Flood risk assessment in the Ubaye Valley (Barcelonnette, France)

Mukolwe, Micah; Di Baldassarre, Giuliano; Bogaard, Thom

DOI
10.1016/B978-0-12-819101-9.00006-6

Publication date
2023

Document Version
Final published version

Published in
Hydro-Meteorological Hazards, Risks, and Disasters

Citation (APA)
Mukolwe, M., Di Baldassarre, G., & Bogaard, T. (2023). Flood risk assessment in the Ubaye Valley (Barcelonnette, France). In J. F. Shroder, G. Di Baldassarre, & P. Paron (Eds.), *Hydro-Meteorological Hazards, Risks, and Disasters* (2 ed., pp. 191-201). (Hazards and Disasters Series; Vol. 5). Elsevier. https://doi.org/10.1016/B978-0-12-819101-9.00006-6

Chapter 6

Flood risk assessment in the Ubaye Valley (Barcelonnette, France)

Micah Mukolwe[1], Giuliano Di Baldassarre[3] and Thom Bogaard[2]
[1]*Masinde Muliro University of Science and Technology, Kakamega, Kenya;* [2]*Delft University of Technology, Civil Engineering and Geosciences Water Management, Water Resources, Delft, the Netherlands;* [3]*Department of Earth Sciences, Uppsala University, Uppsala, Sweden*

6.1 Introduction

6.1.1 Motivation and objective

Floodplain habitation has occurred throughout history, notably due to associated economic benefits for a number of activities, such as trade and agriculture. In many countries, the occupation of floodplains has grown after the construction of flood protection structures (such as levees). This process has led to a reduction in the frequency of flooding; on the other hand, there is a corresponding increase of potential adverse consequences ("levee effect"; Di Baldassarre et al., 2013; Klijn et al., 2004). As a matter of fact, many megacities are located in floodplains or deltas.

Population growth in high-risk areas has often resulted in remarkable damages and fatalities. To assess risk, it is normative to evaluate the potential natural hazards, calculate the susceptibility of the potentially affected population (in relation to the hazard), and combine this output with the consequences (e.g., Apel et al., 2004; Jongman et al., 2012; Moel, 2012; Winsemius et al., 2012; Genovese, 2006; Genovese et al., 2007).

This chapter shows a demonstration of the benefits of risk-prevention measures by applying the KULTURisk methodology (see Chapter 6) to potential flood risk in Barcelonnette (France).

6.1.2 The case study: Ubaye Valley, France

The Ubaye Valley, located in the French Alps (Fig. 6.1), is a popular tourist destination for ski-sports and draws upon a rich historical heritage. Protection

Hydro-Meteorological Hazards, Risks, and Disasters. https://doi.org/10.1016/B978-0-12-819101-9.00006-6

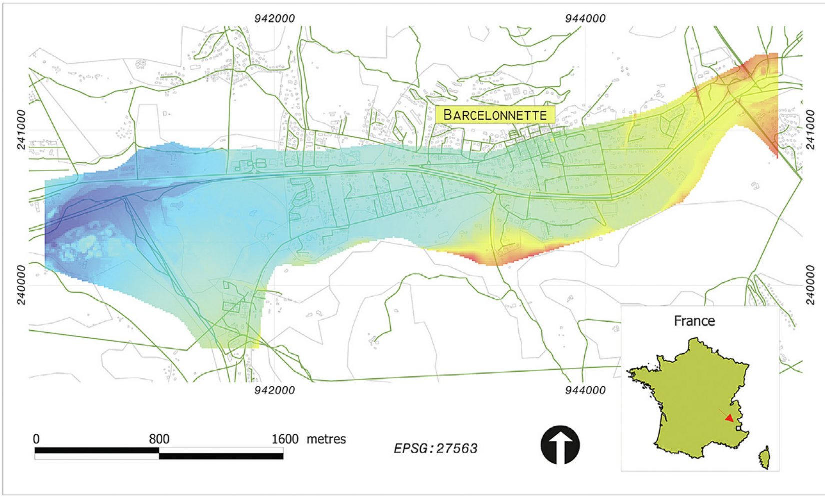

FIGURE 6.1 Barcelonnette town (Ubaye Valley).

of the city of Barcelonnette from flooding has led to levee construction along the river. Also, in the upper catchment, there have been efforts to improve slope stability and reduce debris flows from steep unstable alpine slopes, achieved by construction of check dams and planting of trees (Flageollet et al., 1996; Weber, 1994).

