OECD Reviews of Risk Management Policies

Seine Basin, Île-de-France: Resilience to Major Floods

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Foreword

One of government's key responsibilities is to ensure that large metropolitan areas are resilient to major risks, so as to guarantee the safety and welfare of the public and maintain public confidence. In the light of the Great East Japan Earthquake or the flooding associated with Hurricane Sandy in New York, governments, local authorities and civil society have become increasingly aware of the fragility of major urban centres when faced with a disaster and of the degree to which critical systems are interconnected. Within the framework of global debate on climate change, it is important to question the capacity of cities to adapt to extreme events. Flooding in the region of Île-de-France on the scale seen during the historic flood of 1910 could constitute a major shock and pose an unprecedented challenge to public policy. The Greater Paris project provides a unique opportunity to promote good practices in resilience to encourage sustainable development.

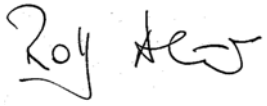
This review was conducted as part of the OECD High Level Risk Forum (HLRF) by the OECD Directorate for Public Governance and Territorial Development. This review is part of a series examining risk management policies and follows on from surveys conducted in Mexico, Italy and Japan. It offers an evidence-based analysis and public policy recommendations to enhance prevention of the risk of the Seine River flooding in Île-de-France. It involved an inclusive and open dialogue with all stakeholders in Île-de-France, allowing an exhaustive, innovative and precise assessment to be proposed that draws on OECD expertise in the areas of economics, governance and risk management; as well as on the experience of other OECD countries on these issues, in particular Denmark, the Netherlands and the United Kingdom.

According to the results of this review, a major flooding of the Seine River in Île-de-France could affect up to 5 million residents, particularly as a result of the effects on critical infrastructure networks. Economic damage has been estimated at between EUR 3 billion and EUR 30 billion for direct damage together with a significant macroeconomic impact on employment, growth and public finances. The outcomes bear witness to the contributions obtained through an innovative approach to risk modelling. The review also identifies obstacles to implementing ambitious prevention policies and proposes ways of overcoming them.

Furthermore, this report also notes the progress made and the many tools employed in risk prevention in France that could contribute to the best practices identified by the OECD. The key is to resolve the governance challenges to bring about fully effective implementation and a lower flood risk in Île-de-France. The complex governance of this strategic region has been affected by the various layers of decentralisation that make the implementation of horizontal policies difficult.

Today there is a dynamic underway to improve governance. Long-term investment projects are envisaged for the region under the Greater Paris project. A transparent, recognised approach to the question of risks will help draw maximum advantage from the opportunities that arise. The review offers policy-making guidelines for the future to enhance flood risk prevention in Île-de-France: development of the risk culture among the general public, companies and decision makers; innovation in urban areas to foster resilience; and promoting a consistent financial approach based on economic efficiency, consideration for the long term and equity in funding.

This review makes a number of recommendations that the French authorities may wish to consider for setting up an ambitious strategy to manage the risk of the Seine River flooding in Île-de-France. The OECD stands ready to continue to support the French government in formulating better risk management policies for better lives.



Rolf Alter

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and Territorial Development

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The OECD review team benefited from the expertise and insights of three international experts (peers) in flood risk management from other OECD member countries, namely Richard Ashley (University of Sheffield, United Kingdom), Ingwer de Boer (Ministry of Infrastructure and the Environment, Netherlands) and Michael Havbro Faber (Technical University of Denmark, Denmark). The team's expertise in risk management was consolidated by the participation of Pierre-Alain Schieb.

This peer review of risk management policies was produced under the auspices of the High Level Risk Forum, which has validated and approved the report's recommendations and principal conclusions, under the direction of Rolf Alter, Director of the Public Governance and Territorial Development Directorate. The project was managed by Charles Baubion, the report's principal author, under the supervision of Stéphane Jacobzone, Deputy Head, Reform of the Public Sector. Jack Radisch, Project Manager, High Level Risk Forum, provided direction and guidance throughout the process.

The OECD Secretariat is particularly grateful to all members of the Seine Grands Lacs EPTB team who paved the way for the collection and analysis of information and enabled various consultative meetings to be held with stakeholders. The OECD Secretariat also thanks the many stakeholders (see Annex A) in Île-de-France for their openness and availability: the representatives of the state both at the national and local level, representatives of local government, the region, the *départéments*, the City of Paris and the other municipal authorities involved, representatives of business in both the public and private sectors, as well as non-governmental organisations. Their participation at the launch of the project on 15 March 2013, in interviews with the peers in May 2013 together with the dialogue on the recommendations to the OECD of 17 September 2013 and their replies to the OECD questionnaire made it possible to collate all of the information necessary to carry out this project.

The economic analysis in the report was developed in partnership with the OECD Economics Department, in particular Balazs Egert at the France Desk, who oversaw the development of the macroeconomic model designed by Christian Siegel (University of Exeter). Catherine Gamper also provided valuable support on the methodology. The information supplied by network operators (RTE, RATP, SNCF, Eau-de-Paris, SEDIF, Orange), the Regional and Interdepartmental Environment and Energy Directorate, the Paris Police, the Central Reinsurance Fund and AXA was fundamental to the assessment. French experts who took part in the meeting held at the OECD on 17 October 2013 led to

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Additional research and analysis was conducted by Juliette Le Pannérer. Lia Beyeler and Sophie Limoges also provided valuable assistance that helped bring it to publication. Kate Lancaster provided editorial review and Jennifer Allain revised the English translation and prepared the manuscript for production.

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Acronyms and abbreviations

AESN	Seine-Normandy Water Agency *Agence de l'Eau Seine-Normandie*
AFPCN	French Association for the Prevention of Natural Disasters *Association Française de Prévention des Catastrophes Naturelles*
CATNAT	Compensation scheme for natural disasters
CCI	Chamber of Commerce and Industry
CCR	Central Reinsurance Fund (French state-owned reinsurance company) *Caisse Centrale de Réassurance*
CDSE	Business Security Directors' Club *Club des Directeurs de la Sécurité des Entreprises*
CDT	Territorial development contract *Contrat de développement territorial*
CEPRI	European Center for Flood Risk Prevention *Centre européenne de prevention du risque d'inondations*
CGDD	General Commission for Sustainable Development *Commissariat Général au Développement Durable*
CMI	Joint Flood Commission *Commission Mixte Inondation*
COGIC	Operational Centre for Interministerial Crisis Management *Centre Opérationnel de Gestion Interministérielle de Crises*
COPRNM	National Policy Board for the Prevention of Major Natural Hazards *Conseil d'Orientation pour la Prévention des Risques Naturels Majeurs*
CPER	State-region planning contract *Contrat de plan État-région*
DATAR	Interministerial Delegation for Territorial Development and Regional Attractiveness *Délégation Interministérielle à l'Aménagement du Territoire et à l'Attractivité Régionale*
DBSN	Seine-Normandy Basin Delegation *Délégation de Bassin Seine-Normandie*
DDT	Departmental Directorate forTerritorial Planning *Direction Départementale des Territoires*

DGPR	Directorate-General for Risk Prevention *Direction Générale de la Prévention des Risques*
DICRIM	Municipal information document on major risks *Document d'information communal sur les risques majeurs*
DRIEA	Regional and Inter-departmental Directorate for Infrastructure and Development *Direction Régionale et Interdépartementale de l'Équipement et de l'Aménagement*
DRIEE	Regional and Inter-departmental Directorate for the Environment and Energy *Direction Régionale et Interdépartementale de l'Environnement et de l'Énergie*
DRIHL	Regional and Inter-departmental Directorate for Accommodation and Housing *Direction Régionale et Interdépartementale de l'Hébergement et du Logement*
EGT	Global Transport Survey *Enquête Globale Transport*
EP Loire	Loire River Basin Authority *Établissement Public Loire*
EPAORSA	Orly-Rungis Seine Amont Public Development Authority *Établissement Public d'Aménagement d'Orly-Rungis Seine Amont*
EPCI	Public agency for co-operation between local authorities *Établissement public de coopération intercommunale*
EPTB	Local public river basin authority *Établissement public territorial de bassin*
EPTB SGL	Seine Grands Lacs Local Public River Basin Authority *Établissement Public Territorial de Bassin Seine Grands Lacs*
ERDF	French electricity distribution network operator *Électricité Réseau Distribution France*
ERDF	European Regional Development Fund
FPRNM	Fund for the Prevention of Major Natural Hazards, or "Barnier Fund" *Fonds de Prévention des Risques Naturels Majeurs*
GDP	Gross domestic product
GIS	Geographic information system
HKWL	Highest known water level
HRA	High flood-risk area *Territoire à risque important d'inondation*
IAU	Institute for Urban Planning and Development of the Île-de-France Region *Institut d'Aménagement et d'Urbanisme d'Île-de-France*

IGN	French National Geographic Institute *Institut Géographique National*
INSEE	National Institute of Statistics and Economic Studies *Institut National de la Statistique et des Études Économiques*
MEDDE	Ministry of Ecology, Sustainable Development and Energy *Ministère de l'Écologie, du Développement Durable et de l'Énergie*
NPV	Net present value
ONRN	National Observatory for Natural Hazards *Observatoire National des Risques Naturels*
ORSEC	Disaster and Emergency Response Organisation *Organisation de la Réponse de Sécurité Civile*
PAPI	Flood prevention action programme *Programme d'action et de prévention des inondations*
PCA	Business continuity plan *Plan de continuité d'activité*
PCS	Local emergency response plan *Plan communal de sauvegarde*
PFRA	Preliminary flood risk assessment
PGRI	Flood risk management plan *Plan de gestion des risques d'inondation*
PLU	Local urban plan *Plan local d'urbanisme*
PPCI	Flood protection plan *Plan de protection contre les inondations*
PPR	Risk prevention plan *Plan de prévention des risques*
PPRI	Flood risk prevention plan *Plan de prévention des risques d'inondation*
PSR	Rapid flooding plan *Plan submersions rapides*
RATP	French state-owned public transport operator in Paris *Régie Autonome des Transports Parisiens*
RFF	French rail network *Réseau Ferré de France*
RTE	French electricity transmission system operator *Réseau de Transport d'Électricité*
SDAGE	Water development and management master plan *Schéma Directeur d'Aménagement et de Gestion des Eaux*
SDRIF	Île-de-France Regional Master Plan *Schéma Directeur Régional d'Île-de-France*

SEDIF	Île-de-France Region Water Authority *Syndicat des Eaux d'Île-de-France*
SGZDSP	General Secretariat of the Paris Defence and Security Zone *Secrétariat général de la Zone de Défense et de Sécurité de Paris*
SLGRI	Local flood risk management strategy *Stratégie locale de gestion des risques d'inondation*
SME	Small and medium-sized enterprise
SNCF	French National Railway Company *Société Nationale des Chemins de Fer*
SNGRI	National Flood Risk Management Strategy *Stratégie Nationale de Gestion des Risques d'Inondation*
STIF	Île-de-France public transport authority *Syndicat des Transports d'Île-de-France*
VNF	French Inland Waterways *Voies navigables de France*
WFD	Water Framework Directive

Executive summary

A major flood of the Seine River, similar to the historic event of 1910, is an important challenge for public policy. The economic, social and human issues at stake are considerable, given the large scale and high vulnerability of the floodplain and because the Paris – Île-de-France region is the principal economic hub in France. Over the last decade, many countries have experienced floods beyond historic records (Prague in 2002, the United Kingdom in 2007, Australia in 2011, Bangkok in 2011, New York in 2012, Germany in 2013). At the same time, vulnerabilities of modern societies and megacities in particular have steadily increased, calling for considering this major risk and its implications in all its multiple dimensions. As the economic impact of a major Seine flood could be significant on national output, it appears important to question the level of protection and the resilience of the Paris metropolitan area with an international perspective. This calls for a collective and voluntary reflexion on flood risk management policies in the Ile-de-France region.

This analysis is supported by an innovative flood risk assessment approach that considers the macroeconomic impacts that could be caused by a Seine flood in Île-de-France. This assessment integrates the different cascading impact of such a major shock through the networks of critical infrastructures that are sustaining the Paris metropolitan functions. The macroeconomic effects on the national economy of different flood scenarios provide an indication of the issues at stake. In terms of public policies, this review concentrated on the reduction of the risk over the medium to long term through prevention efforts and resilience and vulnerability reduction measures. It addresses the key governance issues related to flood risk prevention in Île-de-France. It analyses the different structural and non-structural prevention measures and their effective implementation to strengthen resilience in the region, and looks in depth at existing and potential financing mechanisms for the prevention of this major risk. The review shows overall that an effort to recalibrate, better co-ordinate and refocus public policies would decrease the consequences of the risk. It proposes new avenues for public policies to the French authorities that could support an ambitious integrated strategy for the management of the Seine flood risk in the Île-de-France region

Despite investments in protection, increasing urban development and the interdependence of critical infrastructures have accentuated vulnerability

The probability of a major Seine flood similar to that of 1910 cannot be neglected given the population and assets nowadays located in the floodplain and their vulnerabilities. If protection levels have increased since 1910, investments in infrastructures have been limited over the past decades. It appears that protection levels are not up to the standards of many other comparable OECD countries, particularly in Europe. In the meantime, exposure and vulnerability have significantly increased along

with the massive urban development in Île-de-France and the increased interdependencies of critical infrastructures. A major flood could affect directly or indirectly up to 5 million people and thousands of businesses. It could severely disrupt the continuity of the state and many institutions as well as most of the networks of critical infrastructures (e.g. electricity, transport, communication, water) that are sustaining the largest metropolitan area of continental Europe. Given the hydrological conditions of the Seine basin, the effects of the flood could last over three months. There are in consequence major issues for public policies at stake, not only at the regional but also at the national level.

The macroeconomic impact of a major shock could be significant in terms of GDP, employment and public finances

Direct damages of different flood scenarios centered around the 1910 flood were estimated between EUR 3 billion and EUR 30 billion. Beyond direct damages, a large-scale shock could have important macroeconomic impacts on gross domestic product (GDP) growth with effects on the job market. The macroeconomic model shows a significant reduction in GDP which, over five years, could reach EUR 1.5 billion to EUR 58.5 billion, i.e. a consolidated total of 0.1-3%. The resulting contraction in business activity could have a significant effect on the demand for labour; up to 400 000 jobs could be lost in the worst case scenario. Even if a rebound in business activity could rapidly reduce some of these effects after a year, the harmful consequences of a major Seine flood could be felt over the medium to long term and weigh on public finances. In the case where the impact exceeds the reserves available through the national catastrophe compensation regime CATNAT and the Central Reinsurance Fund, the state could be called on to fully assume its role of ultimate guarantor.

Opportunities are emerging today to address gaps in governance that should be seized to better prevent flood risk

Well-identified governance deficits have affected the design and implementation of flood prevention policies commensurate to the risk level in Île-de-France. These gaps could be filled if opportunities are properly seized. The institutional context has not favoured the emergence of an ambitious and coherent strategy for preventing this risk. The fragmented institutional framework in Île-de-France has been, in the past, a restraint on action. Resulting from successive waves of decentralisation. this institutional and territorial fragmentation has not enabled the proper articulation of the different sectors of public policies for effective flood prevention (e.g. water policy, territorial and urban planning, crisis management).

The response to the major risk of a Seine flood in the Île-de-France region should be based on a revised governance framework. A more transversal and multi-level approach should aim to better align public policies to improve resilience. The on-going implementation of the European flood directive and the development of the Greater Paris project are offering a unique opportunity to revive the policy debate and promote innovative approaches.

A coherent resilience strategy at the metropolitan scale could take advantage of synergies between the different prevention measures

The only way of reducing the Seine flood risk in the Île-de-France region is by means of practical measures aimed at increasing the territory's resilience. A broad range of measures contributes to preventing this flood risk, even if a certain diversity predominates. Whether these measures are regulatory or voluntary or are ensured by the state, local authorities, the public or businesses, this overview highlights the many opportunities for improvement. These opportunities relate to risk awareness and culture, resilience of communities, public services or businesses and hazard mitigation measures like protective or storage infrastructures. .

Positive synergies leading to greater resilience have been identified and could be further exploited. This includes the incorporation of resilience into the development policies of the Greater Paris project, better linking the on-going development of a water culture and the culture of risk, strengthening the alignment between prevention and crisis management policies or the increasing awareness of businesses and network operators. This review also shows that the existing protective and water storage infrastructures are reaching their limitations. At a time when a new hazard mitigation project is proposed, key questions related to the financing of prevention, the prioritising of actions, ensuring equity or the governance of these complex choices should be responded. The local flood management strategy currently under development is an opportunity to organise prevention measures as a whole and prioritise them in a coherent approach to improve resilience also based on innovation.

How to finance resilience within a constrained budget context?

Funding the preventive actions required to increase the level of resilience remains a major issue. Within a context marked by under-investment in the past, and current difficult economic conditions, investment in prevention is made under pressure, in view of the tight fiscal environment and the necessity to decide priorities in public spending both at the level of the state and the local governments.

If specific tools to finance prevention exist in France, particularly through the disaster compensation regime CATNAT, the system is faced with growing demands and has had a limited contribution to reducing the flood risk from the Seine in Île-de-France. Other strategic priorities have mobilised authorities and the available prevention funds in other regions. This led to a certain delay in funding the prevention of this major flood risk which represents a significant share of the total losses caused by flood risk in France. Up to now, the national allocation of resources has not been based on criteria giving priority to resources according to the level of risk. This is changing with the implementation of the EU Floods Directive which identified the most risk-prone territories, of which the Paris metropolitan area is one. There is room for progress in defining a financing approach for prevention which is adapted to the issues at hand. In the context of strained public finances, the question of additional resources and the sharing of efforts (state, local government, businesses, citizens, European funds) may be addressed by setting out a number of principles for an overall financing strategy. The general principle is that the beneficiaries of prevention measures should be the first to finance prevention.

Identification of the beneficiaries helps to determine the primary sources of funding to be raised for such a strategy. Prevention funding must aim at being most effective through an economic approach based on coherency, cost-effectiveness, long term and equity.

OECD recommendations for better Seine flood risk prevention policies in Île-de-France

Increasing the resilience of Île-de-France region to Seine floods requires additional efforts to anticipate and invest in order to better limit this major risk. The objective to strengthen the capacity of the Île-de-France ecosystem to rapidly restore its basic capacities and functionalities from a social and economic perspective. This review highlights several policy options and lines of action that the French authorities may wish to integrate in an ambitious comprehensive strategy for Seine flood risk management in Île-de-France:

- Ensure the appropriate linkages between the various levels of flood prevention– from the exposed Île-de-France metropolis to the river basin.
- Define an ambitious and mobilising global vision over the long term together with actionable principles.
- Break-down the global vision into precise objectives and make the stakeholders aware of their responsibilities.
- Create effective gateways between the flood risk management strategy and related public policies.
- Continue to improve and harmonise risk knowledge and ensure that risk information is made available.
- Reinforce the risk culture of citizens, decision makers and companies.
- Improve territorial resilience, using the opportunities offered by the Grand Paris project.
- Gradually improve the resilience level of critical networks and take steps towards preserving the continuity of business and public services.
- Place the flood protection infrastructures under the responsibility of a single contracting authority.
- Encourage experimentation with regard to the La Bassée storage project.
- Support the local of Seine flood risks management strategy in the Île-de-France by a clear financial strategy.
- Mobilise all the beneficiaries of preventive measures in a multi-level approach.
- Strengthen efforts to clarify the priority criteria for prevention funding from state resources.
- Re-examine the impact of the CATNAT compensation scheme on flood risk prevention.

Assessment and recommendations

Impacts of a major flood of the Seine River in the Île-de-France region

A historic reference: The great 100-year flood of 1910

While the possibility of a major flood of the Seine River may initially seem remote, it comes back regularly and arouses public attention, as was the case during the spring of 2013 when floods took place upstream of the Seine River basin. Even though the flooding did not cause any major damage, it revived the issue of risk management and the region's vulnerability to flooding. The prospect of a historic event is a key concern for French risk management stakeholders. The 1910 flood was particularly destructive in the context of an era marked by industrial and technological progress. Such events illustrate the difficulties societies have in striking a compromise between economic development and managing the increased vulnerabilities of social and economic stakeholders.

In 1924 and 1955 major flood events were seen in the Paris region and in the entire Seine basin. Nevertheless, the lack of a significant flood for more than the past 60 years has lessened the collective memory. Seine floods are characterised by their slow progression and as a result the period of submersion may be very long. For instance, the waters took almost two months to recede in 1910. Even if the effect of climate change on the frequency and extent of the Seine River floods is still uncertain, greater floods than the one of 1910 are still possible, such as the one that occurred in 1658. In other countries, many recent floods have significantly exceeded the 100-year levels. This was the case with the floods in Queensland, Bangkok and Pakistan; as well as during the coastal flooding following Hurricane Sandy in New York, and the 2013 floods in Germany. The EU Floods Directive uses the 1 000-year frequency as a reference for extreme events.

Despite investments in protection, increasing urban development and the interdependence of critical infrastructures have accentuated vulnerability

Since the 100-year flood, the risk of a flood of the Seine River in the Île-de-France region has been reduced in various stages by protective structures, including dams built upstream and river development starting in the 1920s, then in the 1950s up until the early 1990s. Major investments have been limited in the last decades, and it appears that protection levels are not up to the standards of many other comparable OECD countries, particularly in Europe. On the other hand, the exposure to risk and the resulting vulnerability are accentuated by increasing urban density in the leading economic area of France, as well as by the construction of a large number of industrial areas and critical infrastructures (transport, energy, communications, water) along the Seine River. The interdependence of these networks; the interpenetration of production lines and their "just-in-time" operation; the key role played by the mobility of people and exchange in a dynamic economy; urban development and the concentration of populations and capital

are just a few of the many factors which increase modern societies' vulnerability to shocks. Today, these elements justify the importance of an assessment approach in this field in order to re-examine the related public policies.

Today a major Seine flood would have important potential impacts on well-being and on the activities of the government and businesses

The Île-de-France region represents about one-third of the economic activity in France, the second largest economy in the euro area. The seat of the government and major industries are located there, as well as the main decision making and research centres. It represents a large logistics hub for the whole French economy. In the most extreme case, a Seine flood in the Île-de-France region could have direct and indirect impacts on almost 5 million people and a large number of businesses, with significant economic, human and social effects. It could disrupt the functioning of the government and many institutions, as well as most of the infrastructures and critical networks that ensure the daily functioning of the Paris metropolitan area.

The distribution of electricity could be largely affected, with almost one-quarter of power sub-stations flooded or cut off as a precaution and more than 1.5 million customers could experience power cuts. Public transport could be affected with almost 140 kilometres of the 250-kilometre underground network closed as a precaution. The road network could be blocked at many points: the closing of the bridges crossing the Seine, due to their weakened structure, would make it impossible to travel from the right to the left bank. The drinking water supply could be interrupted around Paris where more than 5 million clients could suffer extended water cuts and 1.3 million a deterioration in quality.

The debate on such impacts must examine the sector's interdependencies, for instance, between the critical networks (energy, communications, water, transport) and the large industrial and service sectors. A major flood could affect key sectors such as tourism or food distribution, or the car industry. The issues are therefore major at the national level. Accordingly, preparing for a possible Seine flood and reducing the risk, is an important, complex and sensitive issue for public policy.

The macroeconomic impact of a major shock could be significant in terms of GDP, employment and public finances

Assessments of the economic impacts of various flood scenarios centered around the 100-year flood of 1910 show that a large-scale shock could have a significant macroeconomic impact in terms of gross domestic product (GDP), with repercussions both on employment and public finances. These could come under severe pressure with corresponding deterioration over a long period. According to flood scenarios, the damage from such a catastrophe has been estimated at between EUR 3 billion and EUR 30 billion for direct damage, together with a significant reduction in GDP which, over five years, could reach EUR 1.5 to EUR 58.5 billion, i.e. a consolidated total of 0.1% to 3%. The resulting contraction in business activity could have a significant effect on the demand for labour; up to 400 000 jobs could be lost in the worst case scenario. Even if a rebound in business activity could rapidly reduce some of these effects after a year, the harmful consequences of a major Seine flood could be felt over the medium to long term and weigh on public finances. In the case where the impact exceeds the reserves available through the national catastrophe compensation regime CATNAT and the Central

Reinsurance Fund (*Caisse Centrale de Réassurance*, CCR), the state could be called upon to fully assume its role of ultimate guarantor.

Even if these effects are significant, it should be emphasised that this analysis is an exploratory one, and that it does not implicate a systemic risk with irreversible effects: a variety of budgetary response mechanisms could be rapidly put in place – if they are foreseen and planned in advance. Nevertheless, there is considerable uncertainty and the effects could also be accentuated by the impact of a flood on the rest of the Seine River basin.

Ambitious prevention policies could boost the resilience of Île-de-France in the long term

In light of these issues, such a situation is in no way inevitable: an effort to recalibrate, better co-ordinate and refocus public policies would decrease the consequences of the risk whilst increasing resilience. Apart from longstanding investments made over the last century, additional foresight and investment efforts may enable better management and containment of the risk. The aim is to increase the capacity of the Île-de-France ecosystem to restore its functional capacities rapidly, in both human and economic terms. Given the risks incurred, but also the potential opportunities, a re-examination of the public policies in this sector would appear necessary, whether in terms of crisis management – essential for the authorities – or the prevention policies given in detail below.

Policies for preventing and reducing the vulnerability to such a risk may enable the resilience of the Île-de-France region to be strengthened, commensurate with its resources and economic advantages. The recommendations of this study address the following three concerns:

- governance of flood risk prevention
- resilience measures for the Île-de-France region
- financing prevention.

Governance of flood risk prevention of the Seine River in the Île-de-France region

Towards a shared strategy: Efficient distribution of roles and responsibilities

The response to the major risk of the flooding of the Seine in the Île-de-France region should be based on an appropriate governance framework aiming to organise public policies to improve resilience. Experience in other OECD countries shows that risk management requires the co-ordination of a large number of organisations and resources at various administrative levels, from the private sector and civil society. For each of the phases of the risk management cycle, a robust legal and institutional framework together with well-defined governance mechanisms are necessary to enable an integrated approach for risk management. Hence, an effective prevention policy must be based on a clear definition of the obligations of each stakeholder , supported by incentive and sanction mechanisms to effectively reduce exposure and vulnerability. The key elements of good governance concern the coherence of the legal and regulatory framework and of institutions' mandates to contribute to an established and shared strategy, as well as co-ordination and effective co-operation between the various stakeholders for its implementation. This includes questions of vertical coherence – between the various

administrative levels – and horizontal coherence – between the various spheres of public policy – in the distribution of roles and responsibilities, avoiding duplications of effort and favouring synergies.

The institutional context has not favoured the emergence of an ambitious and coherent strategy for preventing Seine River floods in Île-de-France

Despite a progressive body of legislation (Laws of 1982, 1995 and 2003) and an exemplary set of regulatory, financial and contractual tools (risk prevention plans, CATNAT insurance regime, prevention funds, flood prevention action programmes) for the prevention of risks at the national level, the Seine flood risk in the Île-de-France region is managed within a fragmented framework resulting from successive waves of decentralisation. Despite the risks faced by the region, this has partially hampered the emergence of a global shared vision on flood risk management. The lack of an overall vision in this strategic territory – contrary to other major French rivers such as the Loire or the Rhône – reveals a governance weakness, even if awareness of the issues at stake is emerging. The tools developed at a national level in the past struggled to find a practical and effective application in this region with extraordinary issues at stake.

The institutional fragmentation has been, in the past, a constraint on action

With the prospect of establishing a holistic strategic framework for managing the risk of floods of the Seine River, a particularly acute question of governance is raised in Île-de-France. The institutional and territorial fragmentation in flood prevention results in poor governance, particularly among the various administrative levels. As a rule, in France, mayors and prefects are solely responsible for managing risks, both with regards to prevention and crisis management. In the case of the Île-de-France region, its specific nature and resulting institutional characteristics add another layer of complexity to decision making. The large number of stakeholders involved, whether national, regional, departmental, municipal or metropolitan, makes it difficult to ensure synergies between the various administrative levels.

Apart from questions of multi-level co-ordination, territorial disparities prevent the emergence of a shared vision. Competing views may in fact appear between Paris and its suburbs, the west and the east of the territory at risk, the urban area and the peri-urban and rural areas. Each of these areas has different levels of exposure. Their technical, financial and human capacities to implement public policies independently also vary.

Overcoming administrative fragmentation to facilitate interaction between various public policies

Beyond questions of horizontal and vertical co-ordination between the various administrative levels, there is also a need to address several areas of public policies which contribute to the various dimensions of flood risk prevention. Each of these policies involves specific stakeholders, different territorial sensibilities, as well as different approaches, which may be in conflict or confront each other. Up to now, isolated approaches have often prevailed. The various policies include:

- The risk prevention policy conducted by the Ministry of the Ecology, Sustainable Development and Energy (*Ministère de l'Écologie, du Développement durable et de l'Énergie*, MEDDE) and its decentralised structures in the Île-de-France region.

- The crisis management policy of the Ministry of the Interior (and its Prefecture de Police – Paris Defence area), with a large number of stakeholders in the Île-de-France region.
- The territorial development and planning policy in which the region plays a key role as well as governance at the local level through town planning.
- The water management policy and its institutions, including the Seine-Normandy Water Agency (*Agence de l'Eau Seine-Normandie*), which plans and finances the conservation of water resources in the Seine basin, and the Seine Grands Lacs Local Public River Basin Authority (*Établissement Public Territorial de Bassin Seine Grands Lacs*, EPTB-SGL), an operational stakeholder which historically manages four large dams upstream of the Seine basin with the double objective of combating floods and supporting low water levels.

Well-identified governance deficiencies can be overcome…

The governance of flood risk management and prevention in Île-de-France appears to be very complex. Because of their dispersion, existing efforts cannot be fully effective. The inadequate distribution of responsibilities and resources among stakeholders at various levels has prevented the emergence of a coherent leadership as well as a common vision with shared objectives for the prevention of flood risk. Strategic planning documents on the Seine basin, on the river development or on the development of the Île-de-France region up to now have not allowed for a genuine multi-stakeholder approach or to align the various initiatives on a common strategy for flood risk prevention. Only work undertaken by the General Secretariat of the Defence Area (*Secrétariat Général de la Zone de Defence*) on crisis management has been able to unify metropolitan stakeholders on the development of an emergency response plan.

The appropriate linkage between the two spatial scales, that of the river basin for work on the hazard side, and that of the metropolitan area's exposed area for work on the vulnerability reduction side, is a condition for the successful implementation of effective prevention policies. Furthermore, despite the involvement of a large number of stakeholders, there is no criterion that makes it possible to assess the respective contributions of the preventive measures undertaken by each stakeholder. This lack of performance assessment increases the difficulty in efficiently allocating responsibilities and resources for risk prevention. Subsidiarity, local ownership, monitoring and evaluation of the measures undertaken, as well public engagement and participation in decision making are the principles of good governance which would enable increased responsibility and accountability of the various stakeholders.

… by seizing opportunities that arise, particularly from the Grand Paris project and the EU Floods Directive

Today there is on-going momentum on flood risk management with the implementation of the European Directive on assessing and managing flood risks, for which 2013-15 is a key period: a national strategy on the management of flood risks is being developed and a priority area for flood risk management in the Île-de-France region was recently defined. Comprised of 141 municipalities, this high-risk flood area (HRA) seems to be the appropriate scale to address issues of vulnerability. A flood risk management strategy must be developed by 2015 for this HRA, together with a governance mechanism for its implementation. This is being established, under the

auspices of the state, through a partnership between both prevention and crisis management actors. Local stakeholders such as the EPTB Seine Grands Lacs will be associated to this partnership within its area of jurisdiction. Furthermore, a Flood Prevention Action Programme (*Programme d'Action pour la Prévention des Inondations*, PAPI) was also prepared by the EPTB Seine Grands Lacs and local stakeholders, which anticipates substantial work on the hazard control side and additional actions on the vulnerability of the Île-de-France urban area.

Opportunities are also arising to incorporate resilience into the Grand Paris (Greater Paris) development project. This long-term investment project (transport networks, metropolis status, territorial development contracts) makes it possible to tackle the issue of flood risk at the scale of the Île-de-France urban area and to take major urban projects into account. These opportunities could make it possible to engage the region in an ambitious and long-term resilience approach largely shared with all the stakeholders. Opportunities for the development of the Greater Paris development project in the coming decades can be fully met through a transparent and responsible approach to risk management questions.

Recommendations on the governance of flood risk

1. Ensure the appropriate linkages between the various levels of flood prevention – from the exposed Île-de-France metropolis to the river basin. This will mean engaging a differentiated approach with the stakeholders at the local level in the Île-de-France risk basin, and the upstream territories by means of a partnership from which they will also benefit, and which can also draw on the implementation of the EU Floods Directive. The governance structure envisaged between the state and the local contracting authorities at sub-basin level should be thoroughly explained to the local authorities and benefit from current developments in decentralisation reforms to become well-established locally.
2. Define an ambitious and mobilising global vision over the long term together with actionable principles. This global vision should be consistent with the ambitions of the Greater Paris project and will enable public decision makers and citizens to mobilise beyond the regulatory obligations of the European Directive and risk management policy. The principles for action in the National Strategy for the Management of Flood Risks may be adapted and formulated at the risk basin level (pooling risks, minimising the moral hazard, proportionality of the costs and benefits, subsidiarity and role of the state, adaptability).
3. Break down the global vision into precise objectives and raise stakeholders' awareness of their responsibilities. The local strategy's operational objectives and those of the PAPI should be aligned with each other and with this long-term vision. Economies of scale and greater effectiveness may be achieved by redefining stakeholders' roles and responsibilities, as their numbers and diversity make co-ordination and efficiency more complex. The definition of performance criteria should make it possible to analyse the respective contributions made by the various stakeholders towards flood risk prevention; to monitor the performance of the various initiatives set up; and to establish more rational distributions of responsibilities and resources.
4. Create effective gateways between the flood risk management strategy and related public policies. This involves incorporating the risk of floods in a multi-hazard approach with other aspects of resilience for the development of the Greater Paris project (environment, green economy, well-being). This also means ensuring that the various initiatives and sectoral policies (water management, regional planning) actually incorporate the issue of flood risk management with a view to creating synergies and sharing benefits.

Increasing the resilience of Île-de-France by flood risk prevention

Structural and non-structural prevention measures

The only way of reducing the Seine flood risk in the Île-de-France region is by means of practical measures aimed at increasing the territory's resilience. Even though re-examining governance will allow a vision, objectives and major principles of a flood management strategy to be defined, its implementation should take shape at the local level (in the upstream basin, in exposed territories, in public and private planning and development projects, within companies) in two major areas of actions: hazard control and vulnerability reduction. Structural measures aimed at limiting risk exposure by building infrastructure were given priority in the past. Their financial, social and environmental limits are now leading towards risk control approaches that are more aligned with environmental protection. Reduced vulnerability can also be achieved through non-structural measures. It is fundamental that risk knowledge and awareness be developed to create a culture of risk as a condition for action at all levels. Increasing territories' resilience may be based on a more balanced urban development which incorporates the flood risk appropriately. This includes the question of the critical networks and infrastructures whose vulnerability to floods results in the multiplication of catastrophic effects. On a wider scale, the resilience of firms and individuals should also be developed, for instance through approaches aimed at business continuity.

Synergies between preventive measures could be optimised through a coherent resilience approach

A wide range of measures play a role in preventing the risk of a Seine flood in the Île-de-France region, even if their application is very heterogeneous. Whether these are regulatory or voluntary, set up by the state, local authorities, citizens or firms, opportunities for improvement and numerous synergies could be better optimised in the following areas: risk awareness and culture, territorial resilience, public services and firms, and the options for reducing hazard through protective measures. This includes, in particular, incorporating resilience in policies for the Greater Paris project development; the link between the river culture and the risk culture; the river bank restoration processes and reinforcement of protective infrastructures; and a closer relation between risk prevention policy and crisis management, or the recovery of the hydro systems' flood buffer functions with a view to protecting the environment. The local flood management strategy being developed in Île-de-France is an opportunity to organise all the prevention measures and to establish priorities in a coherent approach towards an ambitious resilience plan for the metropolis.

Risk awareness is progressing thanks to the harmonisation of approaches

Risk awareness is growing and the ongoing harmonisation of approaches will in time allow all the actors involved in risk prevention to have the information enabling them to act coherently. Up to now, the multiplicity of approaches, tools and standards for assessing risks have played their part in causing confusion, preventing stakeholders from coming to agreement on similar results, with each of them tending to develop their own evaluation methods. The current process of sharing and harmonising awareness among the actors in risk prevention and crisis management – including network operators – as well as developing an accurate mapping of the risks with the implementation of the European Floods Directive, allows one to envisage having the tools required to devise

and make a detailed assessment of all the preventive measures. This could be continued with other stakeholders such as the insurance sector, in a consistent comprehensive risk assessment approach, particularly from an economic standpoint. The questions of probability, improved damage functions and evaluating floods by the groundwater level are all subjects for which increased knowledge and closer relations would be relevant. Initiatives carried out at the national level can contribute to improving this situation, particularly by the creation of the National Observatory of Natural Risks (*Observatoire National des Risques Naturels*, ONRN) together with the insurance sector.

Reinforcing the risk culture among citizens and decision makers is essential as the memory of historical floods fades

Citizens' and decision makers' risk perception is very low while vulnerability remains high and in some cases is even increasing. According to all of the stakeholders, the level of information and the degree of awareness of a major flood risk for citizens are insufficient in view of the extent of the danger. There has not been any significant flood for almost 60 years and the impacts of low frequency events such as those of 10 to 30 years ago have nearly disappeared thanks to the upstream dam reservoirs. As a consequence, the flood risk tends to fade from the collective memory. On the other hand, the collective insurance coverage provided by the CATNAT compensation scheme, while presenting many advantages, can create a moral hazard by giving citizens, firms and decision makers the impression that, come what may, they will be compensated for their damage: this does not lead to increased risk awareness or to initiative to try to set up preventive measures. A voluntary approach to raising awareness in Île-de-France is necessary to develop a risk culture.

The effectiveness of risk communication is limited while awareness is slowly increasing in the private sector

The development of a flood risk culture seems to be a subject that many actors support in view of the many initiatives identified in this area. French risk regulations make procedures to inform or consult stakeholders mandatory. However, they do not institute quantified objectives for risk awareness. Their effectiveness and their implementation are quite low and vary depending on the level of commitment of the different local authorities. At the same time, innovative awareness-raising approaches, carried out by actors who are not officially responsible for these subjects, have met with a good response from the population (exhibitions, work in schools, 3D films). The strengthening of the river culture and its appropriation is also a good way of raising risk awareness. It is difficult to have an overall view and to know the impact of all these measures when there is no precise assessment. Overall, it would appear that the public decision makers' failure to communicate on the subject is a major factor limiting the development of a culture of risk. This reveals a low awareness of the risk since flooding continues to be considered unlikely.

In recent years, awareness has increased in companies but is still variable. Large companies in a certain number of sectors (energy, transport, water, telecommunications, banking) have become aware of this risk through their participation in work on crisis management, through the regulation on business continuity for vital sectors or through local initiatives run by the business districts of the Chamber of Commerce. Once businesses become aware of the issue they demand access to accurate information on the risk, both with regard to the precise water levels and the interruption of critical networks.

Conversely, smaller companies or other sectors have only a very limited awareness of the risk. There are very few actions intended for small businesses in this field, nor toward essential stakeholders for resilience development such as those in engineering, urban planning or architecture. Ultimately, the differences in the degree of awareness and commitment between the various sectors and the various stakeholders hamper the development of a genuinely shared culture of safety.

Control of urban development in the floodplain comes up against limited regulatory tools

With regard to the territory's resilience, risk prevention policies based on controlling urban development have only limited resources in respect of the underlying economic issues at stake. The shared responsibilities among stakeholders for land-use planning prevents a coherent management of the risk. The local development approach, instead of encouraging municipalities to limit building in the floodplain encourages them to develop these often very attractive areas. In this context, where the fabric of the urban area does not put the flood issue at the forefront of its planning process and does not set any objectives, public decision makers and planners are ultimately content to live with the regulatory aspects, particularly through the flood risk prevention plans (*plans de prévention des risques d'inondation*, PPRI). These documents, negotiated by the state, and the local activities only determine a few non-constructible zones, they are not standardised across the different departments of the risk basin, they do not impose specific regulations to network operators and they are not restrictive with regard to existing constructions, which are predominant in the Île-de-France region. In this way, during the past 20 years, 1 500 hectares as well as some major infrastructures were built in the floodplain.

Urban planning and innovation policies could use the Greater Paris project as an opportunity to boost resilience

The Greater Paris project includes urban densification and the development of a major transport network by 2030. In this context of a densely populated urban area, this unifying project offers opportunities: a flood-resilient city may emerge from innovative urban projects built all along the Seine. Examples in other OECD countries show that resilience can be the source of innovation and, in this way, participate in green growth. Certain initiatives have proven that it is possible to build an urban environment with infrastructures that are resilient to floods or to improve existing constructions in the presence of a strong political will and a sustainable governance structure to do so. Resilience to floods is at the heart of the project for the urban renewal of the Ardoines district, severely exposed to this risk. Located in the area of the Orly-Rungis Seine Amont Development Agency (*Établissement Public d'Aménagement Orly-Rungis Seine Amont*), this project is directly managed by the state and may serve as an ambitious demonstration of resilience innovations. Similarly, the initiatives around green and blue corridors in the Île-de-France region may incorporate flood prevention even more.

Investment in improving the resilience of the critical networks and infrastructures will be key to ensure resilience for the whole metropolitan area

A particular theme to be taken into account concerns the urban networks and the critical operators which structure the region and enable it to function (electricity, water, telecommunications and transport). Investment in infrastructures planned for the next

30 years could be used to improve the networks' resilience. There is, however, a great heterogeneity between the various operators in terms of risk assessment and preparedness levels for the risk of a major flood. Despite the existing regulatory or contractual context, it appears that the requirements for rapid business recovery are not sufficiently high in the event of a major flood. Work on crisis management has contributed to raising the operators' awareness, to persuade them to assess their vulnerability and the cascading effects they could create for other business sectors. Nevertheless, there are still great differences in their levels of awareness, preparation and resilience to risk. Some have a precise assessment of the impact of the various flood scenarios, have developed business continuity plans (*plans de continuité d'activité*, PCA) and sometimes invested significantly to reduce their vulnerability (including relocation). Others, however, have made few efforts or even are reluctant to share their information, which could be useful for everyone's preparedness. There is no precise standard or overall harmonisation which would determine the resilience and protection levels required and which would measure them with predetermined indicators.

Efforts undertaken to increase the resilience and improve public services and business continuity seem limited

With regard to companies and public services, the development of business continuity and investment in prevention is in its early stages. To ensure the continuity of government services, plans must be developed by all ministries. On the other hand, resilience processes in local authorities and particularly in municipalities are limited: less than 40% of the municipalities concerned have developed a continuity plan and little work on reducing vulnerability has been undertaken. Under these conditions, in the event of a flood, it is uncertain whether a large number of public services would continue to function. The private sector, and in particular large companies, is increasingly encouraged by the markets to take into account its risk exposure, the possible effect on the business plan and the measures likely to reduce the risk. The commitment made by companies in the private sector to improve their own resilience seems to be related to their size or to their sector. While some of the large companies have already developed or are currently developing their own prevention and flood risk strategies in accordance with the regulatory framework and the regulation authorities (banks, telecommunications), overall, small and medium-sized enterprises (SMEs) are still vulnerable and ill-prepared.

The levels of protection against floods are not harmonised at the scale of the Paris urban area

The difference between the levels of protection provided by dykes and clay walls, the levels of maintenance and of investment between the centre and the outskirts of the urban area do not ensure uniform protection for the citizens of Île-de-France, reflecting the historic layers which no longer correspond to today's urban and industrial density. Recent efforts to analyse their vulnerability under the auspices of the state should be emphasised as well as the reinforcement work carried out in some places, albeit in a somewhat fragmented approach due to separate contracting authorities. Contrary to other OECD countries, the lack of any predefined standard level of protection accentuates the negative effects of the lack of any overall management approach for these protections and does not enable the level of investment required to be determined.

Hazard control depends on the effective management of the upstream multiple-use reservoir lakes

The flood hazard is also managed by four reservoir lakes built upstream of the basin in the past. With a storage capacity of 800 million m^3, these big dams can together lower the water level by 70 centimtres in Paris and reduce direct damage by half. They are run by the EPTB Seine Grands Lacs whose missions are gradually being extended to other aspects of integrated water resources management. Since their construction, in the absence of major floods, the functions of these reservoir lakes has become somewhat focused on other uses (low-water support, leisure activities). The establishment of a new fee collected for the low-water support service to the major water users will contribute to the EPTB's budget, thus strengthening this part of its mandate. The optimisation of the management of existing reservoirs with respect to the different uses represents a key issue which should be regularly discussed, particularly in the context of climate change.

The issues of an innovative but costly new infrastructure in La Bassée

A new hazard reduction project has emerged, the La Bassée project, which raises questions on the funding of and priorities in hazard control actions and governance. The innovative approach of this project consists in pumping water from the Seine before it is joined by the tumultuous Yonne River, into storage basins installed along the river. The project was developed with a state-of-the-art approach, including the consultation of local populations upstream through a large and transparent public debate, the incorporation of multiple uses in its design (restoration of wetlands, eco-tourism, economic activities), a positive cost-benefit analysis and a multi-criteria analysis. However, in order to better justify its cost-effectiveness, the project must still demonstrate its operational utility and respond to some key questions related to the definition of its operational rules and the related decision making in times of crisis. The idea to realise this project in stages seems interesting insofar as each stage will enable experimentation to test the structure to reduce the water level in the event of a major flood.

Apart from this potentially large-scale project, other hazard reduction options have also been identified, such as renovating the Joinville-Le-Pont bypass valve, which would protect a large number of the inhabitants at a low cost; the optimisation of existing infrastructures; or the ecological restoration of the basin heads. The same applies for the dykes and clay walls. To the detriment of a comprehensive and genuinely efficient approach, no comparison has been carried out of these different projects in terms of costs and benefits due to the fact that each of them has a different contracting authority. Together, the establishment of the local flood management strategy and the Flood Prevention Action Programme (PAPI) project supported by the EPTB Seine Grands Lacs are an opportunity to make a reasoned and transparent choice *vis-à-vis* all the stakeholders between the various options.

Recommendations for increasing resilience

5. Continue to improve and harmonise risk knowledge and ensure that risk information is made available. Collaboration between the prevention and crisis management stakeholders could be extended to other actors such as the insurance sector, in a coherent global risk assessment approach, particularly from an economic point of view. All information concerning the risks could be centralised whilst abiding to demands of confidentiality, security and competition. This could go hand in hand with the provision of modelling tools and related data according to needs, taking inspiration from the risk observatory established at the national level.
6. Reinforce the risk culture of citizens, decision makers and companies. New communication approaches stressing the positive benefits of greater resilience must aim to increase risk awareness at all levels. Regular information, based on the best available knowledge and to the benefit of a common strategy, could accompany the local flood risk management strategy. This communication strategy should use new technologies (3D imaging, virtual animation, social networks) for specific targets (companies, citizens, decision makers, developers and architects) and its results should be regularly assessed through surveys on risk perception.
7. Improve territorial resilience using the opportunities offered by the Greater Paris project. The definition of a level of resilience for the Greater Paris project, particularly through the local territorial development contracts (*contrats de développement territorial*, CDT) could allow model resilient districts to emerge, such as Les Ardoines. The harmonisation and reinforcement of the risk prevention plans at regional level will enable resilience to be improved towards this predefined level in the long term: these plans should use the latest risk assessments as a basis and their control should be improved. Incentives aiming to reduce the vulnerability of existing constructions could also be envisaged, by using opportunities such as the replacement of electricity metres.
8. Gradually improve the resilience level of critical networks and take steps towards preserving the continuity of business and public services. A predefined level of resilience should also be gradually applied to network operators to improve requirements. New infrastructures, particularly transport, should aim at the greatest resilience to floods. Establishing requirement levels and controlling them may become the responsibility of the sectoral regulator. A mechanism supporting companies in their business continuity approach, and particularly SMEs, could also be developed, for instance the establishment of a risk-diagnosis service, of a dedicated label or the development of risk awareness guides.
9. Place the flood protection infrastructures under the responsibility of a single contracting authority in charge of applying a pre-defined safety standard, based on a common cost-benefit approach, under an appropriate institutional structure. The management and organisation of the maintenance, replacement and work requirements could also be assessed in accordance with common criteria and in comparison with potential new infrastructures. The feasibility of harmonising the protection levels for the whole urban area should be assessed by planning the work over time, giving priority to the most beneficial measures.
10. Encourage experimentation with regard to the La Bassée storage project. Rolling out the La Bassée project in stages should make it possible to adapt the approach through a process of learning by practice and to demonstrate its operational utility, beyond the theoretical cost-benefit studies. The question of the governance of such a structure should also be raised beforehand, particularly regarding decision making in a time of crisis to guarantee its effectiveness.

Financing flood resilience in Île-de-France

How can resilience be financed within a constrained budget context?

Funding the preventive actions required to increase the level of resilience remains a major issue. Within a context marked by under-investment in the past, and the current difficult economic conditions, investment in prevention is under pressure, given the concerns for balancing the budget and the necessity to decide priorities for public spending, on behalf of the state as much as of the local authorities. In the Île-de-France region, as often elsewhere, decisions to undertake and to fund prevention are dependent on the economic context or the triggering role of recent events. The lack of any significant flood event over the past 60 years tends to reduce awareness and does not motivate stakeholders to structure a financial approach to prevention challenges. The differences in the level of risk and the amount of prevention efforts between the different exposed areas of Île-de-France make it difficult to fund infrastructures which would be of greater benefit to some rather than others. This leads to a lack of action for funding more collective resilience. The allocation of prevention resources is a challenge which requires demonstrating that public funds are used as efficiently as possible.

Tools for financing flood risk prevention exist, particularly through insurance

For 30 years now, France has engaged in significant flood risk prevention efforts. A series of innovative tools has been set up with related funding mechanisms. Funding flood prevention is generally based on solidarity mechanisms. In addition to national budget resources, France has established an original collective insurance mechanism, the CATNAT insurance regime, based on a public-private partnership between insurance companies and the state and on the solidarity principle – among all the insured – against the risks of natural catastrophes. This system also makes it possible to make a large contribution to risk prevention funding, particularly for flood risks, without a direct impact on public finances. Flooding is the most frequent as well as the most damaging natural disaster in France. Nevertheless, this system is faced with growing demands.

Additional resources come from the local authorities, which are generally mobilised through contractual tools with the state such as the large river plans (*plans grands fleuves*) and the PAPI or to fund the basin organisation such as the EPTB Seine Grands Lacs which manages the upstream reservoir lakes. Other sources of finance can also be used for prevention, such as those linked to the wider water policy with the water agencies, the network operators and companies which could invest in their own resilience, or the European Union, particularly to implement the Floods Directive.

The financing of flood prevention in Île-de-France has benefited from limited existing resources

With annual average damage from a Seine flood risk equivalent to one-quarter to one-third of annual average damage caused by floods in France – EUR 1-1.4 billion – it would seem relevant to match the prevention efforts to this level of risk. Expenditures on flood prevention in France may be assessed at between EUR 300 million and EUR 450 million, or about one-third of the estimated damage. Such a level of investment in prevention may be considered satisfactory in view of the public expenditure effectiveness criteria, if it is ensured that these funds are allocated as a priority towards the preventive measures which have the greatest benefits. Although important investments allowed the upstream reservoir dams to be built in the past, it appears that the

instruments for funding prevention have played a very small part in reducing the vulnerability of Île-de-France over the last 20 years, compared with other regions or river basins. Other strategic priorities, in particular measures to protect human lives, have mobilised authorities and the available prevention funds. This has led to a certain delay in funding the prevention of this major flood risk, as a flood of the Seine would have limited casualties. Up to now, the national allocation of resources has not been based on criteria giving priority to resources according to the level of risk. This is changing with the implementation of the EU Floods Directive which identified territories at risk of substantial flooding, of which the Paris metropolitan area is one.

The development of a financing strategy may be based on principles aligned with improved governance

There is room for progress in defining a financing approach for prevention which is adapted to the issues at hand. In the context of strained public finances, the question of additional resources and the sharing of efforts (state, local government, businesses, citizens, European funds) may be addressed by setting out a number of principles for an overall financing strategy. Improved governance of risk management could help define a level of risk as a shared objective upon which a financial approach could be developed. The general principle is that the beneficiaries of prevention measures should be the first to finance prevention. Identification of the beneficiaries helps to determine the primary sources of funding to be raised for such a strategy. Prevention funding must aim at being most effective through an economic approach based on:

- Coherence: heterogeneity of the different stakeholders' preventive approaches results in duplicated actions and extra costs, as well as un-cooperative behaviour – "free-riders" – and distortions of competition and levels of service.
- Economic efficiency: a generalisation of cost-benefit studies and multi-criteria analysis, apart from judging the relevance of a specific project, could allow a comparison to be made of the various options available and their benefits, including non-structural measures.
- Long term: long-term investment planning makes it possible to introduce flexibility in choices, to take into account the evolution of knowledge and to reduce uncertainties so as to adjust resources in accordance with needs.
- Equity: this question arises both regarding the strategic allocation of national resources for this territory exposed to significant risk as well as within the Île-de-France region, in view of the differences between the levels of protection.

Existing resources and additional resources

A large number of existing financial mechanisms may be further mobilised to prevent this major risk. Adopting a multi-hazard approach (flood, drought, pandemic, terrorism) can provide access to the funding of the water policy or the management of risks in the wider sense. A long-term approach in relation to the Greater Paris regional development project also opens up avenues. Many European systems also provide funds for risk prevention and this ought to be explored. Several potential sources of additional finance could be mobilised as well. A certain number of actors in the private sector would be prepared to provide resources if they are shown that their contribution to investing in prevention could significantly reduce their level of exposure to risk. Existing taxes on added-value real estate in the flood zone, local taxes or those on the tourist sector could

also be explored as sources of funds. New resources in the form of service fees established for low-flow support by the EPTB Seine Grands Lacs could also inspire a similar system benefiting flood protection, particularly for network operators.

Recommendations for financing prevention

11. Support the local Seine flood risk management strategy in the Île-de-France with a clear financial strategy, taking into consideration national specificities. This could focus on the following elements: sustainability and long-term vision; principles of responsibility and proportionality among the beneficiaries of the measures taken and the financiers; improving effectiveness and equity in resource allocation; synergies with the other sectoral strategies (drought, water, development, crisis management).
12. Mobilise all the beneficiaries of preventive measures in a multi-level approach which would combine local government authorities and state funding, as well as the various network operators, the private sector and citizens by targeted incentives. Additional funding could come from positive incentive mechanisms in existing taxation-raising systems, particularly by bringing together the insurance, real estate and water management sectors.
13. Strengthen efforts to clarify the priority criteria for prevention funding from state resources. This can also consider the possibility of European funding which can be mobilised for implementing the European Floods Directive in high flood-risk areas such as the Île-de-France region.
14. Re-examine the impact of the CATNAT compensation scheme on flood risk prevention. The bill aiming at reducing the system's disincentivising effect could be revived, which would be an opportunity for a wider reflection on funding prevention.

Chapter 1

Impacts of a major Seine flood in the Île-de-France region

The probability of a major flood of the Seine River, of a level equal to the great flood of 1910, cannot be overlooked, given the significance and vulnerability of the assets now situated on the floodplains of the Île-de-France. This chapter provides a detailed analysis of the potential impacts of such an event on the public well-being, the operation of critical networks and business activities. The use of a dynamic model provides an exploratory analysis of the macroeconomic impact of such a large-scale shock in terms of gross domestic product, employment and the public finances.

Introduction

While the possibility of major flooding of the Seine River may initially seem to be remote, it periodically returns to the public consciousness: in 2010, the centenary of the 1910 flood, and in spring 2013 various Seine overflows upstream of the basin raised awareness in this regard. Although the level of flooding did not prompt any concern in Paris, it nevertheless reopened the question of risk management and the region's vulnerability to flooding. Over 100 years after the great flood of 1910, the prospect of a historic event is a key concern for French risk management stakeholders. The 1910 flood was particularly destructive in an era marked by industrial progress. Events of this type illustrate the difficulties societies have in striking a compromise between economic development and managing the increased vulnerabilities of social and economic stakeholders.

Since 1910, the risk of a Seine flood in the Île-de-France region has been lessened first by defensive structures, such as dams built upstream, and various phases of river development in the 1920s, then in the 1950s and more recently. However, the increasing development of this leading French region and the construction of many industrial areas, infrastructure and critical networks (transport, energy, communication, water) alongside the river have increased exposure to risk and vulnerability. The interdependence of these networks, the interpenetration of production lines and their just-in-time operation, the key role played by the mobility of persons and trade in the operation and dynamism of the economy, urban development and the concentration of populations and assets are all key factors of modern societies' increased vulnerability to shocks (OECD, 2011). Today, these elements vindicate the importance of assessment in this field with a view to a re-examination of public policies.

This chapter seeks to understand the impacts of a major flood of the Seine River. It concerns the flood hazard itself and compares it to the recent major floods that have affected OECD countries. The impact of such an event is assessed in relation to public well-being, the operation of institutions and businesses, and the economy. The economic impact could be significant, including at the national level, because of the importance of the Île-de-France region to French gross domestic product (GDP). This chapter makes an exploratory assessment of the macroeconomic impact of various flooding scenarios to take account of the direct and indirect effects of a shock of this nature on the national growth trajectory, employment and public finances.

