted.

7. Integrating the issue of climate change into the public decision-making process

The climate change posited in this context could feasibly be taken into account by adopting the following approach:

- Understanding the statistical trend in the times of weather that can produce this type of event is fraught with difficulty; all authors agree that the distribution of the results obtained from atmospheric water vapour models at the regional level and the large number of hydrological studies which “use climate model outputs” is undoubtedly premature at present; these issues will very probably become clearer over the next 5 years;
- Once modelled, the scenarios for climate change in the Seine basin will be taken into account in practical terms by modifying the structure, if not simply the parameters, of the stochastic process underlying the rainfall-runoff balance in the basin. This would modify extreme flow statistics and would also lead to a new breakdown of inputs in all intermediate situations, at which point the specifications for civil works would need to be reviewed and re-optimised. Higher water levels, or conversely severer droughts in summer, will necessarily impose different requirements with regard to reservoir filling in late spring, either increasing or relaxing the constraints on flood management;
- It would seem that the significant impacts of climate change will be felt within 15/25/50 years. In the meantime, reform of the common agricultural policy might perhaps have led to highly radical changes in land use and agricultural speculation, thereby changing the nature of requirements. Studies must take account of these important data beforehand.

At present, we are facing a critical lack of proper planning for a known contingency, a situation in which the measures that must be taken as a matter of urgency call for significant, and perfectly justified, efforts to be made compared with current practices. Any aggravation of this risk would simply make the relevance of such efforts that much greater and would have little impact on their nature. If the flood of the century were to start occurring every fifty years, would we today adopt a different approach to the planning of the measures to be taken? In theory yes, in practice no¹².

Let us take the case of major civil works. Increased drainage flows, and even more so an exceptional flooding event, would without question prompt the authorities to review current land use policy directions and to restart construction programmes for civil works not deemed timely at present. These possible decisions could therefore become socially essential, even though we are all aware that they only provide a partial answer. However, the fact that such works could become timely within 20 years does not change the way in which their timeliness is viewed today. At the very least, perhaps it might be prudent to set land aside now so that when the moment comes the use made of that land does not make expropriation even more complicated.

8. Conclusion

Lack of adequate defences is not an issue confined to the Third World. Paradoxically, what we are dealing with here is a rich and advanced urban system that is a victim of its own vulnerability to a risk it has not properly taken into account and what we find ourselves facing is a genuine problem of putting appropriate defences in place. This issue largely dominates, and will do for the next few years, the account that is taken of the potential impacts, which are still not easy to study in operational terms, of climate change.

¹². If that were the case, we would not be in our current state of flagrant unpreparedness.