In June 1957, an approximately 1-in-100-year flood wave, resulting from a combination of snowmelt and spring rainfall, caused exceptionally high discharges in the Ubaye River. This resulted in levee overtopping and flooding of surrounding areas of Barcelonnette town in the Ubaye Valley (Flageollet et al., 1996).

Consequently, different flood-risk-reduction measures were being planned in the Ubaye Valley because of the potentially disruptive nature of flood hazard. Thus, the KULTURisk methodology was applied to determine benefits of these preventive options.

6.2 Methodology

6.2.1 Hydraulic modeling

At the core of any flood-risk assessment is the determination of potential flood-event characteristics and resulting intersection with different receptors in the floodplain to assess damages (based on susceptibility and vulnerability). Increasing availability of computing power, along with the development of several hydraulic-modeling algorithms, has led to growth in the use of flood-inundation models in flood-risk management (Dottori and Todini, 2011; Hunter et al., 2007). This growth has been also facilitated by new data sources of topographic information (Di Baldassarre and Uhlenbrook, 2012; Bates, 2012). For instance, technology such as LiDAR (Light Detection and Ranging) facilitates relatively accurate representation of floodplain topography (Cracknell, 2007) that can be used as input for flood-inundation modeling at a high resolution.

In this study, a two-dimensional flood inundation model, LISFLOOD-FP (Neal et al., 2012; Bates et al., 2010) was built for a reach of the Ubaye Valley River covering the Barcelonnette town area. Topography information was derived from a LiDAR survey carried out in November 2011, which was supplemented by additional river bathymetry, cross-sectional data obtained by RTM *(Restauration des Terrains en Montagne).* Model calibration was based on observed water levels during a high flow event in May 2008. This resulted in a main channel Manning's roughness value of 0.040 $m^{1/3}/s$, for which we found the lowest root mean square error (RMSE) between observed and simulated water levels.

This model was then used to simulate the June 1957 flood event, whose characteristics were derived from a postevent analysis based on an analysis of sediment deposition and expert knowledge (Lecarpentier, 1963). In particular, the peak river discharge of the June 1957 flood event was estimated between 420 and 480 m^3/s.

6.2.2 Scenario selection

Implementation of the KULTURisk methodology was based on different receptors: people and economic activities (consisting of buildings, road network, and agricultural assets). Potential flood-risk mitigation measures that may be adopted by civil protection authorities were considered as alternative scenarios. We considered two scenarios: structural measures and nonstructural measures, namely, improvement of conveyance capacities of the bridge cross-sections, and implementation of an early warning system (EWS). A third scenario considers combination of the two. Benefits of these risk-reduction measures were evaluated by comparing potential flood losses with losses resulting from the baseline scenario, which was representative of the situation then.

6.2.3 Regional Risk Assessment

Potential risk to people was defined by the nature of cultural practices and social behavior that characterize the exposure of people to flooding. In this respect, it is important to consider a large number of tourists and occupancy of secondary homes during high season. To this end, exposure of people was calculated by taking the average house occupancy and average floor area. Furthermore, the use of spatial exposure data sets was beneficial in characterizing areas with high damages.

Damage to the road network was calculated as a percentage area of the road network that was affected by flooding. Important aspects of connectivity and inaccessibility of vital location of the valley were taken into account mainly in the social assessment (see below).

Building damage was taken as a function of flood metrics intensity (flood velocity and water depth) and the capacity of exposed buildings to resist destructive forces defined by a depth damage curve. Lastly, for the calculation of damage to agricultural fields, crop damage thresholds were used to determine potential damage.

6.2.4 Social—Regional Risk Assessment

French Statutory considerations govern and give opportunity for public participation in the risk-mitigation process, which raises risk awareness of the population (Schwarze et al., 2011). Weight factors representing the state of receptor vulnerability were determined from stakeholder discussions, field visits, and a literature review. However, it was vital to discuss final indicator weights with stakeholders, given that expert judgment was used to normalize indicator values.