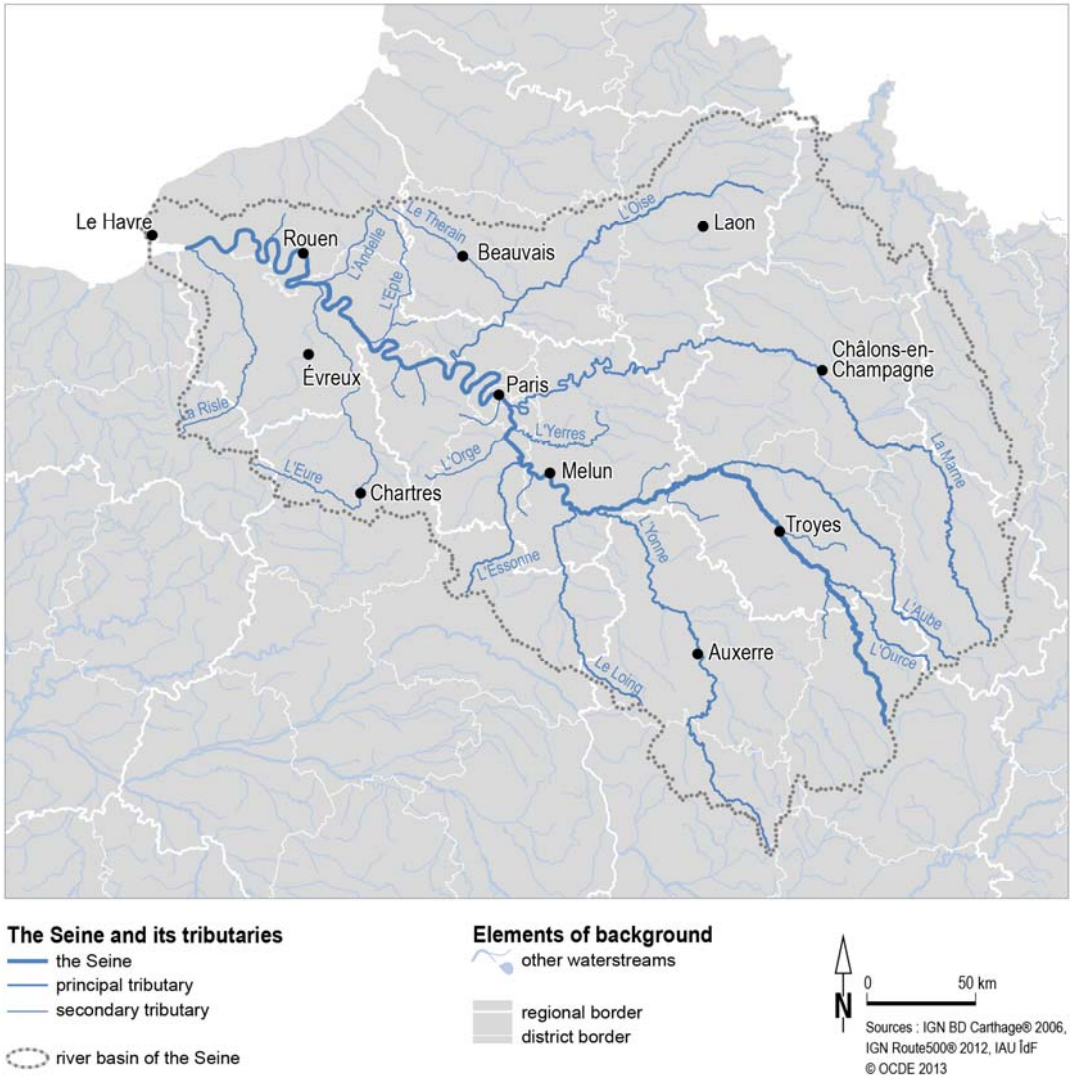
The Seine flood hazard in Île-de-France

An extensive basin with an oceanic river system

The Seine flows for 776 kilometres from the Langres plateau to its outlet into the ocean at Le Havre. Draining an area of 78 600 km², its catchment basin covers 12% of the national territory and is virtually fully contained within the Paris basin. It is characterised by flat terrain with a median altitude of 150 metres, and only 1% of the basin is higher than 550 metres. The moderate altitudes explain the river's very gentle natural slope of between 0.1% and 0.3%, and its many meanders (Meybeck et al., 1998). The Seine basin is subject to an ocean climate with rainfall evenly spread throughout the year as a result of the relatively steady supply of moisture brought by the west winds off the Atlantic Ocean. The moisture results in heavy precipitation on the north-west coastal regions (800-1 100 mm/year in Normandy), whereas precipitation in the plateaux in the centre of the basin (Beauce, Picardy) is less extensive owing to the absence of orographic

obstructions (500-850 mm/year). Maximum precipitation occurs on the eastern and south-eastern uplands (more than 800 mm/year with a maximum of 1 300 mm/year over Morvan (Ducharne et al., 2007).

Figure 1.1. **Map of the Seine basin**



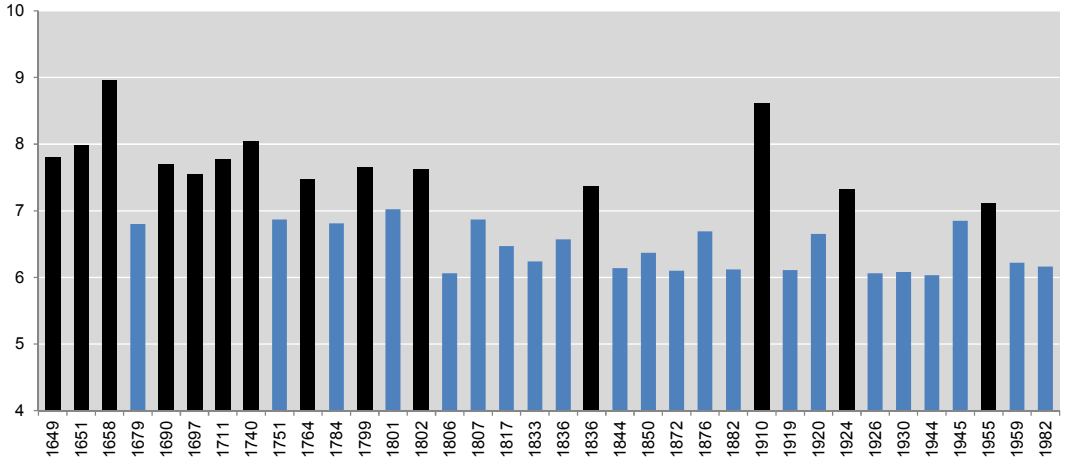
Given these climatic and geological conditions, the Seine and its tributaries are characterised by an oceanic rain system with maximum flow in January-February when evapotranspiration stands at its lowest, and minimum flow in August when evapotranspiration is at its highest. The average flow of the Seine at the Paris-Austerlitz station varies between 542 m^3/s in February to 134 m^3/s in August with an average mean of 307 m^3/s (DRIEE, 2013). Additionally, the annual average flow at the river mouth is relatively low compared with the other major French rivers at around 500 m^3/s. The regimes of the principal tributaries, the Yonne, the Marne, the Aube and the Oise are similar, although the Yonne's is more turbulent because of its steeper gradient, higher rainfall and less permeable basin geology.

Potential for major floods

One of the features of the flow-rate of the Seine is its interannual variability, characterised by extensive floods. The 1910 flood is the best known with an estimated peak flow-rate of between 2 400 m^3/s and 2 650 m^3/s in Paris, more than eight times the river's average. This well-documented flood acts as a benchmark. Its return period is estimated at 100 years, in other words the probability of its occurrence is 1 in 100 each year. Each inhabitant of Île-de-France therefore has a greater than even chance of experiencing an event of this type during his or her lifetime.[1]

The 1910 flood reached 8.62 metres on the Austerlitz gauge. A flood is deemed major when it exceeds 6 metres on the gauge and exceptional when it exceeds 7 metres. Over the past four centuries – the Seine flood records date back to 1649 – the exceptional level has been exceeded around four times per century, and the worst flood was 8.96 m in 1658. Although no major flood has occurred for almost 60 years, the 20th century featured major 50-year floods in 1924 and 1955. The last major flood was in 1982, and its return period was ten years (EPTB Seine Grands Lacs, 2013).

Figure 1.2. **Major Seine floods since 1872**



Notes: Water level as measured on the Paris-Austerlitz gauge. Major floods are higher than 6 metres, and exceptional floods (in black) are higher than 7 metres.

Source: EPTB Seine Grands Lacs.

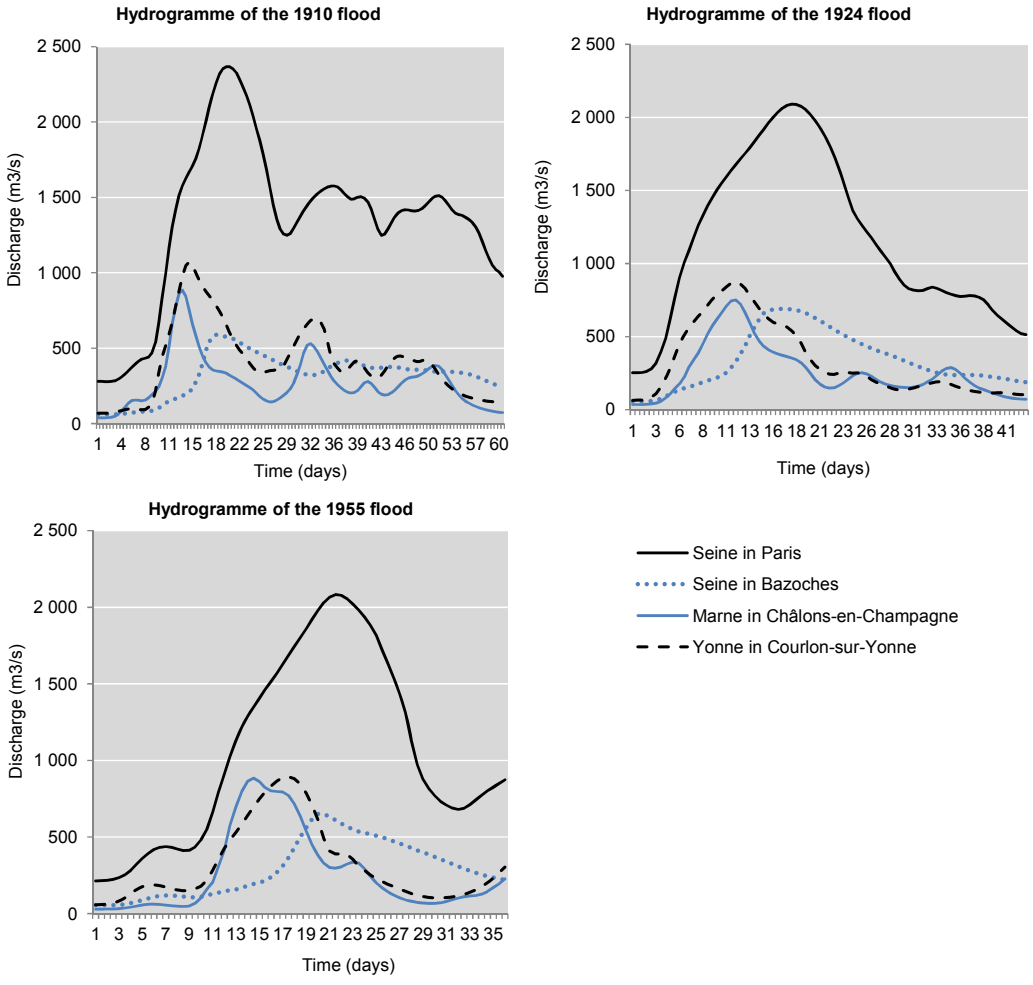
The major Seine floods occur when two hydrometeorological conditions are met: first a high level of groundwater piezometry together with strong recharge from frequent spells of rain over a fairly lengthy period leads to soil saturation and sustained flow-rate in all rivers in the basin; secondly, a cycle of exceptional precipitation then falls throughout the basin for between four and six days. Under these conditions, waves of floods from the various rivers Seine, Marne, Aube and Yonne may reach the Île-de-France at the same time where they converge. The differences between the reaction times for the rivers Marne, Aube and Seine of between 7 and 11 days, and that of the Yonne of between 2 and 4 days, become less marked during steady rainfall, and the flows combine to form a major flood (Chéry, 2000). These conditions are likely to arise between November and April, with the greatest risk in January-February. Nonetheless, it must be noted that flooding has occurred unexpectedly in the basin at other times, e.g. in May (1836), September (1866) and October (1840).

Table 1.1. **Frequencies of major Seine floods in the 20th century**

Year of flood	Return period	Water height on the Austerlitz gauge	Maximum flow-rate
1910	100 years	8.62 m	2 600 m³/s
1924	–	7.30 m	2 200 m³/s
1955	50 years	7.12 m	2 100 m³/s
1945	–	6.85 m	2 000 m³/s
1982	10 years	6.18 m	1 800 m³/s

Source: DRIEE (2013), internal document.

Figure 1.3. **Hydrographs of the floods of the Seine River of 1910, 1924 and 1955**



Source: EPTB Seine Grands Lacs.

Given these conditions, Seine floods are typified by their slow development. The waters rise gradually rather than sharply. The highest speeds for the Seine rising were recorded in Paris in 1910 at 1 metre per day for 3 consecutive days with a maximum of 1.40 metres in 24 hours. It takes 12 days for the flow-rate of the flood to rise from 750 m^3/s to a maximum of 2 400 m^3/s. As a consequence, the time the water takes to recede is even longer because of further spells of rain. It would probably take two months

for the Seine to return to its normal level of 2.50 metres (Ministry of Ecology, Sustainable Development, Transport and Housing, 2011). Similarly, the floods of 1924 and 1955 were very long, and the period of submersion lasted almost a month (EPTB Seine Grands Lacs, 2013).

Impact of climate change

As part of the Climate Change Impact and Management Programme *(Programme gestion et impact du changement climatique*), the Ministry of Ecology, Sustainable Development and Energy (*Ministère de l'Écologie, du Développement durable et de l'Énergie*, MEDDE) financed a project on the impact of climate change on water resources and hydrological extremes in the Seine basin. The use of around 30 hydroclimatological scenarios point, on the one hand, to pronounced drying out during the 21st century in terms of average value and base stream flows, but no conclusions can be drawn on the pattern of high-water flows because the trends vary across the models. Additionally, this study did not identify a specific trend for 10-year and 100-year floods in Paris. Given that precipitation patterns are the most uncertain aspect of the projections, the impact of climate change on the frequency and intensity of this specific meteorological precursor to major Seine floods is not currently significant (Ducharne et al., 2011). In view of the residual uncertainty, it would therefore seem that, for the purposes of assessing public policies, the 100-year flood of 1910 is a key benchmark scenario upon which preventive approaches can be built.

Moreover, anyone giving an overall view of risk management must bear in mind the fact that more severe floods are still possible. For example, in France, levels higher than the 1910 flood were recorded in the 17th century (which also saw three major floods in nine years). This raises the issue of flood return periods, a factor where there are still many uncertainties. In other countries recently, many floods have significantly exceeded the 100-year levels, for example the floods in Queensland, Australia; in Bangkok, Thailand; in Pakistan; the coastal floods following Hurricane Sandy in New York (Table 1.2); and the 2013 floods in Germany.

Table 1.2. **Return period for recent major floods**

Country or city	Year	Flooded river	Return period
Prague (Czech Republic)	2002	Vltava	500 years[1]
United Kingdom	2007	Severn	200 years[2]
Pakistan	2010	Indus	>> 100 years[3]
Brisbane, Australia	2011	Brisbane	120 years[4]
Bangkok, Thailand	2011	Chao Phraya	> 100 years[5]
New York, United States	2012	Floods linked to Hurricane Sandy	400-800 years[6]

Sources: 1. Zizkova, E. (2004), "Les inondations catastrophiques d'août 2002 en République tchèque", *La Météorologie*, No. 46, August, http://documents.irevues.inist.fr/bitstream/handle/2042/36058/meteo_2004_46_34.pdf?sequence=1. 2. Severn Trent Water (2010), *Annex to June Return Board Overview*, Severn Trent Water, Coventry. 3. Japan International Cooperation Agency (JICA) (2012), "JICA's support to "Toward Safe and Resilient Thailand" through revising the comprehensive flood management plan for the Chao Phraya River Basin", forum of 20 February 2012, www.unescap.org/idd/events/2012-South-East%20Asia%20Flood%20Risk%20Reduction%20Forum/JICA.pdf. 4. Queensland Flood Commission Inquiry (2012), "Final report", Queensland Flood Commission of Inquiry, Brisbane, Australia. 5. Aon Benfield (2012), *2011 Thailand Floods Event Recap Report*, Aon Benfield, Bangkok. 6. Lin, N. et al. (2012), "Physically-based assessment of hurricane surge threat under climate change", *Nature Climate Change*, Vol. 2, pp. 462-467, www.nature.com/nclimate/journal/v2/n6/full/nclimate1389.html.

A metropolitan area very exposed to multiple challenges

A central, mobile, connected region, the focal point of vulnerabilities

As a national political, economic and cultural centre, the Île-de-France region acts as a magnet for people, jobs and decision making. It is the wealthiest and most populated of the 22 administrative regions in France. Comprising 8 departments (*départements*) and 1 281 municipalities (*communes*), it is home to 11.9 million inhabitants, or 19% of the French population. It is one of the wealthiest and largest regions in Europe: its total GDP in 2009 was EUR 572 billion, accounting for 30% of national GDP and 5% of European GDP (CCI Paris et al., 2013). With 6 million jobs, this major employment hub for France and Europe is a hotspot for the most highly skilled jobs and for the country's large companies and their decision-making centres (37% of executives and 39% of employees of large companies) (INSEE, 2013b).

National and international flows are growing daily, making the Paris region a European and world hub. In its analysis of French metropolitan areas assessing the relationship between the areas around a centre, the Interministerial Delegation for Territorial Development and Regional Attractiveness (*Délégation Interministérielle à l'Aménagement du Territoire et à l'Attractivité Régionale*, DATAR) discusses a large, integrated system comprising 17 million inhabitants (including Caen, Rouen, Amiens, Le Mans and Orléans) whose daily operations involve connections to the Paris region. The relationship with the Paris urban area is common to all French urban systems (DATAR, 2012). The Paris region is the country's largest exporter and importer. It ranks second among the European regions attracting the largest amount of foreign direct investment. As host to continental Europe's top air hub, it is also the world's top tourist destination and leads the European rankings for hosting international meetings (CCI Paris et al., 2013).

The regional vitality that irrigates the entire national and European economy is underpinned by critical infrastructures that are essential to the metropolitan area's operations, in particular transport, energy, communications and water networks. The interdependence of these networks, the interpenetration of production lines and their just-in-time operation, the key role played by the mobility of persons and trade in the operation and dynamism of the economy, urban development and the concentration of populations and capital are all key factors of modern societies' increased vulnerability to shocks (OECD, 2011). The floods caused by Hurricane Sandy in New York in 2012, the floods of 2011 in Bangkok (Thailand) and Brisbane (Australia) and those in 2002 in Prague (Czech Republic) illustrated the devastating impact that these events can have on the operation, well-being and economies of major cities. The knock-on effects from one sector to another, impacts on regions – even abroad – that are not directly affected, are just examples of the consequences for which OECD countries should prepare in the event of a major incident (Baubion, 2013).

By dint of its location at the confluence of the various Seine tributaries, Île-de-France and its heartland are therefore particularly vulnerable to a major Seine flood. Since 1910, development measures have reduced the hazard through degradation and widening of the riverbed, work on the Paris bridges, the construction of dykes and clay walls along the river and four storage dams upstream. However, defences are not uniform and are below the 100-year level outside the city of Paris, a fact that places them below the protection standards in place in many at-risk zones in OECD countries (Table 1.3). The duration of the flood could also result in water infiltration beyond the dykes through underground

water tables because of the multiplicity of networks and tunnels in the local subsoil. Finally, the possibility of a flood more severe than that of 1910 cannot be ruled out. In parallel, the level of exposure has only grown since 1910, with very significant urban development in flood-prone areas all along the river and the construction of many industrial areas and critical infrastructures alongside it. Today, these elements vindicate the importance of conducting assessments in this field with a view to a re-examination of public policies.

Table 1.3. **Levels of protection in major cities in the OECD**

City	Protection level	Protected area	Date of implementation
Paris urban area	100 years 30-50 years	Paris Departments in the inner Paris suburbs	Existing
Frankfurt (Germany)[1]	200 years 100 years	New districts and critical infrastructures Urban area	Existing
London (United Kingdom)[2]	1 000 years 10 000 years	Coastal areas	Existing Objective 2100
New York (United States)[3]	100 years	Coastal areas	Project 2020
Netherlands[4]	1 250 years 4 000 years 10 000 years	River areas Coastal areas with small populations Areas below sea level	Existing Existing Existing
Oslo (Norway)[5]	100 years 200 years	Residential buildings Industry and critical infrastructures	National standard
Tokyo (Japan)[6]	200 years	River and coastal areas	Current project
Cologne (Germany)[7]	100 years 200 years	River areas Particularly critical areas	Existing
Vienna (Austria)[8]	10 000 years	River areas	Existing
Bratislava (Slovak Republic)[9]	1 000 years	River areas	Existing

Sources: 1. Land de Hesse (2007), "Plan d'action contre les inondations" Landesaktionsplan Hochwasserschutz Hessen, Hessisches Ministerium für Umwelt, ländlichen Raum und Verbraucherschutz; 2. Environment Agency (2012), *Thames Estuary 2100: Managing Flood Risk through London and the Thames Estuary*, Environment Agency, London. 3. New York City Special Initiative for Rebuilding and Resiliency (2013), *A Stronger, More Resilient New York*, City of New York, New York. 4. Dutch Ministry of Infrastructure and the Environment, 2012; 5. NVE (2009), "Flood inundation maps", Norwegian Water Resources and Energy Directorate, Oslo, www.nve.no/en/Floods-and-landslides/Flood-inundation-maps. 6. Cooper, C. and K. Matsuda (2013), "Tokyo prepares for a once-in-200-year flood to top Sandy", *Bloomberg*, 31 May 2013. 7. World Bank (2012), *Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century*, The World Bank, Washington, DC. 8. Kryžanowski, A. et al. (2013), "Structural flood-protection measures referring to several European case studies", *Natural Hazards and Earth System Sciences*, No. 1, pp. 247-274, www.nat-hazards-earth-syst-sci-discuss.net/1/247/2013/nhessd-1-247-2013.html. 9. Kryžanowski, A. et al. (2013), "Structural flood-protection measures referring to several European case studies", *Natural Hazards and Earth System Sciences*, No. 1, pp. 247-274, www.nat-hazards-earth-syst-sci-discuss.net/1/247/2013/nhessd-1-247-2013.html.

Direct and indirect damage

A vast floodplain at the heart of the urban area

Since nearly 500 km² of its area is situated in a floodplain, swathes of Île-de-France would be at risk of flooding in the event of a major flood (Figure 1.4); the central urban area occupies 40% of the floodplain. The developed areas of the departments of the Val-de-Marne and Hauts-de-Seine are particularly exposed as are the 7th, 8th, 12th, 13th

and 15th arrondissements of Paris. Of the metropolitan flood-prone area, 60% is at high or very high risk where flooding could be to a depth of more than 1 metre (IAU, 2010a). The most critical sectors in terms of both the extent of flooding and its depth are the north of the Val-de-Marne around the confluence of the Seine and the Marne and the north of the Hauts-de-Seine in the Gennevilliers loop. In total, 830 000 people living in the floodplain, or 7.2% of the population of Île-de-France, and 55 700 businesses (9.5%) providing 620 000 jobs (11.5%) would be directly affected (IAU, 2011a; 2011b). Many official bodies, business districts and prime heritage and tourism sites are also in the flood-prone area, as are transport, electricity and water infrastructure and several schools and healthcare establishments (Table 1.4).

Figure 1.4. **Map of the floodplain for a 100-year flood**

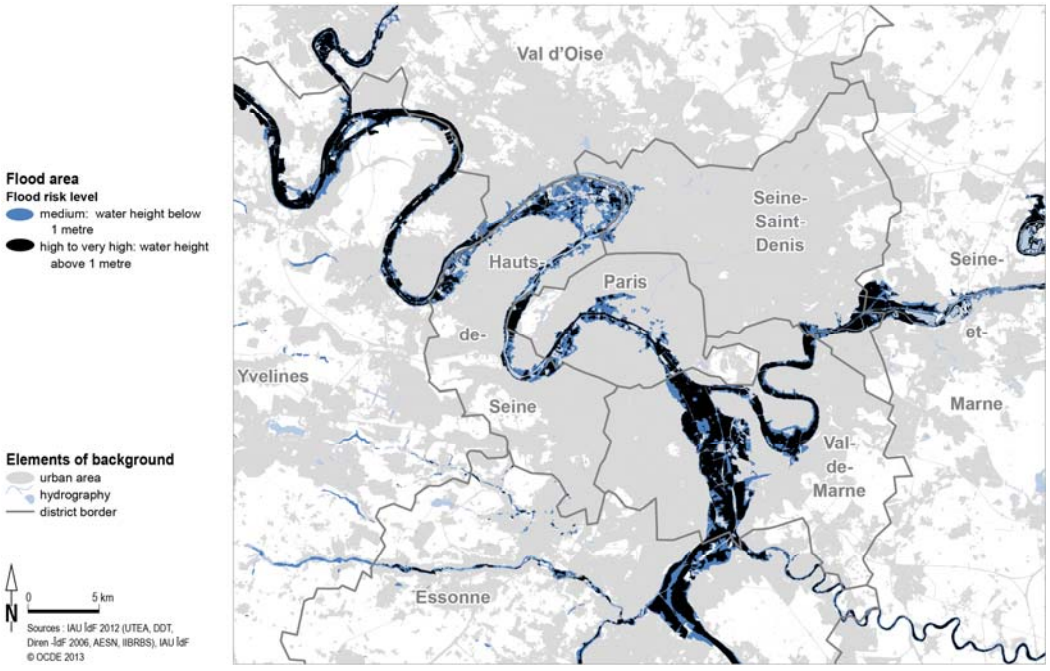


Table 1.4. **Challenges in the floodplain**

463 km² of land
Over of 60 km² of the land is taken up by housing
830 000 inhabitants
55 700 businesses providing 620 000 jobs
Many key government bodies
295 education establishments
79 healthcare establishments
11 637 power stations (outside Paris)
Banks of the Seine are classified as a UNESCO World Heritage Site
Several thousand historic buildings and art galleries
140 kilometres and 41 metro stations
3 major railway termini and all RER stations
85 bridges, extensive areas of 5 motorways and many secondary roads

Source: IAU, SGZDSP, EPTB Seine Grands Lacs, 2013.

Effects multiplied by the impact on critical networks and infrastructure

Extensive flooding of underground spaces and cellars in the urban area and its impact on critical networks, including electricity, water, communications and transport, means that major flooding would have effects beyond the flood-prone area. Indeed, the impact on the well-being of the population, the operation of government and public services and economic life in the Île-de-France region and beyond would be the combined result of the impact of the water and the breakdown or deterioration in services. The various works carried out since the beginning of the 2000s by the General Secretariat of the Paris Defence and Security Zone (*Secrétariat Général de la Zone de Défense et de Sécurité de Paris*, SGZDSP) have made it possible to actively involve network operators in the flooding issue and to evaluate a number of impacts as follows:

- Power distribution would be substantially affected with almost one-quarter of power sub-stations either flooded or cut off as a precaution (DRIEE, 2012). ERDF, the French electricity distribution network operator, estimates that, in an extreme case, more than 1.5 million domestic and business customers, including 377 000 in Paris, would experience power cuts as a result. The area that would potentially be affected by the power cut is around 50% greater than the flooded area.
- A significant proportion of public transport could be affected with almost 140 of the 250 kilometres of the underground network closed as a precaution. Only Line 2 of the metro would be fully operational. The RER network would also be disrupted with Line C the first to be affected when the Seine reaches the 6.30-metre mark. The rail termini of Lyon, Austerlitz and Saint-Lazare are also in the flood-prone area and would experience service disruption (EPTB Seine Grands Lacs, 2013).
- The road network could be closed at many points: the bridges across the Seine would be closed to traffic, due to their weakened structure, making it impossible to travel from the right to the left bank. Five motorways and several major highways, especially along the Seine, would also be inaccessible .
- The drinking water supply could be disrupted in the outskirts of Paris where more than 5 million customers could suffer extended water cuts and 1.3 million a deterioration in quality in the worst case scenario.

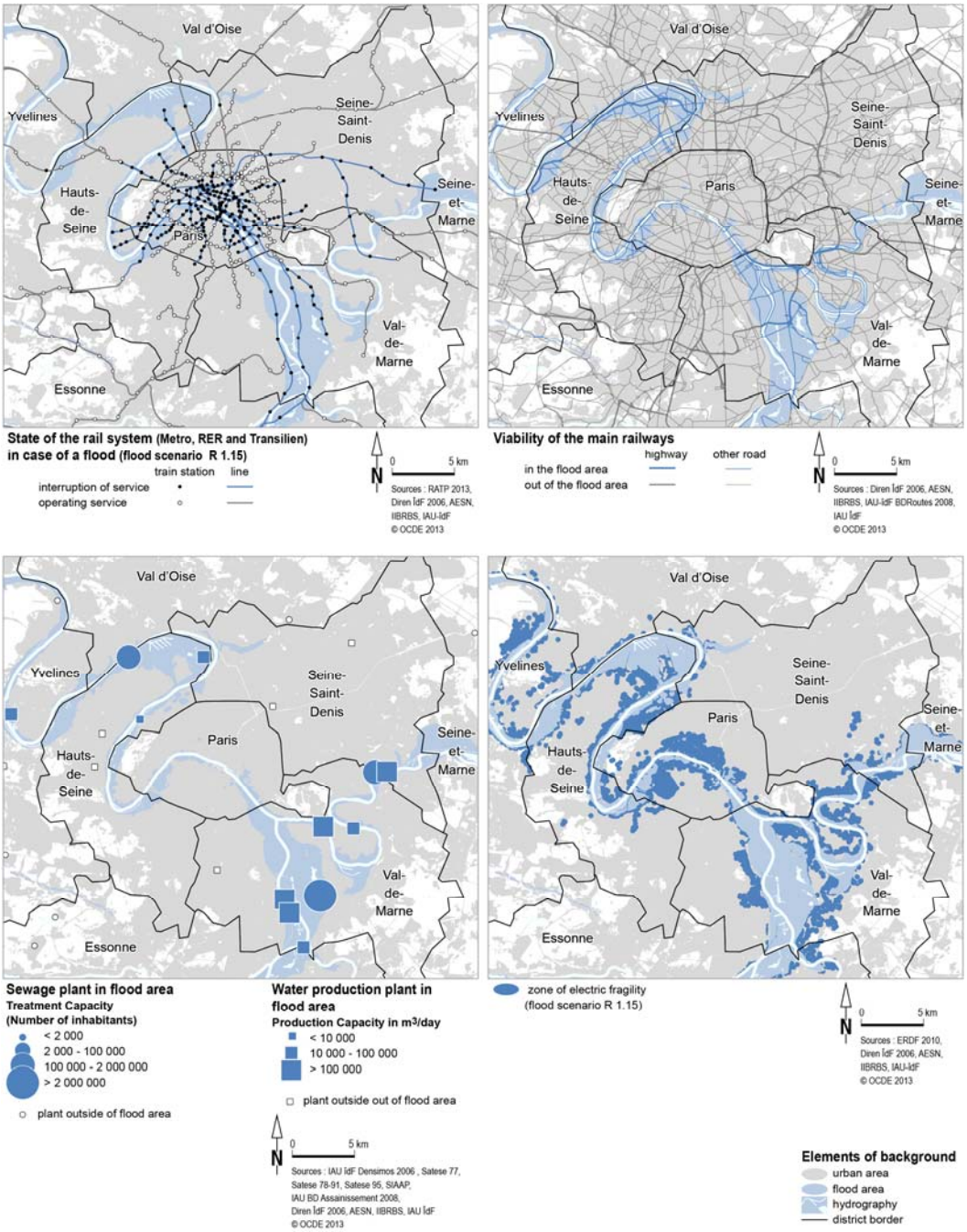
Impacts on well-being, the operation of institutions and businesses

Impact on public well-being

The host of effects on networks would therefore have a wider impact on the residents and workers in Île-de-France, over and above the 830 000 residents of the flood-prone areas. The areas of fragility in electricity and drinking water supply are increased rather than the reverse. The inhabitants of Île-de-France are heavy users of the transport network, with 8.3 million journeys per day on public transport (STIF et al., 2012). It is estimated in total that the power outages, water cuts and the disruption to transport networks would have significant impacts on the daily lives of over 5 million people. The heating system would also be disrupted for many buildings in multiple occupancy, as flooding would probably occur in the winter. Very tall buildings would also have to be evacuated for safety reasons as soon as their electricity and water supplies are no longer guaranteed, especially on the banks of the Seine in the 15th arrondissement. Significant

disruption could persist over several weeks or months while the water subsides and the process of recovery and reconstruction unfolds.

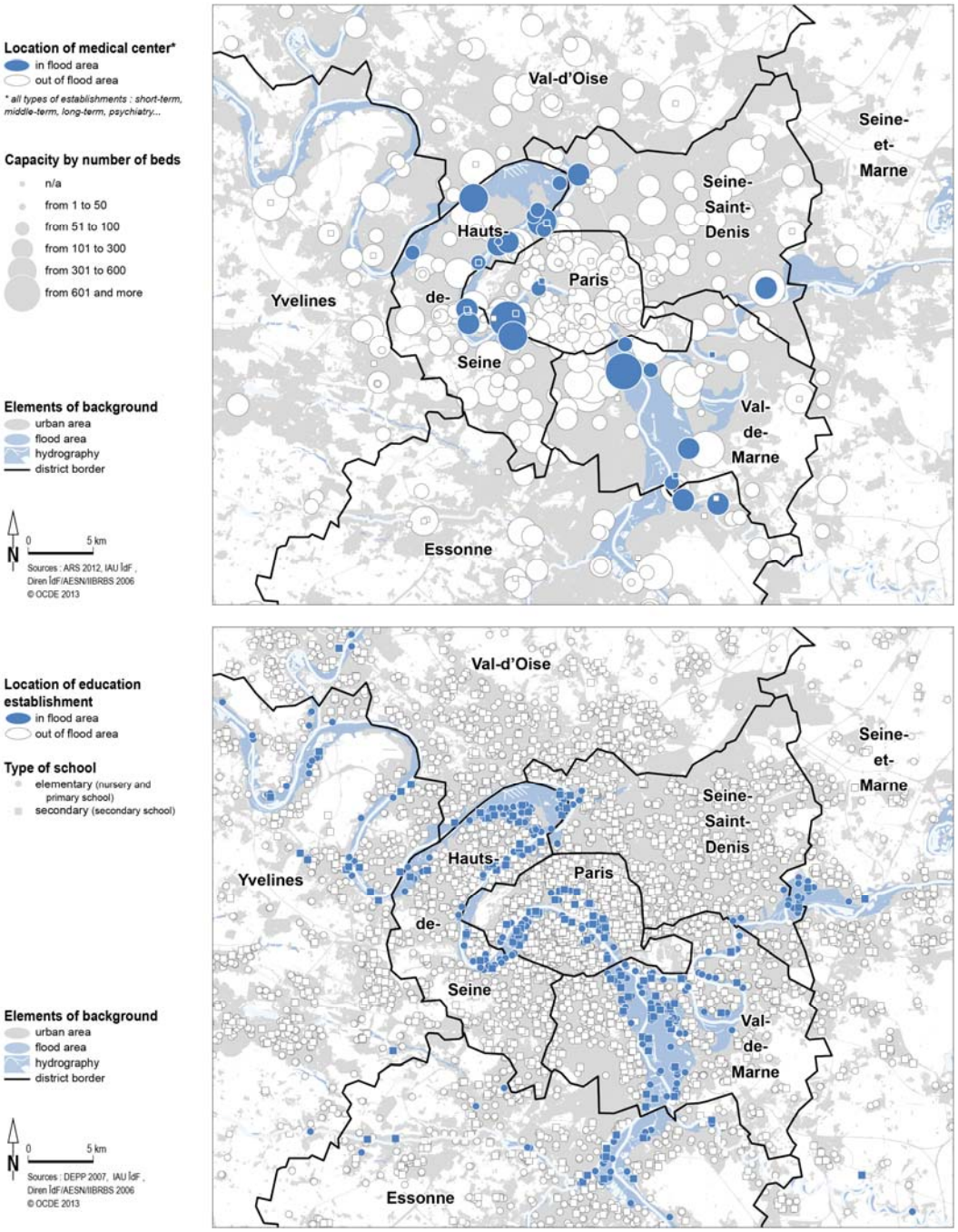
Figure 1.5. **Impact of a major flood on critical networks**



Human fatalities are unlikely because the flooding process is slow. However, many hospital or healthcare establishments would only be able to continue to function on a reduced scale or would have to close temporarily (Figure 1.6). According to the SGZDSP, over 78 000 beds would be directly or indirectly affected, including major hospital facilities (e.g. the Georges Pompidou and Pitié-Salpêtrière hospitals). Major

operations would have to be cancelled and the sickest patients would have to be evacuated outside the urban Paris area. The reduction in available facilities during a crisis precisely when extra facilities could be required might have repercussions on public health, as might the process of evacuating at-risk facilities. In the longer term, the psychological effects of a crisis of this kind could have repercussions on the mental health of the people affected, especially on the most fragile, as shown in the United Kingdom by the Health Protection Agency (HPA, 2011).

Figure 1.6. **Schools and hospital provision in the floodplain**



Lastly, the public might be more broadly affected by wholesale disruption to their daily lives, public services, institutions and businesses across an extensive area in the heart of the region. In addition to the critical networks referred to above, many primary and secondary schools would close, thereby affecting the education system as a whole. Supplies of food, essentials, fuel and cash would be reduced. Telecommunications would also be restricted with networks at capacity or disrupted. Security issues might also arise in this kind of environment. The crisis management apparatus put in place by the authorities (Box 1.1) would, in fact, govern the way society operated during the prolonged crisis period and would be key to limiting its impact on public well-being and people's daily lives.

Box 1.1. The stages in the Disaster and Emergency Response Organisation's flood management apparatus implemented by the General Secretariat of the Paris Defence and Security Zone

As part of crisis preparedness work, the General Secretariat of the Paris Defence and Security Zone (SGZDSP) at Police Headquarters has drawn up a response protocol for various flood scenarios. To that end, working groups involving all the appropriate stakeholders have been in place for several years. Discussions are based around three areas:

- backbone infrastructure networks: electricity, hydrocarbons, telecommunications and water
- essential industries: supplies (petrol distribution, major retailers, currency in circulation), health, hygiene and comfort (refuse, urban heating, sanitation), transport and specific sectors (high-rise buildings, La Défense business district)
- crisis management support procedures: legal framework, public safety, contingencies, operational bases and logistics, plan to transport crisis management staff.

Specifically, a stage-by-stage protocol dependent on the tendency in the level of the Seine as forecast by the DRIEE flood forecasting service triggers various sectoral contingency plans:

- At yellow alert (between 3.2 m and 6.1 m), the embankment roads are gradually closed, the Seine is closed to shipping, and certain stakeholders prepare to implement their contingency plans (RATP for the metro, ERDF for electricity and the Regional Health Service). From 5.50 m, if the trend is upwards, the Neptune Plan to mobilise the army is activated, and public and private operators put the first protection measures in place.
- At orange alert (between 6.1 m and 7.13 m), a minimum traffic plan is implemented in Paris, the continuity plan for government work is activated, the RER C tunnel is flooded as a precaution, and the transport operator RATP begins to shut down its network and to seal all water inlets to the metro. The first signs of damage can be seen in the suburbs of Paris.
- At red alert (between 7.13 m and 8.62 m), the waters of the Seine begin to overtop the riverbanks in the inner suburbs, and the first basements/subsoil areas are flooded in Paris. The electricity supply is gradually cut off in the flood-prone area and beyond. Generators are installed by ERDF teams (1 000 variable-power generators available). Arrangements are triggered to remove vehicles from car parks to previously identified parking areas.
- Beyond this level, the scenario is at its most extreme, and the flooding becomes extremely extensive. The rescue services implement all of the sectoral plans, organise a distribution network for bottled water, food and generator fuel. Telecoms operators deploy additional mobile antennas, and a major flood debris collection centre is organised at the Porte de Versailles. Requisitioned operational bases are set up in the north at Villepinte and in the south of Paris to receive help and resources from the rest of France and Europe.

Box 1.1. **The stages in the Disaster and Emergency Response Organisation's flood management apparatus implemented by the General Secretariat of the Paris Defence and Security Zone** (*cont.*)

This protocol, which was validated by Police Headquarters in 2010, is the subject of continuous development under the aegis of the SGZDSP to make it more robust. It relies on the involvement and commitment of various stakeholders in the public and private sectors, varying according to the sector concerned. There will also be a cost for implementing the protocol, namely the emergency management cost, which is difficult to evaluate. Where different emergency services are concerned, New York City received USD 1.4 billion from the federal government in assistance for emergency response operations, clean up and emergency repair work.

Source: SGZDSP.

Potential impact on the operation of central and local government

Central government institutions would face the same disruption as the public. Many buildings that are key to central government operations are in the flood-prone areas or areas of electrical fragility. The Élysée Palace, the National Assembly, the Palais de Justice and the Police Headquarters (*Préfecture de Police*) on Île-de-la-Cité, the Ministry of the Economy and Finance at Bercy, the Ministry of Foreign Affairs at the Quai d'Orsay, and the future headquarters of the Chiefs of State of the French Armed Forces and the regional prefecture building in the 15th arrondissement are all in the flood-prone area. Ensuring that their activities continue even if at reduced capacity would be key to central government operations running smoothly. A prolonged crisis would have national repercussions if these institutions were prevented from conducting their activities at a time when there was a particular need for them to act.

Where local government is concerned, several town halls, the seat of the General Council of the Val-de-Marne and many public buildings providing essential public services would also be affected and would find it difficult to operate, especially social services. This could also have serious social impacts among populations that have already been made vulnerable by flooding.

In a situation where public expectations of institutions are high in a crisis, and where public confidence in their institutions and their government has been undermined, a major Seine flood could therefore have significant political repercussions.

Impact on business and economic performance

Flooding is a direct concern for 55 700 businesses and 622 000 jobs in the floodplain (IAU, 2011a). The businesses' premises and means of production may be damaged and some or all of their stock destroyed. Consequential operating losses may also be exacerbated by disruption to the electricity, communications and water services; outages will also affect a more extensive area and, therefore, many more businesses. Heavy disruption to the metropolitan public transport network will also prevent many workers from getting to work. Additionally, these effects may persist for a long period, affecting business activities further. Small and medium-sized enterprises (SMEs) account for 85% of businesses in the flood-prone area, and a persistent flood and its consequences could severely affect them, potentially leading to many bankruptcies. Hurricane Sandy led to the bankruptcy of 70 000 SMEs in New York (New York City Special Initiative for Rebuilding Resiliency, 2013).

Several key drivers of economic activity in the Île-de-France region will be affected, principally in the services sector. The central business district in Paris around the 8th arrondissement and La Défense are the region's principal centres of employment in the tertiary sector. They typically have a very high employment density (INSEE, 2009) and are highly vulnerable to flooding. Of the 180 000 employees, 90% travel to La Défense by public transport (IAU, 2011a), where many high-rise buildings will have to be evacuated if their power and water supplies are cut off. The Paris business district is in a flood-prone area of electrical vulnerability. Moreover, the activities in these business quarters focus on computerised services, finance and business services, all areas for which functional telecommunications systems are essential. Many head offices and global business decision-making centres are located there, and a breakdown in their working could have repercussions beyond Île-de-France and the national territory. Other business districts in the heart of the urban area are also in vulnerable locations such as the Seine riverbank and the Val-de-Seine from the 15th arrondissement to Issy-les-Moulineaux, or the area by Lyon-Bercy-Tolbiac rail terminus, also by the river.

The impact of major flooding on tourism could also be serious, as this sector is the source of many jobs in the region. With around 60 million annual visitors and a tourist spend of EUR 16.7 billion in 2008, tourism in Île-de-France creates 600 000 direct, indirect or spin-off jobs (INSEE, 2010). Major heritage and tourist sites such as Notre-Dame, the Louvre museum, the Eiffel Tower and the Musée d'Orsay are in the heart of the flood-prone area. The same is true of many hotels: 13% of hotel rooms in the region are in the flood-prone area, of which 30% are in an area of electrical vulnerability. The top-class hotels in the heart of Paris would be especially affected. Major flooding with effects lasting several months could compromise the tourist season and cause tourists to turn their attention to another destination. The impact of disasters on a country's tourism revenue can be significant: according to the Japanese National Tourism Office, the number of foreign visitors to Japan halved for several months following the Fukushima disaster and took even longer to return to pre-crisis levels (Iyer, 2012); the floods in Bangkok led to losses of more than USD 3 billion in tourism (World Bank and Thai Ministry of Finance, 2012), and the succession of three hurricanes in 2005 and the H1N1 epidemic hugely reduced tourism revenues in Mexico (OECD, 2013).

The industrial sector in Île-de-France is also vulnerable to Seine floods, especially the automotive sector: Île-de-France is the chief French industrial region with 392 000 salaried jobs, and the automotive and transport sector is the largest employer (INSEE, 2013b). Peugeot and Renault are among the ten largest employers (whether public or private sector) in the region. Like Snecma and Dassault, these companies have historically been located on the banks of the Seine, and the work of their factories would be affected by flooding. The supply chains upon which these industrial firms are heavily dependent because of their just-in-time and zero stock philosophies will also be disrupted by the impact on the various critical networks. The ripple effects of this disruption could have a broader impact on their many subcontractors and clients in France and abroad. Automobile and aeronautical products are among the chief export items from the Île-de-France region, accounting for over 17% (CCI Paris et al., 2013). The Bangkok floods in 2011 had serious consequences for the Japanese automotive industry that had built many factories there.

Table 1.5. **Damage and major impacts caused by recent major floods**

City affected	Total costs (EUR billions)	Major impacts and consequences
Prague (Czech Republic)	3.1	Lasting disruption to critical networks (no metro for six months) Impact on heritage
New Orleans (United States)	90	Several months' duration Lasting disruption to sectors of vital importance (no hospital for five years) 50% drop in population
Brisbane (Australia)	11.7	Impact on key economic activities (mining, tourism, agriculture)
Bangkok (Thailand)	36.1	Impact on international production chains (automobiles, hard disks) Impact on tourism
New York (United States)	14.8	Impact on production chains and critical networks 70 000 business bankruptcies as a result of disruption to the power supply

Sources: 1. Munich Re (2013), "Floods dominate natural catastrophe statistics in first half of 2013", press release, 9 July, Münchener Rückversicherungs-Gesellschaft, Munich, Germany, www.munichre.com/en/media_relations/press_releases/2013/2013_07_09_press_release.aspx. 2. National Hurricane Center (2006), "Tropical cyclone report: Hurricane Katrina", National Hurricane Center, Miami, Florida. 3. World Bank and Queensland Reconstruction Authority (2011), "Recovery and reconstruction in the aftermath of the 2010/2011 flood events and Cyclone Yasi", The World Bank, Washington, DC. 4. World Bank and Thai Ministry of Finance (2012), "Thai flood 2011, rapid assessment for resilient recovery and reconstruction planning", The World Bank, Washington, DC. 5. New York City Special Initiative for Rebuilding and Resiliency (2013), *A Stronger, More Resilient New York*, City of New York, New York.

Cultural heritage and environment: Intangible impacts

Major flooding will have repercussions for cultural heritage. The banks of the Seine in Paris are classified as a UNESCO World Heritage Site, as are the Palace of Fontainebleau and the medieval town of Provins, also located in the floodplain (Ministry of Ecology, Sustainable Development, Transport and Housing, 2011). Aside from the impact on tourism, damage to heritage could be very significant. There are many museums by the Seine, and their priceless collections could be affected. During the Prague floods in 2002, many cultural masterpieces, in particular the Malá Strana medieval quarter, a UNESCO World Heritage Site, were covered in mud and seriously damaged. Many archives and historic libraries containing valuable books were also affected: 2 000 m^3 of documents (books and journals, archive documents, files from state or local government bodies, judicial documents) were frozen in a refrigerated warehouse not far from Prague to preserve them with a view to restoration (Machová, 2003).

A Seine flood could cause major environmental damage. All of the water treatment plants in the Paris urban area are alongside the river, and the protection measures in place could be overtopped, not only causing them to stop working and therefore discharge effluent directly into the river, but also flooding effluent storage areas. During Hurricane Sandy, more than 40 million m^3 of untreated water was discharged directly into the natural environment (Kenward et al., 2012). Environmental damage could also result from the presence of large industrial sites, including those subject to the European SEVESO or IPPC directives, and the stores of hydrocarbons and inflammable products at sites on the Seine loop at Gennevilliers or Vitry-sur-Seine. Many polluted areas of land and sites in Île-de-France along the course of the Seine and waste storage sites would also cause serious pollution of the natural environment if they were flooded (Ministry of Ecology, Sustainable Development, Transport and Housing, 2011).

Economic assessment of the impact of various flood scenarios

General approach

Various assessment methods for various prices

In view of the substantial direct or indirect damages and losses, questions should be asked about the overall economic impact of a shock of this extent. Such an assessment requires examining two problems: the cascading effects of disruption to networks on companies' activities and the macroeconomic impact at national level, given the importance of the Île-de-France region to the French economy.

Typically, the direct effects of disasters are distinguished from the indirect effects (Table 1.6). Tangible direct impacts include damage to individuals' physical property (whether movable or immovable) and to businesses (buildings, stock, tools of production) and public facilities. The methods for assessing impacts of this type in the event of a flood are well established and are detailed by the European Floodsite project (Meyer et al., 2009). First, it is necessary to evaluate the spatial characteristics of the hazard (water depth, flood duration), draw up a list of the impacts referred to above in combination with the type of land use and assess their value. Next, application of damage functions produces a value for damage by type of impact (as a percentage of their value) based on the flood characteristics.

Table 1.6. **Types of impact and damage**

	Tangible	Intangible
Direct impact	Physical damage to property – Buildings – Furniture – Infrastructure – Companies' stocks – Companies' equipment	– Loss of human life – Effects on health – Impacts on the environment – Impacts on the cultural heritage
Indirect impact	– Loss of industrial output – Disruption of networks – Cost of emergency response	

Sources: Adapted from Meyer et al., 2012; Penning-Rowsell, E. et al. (2003), *The Benefits of Flood and Coastal Defence: Techniques and Data for 2003*, Flood Hazard Research Centre, Middlesex University; Smith, K. and R. Ward (1998), *Floods: Physical Processes and Human Impacts*, John Wiley and Sons, Chichester.

The process of assessing companies' operating losses and other indirect effects of disasters is less obvious (Rose, 2009). Operating losses of companies affected by flood can be assessed on the basis of the direct damage they experience. However, breaks in or disruption to production processes caused by damage to companies' tools of production or stocks can have effects that cascade down the production and distribution chains and affect the clients and suppliers of the businesses concerned. Indirect or higher order effects are those that are caused not by the disaster itself but by its consequences. They may become apparent beyond the area affected by the disaster and persist afterwards throughout the reconstruction process.

Many *ex post* evaluations ask questions about indirect impacts using businesses surveys or microeconomic or econometric modelling. Price corrections, the effects of substitution, the stimulating effect that post-disaster reconstruction has on demand, and the Schumpeterien effect of creative destruction on productivity[2] are all consequences

that have been studied without any clear conclusions being reached in every case (Przyluski and Hallegatte, 2011). It would nonetheless appear to be common ground that, where an extensive disaster affects critical networks for a lengthy period, the indirect impact is too significant to ignore (Rose et al., 2012). The process of taking account *ex ante* of indirect impacts implies modelling that can incorporate the interdependence that exists between the various economic sectors and agents. It can be done using input-output models or general equilibrium models, although the excessive rigidity of certain models (set prices and no substitution) makes them too pessimistic, and the excessive flexibility of others makes them too optimistic (perfect market). Approaches that steer a middle course are therefore recommended, including by the European Costs of Natural Hazards (CONHAZ) project.

The effects of macroeconomic impacts and impacts on the public finances are often very different and depend on a country's level of development, its business cycle prior to the disaster, insurance and reinsurance coverage, and other factors (Von Peter et al., 2012). For OECD countries, the damage from the Christchurch earthquake in New Zealand amounted to 10% of national GDP without significantly affecting either growth in GDP or public finances (Laframboise and Loko, 2012), whereas the tsunami of March 2011 and the Fukushima crisis in Japan, where estimated damage was 3.5% of GDP, led to a 0.7% contraction in Japanese GDP and a 9.5% increase in the deficit in 2011 (OECD, 2014). Macroeconomic modelling is necessary for *ex ante* evaluation of this type of impact, which requires tools and databases to relate the effects of the disaster on a national or possibly regional scale, in cases where this type of modelling is appropriate. Analysis of the public finances must also have regard to budgetary contingency mechanisms (Phaup and Kirschner, 2010).

Other indirect costs are more difficult to assess. They involve the effects of disasters on individual behaviour. Some methods have been developed to measure the impact of mad cow disease on agricultural exports and tourism in Great Britain for example (Blake et al., 2001), to assess the social amplification of risk and the fear factor on water consumption following a terrorist attack on a water distribution system (Rose, 2009) or the image cost associated with a nuclear accident in France (Pascucci-Cahen and Momal, 2012). Emergency management costs are sometimes also viewed as additional indirect costs (Meyer et al., 2009). Finally, where intangible costs related to human health impacts (including the loss of human life), damage to the environment, natural resources or the cultural heritage are concerned, i.e. impacts where there can be no satisfactory agreement as to a representative market price, the most recent approaches seek to incorporate damage as part of multi-criteria-based analyses and no longer try to monetise them in a more traditional cost-benefit analysis.

The Seine: Choosing an approach

The criteria governing the choice of approach essentially depend on the objectives of the assessment, the sources of data and the available means. In the light of the potential effects of major flooding of the Seine River in Île-de-France, the assessment objective consists of going beyond the direct impacts to raising questions as to the indirect effects, for example the impact of the disruption to networks on economic activities, the macroeconomic impact and the impact on the national public finances.

To the extent possible, the approach consisted in building on and supplementing the work already done by the Seine Grands Lacs Local Public River Basin Authority (*Établissement Public Territorial de Bassin Seine Grands Lacs*) to calculate the direct

effects using coupled hydraulic and microeconomic modelling. Work done by Police Headquarters over the past ten years or so with network stakeholders provided a basis for incorporating vulnerabilities and damage to the various critical networks. The impact of disruption to the networks was discussed and assessed in partnership with the Institute for Urban Planning and Development of the Île-de-France Region (*Institut d'Aménagement et d'Urbanisme d'Île-de-France*, IAU Île-de-France). By integrating all of these microeconomic effects, a coherent initial economic assessment of direct and indirect damages was obtained. Results were categorised in terms of the destruction of public and private capital stock, as well as the fall in business output, for each of the various crisis scenarios.

With regard to the macroeconomic impact, the preference was to use a dynamic general equilibrium model to assess the indirect effects on growth, employment and public finances and, above all, to incorporate non-linear effects. In view of the importance of the Île-de-France region to the French economy (30% of GDP in 2011), a national model was developed to represent the impact dynamically in the short, medium and longer term. The incorporation of the specific features of the compensation funding linked to the French natural disasters insurance system, CATNAT, also made it possible to assess the impact on public debt and to test various scenarios for the budget response to such a catastrophe.

This approach makes it possible to assess all of the direct and indirect tangible costs at the national level. Only the costs of emergency intervention and secondary impacts on the real estate market were not calculated. It does not, however, incorporate the various more intangible impacts on health (psychological impact), the environment or heritage. Nor does it have regard to certain cross-border effects; the model assumes that the French economy operates in isolation. This includes damage to reputation that would affect the image of the Paris region as a destination for tourism or foreign direct investment, as well as the effects on other economies where there is significant integration with France, especially at the European level. Nonetheless, it is accepted that effects on tourism rarely last for more than one season as long as the process of recovery and reconstruction is efficient.

Developing flood scenarios

The first step in quantification is to develop flood scenarios that incorporate the various typical elements of such a crisis, including impact on networks. Reference to the 1910 flood was obviously necessary because of its mean frequency, the various levels of the protection thresholds in the Île-de-France region as a result of that event and the availability of associated information and variations on it at the DRIEE, the EPTB Seine Grands Lacs and the SGZDSP and its partners. Special attention was paid to time, as it has a decisive impact on businesses' operating losses. As a result, three scenarios were drawn up around the 1910 flood on the basis of the outcomes produced by the ALPHEE hydraulic model that the DRIEE and the EPTB Seine Grands Lacs used. The scenarios do not have regard to the effects of the four storage reservoirs upstream of the basin (Box 1.2).

Scenario S1 assumes 80% of the flood intensity of the 1910 event. The waters of the Seine reach a height of 6.90 m on the Austerlitz gauge and stay high for a week. Thanks to well-maintained local defences, the water in the major areas of urban development is largely contained by the protective banks and walls along the Seine. Nonetheless, the flood affects more than 100 000 people and floods 30 000 homes in the outer suburbs

upstream and downstream of Paris. Businesses and public facilities are also directly affected, resulting in operating losses and local disruption to water treatment, electricity and transport networks (in particular the RER C rail line) for at least two further weeks. Although slightly less severe, this scenario is representative of the historic floods of January 1924 and 1955 (around 7.30 m at Paris Austerlitz).

As a result of the works subsequently undertaken on the riverbed and bridges and the action of the reservoirs, the water in scenario S2 is 50 cm below the 1910 level, even though the flood intensity of the scenario is 100% of that of the 1910 event. The water height of 8.15 m at the Austerlitz gauge means that the city of Paris is protected by its banks and walls but the departments in the inner Paris suburbs are not, and the water overtops the defences there and spreads over a large area Over 600 000 inhabitants are directly affected, the bulk of them in the departments of the Hauts-de-Seine and the Val-de-Marne, and around 100 000 homes are flooded. The waters remain high for around two weeks, causing serious damage to businesses in the flood-prone area and a great deal of damage to public facilities and network infrastructure. However, the fact that the defences protect the core urban area means that most functionality in the metropolitan area is restored within one or two months of the end of the crisis period.

Scenario S3 envisages a 15% rise in intensity compared to the 1910 flood, and the water level reaches 9.11 m at Paris Austerlitz. As a consequence, the banks and walls are no longer capable of containing the water in several districts of Paris, and extensive areas of the urban area are submerged. The waters remain high for around one month in some places, directly affecting 1 000 000 people. Power cuts affect around 1.5 million households and businesses, and drinking water is no longer distributed or its quality is impaired for around 6.5 million inhabitants. The underground public transport network is extensively damaged and disrupted for a long period of time and it is impossible to travel from one side of the Seine to the other. Most of the inhabitants of Île-de-France experience a severe deterioration in their living conditions for several months. This major region of Europe experiences disruption to its economic activity for several weeks, and it takes months to restore normal living conditions that allow the inhabitants to return to work at pre-crisis intensity. In the meantime, many SMEs may have gone bankrupt and large companies have (provisionally) re-located their business.

Table 1.7. **Features of the flood scenarios**

Features	S1	S2	S3
Flow intensity (1910 flood)	80%	100%	115%
Maximum water height (Austerlitz)	6.90 m 1924 flood (7.32 m)	8.15 m	9.11 m 1910 flood (8.62 m)
Flood duration	1 week	2 weeks	1 month
Number of inhabitants affected	100 000	600 000	1 000 000
Critical networks – Electricity – Transport – Water	Localised partial disruption for 2 weeks in Paris suburbs	Extensive disruption for 2 months in Paris suburbs	Universal disruption: – 1.5 million customers without power – Metro lines closed for several months – 6.5 million customers without water (or with substandard water)
Disruption to economic activity	2 weeks	1-2 months	2-5 months

Sources: EPTB Seine Grands Lacs, SGZDSP, DRIEE.

Box 1.2. **Action of reservoirs on the flood**

The four reservoirs upstream of the catchment area have a total storage volume of 800 million m^3 to reduce flooding and maintain minimum flow. In a 1910-type flood, the optimum effect of the four reservoirs would be to reduce the water level in Paris by around 70 cm. If that were to happen, the river level would be between scenarios S1 and S2, with some overtopping of the clay walls in the inner Paris suburbs.

The protective effects of the reservoirs could be limited, however, if the flood occurs later in the season when they are already partially full, or if there were a succession of high-intensity floods that filled them to capacity. The preliminary flood risk assessment advocated under the European Floods Directive (Chapter 2) does not incorporate the role played by the reservoirs. During implementation in France, as in the other EU member countries (Chapter 2), the Floods Directive also recommends giving consideration to floods with longer return periods of around 1 000 years. With this in mind, the DRIEE has studied a more extreme scenario where the intensity is more than 40% greater than that of the 1910 flood.

This study uses scenarios S1, S2 and S3 with flow values at 80%, 100% and 115% of the 1910 flood and disregarding the effect of the reservoirs because these were the scenarios used by the various stakeholders in the region to assess the different impacts. The effect of the reservoirs can nonetheless be incorporated into the analysis using the probabilities of the various scenarios occurring; they differ depending on whether the protective effect of the reservoirs is taken into account. To that end, we have used the return periods calculated by the DRIEE for the various water heights with and without reservoirs: the figures where the dams are included are relatively uncertain given the data that have become available since their construction.

Features	S1	S2	S3
Maximum water height	6.90 m	8.15 m	9.11 m
Return period disregarding the reservoir effect	30 years	70 years	150 years
Return period including the reservoir effect	50 years	130 years	> 300 years

Source: DRIEE, EPTB Seine Grands Lacs, 2013.

Microeconomic impacts

Impact assessments of the Seine floods were conducted by the EPTB Seine Grands Lacs in the 1990s and updated using data from 2010 from the "ALPHEE" model. This model is in line with the traditional method for assessing direct costs using spatialised damage functions described above and enables hydraulic/economic coupling. The hydraulic component calculates the depth of the water, the flood time and the percentage of the area flooded over a grid of traps of various sizes in the Seine river-flat. The data on the effects are assessed for each trap using databases, namely the "land use" database of the IAU and the French National Institute of Statistics and Economic Studies' (*Institut National de la Statistique et des Études Économiques*, INSEE) database for resident population, number of dwellings and types of economic activities. The data were updated in 2010. The economic component calculates various direct and indirect impacts on housing, businesses and public facilities (Box 1.3).

The ALPHEE model does not, however, take account of the various types of damage to networks (public transport, roads, power, water) nor of the secondary effects of disruption. Scenarios S1, S2 and S3 were built using the work carried out by the General Secretariat of the Paris Defence and Security Zone involving many network operators. They assessed the impacts of the flood scenarios on their own infrastructure, hence the RATP estimated damage to its network in the order of EUR 1-5 billion, and ERDF has a

precise assessment of the various primary substations and high voltage/low voltage transformer substations that would be affected and/or flooded depending on the extent of the flooded area. Given that the replacement cost is estimated at EUR 20 million for a primary substation and over EUR 20 000 for a distributor, the damage to ERDF ranges from EUR 250 million to EUR 1 billion. Other damage to public facilities and networks is set out in Table 1.8.

Box 1.3. **Damage calculation method used by the ALPHEE software**

Damage to housing is assessed using the damage functions developed in Île-de-France in the 1980s following population land surveys of damage caused by the flood of winter 1981-82. The functions apply to six different types of housing depending on the level of the first floor and whether there is a basement, and estimate the cost of damage using real estate price indexes linked to the quality of the dwelling and the area in question. The indexes were also updated in 2010 using INSEE's data on construction costs.

Damage to businesses is assessed following categorisation into one of 19 classes of activity; damage functions are then used to determine the direct damage to immoveable property, stocks and equipment, and to determine the impact in terms of the fall in turnover in the case of indirect damage. The calculation is performed using the employee density for each type of activity (as obtained from field surveys, statistical methods) and the INSEE data as updated in 2010 for the various effects per employee and per field of activity. Damage to stock and equipment varies in line with the depth and duration of submersion; damage to immoveable property is a percentage of all direct damage, and impacts on turnover are the function of a coefficient depending on the type of activity and are proportional to the length of submersion.

Finally, specific damage functions are also incorporated to assess damage to public facilities (education, health, culture or government buildings). ALPHEE also performs calculations for a number of other types of damage to agriculture or certain associated indirect costs, for example drying of rooms or intervention costs, but we did not deem it relevant to include them here, either because they are negligible or irrelevant, or due to their method of calculation.

Source: EPTB Seine Grands Lacs, (2010), *Actualisation de l'estimation des dommages socio-économiques des crues en région parisienne*, Ledoux consultants, EGEO.

It is also vital to assess the length of time for which critical networks are disrupted in order to be able to calculate secondary impacts. Where the electricity network is concerned, ERDF is required to restore power to 95% of customers within five days of the end of a flood. However, supply can be restored to customers only when the individual electrical systems within buildings have first been reinstated and checked. In addition to these bottlenecks, which will take time to overcome, it will also be necessary to reconstruct certain primary substations, and this type of infrastructure is not available rapidly. The RATP estimates that it will take several months to reopen many lines and restore the metro to working order, and that total reconstruction could take several years in an extreme case. The working groups established by the Prefecture of Police and the responses to the OECD questionnaires indicate, moreover, that disruption to the electricity network will have the greatest impact on the loss of business.

Using the assessments for disruption to the ERDF network and the IAU cartographic analysis, it is estimated that the area affected by power disruption is 50% greater than the flooded area in scenario S3 and that the number of employees affected is 2.6 times higher. Loss of business activity is therefore also 2.6 times higher than the ALPHEE calculation for the flooded area alone. After the flood, these effects continue to be felt by flooded

businesses, whereas power is restored more rapidly to those that experience only a power cut. Therefore, in scenario S3A, it is estimated that 75% of flooded businesses have power restored after two months, whereas the power outage persists for longer in scenario S3B. In relation to the effect on the transport network, the comprehensive transport survey conducted by the Île-de-France public transport authority (*Syndicat des Transports d'Île-de-France*, STIF) in 2012 makes it possible to calculate the number of employees who use transport to get to work and who would be prevented from going because of flooding and its longer term effects (Box 1.4). In scenario S3B, the indirect effects persist for three months in some areas for power and for six months for transport.

Box 1.4. **Calculating the indirect impact of flooding on transport**

An assessment of the various indirect impacts of flooding on transport must avoid the temptation to double count and must therefore distinguish the effects of flooding from the effects of disruption to other networks. The Global Transport Survey (EGT) conducted every ten years by the STIF and the regional prefecture gives a detailed, quantified overview of mobility in Île-de-France and makes it possible to make the most accurate assessment of the effects of disruption.

In scenario S1, the impact on transport is essentially to close RER Line C which carries 500 000 people every day. The EGT tells us that, in Île-de-France, one-fifth of daily journeys are between home and work. The closure of the RER C line will therefore affect 100 000 of those journeys, or 50 000 workers. Other means of transport are available to them but take longer than the average 41-minute journey between home and work in Île-de-France. It is estimated that disruption to the RER C line would double journey time, thereby increasing these workers' commutes to 82 minutes, or around 7 hours per week, or 20% of their weekly working time. If that daily time loss is distributed equally between working time and personal time, the overall effect on business activity equates to a loss of 5 000 full-time equivalent posts, or one-quarter of the effects on business activity as calculated using the ALPHEE model. Assuming a recovery time of (at least) one month, the final equivalent effect in business operating losses directly related to flooding is EUR 190 million.

In scenario S3, in which damage is much more extensive, care must be taken to distinguish the effects on business activity that are associated with transport from those associated with electricity or flooding itself. To that end, the method is to calculate the number of additional workers affected by the disruption to transport or power supplies compared to those already in the flood-prone area or affected by power cuts. According to the EGT, 7.14 million commuter journeys are made in Île-de-France every day, of which 28% are shorter than 3 kilometres. So, 2.57 million workers travel further than 3 kilometresto get to work every day. It is assumed that not all those workers will be able to get to work during the flood period (some of them will be able to walk further than 3 kilometresor travel by bicycle, but others with shorter journeys may not be able to cross the Seine in flood). According to the IAU, 1.78 million workers work in the area affected by the power cuts in scenario S3. If we subtract 28% from that figure to represent those who could walk to work, then 1.28 million workers in the area affected by power cuts would also be affected by the disruption to transport. By removing them from the total number of workers who use public transport to travel to work, then ultimately 1.29 million additional workers would be affected by the disruption to transport during the flood period, amounting to additional business operating losses of EUR 3.74 billion. Road transport resumes in the post-crisis period: 50% of the 2.57 million workers who travel by motor transport can get to work again (car-sharing means that that number can be increased even though damage to road bridges caused by the flooding still imposes restrictions on the traffic, the two effects offset each other). Of the 1.3 million workers prevented from getting to work because of the persistent disruption to damaged public transport, it is estimated that 50% will resolve the problem using alternative means of transport or distance working. Thus, 600 000 workers will continue to be affected over the months following the flood; this is equivalent to a direct effect of flooding on business activity (EUR 1.96 billion) which persists for nine months, easing gradually over that time.

This microeconomic approach assesses direct damage at between EUR 3.2 billion and EUR 29.4 billion and business operating losses at between EUR 0.6 billion and EUR 19 billion depending on the scenario. The analysis is also consistent with the results of the model developed by the Central Reinsurance Fund (*Caisse Centrale de Réassurance*, CCR) using a different method (Box 1.5). All of the estimates of the various microeconomic impacts are summarised in Table 1.8, drawing a distinction between the destruction of public and private capital stock, as well as the temporary or longer term business operating losses resulting from the failure of some businesses located in high-risk or very high-risk areas. The various categories of damage and losses are then used in the next step modelling the macroeconomic impact.

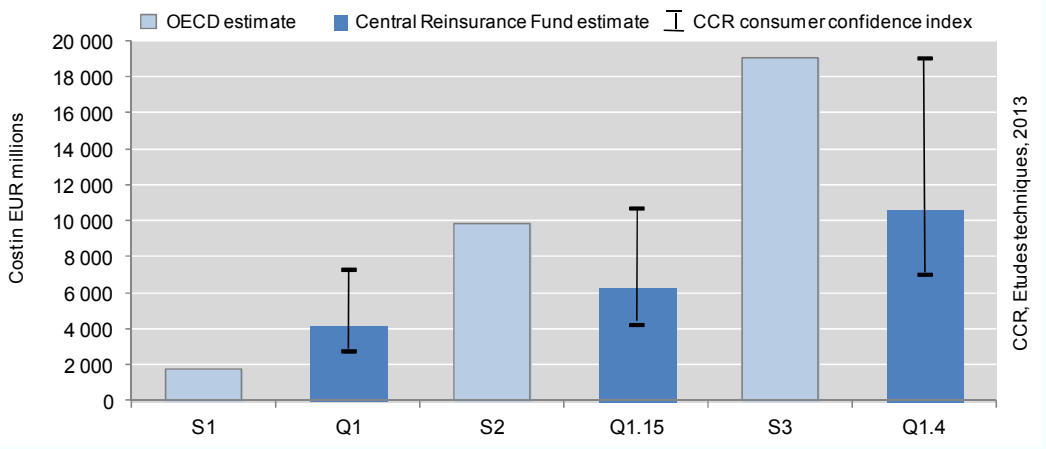
Table 1.8. **Microeconomic impact of flood scenarios**

	Direct and indirect impacts (EUR billions)	S1 Flood: 1 week Indirect impacts: 2 weeks	S2 Flood: 2 weeks Indirect impacts: 2 months	S3 Flood: 1 month Indirect impacts: 2-5 months		Source
Destruction of capital stock	Housing and moveable property	0.76 of which	4.08 of which	6.83 of which 0.39 automotive		ALPHEE[1]
	Stock (businesses) Equipment (businesses) Buildings (businesses)	0.04 automotive 0.81	0.23 automotive 4.71	8.54		ALPHEE
	Destruction of private capital stock TOTAL	**1.57**	**8.79**	**15.37**		
	Networks:					
	– Electricity	0.25	0.50	1.00		ERDF
	– Public transport	–	1.00	5.00		RATP
		1.00	2.00	5.00		SNCF[2]
	– Roads	0.00	0.05	0.10		OECD[3]
	– Water	–	–	1.00		OECD[4]
	– Public facilities and buildings	0.35	1.12	1.93		ALPHEE
	Destruction of public capital stock TOTAL	**1.60**	**4.67**	**14.03**		
Operating losses (fall in turnover)	SME failures (annual impact)	–	–	A 1.25-0.6-0.3-0	B 3 - 1.5 - 0.7 - 0	IAU-IdF[5]
	Total losses (quarterly impact) including:	**0.58**	**5.67**	**12.33**	**12.33+2.69*+0.98****	
	– Direct effects of flooding	0.19	1.06	1.96	1.96	ALPHEE
	– Effects of disruption to power supplies	0.19	2.59	3.20 + 1.47	4.67+0.73*	OECD[6]
	– Effects of disruption to transport	0.19	2.02	3.74 + 1.96	5.70+1.96*+0.98**	OECD[7]

Notes: 1. The results obtained using ALPHEE for specific damage (S1: EUR 1.01 bn; S2: EUR 5.95 bn; and S3: EUR 10.40 bn) appeared to be overvalued in comparison with the work done by the Central Reinsurance Fund (*Caisse Centrale de Réassurance*, CCR). A correction was therefore made by taking the average of the mean cost of damage for the various scenarios as calculated using ALPHEE and the CCR model. The specific damage to vehicles was also calculated at 5.7% of the total damage using the CCR figure. 2. The impact on one section of the RER D line (Paris-Villeneuve Saint-Georges) was assessed at EUR 500 bn by the SNCF, with a service restoration time of 18 months. The impact on the whole line, the very exposed RER C line, the three major Paris termini and many other suburban networks was estimated at ten times that amount in an extreme case. 3. In total, 44 kilometres of motorway and 200 kilometres of other major roads are likely to flood. The damage functions used on the Loire basin put the damage at 10% for a road with pavements. The average construction cost for 1 kilometre of motorway is estimated at EUR 6 bn. 4. Including sanitation, drinking water, treatment plants and their respective distribution networks, the water sector represents in total EUR 30 bn in capital, most of which is located in the flood-prone area along the river. Even though significant investment has been made to protect it from flooding, in an extreme event it is likely that 3% damage will occur. 5. Four thousand SMEs are in a very high-risk area (>2 m water), or disruption to networks will last longer than 3 months: 25% go bankrupt (A) with an estimated annual average turnover of EUR 1.25 bn (OSEO, 2012). Ten percent of the 15 000 SMEs in the high-risk area also go bankrupt. This effect diminishes over the years through new SME start-ups. 6. Network disruption lasts longer than the flooding and affects a more extensive area. The number of businesses affected is double or triple the number in the flooded area, losses are inflated by the same amount. Following the flood, power supplies are gradually reconnected to flooded businesses, thus extending their operating losses after the flood (S3A); half of these effects (*) persist for a second quarter (S3B). 7. See Box 1.4 for additional effects on transport.

Box 1.5. **Damage estimates by the Central Reinsurance Fund**

The Central Reinsurance Fund (CCR) is responsible for the French compensation scheme for natural disasters (CATNAT) and therefore conducts numerous disaster risk assessments. The CCR models flood risk in France using a national deterministic flood model, damage functions that it has constructed over the years and its geolocalised insurance database of insurance companies that obtain reinsurance from the CCR. As part of this project, the CCR has made its own estimates on the impact of various Seine flood scenarios, as depicted below.



In this analysis, the CCR estimates the losses and damage to individuals and businesses but does not include damage to networks or losses stemming from disruption to those networks. A comparison of the two sets of results should therefore contain only direct damage and operating losses directly associated with the floods in Table 1.8. The first results obtained by ALPHEE would appear to be higher than those of the CCR. In fact:

- The ALPHEE hydraulic modelling and the CCR deterministic model did not cover the same area. As a result, the ALPHEE S3 scenario is closer to the CCR estimate R1.4 and the S2 scenario closer to R1.15 in terms of the flood area.
- The direct damage to individuals would appear to be overestimated in ALPHEE with a higher average damage cost in the different scenarios. The option of using the average of the two values provides comparable estimates for the two approaches.

Source: CCR (2013), "La crue de la Seine en Île-de-France, Étude historique de la crue de 1910 – Modélisation de scénarios de reference", internal document.

Macroeconomic impact

A dynamic general-equilibrium model was used to assess the macroeconomic impacts of the various flood scenarios. The model represents the interactions between households, businesses and government, and assesses employment, wages and consumption by households; private investment and output by businesses; and public investment, tax rates and public debt for government. Its operation is based on optimising the well-being of households, business profits and public policy. The model was calibrated for the French economy and, given the data available, 2010 was used as the benchmark year. Figures are given for quarterly intervals, as this struck a good compromise for the various microeconomic effects, damage and losses on the one hand, but also reconstruction under the CATNAT compensation scheme on the other. The microeconomic impact of flooding is aggregated by way of a public and private capital destruction shock (for damage) and a

fall in output (for operating losses) as per the figures in Tables 1.9 and 1.10. Annexes C and D describe the hypotheses underlying the model in greater detail.

Table 1.9. **Calibration of the various shock scenarios**

	S1	S2	S3A	S3B
Destruction of private capital	-0.020%	-0.114%	-0.200%	-0.200%
Destruction of public capital	-0.110%	-0.230%	-0.573%	-0.573%
Temporary fall in output – quarter 1	-0.065%	-0.631%	-1.406%	-1.455%
Temporary fall in output – quarter 2	–	–	-0.035%	-0.383%
Temporary fall in output – quarter 3	–	–	-0.035%	-0.192%

Notes: 1. Private capital and public capital are calculated for 2010 at EUR 7 482 462.235 m and EUR 2 098 771.215 m respectively (for 2010) using OECD.Stat Dataset: 9A. "Fixed assets by activity and by asset, ISIC rev4". 2. The fall in output is calculated using a total value for cumulative turnover of EUR 3 596.4 bn in accordance with the INSEE *ENSANE database*, "Principaux résultats des entreprises par secteur en 2010" ("Key business results by sector in 2010"), www.insee.fr/fr/themes/tableau.asp?reg_id=0&ref_id=NATTEF09225 (accessed in September 2013).

Source: OECD (2013), *OECD Reviews of Risk Management Policies: Mexico 2013: Review of the Mexican National Civil Protection System*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264192294-en.

Table 1.10. **Compensation paid under the CATNAT compensation scheme**

EUR billions

		Scenarios			
		S1	S2	S3	
Direct damage	Housing	0.56[1]	3.70[1]	6.32[1]	
	Businesses	0.73[2]	4.21[2]	7.64[2]	
	Total damage	1.29	7.91	13.96	
Operating losses	Business failures	–	–	0[3]	0[3]
	Total losses	0.09	1.66	3.23	3.23+0.73
	– Direct effects of flooding	0.09[4]	0.80[4]	1.76[4]	1.76[4]
	– Secondary effects	0.00[5]	0.86[5]	1.47[6]	1.47 +0.73[6]

Notes: 1. CATNAT covers 100% of damage to housing and movable property subject to a deductible of EUR 380. If 30 000, 100 000 and 130 000 dwellings are affected, the total deductible amounts are as follows: S1: EUR 10 bn; S2: EUR 38 bn; S3: EUR 51 bn. 2. The deductible for damage to businesses is 10%. 3. There is no specific provision for business failures and associated CATNAT compensation. 4. CATNAT covers operating losses subject to a deductible equivalent to three business days. This equates to 50% of losses for S1 (one week of flooding), 25% for S2 (two weeks) and 10% for S3 (one month). 5. Here, 33% of this damage is the result of secondary effects for businesses that are flooded and therefore covered. 6. This damage relates to disruption to power supplies suffered by businesses in the flood-prone area that will therefore have already paid their deductible.

Source: OECD (2013), *OECD Reviews of Risk Management Policies: Mexico 2013: Review of the Mexican National Civil Protection System*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264192294-en.

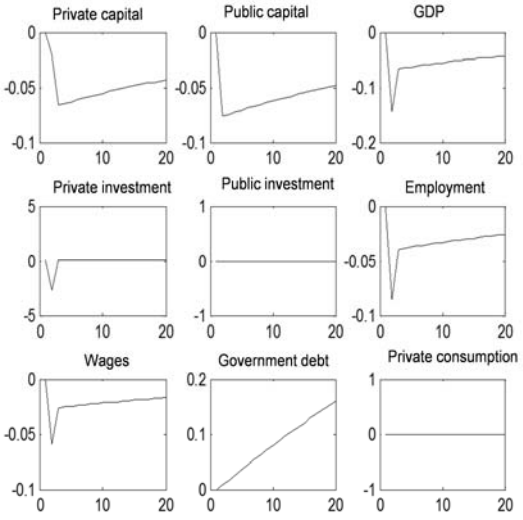
A major Seine flood in Île-de-France would be declared a natural disaster by the government and would trigger the CATNAT compensation mechanism. The reserves in the CATNAT compensation scheme are calculated at EUR 5.7 billion in 2013 (EUR 3.4 billion with the CCR and EUR 2.3 billion with private insurers). In addition, the state guarantee would be automatically triggered to finance other damage and losses that the state budget covers under the system, and that amount would therefore be charged

to the public finances. The system covers all private damage suffered by those inhabitants and businesses directly affected by the flood, including businesses' operating losses provided that the businesses are insured against operating losses under their fire coverage. Payment of compensation is treated under the model as reinstatement of private capital with no effect on the state budget up to the level of the available reserves. Calling in state cover affects levels of debt. By law, reimbursement must be made within three months of the declaration of damage. In the model, the transfers are therefore made in the two quarters following the damage.

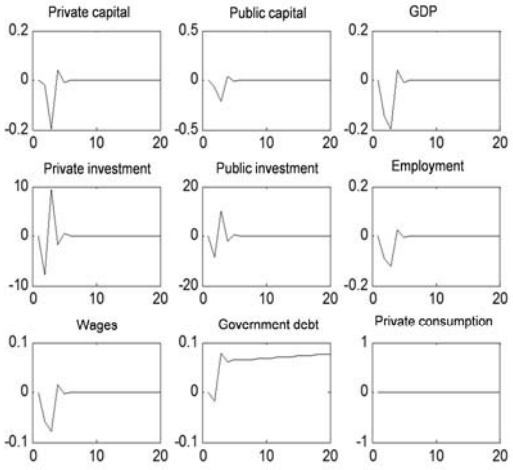
The model calculates that the destruction of public and private capital and the fall in activity result in an immediate fall in GDP and employment in the quarter when the flood occurs. The falls range from -0.15% for GDP and -0.09% for employment in controlled flooding scenario S1, to -2.7% for GDP and -1.6% for employment in the most extreme scenario S3B. The reduction in the tax base that accompanies the economic slowdown leads to an immediate increase in public debt. That debt continues to grow in subsequent quarters as a result of financing needs under the CATNAT compensation scheme and the associated state cover, as well as a tax base that is smaller than pre-flood levels with no change in fiscal policy. The speed of recovery varies according to the scenario, and in scenarios S3A and S3B the impact is extended by SME failures. The effects of increased public investment were also tested by the model with public investment set at optimum levels. This means that, for scenarios S1 and S2, the impact on GDP and employment can be reduced in the medium term. By contrast, the crowding-out effect on private capital means that the impact of the investment on debt levels becomes too great for the positive effect on GDP to have any significance in scenario S3B.

Figure 1.7. **Macroeconomic impact – Scenario 1 (quarterly basis)**

(a) without any change in public investment



(b) with changes in public investment

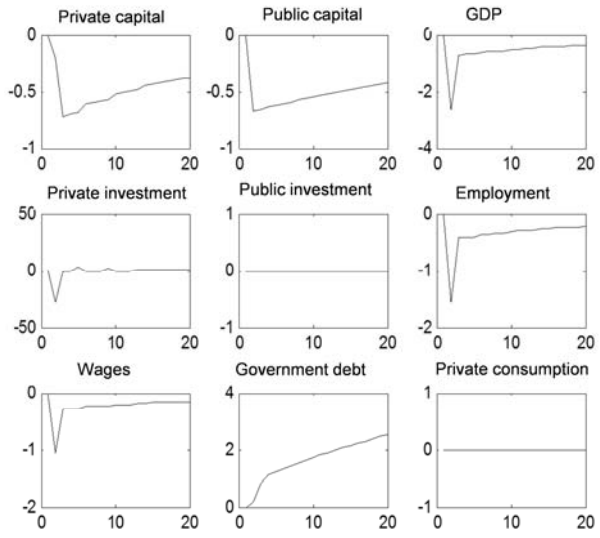


Thus, beyond direct damage, a major shock could have a significant national impact at macroeconomic level in terms of GDP in a steady state, with repercussions for both employment and public finances. The latter would then come under severe pressure and may suffer corresponding deterioration over a long period. The consolidated results over a five-year period show a cumulative loss of GDP for the various scenarios ranging from EUR 1.5 billion to EUR 58.5 billion and an increase in public debt of between 0.1% to

close to 3% (Table 1.11). Most of the effects arise in the year following the shock, and the rebound effect of reconstruction investment restricts the increase in negative macroeconomic effects. From the second year, the rebound may also be very slightly positive in relation to both GDP and employment in the less extreme scenarios. In the extreme scenarios, however, the impact on activity and the workforce is highly significant with a reduction in the order of 300 000 to 400 000 full-time equivalent posts. In France, social safety nets would come under severe pressure, further increasing the effects on public debt.

Figure 1.8. **Macroeconomic impact – Scenario 3A (quarterly basis)**

(a) without any change in public investment



(b) with changes in public investment

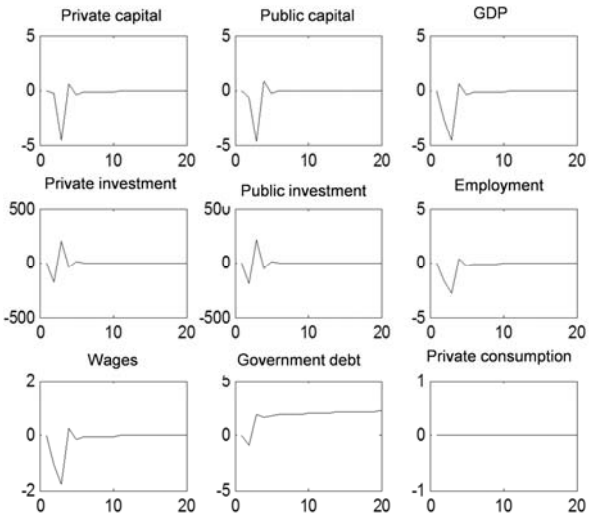


Table 1.11. **Macroeconomic impacts of floods consolidated over five years**

Year												
	%	EUR bn	%	FTE	%	EUR bn	%	EUR bn	%	FTE	%	EUR bn
	S1						S2					
1	-0.078	-1.51	-0.047	-12 698	0.065	1.04	-0.708	-13.7	-0.433	-115 900	0.824	13.1
2	0.000	0.0	0.000	55	0.068	1.08	0.003	0.07	0.002	548	0.852	13.6
3	0.000	0.0	0.000	0	0.071	1.12	0.000	0.0	0.000	1	0.888	14.2
4	0.000	0.0	0.000	0	0.074	1.18	0.000	0.0	0.000	0	0.925	14.8
5	0.000	0.0	0.000	0	0.077	1.23	0.000	0.0	0.000	0	0.964	15.4
	S3A						S3B					
1	-1.730	-33.5	-1.066	-285 665	1.803	28.8	-2.618	-50.7	-1.614	-432 597	2.280	36.4
2	-0.107	-2.06	-0.065	-17 315	1.941	31.0	-0.267	-5.17	-0.162	-43 399	2.539	40.5
3	-0.054	-1.04	-0.033	-8 752	2.060	32.9	-0.129	-2.49	-0.078	-20 915	2.737	43.7
4	-0.004	-0.07	-0.002	-606	2.152	34.3	-0.009	-1.72	-0.005	-1 440	2.866	45.7
5	0.000	0.0	0.000	0	2.240	35.7	0.000	-0.3	-0.000	0	2.983	47.6

Notes: 1. The value used for GDP for 2010 is EUR 1 936.7 bn, the gross public debt for 2010 is 82.6% of GDP and the number of jobs is 26 797 800 according to OECD.Stat. 2. FTE: full-time equivalent posts.

Conclusion

Given the vulnerability of the infrastructure and facilities now in place in the floodplain in Île-de-France, the impacts of a major Seine flood of a level equal to the great flood of 1910 would pose a substantial challenge to government authorities. Many floods have significantly exceeded historical levels in OECD countries recently (Czech Republic 2002, United Kingdom 2007, Australia 2011, United States 2012, Germany 2013) and dictate that all aspects of the risk be considered. In France, such an event would directly and indirectly impact around 5 million citizens and many businesses, resulting in significant economic, human and social effects. Future debate on such impacts must examine the sector's interdependencies, for instance between the critical networks (energy, communications, water, transport) and the large industrial and service sectors. Major flooding could affect key sectors such as tourism or food distribution, or the car industry. These are therefore major national issues.

The assessments that have been conducted show that a major shock could have a significant macroeconomic impact in terms of GDP with repercussions on employment and public finances. The latter would then come under severe pressure and may suffer corresponding deterioration over a long period. The damage from such a catastrophe has been estimated at between EUR 3 billion and EUR 30 billion for direct damage depending on the flood scenario, together with a significant reduction in GDP which, over five years, would amount to between EUR 1.5 billion and EUR 58.5 billion. The fall in business activity caused by the flood would have a significant impact on the demand for labour, with a loss of up to 400 000 full-time equivalent posts in an extreme case. Even if the rebound in business might alleviate some of these effects rapidly after one year, the detrimental consequences of a major Seine flood would be felt over the long term and would weigh on public finances. Should the impact exceed the reserves available to cope with it from the CATNAT compensation scheme, the state would have to assume its full responsibility as guarantor of last resort.

Although these effects are significant, it should be emphasised that this analysis is an exploratory one, and that this is not a systemic risk with irreversible effects: a variety of budgetary response mechanisms could be set up – rapidly if they are anticipated and planned in advance. Nonetheless, there is a high degree of uncertainty: a millennial flood is the extreme scenario that must be considered in public policy under the European Floods Directive. Moreover, the effects could be multiplied if a flood occurred in combination with another major event.

This risk assessment of major Seine flooding in Île-de-France gives a better appreciation of the need to calibrate and re-evaluate public policies in this field both in terms of crisis management – an essential aspect for government – and in terms of the prevention policies addressed in this report. The way to bolster the resilience of the Île-de-France region is through policies of prevention and vulnerability reduction, commensurate with the region's resources and economic advantages.

Notes

1. The probability of non-occurrence is 0.99. Given that life expectancy in France is 82 years, the probability of not experiencing an event of this type is $(0.99)^{82} = 0.44$, leaving a probability of 0.56, or a greater than even chance, that it will be experienced.
2. Replacing destroyed assets with newer technologies can lead to productivity gains once reconstruction is complete.

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Chapter 2

Governance to prevent a Seine flood in Île-de-France

This chapter analyses the deficits in governance that have affected flood risk prevention policies in Île-de-France and explores the opportunities currently available that could overcome them. In the past, the institutional and administrative fragmentation of the region as a result of multiple decentralised tiers might have impeded action. This chapter proposes ways of better harmonising public policies with a view to a bold flood prevention strategy.

Introduction

The response to a major flooding risk of the Seine River in Île-de-France lies in an appropriate governance framework aimed at organising public policies to improve resilience in this strategic area. In addition to the crisis management preparation strategies that need to be established in respect of this key risk, preventive policies will help reduce the vulnerability of the Paris region in the long term.

Experience in other OECD countries shows that risk management requires the co-ordination of a large number of organisations and resources at various administrative levels, along with the private sector and civil society. For each of the phases in the risk management cycle, a robust legal and institutional framework together with well-defined governance mechanisms are necessary for an integrated approach for risk management. Hence, an effective prevention policy must be based on a clear definition of each stakeholder's obligations supported by incentive and sanction mechanisms to reduce exposure and vulnerability effectively.

In terms of governance, the key points concern the coherence of the legal and regulatory framework and the institutions' mandate to the benefit of an established and shared strategy, as well as co-ordination and effective co-operation between the various stakeholders for its implementation. This includes questions of vertical consistency – between the various administrative levels – and horizontal consistency – between the various spheres of public policy – in the distribution of roles and responsibilities, avoiding duplication of effort and fostering synergies.

This chapter sets the strategic flood risk prevention strategy framework in Île-de-France in the broader context of a French national risk prevention policy and other related spheres of public policy (emergency response, regional planning, water management and decentralisation).

Strategic framework for flood risk prevention in Île-de-France

Legal and regulatory framework for risk prevention in France

Like most OECD countries (OECD, 2014), the principal laws on risk prevention over the past 30 years have been formulated and voted on in the wake of major disasters which highlighted the shortcomings in the public risk prevention policies then in place. The laws of 1982, 1995 and 2003 on risk prevention (Box 2.1) followed major floods in France, although none of the events directly affected Île-de-France. The laws established an arsenal of legal instruments based on risk assessment and mapping, information and risk communication, prohibitions or restrictions on local government powers to authorise building in floodplains, and an insurance and finance scheme specifically for prevention. The laws provide a structure for stakeholders' roles and responsibilities in implementing the various tools available. They make it possible to set up a risk prevention policy that abides by the principles of subsidiarity between the various tiers of government and national solidarity to cope with risk. They have their limitations nonetheless, some of which are specific to each individual instrument. However, one key limitation lies in the fact that there are so many of them: the stakeholders in charge of implementation are too thinly spread, resulting in an absence of political will, co-ordination and control (Conseil d'État, 2010). Although these various arrangements have helped to prevent the risk of flood in the Seine basin (Chapter 3), they have not led to the development or emergence of a specific strategy to prevent this undeniably major risk nationally.

Box 2.1. History of the main risk prevention laws in France

The Law of 1982 on Compensation for Victims of Natural Disasters followed the serious floods of 1977, 1980 and 1981-82, including in Île-de-France. When the private insurance market did not cover flood risk, homes and businesses that had suffered harm had to bear the full cost. In response, the 1982 law introduced an original insurance system: the CATNAT compensation scheme. This scheme made it compulsory for the private insurance market to include natural disasters in their insurance cover, while the state guaranteed the financial viability of the system subject to a strict framework: insurance was compulsory regardless of exposure; a single premium and deductible were provided for; the Central Reinsurance Fund (*Caisse Centrale de Réassurance*, CCR), owned by the state, reinsured natural hazards with a state guarantee. Although the main focus of previous laws had been on risk control, the compensation mechanism based on national solidarity required a land-use policy and a degree of urban development regulation to reduce exposure to natural hazards. That was why the 1982 law also introduced risk exposure plans that allowed local bodies to reduce risk, although the system was subject to state control.

The 1995 Law on Increased Environmental Protection ("Barnier Law") was formulated following the floods of 1992, 1993 and 1994. While the CATNAT scheme had proven its use as a public policy instrument, control of urban development in the floodplain had not been effective under the 1982 regulations. The 1995 law unified the various risk prevention instruments under risk prevention plans (*plans de prévention des risques*, PPRs): this key new regional development instrument laid down regulations on urban planning at the local level. Since then, the Ministry of Ecology, Sustainable Development and Energy (*Ministère de l'Écologie, du Développement Durable et de l'Énergie*, MEDDE) has played an important role in promoting the development of PPRs in municipalities exposed to risk. The law also established the Fund for the Prevention of Major Natural Hazards (*Fonds de Prévention des Risques Naturels Majeurs*, FPRNM), or "Barnier Fund", financed by a levy on the CATNAT insurance premium, to finance asset-acquisition measures, the outlay involved in drawing up PPRs, information on prevention and measures to reduce vulnerability to risk.

The 2003 Law on Prevention of Natech Risks and Damage Reparations, or "Bachelot Law", was the result of the Gard floods in 2002. It boosts preventive regulations on hazard information through a series of measures such as a requirement to set flood marks or upgrade the flood forecasting system. The law also recognises local public river basin authorities (*établissements publics territorial de basin*, EPTBs). It extends the departmental tax for environmentally sensitive areas (TDENS) to the acquisition of land that accommodates flood surges. Finally, it provides for public easements for temporary floodwater retention or runoff, enabling the establishment of additional flood expansion areas on private land.

Source: AScA, Ledoux Consultants (2012), "L'agence de l'eau Seine-Normandie et la gestion du risque inondation: Quelle stratégie de positionnement? Synthèse stratégique", Agence de l'eau Seine Normandie, Nanterre, France.

The other key aspect of the regulatory framework relates to local governance, which has been affected by waves of decentralisation that have often shared responsibilities out between local and central levels (see below).

The relative spread of responsibilities and the multiplicity of texts ultimately led the state to adopt a contract-based approach under flood prevention action programmes (*programmes d'action et de prévention des inondations*, PAPIs). Established under a circular from the Ministry of Ecology, Sustainable Development and Energy in 2002, the PAPIs rally central government stakeholders and local authorities to co-operate on integrated, comprehensive prevention projects for flood-prone river systems. In fact, local

contracting authorities develop the programmes and submit them to central government for financial support in a competitive selection process. The integrated approach they use means that all prevention and protection measures can be incorporated: improved knowledge and heightened awareness of risk; establishment of forecast and warning systems; reduction in vulnerability through land-use and urban planning; and development of protective infrastructure in sensitive urban areas and flood surge areas. Between 2003 and 2009, 50 PAPIs were accepted and financed with a total budget of EUR 889 million (one-third from the state and two-thirds from local government and the European Union). Within the allotted budgets, 90% was for structural protection or water regulation projects (Ministry of Ecology, Energy, Sustainable Development and Sea, 2010). A new call for proposals for PAPIs was launched in 2011. Following the floods caused by the storm Xynthia and those in the Var in 2010, a new contractual instrument specifically focusing on flash flooding as a result of dyke failure was formulated in 2011: the rapid flooding plan (*Plan submersions rapides*, PSR). The two instruments have a maximum allowable spend of EUR 500 million for the period 2011-16 marshalled by the state through the FPRNM (Box 2.1) which, together with local government, provides co-finance amounting to around 40% of the total amount. Although the bottom-up approach for PAPIs has brought local contracting authorities to the fore in risk prevention, the selection processes have not necessarily prioritised resource allocation to the most risk-prone areas. Hence, prevention of the Seine flood risk in Île-de-France has benefited very little from this mechanism since it was put in place (see Chapter 4). However, a PAPI on this very risk is in the drafting stage at the Seine Grands Lacs Local Public River Basin Authority (*Établissement Public Territorial de Bassin Seine Grands Lacs*) and may be included in a holistic strategic framework for managing the Seine flood risk.

Box 2.2. **The Loire Grandeur Nature Plan and the strategic approach it takes to flood risk management**

The "Loire Grandeur Nature Plan", or the "Loire Plan", in the Loire basin has steered the development of flood risk management for 15 years towards a strategy of living with floods instead of trying to reduce the flood risk to nil by controlling rivers. The plan provides for a framework of specific measures in support of studies that provide better models of major floods and flood risks, reduce people's and businesses' vulnerability to the direct and indirect consequences of flooding, heighten public awareness of flood risk and beef up flood forecasting.

The process of selecting flood prevention projects is the subject of discussion in the broader context of water use, environmental protection, and preservation of cultural and recreational activities. This holistic approach acknowledges the variety of interests and groups that attach different values to river resources. It also provides a structure that allows for informed trade-offs. Project selection is bound, among other things, with the water policy guidelines on recognition of the contribution made by floods to recharging wetlands and the water table.

The policy is part of the Water Development and Management Master Plan (*Schéma Directeur d'Aménagement et de Gestion des Eaux*, SDAGE) formulated by the Loire-Brittany Basin Committee which includes local government, economic stakeholders, central government authorities and associations, including nature conservation associations.

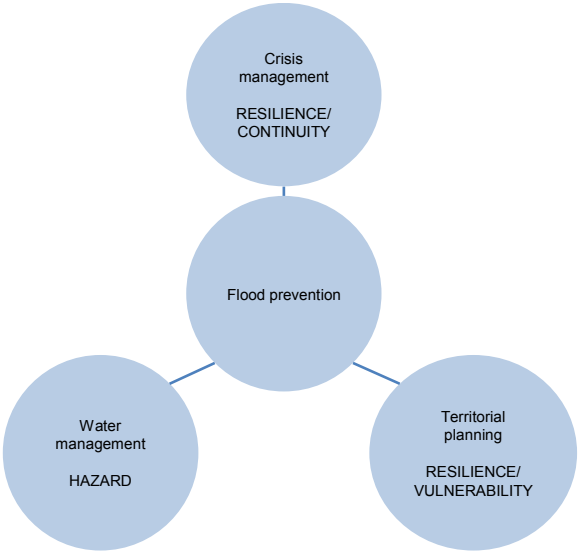
Source: OECD (2010), *Étude de l'OCDE sur la gestion des risques d'inondation: Bassin de la Loire, France 2010*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264056817-en.

The "Grand Fleuve" ("Great River") plans are also key to establishing a flood prevention initiative at territorial level for the major river systems. Launched in 1994 with the Loire River, the plans have since spread to all major French rivers and are, in fact, territorial development action plans along the main river stems. The plans mean that the priority features of territorial development can be included around the major river stems in the state-region planning contracts (*contrats de plan État-région*, CPER) that are signed periodically, providing access to European finance under the European Regional Development Fund. The Seine Plan was developed to facilitate identification and clarification of priorities that central government stakeholders and local authorities (essentially the regions) should consider for sustainable development around the river stem. The first Seine Plan was adopted in 2007 for the period 2007-13. It includes reducing the risk of major Seine flooding similar to that of 1910 among four priority axes. It includes a list of specific projects such as the La Bassée water storage project (Chapter 3) and finance for projects in the fields of hazard control, vulnerability reduction or environmental protection. The new Seine Plan is currently being formulated. By contrast to other "Grand Fleuve" plans (Box 2.2), the Seine Plan has not been politicised and has not been the subject of a communication allowing stakeholders in the basin to take ownership of it (MEDDE, 2012b). It has not therefore become a genuine strategic framework for Seine basin flood management or prevention in Île-de-France in particular.

Interaction with other areas of public policy

Flood risk prevention policies must tie in seamlessly with other areas of public policy if they are to be effective (Figure 2.1). A holistic approach to flood risk management must in effect be based not only on prevention but also on crisis management policy. Similarly, consistency with regional planning and water management policies is necessary to ensure that the benefits of flood prevention policies are fully maximised.

Figure 2.1. **Public policies and their links to flood prevention**



Links to crisis management policies

The policy on crisis management preparedness was revisited in 2004 when the emergency response modernisation law was adopted. By insisting on a society-based approach, the law seeks to increase the commitment of all stakeholders to emergency

response, especially citizens and private stakeholders, supplementing the traditional public stakeholders on the front line organised by the state. The law simplified the structure of emergency planning by combining the multiplicity of previous emergency plans under the single structure of the Disaster and Emergency Response Organisation (*Organisation de la Réponse de Sécurité Civile*, ORSEC) mechanism (Veyret and Laganier, 2013). On permanent watch, ORSEC mobilises and co-ordinates the whole network of emergency response stakeholders under the sole authority of the Prefect at the administrative level appropriate to the crisis. The law also insists on crisis management at the local level by requiring all municipalities subject to a PPR to draw up a local emergency response plan. Operators of public services and networks (water, electricity, health, telecommunications) are also called upon to put business continuity plans in place to keep their businesses or operations running in times of crisis, even if services are reduced. The link with preventive measures is crucial where business continuity of critical network operators is concerned, in particular in relation to flood risk. Network resilience is, in fact, a key factor in overall flood resilience, especially in urban areas. More broadly, the network of the numerous crisis management stakeholders under the ORSEC mechanism also points to potential effective synergistic partnerships with the field of prevention.

The ORSEC emergency management mechanism in Île-de-France for major Seine flooding is one of the rare instances of integrated flood-risk management at regional level. It was updated in 2010. The mechanism was approved by the General Secretariat of the Paris Defence and Security Zone (*Secrétariat général de la Zone de Défense et de Sécurité de Paris*, SGZDSP) because of its role in crisis management for the whole of Île-de-France. It is the result of work done under the aegis of the SGZDSP since the Seine quay flood in Paris in 2001. Indeed, at that time, a decision was taken to improve flood preparedness because the mechanisms in place appeared limited. In the light of the specific vulnerabilities of the Île-de-France metropolitan area (Chapter 1), significant efforts were made to that end over several years to bring together a number of key stakeholders in crisis management, including network operators and the private sector. Subject-based working groups were established and have been working together since 2003 on the management of major flooding. The sectors involved include transport, power, banking, telecommunications, distribution and others. The SGZDSP continues to lead the groups as part of crisis preparedness work. A simulation was conducted in 2010. ORSEC has therefore been involved in raising the awareness of a number of the stakeholders and has made their vulnerability very apparent. Stakeholders are now keen to become more involved in the prevention issues for which there is currently no governance structure in place.

Links with regional planning and decentralisation policy

One major aspect that has led to fragmentation of risk-management responsibilities lies in decentralisation policies; the indirect effects they have had in fields such as this clearly were not fully appreciated at the outset. Regional planning and development policy was largely devolved to local government in the various waves of decentralisation that began in the 1980s, especially in relation to municipalities and regions (OECD, 2006). The 36 700 French municipalities are responsible for urban development matters, which play a key role in reducing exposure and vulnerability to flooding: they must draw up the local urban plans (*plans local d'urbanisme*, PLU) introduced under the Law on Solidarity and Urban Development of 2000. The PLUs set out an overall urban development and planning outline and lay down land-use rules as the central urban

planning document. The risk prevention plan is among the annexes. Introduced under the same law, territorial coherence schemes (*schémas de cohérence territorial*, SCOT) are broader strategic planning tools for the medium to long term. They set out a territorial project for several municipalities or groups of municipalities that seeks to ensure consistency between the various sectoral local policies, especially in the fields of urban development, housing, travel and commercial facilities, with a view to sustainable development. However, regard must be given to the fact that, at municipal level, urban development using the available land reserves, especially in a densely developed region such as Île-de-France, is also often a prime motivator for municipalities, outranking risk assessment policies.

The laws of 2003 and 2004 that comprised the second wave of decentralisation conferred broader regional planning and economic development powers to the 22 French regions. As a result, the regions became responsible for the strategic planning of medium- to long-term regional development. This is reflected, among other things, in their involvement in formulating CPER, a multi-annual programming and funding document (five to seven years) for public policy in the regions. Long-term regional planning is a powerful tool for improving the flood resilience of regions and critical infrastructures.

The development and planning strategy for the Île-de-France region for the next 20 years depends largely on the implementation of the Greater Paris (*Grand Paris*) project and the Île-de-France Regional Master Plan (*Schéma Directeur Régional d'Île-de-France*, SDRIF). The Greater Paris Law adopted in 2010 provides for a national project to develop the Paris region around a modern major transport network. Within that framework, territorial development contracts (*contrats de développement territorial*, CDT) are underway between local and central government to integrate the state-funded transport network into the objectives of balancing and densifying the Paris region. Put to the vote of the Île-de-France Regional Council on 18 October 2013, the SDRIF puts forward a vision of the region for 2030 based on two major objectives: *i)* improved quality of life for residents through developments in housing, employment, public transport infrastructure, and urban and environmental management; and *ii)* improvement in the way the region operates as a metropolitan area through spatial reorganisation of economic development dynamics and the planning of appropriate facilities and transport systems with a view to sustainable development. Resilience to shocks is addressed in the SDRIF, as is resilience to flooding. However, the SDRIF does not commit to any precise objective in that regard: it merely refers to PPRs for local urban planning rules and strategic documents, namely the Seine Plan, the Water Development and Management Master Plan and the future strategy to be introduced pursuant to the European Floods Directive with which it must also comply by law (see below).

Links with water management policy

French water management policy has always been separate from flood prevention (Conseil d'État, 2010) and based principally on managing the various uses of water and the availability of a good quality and quantity of supply. The principles it has enshrined since the first water law of 1964 – management by catchment basin, multi-stakeholder governance, the user-pays and polluter-pays principles and the multi-annual programming of financial support – nonetheless provide an interesting viewpoint for flood management. Those principles formed the groundwork upon which the concept of integrated water resources management was based, a concept that has been broadly adopted internationally (Ministry of Ecology, Sustainable Development, Transport and Housing, 2012). The 1992 and 2006 laws on water gradually extended the water

management approach to environmental conservation, especially when implementing the European Water Framework Directive (WFD). The WFD focuses water management policy on the general objective of attaining high ecological status of bodies of water by 2015, and multi-annual programming essentially concentrates locally on that objective. The SDAGEs are the main programming instruments for river basin districts and are adopted by river basin committees, genuine water parliaments with multi-stakeholder representation (national and local government, users, associations) for the seven major river basins. Water agencies are responsible for collecting fees (for usage and pollution) and for funding the SDAGE guidelines using their multi-annual co-financing programmes. Where water management is concerned, the EPTBs are responsible for the balanced management of water resources and for flood prevention and bring local government bodies together to ensure consistency in the measures taken by local contracting authorities for the basin in question.

There is no shortage of synergies between flood management and water management policy, and they should be better exploited: use of river basin consultative bodies to draw up shared flood strategies, the benefits of multi-usage approaches for water infrastructure, and greater attention to the water cycle in the context of climate change are all opportunities to narrow the gap between the two policies with an eye to greater efficiency and effectiveness. This is even more important today, when the implementation of European Directive 2007/60/EC on the assessment and management of flood risks (European Union, 2007; the "Floods Directive") rightly insists on synergies with the WFD in the light of the outlook for reforms under way in decentralisation of water policy in France (Box 2.3).

Box 2.3. **Regional reform and water policy: Towards new local powers**

As part of the third wave of decentralisation that began in 2012 and was adopted on 10 December 2013, local government was vested with a new power on management of aquatic environments and floods. By 2016, that power will be in the hands of groups of municipalities (inter-municipal co-operation structures [EPCI] with tax-raising powers) in accordance with the Law on Local Government Reform of 16 December 2010. The power to levy a local tax in relation to the new power is vested in the law.

It also provides for the creation of metropolitan areas, including "Greater Paris". The law provides for the municipalities in the inner Paris suburbs to band together in an EPCI with tax-raising powers which will be responsible for regional planning, housing and sustainable development.

At the same time, the government is reviewing water policy as part of a public policy modernisation project. In addition to the debates on the major issues of protecting water resources and pollution control, issues relating to governance and funding have been raised. They relate, in particular, to the synergies between water policy and other major issues such as flood management, as well as financial matters associated with the use of resources collected by water agencies for other related high-priority uses.

Source: Assemblée Nationale (2013), "Projet de loi de modernisation de l'action publique territoriale et d'affirmation des métropoles – Texte définitif", 19 December 2013, Assemblée nationale, Paris, www.assemblee-nationale.fr/14/ta/ta0270.asp; Ministry of Ecology, Sustainable Development and Energy (2013c), "Politique de l'eau", *Document de travail de la table ronde de la conférence environnementale*, Ministry of Ecology, Sustainable Development and Energy, Paris.

The SDAGE for the Seine-Normandy river basin adopted by the Seine-Normandy River Basin Committee in 2009 sets out the objectives that must be achieved in order to implement the WFD. It also identifies eight major challenges and the appropriate guidelines that should be used to address them. The eighth and final challenge concerns flood risk prevention in the river basin. It directs the water stakeholders, meeting in committee, to take action on five fronts: *i)* knowledge and a culture of risk; *ii)* reducing the vulnerability of people and assets; *iii)* developing flood surge areas; *iv)* limiting the negative impacts of defences; and *v)* reducing runoff. However, the tenth funding plan of the Seine-Normandy Water Agency (*Agence de l'Eau Seine-Normandie*, AESN) adopted for 2013-18, which relates to funding the SDAGE guidelines, provides for only very limited funding in these areas: they remain separate from water management policy as it is understood in France, since the law and ministerial framework do not confer powers to that end to the water agencies (Agence de l'Eau Seine-Normandie, 2013).

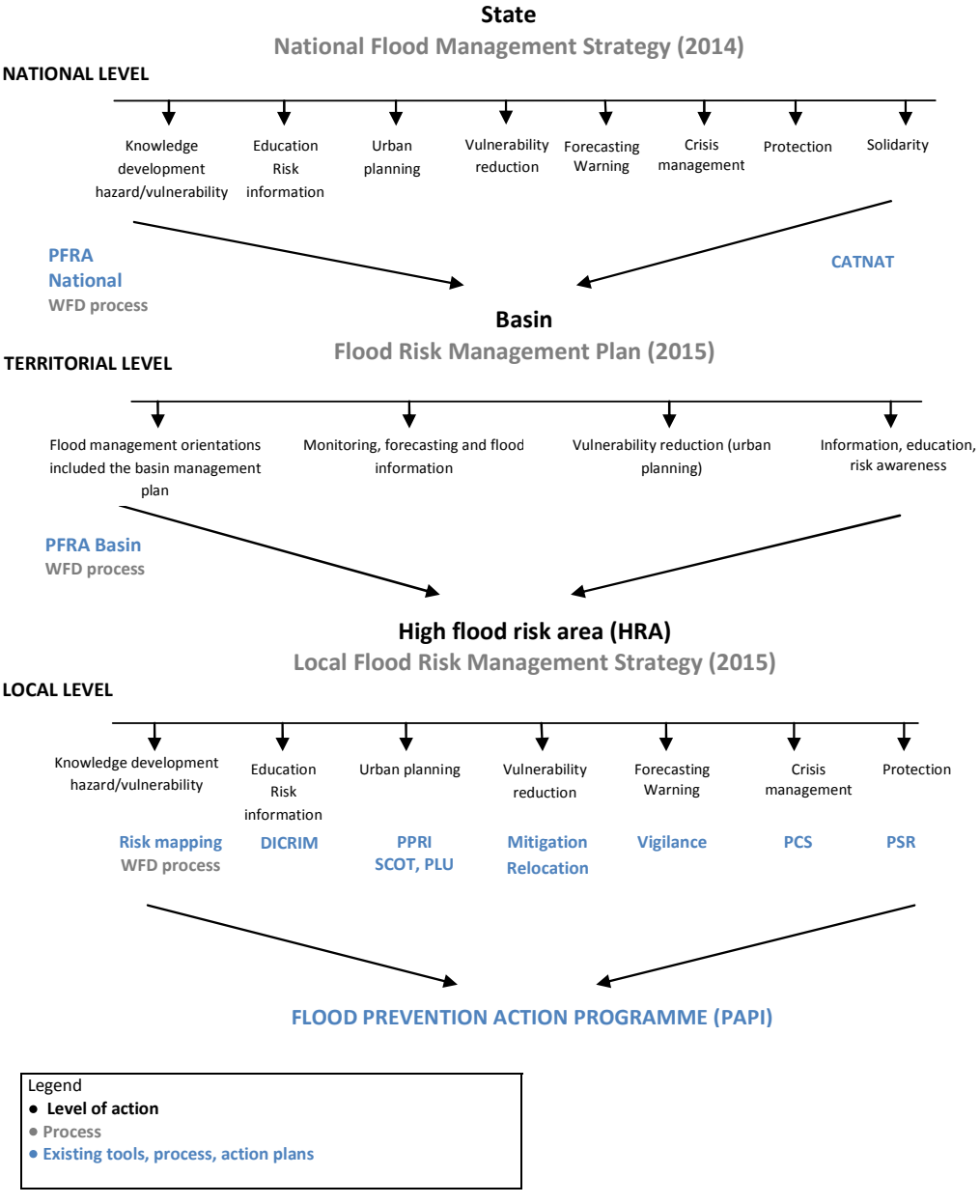
Implementation of the European Floods Directive

Implementation of the Floods Directive could have a significant impact. Transposed into French law under the Grenelle II Law of 2010, the Directive provides for concentrating prevention efforts on the areas where exposure is greatest by establishing rigorous, quantified objectives on vulnerability reduction that focus on the potential impacts of flooding on human health, the economy, the environment and the cultural heritage. While leaving a certain degree of flexibility to EU member countries, the Directive provides for a three-stage strategy linked to a clear timetable. The stages have to be reviewed every six years in a co-ordinated cycle synchronised with the WFD. The strategy includes:

- A preliminary flood risk assessment (PFRA) for the major river basins and nationally to identify the areas at greatest risk. The preliminary assessment was finished in France at the end of 2011 and identified high flood-risk areas (HRAs).
- By the end of 2013, drafting maps of floodplains and the risk of floods with a low, medium and high probability of occurring in the HRAs.
- Formulating a flood risk management plan (*plan de gestion des risques d'inondation*, PGRI) for each river basin (or a single plan for the Seine-Normandy basin) outlining the management objectives and the measures envisaged for attaining them. The plan must state the objectives for reducing the negative consequences for the river basin and must be complete by the end of 2015. The programme of actions that each HRA should take to attain those objectives will be set out in the local flood risk management strategies (*stratégies locales de gestion des risques d'inondation*, SLGRI).
- France also decided to develop a National Flood Risk Management Strategy (*Stratégie Nationale de Gestion des Risques d'Inondation*, SNGRI) to implement the Directive. The aim of the strategy is to supplement local strategies by identifying national objectives and priority areas for action. Developed by the Joint Flood Commission (*Commission Mixte Inondation*, CMI), a national consultative body of all stakeholders, the strategy notes that France is vulnerable to flooding, even though the country has largely been spared major weather events for 50 years or so. The document sets out three strategic objectives: increasing the security of the populations at risk, stabilising then reducing the cost of damage and shortening the recovery time after a disaster. The challenges

identified, namely governance; knowledge; territorial resilience and the stated major principles of subsidiarity and shared responsibilities; solidarity in the face of risk; synergies with other policies; reasonable cost-benefit ratios; and assessments to ensure ongoing improvements to flood management policy; are fully in line with OECD risk management policies.