Indicators were categorized as those based on adaptive capacity, coping capacity, and susceptibility of receptors. Following the determination of normalized indicator values, importance factors weighing the human dimension versus the physical dimension, and those weighing the adaptive capacity, coping capacity, and the susceptibility were determined. To avoid bias, these factors were equally distributed prior to initial discussion with stakeholders.

A major consideration during the analysis was that the population remained relatively stable, approximated at a growth of −0.6% and 1.1% from 1990 to 1999 and 1982 to 1990, respectively (INSEE, 2013). In addition to this, substantial public participation and contribution to risk awareness (e.g., Angignard, 2011) contributes to resilience of the population.

6.2.5 Economic—Regional Risk Assessment

Value factors and *willingness to pay* were the main considerations in determining damage to receptors. Average house rent and contraction costs were readily available; however, for building content value, an estimated *content to value ratio* equal to 50% was used (USACE, 1996). Similar to advice by Messner et al. (2007), agricultural losses were calculated based on characteristics of wheat (Brisson et al., 2010). With regards to damage to roads, losses were calculated arising from debris deposition and road-surface damage, requiring minor road maintenance (Doll and van Essen, 2008).

Physical damage and repair costs of receptors were relatively straightforward to determine; on the other hand, service-disruption costs were difficult to determine due to lack of data. Thus, rough estimate of ratios of structural damage to service-disruption costs was used in the analysis.

Finally, to demonstrate benefits of preventive measures, a relative benefit was calculated that was defined as the relative reduction of flood losses and expressed as a percentage. Thus, the relative benefit in this case can be interpreted as the benefit of *taking preventive action* versus *inaction.*

6.3 Results and discussion

6.3.1 Risk assessment

6.3.1.1 Flood hazard metrics

Scenario 1, which included channel-conveyance capacity improvement (by reshaping the geometry of the bridge), resulted in a significantly reduced floodplain inundation (Werner et al., 2005). The flood hazard to the receptors was based on the two flood-inundation extents shown in Fig. 6.2.

6.3.1.2 Regional Risk Assessment

Results of the Regional Risk Assessment (RRA) show a significant reduction of the risk to receptors as a result of reducing flood water volume in the floodplain (Fig. 6.3). This reduction results in lower (less threatening) flood velocities and water depth, hence lower physical damage (Tables 6.1 and 6.2).

The application of nonstructural measures (EWS) does not have an effect on the flood-wave propagation dynamics, but rather on inherent receptor characteristics, such as alert and evacuation, mitigate effects of flooding. EWS mainly facilitates evasive action to lessen exposure in terms of magnitude and extent (Fig. 6.4).

6.3.1.3 Social—Regional Risk Assessment

Changes in receptor vulnerability were based on the implementation of a reliable EWS (Scenario 2). Being an alpine river recharged by creeks characterized by steep slopes, the Ubaye River basin is a fast-responding catchment. Hence the ability to adequately warn inhabitants of changing river conditions would improve the resilience of floodplain inhabitants. Given that there is no formal EWS implemented, receptors were categorized as being *highly vulnerable* (Indicator value 0.5). Following the application of Scenario 2, including a functioning EWS, the indicator value is expected to improve to a lower vulnerability, *slightly vulnerable* (depending on characteristics of the installed system), that is, indicator value equal to 0.25, according to nomenclature in the methodology. These factors were then combined in a hierarchical structure as specified in the methodology.

Fig. 6.4 shows the resulting decrease in vulnerability of receptors as a result of EWS implementation. Adjusting of factors and weights in the SRRA allowed for inherent study-area characteristics and social sensitivities to be accounted for, while focusing on areas of importance.