Figure 2.2. **Overview of the national flood risk management policy**



Source: Direction générale de la Prévention des risques (2011), "La politique nationale de gestion des risques inondation: Ce qui change aujourd´hui", Ministry of Ecology, Sustainable Development, Transport and Housing, Paris, www.developpement-durable.gouv.fr/IMG/pdf/55_DGPR__Directive_inondation_def_web.pdf.

That general regulatory framework and the motivation engendered by implementing the European Floods Directive (Figure 2.2) will provide the framework for running the Seine flood risk prevention policy in Île-de-France in the years to come. The national preliminary flood risk assessment and the national strategy classified the Seine flood risk as "major". The Île-de-France urban area has been identified as an HRA of national interest and a local flood risk management strategy will be drawn up by 2016. The strategy will be based on various existing strategic documents and frameworks concerning the Seine floods in Île-de-France as described in this section (Table 2.1). An appropriate governance structure will also be established to implement it.

Table 2.1. **Strategic documents for Seine basin flood prevention in Île-de-France**

Document	Date	Area covered	Key stakeholders	Objective
Flood prevention action programme	Objective 2013	Marne-Seine upstream	EPTB-SGL	To implement a comprehensive flood prevention policy in the river basin at risk
Seine Plan	2007-13	Seine-Normandy	DRIEE Regions in the Seine-Normandy basin	To promote development around the river stem
Water Development and Management Master Plan	2010-15	Seine-Normandy	Seine-Normandy River Basin Committee Water agency	To identify the objectives and guidelines for implementing water policy in the river basin
Île-de-France Regional Master Plan	2013-30	Île-de-France	Île-de-France Region	To draw up regional planning and development policy guidelines
ORSEC-flood	2010	Île-de-France	Prefecture of Police – SGZDSP	To provide management in a major flood crisis
Flood risk management plan	Objective 2015	Seine-Normandy	River basin committee	To implement a comprehensive flood prevention policy for the river basin
Local flood risk management strategy	Objective 2015	HFPA Île-de-France	DRIEE-SGZDSP	To implement a comprehensive flood prevention policy for the HFPA

Sources: EPTB Seine Grands Lacs (2013), "Programme d'actions de prévention des inondations de la Seine et de la Marne franciliennes", *Rapport de présentation*, EPTB Seine Grands Lacs, Paris; DRIEE (2011), "Plan Seine", Direction Régionale et Interdépartementale de l'Environnement et de l'Énergie, Paris www.driee.ile-de-france.developpement-durable.gouv.fr/IMG/pdf/PlanSeine20-12sansannexes_cle01b9fd.pdf; Seine-Normandy River Basin Committee, 2009; CGEDD (2013), "Avis délibéré de l'autorité environnementale sur le projet de schéma directeur de la région Île-de-France (SDRIF)", Conseil général de l'Environnement et du Développement durable, http://portail.documentation.developpement-durable.gouv.fr/documents/cgedd/008744-01_avis-delibere_ae.pdf; SGZDSP, 2010; Ministry of Ecology, Sustainable Development and Energy (2012), "Politique de gestion des risques d'inondation", Ministry of Ecology, Sustainable Development and Energy, Paris, www.developpement-durable.gouv.fr/IMG/pdf/politique-gestion-risques-inondation-201211.pdf.

Stakeholders in flood risk prevention in Île-de-France

The prospect of establishing a holistic strategic framework for managing the Seine flood risk raises a particularly acute question of governance in Île-de-France. Flood risk management is the responsibility of a fragmented landscape of authorities in different tiers of government. Ranging from central government to the various tiers of local government, roles and responsibilities are very watered down. As a rule, in France, the mayor and the prefect of the department are solely responsible for managing risks, both in terms of prevention and crisis management. The specific metropolitan nature of Île-de-France and the fact that it is the region of the capital city, together with the specific institutional features that arise as a result, add a further complexity to decision making. This raises many challenges for governance, especially where policy co-ordination is

concerned. A clear understanding of the roles and responsibilities of the various stakeholders is the first step towards better identifying these challenges.

Central government services

Central services

Central government services draw up national flood prevention policy and do not play a direct role in implementing policies on the ground. However, the tools, apparatus and funding mechanisms they develop to implement laws and regulations directly affect policies implemented at the local level.

The Ministry of Ecology, Sustainable Development and Energy (MEDDE) is responsible for prevention of natural hazards in France. Policy is steered by the Directorate-General for Risk Prevention (*Direction Générale de la Prévention des Risques*, DGPR), which co-ordinates risk prevention plan development policy, has drawn up calls for proposals for PAPIs and PSR eligible for funding from the Barnier Fund, and is in the front line of implementing the Floods Directive. Among other things, it has rolled preliminary flood risk assessments out nationally, drawn up the cartographic selection criteria to identify HRAs and organised the preparatory work for the SNGRI. The General Commission for Sustainable Development (*Commissariat Général au Développement Durable*, CGDD) is developing economic tools for it to use in implementing the policies along with methods of cost-benefit and multi-criteria analysis (Chapter 4). The Water Department at the ministry is responsible for the other aspects of water policy.

The Ministry of the Interior (*Ministère de l'Intérieur*) deals with crisis management matters. The Directorate-General for Civil Security and Crisis Management (*Direction Générale de la Sécurité Civile et de la Gestion des Crises*, DGSCGC) has a role in developing public policy instruments for crisis management and crisis preparedness, and these may have links to resilience (business continuity plans for businesses, for example). It also has an operational role in managing major crises that require operational co-ordination of resources at national or international level. In line with the bottom-up approach where response capability gradually increases, the Operational Centre for Interministerial Crisis Management (*Centre Opérationnel de Gestion Interministérielle de Crises*, COGIC) is activated as soon as the local emergency response apparatus and mechanisms in the seven defence zones into which the national territory is divided so require. To that end, it has powerful information systems and databases on hazards and the vulnerability of populations and regions.

The Ministry of Territorial Equality and Housing (*Ministère de l'Égalité des Territoires et du Logement*) deals with regional development and planning matters. It oversees the Greater Paris project and provides the secretariat for the Interministerial Delegation for Territorial Development and Regional Attractiveness (*Délégation Interministérielle à l'Aménagement du Territoire et à l'Attractivité Régionale*, DATAR) which is responsible, under the Prime Minister's supervision, for negotiating the CPER for the period 2014-20.

Through the Insurance Markets and Products Bureau, the Ministry of the Economy and Finance (*Ministère de l'Économie et des Finances*) is involved in regulating the principal preventive funding tool in France, the CATNAT compensation scheme and the associated Fund for the Prevention of Major Natural Hazards, or "Barnier Fund".

Decentralised services

Decentralised central government services in Île-de-France co-ordinate, implement, co-finance and oversee policies in the fields of national risk prevention and management, water management and regional planning described above. These services are organised in a peculiar fashion in Île-de-France, and there are individualised features in the services for the city of Paris and the three departments in the adjoining inner suburbs (Hauts-de-Seine to the west; Seine-Saint-Denis to the north-east; Val-de-Marne to the south-east), and for the four departments in the outer suburbs beyond them (Seine-et-Marne, Yvelines, Essonne and Val d'Oise). Historically, Paris and the Paris region have had two different prefects, a feature that distinguishes them from other French departments: the Prefect of Police is responsible for security matters in Paris and the inner departments, and for crisis management for the Île-de-France defence zone in its entirety; the Prefect of Paris and the Île-de-France Region implement the other national public policies in the inner suburbs in association with the prefectures in the departments of the outer suburbs.

Through the local Regional and Inter-departmental Directorate for the Environment and Energy (*Direction Régionale et Interdépartementale de l'Environnement et de l'Énergie*, DRIEE), a decentralised department of the MEDDE, the regional prefecture (*préfecture de région*) co-ordinates flood risk prevention policies in the inner suburbs in co-operation with the prefectures of the outer suburbs. The DRIEE therefore plays a key role in implementing the Floods Directive, in particular through risk assessment and mapping (risk prevention plans and especially PFRAs). It also provides regional flood forecasts. Through the Seine-Normandy Basin Delegation (*Délégation de Bassin Seine-Normandie*, DBSN), the DRIEE is also responsible for co-ordinating central government water policy measures for the entire Seine-Normandy river basin district, including the works in the Seine Plan, for example. Planning and development matters are the responsibility of the Regional and Inter-departmental Directorate for Infrastructure and Development (*Direction Régionale et Interdépartementale de l'Équipement et de l'Aménagement*, DRIEA). Housing matters fall within the scope of the Regional and Inter-departmental Directorate for Accommodation and Housing (*Direction Régionale et Interdépartementale de l'Hébergement et du Logement*, DRIHL) and its territorial units in the departments. These involve the Greater Paris projects and the implementation of the Île-de-France Regional Master Plan. All of these services are under the authority of the Prefect of Paris, the Prefect of the Île-de-France Region and the Co-ordinating Prefect of the Seine-Normandy river basin.

As Prefect for the Paris Defence and Security Zone, the Prefect of Police (*Préfet de Police*) co-ordinates crisis preparedness measures, especially under the aegis of the General Secretariat (SGZDSP). The SGZDSP is responsible for the ORSEC crisis management mechanism. It leads subject-based working groups that bring all crisis management stakeholders in the private and public sectors together to discuss the key problems of regional vulnerability or emergency response, including the operators of critical networks.

The departmental prefectures (*préfectures de département*) in the inner suburbs are directly answerable to the regional prefecture and Police Headquarters (*Préfecture de Police*) for their implementation of central government policies, whereas the prefectures of the departments in the outlying suburbs have specific territorial services – departmental directorates for administrative areas (*directions départementales des territoires*, DDT) to implement prevention policies.

State operators and state-controlled businesses

The state can also play a role in flood prevention in Île-de-France through its operators, entities and public bodies, whether commercial or not, and through the businesses governed by public law in which it has a shareholding. In that respect, note should also be made of the following:

The Seine-Normandy Water Agency (AESN), answerable to the MEDDE, is responsible for collecting water fees and for co-financing works carried out by local contracting authorities to implement the Seine-Normandy Water Development and Management Master Plan. Its EUR 4.7 billion investment programme for the six-year period from 2013-18 includes some flood prevention measures. Funds it provides may also play a key role in co-financing projects with multiple aims including flood prevention (flow-rate management, restoration of wetlands, purchase of real estate to protect the environment where it can play a role in flood surges, for example). The agency also acts as the secretariat for the Seine Plan in association with the DRIEE.

The Central Reinsurance Fund (CCR) is a business governed by private law of which the French state has full ownership; it provides insurers with reinsurance solutions guaranteed by the French central government. It is against this background that the CCR participates in the CATNAT compensation scheme by offering reinsurance for the scheme while collecting a levy on the premium surcharge for risk prevention that the insurance companies transfer to the CCR to place in the Barnier Fund. The CCR does a lot of work in risk assessment and disaster-related damage estimates.

French Inland Waterways (*Voies Navigables de France*, VNF) is a public body that manages, operates, modernises and develops the 6 700-kilometre-long national network of navigable waterways in France, which includes a large section of the Seine and its tributaries where the VNF manages many works of art as well as 40 000 hectares of publicly owned rivers. The VNF is planning a project to make the Seine navigable by large gauge vessels upstream between Bray and Nogent-sur-Seine, at an estimated cost of EUR 214 million. As manager of the waterway, the VNF may specifically be involved in implementing flood risk management measures. Hence, in Val-de-Marne, the VNF has a role in the contracting process and is the operator of the Joinville-Le-Pont bypass valve, a Seine diversion that has not been operational since 1999 but which has protected many inhabitants in the Marne basin from flooding (Chapter 3).

Other state operators, agencies or businesses of various categories can also contribute to risk prevention in Île-de-France. Some of them have specialist technical or scientific competence that can be called upon if needed for prevention purposes, such as Météo-France for meteorological and climatic data, the National Geographic Institute (*Institut Géographique National*, IGN) for mapping, or the French Geological Survey (*Bureau de Recherches Géologiques et Minières*, BRGM) for subsoil. Others have a specific area of vulnerability that requires action on their part to reduce it. These include the various network operators in the public transport sector (SNCF, RFF and RATP) and in the power sector (RTE, ERDF and Électricité de France), where disruption caused by major flooding could give rise to knock-on effects (Chapter 1). The research institutes are also fully involved in prevention efforts in the form of improving knowledge and expertise. Examples are the National Institute for Research in Science and Technologies for the Environment and Agriculture (*Institut National de Recherche en Sciences et Technologies pour l'Environnement et l'Agriculture*, IRSTEA), the French Institute of Science and Technology for Transport, Development and Networks (*Institut Français des*

Sciences et Technologies des Transports, de l'Aménagement et des Réseaux, IFFSTAR) or the various technical study centres under the MEDDE.

Local government

The powers of the three tiers of local government in France are laid down in law. Under the "general competence" clause, they are free to become involved in any public policy sphere in which, in their view, the interests of their territory are at stake. Municipalities, departments and regions can thus play important roles in flood risk prevention in Île-de-France, whether individually or in specific groups focusing on this or other related issues. This section discusses the different tiers.

The municipalities (*communes*) and their elected representatives are responsible for protecting their citizens and for planning and development matters in their territory. They therefore have many responsibilities in the field of flood risk prevention: where they are subject to a risk prevention plan, they are required to inform citizens of the risks to the municipality in municipal information documents on major risks (*documents d'information communal sur les risques majeurs*, DICRIM), to draw up local emergency response plans (*plan communal de sauvegarde*, PCS) for crisis management and continuity of public services and to annex the risk prevention plan to their local urban plan. Of the 1 281 municipalities in Île-de-France, 141 were included in the "Île-de-France metropolitan HRA" under the Floods Directive. The municipalities are also responsible for drinking water and sanitation services, with several municipalities often choosing to band together to manage these services.

The departments (*départements*) and their elected representatives on the General Council do not have any specifically defined responsibilities on risk prevention in the strictest sense. However, their other powers have led them to take an interest in this sphere of public policy. Thus the three departments in the inner suburbs affected by the Seine flood risk are contracting authorities for dykes and defensive walls to protect against flooding. This stems from the fact that they are responsible for the road network along the quays of the Seine and the Marne. They also manage a particularly flood-prone sewerage system in their department. Additionally, since 1969, the City of Paris and the three departments have been the administrative council and the principal creditors of the EPTB Seine Grands Lacs, the body in charge of flood prevention and managing the flow-rate of the Seine and Marne river stems with the help of its four reservoirs upstream of the basin (see below). Historically, these departments were formed from the Seine department, now superseded, that in fact founded the EPTB Seine Grands Lacs in 1928.

Both a municipality and a department, the City of Paris (*Ville de Paris*), and its council of elected representatives have extended responsibilities for flood prevention because of the city's special status. These responsibilities involve matters of development, planning, management of local defence infrastructures, water and sanitation, and the administration and funding of the EPTB Seine Grands Lacs.

The Île-de-France region and its elected representatives on the Regional Council act on risk-prevention matters, especially through implementation of the Île-de-France Regional Master Plan. With responsibility for transport, the region can play a key role in improving the resilience of transport infrastructure. In financial terms, the region plays a significant role in developing the CPER that provide access to European structural funds such as the European Regional Development Fund. This provides the funding framework for infrastructure projects to protect against flooding and reduce vulnerability to it, in particular with regard to the Seine Plan projects. Through the Institute for Urban Planning

and Development (*Institut d'Aménagement et d'Urbanisme*, IAU), the region has a powerful geographic information system (GIS) that provides it with detailed knowledge and pictures of the areas at major risk, especially in relation to flood hazards.

These government bodies can band together to manage common flood-prevention issues.

The EPTB Seine Grands Lacs is a public body covering the departments of Paris, Hauts-de-Seine, Seine-Saint-Denis and Val-de-Marne to regulate the flows of the Seine and the Marne (Box 2.4).

Box 2.4. **The Seine Grands Lacs Local Public River Basin Authority**

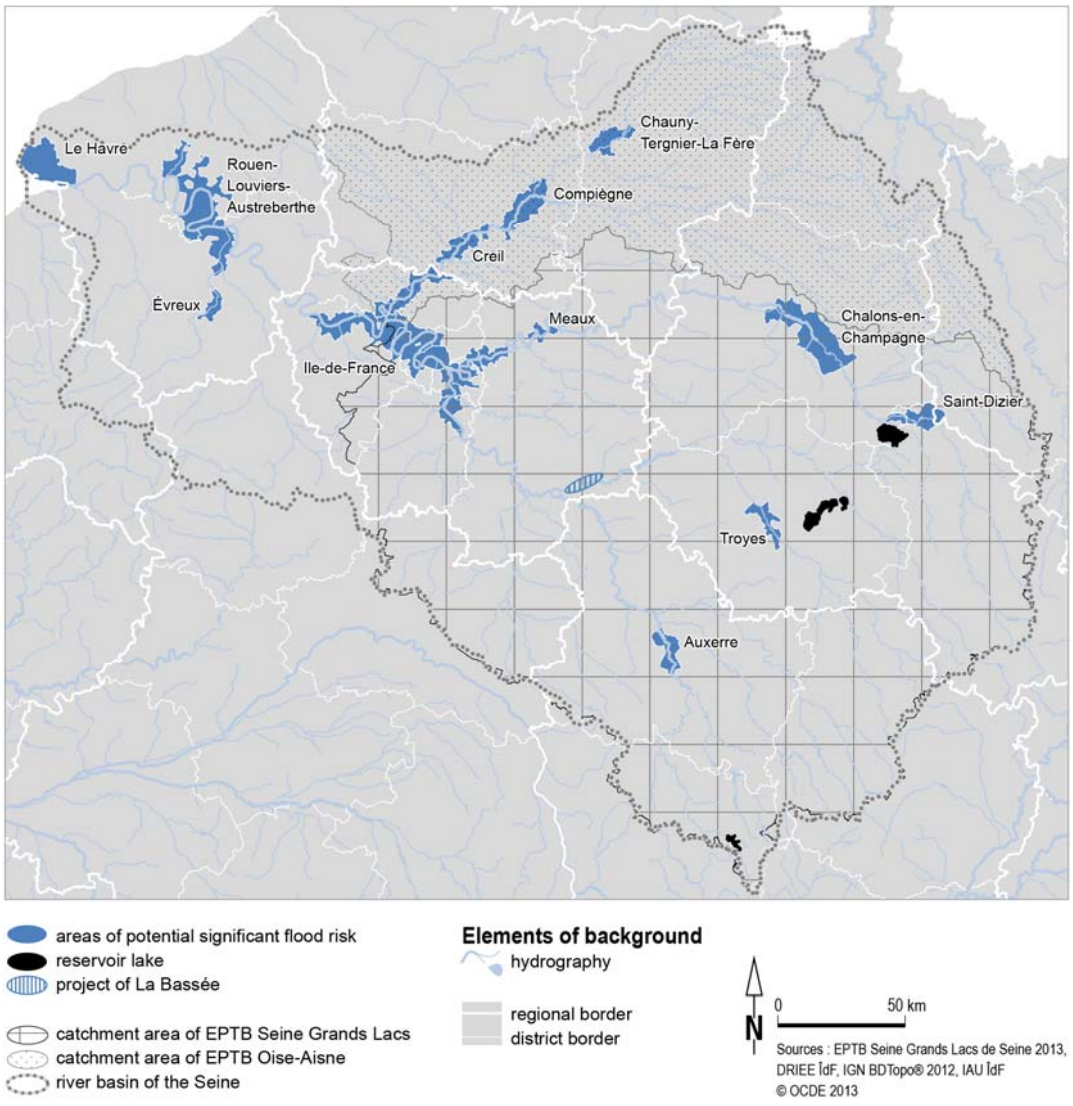
The role of the Seine Grands Lacs Local Public River Basin Authority (EPTB Seine Grands Lacs) is both to support minimum flow-rates of the Seine and its tributaries and to prevent Seine flood risks by reducing flood peaks. To that end, it has four storage reservoirs on the various tributaries upstream of the basin (Yonne, Seine, Aube, Marne) with a total storage capacity of 830 million m^3. The EPTB Seine Grands Lacs is the legacy of the historic floods of 1910 and 1924, and the low-water of 1921, after which the Seine department had the storage dams built. Despite a regional mandate for the whole of the upstream basin, the focus of the measures to combat flooding is essentially to protect the Île-de-France metropolitan area against the hazards of the river and to safeguard the urban areas downstream of the reservoirs in Champagne-Ardenne and Bourgogne. Its Administrative Board and funding are provided by the departments of the inner suburbs, with a half from Paris. With an operating budget of EUR 10-12 million, the EPTB Seine Grands Lacs maintains and manages these works with a staff of 120 officials. Its investment budget is more variable. In 2012, it was authorised to collect a fee for services rendered from the principal users of water because of its work to maintain minimum flow rates. As a result, it anticipates EUR 7.5 million in revenue per year. In relation to its flood-risk prevention mandate, the EPTB Seine Grands Lacs began a study into a new water storage project, the La Bassée project, also focusing on ecological restoration of wetlands. At the same time, it is putting a lot of work into both reducing flood vulnerability and increasing resilience by encouraging local government to take measures as provided for in the Environmental Code for EPTBs. These two complementary measures led to the drafting of the Île-de-France Seine and Marne flood prevention action programme (PAPI) project (Box 2.5), to be implemented under the guidance of the EPTB Seine Grands Lacs with appropriate governance involving all stakeholders, including those at local government level.

Civil society and business

Associations

Several national associations have specific powers in flood prevention. The European Center for Flood Risk Prevention (*Centre européenne de prevention du risuqe d'inondations*, CEPRI) does a lot of work on this issue and has developed expertise that it enables it to help local government in its prevention initiatives. The French Association for Natural Disaster Reduction (*Association Française de Prévention des Catastrophes Naturelles*, AFPCN) provides the secretariat for the French platform implementing the Hyogo Framework for Action. It has put a scientific council in place and organises meetings and seminars to move risk prevention forward in France and promote French approaches abroad. The associations can act as effective conduits to bring prevention issues to the attention of decision makers in the various tiers of the public sector.

Figure 2.3. **Map of the boundaries of the local public river basin authorities in the Seine river basin**



There are other associations linked to specific flood-related issues. For example, environmental associations such as WWF or France Nature Environnement are very active in the areas of water and ecosystem conservation. Although they do not have a detailed position on the Seine flood risk in Île-de-France, they are alert to the infrastructure-related issues. The matters of waste management and pollution associated with disasters are also of interest to them. The French Committee of the Blue Shield tries to raise awareness of how fragile the cultural heritage is in the event of a natural disaster, especially flooding.

Business

The commitment of business to risk prevention depends both on regulations and their degree of awareness. A distinction should be drawn between network-operating businesses which may be subject to specific regulations, especially if categorised in one of the essential economic sectors (*secteurs d'activités d'importance vitale*, SAIV), which

includes operators of critical networks such as transport, electricity, telecommunications, water and financial systems. Other businesses can also be motivated by the specific role they would play in crisis management (refuse collection, distribution sectors).

Table 2.2. **Key risk management stakeholders in Île-de-France**

Key stakeholders	The various public policy fields associated with prevention								
	Risk prevention policy							Other policies	
	Knowledge	Risk culture	Local resilience	Resilience of critical networks and businesses	Defences	Finance	Crisis management	Regional planning	Water management
Ministry of Ecology, Sustainable Development and Energy: Directorate-General for Risk Prevention									
Regional and Inter-**departmental** Directorate for the Environment and Energy	●	●	●	●	●	●	●		●
Regional and Inter-departmental Directorate for Infrastructure and Development			●	●				●	
Regional and Inter-departmental Directorate for Accommodation and Housing			●					●	
Seine-Normandy Water Agency					●	●			●
French Inland Waterways					●				●
Ministry of the Interior: Directorate-General for Civil Security and Crisis Management	●						●		
General Secretariat of the Paris Defence and Security Zone	●	●		●			●		
Ministry of Territorial Equality and Housing: Regional and Inter- departmental Directorate for Accommodation and Housing			●					●	
Ministry of the Economy and Finance						●			
Central Reinsurance Fund (CCR)	●	●				●			
Local government: Île-de-France Region			●			●		●	
Departments		●			●				●
Municipalities		●	●				●	●	●
EPTB Seine Grands Lacs	●	●	●		●		●		●
Critical operators: Network operators				●		●	●		
Private sector: Businesses				●		●			
Insurance companies	●	●				●			
Chamber of Commerce and Industry of Île-de-France	●			●					
Associations		●							

Source: Elaborated by the OECD

Insurance companies are also fully committed to Seine flood risk prevention, as they are fully aware of the risk level facing them in Île-de-France. As the middle-men between the insured and the CCR, insurance companies are stakeholders in the CATNAT compensation scheme and bear the part of the risk that is not reinsured through the CCR. The CATNAT premium surcharge includes all the monies that go into the FPRNM ("Barnier Fund"), the principal source of funding for the national prevention policy. In 2000, the authorities regulating insurance businesses operating in France established the Insurance Companies' Mission for Natural Hazards Awareness and Prevention, or "Natural Hazards Mission" (*Mission des Sociétés d'Assurance pour la Connaissance et la*

Prévention des Risques Naturels, MRN), an association to represent them in public policy debates on prevention and to contribute technical studies to the field.

Stakeholders in institutions or community-based bodies such as the Île-de-France Chamber of Commerce and Industry (CCI Paris) or the Business Security Directors' Club (*Club des Directeurs de la Sécurité des Entreprises*, CDSE), have become aware of the Seine flood risk in Île-de-France and are essential conduits for spreading the message and developing public policies and measures aimed at other businesses, whether major groups or SMEs.

Existing multi-stakeholder and multi-tier consultative bodies

In a situation such as this where responsibilities are relatively thinly spread across not only the tiers of government but also the various public policy spheres, mechanisms for consultation and co-ordination are essential to drawing up and conducting a concerted public policy to prevent a Seine flood. Several existing bodies provide for consultation and co-operation at various levels:

- At national level, the Joint Flood Commission (CMI) was established in 2011 to draw up national strategy options for implementing the Floods Directive. It has responsibility for developing the SNGRI. It also plays a key role in implementing the policy by considering and approving prevention projects in the form of PAPIs and PSRs submitted by local government, thereby opening the way to state funding under the Barnier Fund, among other sources. The commission is composed of representatives from state bodies, local government and civil society from the National Water Committee (*Comité National de l'Eau*, CNE) and the National Policy Board for the Prevention of Major Natural Hazards (*Conseil d'Orientation pour la Prévention des Risques Naturels Majeurs*, COPRNM).
- At river basin level, the Seine-Normandy Basin Committee, for which the water agency provides the secretariat, brings together representatives of the state, local government, associations and water users. It is the key consultative body at this level, in particular where the formulation of the Water Development and Management Master Plan is concerned. It also often has representation on more localised regional committees such as the Île-de-France Rivers Committee (*Commission Territoriale Rivières d'Île-de-France*). Bodies such as these where membership can be extended to include stakeholders can play a key role in consultations on a strategic framework for Seine flood management in the basin, and in Île-de-France in particular. Meetings to that end began in 2012 as part of the implementation of the Floods Directive. Other consultative bodies involved in water management as part of the Seine Plan, the EPTB Seine Grands Lacs (Consultative Committee) or at local level through the water development and management plans (*schémas d'aménagement et de gestion des eaux*, SAGE) and the local water committees mean that different stakeholders are consulted.
- At Defence and Security Zone level, the working groups established under the ORSEC mechanism bring various network operators and the key crisis management stakeholders together in the zone. Established several years ago, these groups have launched an initiative upon which a flood prevention strategy could be based. Incorporating these sectors into the process of improving the resilience of the Île-de-France metropolitan area and the Île-de-France region is a major challenge. Hitherto, however, the involvement of local government in this type of work has been limited.

Each of these bodies can play an important role in flood risk prevention in Île-de-France. They are nonetheless often limited to one specific aspect of prevention policy and do not, in fact, bring all stakeholders together. There is therefore no forum specifically dedicated to Seine flood risk prevention in Île-de-France where all the stakeholders involved could draw up a common strategy and oversee its implementation even if the third wave of decentralisation, currently under way, seeks to restore forums of that kind (Box 2.3).

Tackling the challenges that governance raises for flood prevention in Île-de-France

An opportunity to be seized

Today there is an opportunity to embark upon a deliberate flood risk management strategy in Île-de-France. Many initiatives are converging, and the opportunity to conduct a strategic discussion to formulate such a strategy should be seized.

- The period 2013-15 is key to the implementation of the Floods Directive, which provides for the drafting of a flood risk management plan for the Seine river basin alongside a local flood risk management strategy for the Île-de-France metropolitan HRA by 2015.
- The Greater Paris projects and debates (transport networks, metropolis status, CDTs) make it possible to envisage flood risk on the scale of the Île-de-France urban area, and to take major urban renewal projects into account.
- Today, strategic planning documents offer the possibility of moving the issue forward: the Île-de-France Regional Master Plan incorporates the concept of resilience, the Seine Plan is currently under review, as are the CPER.
- The EPTB Seine Grands Lacs Flood Prevention Action Programme drawn up in consultation with many stakeholders envisages launching a major initiative to improve the resilience of the Île-de-France metropolitan area through specific measures (Box 2.5).
- The recent examples of disasters abroad, in particular the floods caused by Hurricane Sandy in New York City and New Jersey, have helped to raise authorities' awareness of the specific vulnerabilities of extensive metropolitan areas to knock-on effects.

The challenges of multi-tier governance

This is thus the background against which the current situation should be analysed and viewed in order to pick out the issues and challenges that must be addressed. Institutional and territorial fragmentation in the field of flood prevention in Île-de-France engenders deficits in governance, particularly among the various tiers of government. The large number of stakeholders involved whether nationally, in the river basin, the region, the departments, the municipalities or the metropolitan area, makes it difficult to manage the interdependencies between the various levels and the various policy areas involved in flood risk prevention. As part of its work on multi-tier governance, the OECD has drawn up a framework for analysing deficits in governance (Table 2.3) which identifies the various limits that countries frequently encounter when implementing public policies at the local level.

Table 2.3. **Theoretical framework for analysis of multi-tier governance gaps in the implementation of flood risk prevention policies at local level**

Type of deficit	Description
Administrative gap	Lack of co-ordination between institutions and lack of alignment between the various existing initiatives ➔ ***Need for instruments that can help identify the appropriate tier at which a coherent strategy should be formulated***
Information gap	Information asymmetries, lack of harmonisation and of consistency in information on risks and vulnerabilities ➔ ***Need for instruments that can help bring to light, harmonise and share information***
Policy gap	Sectoral fragmentation among the various public policies involved in flood risk ➔ ***Need for mechanisms that can help establish multi-dimensional/systemic approaches at local level***
Capacity gap	Insufficient scientific, technical and infrastructure-related capacity and lack of incentive for local stakeholders to draw up appropriate flood risk prevention strategies ➔ ***Need for instruments that can help bolster local capacity***
Funding gap	Unstable or insufficient resources that constrain effective discharge of responsibilities for flood risk prevention at local level ➔ ***Need for shared funding mechanisms***
Target gap	Different rationalities that generate obstacles to setting convergent targets, especially among stakeholders across different tiers and in the various spheres of public policy ➔ ***Need for instruments to help align targets***
Accountability gap	Difficulty in providing transparency for the various practices in place because of the failure to share information between stakeholders and lack of public interest in the subject ➔ ***Need for institutions to deliver high-quality measures that boost public interest, leadership, monitoring and assessment of measures***

Source: Adapted from Charbit, C. (2011), "Governance of public policies in decentralised contexts: The multi-level approach", *OECD Regional Development Working Papers*, No. 2011/04, OECD Publishing, Paris, http://dx.doi.org/10.1787/5kg883pkxkhc-en; OECD (2012), *Meeting the Water Reform Challenge*, OECD Studies on Water, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264170001-en.

Identifying the right level for risk management

The limit associated with administrative disparity refers to the mismatch between the most appropriate spatial level for implementing a public policy and the administrative limits on the institutions with responsibilities to that end. Where Seine flood prevention in Île-de-France is concerned, the matter of spatial scale arises at two different levels: where reduction of flood risk is concerned, the relevant level is water management and therefore the catchment basin, which is beyond the regional scope of Île-de-France. However, where taking measures on the vulnerability of territories is concerned, the most appropriate level would appear to be that of the basin where the life of the metropolitan area is likely to be affected.

The first stage in implementing the Floods Directive required identification of the areas at significant risk for which a local strategy must be drawn up. The work done under the aegis of the DRIEE to flag the areas in the Seine-Normandy basin identified the "Île-de-France metropolitan" HRA comprising 141 municipalities. This was achieved following extensive work involving consultation with the stakeholders based on the national vulnerability criteria drawn up by municipalities as a result of the preliminary flood risk assessment (PFRA) required under the Floods Directive. The appropriate spatial level for vulnerability matters would appear to have been correctly identified by the HRA. Nonetheless, many local government bodies will have to be brought together to provide governance, unless competence for flood management is transferred to the Greater Paris metropolis that is in the process of being formed (see above).

A different approach towards work on the flood hazard and the catchment basin could have prevailed that would have drawn distinctions between the catchment sub-basins that are the object of the specific prevention initiatives. This is true, for instance, for the EPTB Seine Grands Lacs area and the associated PAPI (Box 2.5), where the spatial scale is the sub-basin upstream of the HRA, thereby involving the upstream areas in a catchment basin initiative. Other sections of the HRA could also benefit from specific shared upstream/downstream approaches, e.g. the Oise basin and the EPTB Oise-Aisne.

Box 2.5. **The approaches set out in the EPTB Seine Grands Lacs flood prevention action programme**

Following the work conducted during the Seine Plan (2007-13) and the public debate on the La Bassée infrastructure project (Chapter 3) held in 2011-12, the EPTB Seine Grands Lacs took the decision to propose approval of a flood prevention action programme (PAPI) to reduce the vulnerability of the Île-de-France region to flooding. The aim of a contractual undertaking of this kind between the state and regional government is to provide a consistent approach to the measures taken by local contracting authorities at the level of the basin at risk for which the state may provide co-funding of up to 40%. The EPTB Seine Grands Lacs project is for the four member departments for the period 2014-19. Its aims include prioritising prevention and crisis management preparation over repairing damage, and there are three prime objectives:

- growing the "flood risk culture" of the people in the floodplain, especially among the key players, whether public or private
- in the short term, stabilising the cost of potential damage linked to floods in Paris and the inner suburbs
- shortening the time by which the principal local public services (health, social and education services) in flooded areas return to normal after major flooding.

Source: EPTB Seine Grands Lacs (2013), "Programme d'actions de prévention des inondations de la Seine et de la Marne franciliennes", *Rapport de présentation*, EPTB Seine Grands Lacs, Paris.

Good co-ordination between these two spatial levels, namely metropolitan vulnerability and the upstream hazard will be a pre-requisite for successful implementation of the Floods Directive in Île-de-France. Local stakeholders' growing appreciation of the challenges recently led to some important factors in clear governance being introduced under the strategic aegis of the central government (Box 2.6).

Establishing objectives that all stakeholders share

In addition to the issues of multi-tier co-ordination between the central government, the Île-de-France region, the departments and municipalities, the local disparities at each of these tiers hamper the emergence of a shared vision. Competing views may, in fact, appear between Paris and its suburbs, the west and the east of the area at risk, the urban area and the peri-urban and rural areas. Each of these areas has different levels of exposure to flooding. Their technical, financial and human capacities to implement public policies independently of a degree of regional solidarity also vary. The area's lack of shared objectives (target deficit) is therefore directly linked to the deficits in information, capacity and funding. They struggle to agree on general flood risk management objectives as a whole. The various stakeholders tend to advocate their own visions and specific interests rather than support the group objectives and adjust their decisions to a

framework that those objectives would define. Consequently, there is no co-ordination or alignment of the various initiatives around a shared flood risk prevention strategy. Stakeholders thereby run the risk of being ineffective, spreading their resources too thinly and of the efforts that they make not being of the greatest possible value and not bearing the best possible fruit.

Here, the development of a local strategy presents a genuine opportunity to align the objectives of the various stakeholders under a shared framework. The establishment of a long-term vision is one means of overcoming obstacles. Pairing that vision with instruments designed specifically to bolster capacity and meet funding needs (Chapter 4) will enable that vision to deliver maximum benefit.

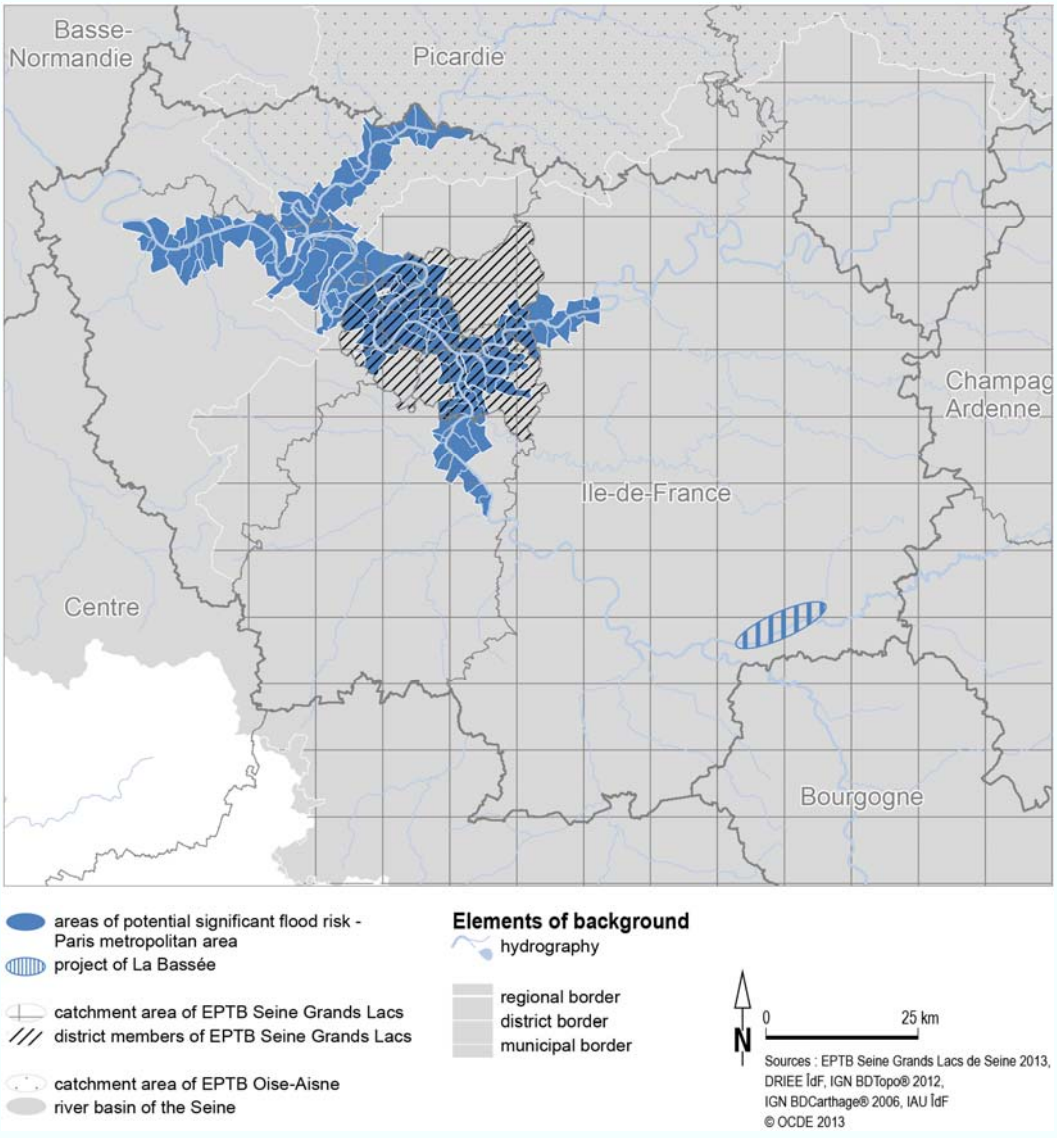
Box 2.6. **How should a local flood risk management strategy be formulated?**

As part of the implementation of the Floods Directive, a local flood risk management strategy must be drawn up by 2015 for each HRA, including the urban area of Paris which covers 141 municipalities. Despite its breadth and the diversity in the areas it incorporates, the authorities have decided that it will be the subject of just one local strategy. In the absence of a government body of local representatives for the whole area, and particularly in view of the fact that there are several EPTBs within it, the state will conduct the local strategy to be co-ordinated by the Prefect of the Île-de-France region, the Prefect for Paris and the Prefect of Police. Together with the prefects of the seven departments concerned, they will draw up a list of stakeholders and determine the central government service with responsibility for co-ordinating the drafting of the strategy, revising it and monitoring its implementation. Provision has been made for the establishment of a Strategy Committee to provide overall control under the shared chairmanship of the Prefect of the Region, the Prefect of Paris, the Prefect of Police and the Prefect of the Paris Defence and Security Zone. This should make it possible to draft the strategy in co-operation with stakeholders and especially local authorities, businesses and associations. In order to engage a large number of elected representatives across this vast area, especially mayors, and in the light of the structures and institutions already in place, there are plans to establish a specific mechanism for governance by creating a second community-linked tier for elected representatives and public and private stakeholders in the form of three territorial committees led by local government, namely:

- an Île-de-France Seine-upstream committee linking the communities upstream of the Seine-Oise confluence led by the EPTB Seine Grands Lacs in association with local community stakeholders and assisted in its work by the DRIEE and the SGZDSP
- a Oise committee linking the communities of the Val-d'Oise along the Oise, led by the Oise Banks Management Authority with the assistance of the EPTB Entente Oise-Aisne, assisted by the Prefect of the Val-d'Oise
- a Seine-downstream committee linking the communities of the Yvelines and a few municipalities in the Val-d'Oise downstream of the Seine-Oise confluence. In the absence of an EPTB, the Prefect of the Yvelines will lead the committee with the support of local partners.

This will enable the formulation of future draft flood prevention action programmes (PAPIs) for these areas in order to implement the individual aspects of the local strategy. Once the objectives and main provisions of the local strategy have been endorsed, subject-based working groups will be established to refine the provisions and break them down into action programmes using an integrated approach in the HRA concerned.

Box 2.6. **How should a local flood risk management strategy be formulated?** (*cont.*)



Ensuring good co-ordination across the various public policy spheres

Beyond these questions of horizontal and vertical co-ordination between the various administrative tiers, there is also a need to address several public policy spheres that contribute to the various flood risk management initiatives (crisis management, regional planning and water management). Each of these policies involves specific stakeholders, different territorial tiers, as well as approaches which may be mutually incompatible, clash with or overlook each other.

Regional planning, development and urban planning policy may, as a result, be in direct conflict with the risk prevention recommendations, especially if more restrictive measures are taken (Chapter 3). While wishing to become more closely involved in flood prevention, water policy stakeholders are against the idea of helping to fund it using the

financial instruments allocated to them specifically for water policy (Chapter 4). Isolated approaches have prevailed hitherto. The various strategy programming documents on the Seine basin (Water Development and Management Master Plan), river planning (Seine Plan) or planning in the Île-de-France region (Île-de-France Regional Master Plan) have not proven capable of constructing a genuine multi-stakeholder initiative with shared objectives.

It would appear that only the work done by the SGZDP to draft the ORSEC crisis management apparatus has succeeded in bringing the stakeholders in the Île-de-France urban area together. The aim of the crisis management initiative in which many network stakeholders and private businesses are involved is to focus on issues of prevention and resilience. The governance linkage between the SGZDP and the Regional and Inter-departmental Directorate for the Environment and Energy as envisaged for the urban HRA, will enable maximum advantage to be drawn from the initiative. The legislation will make the flood risk management strategy under development a requirement, and the strategy will have to be incorporated into the various strategic programming documents, such as the Île-de-France Regional Master Plan and the Water Development and Management Master Plan. The closer linkage between planning and development stakeholders and the water cycle stakeholders will be a pre-requisite for a successful flood prevention strategy within the HRA and the PAPI envisaged by the EPTB Seine Grands Lacs.

Creating conditions for accountability

The complexity and deficiencies in governance mechanisms for flood risk management and prevention in Île-de-France have led to a clear accountability gap in decision making. The complex distribution of responsibilities and resources among stakeholders at various levels has prevented leaders in flood risk prevention from emerging. Despite the involvement of a large number of flood-risk prevention stakeholders, there is no criteria upon which to assess the contributions that the preventive measures have made. The lack of a performance assessment increases the difficulty of allocating responsibilities and resources in the best possible way. The principles of good governance that make local stakeholders accountable are subsidiarity, local ownership, monitoring and evaluation of the measures taken, and informing and involving the public in decision making.

The implementation of the Floods Directive and its six-year cycle of identifying objectives and evaluation makes it possible to envisage increased stakeholder accountability. The central government leadership currently being established under the aegis of the DRIEE and the SGZDSP for the Paris urban HRA should give rise to conditions that are conducive to both commitment and increased accountability on the part of other stakeholders (local government, businesses, the public) and the emergence of local leaders in matters of flood prevention. The establishment of three committees at regional level (Box 2.6), which are themselves answerable to an EPTB where one exists, should help to drive the process of consultation and local decision making.

Box 2.7. **Governance of flood risk in the Netherlands**

Following the floods of 1993 and 1995 in the Netherlands, various stakeholders decided to work together to implement the government's "Room for the River" plan in the Rhine delta. The programme seeks to bolster the river region's flood defences by giving more room to the flow of the river and its tributaries: by 2015, the volume flow rate contained by the river will have increased from 15 000 m^3/s to 16 000 m^3/s with no risk of flooding thanks to work carried out at around 30 sites. The aim is to make this river region, which is inhabited by 4 million people, into a safer, more attractive place.

The effectiveness of multi-tier governance in implementing this programme depends on co-operation between 3 ministries, 5 provinces, 5 regional water authorities and between 30 and 40 municipalities. The Dutch Ministry of Infrastructure and the Environment has overall responsibility for the programme. Using their on-the-ground expertise and their capacity to make refining adjustments in line with regional development, the officials from the provincial executive body, the regional water agencies and the Directorate-General for Public Works and Water Management draw up detailed plans and implement the 30-plus projects.

A special body known as the "Room for the River Directorate" co-ordinates the various stakeholders, including by establishing linkages between the national government and the regions. It also ascertains that the plans are compatible with the rules governing the programme, monitors consistency between the various measures and promotes exchanges of expertise and experience across the 30 or so projects. The directorate is also required to submit reports on project implementation to the minister. The minister, in turn, is responsible for reporting regularly to parliament on the project's progress.

This original model for governance helps to maintain consistency in the programme and to ensure that the various projects are implemented effectively. Co-operation between the municipal, regional and national tiers of government also makes it possible to involve local as well as national stakeholders both in the planning and in the implementation of the plans. Regular informal consultations between the various stakeholders mean that problems are actively resolved by pooling knowledge and experience.

Source: Dutch Ministry of Infrastructure and the Environment, 2012; Room for the River website, 2013.

Conclusions and recommendations

Despite an advanced body of legislation (Laws of 1982, 1995 and 2003) and an exemplary set of regulatory tools for risk prevention at national level (risk prevention plans, CATNAT scheme, flood prevention action programmes), there have not been any encouraging initiatives for managing the Seine flood risk in Île-de-France in recent decades, despite the risks to which the region is exposed.

In view of the issues at stake, the lack of any overall strategic vision for managing this major risk in this key strategic territory – unlike the situation for other major French rivers such as the Loire or the Rhône – reveals a deficit in governance even though awareness is currently emerging. The tools developed at national level have, in the past, struggled to find a practical and effective application in this area where unusual issues are at stake, the management of which has been affected by various waves of decentralisation.

Prompted by the implementation of the European Union Floods Directive, the drafting of a flood prevention action plan for this major risk means that an initiative is now taking shape, especially in the Île-de-France metropolitan HRA. This could make it

possible to involve the region in a bold, long-term resilience approach that enjoys the broad agreement of all stakeholders in the area. Opportunities to develop Greater Paris in the coming decades will be fully realised by taking a transparent approach to the question of risks.

As part of the implementation of the Floods Directive, a local flood risk management strategy is in the process of being drafted. Against that background, action should be taken to:

- Co-ordinate flood prevention actions across the various levels of government – from the Île-de-France metropolitan risk area to the catchment basin. This will mean taking a differentiated approach, involving local tier resilience stakeholders in the risk basin in Île-de-France and the upstream territories in the form of a specific partnership from which they will also benefit, and which may also turn the measures taken to implement the Floods Directive to good account. The governance structure envisaged between the state and the local contracting authorities at sub-basin level should be thoroughly explained to local government and should benefit from current developments in decentralisation that are becoming well-established locally.
- Formulate a comprehensive, bold vision that can engender long-term commitment, accompanied by principles for action. This long-term vision will be consistent with the ambitions of the Greater Paris project and will enable public decision makers and citizens to commit beyond the regulatory obligations contained in the Floods Directive and risk management policy. The principles for action in the national flood risk management strategy may be adjusted and restated at the risk basin level (pooled risk, minimum moral hazard, reasonable cost-benefit ratios, subsidiarity and role of the state, adaptability).
- Break this comprehensive vision down into specific objectives and make stakeholders accountable. The operational objectives of the local strategy and the flood prevention action programme should be aligned with each other and with this long-term vision. Economies of scale and greater effectiveness will be achievable by redefining stakeholders' roles and responsibilities, the numbers and range of which render co-ordination and effectiveness more complex. The definition of performance criteria should make it possible to analyse the respective contributions made by the various stakeholders to flood risk prevention and to monitor the performance of the various initiatives put in place in order to establish a more rational distribution of responsibilities and resources.
- Create effective linkages between the strategy for managing flood risks and related public policies. This involves incorporating and highlighting floods in a multi-hazard approach that includes other aspects of resilience to develop Greater Paris (environment, green economy, well-being). It also means ensuring that the various initiatives and sectoral policies (water management, regional planning) genuinely incorporate flood risk management with a view to creating synergies and sharing benefits.

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Chapter 3

Enhancing resilience in Île-de-France by preventing the risk of flooding

Enhancing resilience in Île-de-France against the risk of flooding of the Seine calls for a broad range of structural and non-structural prevention measures, which will be assessed in this chapter. The areas covered include risk awareness and risk culture, urbanisation and planning, critical network resilience, business continuity and hazard control through protection or storage infrastructure. This will enable synergies to be identified in order to reinforce resilience by harnessing innovation.

Introduction

The significant risk of flooding of the Seine in Île-de-France can be contained or reduced only by specific measures to increase the resilience of this strategic area. Revised governance will allow the vision, objectives and major principles of a flood management strategy to be defined, underpinned by implementation at local level in the catchment area, in exposed areas, in planning and development projects, in businesses, etc. While the La Bassée storage infrastructure project has been under study for over ten years, other risk prevention approaches must also be brought to the attention of decision makers.

Risk prevention policies in OECD countries focus on two principal types of action: hazard control and vulnerability reduction. Engineering or structural measures to limit exposure to flooding seek to harness variability or contain the river by means of storage or protection facilities (dams and dykes respectively). These hazard control approaches were preferred in the past but are now often limited by costs (financial, social and environmental) when new ones have to be built, or by their ageing and rising maintenance costs in the case of existing facilities (OECD, 2006). Softer and more environmentally friendly hazard control approaches have been developed more recently, based on dynamic flood damping or flood retention area conservation.

Reducing vulnerability also involves non-structural measures. The development of risk awareness and a risk culture is essential for laying the foundations for action at any level. Enhancing resilience may be based on appropriate urban planning and development which adequately incorporates the risk of flooding. This addresses the issue of critical networks and infrastructure whose vulnerability to flooding can increase the effects of a disaster, particularly in the case of the Île-de-France metropolitan area (Chapter 1). More broadly, the resilience of businesses and public services must also be developed by business continuity approaches, for example.

This chapter compares all these resilience enhancement approaches involving structural and non-structural flood risk prevention measures for the Seine in Île-de-France to identify priority areas. The essential monitoring measures, incentives and controls in this field are addressed, while their funding will be addressed in Chapter 4.

Knowledge and communication of the risk

Accurate and shared knowledge of the risk underpins any decision making concerning risk prevention, as does the awareness necessary to develop a risk culture. Government services and flood management stakeholders as a whole are aware at a technical level of the risk of the Seine flooding in Île-de-France, and this awareness continues to increase. The lack of a clear, shared and sufficiently widespread view of the level of risk and its precise consequences, however, limits the development of a risk culture and gives rise to differences in assessment and risk preparation levels. Many stakeholders have also spoken of confusion with respect to information and lack of access to it (Box 3.1).

Knowledge and assessment of the risk

Risk assessment allows the nature and characteristics of risks, particularly their magnitude, probability and consequences, to be determined methodically. A systematic approach based on the best scientific knowledge is required in order to ensure that risk management policies and the associated investment can be clearly targeted and can obtain the best return on investment. Poor risk assessment may give rise to uninformed or

arbitrary decision making and thus lead to costly and overly protective policies or, on the contrary, to dangerous negligence in protecting populations and assets.

Box 3.1. **Knowledge of the risk and risk culture**

To carry out this project, the OECD sent a questionnaire to some 150 participants. The response rate was around one-third. The analysis of responses from public stakeholders, businesses and network operators bears witness to varying effects, though several clear trends emerge in relation to knowledge of the risk and risk culture:

- 83% (19/23) of public stakeholders believe that citizens and socio-economic stakeholders "are not sufficiently aware" of the exposure of their activities to flooding
- 70% (16/23) of public stakeholders believe that citizens' and socio-economic stakeholders' awareness of the risk of major flooding is weak or poor; the remaining 30% (7/23) did not answer this question (in other words, all public stakeholders who answered this question answered unfavourably)
- 39% (9/23) of public stakeholders referred spontaneously to the lack of a culture or memory of risk, due in particular to the absence of recent flooding
- 50% (10/20) of private stakeholders and network operators referred more generally to the difficulty of obtaining a good level of information from network operators or government services as the principal difficulty in initiating measures to protect against and prevent flood-related damage
- 35% (7/20) of private stakeholders and network operators referred to the difficulty in obtaining information on the electricity weakness chart as the main difficulty in initiating measures to protect against and prevent flood-related damage.

Source: Questionnaire-based survey carried out by the OECD Secretariat. Public stakeholders who responded were representatives of local authorities as a whole and of the state. Private stakeholders and network operators represent major public or private network management enterprises (electricity, water, telecommunications, transport), other major enterprises in sectors such as banking, insurance or automobiles and several small and medium-sized enterprises (SMEs).

Rigorous risk assessment must consider the hydrological hazard, its consequences, the vulnerabilities of the region and the socio-economic impacts of flooding of the Seine. Cross-referencing the hazard and its consequences with the various assets exposed and their vulnerability allows a risk assessment to be obtained.

Flood mapping and modelling in Île-de-France

The Seine flood risk is precisely known and has been characterised by government departments through various mapping and modelling approaches. Past floods in the Seine basin are well documented, especially the 20th-century floods in 1910, 1924, 1955 and 1982. The chronological series of Seine flow rates and water depths at different measurement points can be obtained from government departments and the Seine Grands Lacs Local Public River Basin Authority (*Établissement Public Territorial de Bassin Seine Grands Lacs*). These data sources form the basis for a variety of flood mapping and modelling, and several maps showing the extent of flooding are outlined below.

The map showing the area with the highest known water levels (HKWL) obtained from a 1996 study by the Seine-Normandy Water Agency (*Agence de l'Eau Seine-Normandie*, AESN) on the whole basin is available and can be downloaded from

the website of the Regional and Inter-departmental Directorate for the Environment and Energy (*Direction Régionale et Interdépartementale de l'Environnement et de l'Énergie*, DRIEE) with a scale of 1:25 000 in the atlas of floodplains in Île-de-France. While the 1658 and 1740 floods reached very high levels (8.96 metres and 8.05 metres on the Austerlitz gauge, compared to 8.62 metres for the 1910 flood), this mapping was based mainly on data relating to the 1910 and 1955 floods of the Seine and the 1926 flood of the Oise.

Maps were also developed by the DRIEE in the 1990s to give a more accurate indication of the water height in flooded areas. Based on 1910 flood water heights measured on Seine bridges, topographic measurements showed the depth of the flood and allowed the "hazardous" and "very hazardous" areas where the water height exceeded 1 m and 2 m respectively to be identified. These 1:10 000 and 1:5 000 scale maps form the basis for the regulatory measurements of the risk prevention plans (*plans de prévention des risques*, PPRs). This zoning is also used by the Institute for Urban Planning and Development of the Île-de-France Region (*Institut d'Aménagement et d'Urbanisme d'Île-de-France*, IAU Île-de-France) to assess the assets exposed in its Visiau-Risque online tool.

In implementing EU Directive 2007/60/EC on the assessment and management of flood risks (the "Floods Directive"), a new envelope was chosen for the preliminary flood risk assessment (PFRA) underlying the procedure for identifying areas at significant risk of flooding. This is the approximated envelope for potential floods (*enveloppe approchée des inondations potentielles*, EAIP), a maximum envelope based on the HKWL map, drawn up in 1910 in the context of the Boreux Plan, the PPR maps and hydro-geomorphological approaches, in order to retain the broadest envelope each time.

In addition to this mapping based on historic data, other approaches based on hydraulic modelling have been developed to represent different flood scenarios and their extent. The ALPHEE model developed by the DRIEE and the EPTB Seine Grands Lacs in the 1990s (Chapter 1) represent the area of the floodplain, which is separated into compartments in which the water level reached and flood duration are calculated according to the different flood scenarios. Benchmark scenarios were established on the basis of the 1910 flood flow. This ranges from scenario R0.6, representing 60% of the flow of the Seine in 1910, to scenario R1.15, which, with 115% of the 1910 flow, does not reach higher than the level the flood reached in 1910 thanks to the work done since then on the bridges and on the bed of the river. These different scenarios were used for crisis preparation work under the ORSEC mechanism and for cost-benefit analyses of prevention measures. More recently, in the context of implementing the Floods Directive, the DRIEE used ALPHEE to establish a 1 000-year flood with a flow 40% greater than that in 1910. Another hydraulic model based on a determinist approach is used by the Central Reinsurance Fund (*Caisse Centrale de Réassurance*, CCR). The impact of climate change on the flood risk in the Seine basin was also assessed under the National Climate Change Adaptation Programme (Chapter 1). This did not enable a significant variation in the flood risk to be identified, neither in terms of intensity nor probability.

The use of different hazard modelling and mapping approaches is not problematic in itself, since neither corresponds to specific objectives or different uses. The existence of these different standards, however, may confuse certain stakeholders and call the coherence of the holistic approach to flood prevention into question. Thus, the fact that the PPR and HKWL zoning maps are different and are both available online could raise concerns. It seems meanwhile that agreement on the probability of different flood

scenarios and the approaches chosen to calculate them is not always apparent. The models used by the CCR and the DRIEE-EPTB Seine Grands Lacs produce a rather different floodplain surface area for the same scenarios. The CATNAT compensation scheme funding policies are thus based on flood probabilities that differ from those produced by the government departments responsible for risk prevention policy. Now that momentum has built up with respect to prevention, approaches must be harmonised so that a hazard and probability assessment can be established among all stakeholders.