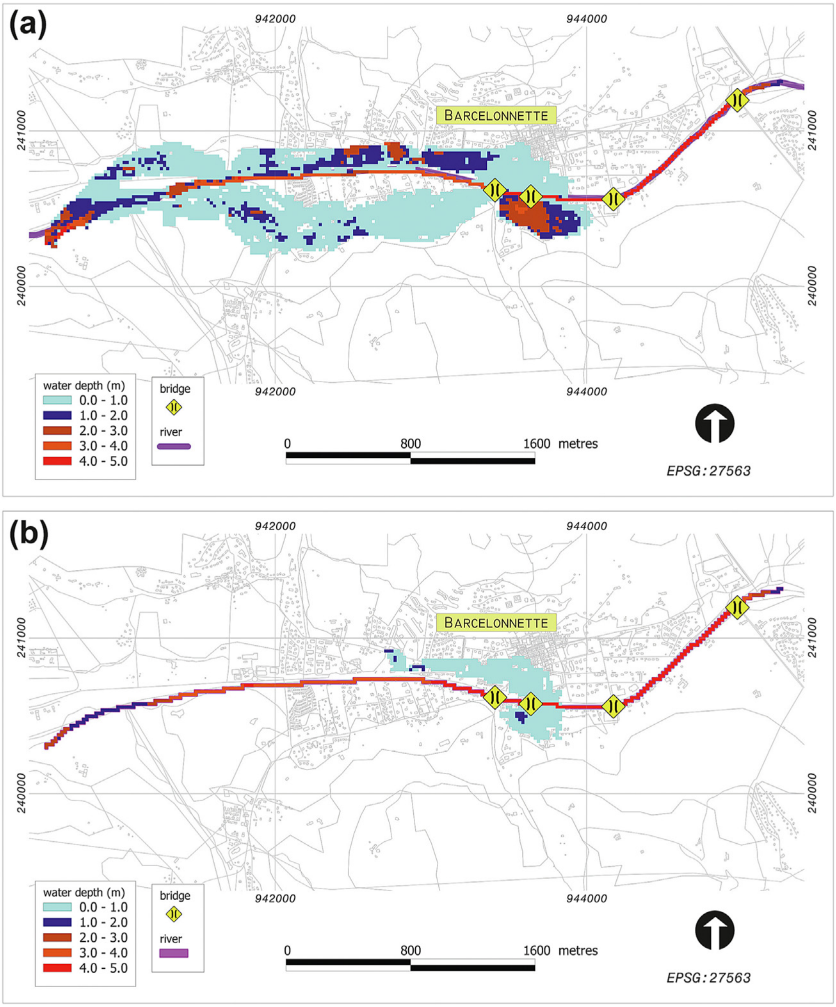

FIGURE 6.2 (A) and (B), Floodplain inundation; baseline and scenario one, respectively.

6.3.2 Social economic RRA

The application of the social economic RRA resulted in aggregated values and damage maps. Clearly, a reduction of flood volumes, that cause floodplain inundation, results in the least damage in monetary terms.

Table 6.3 shows that relative benefits of structural measures are significantly higher than nonstructural measures for this case study. However, it should be noted that costs of implementing the two scenarios are different. Thus, although a reduction of potential flood losses corresponding to the introduction of a reliable EWS is less than that corresponding to structural