Vulnerability analysis and mapping

Several complementary approaches have also been taken by government departments and local authorities to assess exposure and vulnerability to flooding in Île-de-France. Different sources of information are therefore available depending on the objective of the assessment: regulatory tools, project cost-benefit studies, crisis management preparation, strategic plan development, etc.

The implementation of the Floods Directive requires accurate risk maps, for which the DRIEE is responsible. This authority carried out a PFRA for the entire Seine-Normandy basin, specifying the various assets exposed according to the Directive's general principles. All the assets exposed in the broad envelope of the floodplain are surveyed, paying particular attention to human health, economic, environmental and cultural heritage issues. Although it is not intended to be a precise assessment, this PFRA has, above all, enabled high-risk areas (HRAs), including the Île-de-France conurbation, to be defined with specific criteria. The DRIEE has now begun to map the risks affecting this HRA more precisely, as required under the Floods Directive. Maps have thus been developed for different significant, average or low probability flood risks (1 000 year), which record both water heights and many assets. These highly detailed maps were proposed in consultation with the various stakeholders and local authorities in September 2013 and will form the basis for defining the local flood management strategy.

Crisis management preparation also requires information to be available on the different impacts and their vulnerability during a crisis. In the case of a modern metropolis such as the Île-de-France conurbation, critical network correlations are key elements to be considered in assessing knock-on effects. Police Headquarters and its General Secretariat of the Paris Defence and Security Zone (*Secrétariat général de la Zone de Défense et de Sécurité de Paris*, SGZDSP) used the DRIEE R0.6 to R1.15 scenarios to develop crisis preparation strategies under the ORSEC mechanism. Since 2010, thematic working groups have accordingly been organised with all network operators to assess and map their vulnerability and interlinkages. A geographic information system (GIS) has also been developed which allows the impacts on roads and public transport networks, drinking water production systems and the electricity network to be visualised in different scenarios. The SGZDSP also has information relating to the vulnerability of other sectors which are sensitive or essential to crisis management, such as banking, telecommunications and distribution. This information may be difficult to obtain and share, particularly when matters of security, confidentiality or competition are involved.

Its regional development responsibilities caused the Île-de-France region to develop performance tools, such as GIS, to fulfil its remit. The region's IAU thus created the Visiau-Risques GIS tool, available online in a general public version, with a more elaborate version for professionals. This tool contains a comprehensive range of detailed information on the variety of assets exposed as a whole, from public infrastructure to

businesses and habitat, and a layer of information on the at-risk area, based on the PPR zoning which specifies high- and low-hazard areas. This tool has, for example, allowed the IAU to make a precise estimate of the number of people, businesses and jobs affected by the risk of flooding, broken down in detail at local level.

Loss and damage assessment

To date, the economic impacts of flooding have been assessed by the EPTB Seine Grands Lacs in cost-benefit studies of its prevention projects, and by the CCR in developing its CATNAT financial management tools. The EPTB Seine Grands Lacs used the economic modelling component of the ALPHEE model to calculate the economic damage caused by various flood events. This component, developed in the late 1990s and updated in 2010, allows damage to habitat and businesses to be calculated by the statistical spatialisation of assets and damage functions which calculate the latter according to water height and flood duration. This approach, innovative in its day, could now be reappraised to improve its accuracy in light of tools now available, particularly asset geolocation. In addition to its hydraulic model, meanwhile, the CCR has a precise database of assets linked to geolocated insurance contracts and its own damage functions. These are successively adjusted and improved in line with the different floods in France, the respective insured damage being measured by the CCR on an event-by-event basis. These damage assessments are therefore different from those made by the EPTB Seine Grands Lacs.

Chapter 1 of this volume put forward a broader assessment of the loss and damage caused by different flood events. This assessment seeks to bring together and complete all the studies and data identified above in a coherent approach and has thus made it possible to consider the impacts of flooding on critical networks, the indirect impacts linked to interruptions in such networks, and the medium- and long-term macroeconomic effects of a major flood. This approach could be further improved by updating the ALPHEE economic modelling by means of geolocated databases.

Real progress confirmed by knowledge of the risk

The recent hazard and asset mapping developed by the DRIEE on the Île-de-France conurbation HRA in the context of implementing the European Floods Directive is very precise. In particular, it includes relevant information on water levels, which are crucial for assessing damage. The three hazard levels (high, average and low frequency) could be adopted as a benchmark for all initiatives in this area. In the long term, the understanding between the DRIEE and the SGZDSP with respect to the Île-de-France HRA will allow these new maps to include the damage on the networks of the crisis management working groups. To date, the variety of risk assessment approaches, tools and standards has been rather confusing and has prevented stakeholders from reaching agreement on similar results, with each of them tending to develop their own calculation methodology. The current sharing and harmonising of knowledge could be extended to other stakeholders, such as the insurance sector, the EPTBs and the IAU, in a coherent and comprehensive risk assessment approach, particularly at economic level. Questions of probability, loss-function improvement, the harnessing of floods for groundwater recharge through subsoils and the timescale of flooding are areas which merit further development and greater understanding. Initiatives at the national level could help to improve this situation, particularly the creation of the National Observatory for Natural Hazards (*Observatoire National des Risques Naturels*, ONRN) with the insurance sector (Box 3.2), and the Île-de-France Seine and Marne PAPI project (Chapter 2).

Development of a risk culture

Reinforcing risk culture at all levels is an essential aspect of prevention policy. Raising awareness of the risks facing the public, businesses and decision makers can motivate action to reduce vulnerability at each of these levels. Risk communication tools must therefore be developed which allow all parties to have a realistic understanding of the seriousness and frequency of floods and the effects they could have on their homes, businesses, local areas, lifestyles or welfare. Greater risk awareness may also promote and accompany dynamic public action in this field in response to high public demands.

Box 3.2. **The National Observatory for Natural Hazards**

The ONRN was set up jointly by the Directorate-General for Risk Prevention (*Direction Générale de la Prévention des Risques*, DGPR), a department of the Ministry of Ecology, Sustainable Development and Energy (MEDDE), the CCR and the private insurance companies represented by the insurance companies' Natural Risks Mission (*Mission Risques Naturels*, MRN) on 3 May 2012. The observatory was initiated by the National Policy Board for the Prevention of Major Natural Hazards (*Conseil d'Orientation pour la Prévention des Risques Naturels Majeurs*, COPRNM), in response to recommendations in a parliamentary report into the floods caused by cyclone Xynthia in Charente-Maritime.

A public-private tool for sharing and disseminating natural hazard data and indicators, the observatory seeks to connect suppliers and users of hazard data and information. The ONRN has five principal objectives: improve and capitalise on knowledge of hazards and challenges; drive a forward-looking assessment mechanism; contribute to risk prevention piloting and governance; contribute to the economic analysis of crisis prevention and management; contribute towards improving risk culture. The ONRN should thus organise, provide access to and enhance knowledge, and above all produce national and regional indicators.

Such an observatory or its local application could represent an ideal structure for harmonising approaches to assessing the risk of flooding of the Seine in Île-de-France and a unique benchmark for sharing and disseminating information on institutions, businesses and individuals.

Source: Observatoire national des risques naturels (2013), "L'Observatoire national des risques naturels (ONRN)", Ministry of Ecology, Sustainable Development and Energy, Paris-La Défense, www.onrn.fr/site/binaries/content/assets/documents/onrn/201303_brochureonrn_web.pdf.

The absence of significant flooding of the Seine for almost 60 years and the virtual disappearance of low-frequency 10- to 30-year events contained by reservoirs and dykes have dimmed the collective memory of the risk of flooding in Île-de-France. Moreover, while the CATNAT collective insurance coverage offers many advantages, it may involve a moral hazard (Chapter 4) by giving citizens, businesses and decision makers the false impression that they will be compensated for their losses come what may. This does not encourage them to address the risks or to focus on prevention measures. Stakeholders as a whole feel that the level of information and the degree of public awareness of the risk of significant flooding are not commensurate with the gravity of the threat. The development of a risk culture therefore requires a proactive approach in Île-de-France to raise awareness of the significant risk of flooding.

Risk communication tools and their implementation

There are various regulatory measures for providing the public with information on risks, though these have shown their limits in Île-de-France. City councils should make preventive information on risks available via the municipal information document on

major risks (*Document d'information communal sur les risques majeurs*, DICRIM). This procedure is mandatory in every municipality in Île-de-France identified by prefects as being threatened by the risk of flooding of the Seine. The purpose of the DICRIM is to inform the population of the risks to which the municipality is exposed and to identify protection measures. This document also includes the history of the flood risk; a survey of prevention, protection and safeguard measures; an inventory of existing flood markers; and a map of the highest known water levels.

The DICRIM should be displayed in city councils, they must be freely available for consultation at no charge and briefing meetings should be organised every two years to make the public aware of them. Although this document is meant for citizens, in practice it is not widely distributed for educational purposes, since city councils generally do not wish to draw attention to the risks particular to their municipality. In Île-de-France for example, 11 municipalities situated in floodplains which are amongst the 100 most heavily populated French municipalities do not post their DICRIM on their websites (Table 3.1).

Table 3.1. **Absence of DICRIM on websites of municipalities at risk of flooding in Île-de-France**

Municipality	Population	Flood risk prevention plan (PPRI)	Date of approval of PPRI
Boulogne-Billancourt	113 085	Hauts-de-Seine	2004
Argenteuil	102 844	Argenteuil, Bezons	2002
Créteil	89 359	Val-de-Marne	2007
Courbevoie	86 945	Hauts-de-Seine	2004
Colombes	84 572	Hauts-de-Seine	2004
Asnières-sur-Seine	81 603	Hauts-de-Seine	2004
Rueil-Malmaison	79 065	Hauts-de-Seine	2004
Saint-Maur-des-Fossés	75 251	Val-de-Marne	2007
Champigny-sur-Marne	75 090	Val-de-Marne	2007
Levallois-Perret	63 436	Hauts-de-Seine	2004
Noisy-le-Grand	63 405	Seine-Saint-Denis	2010
Neuilly-sur-Seine	60 501	Hauts-de-Seine	2004

Notes: Adapted from Moro (2012). The methodology is based on the INSEE survey of the 100 most heavily populated French cities in 2012, the *DICRIM national database* and the *Gaspar database*, and the official websites of the various municipalities examined. The principal limitation of this approach is that the author is under the impression that municipalities which have not posted their DICRIM online have not produced or communicated it and their communication is therefore poor, while in fact they are under no obligation to post them online.

Sources: *Gaspar database*, http://macommune.prim.net/gaspar (accessed in October 2013); *DICRIM national database*, www.bd-dicrim.fr (accessed in October 2013); Moro, C. (2012), "Ces grandes villes françaises qui cachent leurs risques majeurs" [French cities that hide their major risks], blog i-resilience.fr, www.i-resilience.fr/2012/07/ces-grandes-villes-francaises-qui-cachent-leurs-risques-majeurs (accessed in October 2013).

In addition to the DICRIM, city councils must also ensure that the risk of flooding is substantiated by listing, maintaining and affixing flood markers corresponding to the highest known water levels, which remind people of floods. Like the DICRIM, flood markers have not been widely developed by city councils in Île-de-France. The DRIEE surveys and maps these flood markers via a dedicated website. With the exception of Paris, which has many markers of the 1910 flood and which has doubled their number since 2011, flood markers are not very common along the Seine in upstream and downstream departments, which were not very heavily developed at the time of the 1910 flood.

The 2003 Law on Risk Prevention also introduced a risk communication tool for purchasers and tenants of buildings. Owners or lessors must inform purchasers or tenants of the risks existing in the municipality and of claims that have affected the properties concerned in the past. Municipalities must use this tool to inform citizens of the risks in response to their demands. Communication is effective in this respect, but the level of information communicated often remains basic and limited to a regulatory map.

French regulations make procedures mandatory: information procedures (affixing documents in city councils) or consultation with stakeholders (e.g. with associations or public enquiries) rather than the establishment of quantified risk awareness objectives among the population or with entrepreneurs. These procedures could be more effective in Île-de-France, either by wider dissemination or by presenting the information differently.

Innovative approaches to raising public awareness

Other approaches to raising public awareness of the risk of flooding which are more in step with citizens' expectations have been favourably received. The centenary of the 1910 flood, for example, was an opportunity to rekindle the memory of the risk: many exhibitions, colloquiums, films, information boards, etc. were organised. The Hauts-de-Seine General Council put on a travelling exhibition in several of its municipalities on the impacts of the 1910 flood, comparing it with what would happen today by means of period photographs. Information on this flood, however, does not seem to have been presented in the most effective way: highlighting a period in the past may give the impression that the flood reflected a phenomenon from another age and that progress in the 20th century guards against its effects. Representations of the risk based on modern communication tools, such as 3-D animated maps, may be more appropriate and could reach a broader public (Box 3.3).

The development of a river and water culture is also an opportunity to address the risks involved. The *Festival de l'Oh!* [*Festival de l'Eau*, or Water Festival] organised by the Val-de-Marne General Council under its annual "Blue Plan" was devoted to the flooding of the Seine in 2012. The AESN has proposed an option for raising awareness of water issues in schools which addresses floods and flooding. The many projects to develop river banks in the Île-de-France region over the past ten years (see below) have also allowed citizens to reappropriate the river and its irregular rhythm, the first signs of a risk culture.

A risk culture developing in businesses

Businesses have become increasingly aware of the major risk of flooding of the Seine in Île-de-France in recent years, but to very different extents according to their scale and sector. The creation of working groups focusing on critical sectors under the supervision of the area protection authority has helped to make these public and private stakeholders more aware of the interlinkages and knock-on effects of significant flooding. The leading businesses and operators in the energy, transport, water, banking, distribution and telecommunications sectors have gradually become aware of the risk and have made an effort to mitigate it or to increase their resilience.

Many other major businesses have been made aware of this risk by different means. Networks of the leading companies' risk and security directors can meet in the Business Security Directors' Club (*Club des Directeurs de la Sécurité des Entreprises*, CDSE), for example, which brings together most of the largest French groups. Regulations on key sectors of activity require many enterprises to develop business continuity plans.

Insurance and reinsurance companies have raised their clients' awareness of this risk when discussing their insurance coverage. The reinsurer Swiss Re classifies Île-de-France as one of the world's major at-risk metropolitan areas in its study on the impact of disasters on business activity (Swiss Re, 2013). The Paris Chamber of Commerce and Industry (CCI Paris) also published a special study in 2012 on the risk of flooding of the Seine in Paris (CCI Paris, 2012). Action taken locally at business district level (e.g. La Défense) may also help to raise awareness among the major groups. When they have been made aware, businesses make strong demands for access to precise information on the risk, both with respect to water levels and critical network interruptions (electricity, telecommunications, transport and water).

Box 3.3. **3-D maps: An awareness-raising tool**

The Institute for Urban Planning and Development of the Île-de-France Region (IAU) develops participatory tools for citizens to raise risk awareness. The risk prevention plans (PPR) maps or the map being developed under the Floods Directive are accurate and necessary from a legal and regulatory perspective. Although they are made available to the public, they are not very accessible to non-specialists because of their technicality. The use of simplified mapping tools or 3-D visualisation offers the public a new perception of the risk.

The IAU has produced a video representing the impact of the flooding of the Seine in Charenton-le-Pont and Ivry-sur-Seine. This three-dimensional video is available online and has been viewed around 3 000 times in a year.

Source: IAU (2013a), 3D video available at: www.youtube.com/watch?v=W_wJ8vYtMmU (accessed in November 2013).

The level of awareness of SMEs, on the other hand, remains very limited. There have been no information campaigns aimed specifically at businesses in Île-de-France, particularly SMEs. In partnership with the EPTB Seine Grands Lacs, the CCI Paris has conducted several vulnerability assessments in SMEs in Île-de-France which have highlighted their lack of awareness of the risk of flooding (CCI Paris, 2012). The CCI Paris could do more in this field. The development of flood risk assessment tools for businesses, such as those produced in the Loire basin, could motivate Île-de-France in this respect.

It is also crucial to strengthen the risk culture among certain professions that play a key role in terms of resilience. Action focusing on network and crisis management operators in the SGZDSP is particularly relevant in this regard and has proven its effectiveness. Mechanisms focusing on urban planners and developers, solicitors who provide information for purchasers and householders' associations responsible for maintenance have been used on a limited scale in Île-de-France by the Paris City Council and the EPTB Seine Grands Lacs, for example. This more long-term action may provide substantial leverage for the effective implementation of resilience measures.

Area, public service and business resilience

Increasing the Paris conurbation's resilience to major flooding of the Seine could be based on a range of measures and opportunities at area, business or public service level. Resilience relates to a system's capacity to absorb shocks and regain its ability to function. This multifaceted concept thus focuses on continuity with respect to a range of services, systems and societal functions and ensures links between the prevention action addressed in this study and preparatory and crisis management measures (Baubion, 2013). Appropriate urban planning and development which correctly factors in the risk of flooding may create the foundations for enhancing area resilience. This includes critical networks and infrastructure whose vulnerability to flooding can exacerbate the effects of a disaster. More broadly, business, public service and individual resilience must also be developed by means of business continuity approaches, for example. Many options for improving the resilience of the metropolitan area may thus be pursued through a culture of sharing risks. This requires stakeholders to commit to a common objective and, in particular, to long-term action in terms of urbanisation and infrastructure, both with respect to economic stakeholders and individuals.

Area resilience through urbanisation policies

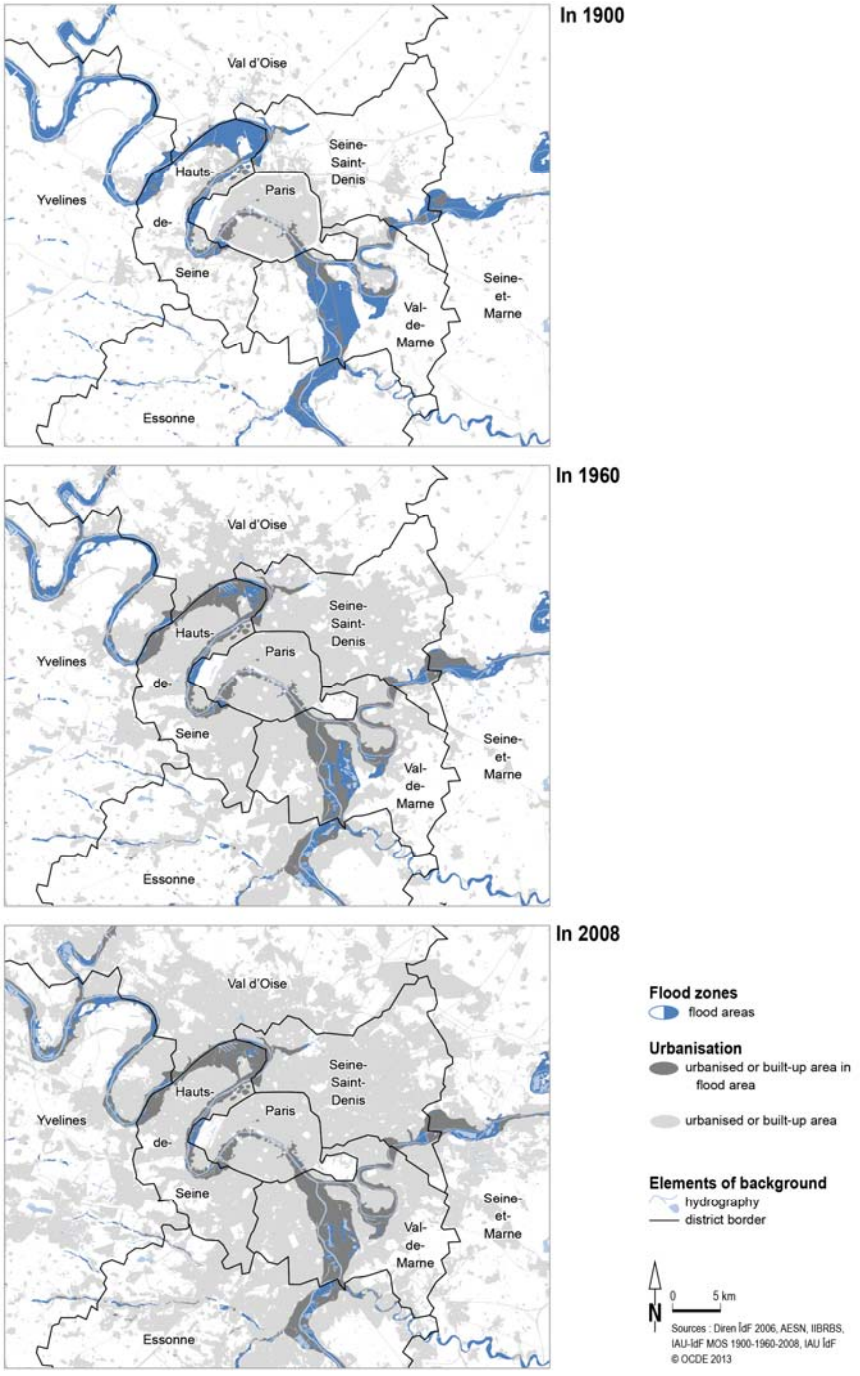
The resilience of areas primarily requires controlled urbanisation of floodplains and consideration of this risk in the strategic planning and design of urban development projects. Since the 1910 flood, the development of the Paris conurbation has given rise to heavy urbanisation on the alluvial plain and urban sprawl, which has been expanding for 40 years (Figure 3.1). The areas of natural expansion of the Seine upstream of Paris in the Val-de-Marne and downstream in the Hauts-de-Seine were heavily exploited initially to develop industry, and then for housing and services. While risk prevention policies based on controlled development or urban renewal did little significantly to mitigate the risk of flooding of the Seine in this largely built-up context, the unifying Greater Paris project offers hope that a flood-resilient metropolis may emerge around innovative urban projects developed along the course of the Seine.

The limits of the PPR regulatory tool

The limits of instruments to restrict building in floodplains have been reached both nationally and in Île-de-France. The management of urbanisation in floodplains in France is based on the PPR established since the 1995 Barnier Law. This state regulatory tool requires municipalities responsible for urban planning and development to ensure regulatory zoning according to the hazard defined on the basis of floodplain atlases, and applies building regulations ranging from a total ban on building to building under certain conditions. This is stipulated and approved by the prefect after a municipal consultation process and a public enquiry. The approval, which is attached to the local urban plan

(*plan local d'urbanisme*, PLU), creates public utility easements, making it effective against third parties with respect to any construction, works or development in the floodplains (OECD, 2010).

Figure 3.1. **Urban sprawl in Île-de-France**



Since its creation in 1995, this tool has become widely established in French municipalities identified as "at risk" by the public authorities: in 2011, over two-thirds of a target of 12 500 municipalities were covered by an approved PPR, and a PPR was prescribed

or in preparation in a further 3 800 municipalities (AScA, Ledoux Consultants, 2012). This tool has therefore been successful to some extent, even if the criteria chosen for whether to prescribe a PPR or not could be improved (Gerin et al., 2012). It seems to be broadly agreed, however, that it is ineffective in genuinely reducing risks.

The PPR is thus often the result of political negotiations between local authorities, the prefect and state technical departments (Grislain-Letrémy et al., 2012). It is therefore difficult for the state to impose a PPR that a local authority does not want (Conseil d'État, 2010). Following the dramatic flooding of the Var as well as that on the Atlantic coast (cyclone Xynthia) in 2010, the Court of Auditors highlighted the shortcomings of this system, concluding that: "Faced with a real thirst to build, generally fostered by local elected councillors, the state has not often shown sufficient determination at departmental level to prevent building in at-risk areas." The lack of procedures ensuring compliance with measures stipulated by PPRs is also underscored.

Flood risk prevention plans in Île-de-France

In the specific case of Île-de-France, notably the metropolitan area, the PPR mechanism is not very effective in reducing the vulnerability to flooding. The PPRs were prescribed for all municipalities at risk of flooding of the Seine, a very large majority of which were approved between 2000 and 2010. The Île-de-France PPRs are departmental in scope, which allows coherent planning at that level but offers no guarantees as to the risk basin as a whole. The PPRs for different departments therefore define areas differently according to the hazard and assets involved and use a very wide range of colour coding to characterise them. This does not provide a clear overview of the at-risk area for establishing a coherent regional approach (Table 3.2); building regulations in each area also vary widely.

Moreover, the different PPRs relating to flooding of the Seine – and the Marne – in Île-de-France are not very ambitious. Very few areas are classified as very high risk because of the slow kinetics of flooding. There are therefore virtually no areas where construction is prohibited in the departments in the inner suburbs. In addition, these documents have little impact on the existing building stock, which is largely in the majority in Île-de-France. Finally, the building regulations in the PPR areas are generally not very restrictive, often merely defining the height of the first floor and the total building area percentage, and they do not impose specific regulations on network operators either (except in Paris).

In its study on urbanisation in the floodplains, the IAU noted that the respective exposed population increased significantly from 1999 to 2006 (+5.9%), with a growth rate slightly above the regional average (+5.3%). Some 80% of this human development occurred in the inner suburbs where departments had established PPRs from 2000 onwards, mostly in high hazard areas (IAU, 2011). A substantial proportion of the population of many municipalities subject to a PPR is therefore located in the floodplains, and this proportion is increasing, despite the declared intention to limit urban density in such areas (Figure 3.2). In the past 20 years, 1 500 ha have thus been developed in the floodplains, and the last major hospital built in Paris, which opened in 2001, and the future headquarters of the French Army are situated in the heart of the Paris district most exposed to the risk of flooding.

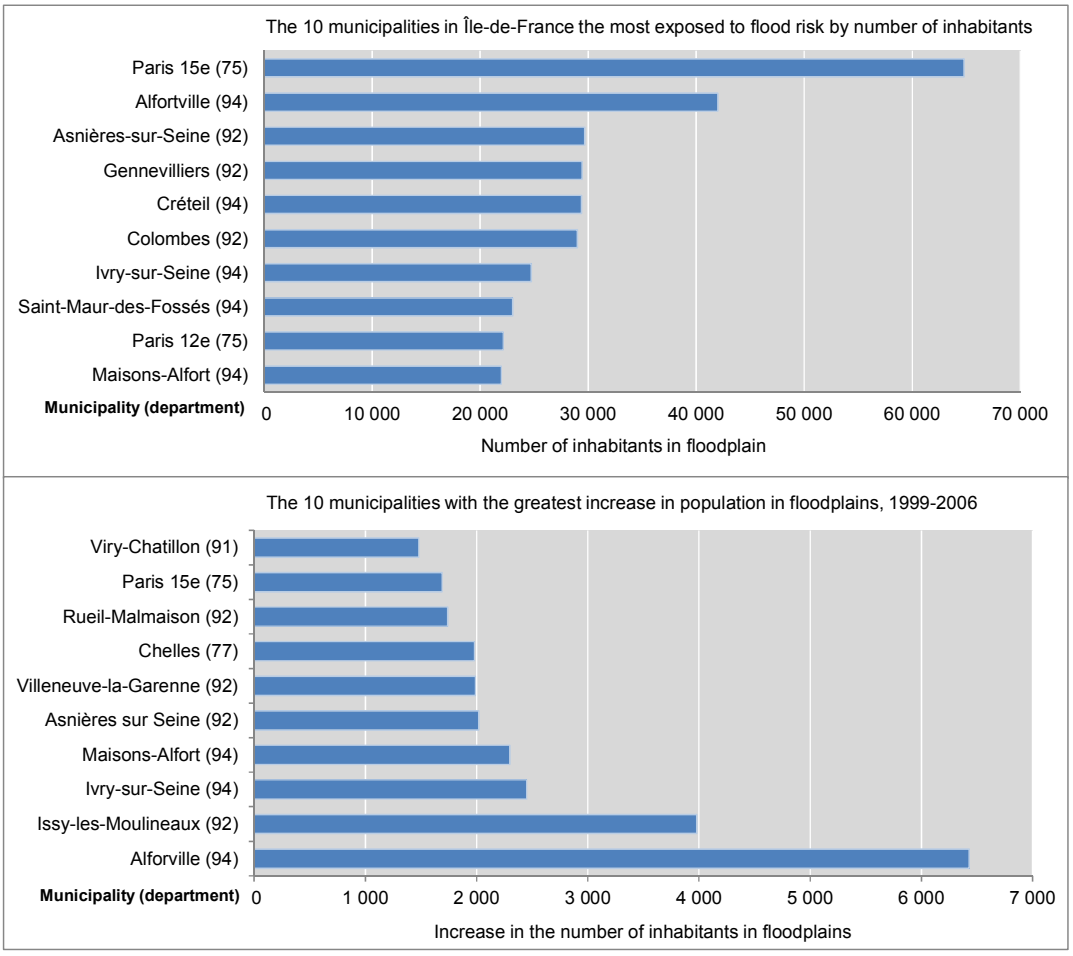
Table 3.2. **Risk prevention plans in departments in the inner suburbs of Île-de-France**

Department	Municipalities	Date prescribed	Dates approved/ revised	Description of areas defined by the regulation
75	1	1998	2003, revised in 2007	Green: flood retention areas Red: principal run-off area Dark blue: high hazard urban areas Light blue: urban areas in floodplain
92	18	1998	2004	Red: high hazard or high storage capacity areas Blue: urban centres Orange: dense urban areas Purple: areas of urban change
93	9	1999	2007 (Seine) 2010 (Marne)	Red: flood retention areas Orange: very high hazard urban area Yellow: high hazard urban area Green: urban centres
94	24	1998	2000, revised in 2007	Red: high run-off areas Green: flood retention areas Dark orange: other high to very high hazard urban areas Light orange: other moderate hazard urban areas Dark purple: high to very high hazard dense urban areas Light purple: areas situated in a moderate hazard area Blue: urban centres
77	8 (Marne) 21 (Seine)	1996/ 1999	2002 (Seine) 2007/09 (Marne)	Red: very high hazard areas Brown: natural or weakly urbanised areas Dark yellow: high storage capacity natural areas Light yellow: weakly urbanised areas Dark blue: densely urbanised areas Light blue: lower risk densely urbanised areas Green: "extremely important" urban centres for the conurbation Grey: sectors to which access is subject to high to very high hazards
78	57	1998	1998, revised in 2007	Brown: major run-off areas Green: non-/not very built-up areas – moderate to very high hazard Dark red: urban centres and urban areas – very high hazard Light red: built-up areas outside urban centres – high hazard Blue: urban centres – high hazard, other urban areas – moderate hazard, highly important areas – moderate to high hazard
91	18	1996	2003[1]	Red: non-built-up areas – high to very high hazard urban areas (urban centre or other) – very high hazard Orange: non-built-up areas – average hazard Blue: urban areas other than urban centres – high hazard Sky blue: urban areas other than urban centres – average hazard Green: urban areas in urban centres – average to high hazard
95	22	1998	1998 (Oise), revised in 2007 1999/2000/2002 (Seine)	Red: urban areas – high hazard Blue: urban areas – average hazard Yellow: sectors identified for facilities of general interest Green: flood retention areas Turquoise: sectors located above the reference flood

Notes: 1. Plan applied in advance in 13 municipalities, expiring in 2005; the moderate to high hazard corresponds to 0-1 metre submersion, high hazard at 1-2 metres submersion and very high hazard greater than 2 metres submersion.

Sources: Préfecture de la Seine-Saint-Denis (2007), *Plan de prévention du risque inondation de la Seine dans le département de la Seine-Saint-Denis: Règlement*; Préfecture de la Seine-Saint-Denis (2010), *Plan de prévention du risque inondation de la Marne dans le département de la Seine-Saint-Denis: Règlement*; Préfecture du Val-de-Marne (2007), *Plan de prévention du risque inondation de la Marne et de la Seine dans le département du Val-de-Marne: Règlement*; Préfecture de Paris (2007), *Plan de prévention des risques d'inondation du département de Paris révisé: Règlement*; Préfecture des Hauts-de-Seine (2004), *Plan de prévention des risques d'inondation de la Seine dans les Hauts-de-Seine: Règlement*; Val d'Oise, Yvelines, Seine-et-Marne and Essonne Prefectures.

Figure 3.2. **Population in floodplains and its growth, 1999-2006**



Source: IAU (2011), "Urbanisation et zones inondables: Les risques encourus", *Note rapide territoires*, No. 557, Institut d'Aménagement et d'Urbanisme, Paris, www.iau-idf.fr/fileadmin/Etudes/etude_839/NR_557_web.pdf.

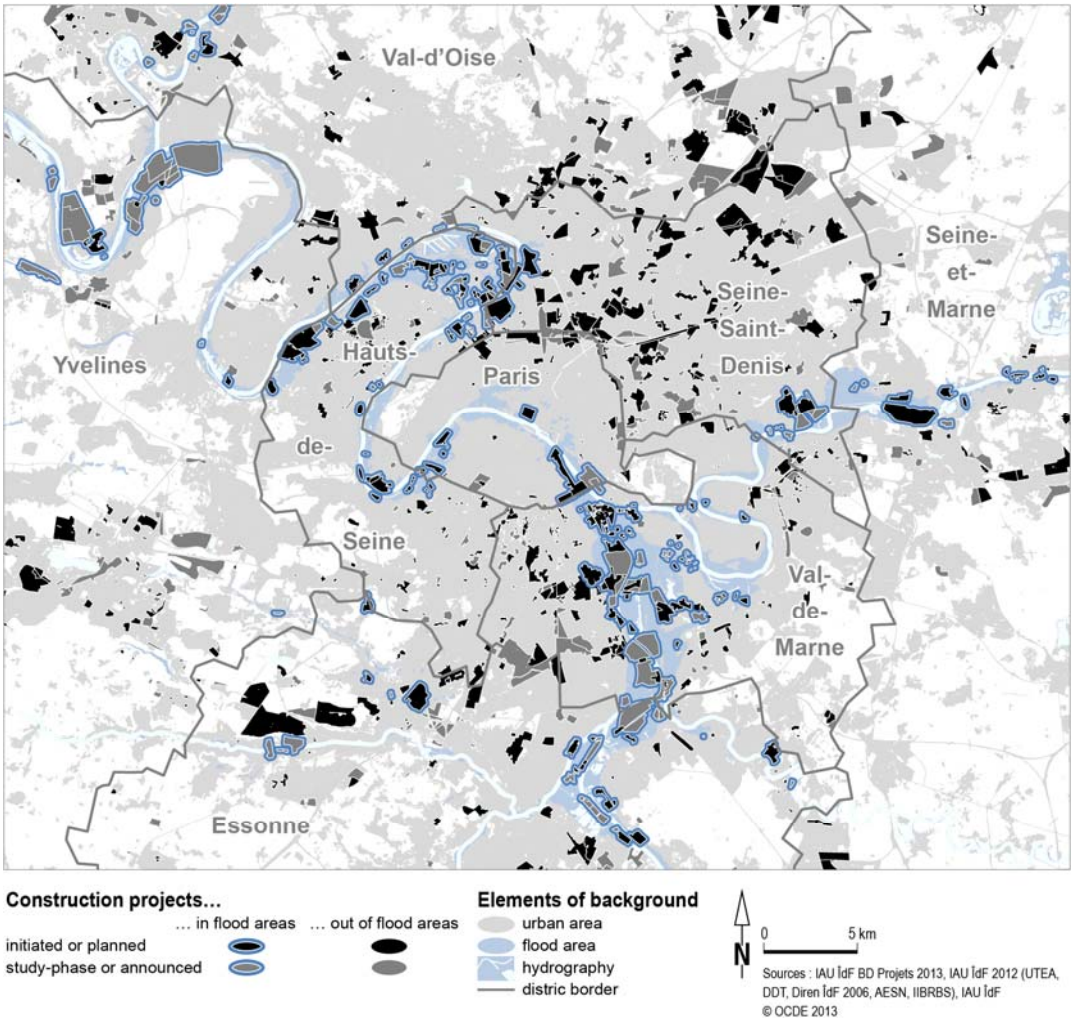
Rather than encouraging municipalities to limit building in floodplains, local development dynamics encourage them to develop these often attractive areas. In their eyes, taking a major flood risk into consideration is counter-productive because it is detrimental to economic development (and therefore local taxation), does not win votes like social infrastructure can, does not necessarily correspond to the demands of the electorate and requires technical capacities which most of the 141 relevant municipalities in Île-de-France do not have. This paradox means that the cost of land is dissociated from its exposure to the risk, with many municipalities with high property prices being situated in floodplains (Reghezza, 2006). Numerous planning projects in floodplains in Île-de-France are therefore in progress, scheduled or under study (Figure 3.3).

The opportunity for Greater Paris to become resilient

The Greater Paris project seeks to respond to the major development challenges facing the Île-de-France metropolitan area. Improving citizens' welfare, attracting business and combating climate change are the foundations for this innovative and green growth-based project (OECD, 2010). Specifically, the project aims to develop a major

public transport network around which high-density poles will form. The construction of 70 000 additional dwellings per year is accordingly envisaged, with an investment of around EUR 30 billion in public transport by 2030.

Figure 3.3. **Planning projects in floodplains**



The Greater Paris project represents an opportunity to take resilience into account in conurbation-wide urban renewal, development and infrastructure projects, since the local implementation of national risk prevention policy via the PPRs has not proven to be effective in Île-de-France. Many of the regional development poles being created are, in fact, situated in floodplains. The list of territorial development contracts – programming and planning tools that seek to achieve the objectives of the Greater Paris project in the regions – is illustrative in this respect. In October 2013, out of the 21 such contracts entered into or under study, 13 were affected by the risk of flooding of the Seine or Marne and are often situated in particularly exposed areas (e.g. Sénart in Seine-et-Marne, Les Grandes Ardoines in Val-de-Marne, La Boucle Nord des Hauts-de-Seine or the Seine-Oise confluence between the Yvelines and the Val d'Oise). Signed between the state and local authorities, these contractual instruments can act as powerful levers for incorporating urban resilience issues and the various environmental objectives: sustainable cities, "soft" densification and the battle against climate change.

To date, flooding of the Seine has not been a factor in the selection criteria for the Greater Paris project, neither in the choice of areas to be expanded nor the location of transport network stations. The expansion envisaged in floodplains should thus be accompanied by measures to reduce the vulnerability of these new districts so as to not increase the conurbation's already high risk level. A proactive approach must therefore be adopted which goes beyond the PPRs. In a context in which the urban fabric does not put vulnerability to flooding in the forefront of planning processes and does not establish objectives, public decision makers and developers ultimately plan solely on the basis of regulatory aspects such as the PPRs, which are often incorporated as a secondary constraint.

River-based innovation

Innovative approaches to urban and architectural design will ensure that resilience and flooding are no longer perceived solely as constraints. Contrary to developments in other OECD countries (Box 3.4), resilience has not yet become a source of innovation in France for design offices or urban development and architectural consultants, as other regulatory constraints on energy, air and water quality or noise have, for example (EPTB Seine Grands Lacs, 2010a). Little consideration has been given to this subject in France.

Box 3.4. **Development of a resilient district in Mayence, Germany**

The German *Land* of Rhineland-Palatinate has 4 million inhabitants, with many towns built in river valleys. The town of Mayence is situated on the banks of the Rhine, downstream of the confluence with the River Main, with Frankfurt further upstream. The redevelopment of two old port districts in this region, Zollhafen and Westhafen, demonstrate the potential for innovative construction in floodplains. In Mayence, Zollhafen is one of the largest container ports on the upper Rhine. In this district where spatially oriented approaches are evolving, the municipality planned the development of a new "town on the river", with 2 500 inhabitants and 4 000 jobs. The Rhine is the largest river in Western Europe, with a discharge that can reach 8 000 m^3/s and a recurrence interval of 200 years at Mayence. Because of its location on a floodplain and outside the defences of the town of Mayence, Zollhafen is flooded during 100-year Rhine floods. The redevelopment was therefore designed to resist floods by means of adapted buildings.

The master plan established binding density and spatial organisation conditions. Ground levels for new buildings must be built at 1.20 m and 1.50 m above the flood level of a 100-year flood. The infrastructure thus remains operational up to at least 200 years. Protection is ensured for existing buildings for a 100-year flood by temporary "retrofit" systems. Different scenarios have been developed: with a 100-year flood, the water is contained and no streets will be flooded; when the recurrence interval is 200 years, some streets will be flooded, but most of the main roads will be saved because their level has been designed to maintain access; for a 200-year flood and an additional 50 cm, corresponding to the extreme level of protection of the town of Mayence, Zollhafen's streets will be flooded, but the buildings will not be affected.

In Germany, building on floodplains was generally prohibited by a federal law in 2005. There are only a few exceptions to the rule, notably the conversion of port cities, when a special application for a building permit must be completed for the regional office of the Ministry of the Environment. The ministry is also currently co-operating with the municipality of Mayence to develop and promote Zollhafen as a model flood-adapted development project.

Source: Webler, H. (2010), "Redevelopment of the Zollhafen Mainz as flood resilient development", IAHR European Congress Edinburgh, 5 May 2010, http://web.sbe.hw.ac.uk/staffprofiles/bdgsa/IAHR_2010_European_Congress/Papers%20by%20session%20final/Flood%20Resilient%20Cities/FRCa.pdf.

At the beginning of the Greater Paris project, ten teams of architects were invited to propose a vision of Greater Paris in an international competition. While the Seine River was one of the subjects for consideration, only foreign teams provided ambitious proposals covering flooding, while only one French team out of the six in competition referred to the subject. These teams nevertheless often made reference to reclaiming the course of the Seine as a driver of development and planning, based particularly on the "blue network" concept. During and as a complement to the "green network", which links green spaces as a continuation of the city towards its rural periphery, the blue network seeks to reconnect the different water areas to incorporate them into an overall plan. Many river and bank enhancement projects have thus been initiated in Île-de-France by municipalities along the Seine, Marne or Oise (IAU, 2013b).

A strong political will and innovation support and dissemination mechanisms should accompany such moves, so that reinforcing a river culture is reflected in flood resilience projects. The dynamics of projects and the development of this culture among elected councillors, the public and developers create the conditions to foster such projects. Many urban renewal projects in floodplains will release spaces for developing resilient districts. The development of the Ardoines district beside the Seine in Val-de-Marne, under the Orly-Rungis Seine Amont Public Development Authority (*Établissement Public d'Aménagement d'Orly-Rungis Seine Amont*, EPAORSA), may serve as a guiding example and ambitious demonstrator, if it fulfils its aim to keep flooding issues at its heart (Box 3.5).

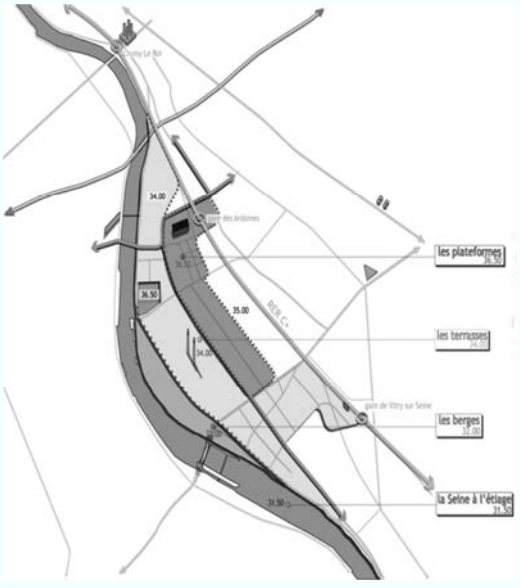
Box 3.5. **Model resilience in the Ardoines district**

Flood resilience is at the heart of the Ardoines urban renewal project in Vitry-sur-Seine, which is heavily exposed to this risk. This plan to build 13 000 dwellings and create 45 000 jobs in the area covered by the Orly-Rungis Seine Amont Public Development Authority (EPAORSA) is driven directly by the state as a measure of national interest. The EPAORSA wanted this urban project to incorporate flood resilience. Once it has been carried out, it will then serve as an ambitious demonstration of innovation in resilience measures.

A guideline plan was produced in 2009 which divided the planning district into three terraced areas:

- a 10-ha public park beside the Seine built by excavating the banks, which five-year floods would overflow
- an intermediate terrace which would accommodate low-density habitats and activities according to a flood-resilient design, with a 50-year protection level
- an upper platform where strategic activities and public infrastructure and facilities would be protected against the most severe flooding.

This ambitious approach has been undermined because of the cost of terracing and operational difficulties. The project is now geared more towards factoring in building resilience objectives and maintaining operations during flooding via an off-water communication network.



Source: Brun, A. and F. Adisson (2011), "Urban renewal and flood risk: The masterplan 'Seine Ardoines'", *Cybergeo: European Journal of Geography* [online], Regional and Urban Planning, Document 561, 29 October 2011, available at: http://cybergeo.revues.org/24751.

Resilience of metropolitan systems and functionalities: Critical networks, businesses, public services

A resilience approach must also include stakeholders who make the metropolitan system work: network operators, businesses and public services. Beyond the region and the building stock, the concept of resilience is based on the notion of the system: this is a matter not only of limiting the impact of a shock but also of rapidly restoring system functionalities. In this respect, urban resilience includes both vulnerability reduction and business continuity measures, in combination with crisis management. Approaches differ significantly according to the stakeholders, in line with the regulations and their own perception of the level of risk.

Critical network resilience and continuity

Urban networks and the critical operators who structure the metropolis and enable it to function (electricity, water, telecommunications, transport) are of particular concern. Their own flood resilience is crucial to that of the metropolitan area as a whole.

In Île-de-France, the resilience or continuity of the activity of critical network operators depends on a variety of regulatory instruments. The 2004 Law on the Modernisation of Civil Security requires stakeholders to ensure public service continuity. Most of these operators have also been identified as crucial to the implementation of the 2006 decree on vitally important activities. Risk analysis-based special protection plans must be put in place. Although the law initially focused on the risk of terrorism, the operators it designates must address all risks in their protection plans, including a major flood of the Seine. The Paris PPR also provides for bodies with a public service remit to draft flood protection plans (*plans de protection contre les inondations*, PPCI) for all establishments situated in floodplains. This also concerns many network operators such as the RATP (*Régie Autonome des Transports Parisiens*, the French state-owned public transport operator in Paris) or waste, district heating and water managers. Finally, specific contractual obligations can be included in delegated contracts. Despite the existing regulatory or contractual context, it seems that standards for a rapid resumption of activity are not sufficiently high in the event of major flooding of the Seine. Thus, while these various instruments exist, they lack a precise standard and overarching harmonisation that would define the required resilience and protection levels and measure them with predetermined indicators (Box 3.6).

Crisis management work carried out in connection with the Paris Defence and Security Zone has helped to raise the awareness of stakeholders and encourage them to assess their vulnerabilities and the knock-on effects they may have for other sectors of activity. Major flood risk assessment, preparation and resilience, however, continue to be highly diverse (Box 3.7). Some have a precise assessment of the impact of different flood scenarios, have developed business continuity plans and have sometimes even invested substantially to reduce their vulnerability (including by relocating). Others have meanwhile made less effort, or are reluctant to share the information they have so that each party involved can make preparations. In these circumstances, it is important to maintain momentum with respect to crisis management under the auspices of the Paris Defence and Security Zone so that it can continue to ensure that structural networks are more resilient. Public authority support could be ensured by establishing metropolitan-wide standards, regulatory measures and incentives.

Box 3.6. **Defining a network resilience indicator as a city resilience indicator**

In their work on network resilience, a team of researchers from the School of Engineering in Paris proposes to define an urban network resilience indicator as a basis for a city resilience indicator. In this analysis, the risk facing technical networks is threefold: material, functional and structural. A resilience indicator has been developed by aggregating three indicators for these three risks:

- the material resilience indicator includes damage incurred by the network, or a damage percentage for example
- the functional resilience indicator refers to the possibility that the network's degraded functions can be fully restored, e.g. by assessing available resources (financial, material and human) in relation to the possible damage
- the structural resilience indicator represents the network's capacity to function while damaged or to propose alternatives, such as a calculation of network redundancy.

A network resilience indicator may thus be defined at the level of the city's different districts and may be compared to the challenges with the help of a GIS, thus enabling a city resilience index to be defined by district and globally making it possible to assess the risk beyond the floodplain and to better target resilience enhancement measures.

Source: Lhomme, S. et al. (2010), "Les réseaux techniques face aux inondations ou comment définir des indicateurs de performance de ces réseaux pour évaluer la résilience urbaine", *Bulletin de l'Association des géographes français*, https://hal.archives-ouvertes.fr/hal-00580025.

Box 3.7. **Network operator resilience measures**

- Transport: the RATP has clearly identified the 446 possible water entry points in its metropolitan transport network and has produced an action and sealing plan within its flood protection plan. It also includes flood risk mitigation in its modernisation work. The SNCF has a protection scheme for its stations but is less well prepared in protecting its network.
- Water: in addition to an emergency plan to supply the metropolis with drinking water, water operators have invested in measures to protect their drinking water production facilities which are located in floodplains. Specific flood protection mechanisms have been introduced (removable protection, pumps). It should nevertheless be noted that resilience levels are not equal at metropolitan area level, with some operators having to interrupt services at a level lower than others.
- Electricity: electricity network vulnerabilities are clearly identified by the operator and efforts have been made to mitigate them. These appear to be too limited to meet the challenges, however, since the electricity network is particularly crucial to the overall resilience of the capital (Chapter 1). To the extent that the investment to be made to meet the risk is particularly significant, the operator favours a crisis management approach while including the "flood" criterion to ensure that investment develops to protect the network in the long term.
- Telecommunications: competition among different operators makes transparency with respect to resilience levels, available resources and investment in this sector more problematic. Orange, a French telecommunications operator, nevertheless seems to be well-prepared for the risk of flooding. It can function independently of the electricity network by using its own generators, thanks to which it can cover 98% of the region. Orange has furthermore relocated its data centres outside the floodplain. This operator's awareness-raising and preparation could serve as a model for other sectors.

Source: Interviews carried out by the OECD Secretariat during the peer review, 2013.

It is also useful to invest in network resilience from the design stage. Thus, while certain stations in the Greater Paris network have been established in floodplains, ensuring that this new critical network enjoys a high level of flood protection is an opportunity to contribute towards metropolitan area resilience through a network that functions in the event of flooding. Substantial investment in the other structural networks (water, electricity, telecommunications) linked to renewal or to the development of new technology (e.g. intelligent networks in the electricity sector) enables stress to be laid on this notion of flood risk resilience in the context of a global strategy. Such a strategy could also favour the development of multi-network passageways such as those in Prague in the Czech Republic (Sternadel, 2008). These passageways housing all the critical networks allow functions to be restored more quickly after flooding by avoiding work on the surface.

Public service resilience

Efforts to ensure public service resilience and continuity appear to be limited and highly variable according to the level of government. At state level, activity continuity plans must be developed in all ministries under the auspices of the General Secretariat for Defence and National Security (*Secrétariat Général à la Défense et à la Sécurité Nationale*, SGDSN), while via the SGZDSP, Police Headquarters organises crisis management under the ORSEC mechanism (Chapter 1). However, reducing the vulnerability of the numerous facilities and buildings in floodplains and the operations of the various public services that depend on them in the event of flooding is far from ensured.

Assessments have been carried out by risk-aware local authorities, such as the local councils in the inner suburbs and in the City of Paris. These represent the first phase in the development of business continuity plans (*plans de continuité d'activité*, PCAs), which are still under consideration. The Hauts-de-Seine General Council has examined the vulnerability of the public institutions for which it is responsible: vulnerability assessments have given rise to the development of vulnerability reduction plans for 41 of the department's sites, notably education institutions. Work to adapt or upgrade facilities has thus been decided in this context. Assessments in the Val-de-Marne have also enabled certain vulnerability reduction measures to be taken to ensure greater resilience. Provision is made in the City of Paris' PPR drawn up in 2007 for a special PPCI to be developed for the 900 public facilities situated in floodplains, including both prevention measures to reduce vulnerability and activity continuity measures. While this appears to be particularly ambitious, its implementation has not as yet been fully effective. The production of a guide by the Regional and Inter-departmental Directorate for Infrastructure and Development (*Direction Régionale et Interdépartementale de l'Équipement et de l'Aménagement*, DRIEA) in 2012 seeks to increase the pace of their development (DRIEA, 2012).

At municipal level, public service and infrastructure resilience measures are limited, as shown by the weak development of the local emergency response plans (*plan communal de sauvegarde*, PCS) prescribed under the PPRs since the 2004 Law to Modernise Civil Security. In 2013, for example, less than 40% of districts in Île-de-France exposed to the risk of flooding had implemented a PCS. Reflecting the low awareness and low flood risk culture at municipal level, flood risk resilience and public service continuity are limited here. The draft PAPI ensured by the EPTB Seine Grands Lacs provides for a broad range of activities in this domain.

Box 3.8. **Heritage and flooding: Transfer of museum reserve stocks**

Public buildings in floodplains include a considerable number of museums of heritage or cultural value which are intangible assets whose loss or damage is inestimable (Chapter 1). The awareness of the public authorities towards the risk of flooding of the Seine for the Louvre's reserve stocks thus led the Ministry of Culture to decide, in September 2013, to transfer them to Louvre-Lens in northern France. Tests on the Louvre's contingency plan in fact showed that the 72-hour time limit provided for in the plan was not sufficient to transfer the reserves located in floodplains.

By contrast, the more recently built National Library of France and the Quai Branly Museum, whose reserve stocks are stored in basements along the Seine, were designed with tanked basements. A 5-metre thick concrete wall protects the reserve stocks of the National Library of France from flooding of the Seine. The reserves are therefore protected by a supplementary cost to be charged to flood risk prevention. However, this type of solution may also help to increase the risk of flooding in neighbouring buildings and structures in the event of rising water levels.

Source: Blue Shield, interview carried out by the OECD.

Business continuity

The commitment of private-sector businesses to improving their own resilience appears to be linked to their scale or sector. The private sector, particularly large enterprises, is increasingly driven by the markets to take account of its risk exposure, the possible impact on its business plan and measures likely to mitigate risks. Risk awareness in the banking and insurance sectors is rather well established. In 2010, the Bank of France organised a market test within the financial community in Paris to test the flood resilience of institutions' critical processes, while Crédit Agricole has developed clear emergency measures which enable the bank to function with a reduced staff in a flood-protected building. AXA also has a business continuity plan and is reconsidering the location of certain strategic activities. In the hotel sector, the ACCOR group, with 55 hotels in floodplains, is also well informed as to the risk of flooding. The group has invested in developing a business continuity strategy and in broad insurance coverage. These approaches could set an example for other businesses.

While some major businesses have now developed or are currently developing their own flood risk prevention and management strategies in line with the regulations and the regulatory authorities (banks, telecommunications), SMEs as a whole remain highly vulnerable and ill-prepared. As for the building stock in Île-de-France, there is no specific public policy instrument to encourage or regulate SME resilience to the risk of flooding of the Seine. The CCI Paris and the respective professional associations can play a key role here by assessing business vulnerability beyond the pilot experiments already carried out, based on the example of the Loire basin (Box 3.9). Experience in business districts or future Greater Paris development areas, for example, may also draw on initiatives to enhance resilience applied in the La Défense business district, which is itself heavily exposed. The concerns of large businesses in La Défense regarding the reality of the economic impacts of major flooding of the Seine and the existence of a structure bringing them together to take issues of common interest forward (Defacto) have enabled this initiative to be launched.

Box 3.9. **Assessment of business vulnerability in the Loire basin**

In the Loire basin, a flood risk prevention programme for businesses undertaken by the Loire River Basin Authority (*Établissement Public Loire*, EP Loire) recently helped to provide information to over 15 000 businesses, despite the difficult economic and financial circumstances. Based mainly on a free vulnerability assessment of businesses located in floodplains, the objective of this "industrial-scale" measure was to reduce the vulnerability of economic activities in the Loire basin and its tributaries to the risk of significant flooding by preserving the vital interests of businesses against a major flood in the Loire catchment area.

This assessment is a useful aid to business decision making in view of that objective: over 15 000 businesses were made aware of the risk of flooding and 2 000 vulnerability assessments were requested by businesses, 1 812 of which had already been carried out or were in progress in 2012. The assessment involves an on-site analysis and the delivery of a report identifying vulnerabilities and establishing a hierarchy according to their gravity and an estimate of potential losses. Businesses that have shown an interest in a vulnerability assessment are then given support in assessing their interest in implementing a range of effective measures to reduce vulnerability, together with an estimate of the cost. In certain cases, the measures recommended may even be co-funded. Some 280 businesses were monitored in this way in 2011, 21 of which received financial support.

Source: Établissement Public Loire (2012), *Rapport d'activité 2012*, Établissement Public Loire, Orléans, France.

Addressing the flood hazard to reduce the risk

Structural and technical measures to control the flood hazard and its variability are usually among the options available for reducing the risk of flooding. Many countries rely on civil engineering work to modify river flows by means of dams and channel them by means of dykes and walls to protect potentially exposed assets. Dynamic flood slowing and flood retention area conservation are new environmental engineering approaches which enable the hazard to be reduced while preserving the environment. Following the 1910 flood, the Picard Commission, set up to assess the crisis and make recommendations for improvements, proposed a number of protection measures that were developed during the 20th century: the bed of the Seine was deepened, bridges in Paris were heightened, dykes and walls were built along the river and four reservoirs were created upstream. The continued growth of the assets exposed to flooding of the Seine in Île-de-France has now raised questions as to the advisable level of protection for this region and the means to achieve it.

Local protection

Flood protection levels are not consistent throughout the Paris conurbation and do not ensure equal protection of the public. The flood protection levels reflect historic strata that no longer corresponds to contemporary urban and industrial density. Thus, while local flood defences (dykes and walls) have been built along the Seine and Marne, they do not cover all of the current built-up areas, particularly in the north and south of the Val-de-Marne and the north and west of the Hauts-de-Seine (Figure 3.4). What is more, these facilities are not scaled at the same level: the City of Paris is protected against a 1910-type flood, while the neighbouring departments of the Hauts-de-Seine and the Val-de-Marne are only protected against a 1924-type flood, which is almost 1.5 metres lower (Table 3.3). These areas were not heavily developed in 1936 when the state began

to build these defences. In terms of current urbanisation, this difference in protection levels raises concerns regarding the economic assets now exposed.

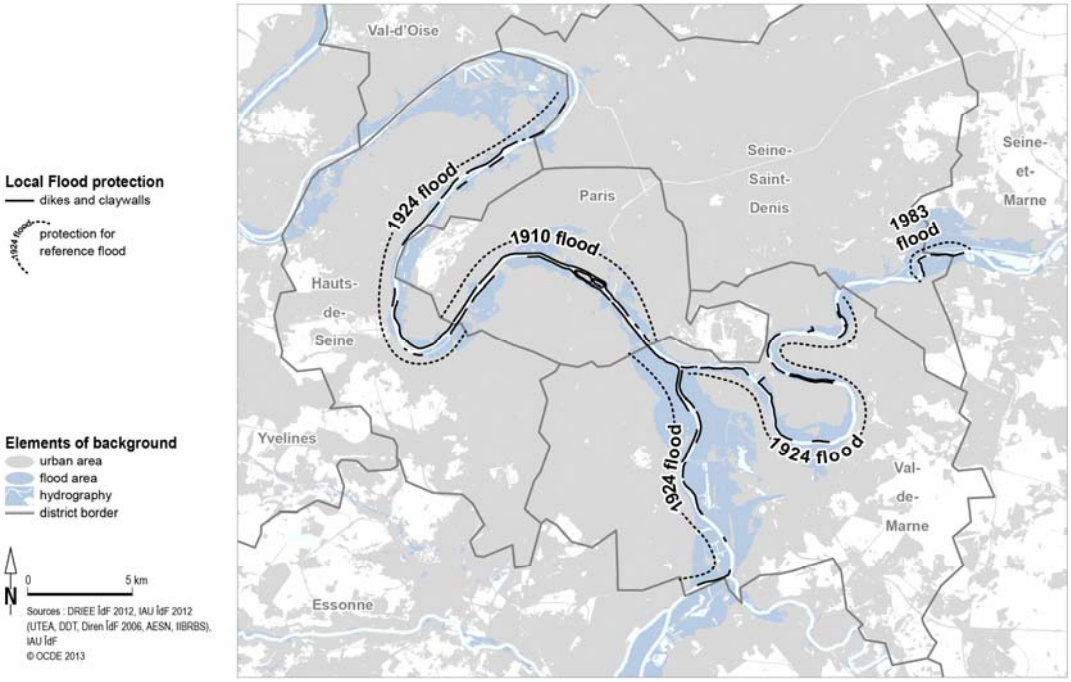
Table 3.3. **Local flood defences in Île-de-France**

River valley concerned	Theoretical protection level	
	Historic flood level	Flood recurrence interval
Seine in departments 77, 78, 91	1955[1]	30 years
Seine in departments 92, 93, 94 ; Marne in department 94	1924	30 years
Seine in Paris	1910	100 years
Marne in departments 77 and 93	1970	8 years
Oise	1926	40 years

Note: 1. In the departments 77, 78 and 91, the defences do not continue along the watercourses and their level of protection is different and therefore not global.

Sources: DRIEE (2013), "Cartographie des zones inondables et des risques d'inondation du TRI Métropole Francilienne, projet de rapport explicative", Direction Régionale et Interdépartementale de l'Environnement et de l'Énergie d'Île-de-France, Paris, www.driee.ile-de-france.developpement-durable.gouv.fr/IMG/pdf/Rapport_accompagnement_IDF_VF_cle03163c.pdf (accessed in November 2013); Roche, P.-A. (2004), "The Seine river flooding in the Île-de-France region: What account is taken of climate change in the decision-making process?", OECD Global Forum on Sustainable Development, Paris, 11-12 November 2004, www.oecd.org/env/cc/33995401.pdf.

Figure 3.4. **Location of dykes and walls in Île-de-France**



The upkeep and maintenance of this protection infrastructure was rather neglected in the past. In the absence of major flooding for almost 60 years, dykes and walls have gradually been perceived more as obstacles to the development of river-based activities, and local residents have created openings in them. What is more, the effectiveness of cofferdam-type structures in closing these gaps in the event of flooding is uneven and

does not guarantee that these defences can play their full role in response to a crisis. By way of illustration, 450 gaps have been counted in the walls in the Val-de-Marne.

The state has reinforced flood defence regulations following recent disasters that have sometimes highlighted design or maintenance defects in these structures. Flood protection mechanisms became a national issue after a succession of breaches of dykes and deadly coastal flooding: flooding in the Camargue in 1993 and 1994, the Gard floods in 2002 and, more recently, cyclone Xynthia in 2010 underscored the inadequacy of existing defences (AScA, Ledoux Consultants, 2012). In response to these shortcomings, Decree 2007-1735 issued by the Ministry of Ecology on 11 December 2007 established state surveying and classification of dykes according to their height and the number of persons protected. The decree defines studies, checks and assessments for each class and sets frequencies for them, as well as potential improvement and restoration work to be carried out by the responsible authorities. Hazard studies, which describe the risks to which defences are exposed and identify means of prevention and protection to mitigate them, must also be carried out on class A, B and C dykes. A national dyke restoration programme was also introduced in 2010 following the Xynthia and Var floods: the rapid flooding plan (*plan submersions rapides*, PSR) provides for works managers to assess projects and establishes an associated funding programme (Chapter 2).

A drive to assess and rehabilitate flood defences was initiated in the departments in the inner suburbs from 2007, albeit unevenly because of differing priorities and resources among the local councils responsible for them. The DRIEE is responsible for controlling this process and for ensuring that resources are correctly allocated via the studies and the work carried out. The department of the Val-de-Marne, which manages 30 kilometres of protection walls along the Seine and Marne, is currently carrying out a hazard study. In Paris, quay walls are currently being surveyed and classified. In order to complete these fixed structures, which have already been significantly heightened, Paris has invested in a system of removable devices, mainly in the form of cofferdams. These are checked regularly by means of annual exercises. Safety assessments and hazard studies for certain facilities will soon be carried out. In the Hauts-de-Seine, the survey and classification process has been completed and the hazard study will soon be undertaken. A multi-annual programme to rehabilitate floodwalls, including the replacement of old cofferdams by new easier-to-handle aluminium equipment has been introduced. The department of Seine-Saint-Denis is planning to take measures to reduce the vulnerability of defences under the PAPI project currently in progress. The measures referred to above to reappropriate the river banks in order to develop a resilient metropolis along the course of the Seine provide synergies when they are designed to take flood protection into account. This applies, for example, in the Hauts-de-Seine with its planning and sustainable management scheme for the banks of the Seine.

While these local defences can play a key role in protecting assets exposed to flooding, the lack of harmonisation and the governance deficit linked to the vast range of project management structures involved is not conducive to a coherent approach. It is therefore difficult to obtain a clear view of the actual level of protection, both in terms of real coverage, the condition of the infrastructure and the solidity of the banks supporting it. Similarly, the lack of a common risk basin or nationwide protection standard does not allow the level of investment required to be defined, as it is in other OECD countries (Box 3.10). The completion of hazard studies scheduled for late 2014 will provide a precise overview of the position. A technical, financial and legal feasibility assessment to standardise these defences in Île-de-France as a whole was proposed in the PAPI project undertaken by the EPTB Seine Grands Lacs.

Box 3.10. **Level of protection in the Netherlands and Norway**

Following the major sea surge in the Netherlands in 1953, many flood risk analyses were carried out to reinforce the protection of the country's coastal and catchment areas. The level of acceptable risk was determined with reference to a 100 000-year flood. This level of acceptable risk was then converted into a reference hazard, calculated with a recurrence interval of 10 000 years for some provinces in mid-Holland, northern Holland and Utrecht, since these areas were below sea level, in some cases by up to 6 metres. Based on this risk assessment method, legally established enhanced protection levels were defined for all coastal areas. For low population density areas along the coast, the recurrence interval considered for an event is 4 000 years. Along rivers, the reference hazard corresponds to a recurrence interval of 1 250 years, while for areas exposed to a combined river and sea risk, the recurrence period is defined at 2 000 years. The dykes intended to ensure protection for inhabitants along the Meuse will be scaled in 2015 for a 250-year event. The urban and industrial districts in the unprotected area are generally higher in relation to the level of the dykes or are required to adopt adapted construction principles.

Flood protection standards in Norway

Types of assets	Protection level recurrence interval	
	Risk of loss of human life	Risk of material damage
Sheds, outbuildings	100 years	50 years
Habitat, motorways with alternative routes	1 000 years	100 years
Schools, hospitals, industry, critical infrastructure	>1 000 years	> 200 years

Following major flooding in south-east Norway in 1995, a government commission made several recommendations to reduce future flood losses. Floodplain mapping begun in 1998 enabled flood protection to be improved by defining differentiated protection standards. The level of acceptable risk as defined by the Norwegian Water Resources and Energy Directorate differs according to the type of risk and the type of assets to be protected. Habitat, for example, is protected against a 1 000-year flood if there is a risk of loss of human life, and a 100-year flood if the risk is material. Industry and critical infrastructure are thus protected against floods with a recurrence interval greater than 1 000 years if there is a risk to human life and greater than 200 years if the risk is material.

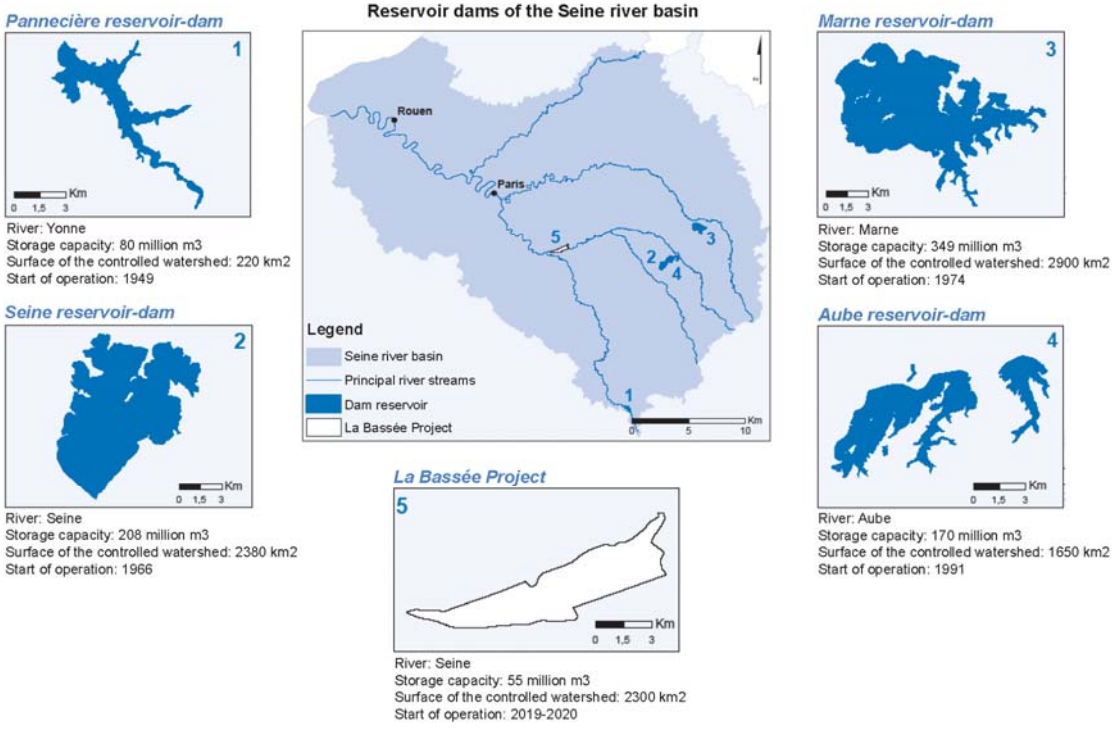
Sources: Dutch Ministry of Infrastructure and Environment (2012), "Le cadre législatif et organisationnel de la gestion du risque d'inondation aux Pays-Bas", audition au Senat du 29 mai 2012; NVE (2009), "Flood inundation maps", Norwegian Water Resources and Energy Directorate, Oslo, www.nve.no/en/Floods-and-landslides/Flood-inundation-maps.

The Grands Lacs de Seine reservoirs

Hazard management is also ensured by reservoirs created upstream of the basin. These facilities, built by diverting the Aube, Marne, Seine and Yonne, control some 17% of the basin as far as Paris (Figure 3.5). They were built gradually between 1949 and 1991, according to a plan defined in 1926 in response to the 1910 and 1924 floods and the droughts in the 1920s. This infrastructure has the capacity to store 805 million m^3 of water – compared to a total volume for the 1910 flood estimated at 3-6 billion m^3 (Roche, 2004) – and would, as a whole, help to lower the water line by 70 cm in the event of major flooding of the Seine with a flow identical to that reached in January 1910. This equates to reducing direct losses from flooding in Île-de-France by half, but is

nevertheless not sufficient to prevent water from submerging local defences in the Hauts-de-Seine and Val-de-Marne.

Figure 3.5. **Storage facilities in the Seine basin**



Source: Central Reinsurance Fund (CCR).

The multi-purpose use of the reservoirs (combating floods/low-water management/leisure) means that the respective rules must be optimised while still ensuring their optimum effectiveness in the event of flooding. Every winter, these facilities dampen low- and medium-level floods and gradually fill up from 1 November to 30 June to be able to ensure low-water management in summer, which forms part of their tasks from 15 June to 15 December. Recurring droughts also contributed to the decision to initiate their construction in 1926. The final two were co-financed by the Seine-Normandy Water Agency on the basis of the latter function. Other uses have also been developed over the years, particularly leisure and tourism around the lakes. This also allows upstream regions to take advantage of this infrastructure and thus contribute to the development of much-needed upstream-downstream water and flood management solidarity. The water regulations for these facilities are defined on the basis of their different uses. They can be adapted according to hydrological conditions on decision of the prefects of the departments in which the dams are located, and in co-ordination with the Prefect of Paris in his capacity as basin co-ordinator, after consulting a technical co-ordination committee. The flood control effect of these facilities may be reduced in two situations: *i)* in the event of successive flooding, since the reservoirs will be full and potentially saturated from the first rains; *ii)* in the event of major flooding at the end of winter, since the reservoirs are generally almost entirely full at the beginning of April. The use of these facilities could be optimised by increasing their storage capacity or improving their emptying capacity.

Box 3.11. **Operational effectiveness of defences during a crisis in Australia**

Floods in Queensland, particularly Brisbane, have demonstrated the importance of ensuring the operational effectiveness of flood risk defences and of regularly reviewing their conditions of use. Hydrologists tasked with investigating the damage caused by flooding in Brisbane, Ipswich, Toowoomba and the Lockyer Valley found that the diversion of water from the saturated Wivenhoe Dam was a crucial factor in floods upstream on 11 and 12 January 2011. According to these specialists, the dam's operational ineffectiveness largely contributed to the scale of flooding in and around Brisbane, which caused considerable damage. Despite the warnings issued by the Australian Bureau of Meteorology concerning the potential power of the La Niña phenomenon, the staff responsible for operating the Wivenhoe Dam did not take any special action to empty the reservoir because its operating conditions did not cover such an eventuality. Ensuring the operational effectiveness of flood defences includes regular reviews of their operating conditions.

Source: Queensland Flood Commission Inquiry (2012), "Final report", Queensland Flood Commission of Inquiry, Brisbane, Australia.

The remit of the EPTB Seine Grands Lacs, which holds and manages these four reservoirs, has gradually expanded to that of a basin-wide organisation. It is responsible for their operational functioning and maintenance and has an annual budget of EUR 10-11 million and 120 staff. Investment costs can vary significantly from year to year, from EUR 6 million in 2010 to EUR 12 million in 2011 and EUR 22 million in 2012, according to the maintenance work required, which will probably increase over the years because of the ageing of the infrastructure (OECD, 2007). The EPTB's budget comes essentially from Paris (50%) and the three inner suburb departments (17% each), as founding members of the institution. Subsidies may come from the state, the Seine-Normandy Water Agency for maintaining the flow during low-water levels, or from EU funds such as the European Regional Development Fund. In 2012, the EPTB Seine Grands Lacs was authorised to charge a new fee for services provided in connection with its low-water management function. This is charged to the main water users, who must pay EUR 0.017 per cubic metre withdrawn in a low-water period. From 2013, the EPTB estimates that it will collect EUR 7.5 million per year via this fee, which will be charged by the Seine-Normandy Water Agency. In addition to this increase in revenue, the remit of the EPTB Seine Grands Lacs is also expanding: it became an EPTB in 2011, which now means that it is a river basin institution for the entire region upstream of Paris, rather than only for the four Île-de-France departments that run facilities in the distant upstream regions solely for the benefit of the Île-de-France conurbation. It also focuses on reducing flood vulnerability, an issue it brings into its area of operations through the PAPI Île-de-France Seine and Marne project which it ensures.

The development of the EPTB Seine Grands Lacs, with its status of a river basin institution whose geographic remit extends upstream and with its new revenue linked to low-water management functions, confirms this body's capacity to operate and maintain its reservoirs. This also raises questions as to the operating rules of the facilities for which it is responsible. Over time, notably in the post-World War II period, it proved possible to construct the Seine reservoirs largely in accordance with recommendations made in the various post-1910 flood reports. In the absence of major flooding since then, the importance of these facilities has been based essentially on their other uses (low-water management, leisure). The remit of the EPTB in relation to low-water management is moreover confirmed by its new right to charge a fee for services provided to major users.

Optimising the management of existing facilities in line with different uses is thus a challenge that must be met on a regular basis, particularly in the light of climate change: prospects for more severe low-water levels could lead to the need to adapt the management rules at the expense of combating floods.

Towards new flood defences?

The EPTB Seine Grands Lacs has proposed a new facility to limit flooding of the Seine in Île-de-France, based on new temporary excess storage measures. Reducing the risk further now requires new approaches to be considered that lay greater stress on environmental preservation. This means reconciling the objectives of achieving a good environmental status for water by 2015 envisaged by the European Water Framework Directive, and preventing flooding by restoring the functioning of water systems. The work carried out following the 1982 floods and up to the beginning of the year 2000 proposed different planning options to reduce the flood peak of the Yonne, which in combination with the peak of the Seine causes the most serious flooding. The EPTB Seine Grands Lacs is thus promoting the La Bassée project (Box 3.12). This has the dual objective of limiting flooding of the Seine and restoring the La Bassée wetlands, the most important in Île-de-France. These wetlands can no longer serve as a buffer zone as they did in 1910 because of the channelling of the river in the 1980s to improve navigability.

Box 3.12. **The La Bassée planning project**

The aim of the La Bassée planning project is to slow flood wave progress by using the last large usable flood retention area to create excess storage basins. Situated upstream of the confluence of the Seine and Yonne, by storing water from the Seine, this area would make it possible to ensure that the flood peaks of these two watercourses do not coincide to create the conditions for major flooding.

The La Bassée area extends over 16 000 hectares and is the most important flood retention area upstream of Paris. This natural function was lost in the 1970s when the Seine was channelled. The aim of the project is to build 19 storage basins for a total volume of 55 million m^3 of water pumped from the Seine. This would make it possible to reduce the level of a 100-year flood in the Paris conurbation by a further 20-30 cm, and to reduce damage in the suburbs of Paris in particular. The project also includes a strong wetlands restoration environmental component.

With an estimated budget of around EUR 600 million, a cost-benefit study estimates that it could have a benefit of around EUR 70 million on average per year (though with high sensitivity to its operating mode in the event of flooding, this result being obtained on the basis of optimum functioning from all perspectives in a crisis). A multi-criteria analysis considering technical, economic and environmental functioning and the impact on habitat and landscape has also been carried out on this project, in comparison with two other hazard mitigation options (multiple damping facilities and a flood control dam on the Yonne).

Source: EPTB Seine Grands Lacs (2011b), "Projet d'aménagement de La Bassée", dossier du maître d'ouvrage, EPTBSeine Grands Lacs, Paris, www.debatpublic-crueseinebassee.org/docs/DMO/Intro/DMOA_la-bassee_1-9.pdf.

The implementation of this innovative project is a promising example in many respects, though it is difficult to persuade decision makers of its merits, particularly at the financial level. The combining of multiple uses (wetland restoration, ecotourism, economic activity), the use of economic assessments via cost-benefit analyses and

comparisons with other options to ensure a multi-criteria analysis and the involvement of local populations upstream through transparent public debate are all part of good practices in OECD countries. Public discussion of the project in 2011-12 fostered by the National Commission for Public Debate (*Commission Nationale du Débat Public*, CNDP) involved the holding of 15 public meetings in the various districts concerned. Some 1 200 people contributed to the debate, and the respective website received 39 300 hits in just over a year. The project did not receive strong support from public decision makers, however, particularly at the financial level. The discussions showed that the risk of flooding is not a priority for certain water and development stakeholders compared to the risk of water shortages. The climate change argument invoked to bring low-water levels into focus amounts to a denial of the fact that, irrespective of such change, the risk of flooding is currently very real.

The EPTB Seine Grands Lacs decided to continue to promote this project and is now proposing to construct a first pilot basin to demonstrate the viability of this technical option. This is because in addition to the financial aspects (see Chapter 4), this project must still demonstrate its operational usefulness and respond to the concerns raised on the governance of such a facility during a crisis. The emerging solution of rolling out this project in phases seems to have potential inasmuch as that each phase financed can prove its usefulness and effectiveness in reducing water levels in the event of major flooding. It will also be necessary to ensure that a project of this kind will not stop the work required on other risk prevention pillars, particularly regional resilience. In addition to this potential large-scale project, other hazard reduction options can be examined. The renovation of the Joinville-Le-Pont sector gate could protect many inhabitants in the loop of the Marne and upstream at little cost. Reflection on the optimising of existing defences or the ecological restoration of headwaters should also be closely considered as part of an overall strategy. As with dykes, because of the different project management structures involved, a cost-benefit comparison of these projects as a whole has not been carried out, at the expense of an overall and genuinely efficient approach.

Conclusion and recommendations

A broad range of measures contributes to preventing the risk of flooding of the Seine in Île-de-France, even if a certain diversity predominates. Whether these measures are regulatory or voluntary or are ensured by the state, local authorities, the public or businesses, this overview highlights the many opportunities for improving risk awareness and culture, resilience, public services and businesses, and hazard mitigation options by means of protective measures. Positive synergies leading to greater resilience have been identified and could be further exploited. This includes the incorporation of resilience into development policies in Greater Paris, the link between the culture of the river and the culture of risk, moves to develop river banks and to strengthen protection infrastructure, the combining of risk prevention policy and crisis management, the increasing awareness of businesses and network operators and the reappropriation of the functionalities of water systems to combat flooding from an environmental protection perspective. The local flood management strategy currently under development is an opportunity to organise prevention measures as a whole and prioritise them in a coherent approach towards an ambitious resilience for the metropolitan area.

Knowledge of the risk is improving, and approaches are being harmonised so that all risk prevention stakeholders will, in due course, have information that allows them to act coherently. To date, the many risk assessment approaches, tools and standards have

combined to sow confusion, preventing stakeholders from agreeing on similar results, since they tend to develop their own calculation methodology. The current drive to share and harmonise knowledge, especially under the guidance of the DRIEE and the SGZDSP, and the development of a precise risk map in implementing the Floods Directive suggest that the tools necessary to design and closely assess these prevention measures as a whole might be available.

Risk perception on the part of the public and decision makers is poor because the memory of historic events is fading although the vulnerability remains. In view of the many initiatives identified in this area, the development of a risk culture in relation to flooding in Île-de-France nevertheless seems to be an area of concern for many stakeholders. These initiatives often complement regulatory measures, the effectiveness and implementation of which vary from one local authority to another. They may draw on innovative risk communication tools which are more effective in raising risk awareness. However, it is difficult to obtain an overall view and to understand their impact and effectiveness in the absence of a precise assessment. Furthermore, the use of different and not always harmonious risk reference materials and benchmarks gives rise to differences in the level of awareness and engagement of stakeholders (large businesses, infrastructure operators, SMEs, the public, local authorities). This hinders the development of a genuinely shared safety culture. It is also clear that the lack of determination of public decision makers to engage with and communicate on this subject is a major constraint on the development of a risk culture and is illustrative of their own weak awareness of this risk, which continues to be perceived as not very likely.

With respect to the region's resilience, risk prevention policies based on urban development management have contributed little, if any, significant reduction in the level of the risk of flooding of the Seine. Regulatory instruments such as PPRs have proven to be limited, particularly because they have no impact on the existing building stock. In this context of a dense urban area, the unifying Greater Paris project offers opportunities: a flood-resilient metropolis based on innovative urban projects along the course of the Seine could emerge. Examples from other OECD countries show that resilience can be a source of innovation and thereby contribute to green growth. Infrastructure investment over the next 30 years could also improve the resilience of networks, which is crucial for the resilience of the metropolitan area as a whole. Great disparities remain, meanwhile, between different network operators in terms of major flood risk assessment and preparation. At business and public service level, the development of business continuity plans and investment in prevention is in its infancy. While some large businesses have developed or are currently developing flood prevention and risk management strategies in accordance with the regulatory framework and regulatory authorities (banks, telecommunications), SMEs as a whole remain highly vulnerable and ill-prepared. Similarly, city councils have also invested little in this regard.

Hazard protection and control infrastructure could be built largely in line with recommendations in the various post-1910 flood reports. Such infrastructure nevertheless has its limits in terms of protection and raises fundamental issues of equity and governance. The difference between the levels of protection sought by dykes and walls, their maintenance and investment between the centre and the periphery of the conurbation do not allow equivalent protection to be ensured among the public in Île-de-France. This is problematic in terms of current urban development, in which the periphery has become much more densely populated. Recent state-promoted efforts to diagnose vulnerability and local reinforcement work should be noted in an approach which is nevertheless fragmented because of different project management structures. Contrary to other OECD

countries, the lack of a predefined standard protection level reinforces the negative effects of the lack of an overall approach to managing these defences. Existing hazard control facilities come under the control of another organisation, the EPTB Seine Grands Lacs, whose remit is gradually expanding to other aspects of water and flood management. Now that the new La Bassée hazard mitigation project is coming to the fore, questions are being raised as to funding, the prioritisation of hazard control action and governance. The establishment of a local flood management strategy and the PAPI project run by the EPTB Seine Grands Lacs jointly represent an opportunity to make an informed choice between the different options and to uphold that choice in total transparency with stakeholders as a whole.

The recommendations set out below should reinforce prevention and resilience efforts at all levels in order to achieve greater flood risk resilience in Île-de-France.

- Continue to improve and harmonise risk awareness and ensure that information on risks is available. The meeting of minds between the Prefecture of Police and the DRIEE could be pursued with other stakeholders, such as the insurance sector, in a global and coherent approach to risk assessment, particularly at economic level. All information on risks could be centralised while respecting confidentiality, security and competition. This could work in parallel with the provision of modelling tools and the respective data according to needs, drawing inspiration from the observatory established at national level.
- Reinforce a risk culture among the public, decision makers and businesses. New communication topics stressing the positive benefits of greater resilience must ensure greater risk awareness at all levels. Regular information based on the best knowledge available at the service of a common strategy could accompany the local flood risk management strategy. This communication strategy should use new technologies (3-D visualisation, virtual animation, social networks), target specific audiences (businesses, the public, decision makers, developers and architects) and be assessed according to results by regular risk perception surveys.
- Improve the resilience of areas by taking advantage of the opportunities offered by the Greater Paris project. The definition of a resilience level for Greater Paris, particularly through regional development contracts, could give rise to model resilient districts such as the Ardoines. Harmonising and reinforcing PPRs at regional level will allow resilience to be raised towards this predefined level in the long term. These plans must be based on the latest risk assessments and their control should be improved. Incentives to reduce the vulnerability of existing buildings could also be envisaged by renewing electricity meters, for example.
- Gradually reinforce critical network resilience and ensure business and public service continuity. A predefined resilience level should also be applied gradually to network operators to raise the requirements. New infrastructure, particularly transport, must ensure maximum flood resilience. The establishment and control of requirement levels could be ensured by the sector regulator. A mechanism to accompany enterprises, particularly SMEs, in their business continuity measures could also be developed, such as a risk assessment service, risk labelling or the drafting of awareness-raising guides.
- Place flood protection infrastructure under the responsibility of a single project management structure with responsibility for establishing a predefined safety standard for all infrastructure, with a common cost-benefit approach framed in an

appropriate institutional structure. The steering and organisation of maintenance, renovation and the need to carry out work could be assessed according to the same criteria in the light of the possible need for new infrastructure. This would involve assessing the feasibility of harmonising protection levels for the conurbation as a whole, with work being done in phases and priority being given to the most beneficial works.

- Favour experimentation in relation to the La Bassée storage project. Stage-by-stage roll-out of the project should make it possible to adapt the approach through practice-based learning and demonstrate its operational usefulness beyond theoretical cost-benefit studies. The governance of such a facility is a matter that should also be determined beforehand, with a view, in particular, to decision making during crises in order to ensure effectiveness.

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Yvelines, Les différents plans de prévention du risque inondation du département des Yvelines.

Chapter 4

Funding increased resilience against flooding of the Seine in Île-de-France

Funding the prevention measures required to increase resilience levels is a major challenge. This chapter focuses on risk prevention funding mechanisms and sources in France and their application to the specific risk of flooding of the Seine in Île-de-France. While this risk has been identified as a national priority, there is clearly scope for progress in funding prevention policies adapted to the challenges. The analysis and recommendations proposed seek to favour approaches to funding which ensure effectiveness and justice.

Introduction

France has been heavily involved in flood risk prevention over the past 30 years. A series of public policy instruments has been introduced, with associated funding mechanisms. In addition to national and local authority budget resources, an original collective insurance mechanism has been established, the CATNAT compensation scheme, based on a public-private partnership between insurers and the state and on the principle of solidarity against natural disaster risks. This mechanism also makes it possible to contribute substantially to risk prevention funding without imposing a direct burden on public finances, particularly for the risk of flooding, which is both the most frequent risk and the one that causes the most serious damage in France.

Many factors are likely to increase the funding needs necessary to improve the resilience of the Île-de-France region to the risk of flooding of the Seine: the increase in the exposure of human, social, environmental and economic assets to the risk of major flooding in the context of expanding urbanisation and the standards demanded by public and economic stakeholders in a modern society, plus the need for catch-up investment in prevention. While a co-ordinated strategy to manage the risk of flooding in Île-de-France has now been put in place with the implementation of the European Floods Directive, this chapter addresses the issue of how to fund increased resilience in Île-de-France, and according to what financial strategy for mobilising and prioritising resources.

In a context in which budget options are tending to narrow under the pressure to balance public finances, resources must be mobilised in response to this major risk on the basis of a range of stakeholders by means of more direct incentives to enhance flood resilience. The various mechanisms for funding flood prevention in France are thus explained with a view to developing a funding strategy based on action principles, in combination with good practices from OECD countries.

Delay in funding flood risk prevention in relation to the Seine in Île-de-France

The risk of flooding of the Seine compared to the risk of flooding in France

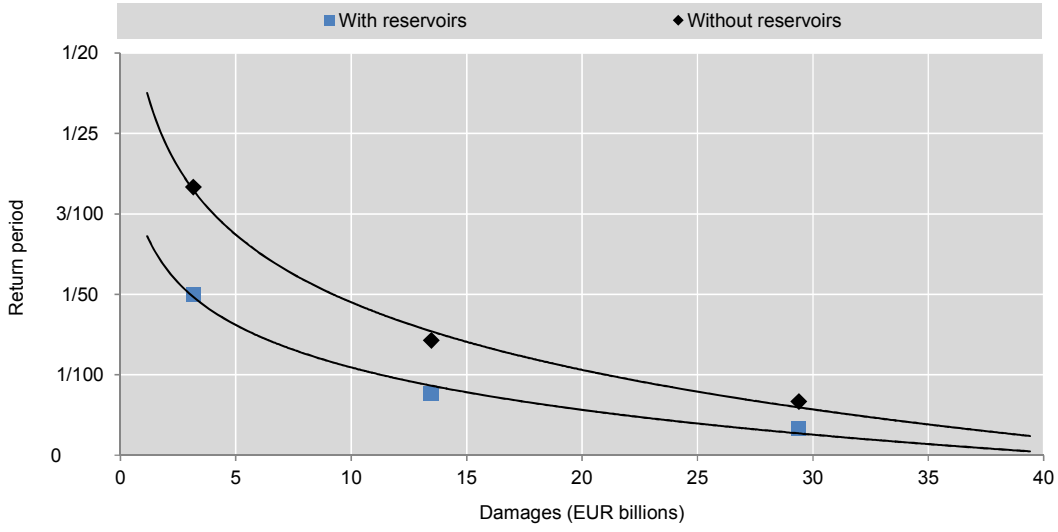
The average annual losses caused by floods in France are estimated at EUR 1-1.4 billion (Ministry of Ecology, Sustainable Development and Energy, 2012a). To make this calculation, the national preliminary flood risk assessment (PFRA) for France in the context of implementing the European Floods Directive incorporated the average cost of insured losses of EUR 400 million calculated by insurance companies on the basis of events of the past 20 years (in relation to current and updated assets). In the absence of a major national incident during that period, such as flooding of the Seine or Loire, an additional charge of EUR 200-300 million was estimated. An estimate of damage covered by insurance of 50-60% of the real damage gives this figure of EUR 1-1.4 billion.

The modelling of the different Seine flood risk scenarios developed in Chapter 1 produces an estimate of the average annual damage caused by flooding of the Seine in Île-de-France of EUR 250-500 million, taking only direct damages into account (Figure 4.1). This represents a quarter to a third of the total damage caused by flooding in France. Prevention efforts must therefore be adequate for this level of risk.

Flood prevention resources in France and in Île-de-France

Few OECD countries have made precise and exhaustive estimates of their risk prevention expenditure (World Bank and United Nations, 2010). It is generally difficult to estimate such expenditure, which in France and elsewhere is often included in a variety of sectoral programmes and makes demands on funding at several levels of government (Chapter 2). As the French Court of Auditors stated, "the administration is not in a position to present a complete and detailed overview of either public or state expenditure" (Cour des comptes, 2009). However, the General Commission for Sustainable Development (*Commissariat Général au Développement Durable*, CGDD), part of the Ministry of Ecology, Sustainable Development and Energy, has published a study in which it estimates the funding generated to prevent natural hazards as a whole in France for the 2009 budget year at EUR 600 million, shared between the state (55%), local authorities (40%) and the European Union (4%) (Ministry of Ecology, Sustainable Development and Energy, 2013c). Most of this funding is devoted to the risk of flooding, which is the most serious risk in France in terms of its frequency, widespread geographic distribution and impact.

Figure 4.1. **Seine flood damage frequency curve**



Source: Elaborated by OECD.

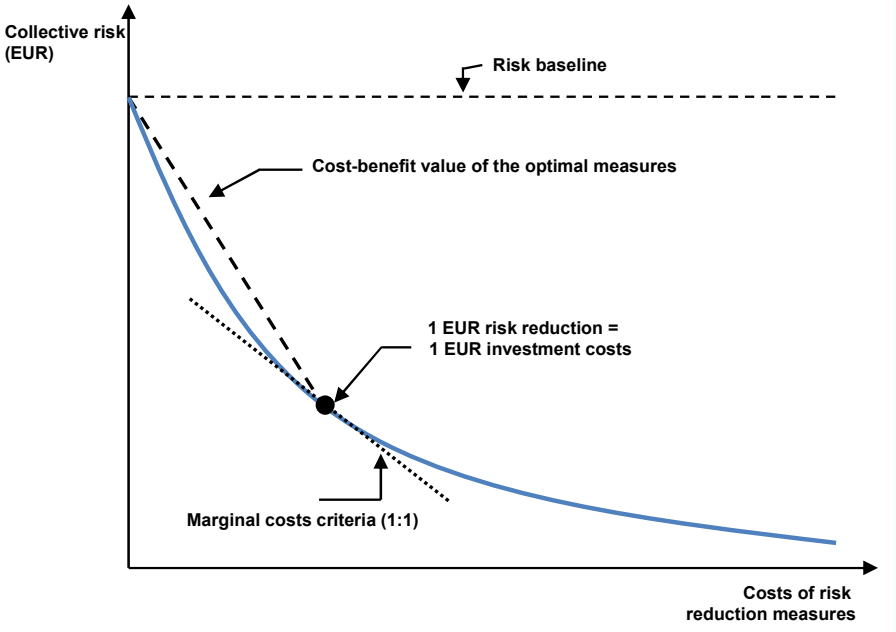
Flood prevention expenditure in France has been assessed at EUR 300-450 million (Ministry of Ecology, Sustainable Development and Energy, 2012b; 2013b; 2013c), corresponding to around a third of the estimated damage. Such a level of investment in prevention can be regarded as satisfactory in terms of the effectiveness of public expenditure (Box 4.1), provided that the most beneficial prevention measures are given priority in allocating these funds.

Against this background, flood risk prevention with respect to the Seine in Île-de-France does not appear to have benefited from a level of investment commensurate with the level of risk over the past ten years. The instruments for funding prevention have, in fact, played a relatively little part in reducing the vulnerability of Île-de-France to this risk compared to other regions or catchment areas. When the principal flood-related contract programmes between the state and the various local authority levels are examined – flood prevention

action programmes (*programmes d'action et de prévention des inondations*, PAPI) and major river plans (Chapter 2) – the Seine basin and the specific risk to Île-de-France within that basin do not appear to be budget allocation priorities (Tables 4.1 and 4.2). Less than 10% of the financial resources of the major river plans are allocated to this risk, either by the state or local authorities. Like the PAPI projects, when the two major calls for proposals were issued by the state in 2004 and 2011, 114 projects were selected and awarded national funding over and above local authority contributions. Only 11 projects concerned the Seine-Normandy basin, 5 of which contribute to mitigating the risk of flooding in Île-de-France, since they are situated upstream of the basin. This corresponds to less than 2% of the resources generated in the past ten years for this major flood prevention contract programme between the state and local authorities. A total of EUR 1.5 billion was subject to contract under the PAPI projects, 35% of which the state was responsible for.

Box 4.1. **How effective is prevention?**

In risk management theory, optimum prevention measures are taken by maximising their benefit for a given cost. Thus, on the basis of an existing risk level, a utility curve can be defined which represents the optimum prevention measures on the basis of collective preference. Since zero risk does not exist, prevention measures become increasingly costly for a benefit that tends to diminish as the risk level falls. The marginal cost of prevention measures thus tends to increase up to a certain level at which the cost-benefit relationship is reversed. Investment in prevention becomes increasingly less profitable until it is no longer profitable after that level. A classic estimate places the latter at between one-third and one-half of the level of the initial risk.



Source: OECD (2014a), "Governing effective prevention and mitigation of disruptive shocks", OECD, Paris.

Table 4.1. **Flood prevention action programmes in the Seine-Normandy basin, 2002-13**

PAPI	Risk mitigation in Île-de-France	Department(s)	Date of labelling	Total amount (EUR)	Part funded by the FPRNM[1] (EUR)
Yerres	Yes	91, 77, 94	2012	1 053 508	395 897
Essonne	Yes	91, 45, 77	2004	6 000 000	..
Austreberthe	No	76	2012	2 710 000	741 900
Armançon	Yes[2]	21, 89	2004	3 998 500	..
Orne-Seulles	No	14, 61	2012	12 382 707	3 476 846
Marne	Yes	94, 93, 77, 02, 51, 52	2009	10 000 000	..
Mauldre	No	78	2003	..	..
Lézarde	No	76	2004	..	..
La Bassée	Yes	77	2004	..	..
Verse	No	60	2013	13 091 760	2 154 210
Bresle-Authie	No	80, 62, 76	2012	2 378 400	848 900
TOTAL Seine-Normandy basin *including flooding in Île-de-France*				51 614 875[3] *21 052 008*	12 387 570[4]

Notes: ..: data not available. 1. Fund for the Prevention of Major Natural Hazards, or "Barnier Fund". 2. The impact of this project on reducing the level of risk in Île-de-France is uncertain. 3. It was not possible to include PAPI contributions for the Mauldre, Lézarde and La Bassée. 4. Taking an average of 24% for the various PAPI in the basin.

Sources: Ministry of Ecology, Energy, Sustainable Development and Town and Country Planning (2009), "Premiers enseignements tirés de la mise en œuvre des programmes d'action de prévention des inondations (PAPI)", rapport du Commissariat général au Développement durable, No. 006319-01, La Documentation française, Paris, www.ladocumentationfrancaise.fr/rapports-publics/094000253; Ministry of Ecology, Energy, Sustainable Development and the Sea (2010), "Des PAPI d'aujourd'hui aux enjeux de la directive européenne inondations", synthèse du séminaire national PAPI du 18 novembre 2009, Ministry of Ecology, Energy, Sustainable Development and the Sea, Paris, www.cepri.net/tl_files/pdf/syntheseseminairepapi.pdf; Ministry of Ecology, Sustainable Development, Transport and Housing (2011a), "Programmes d'action de prévention des inondations, de la stratégie aux programmes d'action, cahier des charges", Ministry of Ecology, Sustainable Development, Transport and Housing, Paris, www.developpement-durable.gouv.fr/IMG/pdf/110215_PAPI_vdef.pdf; Ministry of Ecology, Sustainable Development and Energy (2013a), "Bilan de l'activité de la CMI et des instances locales", Ministry of Ecology, Sustainable Development and Energy, Paris, www.developpement-durable.gouv.fr/IMG/pdf/bilan-cmi-2013-1.pdf.

Table 4.2. **The major river plans, 2007-13**

Major river plans	Flood prevention funding (EUR million)	Financial contribution (EUR million)		
		State	Regions	Others
Garonne Plan	42	33	9	–
Rhône Plan	310	108	83	38 (including ERDF 34)
Loire Plan	127	72	45	8
Seine Plan	70	42	24	3
including flooding in ÎdF	*41*	*27*	*11*	*3*
TOTAL	549	255	161	49

Sources: Rhône Plan inter-regional planning contract, 2007-13; inter-regional planning contract between the state and Haute-Normandie, Basse-Normandie, Île-de-France, Champagne-Ardenne, Picardie and Bourgogne Regions, 2007-13; Loire inter-regional planning contract, 2007-13; Garonne Plan inter-regional convention on the state-region planning contract, 2007-13.

Defining the priorities of prevention policy

Other strategic priorities have mobilised the public authorities and flood risk prevention funding. As in other OECD countries, these priorities often correlate with the most recent events (OECD, 2014a). Significant efforts followed the major floods of the Rhône between 2002 and 2003, for example. With material damage and a significant human toll, these floods, caused mainly by breaches in dykes, confirmed that poor flood defence maintenance posed a serious threat. Significant investment under the Rhône Plan was intended to reinforce dykes in the lower Rhône valley. Similarly, the dramatic floods in 2010 – cyclone Xynthia accounted for 47 victims and over EUR 1 billion in damage because of coastal flooding by sea-water inundation, while the torrential floods of the Var caused 25 victims and EUR 1 billion in damage (Ministry of Ecology, Sustainable Development and Energy, 2012a) – led the public authorities to introduce the rapid flooding plan (*plan submersions rapides*, PSR). The PSR focuses on preventing flooding caused by sea-water inundation, flash floods by water run-off and floods caused by breaches of dykes (Ministry of Ecology, Sustainable Development and Energy, 2011b). It has a budget of EUR 500 million over 5 years (2011-16).

The above examples illustrate the priority attached by the public authorities to protecting human lives. It is difficult to compare choices for prioritising resources, since economic assets and public and human health assets must be assessed according to the same criteria. If this is to be put in monetary terms, a value must be placed on human life. This is possible in the context of multi-criteria environmental analyses (see below) according to hedonic methods, but raises both ethical and practical questions. The risk of flooding of the Seine in Île-de-France, however, is the most significant risk at national level in terms of economic impact, with indirect effects that would affect the national economy as a whole. It is classified as a major risk in the preliminary flood risk assessment.

The significant economic assets involved have caused a delay in funding prevention measures for the risk of flooding of the Seine in Île-de-France. A specific funding strategy must therefore be introduced. In a context in which the public authorities' budget options are limited, such a strategy must be able to rely on all of the available resources, including those in the private sector. Furthermore, the strategy cannot be simply financial: it must be accompanied by a better understanding of governance (Chapter 2) and a rebalancing which enables ambitious prevention measures to be implemented (Chapter 3).

Flood prevention funding instruments

This section provides an overview of the flood prevention funding instruments that contribute or could contribute to increasing the resilience of Île-de-France against flooding of the Seine. Flood prevention funding in France is based mainly on solidarity mechanisms. Much of this funding derives from solidarity among all insured parties through the CATNAT compensation scheme and its Fund for the Prevention of Major Natural Risks (*Fonds de Prévention des Risques Naturels Majeurs*, FPRNM), or "Barnier Fund". A substantial proportion also comes directly from the state budget and therefore from taxation via the Ministry of Ecology, Sustainable Development and Energy's budgetary appropriations. Additional resources provided by the local authorities are more difficult to estimate and are usually generated under the major river plans and PAPI contractual instruments. The local authorities also fund the EPTBs, notably the EPTB Seine Grands Lacs, which manages the dams upstream of Île-de-France.

Instruments at national level

The CATNAT compensation scheme and its disincentive effects in terms of prevention

The CATNAT compensation scheme enables compensation for damage caused by natural disasters and risk prevention policy to be funded without drawing directly on the state budget. It was conceived in the 1980s to offset shortcomings of the insurance market by making it available to cover all individuals and businesses against disaster risks without excessive risk premium variation from place to place. The scheme functions according to the principle of an additional premium at a mandatory state-fixed rate which applies to any insurance contract for damage to or loss of property, irrespective of its exposure to natural disaster risks, the proceeds going to CATNAT reserves. The CATNAT scheme is an original public-private partnership which provides each party with access to the insurance market and coverage against natural disasters under the constitutional principle of solidarity. National solidarity in this respect is expressed in three ways: *i)* the legal obligation to include the additional CATNAT premium in any property damage insurance contract; *ii)* the uniform rate of the additional premium paid by any insured party and fixed by the state; and *iii)* the state guarantee given to the Central Reinsurance Fund (*Caisse Centrale de Réassurance*, CCR). This system has proven its effectiveness since its foundation by allowing broad coverage and compensation for losses in all cases of natural disasters covered by the system. Disputes and appeals are therefore not very common, and civil society stakeholders and insurers agree on the usefulness of the mechanism, which has developed little since its foundation in 1982. Initially established at 2.5%, the premium has now risen to 12% for all-risk home and business insurance and 6% for motor vehicles. These reserves can be mobilised provided a natural disaster is declared by ministerial decree in a restricted area for a specific risk (Grislain-Letrémy et al., 2012).

While the CATNAT and its use over the years has been effective in ensuring collective coverage against natural disaster risks, it has nevertheless had a number of well-identified shortcomings, particularly its disincentive effect with respect to certain prevention efforts (French Senate, 2012; OECD, 2006). The lack of insurance premium adjustment in line with risk levels, for example, does not encourage insured parties to reduce their exposure or vulnerability to natural hazards. This raises a question of a moral hazard, whereby persons most exposed to risks benefit indirectly from transfers from those who are least exposed. Similarly, prevention efforts by individuals are not rewarded by lower premiums. In addition, the too-frequent triggering of the mechanism, even for events with a low recurrence interval of up to a mere ten years, hinders prevention measures. This system, initially envisaged for extreme events, deludes the public and decision makers into assuming that they can take advantage of it irrespective of the circumstances. These consequences have brought about a number of minor modifications to the system and many recommendations over the years, plus an unsuccessful bill drafted to overcome its failings (Box 4.2).

This system also functions thanks to its associated reinsurance contract, proposed by the CCR. Wholly state-owned, the CCR proposes reinsurance underwritten by the state guarantee beyond a certain threshold. This could be put to the test by major flooding of the Seine, for example, which would trigger the state's role as guarantor of last resort (Box 4.3).

Box 4.2. A plan to reform the CATNAT compensation scheme

A plan to reform the CATNAT compensation scheme was submitted to the Senate in April 2012 to address certain gaps in the system, particularly its imprecise legal framework, its detrimental effect on the transparency and equity of the system and its inadequate prevention incentive mechanisms.

The bill amended the insurance code: on the one hand, it specifies the legal framework of the scheme, particularly its scope; on the other it enhances the functioning and transparency of the procedure for recognising the occurrence of a natural disaster (scientific definition of phenomena eligible for the compensation scheme, clear delimitation of the intervention of building insurance and collateral arrangements against natural disasters in terms of compensation for damage, updating of the conditions for benefiting from such arrangements, etc.). The bill also amends the building and housing code by reinforcing prevention incentive mechanisms in the compensation scheme (possibility of a targeted adjustment of premiums paid by insured parties, introduction of prevention rules for building on land exposed to risks, etc.).

Source: French Senate (2012), "Projet de loi portant réforme du régime d'indemnisation des catastrophes naturelles", présenté au nom du Premier Ministre par le ministre de l'Économie, des Finances et de l'Industrie, ordinary session of 2011-2012.

Box 4.3. The CATNAT compensation scheme affiliated to the state guarantee via the CCR

Despite its substantial reserves, the CATNAT compensation scheme would not be sufficient to compensate all the damage caused by a major flood of the Seine in Île-de-France. Its resources could also be heavily restricted by two other major risks in metropolitan France: a major flood of the Loire (OECD, 2010) or an earthquake on the Côte d'Azur. In that event, the call for the state guarantee could then come into play. The CCR proposes a reinsurance contract for the CATNAT scheme for private insurers who collect the CATNAT additional premium. The reinsurance proposed consists of two complementary and inseparable contracts:

- quota-share treaties: the insurer pays half the premium collected to the CCR, which will thus share 50% of the damage to be covered with the insurer
- loss limitation treaties: by paying an additional premium, the insurer ensures that the CCR will take responsibility for losses above a certain amount, generally established at twice the premium collected.

The CCR benefits from the state guarantee when the accumulated reserves cannot meet the contractual obligations to insurers. The multiple natural disaster orders issued in 1999 thus obliged it to bring this guarantee into play for EUR 263 million, following which the additional premium was raised from 9% to 12%. The level for triggering the guarantee in 2013 was around EUR 5 billion for compensation claims under the CATNAT, which would certainly be exceeded in the event of a major flood of the Seine (Chapter 1).

Source: Grislain-Letrémy, C., R. Lahidji and P. Mongin (2012), *Les risques majeurs et l'action publique*, rapport du Conseil d'analyse économique, La Documentation française, Paris.

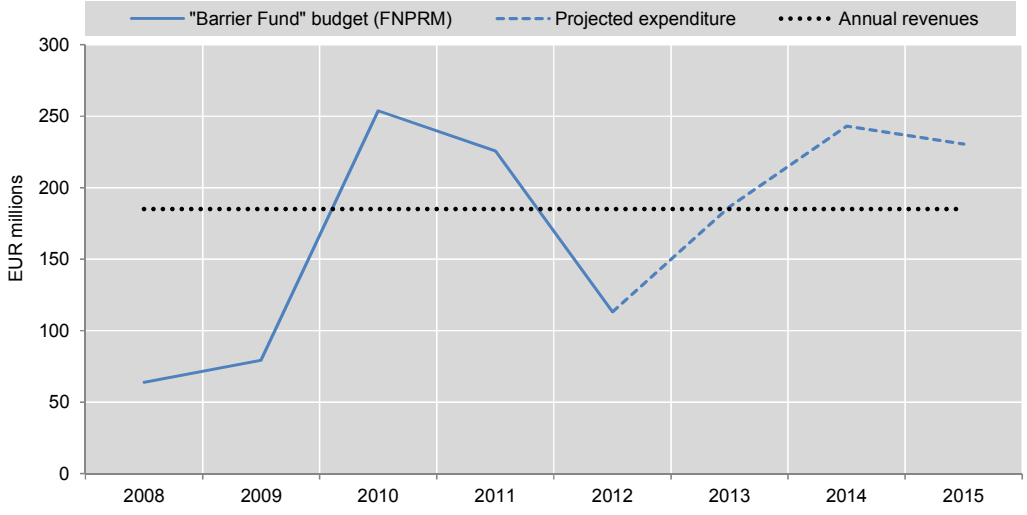
The Barnier Fund for financing prevention

Since the 1995 Barnier Law, the "Barnier" risk prevention fund has been affiliated to the CATNAT scheme by the retaining of a fixed percentage of sums collected. This fund, the FPRNM, thus has the advantage of being disconnected from direct state budget

resources, since it is increased on an annual basis by the insurance premiums of individuals and businesses. Initially established at 2.5% of the total additional premiums collected via CATNAT, the 2003 Bachelot Law allowed this rate to be adjusted by decree, thereby leading to its gradual increase to 4%, then 8% and now 12%. The remit of the Barnier Fund has been gradually expanded at the same time: initially set up to fund measures to purchase assets exposed or significantly damaged in the most at-risk areas, the Barnier Fund became the principal instrument for funding prevention and can now fund the drawing-up of PPRs as well as vulnerability reduction, run-off dampening and water protection measures. It generally involves co-funding with local authorities, with a fixed rate by type of activity ranging from 100% for preparing PPR-type regulatory instruments or departmental documents on major risks, and often 40-50% for other types of action. It is therefore the major financial instrument of the PAPI and PSR programmes referred to above.

The system's strength lies in the reliability of this funding, which is provided on an annual basis to the tune of around EUR 185 million, retained via the tax on the additional CATNAT insurance premium. Fund disbursements, meanwhile, are more variable. They are dependent both on recent disasters – particularly when they lead to asset purchases, such as after the cyclone Xynthia-related floods in 2010 – and on public prevention policy guidelines. Thus the development of flood prevention programmes for 2014 and 2015 is incorporated in Barnier Fund disbursement projections, which will be required to increase in years to come, according to the Ministry of the Economy and Finance's projections (Figure 4.2).

Figure 4.2. **Development of the FPRNM budget and forecast, 2008-15**



Source: Ministry of the Economy and Finance (2013a), "Rapport sur la gestion du fonds de prévention des risques naturels majeurs", Annexe au projet de loi de finances pour 2014, Ministry of the Economy and Finance, Paris, www.performance-publique.budget.gouv.fr/sites/performance_publique/files/farandole/ressources/2014/pap/pdf/jaunes/jaune2014_risques_naturels.pdf.

A substantial proportion of the funding also derives directly from the state budget and therefore from taxation via the Ministry of Ecology, Sustainable Development and Energy's budgetary appropriations adopted annually in the budget act. The budget action line for natural and water risk prevention can be followed specifically in risk prevention

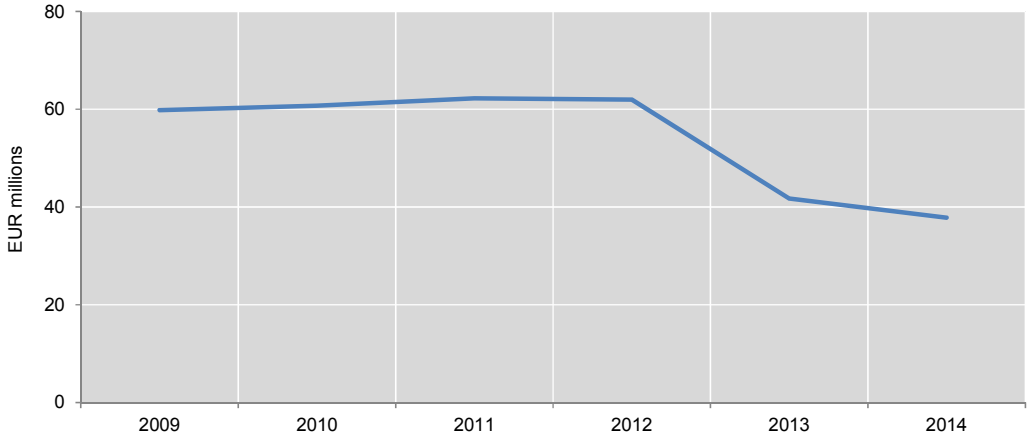
programme 181, on "the environment, sustainable development and energy" remit of the state budget. The monitoring over time of the payment appropriations adopted for this action indicates a significant reduction of almost 40% between 2012 and 2014, doubtless related to budget constraints. Even if the Ministry of Ecology, Sustainable Development and Energy's and other ministries' supplementary budgetary appropriations also come into play in funding prevention, the Barnier Fund and the 181 programme are the main sources of the national part of flood prevention funding. Via the Barnier Fund, therefore, France has a source of funding for virtually constant prevention which represents around three times the budget allocated for prevention under the budget act, a trend that is increasing.

Local authority funding of prevention

Co-funding of prevention by contractual approaches with the state

Contractual approaches between the state and local authorities enable local flood protection funding to be mobilised. Such approaches can be realised via the PAPI projects at risk basin level and via the major river plans at major catchment area level, particularly with the departments and regions and their different groupings. The success of calls for proposals under the PAPI (see Chapter 2) has brought local prevention-oriented project managers to the forefront and local authority funding to accompany them. This funding, however, has not yet enabled resources to be mobilised for the most at-risk areas. When the two calls for proposals were launched by the state, the first between 2002 and 2007 and the second since 2010, many applications for Barnier Fund co-financing were supported by local authorities. The audit conducted in 2009 following the first call – EUR 884 million, 60% of which was provided by local authorities – clearly showed that the increase in the number of projects was not always beneficial to their quality (Ministry of Ecology, Energy, Sustainable Development and Town and Country Planning, 2009).

Figure 4.3. **State budget expenditure on risk prevention, 2009-14**



Source: Ministry of the Economy and Finance (2013b), "Mission ministérielle – annexe à la loi de finance initiale pour 2013 – Écologie, développement et aménagement durable", Ministry of the Economy and Finance, Paris.

The lessons of this first call thus led the Ministry of Ecology, Sustainable Development and Energy to issue a second call with more rigorous selection criteria, particularly with regard to the economic analysis. Under the second call, a cost-benefit

analysis must now be carried out for all projects valued in excess of EUR 2 million (Box 4.4). The audit conducted in 2013 by the Joint Flood Commission (*Commission Mixte Inondation*, CMI) after two years of activity shows that most of the PAPI projects proposed were adopted. Projects were heavily concentrated in south-east France, as they were in the first call, and in the Loire-Brittany basin, particularly on the coast following cyclone Xynthia-related flooding. Currently, out of the 122 high flood-risk areas (HRAs) identified by the Preliminary Flood Risk Assessment provided for in the Floods Directive, 87 were not PAPI projects, while over half the envelope initially envisaged over the five years of the programme was committed (Ministry of Ecology, Sustainable Development and Energy, 2013a). The choice of a clearer resource allocation strategy should emerge from consultations under the National Flood Risk Management Strategy (*Stratégie Nationale de Gestion des Risques d'Inondation*, SNGRI), which may give greater consideration to the asset criterion, in addition to the economic efficiency of cost-benefit studies or multi-criteria analyses, and could add conditionality criteria in order to adjust incentives to ensure more prevention. The United Kingdom's approach, which models funding according to resource prioritisation criteria, is relevant in this respect: all projects submitted are funded, but the state proportion of funding is more substantial for projects located in priority areas (Ministry of Ecology, Sustainable Development and Energy, 2013b). It should be noted finally that virtually all this programme funding contributes to measures seeking to manage the hazard rather than reduce vulnerability.