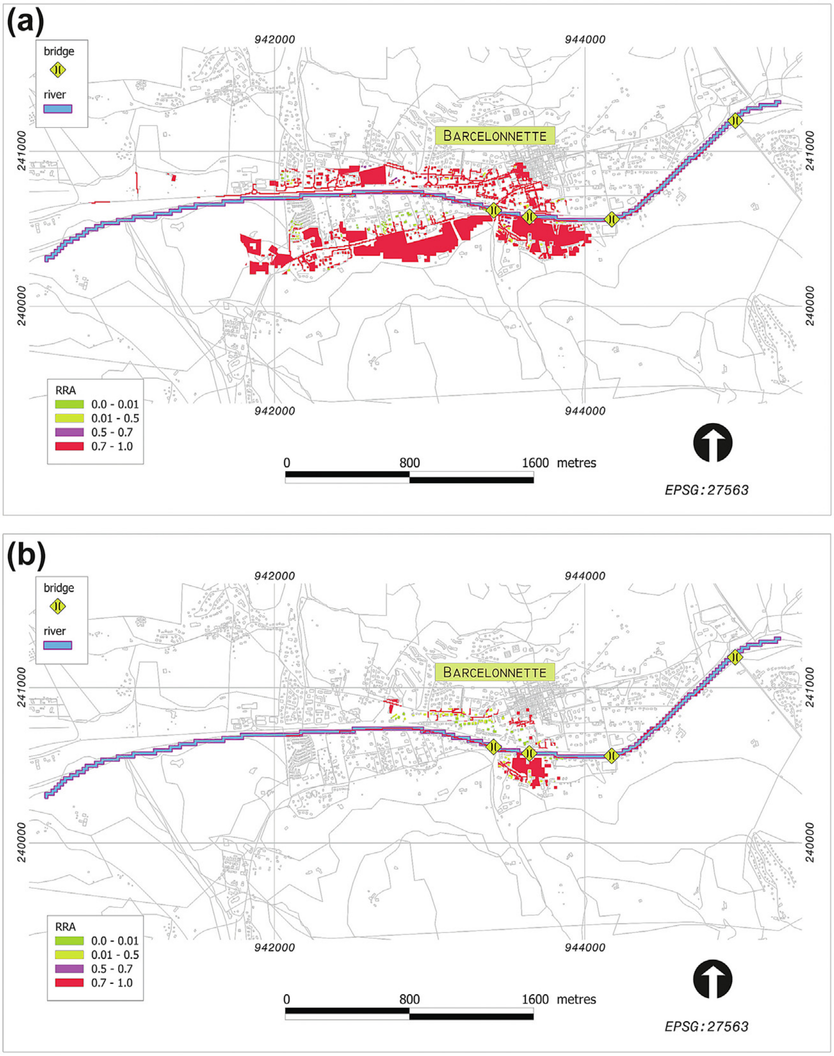

FIGURE 6.3 RRA: (A) Baseline and scenario two, (B) scenario one and scenario three.

measures, it may be less expensive and, therefore, appropriate in a cost–benefit consideration.

6.4 Conclusion

This chapter presented an application of the KULTURisk methodology to an alpine catchment located in the Ubaye Valley. The methodology was found to be adaptable to needs expressed by stakeholders, and the type and resolution of

TABLE 6.1 Percentage of physical damage to receptors.

Receptor	Damage level	Baseline and scenario 2 (%)	Scenario 1 and scenario 3 (%)
Buildings	Inundation	31.83	6.04
	Partial damage	0.00	0.00
	Destruction	0.00	0.00
Roads	Inundated	20.11	6.45
Agriculture	Inundation	10.32	1.08
	Destruction	7.40	0.73

available data. Most notable was the need for continuous interactions with local stakeholders (e.g., Refsgaard et al., 2007) at each stage of application which helped build-up stakeholder confidence in the output and understanding of model assumptions and procedures applied. The KULTURisk methodology was found to be a useful decision-making tool, which gives insight into (physical, social, and economic) benefits of proposed measures for flood risk reduction. Stakeholder participation in the determination of weights resulted in a transparent process and yielded a better understanding of inherent uncertainties in the analysis.

In terms of damage cost, the value of statistical life (VOSL) was found to be the highest value factor. Sensitivity of the VOSL, as compared to damage costs of the other receptors, was attributed to a high value estimated at V3.1 million (OECD, 2012), especially when multiplied by the affected population. It should be mentioned that even without the use of VOSL, which is questionable for ethical reasons (e.g., van Wee and Rietveld, 2013), potential losses

TABLE 6.2 Potential fatalities and injuries (total exposure = 3380 people).

Scenario	Injuries		potential fatalities	
	Number (–)	Percentage (%)	Number (–)	Percentage (%)
Baseline and Scenario 2	60	1.74	3	0.075
Scenario 1 and Scenario 3	11	0.32	1	0.010

The values displayed are as a result of the application of the model in a worst-case scenario application considering maximum possible exposure.

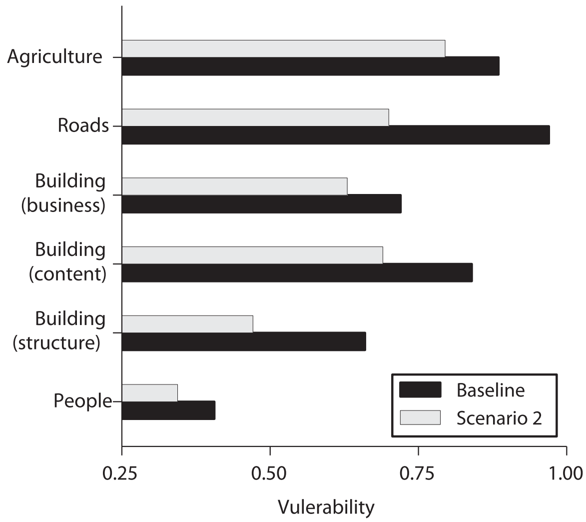

FIGURE 6.4 The benefits of nonstructural measures.

of human lives are the most significant factor triggering efforts for flood-risk reduction.

Results show that risk-prevention measures that bring more benefits would be a reduction of the flood-hazard metrics in the floodplain, coupled with the implementation of nonstructural measures to improve receptor resilience; however, further alternatives and combination of measures may be tested.

The effect of hydraulic-model uncertainty on the flood-risk analysis output is not well understood. As an extension to this work, accounting for hydraulic-model uncertainty within the KULTURisk methodology application would yield insight into suitable methodologies to treat uncertainty.

The methodology may be further improved by accounting for the projected cost of implementation of the proposed measures, which would enable an analysis of the cost—benefit ratios.

TABLE 6.3 Relative benefit of the different scenarios (%).

Receptor	Scenario 1	Scenario 2	Scenario 3
People	64.3	15.4	69.8
Buildings	80.6	18.5	84.3
Infrastructure (roads)	67.9	27.8	76.8
Agriculture	89.6	10.2	90.6

Acknowledgments

This work was funded by the European Union; FP7 KULTURisk project (no. 265280). The authors are deeply grateful to Dr. J-P. Malet and the RTM staff based in the Ubaye Valley for provision of data and critical discussions regarding this work.

References

Angignard, M., 2011. Applying Risk Governance Principles to Natural Hazards and Risks in Mountains. Dortmund University of Technology.

Apel, H., Thieken, A.H., Merz, B., Bloschl, G., 2004. Flood risk assessment and associated uncertainty. Nat. Hazards Earth Syst. Sci. 4 (2), 295−308.

Bates, P.D., 2012. Integrating remote sensing data with flood inundation models: how far have we got? Hydrol. Process. 26 (16), 2515−2521.

Bates, P.D., Horritt, M.S., Fewtrell, T.J., 2010. A simple inertial formulation of the shallow water equations for efficient two-dimensional flood inundation modelling. J. Hydrol. 387 (1−2), 33−45.

Brisson, N., Gate, P., Gouache, D., Charmet, G., Oury, F.-X., Huard, F., 2010. Why are wheat yields stagnating in Europe? A comprehensive data analysis for France. Field Crop. Res. 119 (1), 201−212.

Cracknell, A.P.H.L., 2007. Introduction to Remote Sensing. CRC Press, Boca Raton, FL ([u.a.]).

Di Baldassarre, G., Uhlenbrook, S., 2012. Is the current flood of data enough? A treatise on research needs for the improvement of flood modelling. Hydrol. Process. 26 (1), 153−158.

Di Baldassarre, G., Viglione, A., Carr, G., Kuil, L., Salinas, J., Bloschl, G., 2013. Socio-hydrology: conceptualising human-flood interactions. Hydrol. Earth Syst. Sci. Discuss. 10 (4), 4515−4536.

Doll, C., van Essen, H., 2008. Road infrastructure cost and revenue in Europe. In: Produced within the Study Internalisation Measures and Policies for All External Cost of Transport (IMPACT) Deliverable, vol. 2. CE Delft Report Publication, Delft, the Netherlands number 08.4288.17.

Dottori, F., Todini, E., 2011. Developments of a flood inundation model based on the cellular automata approach: testing different methods to improve model performance. Phys. Chem. Earth, Parts A/B/C 36 (7−8), 266−280 (Final National Report).