Box 4.4. **Cost-benefit and multi-criteria analysis**

The cost-benefit method described in PAPI project specifications provides for project promoters to follow a minimum range of criteria. The study must focus on the structural measures of projects if they exceed EUR 2 million or 25% of the project total. In terms of cost, it must consider both the initial costs as a whole from the time of the study until commissioning, and maintenance and operating costs over time. In terms of damage assessment, the method adopted involves assessing the average annual damage with or without planning in order to obtain the average annual damage avoided. To achieve this, the minimum direct tangible damage must be assessed for four types of asset (housing, economic activity, agriculture and public infrastructure) and three flood scenarios (frequent, average – ~100 years – and extreme). The cost-benefit ratio will then be obtained by dividing the total updated benefit by the total updated cost in the timeframe of the analysis, which must not exceed 50 years, and by using the discount rates established by the French planning authorities. This is referred to as the net present value (NPV). This calculation must be completed by a sensitivity analysis. This figure thus allows the economic efficiency of a project to be determined. It also enables several development options in the same basin to be compared. It is, however, more difficult to use to compare projects in different basins, since the methods involved are generally too dissimilar.

In order also to factor in the more intangible impacts highlighted by the Floods Directive in particular, the CGDD developed a multi-criteria analysis method to complete the cost-benefit analysis. This method considers impacts on human health, the environment or cultural heritage without having to monetise them. Some 20 indicators were thus defined, and a guide for project managers is currently being drawn up.

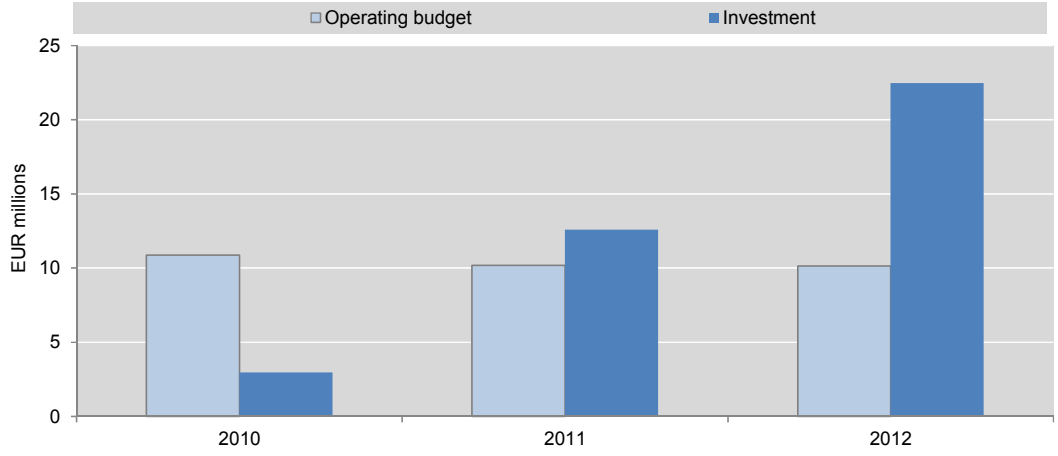
Sources: Ministry of Ecology, Sustainable Development, Transport and Housing (2011a), "Programmes d'action de prévention des inondations, de la stratégie aux programmes d'action, cahier des charges", Ministry of Ecology, Sustainable Development, Transport and Housing, Paris, www.developpement-durable.gouv.fr/IMG/pdf/110215_PAPI_vdef.pdf; Ministry of Ecology, Sustainable Development and Energy (2012b), "Analyse multicritères: Application aux mesures de prévention des inondations", Document de travail, No. 6.B, Commissariat général au Développement durable.

The regions generate flood prevention funding through the major river plans as planning and regional development stakeholders. These plans, which are tools agreed over a seven-year period between the state and the regions in a catchment area, allow the regions' and European funding via the European Regional Development Fund (ERDF) to work together on watercourse planning and flood prevention in particular. Out of the current programming period's EUR 550 million, EUR 160 million come from the regions and EUR 34 million from the ERDF. As flood risk management strategy currently stands at large basin level up to 2015 in terms of Floods Directive implementation, additional resources from EU risk prevention funding mechanisms could be mobilised via the different instruments available (see below).

Local public river basin authority funding: EPTB Seine Grands Lacs

Local authorities also contribute to flood prevention funding when they group together in a local public river basin authority (*établissement public territorial de basin*, EPTB), which is a flood defence management institution at sub-basin level. As a historic manager of dams upstream of the Seine basin, the EPTB Seine Grands Lacs is funded by its historic constituents in the former department of the Seine, i.e. the departments of the inner suburbs (Hauts-de-Seine; Seine-Saint-Denis; and Val-de-Marne) and the City of Paris. They provide its annual operating budget and a large proportion of its investment budget, the City of Paris contributing half and the three other departments sharing the remaining operating and investment costs equally. The tasks of the EPTB Seine Grands Lacs are evenly divided between flood prevention and low-water management. Half of these resources can be considered to be part of flood prevention funding, i.e. EUR 5 million per year for operations and an investment part varying from EUR 1 million to EUR 11 million over the past three years.

Figure 4.4. **EPTB Seine Grands Lacs budget, 2011-12**



Sources: EPTB Seine Grands Lacs (2013), *Rapport d'activité 2012*, EPTB Seine Grands Lacs, Paris, www.seinegrandslacs.fr/rapport-activite/SeineGrandLacs_web.pdf; EPTB Seine Grands Lacs (2012), *Rapport d'activité 2011*, EPTB Seine Grands Lacs, Paris, www.seinegrandslacs.fr/docs/EPTB%20Seine%20Grands%20Lacs/Rapport%20d%20Activit%C3%A9/2011-Rapport-activit%C3%A9-EPTB-Seine-Grands-Lacs.pdf; Les Grands Lacs de Seine (2011), *Rapport d'activité 2010*, Les Grands Lacs de Seine, Paris, http://pascalpopelin.fr/docs/grands-lacs-de-seine/rapport_activite_2010.

Mobilising local funding for resilience

In addition to contractual instruments and action within the EPTB, local authorities can mobilise budgetary appropriations to fund prevention on a complimentary and independent basis. The development of different regulatory tools at municipal level (risk prevention plan, major risks information document, flood markers) requires resources to accompany state co-funding. Similarly, when local authorities manage flood defences, they must have competent maintenance services and have to fund rehabilitation work where necessary. Finally, reducing the vulnerability of local authority-managed public infrastructure is also an area in which their own resources can be put to use. These budgets are difficult to estimate and are relatively variable according to the local authority, its resources and its responsibilities. In a context in which Act III of the decentralisation process could introduce a new flood and aquatic environment management responsibility for local authorities (Chapter 2), the respective resources should be brought into line with the risk level and balanced between the various local authorities facing the same risk.

In the Île-de-France inner suburbs, the departments are thus responsible for managing protection infrastructure (river banks, dykes and walls) and can carry out work to ensure their maintenance and repair, where necessary. The Hauts-de-Seine, for example, has an annual flood risk prevention budget of around EUR 1 million. The City of Paris has invested in a removable protection system. The Val-de-Marne is prepared to co-fund renovation work on the Joinville-Le-Pont sector gate, which was blocked for many years (EUR 3 million). Measures to reduce vulnerability and enhance resilience are also highly diversified according to the department. Like the differences in protection levels referred to in Chapter 3, these individualised local authority actions against the same risk raise the question of equality for citizens facing the risk and equity between areas in the same risk basin. The financial resources of the departments in the inner suburbs, however, are also highly variable, and are generally higher to the west and in Paris than in the east or north.

Other sources of prevention funding

Other sources of funding exist or can be mobilised to fund flood prevention in France and in Île-de-France in particular. This is the case, for example, of water policy financial resources in the broad sense. Network operators and private businesses can also contribute to flood risk prevention funding when they increase their own level of resilience, as can individuals. The European Union is also an additional source of funding in this respect.

Water policy funding

Water policy in France is funded according to the "polluter and consumer pays" principle at large basin level. While it is clear that flood prevention is not part of their remit, it remains the case that there are many synergies between flood prevention and water management, and that water agency funding programmes could contribute in that respect to prevention efforts, provided multiple-use projects are proposed: low-water level management/flood management, wetland restoration/flood retention, restoration of dykes and banks/environmental approaches. In addition, the water authorities have substantial budgets: the Seine-Normandy Water Agency's investment programme stands at EUR 4.7 billion over the six-year period from 2013 to 2018. Therefore, according to an integrated basin rationale which goes beyond the borders of Île-de-France in the strict sense but takes the real circumstances of the river and its tributaries into account, these

resources enabled the final two EPTB Seine Grands Lacs reservoirs built in the 1970s and 1980s to be 30% and 40% funded because of their contribution to low-water management. The protection of drinking water and sewage treatment networks and infrastructure, often situated in floodplains, is also an area in which water authority funding can play an important role. Finally, the funding of the preservation of wetlands, which are often flood retention areas, and the combating of erosion and water run-off both in rural areas (hedge planting, maintenance of grassland, etc.) and urban areas for reasons connected to the quality of water and aquatic environments, which fall within the remit of the Seine-Normandy Water Agency (*Agence de l'Eau Seine-Normandie*, AESN), also contribute to flood risk control.

Meanwhile, the state has recently charged the working capital of water agencies at a rate of 10% under the 2014 budget act. In addition to the allocation of these resources to the general budget, their potential use for flood prevention could be put forward in the context of Floods Directive implementation.

In addition to existing water policy resources, as leading stakeholders, water agencies can also contribute to prevention funding: water agencies have a basin-level financial engineering capacity which allows them to collect fees and charges through water bills and to reallocate these resources to projects with the local authorities. This financial instrument could be useful in implementing other instruments specific to flood management that could be based on the low-water level fee introduced by the EPTB Seine Grands Lacs for the major water users (Box 4.5).

Box 4.5. **EPTB Seine Grands Lacs low-water management charge**

In February 2012, the Prefect of Île-de-France and Seine-Normandy Basin Co-ordinator announced the signature with the concerned prefects of the inter-prefectural order declaring the development, upkeep and operation of the reservoirs managed by the EPTB Seine Grands Lacs as being in the general public interest. This order allows the EPTB Seine Grands Lacs to levy a low-water management charge to fund work on the Seine reservoirs owed by municipalities along the Marne, Aube, Seine and Yonne. The EPTB Seine Grands Lacs set the charge at EUR 0.175/m^3 of water per annum withdrawn from the Seine, Marne, Aube, Yonne and related water bodies. Collected on an annual basis by the Seine-Normandy Water Agency, it must be applied to the municipalities, public agencies for co-operation between local authorities, water agencies and certain manufacturers and farmers if they remove over 80 000 m^3 during the low-water period. The EPTB Seine Grands Lacs obtained EUR 6 million from this charge in 2013.

Source: EPTB Seine Grands Lacs (2013), *Rapport d'activité 2012*, EPTB Seine Grands Lacs, Paris, www.seinegrandslacs.fr/rapport-activite/SeineGrandLacs_web.pdf.

Funding network operator, business and individual resilience

The operators of critical networks (electricity, telecommunications, transport, water) play a fundamental role in the flood resilience of the capital. Since they are particularly vulnerable to potentially very costly damage to the infrastructure they operate, but also to knock-on effects that exacerbate crises, the operators are – or should be – doubly encouraged to invest in risk prevention. Despite the regulations which exist for vitally important sectors of activity (Chapter 3), investment generally appears to be weak compared to the challenges. For example, the electricity network operator ERDF spent EUR 2 million between 2006 and 2012 specifically to reduce the potential impact of

flooding on its network in Île-de-France, which has been assessed at between EUR 200 million and EUR 1 billion if the Seine were to flood. The RATP has invested EUR 6 million since it established its business continuity plan in 2003, with damage to its network estimated at EUR 1-5 billion. This seems all the more inadequate in that many public enterprises are their own insurer. Since, on that basis, they do not benefit from the CATNAT scheme, they must bear any losses themselves. Certain telecommunications and water operators have been able to undertake more significant investment, but in these potentially competitive fields involving several operators, investment levels vary according to the operator and do not necessarily ensure a consistent approach and an equivalent level of service for the various users and clients.

Private businesses, particularly the major groups, invest in flood risk prevention in line with their degree of awareness and the prevailing regulations, particularly those issued by sector regulators. Investment in business continuity is a rather recent trend among major French businesses. Insurers' incentives and the multi-risk approaches adopted generally force them to introduce continuity solutions based on system redundancy, safeguards and fall-back possibilities. Little specific investment in protection measures or vulnerability reduction have been identified in Île-de-France. The relocation of certain data centres or front offices outside floodplains has been envisaged by several businesses. The awareness of SMEs, however, is generally not very well developed (see Chapter 3).

Individuals, meanwhile, contribute to risk prevention funding in two ways: by complying with risk prevention plan measures – which are minimal in the case of the existing buildings that largely predominate in Île-de-France – and as insured parties under CATNAT funding. The latter is not connected to the level of risk (Box 4.2), though it is directly linked to the value of the property insured. In practice, since the introduction of the Barnier Fund, very few natural disaster orders have been issued in Île-de-France, and the region and its inhabitants have therefore been net contributors to the CATNAT scheme and consequently to the Barnier Fund.

European prevention funding

Risk prevention at EU level involves specific instruments, particularly financial instruments, which have been reinforced in recent years. The adoption of the European Commission communication on risk prevention in February 2009 laid particular stress on the need to improve the effectiveness of existing financial instruments. In addition to funding via the European Regional Development Fund already referred to, other European funds which are less well known to prevention stakeholders in France can fund their actions. The European Council's conclusions on innovative solutions for funding prevention also invited the European Commission to compile a list of financial instruments after realising that these resources were not sufficiently used in this area and that few member country projects involved applications for them. Table 4.3 shows the principal EU risk prevention financial instruments. The implementation of the Floods Directive will represent an opportunity to mobilise these resources to the fullest.

Scoping a funding strategy

The risk of flooding of the Seine in Île-de-France is now clearly identified, and a management strategy under the Floods Directive is currently under development for 2015-21. When governance mechanisms are put in place, their funding could benefit

from a number of principles enabling the fullest advantage to be taken of the sources of funding identified above in times of budgetary constraints.

Table 4.3. **European risk prevention funding**

Fund	Date	Objectives and applicable prevention measures
European Regional Development Fund (ERDF)	2006	To reinforce European economic and social cohesion by correcting regional imbalances: 1. To develop plans and measures to prevent and combat natural and technological risks 2. Flood prevention 3. Protection and management of catchment areas, coastal areas, services connected to water and wetlands
Civil Protection Financial Instrument (IFPC)	2007	To support protection of the population, the environment and property in the event of natural or man-made disasters 1. Modelling to reinforce prevention, facilitate the exchange of best practices and disseminate information and know-how on risks 2. Definition of scenarios to reinforce prevention, facilitate the exchange of best practices and disseminate information and know-how on risks 3. Study and research to reinforce disaster prevention, facilitate the exchange of best practices and disseminate information and know-how on disasters
European Agricultural Fund for Rural Development (EAFRD)	2005	To reinforce European rural development policy and simplify its implementation 1. Establishment and implementation of river basin management plans 2. Flood prevention
Structural funds regulation	2006	1. Risk prevention, including the drafting and implementation of plans and measures to prevent and manage natural risks 2. Other measures to preserve the environment and prevent risks
Seventh framework programme 2007-13 (FP7)	2006	To stimulate co-operation to consolidate the European Research Area 1. Research on the environment, risk management and sustainable development 2. Research on the improvement of prevention, mitigation and management strategies within a multi-risk approach 3. Research into methods for assessing risks and their impact 4. Research into prevention strategy indicators 5. Activities connected to public perception and risk communication 6. Research into vulnerabilities
European Financial Stability Facility (EFSF)	2010	To safeguard European financial stability 1. Measures to respond to threats to critical infrastructure 2. Development of effective preparation of citizens for environmental incidents 3. Development of emergency planning measures for potential environmental incidents

Source: European Commission (2012), Catalogue of Disaster Prevention Measures that May Benefit from EU Funding, DG ECHO, European Union, Brussels.

Risk level and resource mobilisation

Defining the funding needs to prevent the risk of flooding of the Seine in Île-de-France is directly linked to the long-term view and the objectives established by the strategy. The choice of an acceptable or optimum risk level (Box 4.1) will then determine the assessment of funding needs for prevention, emergency response capacities and insurance-based risk transfer mechanisms (OECD, 2014a). Governance mechanisms currently being established at risk basin level will be those that are the most likely to define such a level, if they come to represent a collective choice that is sufficiently shared by the various stakeholders, whether beneficiaries or sponsors of the planned prevention measures.

The procurement of funding to allow this acceptable risk level to be achieved must take two principal elements into account: the budget context and poor risk awareness among the leading sponsors. Risk prevention resources are diminishing in budgetary

terms at national level (see above), while CATNAT resources are and will continue to be increasingly sought after in the future under the effect of climate change. Local authorities are also experiencing budget restrictions with a reduction in the state's financial contribution in 2014. In this context, the allocation of resources to risk prevention is a challenge which must demonstrate that public funds will be used as efficiently as possible.

The lack of any significant flooding of the Seine in the past 60 years tends to dim the awareness of stakeholders and does not motivate them to establish a financial approach to prevention challenges. If funding for flood prevention measures in Île-de-France has not matched the risk in the recent past, this is due both to the fading of the collective memory and the range of weaknesses set out in this report. This concerns, in particular, the lack of governance capable of understanding the implications on the appropriate territorial scale, whether regional or basin-wide. Sponsors must be reassured that these obstacles have been overcome in order to obtain their financial support. On the basis of this observation, stakeholders must bear a number of principles in mind before taking decisions.

The beneficiary pays principle

The general principle of funding is based, above all, on identifying the beneficiaries of flood prevention measures and assessing their capacity to contribute funding in proportion to the level of risk the measures will protect them against (OECD, 2003).

The parties primarily affected by flood prevention are the inhabitants of floodplains and the businesses located on them. While they contribute generally to prevention funding through taxation and their contribution to the CATNAT scheme and therefore to the Barnier Fund, such contributions are no different from those of other citizens. Few specific incentives actually concern prevention under the CATNAT scheme and none apply to flooding of the Seine in Île-de-France. The few incentives for the public and businesses to carry out work to reduce vulnerability that can be included in the PPRs and financed under the Barnier Fund are also not applied to any great extent in Île-de-France. Greater progress could be achieved here on the basis of tax credit mechanisms for energy efficient buildings or the raising of elevator safety standards, for example. Such incentives or regulatory measures have attracted investment from individuals seeking to reduce greenhouse gas emissions or improve building safety. At business level, insurance companies could provide more direct incentives by developing policies geared specifically towards business continuity.

Over and above its primary mission of ensuring the safety of the public, the state is also on the front line in preventing the risk of flooding of the Seine in Île-de-France, since its functioning would be seriously disrupted and the economic impact could be national in scope (Chapter 1). Furthermore, as the ultimate guarantor of the CATNAT scheme, state budget resources would be mobilised to compensate individuals and businesses in the event of significant flooding of the Seine. The mobilisation of its own resources to fund prevention is therefore justified and could involve not only risk prevention resources but also civil security and state continuity resources. Similarly, local authorities would also benefit from additional prevention measures enabling them to continue to fulfil their public service remit and maintain the attractiveness of their areas.

Certain specific sectors could also benefit from greater resilience, such as network operators, who are especially vulnerable to flooding and would suffer significant damage in the event of a major flood, particularly since they are often their own insurer (see Chapter 1). It would therefore be justified for them to contribute to common efforts

towards greater resilience, either by reinforcing their own infrastructure or contributing to the funding of a broader metropolitan strategy.

Finally, the insurance sector could also benefit from additional prevention measures that reduce the exposure of their portfolio to the risk of flooding of the Seine in Île-de-France. Insurers, however, traditionally reflect risk levels by adjusting the calculation of their policy premiums. Since the fixed level of the CATNAT additional premium decided by the state does not allow for such adjustments, the sector's contribution to enhanced resilience should include a broader discussion on reforming the CATNAT (see above). It would not, in fact, be justified to increase the level of the CATNAT additional premium or the contribution to the Barnier Fund merely to finance a local flood risk management strategy.

Efficiency of prevention measures

According to OECD principles, the funding of flood risk prevention in Île-de-France should ensure the greatest efficiency through a coherent long-term economic approach, taking equity into account.

Coherence

Greater coherence between public risk prevention policies leads to lower costs and more effective measures. The diversity of approaches between different public policy fields, levels of government and stakeholders has been stressed. This could give rise to redundancy of action and additional expenditure and an overall lack of efficiency in the measures taken, since the level of resilience is often determined by the weakest link. The various local authorities thus invest to a different extent according to their resources, their risk level and their risk perception, which are all interlinked. Similarly, network operators do not work together to ensure the resilience of their common networks, potentially generating distortions in competition and service levels. Un-cooperative "free-riding" has been observed in telecommunications, for example, where certain operators invest in the resilience of multi-network passages which are, in fact, beneficial to all. An improvement in the coherence of measures taken may reduce such additional expenditure and bring about economies of scale by mutualising expenditure that could be allocated more directly to funding prevention measures.

Effectiveness

The search for greater effectiveness in the use of prevention resources cannot be limited to ensuring that approaches are more coherent, which is only one prerequisite. A resource allocation strategy prioritising those prevention measures that are the most effective in reducing the hazard and/or vulnerability must be developed.

To that end, the cost-benefit studies and multi-criteria analyses promoted by the Ministry of Ecology, Sustainable Development and Energy are a step in the right direction. In addition to their usefulness in determining the relevance of a project, they can also allow all the available options and their impact on mitigating risks within the same risk basin to be compared. This includes non-structural measures, the benefits of which must be measureable, particularly with respect to urbanisation. The new knowledge tools relating to the Seine basin in Île-de-France (Chapter 3) and the structure of governance envisaged for the Île-de-France HRA under an economic committee will allow cost-benefit studies to be carried out for each potential prevention measure by means of the same methodological approach, in order to compare and prioritise them.

Long term

The search for lasting financial solutions should enable long-term resilience to be improved. Long-term investment planning also makes it possible to ensure flexibility in making choices, to take into account and adapt to the development of knowledge and to reduce uncertainty. This also allows the level of resources required to be adjusted according to needs. An approach of this kind has been adopted against major risks and the associated uncertainties in OECD countries such as the Netherlands with the Delta Plan, and in the United Kingdom with the Thames Estuary 2100 project (Box 4.6).

Box 4.6. **Long-term flood prevention funding strategies in OECD countries**

In the United Kingdom, Thames Estuary 2100 is a long-term proactive flood risk management plan for London and the Thames estuary in the 21st century. The plan was drawn up in 2002 by the Environment Agency to develop a strategic flood risk management strategy that could be adjusted in the light of climate change uncertainties. The strategy defines local action to be taken in the short, medium and long term: action 0 to be taken in the first 25 years includes, *inter alia*, the joint definition of the funding required for the various measures by the Environment Agency and partners implementing the plan. The works will be funded primarily by the Thames, Anglian and Southern Region Flood Defence Committees under the responsibility of the Department for Environment, Food and Rural Affairs (Defra). Additional support has been obtained from the European Union Interreg 3B funding programme and the Office of the Deputy Prime Minister for two sub-projects.

In the Rhine basin, a ministerial conference on the Rhine in 2001 adopted the Rhine 2020 programme, based on co-operation between nine countries (Austria, France, Germany, Italy, Liechtenstein, Luxembourg, the Netherlands, the Belgian region of Wallonia and Switzerland). The principal objectives of this strategy are to restore the ecosystem, prevent flooding and provide flood defences, improve water quality and protect groundwater. This long-term strategy involves several successive stages. Close to EUR 10 billion has been invested to date in this framework for implementing the flood defence action plan. Many particularly financial regional and local partners are associated with the process of implementing measures, especially in sectors engaged in restoring the environment and preventing flooding.

In the Netherlands, the Delta Fund was established under the Delta Act to fund measures of national importance concerning flood and water resource management. EUR 16.6 billion have been programmed from 2014 to 2028, i.e. around EUR 1 billion per year. Flood risk prevention funding is currently estimated at EUR 1 billion, two-thirds funded by central government and one-third by regional water agencies which collect taxes and levies. The Delta Committee also recommends an increase in flood protection standards compared to current levels by 2050, which means that the respective infrastructure must be reinforced. The Delta programme envisages an outlay of EUR 1.2-1.6 billion per year from 2010-50 to achieve this objective, taking climate change into consideration. These costs do not encompass the water management maintenance and operating costs borne by central government, the regional water agencies and the provinces, estimated by the Delta Committee at EUR 1.2 billion per year.

Source: Commission internationale pour la protection du Rhin (2001), "Conférence ministérielle sur le Rhin 2001: Rhin 2020, Programme pour le développement durable du Rhin",www.iksr.org/fileadmin/user_upload/Dokumente_fr/rhein_2020_fr.pdf; Environment Agency (2012), "Thames Estuary 2100 Plan", TE2100, August, Crown Copyright, London, http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/LIT7540_43858f.pdf; Lavery, S. and B. Donovan (2005), "Flood risk management in the Thames estuary looking ahead 100 years", Royal Society Publishing, London, http://rsta.royalsocietypublishing.org/content/363/1831/1455.full; OECD (2014b), *Water Governance in the Netherlands: Fit for the Future?*, OECD Studies on Water, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264102637-en.

Equity

Questions of equity in funding measures to prevent the risk of flooding of the Seine in Île-de-France arise in some dimensions: the allocation of national solidarity resources for this specific risk and differences in the level of risk and funding within the at-risk area in Île-de-France.

On the first point of national resource allocation, the level of average damage (see above), and above all the impact of major flooding on the functioning of the state and on the national economy (Chapter 1), justify in themselves a state budget contribution to prevention. Moreover, since the principal tool for funding prevention depends on the CATNAT scheme and is therefore indexed to the value of property, the citizens of Île-de-France have contributed heavily to funding the system and therefore to prevention in France since it was set up. With few declarations of natural disasters in Île-de-France and relatively little funding received via the Barnier Fund for floods compared to other French regions, the Île-de-France has, in fact, contributed both to prevention and to post-disaster compensation for other French regions through transfers from this system of solidarity. The question then arises as to whether some of these resources should be refocused on Île-de-France itself because of its vulnerability.

The difference in protection levels between areas within Île-de-France has already been stressed. This favours areas which benefit from existing defences, while areas that do not have them or have them to a lesser extent bear pressure on public finances. A common basin-wide approach would justify protecting the heavily urbanised regions of Île-de-France at the same level because of the assets now situated in the floodplain.

Existing and additional resources

Many existing funding mechanisms can be mobilised to prevent this major risk. A multi-hazard approach (flood, drought, pandemic, terrorism) may open up access to water policy or risk management funding in the broad sense. A long-term approach linked to the Greater Paris regional development process also creates opportunities, and many European mechanisms allow risk prevention to be funded and should be investigated.

Several potential sources of additional funding could also be mobilised. Interviews have shown that a number of private-sector stakeholders are prepared to contribute to the funding of prevention measures if it can be shown that the investment involved could significantly reduce their level of risk exposure, and more effectively than the individual measures they could take themselves. Existing capital gains taxes on immovable property in floodplains and local taxes on sealing or the tourist sector, for example, should be explored as sources of funding. Resources in the form of the EPTB Seine Grands Lacs' low-water management charges could also foster a similar mechanism for the flood protection service, particularly for network operators.

Conclusion and recommendations

The funding of the prevention measures required to raise the level of resilience against the risk of flooding of the Seine continues to be a major challenge in Île-de-France. In a context of underinvestment in recent years and the difficult economic climate, investment in prevention has been under pressure due to the need to balance budgets and prioritise public funding, both by the state and local authorities. In Île-de-France and often elsewhere, decisions to initiate and fund prevention are dependent upon the economic context and the impetus generated by recent events. The absence of

significant flooding for almost 60 years tends to dull the awareness and does not motivate stakeholders to establish a financial approach to prevention challenges. Differences in risk levels and the intensity of prevention efforts in geographical terms also contribute to the difficulty in funding infrastructure that might be of greater benefit to some than others, and to a failure to take action that would enable a collective resilience surplus to be funded.

There is therefore scope for redefining flood prevention funding policies so as better to adapt them to the likely challenges. When public finances are under strain, the issue of additional resources and the sharing of effort (state, local authorities, businesses, the public, EU funds) could be addressed by establishing a number of principles underlying a global funding strategy that could be based on the recommendations set out below:

- Support local strategies for managing the risk of flooding of the Seine in Île-de-France with a clear financial strategy that takes specific national characteristics into account. This could be based on continuity and long-term vision, accountability and proportionality between beneficiaries of measures and sponsors, greater effectiveness and equity in allocating resources and synergies with other sectoral strategies (drought, water, planning, crisis management).
- Mobilise all prevention measure beneficiaries in a multi-level approach involving local authorities and state funding, the various network operators, the private sector and citizens by means of targeted incentives. Additional funding could be generated by positive incentive mechanisms within existing systems of levies and taxes, in association with the insurance, property and water management sectors in particular.
- Continue efforts to clarify criteria for prioritising state investment in risk prevention. This could take into consideration European funding perspectives that could be mobilised to implement the EU Floods Directive in areas at serious risk of flooding, such as Île-de-France.
- Reappraise the CATNAT compensation scheme's impact on flood risk prevention. The bill seeking to reduce the system's disincentive effects could be revived, which would represent an opportunity for broader reflection on prevention funding.

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Annex A

List of stakeholders interviewed

During the mission with international peers in May 2013, the review team met and interviewed representatives of the following institutions:

Government stakeholders

Ministère de l'Écologie, du Développement durable et de l'Énergie, Direction générale de la prévention des risques (French Ministry of Ecology, Sustainable Development and Energy, Directorate-General for Risk Prevention)

Ministère de l'Écologie, du Développement durable et de l'Énergie, Direction Régionale et Interdépartementale de l'Environnement et de l'Énergie d'Île-de-France (French Ministry of Ecology, Sustainable Development and Energy, Regional and Interdepartmental Environment and Energy Directorate)

Secrétariat général de la Zone de Défense et de Sécurité de Paris (General Secretariat of the Paris Defence and Security Zone)

Agence de l'Eau Seine-Normandie (Seine-Normandy Water Agency)

Ministère de l'Économie et des Finances, Bureau des assurances (French Ministry of the Economy and Finance, Insurance Bureau)

Ministère de l'Économie et des Finances, Service du haut-fonctionnaire de Défense et de Sécurité (French Ministry of the Economy and Finance, Senior Defence and Security Official)

Caisse Centrale de réassurance (Central Reinsurance Fund – French state-owned reinsurance company)

Établissement Public d'Aménagement Orly-Rungis Seine Amont (EPA-ORSA) (Orly-Rungis Seine Amont Public Development Authority)

Local government stakeholders

Ville de Paris (City of Paris)

Conseil général des Hauts-de-Seine (General Council of the Hauts-de-Seine)

Conseil général de Seine-Saint-Denis (General Council of Seine-Saint-Denis)

Conseil général du Val-de-Marne (General Council of the Val-de-Marne)

Région Île-de-France (Île-de-France Region)

Établissement Public Territorial de Bassin Seine Grands Lacs (Seine Grands Lacs Local Public River Basin Authority)

Non-governmental, network operators and private sector stakeholders

ACCOR

AXA

Centre européen de prévention du risque d'inondations (European Center for Flood Risk Prevention)

Chambre de commerce et d'industrie Paris Île-de-France (Chamber of Commerce and Industry, Paris Île-de-France)

Club des Directeurs de la Sécurité des Entreprises (Business Security Directors' Club)

Commission nationale du débat public (National Commission for Public Debate)

Crédit Agricole

Eau de Paris (Paris Water Company)

Électricité Réseau Distribution France (ERDF) (French electricity distribution network operator)

Mission Risques Naturels (Natural Risks Mission)

Comité français du Bouclier Bleu (French Committee of the Blue Shield)

Orange (French telecommunications operator)

Régie Autonome des Transports Parisiens (RATP) (French state-owned public transport operator)

Société Nationale des Chemins de Fer Français (SNCF) (French National Railway Company)

Véolia

World Wide Fund for Nature (WWF)

The OECD Secretariat also wishes to thank the following stakeholders who responded to the OECD questionnaire or who commented on the report but could not be interviewed:

Académie de l'Eau

Aliaxis RD

Association Française pour la Prévention des Catastrophes Naturelles (AFPCN) (French Association for Natural Disaster Reduction)

Banque de France

Communauté d'agglomération Plaine Commune

Compagnie Parisienne de Chauffage Urbain (CPCU)

Conseil général des Yvelines (General Council of the Yvelines)

Entente Oise-Aisne

FM Global

Institut d'Aménagement et d'Urbanisme d'Île-de-France (IAU) (Institute for Urban Planning and Development of the Île-de-France Region)

Institut National de la Statistique et des Études Économiques (INSEE) (National Institute of Statistics and Economic Studies)

La Maison de la Mutualité

Lyonnaise des Eaux

Mairie d'Alfortville

Mairie d'Issy-les-Moulineaux

Mairie d'Ivry-sur-Seine

Mairie de Lagny-sur-Marne

Mairie de Nanterre

Mairie de Rueil-Malmaison

Mairie de Valenton

Mairie de Vitry-sur-Seine

Ministère de l'Écologie, du Développement durable et de l'Énergie, Direction Régionale et Interdépartementale de l'Équipement et de l'Aménagement d'Île-de-France (French Ministry of Ecology, Sustainable Development and Energy, Regional and Interdepartmental Directorate for Infrastructure and Development of Île-de-France)

Ministère de l'Écologie, du Développement durable et de l'Énergie, Commissariat Général au Développement Durable (French Ministry of Ecology, Sustainable Development and Energy, General Commission for Sustainable Development)

Renault

Syndicat des eaux de Versailles et de Saint-Cloud (SEVESC)

Syndicat intercommunal de traitement des ordures ménagères (SYCTOM)

Syndicat interdépartemental pour l'assainissement de l'agglomération parisienne (SIAAP)

Tencate Geosynthetics

Annex B

Questionnaires sent to stakeholders

Questionnaire A for public stakeholders and local or regional authorities

A.1. Risk assessment

A.1.a. Roles and responsibilities for assessing vulnerability to flooding in the Seine River basin in Île-de-France

Describe the role and responsibilities of your organisation concerning the following:

- assessment of vulnerability to flooding
- preparation of flood risk maps
- risk assessment of the various types of flooding calculated in terms of probability and consequences
- assessment of the vulnerability of flood protection structures:
  - how are data concerning the above points collected (sources, frequency, etc.)?
  - are there any obstacles to data collection (confidentiality, protection of private data, etc.)? If yes, please provide further details.

A.1.b. Risk assessment methodology

Describe existing programmes aimed at:

- detecting physical vulnerabilities (installations, topographical features, etc.):
  - relating to the public sector (infrastructure)
  - relating to economic stakeholders
- identifying secondary effects of flooding, including the damaging effects of disruption of economic activity.
- How are data collected for the above categories (sources, frequency, etc.)?
- Are there any obstacles to data collection (confidentiality, sensitive information, etc.)? If yes, please provide further details.
- When were the following last updated?
  - floodplain maps

- assessments of the vulnerability of economic activities

- Who carries out the(se) update(s)?
- How is it done?
- Are the revised floodplain map data accessible to economic stakeholders?
- Are the revised data from assessments of the vulnerability of economic activities accessible to economic stakeholders?
- Are the data from network fragility maps accessible to economic stakeholders?
- Are the possible consequences of climate change taken into account when assessing the risk of major flooding and economic vulnerability?

  YES **NO**

  If NO:

  - Should they be taken into account? **YES** **NO**
  - Who should do this?

  If YES:

  - What source is taken as the basis (Intergovernmental Panel on Climate Change, French national study, regional study, other)?

- How is current or future vulnerability assessed?
  - damage to human life
  - damage to buildings, equipment, facilities, infrastructure
  - operating losses
  - civil liability of stakeholders (towards employees, customers, third parties)
  - indirect damage (reputation, opportunity cost)
  - environmental damage
  - damage to heritage.
- Is this "current or future" damage assessed on the basis of:
  - survey(s) of economic stakeholders or of a sample of stakeholders?
  - an econometric model using statistics from the national statistical institute (INSEE), chambers of commerce and industry, insurers or another source?
- Is this damage which could occur now or in the future assessed in euros at 2012 values or using a discount rate?

  What time horizon is used?

  If a discount rate is used, is it:

  - the official rate in France? **YES** **NO**
  - a different rate? If so, which?

- Is the evolution of potential damage as a result of climate change or increased urban population density discussed:

- between public authorities? **YES NO**

If YES, which ones? In what form?

- written consultation
- *ad hoc* or regular meetings
- with economic stakeholders **YES NO**

If YES, are these issues first or also discussed BETWEEN economic stakeholders, as far as you know?

YES NO

- In terms of your organisation, has the prospect of an increased flood risk linked to the possible effects of climate change or increased urban population density led to the adoption of any flood defence objectives relating to:
  - human life **YES NO**
  - damage to property **YES NO**
  - interruptions of service, resilience **YES NO**
  - operating losses **YES NO**
  - environmental damage? **YES NO**
- Are these objectives:
  - quantified **YES NO**
  - subject to a deadline **YES NO**
  - published or known to economic stakeholders? **YES NO**

A.1.c. Self-assessment

- What is your overall assessment of the flood risk and of vulnerability to flooding of the Seine in Île-de-France?

  In terms of probability?
  - in monetary terms (damage)
  - on a subjective scale of 1-10 (1 being the lowest and 10 the highest).
- Has vulnerability (as opposed to exposure) increased or diminished during the past 30 years?
  - If it has increased, explain why:
  - If it has diminished, explain why:
- Are there any economic sectors that are generally more exposed to flooding than others, such as energy, telecommunications, transport or agriculture, for example?

  YES NO
  - ***If YES***, which?

- Do you take economic growth rate into account (GDP, exports, investment, urbanisation, employment) when differentiating between the vulnerability of the various economic sectors?
- Are there any sectors or industries which could suffer unforeseen consequences as a result of flood risk management policy?

  YES **NO**

  - ***If YES***, which?
- Are there any economic sectors where flood damage would have serious consequences for the Seine basin as a whole?

  YES **NO**

  If YES, which?
- Have technological, social or climate changes increased or reduced the vulnerability to flooding of economic stakeholders over the past 20 years (e.g. increased interdependencies of critical infrastructure and of a telecommunications-dependent society)?

  YES **NO**

  Explain:
- Is the economic structure of the flood risk management system in the Seine basin capable of evolving over the next 20 years?

  YES **NO**

  Explain:

A.1.d. The exposure of your own institution:

- To what extent is your own institution exposed to the consequences of major flooding of the Seine and its tributaries?
  - Directly in the geographical area of Île-de-France?

  Explain:
  - Indirectly, as a result of knock-on effects on the rest of the territory within your remit?

  Explain:
- To what extent would an interruption in your services have a domino effect on other public or private institutions or stakeholders, or even on the population in the floodplain?

  Explain:
  - Has this interdependence already been discussed with other stakeholders?

  YES **NO**

  If YES, with whom?

  If NO, why not?

- Is the current or future vulnerability of your institution assessed in terms of:
  - damage to human life
  - damage to buildings, equipment, facilities, infrastructure
  - loss of tax revenue, payments, income or similar
  - civil, parliamentary, disciplinary liability
  - indirect damage (reputation, opportunity costs)
  - environmental damage
  - loss of heritage?
- What major risk-reduction measures have been taken by your institution?
  - Structural measures?

  Which?
  - Non-structural measures?

  Which?
- What other urgent preventive measures would you like your institution to adopt?
  - 1
  - 2
  - 3
  - 4
  - 5

A.2. Strategic decision making

A.2.a. Roles and responsibilities in the adoption of decisions to reduce socio-economic vulnerability to flooding

- What is/are the role/responsibilities of your organisation in terms of decision making and implementation of strategies to reduce socio-economic vulnerability to flooding?

  Role in strategic decision making (examples):
  - regarding level of acceptable risk
  - structural measures budget
  - non-structural measures budget.

  Responsibilities for implementing strategies (example):
  - Drafting of flood risk prevention plans (PPRIs).
- How does your organisation co-ordinate and communicate with other organisations having responsibilities in this field?

Meetings:

- public consultations
- consultations with experts or stakeholders
- other.

A.2.b. The decision-making process

- In terms of strategic decisions (such as the level of acceptable risk), is the start of the decision-making process initiated by:
  - own initiative
  - a state order or recommendation
  - consultation with other local or regional authorities
  - other.
- What is the internal decision-making process of your organisation regarding measures to reduce socio-economic vulnerability to flooding?
  - discussions at a meeting
  - office discussions
  - decisions by a head of department
  - other.
- How are objectives fixed in terms of your own institution's remit?
- How does your organisation consult stakeholders concerning measures to reduce vulnerability and increase resilience to flooding?
- At what stage, if any, are the costs, benefits and risks associated with alternative vulnerability reduction measures taken into account?
- How are financial resources allocated to support measures for flood risk and vulnerability assessment?
- In your opinion, are there any problems regarding the dividing lines between the responsibilities of the various stakeholders?

YES **NO**

If YES, is this due to:

- inadequate regulatory framework
- too many regulatory instruments
- other.

A.3. Framework conditions

A.3.a. Land-use policy in the Seine basin

Describe the role and responsibilities of your organisation in designing and implementing land-use policies with a view to improving resilience to flooding.

Roles:

Responsibilities:

- What land-use criteria do you employ in relation to flood risk and socio-economic vulnerability?
- Is there any inspection mechanism to ensure compliance with land-use policies?

  YES **NO**

  - **If YES**, how many economic stakeholders have been ordered to re-locate their premises due to non-compliant use in the past 20 years?
- Do you think that more non-compliant premises should be re-located in the future?

A.3.b. Self-assessment

- Have recent changes in the regulatory framework had any visible effects in your area of responsibility?

  YES **NO**

  Specify:
- Have the objectives of these changes been achieved?
- Have there been any unexpected effects?

A.4. Flood protection in the Seine basin

A.4.a. Structural flood-defence policies (channels, dams, reservoirs, flood storage areas)

Describe the roles and responsibilities of your organisation in designing and implementing structural defence systems to prevent major flooding.

Roles:

Responsibilities:

- Describe the resources allocated by your organisation to performing such a role in this field. To back up your response, please provide organisational charts, statistics, activity reports and any other information you think would be useful.
- Do decisions to invest in structural defences take the possible consequences of climate change into account?
- Describe the extent to which non-structural flood-protection policies can replace structural measures:

A.4.b. Self-assessment

- Are structural flood-prevention measures sufficient in Île-de-France in the light of land-use changes?

  YES **NO**

  Explain:

- What effects, if any, has that had on the design and type of flood-prevention measures (for example, strengthening of structural or non-structural measures)?

A.5. Information concerning flooding

A.5.a. Increasing the awareness of citizens and socio-economic stakeholders

- Are citizens and socio-economic stakeholders sufficiently aware of the exposure of their activities to flooding?

  YES **NO**

- Are there any surveys which measure the extent of information, awareness and reactivity?

  YES **NO**

  - Are these surveys undertaken regularly? **YES** **NO**
  - ***If YES***, when was the last one?
  - When will the next one be?

- Describe the roles and responsibilities of your organisation in terms of increasing the awareness of citizens and socio-economic stakeholders regarding the risk of major flooding.

Roles:

Responsibilities:

- Describe how your organisation is structured and the resources that it assigns to fulfilling this role. In support of your response, please supply organisational charts, statistics, activity reports and any other information that you think would be useful.
- Who are the main state, regional and local authority players who co-operate with your organisation in terms of raising the awareness of citizens and socio-economic stakeholders regarding their vulnerability to flooding?
- Please describe how co-ordination and co-operation takes place. For example:
  - meetings
  - public consultations
  - consultations with experts and stakeholders
  - other.

A.5.c. Self-assessment

- What is your overall assessment of the awareness of citizens and socio-economic stakeholders in the Seine basin in Île-de-France in the case of major flooding?

- Has the level of awareness increased or decreased over the past 20 years?

A.6. Accelerated resumption of activities

A.6.a. Mitigating the effects of catastrophes

- Describe the efforts of your organisation to encourage the development of business continuity plans between:
  - small and medium-sized enterprises
  - large companies
  - infrastructure network operators
  - administrations.
- Describe policy tools (legal, tax, public awareness incentives, other) used to increase the resilience of economic activities to the consequences of flooding.
- Does your organisation discuss emergency plans with infrastructure network operators and other economic stakeholders?

  YES **NO**

  - ***If YES***, does it organise information exchange forums or meetings on a regular basis?
  - Other forms of consultation.

A.6.b. Insurance coverage in the event of catastrophic flooding

- To the best of your knowledge, is there a problem obtaining insurance against major flood risks for:
  - large enterprises
  - infrastructure operators
  - small and medium-sized enterprises.
- To the best of your knowledge, what is the penetration rate of flood insurance in enterprises?
- Are there any policies to encourage flood insurance coverage aimed at small and medium-sized enterprises?

  YES **NO**

  - ***If YES***, what are they?

A.6.c. Reconstruction and compensation of flood victims

- Among the measures to reconstruct and compensate economic stakeholders following flood damage that is declared to be a "natural catastrophe", are there any regional or local programmes geared to specific economic sectors? For example, agriculture?

  YES **NO**

  - other.

- What share of total reconstruction costs is paid by economic stakeholders and what share is paid by the state?

A.6.d. Self-assessment

- Do you consider that the existing system of assistance in the Seine basin is capable of supporting the recovery of economic activities?
- In your opinion, does the compensation system favour certain economic sectors?

  YES **NO**

  - ***If YES***, which?
- Has the system of compensation changed over the past ten years? What changes would need to be made to the system to provide compensation for the damage forecast for the next 20 years?

Questionnaire B for economic stakeholders and network operators

B.1. Exposure and vulnerability to flooding from the Seine and its tributaries

B.1.a General

- What economic activity does you organisation pursue?
  - NAF [French Nomenclature of Activities] code (if possible)
- Are your activities located in an area liable to flooding, according to the flood hazard map in the flood risk prevention plan (PPRI) for your municipality?
- Are your activities located in a grid fragility area in the case of flooding, according to the electric grid fragility map at the prefecture of police?
- Has your organisation already estimated potential economic losses linked to major flooding in terms of:
  - damage to premises, equipment and stocks
  - loss of productivity
  - downtime
  - loss of sustainable markets (diminished goodwill)
  - impact on sub- or co-contractors?
- Please supply a detailed description (including maps) of:
  - the degree of exposure to flooding of your premises
  - past flooding events which have affected the area where your premises are located.
- How is your organisation affected by flooding in neighbouring municipalities?
  - reduced productivity
  - absenteeism
  - other.

- Would the duration of the disruption affect the chances of survival of your enterprise after:
  - one week's disruption
  - two to three weeks' disruption
  - four weeks' to three months' disruption
  - no effect regardless of the duration.

  Specify:
- What infrastructure networks would cause the most disruption to your activity if service was interrupted? (In the case of several answers, please rank in decreasing order of disruption.)
  - electricity
  - water
  - transport of goods
  - transport of persons
  - telecommunications
  - financial transactions
  - other, please specify
  - none.
- To what extent do managers and staff in your enterprise feel "informed and involved", in your view, regarding the possibility of major flooding of the Seine and its tributaries?
  - very "informed and involved"
  - adequately "informed and involved"
  - not very "informed and involved"
  - poorly "informed and involved"
  - no opinion.
- Are there any measures, among those you have described, which reflect a statutory obligation?
- Other action: (for example: layout of buildings, redundancy of certain systems or equipment)
- What organisational structure has been put in place in response to these responsibilities?
  - Are they sub-contracted out?
- Can you supply information on the resources assigned to performing these actions (annual budget) and on investment over the next 20 years?
- What government incentives has your organisation received to invest in measures to mitigate the effects of flooding?
- What are the main difficulties encountered by your organisation when undertaking activities to protect against and prevent damage linked to flooding?

- What are the causes of these difficulties?
- What measures have been taken to inform the staff of your organisation about the risk of major flooding and to train them on how to act in an emergency?

B.2. Relations with the administrative authorities in the Seine River basin

- With which public authorities does your organisation mostly co-operate with a view to reducing its vulnerability to flooding?
- For each authority mentioned, how are responsibilities shared between it and your own organisation?
- Are organisations such as yours able to participate actively in formulating flood risk management policies, and in particular in responding to the issue of the acceptable level of risk?

YES **NO**

Specify:

- Does your organisation take part in flood simulation, evacuation and rescue exercises? If so, please describe them.

B.3. Overall self-assessment

- What is your overall assessment of the effectiveness of regulatory measures adopted with a view to reducing the vulnerability to flooding of economic stakeholders in the Seine basin in Île-de-France?
  - excellent
  - highly satisfactory
  - fairly satisfactory
  - not very satisfactory
  - highly unsatisfactory.
- Could these policies have unforeseen negative consequences for the activity of your organisation?

YES **NO**

Please explain your answer:

- In your view, how is your organisation's vulnerability to flooding likely to change over the next ten years?
- Do you think that climate change is likely to increase or reduce the vulnerability of your organisation's activities to flooding or to a lack of water during periods of drought?
  - increase
  - reduce.
- Is there an ongoing process in your organisation which analyses vulnerability to flooding?

Annex C

A Dynamic General Equilibrium model to analyse the effects of Seine flooding

To evaluate the macroeconomic impact of a flood in the Paris region, a dynamic general equilibrium model, including both private and public capital, was developed and calibrated to the French economy. Flooding is modelled as a shock, destroying parts of capital stocks and reducing business turnover.

Model setup

Representative household

The representative household derives utility from consuming and having leisure. Consistent with balanced growth, their preferences are given by $\log(C_t) + \nu \log(1 - N_t)$. They discount the future using a factor β. Taking as given interest rates (r^g on government debt and r^p on private debt), wages (w), taxes (τ) and firms' profits (Π), which are distributed as a lump-sum to the households owning the firm, the representative household decides how much to consume (C) and work (N) as well as how much to save in government bonds (S^g) and private corporate bonds (S^p). They solve the following maximisation programme:

$$\max_{\{C_t, N_t, S_t^g, S_t^p\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t (\log(C_t) + \nu \log(1 - N_t))$$

$$s.t. \; C_t + S_t^g + S_t^p = (1 - \tau_t)(w_t N_t + \Pi_t + (1 + r_{t-1}^g) S_{t-1}^g + (1 + r_{t-1}^p) S_{t-1}^p$$

which has the following first-order conditions:

$$1 - N_t = \frac{\nu C_t}{(1 - \tau_t) w_t} \tag{1}$$

$$\frac{1}{C_t} = \beta (1 + r_t^g)(1 - \tau_{t+1}) \frac{1}{C_{t+1}} \tag{2}$$

$$\frac{1}{C_t} = \beta (1 + r_t^p)(1 - \tau_{t+1}) \frac{1}{C_{t+1}} \tag{3}$$

$$C_t + S_t^g + S_t^p = (1 - \tau_t)(w_t N_t + \Pi_t + (1 + r_{t-1}^g) S_{t-1}^g + (1 + r_{t-1}^p) S_{t-1}^p) \tag{4}$$

Equation (1) is the intratemporal condition for the optimal mix of consumption and leisure. Equations (2) and (3) are intertemporal optimality conditions relating future to

current consumption; for both government and corporate bonds to be traded in equilibrium, they require $r_t^g = r_t^p = r_t$. Then the household is indifferent between the two bonds and is only concerned about the total amount of savings $S_t = S_t^g + S_t^p$. The household optimality conditions in this case become:

$$1 - N_t = \frac{vC_t}{(1-\tau_t)w_t} \tag{5}$$

$$\frac{1}{C_t} = \beta(1+r_t)(1-\tau_{t+1})\frac{1}{C_{t+1}} \tag{6}$$

$$C_t + S_t = (1-\tau_t)(w_t N_t + \Pi_t + (1+r_{t-1})S_{t-1}) \tag{7}$$

Representative firm

Following Baxter and King's (1993) seminal work, we assume that output (Y) is produced using public capital (X), private capital (K) and labour (N) according to a Cobb-Douglas technology that exhibits constant returns to scale in the private inputs, private capital and labour:

$$Y_t = A_t X_{t-1}^{\Theta} K_{t-1}^{\alpha} N_t^{1-\alpha} \tag{8}$$

where A_t is a productivity parameter. The subscripts on the public and private capital stock are $t-1$ since in period t only capital that has been build up previously can be utilised for production. Both types of capital depreciate each period at a rate δ.

The representative firm maximises an infinite stream of cash flows, using the households' discount factor Q_t (since the households' are the shareholders). They take interest rates and wages as given, and can borrow by issuing private corporate bonds (B^p) to invest in their capital stock ($I_t^p = K_t + (1-\delta)K_{t-1}$).[1] But as in Kiyotaki and Moore (1997), due to asymmetric information in the capital markets, they can only borrow against collateral, for which they can use up to fraction $\varphi<1$ of their capital stock. The borrowing constraint is therefore $B_t^p \leq \varphi K_t$.

A firm that has outstanding debt B_{t-1}^p and starts the period with existing capital stock $(1-\delta)K_{t-1}$ solves the following equation:

$$\max_{\{K_t, N_t, B_t^p\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} Q_t\left(A_t X_{t-1}^{\theta} K_{t-1}^{\alpha} N_t^{1-\alpha} - w_t N_t - K_t + (1-\delta)K_{t-1} + B_t^p - (1+r_{t-1})B_{t-1}^p\right)$$

$$s.t.\ B_t^p \leq \varphi K_t$$

Assuming that firms' borrowing constraints bind in all periods, and hence $B_t^g = \varphi K_t$ and $\mu_t > 0$, the firm's optimal behaviour is characterised by:

$$1-\varphi = \frac{Q_{t+1}}{Q_t}\left(\alpha A_t X_{t-1}^{\Theta} K_{t-1}^{\alpha-1} N_t^{1-\alpha} + 1 - \delta - \varphi(1+r_t)\right) \tag{9}$$

$$N_t = \left(\frac{(1-\alpha) A_t X_{t-1}^{\Theta} K_{t-1}^{\alpha}}{w_t}\right)^{\frac{1}{\alpha}} \tag{10}$$

where the first equation pins down the optimal investment into the next period's capital stock and the second equation's firms' labour demand. Notice that the first term in the parenthesis in the optimality condition for private investment (equation 9) is private capital's marginal product. It is increasing in public capital due to complementarities in production. Likewise, the optimality condition indicates that there are complementarities between both types of capital and labour.

Profits in period t, which flow back to the households, are:

$$\Pi_t = A_t X_{t-1}^{\Theta} K_{t-1}^{\alpha} N_t^{1-\alpha} - w_t N_t - (1-\varphi) K_t + (1-\delta-\varphi(1+r_{t-1})) K_{t-1} \tag{11}$$

Note that given preferences, in equilibrium the household's discount factor between periods t and $t+1$ is given by $\frac{Q_{t+1}}{Q_t} = \beta \frac{C_t}{C_{t+1}} \frac{1-\tau_{t+1}}{1-\tau_t}$, since the household is indifferent between receiving a dividend (before taxes) of 1 in period t or of $\frac{C_t}{C_{t+1}} \frac{1-\tau_{t+1}}{1-\tau_t}$ in $t+1$. Moreover, since taxes and consumption are constant in steady state, firm's are discounting their future profits with the household's discount factor β.[2]

Steady state conditional on government policies

The government invests in the public capital stock (X), levies income taxes (τ) and issues government bonds B^g. The government's budget constraint in period t is therefore given by:

$$B_t^g + \tau_t(w_t N_t + \Pi_t + (1+r_{t-1}) S_{t-1}) = (1+r_{t-1}) B_{t-1}^g + X_t - (1-\delta) X_{t-1} \tag{12}$$

The market clearing condition for the bond market is:

$$S_t = B_t^g + B_t^p = B_t^g + \varphi K_t \tag{13}$$

The economy is summarised by equations (5, 6, 7, 9, 10, 11). In steady state, with constant policies all variables are constant, the government budget (12) and the behaviour of the household's and firm and are summarised by:

$$\tau(wN + \Pi + (1+r)S) = rB^g + \delta X \tag{14}$$

$$1 - N = \frac{\nu C}{(1-\tau)w} \tag{15}$$

$$1+r = \frac{1}{\beta(1-\tau)} \tag{16}$$

$$C+S = (1-\tau)(wN+\Pi+(1+r)S) \tag{17}$$

$$1-\varphi = \beta\left(\alpha A X^{\Theta} K^{\alpha-1} N^{1-\alpha}+1-\delta-\varphi(1+r)\right) \tag{18}$$

$$N = \left(\frac{(1-\alpha)AX^{\Theta}K^{\alpha}}{w}\right)^{\frac{1}{\alpha}} \tag{19}$$

$$\Pi = AX^{\Theta}K^{\alpha}N^{1-\alpha}-wN-(\delta+\varphi r)K \tag{20}$$

$$S = B^{g}+\varphi K \tag{21}$$

As shown in Annex D, conditional on government policies, this system of equations can be solved for the steady state values of capital, consumption and employment, which yields:

$$K = \frac{\frac{(1-\alpha)\left(\alpha\beta AX^{\Theta}\right)^{\frac{1}{1-\alpha}}}{d^{\frac{\alpha}{1-\alpha}}} - \frac{\alpha\beta\nu}{1-\tau}(r-\tau-\tau r)B^{g}}{(1+\nu-\alpha)d-\alpha\beta\nu\left(\frac{\tau}{1-\tau}\varphi+\delta\right)} \tag{22}$$

$$C = \frac{(1-\tau)(1-\alpha)}{\nu\alpha\beta d^{\frac{\alpha}{1-\alpha}}} \frac{\left(\alpha\beta AX^{\Theta}\right)^{\frac{1}{1-\alpha}} (\nu d-\alpha\beta\nu\left(\frac{\tau}{1-\tau}\varphi+\delta\right))+d^{\frac{1}{1-\alpha}}\frac{\alpha\beta\nu}{1-\tau}(r-\tau-\tau r)B^{g}}{(1+\nu-\alpha)d-\alpha\beta\nu\left(\frac{\tau}{1-\tau}\varphi+\delta\right)} \tag{23}$$

$$N = \frac{(1-\alpha)d-d^{\frac{1}{1-\alpha}}\frac{\alpha\beta\nu}{1-\tau}(r-\tau-\tau r)B^{g}\left(\alpha\beta AX^{\Theta}\right)^{\frac{-1}{1-\alpha}}}{(1+\nu-\alpha)d-\alpha\beta\nu\left(\frac{\tau}{1-\tau}\varphi+\delta\right)} \tag{24}$$

Where:

$$d = (1-\varphi+\beta(\varphi(1+r)-1+\delta))$$

Government

Public policies are chosen to maximise the welfare of the representative consumer, taking into account the effect of these policies on the economy, i.e. by taking into account how private firms and households react to policy changes.

A truly benevolent government's maximisation problem should be to choose $\{X_t, \tau_t, B_t^p\}_{t=0}^{\infty}$ in order to *max* $(\log(C_t)+\nu\log(1-N_t))$ subject to the government's budget constraint (12) and equations (1) to (11), which describe the economy in each period. This optimisation problem, however, is not tractable.[3] Instead, it is assumed that the government solves:

$$\max_{\{X,\tau,B^g\}^{\infty}} (\log(C\ \ ) + \nu\log(1-N\ \ ))$$

subject to the government's budget constraint (12) and equations (15) to (24), which describe the response of the economy if it was in a steady state in each period.[4]

As can be seen from equations (23) and (24), steady state consumption and employment depend on fiscal policies, i.e. $C(\tau,X,B^g)$ and $N(\tau,X,B^g)$. After substituting out the government budget constraint, the maximisation problem is to choose $\{X,\tau\}$ to $max(\log(C\ \ ) + \nu\log(1-N\ \ ))$, and the first order conditions for X and τ are:

$$\frac{1}{C(X,\tau)}\frac{dC}{dX} = \frac{\nu}{1-N(X,\tau)}\frac{dN}{dX} \tag{25}$$

$$\frac{1}{C(X,\tau)}\frac{dC}{d\tau} = \frac{\nu}{1-N(X,\tau)}\frac{dN}{d\tau} \tag{26}$$

An expression for these first-order conditions is shown in Annex D.

Calibration

The model is calibrated to the French economy on a quarterly frequency. The year 2010 is treated as a steady state in the absence of a shock.

As standard in the literature, following Hansen (1985), the elasticity of output with respect to private capital is set to α=0.36. This value is also consistent with recent estimates for the production function in the euro area by Willman (2002). Commissioned by the French government, the Lebègue Report (Baumstark, 2005) suggests the use of an annual discount rate of 4%.

Since the model is at quarterly frequency, the model's discount factor is set to $\beta=\left(\frac{1}{1+0.04}\right)^{1/4}=0.9902$.

There is no consensus in the literature on the depreciation rate of capital,[5] but a wide range of estimates for developed economies, from around 4% (e.g. Hansen, 1985) to 15% or higher (e.g. Piketty, 2013) per year. As a baseline, the depreciation rate is therefore set to a mid-range value suggested by INSEE and referenced in Smets and Wouters (2007), implying at quarterly frequency δ=0.025.

Parameters, including the depreciation rate and the discount factor, are subject to sensitivity analysis to show how the model results change with these parameter values.

The remaining parameters are Θ, ν, and φ, which are chosen to match private capital, public capital and public finances of the French economy as of 2010.

The parameter Θ is the elasticity of output with respect to public capital. To the extent that public investment takes into account how it affects production and GDP, the observed public investment is informative about this parameter.

The parameter ν is a preference parameter capturing the households' disutility from working compared to utility from consumption. As capital and labour are complements in production, changes in employment also affect private capital. Hence the ratio of private capital to GDP in France is informative about this preference parameter of French households.

The last parameter, φ, describes how tight borrowing constraints are for French firms. As lenders can split their financial wealth between lending to firms or the government, but firms' ability to borrow is limited by this constraint, in equilibrium the part of savings that is not lent to firms will go to the government. Hence, the observed government fiscal position is also informative about parameter φ.

While these parameters are clearly calibrated jointly, intuitively Θ is chosen to match investment into public capital, φ to match taxes levied on production activities, and ν is chosen to replicate the private capital to output ratio (see equation 22).

From OECD.Stat Dataset: 9A. "Fixed assets by activity and by asset, ISIC rev4", the private and public capital stock in 2010 are calculated to be EUR 7 482 462.235 million and EUR 2 098 771.215 million (2010 prices).[6] From OECD.Stat Dataset: 14A. "Non-financial accounts by sectors" taxes on production activities are calculated to be 25.68% of GDP.

Table C.1 lists all model parameters and their calibrated values.

Table C.1. **Calibrated parameters**

	Parameter	Value	Source/target
α	Elasticity of output w.r.t private capital	0.36	Hansen (1985)
Θ	Elasticity of output w.r.t public capital	0.2311	To match *X*/*Y*=.5994
β	Households' discount factor	0.9902	Lebègue Report (2005)
ν	Preference for leisure	0.7735	To match *K*/*Y*=2.137
δ	Depreciation rate of capital	0.0250	Smets and Wouters (2007)
φ	Tightness of entrepreneurs' borrowing constraint	0.3828	τ=0.2569
A	Total factor productivity	1	Normalisation

Results

The economy is simulated, starting in steady state, and experiencing flooding at the beginning of the first quarter. The interest rate is taken exogenously (at its steady state level) to reflect the fact that within the euro area interest rates are equalised.

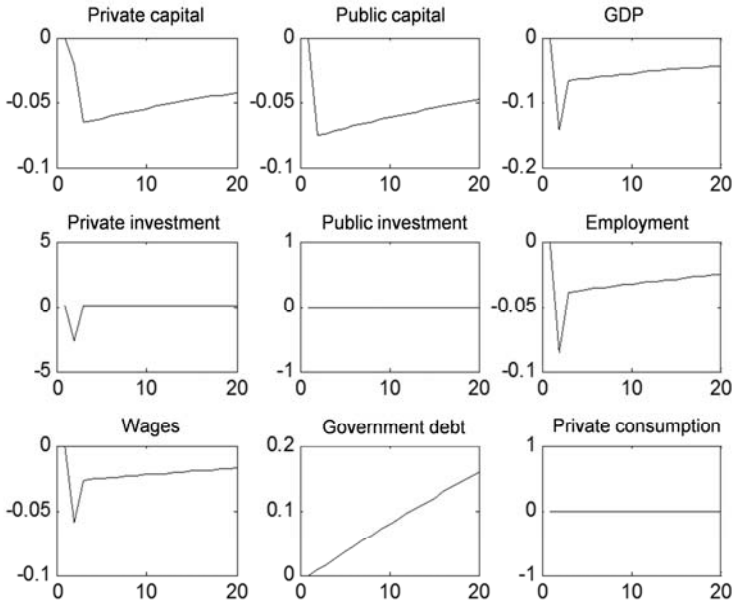
In the first set of simulations, as a benchmark, it is assumed that after the flooding there is no change in fiscal policies. Investment in public capital is therefore as in steady state given by δXss. Since after the shock Xt<Xss, this public investment is higher than break-even investment, i.e. the investment that would be needed to keep capital constant at its current value (δXt). As a consequence, even in the absence of a change in fiscal policies, public capital grows over time, albeit very slowly as there is no additional investment following the destruction caused by the flooding.

In the second set of simulations, it is assumed that public investment responds after the flooding, and as a consequence the economy recovers much quicker.

Results under constant fiscal policies

Figure C.1 shows for scenario 1 the evolution of key variables after the flooding if there was no change in fiscal policies. The graph shows how the variables differ in percentage terms to their initial value, i.e. the value before the flood shock disturbed the economy. The horizontal axis is time, measured in quarters. Period 0 is the economy's initial steady state in the absence of a shock. At the beginning of period 1, the flooding shock occurs; afterwards the economy converges gradually over time to a steady state. Since none of the shocks are permanent, the economy will eventually fully recover.

Figure C.1. **Scenario 1: Constant fiscal policies**



In period 1, when the shock hits, both a part of private and public capital is destroyed, and as a consequence, GDP drops immediately. Since capital and labour are complements in production, employment and wages also fall.[7] As the government's tax revenue falls along with the reduction in economic activity (the tax rate is in this simulation assumed to be constant) but its spending on investment in public capital remains unchanged (again assumed here), government debt rises.

On impact, quarterly GDP drops by 0.15% and employment by 0.09%. In subsequent periods, as more and more capital is rebuilt, the effects weaken and wages recover. Therefore, the substitution effect of lower wages weakens, leading to a rise in labour supply and employment during the recovery, which contributes to the recovery in GDP.

To simulate the different scenarios, shocks to private and public capital stocks are introduced that destroy a fraction (s^K,s^X) at the beginning of period 1. In addition, to model the turnover reduction, a shock to A is introduced (s^A). Based on an initial annual

turnover of EUR 3 596.4 billion. Table C.2 shows the values of these shocks for the different scenarios.

Table C.2. **Calibration of shocks**

	S1	S2	S3A	S3B
Destruction of capital stock				
Destruction of private capital (EUR billions)	1.53	8.56	14.98	14.98
s^K	-0.020%	-0.114%	-0.200%	-0.200%
Destruction of public capital (EUR billions)	1.6	4.67	14.03	14.03
s^X	-0.110%	-0.230%	-0.573%	-0.573%
Turnover reduction				
Persistent due to SME bankruptcy: Year 1			1.25	3.00
Year 2			0.60	1.50
Year 3			0.30	0.70
Year 4			0.00	0.00
Temporary: Business interruption: Quarter 1	0.58	5.67	12.33	12.33
Quarter 2				2.69
Quarter 3				0.98
s^A in quarter 1	-0.065%	-0.631%	-1.406%	-1.455%
s^A in quarter 2	-0.065%	0.000%	-0.035%	-0.383%
s^A in quarter 3	0.000%	0.000%	-0.035%	-0.192%
s^A in quarter 4	0.000%	0.000%	-0.035%	-0.083%
s^A in quarters 5-8	0.000%	0.000%	-0.017%	-0.042%
s^A in quarters 9-12	0.000%	0.000%	-0.008%	-0.019%

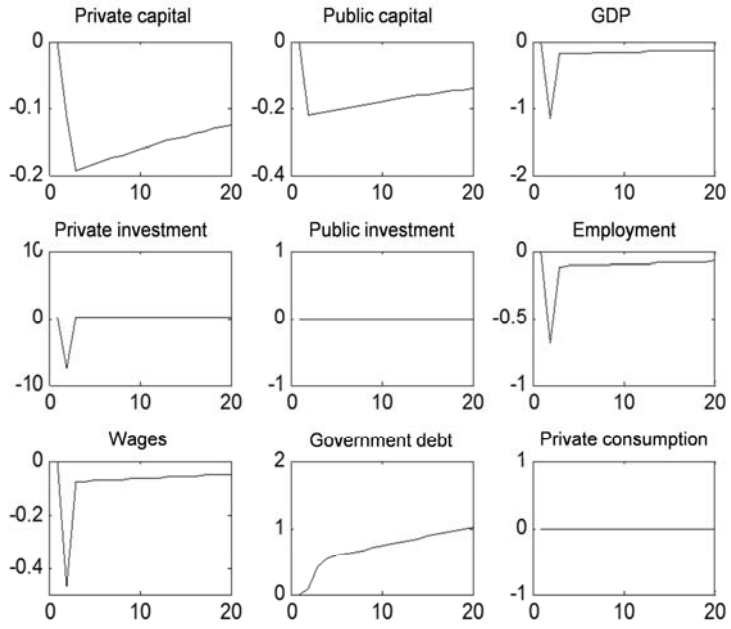
After the flooding, reserves on reconstruction are drawn up, which are introduced into the model as a transfer from the government to firms. Table C.3 summarises these payments, expressed relative to the initial quarterly GDP. Consistent with the CATNAT system's requirement of reimbursements no later than three months after the claim, it is assumed in the simulations that damages in quarter 1 will be reimbursed in quarters 2 (at 75%) and 3 (25%) and damages in quarter 2 will be reimbursed in quarters 3 (75%) and 4 (25%). These reimbursements might increase government debt after the reserves of EUR 5.7 billion are exhausted.

Table C.3. **Calibration of reconstruction reserves**

	S1	S2	S3A	S3B
Private capital	0.266%	1.634%	2.883%	2.883%
1st quarter turnover	0.019%	0.343%	0.667%	0.667%
2nd quarter turnover	0.000%	0.000%	0.000%	0.151%

Figure C.2 plots the transition of the economy when flood scenario 2 occurs in period 1, assuming no change in fiscal policies. Qualitatively, the response of the economy is very similar to scenario 1. However, since the shock is more severe, and more private and public capital is destroyed and the drop in business turnover is higher in the quarter of the flooding, GDP and employment fall by more than in scenario 1. In scenario 2, the contemporaneous reduction in quarterly GDP is 1.16% and in employment 0.69%.

Figure C.2. **Scenario 2: Constant fiscal policies**



In both variants of scenario 3 it is assumed that the flooding leads to a more persistent reduction of turnover due to the exit of some small and medium-sized enterprises. For this reason, the economy of scenario 3 will recover slower than in the previous scenarios. As in scenarios 1 and 2, when the shock hits, some private and public capital are destroyed, and therefore employment, wages, GDP, tax revenue and private consumption fall immediately. Because of the assumed more persistent reduction in business turnover, private investment and therefore production recover slowly. But also in this case, private consumption is unaffected as households can smooth the persistent, but nonetheless temporary, reduction in national income over their infinite planning horizon.

The difference between variant A and variant B of scenario 3 is in the magnitude and persistence of the additional reduction in business turnover. In variant A this additional reduction is much more short-lived than in variant B, and as a consequence private investment and the aggregate economy recover faster in variant A. Since capital and labour are complements in production, employment and wages follow the pattern of private capital and pick up later in variant 3B than in variant 3A. For the quarter in which the flooding occurs, the calibrated model predicts a drop in GDP by 2.62% in variant A and by 2.70% in variant B. Similarly, the contemporaneous fall in employment is predicted to be 1.57% in variant A and 1.62% in variant B.

Summary of the macroeconomic effects under constant policies

The calibrated dynamic general equilibrium model of the French macroeconomy predicts in all scenarios that the destruction of private and public capital along with the turnover reduction due to the flooding leads to an immediate reduction of GDP and employment in the quarter of the flooding, ranging from a drop of 0.15% in GDP and 0.09% in employment in the best case (scenario 1) to 2.7% for GDP and 1.6% for employment in the worst case (scenario 3B).

Figure C.3. **Scenario 3A: Constant fiscal policies**

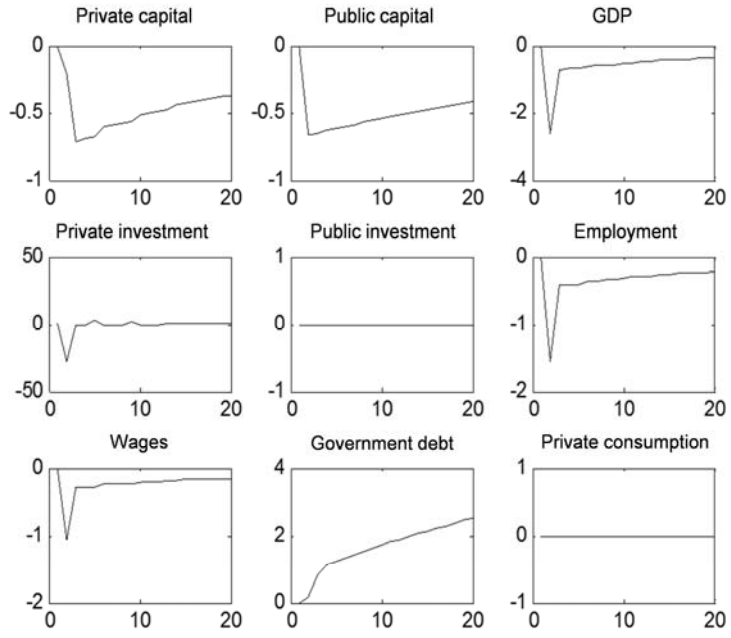
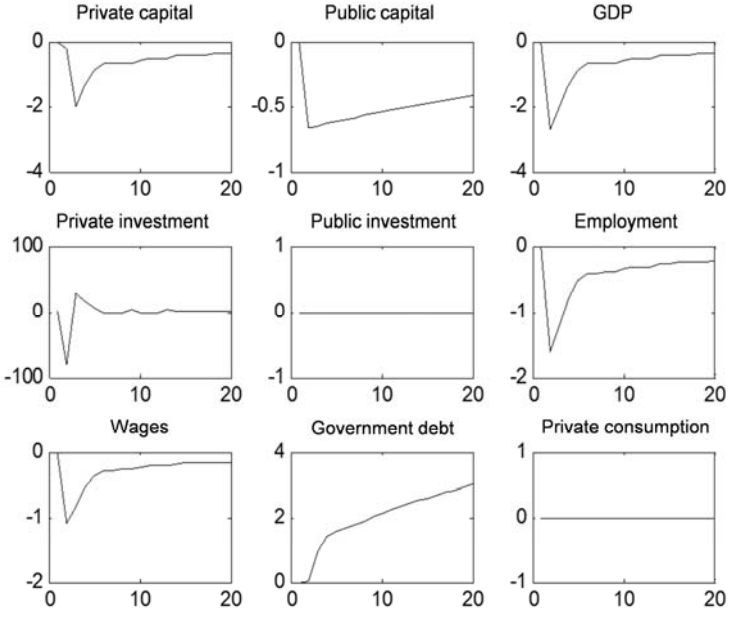


Figure C.4. **Scenario 3B: Constant fiscal policies**



Since the tax base falls with the reduction of economic activity, the model also predicts an immediate rise in government debt between 0.008% (scenario 1) and 0.16% (scenario 3). In subsequent quarters, government debt continues to rise, as reserves from

the CATNAT system are drawn up to finance reconstruction and the tax base remains below its initial level, assuming no change in fiscal policies.

The speed of the recovery varies across the scenarios, with scenario 3 seeing a rather slow recovery due to the persistent reduction in business turnover caused by the exit of small and medium-sized enterprises.

Table C.4 summarises at a yearly frequency the consolidated effects over five years on the GDP, employment and government debt for the different scenarios. The effects on GDP and employment are shown as the yearly average percentage deviation to the value before the flooding; the effect on government debt is shown as the percentage increase in the stock of debt relative to its initial value.

Table C.4. **The consolidated effects under constant policies**

In percentage

Year	Scenario 1			Scenario 2			Scenario 3A			Scenario 3B		
	GDP	Empl	Gov debt	GDP	Empl	Gov debt	GDP	Empl	Gov debt	GDP	Empl	Gov debt
1	-0.084	-0.050	0.035	-0.432	-0.257	0.578	-1.180	-0.705	1.238	-1.729	-1.034	1.562
2	-0.059	-0.035	0.071	-0.172	-0.102	0.701	-0.582	-0.346	1.624	-0.678	-0.403	2.020
3	-0.053	-0.031	0.104	-0.156	-0.092	0.820	-0.498	-0.296	1.977	-0.540	-0.321	2.417
4	-0.048	-0.028	0.136	-0.141	-0.084	0.935	-0.422	-0.251	2.298	-0.422	-0.251	2.755
5	-0.043	-0.026	0.166	-0.127	-0.076	1.046	-0.381	-0.227	2.609	-0.381	-0.227	3.084

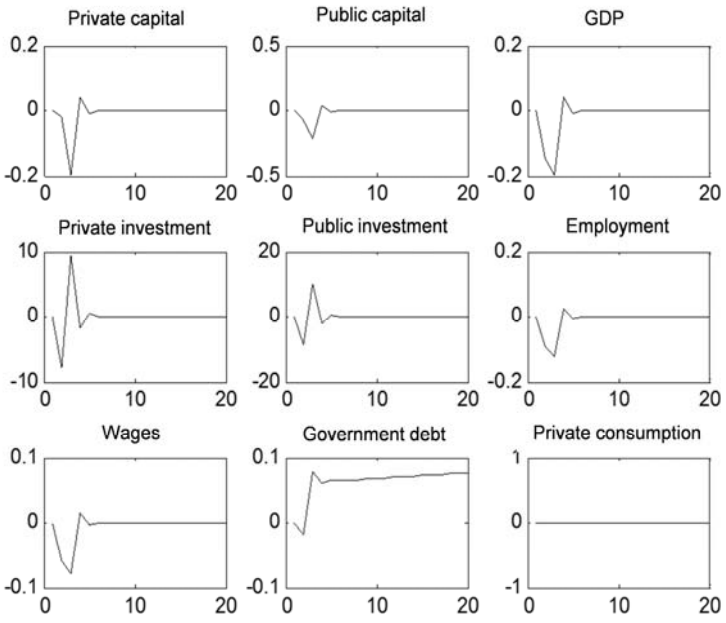
Results when public investment reacts to the shock

The previous section analysed the transition path of the economy assuming no change in fiscal policies. However, since not only the private sector is affected by the flooding, but part of the public capital is also destroyed, there might be a change in public investment following the shock. This section therefore analyses the transition path of the economy assuming that public investment is adjusted according to the optimality condition (25). Figures C.5 to C.8 show the response of the economy to the flooding taking into account how public investment is predicted to change.

Taking into account the change in public investment, Figure C.5 shows the response of the economy in scenario 1.

Upon impact, quarterly GDP and employment fall by 0.15% and 0.09%, which is about the same as in Figure C.1. However, in subsequent periods, the economy behaves differently. In the quarter following the flooding, public investment picks up in order to rebuild the capital stock quickly. As this increases the marginal product of private capital, private investment then increases by more than before. As a consequence, both capital stocks revert more quickly to their steady state values. Since labour is complementary to both, employment and wages also return to their steady state values more quickly. Government debt, however, rises more in the short run compared to the situation of constant fiscal policies. This is to finance the additional public investment that would allow the reconstruction of the public capital stock. In the long run, however, public debt rises in this case by less since the economy, and therefore tax revenue, recover faster.

Figure C.5. **Scenario 1: Assuming change in public investment**



Similarly for scenario 2, when public investment reacts to the flooding, quarterly GDP falls by 1.18% and employment by 0.72%, but compared to the case of constant fiscal policies, the recovery is much faster, as shown in Figure C.6.

In scenario 3, on impact GDP and employment fall by 2.66% and 1.63% in variant A, or 2.74% and 1.68% in variant B. In all scenarios, the policy response entails a cut of public investment during the period of shock, since during that period resources are scarce, turnover reduced and employment below its steady state level. In the quarter following the flooding, however, there is a large increase in public investment in order to restore public capital quickly. As a result, public capital as well as private capital, whose marginal productivity depends positively on public capital, recover fast. Since labour is complementary to both types of capital in production, the path of employment and wages qualitatively follow the same pattern of a faster recovery. While GDP returns much faster to its steady state level when public investment is adjusted according to equation (25), this policy change increases government debt at least in the short run, and in scenario 3B also in the long run.

Figure C.6. **Scenario 2: Assuming change in public investment**

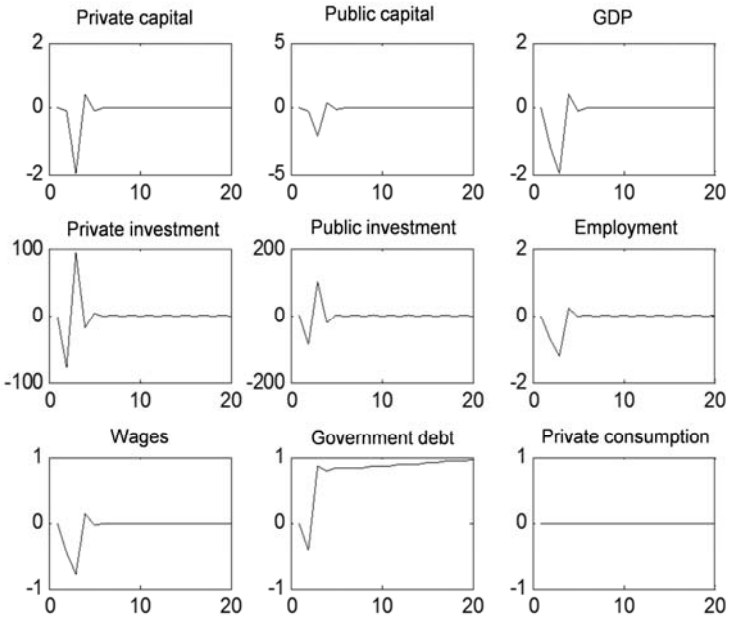


Figure C.7. **Scenario 3A: Assuming change in public investment**

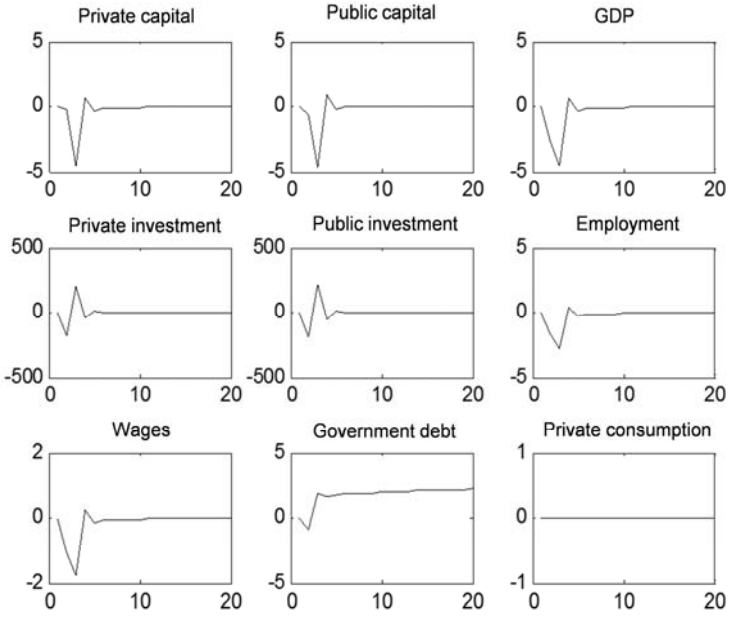
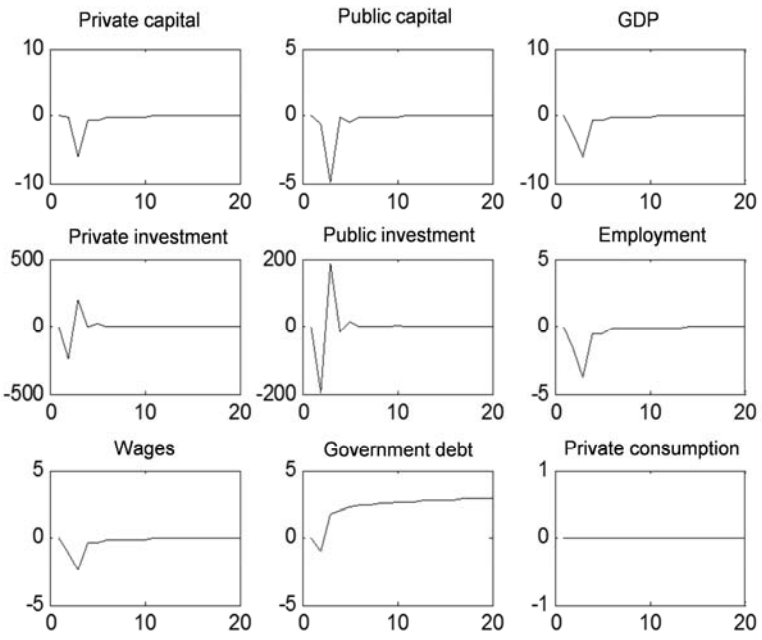


Figure C.8. **Scenario 3B: Assuming change in public investment**



Summary of the macroeconomic effects under optimal public investment

Table C.5 summarises at a yearly frequency the consolidated effects over five years on GDP, employment and government debt for the different scenarios when taking into account the response of public investment. As in Table C.4, the effects on GDP and employment are shown as the yearly average percentage deviation to the value before the flooding and the effect on government debt is shown as the percentage increase in the stock of debt relative to its initial value.

Table C.5. **The consolidated effects under optimal public investment**

In percentage

Year	Scenario 1			Scenario 2			Scenario 3A			Scenario 3B		
	GDP	Empl	Gov debt	GDP	Empl	Gov debt	GDP	Empl	Gov debt	GDP	Empl	Gov debt
1	-0.078	-0.047	0.065	-0.708	-0.433	0.824	-1.730	-1.066	1.803	-2.618	-1.614	2.280
2	0.000	0.000	0.068	0.003	0.002	0.852	-0.107	-0.065	1.941	-0.267	-0.162	2.539
3	0.000	0.000	0.071	0.000	0.000	0.888	-0.054	-0.033	2.060	-0.129	-0.078	2.737
4	0.000	0.000	0.074	0.000	0.000	0.925	-0.004	-0.002	2.152	-0.009	-0.005	2.866
5	0.000	0.000	0.077	0.000	0.000	0.964	0.000	0.000	2.240	0.000	0.000	2.983

Comparing Tables C.4 and C.5 shows that the adjustment in public investment alleviates effects on GDP and employment in subsequent years, but might increase the negative effects in the initial year, as the increase in government investment might crowd out private activity in the short run.

Contribution of each shock (in scenario 3A)

To disentangle the contribution of the three shocks, the economy is simulated, when flooding affects only private capital, public capital or business turnover. Table C.6 summarises the consolidated effects for scenario 3A when public investment responds to the shock.

Table C.6. **Counterfactual scenario 3A: If only one shock**

In percentage

Year	Only private capital			Only public capital			Only turnover		
	GDP	Empl	Gov debt	GDP	Empl	Gov debt	GDP	Empl	Gov debt
1	-0.024	-0.015	0.653	-0.052	-0.032	0.258	-1.66	-1.02	0.84
2	0.000	0.000	0.681	0.000	0.000	0.269	-0.11	-0.06	0.94
3	0.000	0.000	0.710	0.000	0.000	0.280	-0.05	-0.03	1.02
4	0.000	0.000	0.740	0.000	0.000	0.291	0.00	0.00	1.07
5	0.000	0.000	0.772	0.000	0.000	0.303	0.00	0.00	1.12

Comparing the columns of Table C.6 to each other[8] and to the baseline results for scenario 3A in Table C.5 highlights that the reduction in business turnover is by far the most important impact of the flooding on the economy.

Sensitivity analysis

To analyse how robust the numerical results are, a sensitivity analysis is conducted. For different sets of parameter values, the model with optimal public investment is simulated for scenarios 1 and 3A, the two most extreme scenarios. The alternative parameter values considered are for annual discount rate values of 4%, 7%, 10% or 13%, which imply for β at quarterly frequency 0.9902, 0.9832, 0.9765, 0.9699 and 0.9657 respectively. For the depreciation rate δ the alternative values at quarterly frequency are 0.01, 0.018, 0.026, 0.034 and 0.04. Table C.7 shows the implied consolidated effects for combinations of these alternative values.

Comparing Tables C.5 and C.7 shows that the results regarding GDP, employment and government debt are rather robust to these changes in parameter values. Other assumptions of the model are in the specification of preferences. The setup presented here uses log-log-utility in consumption and leisure. This implies an intertemporal elasticity of substitution of 1, which is in this study an innocent assumption, since the interest rate is assumed to be exogenous throughout. Hence, the household does not react to changes of the interest rate but attains steady state consumption in each period. The other elasticity implied by these preferences is a Frisch elasticity of labour supply of unity. The justification for using these preferences is that they are consistent with economic growth, in the sense that a change in an economy's per capita income does not change employment in the long run.

Summary

A dynamic general equilibrium model is utilised to evaluate the macroeconomic impact of flooding in the Paris region. Flooding is introduced into the model as a shock that destroys part of the private and public capital stock, as well as reducing business turnover. Fiscal policies are able to help with the subsequent recovery, but have no scope to alleviate the direct impact of the shock.

Table C.7. **Sensitivity analysis**

	Scenario 1				Scenario 3A		
Year	GDP	Empl	Gov debt		GDP	Empl	Gov debt
			β=0.9902, δ=0.01				
1	-0.074	-0.042	0.048		-1.631	-0.937	1.660
2	0.001	0.000	0.048		-0.086	-0.048	1.751
3	0.000	0.000	0.051		-0.048	-0.027	1.850
4	0.000	0.000	0.053		-0.003	-0.002	1.932
5	0.000	0.000	0.056		0.000	0.000	2.010
			β=0.9832, δ=0.018				
1	-0.079	-0.048	0.069		-1.750	-1.089	1.858
2	0.000	0.000	0.074		-0.109	-0.066	2.059
3	0.000	0.000	0.080		-0.055	-0.034	2.248
4	0.000	0.000	0.086		-0.004	-0.002	2.417
5	0.000	0.000	0.092		0.000	0.000	2.590
			β=0.97645, δ=0.026				
1	-0.080	-0.050	0.074		-1.778	-1.124	1.894
2	0.000	0.000	0.082		-0.113	-0.071	2.165
3	0.000	0.000	0.091		-0.056	-0.035	2.431
4	0.000	0.000	0.100		-0.004	-0.002	2.688
5	0.000	0.000	0.111		0.000	0.000	2.963
			β=0.9699, δ=0.034				
1	-0.081	-0.051	0.076		-1.788	-1.138	1.905
2	0.000	0.000	0.086		-0.116	-0.072	2.240
3	0.000	0.000	0.099		-0.057	-0.036	2.583
4	0.000	0.000	0.112		-0.004	-0.003	2.936
5	0.000	0.000	0.128		0.000	0.000	3.327
			β=0.9657, δ=0.04				
1	-0.081	-0.051	0.077		-1.790	-1.141	1.904
2	0.000	0.000	0.089		-0.116	-0.073	2.280
3	0.000	0.000	0.103		-0.057	-0.036	2.676
4	0.000	0.000	0.120		-0.004	-0.003	3.097
5	0.000	0.000	0.139		0.000	0.000	3.571

Notes

1. Since the return on corporate and government bonds is the same, a firm does not have any incentive to borrow for saving in government debt.
2. This will also be true on the transition path, as it is assumed that taxes and the interest rate remain constant.
3. It is also not clear that in reality governments solve infinite horizon optimisation problems.
4. That is, the derivatives of the equations describing the decentralised equilibrium are taken using the steady state relationship, but evaluated using prices $\{\tau_t, w_t, r_t\}$ of each period.

5. These differences are mainly due to what goods are included in the classification of capital, e.g. durables.

6. Private capital includes fixed assets of the following activities: agriculture, forestry and fishing, mining and quarrying, manufacturing, construction, wholesale and retail trade, repair of motor vehicles and motorcycles, transport and storage (at 50%), accommodation and food service activities, financial and insurance activities, real estate activities, professional, scientific and technical activities; legal, accounting, management, architecture, engineering activities, scientific research and development; other professional, scientific and technical activities; administrative and support service activities, residential care and social work activities, arts, entertainment and recreation, other service activities, activities of households as employers as well as goods and services-producing activities of households for own use. All other fixed assets are classified as public capital.

7. Since also household wealth is reduced by the shock, private consumption also falls (and this income effect implies an increase of labour supply at constant wages). However, due to the constant interest rate, this drop in consumption goes to zero, as households spread the finite drop in household wealth over an infinite time horizon.

8. Most of the increase in government debt when there is only the shock to private capital is due to the state guarantee to reimburse the losses caused by the flooding – excluding these reimbursements, government debt would rise only by 0.04% in year 1 and 0.047% in year 5 if the only shock was to private capital.

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Annex D

Technical annex

Steady state characterisation

To solve the representative firm's optimisation problem we use a Langrean and let the multiplier on the borrowing constraint in period t be μ_t. The Karush-Kuhn-Tucker conditions are then:

$$Q_t(-1+\varphi\mu_t)+Q_{t+1}\left(\alpha A_t X_{t-1}^{\Theta} K_{t-1}^{\alpha-1} N_t^{1-\alpha}+1-\delta\right) = 0$$

$$(1-\alpha)A_t X_{t-1}^{\Theta} K_{t-1}^{\alpha} N_t^{-\alpha} - w_t = 0$$

$$Q_t(1-\mu_t)+Q_{t+1}\left(-(1+r_t)\right) = 0$$

$$\mu_t(\varphi K_t - B_t^g) = 0$$

where the last equation is the comparative slackness condition which requires either $B_t^g=\varphi K_t$ and $\mu_t>0$, or $B_t^g<\varphi K_t$ and $\mu_t=0$.

After collecting terms, they become:

$$1 = \frac{Q_{t+1}}{Q_t}\left(\alpha A_t X_{t-1}^{\Theta} K_{t-1}^{\alpha-1} N_t^{1-\alpha}+1-\delta\right)+\varphi\mu_t$$

$$w_t = (1-\alpha)A_t X_{t-1}^{\Theta} K_{t-1}^{\alpha} N_t^{-\alpha}$$

$$\mu_t = 1-\frac{Q_{t+1}}{Q_t}(1+r_t)$$

Assuming that the borrowing constraint binds in all periods, $B_t^g=\varphi K_t$, and equations (9) and (10) of the main text follow.

Substituting (19) into (18) gives $1-\varphi=\beta\left(\alpha\left(\frac{1-\alpha}{w}\right)^{\frac{1-\alpha}{\alpha}}\left(AX^{\Theta}\right)^{\frac{1}{\alpha}}+1-\delta-\varphi(1+r)\right)$ which pins down the steady state wage as:

$$w=(1-\alpha)\left(\frac{\alpha\beta\left(AX^{\Theta}\right)^{\frac{1}{\alpha}}}{1-\varphi+\beta(\varphi(1+r)-1+\delta)}\right)^{\frac{\alpha}{1-\alpha}} \tag{26}$$

Labour demand (19) in steady state is therefore:

$$N=\left(\frac{1-\varphi+\beta(\varphi(1+r)-1+\delta)}{\alpha\beta AX^{\Theta}}\right)^{\frac{1}{1-\alpha}}K \tag{27}$$

The two equations above together with (15) imply for consumption:

$$C=\frac{(1-\tau)(1-\alpha)}{\nu\alpha\beta}\frac{\left(\alpha\beta AX^{\Theta}\right)^{\frac{1}{1-\alpha}}-(1-\varphi+\beta(\varphi(1+r)-1+\delta))^{\frac{1}{1-\alpha}}K}{(1-\varphi+\beta(\varphi(1+r)-1+\delta))^{\frac{\alpha}{1-\alpha}}}$$

Substituting (27) into (8) gives output in steady state as:

$$Y=\frac{1-\varphi+\beta(\varphi(1+r)-1+\delta)}{\alpha\beta}K$$

Due to constant returns to scale in private capital and labour, steady state output is linear in private capital. Steady state profits (20) are:

$$\Pi=\frac{(1-\beta)(1-\varphi)}{\beta}K \tag{28}$$

The household's income before taxes is then:

$$\begin{aligned}&(wN+\Pi+(1+r)S)\\&=\frac{1-\alpha}{\alpha\beta}(1-\varphi+\beta(\varphi(1+r)-1+\delta))K+\frac{(1-\beta)(1-\varphi)}{\beta}K+(1+r)(B^{g}+\varphi K)\\&=\frac{1-\varphi+\beta(\varphi(1+r)-1+\delta)+\alpha\beta(\varphi-\delta)}{\alpha\beta}K+(1+r)B^{g}\end{aligned}$$

Substituting equations (21) and (26) to (28) into the representative household's budget constraint (17), gives one equation that pins down the private capital stock in steady state as:

$$K=\frac{\frac{(1-\alpha)\left(\alpha\beta AX^{\Theta}\right)^{\frac{1}{1-\alpha}}}{(1-\varphi+\beta(\varphi(1+r)-1+\delta))^{\frac{\alpha}{1-\alpha}}}-\frac{\alpha\beta\nu}{1-\tau}(r-\tau-\tau r)B^{g}}{(1+\nu-\alpha)(1-\varphi+\beta(\varphi(1+r)-1+\delta))-\alpha\beta\nu\left(\frac{\tau}{1-\tau}\varphi+\delta\right)}$$

from which all other variables readily follow using the equations above, as:

$$C = \frac{(1-\tau)(1-\alpha)}{\nu\alpha\beta(1-\varphi+\beta(\varphi(1+r)-1+\delta))} \cdot \frac{\left[\left(\alpha\beta AX^{\Theta}\right)^{\frac{1}{1-\alpha}}\left[\nu(1-\varphi+\beta(\varphi(1+r)-1+\delta))-\alpha\beta\nu\left(\frac{\tau}{1-\tau}\varphi+\delta\right)\right] + (1-\varphi+\beta(\varphi(1+r)-1+\delta))^{\frac{1}{1-\alpha}}\frac{\alpha\beta\nu}{1-\tau}(r-\tau-\tau r)B^{g}\right]^{\frac{\alpha}{1-\alpha}}}{(1+\nu-\alpha)(1-\varphi+\beta(\varphi(1+r)-1+\delta))-\alpha\beta\nu\left(\frac{\tau}{1-\tau}\varphi+\delta\right)}$$

$$N = \frac{(1-\alpha)(1-\varphi+\beta(\varphi(1+r)-1+\delta))-(1-\varphi+\beta(\varphi(1+r)-1+\delta))^{\frac{1}{1-\alpha}}\frac{\alpha\beta\nu}{1-\tau}(r-\tau-\tau r)B^{g}\left(\alpha\beta AX^{\Theta}\right)^{\frac{-1}{1-\alpha}}}{(1+\nu-\alpha)(1-\varphi+\beta(\varphi(1+r)-1+\delta))-\alpha\beta\nu\left(\frac{\tau}{1-\tau}\varphi+\delta\right)}$$

Fiscal policies

To state the government's optimisation problem, notice that the government budget constraint in steady state implies for steady state debt:

$$B^{g} = \frac{\tau(1-\alpha)\frac{1-\varphi+\beta(\varphi(1+r)-1+\delta)+\alpha\beta(\varphi-\delta)}{\alpha\beta(1-\varphi+\beta(\varphi(1+r)-1+\delta))}\left(\alpha\beta AX^{\Theta}\right)^{\frac{1}{1-\alpha}} - \left((1+\nu-\alpha)(1-\varphi+\beta(\varphi(1+r)-1+\delta))-\alpha\beta\nu\left(\frac{\tau}{1-\tau}\varphi+\delta\right)\right)\delta X}{\left(\left(1+\frac{\nu}{1-\tau}-\alpha\right)\left(1-\varphi+\beta(\varphi(1+r)-1+\delta)-\alpha\beta\frac{\nu}{1-\tau}\delta\right)\right)(r-\tau-\tau r)} \quad (29)$$

The government's problem is therefore:

$$max\ (\log(C_t)+\nu\log(1-N_t))$$

$s.t.$

$$B^{g} = \frac{\tau(1-\alpha)\frac{1-\varphi+\beta(\varphi(1+r)-1+\delta)+\alpha\beta(\varphi-\delta)}{\alpha\beta(1-\varphi+\beta(\varphi(1+r)-1+\delta))}\left(\alpha\beta AX^{\Theta}\right)^{\frac{1}{1-\alpha}} - \left((1+\nu-\alpha)(1-\varphi+\beta(\varphi(1+r)-1+\delta))-\alpha\beta\nu\left(\frac{\tau}{1-\tau}\varphi+\delta\right)\right)\delta X}{\left(\left(1+\frac{\nu}{1-\tau}-\alpha\right)\left(1-\varphi+\beta(\varphi(1+r)-1+\delta)-\alpha\beta\frac{\nu}{1-\tau}\delta\right)\right)(r-\tau-\tau r)}$$

where:

$$C = \frac{(1-\tau)(1-\alpha)}{\frac{\alpha}{1-\alpha}} \cdot \frac{\left[\begin{array}{c} \left(\alpha\beta A X^{\Theta}\right)^{\frac{1}{1-\alpha}} \left[\nu\left(1-\varphi+\beta(\varphi(1+r)-1+\delta)\right)-\alpha\beta\nu\left(\frac{\tau}{1-\tau}\varphi+\delta\right)\right] \\ + \left(1-\varphi+\beta(\varphi(1+r)-1+\delta)\right)^{\frac{1}{1-\alpha}} \frac{\alpha\beta\nu}{1-\tau}(r-\tau-\tau r)B^{g} \end{array} \right]}{(1+\nu-\alpha)\left(1-\varphi+\beta(\varphi(1+r)-1+\delta)\right)-\alpha\beta\nu\left(\frac{\tau}{1-\tau}\varphi+\delta\right)}$$

$$\nu\alpha\beta\left(1-\varphi+\beta(\varphi(1+r)-1+\delta)\right)$$

$$N = \frac{(1-\alpha)\left(1-\varphi+\beta(\varphi(1+r)-1+\delta)\right) - \left(1-\varphi+\beta(\varphi(1+r)-1+\delta)\right)^{\frac{1}{1-\alpha}} \frac{\alpha\beta\nu}{1-\tau}(r-\tau-\tau r)B^{g}\left(\alpha\beta A X^{\Theta}\right)^{\frac{-1}{1-\alpha}}}{(1+\nu-\alpha)\left(1-\varphi+\beta(\varphi(1+r)-1+\delta)\right)-\alpha\beta\nu\left(\frac{\tau}{1-\tau}\varphi+\delta\right)}$$

After substituting out the government budget constraint, taking total derivatives of C and N with respect the first-order condition (25) for public capital X is:

$$\left[1-\phi+\beta(\phi(1+r)-1+\delta)-\alpha\beta\nu\left(\frac{\tau}{1-\tau}\phi+\delta\right)\right](\alpha\beta A)^{\frac{1}{1-\alpha}}\frac{\theta}{1-\alpha}X^{\frac{\theta}{1-\alpha}-1}$$

$$\tau(1-\alpha)\frac{1-\phi+\beta(\phi(1+r)-1+\delta)+\alpha\beta(\phi-\delta)}{\alpha\beta\left(1-\phi+\beta(\phi(1+r)-1+\delta)\right)^{\frac{\alpha}{1-\alpha}}}(\alpha\beta A)^{\frac{1}{1-\alpha}}\frac{\theta}{1-\alpha}X^{\frac{\theta}{1-\alpha}-1}$$

$$+\frac{\left(1-\phi+\beta(\phi(1+r)-1+\delta)\right)^{\frac{1}{1-\alpha}}\frac{\alpha\beta}{1-\tau}\dfrac{-(1+\nu-\alpha)\left(1-\phi+\beta(\phi(1+r)-1+\delta)\right)+\alpha\beta\nu\left(\frac{\tau}{1-\tau}\phi+\delta\right)}{\left(1+\frac{\nu}{1-\tau}-\alpha\right)\left(1-\phi+\beta(\phi(1+r)-1+\delta)-\alpha\beta\frac{\nu}{1-\tau}\delta\right)}}{(\alpha\beta AX^{\theta})^{\frac{1}{1-\alpha}}\nu\left[1-\phi+\beta(\phi(1+r)-1+\delta)-\alpha\beta\left(\frac{\tau}{1-\tau}\phi-\delta\right)\right]}$$

$$\tau(1-\alpha)\frac{1-\phi+\beta(\phi(1+r)-1+\delta)+\alpha\beta(\phi-\delta)}{\alpha\beta\left(1-\phi+\beta(\phi(1+r)-1+\delta)\right)^{\frac{\alpha}{1-\alpha}}}(\alpha\beta AX^{\theta})^{\frac{1}{1-\alpha}}$$

$$+\left(1-\phi+\beta(\phi(1+r)-1+\delta)\right)^{\frac{1}{1-\alpha}}\frac{\alpha\beta\nu}{1-\tau}\frac{-\left((1+\nu-\alpha)\left(1-\phi+\beta(\phi(1+r)-1+\delta)\right)-\alpha\beta\nu\left(\frac{\tau}{1-\tau}\phi+\delta\right)\right)\delta X}{\left(1+\frac{\nu}{1-\tau}-\alpha\right)\left(1-\phi+\beta(\phi(1+r)-1+\delta)-\alpha\beta\frac{\nu}{1-\tau}\delta\right)}$$

$$=\left(1-\phi+\beta(\phi(1+r)-1+\delta)\right)^{\frac{1}{1-\alpha}}\frac{\alpha\beta\nu}{1-\tau}\left[\frac{-(r-\tau-\tau r)(\alpha\beta AX^{\theta})^{\frac{-1}{1-\alpha}}}{\nu\left(1-\phi+\beta(\phi(1+r)-1+\delta)\right)-\alpha\beta\nu\left(\frac{\tau}{1-\tau}\phi+\delta\right)}\right.$$

$$\left.+\frac{\tau(1-\alpha)\frac{1-\phi+\beta(\phi(1+r)-1+\delta)+\alpha\beta(\phi-\delta)}{\alpha\beta\left(1-\phi+\beta(\phi(1+r)-1+\delta)\right)^{\frac{\alpha}{1-\alpha}}}-\left((1+\nu-\alpha)\left(1-\phi+\beta(\phi(1+r)-1+\delta)\right)-\alpha\beta\nu\left(\frac{\tau}{1-\tau}\phi+\delta\right)\right)\delta X(\alpha\beta AX^{\theta})^{\frac{-1}{1-\alpha}}}{(1+\frac{\nu}{1-\tau}-\alpha)(1-\phi+\beta(\phi(1+r)-1+\delta)-\alpha\beta\frac{\nu}{1-\tau}\delta)}\right]$$

Similarly, the first-order condition for the tax rate τ is:

$$\frac{1}{C(X,\tau)}\frac{dC}{d\tau} = \frac{\nu}{1-N(X,\tau)}\frac{dN}{d\tau}$$

where:

$$\frac{dC}{d\tau} =$$

$$\frac{-(1-\alpha)+\alpha\left(1+\frac{\tau}{1-\tau}\varphi-\beta+\beta\delta\right)^{-1}\frac{1}{1-\tau}\varphi}{\nu\alpha\beta\left(1+\frac{\tau}{1-\tau}\varphi-\beta+\beta\delta\right)^{\frac{\alpha}{1-\alpha}}}\frac{(\alpha\beta AX^{\Theta})^{\frac{1}{1-\alpha}}\left[\frac{\tau}{1-\tau}\nu(1-\alpha\beta)\varphi+\nu\,(1-\beta+\beta\delta)-\alpha\beta\nu\delta\right]+\left(1+\frac{\tau}{1-\tau}\varphi-\beta+\beta\delta\right)^{\frac{1}{1-\alpha}}\frac{\alpha\beta\nu}{1-\tau}(1-\beta)B^{g}}{\frac{\tau}{1-\tau}(1+\nu-\alpha-\alpha\beta\nu)\varphi+(1+\nu-\alpha)(1-\beta+\beta\delta)-\alpha\beta\nu\delta}$$

$$+\frac{(1-\tau)(1-\alpha)}{\nu\alpha\beta\left(1+\frac{\tau}{1-\tau}\varphi-\beta+\beta\delta\right)^{\frac{\alpha}{1-\alpha}}}$$

$$\left((\alpha\beta AX^{\Theta})^{\frac{1}{1-\alpha}}\frac{1}{(1-\tau)^2}\nu(1-\alpha\beta)\varphi+\left(1+\frac{\tau}{1-\tau}\varphi-\beta+\beta\delta\right)^{\frac{1}{1-\alpha}}\frac{\alpha\beta\nu}{(1-\tau)^2}(1-\beta)\left[\left(\frac{1}{1-\alpha}\left(1+\frac{\tau}{1-\tau}\varphi-\beta+\beta\delta\right)^{-1}\frac{1}{1-\tau}+1\right)B^{g}+(1-\tau)\frac{dB^{g}}{d\tau}\right]\right)$$

$$\left[\frac{\tau}{1-\tau}(1+\nu-\alpha-\alpha\beta\nu)\varphi+(1+\nu-\alpha)(1-\beta+\beta\delta)-\alpha\beta\nu\delta\right]$$

$$-\left((\alpha\beta AX^{\Theta})^{\frac{1}{1-\alpha}}\left[\frac{\tau}{1-\tau}\nu(1-\alpha\beta)\varphi+\nu\,(1-\beta+\beta\delta)-\alpha\beta\nu\delta\right]+\left(1+\frac{\tau}{1-\tau}\varphi-\beta+\beta\delta\right)^{\frac{1}{1-\alpha}}\frac{\alpha\beta\nu}{1-\tau}(1-\beta)B^{g}\right)\frac{1}{(1-\tau)^2}(1+\nu-\alpha-\alpha\beta\nu)\varphi$$

$$\left[\frac{\tau}{1-\tau}(1+\nu-\alpha-\alpha\beta\nu)\varphi+(1+\nu-\alpha)(1-\beta+\beta\delta)-\alpha\beta\nu\delta\right]^{2}$$

$$\left((1-\alpha)\varphi-\left(1+\frac{\tau}{1-\tau}\varphi-\beta+\beta\delta\right)^{\frac{1}{1-\alpha}}\alpha\beta\nu(1-\beta)\left(\alpha\beta AX^{\Theta}\right)^{\frac{-1}{1-\alpha}}\left[\left(\frac{1}{1-\alpha}\frac{1}{1-\tau}\frac{\varphi}{1+\frac{\tau}{1-\tau}\varphi-\beta+\beta\delta}+1\right)B^{g}+(1-\tau)\frac{dB^{g}}{d\tau}\right]\right)$$

$$\left[\frac{\tau}{1-\tau}(1+\nu-\alpha-\alpha\beta\nu)\varphi+(1+\nu-\alpha)(1-\beta+\beta\delta)-\alpha\beta\nu\delta\right]$$

$$-\left((1-\alpha)\left(1+\frac{\tau}{1-\tau}\varphi-\beta+\beta\delta\right)-\left(1+\frac{\tau}{1-\tau}\varphi-\beta+\beta\delta\right)^{\frac{1}{1-\alpha}}\frac{\alpha\beta\nu}{1-\tau}(1-\beta)B^{g}\left(\alpha\beta AX^{\Theta}\right)^{\frac{-1}{1-\alpha}}\right)$$

$$\frac{dN}{d\tau}=\frac{1}{(1-\tau)^2}\frac{(1+\nu-\alpha-\alpha\beta\nu)\varphi}{\left[\frac{\tau}{1-\tau}(1+\nu-\alpha-\alpha\beta\nu)\varphi+(1+\nu-\alpha)(1-\beta+\beta\delta)-\alpha\beta\nu\delta\right]^{2}}$$

and B^{g} given by (29) and its derivative by:

$$\frac{dB^{g}}{d\tau}=\frac{\beta}{1-\beta}\left(1+\frac{\nu}{1-\tau}-\alpha\right)^{-2}\left(1-\phi+\beta(\phi(1+r)-1+\delta)-\alpha\beta\frac{\nu}{1-\tau}\delta\right)^{-2}$$

$$\times\left((1-\alpha)(\alpha\beta AX^{\theta})^{\frac{1}{1-\alpha}}\left[\frac{1+\frac{\tau}{1-\tau}\phi-\beta+\beta\delta+\alpha\beta(\phi-\delta)}{\alpha\beta\left(1+\frac{\tau}{1-\tau}\phi-\beta+\beta\delta\right)^{\frac{\alpha}{1-\alpha}}}\right.\right.$$

$$\left.+\tau\frac{\alpha\beta\phi}{(1-\tau)^2}\frac{\left(1+\frac{\tau}{1-\tau}\phi-\beta+\beta\delta\right)^{\frac{\alpha}{1-\alpha}}-\left(1+\frac{\tau}{1-\tau}\phi-\beta+\beta\delta+\alpha\beta(\phi-\delta)\right)\frac{\alpha}{1-\alpha}\left(1+\frac{\tau}{1-\tau}\phi-\beta+\beta\delta\right)^{\frac{\alpha}{1-\alpha}-1}}{\left(\alpha\beta\left(1+\frac{\tau}{1-\tau}\phi-\beta+\beta\delta\right)^{\frac{\alpha}{1-\alpha}}\right)^{2}}\right]$$

$$-\frac{\phi}{(1-\tau)^2}(1+\nu-\alpha-\alpha\beta\nu\delta)\delta X$$

$$-\left[(1-\alpha)(\alpha\beta AX^{\theta})^{\frac{1}{1-\alpha}}\tau\frac{1+\frac{\tau}{1-\tau}\phi-\beta+\beta\delta+\alpha\beta(\phi-\delta)}{\alpha\beta\left(1+\frac{\tau}{1-\tau}\phi-\beta+\beta\delta\right)^{\frac{\alpha}{1-\alpha}}}\right.$$

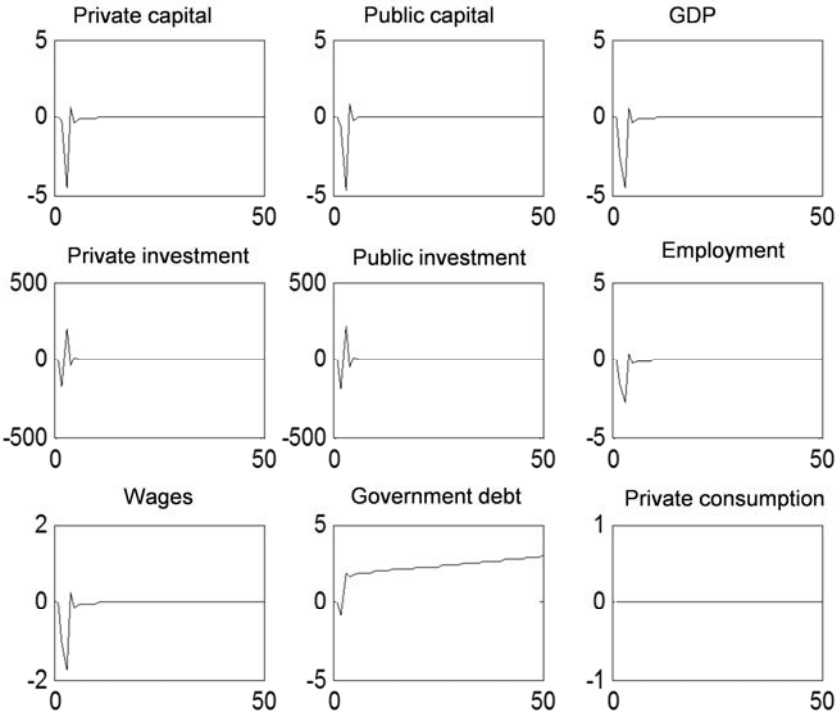
$$\left.-\left(\frac{\tau}{1-\tau}\phi(1+\nu-\alpha-\alpha\beta\nu\delta)+(1+\nu-\alpha)(1-\beta+\beta\delta)-\alpha\beta\nu\delta\right)\delta X\right]$$

$$\left.\times\frac{1}{(1-\tau)^2}\left[\nu\left(1-\phi+\beta(\phi(1+r)-1+\delta)-\alpha\beta\frac{\nu}{1-\tau}\delta\right)+(1+\frac{\nu}{1-\tau}-\alpha)(\phi-\alpha\beta\nu\delta)\right]\right)$$

Long transition path

To show the very long-run behaviour of the economy, Figure D.1 shows the transition path for 50 quarters after the flooding for scenario 3A under optimal public investment.

Figure D.1. **Scenario 3A: Assuming change in public investment**



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