Flageollet, J., Maquaire, O., Weber, D., 1996. The Temporal Stability and Activity of Landslides in Europe with Respect to Climatic Change (TESLEC). Final Report: Part II. National Reports. European Commission-Environment Programme (Ct. EV5V-CT94-0454).

Genovese, E., 2006. A Methodological Approach to Land Use-Based Flood Damage Assessment in Urban Areas: Prague Case Study. Technical EUR Reports, EUR, p. 22497.

Genovese, E., Lugeri, N., Lavalle, C., Barredo, J., Bindi, M., Moriondo, M., 2007. An Assessment of Weather-Related Risks in Europe DA2. 1. Preliminary Month 18 Report on Maps of Flood and Drought Risks. ADAM.

Hunter, N.M., Bates, P.D., Horritt, M.S., Wilson, M.D., 2007. Simple spatially-distributed models for predicting flood inundation: a review. Geomorphology 90 (3−4), 208−225.

INSEE, 2013. National Institute of Statistics and Economic Studies (Institut national de la statistique et des etudes economiques) [Online]. Available: www.insee.fr (accessed 18.06.13.).

Jongman, B., Kreibich, H., Apel, H., Barredo, J.I., Bates, P.D., Feyen, L., Gericke, A., Neal, J., Aerts, J.C.J.H., Ward, P.J., 2012. Comparative flood damage model assessment: towards a European approach. Nat. Hazards Earth Syst. Sci. 12 (12), 3733−3752.

Klijn, F., Van Buuren, M., Van Rooij, S.A., 2004. Flood-risk management strategies for an uncertain future: living with Rhine river floods in The Netherlands? AMBIO A J. Hum. Environ. 33 (3), 141−147.

Lecarpentier, C., 1963. La crue de juin 1957 et ses Consequences Morphodynamiques (These de Doctorat). Centre de Geographie Appliquee, Faculte des Lettres et des Sciences Humaines, Universite De Strasbourg, Strasbourg, France.

Messner, F., Penning-Rowsell, E., Green, C., Meyer, V., Tunstall, S., Van Der Veen, A., 2007. Evaluating Flood Damages: Guidance and Recommendations on Principles and Methods. FLOODsite-Report T09-06-01.

Moel, D.H., 2012. Uncertainty in Flood Risk. Ph.D. thesis. VU University, Amsterdam.

Neal, J., Schumann, G., Bates, P., 2012. A subgrid channel model for simulating river hydraulics and floodplain inundation over large and data sparse areas. Water Resour. Res. 48 (11), W11506.

OECD, 2012. The Value of Statistical Life: A Meta Analysis. ENV/EP0C/WPNEP(2010)9/FINAL. Organisation for Economic Co-operation and Development, Paris, France.

Refsgaard, J.C., Van Der Sluijs, J.P., Højberg, A.L., Vanrolleghem, P.A., 2007. Uncertainty in the environmental modelling process - a framework and guidance. Environ. Model. Software 22 (11), 1543−1556.

Schwarze, R., Schwindt, M., Weck-Hannemann, H., Raschky, P., Zahn, F., Wagner, G.G., 2011. Natural hazard insurance in Europe: tailored responses to climate change are needed. Environ. Policy Governance 21 (1), 14−30.

USACE, 1996. Engineering and Design; Risk-Based Analysis for Flood Damage Reduction Studies. EM 1110-2-1619. U.S. Army Corps of Engineers, Washington, DC.

van Wee, B., Rietveld, P., 2013. Using value of statistical life for the ex ante evaluation of transport policy options: a discussion based on ethical theory. Transportation 40 (2), 295−314.

Weber, D., 1994. Research into earth movements in the barcelonnette basin. Temporal occurrence and forecasting of landslides in the European community. Final Report 1, 321−326.

Werner, M.G.F., Hunter, N.M., Bates, P.D., 2005. Identifiability of distributed floodplain roughness values in flood extent estimation. J. Hydrol. 314 (1−4), 139−157.

Winsemius, H.C., Van Beek, L.P.H., Jongman, B., Ward, P.J., Bouwman, A., 2012. A framework for global river flood risk assessments. Hydrol. Earth Syst. Sci. Discuss. 9 (8), 9611−9659.